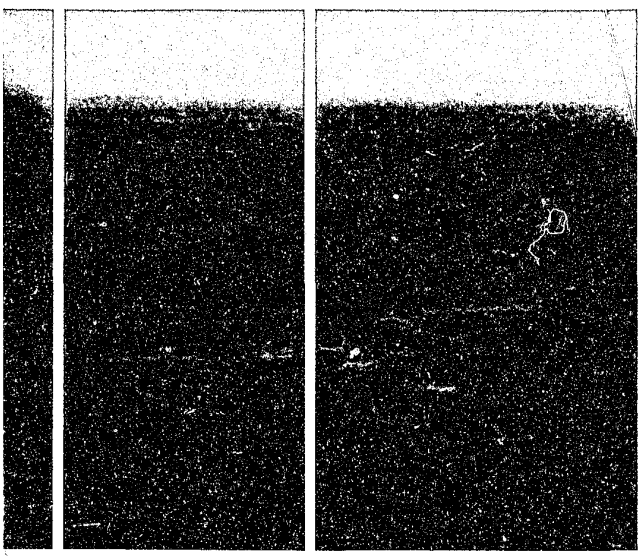
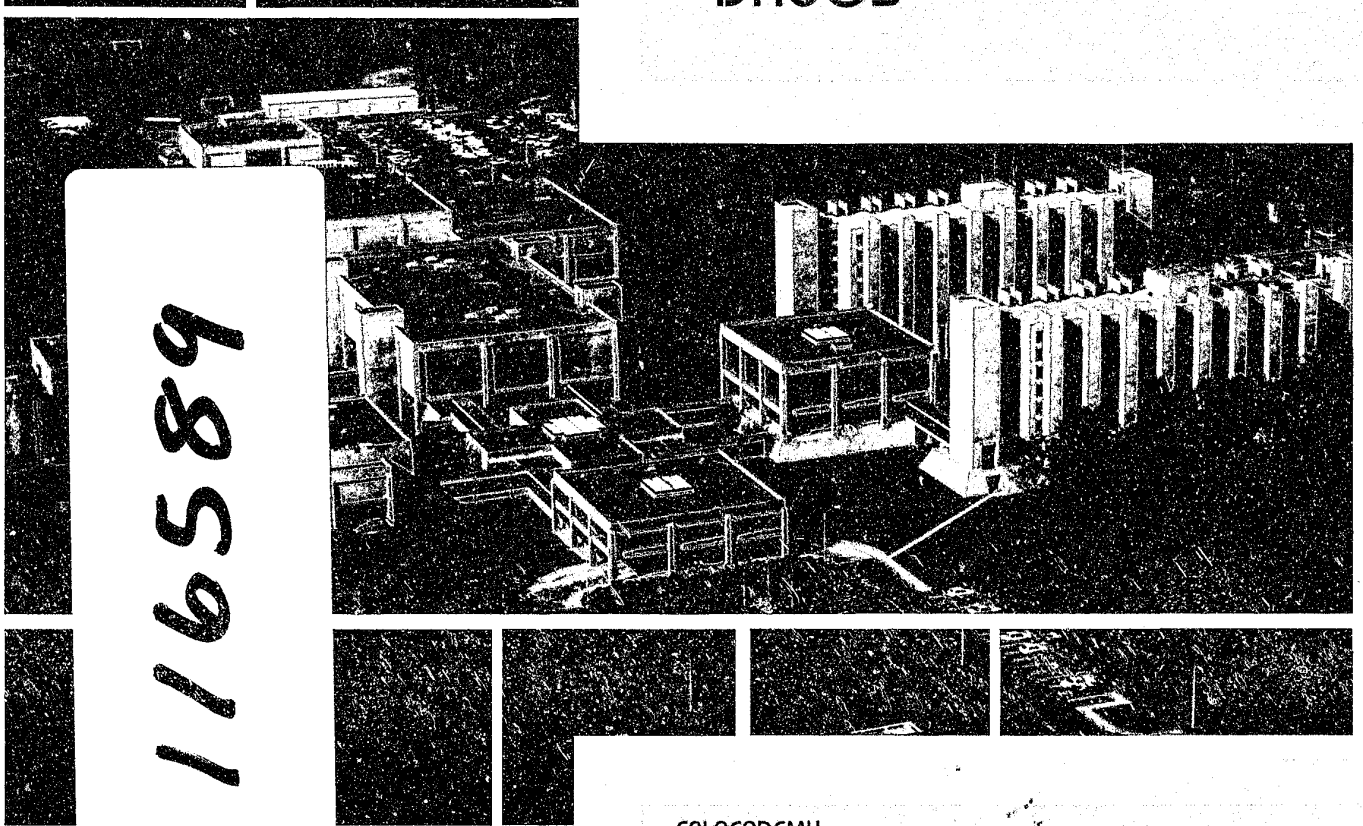
U.S. Department of Justice
Federal Bureau of Investigation

PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM ON DRIVING UNDER THE INFLUENCE OF ALCOHOL AND/OR DRUGS





FBI ACADEMY
QUANTICO, VIRGINIA
MARCH 24 - 26, 1986

116589

Proceedings of the International Symposium on Driving Under the Influence of Alcohol and/or Drugs

Host Laboratory Division
Federal Bureau of Investigation

March 24–26, 1986

Forensic Science Research and Training Center
FBI Academy
Quantico, Virginia

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FOREWORD

On March 24-26, 1986, the FBI Laboratory hosted the "International Symposium on Driving Under the Influence of Alcohol and/or Drugs." The symposium was held at the Forensic Science Research and Training Center, Quantico, Virginia, and there were 168 scientists in attendance representing industry, university and government laboratories in the United States, Canada, England and Sweden.

The symposium program included lectures by prominent scientists on such topics as: the pharmacokinetics of ethanol, driving under the influence of delta-9 tetrahydrocannabinol and metabolites, the pharmacology of central nervous system depressants and the trends in roadside and laboratory testing (techniques and criteria for identification). Also, short oral and poster presentations were given and panel discussions held on a number of topics such as those surrounding breath alcohol testing, instruments and driving impaired versus blood alcohol concentration.

The symposium provided an exchange of ideas which should generate future research into the severe problem of individuals driving under the influence of alcohol and/or drugs. Consequently, I believe the objectives of this symposium were met, to gather respected scientists to discuss the problems associated with analyzing evidence and the method for dealing with those that are driving under the influence of alcohol and/or drugs.

On behalf of the FBI, I would like to thank all those who participated in the symposium.

ROGER T. CASTONGUAY
Assistant Director-in-Charge
FBI Laboratory

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SECTION I

LECTURES

SCOPE OF THE CHEMICALLY IMPAIRED DRIVER

Kimberly C. Frankel

Multnomah County
Portland, Oregon

All 50 states have laws prohibiting the operation of a vehicle while the driver is under the influence of intoxicants. Generally, these laws require the government to prove venue or jurisdiction, identification of the operator or person in physical control of the vehicle and impairment due to the use of alcohol. Some states require the vehicle to have been operated on a public road, while others include areas open to the public, such as parking lots and the like. The terminology used to describe the impairment may also vary to include "under the influence of intoxicants" or "driving while intoxicated." Regardless of the language used, the offense not only includes states of drunkenness or intoxication but also alcohol-related mental or physical impairment that affects behavior. Thus the original laws were directed at behavior, that is, evidence describing the driver's appearance, demeanor, emotional state and driving. This is still the basic proof used in a trial.

In the 1930's, chemical testing began, primarily as a method to corroborate the observations made by witnesses. The earliest presumptive law appeared in 1939 in Indiana. This law directed that a blood alcohol level of 0.05% or less meant that the defendant was presumed not to be under the influence and a level of 0.15% or more meant that the defendant was presumed to be affected. By the mid-1950's, 26 states had adopted presumptive levels, and chemical testing became central to the government's approach.

In 1962, the Uniform Vehicle Code reduced the presumptive level from 0.15% to 0.10%. This same revision expanded the law to designate the state's health agency as responsible for approving testing methods and licensing persons who conduct tests; limitation of blood withdrawal to physicians, registered nurses, or persons acting under their direction or control; use of an independent chemical test at the request of the defendant; disclosure of test information to defendant and counsel at the defendant's request; and admissibility of the "refusal" at trial. Since adoption, the presumptive level of blood alcohol has been reduced in some states to 0.08%.

The earliest Implied Consent Law was enacted in New York in 1953. In 1962, Implied Consent was added to the Uniform Vehicle Code. Implied Consent simply means that a driver operating a motor vehicle on public roads or premises open to the public (depending on the state law) implicitly consents to take a chemical test to determine blood alcohol content. These provisions require that a defendant be under arrest for an offense committed while driving under the influence. They further direct the officer to advise the defendant of the consequences of a refusal before a test is requested. The test is admissible in court, provided the test meets other statutory, regulatory and evidentiary rules.

Refusals prevent the government from conducting any test, and they are reported to the state driver's licensing agency so that this organization can commence proceedings to suspend or revoke the individual's driving privileges. The anomalous nature of implied consent laws and their effect on certain types of alcohol and driving related offenses, other than Driving Under the Influence, will be discussed in the following pages.

In 1962, Nebraska adopted the first "illegal *per se*" law. This means that, at a given blood level, it is illegal in and of itself for a person to drive regardless of the behavioral evidence. Forty-two states have adopted such laws, and the blood alcohol levels range from 0.15% to 0.08%.

In 1976, Minnesota adopted a law that has come to be known as the "Administrative *Per Se*" law. It allows action to be taken on a driver's license for both refusals and driving while the blood alcohol content exceeds a given level (in Minnesota 0.10%). The law allows the officer to immediately take the license of a driver who refuses or fails the test and issue a temporary license. Depending on state law, this license is valid for 7-30 days. At the end of this period, the license will be suspended or revoked, depending on the state. This action can occur with or without such a hearing. The constitutionality of these laws has been tested. Both have been declared constitutional.

In summary, we have moved from simple prohibitions against alcohol impaired driving, determined by behavior, to the somewhat more complex illegal and administrative *per se* laws. In the process, we have altered, ignored and limited some old and basic evidentiary rules and constitutional principles. The following section examines some of these departures.

IMPLIED CONSENT AND THE FOURTH AMENDMENT

The Fourth Amendment provides for obtaining nontestimonial evidence in criminal cases. The amendment states that "The right of the people to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures, shall not be violated, and no warrants shall issue, but upon probable cause, supported by oath or affirmation, and particularly describing the place to be searched, and the persons or things to be seized."

This Amendment, and the case law interpreting it, allow for the seizure of evidence upon probable cause. The requirement for a search warrant largely depends on the practicality of obtaining one without destroying the viability of the evidence.

Implied Consent laws generally state that all drivers, by driving on the roads of a state, implicitly consent to a chemical test to determine blood alcohol content. This is the case unless the driver refuses. If the driver refuses, the government's remedy is generally a license privilege suspension.

No specific showing of probable cause is required to seize the breath sample. In other words, one does not generally encounter motions to suppress breath test results based on a lack of probable cause to search. The probable cause for the seizure of this evidence is supplied by two factors. The first is that the defendant must generally be under arrest, and thus there must be probable cause for the arrest. The second part of the probable cause is supplied by the proven, scientific reliability of the breath test. We, therefore, encounter legal challenges based on lack of probable cause to arrest, lack of reasonable suspicion to stop or failures in the scientific processes.

The other vast departure from general constitutional principles occurs when a defendant refuses a breath test, that is, refuses a seizure of otherwise competent evidence. Ordinarily, if a defendant refuses the seizure of evidence, an officer with probable cause, with or without a search warrant, uses reasonable force to obtain the needed evidence.[1] This process is not available under Implied Consent. While it is a permissible narrowing of a constitutional standard, it is still a legal oddity. The result is the loss of otherwise competent evidence in cases such as vehicular homicide. This is evidence that would otherwise be available if there were no Implied Consent Law.

The Fifth Amendment prohibits compelled confessions or admissions of guilt and further states ". . . nor shall any person . . . be compelled in any criminal case to be a witness against himself . . ." The prohibition is limited to testimony, that is, to a verbal act. It is generally permissible to comment on an accused's refusal to perform a physical act, such as stand in a lineup, be fingerprinted or photographed or give a handwriting exemplar.[2]

Under the Implied Consent laws, some states still hold that a refusal to submit to the test is inadmissible as evidence. States that allow the refusal in evidence do so by statute, as though the procedure were not otherwise permissible. This departure is particularly odd as it encouraged refusals. It is also an inaccurate application of the law. To begin with, a suspect is generally under arrest when offered the breath test. Secondly, the person has generally been advised of his Miranda rights. Finally, the refusal to take a breath test is a refusal to perform a physical act (covered by 4th Amendment rules), not a testimonial matter (controlled by the Fifth Amendment). Thus, even assuming a defendant, under arrest and advised, has chosen to exercise the right to remain silent, the act of refusing to submit to the test should be admitted in evidence, even though the language used would be inadmissible. No statutory changes are needed to accomplish this.

STATUTES AND REGULATIONS

Another slight departure from general rules occurs in the manner in which the breath testing process is regulated. The equipment used to measure the alcohol content of a driver's blood varies not only from state to state but also from agency to agency within a given state. Generally, the statutory law provides the basis for using breath testing equipment, and, as mentioned, state agency regulations enumerate the types of machines to be used and the procedures used for their maintenance and operation. The departure here is not unique, as similar procedures are used, for example, in designating controlled substances (drugs and narcotics).

The legislative scheme used takes control of procedures from the hands of the legislative body and places it with the state agency. To change a statute or law, legislative action is required. However, to change a regulation, the agency whose regulation it is simply enacts a rule change. While these rule changes must be

made in accordance with certain established procedures, the control still rests almost exclusively with the agency. In a real sense, this makes the agency very powerful. Since most of the standards governing breath testing are found in state agency regulations, this constitutes another area of distinction between implied consent and other criminal laws.

EXPERT EVIDENCE AND BREATH TESTING EQUIPMENT

It is important to understand how our current breath testing evidence departs from the ordinary evidentiary rules governing the admissibility of similar evidence. In effect, breath testing equipment offers a measurement of the blood alcohol content of an individual at the time the test is run. Compare this with evidentiary rules governing the normal admissibility of an expert opinion.

Let us take the example of a blood alcohol content result that might be used in a vehicular homicide case. To produce the results of such a test in court, an attorney would offer the testimony, including the qualifications of the technician who ran the test, and, in many instances, testimony regarding the calibration or certification of the blood testing equipment and the way it operates. Additionally, testimony would be presented relating to the way the test was performed, that is, the use of control samples or the like. All of this testimony, offered by a live witness, would be subject to cross-examination as provided for by the Sixth Amendment of the Constitution, which requires both confrontation and cross-examination of witnesses and testimony used against the accused.[3]

Contrast this with our approach in a breath testing case. To begin with, the testing is done by the machine, generally in accordance with administrative rules. Certification and/or calibration procedures used to insure accuracy of the result are represented by documentation as opposed to a live witness. The "expert opinion" of the blood alcohol content, as represented by the breath test result, is offered, in effect, by the machine. Neither the machine nor the documentation relating to its certification or calibration is capable of cross-examination or confrontation. The only live witness is the officer who conducted the test. Generally, unlike a laboratory technician who understands how the equipment reaches its result, the officer is not an expert and cannot be cross-examined on those matters.

We allow this otherwise impermissible procedure due to the inherent reliability of the breath testing process. This is based on the use of proven equipment, checked regularly by competent technicians and operated by properly trained officers in accordance with set procedures developed for the particular piece of equipment. Still, it is a departure from the normal evidentiary rules and constitutional principles.

In summary, each of these variations from expected procedures presents an opportunity for a legal challenge. The following section deals with some of these legal challenges. Some have been resolved, some have not, but they will continue to be raised and it is important to do those things necessary to ensure the continued availability of present breath testing methods.

LABORATORY-RELATED LEGAL ISSUES

BREATH CAPTURE AND EXCULPATORY EVIDENCE

Potential Problems

The defense's right to re-examine evidence to be offered by the prosecution has long been established in the law.[4] In the case of a breath test result, this is not required under present procedures and cases.[5] The principles on which these rulings are based may soon again be called into question. Most of the equipment currently in use can be modified to provide for breath sample capture.

Many states allow a defendant to obtain an independent blood test, thus solving the problems to a great extent. The legal issues are, however, still raised. The court rulings can, and do, vary. Most courts, when presented with evidence of breath capture capability (if it is not required by statute or administrative rule) will declare it to be a matter of weight to be given by the jury to the evidence presented (that is, the breath test results) and allow both the result obtained and the evidence of potential for breath capture. An instruction may be given to the jury as to how to consider this evidence (Appendixes I and II).

It would be possible, however, for a court to exclude the prosecution's use of a breath result based on the unavailability of the sample for retesting. In the context of the trial and a not guilty verdict, the prosecution's appellate review would be severely limited. The possibility might even be dismissed under Brady v. Maryland if it could be shown that exculpatory evidence has been made unavailable to the defense by the government.

Recommendations

Obviously, the problem would be eliminated if police agencies converted to equipment with the breath capture feature. This could be expensive, and smaller agencies might be incapable of financing such a change. The potential problem can more easily be met by providing a statutory right to an independent chemical test (blood, breath or urine) at the request of and paid for by the defendant (Appendix III).

DENTURES, DENTAL ADHESIVES AND RESULT COMPETENCE

Potential Problems

Some work currently being done has shown that tests run on defendants wearing dental appliances (false teeth, bridges or the like) may not be accurate under current standards. Testing procedures require a waiting period after the consumption of alcohol has stopped and before a test is run to ensure that alcohol has been cleansed from the mouth and will not affect the result. Testing has shown that alcohol trapped in a dental appliance can affect the result for up to 25 minutes after ingestion (Appendix IV).

Again, as long as neither statue nor administrative rule provides for the removal of a dental appliance, the more correct legal ruling would allow both the breath test result and the dental information into evidence and would instruct the jury that it is a matter of weight to be given the evidence. It is still possible for a court to reject the breath test on reliability grounds. The same potential difficulty exists when an alcohol based dental adhesive has been used before the test (Appendix IV).

Recommendations

Probably the easiest way to meet this potential problem is to increase the waiting period, based on tests run by individual laboratories using local breath testing equipment. Another possibility would involve a procedural change that would require a test subject to remove dentures before being tested or be deemed to have refused the test. This approach would be cumbersome and might not survive a legal challenge based on an equal protection argument.

In terms of an alcohol-based dental adhesive, closer questioning by an officer as to the time of use and laboratory testing to determine an appropriate waiting period before running a test would obviate the problem. We must also identify those adhesives that have an alcohol base. It is important to remember that no waiting period would be required which would render the test results useless, that is, a period that would substantially diminish the accuracy of the result.

EQUIPMENT CERTIFICATION/ CALIBRATION PROCEDURES

Potential Problems

Because of advances in technology, the years of technical reliability and the government's success rate in trial, the defense has sought new ways to deal with breath test evidence. Some of these approaches have been discussed above. Those challenges do not necessarily require the use of a defense expert and can be raised by simply offering the defendant's testimony, that of a lay witness or cross-examination of a government witness to throw doubt on the reliability of the results. However, other approaches, requiring the use of a forensic expert, are being used.

One of these challenges is to equipment maintenance procedures, including maintenance and certification frequency. This again relates to the contrast between the way we use breath testing equipment and ordinary scientific procedures. For example, a gas chromatograph used to test a blood sample is generally tested with control samples as a part of the testing procedure. Breath testing equipment is usually checked only periodically, pursuant to statute or administrative rule, thus allowing an argument to be made for variances between checks. Experts can be found who will testify that intermittent equipment checking is not a sound scientific procedure. This testimony can be very damaging to the credibility of the government's evidence. Again, the more appropriate court ruling would admit the test result and allow evidence questioning its weight, but the possibility of result exclusion exists.

Recommendations

The basic recommendation is to tighten the certification process by increasing its frequency. This would produce some cost increases and might not be practical in some larger jurisdictions. Another possibility, again at a cost, would involve using a control or simulator solution at the time of each test. At present, a police agency or a state health agency does equipment certifications. The health agency is preferable to the police agency, and an independent technician would be the most effective in terms of the courtroom.

The problem, obviously, is one of the appearance of a conflict of interest, much like a police agency investigating one of its own officers. Finally, a periodic review of regulations and procedures to ensure their currency and accuracy is essential.

OPERATOR PROCEDURES, TRAINING AND COMPETENCE

Potential Problems

In many jurisdictions, questions are being raised relating to officer training and the testing procedures followed. With regard to procedures, some are not current with either the literature or the equipment and are subject to challenges on that basis. The problem with the officer/operator revolves primarily around the certification process. Generally, an officer/operator is schooled and tested once on each new piece of equipment to be used. The individual is thereafter certified.

The courtroom challenge is similar to that used when examining an expert generally. The officer/operator is cross-examined about the time and method of certification and any subsequent training and, finally, is examined from current literature. This is extremely difficult for the witness and substantially weakens the evidence the officer/operator has presented.

Another problem arises when the officer/operator fails to follow strictly the procedures set forth; for example, when he fails to examine a defendant's mouth properly or waits too long before testing. In the latter case, an officer may include in the minimum waiting period the total time spent with the defendant, including that time when the defendant was being transported and sitting behind the officer who was involved in driving the police car.

Here the legal attack can be more devastating. In the earlier examples, weight prevails over admissibility because the regulatory scheme has been complied with and the challenge has asked the officer to go farther than the regulations. The argument made here is that the basic regulatory standards have not been met and, therefore, admissibility may prevail over weight. This varies from court to court and jurisdiction to jurisdiction. If the issue is resolved against the government at pretrial, there is an appeal; otherwise, if during trial, the government must proceed without the test result.

Recommendations

Obviously, procedures must be kept current in accordance with the equipment manufacturers' specifications. This is one of the advantages of controlling procedures based on the regulatory process rather than by statute. Officers should be exposed to continued training and training bulletins. Each state should consider periodic retesting and recertification. This would virtually eliminate the problem.

Controlling the how the officer/operator complies with procedures is somewhat more difficult. The best approach would be to define more clearly the mouth examination and pretest waiting period. For example, the mouth examination should be modified to include the opening, without force, of the suspect's mouth and raising of the tongue. If a suspect resists this process, the problem is the suspect's at trial, for it is the suspect's credibility that will come into question. The pretest waiting period should be defined to be, for example, 15-25 minutes during which the officer/operator remains face-to-face with the suspect, either observing or conversing with the suspect.

RADIO FREQUENCY INTERFERENCE

Potential Problem

It has been argued that certain models of breath testing equipment can be affected by radio frequencies that render the result obtained inaccurate. The challenge can be made by simply cross-examining the officer/operator from the manufacturer's own literature or by producing an expert. The attack generally concerns the weight to be given the result, but an argument can be made for exclusion.

Recommendation

One solution, adopted by Washington State, is to acquire new equipment. Washington will soon have equipment on which a red light activates if radio frequency interference is occurring. Another approach is to specifically test existing equipment with a control sample and common radio frequencies. At least one of the manufacturers supplies a kit to use in such tests—a radio frequency simulator.

CONCLUSION AND SUMMARY

We have advanced from the use of a simple behavioral evidence case to the more complicated and effective breath test machine and presumptive levels cases. Additionally, the law now provides for immediate loss of driving privileges.

The effectiveness of these new laws and the proven reliability of the test results have led to

numerous legal challenges. The fact that the laws involved in Driving Under the Influence cases depart from traditional rules and principles gives some of the challenges real viability. But under the rules governing these cases, each side gives something up, so that the net result is an even one. The law provides defendants with the right to a fair trial, not a perfect one.

APPENDIX I
INTOXILYZER EVIDENCE

In this case, evidence of an Intoxilyzer result has been introduced. To determine if you want to rely on it, you may consider documentation and testimony relating to the machine's accuracy; how the test was performed; the physical condition, appearance and demeanor of the defendant (such as the presence or absence of breath odor, flushed appearance, lack of muscular coordination, speech difficulties, disorderly or unusual conduct, mental disturbance, visual disorders, sleepiness, muscular tremors, dizziness or nausea) and any other evidence that would bear on the accuracy of the result obtained.

The Intoxilyzer result is viewed as expert testimony. As such, you are not bound by it. Keeping in mind the standards I have given you, give it the weight, if any, which you think it deserves.

APPENDIX II
LESS SATISFACTORY EVIDENCE

When you evaluate the evidence, you may consider the power of the prosecution to gather and produce evidence. If the evidence offered by the prosecution was weaker and less satisfactory than other stronger or more satisfactory evidence that the prosecution could have offered, then you should view the weaker and less satisfactory evidence with distrust.

APPENDIX III
ORS 813.150 CHEMICAL TEST AT REQUEST OF ARRESTED PERSON

In addition to a chemical test of the breath, blood or urine administered under ORS 813.100 or 813.140, upon the request of a police officer, a person shall be permitted on request, at the person's own expense, reasonable opportunity to have any licensed physician or surgeon, licensed professional nurse or qualified technician, chemist or other qualified person of the person's own choosing administer a chemical test or tests of the person's breath or blood to determine the alcoholic content of the person's blood or a chemical test or tests of the person's blood or urine or both, for the purpose of determining the presence of a controlled substance in the person.

[1]Schmerber v. California, 384 U.S. 757, 86 S. Ct. 1826 (1966).

[2]Schmerber v. California.

[3]Ohio v. Roberts, 448 U.S. 56, 100 S. Ct. 2531 (1980); Tennessee v. Street, U.S. 105 S. Ct. 2078 (1985).

[4]Brady v. Maryland, 373 U.S. 83, 83 S. Ct. 1194 (1963).

[5]People v. Hitch, 119 Cal. Rptr. 9, 527 P2d 361 (1974); California v. Trombetta, U.S. 104 S. Ct. 2528 (1984).

APPENDIX IV

Form 8

MEMORANDUM

OREGON STATE POLICE

January 11, 1985

~~Salem~~ Portland

To: Captain R. D. Brooke

From: Lieutenant G. A. Knowles

Reference: Alcohol Containing Denture Adhesive / Intoxilyzer

Recently it had been brought to the attention of the Crime Laboratory Division that certain denture adhesives contain ethyl alcohol which may cause a positive reading on breath testing equipment for measuring alcohol in the blood.

This member purchased ½ ounce tubes of "Cushion Grip," a thermoplastic denture adhesive distributed by Plough, Inc., Memphis, Tennessee. The information listed on the container states that a single application lasts up to four days of daily cleaning, soaking and brushing. It is further stated that it does not wash off in water even after repeated cleaning and the adhesive remains soft and pliable recreating a secure seal each time dentures are inserted.

No contents are listed with the product. Analysis of the transparent orange adhesive revealed the presence of ethyl alcohol. The extreme cohesiveness of the material prevented quantitation of the alcohol present.

Breath tests were performed using two ½ ounce sizes of "Cushion Grip" brand denture adhesive, a C.M.I. Intoxilyzer Model 4011-A, and an adult male subject with upper and lower dentures. The Intoxilyzer was certified accurate 22 minutes before testing and values were .01% below expected values from test solutions. The tests were conducted on January 9, 1985 at the Portland Crime Laboratory by this member and Senior Trooper Richard Gray.

For the following tests, the Intoxilyzer was purged at least one time using the "air blank" mode between each breath test. Results are in percent blood alcohol by weight as registered on the Intoxilyzer.

Test #1 Breath test with dentures but without denture adhesive.

Results
.00

Test #2 Breath tests with ½ ounce (one tube) of adhesive used for both upper and lower dentures. The denture adhesive was applied as per directions. The directions require the sealed tube be heated in hot water for five minutes and that a period of five minutes pass after placement of the adhesive on the dentures and prior to inserting into the mouth.

Test #2 (continued)

Time	Results
Immediately after inserting	.00
5 minutes	.02 - .01 (while blowing)
10 minutes	.02
15 minutes	.02
20 minutes	.01
25 minutes	.02
30 minutes	.00
35 minutes	.00
40 minutes	.00

Test #3 Breath tests immediately after Test #2 with the dentures and adhesive removed from the mouth and the mouth kept closed between breath samples.

Time	Results
Immediately after removal	.02
5 minutes	.00
10 minutes	.00
15 minutes	.00

Test #4 After completion of Test #3, the dentures with the adhesive used in Test #2 were replaced into the mouth and the subject rinsed his mouth with a solution of 75% by volume (150 proof) ethyl alcohol.

Time	Results
With dentures and reused adhesive but prior to rinse	.00
Immediately after rinse	.48 (no printout)
5 minutes	.22 - .19 (while blowing)
10 minutes	.07
15 minutes	.02
20 minutes	.02 - .01 (while blowing)
25 minutes	.00
30 minutes	.00

Test #5 Using most of a new tube of adhesive without waiting the five minutes setting time before insertion into mouth and breath sample taken immediately.

Results
.00

Test #6 After completion of Test #5, the dentures and adhesive were removed.

Time	Results
Immediately after removal	.04
5 minutes	.00
10 mintues	.00
15 minutes	.00

Test #7 After completion of Test #6, the dentures with the adhesive used in Test #5 were replaced into the mouth and the subject rinsed his mouth with a solution of 50% by volume (100 proof) ethyl alcohol.

Time	Results
Immediately after rinse	.48 (no printout)
5 minutes	.20 - .18 (while blowing)
10 minutes	.09 - .07 (while blowing)
15 minutes	.04
20 minutes	.02
25 minutes	.03
30 minutes	.03
35 minutes	.01
40 minutes	.01 - .00 (while blowing)
45 minutes	.01 - .00 (while blowing)
50 minutes	.00
55 minutes	.00

Test #8 Breath samples taken with dentures but no adhesive present and with the subject rinsing with 50% by volume (100 proof) ethyl alcohol.

Time	Results
Immediately after rinse	.48 (no printout)
5 minutes	.15 - .13 (while blowing)
10 minutes	.05 - .04 - .05 (while blowing)
15 minutes	.01 - .00 (while blowing)
20 minutes	.00

Test #9 This member placed approximately two grams of adhesive in his mouth. During this test, the material was chewed like gum.

Time	Results
Immediately after placement	.17 - .15 (while blowing)
5 minutes	.26 - .25 (while blowing)
10 minutes	.18 - .17 (while blowing)
15 minutes	.09 - .08 (while blowing)
20 minutes	.06
25 minutes	.05 - .04 (while blowing)
30 minutes	.04
35 minutes	.05
40 minutes	.03
45 minutes	.02 - .01 (while blowing)
50 minutes	.01
55 minutes	.00
60 minutes	.00

Conclusions:

It is first of all difficult to draw conclusions from only one test per experiment. Obviously, many more repeditive tests with a number of test subjects should be performed prior to making generalizations. Also, it would seem that the effects of a variety of denture adhesives should be examined as it is apparent that other denture adhesives contain ethyl alcohol (See memorandum dated January 4, 1985 by Criminalist IV S. G. Snider, RE: Denturite).

Based on the results of these tests, it has been shown that; 1) the presence of an ethyl alcohol containing denture adhesive can produce a reading on the Intoxilyzer for a period beyond 15 minutes (i.e. 25 minutes in Test #2); 2) an alcoholic beverage introduced with recently applied denture adhesive containing ethyl alcohol increased the length of time that the adhesive effects an Intoxilyzer reading (i.e. 20 minutes in Test #4 and 35 to 45 minutes in Test #7); and, 3) the presence of dentures without denture adhesive may retain alcohol in the mouth as long as 15 minutes (i.e. Test #8).

From the results of Test #2, it seems that the alcohol in the adhesive slowly releases into the mouth and affects the reading for a period of at least 25 minutes. The presence of the dentures themselves may prevent trapped alcohol in the adhesive from giving a reading. There appeared to be residual alcohol in the mouth immediately after the dentures and adhesive were removed, but had no effect five minutes after removal (Test #3).

From Tests #4, #7, and #8, the increased time that alcohol effects the Intoxilyzer may be due to trapped alcohol behind the dentures or trapped into the adhesive or denture material itself.

The value of such tests as Test #9, where a portion of ethyl alcohol containing denture adhesive is placed in the mouth without dentures and allowed either to be sedentary or chewed, has little bearing on determining the effect of denture adhesives on breath testing equipment results. The differences in results from tests with dentures (Tests #2, #4, #5, and #7) and tests with only adhesive (Test #9) are evident. Having a situation where only adhesive and not dentures in the mouth is not common and studies performed under such conditions should not be considered valid.

In overcoming possible problems in D.U.I.I. cases, it may be necessary to query defendants as to their use of dentures including the time of insertion or consider dentures as a foreign material and have them removed prior to a breath test.

GAK:aef

cc: Major R. Verbeck
Captain T. Drynan

THE PHARMACOLOGY OF ETHANOL AS IT RELATES TO THE OPERATION OF A MOTOR VEHICLE

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Ethyl alcohol was the first compound intuitively made by man. The inevitable fermentation of gathered and stored fruit must have been a gastronomic annoyance when it became a sole source of food. Hunger-driven consumption of spoiled fruit caused intoxication to accompany the unaccustomed and unwelcome taste. This effect, soon associated with the juice, ultimately became the most appreciated attribute of the fruit. The chemistry of the alcohol was unknown for centuries after its deliberate, though unrecognized, preparation. Fermented fruit and juice were either incorporated into social and religious practices or they were banned by nearly all civilizations. There could have been many philosophical reasons for this prohibition. Whatever they were, they have proven to be more effective than the current focus on safety and health to reduce its consumption.

The sensual pleasure alcohol can produce easily accounts for its popularity. The rationale for the early opposition to it is obscure. Its acute effects may have been offensive, but the consequence of its long-term use was unknown. Drinking alcoholic beverages has been customary for all those who participated in the industrial revolution, the results of which, ironically, have provided the most cogent reasons for its restricted use.

Any effort to prohibit or control the use of alcoholic beverages must recognize its general acceptance. This complicates any plan to cope with the problem it generates. Laws created to guarantee the general welfare must have the approval and/or acquiescence of the majority or they will be ineffective.

If total abstinence from drinking cannot be achieved, the logical compromise is either to prohibit its use or teach the reasonable consumption of ethanol. In either case, the interlocking issues must be understood before the problems can be solved.

Ethyl alcohol is a small, water soluble molecule. It has no reactive groups or configurations that would influence its absorption, distribution or elimination or its effect on the body. The absorption of ethanol into the body obeys principles of simple diffusion. The rate of migration of this alcohol into or within the body is dependent on its concentration in the fluids on either side of a membrane and the nature of the membrane. Its movement depends on its tendency to equilibrate its concentration in the body's water. The equilibration is dynamic rather than static. Because ethanol continuously disappears from the body, its migration across internal membranes is also continuous to maintain uniform concentrations. The movement of body fluids can be rapid. The body's blood passes through the heart in seconds. Therefore, the equilibration of ethanol in body fluids can be rapid and nearly perfect. The tissues supplied by body fluids will also reach near perfect equilibration at a time that depends on their vascular network. Brain tissue will be permeated with ethanol in seconds. Muscle, not as well supplied with blood, will require many minutes for near perfect equilibration. As ethanol is absorbed from outside the body, body tissues will gain ethanol. When this absorption rate of ethanol can no longer exceed the disappearance rate, the concentration of ethanol in body fluids will decline. The action to maintain a uniform concentration will continue until all body fluids have, essentially, zero ethanol.

Unquestionably, ethanol could be absorbed into the body in amounts too small to be easily estimated. Ethanol could be generated within the body in amounts too small to be measured or to have a measurable effect. To alter driving performance significantly or be subject to practical analysis, the concentration of alcohol in body fluids should approach 0.05%. To reach such a concentration, the rate of absorption of ethanol must exceed the rate of its disappearance.

Whether or not ethanol can be absorbed through the intact skin is of academic interest only. Repeated studies have shown that the absorption of ethanol through the intact skin could not be demonstrated by blood analysis. Through broken or scarified skin, the likelihood of demonstrable absorption increases but would be of no practical significance for a Driving While Intoxicated (DWI) charge.

Ethyl alcohol can be absorbed through the lung if it is present in inspired air. The lung has a large surface area and a rich blood supply. It is designed for the rapid exchange of gases and low molecular weight compounds like carbon dioxide, water, oxygen and ethanol. In addition to the action of simple diffusion,

ethanol and water are infinitely soluble in each other. Equilibration of ethanol between alveolar breath and blood would be very rapid. The system is limited by the low continuous concentration of ethanol which could be maintained in the alveolus. Ethanol is irritating to breathe if the inhaled concentration exceeds 15 mg per liter. A very rapid respiratory rate would approach 20 liters per minute. At this rate of respiration, if air with an ethanol concentration of 20 mg per liter were inhaled, 12 mg would be absorbed via respiration, and it would require 4 or more hours to acquire a blood alcohol concentration (BAC) of 0.10%. This assumes no elimination. Actually, the average man could eliminate ethanol at a faster rate. Therefore, under these extreme conditions, ethanol could not be accumulated in this way by most people.

If an alcohol-free individual gargles with a distilled alcoholic beverage or simply holds a teaspoonful of it in his mouth, it will be absorbed so rapidly that within 20 minutes it cannot be detected on the breath. This also applies to ethanol that may be a contaminant in the mouth from alcoholic solvents or antiseptics. A subject who is to have his BAC estimated from a breath analysis should not have any foreign material in his mouth for 20 minutes before the breath sampling. This interval would be adequate to clear the upper respiratory tract of any interfering substance by normal breathing and absorption.

Ethyl alcohol is commonly consumed, and its absorption takes place via the gastrointestinal tract. The stomach is a thick-walled, pouch-like organ with a blood supply designed to serve its nutritional needs but not meant for the rapid absorption of its contents. Water and ethanol are among the relatively few substances that can be absorbed from the stomach. Food causes the pyloric sphincter to close, allowing time for digestive juices, secreted from the stomach walls, to be mixed. If alcohol is taken on an empty stomach, it may pass readily into the small intestine. If its concentration exceeds 25%, it may be irritating and its passage slowed. The presence of carbohydrates in the drink may also retard its movement to the duodenum. Usually, no more than 20% of the ethanol in a single swallow is absorbed from the stomach. The presence of food, requiring digestion time, will cause alcohol to be retained for a longer period and further delay its absorption. The presence of fatty foods also slows the emptying time of the stomach, due in part to the longer digestion interval required. Many factors can affect the time an alcoholic beverage will remain in the stomach, influencing its absorption rate.

The duodenum, the upper portion of the small intestine, is designed for the rapid transfer of diffusible material to the bloodstream. Although it is relatively short, it has a rich blood supply to the villi in its lumen. The villi are folded membranes that increase the inner intestinal surface. The effective absorptive area of the mucosa of the small intestine may be 250 square meters, explaining the rapidity with which diffusible materials can enter the bloodstream. It is not surprising that approximately 80% of the alcohol from a drink is absorbed from the upper small intestine. The speed with which ethanol can be absorbed is quite variable and may range from 30 minutes to 3 hours, depending on the nature of the drink and the presence and nature of the food accompanying or already present in the gastrointestinal tract. Many factors influence the rate of absorption of ethanol, but few, if any, can be quantitated. This problem is further complicated by the inherent differences between people and their responses to their surroundings. Such variables are in addition to those of sex, age and state of health. Based on a best estimate, the assumption that ethanol from a drink will be absorbed in 1-2 hours is appropriate for legal purposes when precise information is not available. However, the limitations of such an estimate must be understood.

Ethanol is absorbed so efficiently that none will be found below the duodenum after a drink. Intestinal contents may contain alcohol rediffused after primary absorption. Once absorbed, ethanol dissolved in blood will be circulated throughout the body. As it passes through organs and muscle, ethanol will diffuse as before. Those parts of the body with the richest blood supply will come to equilibrium with the blood the quickest. Thus, the brain will be in equilibrium much quicker than will muscle. By the time the gastrointestinal contents have equilibrated with the blood as regards ethanol, equilibration will have become near perfect throughout the body's water. The time for this equilibration tends to parallel the time required for absorption. Because of the nature of circulation, arterial blood, brain and lung tissue equilibrate first. Even though the concentration of ethanol in visceral blood continues to rise during the absorption phase, its concentration in pulmonary blood will continue to approximate that in the brain. For this reason, a breath test for ethanol may be superior to direct blood analysis during this time. The peripheral venous blood, returning to the heart, will have released much of its alcohol to the tissue water to which it has been exposed. Therefore, it may lag behind that in arterial blood supplying the brain and lungs. A peripheral venous blood analysis for ethanol may not reflect the concentration in the brain well enough for a satisfac-

tory interpretation of an observed effect to be made. Under these circumstances, the concentration of ethanol estimated from breath analysis, in spite of the inherent disadvantages, will be the most reliable indicator of a DWI offense.

Ethanol can be absorbed from the large intestine as well as from the vagina. These routes should not be overlooked in a medicolegal investigation. Deaths have occurred from acute intoxication resulting from an alcohol douche.

The filtering area of the kidneys is approximately 2 square meters and is permeable to both water and urea. Ethyl alcohol has a molecular weight and size between the two. The kidneys receive about 25% of the cardiac output. The filtering unit, the nephron, is well supplied with capillary beds. Therefore, it is reasonable to assume that urine, formed in tubules from glomerular filtrate, is in near perfect equilibrium with plasma water as regards ethanol. The volume of urine which reaches the bladder per minute can vary widely. It will depend on the need to eliminate or conserve water and to excrete metabolic end products.

The concentration of ethanol in blood plasma is constantly changing due to its rate of accumulation from the gut and its rate of disappearance. Each drop of urine formed will vary in its ethanol content with that in plasma. Since alcohol can diffuse freely to and from circulating fluids and tissues, its concentration in one can be measured in the other. Ethanol, in bladder urine, is literally stored away from the body. Once in the bladder, it cannot readily diffuse. The concentration of ethanol in urine, at any given time, is a poor indicator of its concentration in circulating fluids or tissues. Any urine assay for ethanol will, at best, be a measure of the average concentration in the urine that has been secreted. If the sample collected has been diluted with urine processed before ethanol consumption began, its analysis for alcohol could only reveal whether it had been consumed. Urine tension on the smooth muscle wall of the bladder triggers micturition or, at least, the desire to urinate. The act is voluntary, and one could be ordered to evacuate the bladder so that a specimen of currently processed urine might be collected. The unpredictable specific gravity of the urine sample must be recognized. Finally, the analytical value should be related to a BAC if it is to have any interpretive value. The relationship between a BAC and measurable impairment is not scientifically quantifiable, but it is satisfactory and reasonable for legal purposes, even if it is estimated by breath analysis.

Every route of absorption for ethanol will diffuse it into the bloodstream where it will be rapidly transported to all parts of the body. En route, it will diffuse out of the blood into the water of the tissues. The body parts with the best blood supply will also have the most alcohol. The same logic that explains the absorption of ethanol from outside the body into its cardiovascular network applies to the diffusion of alcohol out of the blood. The forces that disperse the alcohol are inversely proportional to the proximity to true equilibrium. Perfect equilibration of ethanol in body water cannot be achieved. It is controlled, in part, by the absorption and elimination process for ethanol. Other transmission variables such as membrane characteristics and flow rates of body fluids will be influential, but to an unknown degree.

Since ethanol tends to equilibrate with all body water, it is possible to estimate the concentration of ethanol in one part from an analysis of another. The relationship will be most accurate if the absorption of alcohol is nearly complete. This can and should be tested in postmortem cases by an analysis of stomach contents. In any event, the analytical result should not be too high. Any error would be on the low side, if absorption was incomplete and the body was intact. In fatal accidents, the possibility of unabsorbed alcohol from the stomach contaminating a blood specimen must be considered.

Although the concentration of ethanol in body fluids is constant or declining, the total amount present can be estimated. It may be assumed that bone, fat and minerals in the body will not contain much alcohol during intoxication. Infants may have as much as 75% of their total body weight in water. Water content will decline with age. An obese person may have only 45% of his total weight in water. Women are apt to have a higher percentage of their total body weight in fat and, thus, less total body water. A man of average build, weighing 150 pounds, may have 60% of his weight in water. If his BAC is 0.10%, the concentration of ethanol in his body water may be approximately 0.12%. If so, this would indicate the presence of approximately 2.2 ounces of ethanol at the time of measurement. The percentage of body water is unpredictable and may be quite variable. In any specific case, such an estimate would probably be less precise.

To attain the BAC determined, the subject would have to consume and absorb the estimated amount of ethanol corresponding to the amount that disappeared during the drinking and absorption phase. Unless several, well-spaced BACs are determined, the time required for nearly complete absorption will not be known. In spite of the many variables, an estimate of the amount of ethanol consumed could be used to test

the reliability of a subject's recollection. This would be its only legitimate purpose.

As soon as ethanol enters the circulation, it begins to leave the body. An adult can lose 2-3 liters of water per day without exercise. Moisture leaving the body will have the same ethanol concentration found in circulating fluids. Therefore, only a small fraction of the absorbed ethanol can be eliminated unchanged.

Most of the beverage alcohol absorbed into the body must be destroyed by enzymatic degradation. The liver receives approximately 35% of the total cardiac output via the hepatic artery and hepatic vein, which also serve the stomach and duodenum. The liver is quickly supplied with blood enriched with newly absorbed ethanol so that its enzymatic pathway for ethyl alcohol metabolism is quickly saturated, permitting the maximum disappearance rate to be effected quickly. The principal pathway uses alcohol dehydrogenase (ADH), a zinc-requiring enzyme, to remove hydrogen and nicotinamide adenine dinucleotide (NAD) as a hydrogen acceptor. The acetaldehyde that results from this reaction is further oxidized to acetic acid (which joins the acetate pool) and to acetyl coenzyme A (a cofactor for an acetylation reaction in the tricarboxylic acid cycle). Eventually, the carbon and oxygen can be traced to carbon dioxide and the hydrogen to water. A serious consequence of prolonged heavy ethanol use is the excess hydrogen that is produced. The liver requires hydrogen as an energy source, but it can derive approximately 75% of its needs from the metabolism of ethyl alcohol. The energy from ethanol cannot be stored, so its use must be immediate. Excess hydrogen can react with pyruvate to produce lactate, which decreases uric acid excretion by the kidney. If excess uric acid accumulates in joints, a gouty condition can result. Pyruvate is usually converted to carbohydrates. If the diet is inadequate, when glycogen stores are depleted, hypoglycemia can occur, simulating or exaggerating clinical signs of alcoholic intoxication.

The rate at which ethanol disappears from the body may vary in a given individual over the course of his life, depending on his age, the extent of his alcohol use and the state of his health. On a day-to-day basis, the rate of disappearance may be reasonably predictable, but the variables between subjects can greatly exceed that in a single subject. The rate of disappearance has been identified, in the case of blood, with the Greek letter beta (β), and an average value of 0.015% per hour is often cited. This number has been derived from test groups that were not selected to represent the general population or any segment defined in terms of age, sex or health. Groups of men and groups of women were tested independently but were probably chosen for their availability. The range of values which have been quoted for beta extends from 0.010% per hour to 0.030% per hour. A few instances have been reported in which beta was as low as 0.008% per hour or as high as 0.040% per hour. Such a wide range in values for beta is to be expected in a heterogeneous population. All the data reported would probably fall on a Gaussian distribution curve with 90% of the values ranging from 0.015% per hour to 0.020% per hour, inclusive. For most people, the total loss of ethanol from the body per hour would range from 0.33 to 0.44 ounces per hour. From this assumption, the number of ounces of a given alcoholic beverage required to produce a given BAC could be estimated as a range. Given the sex, weight and age of an individual, the reliability of the estimate could improve. The estimate would, necessarily, assume that the ethanol began disappearing from the body at a given rate from the moment of the first drink and would continue at this pace until the body sample was collected for the BAC estimation. With all the possible variables, it would be difficult to estimate a BAC that occurred before or after a blood analysis. To take full advantage of both science and the law, we should define a DWI offense in terms of a BAC estimate, by an approved procedure, within a reasonable time frame relative to the arrest incident.

The presence of ethyl alcohol in the brain depresses its activity. This effect is initiated with the first molecules of the alcohol to enter. Once this toxicant is in, the individual is intoxicated. Thus, by establishing the presence of ethanol in the blood, by definition, we also establish intoxication. The degree of intoxication depends on the concentration of ethanol in the blood. An empirical BAC value should be picked as an offense indicator.

Subjectively, most individuals can detect the effect of ethanol at a BAC too low to produce any objective evidence of intoxication. Ethanol may dilate skin capillary vessels in the scalp or face, resulting in a warm feeling. Nervous tension may be relaxed perceptibly and a pleasant degree of euphoria experienced. Ethyl alcohol can stimulate the flow of gastric juices and initiate or stimulate an appetite. These responses to the action of ethanol can occur at a BAC of 0.01%, a concentration at which time impairment in mental performance can be measured only by the most sophisticated experimental protocols.

As the concentration of ethanol rises in the blood, the effect of the alcohol on the body increases. A BAC of 0.08%, estimated from breath analysis or direct blood analysis, has been associated with a decrement

in the mental and motor skills needed to operate a motor vehicle. This finding has been confirmed by many workers in both laboratory and road experiments. Many surveys of drivers' BACs in both fatal and nonfatal accidents are in agreement. The argument that there is no individual tolerance, regardless of one's previous experience with drinking beverage alcohol, has never been seriously challenged. In spite of the many imponderables inherent in measuring body fluid alcohol and relating it to driver impairment, making a BAC of 0.10% unacceptable in the driver of a motor vehicle is legally sound and scientifically defensible.

If high concentrations of ethanol in a beverage are consumed on an empty stomach, nausea and vomiting may result from its direct irritation. Usually, nausea and vomiting result from the central effect of ethanol on the vomit center in the medulla, triggered from the stomach and/or the duodenum. This center can be activated with a rapidly ascending BAC when it reaches approximately 0.12%. In the presence of a BAC higher than this, the vomit center may become inactive and, if additional alcohol is imbibed, a BAC of 0.35% or more can be reached and the respiratory center blocked. Although most people will die from respiratory depression with a BAC of 0.55%, some will succumb from much lower values. Survival has been reported following a BAC of 1.0% and more. However reliable these figures are to predict a fatal outcome from alcoholic intoxication, a valid observation can be made. The effect of any chemical on any given individual can vary unpredictably in both degree and character, and ethyl alcohol is one of the most variable.

Ethyl alcohol blocks many of the natural restraints to overdosing. It induces a pleasant response, allays caution, and impairs judgement. Serious, predetermined intentions not to overindulge may be frustrated by the social drinking environment, as well as by the first drink or two. Dissolute drinking often precedes motor vehicle operation.

Ethanol can produce relatively minor effects in some body systems. A BAC of 0.30%-0.40% can be associated with a rise in heart rate, but usually it will fall. Blood pressure will fall with a BAC of 0.40% or more, probably due to vasodilation. Most central nervous system (CNS) depressants do not reduce blood pressure. In this case, it may be due to the metabolic release of acetaldehyde, a known vasodilator. The effect of alcohol is more critical on respiration than on the cardiovascular system.

Ethanol acts directly on the *medulla oblongata* and *pons* of the brain to depress respiration. The effect can be life-threatening with BACs exceeding 0.25%. Respiratory depression is a common cause of acute alcoholic death.

Ethanol may interfere with the release of the antidiuretic hormone. This would increase the permeability of the terminal kidney tubule to water and urea, resulting in diuresis.

Ethanol interferes with brain activity and thus can influence standing, walking or turning steadiness. Nystagmus is an arrhythmical oscillation of the eyeballs. It is related to disturbance in the inner ear which can be caused by absorbed ethanol. Nystagmus can be a symptom of a number of medical conditions, including alcoholic intoxication. In the case of ethanol, movement of the eyes may be rotatory if the subject is looking straight ahead, jerky if tracking is attempted or up and down if the person is lying on one side. Nystagmus, when produced by causes other than ethanol, can be responsible for slurred speech, nausea, incoordination and headache. It is evidence of alcoholic intoxication, but it is not diagnostic.

Ethanol's most profound effects are centered in the voluntary nervous system. The simple dulling of sensory input by a low concentration of ethanol in the brain can isolate the subject from perceived distractions. A sense of trouble-free well-being will modify aggravations. Sensitivity to the setting encourages the drinker to reflect its mood. Instinctive behavior tends to dominate conduct. The changes in attitude, perception and judgment can alter skilled performance in a manner difficult to assess. As the concentration of ethanol in the brain increases, all of its effects become more profound. Once subtle errors in driving practice may become recognizable. The sense of caution that may be natural is opposed by an alcohol-supported conviction of overconfidence. As a result, the individual may accept risks or challenges that he would not have considered when alcohol free. Being less alert as a result of his CNS depression, he may overlook important clues that could assist or guide his performance. The time needed to recognize the significance of perceived signs will increase, as will the time required to respond. Impaired judgment will influence the option elected and will reflect the action of an alcohol-clouded brain. Thus, any decision may be questionable. Any impairment in brain function imposed by alcohol will have an exaggerated effect if the subject must respond to a sudden, unexpected event. Mental impairment, due to ethanol, will affect behavior and performance when the concentration in the

brain is low. Mental impairment associated with a BAC of 0.10% is more likely to cause a motor vehicle accident than would the accompanying motor incoordination. As the BAC rises, it will continue to affect the brain's ability to cope with sensory information. Muscle response delay will increase, as will its contribution to accidents. With a BAC of 0.25%, many people will exhibit public intoxication.

Several other important factors must be considered. The literature of the last 10 years suggests that everyone's driving performance declines when a BAC of 0.08% is reached. However, the degree of impairment will not be known. A standard operating procedure (SOP) has not been defined for a sober driver. An unacceptable driver impairment (UDI) has also not been defined. Unquestionably, there are properly licensed, sober drivers who are unable to drive as safely or as well as a counterpart who has a BAC of 0.10%. Fatigue, preoccupation or transient illness in a driver may render him as incapable of safe driving as a BAC of 0.10%. Circumstances surrounding the driver, the condition of the road, weather or the automobile can create hazards. Any of these factors will be exaggerated if the driver has consumed ethanol. There are no legally defined, minimum standards of driving proficiency, either a SOP or a UDI. Some jurisdictions have defined two offenses with different penalties based on a BAC. In general, the degree of impairment cannot be objectively measured and compared with a standard. There is no question that impairment of skills related to driving can be measured in most, if not all, individuals who have a BAC of 0.08% or more. Thus, any arbitrary BAC of 0.08% or more is adequate to be included in a *per se* or *prima facie* law.

When breath or blood tests for ethanol are properly administered, and approved instruments and procedures are used, they can establish ethanol presence at the time of specimen collection with a high degree of reliability. The degree of impairment associated with ethanol consumption can be discussed only by an appropriate expert who has all the necessary information. A ballistics expert can identify a bullet, but only the forensic pathologist should discuss its implication.

Ethanol is ubiquitous. The rate at which it can be absorbed into and eliminated from the body is not uniform. Its influence in the body is varied and often unpredictable. The effect of a given BAC may be different in different subjects and in the same subject at different times. Aside from establishing the presence of ethanol, analytical results should not be scientifically interpreted in a law. The pharmacology and toxicology of ethyl alcohol support this position.

DISCUSSION

Forney: He asked if you would expect an appreciable blood alcohol concentration for someone who rubbed DMSO on the skin. I do not think so.

Question: Will DMSO affect the rate of dissipation or anything?

Forney: I have never really tested it, but I do not think so. Perhaps Kurt Dubowski would know of any reason why DMSO would alter metabolic rate.

Dubowski: It does not induce the enzymes.

Forney: Yes, I would not think it would have any effect.

Question: What sort of lag time would you expect between the vitreous humor alcohol reaching its peak and the blood alcohol reaching its peak after ingestion has ceased?

Forney: I have had bad luck trying to correlate vitreous humor with blood. This is partly explained by the relatively poor circulation in vitreous humor, so it takes a while for it to equilibrate. Usually lag time is about 80% in my laboratory, based on a water content with plasma.

Question: Since nisfunction oxidase and cytochrome P450 play a role in the metabolism of ethanol, how much effect would the induction or reduction of these enzymes by drugs have on the metabolic rate of alcohol?

Forney: Kurt Dubowski will probably discuss that, but the microsomal enzyme oxidase system does not function until the concentration is fairly high, and it accounts for a relatively small percentage of the total metabolism, so it is strictly an ADH rate. There are two or three other enzyme systems that have been identified as handling alcohol, but I think they take a relatively small part of the alcohol.

Mayer: What is your opinion of the validity of the relationship of saliva alcohol levels as compared with blood alcohol levels?

Forney: We have had poor luck correlating saliva with blood on a water basis. It is quite valid to identify

the presence of alcohol if the saliva is properly collected, but I can not comment on the correlation. What few we have done are not good.

Question: Is it a good idea to equate saliva testing with blood alcohol?

Forney: There are some other interesting ways of doing this by simply putting a cup on the skin. You essentially set up a head space and then can analyze the gas in the cup. A good correlation is obtained within 2 or 3 minutes. The air sample in the cup is saturated because alcohol dissipates through the skin.

BLOOD, BREATH AND URINE ALCOHOL CORRELATION, INTERPRETATION AND APPLICATION TO CHEMICAL TEST PROGRAMS

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Blood, breath and urine alcohol tests are practical and effective parts of a properly administered and coordinated Driving Under the Influence (DUI) enforcement program. However, little reliable information exists on the acceptability of the chemical test methods and procedures forensic scientists and administrators use to structure effective chemical test programs. Unfortunately, there is much false and misleading information about the precision and accuracy of contemporary chemical test methods and procedures, and the practical advantages or disadvantages of one sample type (that is blood, breath or urine) versus another.

We often hear that direct blood alcohol tests are more accurate than breath or urine tests in determining a blood alcohol concentration (BAC), that urine alcohol tests are not valid for determining an equivalent BAC because of the variability in the blood-to-urine alcohol conversion ratio and that breath alcohol tests are not valid for determining an equivalent BAC because of the variability in the blood-to-breath alcohol conversion ratio. In the following pages, I will examine and compare actual case results generated by the alternative chemical test methods and procedures in terms of their ability to meet the operational needs of an effective and impartial DUI enforcement program.

I wish to emphasize two key words—procedure and program. Methods for quantitative alcohol analysis which are potentially accurate, precise and cost effective can be rendered ineffective when applied without adequate standards of procedure. For example, only a single breath sample is normally used for a quantitative BAC, although replicate analysis is universally accepted in the scientific community. The same method should be required to validate all quantitative breath alcohol tests.

The word program is significant because no single method, procedure or sample type will provide all the information needed for an effective chemical test program. To have a good program, the analytical methods, standards of procedure and authorizing statutes selected for structuring a chemical test program must interact to provide maximum investigative and statutory information in the most efficient and economic manner—all within the legal constraints of our judicial system. These problems are discussed by Biasotti (1984).

DIRECT BLOOD ALCOHOL TESTS

The direct analysis of blood and its interpretation in terms of driving impairment has been universally established and accepted in our judicial system and presents few practical problems for the analyst or the prosecutor, as shown by the relatively small number of contested cases involving direct blood tests. Direct analysis of blood samples is the standard by which other methods and procedures for alcohol analysis are judged.

ADVANTAGES AND DISADVANTAGES OF DIRECT BLOOD ALCOHOL TESTS

Numerous validated analytical methods and procedures provide the requisite precision and accuracy. Alcohol in the blood circulation has been definitively related to driving impairment. Blood samples allow for the reanalysis of alcohol or drugs when indicated.

However, personnel qualified to obtain blood samples are not generally available near the place of arrest. A BAC result is not immediately available for the investigating officer to consider before appropriate action, such as arrest and detention, release or obtaining medical assistance, is taken. Blood sample withdrawal is medically contraindicated for some persons and is an intrusive procedure that is objectionable to many subjects.

URINE ALCOHOL TESTS

Urine samples, though equal to blood in terms of the ability to quantitate the BAC in a specimen, may present some interpretative problems because, like breath, urine is an indirect means of determining an equivalent BAC. This interpretative problem is more theoretical than practical, provided proper sampling procedures are followed. Determining blood alcohol concentrations from urine samples as a practical equivalent or alternative to blood and breath alcohol

tests is the subject of a comprehensive review paper by Biasotti and Valentine (1985).

The authors conclude that urine tests are a reliable and accurate alternative to direct blood tests when a second sample collected within 1 hour of voiding is provided by a cooperative subject and converted using a urine-to-blood ratio of 1.3:1. The following recommendations have been made as a result of this review:

1. A second urine sample taken at least 20 minutes to 1 hour after first voiding the bladder should be used to determine an equivalent percent BAC.
2. To further validate the accuracy of a BAC determined from the urine sample taken after first voiding and to determine if the BAC has increased or decreased during the time between voiding and the second urine sample, at least a 3-ml portion of the void urine sample should be collected, analyzed and reported together with the second urine sample results.
3. A urine/blood conversion ratio of 1.3:1 should be routinely applied to all urine samples in determining an equivalent BAC; however, for the purpose of legal argument, it should be conceded that a reasonable potential variation of up to 1.5:1 could apply in some cases.

ADVANTAGES AND DISADVANTAGES OF URINE ALCOHOL TESTS

As a nonintrusive sample, urine is available without compulsion or recourse to medical personnel. Urine samples can be preserved, allowing for a referee analysis in contested cases. Urine can be analyzed for the presence of other drugs or intoxicating substances, or both.

However, the 20 minutes to 1 hour waiting time to collect samples is inconvenient for the investigating officer. Also, many investigating officers find it repugnant to witness and collect urine samples.

BREATH ALCOHOL TESTS

Because breath alcohol tests are nonintrusive and provide immediate results, they are the most frequently administered chemical test for alcohol in the United States, but, because of the following inherent attributes, they are the subject of the most debate and controversy in the scientific community and in the courts:

1. Breath alcohol tests are an indirect means of determining an equivalent BAC.
2. Breath tests are generally performed by nonscientific personnel.
3. There is a perception that breath tests are performed by a black box that is susceptible to undetected error.

Issues used to discredit the reliability and accuracy of breath alcohol tests as performed by evidential breath testers (EBTs) to determine an equivalent BAC can be categorized into five main issues:

1. The ratio used to convert a breath alcohol concentration (BrAC) to an equivalent BAC.
2. The specificity of the method used to distinguish alcohol from other possible volatile compounds that could exist in breath samples.
3. Random error caused by intermittent malfunction or failure of an evidential breath test instrument.
4. Preservation of breath samples for referee analysis.
5. Falsification of test results by a breath test operator.

Of these five issues, the first is the most contentious and critical to establishing the validity of breath alcohol tests. Issues 2-5 have been reviewed and addressed in the paper by Biasotti (1984). The second issue has further been definitively addressed as a nonissue in papers by Dubowski and Essary (1983; 1984).

Because the use of breath alcohol tests as an equivalent or alternative to direct blood tests depends on correlation between near simultaneous direct blood and indirect breath alcohol tests, we must understand how the currently accepted average ratio of 2100:1 was established and the practical significance of differences that could occur in an equivalent BAC obtained when this average ratio is applied to individual subjects.

The 2100:1 alveolar breath/blood conversion ratio has, since 1950, been the accepted standard for the calibration of all EBTs designed to analyze alveolar breath samples to determine an equivalent BAC. This ratio is based on comprehensive studies by Harger *et al.* (1950) of the partition of ethanol between air and water and between blood and urine over a range of temperatures. A number of articles have been published citing factors that would influence the conversion ratio in any given test. However, these articles do not indicate the extent to which each factor influences conversion ratios or the cumulative effect of the factors on the accuracy and reliability of the breath test in practice.

It is also a well-established fact that all contemporary EBT instruments calibrated and maintained using a 2100:1 ratio (at 34° C) can reliably measure vapor

alcohol concentrations with an accuracy greater than ±5% of the true value when the vapor is delivered by a breath alcohol simulator (Flores *et al.* 1981; Jones 1976). If these precepts are true, a correlation study of properly conducted breath-blood tests should validate the use of breath alcohol tests to determine an equivalent and accurate BAC.

METHOD

Many blood/breath alcohol correlation studies have been criticized as controlled experiments that do not represent actual case conditions. Other studies have been flawed by erroneous methods or standards of procedures (a classic example is Alobaidi *et al.* 1976). For these reasons, I have selected blood/breath correlation data from actual DUI cases in three California counties where the subject or the arresting officer requested a blood test after the subject had completed a breath test. The use of data from driving cases may be criticized because the time lag between driving and testing would place the driver further along the path of absorption. However, the data from driving cases give correlation ratios similar to those in controlled studies.

The breath and blood tests used for these correlation studies were the result of a California appellate court decision in People v. Trombetta (1976) which held that, when a subject chooses a breath test (the subject has the choice of a breath, blood or urine test), the arresting agency must establish and follow rigorous and systematic procedures to capture and preserve the breath sample(s) or its equivalent for use by the defendant. Before this appellate decision and resolution by the U. S. Supreme Court (1984), the "implied consent" section of the California Vehicle Code was amended to require that subjects choosing a breath test be advised that a breath sample cannot be retained for later analysis and, if the subject wants a sample retained, the subject may provide a blood or urine sample at no cost to him/her.

The correlation results presented as histograms of breath-blood differences (Figures 1-3) were selected using the following common acceptance criteria:

1. All test results are actual DUI cases.

2. All breath tests were conducted using an Intoxilyzer Model 4011 A or AW calibrated and maintained (using a 2100:1, 34°C factor) in conformance with Title 17, Forensic Alcohol Analysis Regulations.

3. Only the highest replicate breath results within 0.02% agreement were used for comparison to a single blood sample result. The single blood result was derived from duplicate analyses that agreed to within 5% of the mean and was then truncated to two figures, as required by Title 17, Forensic Alcohol Analysis regulations.

4. Time difference between breath and blood tests (the blood test always followed the breath test):

   a. For Marin and Contra Costa County, the blood sample results were corrected by back calculation using a 0.018% per hour elimination factor.

   b. For the Santa Clara County data, the times of the blood and breath tests are presumed to be contemporaneous because the time between the blood and breath test virtually never exceeds 1 hour.

The data presented in Figures 1-4 demonstrate that the distribution of the measured BrAC is biased towards an underestimation of the actual BAC when using a 2100:1 (34° C) conversion factor, and that only rarely does the BrAC overestimate the BAC by as much as 0.02%. This rationale is used to support the 1972 Recommendations of the National Safety Committee on Alcohol and Drugs that states in part: "Bearing in mind the requirement of the administration of justice for conservative evidence, thus the committee concludes that the continued use of the 2100:1 factor for the conversion of breath-alcohol to blood-alcohol concentrations is warranted for law enforcement purposes."

In those rare cases when the BrAC exceeded the BAC by more than 0.02%, these differences have always occurred at BAC levels greater than 0.15%. The BrAC can underestimate the BAC at any BAC level as a result of nonalveolar sampling. These low BrAC levels will occur despite all procedural and instrumental safeguards. Minus differences greater than 0.05% frequently occur at BAC levels below 0.10%, where the relative variance is magnified.

In practical terms, it is acceptable to underestimate the true BAC, but it is not acceptable to overestimate the BAC by more than 0.02%. Applying this rationale to a 0.10% *per se* law means that persons with BrAC of 0.12% or greater are unequivocally in violation of the law. Although persons having a measured BrAC of 0.10% to 0.12% probably are in violation of the law, the burden of showing that the 2100:1 conversion ratio does not apply in a specific case should be borne by the defendant or be determined by other relevant evidence. A more rigorous statistical analysis of these cases, such as regression analysis, was purposely omitted because it would only serve to obscure the practical significance of the variance and the BAC at which these variances occur in actual case situations.

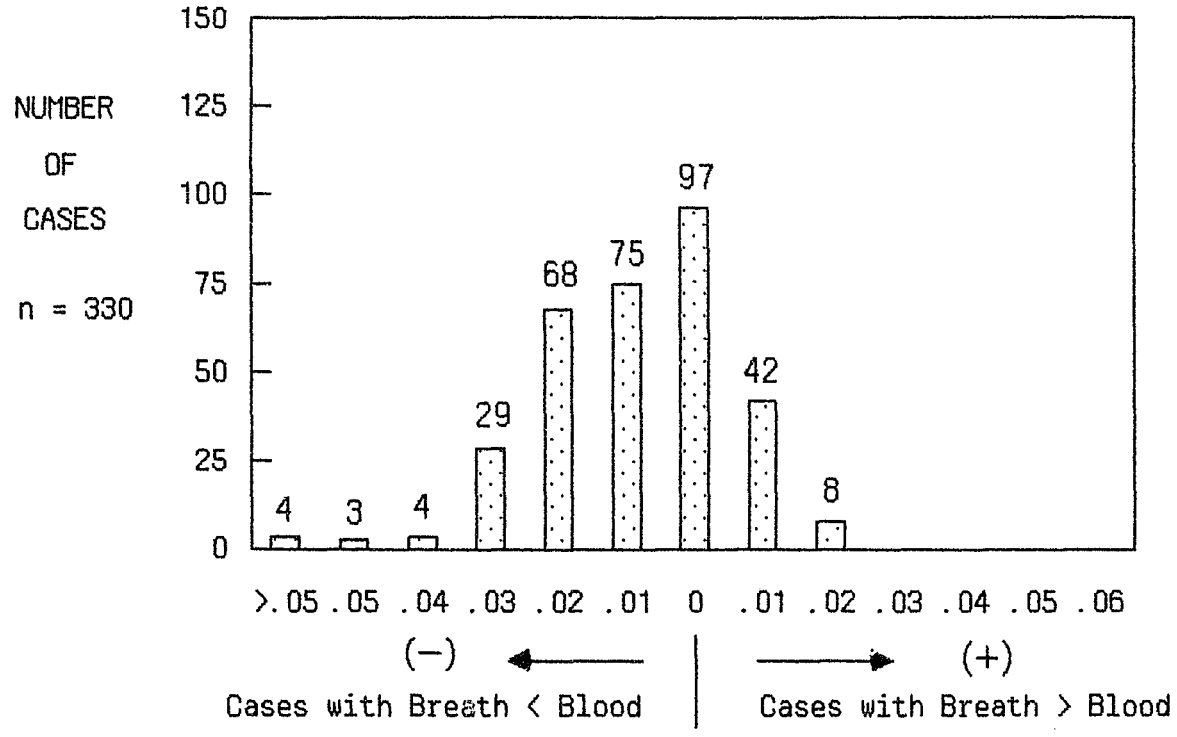
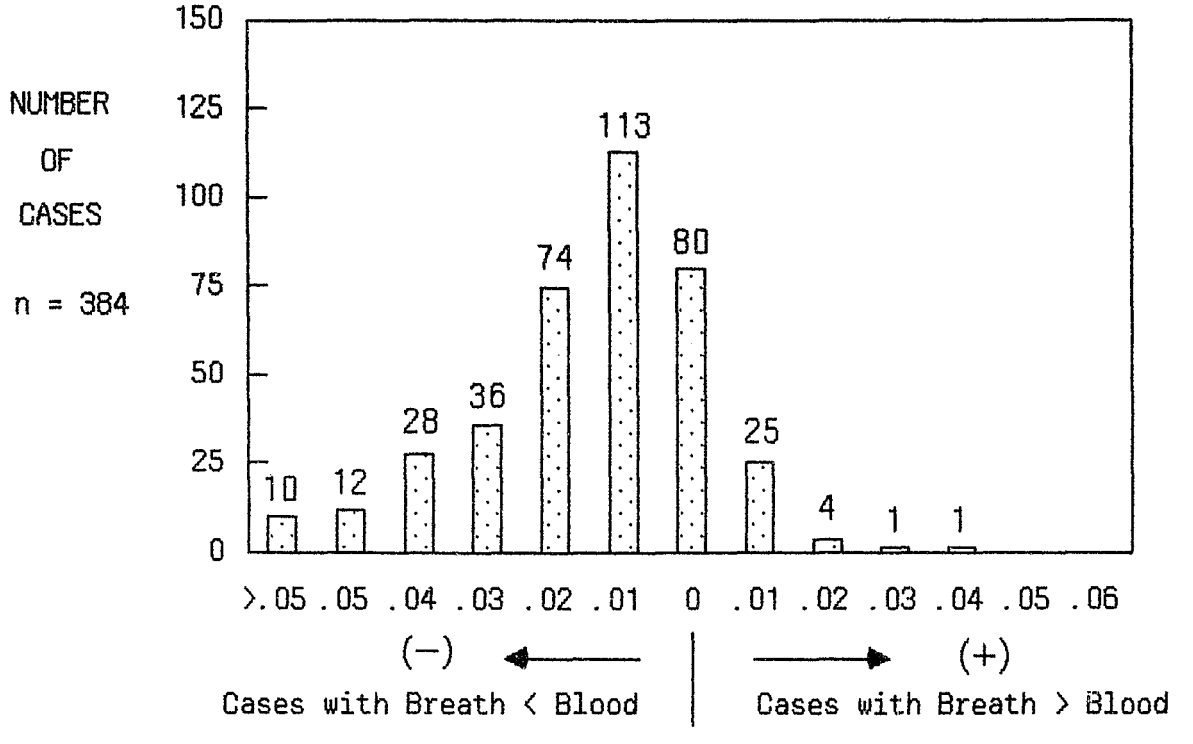


Figure 1. Difference between breath and blood % BAC, Marin County cases, September 1983—September 1985.



One +.03% Diff.; BR .27 & .26%; BL .242% (38 min.)
One +.04% Diff.; BR .39 & .35 & .38%; BL .359% (49 min.)

Figure 2. Difference between breath and blood % BAC, Contra Costa County cases, October 1983—November 1985.

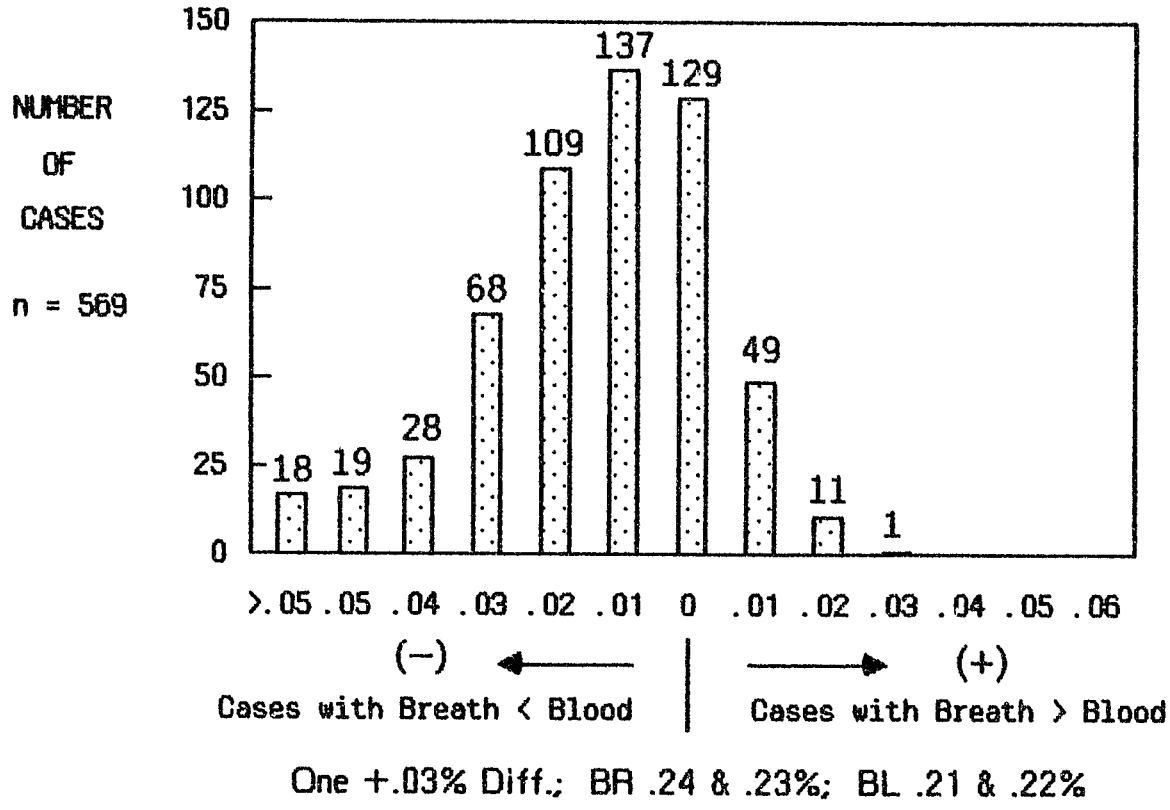


Figure 3. Difference between breath and blood % BAC, Santa Clara County cases, July 1983—June 1985.

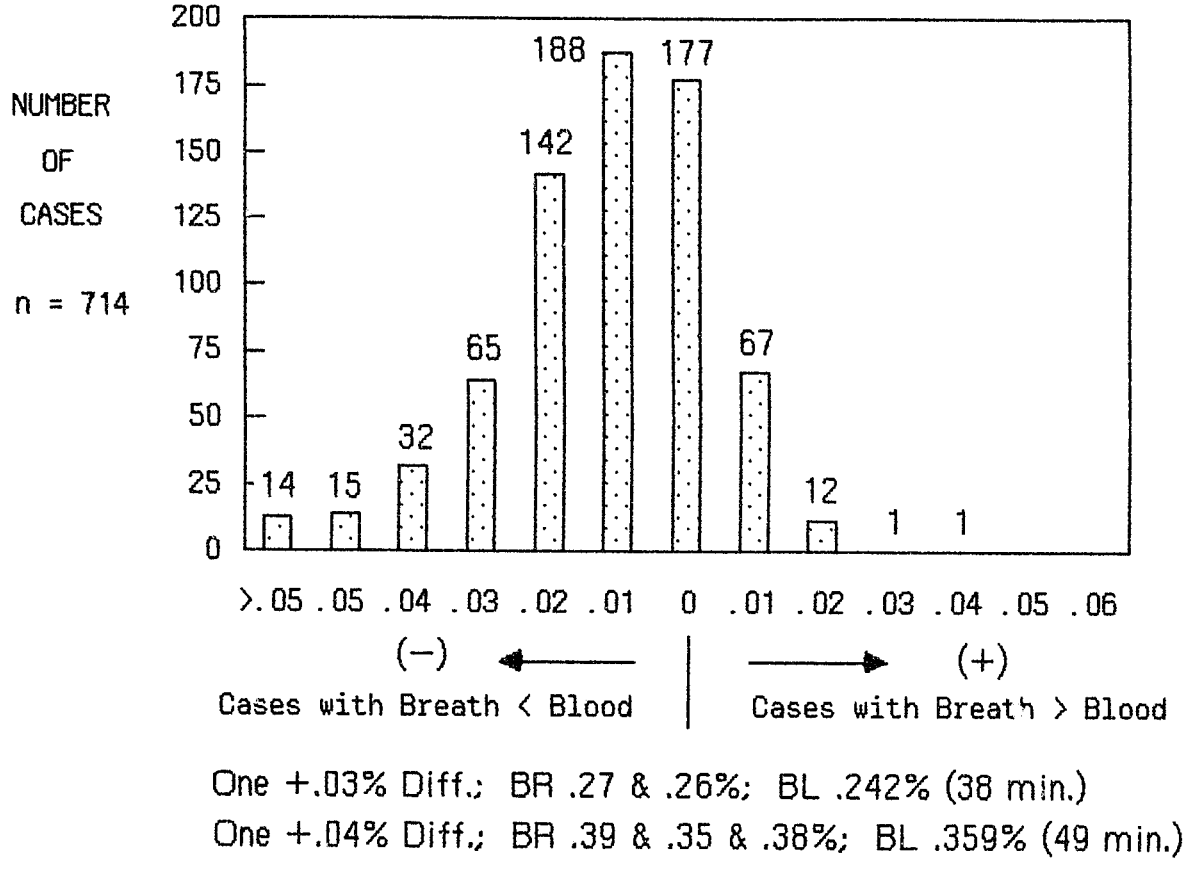


Figure 4. Difference between breath and blood % BAC, Combined Marin and Contra Costa Counties.

DISCUSSION

In the past, most investigators have assumed that the validity ratios for converting a urine-alcohol concentration or a BrAC to an equivalent BAC vary because of inherent physiologic differences. I believe the data presented here for breath/blood, and in previous papers for urine/blood, unequivocally demonstrate that these conversion ratios can and should be applied as fixed constants that vary according to well-defined chemical and physical laws governing the partition coefficients of ethanol and water for urine and for ethanol and breath at a given temperature.

CONCLUSIONS

The actual breath/blood case studies presented here and the urine/blood cases reviewed in previously published papers establish the practical utility and validity of determining an equivalent BAC for:

1. Breath alcohol tests that are conducted using adequately maintained EBTs that are calibrated using a 2100:1 (34° C) breath/blood conversion ratio and operated under rigorous standards of procedure which rule out any reasonable possibility of random or undetected error.

2. Urine alcohol tests that are conducted on a second sample taken 20 minutes to 1 hour after the bladder is first voided and where a urine/blood conversion ratio of 1.3:1 is routinely applied.

If these principles are rigorously and uniformly applied and supported by appropriate DUI statutes, they can maximize the efficiency and effectiveness of chemical test programs in support of DUI enforcement and adjudication.

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DISCUSSION

Francisco: Although you did not present the urine alcohol data, did you take into consideration cases in where there may be a high volume of urine retained within the bladder because of prosthetic obstruction, urethral obstruction or some other abnormal condition that would make your second specimen not a current collection but merely an additional accumulation to a chronic prior urine sample?

Biasotti: I did not assume that, and I recognize that there are all kinds of reasons why that ratio can vary, as pointed out by Dr. Forney and Dr. Dubowski. We reviewed all the literature, both control and case reports, as well as our own where we collected both the void and the sample urine, and then analyzed it to discover what happens in real, not controlled, cases. We did not find a wide degree of variance. The greatest we found was 1.5:1 as opposed to 1.3, and we are willing to concede that. Also, given a known concentration of alcohol in urine, regardless what the current state of the blood alcohol is, you can prove that the subject was at that level sometime in the immediate past, and I think that is indicative.

We did not find, in actual cases, that the ratio of the void to the sample varied by any significant amount at levels in the critical area. They can vary, like breath results, at higher than 0.15%, and they certainly vary at very low levels, but that is not the area where this becomes a critical issue. We are talking about approximately 0.08%-0.15%, and we did not find that to be the case.

I am not implying that urine or breath or any of these are the ultimate answer, but they certainly should not be discounted because of a theoretical variable when practical applications show that they do have a positive value when interpreted correctly.

Watts: Do you have any comments concerning the use of saliva as a roadside screening test, such as in the case of ALCOSCAN test strips?

Biasotti: Yes, we have been approached by the people who are selling the saliva tests for use as preliminary breath tests (PBT). They first asked us about using it as an evidentiary breath test, and I had all kinds of problems with that. Then they suggested it be used as a PBT. Given the limitations of a PBT and given the fact that there are superior, as well as more inexpensive and convenient methods available, such as fuel cells, I do not see any real practical advantage to using them.

Oliver: What limits do you set on your breath test for your duplicate samples?

Biasotti: In California, all forensic laboratories are regulated by a uniform set of standards of procedure by the Department of Public Health. It is required that any breath test must be passed on replicate analysis with proper controls. In order to have a reportable valid test, we must have two breath tests that are in 0.02% agreement.

Hilliard: What type of time variation are we talking about between blood and breath tests in terms of average amounts of minutes between each one, if they are not simultaneous?

Biasotti: It varies from jurisdiction to jurisdiction. In the Morin County Department of Justice laboratory north of San Francisco, where the facilities for the breath and blood tests are adjacent, it would be rare that the time difference would be more than an hour. In Contra Costa County, most blood and breath tests are done within an hour.

To show the display here, we applied a uniform elimination of 0.18%, which I think is reasonable. Even if we did not, I do not think it would change materially or shift the distribution of those differences.

In the Santa Clara County cases, the technician who administers the breath test also takes the blood sample, so it's almost always immediate. If the subject chooses a breath test, it follows within an hour of the initial breath test.

Prouty: You have been very emphatic about the practical value of the second urine test. How do you feel about the value of a single, isolated urine test?

Biasotti: We have not found that it has been necessary. It adds the frosting on the cake in terms of countering the usual arguments we get threatened with all the time. I think this will eliminate any real doubt about what you can say about a single urine test.

If you have just the void, under our regulations it is not a reportable result. The regulations very clearly specify that the only quantitative urine sample acceptable is based on the voiding, 20-minute sample or 20 minutes to 1 hour. Then you find that conversion ratio. We can only say that there is a quantitative amount or there is alcohol present, but no quantitative result.

Question: Of the three bar graphs, one shows an unusually large number compared with the other two that show less than 0.05%. Did Brackett or Halley have any explanation for that?

Biasotti: I think it could be due to two things. One is they have a slightly more negative bias. Most of those that are greater than 0.05% are usually 0.07% or 0.08%. A lot of those are due to near negative blood alcohol levels that exaggerate the difference.

They are all uniformly operated under the same regulations. I feel that our A.W. Plateau Detector is slightly superior to the CMI Slope Detector, which explains why ours may be a little tighter.

Dubowski: Why would a tested subject whose official alcohol result came out 0.05% or less want to go to the trouble and expense of having a blood alcohol test performed?

Biasotti: The subject may not want one performed. Under amended California law if the subject chooses a breath test and the alcohol level does not justify the symptoms, then the officer can, under implied consent, demand that the subject give either a blood or urine sample.

GAZE NYSTAGMUS AND PSYCHOPHYSICAL TESTING

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Law enforcement agencies have, for a number of years, placed a great deal of emphasis on the use of psychophysical testing to determine impairment of subjects suspected of driving under the influence (DUI) of alcohol. Traditional roadside coordination tests have been one of the primary clues an officer has relied on to establish sufficient probable cause to make an arrest for DUI. Although this practice has been accepted by the criminal justice system and law enforcement is generally successful in detecting and prosecuting alcohol impaired drivers, until recently there has been no scientific validation of these psychophysical tests.

Beginning in late 1975, the Southern California Research Institute received a contract from the National Highway Traffic Safety Administration (NHTSA) to conduct research to determine which roadside field sobriety tests were the most accurate. The Los Angeles Police Department (LAPD) was one of the agencies that participated in the research. The study evaluated traditional roadside tests being used for alcohol impairment detection and determined that three tests were significantly more accurate and demonstrative than all others: the walk-the-line test, the one-leg-stand test and the Horizontal Gaze Nystagmus test. The research validated these tests and quantified for the first time the accuracy of sobriety tests. These three tests were termed the Improved Field Sobriety Test by NHTSA, and the results were later published in NHTSA's Manual of Improved Sobriety Testing (1984).

Both the walk-the-line test and the one-leg-stand test are conducted in two phases. First the subject must receive and comprehend the instructions. Then the subject must perform the test. For the walk-the-line test, the subject is told to stand heel-to-toe while receiving instructions on how to complete the test. The subject is directed to pace off a number of steps in a heel-to-toe fashion, turn around and return the same number of steps while counting the steps out loud and watching his feet. The test is conducted on a well-lit, flat, level surface. For the one-leg-stand test, the subject is required to stand on one foot and count out loud from 1 to 30 in 1-second intervals while focusing his attention on his raised foot.

Both the walk-the-line test and the one-leg-stand test are good indicators of the subject's coordination impairment. They also provide a test for divided attention impairment. Alcohol, a central nervous system (CNS) depressant, impairs an individual's ability to do more than one thing at a time. Since a driver must continually divide his attention between steering the vehicle, operating the throttle and brake and observing the environment, the ability to divide attention is a critical driving skill. During each test, the subject must do more than one thing at a time, starting with receiving instructions while standing on a line heel-to-toe during the walk-the-line test. An impaired subject has difficulty maintaining balance while receiving the instructions.

The third test of the NHTSA battery examines the eyes for the presence or absence of nystagmus. Nystagmus means a jerking of the eyes. It generally has a slow and fast phase, and it is named for the fast phase. Nystagmus is either pendular or asymmetric, and it may be voluntary or involuntary.

There are two basic origins of nystagmus. The first form is caused by movement or action of the vestibular system. Among the types of vestibular nystagmus are rotational nystagmus, postrotational nystagmus, caloric nystagmus and positional alcohol nystagmus. The other common forms of nystagmus result directly from neural activity. These forms of nystagmus are optokinetic nystagmus, physiological nystagmus and gaze nystagmus. It is the examination of the eyes for gaze nystagmus that provides the third test of the NHTSA battery.

The test for gaze nystagmus is administered by instructing the subject to stand in a stationary position while holding his head in a level, forward position. The subject is then instructed to follow an object such as a penlight or other stimulus and to track that object with his eyes. The stimulus is held approximately 15 inches from the subject's eyes and moved slowly to each side and up and down.

The officer conducting the test will look for three signs of intoxication. They are the angle of onset, which refers to the position when the eyes begin to jerk as they deviate while looking to the right or left on a horizontal plane, the amount of nystagmus at the maximum lateral extremes and the ability to smoothly track a moving stimulus.

A unique phenomenon results when alcohol is the only drug ingested. There is a direct correlation

between the angle of onset of nystagmus and the subject's blood alcohol content (BAC). By using a simple mathematical formula, a trained officer can predict a subject's BAC within 0.03% approximately 80% of the time. This tool is valuable for law enforcement officers in making a roadside determination of impairment level.

It should be noted that a statistically small percentage of the population exhibits gaze nystagmus when sober. This can be mistaken for a potentially impairing BAC level. There are a number of causes other than alcohol which could account for this. Among these causes are the presence of other drugs, brain damage and illness.

The LAPD has expanded on the NHTSA battery of field sobriety tests by including two more traditional sobriety tests along with an examination of pupillary size and reaction to light to create the Standardized Field Sobriety Test (SFST). The additional sobriety tests are the Rhomberg balance test and the improved finger-to-nose test.

During the Rhomberg test, the subject is instructed to stand with his feet together, arms at his side, and to close his eyes for what he believes is 30 seconds. The officer observes the amount of sway or the loss of balance while measuring the subject's ability to estimate time.

For the improved finger-to-nose test, the subject stands erect with his feet together, eyes closed, and arms to the side. Alternating with his right and left hand, the subject attempts to touch the tip of his nose with the tip of his extended index finger. The officer observes the ability of the subject to coordinate movements to accomplish touching the tip of his nose, retain balance and follow simple directions.

The final procedure of the SFST is an examination of the subject's eyes for pupil size and reaction to light. Pupil size is observed both in normal or available light and in a darkened room with the use of a penlight. Pupil characteristics are very sensitive to drugs, including alcohol. Central nervous system depressants cause a slowing of pupillary response to light. Other categories of drugs cause different pupillary reactions. If the other sobriety tests indicate impairment but the pupils do not react in a manner consistent with alcohol or nystagmus is not present in a manner consistent with the BAC level, then other drugs are suspected.

Up to this point, the use of gaze nystagmus and psychophysical testing has only been discussed relative to testing alcohol impaired drivers. As previously stated, law enforcement has been fairly successful in detecting and prosecuting alcohol impaired drivers. However, as drugs other than alcohol have become more prevalent in society, law enforcement's ability to test the driver impaired by these substances has not increased at the same rate.

In most states, a police officer makes an arrest for DUI based on the totality of circumstances observed prior to the traffic stop and while at roadside. Among the factors considered by the officer are the subject's driving performance, objective symptoms displayed during the traffic stop and performance on a field sobriety test. In some states, a preliminary breath test may also provide additional information for the officer.

The officer then must decide whether to make an arrest based on his observations. If the officer believes that the subject is impaired to the point that a violation of the state's DUI law is present, the subject is arrested and transported to a location for chemical testing.

Most states allow the subject one of three chemical tests at either the choice of the arrestee or the officer. Regardless of who makes the choice, the breath test is universally the most popular, since the results are immediate. Unfortunately, a breath test will not detect the presence of drugs other than alcohol. If the arrestee submits to a breath test and the results are zero or below the legally impaired level, the officer may have no choice but to release the subject. Even if the subject is booked, the chances for a successful prosecution are slim.

Some states, such as California, have a two-test implied consent law that requires the arrestee to submit to a second chemical test to check for the presence of other drugs. Unfortunately, since the chemical test is used only for corroborative purposes to substantiate the arresting officer's opinion, a positive chemical test for drugs will not help in a prosecution unless the arresting officer can give an expert opinion as to the general drug class causing the impairment. Therefore, to be able to successfully prosecute drivers suspected of driving under the influence of drugs other than alcohol, it is imperative that law enforcement officers be able to evaluate a subject for both impairment and the substance causing the impairment.

In the early 1970s, the LAPD recognized this need, and a small group of officers began to conduct research to find out what could be done to train officers to recognize the symptoms of drug intoxication, accurately document these observations in an arrest report and testify about them in court. Their research included working with local medical researchers who were known experts in the field of drug symptoms and who were participating in studies. They

systematized all available information on drug symptoms and studied how combinations of drugs and alcohol affected each other. The officers developed symptom charts listing the characteristics of seven different broad-base drug categories. It was determined that all commonly abused drugs fell into one of these categories. The seven categories of drugs are CNS depressants, CNS stimulants, hallucinogens, marijuana, phencyclidine (PCP), narcotics/analgesics and inhalants.

After several years, this research culminated in the development of the Drug Recognition Expert (DRE) Program. The LAPD currently has approximately 150 DREs who have completed an 80-hour comprehensive course of instruction on drug symptoms. These officers are deployed throughout the City of Los Angeles and are on call to respond to requests for a drug expert (Los Angeles Police Department 1984).

In Los Angeles, when an officer makes an arrest for DUI and drugs other than alcohol are suspected due to a low BAC reading or other objective symptoms, the arrestee is transported to a DRE who conducts a drug evaluation. This consists of the SFST followed by an examination of the subject's pulse, blood pressure, temperature, eyes, signs of drug intoxication such as muscle rigidity, drowsiness or hallucinations and finally, an examination for signs of ingestion such as puncture wounds, debris in the mouth and an inspection of the nasal passages. The symptoms are compared with the drug symptom charts, and a conclusion is made following the completed test.

Since California has a two-test implied consent law, the arrestee must submit to a second chemical test of his blood or urine when drugs are suspected. Laboratory analysis of the blood or urine sample confirms the DRE's opinion, thereby providing the corroboration needed for a successful prosecution. In Los Angeles, the conviction rate for drivers suspected of driving under the influence of a drug or a combination of alcohol and another drug equals or exceeds the conviction rate for straight DUI alcohol.

When only alcohol is suspected of causing impairment, the field sobriety test assists the officer in determining the level of impairment. However, when other drugs are suspected, the testing must determine both the level of impairment and the category of drug causing it. As a result, the psychophysical testing plays a more critical role when drugs other than alcohol are involved.

The testing of a drug impaired driver is done in two phases. The first phase consists of the SFST coordination tests that are used primarily to determine impairment. The subject's performance provides the officer the data needed to determine whether sufficient impairment is present to warrant an arrest.

These coordination tests may also assist in determining the cause of impairment. For example, muscle rigidity, a symptom of PCP intoxication, may be evident, and an accelerated or slowed down counting process may be indicative of a CNS stimulant or hallucinogen that speeds up the internal clock, or a CNS depressant that slows it down.

The second phase is conducted primarily to determine the specific cause of impairment. This portion of the evaluation consists of the physical examination and examination for signs of ingestion. Although the examination for signs of ingestion, blood pressure, pulse and body temperature provides valuable clues for the DRE, the eyes provide the best indicator of the cause of impairment.

The presence of gaze nystagmus indicates that a CNS depressant, PCP or inhalants such as toluene may have been ingested. The other categories of drugs do not cause nystagmus. The size of the pupils and their reaction to light also provide valuable clues. CNS stimulants and hallucinogens dilate the pupils, narcotics, such as heroin, constrict the pupils, and CNS depressants slow the pupil reaction to light stimulation.

Another symptom of drug intoxication involving the eyes is the presence or absence of strabismus, or the nonconvergence of the eyes. The test for strabismus is to move an object such as a pencil from a point approximately 15 inches in front of the eyes to the tip of the nose while the head remains stationary. Nonconvergence is seen when the eyes are unable to converge on the object as it approaches the face. Marijuana, PCP and CNS depressants affect the ability of the eyes to converge.

The DRE is able to predict accurately the presence of drugs through a systematic approach of comparing the results of psychophysical testing to the drug symptom charts. It is a relatively simple process for a well-trained individual when only one drug is actively present. Unfortunately, experience has shown that a significant number of drug abusers do not rely on only one substance. A recent field validation study of the DRE procedures conducted in Los Angeles revealed that 123 out of 173 drivers (71%) arrested for driving under the influence of drugs had two or more active drugs in their bodies at the time a blood sample was taken (within 2 hours of arrest). Eighty (46%) had two substances, 40 (23%) had three substances and 3 (2%) had four active substances.

This multiple drug use makes the task of the DRE considerably more difficult. At this time, there is little research that shows the effects of combinations of drugs, and additional research needs to be conducted. These studies should determine which combinations of drugs cause synergism, potentiation or antagonistic effects.

The experience of the DREs in Los Angeles, through a trial and error method, has resulted in several unvalidated observations (Los Angeles Police Department 1984). It appears that the short-term, or milder drugs such as alcohol, marijuana and cocaine are masked by the dominant drug PCP. The mixing of heroin and cocaine, commonly known as a "speed ball," causes the dominant symptoms of both drugs to be manifested by the subject, except for pupil reaction. Heroin, a narcotic, causes the pupils to constrict, and cocaine, a CNS stimulant, causes the pupils to dilate. When taken in combination, the pupils of the subject will be in the normal range but will have little or no reaction to light.

The LAPD is presently the only law enforcement agency in the United States with a successful, validated program for apprehending, testing and prosecuting drug impaired drivers. On February 1, 1986, the LAPD began the Impaired Driver Apprehension Program. One of the goals of this 3-year grant-funded program is to assist NHTSA in developing DRE Programs with law enforcement agencies throughout the nation based on the Los Angeles model.

As law enforcement continues to make progress in the area of testing the drug impaired driver, it is imperative that the forensic community keep pace. A truly successful nationwide program designed to deal with the threat of the drug impaired driver will require the cooperation of all the essential elements—law enforcement, the courts, the laboratories and the research community. Now is the time to look towards the future.

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DISCUSSION

Haag: I recognize the importance of a standard field sobriety test (FST) battery and a scoring system, but I wonder if any of your group, Southern California Research Institute or others, have applied those tests in a police duress situation, to people either then or later known to be alcohol-free? This would establish how many people can typically pass the test and understand the instructions so we have something against which to compare the failure rate.

Studdard: I did a random study of officers, looking at their arrest record and accompanying them while they were on duty. I found that they release more people than they arrest using that test battery because they are not impaired. But our average blood alcohol concentration (BAC) has dropped dramatically, and they are arresting more intoxicated drivers.

In fact, one Friday night, a team went out and came in with 15 arrests; then they went out on Saturday night and came in with 15 more. The team consisted of two officers on motorcycles with a van following them down the street. The following Friday night they went out and got 15 more. I thought, "Gee, they're doing something right; I'd better go see what they're doing so I can incorporate this in my training program." I found out they were going out and watching cars drive by. As the car would stop at a red light, the officer would pull up alongside, tap on the window and say to the driver, "Follow my light." I stopped the officers because there is a thing called officer safety. They set a record, but they are not going to try it again.

In most cases, those tests are probably the fairest tests. Reciting the alphabet is devastating in Los Angeles because of the school system.

Question: Taking it from a condensed perspective, were there duress situations where there were allegations that the suspect failed the test because of anxiety about the flashing lights and the gun and badge?

Studdard: It is very hard to put people under stress in a laboratory situation. I think probably the best example of that is in law enforcement. In the past we used to release a lot of suspects because when we got them in we saw no objective symptoms of intoxication. We do not have to kick anybody out the back door anymore if officers use the test properly because they have already identified whether the suspect is impaired.

We have brought some people in that the officers thought were impaired, but they were either experiencing a stroke or insulin shock or had other neurologic problems that we were able to identify and get immediate medical treatment for it. We have not had

one individual die in custody who has been examined by a drug recognition expert (DRE). I think that speaks for itself.

Question: In lieu of the Loomis case, are your officers in Los Angeles predicting BACs just informally, or are they making it a part of their arrest report, using the onset of nystagmus?

Studdard: I am a trainer at the Police Academy, and we are training the basic officers and field officers to estimate whether the BAC is going to be above or below 0.105%. The DREs are put through a lot more training, and they are also highly experienced in the use of nystagmus and the FST battery. I would not recommend that the average officer testify to BACs.

Question: Are your DREs putting that down on the report?

Studdard: The DREs in a DRE case will put it down, but they will not do it if it is not a DRE case. They will put the angle of onset down, but they won't put the estimated BAC down. In the DRE report, they may put down something to the effect that the angle of onset is inconsistent with the BAC. If a defense attorney is dumb enough to bring it up, let him bring it up.

Adler: It seems to me it would be very easy for defense counsel, once in court, to shift the burden of proof from how the person operated the motor vehicle, and the fact that a test proved that they had a BAC, to how well they completed the psycho-motor testing.

If I was a defense attorney, this is the defense I would choose because I would be getting away from the crime and emphasizing the results of the psycho-motor test. What difficulties have you found in the courtroom, and have you found attorneys trying to shift this burden of proof onto you?

Studdard: We have had attorneys try to shift the attention. But the prosecutor then establishes with the officer that it is the total picture of what they saw from the time they first saw the suspect driving to how the suspect stopped the vehicle, what objective symptoms they observed and what the nystagmus established. Our DREs do not go to trial.

Francisco: I want to make an observation dealing with the question of stress and field sobriety testing. One significant feature of the horizontal gaze nystagmus is that this is an abnormality that has been documented since the late 1900's. It has been very well established that stress has absolutely nothing to do with the onset or the appearance of horizontal gaze nystagmus. This is probably the single best field sobriety test because the nerve/muscle ratio for the muscles of the eye is quite high. This nerve/muscle ratio shows the earliest changes of the nerve/muscle interaction due to alcohol or other substances. Therefore, this particular phenomenon is more dependent on the effect on the central nervous system than anything else and is not related to stress.

Question: Also, the nice thing about nystagmus is that an individual with a high tolerance to alcohol may be able to adequately complete the rest of the test, but the nystagmus will show the blood alcohol level and whether it is above 0.10%

Question: I find it interesting that in your test you classify PCP as a depressant, rather than as a hallucinogen. Can you explain that, or is it caused by the interaction of PCP with another drug?

Studdard: We do not classify it as a hallucinogen or as a depressant because PCP causes nystagmus as depressants do, but it also increases blood pressure and pulse rate in new users. As far as we are concerned, cyclidines are in a category all their own.

Question: What do you discuss with your officers concerning eye diseases as they affect the angle and degree upon which that object is moved?

Studdard: If one eye does not react, or there is any problem with one eye reacting differently from the other, nystagmus will be discredited and the officers are instructed not to use it as a basis for their evaluation. Normally eye diseases do not cause nystagmus and we have not run into any real problem with that. Both eyes have to move equally.

Question: Is there a different category for the left eye than for the right eye?

Studdard: No, the angle has to be the same.

PHARMACOLOGY OF CANNABINOIDS

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Be forewarned that the pharmacology of cannabinoids is not necessarily the pharmacology of cannabis. However, most of us assume there is more similarity than difference. At times, I will infer cannabinoid pharmacology from data from cannabis or comment on cannabis pharmacology but with most of the data derived from cannabinoid pharmacology. That is the nature of the cannabis/cannabinoid scientific literature. Be also warned that this is not a comprehensive review of the approximately 10,000 citations that are relevant. I have cited some recent articles and included a personal selection of older ones that will point the thoughtful reader in the right direction. One of the problems with the cannabis/cannabinoid literature is that too many of us read reviews rather than primary sources. I have been guilty, since it is a vast literature of varied quality. However, summaries do sometimes omit exceptions that help us understand (if not prove) the rules.

What is the difference between cannabinoids and cannabis? Cannabis, the material from the vigorous plant *Cannabis sativa*, like most natural products contains hundreds of chemicals (Addiction Research Center/World Health Organization 1983; Harvey and Paton 1985; Mechoulam *et al.* 1985; Turner 1985). About 100 of these have been isolated, with structures at least partially characterized, and they are generally termed cannabinoids. However, as with many aspects of cannabinoid pharmacology, even the term cannabinoids does not have a completely agreed on definition. The term cannabinoids was first suggested in 1967 by Mechoulam and Gaoni (Mechoulam *et al.* 1985). Its definition gradually evolved to indicate a group of C_{21} compounds typical of those present in *Cannabis sativa*, including their carboxylic acids, analogs and transformation products.

The definition of cannabinoids is only a chemical one and is, like the definition of steroids, generally accepted to be a class of naturally occurring organic substances and derivatives. The term cannabinoid should be used only with reference to chemical structure and chemical properties (Turner 1985). The term has no physiologic, biochemical, biologic or medicinal connotations, so that terms like cannabinoid activity or cannabinoid-like activity are inappropriate. Numerous biologic and biochemical effects are produced by tetrahydrocannabinol (THC) and by other cannabinoids. The effects of one cannabinoid are not necessarily produced by other or all cannabinoids. For example, consider THC and cannabidiol (CBD). The former causes a marijuana-like or, if you prefer, cannabis-like intoxication, but it is also an anticonvulsant like CBD that, however, produces no measurable mood changes. Chemically, both THC and CBD are cannabinoids. So, although it may be proper to talk about cannabis-like effects, it is quite improper and imprecise to discuss cannabinoid effects.

There are, of course, other legal and practical implications of just how we define or limit definitions of cannabinoids, but the important point is that cannabinoids differ greatly in their pharmacologic properties and biochemistry. Most important, for those of us concerned with behavior and health issues, is that the pharmacology of cannabinoids does not fully describe the pharmacology of *Cannabis sativa*. Of the cannabinoids, only THC and CBD are studied well enough in humans to characterize their pharmacologic properties, and even there many uncertainties remain.

CANNABINOID CHEMISTRY

The renaissance in cannabinoid chemical research began in the 1960's with the identification of the major psychoactive constituent in cannabis (delta-9-THC) and isolation and structural characterization of most of the naturally occurring neutral and acidic cannabinoids (Mechoulam *et al.* 1985). Developments in cannabinoid chemistry evolved very rapidly over the following 15 years or so, with numerous studies of metabolism, identification of additional primary metabolites and characterization of the major metabolic pathways. Two metabolic conjugates have been detected thus far, glucuronides and esters of long chain fatty acids, and their pharmacologic properties have been studied relatively little.

In the last several years, possibly because of research funding cutbacks, research on the chemical aspects of cannabinoids has markedly slowed down, even though many knowledge gaps exist. For example, the lipid solubility of cannabinoids is well appreciated and has been a topic of much research and even more speculation. However, there has been very little attention paid to water soluble constituents of cannabis,

even though they have been shown to have biologic effects similar to THC (Mechoulam *et al.* 1985). Much remains to be worked out in the synthesis of cannabinoids though, understandably, any future efforts would be necessarily linked with applications in medicinal chemistry and pharmacology. One of the great impediments to studies of the biochemistry of cannabinoids has been a lack of suitable *in vitro* models for cannabinoid studies, particularly those that are relevant to the actions of cannabinoids in intact animals. This is mainly why the questions of molecular events in the brain that explain mechanisms of cannabinoid actions remain unanswered.

MECHANISMS OF ACTION

Whether THC or other cannabinoids have specific receptors analogous to opiates or whether they act through more nonspecific membrane or other effects is uncertain (Bloom and Hillard 1985). The membrane lipid interaction hypotheses are the best supported at this time. It is now accepted that the lipid microenvironment around membrane-bound receptors (or binding sites) can affect receptor activity, receptor sensitivity and specificity. Thus, in one sense indirectly but in another sense directly, THC and other cannabinoids may modulate activity (for example, in cholinergic neurons) by these somewhat specific lipid interactions. Cannabinoid membrane effects offer a mechanism to explain interactions between cannabis and other drugs (for example, opiates) that have specific receptors or other drugs (alcohol and cocaine) that share membrane altering properties. Semantic diversions considering what is tissue or membrane binding and what is a real receptor, unfortunately divert efforts to define the nature of this cannabinoid-membrane-receptor interaction.

DOSE CONSIDERATIONS: TETRAHYDROCANNABINOL

THC seems to account for most but not all of the effects of cannabis that we usually consider (Addiction Research Center/World Health Organization 1983; Mechoulam *et al.* 1985; Turner 1985). There is, of course, great variability in the content of THC and other cannabinoids, particularly in the mixture of crushed leaves, twigs, seeds and sometimes flowers that make up marijuana. Some varieties of cannabis contain little or no THC. Other varieties, particularly those selectively cultivated for high THC content, have become more readily available in the last several years. Clearly, the trend in recent years is for a more potent (in terms of amount of THC per unit of weight) product (Turner 1985). The marijuana commonly smoked in the United States is on average four to five times more potent than that of 10 years ago. For example, the amount of THC in illicit samples confiscated during 1984 averaged 4.1% by weight. In contrast, samples from similar illicit sources seized 10 years ago averaged about 1% THC. Carefully cultivated, so-called sensimilla varieties of cannabis contain about 7% THC on average and as high as 14%. Thus, it is not uncommon for North American marijuana smokers to be consuming a product that is as potent or more potent than the cannabis resin (hashish) itself. One might expect more intense and longer lasting states of intoxication, other things being equal. Perhaps even more important is that virtually all laboratory research with marijuana done in recent years has used material with 1% or 2% THC and thus may not be representative of what actually happens in the real world.

KINETICS

Cannabinoids appear to act at multiple sites, within the central nervous system (CNS) and peripherally as well. Most major effects probably result from CNS sites of action. If, as it seems, the mechanisms involve generalized membrane/receptor interactions, one would expect a multiplicity of mechanisms as is the case with alcohol, anesthetic gases and similar drugs. Smoked drugs or inhaled drugs have very special attributes (Jones 1985; Perez-Reyes *et al.* 1981, 1982). When inhaled, THC is absorbed rapidly and probably delivered to the brain rapidly and efficiently, as one would expect of a highly lipid-soluble drug. Peak brain levels, which, of course, are not the same as peak venous blood levels, occur during the smoking process and then decline very rapidly to 5%-10% of the initial levels over the next hour or so.

The rapid disappearance of THC from blood is mainly a consequence of THC entering other tissues, including the brain, rather than simply due to rapid metabolism (Agurell *et al.* 1984, 1985; Hunt and Jones 1980). A relatively slow reentry from tissue depots back into blood and urine persists for weeks after even a single dose of cannabis. The terminal half-life of THC as measured in blood is about 20 hours, though estimates vary as would be expected with a slowly cleared, highly bound substance (Lemberger *et al.*

1971). Of greater significance for those who are attempting to determine time of use or dose is that the terminal half-life of some cannabinoid metabolites may be 50 hours or 6 days or more (Hunt and Jones 1980; Law and Moffat 1985; Law *et al.* 1984). Even after a single dose of THC producing only a few hours of measurable intoxication, up to 10%-20% of the metabolites remain in the body 1 week later (Law *et al.* 1984). Elimination of cannabinoids from the body, at least as measured by sensitive assays, can easily take more than 30 days and, in principle, should take months (Harvey and Paton 1985; Hunt and Jones 1980).

DATA FROM ANIMAL STUDIES WITH TETRAHYDROCANNABINOL

Much of what we know about cannabis effects from controlled laboratory studies, particularly those with animal or *in vitro* systems, are more accurately described as the pharmacology of THC, since it was pure THC that was often used. Although probably quite similar, studies with any pure, simple cannabinoid given parenterally cannot provide a complete picture of cannabis effects. One important example is that the effects of smoked cannabis are quite unlikely to be different from the consequences of orally ingested or even intravenously administered cannabinoids. Yet much of the animal research, particularly long-term studies, must be done with the drug given parenterally or orally because of the difficulties associated with the administration of drugs via inhalation to animals.

PITFALLS IN TRYING TO LINK PHARMACOLOGIC AND BEHAVIORAL EFFECTS

Cannabinoids have some special properties that complicate predictions about their behavioral pharmacology, particularly for those who must deal with forensic issues. First is the very rapid decline in THC blood levels after a dose, particularly after a smoked or intravenous dose (Agurell *et al.* 1985; Domino *et al.* 1984). This rapid decline is almost entirely due to rapid redistribution of the cannabinoids, partially related to its very high lipid solubility and protein binding (Hunt and Jones 1980). Thus, the cannabinoids are disappearing from blood and going into other tissues. Concentrations of cannabinoids in other tissues, particularly in the brain, have not been well studied in animals and virtually not at all in humans, where one would necessarily be limited mostly to post mortem studies. Brain levels seem surprisingly low in a few animal studies (Harvey and Paton 1985). When trying to predict consequences, particularly performance and psychologic effects, it is probably brain levels of THC one is most interested in assessing. This is particularly the case with inhalation administration, since the direct route from lung to brain offers a rapid and efficient transport that can only be mimicked by direct brain injection. Peripheral blood, particularly venous blood levels, can never accurately measure brain levels under such circumstances. Plasma levels of cannabinoids do not predict effects except under very constrained conditions (Cocchetto *et al.* 1981; Hollister *et al.* 1981; Ohlsson *et al.* 1980).

The relatively rapid metabolism to the psychoactive 11-hydroxy metabolite of THC and to dozens of other cannabinoid metabolic products continues at various rates (Foltz *et al.* 1982; Law and Moffat 1985; Wall *et al.* 1983). Each metabolite has its own independent rate of elimination and may interact with other cannabinoids. Slow elimination of a psychoactive drug or its metabolites, especially if the metabolites are not biologically active, does not necessarily lead to effects or toxicity, but the presence of long-lasting metabolites and an almost complete lack of knowledge of their biologic effects must be considered when measuring a compound in urine samples to predict or explain behavior.

Another important aspect of cannabinoid pharmacology that makes predictions about cannabinoid levels and effects on behavior or function difficult is that tolerance develops quite rapidly to many cannabinoids (Addiction Research Center/World Health Organization 1983; Jones *et al.* 1976). Measurable, often marked, tolerance occurs after only a few modest doses and disappears just as rapidly. The mechanism is adaptive functional change rather than change in drug metabolism.

EFFECTS ON BEHAVIOR

An enormous literature describes psychologic and neuropsychologic effects of cannabis on behavior, intellectual functions, memory, attention, information processing, decision-making, perception and psychomotor functions. Under laboratory conditions, cannabis can markedly impair psychomotor performance; for example, measures of coordination (hand steadiness, body sway), tracking (Manno *et al.* 1985), perceptual tasks (particularly those requiring sustained vigilance or under experimenter control) (Moskowitz 1984), automobile driving on simulators or in field test conditions and flying skills as tested on

simulators (Addiction Research Center/World Health Organization 1983). The weight of the evidence suggests that, under proper conditions of dose and task demands, reaction time, simple sensory functions and eye movement are altered. Memory and learning are clearly impaired during the first few hours of drug intoxication.

In most instances, cannabinoid effects in the laboratory are rarely measurable more than 4 hours after a dose is administered. Occasional studies have shown such decrements as tracking impairment persisting for up to 8 hours, and in a handful of studies, mainly on tasks with a heavy cognitive/perceptual/psychomotor integration load, decrements in performance were measurable for 24 hours after dose.

Effects related to long-term use are less well documented and come mainly from animal experiments (Addiction Research Center/World Health Organization 1983). For example, learning deficits are found in rodents for months after long-term marijuana administration has been discontinued.

AUTOMOBILE AND AIRCRAFT OPERATION

The effects of marijuana use on tasks assumed to be important for driving and on driving performance have been measured using driving simulators on closed driving courses or test tracks (Mason and McBay 1985). It is difficult to summarize the results of complex studies in a way that does not lend itself to misinterpretation. The interested reader should read the original sources. In almost all instances, cannabis, when given at moderate to low doses, impairs some but not all aspects of driving performance (Barnett *et al.* 1985; Manno *et al.* 1985; Smiley 1985). Perceptual motor skills, perceptual tasks, decision-making and general car handling skills were reduced. However, many indices of driver performance that are affected by other psychoactive drugs were not impaired. Even the cannabis-induced impairments were not always consistent across individuals and often, though statistically significant from placebo or no treatment, were not large effects. In those instances where combined marijuana and alcohol were investigated, modest, generally additive, effects were reported. As in most studies of marijuana, effects were noted for only a few hours after smoking or oral ingestion. An occasional report of longer lasting effects appears (Barnett *et al.* 1985; Chait *et al.* 1985; Moskowitz 1984).

Despite the frequent mention of marijuana effects on flying skills in many reviews and reports, very little actual research has been done. A pilot in a recent fatal commercial aircraft accident smoked marijuana 24 hours before the crash, raising questions about long-lasting effects on complex tasks (National Transportation Safety Board 1983). One frequently quoted but rather limited study some years ago found that a low dose of marijuana impaired performance on a flying simulator for 4 hours after it was smoked, mainly affecting behavior assumed to be dependent on adequate short-term memory. In a more recent study, experienced private pilots first trained for 8 hours on a flight simulator landing task and then repeated the task after smoking a moderate dose of marijuana. Performance decrements were still evident 24 hours after smoking, particularly in such skills as aligning and landing precisely in the runway center. That the pilots did not subjectively believe their performance was impaired at 24 hours is noteworthy (Yesavage *et al.* 1985).

ACCIDENT SURVEYS ON THE ROLE OF CANNABIS

Although cannabis clearly can alter laboratory performance measures assumed to be important in driving, studies unequivocally connecting increased accidents or similar evidence of unsafe performance with cannabis use do not exist. A Department of Transportation report to Congress dated 1979 concluded that "Whether the differences found in the laboratory [referring to cannabis-induced decrements in performance] are large enough to have an impact in an actual driving situation is unknown," when discussing the overall effects of marijuana use on highway safety. Since then, things have not changed much.

Several reports of accident surveys all suffer from problems posed by the complexities of cannabinoid chemistry and sampling and as well as other epidemiologic design problems (Mason and McBay 1984, 1985). However, although the data are imperfect, the weight of the evidence indicates marijuana-related decrements in auto driving skill. For example, blood samples from young men killed in automobile crashes in four California counties were assayed for a number of psychoactive drugs (Williams *et al.* 1985). Over half of the 440 drivers were killed in single vehicle crashes. Overall, 88% of the drivers were considered responsible for the accident. Their blood was assayed for 23 drugs. One or more drugs were found in 81% of the drivers. Alcohol was measured in 70%, cannabinoids in 37% and cocaine in 11%. Other drugs were detected in under 4% of the drivers. Tetrahydrocannabinol and its acid metabolites were measured at concentrations of 0.2 to over 50 ng/ml in plasma. Cannabinoids were found alone in only 12% of those

samples, but they were found in combination with alcohol in 81% and other drugs in 7% of the victims.

Determining whether marijuana use is over represented in at risk driver populations and relating that overrepresentation to subsequent accident history is not a trivial task. Marijuana users have traits and behaviors that would lead to more accidental deaths even when they had not recently used marijuana (Albert and Simpson 1985; Benson and Holmberg 1984; Morelock *et al.* 1985; Wechsler *et al.* 1984). They do not use seat belts as often. They take more risks. When THC or other cannabinoids are detected in blood or urine specimens from fatally injured drivers, they are almost always found in combination with ethanol. Concentrations of THC are generally low, often less than 5 ng/ml, thus in a range where, as judged by laboratory data, one should not find significant cannabinoid-induced performance decrements. The best defended summary of recent data is that of Mason and McBay (1985), who conclude that if there are drivers impaired by marijuana to the extent that it leads to fatalities, their numbers are small and generally alcohol figures into the accident as well.

IS THERE HOPE FOR A CLEAR MESSAGE?

One might assume correctly that this is a sad state of affairs, considering the importance of establishing relationships between the concentrations of drugs in body fluids and driving impairment. A consensus report concerning drug concentrations and driving impairment was recently published (Consensus Development Panel 1985), though the report actually represents conclusions from a 1983 conference. The committee of experts concluded that ethanol is not a good model for understanding how other drugs might affect driving impairment. In fact, in many ways ethanol is unique among psychoactive drugs in respect to its even distribution in body water, lack of binding to tissues and absence of long-lived metabolites. Alcohol is not only an unusually good model drug for studying relationships between drug effects and performance but also a unique one. Though not talking specifically about cannabinoids, the consensus committee pointed out that determinations of drug concentrations in body fluids are of only limited value for establishing behavioral impairment. The complexity linking blood concentration and resulting impairment is so complicated that it is unlikely that a drug concentration *per se* could ever be defended as a single index of guilt or innocence. The consensus group correctly points out that even the little we know about drug/behavior relationships is from single doses of a single drug, ignoring the vastly more complicated questions related to long-term repetitive use of combined drugs with the combined contributions of tolerance, dependence and drug interactions that will confound predictions. The experts concluded that testing of drugs or drug metabolites in urine is of only qualitative value and indicates only prior exposure. Inferences about the presence of, or systemic concentrations, of a drug at the time of driving or impairment are generally unwarranted.

DRUG INTERACTIONS WITH CANNABINOIDS

Tobacco, alcohol and other drugs with which cannabis is commonly and concurrently consumed share metabolic pathways, so that a variety of interactions are likely (Chesher *et al.* 1985). Metabolism of other drugs may be slowed or enhanced, depending on the timing and sequence of drugs and patterns of use (Benowitz and Jones 1981). For example, alcohol consumed shortly after a marijuana cigarette is smoked produces lower peak alcohol blood levels than would the same dose of alcohol taken before the marijuana is smoked. This is presumably because of slowed gastric emptying time produced by the cannabinoids. Tetrahydrocannabinol may interact with other drugs because of competition for available binding sites on plasma proteins as well as by what is probably the most common mechanism; that is, interactions at a functional level. It appears that functional adaptation in various neural systems can be additive, leading to enhanced or prolonged behavioral and psychologic effects of CNS depressants. On the other hand, diminished effects of CNS depressants may occur in people or animals tolerant to the effects of cannabis, indicating cross tolerance. Cannabis measurably alters the effects of alcohol, barbiturates, nicotine, amphetamines, cocaine, phencyclidine, opiates, atropine and chlorimipramine and, in principle, many other psychoactive and nonpsychoactive drugs (Addiction Research Center/World Health Organization 1983).

DEPENDENCE

Physical dependence, as manifested by withdrawal signs and symptoms,develops relatively rapidly with repeated, frequent, high-dose use of cannabis and more slowly with lesser doses over longer time (Addiction Research Center/World Health Organization 1983). People using cannabis several times daily quite predictably show irritability, nervousness, sleep disturbance, appetite loss, weight loss, sweating and upset

stomach when regular use is stopped abruptly (Jones *et al.* 1976). Whether such withdrawal symptoms necessarily lead to repeated use of cannabis or, for that matter, of any psychoactive drug is too complex an issue to fully resolve here, but one would assume that, under some circumstances, they must contribute to repeated drug use. Is driving behavior altered by the abstinence state? No one knows. An important point is that in recent years growing numbers of marijuana users behave as if they are addicted to cannabis. They seek treatment programs and present many of the same problems as do compulsive users of other drugs—opiates, tobacco, alcohol and other sedative hypnotics.

THE MOST USUAL EFFECTS OF CANNABIS

The most typical and expected effects of cannabis resemble a mild, transient, acute brain syndrome (Addiction Research Center/World Health Organization 1983). Ability to concentrate, attention span, memory, information processing and performance of complex perceptual motor tasks are impaired. Generally, the drug relaxes and decreases inhibitions. Depending on setting and expectations, the user may talk and laugh more frequently or become quiet and noncommunicative. Setting is probably important, just as it is in predicting the effects from a given dose of alcohol.

Cardiovascular effects are prominent, easily measurable and, as all other effects, doserelated (Benowitz and Jones 1975; Jones 1985). Increased heart rate, increased supine blood pressure, decreased standing blood pressure, impaired balance, dilated conjunctival vessels, constricted peripheral blood vessels resulting in cold hands and feet, dry mouth and throat, decreased tearing and increased appetite generally parallel the cognitive effects. Most of the those effects are mainly central in origin, but a variety of peripheral phenomena occur as well, particularly with repeated use. For example, blood volume will increase substantially with repeated use.

The intensity and the duration of all cannabis effects depend on the dose and on the frequency of dose. Easily measurable effects in laboratory circumstances rarely last more than 3 or 4 hours after the subject has smoked a moderate dose. Mostly subjective, hungover feelings consisting of impaired cognitive function, muscle incoordination, and drowsiness may persist for some hours, more particularly after oral administration (Chait *et al.* 1985). Whether any effects from a single dose can be measured 24 hours or later is not completely established, though in some laboratory procedures there are small but inconsistent cannabis versus placebo differences (Barnett *et al.* 1985).

LESS COMMON UNPLEASANT EFFECTS

None of the signs, symptoms and behaviors previously discussed are specific to cannabis intoxication. Thus, they are of diagnostic significance only when history, particularly drug history, and appropriate laboratory confirmation are available. Other drugs, particularly alcohol, are commonly ingested along with cannabis and can produce many similar effects, both physiologic and behavioral (Chesher *et al.* 1985). Anxiety, feelings of panic and paranoid ideation are the most commonly reported acute, short-lasting psychologic effects associated with cannabis use (Halikas *et al.* 1985). Such unpleasant effects are more likely associated with high cannabis doses, but their occurrence is also related to stressful social settings, inexperience with intoxicants and preexisting mental illness. Less marked and transient anxiety episodes are very common in novice users. Symptoms that occur both in controlled laboratory situations and, of course, in regular use rarely last for more than a few hours and are usually decreased by reassurance and a supportive environment (Addiction Research Center/World Health Organization 1983). No specific drug treatment is indicated. In clinical trials involving high doses of THC, disorientation, catatonic-like immobility and a condition of mixed anxiety and sedation were most common in older patients and those with no prior experience with cannabis.

CANNABIS PSYCHOSES

For many years, clinical reports from countries throughout the world repeatedly describe a cannabis-induced, psychotic-like state lasting from a few days up to 4 or 5 weeks after the last use of cannabis (Addiction Research Center/World Health Organization 1983). Mental confusion, recent memory impairment, impulsive behavior, delusions and perceptual distortions are common. From case reports, usually involving only a few patients and not random sampling, the frequency of such a syndrome is uncertain, but it is low. There is no agreement about appropriate diagnostic classification. The differences between acute schizophrenia and so-called cannabis psychoses are not always great. A reliable history of recent cannabis use and the presence of cannabinoid metabolites in urine or blood are useful in confirming the diagnosis. The short-term outcome appears similar whether cannabis or an otherwise occurring acute

schizophrenic psychosis is the proper term. Other scattered case reports suggest causative links between affective disorders, particularly manic episodes, and cannabis use. The weight of evidence suggests that these effects are, in fact, cannabis-induced, but no single case report meets the criteria for an adequate controlled clinical trial and such trials are unlikely.

AMOTIVATION

A less-well defined behavioral syndrome consisting of apathy, emotional blunting and what is thought to be a lack of appropriate concern over the future, together with a general loss of motivation, was observed in cannabis users some years ago and termed the amotivation syndrome. It still remains a matter of dispute among experienced clinicians. Patients who have been heavily using cannabis and showing such behavior do sometimes change to more normal or, at least to the critical observer, more acceptable behavior after some period of cannabis abstinence. Surveys of cannabis users generally find that many former users of cannabis stop because they either experienced a loss of energy or ambition or noticed it in fellow users (Halikas *et al.* 1985).

OTHER CANNABIS EFFECTS

Besides consistent and, at high doses, profound effects on brain function (as would be expected of any psychoactive drug), cannabis produces measurable effects on virtually every organ system that has been carefully studied (Addiction Research Center/World Health Organization 1983). The health consequences of most effects are not established, and the adverse health consequences of many effects are unlikely. Nevertheless, the spectrum of cannabinoid actions indicate at the very least that it is, biologically speaking, a potent group of chemicals.

Smoking cannabis, as might be expected, is likely to produce cellular and lung function alterations. Although similar amounts of carbon monoxide are absorbed while smoking tobacco or marijuana cigarettes, the cannabis tars contain greater amounts of many known carcinogens (Turner 1985). The potential for marijuana smoking to produce bronchitis and functional changes usually associated with early obstructive lung disease is clear. Pulmonary function rapidly improves when frequent marijuana smoking ceases.

Cardiovascular effects have already been alluded to (Jones 1985). At moderate and high doses, orthostatic hypotension can be severe, but tolerance develops very quickly to that effect. The hypotension could easily account for failure on a roadside sobriety test in the first hour after smoking. Cardiovascular effects are probably of little consequence for people who do not have cardiovascular disease. The magnitude of acute cardiovascular changes after smoking a cannabis cigarette is at least as large as that produced by nicotine and tobacco smoking. Whether similar chronic cardiovascular changes might follow is unknown.

At least in North America, cannabis is used to increase appetite, though elsewhere cannabis is believed to decrease appetite and is so used. At high doses, vomiting, diarrhea and abdominal distress can occur. Even modest doses will slow gastric emptying time and gut motility enough to alter absorption of other drugs. The antiemetic effects of cannabis have been investigated therapeutically, but they do not seem to offer advantages over other more readily managed drugs.

Cannabinoids have both mutagenic and carcinogenic effects in *in vitro* systems. However, no cytogenetic or mutagenic effects clearly and unambiguously attributed to cannabinoids have been identified in humans. Both animal and *in vitro* studies indicate immune system suppression by cannabinoids. Although the effects are generally mild compared with other immunosuppressant drugs, one might argue that in especially predisposed individuals, even mild effects might be of significance if a drug is used by large populations.

Animal studies clearly indicate that exposure to cannabis before or after birth interferes with normal growth and development. Cannabis is clearly teratogenic at high doses in some species. Cannabinoids readily cross the placenta. Lasting behavioral effects in offspring of mothers exposed to cannabis during pregnancy have been noted both in animal and in human studies. Birth weight is lower in mothers who regularly use cannabis. One study focusing on the fetal alcohol syndrome found that maternal marijuana use was a better predictor of the occurrence of that syndrome than was alcohol use alone (Hingson *et al.* 1982; 1985). Marijuana, tobacco and alcohol are so often used together that one might expect additive and combined effects on the fetus exposed to an array of toxins. Infants with the stigmata of fetal alcohol syndrome have been born to mothers who used only marijuana and no or very little alcohol during pregnancy (Qazi *et al.* 1985). The behavioral changes most evident in learning and memory persist in animals for some months. Infants exposed to cannabis via their mothers during pregnancy show increased tremor, startle responses, and altered visual tracking in the immediate postpartum period.

Some uncertainty remains about whether cannabinoids cause lasting microscopic or macroscopic changes in brain structure. Two clinical studies reported cannabis-related changes in brain morphology. At least two other studies found no changes in structure using somewhat similar measurements. However, all of those studies, both positive and negative ones, suffer from methodologic and analytic defects. A more recent animal study using computerized tomography reported small but statistically significant brain ventricle enlargement in the frontal and caudate areas in monkeys given moderate doses of THC orally for some years (McGahan *et al.* 1985). The brain scans were done 1 year after the THC was discontinued. One group had received modest doses of oral THC for 2-10 months and the other for 5 years. When compared with the untreated control and the short- term exposed groups, the monkeys who had received THC daily for 5 years had small but statistically significant ventricular enlargement in the frontal and caudate areas of the brain. Such data, of course, are hard to come by and easy to misinterpret, and they need confirmation from other laboratories before a definitive assessment can be made. Such studies, unfortunately, are time-consuming, expensive and, in these days of diminished Federal research support, less likely to be done properly, if at all.

CONCLUSION

The weight of the evidence is that for some people (and animals) long-term use of cannabis is not good for optimal brain function. Clearly, cannabis use alters (damages) brain function (Turkanis and Karler 1985) and impairs many aspects of behavior and thinking for a few hours after a moderate dose. A large dose impairs brain function even longer. Optimal brain function is necessary for optimal behavior. After a moderate dose, THC and cannabinoid metabolites stay in the body for days, weeks or months. Whether one can properly link in a causal way cannabis use, impaired brain function for a few hours, long presence in the body of the drug or its metabolites (and their appearance in urine) and behavior that injures or troubles society is a complex issue. However, in some people, under certain conditions, cannabinoids alter behavior so as to produce harm, but it will not be easy to work out all of the rules to predict who will be affected and when.

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DISCUSSION

Fisher: Given the combination of observable symptoms that a police officer might see, plus a positive finding of marijuana, what opinion might you be willing to give in courtroom testimony?

Jones: There is no specific pathoneumonic unique set of symptoms that cannabis produces that could not be mimicked by something else or confounded by the coexistence of alcohol, barbiturates, benzodiazepines and the like. I have no firm opinion to give.

Peat: The pattern of driving impairment, together with some field sobriety test impairment, would support the finding of marijuana in the blood stream, and THC and carboxy may support those. There are other symptoms and other drugs that induce the same type of appearance.

Siegel: I was interested in Dr. Jones' comment that oral ingestion yields a very low bioavailability for cannabis products, THC, and the like. In the 1970's, it was popular to bake brownies with marijuana and there was a lot of talk at that time about thermal effects. Is there really anything to that? Does the baking phenomenon increase the bioavailability of THC?

Jones: Heating decarboxylates some of the THC, so in principal it might be more psychoactive. I do not think anyone has really looked at it systematically. Maybe what does increase the bioavailability (the amount of THC in the brownie that gets into the venous blood) has more to do with the lipid vehicle in which it is given. People at RTI have shown that in an oil vehicle you get better absorption. So I assume that someone who makes brownies with lots of butter would see more bioavailability than someone who does not make brownies with lots of butter.

Biasotti: Going back to Barry Fisher's question, for those of us who are faced with the day-to-day use of these data, if we were to change that hypothetical-to-lab analysis showing alcohol either to be below 0.10% or negative, and without the presence of other drugs but exhibiting symptoms of marijuana, what would you be able to say in terms of supporting a charge of driving under the influence (DUI)?

Jones: If you could rule out by laboratory tests and observable symptoms the presence of any other

drug, you are left with a suspect who has a dry mouth, strange behavior, dilated or injected conjunctival vessels and so on. You are starting to make a case, but there are any number of things that could account for their behavior, including mental illness or fear. I think to prove the absence of something is very difficult and there is no set of signs and symptoms that cannabis produces that cannot be mimicked by something else.

Peat: If you demonstrate the presence of significant concentrations of THC and carboxy acid in the blood specimen, then I think you have a much better case. But if you demonstrate only a positive urine-cannabis result by immunoassay, I am not convinced at all. The requirement is a demonstration of THC and the metabolite in blood specimens.

Question: Referring to that hypothetical situation, I am not talking about subtle symptoms but about the typical case where the officer can demonstrate obvious field sobriety, with indications of erratic driving, etc. What would the presence of 0.05% alcohol and low concentrations of THC and carboxy in the blood sample do to your interpretation?

Jones: The best prediction of drug effects that alter behavior is the behavior exhibited by the subject. I would put the weight of the decision on the officer's descriptions of behavior. The tissue levels are secondary.

Peat: A concern I have with that example is that hardly any laboratory studies to date have shown such great decrements in driving performance due to marijuana.

Jones: In the laboratory, someone who smokes a cigarette made with sensimilla with 4%-7% THC will experience gross behavioral changes. There is enough postural hypotension that a person who has just smoked a sensimilla joint and is stopped by a police officer and forced to stand up for a roadside sobriety test would faint and fall down. All the laboratory data that we see comes from such relatively minuscule doses of THC that the officers in the real world are seeing effects of what could almost be another drug, compared with the scientific literature about marijuana. I do not think we are ever going to study the high doses because of fiscal and other constraints.

Question: You seem to indicate that frequent users versus infrequent users could be determined by laboratory testing. Would that information be useful in the prosecution of a case?

Peat: If the preliminary urine observations that I reported are confirmed, then it may be possible to differentiate frequent and infrequent uses. It must be remembered that there was an extreme in the study I reported. The infrequent user only used marijuana maybe twice a month and the frequent user used marijuana daily for a number of years. There is going to be a gray area where you might not have a clear differentiation.

Techniques used to detect the presence of marijuana may be time-consuming and expensive, like high performance liquid chromatography (HPLC) radio immunoassay, and can complicate things. If those observations were confirmed in the urine, that may be useful. If the carboxy-THC concentration in blood or plasma were to be used as a mark of the infrequent/frequent user, then it would be easier to do, but I feel that is going to be the less reliable of the two proposed measures.

Briglia: You mentioned that there is not a good correlation between THC levels in plasma and the subjective effects of that drug. Are any data available pertaining to the distribution of THC into the more lipid matrix of brain tissue and its clearance from that particular tissue?

Jones: No. In rabbits and, I think, rats, there are surprisingly low brain levels compared with plasma and blood levels and other organs such as the spleen, liver and lung. In smoking I think you get a very transient and high brain level that can trigger all sorts of psychoactive things. That brain level falls very quickly. The animals are given marijuana intravenously or peritoneally, which differs from a person smoking marijuana. For those of you in a position to get some post mortem brain levels of some cannabinoids, it would be useful to do so.

Cardona: Is it a dangerous practice just to do the analysis to offer the information to the prosecutor's office, in spite of the fact that your testimony is backing up what the officer has observed?

Peat: I think that depends on your prosecutors. Yes, I would be very concerned about offering a report on THC and carboxy-THC blood concentration to a prosecuting agency, unless I was directly involved or some educational process had gone on before that. Lawyers tend to believe that the higher the level of carboxy acid in urine screening, the more stoned a person is. To give a report to a prosecutor or any lawyer without some sort of training could be very dangerous.

Jones: I don't think one can, certainly once you move out of the area of alcohol, predict a likely set of behaviors simply on the basis of a laboratory test.

PHARMACOKINETICS OF DELTA-9-TETRAHYDROCANNABINOL AND ITS METABOLITES

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The true impact of drugs, other than alcohol, on highway safety is relatively unknown. Only in recent years have the incidence and prevalence of drug involvement in traffic accidents been studied. Since marijuana is used extensively, both alone and with alcohol, a number of epidemiologic studies have focused on the incidence of marijuana use in fatally injured drivers. Williams *et al.* (1985) found that 37% of fatally injured drivers in California between the ages of 15 and 34 years had detectable concentrations of delta-9-tetrahydrocannabinol (THC) and one of its metabolites in blood. The study also showed that over 70% of these drivers had alcohol in their blood. These results are in agreement with others (Cimbura *et al.* 1982; Mason and McBay 1984).

Laboratory studies have shown that marijuana impairs perceptual and perceptual motor functions important to driving. For example, Manno *et al.* (1971) found significant impairment on a pursuit meter test at a dose of 50 mcg of THC per kg body weight. Studies of perceptual functions have shown deficits due to marijuana; detection of intermittent random signals in both central and peripheral vision is impaired (Casswell and Marks 1973; Moskowitz *et al.* 1972), as is the ability to perform vigilance tasks (Sharma and Moskowitz 1973). A simulator study by Stein *et al.* (1983) using a graphics display simulator with a sparse visual scene and sophisticated car dynamics showed that marijuana significantly reduced subjects' speed and reaction and increased their random movements. Tracking, *per se*, was not significantly affected.

The major psychoactive component of marijuana is THC, which is metabolized to many different metabolites. Halldin *et al.* (1984) reported over 20 carboxylic acid metabolites of THC which could be detected in urine. There are undoubtedly many other metabolites. The primary metabolic route of THC which is of interest to forensic scientists is the formation of 11-hydroxy-THC (hydroxy-THC) via the hepatic cytochrome P450 enzyme system and the further metabolism of this to 11-nor-9-carboxylic acid THC (carboxy-THC) by liver alcohol dehydrogenases. Sensitive and specific analytical procedures, primarily radioimmunoassay (Peat 1984) and gas chromatography-mass spectrometry (Foltz 1984), now allow forensic scientists to measure the concentrations of THC and its metabolites in body fluids. Behavioral, physiologic and psychologic effects of marijuana are usually measurable for only a few hours after it is smoked (Barnett *et al.* 1985; Chiang and Barnett 1984; Ohlsson *et al.* 1980), whereas the cannabinoids can be detected in body fluids for much longer periods (Ellis *et al.* 1986; Wall *et al.* 1983). It should be noted that a recent report by Yesavage *et al.* (1985) suggests that subjects' ability to perform complex tasks is impaired after they smoke marijuana. The ability to estimate when marijuana was smoked from a quantitative analysis of THC and its metabolites in plasma, blood or other biologic fluids would be very valuable to forensic scientists. To arrive at an accurate estimate, one must understand cannabinoid disposition in both infrequent and frequent marijuana users.

Numerous reports have been published on the plasma time-course curve of THC administered intravenously or orally or by smoking. Several studies have used radiolabeled THC to monitor the concentrations of THC and its metabolites by scintillation counting of various chromatographically separated cannabinoid fractions. Others have used radioimmunoassay or gas chromatography-mass spectrometry to assay THC and specific metabolites. All of these studies indicate that there is a general pattern to the plasma time-course curve for THC. After bolus intravenous administration of ^{14}C-THC, there is a rapid and precipitous drop in plasma concentrations, as shown in Figure 1 (Hunt and Jones 1980). The drug is both metabolized and distributed quickly into tissues and lipid stores. The apparent volume of distribution of the central compartment is close to the volume of plasma in the body because of the compound's high plasma protein binding of 97% (Garrett and Hunt 1974). Subsequently, the rate of loss of THC slows measurably, and between three and five exponentials may be necessary to characterize the plasma time-course curve, the number being dependent on the sensitivity and duration of the plasma assays with respect to dose. For example, four exponentials were needed when plasma concentrations were monitored up to 30 hours (Figure 1). The apparent terminal half-lives for specifically

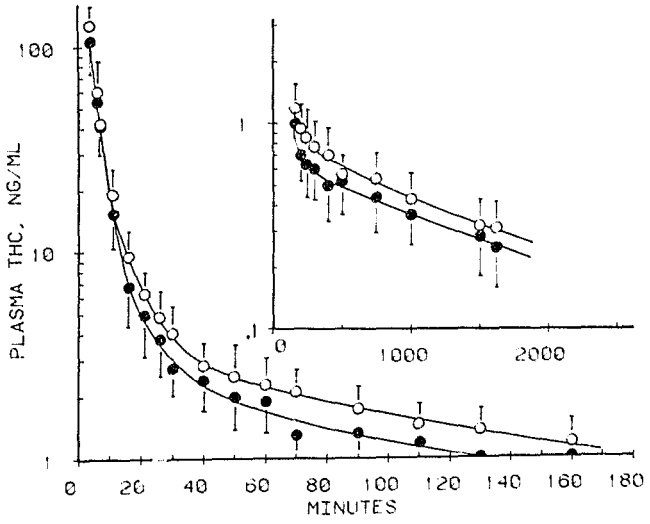

Figure 1. Semilogarithmic plot of average plasma levels v. time following a 2-minute infusion of 2 mg of in six subjects before (0) and after (●) long-term oral THC administration. Each curve is the average computer generated (NONLIN) best fit. Each bar represents 1 SD. The inset is a continuation of the data on a longer time scale. Reproduced from Hunt and Jones (1980) with permission.

analyzed THC were between 19 and 36 hours (Hunt and Jones 1980; Wall *et al.* 1983). These results suggest that there are several body compartments in which the drug has variable rates of penetration, and the findings are consistent with the known distribution patterns of lipophilic THC into fat, its high sequestration in certain organs such as the liver and lung and its extremely high binding and adhesion properties. Similar plasma time-course curves would be expected after a subject has smoked marijuana; Ohlsson *et al.* (1980) showed that the mean plasma curve after smoking is essentially parallel to that after intravenous administration.

Figure 2 shows the plasma time-course curve for THC, hydroxy-THC and carboxy-THC in an infrequent user of marijuana who has smoked 19 mg of THC (Peat *et al.*, submitted for publication). These measurements were made by gas chromatography-mass spectrometry. The curve for THC is similar to that shown in Figure 1 and to that reported by other workers. The half-life of the initial distribution phase was 3.2 ± 0.12 minutes. Chiang and Barnett (1984) previously reported a half-life of 3.1-4.5 minutes by radioimmunoassay. The half-life of the second phase was determined to be 50 ± 1.7 minutes, but this should not be considered to be a terminal half-life. Inspection of this figure also shows that carboxy-THC can be detected in the initial plasma sample after marijuana is smoked, and within approximately 30 minutes its

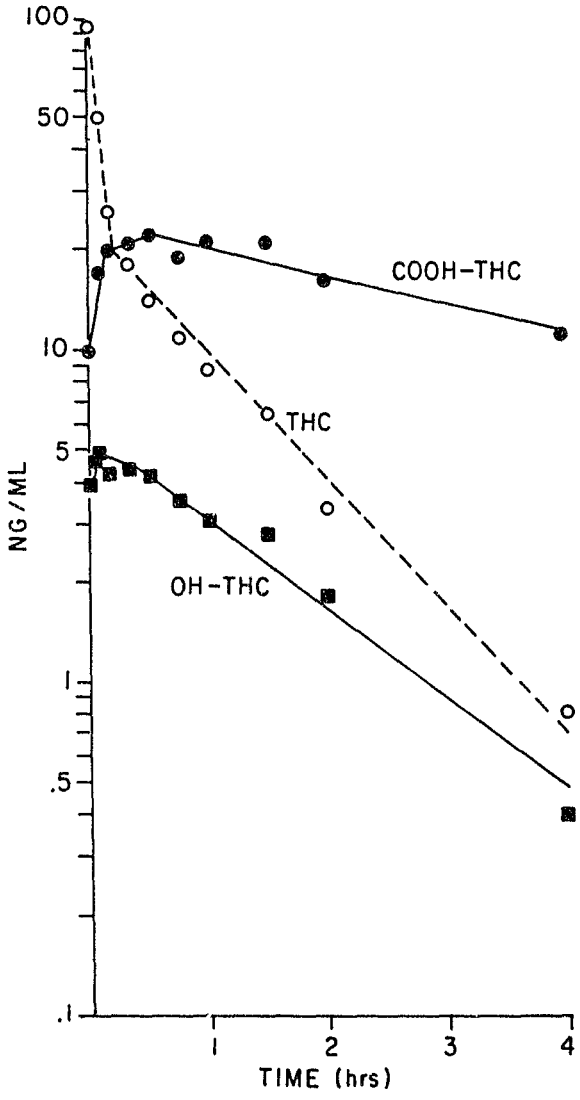

Figure 2. Plasma concentrations (ng/ml) of THC, hydroxy-THC, and carboxy-THC in an infrequent user for 4 hours after smoking a marijuana cigarette containing 19 mg THC.

concentration exceeds that of THC. Previous work by Barnett *et al.* (1982) has shown that THC concentrations peak during smoking. Carboxy-THC can be detected for 6 days after smoking, but plasma concentrations fall below 10 ng/ml within 1 day. The terminal half-life of carboxy-THC was estimated to be 32.8 ± 2.2 hours, and this is in relatively good agreement with the value reported by Hunt and Jones (1980) and Wall *et al.* (1983), although their estimates using radiolabeled tracer studies are somewhat longer.

From the forensic scientist's viewpoint, these data are interesting in that plasma THC concentrations of greater than 1 ng/ml suggest that marijuana has been used within 4 hours; they support other reports by Hanson *et al.* (1983) and Ohlsson *et al.* (1980). It should be noted that blood concentrations of THC

might be expected to be approximately 50% of those in plasma because of the significant plasma protein binding and its poor distribution into red blood cells. However, the interpretation of such concentrations is complicated if frequent users of marijuana are considered. Ohlsson *et al.* (1982) reported that regular smokers of marijuana had concentrations of THC between 0.5 and 1.0 ng/ml. Figure 3 shows plasma time-course curves for THC and its metabolites in a daily user of marijuana who has smoked 19 mg of THC. This individual had not smoked marijuana for the last 12 hours. In five regular marijuana users who smoked an average of 57.8 marijuana cigarettes per month, predose plasma THC concentrations ranged from 0.4 to 1.6 ng/ml. Up to 2 days after these individuals used marijuana, THC concentrations of approximately 1 ng/ml could be detected, indicating

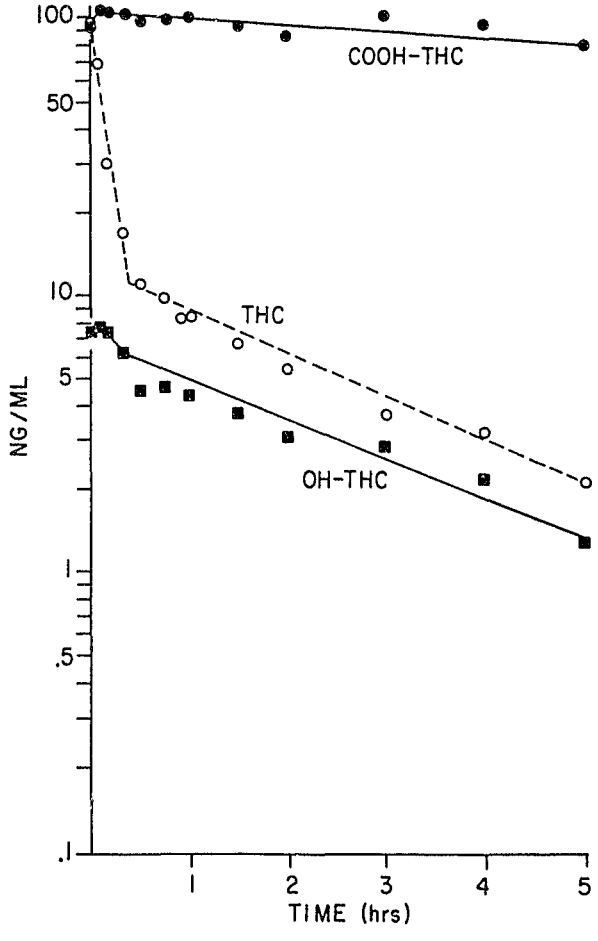

Figure 3. Plasma concentrations (ng/ml) of THC, hydroxy-THC, and carboxy-THC in a frequent user for 5 hours after smoking a marijuana cigarette containing 19 mg THC.

that the interpretation of a plasma or blood THC concentration alone without further information should be attempted only with extreme caution.

There are other differences between the plasma time-course curves for frequent and infrequent users. The concentration of carboxy-THC is significantly higher in the frequent users, with predose concentrations ranging from 11 to 83 ng/ml (mean = 45.8 ± 13.1 ng/ml). Plasma THC concentrations exceeded those of carboxy-THC for a much shorter period of time (approximately 10 minutes). The concentration of carboxy-THC detected may serve as an indication of whether the sample came from an infrequent or frequent user. The half-lives of THC for the second distribution phase and for the initial phase in the carboxy-THC plasma time-course curve were longer than those in infrequent users. The reason for these differences is not clear, although they suggest reduced clearance of THC because of saturation of lipid depots. There was no difference in the terminal half-life of carboxy-THC, estimated to be 40.2 ± 4.7 hours in frequent users. Again, it should be stressed that, because of the analytical technique used to measure THC concentrations, its true terminal half-life was not estimated; this terminal half-life could be the same in both frequent and infrequent users. Indeed, Hunt and Jones (1980) estimated the terminal half-life was the same in individuals administered THC for long periods and in those receiving one dose.

Using a half-life of 18 hours and a use pattern of four cigarettes daily for 4 days, Chiang and Hawks (personal communication) estimated that after a single use of marijuana (containing 2% THC) on day 5, plasma levels will remain greater than 5 ng/ml for 15 hours and will exceed 1 ng/ml for up to 53 hours. This is shown graphically in Figure 4.

To return to the original question of whether it is possible to estimate when smoking occurred from the analysis of a blood or plasma sample, the answer must remain equivocal. Certainly if we know that the sample was collected from an infrequent user (that is, someone who may use it two to three times a month), a plasma concentration of THC in excess of 1 ng/ml and a carboxy-THC concentration in excess of 10 ng/ml suggest use within 4-6 hours. However, if the type of user is unknown, then concentrations such as 1 ng/ml and 10-20 ng/ml, respectively, may be detected for up to 2 days after use in a frequent user. Although information on plasma carboxy-THC concentrations is limited, concentrations in excess of 50 ng/ml are probably from a frequent smoker. This suggestion has yet to be confirmed. Wall *et al.* (1983) reported plasma carboxy-THC concentrations of less than 50 ng/ml in

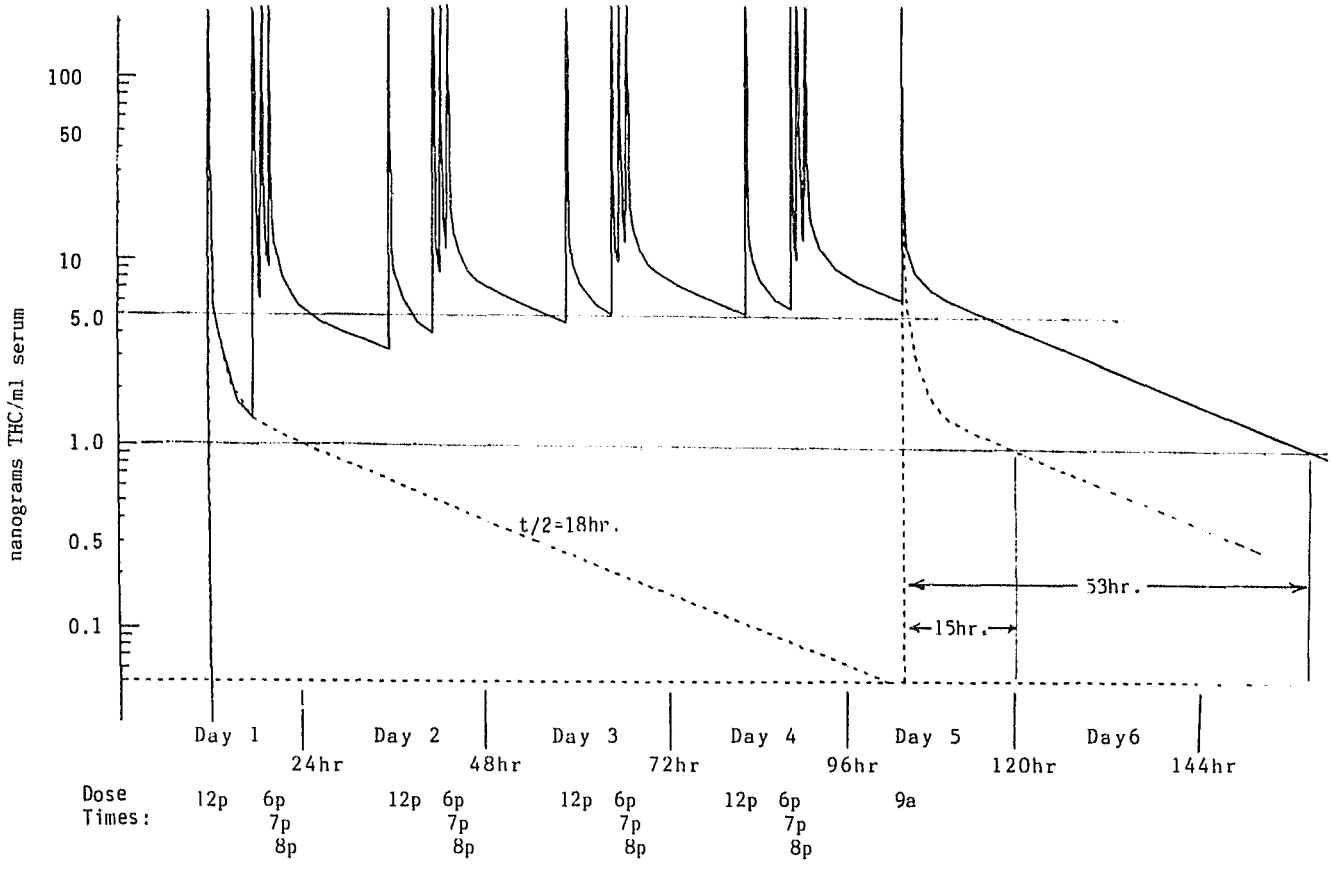

Figure 4. Predicted serum concentrations of THC after long- and short-term marijuana smoking (Chiang and Hawks, personal communication).

six men and six women after intravenous administration of ^{3}H-THC, but their report does not indicate if the subjects were frequent or infrequent users.

The interpretation of analytical data is made all the more difficult if the route of use is unknown and if it could have been used orally. Wall *et al.* (1983) noted that after intravenous doses, the ratio of THC to hydroxy-THC varies from 10:1 to 20:1, whereas after oral doses the ratio is approximately 2:1. The increase in hydroxy-THC concentration and decrease in concentration of THC is attributed to first-pass metabolism. The increased proportion of the active metabolite, hydroxy-THC after oral dosing may make a significant contribution to the observed psychologic effects. As expected, much higher concentrations of carboxy-THC were also noted after oral use, and they were comparable to those seen after smoking in frequent users. Two days after oral use (20 mg THC), the mean plasma concentrations of THC and carboxy-THC in men were 2.2 ± 1.7 and 14 ± 6 ng/ml respectively (Wall *et al.* 1983); comparable concentrations in regular smokers were 0.81 ± 0.16 and 22.8 ± 3.3 ng/ml (Peat *et al.*, submitted for publication). This decrease in plasma THC concentrations seen after oral use, when compared with intravenous administration or to use by smokers, has also been reported by Ohlsson *et al.* (1980) and by Law *et al.* (1984a).

Monitoring of urine samples for cannabinoid metabolites is routinely performed by immunoassay techniques, particularly radioimmunoassay and enzyme multiplied immunoassay (EMIT). The antibodies used in the commercially available procedures have been reported to be specific for cannabinoids with a dibenzopyran nucleus (Jones *et al.* 1984) and to have little or no cross- reactivity for other cannabinoids, other drugs or endogenous chemicals. They are directed against the primary urinary metabolite, carboxy-THC. Although the detection of a drug or drug

metabolite in urine is not considered proof of impairment, considerable work has been done on the excretion of THC metabolites in urine, and some of this information may prove useful in estimating time since use and the type of user involved.

Many people believe that urine immunoassay results will remain positive for a number of days, even weeks, after marijuana is smoked. In fact, the duration of positive urine samples is extremely dependent on the user. Bastiani (1984) compared urinary excretion patterns in frequent and infrequent marijuana users by the EMIT-dau procedure, which has a 20 ng/ml cut-off. Of the less frequent users, all produced presmoking samples that were designated negative. Generally, these subjects were positive for 2-5 days after each dose. In contrast, frequent users produced presmoking positive responses and remained positive for almost the duration of the 25-day study. When the same samples were analyzed by the EMIT-st procedure, with a cut-off of 100 ng/ml, the less frequent users produced positives for only 1-3 days. Thus, the number of positive samples detected is dependent on both the type of user and the sensitivity of the analytical procedure used.

More recent work on frequent users by Ellis *et al.* (1986) has shown that samples can test positive by immunoassay (greater than 20 ng/ml by EMIT-dau) for up to 46 days after marijuana use is stopped and that it may take 77 days to drop below the cut-off for 10 consecutive days. Figure 5 shows the excretion patterns for three cannabis users.

Single or even multiple positive urine tests by an immunoassay technique are only indicators of cannabinoid use and serve no useful purpose in estimating the time of smoking. In an infrequent user, a high immunoassay reading may indicate use within the past 12-24 hours. Peat *et al.* (submitted for publication) have determined the total concentration of unconjugated and conjugated carboxy-THC in urine samples from frequent and infrequent users who smoked 19 mg of THC. Figure 6 shows the mean concentrations versus time; note that there were large differences between individuals in the concentrations determined. As expected, the frequent users had detectable carboxy-THC concentrations in their predose specimens. Although the concentrations were different in the frequent users, the shape of the curve was similar, and both groups excreted approximately 50% of the total amount in the first 24 hours. Concentrations in excess of 100 ng/ml were detectable for up to 1 day in infrequent users and for up to 2 days in frequent users. By 6 days, urine samples were negative from infrequent users, and only low concentrations (less than 5

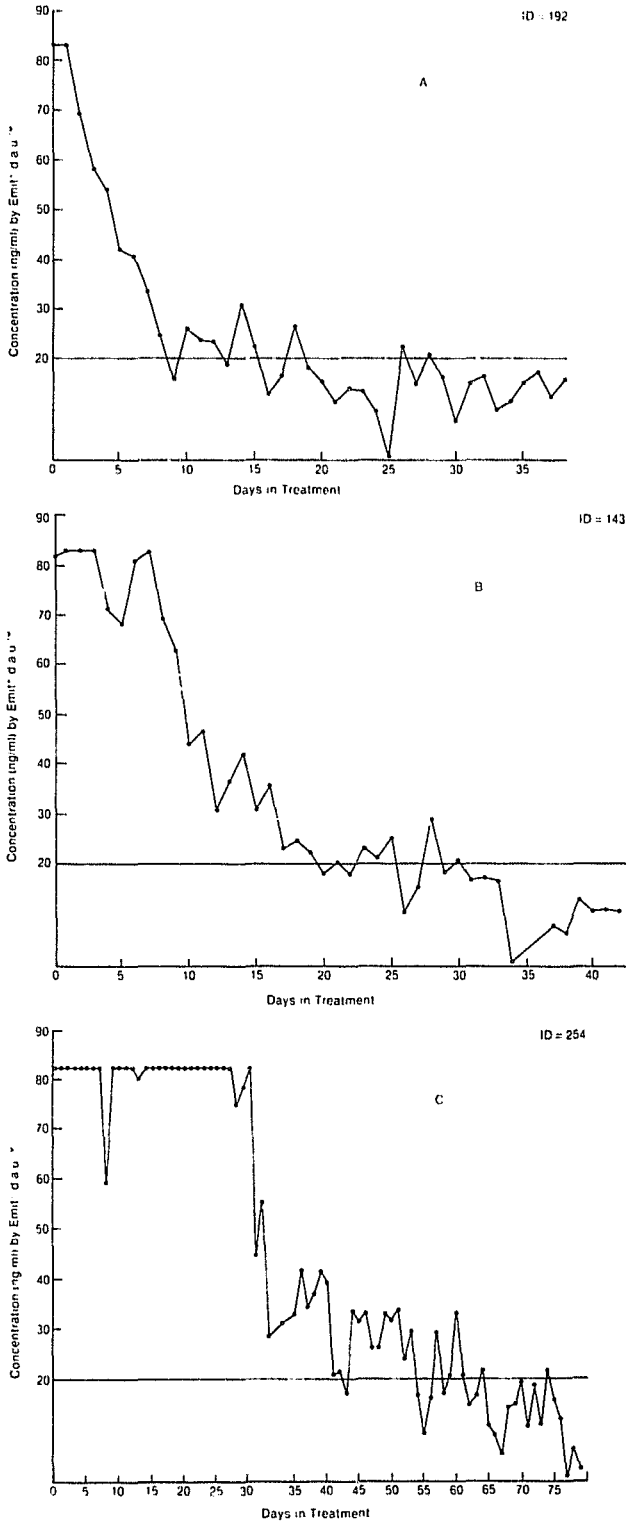

Figure 5. Estimated daily urine level equivalents for three cannabis users. (a) Light user; (b) heavy user; (c) heavy user. Reproduced from Ellis et al. *(1986) with permission.*

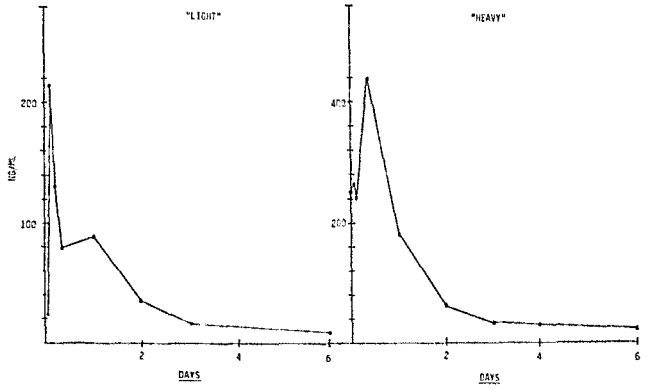

Figure 6. Average urine concentrations (ng/ml) of total conjugated and unconjugated carboxy-THC in frequent (n=4) and infrequent users (n=5).

ng/ml) could be detected in samples from frequent users.

There is a significant discrepancy between urine immunoassay and gas chromatography-mass spectrometry results in frequent users. Preliminary studies by Alburges and Peat (1986), using high performance liquid chromatography-radioimmunoassay to analyze urine samples, have shown a more complicated metabolic picture for a frequent user than for an infrequent user. More importantly, perhaps, they showed that in an infrequent user carboxy-THC is present as a glucuronide conjugate after smoking, whereas for a frequent user both unconjugated and conjugated acid are present. Thus, although urine may not be a good sample for accurately estimating time of use, it may differentiate frequent from infrequent users of marijuana if these preliminary observations are confirmed.

Questions have also been raised concerning the possibility that passive inhalation of marijuana smoke causes positive readings for THC and carboxy-THC in blood and/or urine. Three studies have been published on this. Morland *et al.* (1985) examined blood and urine samples from five volunteers passively exposed to cannabis smoke for 30 minutes. Cannabis smoke was provided by other subjects smoking either marijuana or hashish cigarettes in a small closed car, containing approximately 1,650 liters of air. The smokers were instructed to inhale the smoke as little as possible to increase the amount of side-stream smoke diffusing into the surrounding atmosphere and hence the amount of THC available for passive inhalation. Under these conditions, THC could be detected in the blood of all passive smokers immediately after exposure at concentrations ranging from 1.3 to 6.3 ng/ml. By 2 hours, blood samples tested negative by gas chromatography-mass spectrometry. These results agree with those of Perez-Reyes *et al.* (1983), who detected a maximum concentration of 2.2 ng/ml within 1 hour after exposure to marijuana smoke. These workers also determined urine cannabinoid concentrations by the EMIT-dau procedure. Their results indicated that of 80 urine samples collected in three separate studies, the cannabinoid concentrations in only two specimens slightly exceeded 20 ng/ml. The positive urine specimens were those collected in the first void after exposure. In a third study (Law *et al.* 1984b), four passive subjects were exposed in a room to cannabis smoke for 3 hours. Urine samples collected for 6 hours after exposure from the passive subjects were analyzed by radioimmunoassay and found to be positive. However, the maximum concentration of cross-reacting cannabinoids detected was 6.8 ng/ml.

To summarize the studies on passive inhalation, it is obvious that passive inhalation of cannabis smoke is possible, but it requires extreme conditions of exposure and even then the urine or blood concentrations obtained are extremely low. Unpublished studies by other workers do show greater concentrations, but in these studies conditions were even more extreme than in those already published.

Is there a temporal relationship between THC or carboxy-THC concentrations and the effects produced by marijuana smoking? Figure 7 contains data obtained from an experiment in which six subjects smoked two marijuana cigarettes, each containing 8.8 mg of THC. The second cigarette was smoked 2 hours after the first. The plasma time-course curves for THC and carboxy-THC are similar to those shown in

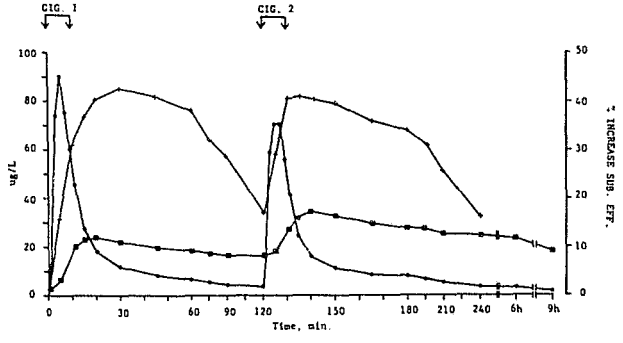

Figure 7. Average plasma concentrations of THC (●) and 9-carboxy-THC (■) and average subjective effects (+) in six subjects after smoking two NIDA marijuana cigarettes, each containing 8.8 mg of THC (1%). Reproduced from Mason and McBay (1985) with permission.

Figure 2. Subjective effects usually begin immediately after the start of smoking, reach their peak between 20 and 40 minutes and usually last up to about 4 hours. Maximal THC plasma concentrations occur within 10 minutes of the start of smoking (Barnett *et al.* 1982). It is evident that THC plasma concentrations decline long before and while peak effects are experienced. In fact, subjective effects appear to correlate better with carboxy-THC concentrations, but this cannabinoid is not psychoactive. The possible reason for the lack of correlation between THC concentration and subjective effects is the time for distribution of THC into brain tissue. It also must be remembered that, after long-term administration of THC, tolerance develops to some of the psychologic effects (Hunt and Jones 1980). This advent of tolerance is not accompanied by significant changes in THC plasma concentration when compared with nontolerant individuals.

Finally, is there a relationship between plasma THC concentration and the deficits in performance noted in driving simulator and/or related laboratory tasks? Barnett *et al.* (1985) examined the correlation between plasma concentrations and three perceptual-motor performance measures related to driving. They found a significant linear correlation between tracking errors under divided attention and THC plasma concentrations over the range 5-25 ng/ml for approximately 2 hours after smoking. A sigmoid relationship was also found between critical tracking breakpoint and log THC plasma concentrations over the range of 2-25 ng/ml for approximately 6 hours after smoking. However, these data must be interpreted with caution, as the extent to which impairment on a laboratory measure predicts driving impairment from smoking marijuana is unclear. In addition, the quantitative relation between statistically significant impairment on these laboratory measures and practical impairment in driving or operating an airplane or machinery is not known. Not withstanding these limitations, Barnett *et al.* (1985) found a consistent relationship between human performance decrement and plasma THC concentrations.

In summary, the interpretation of blood, plasma, or urine THC and/or carboxy-THC concentrations should be approached with caution. In some circumstances, it may be possible to estimate when smoking occurred; however, this should be done with extreme care if no information is available concerning the type of user. Marijuana has been shown to impair certain tasks related to driving, and there appears to be a correlation between certain deficits and plasma THC concentrations. However, much more work remains to be carried out in this area.

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THE BEHAVIORAL PHARMACOLOGY OF CENTRAL NERVOUS SYSTEM DEPRESSANTS

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An examination of the behavioral pharmacology of a psychoactive drug should try to determine if that drug produces adverse behavioral effects. If there is evidence that it does, then more difficult questions follow. At what dose level does the drug impair, which skills are susceptible and what is the practical significance of the potential impairment? With the current prevalence of nonmedical drug use, these questions assume social and safety importance. Several decades and an enormous effort have gone into the study of a single substance, alcohol. As a consequence, its pharmacologic effects are known in considerable detail, and although important issues remain, there is a consensus concerning the effects of alcohol on human performance. The behavioral pharmacology of other psychoactive drugs is markedly less well understood, and the meaning of analytic findings for many of them is limited, at best.

In comparison to the difficulty of studying other drugs, alcohol study has been straightforward. The alcohol molecule is relatively simple and can be traced in the body. Metabolic products are not significant either in amount or activity, and only the parent molecule is of interest. The breath:blood ratio permits quantification of the presence of alcohol with noninvasive methods. This in turn makes possible the laboratory and epidemiologic studies that are essential to the study of behavioral effects of any substance.

Since these characteristics, which have facilitated the study of alcohol, do not apply in total to any other drug, it is unlikely that the same model and methods of study can simply be extended. Rather, different and innovative approaches will be required to pursue the behavioral pharmacology of drugs.

At present, compiling a comprehensive account of the effects of a drug or a class of drugs is a difficult task. The needed research is in its infancy, and many drugs simply have not been studied. Further, the absorption, distribution, metabolism and excretion processes differ from drug to drug. It is safe to state that, in this field at this time, somewhat arbitrary choices may be made as to whether the issue is an investigator's decision about what candidate drugs to study or this reviewer's decision about what literature to cover.

In the latter case, two principal criteria have dictated the choices. First, the drugs appear in significant or increasing numbers in cases of traffic-accident injuries and fatalities; and second, the meaning of blood levels of the drugs is an issue in forensic proceedings. Within the central nervous system (CNS) depressant grouping, hypnotic-sedatives and anxiolytics clearly meet these criteria. Widely used drugs from these categories can be assessed, at least in part, in terms of the issues of interest here.

HYPNOTIC SEDATIVES

Though their use has declined since the advent of the benzodiazepines, the barbiturates remain important in the hypnotic-sedative category (Table 1). The nonbarbiturate sedatives are also of interest (Table 2). Drugs such as Placidyl and Doriden are chemically different but belong pharmacologically to the same class as the barbiturates, and their effects appear to be closely similar.

Many barbiturates have been synthesized, about 50 have been accepted for medical usage and a smaller number have been abused. The barbiturates produce a nonselective depression of the CNS, and their abuse potential is related to the duration of that action, which ranges from very short, to short to intermediate, to long. Phenobarbital is long-acting and widely prescribed but not heavily abused. At the other extreme, the very short-acting barbiturates are used principally as anesthetics and are not available by prescription or from the illicit market. In contrast, the short-to-intermediate duration sleeping pills and sedatives are often misused.

In the United States secobarbital (Seconal), pentobarbital (Nembutal), butabarbital and butalbital are prominent among abused substances. These can be obtained in combination with other active ingredients as well as alone. Butalbital, for example, is available as Fiorinal. There are other barbiturates that are better known in other countries.

A *caveat* of sorts is appropriate as an introduction to a brief report of the literature. Before the development of the benzodiazepines, the barbiturates were the drugs of choice as mood modifiers. Some studies of

Table 1. HYPNOTIC-SEDATIVES: BARBITURATES

Product Name		Duration
Amytal	amobarbital	Short-intermediate
Alurate	aprobarbital	Intermediate
Butisol	butabarbital	Short to Intermediate
Mebaral	mephobarbital	Long
Nembutal	pentobarbital	Short
Pentothal	thiopental	Ultra-short
Seconal	secobarbital	Short
Solfoton	phenobarbital	Long
Tuinal	secobarbital and amobarbital	Short and intermediate
Combinations		
Carbrital	pentobarbital carbromal (nonbarbiturate sedative)	
Donnatal	phenobarbital atropine scopolamine hyoscyamine	
Fiorinal	butalbital aspirin phenacetin caffeine	
Plexonal	barbital butalbital phenobarbital scopolamine	
Sedapap	butalbital acetaminophen	
T-Gesic	butalbital codeine acetaminophen	

Table 2. NONBARBITURATE HYPNOTIC-SEDATIVE DRUGS

Product Name		Effect
Doriden	glutethimide	Hypnotic
Noctec	chloral hydrate	Sedation
Noluda	methyprylon	Hypnotic
Placidyl	ethchlorvynol	Hypnotic
Quaalude	methaqualone	Hypnotic
Valmid	ethinamate	Hypnotic

these drugs were published several decades ago, and a careful reading of that early literature suggests that studies were not always reported, or possibly were not executed, with the rigor that has since become the standard for laboratory drug studies. In evaluating the importance of findings from a particular research study, it is essential to consider not only dose levels but also the details of experimental design and procedure. If doses are high enough, if tests are difficult enough and if performance testing coincides with peak drug effects, it is possible to find almost universal impairment. Similarly, an erroneous finding of no effect may be reported from studies that use very low doses, nondemanding or inappropriate tasks or improper dose-test timing.

With that *caveat* in mind, the literature on barbiturates can be summarized with the statement of two important, consistent findings. The first is that therapeutic doses of the short- and intermediate-acting drugs significantly impair skills performance across a variety of tasks. As would be expected of CNS depressants, the behavioral effects are very similar to alcohol effects and, like alcohol effects, they represent a serious threat to the safe performance of complex man-machine tasks.

The second finding drawn from the research literature is that the impairing effects of these drugs do not correlate with blood levels. Performance deficits and blood levels may not follow the same time course. In addition, significant tolerance to a drug's effects may alter a chronic user's behavioral responses.

Because the findings are consistent, the discussion of specific studies will be limited to a demonstration of the range of tasks that have proved sensitive to barbiturates. Tracking error is increased by 100 mg secobarbital (Schroeder *et al.* 1974). Secobarbital adversely effects higher order attention and memory functions (Evans and Davis 1969). Driving performance, as examined in a driving simulator, was impaired by secobarbital (Loomis and West, 1958). Performance in a flight simulator was significantly impaired by a 200 mg dose (McKenzie and Elliott 1965; Hartman and McKenzie 1966).

Pentobarbital (Nembutal) also is an available drug with a history of abuse. As with secobarbital,

impairment has been reported for a variety of tasks, including tracking (Ellinwood *et al.* 1983), signal detection (Kopriva *et al.* 1974), and information storage and recall (Talland and Quarton 1965).

The experimental literature provides strong evidence that skills performance is impaired by barbiturates, beginning at dose levels that fall within a therapeutic range. Further, the tasks examined in laboratory studies have provided enough evidence to show that there are potential hazards involved with their use.

BENZODIAZEPINES

An extensive literature has developed concerning benzodiazepines, and the findings are similar in many respects to those for alcohol and the barbiturates. Although all of the benzodiazepines (Table 3) are chemically related, there are important differences between them in usage, in pharmacologic activity and in effects. They are extensively metabolized, and a metabolite may itself be an active agent, in which case both parent molecule and metabolite must be taken into account in studies of behavioral effects.

Commonly thought of as appropriate treatments for anxiety and depression, these drugs are also prescribed to relieve muscle spasms, to control convulsive seizures and to aid in alcohol detoxification. In addition, flurazepam and temazepam are effective hypnotic agents that are prescribed for the short-term treatment of insomnia.

Diazepam is the benzodiazepine most often found in accident victims (Bø *et al.* 1975; Williams *et al.* 1985) and studied most extensively in laboratory experiments. Reviews of published studies (Kleinknecht and Donaldson 1975) indicate that its effects are not only dose dependent but also a function of the particular behavioral variable that is studied. Simple reaction time is not sensitive to diazepam effects. Choice reaction time and concentrated attention show small deficits but only with large doses. In contrast, more complex skills are significantly impaired by therapeutic doses. Diazepam-related performance deficits have been reported for tracking performance (Burford *et al.* 1975), as well as for choice reaction time and division of attention (Linnoila *et al.* 1974).

Moskowitz and Burns (1977) reported an increase in tracking error. More importantly, in view of mixed reports for relatively simple tasks, they reported deficits for two more demanding tasks. Performance on a Divided Attention Test, which requires subjects to allocate attention to multiple stimuli, was impaired by 5 mg of diazepam. In the same test battery, a Visual Backward Masking Task demonstrated that diazepam slows the rate of information processing.

Table 3. BENZODIAZEPINES

Product Name		Indication
Ativan	lorazepam	anxiety disorder
Centrax	prazepam	anxiety disorder
Librium	chlordiazepoxide	anxiety disorder alcohol withdrawal
Paxipam	halazepam	anxiety disorder
Serax	oxazepam	anxiety disorder alcohol withdrawal
Tranxene	chlorazepate dipotassium	
Valium	diazepam	anxiety disorder anti-convulsant muscle spasms alcohol withdrawal
Xanax	alprazolam	anxiety disorder
Dalmane	flurazepam	hypnotic
Restoril	temazepam	hypnotic

In a long-term study, subjects took 15 mg diazepam daily for 9 days (Moskowitz and Smiley 1982). The investigators reported substantial impairment in a driving simulator and on the Divided Attention Test after an initial 10 mg dose and again after 9 days of dosing.

Flurazepam and temazepam are effective hypnotics. There also is evidence that their effects persist beyond the period of sleep. The price of a restful night may be impaired performance the following day (Johnson and Chernik 1982).

Because of their therapeutic benefits, the benzodiazepines are widely accepted. Also because of their anxiolytic properties, they are susceptible to misuse and abuse.

CENTRAL NERVOUS SYSTEM DEPRESSANTS: EPIDEMIOLOGY

Laboratory studies demonstrate skills impairment by therapeutic doses of CNS depressants, but do the laboratory deficits translate to performance deficits of practical importance? At present, there is not enough evidence to conclude that increased reaction time in a laboratory task means dangerously slowed responses

in the driving environment. A drug-related change in performance in the laboratory may or may not be associated with serious impairment of overlearned, real-world tasks.

Although there are severe limits to the meaning that can be ascribed to a specific drug blood level in the single case, epidemiologic data are nonetheless critically important. To understand the contribution of a psychoactive drug to injuries and fatalities, it is necessary to have data describing the frequency and distribution of that drug in those populations.

Because it is difficult to obtain the blood samples necessary for epidemiologic drug data, only a limited amount of information is currently available. Turk *et al.* (1974) reported that blood samples were positive for barbiturates in 2.5% of the drivers involved in single-car accidents. Briglia (1966) estimated that barbiturates were present in more than 9% of the drivers involved in multiple-car crashes. For fatalities, the presence of barbiturates has been reported in the range of 1%-4% (Sunshine 1956; Sunshine *et al.* 1968; Perrine *et al.* 1970).

Bø *et al.* (1975) obtained blood samples from seriously injured traffic crash victims who had been admitted to an Oslo, Norway, hospital. Diazepam, either alone or in combination with alcohol, was present in 20.3% of the injured drivers. In the control group of drivers who were sampled at their workplaces, diazepam was found in only 2%.

Skegg *et al.* (1979) linked prescriptions written by general practitioners over a 2-year period with hospital admissions and deaths. These investigators concluded that a significant association existed between the use of minor tranquilizers and the risk of a serious road accident.

In a study of fatalities in California, Williams *et al.* (1985) obtained blood samples from 440 fatally injured male drivers, aged 15-35 years. Drugs, including alcohol, were present in 81% of the fatalities. Alcohol was present most often, but other drugs were detected 322 times. Marijuana accounted for 50% of the detected drugs; CNS depressants were detected 51 times, with diazepam present in 19 cases. Since CNS stimulants were present in 61 samples, at the time and in the location of this study, stimulants may have been slightly favored over depressants among young men.

Another recent study provides current data about drug use patterns among nonaccident, arrested drivers in Los Angeles. During the period of a 1985 study conducted by the National Highway Traffic Safety Administration (NHTSA) and the Los Angeles Police Department (LAPD), officers arrested 210 drivers for driving under the influence of drugs (DUID). As part of the evaluation of drug recognition methods, arrestees were asked to submit to a blood test. One hundred and seventy-three drivers consented to blood sampling, and 6 provided urine samples.

The mean age of the arrestees was just over 27 years, and 92% were male. Taking into account parent molecules only, 14 different substances were identified. In a total of 246 separate identifications, one or more drugs other than alcohol were found in 167 samples. Excluding alcohol, slightly more than half of the samples contained one drug, 40% contained two drugs, and 4% contained three drugs. The distribution of CNS depressants is presented in Table 4, in comparison to data reported by Williams *et al.* (1985). As can be seen in the table, the numbers and distributions of depressants in the two groups were very similar.

Table 4. DRUGS DETECTED IN TWO SAMPLES OF DRIVERS

	Arestees*			Fatalities**		
	No.	% (Sample)	% (Detections)	No.	% (Sample)	% (Detections)
Sample	219	100		440	100	
Drug Detections	246	112		322	73	
Benzodiazepines	13		6	19		6
Barbiturates	5		2	9		3
Non-barb. hypsedatives	2		<1	14		4
Other tranq.	—			2		<1

* NHTSA-LAPD data, 1985

** Fatalities, 1982-1983 (Williams *et al.* 1985)

Table 5. BENZODIAZEPINES IN BLOOD SAMPLES FROM DRUG-IMPAIRED DRIVERS, LAPD/ NHTSA STUDY

	Parent ng/ml	Metabolite ng/ml	Other Drugs Present	
Diazepam	2478	265		———
Diazepam	1211	305		———
Diazepam	295	804		———
Alprazolm	64			———
Chlordiazepoxide	3873		Cocaine	48 / 301
Diazepam	89	59	THC	2.7/ 86
Diazepam	521	307	Cocaine	— / 737
Diazepam	346	1066	Morphine	448
Diazepam	343	< 50	THC	1.1/ 36
Diazepam	246	516	Codeine/ morphine	73 / 26
Diazepam	1745	1545	THC Cocaine	6.7/ 125 33 / —
Diazepam	92	288	THC Morphine	<1.0/ 13 63
Diazepam	233	384	THC Codeine/ morphine	— / 64 30 / 438

If it can be assumed that the drug use practices of fatally injured drivers and arrested DUIDs are representative of drug use practices in general, then CNS depressants appear not to rank as a current top choice. The findings, including data for drugs that are not listed in Table 5, strongly suggest that marijuana, phencyclidine (PCP), and cocaine are more widely used than depressants. In this context, it is relevant to note PCP's mixed properties. Variously classified as an anesthetic, stimulant or hallucinogen, PCP also produces behavioral responses that are depressive. The nature of the subjective experience which favors its choice is not known.

Although other drug types appear to be more widely misused than depressants, drivers who have ingested hypnotic-sedatives and anxiolytics are detected and arrested regularly. Tables 5 and 6 present the barbiturate and benzodiazepine blood levels found

Table 6. BARBITURATES IN BLOOD SAMPLES FROM DRUG-IMPAIRED DRIVERS, LAPD/NHTSA STUDY

	mcg/ml	Other drugs present in sample mcg/ml
Phenobarbital	54	codeine 68/10
Butalbital	11	morphine 81 cocaine 10/106
Butalbital and Phenobarbital	7 10	cocaine —/86
Butalbital	10'	cocaine 42/282

in the Los Angeles DUID samples. These data are recent, and they are of particular interest because reports of driving errors and field sobriety test (FST) performance can be examined in parallel with the chemist's report. The question of interest is the meaning that can be attached to the drug blood levels.

BLOOD LEVELS AND OBJECTIVE SYMPTOMS IN ARRESTED DRIVERS

The expected peak blood level following a single 100 mg dose of a short-to-intermediate duration barbiturate is on the order of 2-3 mcg/ml. In comparing that with the levels found in the arrestee's blood samples, it is important to note that, although the barbiturates did not appear frequently, they also did not appear alone. When they were present, the analyses revealed levels ranging from 10 to 54 mcg/ml. These exceed therapeutic doses and were present in combination with opiates and cocaine, and it is apparent that the use was not medically prescribed.

The arrest reports and standardized drug evaluation reports for these drivers most frequently cite slowness as a symptom. The drivers were slow to respond to a patrol unit's efforts to stop them, proceeding for as much as a half mile after red lights were activated. They were slow in speech and movement, sometimes to the point of stupor. They exhibited very impaired coordination and balance and failed to perform any of the FSTs satisfactorily. Whether the drug combinations included an opiate or a stimulant, their symptoms closely resembled the symptoms of alcohol levels of 0.20% blood alcohol concentration (BAC) and above.

A statement about the expected peak blood levels of benzodiazepines is problematic. Garattini *et al.* (1973) reported that a single dose may produce more than twenty-fold differences in blood levels in different individuals. On the other hand, investigators typically report levels in the range of 250-350 ng/ml following a single 10 mg dose in the laboratory. Long-term dosing can produce levels in excess of 500 ng/ml.

Like the barbiturates, the benzodiazepines were found most frequently in arrested drivers in combination with other psychoactive drugs. A benzodiazepine was the single drug present in only four cases. Note, too, that in these data "benzodiazepine" means "diazepam." Other tranquilizers (Librium and Xanax) were found in only one blood sample each.

The presence of diazepam in the range of 1,200-2,500 ng/ml is interpreted as abusive and impairing use. Blood levels in the 350-550 ng/ml range in combination with tetrahydrocannabinol (THC), opiates or cocaine also reflect misuse. The arrest reports and drug evaluations provide important additional evidence.

A female driver with a BAC of 0.02% had a blood level of 64 ng/ml of Xanax, almost double the expected peak following a single dose at the maximum recommended dose. She claimed to be taking the Xanax by prescription during psychologic treatment. The driving cues, which prompted an officer to stop her, included high beams while passing a marked patrol vehicle, some evidence of weaving, and a slow response to the police vehicle's red lights. She performed FSTs in a moderately impaired manner, was responsive and cooperative, and was the single tranquilizer user who, on the basis of arrest documents, appears to have exhibited only moderate or borderline symptoms.

The most commonly reported symptoms of the diazepam cases are similar to the symptoms of drivers impaired by alcohol and barbiturates. In particular, when the diazepam blood levels were 1,200 ng/ml or higher, these arrestees were slow, disoriented and stuporous. Driving symptoms were typical of those found in persons using depressants; that is, they were slow and inattentive, failed to respond and were weaving and lane straddling.

Symptoms were less clearcut in other arrestees. When the diazepam in the blood was at or near a level more typical of therapeutic use, either when diazepam was the single substance or when it was combined with marijuana or a low BAC, the arrest documents reflect both depressant and stimulant symptoms. The drivers were noted to be unusually talkative and cooperative; these behaviors cannot be considered the norm for either the arrest situation or a depressant drug. Reported driving patterns sometimes included speeding, erratic speed and sudden backing within a traffic lane. Those contrast with their more typical depressant-related behaviors such as extreme slowness, failure to proceed, weaving and lane straddling.

DISCUSSION AND CONCLUSIONS

Depressants exert a diffuse effect on the entire CNS, and behavioral changes occur as the brain's functions are depressed. When a person's abilities to process sensory input and to initiate appropriate responses fall below the threshold demands of a given task, then significant and dangerous impairment exists.

The important forensic issue is the accurate assessment of impairment associated with the presence of a CNS depressant in a given amount in a given individual. A high-priority objective is to determine

whether a predictable relationship exists between the amount of the drug measurable in body fluids and an individual's performance deficits.

It cannot be assumed that some degree of impairment always exists in the presence of a psychoactive drug. That would be a risky and possibly erroneous assumption, since advanced, sensitive analytic techniques can sometimes detect drugs at low levels that exert no effect on behavior. Also, individual differences, most importantly individual tolerances, create a critical and limiting complication. Tissue changes and alterations in liver function occur in response to repeated doses of a drug. To the extent that such chronic tolerance develops, behavioral responses change, and a level that signals severe effects in a one-time user may produce no effects in a longer term, tolerant user.

From the other side of the equation, a given drug dose produces different blood levels in different individuals and in the same individual at different times. Thus, there is no certainty that a specified dose will produce either consistent blood levels or consistent behavioral effects. To further complicate interpretations, the samples at issue are likely to contain multiple substances.

Correlations of blood levels and performance impairment have not been established for depressant drugs. Except in very extreme cases, the exact relationship between a drug and its behavioral effects cannot be established exclusively in terms of a blood level. At present, there is little prospect that presumptive or *per se* levels for drugs are feasible.

Relying solely, or heavily, on the interpretation of chemical tests places the burden of proof on only one piece of evidence. A suggested alternate approach to evaluating the role of a drug requires instead that all available information be fully utilized. I strongly recommend a standardized interpretation of all blood-level information, integrated with the reported symptoms from all other sources and documents.

The term impairment threshold is defined here to take into account both the range of expected blood levels following therapeutic doses and the steady-state levels that occur with long-term dosing. For the CNS depressants most often at issue in forensic proceedings, it is important to determine, with as much accuracy and specificity as possible, the range of blood levels that follow single therapeutic doses. Similarly, when taking into account a drug's absorption, metabolism and excretion characteristics, it is important to project the steady-state levels that will be associated with long-term use of CNS depressants. Although these are values with significant variability and error, they can contribute to the evaluation of a single blood level in a specific case.

Impairment thresholds in this context are defined as levels that exceed therapeutic use and that have more than marginal potential for producing skills impairment. Clearly, this is a conservative definition that permits many blood-level false negatives to occur. The one-time or infrequent user whose performance is degraded by a single, therapeutic dose will not exceed the impairment threshold. On the other hand, the impairment threshold is a defensible definition, which properly used, avoids false positives. Most importantly, it is a single piece of information in a method that requires the use of multiple sources of information.

The systematic integration of symptoms from other sources will serve to confirm or reject the role of a drug at or above threshold level. From this point of view, the single most critical key to valid interpretation of blood levels is the fact that an arrest or accident does not occur in isolation but is both preceded and followed by other significant activities. Notably, the drivers commit driving errors and/or exhibit symptoms and behaviors commonly associated with drug influence.

Blood levels rarely stand alone, and blood levels alone rarely provide sufficient information. But when blood levels that exceed a conservative impairment threshold are integrated with the information in arrest reports, reports of standardized FSTs and reports of standardized drug evaluations, it is likely that the evidence will be more cohesive and convincing than evidence based solely on an attempt to correlate drug blood levels and performance.

In conclusion, analyses of blood samples can identify levels that exceed therapeutic use and impairment threshold. Driving errors, FST performance and other information integrated in a standardized manner can augment the information derived from the blood analysis. Utilization of both kinds of information increases the probability of correctly determining if the presence of a drug in a specific case was a significant source of impairment.

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DISCUSSION

Francisco: I think your approach is excellent, Dr. Burns, except for one problem. Alcohol is a simple drug, and it appears that blood level is an accurate measure of the level in the target organ, but I am not sure this applies to most of the other drugs we are discussing.

Burns: I think that is what I said or tried to say. If not, I apologize.

Grabowski: The issues Dr. Burns has brought up are on how to judge these things, where cutoffs for blood levels are and how to integrate these things with other measures. Dr. Burns has done some excellent performance research.

What is really needed is some sort of performance battery that is administered at the time a person gets a driving license. The results would be included on a magnetic strip on the back of the license to provide a performance baseline for use by a police officer requesting a roadside test if the person gets stopped for any reason.

Performance measures would be useful, but it would be difficult to implement this procedure. How can you actually translate all the performance literature into reality?

Burns: Some of the work that has been going on in terms of trying to develop an interlock system for

the impaired driver overlaps with your idea. The difficulties that have been encountered there foreshadow the difficulties of your idea.

Louie: Have you done any behavioral studies on alcohol combined with drugs from which we could draw conclusions to predict behavior, as we can for marijuana and alcohol, and predict increased depressant activity?

Burns: We have not done any work with hallucinogens, but we have done a lot of work with combined substances. I would take issue with your characterization of alcohol and marijuana as a combination of two depressant activities. I do not characterize the effects of marijuana as being depressant.

For the more exotic drugs such as PCP and the so-called "designer drugs" that are on the streets now, there is very little, if any, information. We have not studied them, and I do not think we ever will. In training programs in California we have been very insistent on avoiding a cookbook approach to training people on how to do a field sobriety test. We believe you need to understand some very basic information about how the category of substances functions and how they work on the individual and put that together with the blood analysis. We cannot hand you a neat package and say, "This is the way you do it."

TRENDS IN ROADSIDE SCREENING

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Drunk driving continues to be one of our nation's most serious public health and safety problems. Some 50% of all drivers killed each year have blood alcohol concentrations (BACs) in excess of the legal limit, 0.10%. In single vehicle crashes, where it is most certain who is at fault, upwards of 65% of those drivers who die are legally drunk. Over the past 10 years, the proportion of the highway deaths involving alcohol has averaged a tragic 25,000 per year. Thus, a staggering one quarter of a million drivers have lost their lives in alcohol related crashes in the last decade. Enforcement is one of the critical elements in a drunk driver control system. If the police do not detect and apprehend drunk drivers, the rest of the system cannot function properly.

Enforcement officials have long recognized that drunk drivers are involved in a disproportionate number of crashes, particularly those that result in fatal injuries. State and local law enforcement agencies have always considered drunk driving to be one of the most difficult factors to address in accident prevention. They are well aware that the rate of arrest and conviction for this offense is far too low to solve the problem.

On any given night, only about 1 in 300 to 1 in 2,000 intoxicated drivers will be arrested for drunk driving. In most areas, less that 1% of the licensed drivers will be arrested for Driving While Intoxicated (DWI) over a 1-year period. The average BAC per arrest is about 0.18% nationally, almost twice the level required for an individual to be considered intoxicated in all states.

One of the most difficult tasks facing a police officer conducting traffic law enforcement is the detection of the alcohol and/or drug impaired driver at roadside. Many operators successfully mask the symptoms, although they may be impaired well over the statutory BAC. Officers participating in a sobriety checkpoint may have a only few seconds to determine that the driver is under the influence. This is reflected by the relatively low number of arrests for DWI at most checkpoints—many result in arrests for less than 1% of the drivers interviewed on a given night.

In 1983, a new type of device was identified as a possible tool to assist police officers in identifying drivers who may be under the influence—a passive alcohol sensor. A passive sensor is an unobtrusive device that "sniffs" the air about a person and examines it for the presence of alcohol. The device then provides a visual readout showing that the person being interviewed does or does not have a high concentration of alcohol about their person. If the concentration appears high, the officer can perform a more thorough examination of the individual to determine if he is DWI.

In theory, the passive sensor should increase police officers' ability to detect alcohol impaired drivers, while minimizing the inconvenience to those drivers who have consumed little or no alcohol. The latter can be especially important in enforcement situations such as checkpoints, where most motorists will not be impaired.

This concept of passive alcohol sensing goes back to the early 1970's, but it became technically feasible only in the past few years. Two types of passive sensors ultimately were developed. The first is a Japanese device built by Honda and based on a Taguchi semiconductor sensor. An evaluation of this type of unit in laboratory and field tests concluded that is has serious shortcomings for police use in the United States. Semiconductors of the type used in this device are not specific to alcohol and can be sensitive to other types of hydrocarbons such as cigarette smoke, exhaust fumes and hair spray. Also, the units were found not to be stable and required frequent calibration. In addition, the device is quite large and made the use of a standard police flashlight difficult in addition to the other functions that routinely occur at roadside.

The Honda device was used by the National Highway Transportation Safety Administration (NHTSA) in a double blind checkpoint project conducted in Cambridge, Massachusetts, in 1984. The device was used by researchers at one of the three roadblock configurations.

The test consisted of the device being held approximately 6 inches from the driver's face. The sniffer provided reliable and accurate results in both identifying drivers who had been drinking and those drivers who had not. In short, approximately 88% of the time, the sniffer correctly determined whether the driver had been drinking. It correctly indicated a sober driver had not been drinking 90% of the time and

correctly indicated that a dosed subject had been drinking 86% of the time.

When compared with results of officers using typical screening procedures, the sniffer identified a higher percentage of the impaired drivers; fewer of the sober drivers were held for interview and fewer drivers between 0.05% and 0.099% were identified for further investigation.

The second device uses an electrochemical fuel cell and is mounted on a standard police-type flashlight. The development of this device was sponsored by the Insurance Institute for Highway Safety (IIHS). The fuel cell detector was selected because it is stable and can be made specific to alcohol.

The IIHS device was field tested in Charlottesville, Virginia, as part of a 1-year project to examine the effectiveness of safety checkpoints as a DWI general deterrence technique. This project found that the passive sensor has a significant effect on the officer's ability to detect impaired drivers.

When the sensor was not in use, police officers detected 45% of the drivers with BACs of 0.010% or greater and 24% of the drivers with BACs between 0.05% and 0.099%.

When the passive sensor was used, police officers detected 68% of the drivers with BACs of 0.10% or greater and 45% of the drivers with BACs between 0.05% and 0.099%.

Research is continuing to determine the usefulness of this type of device for routine patrol operations. The IIHS is examining the use of the devices in San Diego, California, and Chattanooga, Tennessee, but the tests are not complete.

We at NHTSA have tested the devices at the Transportation Systems Center Laboratory in Cambridge, Massachusetts, for accuracy and reliability. The early review of the results shows that the device provides consistent results at the distances of 6, 9, and 12 inches from the source. The final report on this testing is being completed.

The last issue we examined with respect to the passive sensor was the potential legal implications associated with its use. From the outset, the sniffer is clearly an experimental piece of equipment. Consequently, its limited use has not been challenged in a court. We can only guess how it will be received.

The Northwestern University Traffic Institute conducted a legal research study on the potential constitutional aspects of the use of the passive alcohol sensor. It was their opinion that the use of the passive sensor will pass constitutional muster. They used the analogy of the current case law concerning drug sniffing dogs and the use of sensory enhancement devices such as flashlights and binoculars. The feeling of the courts in numerous reviews is that the use of dogs merely enhances the olfactory senses in the same way that a flashlight enhances an officer's sight.

In summary, I believe it is important to reaffirm how the passive sensor is to be properly used. It is intended to alert a police officer that there is a significant concentration of alcohol in the presence of the sensor. This should cause to officer to scrutinize the driver more closely as a possible DWI offender. The sniffer in no way relieves that officer from conducting a thorough investigation.

INTEGRITY AND PRESERVATION OF SPECIMENS FOR ALCOHOL AND/OR DRUG ANALYSIS

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Specimens of ethanol or other drugs which are collected must be obtained in a manner that preserves a representative portion of the original. In practice, a relatively small portion of the entire body blood, breath or urine is actually collected and presented for analysis. Methods of collection and preservation can affect the integrity of the sample being analyzed. This problem may lead to a misinterpretation of results or evidence not being admissible in court.

Each jurisdiction should have a standard procedure to follow when specimens are collected for forensic analysis. A standard blood collection kit should be used, including a standard tube, a specified disinfectant and other accessories such as the needle and blood drawing apparatus. Proper identification labels and seals allow the law enforcement officer and medical personnel to identify the sample later, and they provide for a chain of custody and the integrity of the sample.

For forensic purposes, a nonalcoholic disinfectant should be used to cleanse the skin when blood is to be withdrawn from living persons. Studies on the use of ethanol as an antiseptic swab by Muller and Hundt (1976), Winek and Eastly (1976), Kaye (1980), and Dubowski and Essary (1983) demonstrated that, although the potential for contamination was not great, the most significant contamination occurred with the ethanol-soaked swab held over the needle while it was withdrawn from the arm with a vacuum tube. Goldfinger and Schaber (1982) reported no significant difference in duplicate blood samples when comparing one sample drawn using a nonalcoholic swab and one drawn using an isopropanol swab. This practice is not recommended, however, as some methods of analysis may not distinguish between alcohols or other organic volatiles. To prevent contaminating the blood specimen with exogenous interfering substances during the drawing, aqueous-based disinfectants such as soap and water or aqueous povidone-iodine (Betadine) should be used rather than organic volatile materials. This eliminates the argument in court that elevated ethanol concentrations were found as a result of contamination with the disinfectant during the withdrawal of the blood specimen.

The containers used to collect and store the blood sample should be clean, sterile and well sealed. Commercially available vacuum tubes, such as Vacutainers (Becton-Dickinson, Rutherford, NJ) and Venoject (Kimble-Terumo Inc., Elkton, MD) are suitable for this purpose. The volume of the blood sample collected for forensic ethanol analysis in impaired driving cases should be sufficient to provide for at least duplicate analysis and enough to rerun the analysis at a later time if so ordered by the court. In most cases, a sample size of approximately 10 ml will be adequate. Additional samples may be required if the blood is to be analyzed for other drugs. Smaller sample sizes may be suitable, depending on the requirements of the sample size used in the analysis. Regardless of the size of the blood tube used, it should be filled to near capacity, thus minimizing the air in the tube which can contribute to the potential loss of ethanol through oxidation to acetaldehyde. This oxidation may occur more rapidly at elevated temperatures through the reduction of oxyhemoglobin (Chang *et al.* 1984).

Blood alcohol concentrations determined in traffic law enforcement cases are normally expressed in terms of the grams of ethanol per 100 milliliters of whole blood. An anticoagulant is needed in the collection tube to prevent the blood sample from clotting. If the blood is allowed to clot, the ethanol determination on the remaining serum sample will be higher than the corresponding whole blood alcohol concentration. Potassium oxalate is suitable and widely used as an anticoagulant in blood samples obtained for forensic ethanol determinations. A preservative is needed to prevent the production of ethanol in blood samples from undergoing bacterial fermentation. Studies by Chang *et al.* (1984), Plueckhahn (1968a,b), Meyer *et al.* (1979), Plueckhahn and Ballard (1968), and Blackmore (1968) have shown that sodium fluoride is an effective preservative for this purpose. These studies generally agree that a sodium fluoride concentration of 1% is adequate to prevent bacterial production of ethanol in blood samples, including samples collected post mortem. Sodium fluoride is a potent enzyme inhibitor and inhibits the pathways of glycolysis and glucose fermentation even at lower concentrations; however, a concentration of 1% may be necessary to prevent bacterial action, particularly in post mortem samples.

Blume and Lakatua (1973) studied the effect of microbial contamination of a blood sample and identified a variety of bacterial forms as well as yeasts in the blood sample. Results of their study demonstrated that a 1% sodium fluoride concentration was effective in preventing ethanol production in blood samples inoculated with alpha-streptococci and *Proteus vulgaris* but not in samples inoculated with *Candida albicans*. Ball and Lichtenwalner (1979) reported significant increases in the ethanol concentration of a urine sample from a diabetic patient whose urine contained glucose and *C. albicans*.

Bradford (1966) reported that mercuric chloride at a concentration of 0.01% is an effective preservative for inhibiting the reactions that cause a disappearance of alcohol from the blood. Plueckhahn (1968) demonstrated that even a concentration of 1% mercuric chloride is not always effective in preventing bacterial growth that could lead to the generation of ethanol in post mortem blood samples. Further, mercuric chloride at this higher concentration often causes the sample to become almost solid and difficult to handle due to protein precipitation.

Blood samples collected without a preservative in sterile tubes from healthy living subjects may be reliably analyzed after short periods of time. Kaye (1980) found that blood not containing sodium fluoride could reliably be analyzed for ethanol after about 2 days at room temperature (25° C); under refrigeration (5° C) after about 2 weeks or in a freezer (-15° C) after about 4 weeks. With a 1% sodium fluoride concentration, these times were extended to 2 weeks at room temperature, about 3 months under refrigeration and more than 6 months in a freezer. Winek and Paul (1983) studied the effect of storing unpreserved blood collected under sterile conditions from living humans. They reported that this blood can be stored at room temperature for as long as 14 days without a significant change in ethanol concentration.

Meyer *et al.* (1979) reported that blood samples containing 1% sodium fluoride did not show any significant change in ethanol concentrations when stored frozen at -20° C for 6 months. The samples were thawed and refrozen repeatedly, and this procedure did not appear to affect the ethanol concentrations.

Glendening and Waugh (1965) reported a significant loss of ethanol in fluoride-preserved blood samples stored at elevated temperatures in an automobile trunk for 1 week during hot weather. Samples held at room temperature did not change significantly during periods of less than 2 months, although significant changes did occur after 6 months and longer. Samples stored under refrigeration for 10 months and frozen for 9 months did not show significant changes in ethanol concentrations.

Good forensic practice dictates that blood and urine samples received for ethanol determinations should be refrigerated until they are analyzed. Long-term storage is best accomplished by freezing the samples, thereby preserving the ethanol concentration for several months in case it is necessary to rerun the analysis later.

Blood samples collected in impaired driving cases are usually drawn by venipuncture from the antecubital fossa area of the arm. Although this procedure is adequate for living subjects, the collection of post mortem samples presents a more difficult problem. Plueckhahn and Ballard (1967) reported that, although intact heart blood collected at autopsy appears to be reliable for ethanol analysis, a more suitable blood sample may be obtained from the femoral or auxiliary veins. Suitable samples may also be obtained from the subclavian veins. Additional samples of vitreous humor and urine should be collected when putrefaction has occurred or blood samples are unavailable.

When the blood sample is collected, it should be properly marked to ensure its identification and chain of possession. The blood tube should be labeled with the name of the subject, the date and time that the blood was collected and the name or initials of the medical personnel drawing the blood sample. The tube should then be properly sealed to prevent tampering and be delivered by accountable procedures to the forensic laboratory for analysis. Appropriate records must be maintained throughout this process so that the proper documentation can be made to the courts for the admissibility of the test results.

Collecting breath samples for analysis of ethanol has been researched and practiced for many years. Currently used breath testing instruments designed to analyze a sample immediately collect expired alveolar breath. Although the size of the breath sample collected varies from several hundred milliliters to about 1 ml, a sample size of approximately 100 ml is suitable. Before a breath sample is collected for ethanol analysis, the subject should be observed to ensure that nothing is placed in the mouth that can interfere with the subsequent analysis for ethanol. The collection system should be heated to prevent condensation of moisture from the breath and the loss of ethanol from the breath sample before or after it reaches the collection chamber.

Specimens are taken for analysis either by collecting and storing a whole breath sample or the adsorption or by removing the ethanol from a known volume

of breath. Jetter *et al.* (1941) used magnesium perchlorate as the sorption material to trap the ethanol in breath. Harger *et al.* (1956) studied the use of polyethylene bags, flexible aluminum bags and polyvinyl chloride bags and reported that these containers lost alcohol with storage of a few hours. Salem *et al.* (1960) reported that Saran plastic bags were used to collect and store whole breath samples for 38 and 62 hours with negligible loss of ethanol.

Picton (1978) and Comeau (1976) described the use of the heated indium tube system to collect whole breath samples. The Indium Test Kits (Intoximeters, Inc., St. Louis, MO) contained the indium tube in a template assembly to be used with a crimper designed to collect three separate aliquots of end expiratory whole breath, each containing about 0.25 ml. Storage of the indium capsules after collection of the breath at -20° C, 3° C, or 100° C did not cause any significant changes in the ethanol results for up to 14 days.

Dubowski and Essary (1982) discussed the use of a heated 22-ml glass vial designed to collect end expiratory breath. For an outlet breath, they used a short 16-gauge needle that just penetrated the gray butyl rubber stopper; for an inlet, they used an 18-gauge needle that extended to the bottom of the vial. Reproducible results were reported for storage periods of 7 days. When a virgin Teflon-lined silicone rubber stopper was used, no significant losses of ethanol were found after 14 days of storage.

Dubowski (1977) studied various solid sorbents and found that anhydrous calcium sulfate was suitable for the sorption of ethanol, methanol, acetone and isopropanol. The calcium sulfate, 20-40 mesh reagent grade, was contained in a glass tube (approximately 0.7 x 5 cm) which was stored in screw-capped glass vials before and after exposure to the breath sample. No significant loss of ethanol was found after storage of the tubes for 2 weeks.

Wilkinson *et al.* (1981) used an activated silica gel column placed on the outlet hose of an infrared breath alcohol instrument; the breath sample was pumped through the tube using the internal pump in the instrument. Samples stored up to 120 days in a freezer at -18° C were analyzed with a recovery of 98% of the ethanol. Samples stored at room temperature (20° to 25° C) for up to 381 days showed a recovery of approximately 100% of the ethanol. They determined that at least 1 hour should be allowed for the desorption of ethanol from the silica gel.

Bergh (1985) studied the use of ToxTrap (ToxTrap, Inc., Smyrna, DE) silica gel tubes and demonstrated that some erratic results may be obtained if proper procedures are not used. He concluded that the silica gel must be free of atmospheric moisture, the system must contain no leaks, the purge pumps must be capable of exhausting the collection chamber, the tubes must be properly packed to avoid channeling effects, high storage temperatures should be avoided and the silica gel mesh size should be uniform. In addition, he noted that the collection chamber volumes and temperatures may vary from instrument to instrument.

Procedures used in the collection and storage of whole breath samples or the sorption of the ethanol in the breath must be closely controlled and standardized to obtain acceptable results. As with other evidence, these samples must be properly marked for identification and normal chain of custody records must be maintained.

Specimen storage and preservation for analysis of drugs other than ethanol is a much more complex issue. The containers used in the collection of the specimens and the storage conditions must be considered in terms of their effect on drug and drug metabolite concentrations, protein binding and drug stability.

Garrett and Hunt (1974) studied the physicochemical properties of tetrahydrocannabinol (THC). They reported that with aqueous solutions of tetrahydrocannabinol there was significant binding to the glass, plastic and rubber surfaces. Pretreatment of the glass containers with trimethylsilyl significantly reduced this binding. Wong *et al.* (1982) studied the dissipation rate of delta 9-THC in hemolyzed blood and serum samples during storage at elevated temperatures, by freezing and thawing, with agitation and at ambient temperature changes during mailing. They reported that delta 9-THC remained stable in blood samples for 17 weeks and in serum samples for 13 weeks. There was an inability to detect the delta 9-THC in blood after 23 weeks. Atmospheric conditions and storage temperatures of 60° C for blood and 50° C for serum for 25 hours did not significantly affect recovery. The repeated freezing and thawing of the samples and the agitation they received during mailing resulted in no significant loss of the delta 9-THC.

Foltz (1984) reported that no decreases in cannabinoid concentrations were found in blood collected in grey-stoppered vacuum tubes that were rocked at room temperature for 24 hours. Blood and plasma samples containing THC, hydroxy-THC, and carboxy-THC stored at temperatures of 4° C and -10° C showed no significant loss for 6 months, and samples stored at room temperature remained stable for 1 month before showing significant decreases. Urine samples containing carboxy-THC should be stored frozen and, before analysis, be allowed to stand at room temperature for at least 3 hours after thawing.

The urine sample should be agitated because the carboxy-THC can concentrate in the sediment that often develops when urine is stored.

The stability of tetrahydrocannabinol and its metabolites does not appear to be a significant problem in blood or plasma when proper handling and storage procedures are followed.

Rockerbie and Campbell (1978) studied the stability of 19 classes of drugs or their metabolites in urine specimens. They compared the specimen preservation at room temperature, by refrigeration and with the addition of boric acid, chloroform, sodium fluoride, mercuric chloride and buffers. They reported that urine specimens may be stored at room temperature for weeks without deterioration for most of the drug classes studied except for flurazepam, gluthethimide and secobarbital. The preferred method of preservation was by adding sodium fluoride and then freezing, thawing and filtration.

Studies by Fremstad and Bergerud (1976), Shah *et al.* (1982), and Devine (1984) have reported on the displacement of drugs from plasma-protein binding sites and a redistribution of the drug into erythrocytes caused by rubber stoppers containing the plasticizer tris(2-butoxyethyl)phosphate. The drugs generally affected by this action are the basic lipophillic drugs that are bound to alpha-acid glycoprotein. This interaction results in a lower drug plasma concentration than that present at the time the sample was collected.

Shang-Qiang and Evenson (1983) studied the effect of contaminants in several types of vacuum tubes, including serum separator tubes. They reported the presence of substances in the tubes that produced gas chromatographic peaks with retention times similar to some of the drugs tested. In addition, the partition coefficient during solvent-extraction increased as much as 40% for some drugs and decreased as much as 30% for other drugs.

Similar studies have been reported on the effect of specimen collection and storage in various vacuum tubes on the serum and plasma concentrations of the tricyclic antidepressants (Veith *et al.* 1978; Brunswick and Mendels 1977; Zetin *et al.* 1981). They reported no significant differences between the glass and the Venoject collection system; however, the Vacutainer tube showed a significant reduction in plasma tricyclic antidepressant concentrations.

In a more recent study, Orsulak *et al.* (1984) reported on the evaluation of a new series of Vacutainer tubes that did not contain the plasticizer tris(2-butoxyethyl)phosphate. They found no significant difference in the tricyclic antidepressant concentration between the red stopper (serum) or the green stopper (plasma) tubes. Significant differences were noted using the Becton Dickinson serum separator and serum transport tubes. They reported that serum could be stored refrigerated for up to 4 weeks; however, for longer term storage, the samples should be frozen.

Post mortem concentrations of tricyclic antidepressants are reportedly site dependent, and cardiac blood values can greatly exceed those of peripheral blood (Prouty and Anderson 1984). This points out the importance of identifying the site at which the post mortem blood sample is collected.

Cocaine is rapidly hydrolyzed in the body to benzoylecgonine. Ecgonine and ecgonine methyl ester are other metabolites. This hydrolysis occurs in blood, plasma and urine specimens. Baselt (1983) studied the effect of sodium fluoride, time, temperature and drug concentration on the stability of cocaine in blood and plasma. This study also included the effect of time, pH and fluoride on cocaine stability in urine. At concentrations of 0.1 mg/liter, cocaine disappeared rapidly from blood and plasma that was refrigerated without fluoride. Cocaine was no longer detected in plasma on the third day and in blood on the eighth day. With the addition of sodium fluoride at a concentration of 0.5%, cocaine was detectable in plasma and blood for 21 days at 40%-60% of the original value. At concentrations of 1.0 mg/liter, the cocaine concentrations in nonfluoridated blood and plasma decreased rapidly; however, in the fluoride specimens, 80% of the original concentration was detectable after 21 days. Blood specimens containing fluoride stored at room temperature lost nearly 90% of the cocaine in 21 days. In urine samples, pH appears to be the most significant factor affecting the stability of cocaine. Urine samples stored at pH 5 in the refrigerator appeared stable for 21 days, and significant decreases in cocaine concentrations occurred in samples stored at pH 8.

The benzodiazepines are a frequently prescribed class of medications originally used to treat anxiety and tension. These drugs are frequently encountered in forensic toxicologic analyses. Levine *et al.* (1983) studied the stability of the benzodiazepines in post mortem blood and tissue. They found diazepam to be very stable when stored at room temperature or in the refrigerator for up to 5 months. Nordiazepam was less stable at both temperatures but showed a more rapid decrease at room temperature. Flurazepam was found to be moderately stable under these storage conditions. In contrast, concentrations of chlordiazepoxide and norchlordiazepoxide in blood decreased rapidly when stored at room temperature and were not detectable after 18 days. When they were stored in the refrigerator, there was an initial decrease in drug concentration

followed by a leveling off of the concentration. The addition of sodium fluoride and potassium oxalate had little effect on norchlordiazepoxide disappearance; however, it did partially inhibit the degradation of chlordiazepoxide at room temperature.

Many factors need to be considered when specimens are collected and preserved for drug analysis. Clearly, the specimens should be collected as soon as possible and the analysis performed promptly. Because of the normal delays in sample delivery to the laboratory and the backlogs that frequently occur, specimens should contain a chemical preservative, be delivered to the laboratory promptly and be stored in a frozen condition until the analyses can be performed.

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DISCUSSION

Childs: You recommended freezing samples. A problem with freezing things in glass Vacutainer tubes is that often the glass breaks during thawing. Do you have any suggestions for avoiding this problem?

Van Berkom: We use a lot of Vacutainers, and if they are frozen when they are completely full, breakage is a problem. If you freeze the Vacutainers when they are laying flat and after several aliquots of blood have been removed for analysis, you will not find breakage to be a significant problem.

Driver: How long do you retain the frozen samples after you have completed your analysis?

Van Berkom: It depends on the type of case with which we are dealing. If we are dealing with a regular Driving While Intoxicated (DWI) case, we routinely keep frozen samples for 6 months. We keep samples forever if we get notification from court to do so. If we have a homicide case, we would keep the frozen samples until we get some permanent disposition from the agency.

LABORATORY TESTING TECHNIQUES AND CRITERIA FOR IDENTIFICATION

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This paper reports on laboratory methods for analyzing specimens for the presence of alcohol and other drugs and discuss their reliability and the interpretation of the analytical results. Sample preservation, documentation of chain of custody and the relation of the results to driver impairment are beyond the scope of this presentation.

Alcohol is the most frequently tested drug in traffic related cases. In the most recent Department of Transportation (DOT) Proficiency Testing Project Test (October 1985), 138 laboratories reported results on four samples with target values ranging from 0.058 to 0.339 g of ethanol per 100 ml of blood (gm%). Categorized by method of analysis, they were divided as follows:

Method	Number of Laboratories	Percent
Gas Chromatography		
Headspace	81	58.7
Direct Blood Injection	28	20.3
Enzymatic	16	11.6
Dichromate Oxidation	10	7.2
Other	3	2.2
Total	138	100.0

Among the laboratories using gas chromatographic (GC) methods, all of those using direct injection and 27 of those using headspace reported the use of an internal standard; 54 of those using headspace did not report whether an internal standard was used.

Headspace methods depend on Henry's Law, which states that for solutions at equilibrium the ratio of the concentration of a component in the vapor phase to that in the liquid solution with which it is in contact is a constant. This constant is a function of temperature.

Henry's Law:

$$\frac{\text{Concentration of analyte in vapor phase}}{\text{Concentration of analyte in liquid phase}} = \text{Constant}$$

In a typical headspace technique, 1 ml of homogeneous blood sample (or standard, control or blank) is precisely measured into a sample vial (approximately 20 ml) and a precisely measured amount of internal standard is also added. Enough inorganic salt (such as, sodium chloride) may be added to saturate the solution, achieve salting out and allow a higher concentration of analyte in the vapor. The vial is sealed with a septum and temperature equilibrated, usually 30 minutes or more, at approximately 60°C. After equilibration is achieved, a measured amount of the vapor or headspace is either automatically or manually injected into the gas chromatograph. Typical GC conditions might be:

Injector temperature	170° C
Detector temperature	200° C
Oven temperature	125° C
Carrier gas	Nitrogen
Carrier gas flow rate	30 cc/minute
Injection volume	25 microliter

If a 2-ml inside diameter column, 2 m long, packed with 80/100 mesh Carbopack C with 0.2% Carbowax 1500 is used, analysis time will be about 2 minutes.

In the direct blood injection method, a precisely measured sample of blood (standard, control or blank is mixed with a precisely measured sample of internal standard and diluted with water. The internal standard may be incorporated with the diluent water. A 1-2 microliter sample of the liquid is injected, usually manually, into the gas chromatograph under conditions similar to those used for headspace, except that the injection port temperature is increased by about 50° C to promote flash vaporization. The injection port is usually fitted with a removable liner packed with glass wool to collect proteins and other nonvolatile materials in the blood. The alcohol is quantitated by comparing peak height or area of the ratio of alcohol to internal standard peak heights or areas with a standard curve.

In the enzymatic method, ethyl alcohol in serum or plasma is oxidized to acetaldehyde in the presence of the enzyme alcohol dehydrogenase (ADH) and the coenzyme nicotinamide adenine nucleotide (NAD), which is reduced to NADH. Semi-carbazide is added

to scavenge acetaldehyde and drive the reaction to completion:

$$CH_3CH_2OH + NAD^+ \underset{\text{Dehydrogenase}}{\overset{\text{Alcohol}}{\rightleftharpoons}} CH_3CHO + NADH + H^+$$

The concentration of NADH is measured as a function of its absorbance at 338-340 nm. In the procedure, serum or plasma (control, standard or blank) is measured into pH 9 pyrophosphate buffer. Then NAD and ADH are measured, added, mixed and allowed to stand for at least 15 minutes at room temperature. The absorbance of the solution is measured and compared with a standard curve.

In the distillation, dichromate oxidation method, a measured amount of sample (standard, control or blank) is steam distilled from tungstic acid precipitating solution, and the distillate is mixed with a measured amount of standardized potassium dichromate solution. After oxidation of the alcohol by the dichromate, excess dichromate is determined by back titration.

Although alcohol methods are primarily designed to quantitate ethanol that has been qualitatively indicated by the method itself, the situation is quite different when we consider the analysis of other drugs. Because of their number, diverse nature and range of concentrations, it is common practice to employ one or more screening techniques followed by confirmation and then quantitation. The screening techniques available to us include color, immunologic and thin layer chromatography (TLC) tests. For further characterization, we have high performance liquid chromatography (HPLC), capillary gas chromatography and mass spectrometry.

With the exception of immunologic testing of urine, each of these processes requires a prior cleanup step to remove interfering substances such as salts, proteins and lipids, and this cleanup also incorporates a concentration procedure. Two methods are widely used, solvent and column extraction. These result in a few microliters of extract containing either basic drugs or weak acid and neutral drugs.

These extracts can then be subjected to thin layer, liquid or gas chromatographic separation. It should be emphasized that chromatography does not identify, it separates, and the separation achieved is a function of the system's efficiency, which can be expressed as number of theoretical plates. Thin layer systems generally can generate only about 500-1,000 theoretical plates; therefore we have limited separation capability available. Typically, TLC results in a series of somewhat diffuse and many times poorly separated spots; however, by using a series of oversprays we get additional information from the color that develops, and this information can be indicative of a class of compounds.

With HPLC systems, there can typically be 10,000-15,000 theoretical plates available, which will allow about five times the separation available with TLC. In addition, by employing an electrochemical detector or a ultraviolet detector with variable wavelength capability, another element of confidence toward identity and an enhancement of sensitivity can be achieved. Both TLC and HPLC also have the advantage of separating without vaporization, which is an advantage when dealing with thermally labile compounds.

With capillary or wall-coated open tubular gas chromatography columns, a much greater number of theoretical plates (35,000-300,000, but more typically 50,000) are available, and resolution can easily be increased by a factor of 10 or greater over that expected from TLC. In addition, by utilizing a retention index system for characterizing the separation, the list of possible drugs represented by a peak can be drastically reduced. For example, from a library of about 300 of the most commonly encountered drugs, only 35 pairs are not resolved with a resolution of 10 retention index units or greater. A further advantage of capillary gas chromatography is its ready adaption to mass spectrometry, producing a system that has both separation and identification capability.

Although the screening techniques are useful in reducing the number of cases that have to be processed further, they are labor intensive, use costly reagents and are not readily automated. On the other hand, they can indicate the presence of some drugs (for example, cocaine through its metabolite benzoyl ecgonine, and cannabinoid compounds in urine) more readily than they are detected in blood. If required, these compounds can then be pursued in blood by other mechanisms. This of course requires that both samples be collected and submitted.

We have examined how we determine alcohol and other drugs in biologic specimens. Now, let us examine how well we do it. It is necessary to address both the qualitative specificity and the quantitative accuracy of our efforts.

Considering ethyl alcohol determinations, we seldom really prove that ethyl alcohol is present by

direct means. With GC methods, for example, even if we run the sample on two different columns, we have not demonstrated that there is nothing in the sample which will not co-elute with ethanol. We analyze for those chemicals that might be expected in the sample, such as methanol, isopropanol, acetone, acetaldehyde and formaldehyde, and determine that they do not co-elute with ethanol under the conditions employed. This is certainly not an unacceptable situation, but it is essential that we recognize it.

An idea of the quantitative accuracy of ethanol analyses can be obtained from the DOT data previously referenced. A summary of the results of 138 respondents is listed below for the target value sample of 0.058 g ethanol/100 ml blood:

Target value: 0.058 g/100 ml

Method	Mean, g/100 ml	Standard deviation
GC headspace	0.053	0.0058
GC direct injection	0.056	0.0044
Enzymatic	0.052	0.0108
Dichromate oxidation	0.055	0.0060

Figures 1, 2 and 3 illustrate the range and standard deviation for target values of 0.058, 0.117, and 0.339 g% ethanol. These data illustrate a rather wide variance in interlaboratory test results which conceivably could be a function of inadequate application of standards and controls in these analyses.

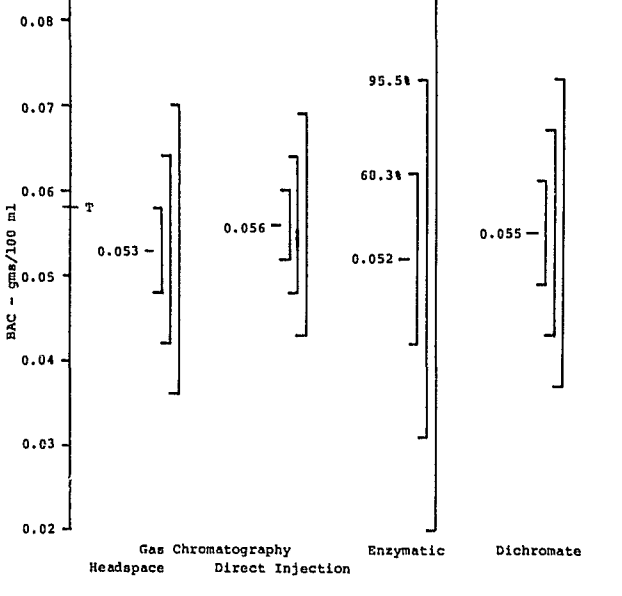

Figure 1. Alcohol proficiency test results.

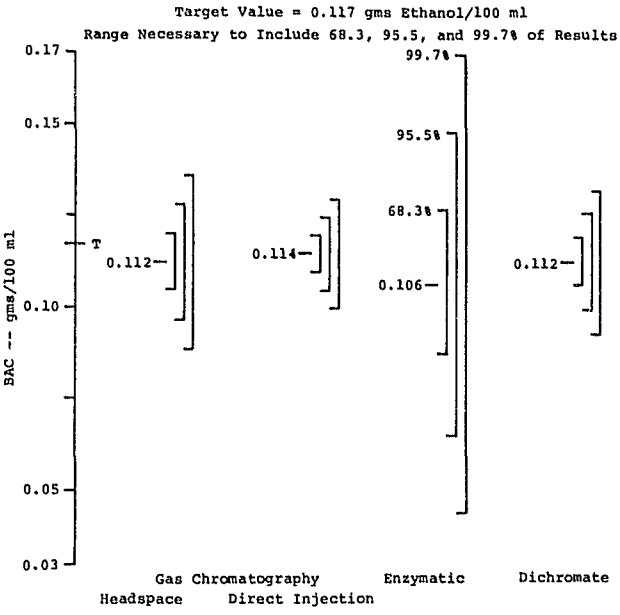

Figure 2. Alcohol proficiency test results.

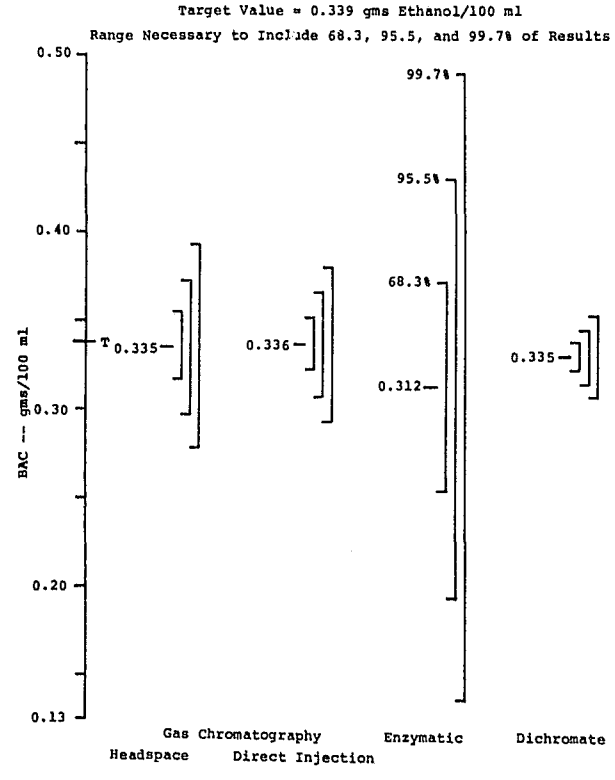

Figure 3. Alcohol proficiency test results.

Alcohol is perhaps the easiest drug for which to analyze. When urine or blood samples are examined for the multitude of drugs available and used, the analytical problem becomes more complicated and the results are indicative of this situation. If we examine the College of American Pathologists' Toxicology Proficiency Testing Program data for the first three quarters of 1985, some indication of performance can be obtained. Table 1 summarizes the qualitative performance for both reference and participating laboratories on a urine sample containing six drugs; Table 2 summarizes the data for a similar slate of drugs in a serum sample. Qualitative performance on this same serum sample is presented in Table 3. These are representative of the performance on the 10 samples analyzed during the time frame considered. For this period, the drugs present are listed in Table 4, and the average results are indicated in Table 5. In attempting to interpret laboratory data, it is essential to be aware of interlaboratory variations, but it is more important to be aware of, and able to demonstrate, intralaboratory performance. The alcohol data would indicate a very wide variance, particularly for the enzymatic method; however, this does not mean that individual laboratories do not perform well. Some of these data are from clinical laboratories, and although presumably used for forensic purposes, in some instances they indicate inadequate quality control. Recent experience has also pointed out that there are laboratories, forensic and clinical, which report results outside of the range of their standardization. In examining the data, there was a 96% report rate for ethanol; however in three samples, 10 false positive results were reported.

When the qualitative results for drugs other than ethanol are considered, the results are somewhat worse. For example, the average rate for reporting the presence of the drugs listed in Table 4 was approximately 51% in urine samples, 54% in blood for participants and only 62% and 70%, respectively, for the reference laboratories. For three urine samples, the average number of false positives reported was 37 per sample, and in blood, 17 per sample for the approximately 200 participants. The referee laboratories were considerably better, having less than 1 false positive per sample. This would appear to represent limited usage of the available techniques for detection and a widespread lack of routine confirmation of screening

Table 1. QUALITATIVE - 5/8 - URINE

Analytes Present	Micrograms per Milliliter	Ref. (#)	(11) (%)	Labs (#)	(214) (%)
Amitriptyline	0.8	9	82	182	85
Chlordiazepoxide	1.0	2	18	50	23
Desalkylflurazepam	1.0	2	18	0	0
Nordiazepam	4.0	3	27	92	43
Nortriptyline	1.1	9	82	175	82
Oxazepam	1.0	1	9	3	1
Benzodiazepines		5	46	110	51

False positives:

Diazepam	15	Desmethyldoxepin	2
Barbiturate	7	Other (1)	10
Ethanol	6		

Table 2. QUALITATIVE - 5/9 - SERUM

Analytes Present	Micrograms per Milliliter	Ref. (#)	(11) (%)	Labs (#)	(214) (%)
Amitriptyline	0.070	8	80	126	63
Chlordiazepoxide	0.69	5	50	88	44
Desalkylflurazepam	0.050	2	20	1	0.5
Diazepam	0.08	4	40	59	30
Nordiazepam	0.34	4	40	105	52
Nortriptyline	0.120	8	801	124	62
Benzodiazepines		2		20	50

False positives:

Ethanol	4	Salicylate	2
Desmethyldoxepin	2	Quinine Metabolite	2
Quinine	2	Other (1)	6

Table 3. QUANTITATIVE - SERUM

Analyte Present	Micro-grams per Milliliter	Laboratories #	Mean	Standard Deviation	Range	Ref. Range
5/9 Amitriptyline	0.070	80	0.063	0.021	0.010-0.118	0.010-0.074
Chlordiazepoxide	0.69	61	0.87	0.37	0.2-2.4	0.7-2.3
Desalkylflurazepam	0.050	0				
Diazepam	0.08	42	0.16	0.09	0.0-0.4	0.1-0.1
Nordiazepam	0.34	65	0.43	0.23	0.1-1.1	0.2-1.1
Nortriptyline	0.12	79	0.12	0.033	0.05-0.21	0.04-0.14

Table 4. LIST OF ANALYTES

Serum	Urine
Acetaminophen	
Amitriptyline	Amitriptyline
Amoxapine	Amoxapine
Butalbital	
Chlordiazepoxide	Chlordiazepoxide
	Chlorpheniramine
Codeine	Codeine
Desipramine	
Desalkylflurazepam	Desalkylflurazepam
Diazepam	
Ethanol	Ethanol
Ethchlorvynol	
Loxapine	Loxapine
Morphine	Morphine
Nordiazepam	Nordiazepam
Norpropoxyphene	
Nortriptyline	Nortriptyline
Propoxyphene	
Salicylates	Oxazepam
Trichlorethanol	

Table 5. PERFORMANCE SUMMARY

	Urine		Serum	
	Labs	Ref.	Labs	Ref.
Average Report Rate, %	50.7	61.6	53.8	70.2
Number False Positive Samples	37.7	0.7	17.4	0.5
C.V., %			34.3	

Excludes: Opiates, Benzodiazepines, Desalkylflurazepam and Oxazepam.

test results. In addition, it would appear that the referee laboratories were much less careless in reporting the results of their analyses.

When quantitative performance is examined by the same set of data, an alarming average 34% coefficient of variation is observed. This data set does include many clinical laboratories that may not achieve the level of performance of many forensic laboratories because their goals and definitions of what is acceptable may be different. In a study reported by Peat and Finkle (1981) in which forensic laboratories participated, the average coefficient of variation for quantitative results was approximately 14%, and the average report rate for qualitative results was approximately 67%.

If this type of data is to be used for forensic purposes, both the interlaboratory and intralaboratory performance must be evaluated and much better performance will have to be achieved.

The data examined here indicate:

1. Many laboratories are failing to confirm screening test results.

2. There is a deficiency in proper utilization of quality control procedures.

To identify a component, it is necessary to show that it could not be anything else or prove that is a specific entity. Screening methods, color tests, TLC and immunologic methods are quite valuable if used within their limitations. They are not usually specific identifying techniques. No chromatographic technique identifies by its own performance. Infrared and mass spectrometry can in many instances supply sufficient molecular structure information to identify a compound. It is therefore necessary to use a definitive identifying technique, such as mass spectrometry, or to use enough complementary indicative techniques producing reinforcing data to make an identification.

High quality capillary gas chromatography is a very powerful tool if properly used. Retention index data under well controlled conditions eliminate a large number of possible compounds and, along with some knowledge of the sample and results of screening techniques, contribute tremendously toward characterization of the components of interest. However, by itself it is not sufficient for identification. We are still faced with the two possibilities: eliminate everything else but the material of interest or specifically characterize it.

Before a substance can be quantitated, the material must first be properly identified. Then we must select a technique for quantitation which has adequate sensitivity for the analyte and which is compatible with the analysis. Sensitivity in this context refers to response per unit concentration or amount of analyte, that is, the slope of the response curve, not the minimum detectable quantity. The response curve must be defined by well-characterized standards that bracket the concentration of the analyte, and it must be documented to be correct by the use of one or more controls.

A final factor to be considered is the analyst. He must be knowledgeable enough to know what constitutes good results, and he must be trained, motivated and provided with adequate time and facilities that will let him exercise his ability.

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DISCUSSION

Question: Do you have any idea what the values were for the fake positives for blood alcohol?

Stafford: No. They were not summarized, and I did not get a list of the values that were reported. There is a possibility these samples were made up from pooled serum, and some of the blood used might have contained alcohol.

Dubowski: That is not the answer. The drugs are dissolved in ethanol. Low concentrations of ethanol are detected by analysts who disregard the lower cutoff and report them as positive.

Cordona: Your mean values for blood alcohol all seem to be constantly lower than your target values. Do you attribute that to shipping or the analysis, or did you make some type of assessment?

Stafford: Those are the reported values. I did not make any attempt to attribute that to anything, and I did not attempt to analyze that particular situation.

Watts: Amphetamines were the one class of drugs that seemed to have a high percentage of false positives. Would any of the methods that were included in the results explain how they received these false positives?

McBay: Thin layer chromatography (TLC). I will explain the way the nomenclature works on those College of American Pathologists (CAP) surveys. Use of the word opiates is not a misidentification that would not be accepted. It is a class identification for the particular immunoassay that they characterize only as opiates and are not identified as codeine, morphine and the like. So that is not an error.

Stafford: Do you have any indication as to how many of those may have been identified as another opiate?

McBay: No, because there are only two classes. They can say opiates only in the case of the barbiturates, as you pointed out, when they say the other classification is barbiturate, that is other than phenobarbital, which is one of the choices they have.

However, one thing to keep in mind is that these laboratories are doing proficiency testing and are willing to participate and send in results. The results, although they cover a broad range, exclude statistically unacceptable results.

Stafford: Another point to be made is that these laboratories are participating in a proficiency testing program in order to improve their performance.

McBay: If you think these results are bad, what do you think of the results from the laboratories not participating?

Stafford: Exactly. Before I started compiling these data, it had been my practice to compare the results of my laboratory with the Department of Transportation results or the CAP results, and I found we were doing well. However, as I started compiling data I became concerned.

McBay: We are one of the referee laboratories. I know what is in the specimens when I give them to the analysts, but I do not tell them. I might specify to do organic bases. We are a busy laboratory. If we are not doing opiate analysis at that particular time, I may not do that part of it, so you will find it lacking. It is not that we can not do a gas chromatography/mass spectrometry; it depends on whether I feel it is necessary.

Some of these drugs, like amoxapene, are in therapeutic concentrations. I would enjoy seeing how forensic chemists would do on therapeutic concentrations of the tricyclics and some of the others.

Peat: The first urine specimen you showed from the CAP contained a contaminated pool. That urine specimen was collected from volunteers and trace

amounts of several drugs were in that pool. So, a number of false positives listed may not be false positives.This comment concerns the older study that Bryan and I did. If you took the alcohol CVs and standard deviations out of there, it comes very close to your figure for the CAP. The alcohol CVs and standard deviations lower that mean to 14%.

When you discussed your chromatography procedures and screening, you did not mention anything about metabolic patterns, particularly TLC, that can give you a hint of the type of drug present based on metabolic patterns.

Stafford: Good point. If in attempting to identify a material you get the parent drug when you run the chromatographic screen and see the metabolites where they ought to be, you begin to have a lot more confidence. It is very helpful to characterize the parent drug and see the metabolites show up.

Wade: A false positive was reported recently for cannabinoids in a serum sample where CAP said there were no cannabinoids. Recently they issued a statement saying there were cannabinoids present.

Dubowski: I will briefly summarize the process. There are referee laboratories that examine the matrix. When questions arise they are re-examined by other laboratories. If a question is raised, what is reported as a false positive is ordinarily something that was not added to the sample but is then recorded as "present above cutoff concentrations."

If that kind of issue is raised, then the referee laboratories are asked to go back and check at the suitable level of sensitivity for the drug in question. That has happened with ethanol, acetone and methanol, which are all solvents added to the specimens in which the drugs are dissolved. They do not disappear during lyophilization, as you would expect. This has happened with the urine specimens.

If it is above the cutoff, they go back and ask the other laboratories who are doing the background check to recheck. If we find it present, it is reported as an unintended contaminant.

A synthetic matrix is now being used to get away from excluding nicotine and cannabinoids in native urine samples.

McBay: You would have more interest in the results if you took the tetrahydrocannabinol (THC) and THC carboxylic acid in the December sample.

Fager: I think you could add to the study's value by compiling a profile of laboratories that analyze well and those that do poorly. You would not necessarily make their names public, but you would get an idea of which laboratory does reliable analyses on things from the street.

Stafford: I do not think many people are going to volunteer to get on such a list. One of the reasons people do participate in proficiency programs like this one is the fact that they remain anonymous. They know how they perform, and they are participating for their own benefit. I think your suggestion is a useful one, but I am not sure that people are going to participate in that kind of exercise.

PERI MORTEM VERSUS POST MORTEM ALCOHOL AND DRUG CONCENTRATIONS

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Post mortem blood is not truly blood. In living subjects, blood is a complex fluid with intricate buffering capacities, the ability to transport dissolved and protein bound substances (such as drugs and alcohols) and the capacity to transport and exchange of free and bound gases. Post mortem blood has few or none of these characteristics. Such specimens rarely look like ante mortem blood or have the same physical characteristics or chemical composition.

Several techniques are used to collect post mortem blood samples for toxicologic evaluation. When a complete autopsy is not performed, the specimen is usually collected with a 25- or 50-ml syringe equipped with a large bore needle that is inserted downward through the chest wall at the third intercostal space near the left border of the sternum in the direction of the heart. If one retains extraction tension on the plunger of the syringe as the needle is advanced into the chest, it becomes obvious when a major vessel or a chamber of the heart is penetrated. This is shown by a sudden rush of blood (red fluid) into the barrel of the syringe. If this technique is used, it is impossible to know the chamber of the heart from which the fluid was extracted. When an autopsy is performed, the rib cage is removed and the organs of the thoracic cavity are exposed; then the pericardial sac is removed, exposing the heart. This procedure allows one to establish definitely the chamber from which the blood is extracted. Peripheral blood is most conveniently collected before autopsy by inserting a large bore needle into the upper thigh in the femoral triangle area. Subclavian venous blood is an additional peripheral specimen that can be easily collected post mortem. This is accomplished by inserting the needle immediately below the distal third of the clavicle in a downward and inward direction towards the jugular notch. Our forensic pathologists now routinely collect cardiac blood, femoral and/or subclavian blood, vitreous humor and urine. Such collections and submissions are particularly indicated in subjects with noted or suspected trauma to the organs of the thoracic cavity.

Numerous factors may influence the quality of the post mortem blood specimens. These include the site of withdrawal and the homogeneity of the specimen (which is profoundly influenced by temperature and the post mortem interval). It is not uncommon to receive cardiac puncture specimens that have a hematocrit of less than 5 or 10. Such specimens would be more accurately described as post mortem blood plasma rather than post mortem blood. It is the policy of our laboratory to describe in the laboratory record the physical appearance and condition of all specimens received for analysis. If an amber fluid is received labelled "heart blood," it is recorded as "an amber fluid labelled heart blood." All of these factors may influence the subsequently determined blood alcohol value.

The salting out effect may also influence the blood alcohol value. In our morgue, 30-ml culture tubes with Teflon-lined screw caps are used as blood containers. The dieners have been provided with a spoonula that, when leveled, holds 200 to 250 mg of sodium fluoride. This amount is theoretically added to each blood tube. Recently we randomly selected 20 prepared but unused fluoride tubes, weighed the sodium fluoride in each tube, and found the mean value to be 420 mg. If 30 ml of blood is placed in such a tube and 5 ml were added to a similar tube, there should be a predictable difference in the subsequently measured blood alcohol concentrations due to loss of alcohol into the headspace of the specimen container of smaller blood volume.

For several years, our laboratory has been investigating the post mortem distribution of drugs in the various body tissues and fluids. These studies have encompassed the measurement of drug concentrations in blood collected from various anatomical sites, including the right and left heart and the subclavian, vena cava and femoral vessels. In 1985, Dal Cortivo (personal communication), appraised me of his findings on the distribution of ethyl alcohol in post mortem specimens. The data appear elsewhere in this proceedings (Briglia *et al* 1988). Dal Cortivo was aware of our ongoing drug distribution studies and suggested that we also look at ethyl alcohol concentrations in these various blood specimens. The following protocol was initiated in October 1985. Whenever we received both heart and femoral blood specimens, the heart blood was first analyzed for ethyl alcohol. If the concentration was 0.02% w/v or greater, the femoral blood was then analyzed. Frequently the second

analysis was conducted several days after the heart blood assay and was often conducted by a different analyst.

Our analytical method for blood alcohol analysis is an automated headspace technique utilizing a Perkin-Elmer F-45 gas chromatograph equipped with a flame ionization detector and a 6-foot x 1/8-inch SS column packed with 0.2% Carbowax 1500 on 80/100 mesh Carbopak B. Normal propyl alcohol is used as an internal standard. All specimens are analyzed in duplicate. Our findings in 24 cases are presented in Table 1. It should be pointed out that these are not

Table 1. HEART BLOOD vs FEMORAL BLOOD ETHYL ALCOHOL CONCENTRATION (% w/v)

Case No.	Heart	Femoral	Case No.	Heart	Femoral	
85-1161	0.246	0.274	85-2286[d]	0.159	0.192	
	0.243	0.273		0.165	0.187	
85-1716	0.156	0.145	85-2353	0.245	0.287	
	0.151	0.150		0.237	0.242	
85-1726	0.055	0.058	85-2496[e]	0.177	0.213	
	0.056	0.062		0.177	0.205	
85-1727	0.139	0.142	86-0041	0.131	0.129	
	0.139	0.145		0.132	0.132	
85-1738[a]	0.134	0.178	86-0156[f]	0.277	0.332	(1/23/86)
	0.136	0.179		0.279	0.331	
85-1764	0.156	0.176		0.255		(3/10/86)
	0.157	0.175		0.253		
85-1770[b]	0.203	0.160		0.239		(4/7/86)
	0.201	0.161		0.239		
85-1922	0.486	0.481	86-0354	0.168	0.164	
	0.479	0.477		0.169	0.158	
85-2133	0.155	0.148	Codeine	46.0	20.0	
	0.149	0.149				
85-2139[c]	0.132	0.169	86-0371	0.084	0.094	
	0.128	0.150		0.086	0.096	
85-2142	0.130	0.137	86-0380	0.039	0.040	
	0.130	0.128		0.039	0.041	
85-2211	0.072	0.087	86-0404	0.138	0.138	
	0.071	0.088		0.145	0.136	
85-2248	0.131	0.134	86-0405	0.035	0.035	
	0.131	0.135		0.036	0.036	
85-2256	0.152	0.148				
	0.156	0.147				
Doxepin	16.8	2.2	mcg/mL			

[a] Less than 3 mls heart blood; 30 mls femoral blood.
[b] 28 mls heart blood; less than 5 mls femoral blood.
[c] No noted differences in volume or appearance of these specimens.
[d] Less than 5 mls heart blood; 16 mls femoral blood.
[e] "Heart blood" in this case is antemortem peripheral blood drawn 60 minutes prior to death.
[f] 5 mls heart blood; 30 mls femoral blood.

select cases. The table includes every submission to our laboratory over a 6-month period in which samples of both heart blood and a peripheral blood (femoral or subclavian) were received and the heart blood alcohol concentration was 0.02% w/v or greater.

Examination of these results discloses that our data do not support the findings of Briglia *et al.* (1986). Admittedly, we have examined only 24 cases compared to their 74; however, I feel that our sample size was large enough for us to draw this conclusion. In only 1 of our 24 cases (85-2130) could the difference in concentration between heart and femoral artery not be explained by volume differences or physical appearance. In this case, the difference in values was 18%. This case contrasts to the number and frequency of those reported by the Hauppauge group. The other noted differences in our study are explainable. The "heart blood" in case number 85-2496 was actually an ante mortem peripheral blood specimen collected 1 hour before death. In four other cases (85-1738, 85-1770, 85-2286 and 86-0156), there were differences between the femoral and heart blood concentrations of 24%, 20%, 14% and 16%. In each of the four cases, the lower alcohol concentration was obtained on the blood specimen of smaller volume. We attribute these differences to the salting out effect of the sodium fluoride. Further evidence of loss of ethyl alcohol into the headspace was obtained by re-assay of the heart blood in case number 85-0156. The original volume of this specimen was approximately 5 ml, compared to the companion femoral blood specimen volume of approximately 30 ml. There was an initial difference in the heart/femoral blood alcohol concentration of 16%. This difference increased to 23% and 28%, respectively, on subsequent analyses. We recognize that a relatively small number of cases has been evaluated to date, and we intend to continue to evaluate heart versus femoral blood alcohol concentrations and to study the salting out effect in greater depth.

For many years, there has been a long-standing premise among forensic scientists that there is no significant change in the blood concentration of most drugs following death. Today we recognize that there are exceptions to this rule. Digoxin has been extensively studied from this aspect. In 1973, Iisalo and Noutila reported that there was a significant difference in ante mortem and post mortem serum digoxin concentrations. In 1975, Holt and Benstead reported that the digoxin concentration of heart blood collected at autopsy was consistently higher than that of blood collected at the same time from the femoral vein. Bandt in 1980 at the American Academy of Forensic Sciences meeting in Los Angeles presented the first evidence of post mortem changes in serum concentrations of several tricyclic antidepressants.

In 1983, our laboratory became actively involved in the study of site-dependent drug concentrations in post mortem blood specimens via two, essentially simultaneous, cases that were investigated by our agency. The first case was that of a 64-year-old woman weighing 56 kilograms who was confined to a psychiatric institution. The patient had been medicated with NORPRAMIN (desipramine), 25 mg three times a day for 13 days. She was found dead at 2 am and was known to be alive on the preceding evening. An autopsy was performed 8.5 hours after the body was discovered with the only significant finding being a cerebellar meningioma. It was the pathologist's opinion that this tumor was not the cause of death, and a drug screen was requested. Toxicologic analysis revealed desipramine in the following concentrations: subclavian blood, 6.1 mcg/ml, vitreous, 0.44 mcg/ml and a total of 12.0 milligrams of desipramine in the gastric contents. This blood concentration was more than 30 times greater than that reported for steady-state plasma concentrations in patients receiving long-term, 75 mg per day doses of desipramine (Baselt, 1982). Study of the medical records showed that the patient received only the prescribed medication at the designated times.

The second case involving tricyclic antidepressants concerned a 43-year-old man weighing 64 kilograms, who had a history of depression and threats of suicide. He was found dead in a locked room 4.5 hours after he had a telephone conversation with an innkeeper, who reported that the man sounded very intoxicated at the time. An empty SINEQUAN vial (doxepin, 100 mg) was found beside the body. The local medical examiner collected a blood specimen by cardiac puncture 2.5 hours after the body was found. The body was then shipped to our facility in Oklahoma City for autopsy. The autopsy was conducted 19.5 hours after the body was discovered. The toxicologic findings are presented in Table 2. The doxepin concentration of the blood specimen collected at autopsy from the right side of the heart was approximately three times greater than the cardiac blood specimen collected by the local medical examiner some 16 hours earlier.

We were stimulated and perplexed by the findings in these two tricyclic antidepressant deaths, particularly because members of this family of drugs are seen more frequently in our laboratory than any other group (more than 200 cases in the past 10 years). During the last 3 years, we have studied 66 deaths in which tricyclic antidepressants were detected; 49 of these were determined to be fatal overdoses and the

other 17 were ruled therapeutic or nonfatal intoxication.

In a number of cases, we also collected samples from the same site at different times. The results of a typical multiphase study (Table 3) show that the concentration of a drug in blood varies not only from one site to another but also at the same site when samples are taken at different times. We concluded that the concentration of a drug in blood is profoundly influenced by the time of post mortem sampling and that no realistic estimate of dose can be made from a post mortem blood concentration. However, drug concentrations in femoral blood appear to change less than those obtained at other sites.

Although I have concentrated thus far on the site-dependent differences of tricyclic antidepressants, this problem is not limited to one family of therapeutic agents. Propoxyphene samples are also site and time dependent, and the differences in cardiac and femoral blood are often greater than those observed with tricyclic antidepressants. Table 4 presents the findings in a mixed drug death involving both propoxyphene

Table 2. DOXEPIN OVERDOSE

Specimen	Doxepin	Nordoxepin
Field blood (Cardiac puncture)	5.6	1.5
Right heart blood (Autopsy)	15.1	1.8
Liver	310	57
Gastric	703 mgs in total specimen	

Concentrations in mcg/mL or mcg/gm

Table 3. AMITRIPTYLINE OVERDOSE

Blood Specimen	PHASE I Anitriptyline/Nortriptyline	PHASE II Amitriptyline/Nortriptyline
Right subclavian	4.6/3.6	6.7/4.7
Left subclavian	4.6/3.5	7.3/4.9
Right heart	4.9/5.3	4.6/4.5
Left heart	—	6.6/7.8
Right femoral	3.1/2.6	—
Left femoral	—	3.4/2.6
Vitreous	—	0.69/0.38

Concentration in mcg/mL Phase I to II time interval = 19 hrs

Table 4. PROPOXYPHENE/MEPROBAMATE OVERDOSE

SUBJECT: 40 year old male
DRUGS: Propoxyphene & Meprobamate
BAC: Negative
TIME LAST KNOWN ALIVE: 0800 hrs 1/12/86
TIME OF DEATH: FD 1100 hrs 1/12/86
AUTOPSY: 1300 hrs 1/13/86

	Heart Blood	Femoral Blood	Liver
Propoxyphene	3.7	0.61	29.0
Norpropoxyphene	4.7	1.4	42.0
Meprobamate	17.0	18.0	—
Carisoprodol	18.0	17.0	—

Concentrations mcg/mL or mcg/gm

and meprobamate. The cardiac blood propoxyphene concentration was 3.7 mcg/ml versus 0.61 mcg/ml for femoral blood, but concentrations of meprobamate and carisoprodol were virtually the same in cardiac and femoral blood. This lack of site-dependent differences was also shown in two other deaths linked to meprobamate.

Phencyclidine and meperidine concentrations in blood also have been found to differ according to site and time of sampling. Table 5 lists our findings for a fatal overdose involving these two drugs. Table 6 summarizes the various therapeutic agents that show site-dependent variability.

The contrasting site-dependence of ethyl alcohol, codeine and doxepin are presented in Table 1. For case 86-0354, death was caused by a combination of ethyl alcohol and codeine. The difference between concentrations of alcohol in cardiac and femoral blood samples was only 5%, but there was a 100% difference in codeine concentrations from the same two sites. In case 85-2256, post mortem alcohol concentrations were virtually the same in cardiac and femoral blood samples, but concentrations of doxepin were 16.8 and 2.2 mcg/ml, respectively. The cardiac blood sample was collected 40 minutes after death (9 hours before autopsy) and the concentration of doxepin was 1.9 mcg/ml, essentially the same as that found in the femoral blood collected at autopsy.

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Table 5. PHENCYCLIDINE/MEPERIDINE OVERDOSE

SUBJECT: 24 year old male
DRUGS: Phencyclidine & Meperidine
BAC: Negative
TIME LAST KNOWN ALIVE: 2300 hrs 3/18/84
TIME OF DEATH: FD 1200 hrs 3/19/84
AUTOPSY: 1030 hrs 3/20/84

RESULTS	PHENCYCLIDINE	MEPERIDINE
Field Heart Blood*	105	68
Autopsy Heart Blood	497	160
Autopsy Femoral Blood	150	59
Autopsy Vitreous	170	80
Autopsy Liver	1300	1700
Gastric	360	140

Concentrations ng/mL or ng/gm

* Collected by Cardiac Puncture 1 ½ hrs after found dead and 21 hrs prior to autopsy.

Table 6. DRUGS OTHER THAN TRICYCLIC ANTIDEPRESSANTS

DRUG	LSC	RSC	RH	F	VC
Chlorpromazine	—	1.5	—	0.70	—
Codeine	—	—	46.0	20.0	—
Diphenhydramine-1	—	—	1.5	0.70	—
Diphenhydramine-2	—	13.5	—	6.50	—
Diphenhydramine-3	—	0.18	—	6.50	—
Ethchlorvynol	9.50	—	6.20	—	—
Lidocaine	—	9.80	—	5.50	—
Meperidine	—	—	0.50	0.15	—
Meprobamate-1*	205	—	207	—	—
Meprobamate-2*	—	7.10	—	7.70	—
Meprobamate-3*	—	17.0	—	18.0	—
Methadone	0.57	—	0.24	—	—
Propoxyphene-1	—	—	4.40	0.40	—
Propoxyphene-2	—	—	—	1.20	5.50
Propoxyphene-3	4.60	—	4.20	0.46	—
Propoxyphene-4	4.40	—	—	0.40	—
Trazodone	7.0	—	8.2	4.80	—
Verapamil	—	9.30	—	5.40	—

Concentrations in mcg/mL
*not site and time dependent
LSC = left subclavian RSC = right subclavian RH = right heart F = femoral VC = vena cava

THE ROLE OF THE EXPERT

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Expert testimony is often used when lay persons lack needed scientific, technical, legal, medical or business knowledge. Rule 702 of the Federal Rules of Evidence allows technical, scientific or specially trained persons to qualify as experts. The following presentation outlines the procedures to use and factors to consider when experts are required.

SELECTION OF EXPERTS

Resumes of potential experts should be checked carefully to ensure that the information is accurate and current and able to withstand ferocious cross-examination. The attorney should interview potential experts at the scene of the challenge or in the expert's working environment. The following factors should be considered when evaluating a potential expert:

1. How will the person handle himself on the witness stand? Is he articulate, likeable and amenable to receiving information from other disciplines? Can he help gather information?

2. Some cases require a line mechanic or a laboratory technician whose expertise in a technical or scientific field is unparalleled. Others require the most experienced, learned academics—persons who can teach a jury about a scientific, engineering, business or technical field.

3. The attorney should give the potential expert enough time to prepare for the interview and should ask enough questions to determine the person's qualifications.

If the expert meets the needs of the case, the attorney should confirm the working relationship in writing. Critical items such as compensation, deadlines and responsibilities should be discussed and set forth in detail. The client should be involved in the selection process, since he or she ultimately bears the financial responsibility for the expert's services. The client should sign the engagement letter.

The experts should be made aware of all available facts, the client's understanding of the case, technical reports, research papers, official investigative records and witnesses' statements. If a particular case involves places or items, the expert should inspect both at once.

The expert's initial evaluation is usually flexible and questioning. At that early stage, the expert's conclusions should be tentative and not committed to writing. Throughout the case, the expert should keep a running list of additional information required for followup and investigation.

If a protocol is involved, the most current version should be located. It can be used to guide for all future investigation. The expert can use it to compare events of the case with that standard for flaws, negligence, omission, oversight and compliance.

INITIAL PLANNING

In a multiple expert case, all expert witnesses should attend an initial meeting. Each should bring results of preliminary studies and fact-gathering efforts so that information can be exchanged. The attorney should open the meeting by explaining that the information discussed will be part of the attorney's work product and thought process. As such, the materials should not be discoverable by opposing counsel. This precaution is mandatory, particularly at early stages when various hypotheses are proposed and some discarded for lack of substance or evidentiary support.

This first meeting helps experts appreciate reciprocal strengths, weaknesses and information. Such a meeting is particularly necessary in multidisciplinary cases demanding a blend of sciences, skills and expertise. The site for the planning meeting should have adequate access to telephones, stenographic services, photocopy equipment and creature comforts.

The client should be intimately involved in preparing the case and should attend the initial conference. The client can see the intensity of attorney and witness work and is able to understand the need to honor financial and other requests by attorney and expert alike.

Minutes of the meeting should be kept in a confidential file retained by the lawyer. In addition, the heading on the minutes should indicate that the meeting is part of the attorney's work product and thought process. Confidentiality can be enhanced by having the client present, making the communication in part an attorney-client privileged item and hence not discoverable. Some laws protect conferences such as this from discovery when experts are considered as confidential consultants to the client.

"Plead not what you can prove not." The technical consultant must assist the pleader in drafting substantive pleadings. Pleadings should not be redundant and should not include questionable allegations. Experts can help word the technical parts of the pleading properly and review discovery requests for completeness.

In technical cases, technical data, forms, procedures, protocols, notes and research materials can be uncovered with expert assistance. The forensic witness can guide collection effort. It is often essential that experts participate at this stage of discovery to ensure the necessary technical materials are available before deposition and to help reduce the costs of the collection effort.

DEPOSITIONS

Preparing for deposition, as well as relating previously obtained materials, should be a joint effort of experts, consultants and lawyers. Essential items to consider in planning depositions include:

1. Technical data from the client.
2. Investigative and technical materials produced by the expert.
3. Pleadings on file in the case.
4. Products of written discovery, such as interrogatories and document production.
5. Standard scientific works relevant to the subject matter.
6. Appropriate legal authorities.

At the deposition, the expert helps the attorney assess the qualifications, capabilities and demeanor of opposing witnesses and experts and question those witnesses. Court approval is often necessary before opposing experts may be deposed. The pleadings must show that the information sought by discovery cannot be obtained by other traditional and less expensive methods. This situation exists under the Federal Rules of Civil Procedure and in states that have adopted similar rules of procedure.

Depositions may be taken either for discovery or in lieu of testimony at court because the witness is beyond the jurisdictional limits of the court's subpoena power. In each instance, appropriate experts should attend depositions to help guide the attorney's questioning. Obtaining prior court approval for the expert's presence at deposition is an effective precaution. In some jurisdictions, such matters would be referred to local counsel, who would then determine whether the expert could attend the deposition. Hearing such matters in foreign territory is risky. The attorney should therefore obtain either stipulation or a court order from the home court in advance of deposition outside the jurisdiction.

Nothing can be as disappointing to the trial lawyer as preparing costly exhibits that are rejected at trial because of inaccuracy or lack of foundation. Exhibits must be accurately and technically correct. Demonstrations must be substantially similar to the subject under litigation to be admissible.

Attorneys should use an expert to prepare exhibits and demonstrative charts and documents, and they should test those items before trial. Trial exhibits should be shown to opposing counsel well before the trial and either stipulation or court order approval should be obtained, if necessary. These are inexpensive prices to pay for guaranteed admissibility of a key chart, exhibit, document or demonstration.

THE FINAL PLANNING CONFERENCE

As with the first planning conference, all experts, the attorney and the client should be present at the final pretrial conference. The client should be present so that his testimony can be sharpened to blend with expert testimony. Often a client will have forgotten essential facts. The expert can ask probing questions to remind the client of events of technical significance.

At this conference, all weaknesses in the case should be exposed and all strengths of the opposition should be examined. Experts should coordinate their testimony. A recalcitrant expert can be identified at this final pretrial conference. Inconsistencies in expert testimony can be disclosed.

This conference is a dress rehearsal. All staging and timing should be practiced. Witnesses, attorney and client should be brought to a peak of performance using video or audio monitoring, if necessary, to identify flaws, weaknesses and idiosyncratic behavior.

Unnecessary exhibits and testimony should be eliminated. Calculations should be rechecked. Data must be summarized whenever possible; the raw data should be available in the courtroom but summaries of voluminous documents should be used.

PREPARATION FOR TRIAL

Preparation for trial is not particularly different from deposition preparation. The attorney should explain the purpose of testimony and describe the physical setting of the hearing room in detail, including positioning of the parties, the attorneys and the dispute resolution panel. The attorney should outline functions of the witness, attorney, jury and fact finder so there are no surprises.

The attorney should emphasize the importance of careful testimony, particularly the hazard of inconsistent testimony between deposition and trial. Witnesses should be admonished to tell the truth and to prepare for deposition or trial testimony by reviewing the facts of the case.

Witnesses should not lose their temper and should speak slowly, clearly and naturally. If they are familiar with the process, they will not fear the examining attorney and the setting.

The attorney should admonish forensic witnesses to answer only the question asked and never to volunteer information beyond the scope of the question presented. The attorney should remind the witnesses that they need not have an answer for every question.

Most witnesses should be reminded that questions can be answered "Yes," "No," "I don't know," "I don't remember," "I don't understand the question" or by a simple uncomplicated factual answer. Witnesses should not memorize their story or their testimony. They should avoid phrases like "I think," "I guess," "I believe" or "I assume." These are weak and insufficient to meet scientific and technical burdens of proof.

Cautioning witnesses to "take a breath" before answering is always good advice. This allows the witness to appear deliberate and affords the witness an opportunity to digest the question and frame an answer. The attorney should warn witnesses about trap words such as "absolutely" or "positively" and about estimating time, space and distance. If technical information is involved, the specifics, not estimates, should be given in the answer.

Fencing or arguing with or second-guessing examining counsel should be avoided. Witnesses should not deny having had prior discussions about testimony in the case if it is true. If a witness makes a mistake, he should quickly correct such it. If a negative or apparently damaging fact or omission has been elicited, the appropriate course is to admit it and move on quickly. To fence, hedge, argue, equivocate or become angry only exposes the witness to further cross-examination and loss of credibility.

Witnesses should never answer too quickly or look to counsel for assistance. The subject of testimony in court, deposition or hearing is not a light matter and should never be the subject of a joking or flippant response. Exaggeration, underestimation or overestimation are all enemies of unwary and ill-trained witnesses.

The demeanor and behavior of witnesses before, during and after the hearing should be the subject of attorney counseling. Clothing, stance and posture are matters the attorney and the expert must review together before trial. The attorney should alert witnesses about hazards of discussing testimony in hallways, restrooms or public areas around the hearing room. Conversations with opposing parties and jurors must be particularly avoided.

Court orders may be necessary to have a consulting expert remain at court or in a hearing room during trial if either side has sought under appropriate rules to exclude witnesses. The use of a key expert during trial often means the difference between success and failure. The way experts are used can be beneficial or disastrous. If the expert is constantly passing notes and conferring with the attorney, the client's case will appear weak to the fact finder. It is better if the expert can be elsewhere in the courtroom, take notes and confer with the attorney during recesses.

At all costs, the expert must be viewed as a professional interested in a factual presentation and not as an advocate for either side. Courtroom tools can make the testimony more effective and should be suggested by the examining attorney. Lapel microphones and telescoping pointers are effective in the expert's hand and allow comfort of movement and strength of presentation.

A final admonition for the expert in court: a trial is a teaching and learning exercise. The expert must transmit knowledge to the fact finder. In most cases, the effectiveness of the teaching will determine the outcome of the contest. As in any stimulating teaching setting, the teacher is likely to be questioned. Cross-examination should be anticipated so that the expert can formulate persuasive responses If the forensic witness identified vulnerable subject areas, the attorney can prepare for expected cross-examination and formulate a strategy for answering questions.

As in all matters of dispute resolution, there are three standard rules to follow when you use the testimony of forensic witness: Prepare. Prepare. Prepare.

UPDATE ON CHAIN OF CUSTODY OF BLOOD AND URINE SAMPLES FOR ALCOHOL TESTING

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For over a century, the results of scientific tests on body parts and substances obtained from human bodies have been frequent subjects of litigation. Over the years, some generally accepted principles have evolved which govern the admissibility of test results in evidence. However, just as scientists can differ as to what requirements must be met to satisfy scientific standards of reliability and trustworthiness,[1] courts in different states, as well as within states, may differ substantially in their application of these general principles to the specific cases before them.

Some courts adopt rather rigid requirements for the admissibility of test results, while others take a more liberal approach, favoring the admissibility of evidence that can be shown to be relevant and allowing the opponent of the test to argue to the finder of fact, whether it be a judge or a jury, about the significance of any perceived deficiencies in that evidence.

In general, courts appear to be moving towards a more liberal approach to the admissibility of evidence, aided in part by statutes providing for the admissibility of test results and other business or official records,[2] as well as by increasing familiarity with tests and test procedures and a need to expedite and reduce the cost of litigation.[3] However, even in states where the courts of last resort adopt a liberal approach to the admissibility of evidence, individual judges can be found who insist on a much more stringent approach. Accordingly, all persons involved in the collection, preservation, transportation and testing of blood and urine samples should perform their work to minimize the opportunities for objection.

Thus, the Minnesota Supreme Court stated, in *State v. Dille*, 258 N.W.2d 565 (Minn. 1977):

> The proponent of a chemical or scientific test must establish that the test itself is reliable and that its administration in the particular instance conformed to the procedure necessary to ensure reliability. [Citations omitted.] Without a foundation guaranteeing the test's reliability, the test result is not probative as a measurement and hence is irrelevant.[4]

As indicated in Dille, relevance is a prime consideration in legal proceedings. Evidence is admissible if relevant and of other requirements are met, and it is inadmissible if not shown to be relevant. Relevance is defined in Fed. R. Evid. 401 as follows:

> "Relevant evidence" means evidence having any tendency to make the existence of any fact that is of consequence to the determination of the action more probable or less probable than it would be without the evidence.[5]

When physical evidence is involved, each item of evidence must be identified or authenticated. With respect to blood and urine samples, for example, it is necessary to show that the sample said to be taken from the test subject was, in fact, taken from that person and not materially changed between the time it was collected and analyzed. Fed. R. Evid. 901(a) provides that:

> The requirement of authentication or identification as a condition precedent to admissibility is satisfied by evidence sufficient to support a finding that the matter in question is what its proponent claims.[6]

One way to identify and authenticate an item of physical evidence is to provide evidence of a chain of custody or chain of possession sufficient to show that the item offered in evidence is what it is purported to be.[7] The other common method, ready identification, is used when the item has unique characteristics that make it readily identifiable. In such cases, a chain of custody is not required.[8] However, one vial of blood or urine looks like any other vial, although steps can be taken to make a sample less similar by tags, markings and seals. To the extent that a blood sample can be made readily identifiable and unique, the necessity for a chain of custody can be reduced.

As stated by the Utah Supreme Court in *State v. Watson*, 684 P.2d 39, 40 (Utah 1984):

> The so called chain of custody doctrine has its greatest force where the physical evidence in question is fungible or subject to alteration. In

those circumstances, the chain of custody is required to show that there has been no tampering, alteration, or substitution of the evidence.

Under the strictest chain of custody opinions, every person who ever had possession of the test sample must testify, identifying the sample as the one in question and providing testimony tending to show that there was no alteration of the sample while in the possession of each witness. One example of such a case is *Novak v. District of Columbia*, 82 D.C. App. 95, 160 F.2d 588 (1947), in which all witnesses who handled the urine sample in a driving while intoxicated (DWI) prosecution testified as to their handling of the sample, but one of the witnesses was never asked to identify the sample as the one involved. Most courts today would consider such a position untenable.

On the liberal side, the Minnesota Supreme Court long ago rejected such rigid requirements. In *Lestico v. Kuehner*, 204 Minn. 125, 283 N.W. 122, 283 N.W. 125 (1938), a blown tire was offered in evidence in a personal injury action and objected to on chain of custody grounds. The opponent insisted that testimony was required from each person who had been in possession of the tire at all times from the accident to the trial. An exasperated Supreme Court chided all concerned for wasting court time and taxpayer's money in an effort to lay foundation for the tire:

> The tire had been removed and repaired in Minneapolis. The thought of objections and sustaining rulings was that no sufficient foundation could be laid except by testimony not only as to genuineness, but also the absence of tampering, from every person through whose hands the casing had passed in the meantime.
>
> There is no such rule and never has been. It was immaterial who handled the tire so long as it could be identified. If changes had destroyed its identity or had made the object wholly worthless or of questionable value as evidence, an entirely different situation would have been presented. If there had been alterations in the casing, they might or might not have been susceptible of honest explanation. But here were no changes and there was no good reason for delay in getting the casing into evidence. For the "chain of possession" theory in particular, there was no valid objection.

More recently, the Minnesota Supreme Court has reaffirmed that position, in the context of a criminal prosecution of a drug charge, stating that admissibility should not depend upon the prosecution negating "all possibility of tampering or substitution, but rather only that it is reasonably probable that tampering or substitution did not occur."[9] In an unreported decision, one Minnesota trial judge aptly stated the case against rigid application of chain of custody standards:

> The real problem with the "chain of custody" rationale is that pushed beyond its proper role as a rule of thumb, it gives rise to a "possibility of tampering" test. Under this supposed test, if an hypothesized mischief-minded villain could have possibly tampered with the object or exhibit, foundation is lacking. There is no case authority for such a test, and no logical reason why such a perverter should be concocted. If the object/exhibit is shown to be relevant, material and competent, it should be received and weighed along with all the other evidence by the fact finder.[10]

It appears that the current weight of appellate judicial opinion agrees with the approach taken by the Minnesota Supreme Court, as numerous examples cited in the following pages will indicate.

One typical example of such cases is *Parker v. State*, 170 Ga. App. 655, 317 S.E.2d 891, 317 S.E.2d 892 (1984), in which the appellant was unsuccessful in his assertion that the State failed to establish a proper chain of custody of his blood sample. The Court noted that:

> . . . a police officer observed the blood drawn and sealed in two tubes, and took the sample to the police station, sealed it with evidence tape and placed the sealed container(s) in a refrigerator and locked the refrigerator. It was sent to the crime lab by certified mail and when received, the seals on each of the three containers used were intact and there was no evidence of tampering.
>
> . . . Where there is only bare speculation of tampering, it is proper to admit such evidence and let what doubt remains go to its weight.

In other words, "due process of law" is not synonymous with a requirement that scientific tests be shown to be absolutely exact and error-free.[11]

Thus, it is now commonly held that a perfect or complete chain of custody is not an absolute requirement.[12] Indeed, where a conviction is reversed and a new trial granted on the grounds that there was an insufficient chain of custody in the first trial, a

complete chain can be shown on the new trial, and the same test again admitted into evidence.[13]

IDENTITY OF SUBJECT

The first step in the process consists of being able to show that the blood or urine sample came from the person in question. This may be done by having the person who collected the sample testify that the sample came from the person or by having another person testify that he or she saw the sample being taken from the person by another. Under appropriate circumstances, it may be possible to establish this fact by even less direct evidence, although such risks should not be taken unnecessarily.

For example, in *Timmons v. State*, 286 Ark. 42, 688 S.W.2d 944 (1985), a rape case, the prosecution called as a witness the serologist who analyzed the specimens in the "rape kit" but failed to call the person who collected the samples and put them in the kit, attempting to rely entirely on the fact that the kit contained indications that the sample had been collected from the victim. The Court held that this was insufficient to show that the sample had come from the person named in the kit.

In *Lynch v. State*, 687 S.W.2d 76 (Tex. App. 1985), a doctor testified that he directed a nurse to draw the sample but did not know which nurse drew the sample and did not see the sample drawn or observe the labeling of the blood sample. The Court held that this was not sufficient to show that the sample had actually come from the suspect.

It has long been standard practice to label blood samples, but there appears to be some variation as to the degree of labeling which may, under some circumstances, create problems in court. For example, in *Orr v. State*, 472 N.E.2d 627 (Ind. App. 1984), the hospital's blood sample logbook contained two entries, one for "Orr" and one for "Clyde Orr." Orr speculated that there might have been another person there with the same last name, tested at or about the same time, and that since his hospital patient number was not printed on the test requisition form, the evidence was not sufficient to show that the sample analyzed had been taken from him instead of his hypothetical namesake. However, the physician who ordered the blood test testified that there was only one Orr in the emergency room that morning, and this was sufficient to show that he was the one.

Minnesota has had a pair of cases in which the Court rejected claims that there was insufficient evidence that the sample came from the person in question. In *Ritter v. Village of Appleton*, 254 Minn. 30, 93 N.W.2d 683 (1958), a two-vehicle crash killed the drivers, Steve Ritter and Henry Hanson, as well as Patricia Ritter and Fred Howard. Blood samples were taken from both drivers by a mortician. It was unclear who labeled the samples, but the testimony indicated that it was not likely that the samples were mixed up. The Court found this to be sufficient. More recently, in *Dick v. Molitor*, 305 Minn. 390, 234 N.W.2d 583 (1975), Clell King, his wife Juanita and his father Adam were killed in a crash. A mortician drew the sample from Clell King after identifying the body, and this was sufficient. There was no reasonable possibility of confusing Clell and Juanita King's bodies, and the age difference between Clell King and his father made confusion unlikely there as well.

In *Renner v. Commissioner of Public Safety*, 373 N.W.2d 628 (Minn. App. 1985), numerous objections were made to a urine test of a sample collected from a catheter and drainage bag used as part of routine trauma procedure. Because the officer's handwriting was less than exemplary, the crime lab analyst recorded "Wendy Renner" as "Wanda Benner." However, since the officer obtained only one sample from only one person at the hospital on that date and all parts of the test kit bore the same serial numbers, the evidence was sufficient to show that the sample came from Renner, especially since there was no evidence that there was anyone else in the hospital with a similar name.

IDENTITY OF PERSON DRAWING SAMPLE

In addition to being able to demonstrate that the sample actually came from the person in question, records should show clearly which individual actually administered the test. Where there is no evidence about who drew a blood sample, it may not be possible to have the test admitted. Thus, in *Grala v. State*, 414 So.2d 621 (Fla. App. 1982), the Court held that it was an error to admit into evidence a 0.23% blood alcohol concentration (BAC) blood sample in a triple manslaughter case where the sample was drawn by "an unknown person."

While every effort should be made to accurately identify the person who draws the blood sample, ambiguity as to which of several qualified persons drew the sample is not necessarily fatal. Thus, in *State v. Sneva*, 353 N.W.2d 134 (Minn. 1984), a prosecution for "criminal negligence" under Minnesota's vehicular homicide statute, the appellant claimed that the evidence was insufficient to show that the blood sample was his, that it was properly drawn and preserved, and that the expert involved was properly qualified. Without bothering to set forth the underlying facts, the Court stated that "[o]ur examination of

the record satisfies us that the trial court did not abuse its discretion in overruling the foundational objections to the admissibility of this evidence."

A check of the appellate briefs filed in *Sneva* indicates that the State Trooper was not allowed into the emergency room where the suspect was being treated for his own injuries. He gave the blood kit provided by the Bureau of Criminal Apprehension laboratory to a nurse, who disappeared into the room and returned with the blood vial containing the sample said to be drawn from Sneva. She initialled the blood vial in the space normally used by the person drawing the blood, even though she probably did not do so; the policy at St. Paul Ramsey Hospital is to have only physicians draw blood samples for forensic testing. She gave the Trooper the name of a doctor whom he listed in his report as the one who actually drew the sample.

At trial, the nurse was unable to recall drawing the sample, asking anyone else to do so or seeing it done. The doctor was unable to recall drawing the sample, being asked to do so or even having seen Sneva. He was very busy with three patients in critical condition, was shorthanded and apparently did not have time to worry about the names of the people being treated. Despite these ambiguities, it was apparent that the test was collected in a hospital by an apparently qualified person, using the BAC kit. Since such samples are normally drawn according to a routine procedure, the fact that nobody could recall seeing the sample drawn was not fatal.

Sneva is not a completely isolated case. Courts increasingly accept the proposition that tests taken in a medical setting are most likely to have been taken properly. Accordingly, it is not always necessary to have the person who actually drew a blood sample testify to that fact in order to establish that it was been drawn in a medically and legally acceptable manner.[14]

QUALIFICATIONS OF THE PERSON DRAWING THE SAMPLE

As a matter of common sense, only properly qualified persons should draw blood samples. Generally speaking, many people with training as physicians, nurses, medical technicians, medical technologists and paramedics have the necessary training and should be able to draw blood samples from living persons. Where samples are taken from dead bodies, morticians can and have done so for years in assisting coroners in the performance of their duties.[15]

In many states, there are statutory restrictions on the types of persons who, though medically qualified, are legally permitted to draw blood samples for alcohol testing. Minnesota's Implied Consent Statute, Minn. Stat. par. 169.123, subd. 3 (1984), states, for example, that "[o]nly a physician, medical technician, physician's trained mobile intensive care paramedic, registered nurse, medical technologist or laboratory assistant" may draw blood samples for alcohol testing.[16]

Until 1983, the statute also provided that "[t]he person administering a test . . . shall be fully trained in the administration of the test pursuant to standards promulgated by rule by the commissioner of public safety." Believing that it would be presumptuous for the Commissioner of Public Safety to tell doctors and nurses how they should be trained to draw blood and how to do it, the adopted rule provided only that the persons be trained and employed in the occupations listed in the statute. Some defense attorneys managed to persuade a few judges that the rule was legally insufficient for failure to spell out in detail how medical personnel should be trained to draw blood and to spell out in detail the procedures by which blood samples should be collected, requiring the suppression of *all* blood, breath and urine tests.[17]

After several decisions were issued in favor of that position, all of which were appealed, the statute was amended in 1983 to eliminate any requirement that any rule exist relating to the training of persons drawing blood or urine samples, eliminating any suggestion that formal rules must be adopted to spell out how samples are collected, and requiring that breath test operators only have completed a course of training given by the Commissioner of Public Safety. As to the court rulings, the Minnesota Supreme Court reversed the trial court decisions and upheld the legal sufficiency of the rules that had been in effect.[18]

One way to establish the qualifications of the person drawing the blood sample is to have the person testify in person. However, this is not always possible or desirable. Whether a nurse who draws a blood sample is legally qualified is not the sort of question about which there can be much doubt, and it is a waste of the Court's time, as well as that of the nurse and all other participants in a trial, to require the presence in all cases of the doctor or nurse to testify that they are, in fact, doctors and nurses. Accordingly, several states have adopted statutes that provide for having those persons simply sign an official form that can be admitted into evidence to show the name and qualifications of the person drawing the sample and certifying that the test sample was properly drawn.[19] The validity of such provisions has been upheld, and the lack of testimony to corroborate the contents of the report is not a basis for excluding a test result.[20]

The qualifications of the person drawing the blood sample can also be established by the testimony of other persons who have sufficient knowledge. Obviously, other hospital personnel would be in a position to testify, but that is not always necessary. In several cases, the testimony of police officers has been sufficient to establish the qualifications of the nurse. Thus, in both *State v. Hanson*, 345 N.W.2d 845 (N.D. 1984), and *Harbin v. City of Huntsville*, 333 So.2d 625 (Ala. Crim. App. 1976), the officer's testimony that the nurse wore a white uniform with a name tag identifying her as "R.N." or "Registered Nurse" was sufficient. In *Palbicki v. Commissioner of Public Safety*, 347 N.W.2d 512 (Minn. App. 1984), the nurse appeared at the police station in civilian clothing, and the officer's testimony that his department retained her to come to the station to draw blood samples and that she is a nurse was sufficient. In *Joelson v. State*, 674 P.2d 229 (Wyo. 1983), the opponent asserted that the presence of the letters "R.N." after the name of the nurse who drew the blood sample was insufficient to show that she was, in fact, a nurse. Considering the claim frivolous, the Wyoming Supreme Court noted that their dictionary gave two meanings for that abbreviation: registered nurse and Royal Navy, and concluded that "We do not believe Theresa Hansen was indicating that she was a member of the Royal Navy."

In one unreported Minnesota trial court decision, *State, Department of Public Safety v. Bartel*, Anoka County Court File No. 16196(1554), decided May 14, 1980, by the Honorable Daniel M. Kammeyer, the opponent claimed that there was insufficient evidence to show that the person who drew the blood sample was, in fact, qualified to do so, where that person was unavailable for testimony and did not appear. In rejecting that objection, the Court stated:

> It may well be that there are impostors who don hospital garb and who roam the halls of Mercy Hospital at 4:00 in the morning, lying in wait to draw blood from unsuspecting DWI motorists upon requests from police officers; this Court however has not chosen to indulge in such fanciful speculations.

Finally, any statutory listing of persons legally qualified to draw blood samples need not be strictly and narrowly construed. For example, with respect to the drawing of blood samples, there is little practical difference between a medical technologist, medical technician or laboratory assistant. A person whose duties fall within areas normally the function of the occupations listed in the statute should qualify even if their job title at the hospital does not exactly match statutory terms. Some hospitals employ a phlebotomist who does nothing but draw blood samples. Common sense would dictate that such a person would be within the meaning of medical technologist or medical technician or some other appropriate term in the state statute in question. Thus, for example, in *State v. Counts*, 457 So.2d 568 (Fla. Dist. App. 1984), the Court held that a first- year resident was a physician for purposes of the statute governing the taking of blood samples, even though he could not yet qualify for licensing as a physician in the State of Florida.

PROPER COLLECTION PROCEDURES

It is also necessary to show that the sample was collected in a proper manner so that the sample can be relied on as being an accurate and trustworthy representative sample of the person's blood or urine. States vary considerably in the detail in which procedures are spelled out, but all procedures seem to share the requirements that the area from which a blood sample is taken be swabbed with a nonalcohol substance and that sterile equipment be used to collect the sample. Some states, such as Louisiana, require allowing of "strict compliance with the officially promulgated methods, procedures, and techniques in the chemical analysis of the defendant's blood."[21]

Other states, such as Minnesota, recognize that there is more than one trustworthy way in which the sample can be taken and do not require absolute compliance with some prescribed method. For example, as long as the arm of the subject is cleansed with a nonalcoholic substance, it does not matter if the cleansing agent is Betadyne, iodine, Phisohex, Ivory soap or something else. As long as the needle is sterile, it is of no consequence whether it is a disposable double-ended needle used with a Vacutainer or a regular single-ended needle attached to a standard glass syringe.[22]

With urine tests, states vary as to their requirements as well. Some, such as California, require the suspect to void the bladder, wait 20 minutes, and then collect the sample, with failure to provide a sample at that point being a "refusal."[23]

Other states, such as Minnesota, prefer to analyze a sample rather than face the prospect that the person will not be able to produce a second void sample within a reasonable period of time. Accordingly, there is no requirement in Minnesota that a suspect empty the bladder, wait and then submit the test sample.[24] The only requirement is to get the sample into the

bottle in a manner not likely to result in contamination. Thus, in *State v. Martin*, 300 Minn. 552, 220 N.W.2d 361 (1974), the Minnesota Supreme Court reversed a trial court ruling suppressing the results of a urine test because the method used had been "in poor taste and improper" because the sample was provided right at the scene of the arrest, on the side of I-94 near Snelling Avenue in St. Paul at about 3:30 a.m. As far as the statute is concerned, a urine test can be administered anywhere, anytime, although the driver could have properly insisted on more private accommodations.

In Minnesota's only recent challenge to a urine test, *Renner v. Commissioner of Public Safety*, 373 N.W.2d 628 (Minn. App. 1985), numerous objections were rejected as going to the weight to be given the test result, and not its admissibility. In *Renner*, the suspect was unconscious following a head-on crash, and a catheter had been inserted as part of routine trauma procedure. Because the arms were already occupied with intravenous lines, the nurse suggested that they simply use some of the urine collected in the drainage bag. The evidence showed that the catheter and drainage bag were sterile, and that some urine was poured into a sterile cup which came as a part of the catheter kit and poured from that into the sample bottle provided in the kit supplied by the Bureau of Criminal Apprehension laboratory. The kit was a commercially prepared kit containing, *inter alia*, a manila envelope bearing some instructions. One of them was that samples were to be deposited directly into the sample bottle and not poured from container to container. The opponent argued that the instruction on the manila envelope was a rule or regulation that had to be obeyed for the test to be admissible but offered no evidence to suggest that pouring the sample from one sterile container to another and then into the sample bottle could increase the test result—which happened to be exactly 0.10%. Rejecting this and many other claims, the Court found the sample to have been properly obtained.[25]

Where there are formal regulations or rules dealing with testing procedure, trial courts should take judicial notice of the contents of those rules, just as they do of state statutes, so that it should not be necessary to offer copies of the rules and procedures as foundational evidence for the test result.[26] However, if copies of the rules are not readily available to the trial court, the proponent of the test should be prepared to provide a copy of the rules for which judicial notice is sought.[27]

Other than the many cases cited in the Annotation cited earlier,[28] there have been a number of interesting recent decisions around the country rejecting claims that the evidence did not show that the samples were properly collected. Thus, in *State v. Hennessee*, 13 Ohio App.3d 436, 469 N.E.2d 947 (Ohio App. 1984), involving a urine test, the driver claimed that there was not a proper chain of evidence because nobody actually testified to seeing him provide the sample that was tested. The Court held that the trial court had not committed any error in allowing the test result into evidence.

In *Zimmerman v. State*, 469 N.E.2d 11 (Ind. App. 1984), the appellant claimed that the chain of custody of the sample bottle into which his blood sample was placed was not sufficient to show that the bottle was sterile. Noting that he offered absolutely no evidence that the container was actually contaminated, the Court held that the mere possibility that evidence might be contaminated or tampered with is insufficient to warrant the exclusion of the evidence.

In *State v. Vetsch*, 368 N.W.2d 549 (N.D. 1985), a nurse testified that she followed procedures in effect at the time of the test but had completed an outdated certification form that recited compliance with an outdated procedure. The North Dakota Supreme Court concluded that the test results were admissible.

MARKING AND SEALING

One reason for the increased willingness of courts to accept blood and urine test evidence without a complete chain of custody is that most states have well-developed procedures for marking and sealing items of evidence which render the establishment of a complete chain of possession unnecessary; if it is shown to have been adequately marked and sealed when it left the possession of the officer administering the test or supervising its administration and arrives in the hands of the analyst in a sealed condition, the probability of alteration, substitution or tampering somewhere in between has been eliminated as a practical possibility. However, this does not preclude the opponent of a test from looking hard for some discrepancy and asserting that it is evidence of tampering or substitution.

Thus, in *Renner v. Commissioner of Public Safety*, 373 N.W.2d 628 (Minn. App. 1985), the handwriting of the officer who filled out the identification card included with the sample was such that the analyst guessed that he had written "Wanda Benner" instead of "Wendy Renner." The Court concluded that this discrepancy did not give rise to any inference that the sample actually came from a different person where there was no indication that anyone else by that name existed, let alone was present at the hospital where the test sample was collected, and provided any sample for

testing which could have been substituted. Likewise, perceived discrepancies between the testimony of three officers who handled the sample before mailing as to who sealed what, when and where, whether the information card was put inside or outside the manila envelope before it was sealed and all components sealed into the styrofoam mailing container did not give rise to any inference of tampering where the kit and all of its contents appeared to be free from any tampering when they arrived in the hands of the analyst.

In *Heavener v. State*, 706 P.2d 905 (Okl. Crim. App. 1985), a doctor testified to his collecting of the samples and placing them in a "rape kit" which he sealed and turned over to an officer. The officer testified to his receipt of the sealed kit and to his delivery of the sealed kit to the crime laboratory. The chemist testified to receiving the sealed kit from the officer. The appellant alleged that the evidence was insufficient because the officer did not testify to his actual handling of the kit, and the doctor did not testify regarding the preservation of the specimen. The Court held, as usual, that the evidence was admissible because, although the State did not exclude every possibility of tampering, there was nothing in the evidence to suggest that the evidence had been altered in any way.[29]

As with most other steps in the chain of custody of a test sample, it is not always essential to have the testimony of the person who actually sealed the items in the blood kit. Thus, in *People v. Sutherland*, 683 P.2d 1192 (Colo. 1984), Trooper Chrysler had Ruth Ziegler draw the blood sample and watched her do so. She turned the sample over to him, and he sealed the vial. Chrysler then turned the vial over to Sgt. King, who sealed it in the kit and mailed it to the laboratory, where it arrived in a sealed condition. Although Sgt. King was not called as a witness, the test was admissible. The Court held that in the absence of any evidence of tampering or lack of authenticity, it was not necessary to call each witness who handled the sample.[30]

In *Cunningham v. State*, 255 Ga. 35, 334 S.E.2d 656 (1985), the driver alleged that an unspecified discrepancy in testimony as to the amount of blood drawn, together with a break in the "chain of custody," showed that the sample had been tampered with. The Court disagreed, noting that the blood was collected in self-sealing tubes, which were placed in an envelope and stapled shut. After having spent some time in a refrigerator under the custody of police officers, the vials arrived in the hands of the analyst sealed, in the stapled envelope, with no signs of tampering.

Although the practice of sealing evidence kits is very common and is accorded great credibility by the courts, some evidence is not handled quite so carefully. It does not follow, however, that the probative value is invariably so compromised as to render the evidence inadmissible. In *State V. Nason*, 498 A.2d 252 (Me. 1985), the Court held that evidence in a cocaine case was admissible even though the evidence envelopes were in a room to which other officers had access, the items in one of the envelopes were not those listed as contents and the envelopes were not sealed as he had left them. Noting that the appellant did not allege that any tampering or substitution had actually occurred, the Court held that the claim that the State had failed to prove a proper chain of custody was without merit, and that a minor interruption in the chain of custody does not affect admissibility.

Although the practice of marking items of evidence so that the item can later be identified is well established, there may be situations when it has not been done. If the identity of the item can still be established by other means, the lack of marking would not be fatal. Thus, in *Henning v. State*, 477 N.E.2d 547 (Ind. 1985), involving the robbery of a cab driver, the officers failed to mark the brick used as a weapon to bludgeon the driver. However, they had photographed the inside of the cab, including the blood-stained brick. Even though there was a chain of custody objection, the Court held that the photograph and testimony were sufficient to show that the brick offered in evidence was the same brick found in the cab.

Although blood samples or urine samples are not as readily identifiable as a blood-stained brick, they can be collected in vials that have securely attached labels bearing serial numbers and places to record names and dates. Even if the blanks have not been filled in, if the serial number has been recorded in the reports as relating to the test in question, it should be possible to still lay sufficient foundation for admissibility of the test result.

TRANSFER, STORAGE AND DELIVERY

Samples can be delivered by the collecting officer personally to the analyst, but they are more often relayed through several hands or through the mail. Where more than one exhibit is being handled at a time, some ambiguities can arise in the course of a trial. Thus, in *McDonald v. State*, 351 N.W.2d 658 (Minn. 1984), a drug case, a large number of exhibits were boxed together. All individuals who handled the evidence were called as witnesses, but one officer did not testify specifically to receipt and handling of the

Dilaudid pills in one of the envelopes in the box, and another failed to locate the Dilaudid pills in the exhibit while on the stand. The Court held that this did not affect the adequacy of the foundation. A perfect chain of custody is not essential.

In *People v. Arthur*, 99 A.D.2d 595, 471 N.Y.S.2d 412 (A.D. 3 Dept. 1984), a nurse took the blood sample in a self-sealing vial in the presence of the officer and then handed it to him. He labeled it, took it to the office and sealed it in a container. He then gave it to another officer for mailing. Another officer, who may or may not have been the same another officer, completed some paperwork for mailing and gave it to a secretary to take to the post office. She testified to receiving the kit and mailing it. The gap in the chain of custody between the time when the first officer took the sample to the office and another officer took possession was not fatal because the sample had been sealed by the first officer and was still sealed when it got to the laboratory, with no evidence of tampering.

In *Gothard v. State*, 452 So.2d 889 (Ala. Crim. App. 1984), a complete chain of custody was established, but there was a discrepancy as to the date of the transfer from one person to another. One said he delivered the sample about noon on October 12, 1981, and the other stated that he received the sample from the first witness about 10:25 a.m. on October 13, 1981. Since all transfers were accounted for, the discrepancy was immaterial.

Where the arresting officer testifies that he placed the blood sample in the lock box at the police station and the analyst testified that she removed the sample from the lock box, there is no break in the chain of custody.[31]

Although the use of locked containers enhances security, it is not essential that evidence be kept under lock and key at all times to be admissible. Thus, in *Harris V. State*, 480 N.E.2d 932 (Ind. 1985), a rape case, the fact that a police officer left the suspect's comb on his desk in an unlocked room to which other officers had access, left the room for a short time and found the comb still in the same place did not affect the admissibility of the comb.

Likewise, in *Gambill v. State*, 479 N.E.2d 523 (Ind. 1985), a murder prosecution, blood samples were put in a refrigerator at the police station to which only two officers had access. Several days later, the samples were mailed to the Federal Bureau of Investigation (FBI) laboratory. The appellant asserted that this chain of custody was defective, but the Court found that he raised no more than a mere possibility of tampering, and that this was insufficient to warrant a decision holding the chain of custody inadequate.

The same result was reached in *State v. Bailey*, 334 S.E.2d 266 (N. C. App. 1985), in which the blood sample was placed in an unlocked refrigerator at the hospital and then in another unlocked refrigerator in the officer's home. The Court concluded that while the appellant "can show potential weak spots in the chain of custody," this affected only the weight to be given the evidence, not its admissibility.

RECEIPT AND CHECKING

Crime laboratories and analysts normally keep quite accurate records on their receipt of samples and note any unusual observations, such as broken seals. It should be possible, therefore, to demonstrate at trial the date and time of receipt, from whom the sample was received, by whom the sample was received and the condition in which the sample kit was received. If those facts cannot be shown, the opponent may well raise objections to the perceived deficiencies in the chain of custody. However, it does not follow that the objection will be successful.

Thus, in *Lambert v. State*, 462 So.2d 308 (Miss. 1985), a murder case, the state failed to call as witnesses the actual crime laboratory employees who received the samples when they were delivered to the laboratory. The officer who delivered one exhibit to the laboratory could not recall the name of the technician to whom he delivered it. Likewise, the pathologist who performed the autopsy on the victim was unable to recall the name of the crime laboratory personnel who received some evidence from him. Since there was no indication of tampering or substitution, the incomplete chain of custody was not fatal.

TESTING

Once a test sample has been received and tested, questions can arise as to how necessary it is to have the analyst actually testify to that fact. In *Howard v. United States*, 473 A.2d 835 (D.C. App. 1984), the Court concluded that the results of tests on heroin by the Drug Enforcement Administration (DEA) laboratory could properly be admitted into evidence under the business records exception to the hearsay rule and without violating the suspect's constitutional right to confront witnesses against him and noted that most state and Federal courts were in agreement on this point. Among the many cases cited were several specifically relating to reports of tests for alcohol: *Kay v. United States*, 255 F.2d 476 (4th Cir.), *cert. denied*, 358 U.S. 825, 839, 79 S.Ct. 42, 3 L.Ed.2d 65 (1958) (report of alcohol level in appellant's blood); *State v. Larochelle*, 112 N.H. 392, 297 A.2d 223 (1972) (report

of alcohol level in appellant's blood); *State v. Torello*, 103 Conn. 511, 131 A. 429 (1925) (report of alcohol content of liquor). Although some courts disagree, the Court stated:

> In analyzing the reliability of the evidence in question, it is significant that the identity of a controlled substance, the fact sought to be established through admission of the DEA reports, is determined by a well recognized chemical procedure. Thus, the reports contained objective facts rather than expressions of opinion. In addition, the chemists who conduct such analyses do so routinely and generally do not have an interest in the outcome of trials. In fact, as employees and scientists, they are under a duty to make accurate reports. It is difficult to perceive any motive or opportunity for the chemists to falsify. We therefore conclude that the DEA records are sufficiently trustworthy to satisfy the purpose of the Confrontation Clause. Appellant was not denied his right of confrontation.

One of the contrary decisions cited in *Kay* was *United States v. Oates*, 560 F.2d 45 (2d Cir. 1977). It is possible that the issue would now be decided differently in the Second Circuit, since, in *United States v. Mendel*, 746 F.2d 155 (2d Cir. 1984), the same circuit held that the reports of blood tests on animal done by the U.S. Department of Agriculture laboratory were admissible as business records.

There have been instances where the analyst has died before trial, making it impossible to present live testimony by the analyst himself. There are several cases that uphold the propriety of admitting the reports of dead witnesses.[32]

Accordingly, states are free to enact statutes under which the results of routine tests on blood and urine samples can be admitted into evidence without violating the rights of the accused. Minnesota's version of such a statute is found at Minn. Stat. par. 634.15 (1984). The statute makes it possible for the Bureau of Criminal Apprehension laboratory to handle a larger number of cases with the same number of personnel, as court time is substantially reduced. At the same time, if there is any real question about the test itself, the statute allows the opponent of the test to require that the evidence come in by live testimony, merely by making a written demand more than 10 days before the trial.[33]

In *Roche v. Commissioner of Public Safety*, 372 N.W.2d 92 (Minn. App. 1985), the Court held that there is no requirement for additional evidence on the competence of the person drawing the blood sample if the report of drawing the blood sample complies with statutory requirements.[34]

POST TEST PRESERVATION

After conducting tests, most laboratories preserve the sample remaining until after the known proceedings have been resolved. It may be independently tested. It may be retained and offered in evidence at trial. Sometimes this becomes impossible, and there is no blood sample to offer at trial.

Since one blood sample looks very much like another, it would seem that the sample itself would be of very little assistance to a judge or jury attempting to decide if the test result accurately and reliably indicates an alcohol concentration of 0.10% or more. Nothing can be learned about the alcohol content of the sample by looking at it. Accordingly, it would seem to have no use at trial except to show, by the markings on the vial itself, that it was the sample tested. It is, however, the test result, not the appearance of the sample itself, which is the ultimate item of evidence for which all other effort prepares.

Because it is the test result, not the test sample, which is the object of the effort, the absence of the test sample should not be any more fatal to the introduction of the test result than the absence of some person who may have relayed the sample to the laboratory. There does not seem to be any greater need to produce the actual sample in a case of a blood test than in a breath test, where samples are seldom preserved for later analysis. Thus, in *State v. Dille*, 258 N.W.2d 565 (Minn. 1977), the Court rejected the claim that the test sample itself had to be offered in evidence for the test result to be admissible.

Likewise, in *State v. Disch*, 119 Wis.2d 461, 351 N.W.2d 492 (1984), the Wisconsin Supreme Court reversed a trial court decision suppressing the results of a blood test where the remainder of the sample had been consumed in an additional test for controlled substances. In view of the defendant's opportunity to cross-examine those who analyzed the blood sample, and the right she had to have a separate sample taken for her own use, the inability of the State to provide her a portion of the sample did not deprive her of her right to due process of law. On the same day, the Court decided *State v. Ehlen*, 119 Wis.2d 451, 351 N.W.2d 503 (1984), holding that the destruction of the remainder of the blood sample by the hospital according to standard hospital procedures between 2 and 7 days after it had been analyzed did not require suppression of the test result. Accordingly, while preservation of the sample for later use is desirable, its

unavailability is not necessarily fatal to the admissibility of the test result itself.

CONCLUSIONS

Improvements have been made in the methods by which blood and urine samples are collected, preserved, stored, transmitted and tested. In addition, most courts have increasingly come to regard scientific testing procedures as reliable routines instead of some arcane mumbo jumbo and have increasingly tended to relax formerly strict foundational requirements for admissibility. However, problems can and do continue to arise. Despite the most careful training, human memories can fail, and a host of possible misadventures can interrupt the normal processing of any given sample. However, so long as it can be shown that good-faith efforts have been made to follow normal recommended procedures and there is no real likelihood that the sample has been contaminated, tampered with, altered or substituted, many of the problems that once contaminated, tampered with, altered or substituted, many of the problems that once would have resulted in exclusion of the evidence are now dismissed as affecting only the weight to be given the evidence and not its admissibility.

For continued progress to be made in this area, people involved in law enforcement must continue to improve their level of competence and training, modify procedures that need changing in the light of experience and seek new means of providing greater degrees of certainty about the reliability of their tests. At the same time, they must seek methods of maintaining high standards with fewer resources in times of economic retrenchment.

Overall, the development of case law has been one of increasing faith in the trustworthiness of test results. With continued effort and dedication, the positive trend of the past few decades is likely to continue.

FOOTNOTES

[1]Proponents of scientific tests commonly find that, no matter how elaborate and careful their procedures, the opponent can find an expert who will assert that good science requires at least one more safeguard than is present in the specific case. In Minnesota, for example, when Breathalyzer Models 900 and 900A were used for breath testing, an expert who had trained operators on those instruments in another state, where the manufacturer's recommended test procedure was used, would testify that this procedure was invalid and unreliable because it did not include a test of the room air and a simulator sample with each test subject. When faced with a test that included those steps, he would testify that this procedure was also invalid because at least two subject samples were required for a valid and reliable test. Yet, when confronted with a test where that was also done, he would testify that this procedure was also deficient because at least two more samples, taken 30 minutes after the first two samples, was the minimum requirement for a scientifically valid and reliable test. In short, to paraphrase Gilbert and Sullivan's line from Pirates of Penzance, a forensic scientist's lot is not a happy one.

[2]See, for example, Minn. Stat. par. 634.15 (1984), which specifically authorizes the admission of test reports in criminal and implied consent cases, without the live testimony of the person who analyzed the sample, from laboratories of the Minnesota Bureau of Criminal Apprehension (MBCA) or approved by the MBCA, and the laboratories of the FBI, BATF, DEA and Postal Inspection Service. In addition, reports relating to the collection of blood samples are admissible without the presence of the person who collected the sample. However, the opponent may require live testimony by making a written demand at least 10 days before the hearing or trial.

[3]As a practical matter, something has to give when the same person is required to be a witness in three simultaneous trials, whether the courtrooms involved are in the same courthouse or widely separated within the state. If routine testimony as to routine tests and testing procedures can be avoided, all three cases can proceed instead of either having to have two of them postponed, or, even worse, decided without relevant and probative evidence about which there is no serious dispute.

[4]See also 258, N.W.2d (Minn. 1977). Although the language used appears to support the proposition that the accuracy and reliability of a test must be proved beyond every conceivable speculation before it can even be considered, the Minnesota Supreme Court follows a liberal position as to admissibility. In *Dille* itself, the opponent objected that there was no direct evidence that the needle and syringe used to draw blood were sterile, that there was no evidence as to the nature and effect of an unidentified "white chemical" in the blood vial, that the blood sample itself was not offered in evidence, that the testing method could not distinguish between alcohol from different sources, and that it was not sufficient that the sample was analyzed only once. The Court concluded that the fact that the sample was drawn in a medical facility was sufficient to show that the needle and syringe, which had not been used before, was sterile; that the fact that the blood vial with the unidentified white powder came from a kit provided by the MBCA provided adequate evidence of its trustworthiness; that the blood sample was not essential; and that the other objections were insubstantial. In short, all objections went to the weight to be given the test evidence and did not affect the admissibility of the test result itself.

[5]State rules of evidence generally follow the language and numbering of the Federal rules. For example, Minn. R. Evid. 401 is identical in wording to Fed. R. Evid. 401.

[6]Again, many state rules are identical. See, for example, Minn. R. Evid. 901(a).

[7]For many earlier cases on the subject, see, Annotation, 21 A.L.R.2d 1216.

[8]For example, in *State v. Fox*, 689 P.2d 252 (Mont. 1984), a theft prosecution, a computer and disk drive bearing serial numbers and Canadian stock stickers, as well as an electric guitar, were so readily identifiable that no chain of custody was required. Likewise, in *State v. Watson*, 684 P.2d 39 (Utah 1984), a robbery prosecution, the cowboy hat and leather vest taken from the suspect were unique and readily identifiable, making it unnecessary to show a chain of custody.

[9]*State v. Hager*, 325 N.W.2d 43, 45 (Minn. 1982).

[10]*State, Department of Public Safety v. Bartel*, Anoka County Court File No. 16196 (1544), decided May 14, 1980, by the Honorable Daniel M. Kammeyer. In Bartel, several persons involved in the transfer of the sample from the arresting officer to the analyst were not called as witnesses.

[11]*Peranzo v. Coughlin*, 608 F.Supp. 1504, 1509 (S.D.N.Y. 1985), involving urine tests of prisoners to detect the presence of drugs. The tests were assailed as being fallible. However, the Court concluded that states are not required "to implement all possible procedural safeguards against erroneous deprivations of liberty when utilizing the results of scientific testing devices in accusatory proceedings."

[12]See, for example, *People v. Shiflet*, 125 Ill.App.3d 161, 80 Ill. Dec. 596, 465 N.E.2d 942 (1984) (blood sample from murder victim); *Spivey v. State*, 170 Ga. App. 196, 316 S.E.2d 822 (1984) (blood test offered by DWI defendant).

[13]*People v. Snyder*, 494 N.Y.S.2d 481 (A.D. 3d Dept. 1985).

[14]See, for example, *Keenan v. State*, 700 S.W.2d 12 (Tex. App. 1985) (not fatal to fail to call doctor who drew sample where there was testimony from medical technician who assisted in collection and officer who received the blood vial from the doctor); *State v. Mary*, 368 N.W.2d 116 (Iowa 1985) (nurse who drew the sample died before trial and could not testify); *State v. Harris*, 472 A.2d 755 (Vt. 1984) (no need to call the doctor who drew the blood where the officer witnessed and testified to the procedure); *State v. Hanson*, 345 N.W.2d 845 (N.D. 1984) (no need to call nurse who drew blood where officer could testify that he witnessed blood drawn in the hospital under very clean and sterile conditions); *State v. Rypkema*, 466 A.2d 1324 (N.J. 1983) (absent evidence the sample was improperly drawn, it was not necessary to produce the person who drew the blood to show that it was done in a medically acceptable manner).

[15]See, for example, *Dick v. Molitor*, 305 Minn. 390, 234 N.W.2d 583 (1975); *Ritter v. Village of Appleton*, 254 Minn. 30, 93 N.W.2d 683 (1958); *Nichols v. McCoy*, 38 Cal.2d 447, 240 P.2d 569 (1952); *Barton v. Commonwealth*, 257 Ky. 23, 77 S.W.2d 397 (1934).

[16]Paramedics were included at the request of the Cottage Grove Police Department, some of whose officers are qualified paramedics, after two blood samples that tested 0.20% or higher were suppressed in DWI cases because paramedics were not among the list of persons authorized to draw blood. Coincidentally, Cottage Grove was in a legislative district represented by one of the most influential legislators, and the statute was very speedily amended. Since then, the Cottage Grove paramedics have drawn a substantial proportion of blood samples taken in their county at the request of their own officers and officers from neighboring departments. This has been partly because of their ready availability and partly because one hospital reacted to the amount of time its employees were required to appear in court by refusing to allow blood samples to be taken by their employees.

[17]The rule also failed to detail the training program for breath test operators or the procedures to be used. Minnesota has not favored adopting very detailed regulations for several reasons, among them that the argument that the rulemaking procedure is very time-consuming and expensive, making it very difficult to make adjustments when they appear to be desirable and that adopting formal rules tends to cast procedures in concrete, making it more difficult to improve procedure and also tending to result in the automatic exclusion of any test that does not conform to every requirement of a stated procedure even if the deviation does not affect the test result or the reliability of the test result. The more detailed a formal procedure gets, the more an opponent can spend time trying to assert less than perfect compliance with each item. For example, in departments that test large numbers of DWI suspects, the Breathalyzer or Intoxilyzer is not shut off after each test, and arguments can be made that the officer did not comply with the test procedure because he did not start the test by turning on the instrument as set out in step one of the checklist.

[18]The lead case in the series of decisions on the so-called "Rochester rules issue," which arose in the Rochester area, was *Quimby v. State, Department of Public Safety*, 351 N.W.2d 629 (Minn. 1984).

[19]See, for example, Minn. Stat. par. 634.15, subd. 1 (1984), which provides, in part:

> In any hearing or trial of a criminal offense or petty misdemeanor or proceeding pursuant to section 169.123, subdivision 6, the following reports shall be admissible in evidence:
>
> . . . (b) A report of a blood sample withdrawn under the implied consent law if:
>
> (i) The report was prepared by the person who administered the test;
>
> (ii) The person who withdrew the blood sample was competent to administer the test under section 169.123, subdivision 3; and
>
> (iii) The report was prepared consistent with any applicable rules promulgated by the commissioner of public safety.
>
> . . . a blood sample report described in clause (b) purported to be signed by the person who withdrew the blood sample shall be admissible as evidence without proof of the seal, signature or official character of the person whose name is signed to it.

[20]See, for example, *Roche v. Commissioner of Public Safety*, 372 N.W.2d 92 (Minn. App. 1985); *Glick v. Commissioner of Public Safety*, 362 N.W.2d 15 (Minn. App. 1985). A similar form may have also been involved in *Joelson v. State*, 674 P.2d 229 (Wyo. 1983).

[21]See, for example, *State v. Corkran*, 448 So.2d 1346, 1350 (La. App. 1984), writ denied, June 1, 1984.

[22]Minnesota's reported decisions relating to alleged or demonstrated deviations from optimal procedures have largely involved breath tests. In those cases, the courts have repeatedly held that mere claims or even demonstrations of some deviation from recommended procedures do not affect admissibility. The driver must, in fact, show that there was a problem that affected the accuracy of the test and falsely elevated the test results. See, *Scheper v. Commissioner of Public Safety*, 380 N.W.2d 222 (Minn. App. 1986) (not fatal that officer did not check for belching during the observation period); *Abe v. Commissioner of Public Safety*, 374 N.W.2d 788 (Minn. App. 1985) (87% correlation between results of two Intoxilyzer samples was not fatal where all test results were at or above 0.100%, despite recommendation that there be a correlation of 90% or better); *Johnson v. Commissioner of Public Safety*, 374 N.W.2d 577 (Minn. App. 1985 (fact that "control standard" test of a certified 0.11% simulator solution gave a result of 0.099%, below the minimum standard of 0.100%, was not fatal to a test that showed an alcohol concentration of 0.16%); *Zern v. Commissioner of Public Safety*, 371 N.W.2d 82 (Minn. App. 1985) (89% correlation between samples in Intoxilyzer test instead of recommended minimum correlation of 90%); *Kooi v. Commissioner of Public Safety*, 363 N.W.2d 487 (Minn. App. 1985) (possibility of noncontinuous observation not fatal where there was no evidence that anything happened to interfere with the accuracy of the test); *Tate v. Commissioner of Public Safety*, 356 N.W.2d 766 (Minn. App. 1984) (person who accompanied suspect to bathroom during observation period not called; not fatal absent evidence that something happened in the bathroom to affect the test result adversely to the suspect); *State, Department of Public Safety v. Habisch*, 313 N.W.2d 13 (Minn. 1981) (use of simulator solution for

period longer than recommended due to unavailability of replacement solution no bar to admissibility of Breathalyzer test result).

[23]See, *Miles V. Alexis*, 118 Cal. App.2d 566, 173 Cal. Rptr. 473 (1981).

[24]In addition to the decreased likelihood of being ab'e to get a tes sample if a second void procedure is required, there are some othe reasons supporting this approach. Although it is possible for a person to consume quantities of alcohol, go to sleep, wake up and start driving without going to the bathroom, so that the amount of alcohol in the urine is far above the level of alcohol in the blood, common sense and the diuretic effects of alcohol make the possibility rather remote. In addition, before abandoning the blood alcohol content standard for alcohol concentration, Minnesota used a 1.5:1 conversion factor for converting urine alcohol to blood alcohol equivalent, even though studies indicate that the real ratios vary between approximately 1.1:1 and 1.45:1, with an average of about 1.3:1. By using so large a conversion ratio, Minnesota spotted the person so wide a margin, compared with the 1.3:1 average used in other states, that it was sufficient to take care of any reasonably possible factual situation. This 1.5:1 conversion ratio was built into the statutory definition of alcohol concentration with respect to urine tests. On the average, urine tests in Minnesota give the lowest readings of all, with blood tests giving the highest readings of samples taken simultaneously.

[25]Among the other objections were ambiguities as to the order in which the items of the kit were reassembled and sealed and suggestions that there had been tampering because one person indicated that the identification card was inside the manila envelope and another indicated that it was outside, that it was fatal to fail to test the sample for the presence of blood when the attending physician had the catheter inserted partly to check for the presence of blood in the urine' that it was fatal to fail to call the nurse who actually inserted the catheter, and that a margin for error must be allowed so as to disqualify a test result of only 0.10% alcohol concentration.

[26]See, *State v. Corkran*, 448 So.2d 1346 (La. App. 1984). Until fairly recently, a number of states, mainly in the Deep South, have required certified copies of official test procedures as part of the foundation for a test, especially with breath tests. None of the decisions seem to provide a very sound rationale for requiring the court's time to be taken up in reinventing the wheel in every case involving a test. In Minnesota, an officer's testimony that he followed the prescribed procedure is sufficient, as in *Berge v. Commissioner of Public Safety*, 374 N.W.2d 730 (Minn. 1985), in which the Supreme Court held that a trial court was not justified in rejecting a test that showed an alcohol concentration of 0.10% or more and the test operator testified that he administered the test in accordance with Bureau of Criminal Apprehension procedures and believed the result to the accurate.

[27]See, *State, Department of Highways v. Halvorson*, 288 Minn. 424, 181 N.W.2d 473 (1970) (regulation defining "peace officer" for purposes of implied consent statute).

[28]Annotation, 21 A.L.R.2d 1206, and Later Case Service supplements.

[29]Cases involving the sealing of breath samples for later analysis by another include *State v. Pickering*, 491 A.2d 560 (Me. 1985); and *State v. Comstock*, 494 A.2 35 (Vt. 1985). In both cases, the sealed samples arrived in a sealed condition with no evidence of tampering, rendering the chain of custody argument meritless.

[30]To the same general effect, see *People v. Arthur*, 99 A.D.2d 595, 471 N.Y.S.2d 412 (A.D.3 Dept. 1984).

[31]*Reardon v. State*, 695 S.W.2d 331 (Tex. App. 1985).

[32]See, *State v. Best*, 146 Ariz. 1, 703 P.2d 548 (1985) (report of deceased fingerprint examiner); *State v. Silva*, 137 Ariz. 339, 670 P.2d 737, cert. denied, U.S., 104 S.Ct. 500, 78 L.Ed.2d 692 (1983) (report of deceased police officer used to prove chain of custody); *People v. Porter*, 46 App.Div.2d 307, 362 N.Y.S.2d 249 (1974) (report of analysis of blood sample by deceased chemist).

[33]Because the statute explicitly allows a defendant the chance to require live testimony, the only appellate decision challenging the constitutionality of the statute was *Bernstein v. Commissioner of Public Safety*, 351 N.W.2d 24 (Minn. App. 1984), in which the driver was able to persuade a trial court that the statute was enacted in a bill that violated the constitutional prohibition on laws embracing more than one subject (the bill also included Minnesota's "Lee Marvin bill" relating to palimony). The Court of Appeals reversed.

[34]*Accord, Glick v. Commissioner of Public Safety*, 362 N.W.2d 15 (Minn. App. 1985) (same judge, same issue, same ruling).

SECTION II

EXTENDED ABSTRACTS

ALCOHOL IN BLOOD AND URINE SPECIMENS FROM DRIVERS IN THE REPUBLIC OF IRELAND

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In 1969, prescribed level offenses were introduced for drivers impaired by alcohol. A government-funded independent body known as the Medical Bureau of Road Safety was established to analyze all blood and urine specimens taken for the police under our Road Traffic Acts. The Medical Bureau of Road Safety is located in The Department of Forensic Medicine, University College Dublin. The following methods are used to collect specimens. After an initial screening with a breath tube, the arrested person has the choice of providing a blood or urine specimen. The specimen is separated into two bottles and after the bottle is sealed, the arrested person has the option of retaining either sample for private analysis.

From the start of the operation, all specimen bottles have had the appropriate preservative (and anticoagulant in the case of blood) added in the Bureau Laboratory, and when made up, all specimen kits for the police have been issued from the Bureau. Analyses for ethanol have all been carried out by gas chromatography. Since 1973, head space gas chromatography has been the only method used. Our head space equipment is all from Perkin-Elmer Ltd., and we have one remaining F40 and a number of F45s with a SIGMA 2000/HS 100 assembly just commissioned. For integration, we use a Hewlett-Packard 3380A or a Perkin-Elmer LCI 100 or from Spectra-Physics a System 1 or a 4290.

We considered introducing a fully automated system linked to a central computer but found it more prudent to attach an independent integrator to each gas chromatograph. n-Propanol is used as the internal standard both here and at the Home Office Forensic Science Laboratory. The analytical columns used are 0.2% Carbowax 1500 on Carbopack C (Supelco, Inc., Bellefonte, PA.) and 10% Carbowax 400 on Chromosorb W. We prepare the main working ethanol standards and cross-check them frequently against standards from Great Britain.

All specimens are analyzed independently by two operators. We deduct 6% from the average of the analytical results obtained to obtain the reported figure. The certificate of analysis is sent to the police station on the same day that a duplicate certificate of analysis is sent by registered mail to the arrested person.

Initially, the prescribed blood alcohol concentration was 125 mg/dl, with urine results being converted to equivalent blood using 1.00:1.33 (0.75%) as a conversion factor. From 1970 to 1978, we had no less than five interruptions to the taking of specimens; all of them were due to legal decisions on technical defenses associated with the working of the law in question. Because of the small number of laboratories available for the analysis of the specimen retained by the arrested person, it was written into the law that an arrested person could request a reanalysis of the specimen and furthermore be present in the laboratory to watch the reanalysis. In 1978, this option was dropped when the current, more briefly worded law was passed. This 1978 law introduced one limit for blood at 100 mg/dl and a separate limit for urine at 135 mg/dl. Since then, approximately 9,000 specimens have been analyzed each year. Tables 1, 2 and 3 show the current pattern of results. It is remarkable how little the pattern has varied from year to year. The conviction rate for results over the limit in 1984 was approximately 80%.

The Republic of Ireland has a population of about 3.5 million and an area roughly 75% that of the State of Virginia. The pattern of road death since 1960 is shown in Figure 1. It also shows the total number of specimens analyzed each year. Figure 2 shows in detail the total number of specimens analyzed each year. Figure 3 shows, for 1977, a typical facet of our drink/driving problem. A variety of factors could be involved. Alcohol impairment, fatigue and visibility problems combine with the Irish social pattern whereby people in general go to bed later than people in most European countries. Figure 4 shows number of injured and killed combined, in the period from 1977 to 1985. Although the total number of persons killed is falling, the combined figure for injured and killed remained relatively unchanged, until 1985 when a significant reduction was recorded.

To summarize, although as a people we have been slow to accept this type of law, some progress is being made against the problem of injury and death on our roads. Although the economic recession has reduced leisure time and night driving, road engineering, law enforcement and education measures have contributed to this progress.

Table 1. BLOOD ALCOHOL LEVELS

Alcohol mg/dl	1984 no.	%	1985 no.	%
0 - 107	171	6	173	6
108 - 135	146	5	137	5
limit 135 mg/dl				
136 - 200	648	23	569	21
201 - 267	1 009	35	932	34
>267	896	31	927	34
total:	2870		2738	

Table 2. URINE ALCOHOL LEVELS

Alcohol mg/dl	1984 no.	%	1985 no.	%
0 - 80	306	6	248	5
81 - 100	237	4	196	4
limit 100 mg/dl				
101 - 150	956	17	900	18
151 - 200	1 722	31	1 522	31
>200	2 343	42	2 101	42
total:	5 564		4 967	

Table 3. COMPARISON WITH PREVIOUS YEARS

Alcohol content (mg/dl)	1979 - 1983 %	1984 %	1985 %
≤100*	10.7	10.2	9.8
101 - 200	49.7	51.4	50.9
>200	39.6	38.4	39.3

*AND EQUIVALENT FOR URINE SPECIMENS

ACKNOWLEDGEMENT

For help in preparing this presentation, the author wishes to thank R. Hearne of An Foras Forbartha (The National Institute of Physical Planning and Construction Research) Dublin, and M. F. Christian of the Department of Civil Engineering, University College, Dublin.

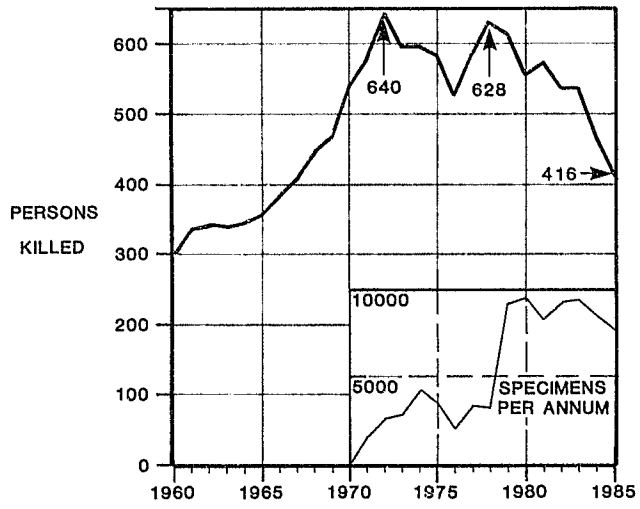

Figure 1. Persons killed, 1960-1985. Specimens received 1970-1985 (inset).

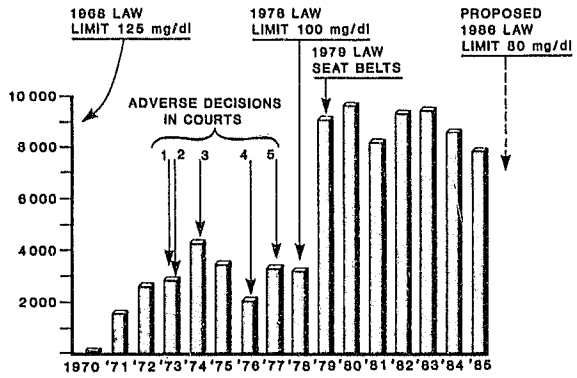

Figure 2. Specimens received.

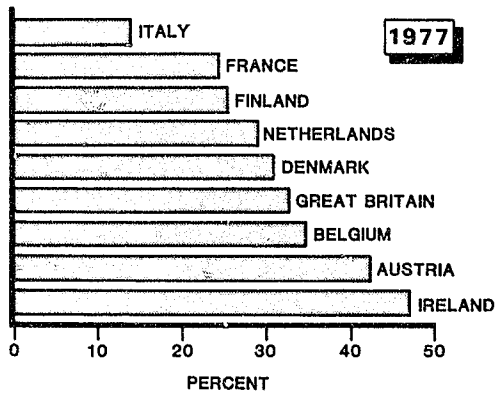

Figure 3. Percentage of fatalities and injuries at night (1977).

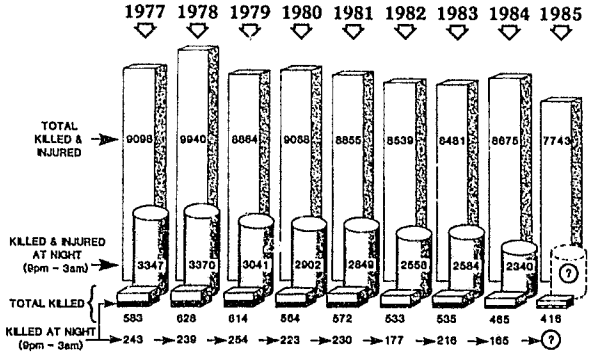

Figure 4. Persons killed and injured, 1977-1985.

LABORATORY SUPPORT LEADING TO AN ENFORCEABLE *PER SE* LAW: A CASE HISTORY

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Connecticut has been using a remote breath collection system to determine violations of the driving while under the influence (DUI) of alcohol statutes for more than 15 years. State statutes have placed the control of all such analyses under the direction of the Commissioner of Health Services. Under this system, the officer was responsible only for collecting a suitable sample and did not become involved in the analysis. The central laboratory was responsible for performing analyses, under the supervision of the toxicologist. The toxicologist was the expert witness who presented the analytical data and the interpretation of the data to the courts. Over many years, the credibility of the laboratory became so established that challenges to the analytical data were infrequent.

In 1981, the basic state laws and regulations were revised to allow analysis of breath for DUI violations to be conducted at laboratories not controlled by the Commissioner of Health Services, but the Commissioner remained responsible for the program to ensure the continued reliability of the testing. The Intoximeter 3000 system (Intoximeters, Inc., St. Louis, MO) was selected by the Toxicological Services Laboratory for its accuracy, reliability, specificity and ability to allow for modification and expansion as needed.

The system is designed to require an internal and external standard, and a specific sequence must be followed with specific data to be entered with each test. If any of these factors are missing or do not meet the present parameters, the instrument will abort the test. A second test, required to be taken 30 minutes following the first, allows the toxicologist to interpret the results concerning the alcohol absorptive and metabolic state of the individual at the time of the alleged offense. The credentials of the operators and the calibration and maintenance of the equipment are controlled by the Department of Health Services. The administrative regulations of the department were changed to reflect all the changes in the law and to be consistent with both statutory requirements as well as good laboratory practice.

The calibration and a report of every test conducted with an instrument are recorded in a permanent record book. This record includes the identity of the operator, the subject, the time and the date of the test. Complete records are maintained on all certifications of instructors and operators, as well as calibration data and repair records on each instrument. In this manner, the laboratory is able to maintain and guarantee the reliability of the testing procedure. This system has led to the imposition of a *per se* standard for operating a motor vehicle under the influence of intoxicating liquors.

In the future, we plan to upgrade the acetone detector. The reliability of the entire system will be further enhanced when we can conduct calibration checks of each instrument from the laboratory and transfer test results from each instrument to a central data base via telephone lines to the host computer in the laboratory.

ONLINE QUALITY CONTROL OF ETHANOL DETERMINATIONS IN SUSPECT DRUNKEN DRIVERS

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Driving under the influence is considered a serious offense, and legislation to monitor the ethanol concentrations in suspect drunken drivers was implemented in Sweden in 1934. The present law on drinking and driving presumes that a person with more than 0.49 promille, or, alternatively, with more than 1.49 promille ethanol in whole blood, is unfit for driving. If caught at the wheel, he will be charged in court for first or second degree drunken driving.

To enforce the law, blood samples from about 20,000 driver suspects, apprehended all over Sweden, are analyzed each year at a central laboratory. According to official regulations, the ethanol concentration reported to the police must be certified with a probability level at 99.9% and the laboratory costs for each case must not exceed SEK 150 ($20.00). The monetary demands allow only three independent tests on each sample. The mean value generated from the results of these is subsequently reduced by a factor whose size is based on the statistical errors of the determinations. If the estimate of the subtraction term is incorrect, the number of default court decisions with convicted innocents (type I error) or acquitted offenders (type II error) will be too high.

Perhaps the most obvious way to estimate the statistical error of the ethanol determinations would be to calculate the root mean square from the three values generated on each blood sample and to assume that these are t-distributed. By such a technique, the number of type I errors would be kept constant, whereas type II errors would vary and on the whole be fairly large. This problem arises because only limited statistical information can be obtained from the three determinations on each sample. If the general structure of the analytical errors is the same in every series of determinations, the size of the subtraction term could, instead, be estimated from the root mean square of normal distributed data generated in a large population of ethanol determinations. However, this statistical approach required that the size and structure of the analytical errors be controlled on a daily basis.

In the present study, the ethanol concentrations in blood samples from 4,200 drunken driver suspects were determined by three independent technicians using three headspace gas chromatographs each with a different packed column material. From a regression analysis by the method of maximum likelihood, the root mean square(s) varied with the average ethanol concentration (promille) above 0.49 promille in the sample according to the equation: s=0.01102. The concentration range from the three independent determinations on each sample was, therefore, normalized to unit(s) and then transferred online to a desk computer along with the identification number of the sample. The normalized ranges were automatically printed out on control charts after each run of 50-90 samples, and the cluster of dots obtained became distributed within tolerance limits fixed by the statistical errors of the method. These control charts are now routinely used as an important tool in the daily laboratory work to reaffirm the size of the subtraction term and to identify analytical disturbances, or outliers, and occasionally on request by the court of justice to ascertain the general quality of the laboratory analyses.

THE USE OF THE ALCO-SENSOR III AS AN EVIDENTIAL BREATH ALCOHOL TESTER IN IDAHO

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The Alco-/Sensor 111 (Intoximeters, Inc., St. Louis, MO) was approved for use in Idaho in 1984 as a potential replacement for the MOBAT (Luckey Laboratories, San Bernadino, CA) (McDonough 1985). A pilot program using volunteer agencies was created in March, 1985, to provide additional information about the fuel cell-equipped Alco-Sensor, performance of the printer and Alco-Sensor in heavy field use, judicial acceptance, maintenance and calibration records. The program ended on September 1, 1985, but the evaluation was continued to 1986.

The following equipment and materials were used:

1. RBT III - Alco-Sensor III and rechargeable printer set
2. Mark IIA simulators (National Draeger, Pittsburgh, PA)
3. Simulator solutions prepared and analyzed by Forensic Laboratory (Smith 1951)

All RBT III sets were sent from the factory to the Forensic Laboratory, where the printers and the Alco-Sensors were calibrated and tested. The equipment was then sent to the agencies, where calibration checks were performed weekly using the simulator solutions. If the results were not within 10% of the solution value, the instruments were recalibrated. Driving Under the Influence (DUI) suspects were tested at the agencies using a printer-controlled program of BLANK, SAMPLE, BLANK, SAMPLE, BLANK.

Two-hundred breath tests were performed by 11 agencies; the refusal rate was 5%. Four Alco-Sensors out of a total of 23 were returned to Intoximeters, Inc. to correct temperature sensitivity, and two units damaged by freezing temperatures were returned. Eight Alco-Sensors were recalibrates after initial calibration in March 1985.

Ten of the original printers were returned for electric repairs and circuit redesign. Other printers were returned for handle repair, clock adjustment and battery circuit checks. None of the printers would work when the "LOW BATTERY" signal was on.

The initial testing of the Alco-Sensor III by McDonough (1985) exposed them to temperatures from 40° C to 54° C, but the temperature range was not low enough. Two Alco-Sensors were inactivated by temperatures as low as -40° F and required repairs at the factory. The temperature sensitivity problem was discovered in the field, since laboratory testing based on the McDonough report did not include temperature testing. Although the instrument can easily be used in patrol cars, the Alco-Sensor and its printer cannot be left in the vehicle, where they could be exposed to extreme temperatures.

The printer used in the program was not the same printer tested by McDonough. The long testing sequence used in Idaho required expanded memory capacity and additional circuitry. Idaho was a proving ground for the new printer, and most problems were corrected. The agencies routinely recharged the printer weekly or monthly to combat the low battery problem.

The Alco-Sensor III has earned a reputation in Idaho as an accurate and reliable instrument, and its use as an evidential breath tester is being expanded to the rest of the State.

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DISTRIBUTION OF ETHANOL IN POST MORTEM SPECIMENS

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The distribution of ethanol in post mortem tissues and body fluids has been previously investigated (Backer *et al.* 1980; Budd 1982; Winek *et al.* 1982), but little information is available regarding variances in ethanol concentrations among different blood samples in the same individual. The purpose of this study was to identify and document these differences.

Ethanol was determined by gas chromatography in a variety of tissues and body fluids secured at autopsy in 74 cases. Specimens tested included right heart blood, left heart blood, femoral blood, pericardial fluid, cerebral spinal fluid, vitreous humor, urine, gastric content, and brain. Only those cases with no trauma to the chest organs or viscera were included.

Samples were prepared for gas chromatographic analysis by diluting 1 part body fluid with 10 parts 0.02%w/v aqueous n-propanol as internal standard. Tissues were treated in a similar manner by homogenization with the diluent. All samples were then centrifuged at 2,000 rpm for 5 minutes and 1 microliter of supernatant fluid was chromatographically analyzed.

A 1.8 m x 2 mm (internal diameter) Carbopack B coated with 5% Carbowax 20M column at 85° C with flame ionization detection was used. Helium served as the carrier gas at a flow rate of 30 ml per minute. Detector and injector temperatures were 200° C. These parameters provided retention times of 1.4 and 3.0 minutes for ethanol and n-propanol, respectively.

Eleven of the 74 cases examined had differences in ethanol concentrations among blood samples greater than 50% (Table 1). An additional 16 cases had variations among blood samples of 25%-50%. The greatest variability observed among blood samples was in excess of 400%. These differences usually occurred when the gastric alcohol concentration was 0.5% or greater.

When the lowest within-case blood ethanol concentration was 0.02%, there was a 37% incidence of variation greater than 25%. When the lowest within-case blood ethanol concentration was 0.05%, there was a 33% incidence of variation greater than 25%. Motor vehicle-related fatalities manifest similar within-case variabilities among blood specimens. These data are shown in Table 2.

Table 1. ETHANOL DISTRIBUTION IN 11 CASES WITH VARIATION AMONG BLOOD SAMPLES OF AT LEAST 50%

Case No.	Right Heart Blood	Left Heart Blood	Femoral Blood	Gastric	% Var. Blood
10	.039	.023	.060	.271	161
19	.084	.272	.206	1.49	224
22	.070	.156	.043	1.20	263
25	.033	.019	.054	.166	184
28	.029	.023	.045	.028	96
30	.034	.025	.039	.029	56
49	.147	.364	.092	5.09	296
58	.019	.023	.045	.091	137
60	.037	.034	.066	.264	82
63	.460	NA	.087	3.03	429
70	.131	.120	.180	NA	50

NA: Not available

Our results show that a significant number of cases had marked variations in alcohol concentration among blood samples in the same individual. Furthermore, these variabilities appear to increase with the alcohol concentration in gastric contents. These findings strongly suggest that post mortem blood is not an appropriate specimen for alcohol determination and that interpretation of data from post mortem blood samples may be open to question.

Table 2. VARIATION AMONG BLOOD SAMPLES ON INDIVIDUAL CASES

No. Cases	Blood EtoH Range	25%-49%	50%-99%	≥ 100%	≥ 25%
72	0.02-0.46	16 (22.2%)	4 (05.6%)	7 (09.7%)	27 (37.5%)
60	0.05-0.46	15 (25.0%)	1 (01.7%)	4 (06.7%)	20 (33.3%)
19 (MVA)	0.02-0.38	5 (26.3%)	1 (05.3%)	2 (10.5%)	8 (42.1%)
18 (MVA)	0.05-0.38	5 (27.8%)	1 (05.6%)	1 (05.6%)	7 (38.9%)

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EVALUATION OF THE ADSORPTION AND DESORPTION OF ETHANOL FROM BREATH SPECIMENS USING SILICA GEL

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Law enforcement agencies routinely utilize the results of ethanol analysis as a component of traffic violation investigations. As a result of recent concern about the rights of the defendant at a trial, the retention and preservation of the ethanol content of breath has now become an important legal issue. This research was undertaken to provide an independent comprehensive evaluation of the technical ability of silica gel breath collection tubes (Toxtrap, Federal Signal Corp.) to retain the ethanol content in breath. Laboratory, field and human studies were conducted to determine if an adequate scientific basis existed to recommend use of such procedures in judicial and other situations.

Employing silica gel breath collection tubes, *in vitro* delayed vapor ethanol analysis techniques were developed and subsequently evaluated. Vapor ethanol samples were collected onto silica gel using the BAC Verifier, Breathalyzer 900A, Intoxilyzer 5000 and Intoximeter 3000. Statistical analyses revealed good accuracy, precision and correlation between direct and delayed vapor ethanol determinations (range = 0.000-0.250 g/210 liters, N = 42, r > 0.99). The results are summarized in Tables 1 and 2.

Vapor ethanol specimens (0.150 g/210 liters) collected onto silica gel and stored at -16° C, room temperature, 32° C and 49° C were analyzed at various times during a 50-week period. The results of these analyses are shown in Tables 3 and 4. The results of all delayed vapor ethanol analyses were within ± 10%, and thus, the ethanol content of the silica gel was stable under the conditions tested in this study.

A field evaluation study of eight randomly selected Breathalyzer instruments was performed. With a single vapor ethanol solution (0.100 g/210 liters), excellent accuracy and precision was achieved. The

Table 1. LINEAR REGRESSION ANALYSIS: CORRELATION BETWEEN DIRECT VAPOR ETHANOL DETERMINATIONS AND DELAYED VAPOR ETHANOL DETERMINATIONS

Instrument	Slope	Y-Intercept	Correlation Coefficient	Coefficien of Determination
BAC Verifier	0.9995	-0.0001	0.9978	0.9956
Intoxilyzer 5000	1.0383	-0.0045	0.9959	0.9918
Intoximeter 3000	1.0057	+0.0011	0.9991	0.9982

Table 2. DELAYED VAPOR ETHANOL ANALYSES: AVERAGE STANDARD DEVIATION

Instrument	Detection Technique	Average Standard Deviation at Vapor Ethanol Concentrations 0.050, 0.100 and 0.150 g/210L (g/210L)	
		Direct Analysis	Delayed Analysis
BAC Verifier	Infrared	0.0013	0.0025
Intoxilyzer 5000	Infrared	0.0014	0.0062
Intoximeter 3000	Infrared	0.0009	0.0026
Breathalyzer 900A	Dichromate Oxidation	0.0014	0.0016

Table 3. RESULTS OF DELAYED VAPOR ETHANOL ANALYSES OF SILICA GEL SAMPLES STORED AT VARIOUS TEMPERATURES

	Delayed Vapor Ethanol Concentration (g/210L)			
	Storage Condition			
Storage Interval (weeks)	-16°C	room temperature	32°C	49°C
Target Value	0.150	0.150	0.150	0.150
1	0.152	0.155	0.153	0.156
2	0.156	0.154	0.150	0.153
3	0.152	0.151	0.152	0.146
4	0.152	0.155	0.152	0.150
6	—	0.148	0.149	—
7	—	0.144	0.139	—
9	—	0.153	0.148	—
12	0.154	0.154	0.143	0.144
15	—	0.145	0.144	—
21	—	0.148	0.139	—
31	—	0.141	0.139	—
42	—	0.147	0.139	—
50	—	0.152	0.135	—

Table 4. LINEAR REGRESSION ANALYSIS DATA FOR VAPOR ETHANOL SAMPLES PRESERVED ONTO SILICA GEL AND STORED AT VARIOUS TEMPERATURES

Storage Condition	Mean Vapor Ethanol Concentration ± S.D. (g/210L)	Correlation Coefficient	Slope
room temperature	0.150 ± 0.0046	-0.3606	-0.0001
-16°C	0.153 ± 0.0018	0.1781	0.0001
32°C	0.145 ± 0.0062	-0.8257	-0.0003[a]
49°C	0.150 ± 0.0049	-0.7820	-0.0009

[a] slope was determined by linear regression analysis and was found to be statistically significant from zero ($p<0.001$)

mean delayed vapor ethanol concentration was 0.100 g/210 liters (N = 80) with a standard deviation and systematic error of 0.0020 g/210 liters and 0.0%, respectively. The results are shown in Table 5.

An *in vivo* study employing volunteer subjects (N = 10), silica gel breath collection tubes and a Breathalyzer 900A was conducted. Data collected during the study and statistically analyzed revealed excellent correlation between blood, direct breath and delayed breath ethanol determinations (N = 30, range = 0.000-0.308 g/210 liters, $r > 0.99$). In addition, with the blood ethanol concentration as the reference, delayed breath ethanol analysis is slightly less accurate than direct breath ethanol analysis. The results are shown in Table 6.

We conclude that delayed vapor ethanol analysis techniques employing silica gel are adaptable to most quantitative breath ethanol analyzers, and thus, these techniques appear to satisfactorily predict the original vapor ethanol concentrations. These methods can be used regularly in the laboratory and field for law enforcement and research purposes. Although the

results obtained during this study were significant, it is essential to note that the collection and delayed analysis was performed by one experienced operator under relatively strict and ideal conditions, and consequently, a lesser degree of accuracy and precision would be expected if these techniques were applied in the field using multiple operators, instruments and solutions.

Table 5. DELAYED VAPOR ETHANOL ANALYSES: SUMMARY OF DATA OBTAINED FROM BREATHALYZER COMPARISON STUDY

Breathalyzer Model & Code Number	Chamber Volume (mL)	Mean Direct Vapor Ethanol Concentration (g/210)	Mean Delayed Vapor Ethanol Concentration (g/210L)	Standard Deviation (g/210L)
900A/1	56.5	0.100	0.099	0.0009
900A/2	57.0	0.100	0.100	0.0019
900A/3	56.5	0.100	0.103	0.0014
900A/4	56.0	0.101	0.101	0.0007
900/5	not measured	0.099	0.101	0.0014
900/6	56.5	0.102	0.099	0.0011
900/7	56.0	0.102	0.100	0.0008
900/8	57.0	0.101	0.098	0.0014

N = 8 per instrument, total number = 80

Table 6. RESULTS OF IN VIVO STUDY: LINEAR REGRESSION ANALYSES

Variable (X vs. Y)	Best Fitting Straight Line	Correlation Coefficient
blood vs. delayed breath ethanol	$y = 0.930x + 0.0062$	0.9964
blood vs. direct breath ethanol	$y = 0.940y + 0.0024$	0.9958
delayed breath vs. direct breath ethanol	$y = 1.008x - 0.0036$	0.9966

RETAINED BREATH SPECIMENS: THEIR LONG-TERM STABILITY AND VALUE IN ASSESSING THE OCCURRENCE AND CONCENTRATION OF OTHER VOLATILES IN THE BREATH

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Since 1979, Arizona has required breath samples from driving while intoxicated (DWI) arrestees to be collected and retained for independent evaluation. Two collection systems are used: the indium tube collection system (Intoximeters, Inc., St. Louis, MO) and silica gel collection tubes (Lucky Labs SM-10 or Toxtrap, Federal Signal Corp.). The silica gel tubes are used with modified Intoxilyzer model 4011AS and model 5000 instruments.

The indium tube system provides three equal samples of a single, last-phase breath specimen that is in a 12-cm long indium tube of constant internal diameter. Once the capsules are properly sealed by the operator, there is no communication of gases between the three capsules, and they may be separated with a knife. Two of the three samples are analyzed shortly after being collected, when the precision of the analysis and integrity of the crimp are determined. Long-term stability studies can be conducted by comparing the initial results with results from the final capsule after months, or years, of storage.

By selecting the appropriate analytical system, other volatiles can be detected. In one experiment, a Mark IV Gas Chromatograph Intoximeter functioning in the differential mode was coupled to a Hewlett-Packard 3393A integrating recorder. Operational parameters were selected so that acetaldehyde and acetone in vapor concentrations as low as 10 mg/liter (equivalent to blood levels of approximately 0.0002% and 0.0003% w/v, respectively) could be detected and resolved from any ethanol in the sample. Approximately 1,300 silica gel specimens and 700 indium collection tubes from DWI arrestees were subjected to gas chromatographic analysis. The sensitivity of contemporary Intoxilyzers (Model 4011AS and 5000) to these potential interferents was evaluated, as well as the ability of the silica gel tubes to trap substances other than ethanol.

The third capsules from the 245 triple indium tube specimens stored at room temperature (22°-25° C) for 1.5-3 years were tested and compared with the replicate results for the previously analyzed capsules. Table 1 shows the degree of reproducibility between the two capsules in the initial analysis, and

Table 1. REPRODUCIBILITY OF REPLICATE RESULTS FOR TWO OF THREE INDIUM TUBE SAMPLES

DIFFERENCE[a] [% BAC]	NUMBER	% OF TOTAL
0.000	55	22.4
0.001	50	20.4
0.002	65	25.6
0.003	30	12.2
0.004	18	7.3
0.005	18	7.3
0.006	5	2.0
0.007	1	0.4
0.008	1	0.4
0.009	1	0.4
0.012	1	0.4
TOTAL	245	99.7%

[a] Range of BAC Values = 0.042%-0.352%w/w

Table 2 illustrates the degree of retentivity of the initial alcohol reading.

Trace amounts of acetaldehyde were detected in nearly all of the specimens analyzed. The concentrations were all quite low, about 12 mg/liter in silica gel samples and 22 ml/liter in indium tube samples. The highest acetaldehyde values for each collection device were 22 and 32 ml/liter, respectively. Vapor concentrations of approximately 180 mg/liter are necessary to produce an apparent 0.01% breath alcohol concentration (BAC) on the 4011AS and model 5000 Intoxilyzers. Traces of acetone (16% and 12% mg/liter) were detected in two silica gel samples, one of which was subsequently determined to have come from the location of the Intoxilyzer. Acetone concentrations of approximately 60% mg/liter are required to produce an apparent 0.01% BAC on the 4011AS Intoxilyzer (the M5000 subtracts out any detected acetone). The chromatogram of Figure 1 illustrates the system's ability to detect amounts of acetaldehyde and acetone at levels well below those that could contribute to a

Table 2. DEGREE OF AGREEMENT BETWEEN THE STORED 3RD INDIUM CAPSULE AND THE PREVIOUS AVERAGE RESULT FOR TWO CAPSULES

PRECISION	NUMBER	% OF TOTAL[a]
Within 0.01% or less	193	78.8
Within 0.02%	28	11.4
Within 0.03%	16	6.5
Within 0.04%	2	0.8
Within 0.05%	1	0.4
	240	

[a] Three retained samples (a 0.13%, 0.27% and 0.34%) were found to have no detectable alcohol upon analysis. Two others fell from a 0.10%BAC to a 0.02% and a 0.17%BAC to a 0.01% value, respectively.

test result on a current Intoxilyzer. This chromatogram shows an acetaldehyde peak three times greater than the average value obtained in case work. The acetone peak is comparable to the one instance in 3,000 subject samples tested.

The shelf-life of properly sealed indium-encapsulated breath specimens has been demonstrated to be at least 2 years when they are stored at room temperature. Volatiles known to occur in breath are readily retained by both types of collection devices. A study of a large number of actual case samples supports the conclusion of other researchers that the volatiles are found in ambulatory drivers at low concentrations and

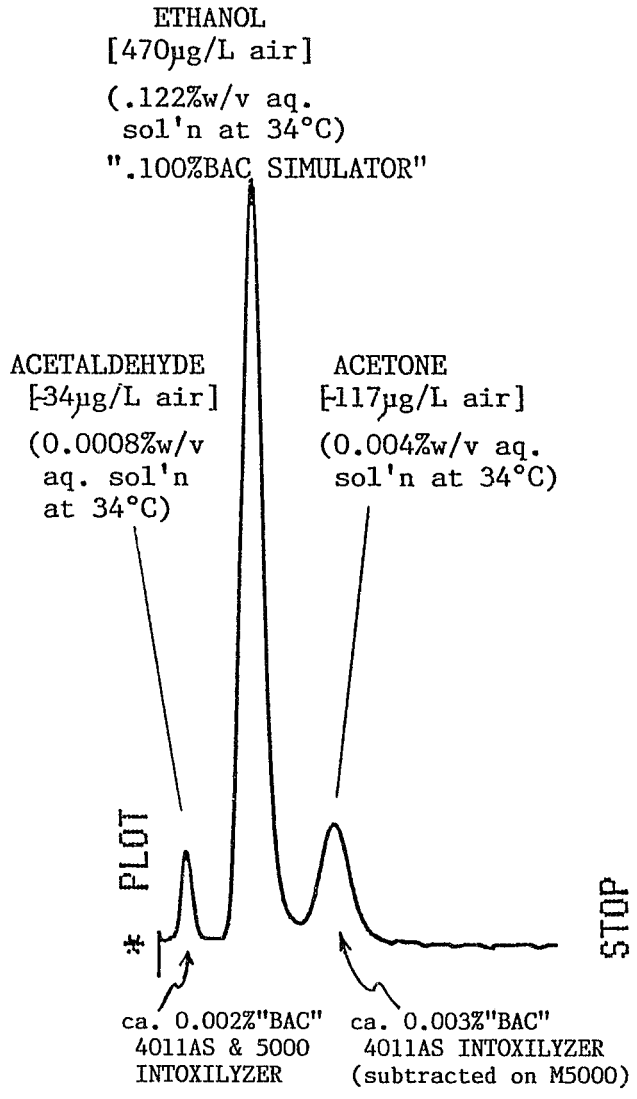

Figure 1. Gas chromatogram of system performance on breath samples.

that they are of no concern when nonspecific breath testing equipment (for example, the Intoxilyzer) is used.

PHENCYCLIDINE, ALCOHOL AND DRIVING UNDER THE INFLUENCE

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The abuse of phencyclidine (PCP) has surpassed other drug problems in several areas of the United States (Lerner 1980). Unlike other street drugs, its physiologic effects are nearly indistinguishable from schizophrenia. Phencyclidine has anesthetic, stimulant and hallucinogenic properties, although all three may not be exhibited in the same person at the same time. The effects of PCP in humans are highly dose dependent (Tennant 1983). Some of the overt symptoms are closely related to those seen in persons under the influence of alcohol.

Alcohol impairment of drivers has been studied at great length, but with multiple drug use the symptoms observed may not always be definitive. Forensic laboratories have seen an increase in the request for routine sample analysis for more than one drug in a single biologic fluid. Enzyme immunoassay (EIA) and radioimmunoassay (RIA) have been used routinely to screen for multiple drug use. Basic extraction and gas chromatography/mass spectroscopy (GC/MS) have been valuable for nanogram detection.

For approximately 2 months, our laboratory compared 71 specimens with the accompanying field reports. In all cases, the officer observed symptoms consistent with PCP ingestion and was looking for confirmation by toxicologic analysis. All samples were positive for PCP. The PCP levels ranged from 7 ng/ml to 132 ng/ml with an average level of 39 ng/ml (Table 1). Thirty (42%) of the subjects admitted having ingested PCP in one form or another (Table 2). Thirty-eight (53%) admitted to alcohol ingestion, with blood alcohol levels ranging from 0.00 g% to 0.21 g% (an average of 0.04 g%), and 12 (17%) admitted to use of other drugs (Tables 2 and 3). It has been reported that the pulse rate of people under the influence of PCP is higher than normal. We observed a range of 80-140 beats per minute with an average of 105 (Table 4).

Table 1. TOXICOLOGICAL LEVELS OF PCP

ng/ml	Freq.
10	4
10 – 19	9
20 – 29	14
30 – 39	16
40 – 49	11
50 – 59	3
60 – 69	4
70 – 79	3
80 – 89	2
90 – 99	1
100	1

Table 2. ADMISSION OF DRUG USE

Name	Freq.
Alcohol	38
Phencyclidine	30
Marijuana	10
Cocaine	2
Polydrug	23
Nothing	14
Not Asked	3

Table 3. BLOOD ALCOHOL CONCENTRATIONS

% BA (g%)	Freq.
0.00 – 0.02	14
0.03 – 0.06	4
0.07 – 0.10	6
0.11 – 0.14	
0.15 – 0.18	0
0.19 – 0.22	1

Table 4. PULSE RATES OF PCP USERS

Beats/Min.	Freq.
70 – 79	1
80 – 89	10
90 – 99	4
100 – 109	16
110 – 119	9
120 – 129	7
130 – 139	1
140 – 149	4

In conclusion, the data show that many people using PCP also use other drugs. Thus, samples should be analyzed for multiple drug use. Each sample should be screened for alcohol, since it appears to be the drug of choice with PCP. In addition, the data indicate that subjects show tolerance to the symptoms used as criteria for determining if a person is under the influence of PCP. This study suggests that forensic laboratories need to screen for multiple drug use.

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CORRELATION OF INTOXILYZER 4011A BREATH ALCOHOL RESULTS WITH BLOOD ALCOHOL RESULTS OBTAINED FROM INDIVIDUALS UNDER ARREST FOR DRIVING UNDER THE INFLUENCE OF ALCOHOL

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The reliability of breath alcohol testing to estimate blood alcohol levels has been well established. Numerous researchers have correlated breath alcohol levels to blood alcohol levels using a variety of different instruments. The Intoxilyzer has been used on many such occasions. From 1978 to 1980, several studies were performed in Orange County using various Intoxilyzer models to compare breath alcohol levels and blood alcohol levels in driving under the influence (DUI) arrestees. That data representing 314 subjects were presented at American Association of Forensic Scientists in February 1981. From 1983 through 1985, another study was conducted using the Intoxilyzer Model 4011A and blood and breath samples from DUI arrestees. The parameters and data from that study are presented here.

Duplicate breath samples were analyzed by a trained forensic technician after a law enforcement officer observed the subject for at least 15 minutes. The alcohol content was measured to the second decimal place and the third figure truncated, as required for forensic alcohol analysis in California. An acceptable result required the two samples to agree within 0.02%. Venous blood samples, collected within 20 minutes after the breath samples, were analyzed in duplicate with a Perkin-Elmer Model F45 or Model 2000 head space gas chromatograph using an internal standard of n-propanol. The blood alcohol concentrations (BACs) range from 0.00%-0.30% with a median value of 0.15% (Figure 1). Correlation of the truncated average breath with blood levels yielded a coefficient of 0.96 and the regression line: Breath = 0.871 BAC + 0.006 with a standard error of estimate (SEE) = 0.0123 (Figure 2). Inference of the BAC from the

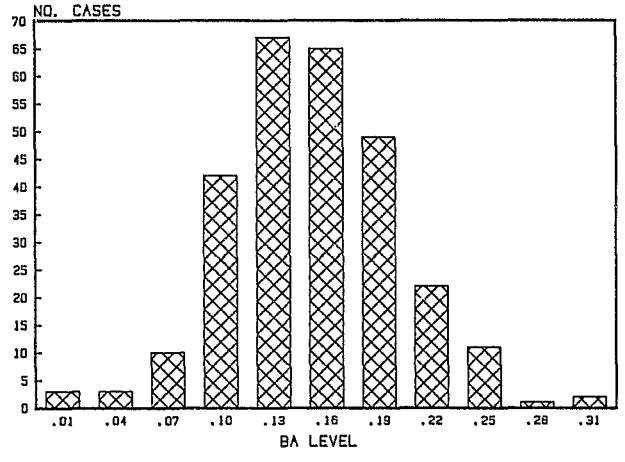

Figure 1. Blood alcohol level distribution, all cases.

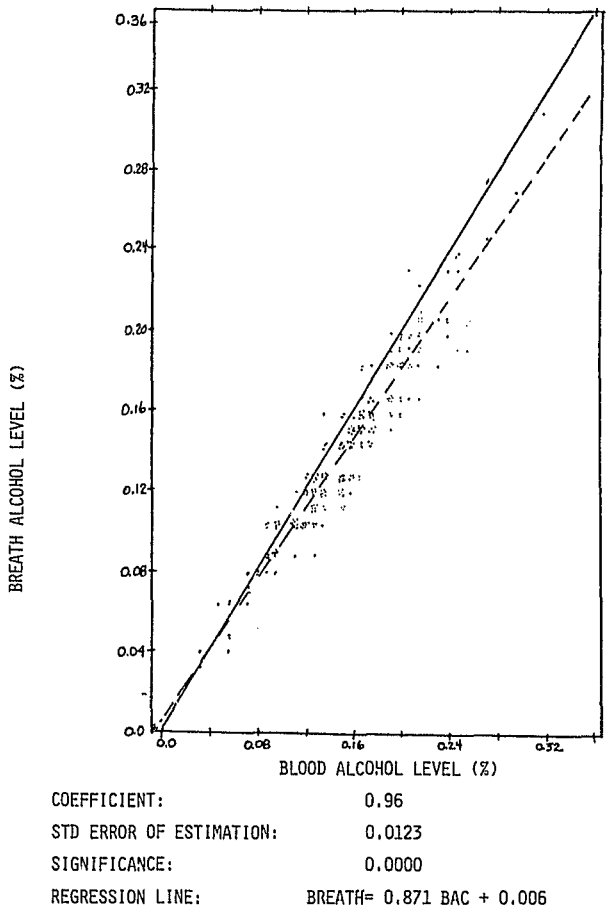

Figure 2. Scattergram of blood/breath ratios.

breath level using the truncated breath average follows the regression: BAC = 0.0161 Breath + 0.006, SEE = 0.0136, with normally distributed residuals. Because there were relatively few data points below 0.10% BAC, caution should be used in predicting levels below this value.

Figure 3 illustrates the distribution of blood minus breath differences. In 6.6% of the cases, the BAC was less than the breath alcohol concentrations and the mean (0.121%) was significantly lower than the remaining cases (0.156%). BACs below 0.10%, where the blood is lower than the breath, make up 3% of the samples but only 8% of the total sample.

The median calculated blood breath ratio of the sample was 2,309:1 with a mean of 2,318 and standard deviation of 224. In our sample, the distribution of calculated blood breath ratios was not normal, a situation that calls for great caution when making inferences about extreme ratios in the population (Figure 4). The two extreme calculations 1,575 and 3,150, were calculated from 0.03% and 0.06% BACs. Figure 5 demonstrates the misinformation that can result from trying to calculate a blood-breath ratio at low blood alcohol levels.

Since each value used has been truncated, an apparent variation of 0.01% may actually be as little as 0.001%. This becomes particularly significant at low BACs when compounded with sampling error and instrumental variation.

As shown in previous studies breath instruments calibrated using a 2100:1 ratio tend to underestimate the BAC. We found the mean difference to be 0.014% BAC.

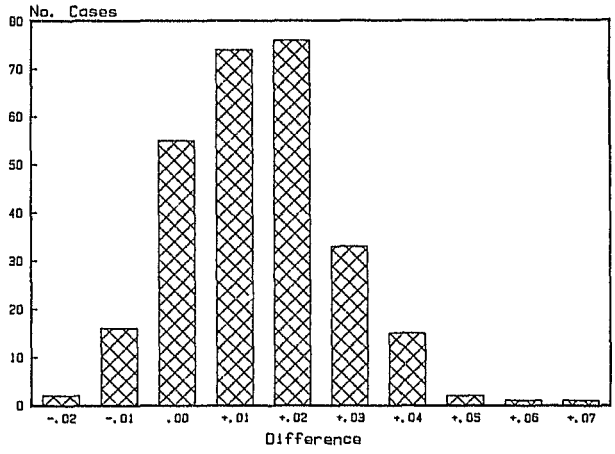

Figure 3. Blood minus breath values, all cases.

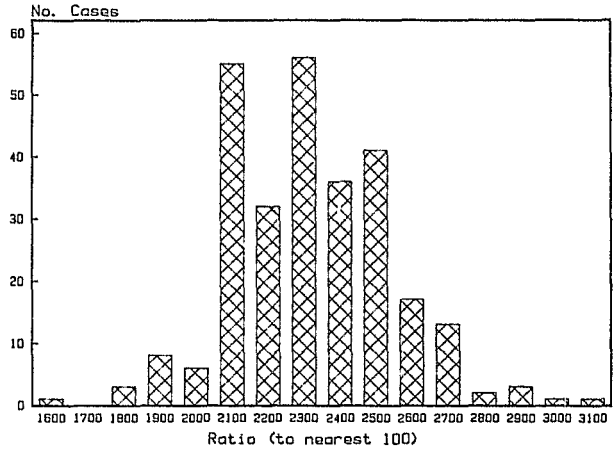

Figure 4. Calculated blood/breath ratios, all cases.

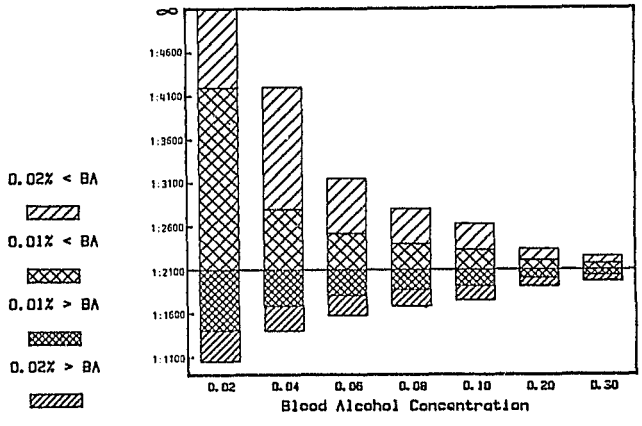

Figure 5. Calculated blood/breath ratios, effect of a 0.02% variation.

A COMPARATIVE FIELD STUDY OF BLOOD AND BREATH ANALYSIS WITH THE INTOXILYZER 5000

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Over 6,000 breath tests were performed in Sacramento County between January 1, 1985, and November 2, 1985. Of these, 600 subjects also decided to give a blood sample. Over 200 were retained for subsequent comparative analysis in which the breath analysis was performed no later than 15 minutes after the blood was drawn.

Breath alcohol analyses were performed on the Federal Signal Intoxilyzer 5000 using infrared spectrophotometry. Blood alcohol analyses were performed on a Perkin-Elmer model F-45 heated head space gas chromatograph in conjunction with a Perkin-Elmer model Sigma 15 data station.

In 91% of the examined cases, the breath alcohol analysis was less than or equal to the corresponding blood alcohol concentration, and in 9% of the examined cases the breath alcohol level was greater than the corresponding blood alcohol level. Overall, 6.1% of the samples exhibit a breath alcohol level 0.01% greater than the blood alcohol level (2.3% at 0.02% deviation, and 0.5% at 0.03% deviation). In examining these data, it must be remembered that only the higher of the two breath samples is utilized for the comparative analysis. In this manner, the maximum amount of deviation between the blood and breath results can be obtained.

The one apparent 0.03% discrepancy is actually a 0.02% variation disguised by the imposed guidelines of Title 17 of the California Administrative Code, which states that the third decimal place must be truncated. The blood alcohol results are 0.221% and 0.218% with a mean value of 0.2195%, which for all practical purposes is 0.22%. However, in keeping with the guidelines of Title 17, this is reported as 0.21%. This produced an apparent 0.03% discrepancy from the 0.24% breath alcohol result.

In an earlier preliminary abstract, it was erroneously reported that a breath alcohol analysis was found to be 0.04% greater than the blood alcohol analysis. A closer examination reveals that the blood vial had broken before its analysis, spilling all of the blood into a cardboard tray where it sat for approximately 20 minutes before it was transferred into a capped glass vial. The discrepancy arising between the breath level and blood level in this particular instance can certainly be explained by the loss of alcohol resulting from its prolonged exposure to the atmosphere and to the cardboard surface.

Breath alcohol analysis is a valid and practical method for determining the blood alcohol levels in most cases. It must be remembered that the purpose of alcohol analysis in driving under the influence (DUI) cases is to substantiate the observations of the arresting officer. Therefore, when the validity of the breath analysis is in question, the outward symptoms exhibited by the defendant must be considered. A calculation of the blood-to-breath ratio from these data is not considered to be significant because breath alcohol analyses are carried out only to two decimal places (which can therefore introduce a significant error at the lower alcohol levels), and it is not possible to determine if all individuals tested were in the post absorption stage.

NEW ENZYMATIC TEST STRIP FOR ALCOHOL IN SALIVA: ITS UTILITY IN ROADSIDE AND CONSUMER USE

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A new technique has been developed to determine blood alcohol concentrations (BAC) through a simple, quick, direct measurement of alcohol in saliva. Saliva alcohol concentrations correlate very closely to BAC. The ALCOSCAN Saliva Alcohol Test uses enzymatic oxidation of ethanol by alcohol oxidase and an indicator system that produces an intense and stable blue color. The chemicals are contained on a small and inexpensive test strip that is easily carried in the pocket and is highly specific for alcohol. The test strips are individually wrapped in foil to ensure stability and integrity. Alcohol concentration is determined by reference to a color chart or by reflectance photometry. This method has shown a high degree of correlation with head space gas chromatography for both serum and saliva samples ($r=0.987$, $m=1.02$ and $b=-0.01$) and with other enzymatic methods ($r=0.993$, $m=1.10$ and $b=-15.0$). ALCOSCAN saliva test results also have been highly correlated with breath analysis by the Intoxilyzer 5000. The ALCOSCAN Test has been evaluated as an aid to driving under the influence (DUI) enforcement in DUI stops and sobriety checkpoint situations and also for its utility as a consumer device. This report summarizes the results.

The ALCOSCAN Test Strip has been evaluated for more than 1 year at the roadside by the Menlo Park Police Department as a complement to field sobriety testing. It was very useful in situations when the actual BAC is 0.05%-0.15%. Before testing the ALCOSCAN Reagent Strips, the Menlo Park Police Department average BAC at time of arrest was 0.19%-0.24%. After the strips were in use, the average fell to 0.17% BAC. Arrests made using ALCOSCAN test strips were twice as numerous in the 0.10%-0.15% BAC range compared with the period when it was not used. In addition, false arrests dropped to zero versus 2%-4% when it was not used (Figure 1).

ALCOSCAN test strips were evaluated by the Burlingame Police Department as an integral part of a Sobriety Checkpoint Procedure. Of the 336 motorists screened at the checkpoint, 14 were given field sobriety tests (FSTs). Five of the 14 refused the ALCOSCAN test but passed the FSTs and were released. Of the other nine who agreed to take the ALCOSCAN test, six showed BACs between 0.03% and 0.08%. Four were released to other drivers, and two with BACs of less than 0.05% were allowed to proceed. ALCOSCAN Test results were at or above 0.10% BAC for the remaining three and they were arrested. The evidentiary results for these three were: 0.10% (breath), 0.12% (breath) and 0.21% (blood).

According to the Commander, the two individuals with borderline BACs probably would not have been arrested had it not been for the positive ALCOSCAN test results because little or no driving performance was observed and they did reasonably well on the FSTs.

As a test for consumer use, 12 individuals not familiar with the test procedure were given enough alcohol of their choice to produce approximately a 0.10% BAC. The individuals were then given test kits and observed as they read the instructions and performed the test on themselves without verbal assistance. They were then given an Intoxilyzer 5000 breath analysis and evaluated for correct performance of the test and accuracy of color interpretation.

Nearly all the participants misperformed the test, as they had difficulty comprehending the instructions. However, even when intoxicated, their ability to distinguish color levels and to estimate concentration using the visual comparator was quite good—generally within 0.02% of the actual value as measured by the reflectance photometer.

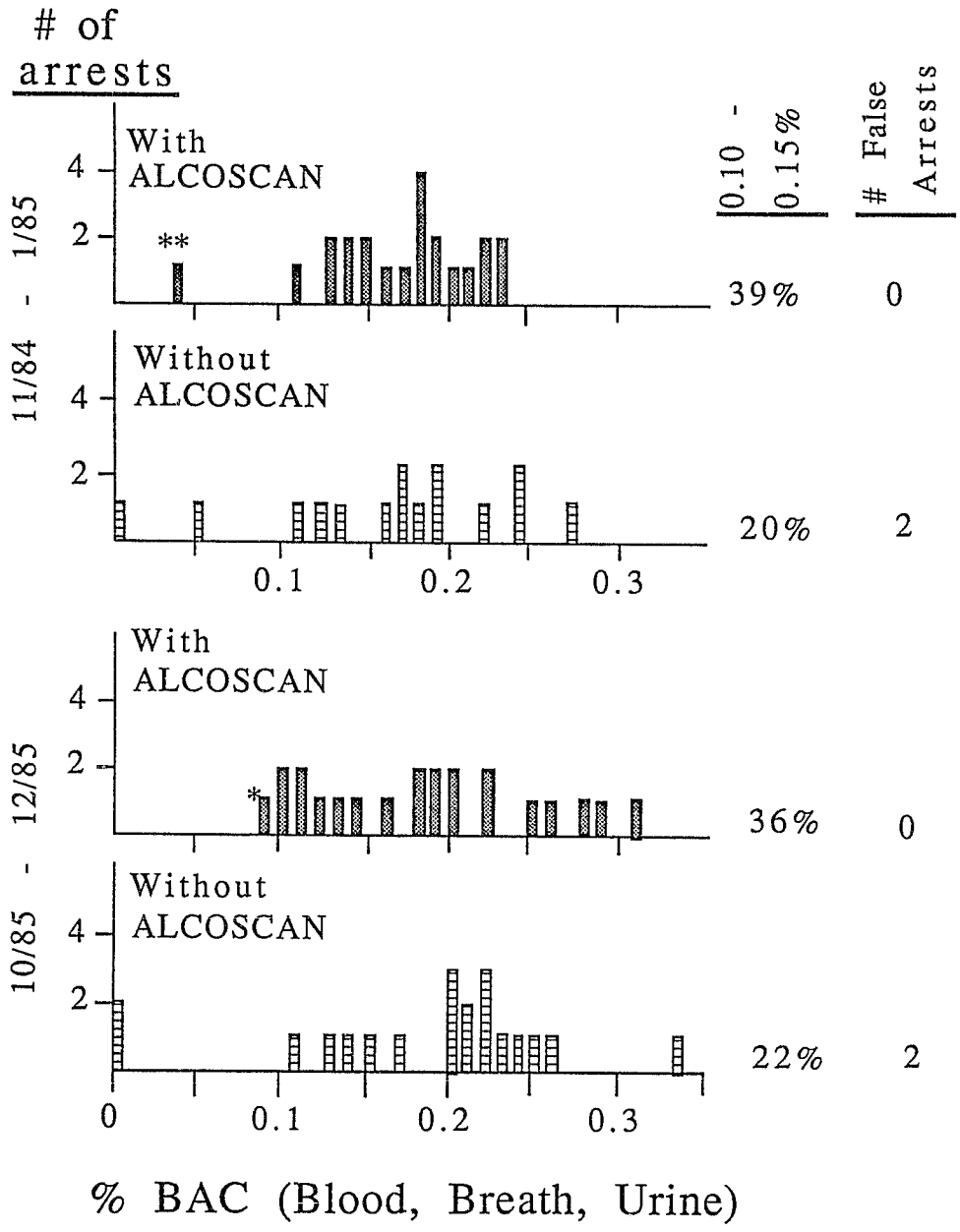

Figure 1. Menlo Park Test Data.

ALCOSCAN Test Strips were found to be a potentially valuable aid in establishing the magnitude of blood ethanol concentration at the roadside and have proven especially effective in borderline cases. However, the ALCOSCAN Test Kit in its current configuration is still too complex for unfamiliar and intoxicated individuals to use correctly for self-testing, although color interpretation does not appear to be affected.

COMPUTERIZED BREATH ALCOHOL TESTING SYSTEM IN TENNESSEE

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The State of Tennessee has recently begun a new breath alcohol testing program using the Intoximeter 3000. This instrument uses infrared absorption for the quantitative determination of ethyl alcohol. The unique feature of this statewide program is the connection of each Intoximeter 3000 to a central computer, located in the Nashville State Crime Laboratory. The hardware includes an IBM-AT personal computer with 640 kilobytes random access memory, one floppy drive, a 40-megabyte hard disk, and a 25-megabyte tape backup. The software (CONTROLLER, copyright Intoximeter, Inc.) in the central computer uses Revelation as the data base manager.

When a breath alcohol test is run on the Intoximeter 3000, the results are stored in the instrument's memory, which holds up to 30 sets of test results. The central computer polls each remote Intoximeter 3000 according to a preset schedule, transferring all test data stored in each Intoximeter 3000 automatically into a data base maintained in the computer. In addition to monitoring test data, instrument performance data stored in the Intoximeter 3000 with each test as a standard procedure are also transferred into the data base. This lets the Tennessee Crime Laboratory monitor the performance of each remote instrument and diagnose the need for preventative maintenance. Recalibrations and troubleshooting any Intoximeter 3000 can be performed from the central computer.

The system can generate a large number of reports in various formats. It is user-friendly, and any of the standard reports can be easily generated by a one-touch command, according to a set of choices displayed on the computer screen. One of the most important diagnostic features is the Standard Deviation Report, which will isolate any Intoximeter 3000 with inconsistent test readings or faulty components. Additionally, the Tennessee Bureau of Investigation (TBI) Crime Laboratory personnel periodically conduct tests on each Intoximeter 3000, using alcohol standards to further monitor instrument performance. This computerized alcohol testing system provides reports for program management and technical personnel, efficient documentation of the performance of each Intoximeter, as well as the ability to retrieve any test for a particular subject for court purposes.

Funding for this program is attained through a $10 court cost fee that is assessed for each case filed. Local governing bodies responsible for funding sheriff's offices and police departments may purchase an Intoximeter 3000 (there are presently 80 instruments in service) by retaining the $10.00 service fee until the purchase price is recovered. The local governing agency purchases the Intoximeter 3000 and funds the telephone line for the modem; in return, the TBI Crime Laboratory certifies the instrument, provides all maintenance, parts and dispensable supplies and furnishes expert testimony in support of the use of the instruments.

The TBI also plans to incorporate all blood alcohol and/or drug testing data related to driving under the influence of an intoxicant into the computer. This will allow all chemical test data relative to the drinking driver problem in Tennessee to be analyzed. The computer system present these data in either spreadsheet or graphic form, for display or in printed forms.

COMPUTERIZED BREATH TESTING: WASHINGTON STATE'S BREATH TEST PROGRAM WITH THE BAC VERIFIER DATAMASTER

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Washington State Patrol
Crime Laboratory

The state of Washington has recently implemented a computerized Breath Testing Program. The program uses a network of approximately 180 BAC Verifier Datamaster Infrared Breath Test instruments (Verax systems, Inc., Fairport, NY). Each instrument is linked to a host computer located in the State Patrol Crime Laboratory in Seattle.

At the time of testing, the operator enters data in response to prompts displayed on the breath test instrument. The following information must entered into the system:

1. Observation time (time mouth is checked)
2. Operator's name
3. Arresting agency
4. Subject's name
5. Subject's date of birth
6. Subject's sex
7. Subject's ethnic group
8. Arrest location (including county, road type, and court jurisdiction)
9. Nature of crime
10. Accident involved and type
11. Drinking location (location prior to arrest)
12. Occupation
13. Simulator solution batch number (external standard)
14. Simulator temperature

The data for each question are entered through a keyboard before the breath samples are provided. Two breath samples are collected, and a simulator standard (0.100% blood alcohol concentration [BAC] equivalent) is sampled between the two. Breath test results are reported to two digits and the simulator results reported to three. A printout is provided at the end of the test procedure.

The results of all data entry and breath test results are stored in internal random access memory. The instrument is a microprocessor controlled with approximately 8 kilobytes of random access memory to allow for nearly 100 breath test records. The instrument contains a 300-baud modem to allow for telecommunications.

The host computer consists of an IBM PC, an IBM color printer, a color PGS monitor, a 20-megabyte fixed disk, and a Hayes auto dial modem. The software in the host computer consists of a communications program (Crosstalk and Transporter) and a data base management system known as Revelation. The host computer calls up the breath test instruments according to a preset schedule, transfers the data to the fixed disk and then clears memory at the instrument. The data base management system provides statistical analysis and various report formats for the data.

Data analysis and reports provide an excellent tools for law enforcement, courts, educators, traffic safety groups, liquor control agencies and others. A more complete profile of the driving while intoxicated enforcement program is now available.

RECENT DEVELOPMENTS IN ARIZONA LAW AND ITS IMPACT ON DUI TRIALS

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Tucson, Arizona

Intoxilyzers have been used in Tucson since 1981 and, until 1984, the accuracy of each device was monitored through a quality assurance program. This program was designed by the Tucson Crime Laboratory and performed on each device every other week. Between 1981 and 1984, all quality assurance procedures throughout the State of Arizona were subject to Arizona Department of Health Services (ADHS) approval. However, each jurisdiction performed its testing differently. In Tucson, an expert's testimony that a particular Intoxilyzer was operating accurately met the court requirements for the admissibility of a breath test result.

This changed when the Arizona Supreme Court found breath test results inadmissible (*State v. Fuenning*). Fuenning was tested in a jurisdiction that had an Intoxilyzer, but no maintenance records could be produced to prove quality control standards had been met. The Court felt the defendant had been denied an accurate test. Additionally, the Court ruled any breath test result inadmissible if different jurisdictions continued to perform different levels of quality assurance. An emergency session of the legislature convened to modify the ADHS procedures to conform to the Supreme Court ruling.

The *Fuenning* ruling was made at the beginning of 1984, but it was not until May 1984 that ADHS began a uniform statewide quality assurance program. Quality assurance became a state-administered function, with every jurisdiction throughout the state performing minimal standards of quality control to comply with the Court's ruling. Figure 1 shows the pre-*Fuenning* directions used by Tucson Police for giving a breath test; Figure 2 shows the checklist used by every jurisdiction in Arizona for an Intoxilyzer 4011 AS Modified Breath test; Figure 3 is the checklist used by our crime laboratory in Tucson pre-*Fuenning*; and Figures 4 and 5 are the standard ADHS issue. (Note that the beam attenuator test is no longer performed.) A strict interpretation of the *State v. Fuenning* decision made inadmissible any breath test evidence provided by an agency that failed to meet the minimal standards for quality assurance. This could deny exculpatory evidence to someone arrested for driving under the influence (DUI) with a blood alcohol concentration (BAC) below the legal limit for the state. In *State v. Seidel*, the Court solved this problem. An individual involved in an accident had a BAC of 0.07% on a breath test administered under the old system. This evidence, although on the side of the defense, could have been inadmissible due to the ruling in *State v. Fuenning*. In this instance, the State Supreme Court allowed the evidence, citing the requirements of *Frye v. United States* 293 F. 101 (D.C. Cir. 1923).

Breath test results are now admissible if minimal standards of quality assurance are maintained or if expert testimony is obtained attesting to the accuracy of that a particular test.

During the period that test results were inadmissible, the prosecution had to show impairment by other means. The officer's observations during the arrest provided most of this evidence. A substantial drop in conviction rates, which returned to previous rates after the Supreme Court's decision, demonstrates how important breath test results are to a jury's consideration.

TUCSON POLICE DEPT. INTOXILYZER CHECK LIST

Instrument Serial Number:_____ Report Number:_____

Name of Subject:_____ Citation Number:_____

Date:_____ Time:_____ Blood Alcohol:_____

Operator:_____ P.R. Number:_____

RIGHT TO THE BREATH SAMPLE

You have the right to have the breath sample tested by an expert of your own choosing at your own expense. If you choose to have the breath sample preserved, it will be held at the Tucson Police Department, 270 S. Stone, Evidence Section for thirty (30) days for you or your authorized representative to pick up. If you choose to have the breath sample preserved and you are subsequently convicted, you will have to pay a fee of approximately $_____ for the care and custody of the sample whether or not you pick up the breath sample or have it analyzed.

DO YOU WANT THE BREATH SAMPLE PRESERVED?

YES-I want the breath sample preserved. NO--I do not want the breath sample preserved.

_____ _____

If you want the breath sample preserved, but refuse to sign, it will be assumed that you DO NOT WANT the breath sample.

NOTICE OF DISPOSAL OF THE BREATH SAMPLE

If you have the breath sample preserved, you have thirty (30) days in which to pick up the breath sample. After thirty (30) days the breath sample will be destroyed.

THIS IS THE ONLY NOTICE YOU WILL RECEIVE. IF YOU DO NOT PICK UP THE BREATH SAMPLE WITHIN THIRTY (30) DAYS, YOU ARE DEEMED TO HAVE WAIVED ANY RIGHT TO TEST THE SAMPLE.

RIGHT TO AN INDEPENDENT BLOOD TEST

YOU HAVE THE RIGHT TO AN INDEPENDENT BLOOD TEST AT YOUR OWN EXPENSE.

YES--I want a blood test at my own expense. NO-- I do not want a blood test.

_____ _____

If you want a blood test, but refuse to sign, it will be assumed that you DO NOT WANT THE TEST.

( ) If you are released by the officer, you must obtain a blood test on your own.
( ) If you are not released by the officer, you will be taken to Kino Hospital for a blood test at your own expense.

I hereby certify that I have received the above notifications.

I hereby certify that I have read the above rights to the suspect and witnessed his answers and signatures.

_____ _____

WAIT AT LEAST FIFTEEN (15) MINUTES AFTER LAST DRINK OR REGURGITATION BEFORE CONDUCTING ANALYSIS

( ) 1. *Power switch is in ON position, READY light is illuminated.*
( ) 2. *Insert Test Record Card.*
( ) 3. *Connect BREATH TUBE to the PUMP TUBE.*
( ) 4. *Turn MODE SELECTOR switch to ZERO SET. Adjust ZERO SET knob so that display reads .003, .002,..001, or .000.*
( ) 5. *Turn MODE SELECTOR switch to AIR BLANK.*
( ) 6. *After AIR BLANK CYCLE is complete, turn MODE SELECTOR switch to ZERO SET. Readjust ZERO SET to obtain proper reading. (.003, .002, .001, or .000)*
( ) 7. *Turn MODE SELECTOR switch to BREATH MODE. Disconnect BREATH TUBE from PUMP TUBE.*
( ) 8. *TAKE BREATH SAMPLE. Green breath light must be on a minimum of four (4) seconds and digital display must level off.*

IF YOU INTEND TO PRESERVE THE SAMPLE, CONTINUE THE SEQUENCE. IF NOT, PREFORM STEPS 10, 12, AND 13 ONLY.

( ) 9. *Remove caps and attach SM-10 sample tube to breath sample outlet.*
( ) 10. *Connect BREATH TUBE to PUMP TUBE. Turn MODE SELECTOR switch to AIR BLANK, until pump stops.*
( ) 11. *Remove SM-10 sample tube and RESEAL with caps immediately.*
( ) 12. *Remove Test Record Card.*
( ) 13. *Return BREATH TUBE to inside of instrument.*

TPD-1080(11/80)

Figure 1. Pre-*Fuenning* directions for giving a breath test.

ARIZONA DEPARTMENT OF HEALTH SERVICES

STANDARD OPERATIONAL CHECKLIST
INTOXILYZER MODELS 4011A MODIFIED & 4011AS MODIFIED*

AGENCY TUCSON POLICE DEPARTMENT

NAME OF SUBJECT _____ DATE _____

INSTRUMENT SERIAL NO. _____ LOCATION OF TEST _____

OPERATOR _____ TIME OF TEST _____

TEST RESULTS 0. _____ % w/v BAC SAMPLE COLLECTED - YES XXX NO _____

Immediately preceding the administration of the test the subject was observed for 20 minutes from _____ to _____ by _____

( ) 1. Power switch is in "ON" position and the green "READY" light is illuminated.

( ) 2. Insert a test record card.

( ) 3. Connect breath tube to the pump tube.

( ) 4. Turn Mode Selector Switch to "Zero Set." Adjust Zero Set Control so that a .003, .002, .001 or .000 is displayed.

( ) 5. Turn Mode Selector Switch to "Air Blank."

( ) 6. After cycle is completed, turn Mode Selector to "Zero Set." Recheck "Zero Set" to verify proper setting.

( ) 7. Turn Mode Selector Switch to "Breath Test." Disconnect the breath tube from the pump tube. Insert a mouthpiece into the breath tube. Have subject blow into the instrument as long as possible until a printout is obtained.

( ) 8. A. If a sample is to be collected remove the plastic caps from the breath collection tube and insert the end ofthe tube into the exhaust tube of the instrument.

OR

B. If a sample is not to be collected, continue to step 9.

( ) 9. Connect Breath Tube to the Pump Tube. Turn Mode Selector Switch to "Air Blank."

( ) 10. When pump stops, if sample was collected, remove breath collection tube and firmly cap both ends.

( ) 11. Remove test record card.

( ) 12. Push breath tube back into instrument.

*WITH OR WITHOUT BEAM ATTENUATOR

DHS/DCS/Bureau of Laboratory Services/Form C109 (5-84)

Figure 2. Checklist used with Intoxilyzer.

INTOXILYZER QUALITY ASSURANCE RECORD

Date:_____ Time:_____

Intoxilyzer Serial Number:_____

Test Location:_____

CALIBRATION VERIFICATION CHECK

Alcohol-free Subject Test Result:_____

Wet Bath Simulator	Beam Attenuator
Temperature:_____	Serial Number:_____
Test Solution Used:_____	Certified Reading:_____
Test Results:_____,_____	Test Results:_____

MAINTENANCE CHECK

OPERATIONAL

	YES	NO	REMARKS
Power Switch			
Power Indicator			
Display			
Breath Hose			
Pump Hose			
Ready Indicator			
Zero Adjust			
Mode Selector Switch			
Breath Strength Indicator			
Cycle Complete Indicator			
Printer			
Error Indicator			
Interference Indicator			

Checked By:_____

COMMENTS:_____

_____

_____

_____

Figure 3. Pre-*Fuenning* checklist used by Tucson Crime Laboratory.

THIS REPORT PREPARED PURSUANT TO DUTY IMPOSED BY A.C.R.R. R9-14-415.A.

ARIZONA DEPARTMENT OF HEALTH SERVICES

STANDARD QUALITY ASSURANCE PROCEDURES
INTOXILYZER MODELS 4011A MODIFIED & 4011AS MODIFIED

FUNCTION AND ACCURACY TEST PROCEDURE*

INTOXILYZER SERIAL #_____LOCATION_____

DATE_____19____TIME_____

FUNCTION AND ACCURACY TEST PROCEDURE

_____ Instrument ON and green READY light illuminates.

_____ ZERO ADJUST function operational.

_____ AIR BLANK cycle time to completion = _____seconds.

_____ Test on alcohol-free subject gives_____result and instrument prints result in_____seconds minimum time.

_____ ERROR recognition logic system functioning.

_____ INTERFERENCE (Acetone) detection system functioning (4011AS Modified only).

_____ Proper sample recognition system functioning.

_____ Completeness of sample purge with collection tube.

CALIBRATION TESTING WITH A _____% BAC Standard

RESULTS:_____

Instrument operating properly and accurately - Yes___No___

Checked by_____

_____% alcohol standard collected for subsequent analysis.

COMMENTS:_____

_____

_____

_____

_____

_____

* FOR DEVICES WITH OR WITHOUT SAMPLE PRESERVATION MODIFICATION OR BEAM ATTENUATOR

DHS/DCS/Bureau of Laboratory Services/Form C111 (5-84)

Figure 4. ADHS checklist.

THIS REPORT PREPARED PURSUANT TO DUTY IMPOSED BY A.C.R.R. R9-14-415.A.

ARIZONA DEPARTMENT OF HEALTH SERVICES

STANDARD QUALITY ASSURANCE PROCEDURES
INTOXILYZER MODELS 4011A MODIFIED & 4011AS MODIFIED

STANDARD CALIBRATION CHECK PROCEDURE*

( ) 1. Pour a standard alcohol solution of known value into a clean dry simulator jar and assemble the simulator. Insure that a tight seal has been made. Standard value:_____%.

( ) 2. Plug in the simulator and allow the temperature to reach 34° ± .2° C.

( ) 3. The Intoxilyzer is turned on and the green "ready" light is illuminated.

( ) 4. Insert the test record card.

( ) 5. Turn the Mode Selector switch to "Zero Set." Adjust the Zero Set Control until a .003, .002, .001 or .000 is displayed.

( ) 6. Connect the pump tube to the breath tube and turn the Mode Selector switch to "Air Blank."

( ) 7. After the cycle is complete, turn the Mode Selector to "Zero Set." Recheck "Zero Set" to verify proper setting.

( ) 8. Connect the pump tube to the simulator inlet. Connect the breath tube to the simulator outlet. (Double check the Intoxilyzer-Simulator connections for correctness).

( ) 9. Turn the Mode Selector switch to "Calibrator." At the end of the cycle record the displayed three digit result. Test result:_____%.

( ) 10. Disconnect the simulator from the Intoxilyzer. Connect the pump tubes to the breath tube. Turn Mode Selector switch to "Air Blank."

( ) 11. At the completion of the "Air Blank" cycle, return the Mode Selector switch to "Zero Set."

( ) 12. Remove the test record card and attach the test record card to the completed checklist.

DATE	TIME	NAME/POSITION	INTOX. SER.#	LOCATION

* FOR DEVICES WITH OR WITHOUT SAMPLE PRESERVATION MODIFICATION OR BEAM ATTENUATOR

DHS/DCS/Bureau of Laboratory Services/Form C111 (5-84)

Figure 5. ADHS checklist.

CERTIFICATION OF BREATH TESTING OPERATORS AND INSTRUMENTATION FOR DWI CASES IN THE STATE OF RHODE ISLAND

D. C. Hilliard and D. R. DeFanti

Rhode Island State Crime Laboratory
Kingston, Rhode Island

An alcohol training program for breath analysis has been conducted jointly by the Rhode Island State Crime Laboratory and the University of Rhode Island's College of Pharmacy, Department of Pharmacology and Toxicology, since 1959. The program consists of a 64-hour training session and provides certification of operator's primarily on the BAC Verifier (Verax) and the Breathalyzer 900 (Smith & Wesson) for backup purposes.

Training is divided into three segments. The first involves familiarization with the breath testing instruments, the second includes classroom lectures, covering a variety of alcohol related topics, and the third consists of three controlled drinking sessions over a 3-day period, during which each individual has the opportunity to be a drinker, a buddy and an operator. Each drinker is assigned a buddy who is completely responsible for the drinker. Operators are encouraged to run as many breath tests as possible on all drinkers.

The drinking protocol provides three 30-minute drinking sessions during the morning. Each drinking session is followed by a 30-minute testing session for psychomotor and breath testing. Baseline testing is performed before drinking. Psychomotor and breath testing continue hourly until the drinker attains a zero breath test. Blood samples are drawn from drinkers on a voluntary basis during breath testing after the second or third drinking session. Blood alcohol concentrations (BACs) samples are determined by direct injection gas chromatography or by enzymatic analysis.

Certification of operators is based on a written exam and satisfactory completion of a practical exam on the instrument(s) for which they will be certified. Through this program, 995 individuals have been certified as operators of one or more breath testing instruments. During training, each individual can perform up to 150 instrument tests with 50-100 tests performed on human subjects.

Data generated from the controlled drinking sessions provide correlations for evaluating the effect of alcohol on psychomotor skill levels and for evaluating and certifying breath testing instruments through instrument-to-instrument and blood-to-breath correlations. Since 1972, some 638 blood-to- breath correlations have been generated. The average values for these data are presented under three category headings: averages from colorimetric analyzers, averages from infrared analyzers and total averages for all data (Table 1). The total averages are also displayed in graph form (Figure 1). The data demonstrate that the average breath analyzer reading is generally at or below the actual blood alcohol level. Calculations have shown that 94% of the breath analyzer readings were equal to or below the actual BAC ± 0.01%. Also for BAC values from 0% to 0.09%, which make up 89% of the correlations, the correlation line for the data is not significantly different from a theoretical correlation line.

The Health Department has certified the following quantitative breath instruments based on correlations generated by the program: Breathalyzer series 900, 1000, and 2000 (Smith and Wesson); Intoxilyzer series 4011 and 5000 (Federal Signal Corp.); and the BAC Verifier (Verax).

ACKNOWLEDGEMENTS

The authors wish to acknowledge the Rhode Island Department of Health and members of the Division of Drug Control, and Charles Hachadorian, Jr., Administrator, for their continued assistance and support of this program.

Table 1. CORRELATIONS OF QUANTITATIVE BREATH INSTRUMENTS[a]

BAC[b]	Colorimetric[c]	Infrared[d]	Total
.00	.010±.009 (15)	.006±.006 (28)	.008±.007 (43)
.01	.019±.012 (19)	.010±.005 (32)	.013±.009 (51)
.02	.021±.007 (43)	.020±.006 (30)	.020±.006 (73)
.03	.030±.008 (40)	.030±.012 (40)	.030±.010 (80)
.04	.039±.008 (39)	.040±.007 (43)	.040±.008 (82)
.05	.047±.008 (39)	.051±.012 (38)	.049±.011 (77)
.06	.058±.013 (41)	.063±.008 (26)	.060±.012 (67)
.07	.061±.011 (28)	.071±.011 (27)	.066±.012 (55)
.08	.069±.012 (15)	.075±.015 (29)	.073±.014 (44)
.09	.082±.012 (17)	.079±.022 (12)	.081±.016 (29)
.10	.085±.015 (19)	.080±.000 (2)	.084±.014 (21)
.11	.097±.015 (3)	.107±.012 (6)	.103±.013 (9)
.12	.110±.000 (1)	.120±.014 (2)	.117±.012 (3)
.13	.140±.000 (1)	.123±.006 (3)	.128±.010 (4)

[a] Breath Instrument data is reported as: $\overline{X}$±S.D.(n), where $\overline{X}$ is the mean Breath BAC, S.D. is the standard deviation of the mean and n is the number of correlations at that level.

[b] BAC levels are based on analysis of blood samples by gas chromatographic or enzymatic analysis.

[c] Breath values obtained from Breathalyzer 900 series (Smith & Wesson).

[d] Breath values obtained from the following instruments: Breathalyzer 2000 (Smith & Wesson); Intoxilyzer series 4011 and 5000 (Federal Signal Corp.); BAC Verifier (Verax).

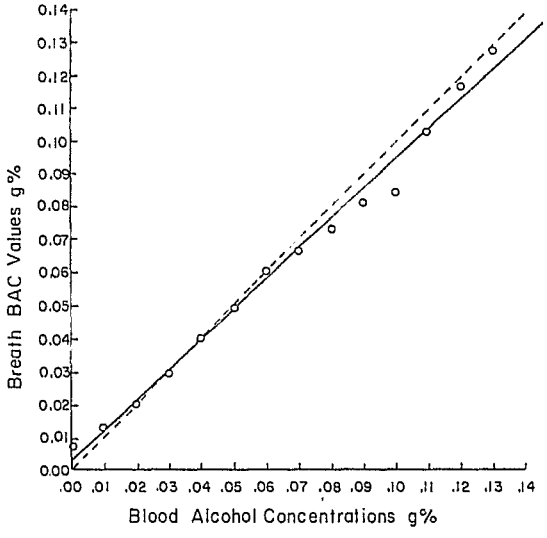

Figure 1. Average values for blood/breath correlations.

CERTIFICATION OF THE FIRST MOBILE UNITS, BREATH ALCOHOL TESTING (BAT) VANS IN KANSAS AND THE INTOXILYZER PROGRAM OF THE WICHITA POLICE DEPARTMENT

M. C. Ayers

Wichita Police Department Laboratory
Wichita, Kansas

In November 1982, the Wichita Police Department received a grant to buy four Intoxilyzers, Model 4011 AS. Two were used in a stationary mode, one at the booking desk and the other in the laboratory for the quarterly proficiency testing and teaching of all certified operators, and the remaining two were placed in vans.

Currently, we have 60 operators with 8 assigned to the mobile units. The eight who are assigned to the BAT vans perform job functions related only to driving under the influence (DUI) cases. They perform the breath tests, transport the drunks to the booking desk, fill out all paperwork and turn in any physical evidence. Most of the other operators are assigned to the traffic section as radar officers, motor officers or traffic safety officers who investigate accidents.

Two other agencies also use the Intoxilyzers. The Sedgwick County Sheriff's Department has 16 operators and the Derby Police Department, from a small nearby town, has 6 operators. Both agencies use our booking desk instrument. Our mobile units were the first in the state, and they had to be able to function acceptably over a wide range of conditions before the Kansas Department of Health and Environment would provide certification.

The following situations were foreseen as potential trouble spots and were investigated: adequate power supply, van interior temperature range, assurance of proper Intoxilyzer functions, interfering substances and radio frequency interference (RFI).

The Intoxilyzer requires 110 volts at 60 Hz and consumes approximately 300 watts at full power. Adequate power is supplied by an ONAN Series BFA 4000 watt generator, driven by a 2-cylinder, 4-stroke, air-cooled gasoline engine. The instrument's electric outlet is supplied with a Wolsk "soundoff" power monitor that emits a loud shriek when the power drops below 104 volts.

The vans are equipped with good heaters and adequate air conditioning, and extra insulation was added to the ceiling and sun reflective film was placed on the windows. A stable, acceptable temperature can be maintained by seating the defendant in the van, closing the doors and waiting a minute or two for temperature stabilization. CMI, Inc., claims that their instrument produces satisfactory results over a temperature range of 60°-100° F. The effects of temperature are minimized by noting the interior van temperature and airblanking and zero setting the instrument immediately before it is used by the subject.

To check proper Intoxilyzer function, we use a wet simulator and a known alcohol water solution provided as a certified standard by the Kansas Department of Health and Environment, Office of Laboratories and Research. These yield readings of 0.100 g/210 liters at 34° C, and they are run as a calibration check before and after each breath test. All results are stamped on the subject's test record card.

Initially, the vans were propane powered. If large amounts of propane were present, the interference light would be illuminated, although persistent low levels of propane were not found to be a problem. Since the initial setup of the vans for propane, the vans and generators have been converted to gasoline. We found that propane generators would not function during our usual cold Kansas winters.

Even though the National Highway Transportation Safety Administration has reported that the Intoxilyzer 4011AS is not susceptible to RFI, we conducted our own tests in 13 locations where there was a potential source of RFI. Our findings support their position. Test locations included the vicinity of radio transmitter towers of the police department and the electric utility, the electric generating plant, between transmitter towers of two television stations (combined broadcast power of 468,000 watts), and the end of the runway at McConnell Air Force Base.

Currently we are running over 2,000 breath tests per year for a city whose population is 280,000.

A SURVEY OF DRUG/DRIVING CASES ANALYZED IN THE METROPOLITAN POLICE LABORATORY FROM MAY 1983 TO MAY 1985

A. J. Clatworthy

The Metropolitan Police Forensic Science Laboratory
London, England

The United Kingdom's Road Traffic Act of 1972 deals with two types of offenses involving drinking drivers. One offense deals with drivers having excess alcohol in the blood (statutory limit 0.08%) and allows a police officer to require a specimen from the subject. The second type of offense deals with drivers who are unfit because of drink or drugs and only allows the police officer to request a specimen. In the latter case, the driver does not commit an offense by refusing to provide a specimen and proceedings could be brought against the subject using the evidence of the police officers and the result of any medical examination.

In May 1983, the Transport Act 1981 allowed breath specimens to be taken in place of blood specimens (statutory limit 35 micrograms %). This decreased the number of samples submitted to the laboratory for analysis from 20,000 to 6,000 in 1985. This legislation also allowed a police officer to require a blood sample in driving while unfit cases and made it an offense to refuse to supply a specimen. It also defined a drug as an "including any intoxicant other than alcohol." This distinction had become necessary because the existing definition did not cover young motorcyclists who sniffed glue and attempted to drive.

Since May 1983, a police officer can arrest someone he suspects of driving while unfit through drink or drugs on the basis of the person's driving performance. The person will be taken to a police station, where the pertinent information will be given to the station sergeant.

If an Intoximeter is available, the sergeant may require two breath samples. When the lowest result is above the proscribed limit, the motorist will probably be charged with the excess alcohol offense unless a more serious charge such as reckless driving is anticipated. If the lower figure is below the limit, the sergeant will ask a qualified police surgeon to examine the motorist to determine his fitness to drive. If no Intoximeter is available, a blood sample will be required for laboratory analysis for alcohol.

Whenever the doctor determines that the motorist is unfit to drive or that there is insufficient evidence, he advises the sergeant that the motorist's condition might be due to drugs and alcohol. The sergeant may require a blood or urine sample for laboratory analysis. Blood samples are usually taken with a 5-ml disposable syringe and divided into two glass vials containing fluoride/oxalate. One vial is offered to the motorist.

The sergeant then completes a form from the procedural booklet which asks for details of drugs found or suspected, the doctor's findings and the motorist's condition. The form is submitted to the laboratory with the sample. All samples are first analyzed for alcohol and then frozen pending analysis for drugs. Screening for drugs is usually performed by radio immunoassay unless the information supplied indicates an unusual drug, such as an antihistamine, is present.

Gas liquid chromatography, high pressure liquid chromatography and mass spectrometry are used, as needed, to identify drugs in positive samples. The drug(s) and their metabolites are then quantified in duplicate to allow a concentration to be reported.

The survey covers the result of samples submitted in 436 cases involving unfitness to drive. Drugs alone were detected in 52% of the cases, drugs in combination with alcohol in another 26%, alcohol alone in 12% and neither drugs nor alcohol in the remaining 9%. When drugs were suspected of being ingested, one or more of these were detected in 75% of the samples.

The overall results are shown in Figure 1, which is tabulated by percentage detection in the total samples analyzed. The benzodiazepine group of drugs were most frequently detected (35%). Cannabinoids were the most common drug found (30%), followed by diazepam (20%) and morphine (15%). As many as five or six drugs were found in some blood samples, but in most cases a single drug (and/or metabolite) was found with or without alcohol. In both cases, cannabinoids were the commonest.

To test the effectiveness of the system, I examined court proceedings in as many of these cases as possible. When low alcohol and/or no drugs were reported, prosecutions were infrequent and convictions very rare. When the doctor certified impairment or advised that the condition was due to drugs, prosecution was very common and convictions reached 60%. The system described appears to be working well and is supported from the court results obtained to date.

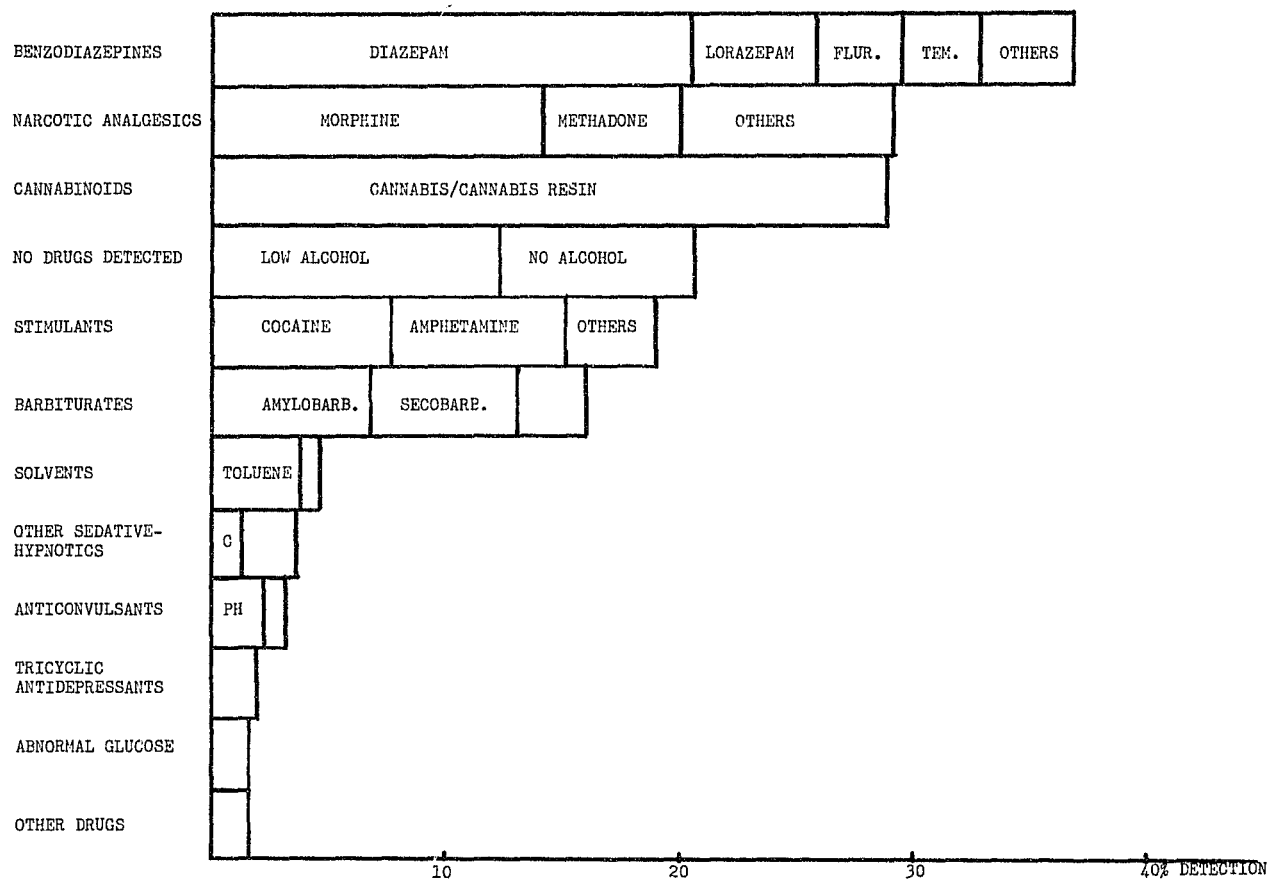

Figure 1. The results of Analysis of drug driving samples in the metropolitan police laboratory

PRELIMINARY SCREEN REPORTING PROCEDURE FOR UNDER THE INFLUENCE OF DRUGS CASES

J. A. Eras

Los Angeles County Sheriff's Department
Los Angeles, California

The Los Angeles County Sheriff's Criminalistics Laboratory uses rapid screening by either enzyme immunoassay (EIA) or radioimmunoassay (RIA) to identify drugs in blood and urine samples. A positive screen is confirmed by either gas chromatography or gas chromatography/mass spectrometry (GC/MS). Under the influence of drugs cases, which require a laboratory analysis to prove a key element of the crime, cannot move forward in the judicial process if the crime laboratory is slow in reporting the results of analysis. Such delays create a bottleneck in the litigation of these cases. Accordingly, for court filings and arraignment proceedings, the result of the screening test is reported to the submitting agency by a countywide computerized communication system known as the Justice Data Interface Controller (JDIC). The sample is then returned to the agency with a copy of the JDIC report. With the automated EIA and RIA instrumentation used by the Los Angeles County Sheriff's Department, one analyst can screen up to 200 samples per day. The normal turnaround time for a screening test to be reported to the submitting agency is 2 to 3 days. If a not guilty plea is entered and the case is set for trial, the sample must be returned to the laboratory for confirmation. A minimum of 10 working days must be allowed for a confirmation test.

During 1984 and 1985, approximately 30,000 under the influence of drugs cases were screened. These fell into three categories of results: 1.) samples in which the screening results were positive (22,300); 2.) samples in which the results were weakly positive (2,000); 3.) samples in which no drugs were detected (5,720). The first two groups accounted for 24,300 (81%) of the total samples submitted. The remaining 19% were reported as having no drugs detected. The 2,000 cases that indicated a weak positive required confirmation, and a final report was issued. A preliminary positive report was issued for the remaining 22,300 cases that screened positive. Of these, only 1,972 cases were returned for confirmation; the remaining 20,300 cases were adjudicated without laboratory confirmation. In most of these cases a guilty plea was entered, thus saving the laboratory countless hours in unnecessary confirmations.

This preliminary reporting procedure is still undergoing fine-tuning changes to arrive at the proper screening cutoff levels to avoid false positives or false negatives. The successful outcome of this program has depended on close collaboration and cooperation between the laboratory, the police agencies served and the District Attorney's Office (prosecutor).

In conclusion, the results of this preliminary reporting procedure have shown that it is not practical (or realistic) to confirm immediately all cases that are screened positive. This has allowed the toxicology staff more time for the less routine and more time-consuming analyses.

Table 1. 1984 AND 1985 DRIVING UNDER THE INFLUENCE (DUI) AND UNDER THE INFLUENCE (11550A AND B) CASES

	1984		1985	
	DUI	11550	DUI	11550
Total	2,844	13,585	2,511	14,189
Total (DUI and 11550)	16,429		16,700	

Table 2. SCREENING RESULTS

1984

Total positive drug screens reported, 10,843
Total returned for confirmation, 1,175 (10.8%)

1985

Total positive drug screens reported, 11,446
Total returned for confirmation, 797 (7%)

CANNABINOIDS IN CALIFORNIA TRAFFIC SAFETY - 1985

N. A. Wade

California Department of Justice
Sacramento, California

California is 75% nonurban and produces 25% of the nation's agricultural crop. But even surpassing that 25%, the biggest cash crop in California is marijuana. A total of 3.5 billion dollars worth of marijuana has been seized in California. I suspect that the problem is not just in California but is nationwide.

All the toxicology for the Department of Justice, including analysis of blood samples for drugs, is done in the Sacramento Laboratory. We do have 11 regional laboratories that cover the whole state from Mexico to Oregon. We do not cover some of the more populous counties such as Los Angeles, San Francisco, San Diego and even Sacramento County. So the results I am reporting on cover 46 counties that we serve of the 52 in the State of California, representing about 18 million people. Using a methanol extract and the Roche Abuscreen Kit (Nutley, NJ) at a sensitivity level of 10 nanograms per milliliter of carboxy-THC, we examined 2,500 driving related cases collected since January 1985 and found that 60% were positive by RIA for cannabinoids. We had a 95% confirmation rate by gas chromatography/mass spectrometry (GC/MS) of these positive results. This information makes be believe that we do have a problem in California with cannabinoids and traffic safety.

Cannabinoids analyzed by GC/MS are primarily measured against blood standards that we have prepared from standards obtained from the National Institute of Drug Abuse (NIDA): 5 and 10 nanograms per milliliter for Delta-9-THC and 5 and 50 nanograms per milliliter for Carboxy-THC blood standards. In the last 3 to 12 months, we have added an external quality control sample from Utak laboratories (Saugus, CA) at 5 nanograms per milliliter for Delta-9-THC. Utak seems to be able to produce this standard very well in lyophilized serum (in a proprietary solution) made just for us. They also provide us with 20 nanogram per milliliter samples of carboxy-THC in lyophilized serum.

After examining arrest reports produced by the California Highway Patrol in our jurisdiction, I have been able to compile statistics on local drug and marijuana use (Table 1). The reports examined dealt only with alcohol and marijuana. Eighty-two percent of the subjects were male, and 18% were female. Their mean age was 25 and 99.5% were Caucasian. A single vehicle was involved 98% of the time. Most of the subjects were stopped for erratic driving; only about 10% were actually involved in vehicle accidents. Twenty-three percent had a green tongue, 45% had dilated pupils. Rebound dilation was found in about 15% of these cases. (There is no clinical explanation, to this date to explain rebound dilation.) Bloodshot eyes were seen in 82%, slurred speech in 68%. The smell of marijuana was detected in the car or on the person in 27% of these arrests. Marijuana was found about 41% of the time. Fifty-two percent of the drivers exhibited a weaving pattern that was recognizable in driving behavior and about 41% were speeding. The subjects failed at least two of the field sobriety tests 84% of the time.

Toxicology results, field sobriety tests, and analysis of driving patterns are all necessary as testimony in

Table 1. ARREST REPORT PROFILE

82%	MALE
18%	FEMALE
25	MEAN AGE (16-48)
99.5%	CAUCASIAN
00.5%	BLACK
98%	SINGLE VEHICLE INVOLVED
23%	GREEN TONGUE
45%	DILATED PUPILS
82%	BLOODSHOT EYES
68%	SLURRED SPEECH
27%	SMELL OF MARIJUANA
41%	MARIJUANA FOUND
52%	WEAVING PATTERN
41%	SPEEDING
84%	FAILED AT LEAST TWO FIELD SOBRIETY TESTS (Standing on one foot 86%) (Heel to toe 50%) (Alphabet test 50%)

all types of cases of driving impairment. I firmly believe that the toxicology result on marijuana cannot stand by itself. You cannot take concentrations of THC and correlate them to driving impairment at a *per se* level as you can for alcohol. It is up to the District Attorney to make the final judgement and really up to the jury to determine whether the person is innocent or guilty. We play only a very small part, and we are just a part of the total prosecution picture and criminal justice system.

SCREENING OF BASIC DRUGS IN BIOLOGICAL SAMPLES USING DUAL COLUMN CAPILLARY CHROMATOGRAPHY AND NITROGEN-PHOSPHORUS DETECTORS

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Nitrogen phosphorus (N/P) detectors have been extremely useful for toxicology drug testing (Forester *et al.* 1978). Detector selectivity provides for minimum sample preparation and gives a detection limit of 100 ng/ml for most drugs. The introduction of fused silica capillary columns having low column bleed and a high degree of inertness makes them excellent partners for the N/P detector (Anderson *et al.* 1983; Koves and Wells 1985). The method presented screens for basic and neutral drugs, including amphetamines. Underivatized extracts are analyzed simultaneously on two complementary capillary columns placed in one injection port, using split injection.

Stock standards were prepared in methanol at a concentration of 1 mg/ml. Working standards and the internal standard SKF-525A were prepared in water at 10 mcg/ml.

An HP 5890 gas chromatograph was equipped with capillary split injector dual nitrogen-phosphorus detectors and two HP 3393 integrators. Samples were injected via a HP 7673 liquid autosampler. The two cross-linked fused silica columns used were an Ultra-1 (methyl silicone) and an HP-17 (50% phenyl methyl silicone), both 12.5 m x 0.32 mm internal diameter, 0.5-micron film thickness (Hewlett-Packard, Avondale, PA). The two columns were placed through a graphite two-holed ferrule. The ferrule has been previously performed by syringe plungers (Doshier 1986).

The linear velocities at 250° C were 52 and 47 cm/second for the methyl and phenyl methyl columns, respectively. The split flow was 10 ml/minute. The detector gas flows were: hydrogen, 2 ml, air, 80 ml and helium makeup 30 ml/minute. The temperature program was 110° C, for 1 minute, a rate 10° C per minute to 280° C, and hold for 7 minutes.

To prepare the samples, 2 ml of blood was buffered to pH 9.0 with borate buffer and extracted with butyl chloride (Pierce *et al.* 1978). Control and blank bloods were prepared in the same manner. All samples were spiked with 200 ng internal standard prior to extraction. The butyl chloride extracts were evaporated to a residue and made up in 50 microliters hexane-ethanol (1:1). The hexane-ethanol was transferred to a 100-microliter insert autosampler vial, and 2 microliters were injected. Additional cleanup was required for aged blood or urine samples. The butyl chloride was extracted into 2 ml of 1N sulfuric acid and washed with 5 ml of hexane. Saturated sodium hydroxide was added to the acid phase until the pH was 9-10, and then re-extracted into 5 ml butyl chloride (Crouch *et al.* 1983). The back extraction procedure is desirable if the extracts are to be confirmed by gas chromatography-mass spectrometry.

The success of the method depends on four areas: the inertness of the system, nitrogen detector optimization, extraction technique and lack of contamination. The deactivation of the fused silica liner is essential for good chromatography on the capillary system.

Drug standards at 10 ng/ml in hexane-ethanol were injected onto the dual capillary system, and the RRt to SKF-525A was calculated for 112 drugs on both columns. The within-run Rt reproducibility was monitored with 20 injections of SKF-525A. The run-to-run Rt reproducibility was monitored for 100 injections of SKF-525A over a 4-week period (Table 1). The run-to-run reproducibility was calculated for 15 drugs from 14 injections over a 4-week period (Table 2).

Blood was spiked at 250 ng/ml with water standards. The blood was extracted in duplicate through the back extraction procedure. Standards at 500 ng in water were buffered to pH 9.0 with borate buffer and extracted into butyl chloride in triplicate for the standard drug response. The percent recovery was calculated for 13 drugs (Table 3). Eleven consecutive blood extractions were evaluated for variability in recovery of the internal standard, SKF-525A (Table 4).

Table 1. SKF-525A RETENTION TIME REPRODUCIBILITY

Column	WITHIN-RUN VARIATION Mean Retention Time	Standard Deviation
METHYL SILICONE	13.037	0.002
50% PHENYL METHYL	13.740	0.001
		N =20
Column	RUN-TO-RUN VARIATION Mean Retention Time	Standard Deviation
METHYL SILICONE	13.018	0.014
50% PHENYL METHYL	13.728	0.009
		N =100

Table 2. RETENTION TIME REPRODUCIBILITY DRUG

DRUG	MEAN RRT*	Standard Deviation
ALPRAZOLAM	1.348	0
AMPHETAMINE	0.100	0
BENZPHETAMINE	0.636	0
CHLORDIAZEPOXIDE	1.099	0
COCAINE	0.904	0.001
DESMETHYLDIAZEPAM	1.087	0
DIAZEPAM	1.055	0.003
FLURAZEPAM	1.270	0.001
LIDOCAINE	0.665	0.001
MEPERIDINE	0.564	0.001
METHADONE	0.875	0
METHAMPHETAMINE	0.127	0
OXYCODONE	1.106	0.001
PHENCYCLIDINE	0.682	0
PROPOXYPHENE	0.908	0

*Relative to SKF-525A.

Figures 1-3 are examples of test mixtures injected on a dual column capillary system. Figure 4 shows a chromatogram of a single step versus a back extraction procedure for control blood.

In the linearity study, methamphetamine, diazepam and cocaine were injected in the amount of 2, 4, 5, 10 and 20 ng. The results were plotted and the system was found to be linear for these drugs. Figure 5 illustrates the results from two of three drugs.

Table 3. DRUG RECOVERIES BACK EXTRACTION PROCEDURE

AMPHETAMINE	53%
METHAMPHETAMINE	86%
BENZPHETAMINE	39%
OXYCODONE	68%
PHENCYCLIDINE	78%
DIAZEPAM	22%
DESMETHYLDIAZEPAM	66%
FLURAZEPAM	90%
MEPERIDINE	73%
LIDOCAINE	67%
AMITRIPTYLINE	74%
METHAQUALONE	11%
ALPRAZOLAM	60%

Table 4. SKF-525A RECOVERY WITHIN RUN

BLOOD EXTRACTION	% RECOVERY
1	37.5
2	42.8
3	44.8
4	52.9
5	34.2
6	30.0
7	23.2
8	39.9
9	37.4
10	51.3
11	61.1

In conclusion, we have found that the combination of fused silica capillary columns and nitrogen phosphorus detectors makes for a stable screening system for basic and neutral drugs in biologic samples. The dual column split injection system is capable of giving both reproducible and linear results for underivatized drugs.

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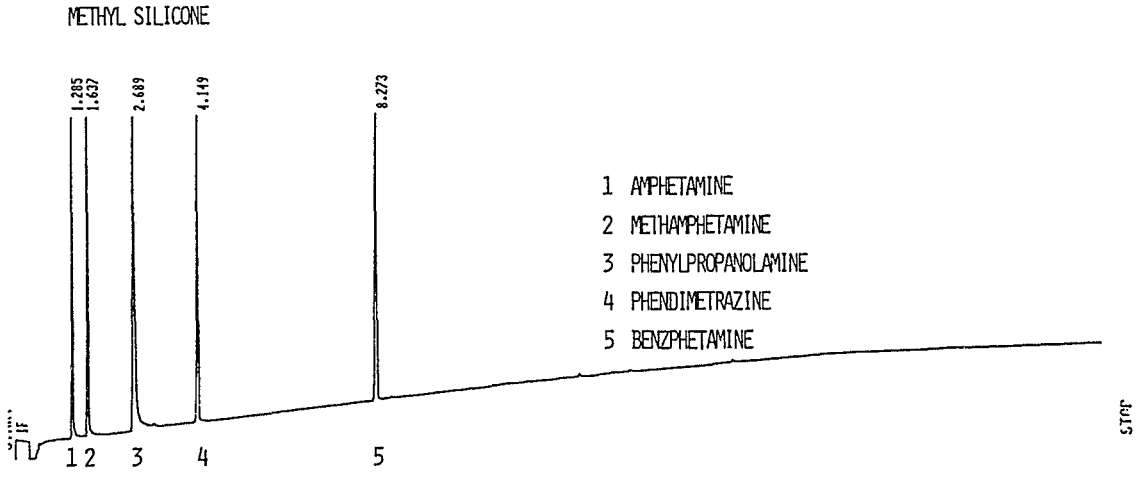

Figure 1. Amphetamine mix: 10 ng per component.

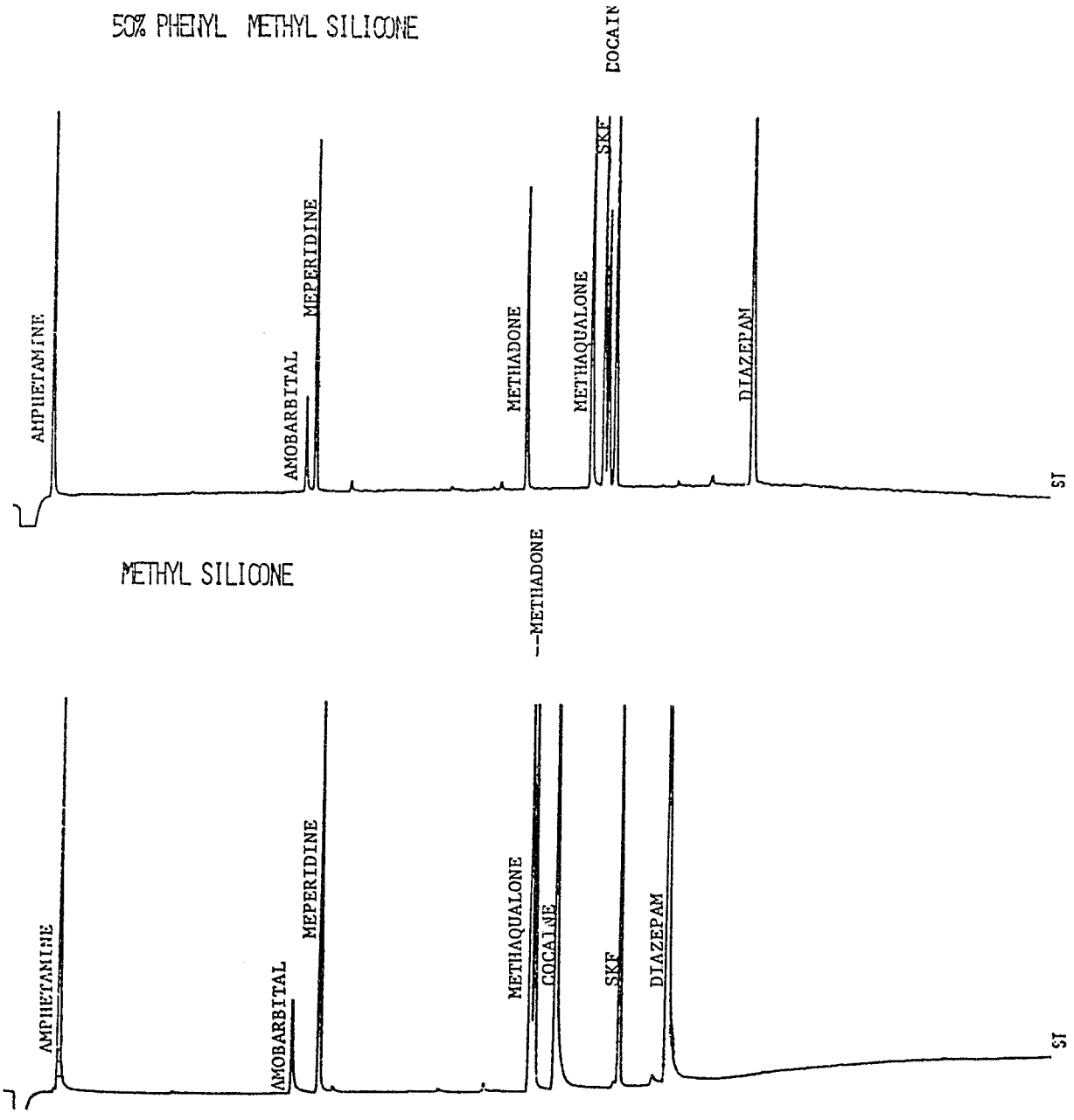

Figure 2. Test mixture: 10 ng per component.

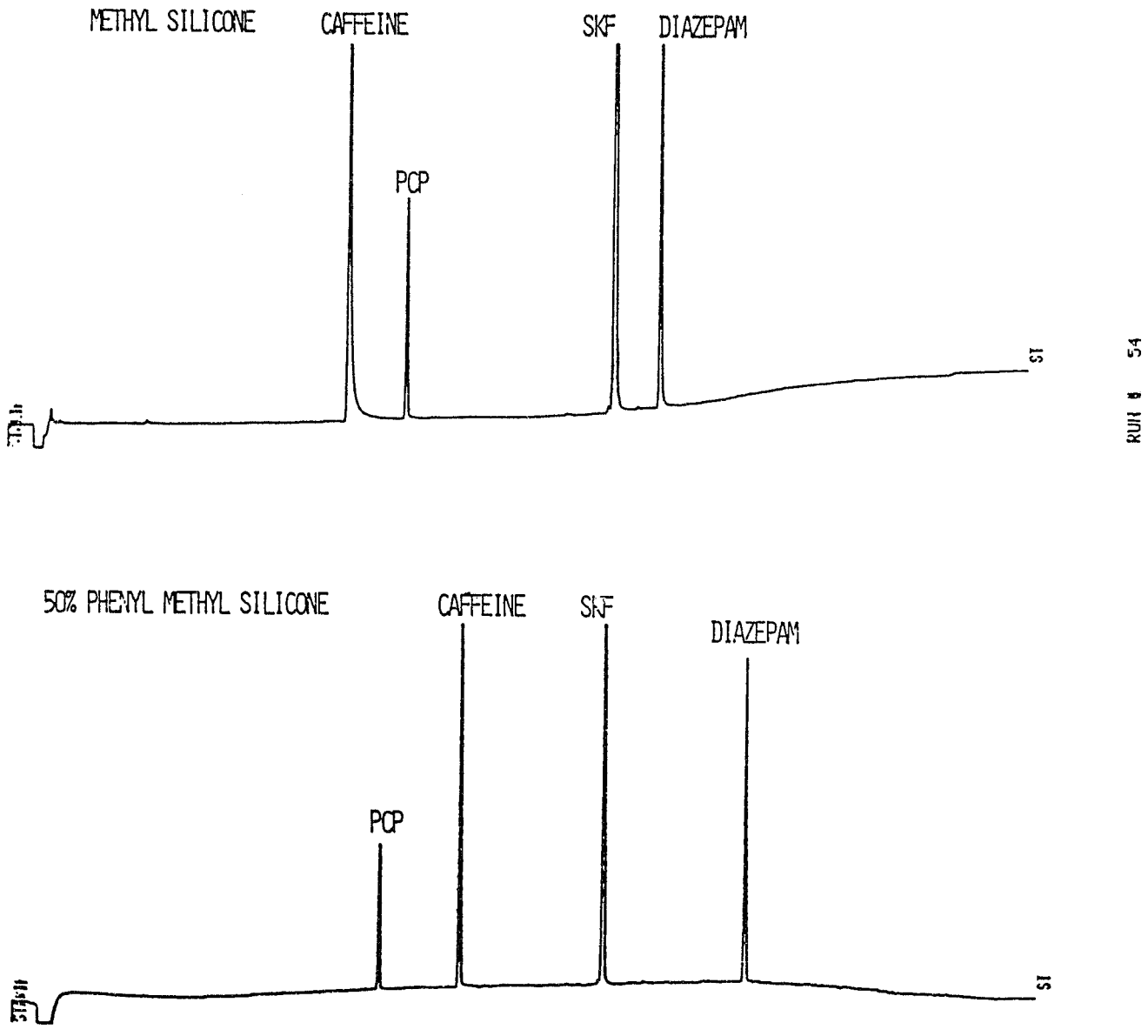

Figure 3. Test mixture: reversal of elution order for PCP, Caffeine.

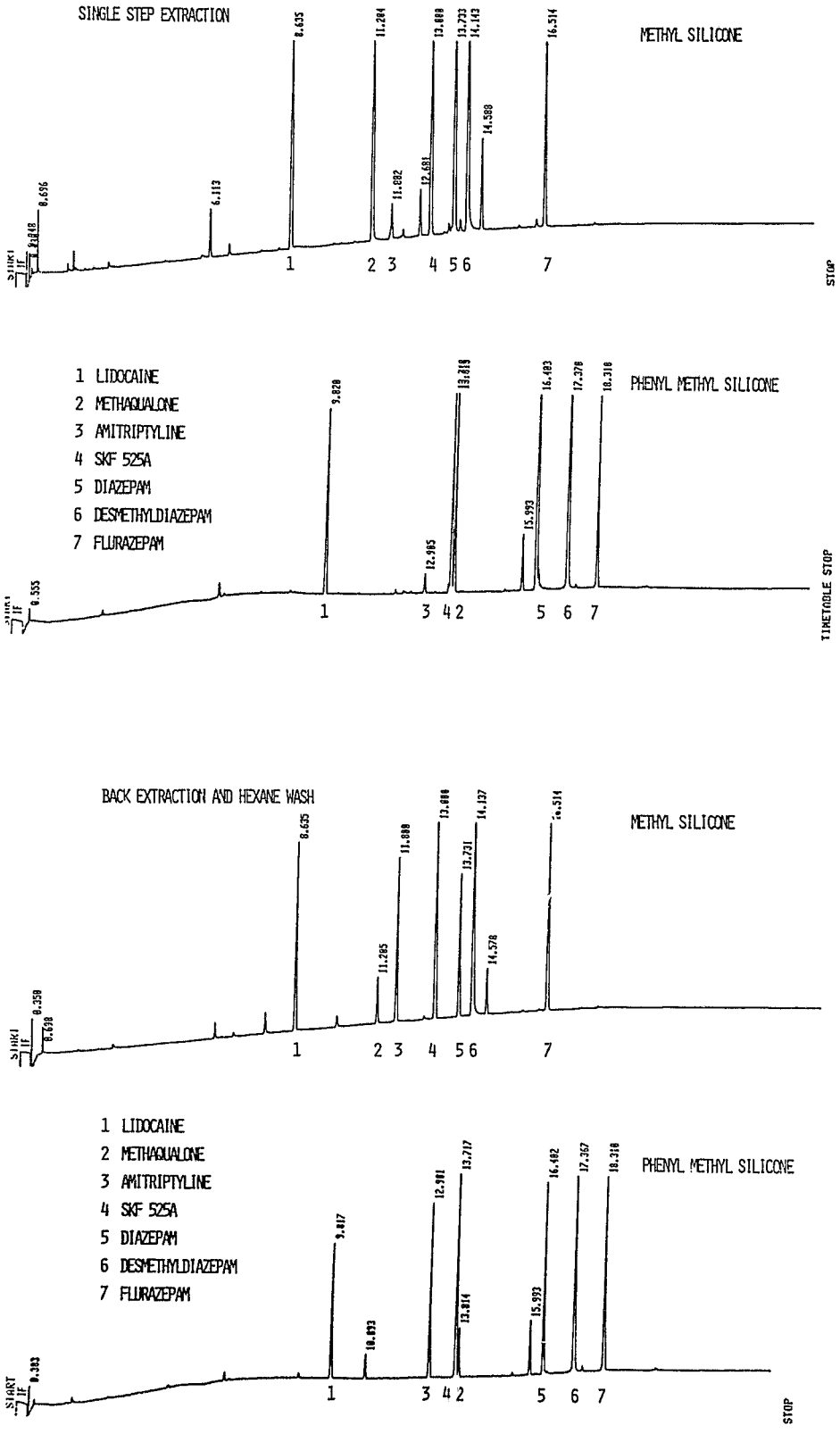

Figure 4. Blood extraction: Single step vs. back extract.

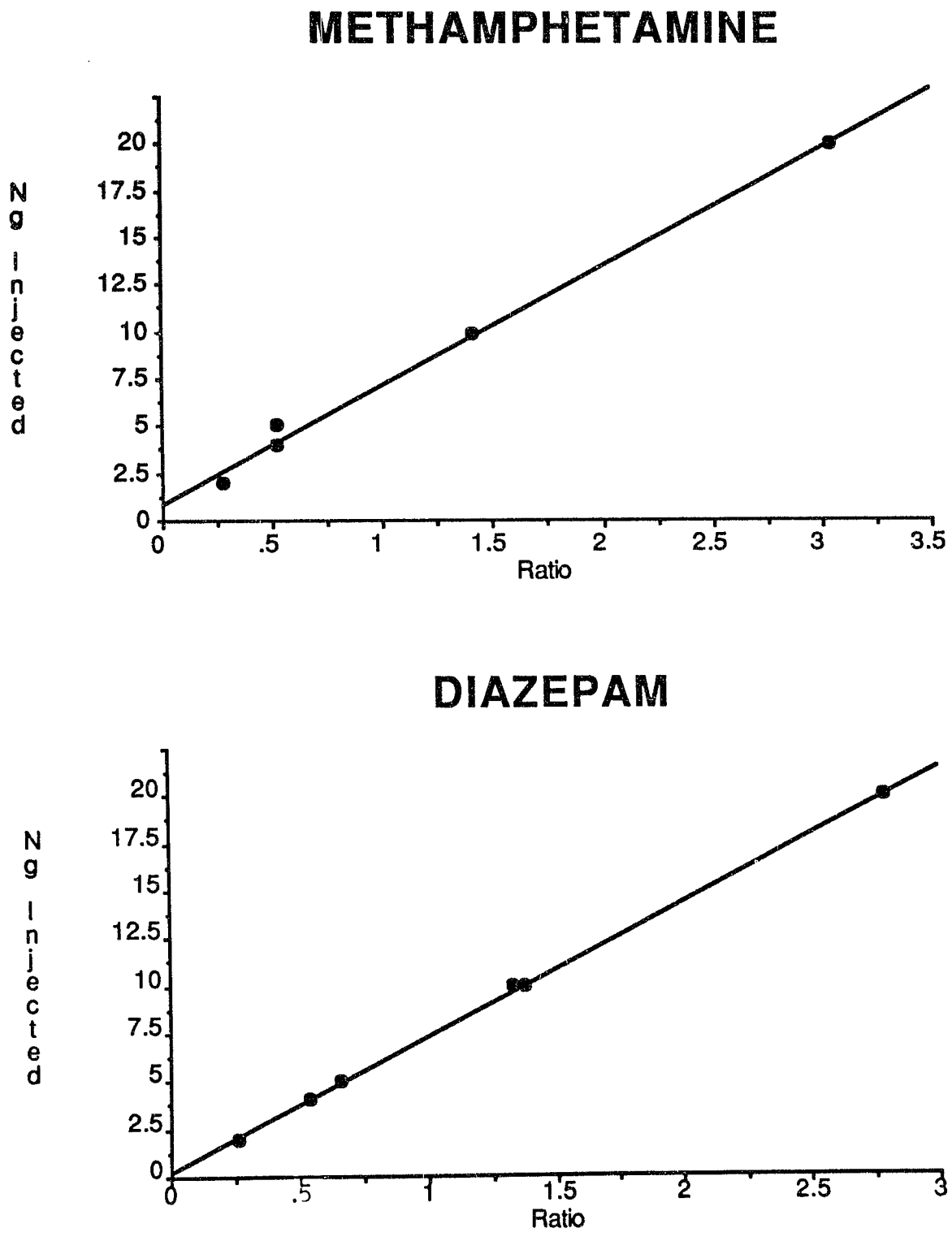

Figure 5. Linearity of N/P response.

CORRELATION OF DRUG CONCENTRATIONS AND DRIVING IMPAIRMENT

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Alcohol, marihuana, diazepam and cocaine are the drugs most often mentioned in relation to driving impairment. Methaqualone and barbiturates, except phenobarbital, are used infrequently. When other drugs are found, alcohol at impairing concentrations is found in most drivers. The signs, symptoms and amount of impairment expected at various concentrations of alcohol have been reported many times. Most of the other drugs do not produce characteristic signs and symptoms.

Insight into the size and complexity of the problem of drugs and possible driving impairment can be obtained by reviewing four studies of the incidence of drugs in drivers killed in crashes. These are summarized in Table 1. Ethanol was found in 64% of the drivers and in 87% of the drivers who had evidence of marijuana in their blood. Only evidence of marijuana was found in 1.7% of the drivers. This is significant because most of the drivers could have been charged with alcohol impairment even when other drugs were present. There is no evidence that the few whose blood contained only marijuana were impaired.

Fifty-three percent of the 19 drivers in whom marijuana alone was found were estimated to be responsible for their crashes compared with 71% of the 78 drug free drivers (Williams *et al.* 1985). In another study, tetrahydrocannabinol (THC) was found in the blood of 8 (20%) of 40 drivers considered responsible for crashes compared with the finding of THC in the blood of 38.5% of those not considered responsible for crashes (Garriott 1986).

It would be expected that the widely used drug, diazepam would be found in many people. The following statement concerning diazepam is pertinent. Because of the variability of blood/level impairment correlations, drug plasma level cannot be used to document impairment in the medical or legal system unless appropriate caveats are accepted (Haight 1985). Alcohol was found in 36 of the 47 (11%) young California drivers whose blood contained cocaine (Williams *et al.* 1985). It has been reported that cocaine has no effect on performance in rested subjects but improves performance in sleep-deprived subjects (Fischman 1985).

A number of other drugs were found, but each was found only a few times. Some of them are widely used and would be expected to have an effect on performance. Hypnotics, sedatives, codeine, propoxyphene, antidepressants, diphenhydramine and many other drugs would be included in this group. These add to the complexity of the analyses but more importantly make the interpretation of the results difficult or impossible.

A recent review of the subject of drugs and driving offers evidence of decrements in some tasks after drugs that may or may not be relatable to driving are administered. Plasma diazepam concentrations were the only drug concentrations found in this review (Haight 1985).

A consensus panel concluded that providing expert opinions concerning the possible impairment of driving ability based on body fluid concentrations of drugs requires access to a body of knowledge on the measurement of driving ability, the chemical analyses of body fluids, and particularly the correlation and interpretation of those measurements. Such a body of knowledge is not yet sufficient for dealing with drugs such as marijuana, sedative-hypnotics, antihistamines, and benzodiazepines (Blanke *et al.* 1985).

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Table 1. INCIDENCE OF DRUGS IN DEAD MOTOR VEHICLE OPERATORS

Reference:	Cimbura *et al.* (1982)	Mason & McBay (1984)	Williams *et al.* (1985)	Cimbura *et al.* (1986)	Total
Place	Ontario	NC	CA	Ontario	
Years	1978-79	1978-81	1982-83	1982-84	
Number of cases	401	600	440	1169	2610
Alcohol+	229	476	308	667	1680
THC	15	47	162	127	351
THC+ Alc+	14	41	132	107	294
THC+ only	1	4	19	20	44
THC < 5 ng/ml	13	19	139	107	278
THC > 4 ng/ml	2	28	23	20	73
Diazepam+	12		19		31
Cocaine+	0	2	47		49
Other drugs: Number found	27	5	11+		
Times found	71	40	94		205

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SECTION III

PANEL DISCUSSIONS

PANEL DISCUSSION
IMPAIRMENT VERSUS BLOOD ALCOHOL CONCENTRATION

MODERATOR: *Jerry T. Francisco*, University of Tennessee at Memphis

This panel discussed personal observations of driving impairment due to alcohol consumption versus chemical tests to evaluate level of impairment. One side maintains that results of chemical tests should be used as the primary evidence in court and observations used only as supporting evidence, and the other side believes that observations should be used as the primary evidence in court and chemical test results supplied as supporting evidence.

The Los Angeles Police Department is training a drug specialist examiner to make specific observations of body language to deduce an individual's level of driving impairment. How well an officer conveys to the jury how and why he ascertained that a suspect was impaired is important. In Arizona, the conviction rate for driving under the influence (DUI), based on an officer's observations, decreased significantly when it was ruled that breath test results were no longer admissible as evidence. Officers who have been trained to explain sobriety field tests for DUI to a jury have a higher conviction rate based on observation whether or not the breath test results are used as evidence.

The amount of alcohol consumed is equal to the blood alcohol concentration (BAC), and the BAC is approximately equal to the level of impairment. Impairment levels fluctuate depending on many factors. For example, an individual's adaptive tolerance or compensation for alcohol consumed may influence the level of impairment observed by others.

As an individual consumes more alcohol and judgment becomes more clouded, he loses the ability to decide whether he can safely drive. It is believed that most people learn about the effects of alcohol from personal experience and are therefore unable to make rational judgments regarding their level of impairment. Alcohol consumption alone, without the task of driving, is neither a necessary nor sufficient condition to cause an accident. Establishing a BAC level of 0.10% for DUI is a political decision because the public does not believe a level of 0.10% represents a significant level of impairment.

Field sobriety tests do not measure judgment or reaction time but rather measure a function of nerve/muscle interaction. Currently, support is growing for establishing drug recognition training of law enforcement officers, as well as placing trained officers on the street to make various physical first-hand observations to better predict whether a person is under the influence of some type of drug.

PANEL DISCUSSION
ROADSIDE TESTING TECHNIQUES

MODERATOR: *Richard Studdard,* Los Angeles Police Department

The purpose of this panel was to discuss techniques of roadside drug testing.

The certification process for individuals learning to evaluate nystagmus as part of a field sobriety test (FST) battery should be taught in stages. Drug recognition experts are being trained to estimate from the angle of onset of nystagmus what the blood alcohol concentration (BAC) is, so that they can correlate it to the drug involved. Every time a police officer makes an arrest or has contact with someone exhibiting nystagmus, it is recommended that the officer enter in a log the subject's name, angle of onset and BAC. In this manner, the police officer gains the experience needed to enhance his formal training.

In California, if a person refuses to perform the FSTs, the Consciousness of Guilt statement applies. Generally, someone Consciousness of Guilt statement applies. Generally, someone who is suspected of driving under the influence (DUI) is not advised of Miranda rights until chemical tests are completed. The FST battery is in two phases. A field officer will evaluate nystagmus, have the DUI suspect perform walk-and-turn, one-leg stand, finger-to-nose and Romberg tests and check his pupil size and reaction to light. The suspect will then be brought in for breath, blood and urine tests. He will also have his pulse rate checked three times and his blood pressure checked at least once.

In some cases, an entire arrest is based solely on the results of the nystagmus test. However, the nystagmus test is only one part of the FST battery and should be used as such by drug recognition experts (DREs). If too much weight is placed on the nystagmus test results, a case may be lost in court. Results of divided attention, walk-and-turn and one-leg stand tests provide valuable information as to the degree of impairment of an individual.

An officer testifying in court should report good FST results as well as poor to show that the officer is being objective about what was observed.

In arrests made nationwide, BAC averages are 0.16%-0.18%. Because of the aggressive DUI program in Los Angeles, BAC averages are 0.135% in arrested suspects. The National Highway Traffic Safety Administration (NHTSA) says that police are arresting individuals with BACs of 0.18%, but that it is the individuals with BACs of only 0.11% who are causing fatalities. Because of this, it is believed that the BAC standard of 0.10% should be lowered to 0.08%.

By selecting at least one officer from each state to go to Los Angeles to be trained as a DRE, use of the field sobriety test battery would spread nationwide. Drug recognition expert criteria will normally not apply to the street officer because the street is not an ideal or proper place for conducting the tests. Therefore, a police station must have space set aside in to properly conduct the tests. A model for alcohol detection showing correlation between level of alcohol consumed and degree of impairment cannot be applied to drugs because, unlike alcohol, the more complex effects of drugs do not necessarily correlate with the amount consumed.

PANEL DISCUSSION
CANNABINOID CONTROVERSIES

MODERATOR: *Michael A. Peat,* Chemical Toxicology Institute

The purpose of this panel was to discuss the minimum levels of marijuana detection resulting in positive laboratory findings in blood and urine specimens, use of non-gas chromatography mass spectrometry techniques and interpretive problems in marijuana detection.

No direct correlation exists between degree of impairment and concentrations of tetrahydrocannabinol (THC) and carboxy acid in blood or urine samples. Studies have been performed on relatively infrequent users of marijuana, but no laboratory studies are known to have been performed on heavy, frequent users.

The time span between when the drug is introduced and a sample is collected influences the amount of THC that is detected in blood or urine samples. The amount of carboxy acid in the blood depends on whether the suspect is a frequent user of marijuana. The problem with THC and carboxy acid detection in blood is the linking of these blood results to the time that the impairment of driving skills or related tasks were observed and back-extrapolating marijuana results based on published PK curves.

Currently, there is no definitive number for a plasma concentration of THC that would indicate impairment. In the case of a suspected drugged driver, it is important that the arresting police officer perform a very good workup from the start of the arrest because convictions cannot rest solely upon results of THC concentrations in blood.

PANEL DISCUSSION
WHAT CONSTITUTES A POSITIVE FINDING?

MODERATORS: *Leo A. Dal Cortivo*, Division of Medical-Legal Investigations, Office of Medical Examiner

Richard W. Prouty, State of Oklahoma Board of Medicolegal Investigation

The purpose of this panel was to discuss quantitative analysis for detecting alcohol and drugs in blood. Generally, two-column analysis with different columns would constitute a positive result when using gas chromatography (GC) quantitation to determine ethanol concentration in blood. Two systems are used to verify that no other interfering compounds are in the blood sample. Many analysts would be satisfied with the use of one column when analyzing alcohol concentration in blood.

It must be emphasized that GC is not a specific tool. Gas chromatography is capable of separating closely related compounds in a series, but it does not provide the structural identification that infrared or mass spectrometry provides. Many laboratories use thin layer chromatography (TLC) to promote identification from thin layer systems.

Some forensic scientists prefer to run samples without any knowledge of what the arresting officer observed in the field sobriety tests. Others prefer being informed of the results of the field sobriety tests before running samples.

In trying to decide what constitutes a positive indication of drug use, should the decision be limited to forensic scientists and laboratory analysts, or should public acceptance of a prescribed limit also be considered? The public as jurists have significant input in the final decisions in court.

Standards should be set in all forensic science laboratories so that each analyst follows the same procedures in testing samples. At issue is what criteria should be established in the laboratory to label a sample positive, not whether or not the analysis was performed correctly. A major cause of problems in identification is incomplete documentation. Accurate recordkeeping and documentation should be an integral part of the experimental procedure.

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