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# The Likelihood of Acetone Interference in Breath Alcohol Measurement

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16. Abstract

This report discusses the significance of possible interference of acetone in breath alcohol testing. The following dimensions were considered:

1) what levels of acetone concentration may appear on the breath,
2) what levels of acetone concentration may produce significant breath alcohol concentration (BAC) readings on breath testers,
3) which instrument types may be sensitive to the presence of acetone.

The issue of acetone interference was found to have no practical significance in traffic law enforcement for the following reasons:

1) the level of acetone on the breath that would be required to produce even minimal BAC readings (e.g. 0.01% BAC) is rarely seen in on-the-road arrest situations (i.e. less than 0.028%).
2) Diabetic and dieting individuals who are well enough to drive do not have sufficient levels of acetone on their breath to increase BAC readings more than a very small amount (a practical maximum of 0.01%-0.02%).
3) The number of evidential breath testers in use that are unable to discriminate between acetone and ethyl alcohol is very small, estimated to be less than 1,000 nationwide. Most commercially available evidential breath testers sold today are made to distinguish acetone from ethyl alcohol, so that the issue is moot in these cases.

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The human body normally produces small amounts of acetone, which appear in breath at concentrations too low to be a practical interferent in breath test instruments designed to measure breath alcohol concentrations. However, diabetics and persons on weight reduction diets are known to generate acetone at higher than normal levels. The degree to which acetone affects the reading of certain chemical breath test instruments has been a topic raised in legal and law enforcement circles.

This report discusses the significance of possible interference of acetone in breath alcohol testing. The following dimensions are considered:

- o what levels of acetone may appear on the breath.
- o what levels of acetone may produce significant Breath Alcohol Concentration (BAC) readings
- o which instrument types may be sensitive to the presence of acetone

The likelihood that DWI suspects may have sufficient acetone on their breath to produce interference was found to be not significant.

## II. Background

Breath test results are the primary source of evidence used to remove drinking drivers from the road. The concept of breath alcohol measurement for the determination of blood alcohol concentration (BAC) is well accepted in the United States, and its basis is scientifically sound (Jones, Wright, and Jones, 1975). The breath test can be administered by an arresting officer in a short time, and the cost of testing in terms of training, equipment, supplies, and logistics is significantly less than that for blood or urine testing. For these reasons, breath testing has become the principle means of determining BAC in this country.

One purpose of breath alcohol tests used by the police is to determine impairment of driving ability (judgment, motor control) caused by the effect of ethyl alcohol on the brain. For that reason, it has been necessary to establish a critical threshold level above which significant impairment is certain.

In the process of demonstrating the validity of breath alcohol measurements for determining blood alcohol content, the pioneers of breath testing have had to deal with questions regarding the possibility of interference by other substances in the breath. The fact that ethyl alcohol is volatile and is partitioned between pulmonary capillary blood and

alveolar air makes breath a useful fluid for BAC determinations. Because the deep lung breath corresponds to the alveolar air, it reflects ethyl alcohol concentration in the blood. However, if the breath sample is not "deep lung air," but a mixture of freshly inhaled air with deep lung air, the BAC measurement will underestimate the actual BAC. Rather than being a negative factor, this fact is useful to police and the courts, because it ensures that any failure to get a deep lung breath sample will result in an outcome favoring the driver, thereby reducing the likelihood for false arrests of drinking drivers.

On the other hand, a false positive BAC could result from a test, if the breath contained a substance which the testing device could detect but not distinguish from ethyl alcohol. For this to be a serious possibility, the interfering substance would need to appear in the breath at high enough concentrations to produce a significant degree of interference in the measurement of ethyl alcohol. It would also be necessary for the sensor system of the breath tester to respond to the interfering substance with sufficient sensitivity.

The major breath components (nitrogen, oxygen, carbon dioxide, and water) present no analytic problems because they have vastly different chemical and/or physical properties from ethyl alcohol. Other "normal" breath components are present at such low concentrations that they also do not present an analytical problem. Acetone, however, may appear at higher than normal levels in diabetics and dieters, and therefore has been considered suspect as a interfering substance in the accurate measurement of ethyl alcohol.

## III. Model Specifications for Breath Alcohol Testing Devices

The NHTSA Conforming Products List (see Federal Register, Vol. 49, No. 242, p. 48864 dated December 14, 1984) for evidential breath alcohol testing equipment was established in the early 1970s to ensure the efficient use of Federal funds by the States when purchasing equipment under Section 402 or 403 of the Highway Safety Act of 1968, and to encourage the development of breath measurement technology available to law enforcement.

Equipment is regularly tested to determine whether it meets the Model Specifications published by NHTSA in 1984. Those guidelines specify accuracy and precision tolerances for the measurement of alcohol under operating conditions thought likely to be encountered during police use.

## IV. Breath Alcohol Test Devices.

The scientific basis for determining BAC from breath samples is firmly established. Current technology meets the needs of police for accurate and speedy results without the need for direct involvement of trained medical or scientific personnel. Consequently, breath testing has become the predominant method for measuring blood alcohol concentration in all of the 50 States and plays a significant role in the enforcement of drunk driving laws.

From its initial development in the 1930s, the breath test device has evolved to newer versions as technology has rapidly changed. While the level of the BAC can be stated in a quantitative way, its relationship to impairment of judgment and motor control cannot be so stated. However, both laboratory and field data support the conclusion that drivers exceeding the 0.10% BAC level constitute a significant hazard to highway safety. There are some experts who favor setting the critical level at 0.08%. The probability of a drunk driver being involved in a fatal crash rises sharply at 0.08% to 0.10%, as shown in Figure 1. This curve represents the data from a large number of accidents and relates the relative probability of fatal crash involvement to BAC. Many States have enacted laws that make driving with a BAC greater than 0.10 % illegal per se, so that the exact BAC is not as critical once the determination is made whether or not it is above 0.10%.

The required accuracy of the evidential breath tester is determined by the above considerations. The NHTSA Model Specifications for Evidential Breath Alcohol Devices calls for nominal accuracy of plus or minus 5 % at the critical 0.10 % BAC level, since police can truncate test results to the second place with that level of accuracy. Because the usual practice is to truncate to the second place, a reading of 0.099 would be read and reported as 0.09 rather than 0.10 %.

There are sources of variability in breath test measurements which work both for and against the accused. The aforementioned practice of truncating is one example of a practice which favors the suspected offender. Another is the correlation factor used to calculate Blood Alcohol Concentration (BAC) from breath level concentration (National Safety Council, 1976), which typically results in a low bias in BAC measured by breath of from 10-20% in favor of the accused (Jones, Wright, & Jones, 1975; Flores, 1975), depending on whether the sample is truly alveolar (i.e., deep lung) air. On the other hand, a high oral temperature, as high as 104° F., may tend to remove the inherent low bias in the BAC derived from breath measurement. The incidence of apprehended drunk drivers with high oral temperatures can safety be assumed to be insignificant, however. Another possible cause of error against the accused is the presence of mouth alcohol due to recent ingestion, regurgitation, or belching. These sources of variation are easily avoided in normal police procedures by observing the individual for a sufficient period (15-20 minutes) prior to testing.

An additional possible source of variation common to BAC determined by any means (breath, blood, or urine) is that due to interfering substances. In the case of breath measurement, the possibility of interfering substances is limited to volatile substances to which the breath tester responds and which it cannot distinguish from ethyl alcohol. The substance must also be present in sufficient concentration to cause significant error in the BAC reading. The number of substances which can appear on the breath in significant concentrations and be detected as alcohol is limited (see Table 1).

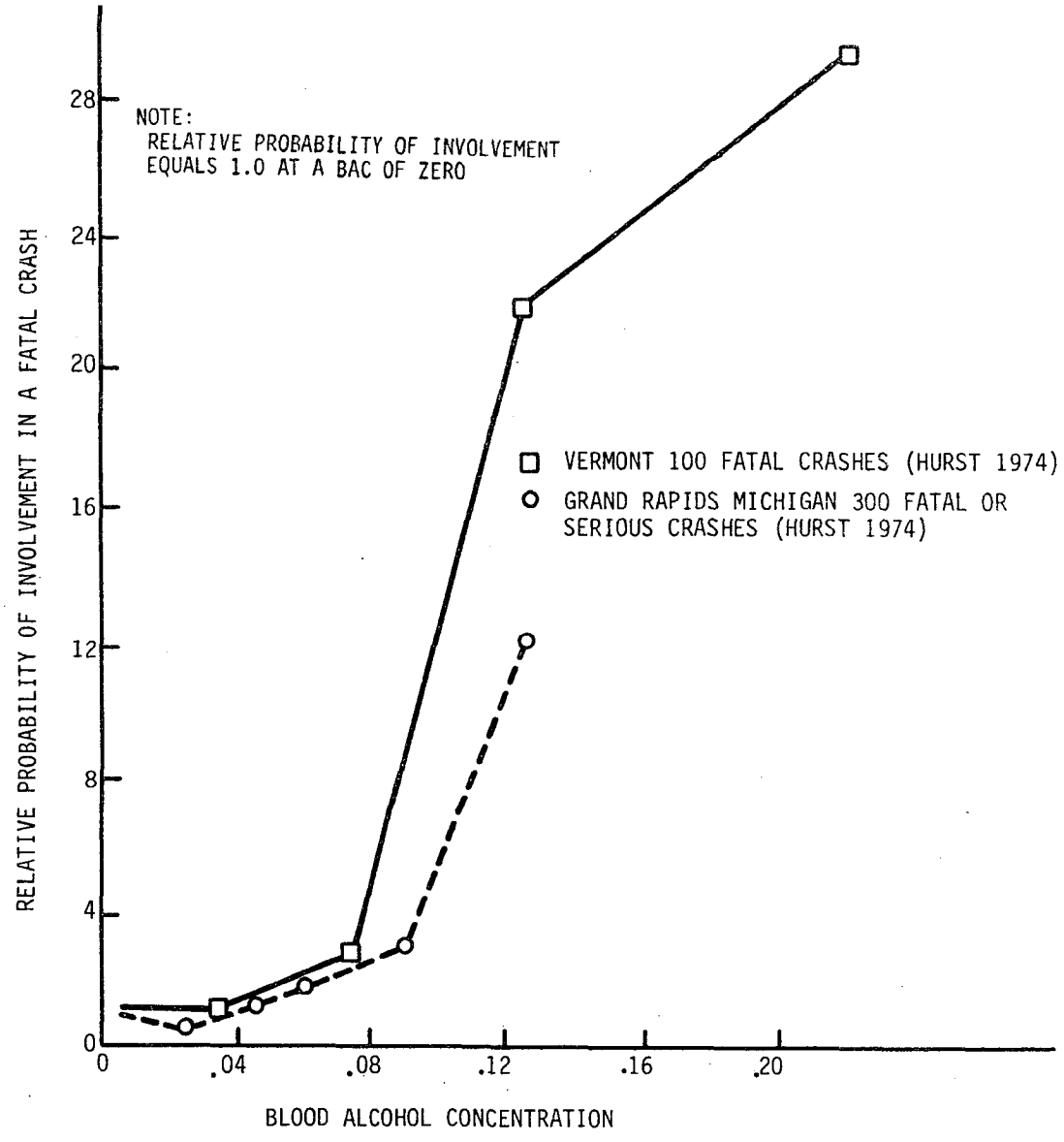


FIGURE 1. RELATIVE PROBABILITY OF FATAL CRASH INVOLVEMENT VS. BAC.

Table 1.

"Normal" Components of Alveolar Air

| Component | Percentage |
|---|---|
| Nitrogen | 75 % |
| Oxygen | 14 % |
| Water Vapor | 6 % |
| Carbon Dioxide | 5 % |

Trace components (at or below microgram/liter concentrations; see Krotoszynski, et al., 1979)

Acetaldehyde
Various alcohols, including ethyl alcohol
ketones, including acetone
carbon monoxide

Ingested Volatiles usually appear on the breath at very low levels (nanogram per liter range) and depend on foods and beverages ingested. However, significant quantities of ingested methyl and propyl alcohol and other organic solvents, have been reported in rare instances. Inhalation of industrial vapors on long exposure can build up significant breath concentrations. Tobacco smoke contains carbon monoxide and other volatile reducing substances; however, these are easily cleared from the breath by the standard police procedure requiring a 15-20 minute waiting period before breath testing.

Each breath tester type uses different chemical or physical properties of ethyl alcohol for detection and quantitation. The detection/quantitation principles used in current breath testers are widely employed in research and in industrial analytical application. They are:

- o oxidation-reduction reaction, monitored photometrically (Breathalyzer scheme)
- o gas chromatography
- o electro-chemical oxidation (fuel cell)
- o surface catalytic oxidation (catalytic burner)
- o infra-red photometry (non-dispersive)
- o semi-conductor detector (Taguchi-type)

A brief description of each instrument class and the nature of possible interference appears in the appendix.

## V. Measurement of Acetone Presence

Even though there are more than thirty evidential breath test models on the NHTSA Conforming Products List, only certain models of two current instrument types (infra-red and semi-conductor instruments) are unable to distinguish acetone from ethyl alcohol. Two instruments so affected and tested were the C.M.I., Inc. Intoxilyzer Model 4011A (infra-red) breath tester, which is on the CPL, and a semi-conductor breath tester which is not on the CPL now, Alcohol Countermeasures Systems' ALERT Model J3C. (The ALERT breath tester was developed by Borg-Warner in the early 1970s and subsequently sold to Alcohol Countermeasures Systems, Inc., where further modifications were made).

These two models do not incorporate acetone detection/warning circuitry, and were used to obtain data which would demonstrate the magnitude of the interference problem for infra-red and semi-conductor type breath testers without such circuitry. The degree of interference can be expected to vary somewhat from instrument to instrument depending on quality of individual circuits, band pass filters, sensors, etc. For example, it is possible to select band pass filters from a given production batch which will be essentially free from acetone interference. One instrument of each model was tested, so that between instrument, within model variability was not considered. Nevertheless, the results obtained still illustrate the magnitude of acetone presence one may expect of these types of breath testers.

In Figure 2, the response of the CMI Intoxilyzer 4011A to acetone is presented. The acetone-in-air sample was generated using a standard 34° Centigrade wet "simulator" containing aqueous acetone. The water/air partition coefficient for acetone at 34° C. necessary to determine the

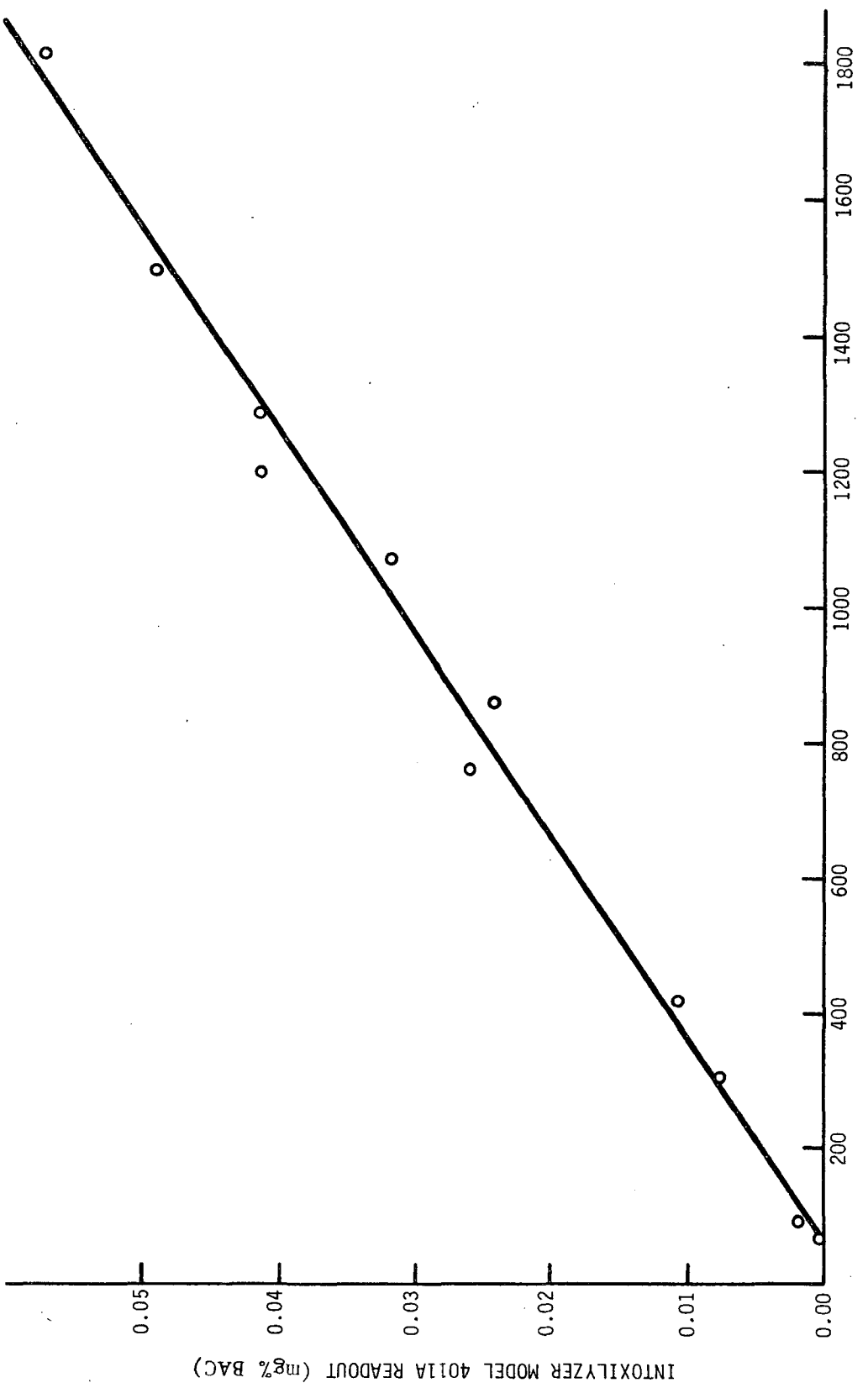


FIGURE 2. RESPONSE OF INTOXILYZER 4011A TO ACETONE.

acetone concentration in the air passed from the simulator into the breath tester was experimentally determined to be 365:1 (i.e. 365 volumes of headspeace air contain the same amount of acetone as one (1) volume of solution).

Criteria for interference from endogenous substances contained in the evidential breath tester Model Specifications state that no substance should produce interference greater than 0.01 % BAC. Using that criterion, it is clear that interference for the CMI Intoxilyzer 4011A instrument commences at approximately 400 micrograms of acetone per liter of air on breath.

Results obtained with the ALERT J3C breath tester, which has a numerical read-out, are shown in Figure 3. As indicated above, this device is no longer on the NHTSA CPL; it is also no longer sold. Nevertheless, the data show that the presence of acetone produced a BAC reading of 0.01 % at approximately the 200 microgram/liter level and that this type of sensor is more sensitive to acetone than the infra-red type.

## VI. Acetone Levels on the Breath

Acetone is a substance which occurs naturally in the blood, but its concentration is usually so low that it cannot be detected at all by breath testers currently in use by the police. Similar to volatile alcohols, including ethyl alcohol, acetone from external sources may appear in the breath at high concentration if ingested orally, or through the lungs as a vapor after long exposure to an environment with a high acetone concentration.

Only endogenous acetone generated by bodily processes will be considered in this report, as the exogenous is so rarely encountered that documentation is virtually non-existant.

Even though the level of acetone found in the normal person's blood is too low to cause interference in breath alcohol testing, the issue of interference has been raised continually throughout the development of breath testing equipment. The issue has been raised because diabetics and persons on weight reduction diets are known to generate acetone at higher than normal levels. However, little data have been available in the published literature with which to evaluate the problem.

### The Medical Literature on Diabetic and Dieting Patients

A summary of seven articles (reported in Table 2) lists the acetone levels of 1,250 dieting and diabetic patients of various types. The articles are listed chronologically and differentiate between diabetic, dieting, and control groups. The diabetic group was further identified according to disease severity or type (juvenile or adult onset). Comparisons of acetone concentration ranges, averages, and standard deviations reported show that overlaps occur among groups and that groups with low average concentration may have members with very high concentrations relative to the group average. For purposes of comparson,

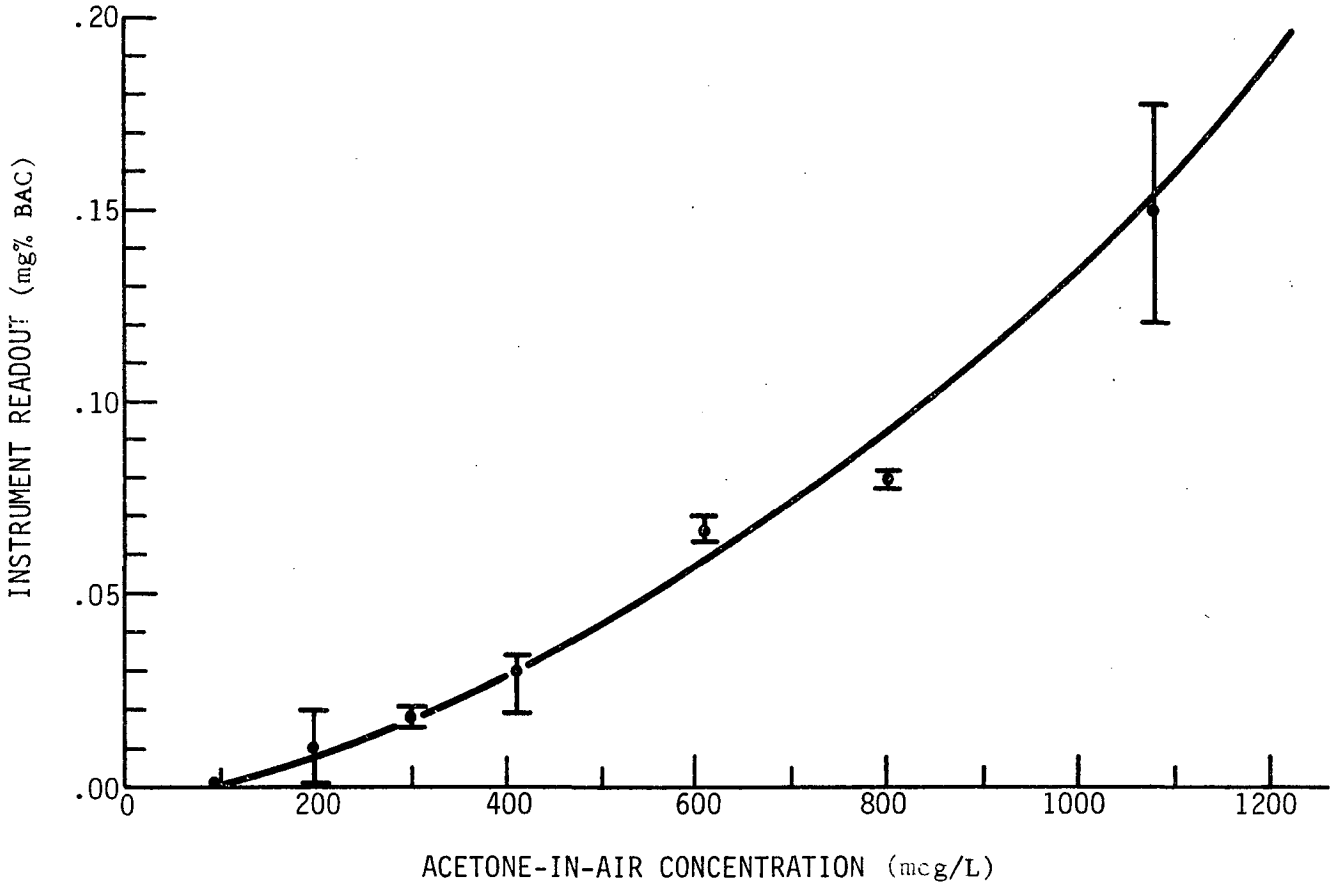


FIGURE 3. RESPONSE OF ALERT J3C TO ACETONE. EACH DATA POINT CORRESPONDS TO THE AVERAGE OF FOUR TESTS.

Table 2

REPORTED ACETONE LEVELS IN DIABETIC AND DIETING PATIENTS

| Source | Patient Type | Number of Cases | Breath-Acetone Concentration (mcg/l)** Mean | Standard Deviation | Range |
|---|---|---|---|---|---|
| Briggs and Shaffer (1921) | "Acidotic diabetic" | 4 | | | 278-560 |
| | Severe Diabetic | 4 | | | 100-600* |
| | Severe Diabetic (died shortly later) | 1 | | | 1680* |
| | Dieting (3 day fast) | 2 | | | 66-163 |
| Stewart & Boetner (1964) | Controls | 40 | - | - | 0.6 - 1.6 |
| | Adult onset Diabetics | 96 | 4.5 | 13.6 | |
| | Juvenile onset Diabetics | 129 | 30.1 | 116.2 | |
| | Acidotic Diabetics | 15 | - | - | up to 19,000 |
| Rooth & Ostensen (1966) | Controls | 67 | 1.10 | 0.88 | |
| | "Boderline" Diabetics | 40 | 0.8 | 0.41 | |
| | "Chemical" Diabetics | 42 | 1.17 | 0.95 | |
| | Adult onset Diabetics | 20 | 1.70 | 1.03 | |
| | Juvenile onset Diabetics | 49 | 4.42 | 4.94 | |
| | Dieting | 5 | - | - | 3-100 |
| Tassopoulous, Barnett & Fraser (1969) | Controls | 23 | 1.04 | 0.29 | -- |
| | Outpatient diabetics | 280 | - | - | 1.25-12.29 |
| | Hospitalized diabetics | 287 | - | - | 0.94-11.80 |
| | Dieting | 5 | - | - | up to 250 |
| Sulway, Trotter, Trotter, & Malins (1971) | Hospitalized Diabetics (measured on admission) | 12 | - | - | up to 527* |
| | Acidotic Diabetics | 27 | 1280* | 533 | |
| Mason & Hudson (1974) | Controls | 50 | - | - | 0 - 8.5 |
| | Outpatient Diabetics | 55 | 17.8 | 43.2 | -- |
| | Hospitalized Diabetics | 25 | 23.4 | 40.9 | -- |
| Lindner & Blackburn (1976) | Dieting (protein sparing diet) | 167 | - | - | 2.12 - 303 |

*These studies reported acetone levels in terms of mg/100 ml. blood-acetone. Values reported on this table represent the Breath-Acetone equivalent (in micrograms[mcg]/liter) based on a conversion factor of 330:1 (volume of breath/volume of blood).

**For frame of reference, 303 micrograms/liter Breath-Acetone is equivalent to 0.01 g/ml blood acetone.

Table 2 (continued)

SUMMARY OF ABOVE FINDINGS

| Type of Subjects | Total Number of Subjects in All Studies Cited | Range of Breath Acetone Levels (mcg/L) |
|---|---|---|
| Acidotic Diabetic | 36 | 0 - 19,000 |
| Hospitalized & Juvenile Onset | 502 | 0 - 527 |
| Adult onset and less severe types | 533 | 0 - 300 |
| Dieting | 179 | 2 - 303[a] |
| Controls | 180 | 0 - 9 |

[a] includes three diabetics

whenever results were reported in terms of blood-acetone concentrations, those values were converted to breath acetone values in micrograms/liter (as indicated by asterisks in the table) using the ratio 330 to 1 breath volume to blood volume equivalent (Mason and Hutson, 1975).

Considering all of the studies cited, 1,071 were diabetic patients and 179 were diet patients. Diet patients were classified according to type of diet: restricted calorie, no calorie, and protein-sparing (no carbohydrate). The no calorie and protein-sparing types of diet appear to produce similar levels of acetone in the blood.

These data show that in a diabetic who is not in a state of "control" (acidotic or seriously ill), acetone levels can increase hundreds or even thousands of times higher than normal. However, these individuals are generally so ill that it is probable they would be hospitalized and it is unlikely they would be able to drive a car. They are, therefore, not a factor in acetone interference assessments. The remaining diabetic patients can be separated according to maximums in acetone concentration, although wide fluctuations can be seen in both of the resulting groupings. Patients suffering from juvenile onset diabetes grouped with patients reported as "hospitalized" (probably primarily juvenile onset also) have acetone levels up to about 500 micograms/liter compared to the adult onset and less severe types who range up to about 135 micrograms/liter. Persons on diet programs can generate acetone levels to about 300 micrograms/liter, if the diet excludes carbohydrates, as the no calorie and protein-sparing diets do.

To obtain additional data on the level of acetone in diabetic and dieting patients, the University of Tennessee was contracted to gather this information from a sample of licensed drivers (see Table 3). A total of 205 diabetic patients, 205 dieting patients and 50 control patients were tested. All patients were under the care of physicians specializing in diabetes, or experienced in weight loss programs. All were out-patients. Of all 460 patients tested, only three had breath acetone levels above 150 micrograms/liter, namely 161, 315, and 448 micrograms/liter. Medical personnel immediately recognized that these three patients were not in "control", and they were given necessary medical treatment. At the 3-sigma level, the acetone concentration in the dieters in Table 3 ranged to 50 micrograms/liter, considerably lower than the maximum seen for comparable subjects of Lindner and Blackburn (1976), but consistent with the data of Rooth and Ostensen (1966). The latter only tested five dieters, however. The data collected by the Tennessee researchers are consistant with those in Table 2, representing 1,250 diabetic and dieting patients. It was also determined that ethyl alcohol had no effect on the measured acetone level in a subgroup of the dieters.

On the basis of the literature on diabetic and dieting patients summarized in Tables 2 and 3, a reasonable estimate of the practical maximum level at which acetone may be encountered in the breath of diabetics and dieters who are not hospitalized is about 300 micrograms/liter.

Table 3

BREATH ACETONE LEVELS IN DIETING AND DIABETIC HUMAN SUBJECTS*

| | N | Breath-Acetone Concentration (mcg/l) | | |
|---|---|---|---|---|
| | | Mean | Standard Deviation | Range |
| Dieters | 205 | 10.9 | 14.2 | 0.91- 94.0 |
| Diabetics | 205 | 10.9 | 227. | 0.91-449.0 |
| Controls | 50 | 2.1 | 0.85 | 0.01- 0.21 |

*This work was completed in 1981 by Dr. D. T. Stafford (Principal Investigator) of the University of Tennessee, Center for the Health Sciences, Memphis, TN under U. S. Department of Transportation Contract # DTRS-57-80-C-00021.

## Incidence of Acetone Among DWI Arrestees

The incidence of measurable levels of acetone in the gas chromatograph records of DWI arrestees were also examined, and are summarized in Table 4. These DWI acetone incidence data were obtained from State agency laboratories in Minnesota, Wyoming, Iowa, and Kansas. It was verified that the procedures and equipment used to make these recordings ensured the separate detection and quantitation of ethanol and acetone, if either were, in fact, present. The recordings were then examined individually to identify those pertaining to DWI arrestees and to determine the amount of acetone present.

The data summarized in Table 4 show that 28,352 individual DWI records were examined from Minnesota, Wyoming, and Iowa. Of that group, only eight recordings showed breath acetone appearing at 300 micrograms/liter or greater. That amounts to less than 0.03 percent of the total recordings examined.

It should be noted that the Iowa data did not include recordings with acetone present at less than 300 micrograms/liter. The Kansas data included measurements on samples taken from a variety of medical sources, and show a range and frequency of acetone occurrence in a population which apparently includes a number of severely sick persons. These data are included in Table 4, even though they are not as useful as the data from the other states.

## VII. Summary of Findings

While there are some ten million diabetics in this country and untold numbers of supervised and unsupervised dieters, indications are that the number of each group with acetone levels high enough to interfere with breath test readings is actually very small. The issue of acetone interference in breath alcohol testing has no practical significance in traffic law enforcement. It should be noted that this conclusion is consistent with the work of Dubowski (1983, 1984).

The group of diabetics with the highest reported levels of breath acetone, acidotic diabetics, are persons whose illness is so serious that death may result. While the threshhold for acidosis may be as low as 150-300 micrograms/liter (Mason, and Hutson, 1974; Stafford, 1981), breath acetone levels up to the 1,000 micrograms/liter range may appear in these acidotic persons, who are usually hospitalized.

It is not likely that dieters would become acidotic to the extent that acetone levels rise to the maximums seen in the acidotic diabetic, except in very extraordinary cases. Occasionally, news accounts will relate the death of a person who had not been medically monitored, following a protein-sparing diet. Although the acetone levels of these persons may have become very high compared to more typical dieters, the traffic safety significance of this type of dieter may be assumed to be very low.

Table 4

INCIDENCE OF ACETONE FOUND IN GAS CHROMATOGRAPH (GC)
RECORDS OF DWI ARRESTEES IN FOUR STATES

| Jurisdiction | Number of GC Records Reviewed | Dates | No. Records Positive for Any Acetone N | % | No. Records Above 303 Micrograms/Liter N | % | Mean of Cases above 303 mcg/l | Range |
|---|---|---|---|---|---|---|---|---|
| Minnesota | 10,420 | Dec. 1978 to Oct. 1980 | 11 | 0.106 | 6 | 0.058 | 657 | 303-1182 |
| Wyoming | 2,932 | 1971 to 1978 | 58 | 1.98 | 1 | 0.034 | 545 | ---- |
| Iowa | 15,000 | 1972 to 1979 | (a) | ---- | 2 | 0.013 | 424 | 303-545 |
| Kansas(b) | 13,000 | Jan. 1971 to Sept. 1977 | 147 | 1.13 | 51 | 0.392 | 539 | 333-1003 |

(a) Not reported because only cases > .01 grams/100 ml Blood Acetone (= 303 micrograms/liter breath acetone) reported.
(b) Sample includeds both medical and DWI cases; DWI cases were not separated out.

Sources of Data:

Minnesota: Minnesota Bureau of Criminal Apprehension
Alcohol Section
1346 University Ave.
St. Paul, MN 55104

Wyoming: Wyoming Chemical Testing Program
Public Health Laboratory Services
State Office Building
Cheyenne, WY 82001

Kansas: Department of Health and Environment
Office of Laboratories and Research
Forbes Building #740
Topeka, KS 66620

Iowa: Bureau of Criminal Investigation
Department of Public Safety, Criminalistics Lab
Wallace Building
Des Moines, Iowa 50319

A clear interpretation of the data from the medical literature (summarized in Tables 2 and 3) is complicated by the group designations used by the various authors. The diabetic patients in the Rooth & Ostensen (1966) study had low acetone levels and exhibited comparatively less variability. Their results indicate maximum acetone levels of about 20 micrograms/liter (mean + three-sigma for the juvenile onset group). In Tassopoulous, Barnett and Fraser (1969), the maximum in the diabetic data is about half of that. The remaining non-acidotic diabetic data, including the data in Table 3 (Stafford, 1981), indicate that maximum levels reached were due to rare outlaying cases. The data for the dieters (Rooth & Ostensen, 1966; Tassopoulous, Barnett, & Fraser, 1969; Lindner & Blackburn, 1976) including the data in Table 3 (Stafford, 1981), indicate that maximum breath acetone levels are less than those seen for outpatient diabetics by several hundred micrograms/liter. On the basis of these results on diabetic and dieting patients, a reasonable estimate of the practical maximum level at which acetone may be encountered on the breath is 300 micrograms/liter. Values exceeding 300 micrograms/liter are exceedingly rare and will almost always involve patients who require hospitalization and are not likely to be able to drive a car.

Finally, the frequency of occurrence of acetone among DWI arrestees at levels greater than 300 micrograms/liter is 8 in 28,352 cases, or about 0.03%. These data are consistent with what we find in the medical literature for diabetics and dieting patients.

Additional information

In recent years, manufacturers have responded to the issue of possible acetone interference with breath alcohol measurement for a number of reasons. The concern of police agencies that courts may not accept BAC readings of devices not designed to sense acetone independently from alcohol, coupled with keen competition for sales, have shaped manufacturers' responses.

Virtually all infra-red type breath tester manufacturers now offer equipment which incorporates acetone warning circuitry. There are approximately 1,000 older infra-red type evidential breath testers in use by police, which cannot detect the presence of acetone. These models are included in the NHTSA Conforming Products List. Of these, about two-thirds could be retrofitted with acetone warning circuitry. The remaining third cannot be retrofitted. However, many of these older units may be near the end of their useful life.

The semiconductor type of breath tester finds almost exclusive application in preliminary breath testing, where the acetone question is not considered important, because the results are not used in court. However, the Conforming Products List contains one semiconductor type breath tester which meets all of the performance rquirements of the NHTSA model specifications for breath alcohol testing devices.

Conclusions

Data regarding the incidence of measureable levels of acetone in the gas chromatograph records of 28,352 DWI arrestees in three States revealed only eight (8) cases (i.e. 0.028%) where breath acetone concentrations above 300 micrograms/liter were reported.

A review of the medical literature revealed that:

o For dieting patients, no cases of breath acetone concentration above 303 micrograms/liter were reported.

o for diabetic patients, the likelihood of finding an ambulatory patient displaying breath-acetone levels above 300 micrograms/liter is very low. While diabetic patients with breath acetone levels above this level have been reported in the literature, these individuals are generally so ill that it is probable they would be hospitalized and it is very unlikely they would be able to drive a car.

Only two quantitative evidential breath testers cannot distinguish between acetone and ethyl alcohol. Laboratory testing revealed that:

o For the Intoxilyzer 4011A, which is currently on the NHTSA Conforming Products List (CPL), acetone concentrations greater than about 400 micrograms/liter were required to produce false BAC readings of 0.01%.

o For the ALERT J3C, which is no longer on the CPL and is only in limited use by the military, acetone concentrations greater than about 200 micrograms/liter were required to produce false BAC readings of 0.01%.

The issue of acetone interference is breath alcohol testing has no practical significance in traffic law enforcement for the following reasons:

1) The level of acetone on the breath that would be required to produce even minimal BAC readings (e.g. 0.01% BAC) is rarely seen in on-the-road arrest situations (i.e. less than 0.028%).

2) Diabetic and dieting individuals who are well enough to drive do not have sufficient levels of acetone on their breath to increase BAC readings more than a very small amount (a practical maximum of 0.01%-0.02%).

3) The number of evidential breath testers in use that are unable to discriminate between acetone and ethyl alcohol is very small, estimated to be less than 1,000 nationwide. Most commercially available evidential breath testers sold today are made to distinguish acetone from ethyl alcohol, so that the issue is moot in these cases.

## Appendix

## Types of Breath Test Instruments

### Photometric Monitoring of Oxidation-Reduction Reaction

The first successful breath test devices deployed for police use were based on oxidation-reduction reactions, which had been used in analytical chemistry for many decades. In these schemes, the concentration of the oxidizing material (only potassium dichromate in sulphuric acid is currently used in breath testing) is monitored photometrically. The reducing agent is ethyl alcohol. Measurement is made before and after each test and the quantity of dichromate consumed is related to the amount of alcohol which was present. The quantity is, by appropriate controls, converted to BAC. Any substance present which will react with the dichromate will be counted as alcohol. The "trace" components listed in Table 1 may be oxidized by dichromate. Because of concern regarding the possible rare case of an individual having acetone in his breath far beyond normal trace levels, dichromate solutions used in current breath testers contain silver nitrate which catalyzes the reduction of ethyl alcohol. As a result, acetone present in the breath will react with the dichromate at a rate sufficiently slower from that for ethyl alcohol, which allows practical specificity to be achieved.

### Gas Chromotography

The development of gas chromotography as a general and very powerful analytical tool has had a profound effect in the study of chemical systems and is directly applicable to breath test instrumentation for police use. The process involves injection of a multicomponent sample, usually gaseous or liquid, into a carrier stream of inert gas. This sample mixture flows through a "column" of material which, by largely physical interaction between the sample and the material in the column, causes a separation of the sample components which elute from the column separately and are then separately detected and quantitated by one of several means. The nature of the process allows complete specificity under controlled conditions.

### Electrochemical Oxidation (Fuel Cell)

Oxidation-reduction reactions in fuel cells result in the passage of electrical current through the cell. The oxidation reaction occurs at one electrode and the reduction at the other. Which reaction occur depends on the voltage applied across the cell. When applied to breath testing, ethyl alcohol being the substance oxidized, the voltage applied precludes oxidation of acetone and most of the substances listed in Table 1, except for carbon monoxide and possibly other gases and vapors in tobacco smoke. Since tobacco smoke is easily avoided by observation of the normal 15 minute waiting period before testing, fuel cell testers are in practice, specific for alcohol.

Surface Catalytic Oxidation (Catalytic Burner)

This process involves the oxidation of substances at the surface of a catalyst, such as platinum while monitoring temperature change. Most combustible gases and vapors can be so oxidized, so that most of the trace substances in Table 1 will react. However, for other reasons, instruments based on this principle have not found acceptance by police. In effect, no devices based on this process are currently used in traffic law enforcement, nor is there reason to expect this situation to change in the future.

Infra-red Photometry

Like the oxidation-reduction process and gas chromatography, infra-red photometry is a general and widely used tool in analytical chemistry, which has been applied to breath testing. Because of its reliability and ease of operation, it has gained a large share of breath tester market sales in recent years. Its position in the market can be expected to continue to grow.

The concentration of a substance can be determined by measurement of the attenuation of a beam of radient energy through that substance according to the Beer-Lambert Law. Normally, a narrow wavelength band of radient energy is selected, the attenuation of which will correspond to absorption of that radient energy by the substance to be measured. The absorption will correspond to specific energy state transitions. In the infra-red region of the electromagnetic spectrum, the transitions involved correspond to bond stretching, rocking, and rotating motions. Organic molecules characteristically have bonds which are optically active in this region leading to rich infra-red spectra which may lead to interference in the analysis of mixtures. In breath testers, the C-H stretch of ethyl alcohol which corresponds to absorption centered at 3.9 microns is used, because it is clear of interference by the absorption spectra of water vapor. However, absorption by some of the trace substances of Table 1 occurs in this region, notably by acetone and other alcohol. Figure 2 shows the spectra of these compounds in this region. A common procedure for analysis of mixtures in analytical chemistry is the so-called "indirect" approach wherein two fundamentally different measurements are made on the mixture. It is only necessary that the measurement result is the sum of the results that would be obtained if the mixture componenets were measured separately. The measurements may or may not be of the same type. For instance, some infra-red based breath testers address the question of possible acetone interference by using two band pass filters to obtain two measurements of the mixture at two separate wavelength areas of the ethanol and acetone combined spectrum. Another uses only one band pass filter at 3.9 microns; the result of that measurement is combined with a measurement on the mixture using a semiconductor sensor (see below). The equations by which the components of the mixture are calculated are embodied in the electronics of the breath tester and rather than display concentration of alcohol alone,

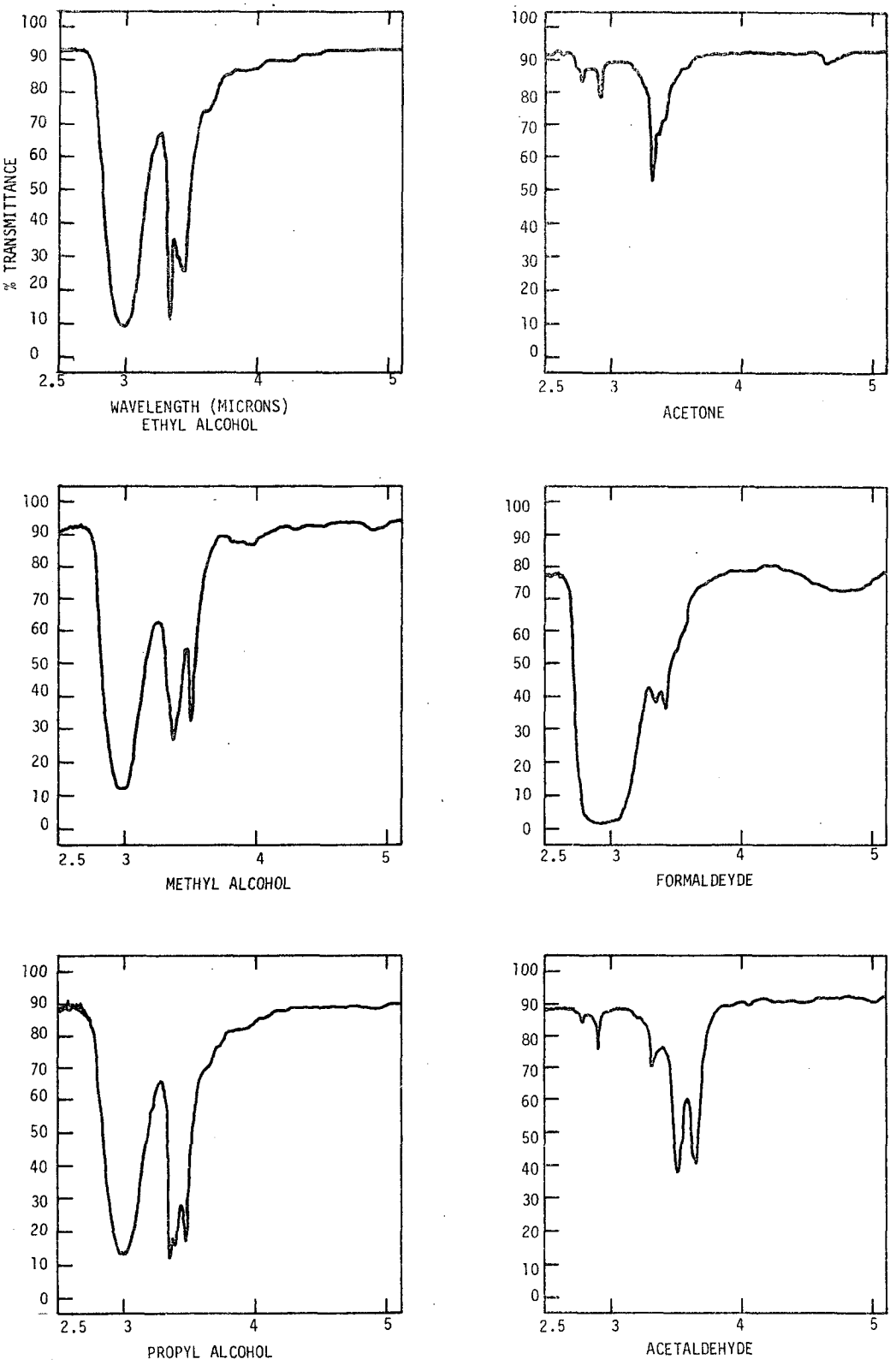


FIGURE 4. INFRA-RED SPECTRA NEAR 3.5 MICRONS: ETHYL ALCOHOL, METHYL ALCOHOL, 1-PROPLY ALCOHOL, ACETONE, FORMALDEHYDE, ACETADLDEHYDE.

alcohol and interferrent concentration is displayed with indication of the presence of an interferent if it is present above a selectable level. In practice, the breath tester is adjusted so that when acetone is present above the pre-selected critical level, the relationship between the outputs of the dual sensors is used to activate an acetone warning signal.

Semiconductor Gas Sensor (Taguchi Cell)

These sensors are thought to operate by the action of combustible gases on oxygen species present on the heated surface of the semi-conductor, tin oxide. Response of the sensor to these gases is exponential so that at alcohol concentrations of about 0.15 % BAC and above, response falls off. Below 0.15 % BAC, the response is linear. Since this behavior does not lead to false positive BACs, the sensor has found police use. Recent developments indicate that non-specificity of the sensor can be overcome by taking advantage of differences in diffusion rate of species associated with ethanol detection and acetone detection, or by use of more than one sensor operated at different temperatures and application of the "indirect" approach discussed above.

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