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Useful DUI Studies

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SPECIAL TOPICS SERIES

APRI

American
Prosecutors
Research Institute

Alcohol Toxicology for Prosecutors

Targeting Hardcore Impaired Drivers

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July 2003

American Prosecutors Research Institute

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Introduction: Using the Science of Toxicology as a Sword

Alcohol is the most used intoxicating substance in our society. Consider these facts:*

- 82% of people age 12 and older have used alcohol at least once in their lifetimes.
- Nearly half of all Americans age 12 and older (about 109 million people) have used alcohol in the past month.

The majority of Americans can drink without causing problems for themselves or their community, but as any prosecutor knows, at the center of a large number of cases is alcohol abuse and dependence. This is especially true of the hardcore impaired drivers who routinely appear in court.

Every defendant in a vehicular homicide or DUI has some basic knowledge of how alcohol works in the human body. Prosecutors hear it daily from the witness box:

> *"Yeah, I had a huge meal that night. Probably the biggest I ever had in my life. Ribs, chicken, shrimp, salad, potatoes and apple pie. Then, right before I left the restaurant—only 10 minutes before the police stopped me—I drank two mixed drinks. Rum & Coke with lots of ice."*

The defendant is claiming he wasn't impaired at the time of arrest because (1) the meal was so large it countered any effects of alcohol; (2) he had not absorbed the alcohol he drank until well after the time of arrest; and (3) the blood test taken an hour later reflects a blood alcohol level much higher than at the time of driving.

**Substance Abuse in Brief*, April 2003, Vol. 2, Issue 1, National Clearinghouse for Alcohol & Drug Information, Substance Abuse & Mental Health Services Administration, U.S. Department of Health & Human Services.

This defendant knows what most people and jurors know through their life experiences: *what* you eat and drink, and *when* you eat and drink directly impacts the effect of alcohol. For prosecutors, this means being prepared to combat bar room beliefs and conventional wisdom about alcohol through the science of toxicology.

Prosecutors can easily skewer defenses like those above by understanding toxicology principles such as how the body absorbs, distributes and eliminates alcohol. Prosecutors can even go back in time through retrograde extrapolation and scientifically estimate a defendant's blood alcohol concentration. And, for defendants who claim that they drank after they fled from the incident, the science can be used to show the defendant was still above the legal limit at the time of driving. In the end, the science of toxicology enables prosecutors to seek the truth and dispense justice.

This publication serves as a guide to the basic principles of toxicology and the role of experts in this science. Patrick Harding, Toxicology Section Supervisor in the Wisconsin State Laboratory of Hygiene, brings to these pages more than 25 years of experience in the field of forensic toxicology. He is chair of the National Safety Council Committee on Alcohol and Other Drugs and on the Board of Directors of the International Association for Chemical Testing. He has testified in more than 500 cases and garnered a national reputation as a lecturer to law enforcement officers and prosecutors. He also regularly teaches at the Ernest F. Hollings National Advocacy Center for the National District Attorneys Association's *Lethal Weapon: DUI Homicide* course.

For their invaluable review and assistance with the technical material, I would like to acknowledge research scientist and training specialist Paul Glover of North Carolina Department of Health & Human Services Forensic Alcohol Branch and Chip Walls, Technical Director of the Forensic Toxicology Laboratory at the University of Miami School of Medicine. Also, my thanks for the invaluable insight from Assistant District Attorney Jennifer Sommers of Monroe County, New York, who read the work through the lens of a masters degree in toxicology as well as years in the trenches prosecuting cases. And finally, a big APRI thank

you to Assistant District Attorney Jane Starnes of Georgetown, Texas, who brings a bit of Texas flavor to inspire readers with her success story of using retrograde extrapolation.

John Bobo
Director, National Traffic Law Center
American Prosecutors Research Institute
July 2003

Interpretation of Alcohol Results

By Patrick Harding,
Toxicology Section Supervisor
Wisconsin State Laboratory of Hygiene

Alcohol is a legal drug that is readily available, widely used and frequently abused with a well documented correlation between driver alcohol use and traffic crashes.[1] Most people have some idea of the pharmacology and toxicology of alcohol from personal experience or observation of others. Unfortunately, this leads to misconceptions about how alcohol is processed by the body (*pharmacokinetics*) and also how it acts on the body (*pharmacodynamics*). Most people have an idea of how a "drunk" person behaves without realizing that an *impaired driver* may not appear "drunk." For prosecutors, the challenge is to overcome pre-existing misconceptions about alcohol that judges and jurors may have.

In evaluating a case, a prosecutor's most crucial decision may be determining when an expert is needed to interpret the alcohol test in the context of the facts. A forensic toxicologist, or an expert trained in forensic toxicology, with appropriate experience and training in the pharmacology and toxicology of alcohol, can interpret the test results as they relate to the defendant's conduct.[2]

Measuring Alcohol

To interpret an alcohol test result, you must first understand how ethyl alcohol is measured in alcoholic beverages and how it is measured in the body.

Ethyl alcohol (the chemical name for the alcohol that we consume) is a small, water-soluble molecule that is readily absorbed and distributed by the blood throughout all of the water-containing components of the body. Ethyl alcohol is eliminated from the body by metabolism, excretion and evaporation. The process of alcohol metabolism begins at nearly the same time the alcohol is absorbed and continues until all of the alcohol is

removed. The measured *alcohol concentration* (AC) at any time results from the interaction of all of these processes.

Alcohol proof. Alcohol is commonly sold as beer, wine and distilled spirits. The concentration or strength of alcoholic beverages is measured in percent alcohol by volume or proof. The alcohol concentration of beer and other malt beverages is typically 3–6 % alcohol by volume. AC in wines is usually 9-14% by volume. AC in distilled spirits is expressed using the proof system, where the actual AC is one half of the proof.

Example: 80 proof distilled spirits are 40% alcohol by volume.

Alcohol in the body. Alcohol is readily detected in any bodily fluid that contains water, as well as in breath. The most common samples collected for law enforcement purposes are breath, blood and urine. Serum and plasma samples are usually obtained for medical purposes and are sometimes introduced for forensic purposes.

Forensic samples. In impaired driving cases, blood and urine samples are most often analyzed by gas chromatography in a forensic or hospital toxicology laboratory. Forensic samples are *whole blood* collected in vials containing an anti-coagulant and preservative. The analyst (chemist, toxicologist, criminalist, medical technologist, etc.) will possess a scientific degree and may be able to provide expert testimony to interpret the result. Law enforcement personnel, using devices designed for providing a legally admissible alcohol result, only analyze breath samples, and they may have little or no scientific background and be unable to provide testimony beyond the operation and operating principles of the instrument used.

Medical samples. Analyzed by hospital medical technologists using automated clinical analyzers, test results are frequently reported as being from "blood" even though serum or plasma was actually analyzed.

- *Serum* is the liquid that remains when blood is collected without an anti-coagulant and allowed to clot.

- *Plasma* is the liquid separated from whole blood treated with an anticoagulant when the blood cells are removed.

Hospital analysts may not be able to provide more than basic testimony about the analysis. Be sure to check with them before trial as to the level of their expertise.

Most statutes define AC in grams of alcohol per 100 milliliters (g/100 mL) of blood or urine and grams of alcohol per 210 liters (g/210 L) of breath. Medical AC results in serum and plasma samples are often expressed in milligrams of alcohol per deciliter (mg/dL). Milligrams are converted to grams by dividing by 1000. One dL = 100 mL. See example of conversion in Step 1 below.

Converting serum & plasma results to whole blood. Since it represents the water portion of whole blood, serum or plasma will have a higher AC than the whole blood from which it is derived. This means that serum and plasma alcohol results must be reduced to obtain a whole blood equivalent. The average ratio of serum and plasma AC to whole blood AC is approximately 1.14:1 (range 1.04:1 – 1.26:1).[3]

To convert a serum alcohol concentration to a whole blood equivalent:

Step 1. If necessary, convert the units to g/100 mL.

mg/dL = mg/100 mL

$$\frac{\text{mg/100 mL}}{1000} = \text{g/100 mL}$$

120 mg/*dL* = 0.120 g/100 *mL*

Step 2. Convert serum alcohol concentration (SAC) to an equivalent whole blood concentration (your witness may use a different average ratio than 1.14:1): Whole Blood AC = SAC /1.14.

$\frac{0.120}{1.14}$ = 0.105 g/100 mL = average whole blood equivalent

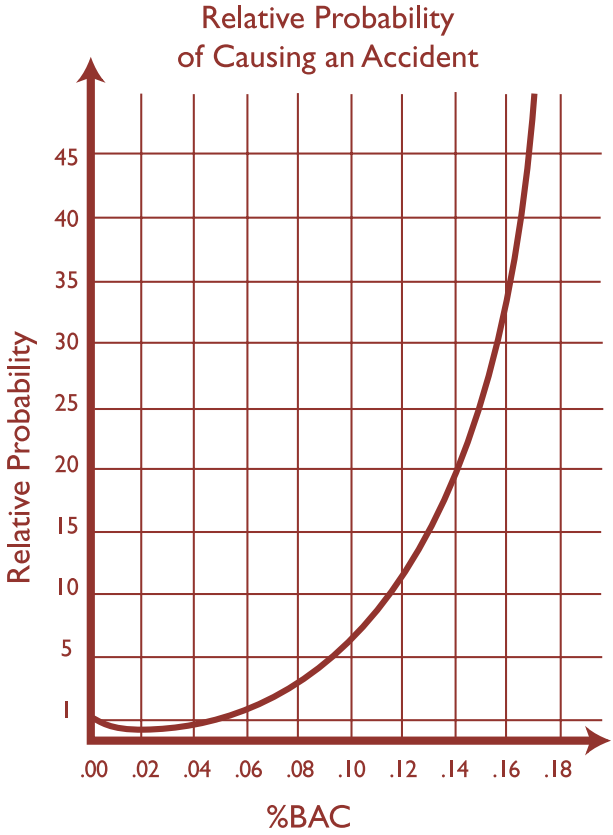
Effects of Alcohol in a Nutshell

The *pharmacodynamic* properties of alcohol classify it as a central nervous system depressant. Alcohol effects are dose-related. The more alcohol consumed the greater its effects. Alcohol impairs both cognition (the process of knowing, thinking, learning and judging) and psychomotor skills (voluntary movement). Alcohol first affects the most recently developed parts of the brain, which are responsible for judgment, inhibition, personality, intellectual and emotional states. As AC increases, the impairment of psychomotor functions such as muscular coordination, balance, eye movement, etc. also increases. As AC continues to increase, involuntary movement, such as respiration, is affected, leading to possible coma or death.

Much research has been done on the effects of alcohol on driving by studying individual driving-related tasks, operation of driving simulators, closed-course driving and the causes of crashes. Alcohol affects one's driving ability so dramatically because it increases reaction time and decreases information processing rate. It also impairs vision and visual perception, judgment and risk assessment. Tasks that require decision making or divided attention are especially sensitive to the effects of alcohol. Impairment of at least some skills and behaviors can be demonstrated at ANY measurable AC.[4] As alcohol concentrations increase above zero, the relative risk of being involved in a traffic crash also increases. (*Figure 1.)* The Committee on Alcohol and Other Drugs of the National Safety Council concluded that all individuals are impaired with respect to operating a motor vehicle at alcohol concentrations of 0.08 and above, while some individuals are impaired with respect to driving at concentrations below 0.08.[5]

Note: Impairment studies compare a subject's performance before and after alcohol dosing. An expert cannot state with certainty that one person is more or less impaired than another at a given AC, but an expert can say whether that person would be impaired compared to his or her own performance without having had any alcohol.

FIGURE 1



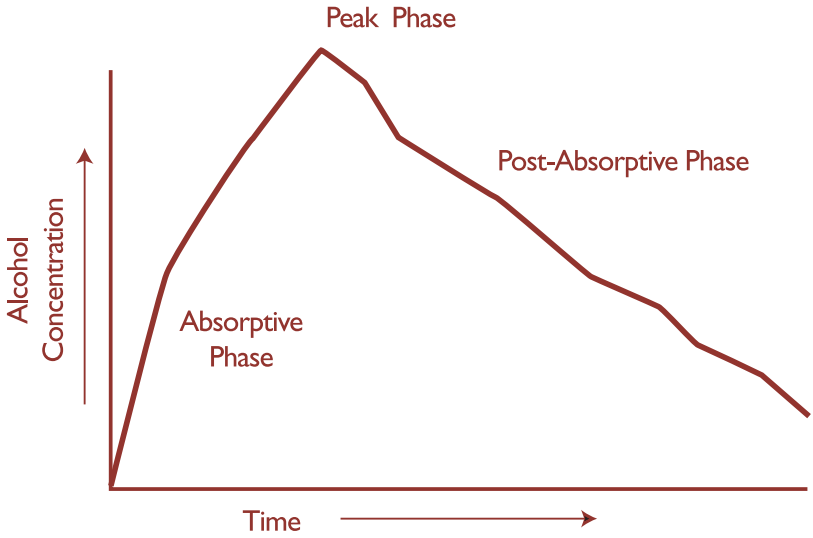
The Role of Alcohol in Traffic Accidents
The Grand Rapids Study [6]

Alcohol Concentration (AC) Curves

The time course of AC from the time of ingestion can be illustrated using a generalized alcohol curve. (*Figure 2.)* The curve can be divided into three phases: *the absorptive phase, peak phase* and *post-absorptive phase*. The duration of each phase, and therefore the shape of an alcohol curve

FIGURE 2

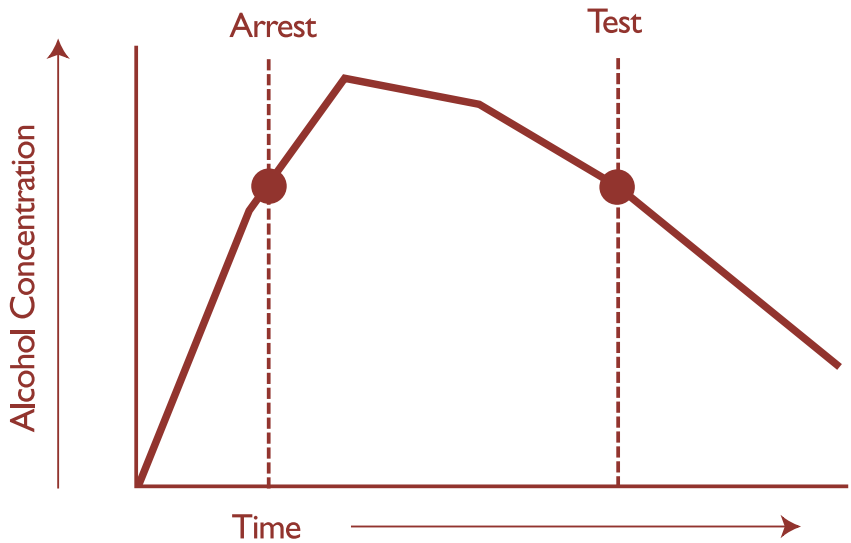
General Alcohol Concentration Curve



for a given situation, will vary according to any factors that affect the processes of absorption and elimination of alcohol, all of which occur simultaneously. If alcohol is absorbed more rapidly than it is being eliminated, the alcohol concentration will rise over time. If absorption and elimination rates are equal, the alcohol concentration will remain constant and a longer peak phase will result. Finally, when absorption has been completed, the alcohol concentration will decrease until the alcohol is completely eliminated. Be aware that any given alcohol concentration other than the peak AC will be achieved at least twice during a drinking session, once on the way up and again on the way down. (*Figure 3*.) An alcohol concentration from a single sample cannot by itself be used to predict whether a subject is absorptive, post-absorptive or at a peak AC. The measured alcohol concentration only provides a snapshot of the AC at the time of collection.

FIGURE 3

Alcohol Concentration Can Be the Same at the Time of Test as Arrest



Alcohol Concentration (AC) Estimates

The prosecutor may need to establish an AC at time of driving, rather than at the time that the test sample was obtained. Sometimes a sample cannot be taken until several hours after the driving, requiring expert testimony to relate the AC to the time of driving. The estimate may be complicated by allegations that additional alcohol was consumed after the crash or traffic offense and prior to obtaining the sample. The defense may claim that the alcohol concentration at the time of the offense was lower than at the time of the test due to the consumption of alcohol just prior to the offense (the so-called rising curve defense). The defense may also use an AC estimate based on the drinking history in an attempt to discredit the test result (i.e. "I only had two beers"). Conversely, the prosecutor may wish to discredit the defendant's drinking history by using the test result. Other scenarios, some quite imaginative, may be posed as defenses. A basic understanding of the principles of alcohol pharmacokinetics will aid in effectively dealing with these issues in court.

Note**:** By itself, the measured AC cannot be used to reliably estimate an AC at any other time, but the measured AC can be used as the foundation of an estimate when knowledge of how alcohol is absorbed, distributed and eliminated is combined with the facts surrounding the case.

Absorption

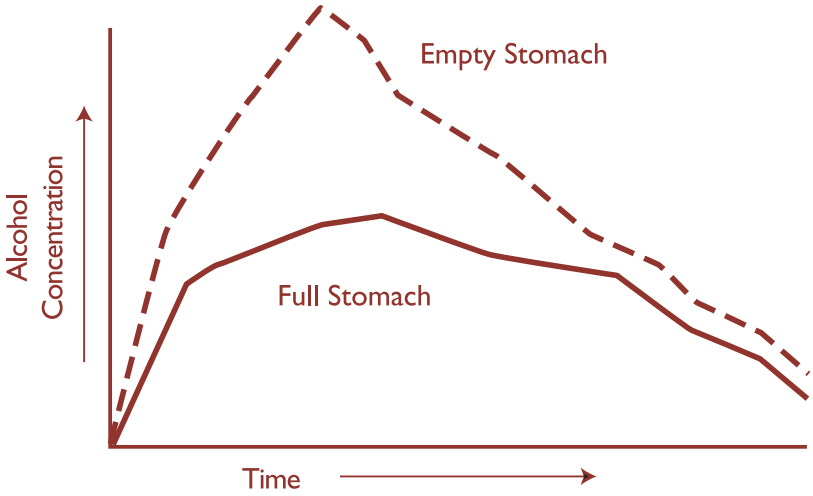
Absorption is the process of moving alcohol from outside the body into the bloodstream where it can be distributed throughout the body. As a small, completely water-soluble molecule, ethyl alcohol is readily absorbed into the mucous lining of the digestive tract. When it comes into contact with the digestive tract, alcohol is absorbed via simple diffusion into the mucous lining and then into the blood. The amount absorbed at any given site depends upon the surface area, the thickness of the lining and the blood supply. Unlike most other ingested substances, alcohol is not digested and can be absorbed unchanged directly through the stomach lining. Only about 20-25% of ingested alcohol is absorbed in this manner because the stomach has a relatively small surface area and limited blood supply. The remaining 75-80% of the alcohol is rapidly and efficiently absorbed when it leaves the stomach and enters the small intestine, which has a large surface area and rich blood supply.

Rate of Absorption and Time to Peak

Because alcohol is rapidly absorbed once it reaches the small intestine, anything that delays the stomach from emptying its contents into the small intestine will slow the rate of alcohol absorption. The most rapid absorption takes place when a 20% solution of alcohol is consumed on an empty stomach. Diluted drinks take somewhat longer to absorb. In concentrated drinks (greater than 40% by volume) alcohol acts as an irritant to the gastric lining and will be retained in the stomach until it can be diluted. Alcoholic beverages containing ingredients that require digestion, such as carbonated beverages, may also slow absorption somewhat. Absorption may also be affected by emotional state, shock and medications that impact stomach function and the general condition of the gastrointestinal tract. **The most important factor affecting absorption**

FIGURE 4

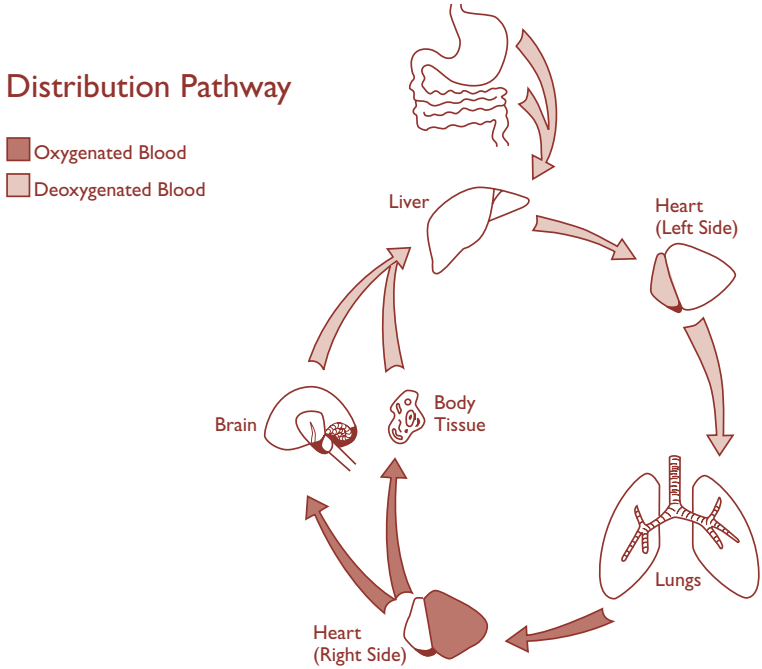
Impact of Food on Alcohol Absorption



is the presence of food in the stomach concurrent with alcohol. Food requires digestion and any alcohol trapped in food particles will take longer to be absorbed. The extent of the effect depends on the amount and type of food. *Figure 4* illustrates the effect of food on alcohol absorption. The delay in absorption causes a lower peak alcohol concentration that lasts longer compared to consumption on an empty stomach.

Absorption rates and times vary considerably between subjects—even within the same subject at different times under similar conditions. The rate of alcohol absorption is non-linear. An initial rapid rise in AC is followed by a gradual tapering off until a peak concentration is attained. Of greatest forensic use is the time it takes for alcohol to reach its peak concentration after consumption. **Peak concentrations are generally attained within 30 – 60 minutes of the cessation of drinking**. Because of the initial rapid rise of AC after drinking, most of the peak AC is reached within the first 30 minutes. This is true whether or not food is present, even though food can affect the magnitude of the peak

FIGURE 5



concentration.[7] When alcohol is consumed successively over time, as in a social drinking situation, peak concentrations are generally attained within 30 minutes of the last drink and may even be attained before the last drink is finished.[8]

Distribution

Once absorbed, alcohol is transported by the blood and distributed throughout the body. (*Figure 5*.) As blood flows to the body's organs and tissues, alcohol diffuses across membranes into all areas that contain water. Alcohol always moves by simple diffusion from a higher concentration to a lower concentration.

Because **alcohol is completely soluble in water**, the AC in the whole body is directly proportional to total body water content. Water content varies from person to person. Obese individuals have less water per

pound of body weight than individuals of average build because fat cells contain little water. Females tend to have a higher proportion of body fat than males. **About 68% of an average male's body weight is due to body water, while the percentage is 55% for average females**. In general, the heavier a person is, the greater the amount of alcohol that must be consumed to reach a specific alcohol concentration in the body. The relative alcohol concentration in any fluid or tissue is also directly related to its water content. The higher the water content, the higher the relative alcohol concentration.

The table of average distribution ratios below shows differences in alcohol concentration relative to whole blood.

Distribution Ratios	
Whole Blood	1.00
Blood Plasma/Serum	1.14
Blood Clot	0.77
Urine	1.35
Brain	1.17
Saliva	1.12
Liver	0.91
Whole Body: men	0.68
Whole Body: women	0.55
Fat	0.019

Elimination

Alcohol is eliminated from the body through metabolism, excretion and evaporation. **Metabolism accounts for approximately 95% of alcohol elimination**. Enzymes act on alcohol molecules to change them into other compounds; these by-products are further metabolized. Alcohol dehydrogenase (ADH) in the liver is the enzyme that is primarily responsible for alcohol metabolism. ADH is also located in the stomach lining, causing a small portion of an alcohol dose to be eliminated before it has a chance to be absorbed. Other enzyme systems also act on alcohol, coming into play especially at higher alcohol concentrations.

Alcohol is also excreted unchanged through urine, tears, sweat, semen and saliva. Each drop of urine that is produced and pooled in the bladder reflects the alcohol concentration of the circulating blood at that time. Because alcohol has a high vapor pressure at body temperatures, alcohol will evaporate from the blood into the lungs and be excreted in breath, allowing it to be measured in a breath sample.

Rate of elimination. The average rate of elimination (combining metabolism, excretion and evaporation) is between 0.015 to 0.018% per hour. Expressed in terms of common alcohol measurement units this is 0.015 - 0.018 g/100 mL or g/210 L per hour. Although the range of rates reported in the scientific literature can be quite large, as a practical matter you can expect a range of rates from 0.01 to 0.025% per hour in drinking drivers. Inexperienced drinkers tend to have a lower average rate than moderate drinkers, while chronic drinkers and alcoholics will have the highest average rates of elimination. Elimination rates do not vary significantly within the same person at different times, although alcohol will be eliminated more rapidly during periods of heavy drinking. At low AC's (0.02 and below), the rate of elimination slows considerably as the enzymes no longer have enough alcohol available to work at peak efficiency.

Because metabolism accounts for the vast majority of elimination, there is no practical way for a subject to alter it. As long as blood is flowing to the liver, alcohol will continue to be metabolized.

Calculating Alcohol Concentrations (AC)

An AC can be calculated based on a person's weight, gender and amount of alcohol consumed using the Widmark formula, named for Erik M. P. Widmark, the pioneering Swedish scientist who studied alcohol in the 1930's. Calculations using the Widmark formula can be used to show the maximum AC for a given person and given dose of alcohol. Conversely, the formula can be used to calculate the minimum amount of alcohol that must be consumed to achieve a given AC.

In simplified terms, the formula can be given as follows:

$$AC = \frac{\text{Alcohol dose in grams}}{\text{Body weight in grams x r}} \text{ x } 100$$

r = the whole body alcohol distribution ratio:
r = 0.55 for females
r = 0.68 for males

The alcohol dose in grams can be calculated using the following formula:

(Volume of drinks) x (AC of drinks) x 0.789 = grams of alcohol consumed.

Where the following conversion factors are used:
1 fl. oz. = 29.6 mL
1 mL alcohol = 0.789 grams alcohol

Example: If a 180 pound male defendant drank 3 fluid ounces of 86 proof whiskey, what would his maximum alcohol concentration be?
Hint: first determine the alcohol dose in grams, convert body weight to grams and then use Widmark's equation.

Step 1: Calculate the AC of drinks in 3 fl. oz. of 86 proof whiskey.

Beverage AC = 1/2 of proof
86 proof = 43 % by volume

Step 2: Convert the drinks consumed from ounces to milliliters.

1 fl. oz. = 29.6 mL
3 fl. oz. x 29.6 mL/fl. oz. = 88.8 mL

Step 3: Using the results from Step 1 & 2, calculate the alcohol dose consumed.

(Volume of drinks) x (AC of drinks) x 0.789 = grams of alcohol dose consumed.

88.8 mL x 0.43 x 0.789 g/mL = 30.1 g

Step 4: Convert the defendant's weight from pounds to grams.

1 pound = 454 grams
180 x 454 = 81,720 grams

Step 5: Now, plug the results from step 3 and 4 into Widmark's equation to calculate the defendant's maximum AC. Don't forget to use the distribution ratio of 0.68 for men or 0.55 for women.

$$AC = \frac{\text{Dose of alcohol, grams}}{\text{Body weight, grams x r}} \text{ x } 100$$

$$AC = \frac{30.1}{81{,}720 \text{ x } 0.68} \text{ x } 100 = \frac{30.1}{55569.6} \text{ x } 100 = 0.054$$

Answer: Approximately 0.05.

Question: What would the maximum alcohol concentration be if the defendant in the above example was a 120 pound woman who consumed 3 fl. oz. of 86 proof whiskey?

$$AC = \frac{30.1}{50880 \text{ x } 0.55} \text{ x } 100 = \frac{30.1}{27{,}984} \text{ x } 100 = 0.107$$

Answer: Approximately 0.11.

AC calculation charts based on the Widmark formula, such as Appendix 1 and 2, are widely available. Such charts typically define a "drink" as being one 12-ounce beer, 1 ounce of 100 proof distilled spirits or 4-5 ounces of wine. Each drink, as defined, will contain the same amount of alcohol.

The above calculations can only be used as a general guideline; there are many limitations that apply. The calculation only provides an estimate for the maximum AC, assuming complete absorption of a single dose of alcohol. Any factual variations in the figures, such as amount consumed, strength of drink, etc. will obviously affect the result. The formula also assumes an average distribution of body water. If the individual is obese, either a lower r value or an ideal weight should be substituted in the equation. Insurance companies publish tables of desirable weights that can be used for this purpose.

Estimating AC when drinks are consumed over time. The formula can be used to estimate AC when drinks are consumed over time by subtracting from the AC result, the amount of alcohol which would have been eliminated. Using an average rate of elimination, subtract 0.015 times the number of hours from estimated AC.

$$AC = \left[\frac{\text{Alcohol dose in grams}}{\text{Body weight in grams x r}} \text{ x } 100 \right] - [\text{elapsed time x } 0.015]$$

Example: A 120 pound female defendant of average build consumed 6 drinks containing 1 ounce each of 80 proof (40%) alcohol from 10:00 pm to 2:00 am. What AC will be achieved at 3:00 am?

Time from start of drinking to 3:00 am = 5 hours

$$AC = \left[\frac{6 \text{ oz. x } 29.6 \text{ x } 0.40 \text{ x } 0.789}{120 \text{ x } 454 \text{ x } 0.55} \text{ x } 100 \right] - [5 \text{ x } 0.015] = 0.187 - 0.075 = 0.112$$

Answer: The maximum expected AC at 3:00 would be approximately 0.11.

A calculated alcohol concentration is not as accurate or reliable as a measured AC. There is simply too much uncertainty in the calculation to use it for anything more than a general guideline or rough estimate.

Going Back in Time: Retrograde Extrapolation

Retrograde extrapolation is the process of estimating an alcohol concentration at an earlier time from a measured alcohol concentration at a later time. In most traffic cases, this means providing an estimate of AC at the time of the offense based on the measured AC at the time a sample of blood, breath or urine was obtained. Your witness must be provided with as much information about the case as possible. Useful information includes:

Time of offense
Time of test
Test result
Gender
Weight
Height
Food consumption

Drinking history
- *Number of drinks*
- *Size of drinks*
- *Concentration of alcohol in the drinks*
- *Timing of drinks*

An expert's estimation and testimony at trial will only be as good as the information provided. When there is a delay between the time of the crash and the test, a thorough police investigation is paramount. The most important parts of the drinking history for purposes of retrograde extrapolation are alcohol consumption in the hour prior to the offense and any consumption after the offense but before the test. Knowing where the defendant last consumed alcohol and its distance to the place of arrest can provide a minimum estimate of time to last drink. Similarly, developing a time line and assessing the availability of alcohol from the time of a crash to the time that police contacted the defendant will help in determining the likelihood of post-crash alcohol consumption.

Using Retrograde Extrapolation

Alcohol eliminated, estimating maximum AC.
Remember that as long as alcohol is present in the body it is being eliminated. Therefore the first step in a retrograde extrapolation is to estimate the amount of alcohol eliminated in the time between the offense and the test. Multiply the number of hours elapsed by the rate of elimination. An average rate may be used, remembering that the actual rate may be higher or lower than the stated average. This calculated amount must be *added* to the test result since it represents alcohol that was present at the time of the offense but eliminated before the test was taken.

Measured AC + [(Time of test – Time of driving) x 0.015] = Maximum AC

Example: A defendant is stopped by police at midnight, but the blood is not drawn until 3 am. Results from the state lab show the defendant's AC to be 0.07 g/100 mL. What would the defendant's maximum AC be at the time of driving?

0.07 + (3 hours x 0.015) = 0.115

Answer: The maximum AC at the time of driving was between 0.11 and 0.12.

Note: The resulting AC provides a good estimate only if there was no *unabsorbed alcohol* from recent drinking at the time of offense, and/or there was no alcohol consumed after arrest and before the test. As such, it represents the maximum AC at the time of driving.

Unabsorbed alcohol: estimating minimum AC. The minimum AC at the time of driving is obtained by subtracting the effect of unabsorbed alcohol from the maximum AC previously calculated. The amount to be subtracted is calculated using the Widmark formula given previously.

Maximum AC – (Effect of unabsorbed alcohol) = Minimum AC

To estimate the effect of unabsorbed alcohol, estimate the amount of alcohol and its effect on a person of the defendant's weight, gender and body build. Alcohol takes time to be absorbed after cessation of drinking. The amount of time it takes is highly variable, difficult to predict and impossible to determine after the fact. In spite of this, an expert can provide a useful estimate based on facts and assumptions that have a solid foundation in the scientific literature.

> **The fact that a large portion of an alcohol dose is absorbed within the first 30 minutes of consumption limits the extent that unabsorbed alcohol can affect a calculation.**

This is true even if food is present in the stomach. Also, remember that in social and prolonged drinking situations the peak AC is reached shortly after, or even before, the last drink is finished. Studies have shown that in the majority of cases, the rise in AC following a drink is no greater than 0.02 under a variety of dosing conditions, including food in the stomach.[9] This makes it unlikely, though not impossible, for a subject's drinking history to account for a large difference between an AC at the time of driving and the time of the test. If it can be determined that the last alcohol consumption occurred an hour or more prior to the time of the offense, absorption would have essentially been completed and no significant effect would be expected.

The amount of alcohol consumed within 30 – 60 minutes prior to the offense has the most forensic relevance. The method that a given witness uses and the assumptions upon which the calculation is based may vary. Many experts simply subtract the effect of one drink from the maximum for every estimate. Others may provide a conservative estimate by subtracting the effect of all alcohol consumed 30–60 minutes prior to the offense. The prosecutor should discuss the details of the case and find out what the witness will be able to say on the stand prior to the trial.

Example: A 5'10", 180 pound male defendant is arrested for DUI at 1:30 am. His AC at 2:30 am was measured at 0.13. His last drink was consumed rapidly at 1:25 am and consisted of 2 oz. of 80 proof liquor. What was his AC at 1:30?

Step 1. Estimate the alcohol eliminated from 1:30 to 2:30 am and add it to the test result.

$$0.13 + (1 \times 0.015) = 0.145$$

Step 2. Estimate the effect of unabsorbed alcohol. Assume that all of the last drink was unabsorbed (this is a conservative estimate since some of the last drink would have been absorbed by 1:30)

$$\text{Unabsorbed effect} = \frac{2 \times 29.6 \times 0.4 \times 0.8}{180 \times 454 \times 0.68} \times 100 = 0.034$$

Step 3.

$$0.145 - 0.034 = 0.111 \text{ (round to 0.11)}$$

Answer: Even assuming that all of the last drink was unabsorbed, it is unlikely (but not impossible) that the defendant's AC would have been below 0.10 at 1:30. But, **this calculation shows beyond a reasonable doubt that the defendant's AC would have been above 0.08 at 1:30.**

Post-Incident Drinking

Defendants may claim that alcohol was consumed after a crash, for instance, to "calm their nerves." A prosecutor may only become aware of this alleged alcohol consumption shortly before or during the trial. The effect of post-incident alcohol can be estimated using the same techniques described for unabsorbed alcohol. The magnitude of the effect will still depend on the amount of alcohol consumed, body weight, gender, time of consumption, etc. In this instance, however, the effect of all of the alcohol consumed is subtracted from the preliminary maximum AC estimate. It is important to still consider the effect of unabsorbed alcohol consumed prior to the incident in this calculation.

Maximum AC – (Unabsorbed alcohol effect) – (Post-Incident consumption effect) = AC at time of crash

Always try to provide your expert with enough information to perform an estimate prior to testimony. In this way the prosecutor can assess the impact of post-incident consumption ahead of time. In some cases, the amount of alcohol allegedly consumed is insufficient to place the defendant below the applicable per se level at the time of driving. In other cases, even though the alleged consumption would put the defendant below the per se level, it can be shown that the amount allegedly consumed is highly unlikely given the other known facts of the case.

Realities of AC Estimates

There are some practical considerations that a prosecutor should keep in mind regarding alcohol estimates.

1. An estimate, whether retrograde or forward, cannot be made with the same accuracy as the measured result.

2. Gender and obesity must be considered when using the Widmark equation or when using calculation charts and programs. Make sure the correct factor is used for males and females. For obese or overweight individuals use a lower r value or substitute an ideal weight (such as from insurance tables).

3. Only establish whether the AC at the time of the offense is above the applicable legal limit. It is usually not necessary for the witness to estimate what the AC would have been if it had been measured at the time of the offense. The more general the estimate, the less likely that the estimate can be challenged by "muddying the waters."

4. Understand that the witness must always make certain assumptions and be comfortable in using them.

Interpreting Multiple Test Results

Sometimes more than one alcohol test result is available in a case. Interpreting these results presents its own set of considerations.

Multiple breath results. You cannot infer a subject's position on an alcohol curve from a duplicate breath analysis[10]. The samples are taken too closely in time and there may be too much biological variability in delivering the two samples to draw any valid conclusions of "rising" or "falling" ACs.

Use caution when interpreting breath AC results taken over time, i.e. two reported results obtained more than a half hour apart. Breath AC reporting protocols usually use the lower result of two separate breath samples, after truncating (dropping) the third decimal place. This practice may mask the true differences in AC over time.

Multiple blood specimens. Two or more blood specimens, taken at least one hour apart, may be used to provide an indication of elimination rate, as the subject is usually post-absorptive by the time that blood samples are obtained. Note that this calculation can only be used as a guideline. Elimination rates are determined from more than two measurements. Inter-laboratory variability must be taken into account if the samples were analyzed by more than one laboratory.

Medical and forensic blood specimens. Medical alcohol tests are most likely performed on serum samples. A conversion to a whole blood equivalent must be made before comparing the two. Because of variability in the conversion and potential inter-laboratory differences, caution should be used in comparing the two results.

Breath and blood specimens. Breath and blood do not provide equivalent measurements. Breath testing instruments in the United States can be expected to underestimate the co-existing blood AC by 10 -15%, and often even more. Because of the uncertainty of an individual's blood:breath ratio at any given time, breath and blood specimens should not be used to infer or calculate a subject's position on an alcohol curve.

If both tests are available for use in a retrograde extrapolation, choose only one to work with.

Common Defenses

CLAIM: The defendant did not drink enough alcohol to achieve the measured result.
REALITY: Estimates of AC based on drinking histories can be notoriously inaccurate, even when the drinking occurs under scientifically controlled conditions. Forensically valid measurements have an established accuracy and precision that makes them a much more reliable indicator of AC than a calculated estimate.

CLAIM: The defendant drank just prior to the traffic offense; therefore, at the time of driving, his AC was lower than the AC sample obtained later – the Rising Alcohol Curve Defense.
REALITY: AC rarely rises more than 0.02 after the last drink in social drinking situations. Enough alcohol must be consumed to overcome the amount eliminated between the time of the offense and time of test to make a difference between the test result and the legal AC limit. Remember that alcohol is more rapidly absorbed in the first minutes following consumption, and that any potential effect of unabsorbed alcohol can be estimated by an expert using retrograde extrapolation.

CLAIM: The test result is invalid because alcohol was consumed after the crash.
REALITY: The result is still valid, but needs to be interpreted in the context of the claims. Consult your expert to determine the effect of the alleged consumption relative to the measured AC. Before trial, ask your expert to calculate how much post-crash alcohol the defendant would have had to consume to be below the legal AC at the time of the crash. That way you know ahead of time whether the defense claim has any validity and how that will impact your case.

Often, it isn't possible for the defendant to have consumed enough alcohol from the time of the crash to the test. The amount and time of the alleged consumption can be established through cross-examination, offi-

cer testimony, receipts, etc. Develop a time line from the crash time to the time at which the defendant was in custody. When did the incident occur? Where did the defendant obtain/consume alcohol afterwards? Did the defendant leave the scene? How far did the defendant go to get alcohol? How did he or she get there? How much time did it take? Are there any witnesses to corroborate the story?

CLAIM: The blood test is inaccurate based on a defense test of the same sample. When the defense tested the prosecution's blood sample, the defense test results were lower than the prosecution's test. Therefore, this creates a reasonable doubt to the reliability of the prosecution's test.
REALITY: Although blood alcohol concentrations are relatively stable, they will decrease over time. Every time a blood sample is opened, a small amount of the alcohol in it will be lost due to evaporation. In addition, non-enzymatic oxidation of the alcohol can occur (reducing the amount of alcohol) even in the presence of a preservative. Therefore, the elapsed time between the two analyses may be very important. In addition, some differences between results from different laboratories are expected. It is up to the defense to show that their result is more accurate and reliable than the original result. The prosecutor should examine the validity of the defense result with the same scrutiny that is given the prosecution's result.

Endnotes

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4 Studies showing impairment at low AC levels.
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5 "Every person, regardless of that person's previous experience with alcoholic beverage consumption, is impaired in driving performance if that person's alcohol concentration is 0.08* or more. *Alcohol concentration means either grams of alcohol per 100 ml of blood or grams of alcohol per 210 liters of breath." National Safety Council Committee on Alcohol and Other Drugs, October 26, 1997.

6 Borkenstein, R.F., et al., "The Role of the Drinking Driver in Traffic Accidents," Department of Police Administration, Indiana University (1964).

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b. Jones, A. and Neri, A. "Evaluation of Blood-Ethanol Profiles After Consumption of Alcohol Together With a Large Meal," *Journal of the Canadian Forensic Science Society*, vol. 24, no. 3, 1991, pp. 165-173.

8 Winek, C., Wahba, W, and Dowdell, J., "Determination of Absorption Time of Ethanol in Social Drinkers," *Forensic Science International*, vol 77, 1996, pp. 169-177.

9 Gullberg, R., "Variation in Blood Alcohol Concentration Following the Last Drink," *Journal of Police Science and Administration*, vol. 10, no. 3, 1982, pp. 289-296.

10 Duplicate breath tests refers to the common practice of analyzing two breath samples on each subject, usually taken 2-10 minutes apart.

First Person Prosecutor: Retrograde Extrapolation of Guilt

By Jane Starnes
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Those of us who try felony cases know that sometimes putting on a trial feels more like putting on a Broadway production, with all the drama involved. The last thing you need is evidentiary problems. But, if it feels like courts have made it more difficult to introduce blood and breath test evidence in the last few years, you're right. Remember when your biggest problem introducing evidence of a blood test in an alcohol-related case was whether you could find the nurse who drew the blood? Then, you'd just pray that she used Betadine instead of alcohol to swab the sample site. I truly miss the days when you could just put on the technical supervisor and say, "So, explain to the jury what retrograde extrapolation is," and he'd launch directly into his testimony about extrapolation and apply it to your defendant. As H.I. McDonnough said in *Raising Arizona*, "Those were the salad days."

In a recent intoxication manslaughter case, I had two blood samples: the hospital sample (drawn for medical purposes) and the mandatory law enforcement sample (drawn pursuant to statute as a result of a fatality). Finding the nurse (and yes, she used Betadine) was the least of my worries. To get both of these samples into evidence, I had to overcome the defense attorney's motion to suppress on chain of custody issues. Yet, after building the chain a link at a time, I still had to overcome the biggest obstacle to the blood test evidence: introducing retrograde extrapolation evidence. Jurors have to understand how tests taken hours after the wreck demonstrate that the defendant was intoxicated at the time of the wreck. The only way to do that is through retrograde extrapolation. But first, you have to get the evidence past the judge, and remember—no more salad days.

Many states require a *Frye* or *Daubert* hearing prior to admitting evidence of extrapolation in breath or blood tests, and courts readily exer-

cise the "gatekeeper" function dictated by these cases. In Texas, a number of judges are interpreting the case law to mean that 1) extrapolation evidence is never admissible, or 2) without extrapolation, your test is inadmissible because it's irrelevant. Not true. But, to get past your "gatekeeper" in a hearing about the reliability and validity of the science of toxicology, you should know some individual characteristics about your defendant, such as:

- The age and sex of the defendant
- Weight of the defendant
- Amount of alcohol consumed and volume of drinks
- Type of alcohol consumed
- Information about the length of the drinking spree
- Information about when and what the defendant last ate
- Drinking method (sipping, chug-a-lug, etc.)

How do you find out all these individual characteristics? Here are some suggestions:

- **Subpoena witnesses, particularly the defendant's drinking buddies, to grand jury, put them under oath, and question them**. I've found that there's nothing like a grand jury subpoena, especially after a witness calls his lawyer, who explains how perjury works, to make one of the defendant's friends, particularly a teenager, start spilling his guts. In my case, I was able to determine that my defendant and his four buddies were going to an out-of-town football game. During their road trip, they bought two 18-packs of Miller Lite, 12 ounce beers. We discovered what time they started drinking, that they took a break in the middle of the drinking binge, what time they started up again, and what time they stopped drinking (also known as the time the beer runs out). We found out what food was eaten and at what time. The buddies were able to give me an idea how many beers were consumed by each of them, and they could describe the drinking pattern. Friends can also shed some light on the defendant's drinking experience, such as how many years he's been drinking and how often they've seen him drink. You'll want to know this, because a hardcore alcoholic will eliminate and absorb differently than a novice drinker.

- **Subpoena the defendant's hospital records.** You will probably have already done this to get the blood test results, but the defendant's age and weight will be in here, too. You can also find this information in jail booking sheets, but as long as you're putting on medical personnel anyway, why not have the nurse who drew the blood read off age and weight during her testimony?

- **Issue a search warrant on hospital blood.** In jurisdictions where prosecutors are statutorily prohibited from issuing subpoenas on medical records, issue a search warrant for the medical blood sample. After all, it is evidence of a felony in possession of the hospital. There is no reason why this evidence should not be seized and tested as a routine course of the investigation.

- **Talk to the officers who were at the scene.** In my case, bottles of beer were found in the car and on the ground, along with a half-eaten pizza.

- **Talk to officers who went to the hospital.** See if the defendant made any statements while there. Did the defendant's drinking buddies go to the hospital, too? These days, with cell phones, news of a car wreck travels quickly, and you may find your pool of witnesses at the hospital.

- **Look at all your scene photos for food and drink evidence.** My defendant was so cool that he superglued Miller Lite bottle caps onto the dashboard of a two week old car.

Getting your extrapolation evidence admitted also takes a great deal of preparation of your expert witness. Discuss all the individual characteristics you've discovered with your expert. Discuss how he would affect calculations of various elimination rates. (If your expert insists that there is just one standard elimination rate, be scared.) If your expert is the egghead type who can't speak plain English, work with him until he can. Get him to explain his testimony to a "scientifically challenged" person. In my case, we shut one of our experts in a room with my investigator, Dean, until Dean could come out and explain the expert's testimony to

me. About a half hour later, Dean came out looking like the light bulb had lit up. He would have shouted, "Eureka!" except Dean thinks that's a vacuum cleaner. Dean sat down and not only explained the testimony to me where it made sense, but he was able to draw a diagram along with his explanation.

Another reason for talking at length to your expert before trial is that he or she can do many of the calculations beforehand and avoid making mathematical errors on the stand. Besides, how boring is it for the jury to sit there in silence while the witness does a math problem?

As for my case, we originally got a hung jury, but then the defendant pled guilty rather than go through another trial. He's now in prison. The victims' parents and I, along with a very dedicated paramedic, have given several presentations at local high schools based on this case. We even had the defendant's wrecked Z28 towed to the schools so that the kids can see with their own eyes the car in which their friends took their last ride. Sometimes the audience is in tears, but some of the kids will still have this glazed-over, bored look that anybody with a teenager has seen a million times. But, at every presentation, at least two or three kids come up and hug the victims' parents, and tell them how sorry they are. The parents always say, "If we just reached one."

Sometimes it feels like we're faced with a never-ending stream of drunk driving cases. Sometimes it feels like we're beating our heads against the wall when we go up against aggressive defense lawyers, deal with uncooperative witnesses, and juries who are all too eager to say, "There but for the grace of God . . ." and find a defendant not guilty. But like those high school kids, if we can just take impaired drivers off the road one defendant at a time, we've made a difference.

Appendix I
Alcohol Chart for Males

Prepared by the Wisconsin Department of Transportation

Body Weight	Number of Drinks 1	2	3	4	5	6	7	8	9	10	11	12
100 lb.	.038	.075	.113	.150	.188	.225	.263	.300	.338	.375	.413	.450
110 lb.	.034	.066	.103	.137	.172	.207	.241	.275	.309	.344	.379	.412
120 lb.	.031	.063	.094	.125	.156	.188	.219	.250	.281	.313	.344	.375
130 lb.	.029	.058	.087	.116	.145	.174	.203	.232	.261	.290	.320	.348
140 lb.	.027	.054	.080	.107	.134	.161	.188	.214	.241	.268	.295	.321
150 lb.	.025	.050	.075	.100	.125	.151	.176	.201	.226	.251	.276	.301
160 lb.	.023	.047	.070	.094	.117	.141	.164	.188	.211	.234	.258	.281
170 lb.	.022	.045	.066	.088	.110	.132	.155	.178	.200	.221	.244	.265
180 lb.	.021	.042	.063	.083	.104	.125	.146	.167	.188	.208	.229	.250
190 lb.	.020	.040	.059	.079	.099	.119	.138	.158	.179	.198	.217	.237
200 lb.	.019	.038	.056	.075	.094	.113	.131	.150	.169	.188	.206	.225
210 lb.	.018	.036	.053	.071	.090	.107	.125	.143	.161	.179	.197	.215
220 lb.	.017	.034	.051	.068	.085	.102	.119	.136	.153	.170	.188	.205
230 lb.	.016	.032	.049	.065	.081	.098	.115	.130	.147	.163	.180	.196
240 lb.	.016	.031	.047	.063	.078	.094	.109	.125	.141	.156	.172	.188

Appendix 2
Alcohol Chart for Females

Prepared by the Wisconsin Department of Transportation

Body Weight	Number of Drinks 1	2	3	4	5	6	7	8	9	10	11	12
90 lb.	.053	.106	.159	.212	.265	.318	.371	.424	.477	.530	.583	.636
100 lb.	.047	.094	.141	.188	.235	.282	.329	.376	.423	.470	.517	.564
110 lb.	.042	.084	.126	.168	.210	.252	.294	.336	.378	.420	.482	.504
120 lb.	.038	.076	.114	.152	.190	.228	.266	.304	.342	.380	.418	.456
130 lb.	.036	.072	.108	.144	.180	.216	.252	.228	.324	.360	.396	.432
140 lb.	.033	.066	.099	.132	.165	.198	.231	.264	.297	.330	.363	.396
150 lb.	.031	.062	.093	.124	.155	.186	.217	.248	.279	.310	.341	.372
160 lb.	.028	.056	.084	.112	.140	.168	.196	.224	.252	.280	.308	.336
170 lb.	.027	.054	.081	.108	.135	.162	.189	.216	.243	.270	.297	.324
180 lb.	.026	.052	.078	.104	.130	.156	.182	.208	.234	.260	.286	.312
190 lb.	.025	.050	.075	.100	.125	.150	.175	.200	.225	.250	.275	.300
200 lb.	.023	.046	.069	.092	.115	.138	.161	.184	.207	.230	.253	.276
210 lb.	.022	.044	.066	.088	.110	.132	.154	.176	.198	.220	.242	.264

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