Literature Review of Scientific Papers Concerning the Scientific Soundness of Time of Test Laws

Laws that prohibit driving after the consumption of an impairing amount alcohol generally fall into one of two categories; laws that define the offense at the time of driving or laws that define the offense at the time that the specimen was taken. The later are often referred to as time of test laws and they usually restrict the time that the specimen may be taken to a specific time period after the arrest or crash to two or three hours. Time of test laws greatly reduce the need for extrapolation of the alcohol concentration from the time that the specimen was taken back to the time of driving in order to prove the offense.

The Subcommittee on Alcohol Technology, Pharmacology and Technology is attempting to determine if time of test laws are scientifically sound and supported by the scientific literature. To accomplish this, the committee has reviewed more than 50 scientific papers and other important documents that deal the subject. A brief summary has been prepared for each paper.

The papers have been placed into one of the following groups:

A. Studies that attempt to determine the phase of alcohol absorption and metabolism of drinking drivers (n = 3 papers)

   Summary: Alcohol measurements performed within 2 hours of driving typically reflect, within the limits of experimental variability, the level at the time of driving and approximately 90% of these drivers were in the post absorptive plateau or elimination phase at the time of their crash or arrest.

B. Studies that express support for time of test laws (n = 3 papers)

   Summary: Speculation about the status of alcohol absorption in intoxicated drivers can be avoided by statutory definition of the analytical result at the time of the test as the relevant figure for prosecution. In cases where the statutory period of two or three hours between the driving and the time of the test is exceeded, error can be minimized by only extrapolating back to the end of the two or three hour period.

C. Studies that contain results that either support time of test laws or convey concerns about retrograde extrapolation (n = 19 papers)

   Summary: In view of the many variables, the results of retrograde extrapolation cannot be accepted as absolute proof of the alcohol concentration at a time prior to sampling in a given individual but can be used as a guide of what could be expected in an average person. A prediction of the peak alcohol concentration based on the Widmark's equation cannot be more than a rough guide. The degree of error in extrapolations is too great and so should be used with great caution or not at all. Until the necessary legislation is formulated; however, forensic scientists are obliged to provide the court with expert opinions on the alcohol concentration at the time of offense.

D. Studies that focus on the time necessary to achieve peak alcohol concentration following the consumption of alcohol (n = 13 papers)

   Summary: In both bolus and social drinking situations, time to peak alcohol concentration is generally less than 60 minutes.

E. Studies of a more general nature that deal with alcohol absorption, distribution, and/or elimination (n = 15 papers)

Summary: The absorption, distribution, and elimination of alcohol in the human body are discussed in detail.

F. Studies that tend to support retrograde extrapolation or have concerns about time of test laws (n = 3 papers)

Summary: Retrograde extrapolation is applicable in the forensic setting with scientific reliability when reasonable and justifiable assumptions are utilized and may be preferable to time of test laws in some abnormal drinking scenarios.

Time of Test References with Summaries

A. Studies that attempt to determine the phase of alcohol absorption and metabolism of drinking drivers.

1. "Differences Between Roadside and Subsequent Evidential Breath Alcohol Results and Their Forensic Significance," by R.G. Gullberg in *Journal of Studies on Alcohol*, Vol. 52, No. 4, 1991, pp. 311-317.
Summary of results: "Breath alcohol measurements performed within 2 hours of driving typically reflect, within the limits of experimental variability, the level at the time of driving. These results suggest that a legal interpretation of the results should be based on the results obtained at the time of test rather than those that are presumed at the time of driving."

2. "Comparing Roadside with Subsequent Breath Alcohol Analyses and Their Relevance to the Issue of Retrograde Extrapolation," by R.G. Gullberg and A. J. McElroy in *Forensic Science International*, 57 (1992) pp. 193-201.
Summary of results: "Tests conducted within 2 hours of driving will provide good estimates of alcohol concentration at the time of driving." The key is that this is still an estimation and to use the data to support ones estimation is too technical and would be confusing to the jury.

3. "Status of Alcohol Absorption in Drinking Drivers Killed in Traffic Accidents," by B.S. Levine and J.E. Smialek in *Journal of Forensic Sciences*, Vol. 45 (1) 2000, pages 3-6.
Summary of Results: By comparing alcohol concentrations in the blood and urine of deceased drunk drivers, the author's conclude that over 90% of these drivers were in the post absorptive plateau or elimination phase at the time of the crash. All subjects had died instantly or within 15 minutes of the crash, and autopsies performed by the Office of the Chief Medical Examiner, State of Maryland within 24 hours of the crash. The prompt handling is credited for the integrity of the specimens, as cessation of metabolic functions at death can cause changes in the hematocrit, thus making the BAC questionable, and in my mind, the use of UAC equally questionable, however, results concur with most other studies concerning living drunk driving subjects. Supports Time of Test simply in adding weight to evidence that subject is most likely in the post absorptive stage.

B. Studies that express support for time of test laws

1. "Absorption, Distribution and Elimination of Alcohol: Highway Safety Aspects," by K.M. Dubowski in *Journal of Studies on Alcohol*, Supplement No. 10, July 1985, pp. 98-108.

Summary of results: Extrapolation of a later alcohol test result to the time of the alleged offense is always of uncertain validity and therefore forensically unacceptable. The laws of different jurisdictions address this problem in various ways, as by specifying that the analysis result at the time of the test shall govern, or by judicially approving retrograde extrapolation of results, or by defining the offense to consist of driving a vehicle after having consumed sufficient alcohol to reach a specified alcohol concentration "at any relevant time after the driving."

2. "Peak Blood-Ethanol Concentration and the Time of Its Occurrence After Rapid Drinking on an Empty Stomach," by A.W. Jones, K. Jonsson, and A. Neri in *Journal of Forensic Sciences*, Vol. 36, No. 2, 1991: pp 376-385.
   Summary of results: The article illustrated that individuals have different rates at which peak BECs (blood ethanol concentration) are reached along with the numerous factors involved. To provide an expert opinion about the status of ethanol absorption forensic scientists must have accurate information. A large body of evidence does point to the notion that most drunk drivers have passed the peak BEC and are most probably in the post absorptive phase of ethanol metabolism. Speculation about the status of alcohol absorption in drunk drivers can be avoided by statutory definition of the analytical result at the time of the test as the relevant figure for prosecution. This approach is highly recommended when per se statutory limits of alcohol concentration are enforced.

3. "Rising Blood Alcohol Concentration" by A.W. Jones, Barry Logan in Drug Abuse Handbook, edited by Steven B. Karch, M.D., 1998, CRC Press LLC, Section 13.2.1.3: pp. 1010-1012.
   Summary of results: "Much can be gained by statutory definition of the relevant BAC or BrAC as that prevailing at the time of the chemical test and not at the time of driving. Unfortunately, many jurisdictions persist with using BAC or BrAC at the time of driving as the figure needed for prosecution of DUI suspects. Other jurisdictions accept the chemical test result, provided it was obtained within two hours of the driving, as being equivalent to the BAC at the time of driving. Samples of blood or breath taken outside this time frame require the prosecution to estimate the BAC from time of sampling to the time of driving which is always subject to some uncertainty. In cases where the statutory period of two or three hours between the driving and the time of the test is exceeded, error can be minimized (in the defendant's favor), by only extrapolating back to the end of the two or three hour period."

C. Studies that contain results that either support time of test laws or convey concerns about retrograde extrapolation

1. "Principles and Applications of Medicolegal Alcohol Determination" by E.M.P. Widmark. Translated from the 1932 German edition. Biomedical Publications, Davis, CA, 1981.
   Summary of results: this paper is of great historical value and the origin of retrograde extrapolation. With sufficient information one may estimate alcohol concentrations at times other than time of test.

2. Testimony given before the Committee regarding the new Breathalyzer legislation proposed in Bill C150 Canada Parliament. Minutes of proceedings and evidence of the Standing Committee on Justice and Legal Affairs, Ottawa, Queen's Printer, 28th Parliament, 1st Session, March 18, 1969; pp 451-469.
   Summary of results: Testimony to Canadian Committee of Parliament concerning time of test law. Testimony supports time of test, but is very weak and non-scientific.

3. "Blood Alcohol Calculations" by W.E. Cooper, T.G. Schwar, L.S. Smith in Alcohol, Drugs and Road Traffic, 1979, Juta & Company Ltd., Chapter 23.
Summary of results: Conclusion of Authors: "In view of the many variables, the results of back-calculations cannot be accepted as absolute proof of the blood alcohol level at a time prior to sampling in a given individual but can be used as a guide of what could be expected in an average person."

4. "The Absorption and Elimination of Alcohol" in Drink, Drugs and Driving, Second Edition by H.J. Walls and Alistair Brownlie, Sweet and Maxwell, London, UK, 1985: pp 9-21.
Summary of results: "The three most important quantities of which the blood-alcohol curve is an expression are: 1) the time until the peak 2) the concentration at the peak 3) the rate of fall of the blood-alcohol concentration after the peak. A prediction of the peak concentration based on the Widmark's equation cannot be more than a rough guide. A constant rate of disappearance of blood alcohol, which accords reasonably well with the experimental results, should be assumed in practice if any calculations have to be made. Careful and reliable experimenters have found some evidence that the rate varies slightly with the blood-alcohol level, age and degree of habituation of alcohol."

5. "Blood Alcohol: The Concentration - Time Curve and Retrospective Estimation of Level," by M. J. Lewis in *Journal of the Forensic Science Society* 1986; 26: 95-113.
Summary of results: This paper discusses the variable metabolic rate of alcohol and the use of Michaelis-Menton kinetics in conjunction with the traditional steady-rate elimination to give a more realistic assessment of retrospective estimates. Attention is given to the differences observed for various AC levels (high and low). Estimates based on linear extrapolation are more accurate when AC levels are relatively low and are being made in relatively short time spans from the time of the incident.

6. "The Individual and the Estimation of his Blood Alcohol Concentration from Intake, with Particular Reference to the "Hip-flask" Drink" by M.J. Lewis in a Commentary in *Forensic Science Society* 1996, pp. 19-27.
Summary of results: Introduces a concept of Specific Volume of Distribution for alcohol within the body, which allows for tailoring retrospective estimation to the *individual*. Specific discussion is given to the metabolic process involving the extra-drink situation.

7. "Problems and Pitfalls with Back-Tracking BAC to the Time of Driving" by A. Wayne Jones in *DWI Journal: Law and Science*, Vol. 3, No. 6, 1988.
Summary of Results: Retrograde extrapolation in DWI cases is problematic, with laboratory and controlled tests not always being indicative of drinking in the wild where the control of eating, drinking is not present. The degree error in extrapolations is too great and so should be used with great caution or not at all.

8. "Pharmacokinetics of Alcohol and the Law" by Peter Taberner *in Trends in Pharmacological Sciences*, Vol. 9, No. 2, 1988: pp 47-48. Elsevier Publications.
Summary of results: The author uses one subject to demonstrate three drinking scenarios. He briefly discusses the pitfalls of testifying about back extrapolation due to the many variables involved.

9. "Disappearance Rate of Alcohol from the Blood of Drunk Drivers Calculated from Two

Consecutive Samples; What do the results really mean?" by W. Neutebam and Wayne Jones in *Forensic Science International*, Vol. 45, 1990: pp 107-115.
Summary of Results: 1314 cases evaluated from double samples of blood collected over 5.5-year period in Sweden. Time between samples for each case was 10 - 40 minutes. Range of elimination rates were 0.10 mg/ml/hr - 0.64 mg/ml/hr, with mean of 0.22 mg/ml/hr. BAC of targeted population coincided with BAC of overall population of tested drunk driving suspects in Sweden, so materials are representative. Paper supports Time of Test Law due to range of elimination rates, even though mean of samples is consistent with elimination rate/range used for retrograde extrapolation.

10. "Backtracking Booze with Bayes - the retrospective interpretation of blood alcohol data" by P.R. Jackson, G.T. Tucker and H.F. Woods in *British Journal of Clinical Pharmacology*, Vol. 31, No. 1, 1991: pp 55-63.
Summary of results: Paper describes a computer simulation utilizing a Bayesian method used to conduct retrograde extrapolation of a subject's alcohol concentration based on testimony in a court case. Explains difficulties in performing retrograde extrapolation.

11. "Evaluation of Blood-Ethanol Profiles After Consumption of Alcohol Together with a Large Meal," by A.W. Jones and A. Neri in *Journal Canadian Society of Forensic Science*, Vol. 24, Num. 3, September 1991, pp. 165-173.
Summary of results: Subjects drank for three hours. The time from end of drinking to maximum BrAC averaged 12 minutes range 4 to 22 minutes. "The results presented in this paper emphasize the need for caution when engaging in retrograde extrapolation of BAC for legal purposes. In some individuals, the absorption of alcohol might proceed for several hours after the end of drinking. However, despite this prolonged absorption phase, about 80% of the final peak BAC seems to be reached within 0-10 minutes after the end of eating and drinking. This is an important observation. The problems and uncertainties associated with back estimation of BAC could be avoided if drinking and driving statutes were defined as the BAC existing at the time of sampling as the relevant figure for prosecution. Until the necessary legislation is formulated, forensic scientists are obliged to provide the court with expert opinions on the BAC at the time of offense."

12. "Ethanol Kinetics: extent of error in back extrapolation procedures" by Y. Al-Lanqawi, T.A. Moreland, J. McEwen, F. Halliday, C.J. Durnin, I.H. Stevenson in *Br. J. Clin. Pharmac.* (1992), 34, pp. 316-321.
Summary of results: "These results indicate that because the kinetics of ethanol are associated with substantial inter-subject variability the use of a single slope value to back calculate blood concentrations can give rise to considerable error." Lack of cooperation from suspected offenders might also be a problem.

13. "Guidelines for Retrograde Extrapolation of Blood Alcohol Concentrations" by B. Hodgson and D. Taylor in Proceedings of the 12th International Conference on Alcohol, Drugs and Traffic Safety, Cologne, Germany, 29 September - 2 October 1992, Band 1, Verlag TÜV Rheinland, Cologne, 1993: pp 452-455.
Summary of results: "In relation to the established guidelines, our data suggest that the lower limit of 10 mg% per hour is more than generous, especially for women. On the other hand the data indicate that we should be more flexible with an upper limit. Indeed the data support the contention of some experts (2) that employing a range of 10 to 25 mg% per hour is more realistic, again

especially for women. Since the great majority of retrograde calculations are for charges against drinking drivers, an upper limit is not nearly as crucial as a lower limit.

The experiments precluded us from making definitive conclusions about the occurrence of a plateau or its duration. There was no predictable pattern indicating when a plateau is likely to occur, but the data does support the use of 60 minutes as a reasonable period in back extrapolation calculations. This duration could be applied in any drinking situation: social or larger."

14. "Mathematical Modeling of Ethanol Metabolism in Normal Subjects and Chronic Alcohol Misusers," by G..D. Smith, L.J. Shaw, P.K. Maini, R.J. Ward, J.J. Peters and J.D. Murray in *Alcohol and Alcoholism*, Vol. 28, No. 1, 1993: pp 25-32.
Summary of results: The results presented here could have two different effects on the so-called "back-tracking" procedure. Since one of the test groups appears to metabolize ethanol some 30% faster, use of a standard rate based on control subjects would underestimate the backtracked value. Secondly, since a large number of subjects in various groups showed a first order phase to the disappearance of ethanol from the blood, the timing of the blood sample becomes important. If the blood sample is taken within 1 hr of the last drink, extrapolation could result in too high a value.

15. "Disappearance Rate of Ethanol from the Blood of Human Subjects: Implications in Forensic Toxicology," by A.W. Jones in *Journal of Forensic Sciences*, Vol. 38, No. 1, 1993: pp 104-118.
Summary of results: The study confirms Widmark and that a realistic value for elimination of 16 mg/dL/h is valid for moderate male drinkers. The study shows that variable rate of elimination might be as low as 8 mg/dL/h or as high as 36 mg/dL/h. The study also shows different factors could cause variation but will be within a given range of elimination.

16. "Considering Measurement Variability when Performing Retrograde Extrapolation of Breath Alcohol Results - Letter to the Editor," by Rod Gullberg *in Journal of Analytical Toxicology*, Vol. 18, March/April 1994: pp 126-127.
Summary of Results: Letter explains that variables associated with a pair of breath samples taken 1.5 hours after the incident in question. It is statistically probable that the BrAC at the time of the incident would be measurably the same as the BrAC at the time of the analysis.

17. "Guidelines for Estimating the Amount of Alcohol Consumed From a Single Measurement of Blood Alcohol Concentration: Re-evaluation of Widmark's Equation" by R.G. Gullberg, A.W. Jones in *For Sci Intl*, 69 (1994) pp. 119-130.
Summary of results: "Indeed, we do not intend to encourage back estimation but instead we want to highlight the uncertainty associated with such calculations. Estimating the amount of alcohol consumed is difficult to defend since drinking histories are often unreliable and values for $\exists$ and Δ are unknown for individual drunk driving suspects. Moreover, the phase of alcohol metabolism when the blood was drawn is uncertain even if a rising BAC seems unlikely." "Widmark's method provides reasonable estimates of the actual amount consumed and the uncertainty in this computed value is about ~±20%."

18. "Letter to the Editor Author's Response," by R.G. Gullberg and A. J. McElroy in *Forensic Science International*, 73 (1995) pp. 213-215.
Summary of results: This letter addresses Dr. Hlastala's criticism of their conclusions of the above paper. The authors feel that Dr. Hlastala completely misinterpreted their conclusion that evidentiary breath alcohol analyses performed within 2 hours of driving appear to be good

estimates and certainly not overestimates, of the BrAC at the time of driving for medico-legal purposes. The authors admit that it is possible that the BrAC could be increasing, but in their study there was no measurable change of increase over time. Only 2.5% of the individuals measured were decreasing, everyone else remained the same. The authors still feel that extrapolation is unwarranted in these cases.

19. Report: "Toward Eliminating Impaired Driving". Report of the Standing Committee on Justice and Human Rights, House of Commons, May 1999. pp 23-24. Available on the Parliamentary Web site: www.parl.gc.ca/InfoComDoc/36/1/JURI/Studies/Reports/jurirp21-e.htm
Summary of Results: This committee is in Canada. Canadian law allows peace officer to demand breath or blood test within two hours after offence. Sample taken within two hours indicates subjects BAC at the time of offense provided other specific requirements are met. The committee recommended that the law be changed to allow police officers to *demand* a breath or blood test up to three hours after offence. Presumption of BAC at the time of offence is still limited to breath or blood test taken within two hours after offence.

D. Studies that focus on the time necessary to achieve peak alcohol concentration following the consumption of alcohol

1. "Ethanol Absorption After Bolus Ingestion of an Alcoholic Beverage. A Medico-Legal Problem," by E. A. Dittmar and V. Dorian in *Canadian Society of Forensic Science Journal*, Vol. 15, No. 2 (1982) pp. 57-65.
Summary of results: With social drinking or bolus ingestion, the alcohol level will plateau in no more than an hour from last ingestion.

2. "Blood Alcohol Concentrations Reached in Human Subjects after Consumption of Alcoholic Beverages in a Social Setting" by Nizar Shajani and Heather Dinn in *Canadian Society of Forensic Science Journal*, Vol. 18, No. 1, 1985: pp 38-48.
Summary of results: Rather than take a clinical approach to administering alcohol to their subjects, the authors of this study administered alcohol over an extended period of time (4 hrs) and under a relaxed social environment. The following results were observed: 1) the average time for the 8 men and 8 women to reach max. BAC after last drink was 35 min., 2) the average post absorptive rate of elimination is 0.193g/hr., 3) the authors report that their experiment supports their standing with regards to retrograde extrapolation, i.e., when giving an opinion to always qualify it in court by stressing the result is the **theoretical maximum** absorption rate, and, lastly, the calculated BAC results were 27% higher than the actual experimentally obtained BAC.

3. "Status of Alcohol Absorption Among Drinking Drivers - Letter to the Editor" A.W. Jones *Journal of Analytical Toxicology*, Vol. 14, May/June 1990, pp. 198-200.
Summary of results: Results support the notion that after heavy social drinking over several hours the BAC profile should be postabsorptive 30 minutes after end of drinking. Three lines of evidence support the notion that the vast majority of suspects are postabsorptive or on a plateau when blood is taken for ethanol determination.

4. "Concerning Breath Alcohol Measurements during Absorption and Elimination - Letter to the Editor," by R. Moore in *Journal of Analytical Toxicology*, Vol. 15, November/December 1991, pp. 346-347.

Summary of Results: " This study documents short times to peak, ...these times are comparable to other studies involving social drinking conditions indicating that a test result would more likely under-approximate than over-approximate the subjects alcohol concentration the time of driving."

5. " Consumption of a Large Dose of Alcohol in a Short Time Span," by J.T. Jakus, N.K. Shajani, and B.A. Image in *Forensic Science International*, 56 (1992) pp. 113-125.
   Summary of results: This study showed very little difference in time to peak between fed and fasted subjects with an average time of 36 minutes and a range of 12 – 74 minutes for both groups. Some of the fed subjects showed a plateau region in the peak portion of the alcohol curve. To address this, the author suggests a horizontal extrapolation back to the time of offence to give a minimum value assuming the peak BrAC had been reached.

6. "The Effect of Food on Alcohol Absorption and Elimination Patterns," by R.L. Watkins and E.V. Adler in *Journal of Forensic Sciences*, Vol. 38, No. 2, March 1993, pp. 285-291.
   Summary of results: Two separate studies run on nine individuals; six male and three female. Full stomach vs. empty stomach. Each subject was administered a 15% diluted alcohol solution with 12.1 minute average consumption. Testing with 4011AS-A in 8-minute intervals for 4 hours.
   1. Both had total average absorption in 41 minutes.
   2. Both had total average elimination in 5 hours.
   3. Paper considers elimination rate very significant; 0.017 BrAC/h full stomach vs 0.020 BrAC/h empty stomach.

7. "Breath Alcohol Concentrations Measured in a Social Drinking Study" by Vickie Watts, Tom Simonick in *The DRE*, Spring 1995, Vol. 7, No.1.
   Summary of results: Subjects reached peak alcohol concentration in 27 min. (range12 to 61) after drinking alcohol in a social setting after a moderate to heavy meal. Six of 15 subjects exhibited a pronounced plateau in their alcohol concentration curves. Retrograde extrapolation for all of the 6 subjects who plateaued would likely yield an alcohol concentration higher than actually achieved.

8. "Variability of Ethanol Absorption and Breath Concentrations During a Large Scale Alcohol Administration Study," by P.N. Friel, J.S. Baer, and B.K. Logan in *Alcoholism: Clinical and Experimental Research*. Vol. 19, No. 4, August 1995, pp. 1055-1060.
   Summary of results: 77 female and 97 male college aged subjects, who were classified as heavy drinkers, were given calculated doses of 100 proof vodka over a 10 min. period to theoretically peak at 0.075. The subjects were stressed during the dosing by having them answer computer-based questions and performing BAC tests. The results were as follows: 1) although the mean time-to-peak was 39.6 min, there was substantial variability in EtOH absorption (time-to-peak varied from 10-91 min.), this absorption variability resulted in increased subject variability in breath alcohol concentrations, especially during the first 30 min. of the study, 2) the actual BAC's achieved were lower than expected, and 3) the average female BAC's were consistently lower than mean male BAC's. The authors conclude that the stress procedures may have contributed to the altering of ethanol pharmacokinetics. Although they state that the stress induced administration of alcohol had little or no effect on the rate of alcohol absorption (time-to peak) when compared to other studies, they theorize that the lower than expected BAC's might be caused by a stress effect resulting in either a reduction in the extent of ethanol absorption, an increase in it rate of elimination, or both. As far as the phenomenon concerning the women's lower than expected BAC's the authors suggest that this may be due to the lower body fat content, and higher body water content in the young

the differences between a vehicle in 1960 and one today. Forty plus years can fill in many gaps in knowledge. This shortage of information exaggerates the evidence of differing effects of alcohol caused by tolerances, both physical and mental.

3. "A Study of the Metabolism Rates of Alcohol in the Human Body" by R.P. Shumate, R.F. Crowther and M. Zaratshan in *Journal of Forensic Medicine*, Vol. 14, No. 3, 1967: pp 83-100.
Summary of results: This study focused on elimination rate in the post-absorptive phase of alcohol elimination. The authors noted problems with early Breathalyzer precision, residual alcohol, and obtaining adequate samples from highly intoxicated subjects. The average elimination rate was found to be 0.017 g/210 L. Women had a slightly higher elimination rate than men.

4. Alcohol and the Impaired Driver. A Manual on the Medicolegal Aspects of Chemical Tests for Intoxication. American Medical Association, Chicago, 1968: pp 21-22.
Summary of results: "In making the determination, the ranges and the mean figures should be given. The extrapolation should not exceed that which would be reasonable in terms of the time during which the person consumed the alcohol or at which the last drink was taken."

7. "Variations in Absorption and Elimination Rates of Ethyl Alcohol in a Single Subject" by John Wagner and Jayant Patel in Research Communications in *Chemical Pathology and Pharmacology*, Vol. 4, No. 1, 1972: pp61-76. PJD Publications Ltd, 10 Oakdale Drive, Westbury, NY 11590.
Summary of results: The results presented here question whether administration of alcohol orally to each subject only once is sufficient. This study found a wide variation in the estimated parameters in the same subject from one time of administration to the next.

8. "Influence of Alcohol Intake, Length of Abstinence and Meprobamate on the Rate of Ethanol Metabolism in Man" by Guillermo Ugarte, Tamara Pereda, Maria Eugenic Pino and Henán Iturriaga in *Quarterly Journal of the Studies on Alcohol*, Vol. 33, No. 3, 1972: pp 698-705.
Summary of results: Study shows increase of oxidation in alcoholics immediately after alcohol withdrawal. This demonstrates that drugs (meprobamate) which induce microsomal enzymes are much less effective, more data, specially in humans, are necessary to understand fully the role of catalase and microsomal enzymes in the adaptive increased ethanol metabolism.

9. "On the Accuracy of Back Calculations to Establish Blood Alcohol Levels at the Time of Incident" [English translation] by Michael Köhler and Franz Schleyer in *Blutalkohol*, Vol. 12, 1975: pp 52-56.
Summary of results: Sixty-three individuals were blood tested in the post-peak phase for retroactive extrapolation. Testing was started 120 minutes after last drink. The elimination factor of 0.01 g/210L was accurate for individuals under 0.080. With levels above that the most accurate elimination rate was 0.019 g/210L.

10. "Elimination of Ethanol in Humans - A Critical Review" by Michelle Holzbecher and Al Wells in *Canadian Society of Forensic Science Journal*, Vol. 17, No.4, 1984: pp 182-196.
Summary of results: Authors give detailed explanation of the metabolism of ethanol in humans. They reference the work of other researchers and their findings on things, which may influence the elimination of ethanol in humans and conclude nothing except fructose can influence the rate of elimination rates in humans. Fructose increases the elimination rate in humans. In the authors opinion, it is safe to assume that the elimination rates of ethanol in the range of 10-20 mg % / h are applicable for legal interpretation for the vast majority of subjects. In the case of extrapolation of

ethanol levels from an allegedly known ethanol consumption to future points in time, a possibility of slightly higher elimination rates than 20 mg%/h might be considered for maximum benefit for the person.

11. "The Rate and Kinetic Order of Ethanol Elimination" by Charles L. Winek, Kathy L. Murphy in *For Sci Intl*, 25 (1984) pp.159-166.
Summary of results: Paper concludes ethanol elimination is a zero order process. Weak experimental design and resulting data did not fully support conclusion. The absorption data in this study are in agreement with the values of 30-60 min. reported elsewhere.

12. "Calculating the Maximum Blood Alcohol Concentration. Its Evidentiary Value in Assessing Criminal Responsibility" [English translation] by J. Gerchow, U. Heifer, G. Schewe, W. Schwerd and P. Zink in *Blutalkohol*, Vol. 22, Supplement 1, 1985: pp 77-107.
Summary of results: In the case of traffic offences, "The assumption is that a regularity exists which is generally held to be valid for cases which are actually only similar, not identical. This practice has no doubt proven itself in the case of traffic offences. This is because the application of ceiling values offers the greatest degree of security in avoiding prejudicial treatment in individual cases."
The study attempts to answer "...whether the principle (taken for granted in the case of traffic offences) of establishing the lowest conceivable value within the context of back-calculations must necessarily lead to the best value being established by back-calculation when culpability is to be judged."
The report seeks a maximum back-calculated value which is backed up statistically.
The summary and conclusions offered are as follows:
"1. A value of 0.29 ‰/hr or any other maximum back-calculated rate which is related fixedly to the hour cannot be justified for the demands of forensic practice.
2. It has proven necessary to use a staggered maximum back-calculation rate.
3. This back-calculation procedure is backed up by experiments up to the sector where blood alcohol concentrations amount to 4 g‰ and over a back-calculation period of ten hours."
Conclusions on the value of the blood alcohol concentration in assessing criminal responsibility include:
"...a blood alcohol finding which is taken at one single point is as a rule inadequate to assess criminal responsibility..." and
"...even the most probable blood alcohol concentration must be placed in a relative context when assessing criminal responsibility."

13. "Medicolegal Alcohol Determination: Implications and Consequences of Irregularities in Blood Alcohol Concentration vs. Time Curves - Letter to the Editor" by G. Simpson in *Journal of Analytical Toxicology*, Vol. 16, July/August 1992: pp 270-271.
Summary of results: Author used old Dubowski data combined with Baselt & Danhof data to establish that emotional and physical factors can alter absorption and elimination rates by 'spiking' or temporarily blocking metabolism. There was no experimentation performed by this author and therefore establishing anything that proves or disproves extrapolation is in question. These are the same arguments we have all heard from the defense for years. The author rightfully pointed out that exact numbers are impossible, but drew the conclusion that even broad variations that better explain general absorption and elimination can not be credible due to possible irregularities.

14. "Alcohol/Body Fluids" by R. Denney in Encyclopedia of Forensic Sciences. Editor-in-Chief Jay

Siegel, Academic Press, London, UK, 2000: pp 80-86.
Summary of results: This paper discusses how alcohol is absorbed, distributed, and eliminated throughout the body. Alcohol in saliva and urine are discussed, as well as the difficulty in obtaining these samples.

15. "Ethanol. 6.2. Pharmacokinetics, metabolism and duration of action" & "6.7. Case reports" in The Forensic Pharmacology of Drugs of Abuse by Olaf Drummer, Arnold, London, UK, 2001. pp 278-289 & 309-310. Distributed in Canada and the USA by Oxford University Press.
Summary of results: "This article reviews the pharmacokinetics of ethanol and how this effects our ability to measure and interpret the presence of ethanol. 1) Absorption, (Widmark, effect of food), 2) Metabolism (role of ADH), 3) Age, gender, & genetics 4) Excretion and detection times 5) Case reports. The article illustrates how many factors are considered in determining back-calculated BACs."

F. Studies that tend to support retrograde extrapolation or have concerns about time of test laws.

1. "Alcohol Pharmacokinetics and Forensic Issues: A Commentary" by Jatinder Khanna, Eugene LeBlanc and Joel Mayer in Human Metabolism of Alcohol, Vol. 1. Editors Kathryn Crow and Richard Batt, CRC Press Inc, Boca Raton, Florida, 1989: pp 59-70.
Summary of Results: This paper describes "problems" with the Canadian law that accepts breath tests taken within two hours of incident as reasonable estimate of BAC at the time of offense. The authors' arguments are that subjects may engage in drinking patterns that are not normal, differences in absorption rates, and differences in elimination rates. However, the authors do state that breath tests taken more closely following the offense will result in minimal differences between time of test vs. time of offense. Chemical tests taken closer to two hours after offense are more unreliable. The authors also feel that, although back extrapolation is possible, it is safer to give only ranges of possible BAC's because of individual differences.

2. "Retrograde Extrapolation of Blood Alcohol Data: An Applied Approach" by M. Montgomery and M. Reasor in *Journal of Toxicology and Environmental Health*, Vol. 36, 1992: pp 281-292.
Summary of results: Retrograde extrapolation is a mathematical process, based on sound scientific principles, that is used routinely in pharmacology, toxicology, and clinical medicine. This process may be applied to the situation of ethyl alcohol consumption with reliability when reasonable assumptions are made concerning absorption rates, elimination rates, and patterns of alcohol consumption, including drinking duration and volume consumed. By utilizing an established range of values for the elimination rate of alcohol of 0.015-0.020 g/dl/h, a relatively narrow range of extrapolated blood alcohol concentrations (BACs) can be determined in situations where the time frame in question is after peak alcohol absorption into the blood. A wider range of elimination rates of 0.01-0.03 g/dl/h may be applied and will satisfy the possibility of nonlinear kinetics within an individual; however this wider range will have little practical effect on the predicted BACs. When the time point in question is prior to peak absorption, a wider range of predicted BAC values will result. The extent of this range will be influenced by the amount of information available concerning the temporal pattern of alcohol consumption. Reported drinking volumes are notoriously inaccurate and, in fact, are of little practical use. Given the parameters of body weight and time duration between initiation of drinking and determination of the BAC the number of "drinks" consumed may be reliability calculated. Retrograde extrapolation is applicable in the forensic setting with scientific reliability when reasonable and justifiable assumptions are utilized.

3. "Estimation of Blood Alcohol Concentrations after Social Drinking" by A.R. Stowell and L.I. Stowell in *Journal of Forensic Sciences*, Vol. 33, No. 1, 1998: pp 14-21.
   Summary of results: "The results showed that actual BACs were usually within or very close to the range of 'forward' estimates based on the known alcohol doses. Furthermore, most BACs measured about an hour after cessation of drinking were within or very close to the predicted range based on back extrapolation from the actual 3.5 hour BAC result."