# Varying Length of Expirational Blow and End Result Breath Alcohol

C. Dennis Simpson, Ed.D.
Specialty Program in Alcohol and Drug Abuse
College of Health and Human Services
Western Michigan University

Jessica A. Kerby, M.A.
Specialty Program in Alcohol and Drug Abuse
College of Health and Human Services
Western Michigan University

Scott E. Kerby, M.A.
Specialty Program in Alcohol and Drug Abuse
College of Health and Human Services
Western Michigan University

Abstract

This study was conducted to examine the effect of length of exhalation on breath alcohol results using extreme durations of exhalation. Sixty male subjects were administered 2.40 ml of alcohol per 1 kg of body weight over a 30 minute period. Two BAC DataMaster alcohol breath tests were administered to each subject, the first for an exact duration of 6 seconds (Short Duration Exhalation) and the second for exactly 24 seconds (Long Duration Exhalation). Long Duration Exhalation results consistently exceeded the Short Duration Exhalation and this difference was statistically significant. Also, age was found to be correlated with the deviation between Short and Long Duration Exhalation results. These results raise concerns as to the reliability and validity of the BAC DataMaster when tests are not given to exact duration of exhalation and findings further suggest that the reliability and validity may also be compromised by factors such as age.

## Introduction and Literature Review

The alcohol breath test (ABT) was first introduced in the early 1950's for the purposes of measuring blood alcohol concentration (Harger, Forney, & Barnes, 1950). The earliest ABT devices used a galvanometer in the null balance photometric system to measure the color decrease in reagent (Lucas, 1986), but beginning in the 1970's infrared technology began to be used. Infrared ABT instruments are now commonly used by policing agencies, courts, athletics, business and industry, and education (Inaba and Cohen, 2000).

One of the five current infrared ABT instruments on the market is the BAC DataMaster which uses a 3.44 micron bandwidth to determine alcohol and a 3.37 micron bandwidth to determine acetone (National Patent Analytical System, 1997). The BAC DataMaster was tested against federal standards for devices to measure breath alcohol (National Highway Transportation Safety Administration, 1984), found to meet compliance standards, and placed on the federal conforming products list (National Highway Transportation Safety Administration, 1998). Federal standards require the infrared ABT to not exceed a standard error of +/- .0042g/210 ml of breath in a controlled laboratory setting using a water bath simulator. Standard error for the BAC DataMaster, determined in field situations, has indicated an error rate in excess of federal standards (Gullberg & Logan, 1998). The National Safety Council Committee on Alcohol and Other Drugs has set an acceptable error rate of .02/210 ml between duplicated samples for infrared ABT instruments (National Safety Council Committee on Alcohol and Other Drugs, 1979). This means that when two or more BAC DataMaster breath tests are performed on the same individual in close time proximity, the amount acceptable variance differs based on the blood alcohol level. At the 0.00-.0.14 range, a variance of plus or minus 0.01 is allowable, between blood alcohol readings of 0.15-0.24, a variance of plus or minus .02 is permitted, between 0.25-0.34 the variance may be plus or minus .03, and above a blood alcohol level of 0.35 the variance between administrations should not exceed 0.04 (State of Michigan, 2003).

The BAC DataMaster has a set partition ratio of 2100 to 1 based upon Henry's Law and assuming a closed system as exists in the water bath simulator in a laboratory. In an open system, as exists in human breathing, research has demonstrated a variance in actual partition ratio between 1555 to 1 and 3005 to 1 (Dubowski, 1985). This indicates that a fixed partition ratio of 2100 to 1 for all ABT tests will underestimate the BrAC 77% of the time and overestimate the BrAC 23% of the time given a normal distribution of the subject population in the post-absorptive phase.

A concern related to the BAC DataMaster, and all infrared ABT instruments, is the effect of length of exhaled blow on the results. The assumption of all ABTs until the 1990's was alveolar air contained a steady state equilibrium to the 2100 to 1 partition ratio and an alveolar plateau would result in ABTs as a result of long steady exhalation of breath (Fowler, 1948; Rahn, et.al. 1946; Henry, 1803). While that has maintained as fact in a closed system, the human breathing process is an open system and respiratory research has meaningfully advanced in the last 50 plus years.

Beginning with the research of Wright et.al. (1975), the respiratory function regarding the sources of alcohol in the breath has been defined from a thermodynamic model. This model has been detailed by Hlastala (1985, 1988, 1998a, 1998b, 2001, and 2002) and supported by Labianca (2002). This thermodynamic model shows alveolar alcohol is not contained in the breath, but rather the alcohol in the breath is a direct result of the heating and cooling process of inhaled and exhaled air in the open respiratory system of the human body. This thermodynamic model also is supported by Jones (1983) who indicated the alveolar alcohol core partition ratio would be 1756 to 1 instead of 2100 to 1.

This thermodynamic model of the respiratory system not only explains variances between individual results in exhaled air containing alcohol, but also explains why the upward slope of the breath alcohol curve continues until breathing into the instrument ceases. This variance in breath alcohol concentration has been shown between duplicate tests on the same subject to be .02 (Gullberg, 1987; Gullberg, 1988). In neither of these studies was an attempt made to use extremes of breath exhalation duration to determine the effect of these extremes on results. The purpose of the current study was to examine the effect of length of exhalation on breath alcohol results using extreme durations of exhalation.

## Methods

### *Population*

Sixty male subjects were recruited for this research. These sixty subjects were randomly selected from a pool of over 500 who had responded to advertisements for participation in alcohol research projects on humans. Prior to becoming a subject in the study each participant was screened using a three-tiered process. The first level of screening was to obtain two separate documents indicating the subject was a minimum of 21 years of age. The second level of screening was for the subject to complete the Substance Abuse Subtle Screening Inventory - 3 (SASSI-3) which would determine the probability of the subject being alcohol dependent. The third level of screening was to have the subject blow long and steady through an unattached DataMaster mouthpiece for 24 seconds. Of the original randomly selected subjects none were excluded due to age, six were excluded due to their having SASSI-3 results indicating a high probability of alcohol dependence, and four were excluded due to their inability to continue the long steady blow for 24 seconds. The ten original subjects excluded during screening were replaced by randomly selected replacements from the pool. All ten replacements successfully met the three screening criteria. The study subjects ranged in age from 22 to 59 years. Each subject reported to the research clinic 12 hours prior to initial ingestion of alcohol. Each subject was placed to a 12 hour fast, excepting water, prior to initial ingestion of alcohol. Each subject was given a breath alcohol test upon reporting to the research clinic and all subjects displayed an initial result of .00.

*Conditions*

Upon completion of a 12 hour fast each subject was administered 2.40 ml of alcohol per 1 kg of body weight to have an anticipated grossly approximate .10g/210 ml result. Alcohol intake was divided into two drinks containing equal parts of 50 percent alcohol and distilled water. Each participant ingested a single drink in a period of 15 minutes, for a total alcohol consumption time of 30 minutes. At the end of the alcohol ingestion period each subject's mouth was examined by an off-duty police officer, certified in BAC DataMaster administration, using a flashlight, tongue depressor, and gloves to raise the tongue. No foreign objects were observed in the oral cavity of any of the subjects nor was mouth blood present. Each subject then was observed for a period of 60 minutes by a trained observer to assure no incidents or symptoms of vomiting, belching or burping occurred. At the end of 60 minutes each subject's mouth was re-examined to assure no foreign object or blood was present in the oral cavity. Following the end of the 60 minute observation period, also used to assure sufficient time to place the subject beyond the first-order pre-absorptive state (Gullberg, 1989) and oral examination, each subject was taken to the BAC DataMaster testing room.

The BAC DataMaster used for the study was installed in the university research laboratory in 1999. Calibrations have been conducted on a 120 day basis by the manufacturer's agent and simulations were conducted daily throughout the study period. For purposes of this study, a total flow reduction valve was placed between the mouth piece and BAC DataMaster tube. The valve did not inhibit flow during the timed periods, but would automatically totally eliminate breath flow when commanded by its attached Hewlett-Packard computer. The computer was programmed to close the valve at exactly 6 seconds on each first exhalation and at exactly 24 seconds on each second exhalation. Timing for the 6 seconds and 24 seconds was controlled through an atomic time synchronizer 3.9, which received time from the National Institute of Standards and Technology Cesium Atomic Clock (NIST F-1).

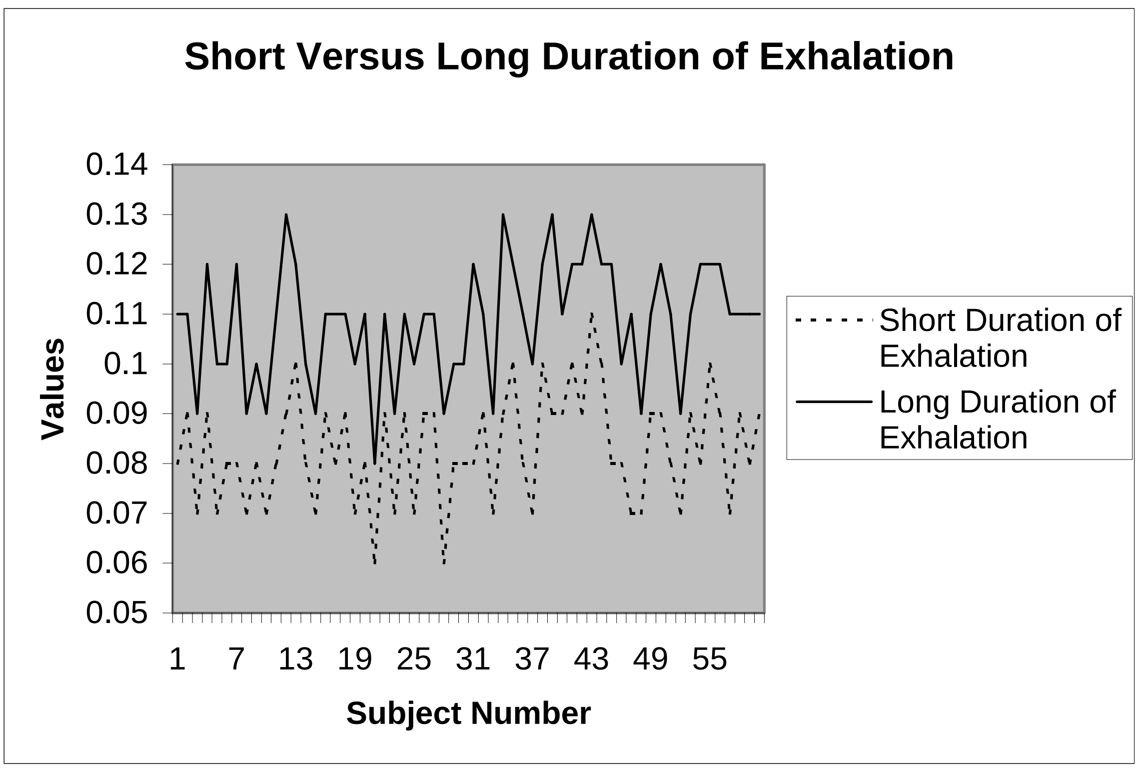
Upon entering the research laboratory, an off-duty police officer certified in BAC DataMaster operation inputted the subject data into the instrument. When this was completed and the BAC DataMaster purged itself and validated its internal standard, the officer gave the subject the following command, as recommended by the manufacturer: "Place your mouth on the mouth piece and blow long and steady into the tube until I tell you to stop" (National Patent Analytical System, 1997). The exhalation was stopped by the flow reduction valve at exactly 6 seconds. The BAC DataMaster then purged itself, reverified its internal standards, and indicated it was ready for the duplicate breath sample exhalation. The off-duty police officer then gave the same command as with the first exhalation sample. The second exhalation sample was stopped by the flow reduction valve at exactly 24 seconds. The first exhalation breath sample was titled DataMaster-Short Duration Exhale (DM-SDE) and the second exhalation breath sample was titled DataMaster-Long Duration Exhale (DM-LDE) for purposes of the study. There was an a priori decision not to conduct a third sample in the cases where the DM-SDE and DM-LDE were beyond acceptable variances of the instrument. Given the breath alcohol level of study participants, the variance between administrations should not exceed plus or minus .01 (Michigan State Police, 2003). Since the variance exceeded .01 for all participants, third samples were not taken.

Results for each subject were printed on the DataMaster ticket and immediately entered into the data management program at the research laboratory. Results of each DataMaster ticket were checked for accuracy a second time after data entry.

Results

In all subject cases the DM-LDE exceeded the DM-SDE (see Figure 1). The mean DM-SDE score for all subjects was .0828 and the mean DM-LDE score for all subjects was .1085.

Figure 1



A correlational (dependent samples) t-test revealed that the difference between these means was significant (t=-26.692, p<.001) (see Table 1). Also, in all subject cases the difference between the DM-SDE and the DM-LDE exceeded the acceptable variance in the software of the BAC DataMaster. The minimum deviation between the DM-SDE and the DM-LDE was .02 and the maximum deviation between DM-SDE and DM-LDE was .04.

Table 1

| | | | | 95% Confidence Interval of the Difference | | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Deviation | Std. Error Mean | Lower | Upper | t | df | Sig. (2-tailed) |
| Data Master - Short Duration of Exhalation Data Master - Long Duration of Exhalation | -.02567 | .00745 | .00096 | -.02759 | -.02374 | -26.692 | 59 | .000 |

The results, while demonstrating the difference in measured breath alcohol concentration for the extremes of a short exhalation and a long exhalation, do demonstrate a skew. Table 2 presents the frequency of deviations. For the subjects tested there was a 58.33% probability of the deviation between DM-SDE and DM-LDE being .02, a 26.67% probability of the deviation being .03 and a 15% probability of the deviation being .04. These probabilities are limited to the extent of the population in the study.

Table 2

Frequency of Deviation between DM-SDE and DM-LDE

| Deviation | f |
|---|---|
| .02 | 35 |
| .03 | 16 |
| .04 | 9 |

An exploratory correlation analysis was conducted to determine if there is any relationship between age and DM-SDE, age and DM-LDE, and age and the deviation between DM-SDE and DM-LDE. Correlations between age and DM-SDE and between age and DM-LDE were non-significant. However, the correlation between age and deviation was significant ($r=.328$, $p<.05$) (see Table 3). This suggests that the deviation tended to increase with age.

Table 3

| | | Subject Age | Data Master - Short Duration of Exhalation | Data Master - Long Duration of Exhalation | Deviation |
|---|---|---|---|---|---|
| Subject Age | Pearson Correlation | 1 | -.158 | .061 | .328(*) |
| | Sig. (2-tailed) | | .228 | .644 | .010 |
| | N | 60 | 60 | 60 | 60 |
| Data Master - Short Duration of Exhalation | Pearson Correlation | -.158 | 1 | .790(**) | -.201 |
| | Sig. (2-tailed) | .228 | | .000 | .124 |
| | N | 60 | 60 | 60 | 60 |
| Data Master - Long Duration of Exhalation | Pearson Correlation | .061 | .790(**) | 1 | .441(**) |
| | Sig. (2-tailed) | .644 | .000 | | .000 |
| | N | 60 | 60 | 60 | 60 |
| Deviation | Pearson Correlation | .328(*) | -.201 | .441(**) | 1 |
| | Sig. (2-tailed) | .010 | .124 | .000 | |
| | N | 60 | 60 | 60 | 60 |

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

## Discussion

The purpose of the study was to determine if the length of exhalation into the BAC DataMaster produced effects upon reported breath alcohol results. The basis for the study was the previously cited work of Hlastala (1985, 1988, 1998a, 1998b, 2001, 2002), Labianca (2002) and Jones (1983) who supported the open system thermodynamic model of breath alcohol concentration. This model predicts there will never be a plateau in slope until the individual stops blowing into the ABT instrument. This study addressed extremes in length of duration of exhalation of 6 and 24 seconds to produce data regarding deviations between duplicate ABT results. The results of the study indicate the extremes of duration of exhalation will consistently produce duplicate test data that differ beyond the variance acceptable to the manufacturer and to administrative and legislative mandates.

The range of differences between the DM-SDE and DM-LDE was .02 to .04 with the DM-LDE always exceeding the DM-SDE within this range. This raises concerns as to the reliability and validity of the measure of ABT results when tests are not given to exact duration of exhalation and ABT results are the only measure used in determining the actual level of bodily alcohol. One limitation of this research is all participants were given the short duration test prior to the long duration test, raising the issue of order effects. However, if order effects were at work, one would expect the breath alcohol level to decrease over time, as the body metabolizes alcohol. Hence, lower ABT levels would be found at the second administration. This was not the case in this research, as the results of the second administration (long duration) always exceeded the first. Nonetheless, future research in this area may be strengthened by providing the tests in a counterbalanced order.

Furthermore, findings of this study suggest that the reliability and validity of ABT results may be further compromised by age. This finding may be related to changes in lung functioning over time. Research has shown that lung function declines with age, especially if disease or injuries have affected the lungs (Griffith, et al., 2001; Knudson, Clark, Kennedy, & Knudson, 1977; Turner, Mead, & Wohl, 1968). Hlastala and Anderson (2007) have found that breathing pattern and lung size influence ABT outcomes. It seems possible that overall lung functioning may also impact ABT readings, such that outcomes become more volatile and less reliable with decreases in lung functioning. This represents a promising avenue for future research.

The results of this study support the open system thermodynamic model of breath alcohol. The results of the study fail to support the model of an alveolar plateau existing with the flat slope during the exhalation process.

## Conclusion and Inferences

The BAC DataMaster, as any breath alcohol instrument, can only measure the quantity of alcohol in the breath entered into it at volume and time of measure. This study, as well as the work of Hlastala (1985, 1988, 1998a, 1998b, 2001, 2002) and others, demonstrates that duration of exhalation will affect breath alcohol results in a meaningful manner. As such, it is logical to infer a set amount of time should be the standard for duration of exhalation in determining breath alcohol concentration as a physiological discrete, reliable and valid result. Yet the research based variation in partition ratio between individuals (1555 to 1 vs. 3005 to 1) precludes setting a specific duration of exhalation which would provide a valid comparison between any two given individuals. This would preclude going to a set time of duration of exhalation as suggested by Rockerbie (1999). The variance in partition ratio between individuals directly relates to the variance between individuals in respiratory vital capacity. This variance, not including extremes, is 2.48 liters to 6.32 liters (Hlastala, 2001). The differences in vital capacity also preclude setting an exact time for duration of exhalation.

Unless the issues of meaningful variances among individuals regarding partition ratio and vital capacity can be resolved it is improbable any duration of exhalation can assure a valid breath alcohol result, excluding a significant error rate. The inference from this is to identify and use a bodily alcohol measure, such as whole blood, which has a very minimum error rate.

A final inference has to do with the deviations found in the results. The deviation in duplicate exhalations of .02 is supported by Gullberg (1987 and 1988). The .03 and .04

deviations are actual deviations of subjects in this study. These may be actual individual differences or may be measures taken at differing slopes of the ABT exhalation curve (Dubowski, 1985). Future research to determine the cause of the .03 and .04 deviations is suggested.

References

Dubowski, K. M. (1985). Absorption, Distribution and Elimination of Alcohol: Highway Safety Aspects. *Journal of Studies on Alcohol, 10,* 98-108.

Fowler, W. (1948). Lung Function Studies: The Respiratory Dead Space. *American Journal of Physiology, 154*, 405-416.

Griffith, K. A., Sherrill, D. L., Siegel, E. M., Manolio, T. A., Bonekat, H. W., & Enright, P. L. (2001). Predictors of loss of lung function in the elderly. *American Journal of Respiratory Critical Care Medicine, 163*, 61-68.

Gullberg, R. G. (1987). Duplicate Breath Testing: Statistical or Forensic Significance of the Differences. *Journal of the Forensic Science Society, 27,* 315-319.

Gullberg, R. G. (1988). *Duplicate Breath Testing: Some Statistical Analysis, 37*, 205-213.

Gullberg, R. G. (1989). Breath Alcohol Test Precision: An In Vivo vs. In Vitro Evaluation. *Forensic Science International, 43*, 247-255.

Gullberg, R. G. and Logan, B. K. (1998). Reproducibility of Within Subject Breath Alcohol Analysis. *Medical Science and Law, 38 (2),* 157-162.

Harger, R. N., Forney, R. B., and Barnes, H. B. (1950). Estimation of the Level of Blood Alcohol from the Analysis of Breath. *First International Conference on Alcohol and Traffic*, Stockholm, Sweden, 107-121.

Henry, W. (1803). Experiments of the Quantity of Gases Absorbed by Water at Different Temperatures and Under Different Pressures. *Philosophical Translation: Research Society of London, 93*, 29-42.

Hlastala, M. P. (1985). Physiological Errors Associated with Breath Alcohol Testing. *The Champion*, July, 16-19.

Hlastala, M. P. (1988). Physiology of Alcohol in the Body. *Trial News, 23(8),* 2-14.

Hlastala, M. P. (1998a). A New Paradigm for the Alcohol Breath Test. *DWI Journal*, *13*, 1-7.

Hlastala, M. P. (1998b). The Alcohol Breath Test: A review. *Journal of Applied Physiology, 84(2)*, 401-408.

Hlastala, M. P. (2001). Breathing Related Limitations to the Alcohol Breath Test. *DWI Journal: Science and Law, 17,* 1-4.

Hlastala, M. P. (2002). The Alcohol Breath Test. *Journal of Applied Physiology*, *93*, 405-406

Hlastala, M. P. & Anderson, J. C. (2007). The impact of breathing pattern and lung size on the Alcohol Breath Test. *Annals of Biomedical Engineering, 35*(2), 264-272.

Inada, D. S. and Cohen, E. (2000). *Uppers, Downers, All Arounders*. 4th edition, Ashland, Oregon: CNS Publications.

Jones, A. W. (1983). Determination of Liquid/Air Partition Coefficients for Dilute Solutions of Ethanol in Water, Whole Blood, and Plasma. *Journal of Analytical Toxicology*, *7*, 193-197.

Knudson, R. J., Clark, D. F., Kennedy, T. C., & Knudson, D. E. (1977. Effect of aging alone on mechanical properties of the normal adult human lung. *Journal of Applied Physiology, 43*(6), 1054-1062.

Labianca, D. A. (2002). The Flawed Nature of the Calibration Factor in Breath Alcohol Analysis. *Journal of Chemical Education, 79(10)*, 1237-1240.

Lucas, D. M. (1986). The Breathalyzer and How It Works. In: McLeod, R. M., Takach, J. D., Segal, M. D., (Eds.), *Breathalyzer Law in Canada* (pp. 1-11). Toronto: Carswell Company.

Michigan State Police (2003). Michigan Breath Test Operator Training Manual. Retrieved

August 14, 2007, at http://www.owidefenselaw.com/DATAMASTER%20Michigan%20Breath%20Test%20Operator%202003%20Training%20Manual.pdf

National Highway Transportation Safety Administration (1984). Highway Safety Programs: Standards for Devices to Measure Breath Alcohol. *Federal Register, 49*: No. 242.

National Highway Transportation Safety Administration (1998). Conforming Products List of Evidential Breath Measurement of Devices. *Federal Register, 63*: No. 10066.

National Patent Analytical System, Inc. (1997). *BAC DataMaster Basic Operations Guide*. Mansfield, Ohio: National Patent Corporation.

National Safety Council on Alcohol and Other Drugs (1979). *Recommendation of the Committee on Alcohol and Drugs, 1936-1977*. Chicago.

Rahn, H. Mahoney J., Otis A. B. and Fenn, W. O. (1996). A Method for the Continuous Analysis of Alveolar Air. *Journal of Aviation Medicine, 7,* 173-178.

Rockerbie, R. A., (1999). *Alcohol and Drug Intoxication*. Victoria, British Columbia: Trafford Press.

Turner, J. M., Mead, J., & Wohl, M. E. (1968). Elasticity of human lungs in relation to age. *Journal of Applied Physiology, 25*(6), 664-671.

Wright, B. M., Jones, T. P. and Jones, A. W. (1975). Breath Alcohol Analysis and the Blood: Breath Ratio. *Medical Science and Law, 15,* 205-210.