AN EVALUATION OF POCKET-MODEL, NUMERICAL READOUT BREATH ALCOHOL TESTING INSTRUMENTS

A Dissertation

by

WILLIAM EDWARD VAN TASSEL

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2003

Major Subject: Health Education

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Approved as to style and content by:

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ABSTRACT

An Evaluation of Pocket-Model, Numerical Readout

Breath Alcohol Testing Instruments. (August 2003)

William Edward Van Tassel, B.B.A., Texas A&M University;

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Chair of Advisory Committee: Dr. Maurice E. Dennis

Eight small-scale breath alcohol measurement devices were tested for accuracy, precision and the ability to not yield false positive and false negative readings. These pocket-sized breath testers (PMBTs), which provided numerical readout of BrAC to the 100^{th} of a percent, were smaller than evidential and preliminary breath test instruments (EBTs and PBTs). The smallest devices were approximately the same size as a cigarette lighter. Designed to provide drinkers feedback about their individual alcohol levels, the PMBTs ranged in price from $40-100 USD.

The devices were first tested under laboratory conditions with alcohol solution simulators providing the alcoholic samples. They were then tested with human drinkers, under controlled field conditions. Each device was tested at multiple alcohol levels.

Two of the eight PMBTs failed to complete all levels of testing and were excluded from the study. All PMBTs demonstrated the ability to not yield false positive and false negative readings. No device met NHTSA performance criteria for accuracy (systematic error) in testing EBTs at every alcohol level tested. An interaction between PMBTs and the alcohol test levels was found. Thus, accuracy was found to be dependent upon the

alcohol level at which the devices were tested. No device met NHTSA performance criteria for precision in testing EBTs at every alcohol level tested. Further, precision varied depending on the testing condition, as there was less precision under controlled field conditions than under laboratory conditions. Five of the six PMBTs that completed the testing overestimated BrAC; only one device read below actual BrAC.

Ramifications of the findings are discussed, regarding the overestimation and underestimation of BrAC and the possibility of manufacturers intentionally calibrating the devices to overestimate BrAC. Potential PMBT users are discussed and areas for future research are addressed.

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One's family certainly is a substantial factor in the ability to pursue a doctorate. To this end, I express special thanks to my mom, who has been wholly supportive in my academic efforts. Her dedication in capturing and relaying to me virtually all traffic and alcohol-related events in the media has been especially helpful. It's great having one's own personal clipping service! To my father goes special appreciation. His input regarding the study and draft documents was of great use and he consistently confirmed that this research was of real value. Somehow he always knew I would make it!

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Doing research with human participants can greatly complicate the conduct of research. However, several people helped reduce the burden of acquiring qualified participants for this research. My thanks go to Dottidee Agnor, Gayden Darnell, Beth Tessandori and Dr. Jerry Elledge. My appreciation is also extended to those who helped me corral and monitor the participants, including Donna Adler, Romona Clark, Jodi Luecke and Christie Dickson.

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CHAPTER I

INTRODUCTION

While automobiles have only recently reached the century mark of existence, they have provided a degree of personal mobility never before experienced. Automobiles provide rapid transportation, permit infinite recreation options and afford their users wide choices regarding where to live and work. This individual mode of transport is widely available, relatively affordable and facilitated by solid roadway infrastructures. In the United States (US) and many other nations, automobiles have become the mechanized equivalent of freedom.

Unfortunately, each time a driver operates a motor vehicle there is a risk of serious or fatal injury. With over 220 million registered vehicles in the US, crashes are inevitable (National Safety Council, 2002). Causal factors include vehicle malfunctions, poor environmental conditions and human error (Fell, Hendricks & Freedman, 2000; Shinar, 1978). These negative events can cause sudden and violent impacts, resulting in property damage and injury or death of vehicle occupants.

Each year in the US, over 40,000 people die as a result of motor vehicle collisions. This degree of loss equates to approximately three commercial jet aircraft crashing each week. While losing so many lives in "chunks" in such an aviation scenario would likely

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This dissertation follows the style and format of Accident Analysis and Prevention.

cause widespread panic, the yearly number of automotive-related deaths appears to be far less a social concern. One factor may be the pattern of automobile crashes: the pattern is diffused, with injuries and deaths occurring over many small, discrete crashes throughout the year, spread over the entire US (”Low Priority,” 2002).

In fact, automobile crashes are the leading cause of death for Americans age 1-34 (Insurance Institute for Highway Safety, 2002). In addition, over two million people annually suffer from disabling injuries as a result of car collisions (National Safety Council, 2001). Further, the economic costs of motor vehicle collisions are staggering. Such costs include medical expenses, productivity losses, employer costs and property damage (National Safety Council, 2001). The U.S. Department of Transportation (2002a) estimates that the annual cost of such crashes to society exceeds $150 billion. This equates to a yearly cost average of approximately $790 per licensed driver in the US. Regardless of how automobile crash results are measured, motor vehicle collisions represent a major threat to public health and an enormous drain on the U.S. economy.

Only partially consoling is the fact that the motor vehicle crash rate was even worse in years past. From the US peak death rate per 100,000 population of 30.8 in 1937, the national rate has decreased to a rate of 15.4 in 2001, a decline of 50% (National Safety Council, 2002). Many factors are credited with reducing injury and death rates, including:

(a) Vehicle advances such as padded interiors, airbags, anti-lock braking systems, improved tires and traction control systems (Davis, 2002; National Highway Traffic Safety Administration, 2003a);

(b) Roadway improvements such as improved guardrails and lighting, and rumble strips (National Highway Traffic Safety Administration, 2003b);

(c) Legislative initiatives aimed at raising the cost of unsafe driving behavior (National Highway Traffic Safety Administration, 2003b);

(d) Advances in enforcement operations such as electronic speed measurement, improved communications and accident reduction efforts (National Highway Traffic Safety Administration, 2002).

In general, most crashes have been found to be attributed to human error/impairment as opposed to vehicular or environmental factors (Fell, Hendricks & Freedman, 2000; Moskowitz, 2002). Contributing to this finding is the myriad of ways that drivers can be impaired, including:

(a) Distraction (AAA Foundation for Traffic Safety, 2001);

(b) Fatigue/drowsiness (National Highway Traffic Safety Administration, 1998);

(c) Road rage/aggressive driving (AAA Foundation for Traffic Safety, 1997);

(d) Drugs, including alcohol (Dennis, 1995; Moskowitz & Robinson, 1988).

Of all the causes of motor vehicle crashes, alcohol-related crashes remain the single largest factor. Alcohol, a legal depressant drug, is widely available and widely abused in the US (Hanson, Venturelli & Fleckenstein, 2002). Almost 40% of all motor vehicle fatalities result from alcohol's deleterious effects on driving ability (National Safety

Council, 2001). The National Highway Traffic Safety Administration (NHTSA) defines an alcohol-related crash as one in which "either a driver or a nonoccupant (e.g., pedestrian) had a blood alcohol concentration (BAC) of 0.01 grams per deciliter (g/dl) or greater in a police reported traffic crash" (Mothers Against Drunk Driving, 2003, p.2). Compared to total crashes, state fatal alcohol-involved crash rates range from 23.9% (Utah) to 50.4% (Texas) (National Safety Council, 2002).

Fortunately, the alcohol-involved crash rate has declined in recent years (Moskowitz, 2002). Since 1982, the percentage of US fatal crashes involving alcohol has declined nearly 50% (Jones & Lacey, 2001). Several efforts have been credited with the progress to date, including:

(a) Efforts of organizations such as Mothers Against Drunk Driving and Remove Intoxicated Drivers;

(b) Federal, state and regional programs aimed at reducing the incidence of impaired driving;

(c) A growing social intolerance of the act of driving while impaired (Jones & Lacey, 2001);

(d) Use of technology to determine drivers' alcohol levels (Harding, 1996; Dubowski, 1992).

While the incidence of impaired driving has declined over the last two decades, progress seems to have leveled off over the past few years. It has been noted that the number of alcohol-related crashes has reached a plateau, with little change over the past several years (Jones & Lacey, 2001; "Progress Against," 2002).

There is consensus that the most effective way to prevent alcohol-impaired driving behavior is to avoid driving after consuming *any* alcohol (Burns & Fiorentino, 2002; Muhammad, 2000). Unfortunately, some people do choose to, and even plan to, drive after consuming alcohol, with sometimes catastrophic results (Jones & Lacey, 2001).

Several objective methods of determining blood alcohol levels have been developed, including measuring saliva, vapors emanating from the eye, blood, urine, tissue, spinal fluid and deep-lung breath (U.S. Department of Transportation, 1994; Caplan, 1996, National Highway Traffic Safety Administration, 1982). Developed in the 1940s, measurement of blood alcohol levels from breath samples was originally designed for law enforcement forensic purposes, but has since spread to other areas, including the medical, aviation, trucking and other transportation and non-transportation oriented industries (Mason & Dubowski, 1996; Harding, 1996; Freudenrich, 2002). Breath testing involves measuring the amount of alcohol captured in expired deep-lung air. Use of breath alcohol concentration (BrAC) has become a very common method of determining blood alcohol concentration (BAC), as it does not require using trained medical personnel to obtain and analyze blood samples (Mason & Dubowski, 1996; Harding, 1996; CMI, 2002a).

Two main types of breath alcohol testing devices exist: disposable and reusable. Disposable devices are inexpensive and typically involve the user exhaling through a clear plastic cylinder approximately the size of a cigarette. The tube contains a mixture of chemicals that reacts as breathe-borne ethanol flows through. Users interpret any

resulting change in color of the mixture to assess their blood alcohol level. Such devices are usually set to react at specific alcohol thresholds, such as .04 or.08 (AlcoPro, 2003).

Several types of reusable BrAC measurement devices have been developed. The most often used devices are large fixed based units primarily used for law enforcement evidentiary purposes. One of the first of these devices was the "Breathalyzer," invented in 1954 by Dr. Robert Borkenstein (Ezelle, 2002). Known as evidentiary breath testers (EBTs), these devices, such as the Intoxilyzer 5000, represent the most accurate breath alcohol measurement instruments available (CMI, Inc., 2002a). These BrAC devices generally remain at one location, require regular calibration and necessitate thorough training of their operators (Taylor & Hodgson, 1995; Dubowski & Essary, 1992). EBTs provide a digital readout to the 1000^{th} of one percent BrAC.

Preliminary breath testers (PBTs) are approximately the size of a VHS cassette. These hand-held, battery powered screening devices are used in the field to supplement a law enforcement officer's observations in determining whether a suspected alcohol-impaired driver should be arrested (Olson, 1986; Forrester, 1997). Results from PBTs may or may not be introduced as court-reported evidence. These instruments also provide a digital readout of BrAC, either two or three digits to the right of the decimal.

Passive alcohol sensors (PASs) surreptitiously collect normally exhaled breath from drivers during an interaction with law enforcement personnel. Designed to help officers screen potentially impaired drivers, these devices require no action by motorists and are built into innocuous-appearing devices such as flashlights and clipboards. PAS instruments help determine whether alcohol is present and, if so designed, approximately

how much. An effective PAS will minimize false positive readings (where low BrACs are incorrectly identified as high BrACs) and maximize the likelihood that high BrACs are detected (Lestina & Lund, 1992). Results are displayed either numerically or by a series of lights.

Breath alcohol ignition interlock devices (IIDs) are designed to prevent drivers who have consumed even small amounts of alcohol from starting their automobiles. About the size of an electric razor, these breath analysis devices are hard-wired into a vehicle and will not permit engine ignition if the driver's breath has a breath alcohol concentration higher than a predetermined threshold, usually .025 (Voas, Blackman, Tippetts and Marques, 2002). IID users are generally DWI offenders who have received permission to resume driving after having lost all such privileges for some period of time (Frank, 1997). Modern IIDs log all start attempts and violations and also mandate "rolling retests," which require the driver to periodically provide additional breath samples in order for the vehicle engine to continue running (Smart Start, 2003; Comeau, 2000; Marques, Voas, Tippetts & Bierness, 1999).

Coin operated breath measuring devices permit users to self-test their alcohol level. Slightly smaller than cash register machines, these instruments are designed for establishments that serve alcohol, including hotels and bars (Wundersitz, 2002). For each single use of the instrument, users pay a small fee, which generally includes a fresh mouthpiece (The Alcohol Alert System, 2002). Currently, coin operated breath testers (COBTs) are not widely available in the US.

The sixth group of breath test devices consists of a relatively new class of testing devices. Yet to acquire a commonly used label or acronym, these portable units are designed more for personal/civilian use, rather than for law enforcement applications. These battery-powered devices are even smaller than PBTs, with some being quite thin and not much larger than a pack of chewing gum (Stellin, 2001). They generally do not permit user calibration, require no training other than reading the manufacturer's operating instructions and, at a cost of $25 to $150, are far less expensive than both EBTs and PBTs.

This group of devices provides information about BrAC in one of two ways. First, some devices provide a qualitative readout, generally using a system of lights to provide information to the user. This can take the form of a binomial system (alcohol present or alcohol not present) or a system of ranges (e.g., BrAC ranges of .00-.04%, .04-.08%, .08-.12%, .12-.15% and .15% and higher). Second, other devices provide a quantitative readout, generally in 100th percent of BrAC. This paper shall refer to these devices as "pocket-model breath testers" (PMBTs). Images of the PMBTs tested in this study are provided in Appendix A.

EBTs, PBTs, PASs, IIDs and COBTs have all undergone rigorous laboratory and field-based analyses to evaluate their performance. However, there is a lack of evaluation of the newer, lower-cost PMBTs. Given that drivers are generally poor estimators of their own alcohol level (Silverstein, Nathan & Taylor, 1974; Van Tassel & Manser, 2000), the best option for any drinker is to not drive after consuming any alcohol. Sadly, people do all too often elect to drive after drinking. In situations where

the optimal rule of no-driving-after-drinking fails, the next best option might be to facilitate feedback of drinkers' own alcohol levels. Such feedback might result in better decisions about whether or not to drive. PMBTs have the potential to fulfill this function, and researchers have identified the need to develop and validate alternate methods of informing drinkers about the alcohol levels they have achieved (Dubowski, 1985). This study seeks to evaluate the performance of small-scale breath testers.

1.1. Statement of the Problem

Determination of breath alcohol from expired air is a commonly used method to measure blood alcohol concentration. The traditional devices used to obtain measurements of BrAC (EBTs, PASs, PBTs, CODs and IIDs) have been evaluated thoroughly to assess their performance. These units have been shown to demonstrate sufficient precision and accuracy to be used for their intended purposes.

A new class of measurement devices, pocket-model breath testers, has been released for public use within the past few years that may have the potential to help reduce the incidence of alcohol-impaired driving. These units have not yet undergone rigorous evaluation of their performance and an exploratory evaluation is needed prior to any widespread use.

1.2. Purpose of Study

The purpose of this exploratory study is to evaluate the performance of commonly available quantitative pocket-model breath testers (PMBTs). The evaluation consisted of

two experiments. The first was designed to assess the accuracy and precision of measurements made under laboratory conditions. The second was performed to assess the accuracy and precision under simulated field conditions.

1.3. Value of Study

Individuals sometimes make important decisions after consuming alcohol, including decisions about driving. Poor decisions can result because decision-making ability is the first human function to be affected by alcohol (Texas DWI Education Program, 2001). Thus, not only do drinkers tend to make poor decisions, but because of alcohol impairment, they do not *recognize* that their decision-making ability has been affected.

In most drinking situations, the sole input drinkers have about their current BAC is their subjective estimate; there is rarely an available method for them to obtain a quantitative measure of their BAC. Perhaps not surprisingly, drinkers' subjective estimates of BAC, made in the absence of accurate feedback, have been found to be of low accuracy (Silverstein, Nathan & Taylor, 1974).

It has been recommended for some time that new and better means of providing drinkers information about their current alcohol level be validated (Dubowski, 1985). As most states' laws involve a numerical expression of intoxication (e.g., .08% BAC), drinkers' decisions might benefit from numerical input regarding their current BrAC. The PMBT devices to be examined in this study have the potential to provide such quantitative input, possibly aiding drinkers in making better decisions after alcohol is

consumed. Better decisions regarding driving by people who have consumed alcohol could lead to fewer alcohol-related injuries and deaths.

1.4. Research Hypotheses

1.4.1. Experiment One

1.4.1.1. Hypothesis One

Under laboratory conditions, each PMBT device will be less accurate than the National Highway Traffic Safety Administration (NHTSA) criteria at each alcohol level (will yield a systematic error greater than ± .005).

H_O: Systematic error $\leq \pm .005$ at each alcohol level

H_A: Systematic error $> \pm .005$ at each alcohol level

1.4.1.2. Hypothesis Two

Under laboratory conditions, each PMBT device will be less precise (more variable) that the NHTSA criteria at each alcohol level (will yield a standard deviation greater than .0042).

H_O: Standard deviation $\leq .0042$ at each alcohol level

H_A: Standard deviation $> .0042$ at each alcohol level

1.4.1.3. Hypothesis Three

Under laboratory conditions, each PMBT device will become less accurate as test BrAC increases (systematic error will increase when measured at .02, .04, .06, .08, .10 and .16).

H_O: Systematic error at $.02 \leq .04 \leq .06 \leq .08 \leq .10 \leq .16$

H_A: Systematic error at $.02 > .04 > .06 > .08 > .10 > .16$

1.4.1.4. Hypothesis Four

Under laboratory conditions, each PMBT device will become less precise (more variable) as test BrAC increases (standard deviation will increase when measured at .02, .04, .06, .08, .10 and .16).

H_O: Standard deviation at $.02 \leq .04 \leq .06 \leq .08 \leq .10 \leq .16$

H_A: Standard deviation at $.02 > .04 > .06 > .08 > .10 > .16$

1.4.2. Experiment Two

1.4.2.1. Hypothesis Five

Under simulated field conditions, each PMBT device will yield results significantly different than results from a calibrated Intoxilyzer 5000 breath alcohol test instrument.

H_O: Intoxilyzer = A = B = C = D = E = F = G = H at each alcohol level

H_A: Intoxilyzer $\neq$ A $\neq$ B $\neq$ C $\neq$ D $\neq$ E $\neq$ F $\neq$ G $\neq$ H at each alcohol level

1.5. Independent Variables

IV_1: Simulator solution alcohol concentration (Experiment One).

IV_2: PMBT used by each participant (Experiment Two).

IV_3: Amount of alcohol consumed by each participant (Experiment Two).

1.6. Dependent Variable

DV_3: BrAC measurement result (Experiments One and Two).

1.7. Operational Definitions

(a) Accuracy- A measure of the closeness of agreement between the result of analysis and the true value of the quantity being measured; the proximity of a quantified measurement result to the true value of the property being measured.

(b) Blood Alcohol Concentration (BAC)- Grams of alcohol per 100 milliliters of blood. This is equivalent to the metric used to measure breath alcohol concentration (BrAC), grams of alcohol per 210 liters of breath.

(c) Breath Alcohol Concentration (BrAC)- Grams of alcohol per 210 liters of breath. This is equivalent to the metric used to measure blood alcohol concentration (BAC), grams of alcohol per 100 milliliters of blood.

(d) Precision- Closeness of agreement between independent results of measurements obtained by a procedure under prescribed conditions; the variation or scatter of

the measurements about the mean; the degree to which replicate measurement results agree amongst themselves.

(e) Alcohol Solution Simulator- A device containing approximately 500 ml of an ethanol/water solution heated to a known and constant temperature and designed to provide a known vapor concentration of ethanol for calibration and testing of instruments.

Unless otherwise stated, all measurements results in this study will be expressed in terms of BrAC, grams of alcohol per 210 liters of breath.

CHAPTER II

REVIEW OF LITERATURE

2.1. Modern Breath Alcohol Testing

With references to the methodology made as early as 1874, breath alcohol analysis has developed into a primary method of measuring the concentration of alcohol in the body (Lucas, 2000; Deveaux & Gosset, 2000). Several advantages have led to its increased use throughout the world. First, unlike measuring alcohol directly from blood, medical personnel are not required to collect a sample. Second, no laboratory services are necessary for sample analysis. Third, it offers immediate results. Fourth, it minimizes the time between the event or arrest and the subsequent testing (Mason & Dubowski, 1996; Harding, 1996; National Highway Traffic Safety Administration, 1982). These advantages have combined to move breath testing to the forefront of alcohol measurement. Modern breath testing instruments have developed to the point that when used by people with limited or no scientific training, they can provide reliable results under non-laboratory conditions (Harding, 1996).

The basic process of breath alcohol testing can be divided into three components (Dubowski, 2002):

1. Input Phase. The participant provides a breath sample into a measurement instrument.

2. Analysis Phase. Any ethanol present in the breath sample is identified and quantitated.
3. Output Phase. The measurement instrument displays the results of the test.

Secondary phases would include the interpretation and use of the results, and quality assurance efforts.

Breath alcohol measurement is based on the principle of equilibrium. This principle asserts that the ratio of alcohol concentrations between a blood sample and a breath sample is a *constant* value (National Highway Traffic Safety Administration, 1982). That is, arterial blood is in equilibrium with deep lung (alveolar) air (Hlastala, 1998). Not surprisingly, the concentration of alcohol in blood is much higher than that of alcohol in alveolar air. A ratio of 2100:1 has traditionally been used to describe the relationship between alcohol in deep lung breath and blood, respectively (Mason & Dubowski, 1996; Hlastala, 2002; CMI, 2002a). This ratio is generally referred to as the "partition ratio" (Melethil, 2002).

As states began to adopt *per se* intoxication laws, their statutes frequently and logically included a metric commonly used to specify the amount of alcohol in the blood: grams of alcohol per 100 milliliters of blood (Dubowski, 2002; Gullberg, 1990a). However, as the use of breath alcohol testing spread, it became the norm to express breath alcohol results in a metric more closely aligned with its gaseous-form sample source: grams of alcohol per 210 liters of breath (Jones, 2002). Thus, each method

dictated its most appropriate and scientifically sound metric. Most states' statutes included only the original metric used for blood alcohol measurement, however.

In order to provide any sort of meaningful comparison between BrAC and BAC, it became necessary, using the partition ratio, to *convert* BrAC results to BAC results. This conversion has traditionally been a substantial source of contention. The originally applied ratio of 2100:1 may have been somewhat arbitrarily employed (Mason & Dubowski, 1996). In addition, contention over the ratio has arisen because of claims that the partition ratio may *not* be constant (Hlastala, 1998); it may *vary* depending on a number of factors (Jones & Andersson, 1996). Factors said to affect the partition ratio include breath temperature, breathing technique just prior to providing a sample (hypo- or hyperventilation), hematocrit value, alcohol loss to the airway mucosa and atmospheric pressure (Melethil, 2002; Hlastala, 2002).

Today, many states have amended legislation to include *both* blood and breath metrics in their definition of intoxication. Thus in those states, if a suspect provides a blood sample that exceeds a specified number of grams of alcohol per 100 milliliters of blood, *or* provides a breath sample that exceeds a specified number of grams of alcohol per 210 liters of breath, he or she is considered legally intoxicated. By including both definitions, the matter of converting breath alcohol results to blood alcohol results became moot (Jones, 2002).

Not every interested party believes that breath alcohol testing is completely accurate and precise. Detractors counter with claims that too many factors can interfere with such testing to permit its use in evidentiary circumstances. It has been claimed that asthma

inhalant and nasal spray chemicals can inflate test results (Logan, Distefano & Case, 1998). Residual alcohol or mouthwash in the mouth has also been said to inflate test results (Harding, 2002; Spector, 1971). In addition, interference from radio frequencies has been cited as affecting test results (Gullberg, 2002a). Some detractors remain quite vocal in their opposition to breath testing. One such detractor, Tucson defense attorney James Nesci, proclaimed "breath testing in general is a load of crap, just pseudoscience that they try to pull off" (Joseph, 2002, p. 3).

Effective quality control measures adequately address most, if not all, these challenges. For example, concerns about inhalant and nasal sprays and residual mouth alcohol can be addressed simply by employing a 15 minute deprivation period, where the subject is not permitted to ingest any material for 15 minutes prior to providing a breath sample. During the deprivation period, these potential interferents will have dissipated (Logan, Distefano & Case, 1998; Brown, 1994). Claims that dentures and mouth jewelry, such as tongue piercings, retain alcohol in the mouth and thus inflate results have also been scientifically refuted (Harding, McMurray, Laessig, Simley, Correll & Tsunehiro, 1992; Logan & Gullberg, 1998). Regarding radio frequency interference, most modern evidential breath test devices feature shielding specifically designed to prevent such interference (Gullberg, 2002a).

Non-invasiveness, advances in technology, immediate results and other factors have led breath alcohol analysis to become more accepted worldwide. It has become the standard measurement system used in the prosecution of impaired driving cases (Gullberg, 2000; National College for DUI Defense, 2002).

2.2. Breath Alcohol Detection Technology

2.2.1. Infrared Spectroscopy

Analysis of breath alcohol through infrared (IR) spectroscopy has become widespread; it is currently the most common method of measuring breath alcohol (Intoximeters, 2002; Dubowski, 1992). IR analysis is based on measuring the amount of IR that is absorbed by a substance (Drug Library, 2003). In fact, specific molecules can actually be identified by the way they absorb light (Freudenrich, 2002), similar to the way fingerprints can be used to identify specific humans (Fiandach, 2002).

Infrared devices have breath sample chambers, into which a subject provide a breath sample. IR light of a specific frequency is then passed through the chamber. Ethanol absorbs some of the IR light (Gullberg & Zettl, 2002). A photocell at the receiving end of the chamber measures the residual amount of IR received and compares it to the amount originally emitted (Freudenrich, 2002). The alcohol concentration of the sample is proportional to the amount of infrared light that is absorbed (Harding, 1996).

The foundational principle of this type of analysis is the Beer-Lambert Law. In this context, it posits that the concentration of any alcohol present is directly proportional to the amount of IR absorbed by alcohol dissolved in alveolar air. Basically, if the amount of IR that has been absorbed is known, the concentration of the alcohol can be computed (Fiandach, 2002; Gullberg & Zettl, 2002).

Infrared measurement instruments also feature the ability to detect for the presence of residual mouth alcohol. This is possible due to the instrument's capacity to *continuously*

measure the alcohol in a subject's breath as he or she exhales into the breath sample chamber (Harding, 1996). When plotted with time (in seconds) on the x-axis and BrAC on the y-axis, subject breath samples with and without residual mouth alcohol will yield very different breath exhalation profiles. Samples with residual mouth alcohol will yield a high alcohol level from the very beginning of a long breath, then taper off. Samples without residual mouth alcohol will slowly build in alcohol amount, peaking at the end portion of a long breath. The capability of infrared devices to detect these differences is called "slope detection." Devices so equipped can be programmed to not provide a result under residual mouth alcohol conditions and to notify the operator that an error has occurred (Harding, 1996). As previously mentioned, the employment of a 15 minute waiting period prior to any breath test should serve to effectively eliminate concerns about residual mouth alcohol. Current devices employing infrared spectroscopy include the Intoxilyzer 5000 series (CMI, 2003a) and the BAC Datamaster series (National Patent Analytical Systems, 2003).

2.2.2. Chemical Oxidation/Photometry

Breath alcohol measurement through chemical oxidation is the oldest testing technique still in use (Dubowski, 1992). It is the system that moved breath alcohol measurement into widespread use among law enforcement (Harding, 1996). Chemical oxidation involves noting the change in color resulting from a chemical reaction between alcohol in breath and normally inert detection chemicals (Freudenrich, 2002).

The technique involves directing a subject's breath sample into a vial or ampule containing oxidizing chemicals that react with ethanol. The most common chemicals used in these ampules include sulfuric acid, silver nitrate, potassium dichromate and water (Freudenrich, 2002). After the breath sample is introduced to the chemicals, any alcohol is oxidized (burned) to acetic acid (National Highway Traffic Safety Administration, 1982). This results in a proportional change in the color of the original chemicals, generally from yellow to shades of green. This change in color occurs due to a decrease in the amount of ultraviolet light absorbed by the chemicals (Harding, 1996). The color change is then measured by a photometer, the result of which is revealed via analog or digital display (Dubowski, 1992).

Chemical oxidation of breath alcohol is a very precise and accurate technique. In addition, it is selective and sensitive for alcohol, and is effective in ignoring the presence of other volatile substances (Dubowski, 1992).

2.2.3. Fuel Cell/Electrical Oxidation

Originally developed to provide power for the aerospace industry, fuel cell technology was adapted to the measurement of breath alcohol. Discovered in the 1800s, fuel cell technology was first shown to be capable of specifically identifying alcohol in the 1960s by researchers at the University of Vienna (Intoximeters, 2002). A fuel cell is basically an electromechanical device capable of converting an oxidant and a fuel into direct current (Harding, 1996). For breath alcohol measurement, atmospheric air is the oxidant and ethanol is the fuel.

A fuel cell generally consists of two platinum electrodes, between which is sandwiched an electrolyte material capable of conducting ions (CMI, 2002b; Dubowski, 1992). As a subject's expired air flows through the fuel cell, the alcohol is oxidized, resulting in the creation of an electrical current (Harding, 1996). As more alcohol is converted to water through oxidation, the current grows stronger. Thus the current created is proportional to the amount of alcohol that is exposed to the fuel cell. This current flows by wire from the electrode to a microprocessor that calculates and displays the resulting concentration of alcohol in the breath sample (Freudenrich, 2002).

Fuel cells have shown to be highly resistant to interference from other chemicals (Dubowski, 1992). However, the sensitivity of the devices changes over time, necessitating more frequent calibration than some devices employing other technology (Harding, 1996). Fuel cell technology continues to develop, as does the number of applications in which it is used. For example, fuel cell technology has since expanded into automobile applications (Autoweek Online, 2002). Current breath alcohol testing devices employing fuel cell technology include the Alco-Sensor (Intoximeters, 2003) and the Intoxilyzer 400PA (CMI, 2003b).

2.2.4. Solid State Semiconductor (Taguchi) Gas Sensor

Patented in the US in 1973, Taguchi semiconductor sensors are solid state devices capable of measuring alcohol (Dubowski, 1992). These units generally require little power to operate and are inexpensive and small. The sensor itself is an N-type (negative) semiconductor, comprised of a stannic oxide bead placed in a ceramic

cylinder. The porous sensor requires being heated to operational temperature prior to use (Harding, 1996).

As breath is passed through the cylinder, the bead absorbs alcohol, which causes an increase in electrical conductivity. This rise in conductivity is in proportion to the concentration of the alcohol in the breath, which is measured electronically and converted to direct current voltage (Harding, 1996; Dubowski, 1992). Results are displayed through a series of lights or a digital readout (Dubowski, 1992).

Taguchi sensor detectors are not specific for alcohol; such sensors will respond to almost any combustible gas. While quite sensitive, Taguchi sensors lack inherent stability, and thus require more frequent recalibration (Harding, 1996; Dubowski, 1992). Current devices employing Taguchi sensor technology include the A.L.E.R.T. Model J4 (Columbia Laboratory Services, 2003) and ignition interlock devices (Harding, 1996).

2.3 Breath Alcohol Sample Simulators

In order to assure the proper functioning of BrAC measuring devices and to ensure that their operators are properly trained as required, it is necessary to have access to a method of introducing alcohol vapor into BrAC testing instruments. One option is to have humans who have consumed alcohol provide breath samples. While such a procedure might be optimal, especially in terms of testing under simulated field conditions in which devices would be expected to be used, it is impractical to expect to have volunteer drinkers on hand for every testing and training procedure.

For these reasons, the breath alcohol sample simulator was created. Generally known as "simulators," these devices deliver alcohol vapor specimens of known concentration to BrAC measurement instruments (Dubowski, 1994). Originally designed to provide simulated breath alcohol vapor specimens for use in operator training, simulators are now also used to aid in calibrating and assessing the performance of BrAC analyzing devices (Dubowski, 1992).

There are two types of simulators: dry gas and wet bath. Dry gas simulators use an inert gas, such as nitrogen, to represent specific alcohol concentrations. The gas is contained in a pressurized cylinder which, when depleted, must be refilled. Increasingly used in the US, dry gas simulators have been found to demonstrate acceptable performance to be used for forensic and other purposes (Dubowski & Essary, 1996).

About the size of a coffee can, closed system wet bath simulators contain an aqueous solution, through which air can be directed (see Appendix B). This solution is mixed from precise amounts of water and ethanol; thus, the exact concentration of the solution is known (Harding, 1996). Generally, a simulator will contain 500 ml of the aqueous solution and will be heated to a constant temperature of 34 degrees Celsius (Speck, McElroy & Gullberg, 1991; Dubowski & Essary, 1991). This temperature is used because it approximates the temperature of human breath (Gullberg & Zettl, 2002).

As air is passed through the simulator, it takes on the alcohol properties of the mixture, then flows into a BrAC measurement device. This transference of alcohol properties to the introduced air is based on Henry's Law, which states that at a given temperature in a closed system, the alcohol concentration of the air will be proportional

to the alcohol concentration of the solution (Gullberg & Zettl, 2002). This law allows the alcohol concentration of the simulator headspace vapor to be of known quantity (Gullberg, 2000).

Wet bath simulators provide breath test users with several advantages. First, solutions can be prepared to virtually any alcohol concentration of interest (Harding, 1996). By precisely varying the mix of water and ethanol, the user can create any alcohol level desired. Second, simulators provide samples with properties similar to that of human breath, in that they flow dynamically. This type of system is superior to fixed-volume static samples (Dubowski, 1992)

However, wet bath breath alcohol simulators are limited in performance by the fact that the water/ethanol solution will decrease in alcohol concentration as air is passed through the mixture. The rate of depletion is relatively slow, with a 1% depletion resulting after approximately 25 tests. A one percent depletion limit has been noted to be acceptable for research and calibration purposes (Dubowski, 1979). Common practice is to discard simulator solutions after a maximum of 25 tests.

Support for the use of simulators in breath alcohol testing is widespread among researchers. In their research, Dubowski and Essary (1991, 1992) have concluded that simulators are capable of providing satisfactory and appropriate samples for the testing of BrAC measurement devices. Simulators have also been found to be very reliable for this function as well, capable of providing, over multiple tests, consistent and uniform breath alcohol samples (Gullberg 1989, 2000).

2.4 Breath Alcohol Measurement Devices

Numerous studies have assessed the performance of breath alcohol measurement instruments. Generally, these studies have used for comparison either blood results or results from an EBT or both. The literature dealing with the performance of each type of device will be discussed.

2.4.1. Evidential Breath Testers

The largest BrAC testing devices, evidential breath testers (EBTs) have been found to be sufficiently accurate and precise for their main purpose of providing evidence for use in the adjudication of criminal proceedings. The potential for substantial impact of breath alcohol testing on the outcome of impaired driving cases has prompted the National Highway Traffic Safety Administration (NHTSA) to develop performance standards for EBTs. Specific standards have been set for precision, accuracy, acetone interference and blank readings.

For precision and accuracy, all potentially eligible EBTs are tested by NHTSA 10 times at four levels of alcohol concentration: .02, .04, .08 and .16. At each level, the systematic error (the measure used to assess accuracy) must be $\leq \pm .005$ and the standard deviation (the measure used to assess precision) must be $\leq .0042$. The sole exception to these standards occurs with the test at the .16 level; here, the systematic error must be $\leq \pm .008$. The same $\leq \pm .005$ and $\leq .0042$ standards apply when testing with acetone, which is tested at .02. Blank readings, using alcohol-free human breath, must result in systematic error $\leq \pm .005$, with no single result exceeding .005 (U.S. Department of

Transportation, 1993). The EBTs that do meet the specifications can be placed on NHTSA's Conforming Products List (U.S. Department of Transportation, 2002b).

In a study of retrospective data, Harding, Laessig & Field (1990) compared the performance of EBTs against blood test results. The researchers examined 395 pairs of blood and breath alcohol test results, each pair of which were obtained within 60 minutes of each other. The EBT used was an Intoxilyzer 5000. The analysis revealed that the breath and blood results were in close agreement, demonstrated by a correlation coefficient (r value) of .94. Further, it was found that the EBT results systematically underestimated blood tests results by a mean of 11.5%. BrAC results were lower than BAC results for 67% of the cases, with BAC results exceeding BrAC results only 2% of the time. Thus, the EBTs tended to underestimate participants' actual blood alcohol concentrations, with the bias falling in favor of the suspect.

Taylor and Hodgson (1995) compared three different EBT devices against blood results from 18 male and female volunteers. The participants consumed alcohol, then provided breath and blood samples. Strong relationships were found between the EBTs and the blood results. Correlation coefficients ranged from .971 to .989, indicating strong relationships between results obtained directly from blood and results obtained through deep lung breath samples. In addition, the results showed that all three EBTs' measurements fell below those of the blood samples, thus underestimating blood alcohol concentration.

In their study of low BACs, Dubowski and Essary (1999) collected pairs of breath samples from 62 law enforcement breath testing sites using Intoxilyzer 5000-D EBTs. The data were from drivers who had been suspected of driving while impaired by alcohol, with their breath alcohol concentrations ranging from 0.00 to .059. It was concluded that EBTs can provide accurate measurements of low BrACs. The researchers further noted that the EBTs' performance, in terms of precision, accuracy and sensitivity, was quite adequate for use in forensic, research and clinical applications.

In a comparison of blood alcohol concentrations and EBT BrAC results, Italian researchers examined results from tests performed on weekend nights between 1997 and 1999 (Zancaner, Giorgetti, Cavazeran, Snenghi, Castagna & Ferrara, 2000). The study involved 278 pairs of breath and blood tests, where each pair of tests was performed within 10 minutes of each other. Breath test results were obtained at the roadside, using an EBT powered by a vehicle engine. The results indicated good agreement between the breath and blood results. The median difference between the two types of results was 5.2% and the results exhibited a strong correlation of .96.

The researchers also found that the relationship between breath and blood results was related to the alcohol concentration. BrAC results were found to be higher than BAC results at alcohol concentrations below .10. BAC results were higher than BrAC results at alcohol concentrations at and above .10. The authors concluded by recommending conducting breath tests in controlled conditions, such as at a law enforcement site, to confirm breath test results performed at the roadside.

Method, Reed, Kamendulis and Klaunig (2002) performed a study of the stability of Datamaster EBTs. Over a 3 year period, simulators were used to deliver surrogate samples, resulting in the collection of 771 data points. Results indicated that over time, there was a tendency for a slight decrease in breath test results. Further, all EBT test results were equal to or below the alcohol concentration sample provided by the simulators; no overestimation by the EBTs occurred. The authors conclude that EBT results under these conditions would be biased in favor of the suspect.

In sum, EBTs' performance has been repeatedly demonstrated to be of adequate precision and accuracy for its purpose. In fact, it has been claimed that the performance of EBTs for forensic purposes is *better* than it needs to be (Gullberg, 2002b). Additionally, there have been calls for the development of *roadside* evidential breath test devices (Reckers & Breen, 2002; Scott & Breen, 2000). EBTs continue to be the most widely used breath alcohol testing instruments.

2.4.2. Preliminary Breath Testers

Preliminary breath testers (PBTs) are designed to serve as pre-arrest alcohol screening devices to aid field officers in determining whether a suspected impaired driver should be arrested. Compared to officers having to make such decisions without this technology, PBTs can help identify intoxicated drivers who might be able to mask traditional signs of impairment and can help identify drivers for whom a medical condition, as opposed to an ingested drug, might be the cause of suspect behavior (National Highway Traffic Safety Administration, 1982).

According to the National Highway Traffic Safety Administration (1982), the proper use of PBTs can result in the following:

(a) An increase in the number of DWI arrests;

(b) A decrease in the mean BACs of those arrested;

(c) General acceptance of PBTs by law enforcement officers.

However, in his review of portable breath testing devices, Olson (1986) differs slightly in his assessment of expected results of the use of PBTs. While he agrees that the number of DWI arrests should rise, he argues that the mean BAC of arrestees will not necessarily decrease. Olson cites the common problem of subjects not blowing long or hard enough into PBTs as partially responsible for the uncertainly of effect upon mean BAC of those arrested.

In its PBT instruction manual, NHTSA cites the experiences of five states using PBTs. It noted that employment of PBTs could be attributed to a mean increase in arrests of 53% and a mean decrease in average BACs of those arrested of 17% (National Highway Traffic Safety Administration, 1982). In another year-long study of six states' results of over 3,600 preliminary breath tests, the agency noted that the mean BAC of those arrested decreased from .201 to .172, a 14% drop. In addition, feedback about PBTs was obtained from law enforcement officers, with 75% stating that PBTs were a good idea.

In the late 1970s, Jones & Goldberg (1978) began a four-part study on an early PBT model, the Alcolmeter Pocket Model. Their first research tested the device using simulators, at five alcohol levels. Results were positive, as the researchers noted a mean correlation between the simulated alcohol samples and the PBT of .967. The Alcolmeter

demonstrated good precision, yielding a standard deviation of .0175, or 1.91% of the mean alcohol concentration. Their assessment of accuracy revealed that the PBT systematically underestimated BAC by 3-12%. They also noted that the Alcometer was very stable, with only a slight downward trend in results over repeated use.

Jones' (1978) second study involved human drinkers. Thirty-nine male participants first provided a total of 120 alcohol-free breath samples. All PBT results were negative for alcohol. Participants then consumed alcohol and provided breath and blood samples. Jones found that the relationship between the PBT BrAC results and the blood test results was dependent on whether the participant was in the absorptive or elimination phase. During the absorptive phase, the PBT results were higher than BAC results; during the elimination phase, the PBT results were lower than BAC results. Precision was found to be highest during the elimination phase, however the instrument became less precise as the alcohol concentration increased. Jones also emphasized that the standard error estimate (S_{yx}) is a good estimate of overall error associated with breath test results.

In the third study, Jones performed a controlled field trial of the Alcolmeter (Jones, 1985a). This involved 10 police officers consuming one of two doses of alcohol and providing blood samples and breath samples with a PBT. The overall relationship between the two types of results was strong, with a correlation coefficient of .95. As in the second study, he noted that the standard deviation of the PBT measurements increased with increasing alcohol concentration, indicating that precision was a function of alcohol level. BrAC measurements were found to underestimate actual BAC by

5.1%. Jones concluded that the Alcolmeter's precision and accuracy was satisfactory and thus it would be practical and useful for use as an alcohol screening device.

The final study involved using 84 Alcolmeters at roadblock checkpoint, traffic crash and traffic offense events throughout Sweden (Jones 1985b). Breath and blood samples obtained from 333 drivers were pooled. Since the blood tests were performed up to 220 minutes after the PBT tests, the blood test results were adjusted to reflect for alcohol eliminated during the delay between tests. The rate of .015 g/ml per hour was used for this adjustment. The relationship between the blood and breath tests was statistically significant, yielding a correlation coefficient of .84. At alcohol levels below approximately .08, BrAC results were found to exceed BAC results. At alcohol levels at or above .08, BAC results exceeded BrAC results. Further, the Alcolmeter's false positive rate was relatively low, at 5% of all tests. Overall, each of the four tests of the Alcolmeter supported its continued use.

In his discussion about the advantages of PBTs capable of collecting evidential data, Forrester (1997) described two studies examining PBT performance. The first study used three participant drinkers who provided breath samples through an Intoxilyzer EBT and an Alco-Sensor IV PBT, along with blood samples. Results indicated that the devices' results agreed with each other to within a mean of .004. The PBT results were found to be approximately 9% below the blood results. The second study involved 412 participants under field conditions, who provided breath results with a PBT and blood results. Breath results were again found to be slightly below blood test results. The study concluded that PBTs demonstrate acceptable consistency for use in the field.

Reckers and Breen (2002) also examined the performance of PBTs for evidential applications. Two Alco-Sensor IV-XL PBTs were used, as was a Datamaster EBT. After consuming known amounts of alcohol, three volunteer participants provided breath samples with both types of devices. The differences in performance between the two types of instruments were quite small. Mean PBT breath results were found to be within .005% of mean EBT breath results. There was a small overall mean difference between the device types of .0018%. The authors concluded that the Alco-Sensor IV-XL PBT shows promise as an evidential breath testing instrument.

PBT instruments continue to be employed a variety of testing applications, including law enforcement, drug abuse treatment centers and operators of large motor vehicles and aircraft (National Commission Against Drunk Driving, 2002a). Their performance and ability to evaluate drivers' alcohol levels close to the time of driving make them a useful tool in the fight against impaired driving (Gullberg, 1991).

2.4.3. Passive Alcohol Sensors

The least intrusive of breath alcohol test devices, passive alcohol sensors (PASs) capture drivers' breath without their knowledge or active participation; hence the "passive" descriptor (National Commission Against Drunk Driving, 2002b). As with PBTs, PAS instruments do not capture evidential test results. Rather, they are intended to aid law enforcement officers in their initial screening of suspected impaired drivers (Wells, Preusser & Williams, 1992).

In an early study of PAS devices, Jones and Lund (1986) examined the performance of PASs used in sobriety checkpoints. The data were collected from checkpoints performed in Charlottesville, Virginia on weekend nights over a period of two months. Officers stopped all motorists arriving at the checkpoint and examine their drivers' licenses. It was at this point that officers used PASs to check each driver's breath for the presence of alcohol. If as a result of that interaction an officer suspected that a driver was impaired, he or she would ask the driver to provide a breath sample through an Alco-sensor II PBT. The officer would then take the appropriate action, based on the result of the PBT test.

Data from 1644 drivers were used in this study. At checkpoints where PAS devices were used, the detection rate of impaired and intoxicated drivers improved significantly, compared to checkpoints at which PAS devices were not used. For drivers with BrACs between .050 and .099, detection rates increased from 24% to 45%. For drivers with BrACs at or above .10, detection rates increased from 45% to 68%. These correspond to percentage increases of 88% and 51%, respectively. In addition, the number of drivers with BrACs between .020 and .049 who were unnecessarily detained decreased by 56%. Compared to the Alco-sensor II results, the PAS units were found to underestimate BrAC at levels .02 and higher by a factor of two. Overall, detection rates at sobriety checkpoints increased and the detention of drivers with low BrACs decreased, indicating support for PAS devices in these enforcement circumstances.

Lestina and Lund (1992) tested two different brands of PASs under laboratory conditions. Twelve volunteer drinkers provided breath samples for 12 models of each

brand of PAS device. These results were compared to breath samples collected with an Alcolmeter PBT. A major variable under examination was the distance between participants' mouths and the PAS devices; each drinker provided breath samples with their mouths at 12.7, 19.1 and 25.4 cm from the PAS units. Results showed that at distances of 19.1 and 25.4 cm, neither device performed well; both models performed best at 12.7 cm from drinkers' mouths. False positive results at the .02 BrAC level ranged from 13% to 20%. The authors concluded that the PAS units tested performed with sufficient reliability to be used as roadside alcohol screening devices and that their performance would be most optimal in the detection of drivers with high BACs.

In their study of PAS devices, Foss, Voas and Beirness (1993) conducted interviews with 1,145 drivers in Minnesota parking lots between 10:00 p.m. and 3:00 a.m. Drivers voluntarily submitted to the interviews and provided breath samples through an Alco-sensor III and a PAS instrument. Results indicated that the two devices' performance was similar, as evinced by a correlation coefficient of .87, with the PAS results falling consistently below the PBT BrAC measurements. It was found that PASs resulted in decision accuracy levels of at least 95% when analyzed at discrete alcohol concentrations of .02, .05, .08 and .10. Further, the PAS units demonstrated low rates of false positive outcomes, with less than 4% of drivers being erroneously judged to exceed .10 BrAC. Even at low BrACs, PAS performance was good, with 93% of drivers at .02 BrAC being detected. The study supported the use of PAS devices and predicted that widespread application of these instruments would improve the ability of law enforcement to reduce the incidence of impaired driving.

Ferguson, Wells and Lund (1995) also examined the performance of PAS instruments employed at sobriety checkpoints. As standardized field sobriety tests (SFSTs) are commonly employed by law enforcement at checkpoints to help identify suspected drinking drivers, this study sought to determine the effects of adding PAS analysis to the performance of SFSTs. At six sobriety checkpoints performed in Fairfax County, Virginia in 1993, 5,192 drivers were interviewed. Approximately half of the drivers were evaluated with both SFSTs and PAS devices; the other half were evaluated using only SFSTs.

The study found that the combination of SFSTs and PAS units resulted in improved identification of impaired drivers than the use of SFSTs alone. At BrACs between .05 and .10, the combination resulted in a 77% improvement in identification of impaired drivers. At BrACs above .10, the combination resulted in a 29% improvement. The authors thus noted that the use of PAS instruments might be most effective in the identification of drivers around the moderate BrAC level of .05 to .08. In addition, the authors did caution that because PAS instruments draw in ambient air in addition to drivers' breath, they are incapable of providing accurate numerical estimates of BAC, thus reemphasizing these devices' use as qualitative screening tools, rather than quantitative measurement instruments.

Research indicates that PASs can be effective in improving the identification of impaired drivers by law enforcement officers. Originally contained within innocuously appearing flashlights, other versions are now available, including a model built into a clipboard (PAS Systems International, 1999).

2.4.4. Ignition Interlock Devices

Ignition interlock devices (IIDs) are designed to prevent drivers convicted of DWI from starting their motor vehicles if they have alcohol in their bloodstream (Coben & Larkin, 1999). In the US, this threshold level is generally set at .025 (Voas, Blackman, Tippetts and Marques, 2002). The idea of preventing drivers from driving after consuming alcohol first surfaced in the late 1960s. Introduced to the US in the mid 1980s, IIDs have spread in application, with over 43 states having adopted some form of legislation addressing the use of these devices (Frank, 1997; Governors Highway Safety Association, 2003).

IIDs consist of two components. First is the head unit, which serves to collect a sample of the driver's breath. Second is the control module, which is securely connected to the vehicle. It performs the analysis of the breath sample and, if warranted, prevents ignition of the vehicle's engine (Comeau, 2000). Modern IIDs are capable of recording all attempts to start a vehicle and can require vehicle operators provide rolling retests. These latter tests involve drivers having to perform additional alcohol-free breath tests while driving in order to *keep* the vehicle's engine running (Marques, Voas, Tippetts & Beirness, 1999).

Most research into IIDs has focused on the devices' impact on DWI recidivism, rather than their accuracy and precision. Every identified study of IIDs' impacts on recidivism found that the devices are, when installed on a vehicle, effective in reducing recidivism (Tippetts & Voas, 1997; Beck, Rauch & Baker, 1997; Voas, Marques, Tippetts &

Beirness, 1999; Weinrath, 1997). Other research involving IIDs has examined less impact-oriented issues, including:

(a) The use of IID-recorded start attempts to identify drivers at highest risk for DWI recidivism (Marques, Tippetts, Voas & Beirness, 2001);

(b) The ability to and result of efforts to motivate DWI offenders to enter an IID program (Voas, Blackman, Tippetts & Marques, 2002);

(c) The use of global positional satellite (GPS) technology to precisely monitor the location of a violator's vehicle (Comeau, 2000);

(d) The impact of combining adding human services intervention efforts to IID programs (Marques, Voas, Tippetts & Beirness, 1999);

Ignition interlock devices continue to be the subject of administrative and impact evaluation. While past research indicates IIDs can have positive impact while installed, their long term behavioral effects remain undetermined.

2.4.5. Coin Operated Breath Testers

Designed for point-of-purchase breath alcohol testing, coin operated breath testers (COBTs) permit drinkers to self-test their BrAC. These counter- or wall-mounted devices hold the potential to earn profits for establishments that offer them for their patrons' use. Several other potential benefits have been noted by COBT distributors. First, it is claimed that COBTs serve to reduce impaired driving. Second, they can serve to educate consumers, thereby encouraging them to drink moderately and at an appropriate pace. Third, COBTs offer establishments an objective and tactful way to

cease service to specific individuals and thus prevent service of additional alcohol to an intoxicated patron (The Alcohol Alert System, 2002). While some of the distributors' claims may come across as too-good-to-be-true, what little research exists on COBTs tends to support the performance of the devices.

As with IIDs, most research into COBTs has focused on social impacts. Identified studies have supported the use of COBTs as part of an overall impaired driving prevention strategy (Haworth and Bowland, 1995; Wundersitz, 2002). However, the availability of these devices in the US remains limited.

2.4.6. Pocket-Model Breath Testers

There is a lack of evaluation of the performance of pocket-model breath testing devices. Published works concerning PMBTs generally consist of newspaper or Internet articles introducing and describing the devices. Only one scientific study examining a PMBT could be identified. NHTSA tested one such model, sold as the ABI, and found that it met the Federal performance standards for alcohol screening devices (U.S. Department of Transportation, 2002b).

In a *New York Times* article, Stellin (2001) described the units' technologies, accuracy, costs and sizes. A member of the New York Highway Patrol who was interviewed for the article stated that using PMBTs was better than guessing about how much alcohol is too much.

In his article in *The Courier-Journal*, Muhammad (2000) wrote that such devices have sales appeal that is politically correct, but raised questions about the devices' initial

calibration. He also posited that PMBTs could be used to persuade party guests to engage a taxi rather than drive home themselves and/or to allow the body to learn individual cues associated with intoxication. Muhammad further suggested that, if wisely used, the devices could help prevent a DWI arrest or an alcohol-related motor vehicle crash. However, he cautioned that if used unwisely, PMBTs could cause a drinker to think he or she is more sober than he or she really is.

CNN interviewed a law enforcement officer involved in DUI training about PMBTs (CNN, 2002). The officer agreed that such devices were needed because of alcohol's effects on the brain and the resulting inability to think clearly. He also emphasized that the decision about whether or not to drive should be made prior to the consumption of any alcohol.

WCCO-TV (2003) tested two PMBTs using human drinkers, comparing the results to Minnesota's state-approved EBT. They found that one device did not work at all and the second device, the ABI Personal Breath Alcohol Screener, read higher than the state's EBT, at multiple BrACs.

The relative lack of experimental research on PMBTs has been repeatedly confirmed, indicating a need to examine these devices' performance (A.W. Jones, personal communication, December 6, 2002; M. Cowan, personal communication, April 1, 2002; M. Parker, personal communication, April 1, 2002; R. G. Gullberg, April 1, 2002; J. F. Frank, personal communication, April 2, 2002). Parties who might be interested in an analysis of the performance of these devices could include drinkers, alcohol-serving

establishments, emergency room personnel, probation officers, workplace testing personnel, law enforcement and the devices' manufacturers.

CHAPTER III

METHODOLOGY

3.1. Test Devices

Eight small scale, reusable breath alcohol testing devices were procured for this study. All were readily available; one device was obtained through a local retailer and all others were obtained via Internet-based retailers. Per device costs ranged from $40 to $104, excluding shipping charges. All the devices provided numerical readouts of estimated BrAC, to the hundredth of one percent (two digits to the right of the decimal). One of the devices tested, the ABI Professional Breath Alcohol Screener, is on NHTSA's Conforming Products List.

The option of requesting the manufacturers and/or merchants of the devices to provide the instruments free of charge for testing was considered and discarded. This decision helped keep the study as pure from potential contamination as possible, serving to maximize study integrity. Had the manufacturers been aware of the study and provided the devices, the chance of obtaining a device whose performance would be substantially different from the population of all devices of that model would have increased, weakening the study.

The devices were of two types: those that employed a mouthpiece to facilitate direct insertion of breath to the unit's sensor (4), and those that did not feature a mouthpiece (4). The latter devices featured a breath port into which the user expires his or her

breath. Descriptions and specifications of each device tested can be found in Appendix A. Upon acquisition, each device was randomly assigned a letter, ranging from A to H.

Only one of each model of device was tested. The author recognizes the possibility that any device's performance could have been affected by handling prior to arrival for testing. Each device did arrive apparently undamaged, with all packing materials intact and unblemished. Great care was exercised in the storage and handling of each device upon arrival, so as to minimize the effects upon performance. All devices were stored and transported together in the same container, such that all devices would be subject to identical conditions (temperature, movement, etc.). In addition, no test device was used other than during the testing procedures, reducing the possibility of performance differences resulting from differential use.

3.2. Pilot Testing

All pilot and additional laboratory testing was conducted at the Texas Department of Public Safety (DPS) building at 1540 East Highway 6 Bypass, Bryan, Texas. This location's breath testing technical supervisor, Margaret Parker, oversees such testing operations throughout nine counties and facilitated the testing of the instruments. All data were collected in the facility's conference room, under fluorescent lighting conditions. There were no nearby sources of radio frequency interference.

3.2.1. Phase One Pilot Testing

This testing had several goals:

(a) Determine the appropriate testing time interval, partially dependent upon the devices' recovery times;

(b) Create a method of consistently delivering alcohol samples to the devices;

(c) Develop the apparatus to deliver an alcohol sample to the non-mouthpiece devices.

Based on this testing, it was determined that the time interval between successive tests could not be less than two minutes. Thus the minimum testing interval was set at two minutes.

Further, an alcohol sample delivery system was developed for both types of devices. The system for mouthpiece devices used surgical tubing to direct the alcohol sample. At the input (human) end of the tube, a standard DPS mouthpiece was attached; the other end of the tube was connected directly to the solution simulator. The simulator's exit tube was connected directly to the device's mouthpiece. Plastic, funnel-shaped reducers were used as needed to ensure proper mating between the connections. This provided direct input with a flexible tube through which the alcohol sample could flow without contamination or dilution.

The delivery system for non-mouthpiece devices also used surgical tubing with a DPS mouthpiece at the input end. Most of the non-mouthpiece devices' instructions stated a recommended distance between the user's mouth and the device's input port. This distance ranged from 1.3 cm to 3.8 cm. If a non-mouthpiece device's instructions did not include such a recommended distance, the distance was set at a default of 1.3 cm.

As several of the non-mouthpiece devices were quite small, a small vice was used to hold the smaller devices steady for all tests. Cardboard or thin rigid plastic was used to form a stable mounting point for the tubing; the mounting extended perpendicularly from each non-mouthpiece device, allowing the tube to be pointed directly at the devices' input ports.

It was also determined that wet bath breath alcohol solution simulators could be effectively used to deliver alcohol samples to both mouthpiece and non-mouthpiece devices. National Draeger, Inc. Mark IIA simulators (see Appendix B) were used for this purpose (Draeger, 2003). The alcohol mixtures consisted of a combination of distilled water and a predetermined amount of 200 proof alcohol designed to produce certain equivalent measures of BrAC. The alcohol came from the DPS stock. The DPS technical supervisor prepared all the solution sample mixtures according to DPS standards.

For each group of tests at each alcohol level, 500ml of mixture was inserted into the simulator. The solution was then warmed by the simulator's integral heating element to the proper temperature, 34ºC, ±.5ºC. Temperature was verified at the start of each test run with an NIST-certified thermometer. The simulator's integral agitating propeller served to maintain a properly blended solution.

Because a given simulator sample's alcohol strength will diminish as breath is blown through the mixture, only 20 tests were conducted with each sample. After 20 tests, the solutions were discarded. Further, solutions were changed to different alcohol strengths only on an increasing basis. That is, only the next stronger solution was permitted to be

inserted into a given simulator. This was done to avoid a situation where any residual alcohol in a simulator would be at a strength higher than the subsequent mixture, possibly contaminating the next mixture.

3.2.2. Phase Two Pilot Testing

This testing had two goals:

(a) Test the devices' abilities to resist yielding false positive readings;

(b) Test the devices' abilities to resist yielding false negative readings.

Eight devices were tested in this experiment. To assess their ability to minimize false positive readings, each device was tested 20 times at an alcohol level of .00. This is the same concentration at which NHTSA tests PBT devices. To create this non-alcohol sample, only pure distilled water was inserted into the simulator, so as to employ the same procedure of blowing through a simulator at all alcohol levels. To assess the device' ability to minimize false negative readings, each device was tested 20 times at an alcohol level of .032. NHTSA also specifies this test level in its testing protocol.

After installing fresh batteries in all devices and prior to collecting data at either level, two "warm-up" tests were performed, but data were not recorded. This was done in order to:

(a) Ensure that each device's sensor had reached operating temperature;

(b) Determine that each device was functioning properly.

Tests were conducted at two minute intervals. At the halfway mark (after 10 tests), the tubing was temporarily disconnected between the simulator and device and shaken to

remove any condensation that might have accumulated in the system. To enhance consistency among samples, a single human provided all breath samples for all alcohol positive tests.

To advance to Experiment One, each device was required to meet the following performance criteria:

(a) Yield no more than one positive result in 20 trials at an alcohol level of .00 (positive equaling .02 or higher);

(b) Yield no more than one non-positive (below .02) result in 20 trials at an alcohol level of .032.

Data were recorded on pre-prepared data forms, along with the temperature of the solution.

For all pilot testing and Experiment One, human breath was expired through the simulator mixture into each device. Prior to providing breath samples through the simulators, the human breath provider's BrAC was measured using a calibrated Intoxilyzer 5000 (Intoxilyzer) to ensure that the provider's breath was free of alcohol. This model Intoxilyzer is the latest version used by DPS. The Intoxilyzer instruments are the only evidential breath testing equipment used in Texas; it is the standard used throughout the state.

In addition, each solution mixture was tested 20 times, in recirculation mode, by a calibrated Intoxilyzer in order to confirm the targeted strength of the mixture. No data were recorded from the pilot tests, all of which were performed at .08 alcohol

concentration. All breath samples were provided by one individual, who was trained *a priori* by Department of Public Safety personnel to provide adequate breath samples.

3.3. Experiment One

The goal of this experiment was to assess the accuracy and precision of the devices at multiple alcohol levels, under laboratory conditions. In its assessment of these measures, NHTSA tests each device at the following alcohol levels: .02, .04, .08 and .16. In order to maintain a full range of .02 increments between .02 and .10, the devices were also tested at the .06 and .10 alcohol levels. Each device was tested 20 times at each alcohol level, resulting in a total of 120 tests per device.

Alcoholic simulator solutions were created by the method given in the Pilot Testing. As in the Pilot Testing, two warm-up tests were performed with each device at each alcohol level, prior to collecting data. Also, the same procedure for removing any condensation was employed. Tests were conducted at two minute intervals. Data were recorded on pre-prepared data forms, along with the temperature of the solution.

3.4. Experiment Two

The goal of this experiment was to assess the devices' performance under actual drinking (in vivo) conditions. As such, volunteer participants agreed to consume alcohol and provide numerous breath samples. For such tests to be performed, it was necessary to obtain approval from the Texas A&M University Institutional Review Board (IRB),

which oversees all research involving humans. All aspects of this study were approved by the IRB.

3.4.1. Participants

3.4.1.1. Participant Eligibility

Participants were limited to those between the ages of 21 and 34. This limitation was imposed for several reasons. First, this age range represents the group of drivers that are most involved in fatal DWI behavior in Texas (Texas Department of Public Safety, 1999). Second, the age range was limited to restrict the effect of large age variation on the breath test results. A total of eleven (11) participants from the local community were included in the study.

3.4.1.2. Participant Screening

Potential participants were pre-screened to exclude:

(a) Pregnant females

(b) Non drinkers

(c) Heavy/problem drinkers

(d) Alcoholics

(e) Diabetics

(f) Those allergic to alcohol.

The *Alcohol Use Disorder Inventory Test* (AUDIT) questionnaire developed by the World Health Organization in 1987 and the Numerical Drinking Profile were used as the first-line screening instruments (see Appendixes C and D). Potential participants scoring a 6 or below on the AUDIT were eligible for participation. Alternatively, potential participants with an NDP score of 3 or less were eligible to participate.

Several other questions were also presented along with the alcohol abuse screening instruments, to ascertain whether participants were diabetic, allergic to alcohol, and/or in poor health. Potential participants who answered affirmative to any of these questions were excluded from participation. Prospective female participants were required to administer a portable pregnancy self-test on the day of the study to exclude all who tested positive.

All potential participants were informed that they would consume alcoholic beverages, provide multiple breath tests, could withdraw at any time, but must remain at the testing site until their BrAC returned to 00. They were further informed that the target peak BrAC would be .09.

3.4.2. Testing Location

Experiment Three was conducted at the Texas Transportation Institute Gibb Gilchrist Building on the West Campus of Texas A&M University. A large, first-floor classroom was used, access to which was facilitated by Dave Willis, Director of the Center for Transportation Safety (personal communication, October 20, 2002). To reduce possible complications associated with too many participants present at one time, two drinking

sessions were performed, with five and six participants in the first and second sessions, respectively.

3.4.3. Materials

3.4.3.1. Measurement

3.4.3.1.1. BrAC Instrumentation

One Intoxilyzer unit was used at the testing location with a second unit immediately available for backup. All eight PMBT devices were present as well, along with all necessary tubing and connecting apparatus used for the collection of breath samples. Drinking straws cut in half in length were used as mouthpieces. This mouthpiece was economical, and easily replaceable should participants chew on or lose them.

3.4.3.1.2. Participant Data Collection Instrumentation

Several measurement instruments were used to collect data from the participants throughout each session, including:

(a) Body weight scale

(b) Pregnancy tests (Equate brand, procured from WalMart)

(c) Ruler (for measuring height)

(d) Oral thermometer

(e) Body water content device (model BIA 3000)

(f) Stopwatches.

3.4.3.2. Dosing

To ensure the precise administration of alcohol to each participant, specialized dosing equipment was present, including a graduated cylinder scaled in milligrams, a calculator to compute doses to be administered, and an alcoholic beverage. The beverage served to each participant was a mixture of vodka and orange juice, served over ice. The vodka was 100 proof Smirnoff Number 57, procured from a local liquor merchant.

3.4.3.3. Administrative

Several administrative materials were used to facilitate the sessions. A large-readout digital clock was positioned in the testing room to record the time of each sample collected. To ensure seamless operation of the instruments to be tested, extra batteries were present for each device. In addition, a first-aid kit was present during all testing.

3.4.3.4. Participant Accommodation

In order to assure a minimum level of comfort for participants during the sessions, a controlled amount of food and beverages were on hand, including:

(a) Breakfast foods- bagels, bananas, raisin bread

(b) Miscellaneous snacks, including pretzels and party mix

(c) Bottled water.

The point during the sessions that each participant was given access to these food was strictly controlled. Various forms of entertainment were provides as well, including:

(a) Games- cards, board games

(b) Music- radio/CD player

(c) TV/VCR with assorted videos.

3.4.3.5. Additional Materials

To further support the smooth conduct of each session, additional materials were on hand. A box was provided for car keys, as any participant who drove to the testing location had to relinquish his or her car keys. A portable folding cot, borrowed from the Texas Transportation Institute, was present to support the acquisition of data regarding each participant's current body water content. Both cotton and paper towels were on hand for any use required.

3.4.4. Personnel

In addition to the researcher, the DPS technical supervisor was present for the duration of each session. This person assumed total responsibility for the operation of the Intoxilyzer. Further, two sober volunteers were present for each session. These personnel assisted with the acquisition of data and monitoring of participants.

3.4.5. Procedure

3.4.5.1. Initial Setup

The afternoon prior to each session, the classroom tables and chairs were arranged to facilitate testing and participant comfort. The evening prior to each session, final contact was made with each participant to review procedures and to maximize the chances that each participant would be present on time and at the proper location. Participants were asked to refrain from consuming alcohol that evening, to get a full night's rest and to avoid eating any breakfast foods prior to arrival at the testing site.

Upon arrival of volunteer personnel the mornings of the sessions, the Intoxilyzer and PMBT devices were placed into their respective testing locations. At that time, fresh batteries were installed in all PMBT devices. Breakfast foods were available for consumption.

3.4.5.2. Upon Arrival of Participants

As participants arrived, introductions were made and each was thanked for their participation and informed that he or she could partake of the breakfast foods. A light breakfast was provided to control, to the degree possible, how much food was in each participant's stomach prior to consumption of alcohol. This helped ensure that all participants had consumed at least some food that morning, thus minimizing any differences in absorption time among participants. In addition, this step was taken to

prevent participant discomfort that could result from consuming alcohol on an empty stomach.

After all participants had arrived, the researcher thanked them as a group and informed them about how the day was to proceed. They were reminded that any participant could withdraw from the experiment at any time, but once alcohol was consumed, participants would have to remain at the testing site until their BrACs returned to 0.00, as measured on the Intoxilyzer.

At this point, participants completed the Informed Consent forms (see Appendix E). Each participant also agreed not to drive for 12 hours following the conclusion of the experiment. All were assured that they would receive transportation home, should they be unable to secure rides themselves.

During this meeting, participants were informed that the sober volunteers would guide them through all the testing and would watch for any signs of discomfort or any other problems on the part of the participants. The locations of the bathrooms were identified and participants were informed that whenever they needed to use the bathroom, a sober volunteer would accompany them to the bathroom door. This was done to ensure that all participants were supervised at all times, and that no participants with a positive BrAC left the testing facility.

The possibility of becoming ill due to the consumption of alcohol was discussed. A trashcan was present in the event of regurgitation and towels were available for any necessary cleanup. They were also informed that any participant who became sick would no longer be able to consume alcohol nor would they be allowed to provide breath

samples. Any ill participant would be removed from the study, but would be required to remain at the test site, unless medical attention became necessary.

Following this meeting, female participants completed the portable pregnancy tests. The results of the tests were visually confirmed by a female sober volunteer. Each participant's body weight was then measured. No participant's weight was made available to the other participants.

To help maximize the consistency among the breath samples to be obtained, participants received training in providing breath samples. Each participant provided several breath samples into the Intoxilyzer, monitored by the DPS breath test technician. Once the technician was satisfied that each participant had reached the required level of competency, participants were permitted to provide samples into the test devices. Table 1 contains information on participant variables.

Table 1
Participant Variables

Participant	Sex	Age	Weight (kg)	Height (cm)
1	M	23	100.9	173
2	M	22	105.9	190
3	M	23	75.9	177
4	F	22	69.1	166
5	M	23	125.9	196
6	F	22	69.1	168
7	M	23	97.7	182
8	F	32	77.3	172
9	F	22	56.4	169
10	F	22	50.0	164

3.4.5.3. Dosing

The amount of alcohol that each participant would consume to reach a target peak BrAC of .09 was computed as a function of body weight. This target peak BrAC was chosen to maximize the chances of being able to capture data from each participant during the post-absorptive phase as he or she "passed" through the .08 BrAC level, the first level at which it was intended participants be tested. The DPS formula for dosing participants was used: .9 ml per pound of body weight. Each participant was to consume three alcoholic beverages, each of equal strength. Thus each participant's total amount of alcohol to be consumed was divided by three.

The breath test technician then mixed the first round of drinks, mixing the ice, vodka and orange juice. In accordance with DPS research procedures, participants were given 15 minutes to consume each drink, for a total consumption period of 45 minutes. As consumption began, a stopwatch was started to monitor the timing of consumption. Participants were given a timed countdown during each drinking segment.

At the end of the first and second 15 minute consumption periods, fresh drinks were prepared using the aforementioned procedure. Participants were closely monitored for signs of discomfort or other problems.

3.4.5.4. Waiting Period

Following the consumption period, a 15 minute waiting period was induced. The purpose of this period was to allow time for any residual mouth alcohol to dissipate and to ensure that nothing else was ingested during this time. This waiting period is

recommended as part of any breath testing program (Dubowski, 1994; Gullberg, 2000) and is standard procedure for Texas DPS. Again participants were closely monitored for discomfort or other problems.

3.4.5.5. Confirmation of Post-Absorptive Phase

At the conclusion of the waiting period, each participant was tested using the Intoxilyzer. The goal was to identify the point at which participants' absorption had ended. Participants provided BrAC samples approximately every five to ten minutes during this monitoring phase. Having two successive downward BrAC readings was used as the criteria for a participant to be considered in the post-absorptive phase.

3.4.5.6. BrAC Data Collection

Once a participant had been identified as being in the post-absorptive phase, he or she was monitored so that a reading could be obtained at the .08 level. The goal was to test each participant at four distinct declining levels: .08, .06, .04 and .02. As it would be very difficult, due to random fluctuations and error, to capture a participant at exactly the .08/.06/.04/.02 level, a range of acceptable BrACs was used. Participants' measurements could fall between ±.005 of the target level. Table 2 shows the target levels and the associated acceptable range parameters.

When a participant was confirmed to be in the post-absorptive phase *and* within the first range of testing (.075-.085), he or she would then provide a second sample with the Intoxilyzer and then would provide duplicate samples with all test devices. Duplicate

Table 2
Acceptable Range for
Individual Testing

Target Level	Acceptable Range
.08	.075-.085
.06	.055-.065
.04	.035-.045
.02	.015-.025

samples, which have been rated quite adequate for forensic uses, were collected at every test, on every device (Gullberg, 1989). All data, including the time of each test, were recorded on pre-prepared data forms.

In order to reduce any effects of the order of treatment, the order in which participants provided samples with the devices was counterbalanced. A Latin Square system was used to create different specific orders so that every participant used a different order, with all eight devices (Bordens & Abbott, 1996). Latin Square treatment ordering systems are appropriate when the researcher is willing to set the number of treatment orders equal to the number of treatments, in this case eight. This involved creating eight distinct, randomly generated treatment orders. These orders were then randomly assigned to participants at the beginning of each data collection session. Appendix F provides the specific counterbalanced orders of treatment.

Because the number of participants exceeded the number of treatment orders, eleven and eight, respectively, once all eight treatment orders had been assigned once, the remaining three participants were assigned the first three sequential testing orders. Participants one through eight were assigned orders one through eight, respectively, and participants nine through eleven were assigned treatment orders one through three.

Thus, treatment orders one through three were used twice and treatment orders four through eight were assigned only once.

After each participant had provided duplicate samples using each test device, they returned to the Intoxilyzer to provide a final pair of samples. Thus, a full "round" of testing involved:

1. Providing initial (Pre) duplicate samples on the Intoxilyzer
2. Providing duplicate samples on each test device, according to the individually assigned treatment orders
3. Providing final (Post) duplicate samples on the Intoxilyzer.

Once a participant had undergone the first round of testing at .08, he or she was allowed access to the light snacks and bottled water. These materials were withheld until that point to ensure that each participant was in the post-absorptive phase so as to eliminate the possibility of food delaying any further absorption of alcohol. Participants were periodically tested with the Intoxilyzer to identify the point at which they passed into the next lower testing range. In between providing breath samples, participants had access to games, Fatal Vision® impairment-simulating goggles, music and assorted videos.

As each participant's BrAC was found to be within the next lower test range, he or she again provided duplicate breath samples for each device, according to his or her assigned treatment order. After completing the round of tests, participants again provided two final samples for the Intoxilyzer. This sequence continued through all four test ranges.

Between rounds of testing, participant variables were measured, including:

(a) Body water content

(b) Oral temperature

(c) Height

(d) Resting heart rate.

The results of these measurements were recorded on Participant Data Sheets (see Appendix G).

After each participant completed the round of tests at .02, his or her BrAC was periodically monitored using the Intoxilyzer. Once a participant's BrAC reached 0.00, he or she was permitted to leave the test site, via either by being picked up or a ride home by the research personnel. No participants were allowed to leave until a 0.00 level had been reached. Each data collection session took approximately eight hours. Participants were thanked as they left the test site, and thanked again via email the following day.

3.5. Limitations of the Study

This study involved several limitations, which should be taken into account when assessing the study's value in advancing the literature and generalizing the results to other populations. First, only devices available in the U.S. were tested. The author recognizes that, due to the relative ease of acquisition of products from other countries because of the Internet, several additional numerical readout devices could have been obtained. However, due to the additional shipping charges that would have been involved, there would likely be little reason for any U.S.-based user to purchase a device

from a non-U.S. retailer. Thus, the devices tested are considered representative of the devices conveniently available to U.S.-based users.

Second, only one of each model of PMBT was tested. It is possible that any single device might not be reflective of the model line's true performance capabilities. However, it is likely that users will only purchase a single instrument, and thus will have only one model for their use. In this respect, by testing only one of each model, this study reflects the likely actual purchase/use scenario.

Third, the age range of participants in Experiment Two was restricted to 21-34 years. This limitation was imposed to use participants within the age range most likely to be involved in alcohol-related crashes (Texas Department of Public Safety, 1999). This could limit the degree to which results could be generalized to other age groups.

Lastly, although Experiment Two was designed to simulate actual drinking conditions, the participants did not have full control over use of the devices. Instead, participants were told how and when to use the devices. In an actual drinking scenario, at a bar, for example, drinkers would have to complete the additional tasks of determining how to use the devices and make decisions regarding when to use them. These variables were controlled for the purpose of reducing the influence of factors other than the independent variables of interest. Thus, Experiment Two's conditions cannot be viewed as a totally realistic social drinking scenario.

3.6. Delimitations of the Study

The study also necessitated several delimitations to maximize the ability to test the hypotheses in question. First, all samples were collected under controlled situations, whether in the DPS laboratory or at the TTI facilities. These arrangements were designed to help reduce the influence of outside factors affecting the dependent variable of interest. Second, in Experiment Two, only data collected after participants were found to be in the post-absorption phase were used for analysis. No data collected during the absorption or diffusion phases were analyzed, although participants were measured during these phases to determine the point at which each participant had moved to the post-absorption phase.

CHAPTER IV

RESULTS

4.1. General

A total of eight devices were included in the study. Because of poor function, two devices' results had to be discarded. During Experiments One and Two, Device G displayed its maximum value, .19, on virtually all tests, regardless of the level of alcohol at which it was tested; it exhibited no ratio scale properties, yielding essentially only binomial results. Thus Device G's data were excluded from analysis.

Approximately halfway through Experiment Two, Device H simply stopped functioning. Although its integral power light indicated it was receiving full power, it began to show .00 readings at all alcohol levels. Installing fresh batteries did not alleviate this problem. Thus, Device H's data were excluded from analysis. Because full and useful data were not obtained for these two devices, they were both eliminated from analysis in both experiments. The six remaining instruments yielded complete data for all tests.

4.2. Pilot Testing

One goal of the pilot testing was to provide a level of initial screening of performance to determine whether devices would advance to further testing. In the assessment of the

devices' abilities to minimize false positive and false negative readings, 320 total tests were performed (eight devices, each tested 20 times at .00 and at .032).

In the assessment of false positives using the .00 simulator mixture (distilled water only), all devices displayed .00 on all 20 tests. That is, no device yielded results above .00 at any time during this testing.

In the assessment of false negatives using the .032 simulator mixture, all devices yielded readings at or above the .02 threshold level. That is, no device read below .02 during this testing. Figure 1 shows the mean BrAC results of each device when tested at .032.

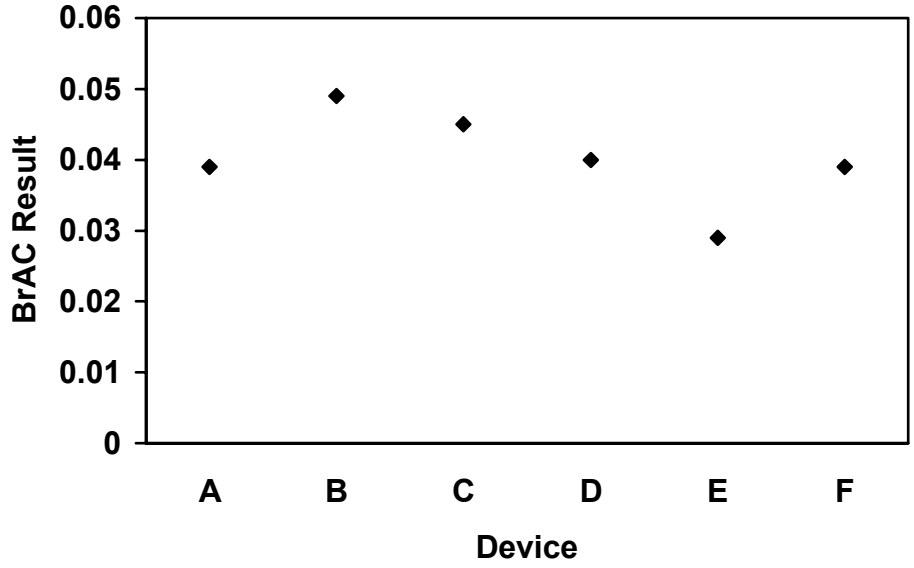

Figure 1. Mean BrAC results of each device tested at .032.

4.3. Experiment One

In the assessment of the devices' accuracy and precision in this experiment, 960 total tests were performed: eight devices, each tested 20 times at six different alcohol levels. As in the pilot testing, the validity of each simulation concentration was verified through 20 tests using the Intoxilyzer.

Table 3 contains the mean values broken out by device at each concentration level. Figure 2 shows the graphic representation of these results. Figure 3 shows each device's accuracy results separately, plotted against the simulator standards. No single device met the NHTSA criteria for accuracy at all concentrations. The mean results show that five out of the six devices read higher than the simulator standard.

Table 3
Mean Test Results for
Each Device at Each Concentration

Simulator	Device					
Conc	A	B	C	D	E	F
.02	.010	.036	.030	.020	.014	.034
.04	.047	.069	.038	.048	.062	.047
.06	.094	.117	.082	.084	.060	.057
.08	.080	.152	.119	.132	.081	.073
.10	.095	.196	.155	.181	.109	.080
.16	.141	.327	.250	.190	.169	.117

To assess precision, the standard deviation (SD) of results was computed for each device at each concentration level. This yielded a value that reflects the spread of scores of each device at each concentration (the smaller the SD value, the tighter the dispersion of the scores around their mean). In certifying devices for its Conforming Products List,

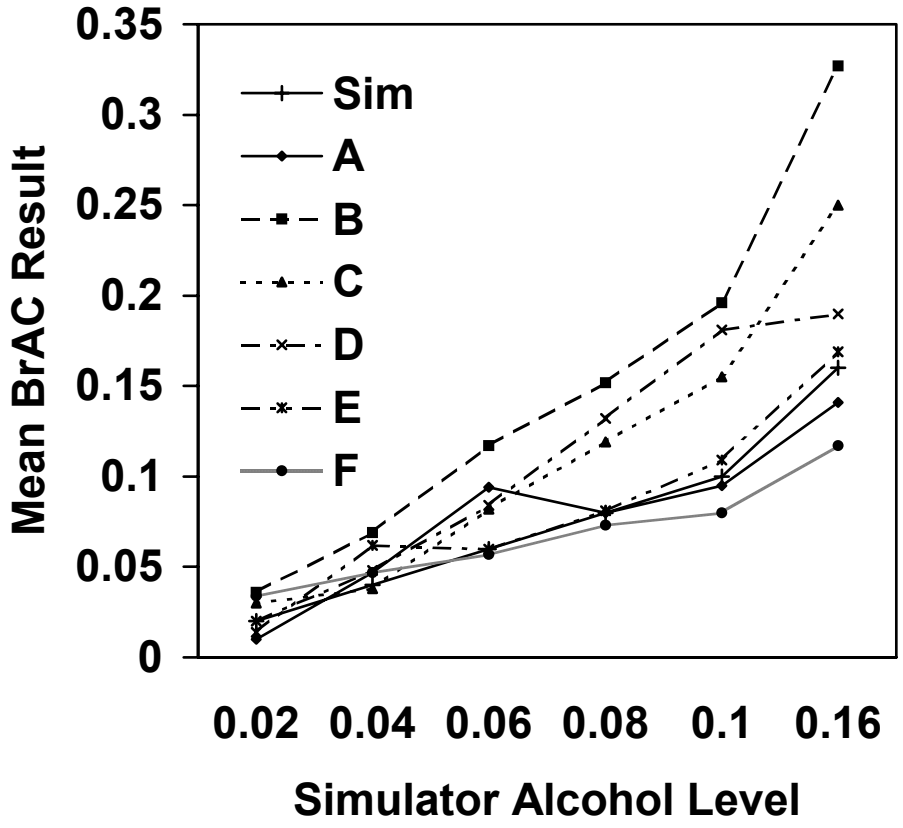

Figure 2. Mean BrAC results of devices at each simulator concentration.

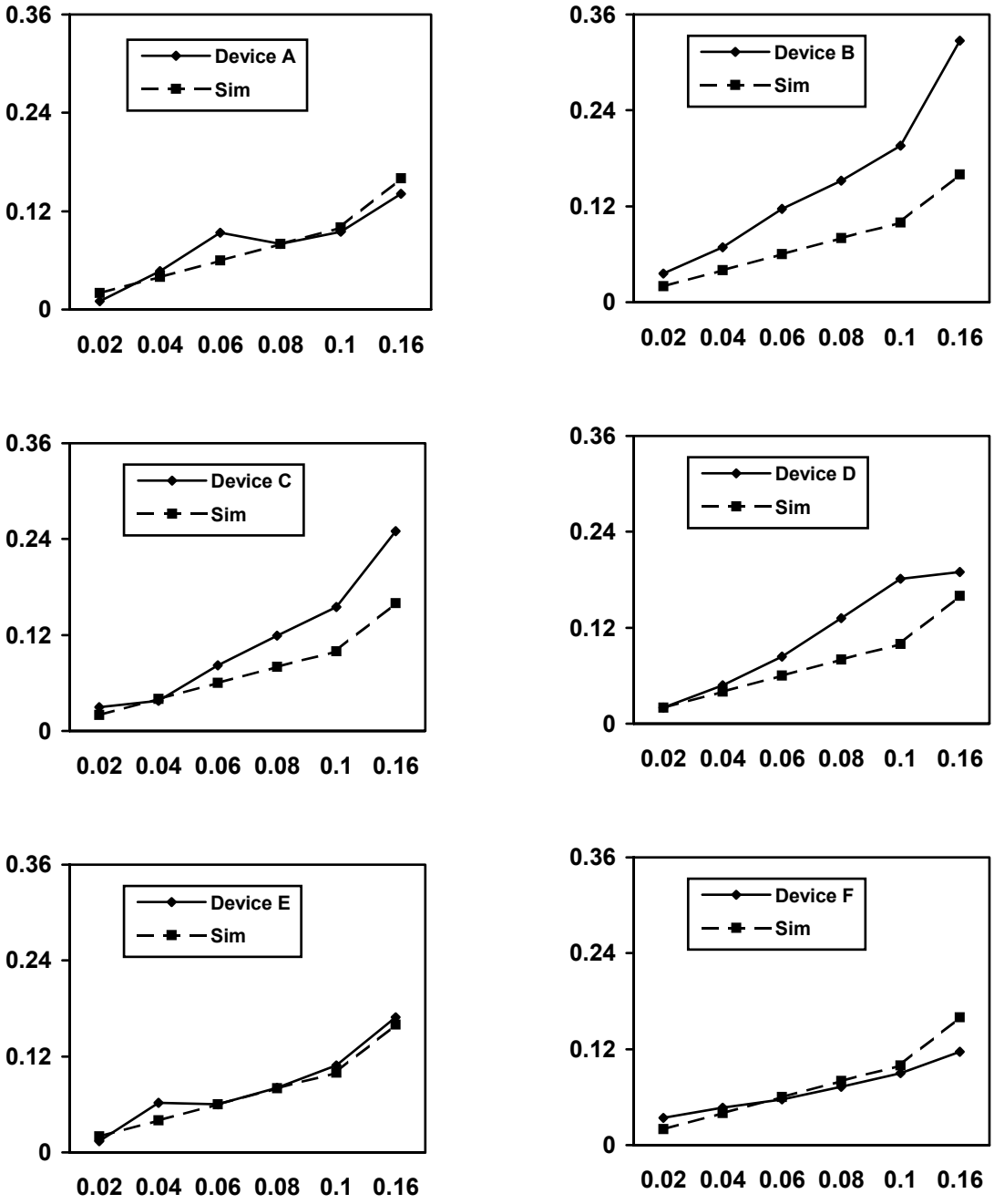

Figure 3. Mean results for each device at each simulator concentration. Simulator test level is shown on X-axis, test result on Y-axis.

NHTSA requires that the standard deviations of results at each of these concentrations be ≤ .0042. Table 4 contains the SDs for each device at each level. Those results marked with an asterisk meet the NHTSA standard for precision. Figure 4 displays the devices' precision across the six alcohol levels. No single device met the NHTSA criteria for precision at all concentrations.

Table 4
Standard Deviations for Each Device at Each Concentration

Simulator	Device					
Concentration	A	B	C	D	E	F
.02	.0000*	.0051	.0000*	.0000*	.0049	.0052
.04	.0047	.0037	.0044	.0052	.0052	.0042*
.06	.0050	.0066	.0089	.0088	.0000*	.0043
.08	.0000*	.0049	.0049	.0135	.0031*	.0055
.10	.0051	.0083	.0076	.0185	.0031*	.0073
.16	.0072	.0109	.0132	.0000*	.0059	.0043

Note. * SD ≤ .0042

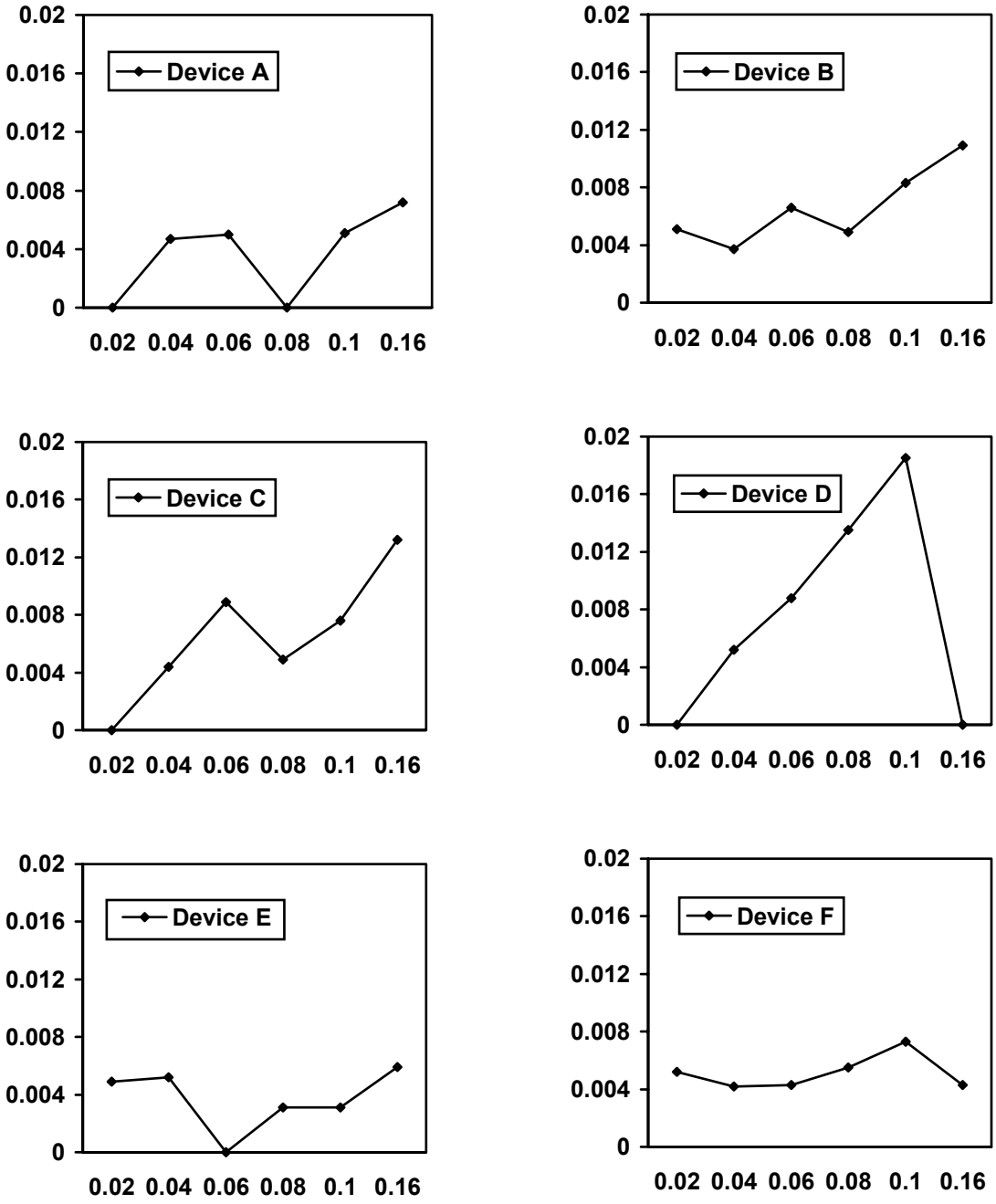

Figure 4. Standard deviations of each device at each simulator concentration. Simulator test level is shown on X-axis, standard deviation on Y-axis.

4.4. Experiment Two

4.4.1. Participant Eligibility

All females performed a portable pregnancy test during the orientation phase and all results indicated negative. A single sober volunteer confirmed all pregnancy test results as being negative. Thus, all female and male participants were eligible to continue in this experiment.

4.4.2. Participant Functioning

Eleven people participated in the third experiment, with five and six participants in sessions one and two, respectively. During the first session, one female participant became ill during the consumption phase, after having consumed approximately two-thirds of the total dose. After she regurgitated, she remained at the testing site, and a sober volunteer was assigned to closely monitor her. The monitor administered cold towels to the participant's forehead and neck, with positive results. She continued to feel better as time passed. Because of this event, this participant was withdrawn from the experiment and was not permitted to consume additional alcohol. Thus, no data were collected from this participant, who remained at the testing site until her BrAC reached .00.

After consuming the full dose assigned, participant four reached a peak BrAC of only .067. She agreed to consume an additional measured alcoholic beverage to reach the target peak BrAC of .09. This additional dosing was successful; she subsequently

reached the target peak. A total of ten participants completed a total of 640 tests (ten participants providing duplicate samples at four concentrations with each device).

4.4.3. Data Screening

4.4.3.1. Duplicate Samples

For analysis, the duplicate results from each device at each level were averaged, and the mean was carried forward into subsequent analysis. The acquisition of duplicate readings was performed to help reduce the impact of any single measurement. Table 5 displays the means and standard deviations of the means of the duplicate samples from all ten participants for each device at each concentration.

Table 5
Means and Standard Deviations for Each Device at Each Concentration

	Concentration			
Device	.02	.04	.06	.08
Intox	.023 (.001)	.039 (.005)	.058 (.004)	.080 (.004)
A	.060 (.016)	.083 (.018)	.104 (.018)	.152 (.042)
B	.069 (.021)	.122 (.039)	.146 (.046)	.178 (.059)
C	.038 (.008)	.070 (.012)	.095 (.022)	.123 (.018)
D	.042 (.012)	.073 (.034)	.096 (.033)	.093 (.040)
E	.038 (.007)	.065 (.015)	.081 (.013)	.103 (.012)
F	.020 (.009)	.033 (.017)	.037 (.012)	.043 (.010)

4.4.3.2. Pre and Post Intoxilyzer Readings

The purpose of collecting duplicate readings from the Intoxilyzer before *and* after each round of tests was to capture the results of any significant elimination occurring

during each run through the devices. The mean and standard deviation of the results of the pretest Intoxilyzer tests were .05006 and .021, respectively. The mean and standard deviation of the results of the posttest Intoxilyzer tests were .04646 and .021, respectively. The mean and standard deviation of the Pre and Post Intoxilyzer differences were .0036 and .0044, respectively.

To determine if there was a statistical difference between the Pre and Post readings, a one-tailed, paired sample t-Test was performed, using an alpha level of .05. This revealed a significant difference in BrAC between the Pre and Post Intoxilyzer tests ($t = 6.50$, $p \leq .000$, one-tailed).

If this significant elimination was left unaccounted for, it would be impossible to attribute any subsequent differences observed between the Intoxilyzer and the test devices exclusively to the performance of the devices. Thus, to eliminate this potential confounding factor, it was necessary to correct for the significant elimination between Pre and Post Intoxilyzer tests during runs through the test devices.

The total difference over time between the mean Pre and Post Intoxilyzer readings was .00360 (.05006 - .04646), equating to a mean elimination rate of .00045 per device (.00360/8). The mean elapsed time for a participant to make a complete pass through all the devices, providing duplicate samples, was 13.4 minutes. Thus, over this period of time, the mean amount of alcohol eliminated was .00360. This equates to a mean hourly elimination rate of .016, which falls in line with accepted rates of elimination between .015 and .017 (Baselt, 1996).

To accomplish the correction, each device score was corrected *backward* in time toward the Pre Intoxilyzer reading. That is, a multiple of .00045 was *added* to each reading, depending on the order in which each device was in a given participant's assigned treatment order (excluded devices G and H's positions in the assigned treatment orders were accounted for in this correction procedure). Table 6 shows the order of the device, following the Pre Intoxilyzer reading, and the corresponding amount added accomplish this correction. Table 7 shows the corrected means and standard deviations for each device at each level.

Table 6
Amount Added to Each Device, Based on Testing Order

Order Of Device	Amount Added
1	.00045
2	.00090
3	.00135
4	.00180
5	.00225
6	.00270
7	.00315
8	.00360

4.4.3.3. Outliers

To identify potential extreme cases, standardized scores (Z-scores) were computed for each case for all the devices, including the Intoxilyzer. A Z-score is the number of standard deviations that a value is below or above the mean. Cases whose standardized scores exceed 3.29 were considered potential outliers (Tabachnick & Fidell, 1996). No

Table 7
Corrected Means and Standard Deviations for Each Device at Each Concentration

	Concentration			
Device	.02	.04	.06	.08
Intox	.023 (.001)	.039 (.005)	.058 (.004)	.080 (.004)
A	.062 (.016)	.085 (.018)	.106 (.018)	.154 (.042)
B	.071 (.021)	.124 (.039)	.148 (.047)	.180 (.058)
C	.039 (.007)	.071 (.011)	.097 (.021)	.125 (.017)
D	.044 (.012)	.075 (.034)	.098 (.033)	.095 (.040)
E	.040 (.007)	.066 (.015)	.082 (.013)	.105 (.011)
F	.023 (.009)	.035 (.017)	.038 (.012)	.045 (.009)

single case exceeded the 3.29 threshold; thus, each variable was considered to be free of outliers.

4.4.3.4. Nonlinearity and Heteroscedasticity

To assess nonlinearity and heteroscedasticity, bivariate scatterplots were created and examined at each level of concentration between the Intoxilyzer and each device (Tabachnick & Fidell, 1996). The plots did not reveal evidence of nonlinearity nor deviation from homoscedasticity.

4.4.3.5. Normality

Normality of distributions was assessed by analyzing skewness and kurtosis values. A relatively conservative alpha (.001) was used to assess the Z-scores computed for skewness and kurtosis (Tabachnick & Fidell, 1996). No Z-score exceeded the alpha-

defined criterion value of 3.75. Thus, the distributions of all variables were considered to be approximately normal.

4.4.4. Main Analysis

Fortunately, the data involved in this study lend themselves well to graphical representation. Figure 5, which displays the means of each device at each concentration in line graph form, provides another graphical display of the data. The mean results show that five of the six devices read higher than the Intoxilyzer. Figure 6 shows the devices' accuracy on an individual basis, plotted against the Intoxilyzer results. Figure 7 show each device's precision under the simulated field conditions.

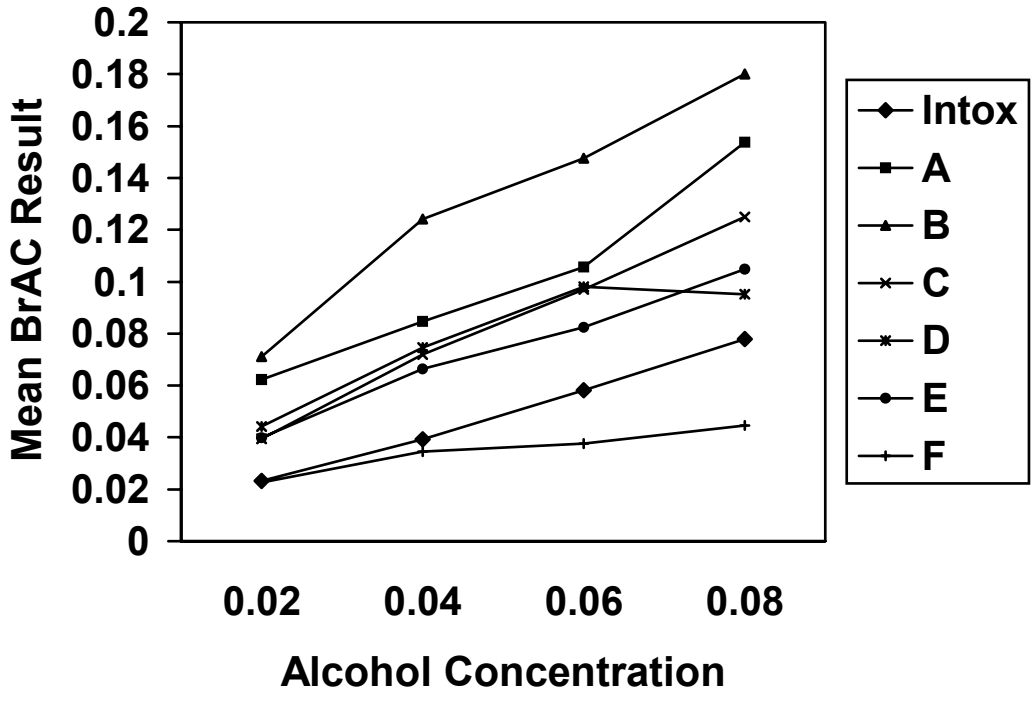

Figure 5. Mean BrAC results for devices at each alcohol concentration.

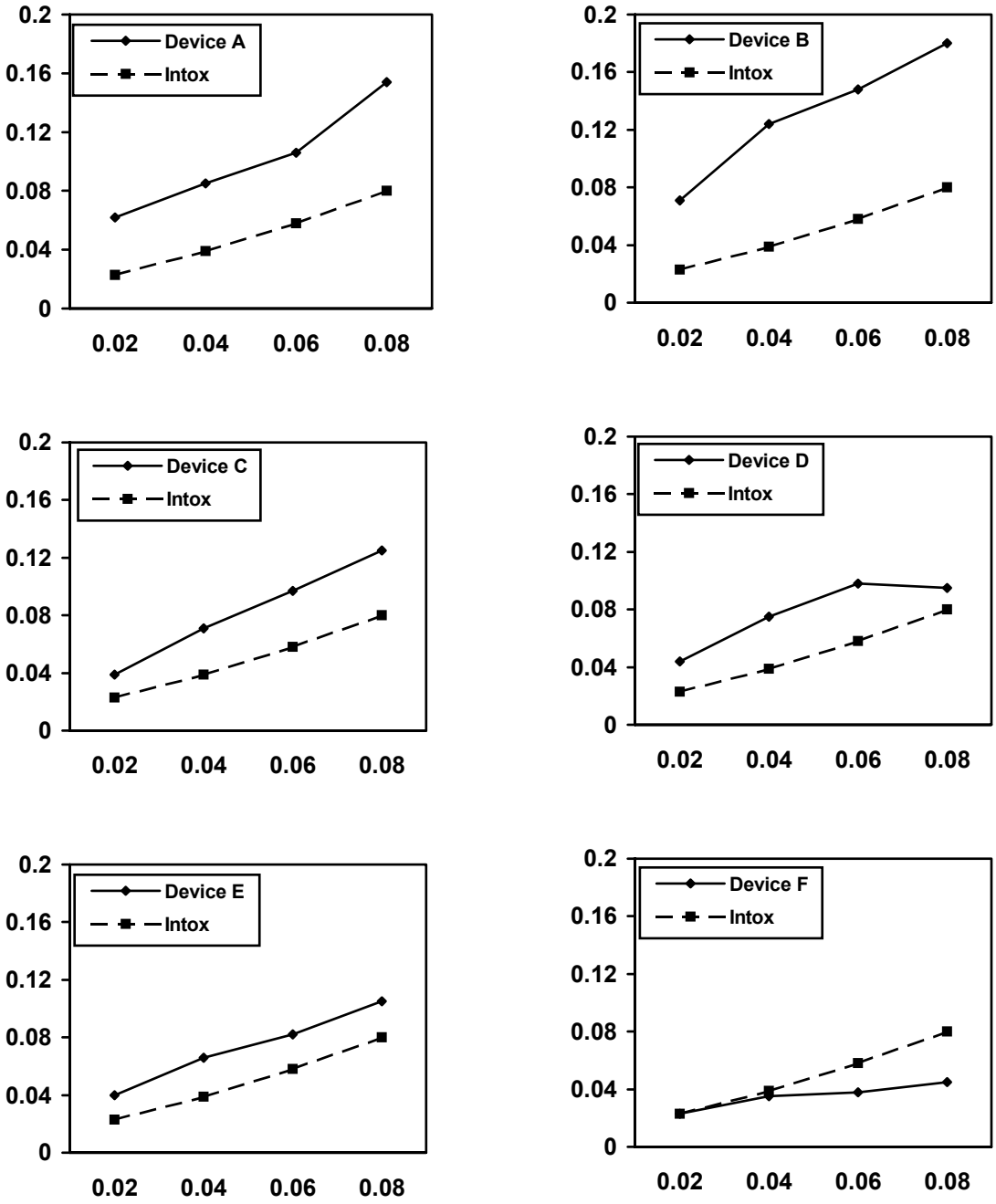

Figure 6. Mean Intoxilyzer and device results for each device at each concentration. Test level is shown on X-axis, test result on Y-axis.

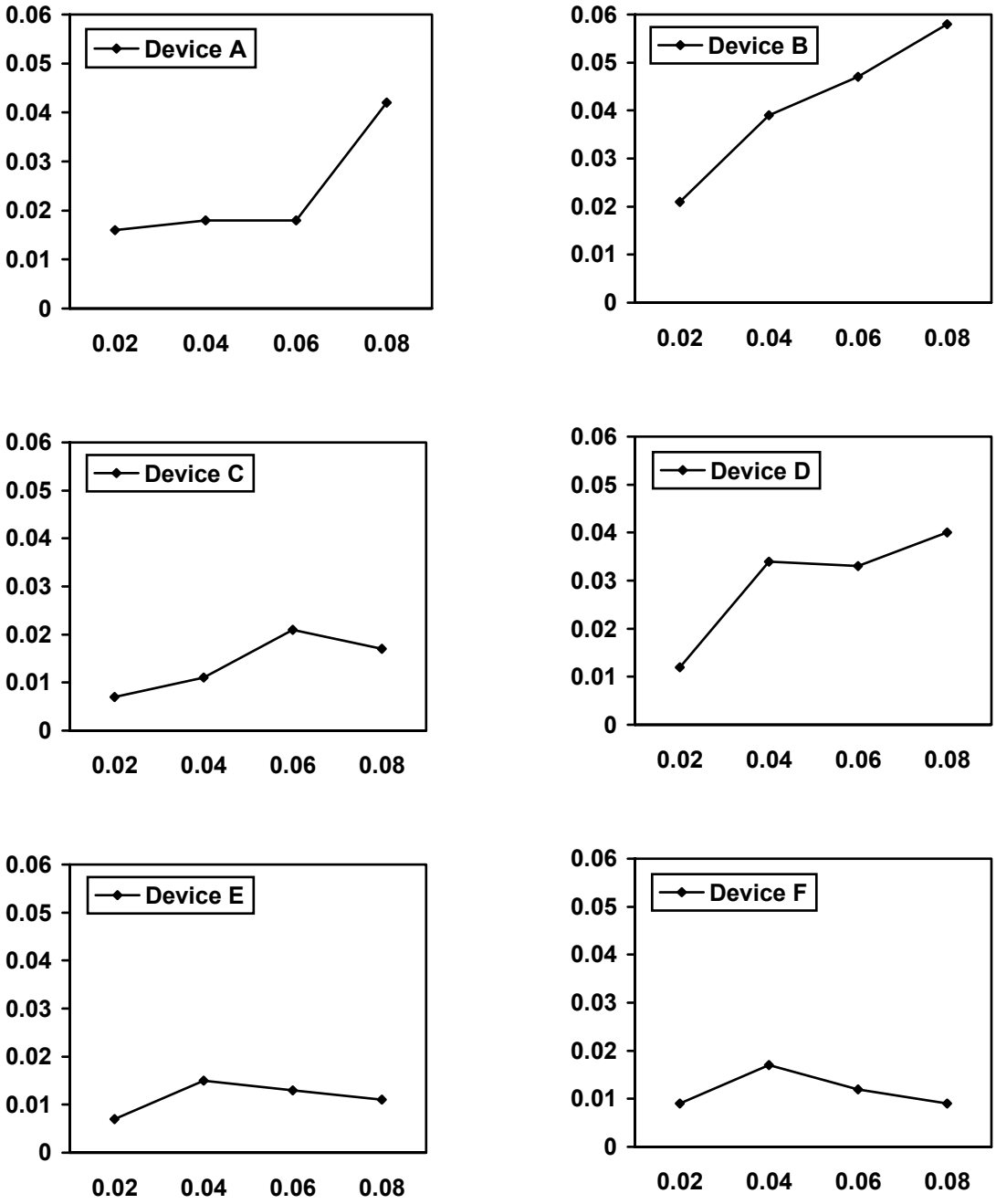

Figure 7. Standard deviations of each device at each concentration. Test level is shown on X-axis, standard deviation on Y-axis.

The next goal was to determine whether the results of the test devices were significantly different from those of the Intoxilyzer. A two-way Repeated Measures Analysis of Variance was performed, as each participant provided samples at each concentration and with each device (Field, 2000). That is, each participant provided measurements at each combination of the independent variables (Concentration and Device). Note that the results of seven instruments are included in this analysis: the six test devices plus the Intoxilyzer. Table 8 shows the results of the related Mauchly's Test, which tests for the condition of sphericity.

Table 8
Results of Mauchly's Test

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.
Concentration	.304	9.193	5	.104
Device	.000	71.666	20	.000

Mauchly's test was found to be significant for Device at the .05 level, indicating that the condition of sphericity was not met for that variable. Thus, the F-values in the main analysis required correction. Table 9 shows the results of the Repeated Measures Analysis of Variance, with both uncorrected and corrected degrees of freedom available for correction due to violation of sphericity. The Greenhouse-Geisser, Huynh-Feldt and Lower-bound correction factors, which adjust the degrees of freedom used to assess the observed F-ratio, are labeled GG, HF and LB, respectively. The condition under which sphericity is assumed is labeled as SA.

Table 9
Results of Repeated Measures Analysis of Variance

Source		Sum of Squares	df	Mean Square	F	Sig.
Concentration	SA	.17700	3.000	.05912	147.270	.000
	GG	.17700	1.885	.09412	147.270	.000
	HF	.17700	2.367	.07492	147.270	.000
	LB	.17700	1.000	.17700	147.270	.000
Error (Conc)	SA	.01084	27.000	.00040		
	GG	.01084	16.961	.00064		
	HF	.01084	21.307	.00051		
	LB	.01084	9.000	.00120		
Device	SA	.24100	6.000	.04011	29.667	.000
	GG	.24100	1.566	.15400	29.667	.000
	HF	.24100	1.838	.13100	29.667	.000
	LB	.24100	1.000	.24100	29.667	.000
Error (Device)	SA	.07302	54.000	.00135		
	GG	.07302	14.098	.00518		
	HF	.07302	16.544	.00441		
	LB	.07302	9.000	.00811		
Concentration * Device	SA	.00321	18.000	.00179	7.776	.000
	GG	.00321	4.355	.00738	7.776	.000
	HF	.00321	8.945	.00359	7.776	.000
	LB	.00321	1.000	.03213	7.776	.021
Error (Conc * Device)	SA	.03718	162.000	.00030		
	GG	.03718	39.194	.00095		
	HF	.03718	80.501	.00046		
	LB	.03718	9.000	.00413		

Note that repeated measures analysis yields a separate error term for each main effect and interaction. The Lower-bound correction factor was selected because it is the most conservative of the three corrective options. This factor was used to assess all three effects, the main effects for Concentration and Device and the interaction, even though

the assumption of sphericity was not violated for Concentration. Table 10 contains only the Lower-bound results of the analysis.

Table 10
Results of Repeated Measures Analysis of Variance, Lower Bound Values

Source	Sum of Squares	df	Mean Square	F	Sig.
Conc	.17700	1.000	.17700	147.270	.000
Error (Conc)	.01084	9.000	.00120		
Device	.24100	1.000	.24100	29.667	.000
Error (Device)	.07302	9.000	.00811		
Conc* Device	.00321	1.000	.03213	7.776	.021
Error (Conc* Device)	.03718	9.000	.00413		

There was a significant main effect of Concentration ($F(1, 9) = 147.27$, $p < .001$). This indicated that if the different devices are ignored, there were significant differences among results at the four levels of concentration. This result was expected; indeed the different levels of concentration should be reflected in the measurements at each level. There was also a significant main effect for Device ($F(1, 9) = 29.667$, $p < .001$). This indicates that if the different concentrations are ignored, there were significant differences among the seven devices.

A significant interaction between Concentration and Device was also observed ($F(1, 9) = 7.776$, $p < .05$). This indicates that the devices produced different results

depending on the level of alcohol concentration. That is, the effect of Device was *not* independent of Concentration.

When a significant interaction is observed between variables, interest in their main effects becomes secondary to the interaction relationship (Howell, 1997). To explore the dynamics of the interaction between Concentration and Device, it was necessary to compute simple main effects. These values show the effect of Device, collapsed across levels of Concentration, and the effect of Concentration, collapsed across levels of Device. Table 11 contains the simple main effects. Due to the existence of separate error terms for each effect, pooled error terms were computed to assess each set of simple main effects, using Equation 1.

Table 11
Simple Main Effects

Source	SS	df	MS	F
Concentration				
Conc at Device Intox	.017774	3	.005925	2.220883
Conc at Device A	.045692	3	.015231	5.709106*
Conc at Device B	.062725	3	.020908	7.837359*
Conc at Device C	.039727	3	.013242	4.963791*
Conc at Device D	.018572	3	.006191	2.320517
Conc at Device E	.022445	3	.007482	2.804456
Conc at Device F	.002560	3	.000853	.319863
Error		18	.002668	
Device				
Device at .02	.019947	6	.003325	.543022
Device at .04	.053856	6	.008976	1.466128
Device at .06	.075048	6	.012508	2.043060
Device at .08	.123963	6	.020660	3.374665*
Error		18	.006122	

Note. * $p < .05$

$$\frac{SS_{MainEffect} + SS_{Error}}{df_{MainEffect} + df_{Error}} \quad (1)$$

For Concentration at Device, the error term used was

$$\frac{.07302 + .03718}{9 + 9} = .00612$$

Critical Value (3,18) = 3.16

For Device at Concentration, the error term used was

$$\frac{.01084 + .03718}{9 + 9} = .00267$$

Critical Value (6,18) = 2.66

Since the main focus was among differences between certain pairs of devices, the simple main effects showing the effect of Device collapsed across levels of Concentration were of most interest. Only at one alcohol level, .08, was the F value for Device significant at the .05 level. This indicates that at this alcohol level, there are differences among the seven devices, but the F value does not indicate between which pairs of devices those differences exist. Thus it was necessary to perform multiple comparison (post hoc) analysis to determine the specifics of the relationships. At the three lower alcohol levels (.02, .04 and .06), the test devices' results were not found to be significantly different from those of the Intoxilyzer.

The relationships of most interest were those between the Intoxilyzer and each test device (i.e., Intoxilyzer and Device A, Intoxilyzer and Device B, etc.). Relationships between pairs of test devices are not of interest in this study. Dunnett's Test was selected as the appropriate multiple comparison method because it is specifically designed to examine comparisons between multiple experimental treatments and a single control treatment. Its strength is increased power, relative to other tests such as Fisher's LSD, Tukey's tests or the Scheffé test (Howell, 1997). For this study, the test devices were considered the experimental treatments and the Intoxilyzer was considered the control treatment.

Accordingly, Dunnett's Test was used to compute the critical difference that must exist between means to be considered significantly different at the .08 alcohol level. Equation 2 represents the computation to arrive at this critical difference value (Howell, 1997).

$$\text{Critical value}\,(\overline{X}_c - \overline{X}_j) = t_d \sqrt{\frac{2MS_{error}}{n}} \qquad (2)$$

The critical value for a significant difference to exist between the Intoxilyzer and any test device was computed to be .099028. Table 12 displays the values of the differences between the results of the Intoxilyzer and each test device at the .08 level. For the performance to be considered significantly different from the Intoxilyzer, the value shown in the table must exceed .099028.

Table 12
Differences Between Intoxilyzer and
Each Device at .08 Concentration

Device	Difference
A	.074055
B	.100010*
C	.045330
D	.015465
E	.025285
F	.034950

Note. * > .099028

Only Device B (at the .08 level) was significantly different from the Intoxilyzer. At that level, the mean of Device B's results was .18 and the mean of the Intoxilyzer's results was .08. Despite the apparent large differences between means shown in Figure 6, the remaining devices were not significantly different from the Intoxilyzer at the .08 alcohol level or at the other three levels.

In addition, the relationship between each test instrument and the Intoxilyzer was examined. Table 13 displays the Pearson Product Moment correlations between the Intoxilyzer and each test device. These relationships are further represented in Figure 8, shown in decreasing strength with the Intoxilyzer.

Table 13
Correlations Between
Intoxilyzer and Each Device

Device	Correlation Value with Intoxilyzer	Sig.
A	.818	.000*
B	.636	.000*
C	.891	.000*
D	.497	.001*
E	.899	.000*
F	.588	.000*

Note. * Significant at the 0.01 level (2-tailed)

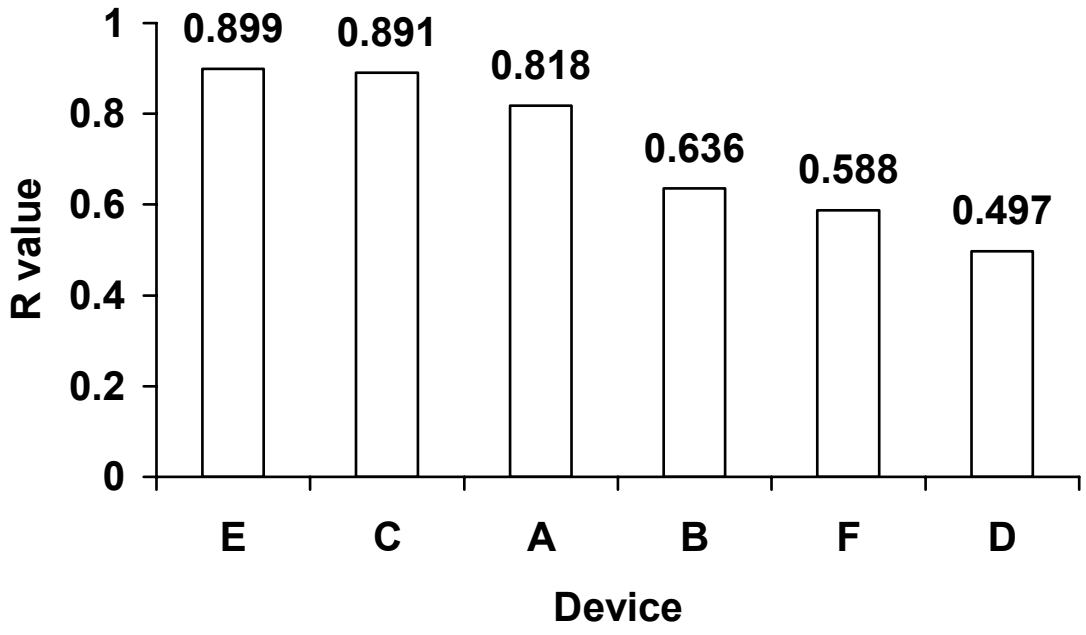

Figure 8. Correlations between the Intoxilyzer and each device.

CHAPTER V

DISCUSSION

5.1. Hypotheses Testing

At the outset, specific research hypotheses were proposed for testing. Each hypothesis will be examined in turn.

5.1.1. Experiment One

5.1.1.1. Hypothesis One

Under laboratory conditions, each PMBT device will be less accurate than the National Highway Traffic Safety Administration (NHTSA) criteria at each alcohol level (will yield a systematic error greater than ± .005).

H_O: Systematic error ≤ ± .005 at each alcohol level

H_A: Systematic > ± .005 at each alcohol level

This hypothesis was rejected. Experiment One revealed that only three devices yielded a systematic error ≤ ± .005, each at only one of the six concentrations (see Table 3). No single device met the NHTSA criteria for accuracy at all concentrations.

5.1.1.2. Hypothesis Two

Under laboratory conditions, each PMBT device will be less precise (more variable) than the NHTSA criteria at each alcohol level (will yield a standard deviation greater than .0042).

H_O: Standard deviation ≤ .0042 at each alcohol level

H_A: Standard deviation > .0042 at each alcohol level

This hypothesis was rejected. Experiment One revealed that five of the devices yielded standard deviations ≤ .0042, but not at all six concentrations (see Table 4). No single device met the NHTSA criteria for precision at all concentrations.

5.1.1.3. Hypothesis Three

Under laboratory conditions, each PMBT device will become less accurate as test BrAC increases (systematic error will increase when measured at .02, .04, .06, .08, .10 and .16).

H_O: Systematic error at .02 ≤ .04 ≤ .06 ≤ .08 ≤ .10 ≤ .16

H_A: Systematic error at .02 > .04 > .06 > .08 > .10 > .16

The results failed to support the rejection of this hypothesis. Table 5 shows no clear trend of increasing SE of each device at each concentration. Rather, the devices' SEs seems to defy an increasing or decreasing trend across concentrations; Figure 3 confirms the lack of observed increasing or decreasing trends.

5.1.1.4. Hypothesis Four

Under laboratory conditions, each PMBT device will become less precise (more variable) as test BrAC increases (standard deviation will increase when measured at .02, .04, .06, .08, .10 and .16).

H_O: Standard deviation at $.02 \leq .04 \leq .06 \leq .08 \leq .10 \leq .16$

H_A: Standard deviation at $.02 > .04 > .06 > .08 > .10 > .16$

The results failed to support the rejection of this hypothesis. Figure 4 shows no clear trend of increasing SD of each device at each concentration. Rather, the devices' SDs showed no consistent increasing or decreasing trends across concentrations. No single device yielded an increasing trend across all concentrations, although Device D experienced an increasing SD trend until the .16 alcohol level was reached.

5.1.2. Experiment Two

5.1.2.1. Hypothesis Five

Under simulated field conditions, each PMBT device will yield results significantly different than results from a calibrated Intoxilyzer 5000 breath alcohol test instrument.

H_O: Intoxilyzer = A = B = C = D = E = F = G = H at each alcohol level

H_A: Intoxilyzer ≠ A ≠ B ≠ C ≠ D ≠ E ≠ F ≠ G ≠ H at each alcohol level

Overall, the results failed to support the rejection of this hypothesis. Only one test device, at one concentration (Device B at .08) differed significantly from the Intoxilyzer. Though Figure 5 suggests large differences between the test devices and the Intoxilyzer, the within-device variability was substantial enough to prevent the devices from yielding results significantly different from the Intoxilyzer.

5.2. Precision

The test devices tended to perform with less precision than that required by NHTSA. When tested using simulators, the mean SD of the devices exceeded the NHTSA maximum .0042 criteria by 31%. In Experiment Two, the devices' mean SD was over five times the Intoxilyzer mean SD.

Precision is the foundation for effective breath test devices. It could be argued that to be useful, a device must first exhibit acceptable precision before accuracy is addressed. A device could exhibit systematic readings above or below one's true BrAC and still be of utility to its user, but if the device does not exhibit adequate precision, then the device's utility would be substantially, if not completely, diminished. Thus, a device could be precise but of limited accuracy and still be of use. However, a device that exhibits accuracy but little precision would be of limited or no use.

A user's perception of a device's precision would likely develop from his or her repeated testing of the device. If repeated readings were relatively similar, then a user might not question the device's consistency at all. However, if its readings were random and different, a user might completely discount the device as useless. Rather than a

device meeting or not meeting an *a priori* objective standard for precision, it may be that each user will self-determine his or her tolerance for consistency.

5.3. Accuracy

The test devices, as a whole, tended to yield readings consistently higher than the standards to which they were compared. The sole exception to this finding was Device F, which in Experiment Two consistently read below the Intoxilyzer results. One device, Device B, yielded readings up to 225% higher than the standard.

In theory, if a given device did read consistently high or low, *and* the user was aware of this performance aspect, the user could "correct" for these differences and take the provided data and convert it to useful information. However, given that many users may have a positive alcohol level, and given that judgment and reasoning are the first areas of the brain to be affected by alcohol, users may be unable to effectively perform this correction, even if they had correct information on a given device's performance.

In terms of application, if these devices were to err, it could be argued that it would be preferred that they *overestimate* BAC. That is, it would be better if they yielded results *higher* than users' actual BrACs, rather than lower than actual BrACs. An above-actual BrAC trend would be in what could be considered the "conservative" direction. If users are employing the information from these devices to make decisions after having consumed alcohol, it would be preferable if they believed that their alcohol levels were *at or higher* than their actual levels. Thus, given that error in accuracy exists, it is at

least in the "preferable" direction. It is unknown if the devices' tendencies toward above-true readings were intentional on the part of the devices' manufacturers.

Device F's performance is of special concern in this respect. Its readings could cause a user to believe his or her BAC is *lower* than it actually is. If the user is employing the information to make a decision whether to continue to drink or to operate a motor vehicle, the user might come to believe that his or her ability to drive is *not* impaired when in reality it is, with potentially tragic consequences. It is even possible that this type of information would be *more* harmful than having *no* objective measure of one's alcohol level.

However, if a device reads so high that the user *disbelieves* its result, the user could completely discount and/or discard the result. For example, if a drinker of average weight consumed two standard drinks and a correctly-used device subsequently yielded a BrAC of .08, this reading might be considered unrealistically high (the true BrAC would be approximately .04-.05), with the device becoming considered ineffective by the user. In terms of design, a balance between believable/reasonable readings and unbelievable/unreasonable readings must be achieved to result in the devices' applied utility.

The finding that the devices' results were not, with one exception (Device B at .08), significantly different from the Intoxilyzer results under actual drinking conditions speaks to both precision and accuracy. When the results are represented graphically (see Figure 6), the degree of positive systematic error relative to the Intoxilyzer appears to be substantial. Device B, for example appears to read quite high, relative to the standard.

However, the variability of the test devices' results was substantial and apparently without pattern. For example, at the .06 level, the mean BrAC result for Device B was .148, yet its readings over the ten tests at that level ranged from .042 to .193, indicating substantial variability in measurement.

This degree of error was large enough to preclude the test devices' results being judged as significantly different from those of the Intoxilyzer (with Analysis of Variance, the greater the variance, the less likely differences will be detected). In this case, it suggests a situation where the strict statistical results do not necessarily match the possible applied interpretations of the devices' performances. The lack of statistically significant differences between the test devices and the Intoxilyzer at the three lowest alcohol levels certainly would not preclude a user from determining that a given device's performance at a certain alcohol level would be so far off from the true BrAC as to be considered unfit for its purpose.

5.4. Relationship to Intoxilyzer

Experiment Two used an Intoxilyzer 5000 as the standard to which the test instruments were compared. The main analysis sought to assess the existence and specifics of any *differences* between this standard and the devices. However, the *relationship* between these devices and the Intoxilyzer can also provide a picture of the devices' performance. Table 13 contains the correlation values for each pair of instruments. Of first note is that all the correlation values are positive. This means that

all Intoxilyzer-test device pairs covary in the same direction. That is, as the Intoxilyzer readings increase, so do those of the corresponding test device.

Second, all the correlations are statistically significant. This means that the relationship between the Intoxilyzer and each device is not linearly independent. The results confirm that there is some meaningful relationship between the pairs of instruments. Third, the test devices' correlations with the Intoxilyzer are not equal. Some test devices' results are closer to the Intoxilyzer's performance than others. Device E and Device D, respectively, are most and least correlated with the Intoxilyzer.

These relationships are reflected in the plots of the means of the instruments appearing in Figure 6. Note that a significant and/or high correlation between two variables does not necessarily mean that their numerical values are close to one another, only that the values covary. For example, a test instrument could have a significant and high correlation with the Intoxilyzer, yet read 50% higher than the Intoxilyzer.

5.5. Summary

The results of the study lead to several areas of summarization. First, this is the first study that could be identified which thoroughly evaluated the performance of pocket-model breath testers. As such, it was exploratory in nature. It also focused on the group of devices as a whole, and examined each device's performance in detail.

Second, as a group the devices did not meet the NHTSA criteria for precision. This is not particularly surprising, as one would not expect devices costing as little as one-twelfth the average PBT to perform as well as the more expensive and complex

instruments. However, as discussed previously, this does not necessarily mean that these devices are not useful. Indeed, intended users might be willing to accept levels of precision far lower than NHTSA requires. NHTSA-certified devices tend to be used for law enforcement forensics purposes, which understandably require stringent performance specifications. The results of such devices are sometimes introduced as evidence in courts of law, with far-reaching legal and personal ramifications.

In comparison, the PMBTs are far more likely to be in more casual circumstances and manner, by drinkers for whom the utility of the devices would not often extend beyond personal use in decision-making. While the devices might be considerably less precise than other classes of breath testing instruments, their performance could still be considered by their users as completely acceptable.

Third, the devices as a whole did not meet the NHTSA criteria for accuracy. In addition, the devices tended to overestimate actual BrAC. Thus, the instruments provided results in a conservative direction, in terms of the use of results in making decisions. If NHTSA certified instruments exhibited this same tendency and the results of which were attempted to be used in the prosecution of suspected alcohol-impaired drivers, the results would likely be inadmissible because of the strong prejudice against the suspect.

It is possible that users, if aware of a device's tendency to read high, could perform a reasonably accurate correction to obtain a useful approximation of their alcohol level. However, if a device reads consistently and unrealistically high, there could be a risk of

the user discarding the results of the instrument and determining its overall utility to be zero.

Fourth, the devices exhibited no clear trend of decreasing precision. This was surprising, given the expectation that the devices' performance in this area would deteriorate as the tested alcohol levels increased. It appears that the precision among different levels of alcohol concentration approached a pattern of randomness; no clear pattern of change in performance was evident. Fifth, no clear trend of increasing systematic error was observed. Also surprising, it was expected that systematic error would increase with the tested alcohol level.

Sixth, the performances of the devices were dependent upon the levels of alcohol at which they were tested. Revealed by the significant interaction between Device and Concentration in Experiment Three, this was not expected. Review of the graphical representations of these data indicates that the devices' performancse most closely match that of the Intoxilyzer at the lowest test level (.02). As the alcohol level increased, the dependence upon the concentration levels became more variable. This could have implications regarding the devices' use in actual drinking conditions, where some drinkers' alcohol levels could be substantially above the maximum tested in Experiment Two. Because it was deemed inappropriate and potentially unsafe to dose participants to higher levels than the maximum levels achieved, no data were collected at higher levels from human participants. Although the laboratory-based Experiment One was able to test the instruments at higher levels, the devices' performance at higher levels with

human participants could provide additional information with which to assess the instruments.

Seventh, virtually every breath test instrument, regardless of price or complexity, requires users to wait up to 15 minutes before providing a sample. This function is imposed to allow adequate time for any residual mouth alcohol to dissipate, so that the sample reflects the alcohol level in the blood and lungs as accurately as possible. It is quite possible, however, that this waiting period would *not* be strictly observed by users of PMBTs. In a situation where a drinker is at a party, perhaps among friends who also wish to test their alcohol levels, the waiting period may even be nonexistent. In this case, the results of the test could yield a reading that is much higher than the true BrAC. There seems to be little that can be done to overcome this possibility with these devices. To achieve the best results, users will have to follow the manufacturer's directions closely.

CHAPTER VI

RECOMMENDATIONS AND CONCLUSION

6.1. Recommendations for Future Research

During the efforts to answer the questions proposed in this study, several other potential related areas for quantitative and objective research surfaced, including:

(a) Specificity. While all the devices tested did successfully detect the presence of alcohol, it is possible that substances other than alcohol could cause the devices to register the presence of alcohol (Harding, 1996; Dubowski, 1992). Thus additional testing to assess the instruments' specificity to alcohol should be performed. Substances such as tobacco, perfumes and colognes and others could be studied in this respect.

(b) Impact Resistance. Due to the portable nature of these devices, it is quite likely that users will wish to transport them. As a result, the instruments could be subjected to physical jostling and impacts. Research should be undertaken to evaluate the short- and long-term effects of physical impacts. One option could involve testing the devices on a shake table, a system that subjects objects to vibrations at specified frequencies and on multiple axes.

(c) Ambient Temperature. Although it is likely that these instruments will most often be used indoors, at comfortable room temperatures, they could be used in more extreme temperature environments. Thus, the impact of substantially

colder and warmer ambient temperatures upon the devices' performance should be assessed. Results could lead the manufacturers in developing recommended use protocols.

(d) Calibration. Given that virtually all PMBTs are calibrated at the factory and do not permit subsequent (re)calibration by their users, the duration of calibration is of interest. The performance of devices could be affected by changes in calibration, possibly gradual, over time and through repeated use. The accuracy and precision of a given device could be assessed, using time and/or level of use as independent variables. This could give potential purchasers some information regarding devices' anticipated lengths of service. Also, the option of presenting used devices to the manufacturers for recalibration could be explored.

(e) Inter-model Performance. This study examined only one model of each device available. No information about variability among multiple models of the same device was obtained; this area of interest remains open. A suitable number of the same model of device should be obtained, then tested for performance differences among the units. This could reveal useful information regarding the effects of quality control and inter-device reliability.

(f) Actual Drinking Conditions. Although this study tested the devices using human participants (Experiment Two), the conditions under which this took place remained under control by the research personnel. An appropriate next step, following these experiments, would be to test the devices under less controlled, more realistic conditions.

At least two possible scenarios exist in this regard. First, the device could be tested in social situations, such as at bars and private parties, in which the researcher manipulates the devices. That is, the researcher would provide the instruments, ensure that they are properly warmed up, explain to participants how to use them, and even maintain physical control of the instruments. This could result in the acquisition of more real-world data under the supervision of the researcher.

Second, the devices could be tested in these same situations, yet without the researcher's guidance as to when and how to use the devices. Thus, participants would be required to make their own decisions regarding the application of these devices. A controlled drinking situation similar to that used in Experiment Two could be employed. This could yield valuable information regarding how such instruments would actually be used under conditions that would be considered realistic and expected by manufacturers and users.

(g) Device Readout System. This study examined only devices that provide a numerical readout of estimated BrAC. As previously noted, other PMBT devices that provide ranges of output or binary output are available. These devices should undergo rigorous evaluation as well. This might require the use of research designs different from those employed in this study, appropriate to the categorical nature of the data that these devices provide. Several issues could be of interest, including:

(1) Minimum Response Level- the lowest value at which the devices read positive for alcohol

(2) Category Threshold- the actual levels at which devices indicate that a user has moved to the next higher category (in order to assess the accuracy of manufacturer-claimed and -specified thresholds)

(3) Maximum Response Level- the highest level of BrAC to which the devices would respond.

(h) Law Enforcement Application. PMBTs might be able to play a role in the enforcement of impaired driving laws. The generally accepted non-technological system of assessing impairment is the application of standardized field sobriety tests (SFSTs). These tests were developed to aid law enforcement officers in evaluating a suspected impaired driver. These partially subjective tests are widely used and involve suspects performing several psychomotor tasks such as heel-to-toe walking, balance maintenance and officers observing suspects' eyes for signs of alcohol impairment (Stuster, 2001).

However, concerns about officers' abilities to administer these tests *exactly* as specified have been raised. A major concern is officers' abilities to continue to perform the tests in a precisely standardized way, over the officer's career. In his study of the maintenance of SFST administration skills, Merkley (2002) found a gradual but definite deterioration in officers' abilities to perform the tests. Thus, there may be a growing need to further objectify methods of approximating a

driver's BAC at the initial point of contact. One of the test devices, the ABI unit, has already been placed on NHTSA's PBT Conforming Product List. Additional research could explore the potential for other PMBT devices, including those with non-numerical output features, to aid officers in assessing suspected impaired drivers' alcohol levels.

These devices' performances in all of the areas discussed herein are ripe for future evaluation. Therefore, further research should be conducted toward answering these questions.

6.2. Recommendations for PMBT Manufacturers

This study revealed several recommendations for manufacturers who are interested in developing increasingly effective PMBTs, including:

(a) Start Timer. A countdown timer could be integrated to help the user determine when the required waiting period is complete. The user could be alerted by an audible alarm, perhaps complemented by a vibrating mechanism. The user simply punches a button, and 15 minutes later, the device alerts him or her that it is ready for use.

(b) Recovery Alert. Similarly, an alarm could be employed to notify the user when the device is fully recovered from the previous test. This way, the user would not have to watch the instrument uninterruptedly, waiting for it to indicate readiness for testing.

(c) Poor Sample Alert. A system could be integrated to monitor the airflow (a miniature spirometer) and the length of expiration. If either of these do not meet the device's internal requirements, the test would be aborted. This could be substantially helpful, as most first-time users tend to not exhale long enough to obtain a full sample of deep-lung air. Accordingly, there would need to be a system to inform the user as to *why* the test was aborted, informing he or she of the need to blow harder or longer on the next attempt.

(d) Sample Alert Beep. This alert would inform the user, once blowing, when he or she can stop blowing into the device. This would simplify the test procedure: blow until you hear the beep. It could also aid in the collection of more consistent samples.

(e) Distance Mechanism. For non-mouthpiece instruments, a mechanism could be employed to ensure a consistent distance between the user's mouth and the device's input port. This could involve, for example, a short arm that can be swiveled upward (like the antenna of an inexpensive hand-held two-way radio), the tip of which could rest on the user's chin.

(f) Calibration System. An effective system by which the user could calibrate the instrument would further aid in obtaining accurate and precise results. With the expectation that any instrument's calibration will change over time and use, a method to reset its measurement system should only enhance a device's utility. This could even be made to occur automatically, performed each time the Start

Timer (see above) is activated. Such an automated function could reduce the chance of increased operator error due to existing alcohol impairment.

(g) Design. The devices tested were all sole-function units, similar in appearance to no other object. Perhaps these devices could be made to simulate common objects, such as a pager, or be integrated into cell phones, personal digital assistants (PDAs), wallets/pocketbooks, voice recorders, flashlights, cigarette lighters, or other items that would not be considered unusual if present in an actual drinking situation. Some potential users might prefer devices whose purpose is relatively concealed.

(h) Protection. Several devices tested came with protective cloth bags. These could be effective in preventing damage in between uses, but a hard-plastic, form-fitted sheath could provide even more protection. Such forms should not be difficult to prepare, especially if they are initially designed in conjunction with the device.

(i) Power Source. All the devices tested were battery-powered. For real-world use, this would necessitate occasionally replacing discharged batteries. One option would be to use integrated rechargeable batteries. A table-top charger could be included with the testing instrument.

(j) Drink Counter. Some users might find it useful to keep an objective measure of the number of drinks they have consumed. A simple clicker-type counter integrated into a device could serve this function.

(k) Useful Information. The devices could also contain information useful to drinkers, such as a toll-free number to call for a taxi. They could also display

appropriate preventive messages, such as “Don’t drink after drinking!” or “If in doubt, call a cab!” or other suitable text.

In general, it has been recommended that PMBT-type devices should remain as simple as possible. A.W. Jones suggested that such devices should not be made too complicated and that simpler devices that place little interpretive demands on their users could hold the most potential for effective application (personal communication, December 11, 2002). Given that many drinkers would use such devices in an alcohol positive state, minimizing the devices’ complexity of use could result in optimal utility for the user.

6.3. Recommendations for Addressing Research Methodological Issues

This study revealed several insights into the testing of PMBTs, which might assist in additional research of these devices. These include:

(a) Simulator Solutions. The simulator solutions used in the pilot testing and Experiment One were invaluable. These units provided stable and easy-to-use samples with which to test the devices under highly controlled conditions. The national specifications for the use of simulators are easily obtained and promote consistency among research efforts using simulators. Where highly controlled conditions are sought, simulators are quite capable of contributing to reducing the impact of extraneous variables.

(b) Human Participants. Experiment Two involved two separate drinking sessions, and accommodated a maximum of six drinkers per session. This was a

manageable number of drinking participants. However, several factors could affect the decision regarding how many drinking participants can be accommodated in future projects, including:

(1) Number of sober volunteers. The presence and assistance of sober volunteers is invaluable. They can assist with the testing of instruments and the control and comfort of participants. Having at least one sober volunteer per drinking participant is ideal. Additionally, as the number of volunteers present increases, so does the number of drinking participants that can be handled.

(2) Number of devices to be tested. The number of devices can be a factor because if the number of devices is few and the number of drinking participants is large, substantial delays could result in obtaining measurements from each drinker. This potential problem could be ameliorated by selecting an appropriate experimental design. For example, it may not be necessary for each drinker to provide duplicate samples with each device at each alcohol level (a completely within-subjects design).

(3) Testing facilities. If the testing facilities are large enough, they may not have an impact on the maximum number of participants. However, most testing facilities will not be unlimited in size, and the size should be taken into account in

determining how many participants can be comfortably accommodated.

6.4. Conclusion

This exploratory study showed that the tested devices demonstrated the ability to detect the presence of alcohol. However, as a whole, the devices exhibited less precision and greater systematic error than NHTSA standards specify for instruments to be placed on its Conforming Products List. Further, the devices as a whole overestimated actual BrAC. Thus, the systematic error was in a conservative direction.

Additionally, this systematic error was different at different levels of alcohol, as evinced by the significant interaction between Device and Concentration. The devices' performances under human drinking conditions appeared to decrease somewhat as alcohol levels increased. Further, under actual drinking conditions, the devices were not (with one exception, Device B at .08) found to have performed differently from the Intoxilyzer, despite sometimes large percentage differences between mean results. This suggests that the test devices' variability is large enough to warrant concern over their ability to perform their intended function: providing users with usable information regarding individual alcohol levels.

Devices A, C and E were the best performing devices, in terms of accuracy and precision. Any of these three has the potential to provide users with information that could be effectively used to make improved decisions regarding personal alcohol levels. The lower performing devices (B, D and F) are not recommended for use by people

seeking to obtain useful information regarding personal alcohol levels. Device F could be especially risky to use, as it consistently underestimated BrAC. However, more research is needed before any device receives solid recommendation or condemnation for use as intended.

Although other aspects of these devices' performances remain to be investigated, it is hoped that this study contributes to the understanding and potential uses of this relatively new class of breath alcohol testing devices. It is also hoped that the study contributes toward the eventual improvement of information that consumers of alcohol can use to make better decisions, and toward reducing the incidence of impaired driving throughout the world.

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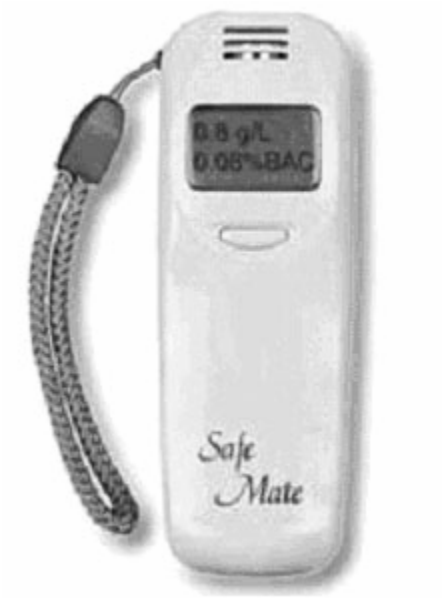
APPENDIX A

SAMPLE IMAGES OF QUANTITATIVE PMBT MODELS

Device A: Safe Mate



Energy Source	2 AA batteries
Battery Life	Can use more than 800 times
Display	20 stage LCD
Dimensions	89.5×30×16.5mm
Weight	43g (including batteries)
Material	ABS Resin (Acrylic Fiber)
Sensor Type	MEMS Semiconductor

A Fast, Reusable, Pocket-sized Alcohol Detection Device for Use Anywhere, Anytime Alcohol Consumption or Intoxication is a Concern. Digital LCD Readout of Percentage BAC test results, Manual and Self-Calibration Feature. Micro Sized, Discreet. Incorporates the new MEMS* microchip gas sensor technology.

Despite its micro size, the SAFEMATE™ Personal Digital Alcohol Breath Analyzer is a sensitive scientific instrument employing the latest semiconductor technology to convert breath alcohol content to equivalent blood alcohol content (BAC) within seconds. Results are displayed digitally on a backlit LCD display panel. The SAFEMATE™ employs the recently developed and most advanced *MEMS" gas sensor which is alcohol specific thereby minimizing the possible interference from other environmental factors.

Device B: Blue Breathalyzer

The Blue is a popular consumer-oriented breathalyzer. Manufactured in the U.S. by Lifeloc Technologies, the Blue uses a highly-selective semiconductor sensor to provide reliable accuracy from 0.00 to .40% BAC. The Blue comes with removable mouthpieces shaped to help maximize testing accuracy and extend the life of the unit. The three digit LED displays the exact BAC value, not just a range. The Blue uses semiconductor technology very similar to the CA-2000, providing amazingly fast and accurate results.

Sophisticated, highly-selective semiconductor sensor provides highly reliable accuracy

3 digits digital LED display (0.xx% BAC/BRAC)

Wide detection range : 0.00 - 0.40% BAC

Long-term stability

Compact & light weight hand-held device

Short warm-up, response, and recovery times

3,000 test lifetime

4 AA Batteries included

Audible alarm alerts user to positive test

Device C: AlcoScan CA2000

- Sophisticated, highly-selective semiconductor sensor provides highly reliable accuracy
- 3 digits digital LED display (0.xx% BAC/BRAC)
- Wide detection range : 0.00 - 0.40% BAC
- Long-term stability
- Compact & light weight hand-held device
- Short warm-up, response, and recovery times
- 3,000 test lifetime
- 9V Alkaline battery & one cigar Jack DC adapter included
- Audible alarm alerts user to positive test

SPECIFICATIONS

- **Size:** 120 mm x 60mm x 25 mm
- **Weight:** 200 gram
- **Housing:** Shock resistant, molded plastic
- **Sensor:** Highly selective semi-conductive oxide alcohol sensor
- **Response time:** 3 sec
- **Warm up time:** 20 sec
- **Recovery time (sensor pure):** 30 sec
- **Battery life:** About 200 tests
- **Battery:** 9V alkaline
- **External power supply:** Optional 12V DC adapter
- **Accuracy:** 0.01% at 0.10%BAC

Device D: Elan

Specifications
Size: 3.50 in x 1.25 in x 0.5 in
Weight: 105 grams
Sensor: Semi-conductor sensor
Specificity: Specific for alcohol
Ambient Temperature: 0 °C to 40 °C (30 °F to 100 °F)
Purge Cycle (Initial Test): 6 seconds
Breath Sample: 5 second moderate and continuous breath sample
Analysis Time: 10 seconds
Recycle (Recovery) Time: 10 seconds
A higher reading will take a longer recycle time
BAC Readout Format: % BAC
Range of Measurement: 0.000 to 0.350% BAC (0 to 350 mg%)
Accuracy: ±0.01 @ 0.100% BAC (±10 @ 100 mg%)
Smoking Caution: Wait 10 minutes
Drinking Caution: Wait 10 minutes
(After consumption of alcohol)
Display: 3-Digit LCD readout
Battery Pack: Two (2x) "AAA" alkaline battery (Included)
Mouthpieces: NONE, Passive Test Only

Device E: ABI Professional Breath Alcohol Screener

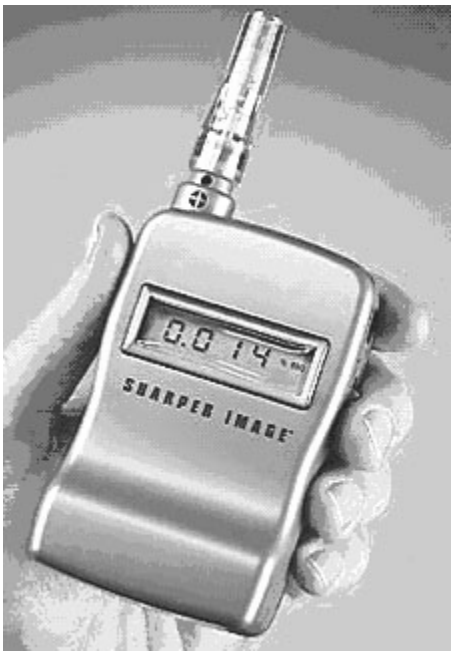
Features of the ABI:

- Blow-time is 4.5 seconds (per DOT regulations)
- Analyze blood alcohol percentage
- Breathalyzer
- Indicate 0.01-0.40 %BAC Range
- Alcohol detector/tester
- DOT Approved Instrument

ABI Complete Package Includes:

- Breathalyzer
- Hard plastic cover for safe carriage
- Car adapter
- 9V DC battery, 300+ tests
- Hand carry bag
- 5 Mouth Pieces - extra pieces available
- Hand strap

Device F: Sharper Image BT300



Digital Alcohol Breath Tester lets you know who's had enough.

- Accurately estimates your blood alcohol content (BAC) in just seconds.
- Digital Signal Processor technology.
- Blow into tube. Reading is indicated on the LCD screen to nearest .001 percent.
- Warnings alert you to a BAC of 0.050% or higher.

Find your blood alcohol content (BAC) in seconds simply by blowing into the Digital Alcohol Breath Tester. Easy to use and completely non-invasive, it displays your BAC within a range of .000% to .200% The LCD screen lights for easy reading at night and warns you with beeps and an on-screen alert when your BAC surpasses 0.050%.

Measures a compact 4 3/4" x 2 1/2" x 1 1/4". Runs on one 9v battery (included). Comes with two plastic mouthpieces. 90-day warranty. Caution: The impairment effects from a specific alcohol level can vary from driver to driver. Never drink and drive.

Device G: PNI BT3300

PNI BT3300 Digital Alcohol Detector Features:

- Utilizes advances semi-conductor gas sensor technology to measure the level of alcohol in your blood via a breath sample
- Easily fits into your pocket, purse, or day planner, about the same size as a lighter
- Clearly displays level of blood alcohol concentration (%BAC) in increments of 0.01% ranging from 0.00% to 0.19 %BAC
- Simple to use, takes only a few seconds
- Audible alerts tell you when the unit is ready for use and after a breath sample registers
- Error warning tells you when an incomplete breath sample was taken
- Operates for over 300 uses on 2 AAA batteries
- Dual battery low alerts tell you when the batteries should be replaced, and when they are too low to take an accurate reading
- 3.5" long x 1.25" wide x 0.5" thick, 1.6oz.

Device H: AlcoScan AL2000

The AlcoScan AL2000™ Alcohol Breath Analyzer is a highly sensitive scientific instrument which employs an advanced integrated microchip to determine equivalent blood alcohol content within a ten step range of <.01% to .10>%. Easy and convenient to use, the AlcoScan AL2000 has 10 progressive LED indicators plus audible warning codes to clearly indicate levels of intoxication within seconds.

The AL2000 employs the recently developed and most advanced *MEMS gas sensor which is alcohol specific eliminating the possible interference from other environmental factors. This professional LED step model is used by many law enforcement and institutional agencies as a relatively low cost frontline field sobriety test for suspect drunk drivers and intoxicated individuals.

Ten (10) Progressive levels of calculated BAC % from <=0.01% through => 0.10%
Accurate to within (+/-) 10% of calculated versus actual BAC levels
Colored LED 10 Step Display with Audible Beeps
Power on Self Test and Visual Ready Prompt
No special Mouthpiece Required
Displays Test results in Two (2) Seconds
Test Recycle time < Twenty (20) Seconds
Advanced Semiconductor Microchip Alcohol Sensor
Power Supply: Three 1.5V AAA Batteries (included)
Approximately Three (3) Continuous Hours Usage Time Between Battery Change
Weight: 125 grams, 4.4 ounces
Dimensions: H=14 cm (5.5") W=5 cm (2") Depth=2 cm (.7") Pocket sized

APPENDIX B

CLOSED SYSTEM WET BATH SIMULATOR

The Draeger Mark IIA Simulator is the preferred, court-proven breath alcohol simulator. The Mark IIA provides an electronically controlled alcohol reference gas to the breath analyzer by converting an alcohol solution (with a precisely known concentration of alcohol) to a vapor, simulating a human breath sample.

The Mark IIA is designed for use with all Draeger alcohol-measuring devices, as well as, other Evidential Breath Testers (EBT) or Preliminary Breath Testers (PBT). Frequent calibration testing of an EBT or PBT with the Mark IIA Simulator assures calibration integrity, aiding accuracy verification in court.

Features Include:

Mercury temperature sensor
34°C ± .2°C (NHTSA)
6 foot power cable
Solution volume: 500 ml

APPENDIX C

THE ALCOHOL USE DISORDER INVENTORY TEST

Participant Screening Instrument

This document is intended to provide project personnel information about potential participants in a study in which alcohol will be consumed. Please be honest in answering the following questions.

Additional Details

Length of Study: The entire session is expected to take between 7-8 hours, including time for consumption and elimination of alcohol.

Females: No pregnant females will be permitted to participate in this study. All females selected for participation will have to perform a portable pregnancy test before being allowed to consume alcohol.

Non-drinkers: Non-drinkers will not be permitted to participate in this study.

Body Weight: Your body weight will be used to determine how much alcohol you will be asked to consume.

Restricted Location: Once you agree to participate and begin consuming alcohol, you are free to withdraw from the study at any time, but you must agree to remain at the testing site until your blood alcohol level returns to 0.00%. Any participant who attempts to leave the testing site before all his/her alcohol is eliminated will be forcibly retained at the testing site.

Breath Tests: You will be asked to performed repeated deep-lung breath tests, perhaps over 200 during the study.

Food: Only a few light snacks will be provided during the study, as it must be ensured that ingested materials do not interfere with the breath tests.

PART I

Please mark "True" or "False" to the following questions:

_____ I am not allergic to alcohol and have no reasons to believe I would experience any negative consequences as a result of consuming alcohol.

_____ I am in good health and have no reasons to believe I should not be a candidate for this study.

_____ I have consumed alcohol in the past and do not currently consider myself to be a non-drinker.

_____ I am not diabetic.

PART II

Alcohol Use Disorder Inventory Test (World Health Organization, 1987)

This instrument will be used to identify potential participants for an alcohol-related study. Please circle the letter corresponding to your answer.

1. How often do you have drinks containing alcohol?
   (one drink is a beer, glass of wine, or mixed drink)

   a. Never
   b. Monthly or less
   c. 2-4 times a month
   d. 2-4 times a week
   e. 4 or more times a week

2. How many drinks containing alcohol do you have on a typical day when you are drinking?

   a. 1 or 2
   b. 3 or 4
   c. 5 or 6
   d. 7 to 9
   e. 10 or more

3. How often do you have six or more drinks on one occasion?

   a. Never
   b. Less than monthly
   c. Monthly
   d. Weekly
   e. Daily or almost daily

4. How often during the past year have you been unable to stop drinking once you started?

   a. Never
   b. Less than monthly
   c. Monthly
   d. Weekly
   e. Daily or almost daily

5. How often during the past year have you failed to do what was normally expected of you because of drinking?

    a. Never
    b. Less than monthly
    c. Monthly
    d. Weekly
    e. Daily or almost daily

6. How often during the past year have you needed a drink in the morning to get going after a heavy drinking session?

    a. Never
    b. Less than monthly
    c. Monthly
    d. Weekly
    e. Daily or almost daily

7. How often during the past year have you had a feeling of guilt or remorse after drinking?

    a. Never
    b. Less than monthly
    c. Monthly
    d. Weekly
    e. Daily or almost daily

8. How often during the past year have you been unable to remember what happened the night before because of drinking?

    a. Never
    b. Less than monthly
    c. Monthly
    d. Weekly
    e. Daily or almost daily

9. Have you or someone else been injured as a result of your drinking?

    a. No
    b. Yes, but not in the past year
    c. Yes, during the past year

10. Has a relative, friend, doctor or other health worker been concerned about your drinking or suggested you cut down?

    a. No
    b. Yes, but not in the past year
    c. Yes, during the past year

Thank you for your participation! You will be contacted if selected to participate.

Name _____

Phone # _____

Email _____

Alcohol Use Disorder Inventory Test World Health Organization, 1987

Scoring:

Questions 1-8	a = 0 points b = 1 point c = 2 points d = 3 points e = 4 points
Questions 9-10	a = 0 points b = 2 points c = 4 points

Totals:

8-15	may indicate a problem with alcohol use
16 or more	suggests a more serious problem; you should contact your physician or an alcohol-treatment program for help

APPENDIX D

THE NUMERICAL DRINKING PROFILE

NDP - ADAPTED

Name _____ Date _____

Please read each question carefully, and then check the most correct answer in the box provided. Check only one box for each question.

1. How many times have you been arrested on charges involving alcohol? (Do not count the present DWI arrest.) _____(Times)

2. Is someone close to you concerned about your drinking?
   Yes ( ) No ( )

3. With whom did you do most of your drinking before this arrest?
   Husband/Wife ( ) Relative ( ) Friends ( )
   Strangers ( ) Alone ( )

4. Do you believe your drinking may be causing you problems?
   Yes ( ) No ( )
   No, but it used to cause me problems ( ) Not Sure ( )

5. Do you want help for a drinking problem?
   Yes ( ) No ( ) Not Sure ( )

6. Do you feel you are a normal drinker?
   Yes ( ) No ( )

7. Have you ever awakened the morning after some drinking the night before and found you could not remember a part of the evening?
   Yes ( ) No ( )

8. Does your wife, husband, a parent, or other near relative ever worry or complain about your drinking?
   Yes ( ) No ( )

9. Can you stop drinking without a struggle after one or two drinks?
   Yes ( ) No ( )

10. Do you ever feel bad about your drinking?
    Yes ( ) No ( )

11. Do your friends or relatives think you are a normal drinker?
    Yes ( ) No ( )

12. Do you ever try to limit your drinking to certain times of the day or to certain places?
Yes ( ) No ( )

13. Are you always able to stop drinking when you want to?
Yes ( ) No ( )

14. Have you ever attended a meeting of Alcoholics Anonymous?
Yes ( ) No ( )

15. Have you gotten into fights when drinking?
Yes ( ) No ( )

16. Has drinking ever created problems between you and your wife, husband, parent, or other near relative?
Yes ( ) No ( )

17. Has your wife, husband, a parent, or other near relative ever gone to anyone for help about your drinking?
Yes ( ) No ( )

18. Have you ever lost friends because of drinking?
Yes ( ) No ( )

19. Have you ever gotten into trouble at work because of drinking?
Yes ( ) No ( )

20. Have you ever lost a job because of drinking?
Yes ( ) No ( )

21. Have you ever neglected your obligations, your family, or your work for 2 or more days in a row because you were drinking?
Yes ( ) No ( )

22. Do you drink before noon fairly often?
Yes ( ) No ( )

23. Have you ever been told you have liver trouble? Cirrhosis?
Yes ( ) No ( )

24. After heavy drinking, have you ever had Delirium Tremens (DT's) or severe shaking?
Yes ( ) No ( )

25. After heavy drinking, have you ever heard voices or seen things that weren't really there?
Yes ( ) No ( )

26. Have you ever gone to anyone for help about your drinking?
Yes ( ) No ( )

27. Have you ever been in hospital because of drinking?
Yes ( ) No ( )

28. Have you ever been a patient in a psychiatric hospital or on a psychiatric ward of a general hospital?
Yes ( ) No ( )

29. Have you ever been in a hospital to be "dried out" (detoxified) because of drinking?
Yes ( ) No ( )

30. Have you ever been in jail, even for a few hours, because of drunkenness behavior? (Count the present arrest)
Yes ( ) No ( )

NUMERICAL DRINKING PROFILE (NDP)
(Adapted Version)

The **Numerical Drinking Profile** uses personal data items and the score from the modified scoring version of the **MAST (Michigan Alcoholism Screening Test)** to aid instructors in determining the extent of a person's drinking problem.

The personal data items (questions 1-5 on the NDP) relate to the number of alcohol arrests, with whom they did most of their drinking, alcohol causing them problems, someone being concerned about their drinking, and whether they want help for a drinking problem.

The MAST portion consists of 25 yes/no questions about drinking (questions 6-30 on the NDP). Scores may range from 0 to 25 with scoring done by adding one point for each response which matches answers identified as an indication of an alcohol problem.

Classification of DWI offenders along the problem-drinking continuum is done by a process of elimination. There are 3 main categories: Evident Problem, Potential Problem, and No Problem. The scoring procedure is as follows:

1. Score the MAST portion of each person's NDP (questions 6-30) using the MAST key provided. (see following page)

2. Enter the name of each person on the NDP Worksheet.
3. Fill in the boxes under the "Evident Problem," "Potential Problem," and "No Problem" categories for each person. This is done by placing a check mark in each box with which the person's answers on the NDP Test Form agrees. Place a zero in any box for which there is disagreement by the person so that you will know each answer has been considered. **Note: Any one answer which agrees with an item in a higher category automatically places the individual in that category. There is no need to score the other categories.**

Total the check marks for each category and enter the total number of items checked for each category in the appropriate box. Refer to the NDP key to determine into which category each person belongs.

Be sure that the correct category is consulted to prevent an inappropriate classification.

MAST KEY

6. NO	11. NO	16. YES	21. YES	26. YES
7. YES	12. YES	17. YES	22. YES	27. YES
8. YES	13. NO	18. YES	23. YES	28. YES
9. NO	14. YES	19. YES	24. YES	29. YES
10. YES	15. YES	20. YES	25. YES	30. YES

Place a check mark for each answer on the person's MAST Test (items 6-30) which agrees with the keyed responses.

Place a zero (0) on any item for which the person disagrees with the keyed response.

The total number of checks on numbers 6-30 = MAST score.

NDP KEY

NOTE: Any one answer which agrees with an item in a higher category automatically places the individual in that category. (For example, one or more agreeing answers in the Evident Problem category means that the other categories do not apply.)

EVIDENT PROBLEM

1 qualifying answer	= NDP of 6
2 - 3 qualifying answers	= NDP of 7

POTENTIAL PROBLEM

1 qualifying answer	= NDP of 2
2 qualifying answers	= NDP of 3
3 qualifying answers	= NDP of 4
4 - 6 qualifying answers	= NDP of 5

NO PROBLEM

3 qualifying answers	= NDP of 1

APPENDIX E

INFORMED CONSENT FORM

Informed Consent
An Analysis of Performance of the Next Generation of Breath Alcohol
Instruments: Civilian Breath Testers

Introduction

- I understand that I will participate in a Texas A&M University Center for Alcohol and Drug Education Studies (CADES) research study to examine the reliability and validity of a new class of breath alcohol measurement devices: civilian breath testers. I understand that the experiment will be an 8 hour period at the Texas A&M University Riverside Campus and that I will be one of approximately 20 participants involved in the study. I will be asked to consume 101 proof (50.5% alcohol) alcoholic beverages and that the target maximum breath alcohol concentration (BrAC) for all participants will be .08% (80 mg/dl; approximately 3 drinks for females and 4 drinks for males).

- I understand that I will be asked to provide numerous breath samples into several breath alcohol measurement devices and that I will be asked to provide saliva samples for a saliva-based breath alcohol measurement device.

- I understand that this study will last a total of approximately 8 hours, including the time it takes for my BrAC to return to 0.00.

- I understand that discomfort might result from possible hangover effects of alcohol consumption.

- I understand that I may benefit directly by gaining personal experience about the relationship between subjective feelings of alcohol impairment and the quantitative measurement of my BrAC.

- Although no monetary compensation will be provided, I understand that my participation is voluntary and that I may withdraw from the experiment at any time. I further understand that if I withdraw from the experiment prior to its conclusion, I agree to remain at the testing site until my BrAC returns to 0.00.

- Should I, in the judgment of the project personnel, become a risk to self or others, my participation will be terminated by the principal investigator.

_____ _____

Initial/Date

- I understand that in the event of a medical emergency, project personnel can contact medical attention providers on my behalf and that all medical expenses incurred will be my responsibility.

- I understand that I will be asked to complete a pre-screening instrument and a survey regarding my experiences in the study.

- For female participants: I understand that pregnant women should not consume alcohol and I agree to remove myself from any participation if I am pregnant. I further understand that I will have to perform a portable pregnancy test before being allowed to consume alcohol.

- I understand that this study is confidential and that the researchers will securely store all information related to the study in Room 204, G. Rollie White Coliseum, for a period of three (3) years.

- I understand that my car keys will be collected upon arrival at the testing site and that they will not be returned to my until my BrAC has returned to 0.00.

- I understand that law enforcement personnel can detain me if I attempt to leave the testing site prior to my BrAC returning to 0.00, even if I have withdrawn from the study before its conclusion.

- I understand that a specific individual will be assigned to monitor me throughout the experiment and that this person will remain near me at all times.

- Any significant new findings developed during the course of the research that may relate to my health or my willingness to continue participation will be provided to me immediately upon discovery.

I understand that this research study has been reviewed by and approved by the Institutional Review Board – Human Subjects in Research, Texas A&M University. For research related problems or questions regarding subjects' rights, I can contact the Institutional Review Board through Dr. Michael W. Buckley, Director of Support Services, Office of Vice President for Research at (979) 458-4067.

I have read and understand the explanation provided to me. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this study.

I have been given a copy of this consent form.

_____ _____
Signature of Subject Date

_____ _____
Principal Investigator Date

Contact Person: Dr. Maurice E. Dennis
or William E. Van Tassel
G. Rollie White Coliseum, Room 204
Texas A&M University
College Station, Texas 77843-4243
(979) 845-3019
med@hlkn.tamu.edu or wvantassel@hlkn.tamu.edu

APPENDIX F

LATIN SQUARE COUNTERBALANCING SYSTEM

Latin Square

1. **Bordens & Abbot (1996)**
2. **Appendix column #32, selected by Kathy Durkin**
3. **#25 selected by Christie Dickson**
4. **Column #32**

	1	2	3	4	5	6	7	8
1	F	H	A	B	D	G	C	E
2	C	E	F	G	A	D	H	B
3	D	F	G	H	B	E	A	C
4	H	B	C	D	F	A	E	G
5	E	G	H	A	C	F	B	D
6	A	C	D	E	G	B	F	H
7	G	A	B	C	E	H	D	F
8	B	D	E	F	H	C	G	A

APPENDIX G

PARTICIPANT DATA SHEET

Participant Data Form

Participant Number _____

Name _____ Age _____

Sex ____ **Date of Birth**

_____

Pregnancy Test
Verification _____ (Pos. or Neg.)

Weight _____ lbs.

Height _____ cm.

Heart Rate _____

Oral Temperature _____

Body Water Content:

Resistance	
Reactance	

Spirometry Results

_____

_____

VITA

WILLIAM EDWARD VAN TASSEL

Address 158 Read Building, Dept. of HLKN, College Station, TX 77843

Education

Texas A&M University, College Station, TX
Ph.D., August 2003
University of Central Oklahoma, Edmond, OK
M.A. Psychology, August 1997
Texas A&M University, College Station, TX
M.B.A., May 1992, B.B.A., May 1990

Professional Experience

Assistant Lecturer. Texas A&M University, Health & Kinesiology. Teaching undergraduate classes in the Health and Safety Program. September 2002 – August 2003.

Research Associate. Center for Alcohol and Drug Education Studies. Responsible for conducting and oversight of alcohol and drug related Research. September 1999 to December 2001.

Selected Publications

Van Tassel, W.E. & Dennis, M.E. (2002). Beyond the norm with instructor preparation: Observational experiences. The Chronicle of the American Driver and Traffic Safety Education Association, 50(4), 3, 12.

Van Tassel, W.E. & Dennis, M.E. (2002). Civilian breath testers: A new approach to breath-alcohol testing. Texas Journal of Alcohol and Traffic Safety. Volume 02(3), 3-4.

Van Tassel, W.E. & Dennis, M.E. (2002). Beyond the norm with instructor preparation: Special topics. The Chronicle of the American Driver and Traffic Safety Education Association, 50(3), 4, 14.

Van Tassel, W.E. and Manser, M.P. (2000). Participant-predicted, observed and calculated peak blood alcohol levels: A gender-specific analysis. Proceedings of the 44th Annual Conference of the Association for the Advancement of Automotive Medicine. Chicago.

Professional Activities

OSHA Training Institute Southwest Education Center. Contract Instructor. 1997 – current.

Editor of *The CADES Newsletter*, a publication of the Center for Alcohol and Drug Education Studies at Texas A&M University. 1998 – 2003.