University of Massachusetts Law Review

Volume 7
Issue 1 *Trends and Issues in Technology & the Law*

Article 4

March 2014

The Science Behind Breath Testing for Ethanol

Thomas E. Workman Jr.

UMass Law Review

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7 U. MASS. L. REV. 110

ABSTRACT

Nationwide, law enforcement officers utilize breath-test machines to identify suspected drunk drivers. When defense attorneys represent a client who has been charged with alcohol related driving crimes, it is important to understand the science and methodology behind alcohol breath-testing, and specifically the functionality of the device used to test their client. This article explains the various methods of testing and types of devices used, as well as their effectiveness, by examining the scientific principles associated with common testing measures. This article serves as an aid to the practicing attorney who, by understanding the science and methodology of breath-testing, will be better situated to assist defendants facing breath-test evidence.

AUTHOR

Thomas Workman is an Attorney, licensed in Massachusetts. He operates a Forensic Consulting business, providing analysis and testimony concerning legal matters that incorporate computers and how computers produce evidence for Judges and Juries. Workman is also an adjunct Professor at the University of Massachusetts Law School. Workman operates a website, computers-forensic-expert.com, where his current Curriculum Vitae can be found.

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I. INTRODUCTION

Driving an automobile while under the influence of an intoxicating beverage is a serious societal problem.[1] To combat the problem of intoxicated drivers, starting in 1938, machines began to appear that facilitated the measurement of how much ethanol was present on the breath of a suspected drunk driver.[2] The advent of "per se" statutes made it a crime to drive with a level of ethanol in the blood or breath that exceeded statutory limits,[3] and with these statutes came the necessity to measure the amount of ethanol in the driver's body.[4] Breath testing became the preferred method of measuring alcohol concentration on the breath of a driver because of the simplicity of its administration.[5] Given this backdrop of legal fabric, it is common for an attorney representing a client charged with driving under the influence of ethanol to encounter a measurement of ethanol in the breath of the client. This article is presented to assist attorneys representing a client charged with driving under the influence of alcohol when a test of the client's breath for ethanol has been introduced as evidence of intoxication.

Over the years, machines have been developed that analyze a sample of human breath and report the amount of alcohol contained in that breath sample.[6] In the United States, these machines are categorized as "preliminary", "self-initiated", or "evidentiary" testing machines. The category of the device determines what judicial proceedings will consider the test results.[7] What makes a machine an

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[1] U.S. Department of Transportation, DWI Detection and Standardized Field Sobriety Testing Student Manual. II-1 (Feb. 2006) citing R.F. BORKENSTEIN, ET AL., ROLE OF THE DRINKING DRIVER IN TRAFFIC ACCIDENTS (1964) "Averaged across all hours of the day and all days of the week, two percent of the drivers on the road are DWI."

[2] Tony Long, *Set 'em Up, Joe . . .for a Breath Test*, WIRED, http://www.wired .com/thisdayintech/tag/rolla-n-harger/ (last visited Mar. 21, 2012).

[3] 2 P.C. GIANNELLI & E.J. IMWINKELRIED, SCIENTIFIC EVIDENCE, § 22.01 (4th ed. 2007).

[4] *Id.*

[5] ANDRE A. MOENSSENS ET AL., SCIENTIFIC EVIDENCE IN CIVIL AND CRIMINAL CASES, 200 n.1 (5th ed. 2007).

[6] Kevin Trombold, Out with the Old, In with the New: A Historical Review of the Future of Breath Testing with the Draeger, in UNDERSTANDING DUI SCIENTIFIC EVIDENCE, 339-85 (2011 ed.).

[7] LAWRENCE TAYLOR & STEVEN OBERMAN, DRUNK DRIVING DEFENSE § 5.06 (discussing preliminary devices), § 2.01 (discussing self-initiated devices), § 7.05 (discussing evidentiary machines) (7th ed. 2010).

"evidentiary", "self-initiated", or "preliminary" machine varies from state to state, but there are some common attributes worth understanding.

Preliminary machines are usually portable, battery-powered, and provide results on a small display within the device.[8] The test results are displayed within seconds of the subject's exhalation into the device. Results disappear once the officer observes the results and turns the machine off, or when another breath sample is submitted to the machine for analysis.[9] Preliminary machines are typically assigned to a police officer or a police car. They are usually the size of a few packs of cigarettes, lightweight and hand-held.[10] Modern preliminary breath test machines are electronic devices, often controlled by a microprocessor. They utilize an electrochemical fuel cell to measure the amount of alcohol contained in the subject's breath.[11]

Self-initiated machines operate in the absence of a government agent.[12] They include ignition interlock devices that are installed in vehicles and machines installed in a subject's home. These devices often require the submission of a breath sample at times that cannot be predicted by the subject being monitored.[13] They usually require an installation procedure and often include anti-tampering technology to ensure that they are not de-activated.[14] Modern self-initiated machines are electronic devices, controlled by a microprocessor. Like preliminary machines, they utilize an electrochemical fuel cell, however they usually do not display the results of a test for the subject, but do have a mechanism for communicating failed tests or refusals.[15]

Evidentiary machines are usually not portable, although some jurisdictions have deployed evidentiary machines in a custom vehicle referred to as a BAT[16] Mobile, or in a police cruiser powered by the police car's twelve-volt electrical system. Test results may be displayed so that they are visible to the police officer administering the

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[8] *Id.*

[9] *See id.* § 5.06.

[10] *Id.*

[11] *Id.*

[12] Thomas E. Workman, *Violating the "Alcohol Fee" Probation Requirement – Learning from the Galluccio Matter*, 12 MASS. B. ASS'N J. 4, 4-6 (2010).

[13] *Id.*

[14] *Id.*

[15] *Id.*

[16] An abbreviation for a "Breath Alcohol Testing" mobile unit; essentially a van that is outfitted with an appropriate internal configuration suited to testing drivers in a van that is outfitted to take the breath testing room and equipment to the roadblock.

test, but the test results are characteristically saved in the machine and printed at the time the test is administered. When properly maintained and in good working order, evidentiary machines are intended to produce measurements that are admissible at trial to prove the amount of alcohol present in a human subject at the time of the test.[17] Modern evidentiary breath test machines are electronic devices, controlled by a microprocessor and utilize complex software programs to interpret the readings. They utilize electrochemical fuel cells or infrared measurement of the breath sample in order to calculate the amount of ethanol contained in the subject's breath.[18]

Each type of machine will be introduced, including the scientific principles employed by each type of machine. The material provides a background for the attorney who represents clients accused of driving-related crimes that involve alcohol.

A. An Introduction to Preliminary Breath Test Machines

Preliminary Breath Testing machines (sometimes called "PBTs") are manufactured by many different companies, but all share the attributes of being handheld and relatively inexpensive.[19] They typically employ an electrochemical fuel cell in order to measure the amount of alcohol contained in the breath.[20] They utilize a disposable mouthpiece, usually made of clear plastic and individually wrapped, which should be changed for each subject.[21] PTBs are intended to be administered by a law enforcement officer or judicial officer (such as a probation officer), and usually measure a single exhalation of breath from the subject.[22]

Measurements from a PBT are often inadmissible in court because they are looked upon as lacking the requisite accuracy needed for evidence because they[23] often do not have the necessary laboratory calibration and certifications necessary to monitor the performance of the machines. In most states, results are intended to be for "screening purposes" only, and are sufficient to establish probable cause for an arrest or search warrant basis, but not a conviction.[24]

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[17] Workman, *supra* note 12.
[18] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL 401 (5th ed. 2008).
[19] *Id.*
[20] *Id.*
[21] *Id.*
[22] *Id.*
[23] 501 MASS. CODE REGS. 2.01 (LexisNexis 2012).
[24] *Id.*

The administration of a test with a PBT is typically performed at the time of initial contact between a law enforcement officer and the subject, such as, after the law enforcement officer stops the subject's motor vehicle, or when the law enforcement officer arrives at the scene of an accident.[25] While most states have a requirement that the subject be observed continuously for 15 to 20 minutes prior to supplying a breath sample, that protocol is rarely part of the PBT testing procedure.[26] The observation period is required to insure that the measurement of breath is not contaminated from something in the mouth or from a burp, belch, or regurgitation which might interfere with accurate results.[27]

B. An Introduction to Self-Initiated Breath Test Machines

There is a newer class of breath testing machines used without a law enforcement officer, described as "self-initiated" machines.[28] These machines are typically dedicated to a single person for an extended period of time, and include machines that are installed in automobiles (often referred to as ignition interlock devices, or IIDs),[29] as well as machines employed by probation departments to insure that probationers remain alcohol-free.[30]

Self-initiated machines are semi-permanently installed and often include anti-tampering technology that detects, then reports any attempts to disable or remove them. There is also technology unique to this class of machines that is dedicated to identifying the subject who is supplying a breath sample, either by recording a photographic image of the driver, or through the use of voice recognition that guarantees that the probationer, and not another person, exhales into the machine.[31]

Self-initiated machines record all tests conducted or refused. The tamper-resistant mechanisms electronically transmit results and

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[25] U.S. Department of Transportation, DWI Detection and Standardized Field Sobriety Testing Student Manual VII-8 (Feb. 2006).

[26] *Id.*

[27] TAYLOR & OBERMAN, *supra* note 7, at § 6.01[b].

[28] The term "self-initiated" is the author's reference to a class of devices that operate without the presence of a law-enforcement officer. From the perspective of the test subject, a request for a breath-sample is initiated without any visible interaction with a law enforcement officer.

[29] *Ignition Interlock Device*, WIKIPEDIA, http://en.wikipedia.org/wiki/Ignition_interlock_device (last visited Mar. 20, 2012).

[30] Workman, *supra* note 12.

[31] *Id.*

refusals to the organization that oversees the administration of the testing.[32] Machines used by probation departments tend to utilize a dedicated telephone line to transmit information in real time to the probation authorities. Ignition interlocks ordinarily store results and refusals in a dedicated memory, read when the system undergoes routine maintenance.[33]

Ignition interlock devices request a breath sample, either when a driver attempts to start the car (a time predictable by the subject), or at completely random times (requested by the IID at unpredictable intervals after the car has been started).[34] In the case of self-initiated devices installed in a probationer's home, random testing may be initiated via a telephone call by the probation department. The sample is requested without any concern for contaminants, there is no "observation period" to ensure a quality sample, and most of these machines employ an electrochemical fuel cell that measures only one portion of the breath sample.[35]

C. An Introduction to Evidentiary Breath Test Machines

Evidentiary Breath Test machines are manufactured by four manufacturers in the United States: CMI, Draeger, Intoximeters, and National Patent.[36] All of the machines employ infrared spectroscopy and measure in the 3–4 micron range and/or the 9–10 micron range, and some utilize an electrochemical fuel cell.[37]

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[32] *Id.*

[33] *Id.*

[34] *Draeger Interlock XT*, DRAEGER, http://www.draeger.com/AU/en/products/alcohol_drug_detection/interlock/cdi_interlock_xt.jsp (last visited Mar. 20, 2012).

[35] *Id.*

[36] Conforming Products List of Evidential Breath Measure Devices, 75 Fed. Reg. 47, 11624-25 (Mar. 11, 2010).

[37] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 237-47.

Manufacturer	**Model**	**Infrared 3 to 4 Micron**	**Infrared 9 to 10 Micron**	**Electro-chemical Fuel Cell**
CMI	Intox 5000	Yes, 3 or 5 filters	No	No
CMI	Intox 8000	Yes	Yes	No
Draeger	7110	No	Yes	Yes
Draeger	9510	No	Yes	Yes
Intoxi-meters	EC IR II	Yes	No	Yes
National Patent	Data-Master	Yes	No	No

Many states require that the law enforcement officer who conducts the test be authorized to administer a test under a permit, granted by the state agency, that manages the breath testing program.[38] These machines have incorporated a built-in printer that produces a report of the testing steps performed, as well as data about the subject, the officer administering the test, and the breath test itself.[39] They also employ a memory device that records information about the tests administered, as well as routine inspections and other events.[40] The analysis of this recorded information is accomplished with software applications dedicated to the collection and reporting of machine data.[41]

Evidentiary breath test machines are usually deployed in a permanent location, although some newer machines are equipped with a handle and a claim that they can be used in a police car.[42] They are invariably larger in size than their PBT cousins, with their weight

[38] *See, e.g.*, 501 MASS. CODE REGS. 2.01 (LexisNexis 2012), Fl Admin. Code 11-D8 (LexisNexis 2012).

[39] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 237-47.

[40] Thomas Workman, *The Intoximeter "IntoxNet" Database Teaches How the EC/IR II Really Works, and Sometimes Doesn't, in* UNDERSTANDING DUI SCIENTIFIC EVIDENCE, 432-58 (2011).

[41] *Id.*

[42] Conforming Products List of Evidential Breath Measure Devices, 75 Fed. Reg. 47, 11624-25 (Mar. 11, 2010).

measured in pounds instead of ounces.[43] It is common that the evidentiary testing protocol incorporates a certification step[44] which employs a simulator.[45] Since simulators can spill their liquids when moved, the equipment must be placed on a table or bench when used.[46] PBTs rarely (if ever), collect multiple breath samples before rendering a measurement. Thirty states require two breath samples[47] as a prerequisite to an evidentiary breath test.

II. HOW ELECTROCHEMICAL FUEL CELLS WORK

An electrochemical fuel cell generates an electrical current from the energy produced when a chemical reaction occurs.[48] During the testing procedure, the fuel cell draws in a sample of air that may contain the chemicals the device is intended to measure.[49] As these chemicals react, a new compound is formed, and each time a molecule is converted, electrons are released.[50] Electrons flow from the chemical reactions and create an electrical current which is measured by the fuel cell. "A fuel cell is an electrochemical device that converts chemical energy of reactants (both fuel and oxidant) directly into electrical energy."[51] Said another way, an electrochemical fuel cell generates an electrical current by facilitating a chemical reaction in the

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[43] *Intoxilyzer 5000*, AUSSCO, http://audiometry.com/Intoxilyzer http: //audiometry.com/Intoxilyzer%205000%20CMI.htm %205000%20CMI.htm (last visited Mar. 20, 2012) (For example, the Intoxilyzer 5000 weighs about 30 pounds).

[44] Not all states incorporate a simulator in their evidentiary breath test machines. For example, Georgia only requires that the machine be tested with a simulator in each calendar quarter, so that certification can take place 179 days apart, at the beginning of one quarter and the last day of the next quarter.

[45] *See* discussion on wet bath and dry gas simulators *infra* PartVI.G.

[46] The author has damaged several simulators that he has attempted to transport to hearings, with the mercury thermometers and glass jars shattering on more than one occasion, and the solutions spilling from the jars, unless emptied prior to transport.

[47] According to a survey conducted by Dr Wanda Marley in April of 2010, the states that require two breath samples for every test are: Alabama, Arizona, Arkansas, California, Colorado, Connecticut, Florida, Georgia, Idaho, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Nevada, New Hampshire, New Jersey, New Mexico, North Dakota, Oklahoma, Oregon, Pennsylvania, Rhode Island, Texas, Virginia, Washington, Wisconsin, and Wyoming. Dr Marley can be contacted through her website, http: //www .rockymedleg.com/.

[48] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 241.

[49] *Id.*

[50] *Id.*

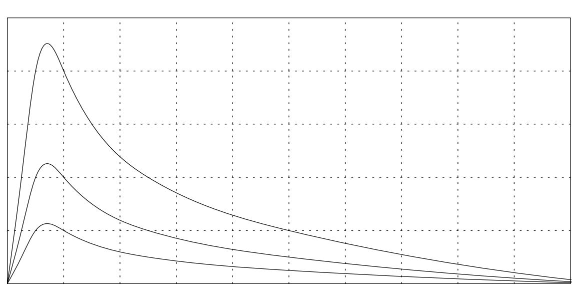
[51] XIANGUO LI, PRINCIPLES OF FUEL CELLS 5 (Taylor & Francis, 2006).

breath sample provided by the test subject. When the test is performed, the machine presents a small sample of the subject's breath to the fuel cell, where the ethanol is converted, releasing an electrical current.[52] The electrical current is measured in order to calculate how much ethanol is present.[53]

The "source fuel" in an electrochemical fuel cell is the chemical acted upon. In the case of a breath testing machine, that "fuel" is alcohol.[54] The "oxidant" is oxygen contained in the exhaled breath. The electrolyte is the chemical coating deposited on the plates in the fuel cell, and is supplied by the manufacturing process that creates the fuel cell. In the case of breath testing, the sample is drawn into the fuel cell and the chemical reaction is permitted to continue until there is no more fuel to be converted.

In a breath testing fuel cell, the fuel is ethanol, the oxidant is oxygen, and the byproduct of the chemical reactions is acetic acid.[55] The chemical reaction begins slowly, typically taking a few seconds to reach a maximum.[56] The reaction continues, but slows as the "fuel" is consumed.[57] Eventually, the amount of electrical current becomes negligible, and the machine converts the recorded electrical signal to a concentration.[58]

If the strength of the electrical current is graphed as a function of time, over approximately half a minute, the graph would look like the chart shown below, showing fuel cell electrical response as a function of time, for three concentrations:[59]



[52] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 241.
[53] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 241.
[54] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 241.
[55] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 241.
[56] Workman, *supra* note 40 at, 432-58.
[57] Workman, *supra* note 40 at, 432-58.
[58] Workman, *supra* note 40 at, 432-58.
[59] *Fuel Cell Technology Applied to Alcohol Breath Testing*, Figure 4, INTOXIMETERS, INC. http://www.intox.com/t-fuelcellwhitepaper.aspx (last visited Mar. 20, 2012).

Manufacturers of machines that utilize fuel cells advertise that the fuel cells are "specific to ethanol", however, this self-serving claim is impossible to prove.[60] Literature demonstrates that chemicals in the alcohol family, and possibly other types of chemicals as well, are processed as "fuel" in a fuel cell of this design, producing an electrical signal that would be processed by the machine.[61]

III. How Infrared Light is Used to Measure the Amount of Alcohol Present

All chemical molecules are made up of atoms.[62] Atoms are the building blocks of all compounds, and their properties are defined in the Periodic Table of Elements[63], reproduced below.

Group → / ↓ Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba		72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra		104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo
Lanthanides				57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
Actinides				89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Organic chemistry is the study of compounds that contain carbon.[64] Carbon is unique among elements, in that carbon has four covalent

[60] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 241 (Some in the breath testing manufacturing community seem to confuse the notion that because ethanol reacts in a fuel cell, it is scientifically incorrect to conclude that only ethanol produces a reaction. Other treatises use words to hedge the specificity, such as "Fuel cells are relatively specific for ethanol. Fuel Cells can potentially respond to other ethanols . . .").

[61] *Id.*

[62] MERRIAM-WEBSTER'S COLLEGIATE DICTIONARY 800 (11th ed. 2003) (Molecule: "the smallest particle of a substance that retains all the properties of the substance and is composed of one or more atoms.").

[63] *Periodic Table*, WIKIPEDIA, http://en.wikipedia.org/wiki/Periodic_table (last visited April 3, 2012).

bonds that are strong enough to form stable compounds, but weak enough to easily react to form new compounds.[65] Carbon can also bond to itself, forming long chains of extremely complex molecules, such as DNA, or simple compounds with a single carbon atom, such as Methane.[66] Organic chemicals include a family of compounds referred to as "alcohols", which includes grain alcohol or ethanol.[67]

Organic compounds are formed when atoms (including at least one carbon atom) join together, connected by electrical bonds.[68] These bonds are predictable in their strength, since they result from the electrical attraction of an electron to a positive charge in an atom's nucleus.[69] Since the force that joins the atoms together is known, and the mass of the atoms so connected can be calculated, the atoms are known to vibrate, moving away from one another and then closer to one another, as if they are connected by a spring.[70] The frequency at which the atoms vibrate can be calculated with Hooke's law.[71] When molecules are exposed to energy that matches the resonant frequency of the molecular bonds, that energy will be converted to kinetic energy expressed as movement.[72] The bonds are essentially excited, causing the atoms to move toward and then away from one another utilizing the introduced energy.

In the instance of breath testing machines, the energy supplied is infrared light, which happens to match the resonant frequency of organic molecules (and also inorganic molecules).[73] As the infrared light is absorbed, the molecular bonds of the molecules vibrate in response.[74] The amount of infrared light that is absorbed by the

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[64] MERRIAM-WEBSTER'S COLLEGIATE DICTIONARY 874 (11th ed. 2003) (Organic Chemistry: "a branch of chemistry that deals chiefly with hydrocarbons and their derivatives.").

[65] ADVANCED ORGANIC CHEMISTRY 1-4 (4th ed. 2000).

[66] JOHN MCMURRAY, FUNDAMENTALS OF ORGANIC CHEMISTRY 2-3 (John Holdcroft et al. eds., 5th ed. 2003).

[67] *Id.*

[68] *Id.* at 2.

[69] ADVANCED ORGANIC CHEMISTRY 14 (4th ed. 2000).

[70] , *Hooke's Law*, ENCYCLOPEDIA BRITTANICA, http://www.britannica.com /EBchecked/topic/271336/Hookes-law (last visited Mar. 20, 2012).

[71] *Id.*

[72] Known as the first law of Thermodynamics, or the law of the conservation of energy. G. Sarton et al., *The Discovery of the Law of Conservation of Energy*.13 U. Chi. Press 1, 18-49 (1929).

[73] SIEGFRIED WARTEWIG, IR AND RAMAN SPECTROSCOPY (Wilevy-VCH, 2003).

[74] *Id.*

molecules is measured, and used to infer which chemical structures are present.[75]

To make a measurement of how much infrared light is absorbed at a given frequency one must have: a light source that emits light at the frequency of interest, a chamber that can both contain the subject's breath, and through which a column of light can be directed, a mechanism to isolate the frequency of infrared light of interest, and a detector to measure how much light is transmitted through the subject's breath.[76] The detector is traditionally an electrical component, which is converted to a digital signal, and then processed by a microprocessor, under the control of software designed to make periodic measurements of the light absorbed at various frequencies.[77]

When multiple infrared frequencies are employed to evaluate the sample, a means to present different filters is required. This is accomplished through a mechanical disc that spins at a speed sufficient to intermittently present a filter in the path of the light before the light reaches the detector.[78]

IV. HOW ALCOHOL GETS INTO HUMAN BREATH

Chemical compounds, including ethanol, are present in an exhaled breath as either a result of evaporation or due to an exchange between a body fluid that contains ethanol and breath passing over that body fluid.[79] Evaporation can occur if a liquid that contains alcohol is in the airway or the mouth, and that alcohol evaporates from the liquid to air in the breath.[80] An exchange takes place in the lungs, in an area called the alveoli, or the alveolar sacs.[81] In the alveoli, there is an exchange between the blood flowing through the lungs and the air in the lungs.[82] Carbon dioxide is released into the breath to be exhaled, and oxygen is

[75] *Id.* at 29-30.
[76] TAYLOR & OBERMAN, *supra* note 7, at 634.
[77] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 229, 235.
[78] TAYLOR & OBERMAN, *supra* note 7, at 637.
[79] Michael P. Hlastala, *Paradigm Shift for the Alcohol Breath Test*, 55 J. FORENSIC SCI. 451, 451 (2010).
[80] *Id.* at 453.
[81] *Id.* at 451.
[82] *Id.*

absorbed by the blood vessels.[83] Other chemicals in the blood, if they are volatile[84], will evaporate from the blood and enter into the breath.

The government's theory of breath testing is that the exhaled air contains ethanol that comes from the deep lung air (air that originates from the deepest part of the lungs, specifically air from the alveoli).[85] In this theory, breath contains more ethanol at the end of expiration because the last air expired represents deep lung air, and this part of the sample is the best and truest measure of ethanol in a subject.[86]

Alcohol also enters the breath if the subject burps or belches, and this is the reason for the "observation period", which typically requires the operator to observe the subject for a continuous period of 15 to 20 minutes prior to the administration of a test.[87] During that observation period, the subject is also prohibited from drinking any beverage, which of course would disturb any subsequent measurements.[88]

As the air travels from the alveola in the lungs, through the bronchial tubes, the pharynx, and finally into the oral cavity, the exhaled breath interacts with the tissues, both depositing ethanol and accepting additional ethanol as it travels.[89] This phenomenon is well accepted by the medical community[90], but is conveniently ignored and condemned by the law enforcement community.[91] It is not difficult to understand that the breath does not travel magically from the lungs to the breath tube, and that in between, human tissues are exposed to the breath and can change it. The physiology is not consistent with the government's theory.

A. Understanding the Partition Ratio and Henry's Law

The exchange of alcohol and air in the lungs is said to take place, in the government's theory, in a "closed system, at a consistent temperature and pressure". The lungs in actuality are not a closed system, because they are not sealed off and the breath is not allowed to

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[83] *Id.*

[84] *See generally id.* at 452 (A compound is said to be volatile if it will evaporate from the solvent it is dissolved in. In the case of breath testing, the volatile compound is ethanol, and the solvent is the blood of the subject.).

[85] Lawrence E. Wines, *Developments in Breath-Testing Science and Evidential Breath Alcohol Testing*, *in* UNDERSTANDING DUI SCI. EVIDENCE 83, 87 (2011).

[86] Swartz, *supra* note 86, at 6.

[87] TAYLOR & OBERMAN, *supra* note 7, at 553.

[88] *See* TAYLOR & OBERMAN, *supra* note 7, at 556.

[89] *See* Hlastala, *supra* note 79, at 453-54.

[90] *See generally* CURRICULUM VITAE, http://www.mphlastala com (last visited Mar. 15, 2012) (Dr. Michael Hlastala is the foremost authority on this topic).

[91] Swartz, *supra* note 86, at 6.

remain in one place for an extended period of time (unless the subject is dead). Henry's Law states that in a closed system, at a given temperature and pressure, a solute[92] and a solvent will reach equilibrium.[93] Every combination of solvent and solute will reach an equilibrium at a different level of evaporation. As scientists measure the amount of the solute in the air and compare that to the amount in the solvent, this is expressed as a ratio of units in the air for every "n" units in the solvent.[94] For ethanol and water, that ratio is 2100:1, one part of ethanol in the air to ethanol dissolved in water. This ratio is the basis of the Henry's Law constant, also called the "Partition Ratio".[95]

Like so many formulas that are encountered, arriving at a number for the Henry's Law constant for water and ethanol is not an easy task. A list of Henry's Law constants is accessible through the internet[96]. Of particular importance is the range of measurements reported, which represent a range from 120 to 220, a range of almost double the low end value reported.[97] These measurements, which are supported by peer reviewed published articles reporting the numbers shown, represent the variability in measuring the ratio of ethanol in the air above a solution of dissolved ethanol in water.[98] Such measurements are made in laboratory conditions, after the air and liquid have had ample time to reach equilibrium. Variations have nothing to do with human physiology; these variations are all attributed to the science of measurement. The table for Henry's Law constants, as they relate to ethanol and water, are reproduced from Rolf Sander's work[99] here:

[92] *See* Hlastala, *supra* note 79, at 452 (A "solute" is a compound that is volatile, that is it will evaporate, and which is currently dissolved in a given solvent. In breath testing, the solute is ethanol, and the solvent is blood.).

[93] Swartz, *supra* note 86, at 6.

[94] TAYLOR & OBERMAN, *supra* note 7, at 515-21.

[95] TAYLOR & OBERMAN, *supra* note 7, at 516.

[96] Rolf Sander, *Compilation of Henry's Law Constants for Inorganic and Organic Species of Potential Importance in Environmental Chemistry*, MAX-PLANCK INST. VERSION 3 (April 1999), http://www.rolf-sander.net/henry/henry.pdf .

[97] *Id.*

[98] *Id.*

[99] *Id.*

substance	$\frac{k_H^{\ominus}}{[M/atm]}$	$\frac{-d \ln k_H}{d(1/T)}$ [K]	reference
ethanol	1.9×10^2		*Butler et al.* [1935]
C_2H_5OH	2.2×10^2		*Burnett* [1963]
	1.6×10^2		*Timmermans* [1960]
	2.0×10^2		*Gaffney and Senum* [1984]
	1.9×10^2	6600	*Snider and Dawson* [1985]
	2.3×10^2		*Rohrschneider* [1973]
	1.2×10^2		*Yaws and Yang* [1992]
	1.5×10^2	6400	*Schaffer and Daubert* [1969]
	2.0×10^2		*Meylan and Howard* [1991]

A recent Champion article on partition ratios, authored by Dr. Dom LaBianca[100], presents the science of breath testing and partition ratios. It is a must read for anyone exploring this area of the science of breath testing.

B. Beer Lambert's Law

The amount of infrared light absorbed by compounds present in the chamber is predictable if the length of the path of light is known, and the concentration of the compound that is absorbing the infrared light is known. This relationship is expressed in Beer Lambert's Law. [101] To be applied, the following five conditions must be met[102]:

1. The absorbers must act independently of each other;[103]
2. The absorbing medium must be homogeneously distributed in the interaction volume and must not scatter the radiation[104];
3. The incident radiation must consist of parallel rays, each traversing the same length in the absorbing medium[105];
4. The incident radiation should preferably be monochromatic, or have at least a width that is more narrow than the absorbing transition[106]; and

[100] Dominick A. Labianca, *Flawed Conclusions Based on the Blood/Breath Ratio: A Critical Commentary*, THE CHAMPION, June, 2010 at 58, *available at* http://www.nacdl.org/champion.aspx.

[101] *See* MARGARETA AVRAM, INFRARED SPECTROSCOPY 108-09 (Ludmila Birladeanu trans., 1966) (1972).

[102] *Id.*

[103] *Id.*

[104] *Id.*

[105] *Id.*

[106] *Id.*

5. The incident flux [light passing through the sample] must not influence the atoms or molecules; it should only act as a non-invasive probe of the species under study.

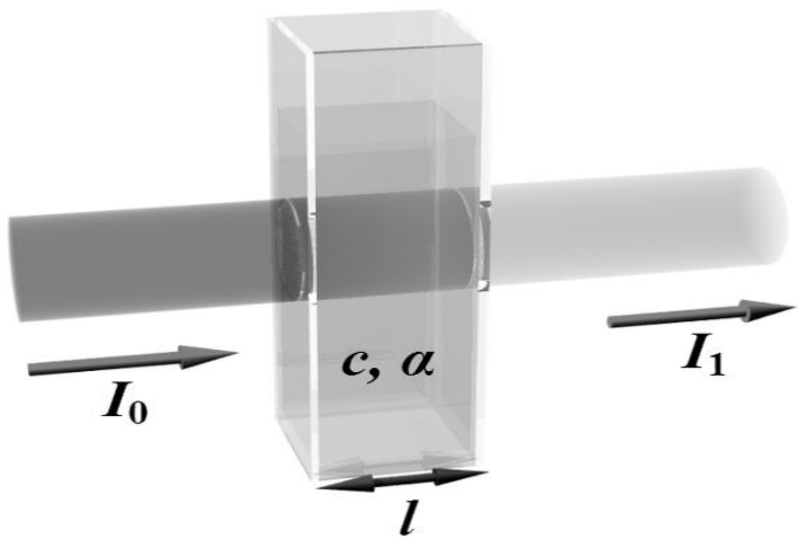

Diagram of Beer–Lambert absorption of a beam of light as it travels through a cuvette of width ℓ.[107]

C. Scientific Foundations for Infrared Spectroscopy

The science of infrared spectroscopy has well documented principles which must be followed in order to properly use the technology.[108] These requirements are consistently taught in the treatises, and are as follows:[109]

The spectrum must be adequately resolved and of adequate intensity.

The spectrum should be that of a reasonably pure compound.

The spectrophotometer should be calibrated so that the bands are observed at their proper frequencies or wavelengths.

The first requirement mandates that the full spectrum of the compound of interest must be collected and evaluated. Breath testing

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107 *File: Beer Lambert.png*, WIKIPEDIA, http://en.wikipedia.org/wiki/File:Beer_lambert.png (last visited Jan. 29, 2006) (released by creator into public domain).

108 Thomas E. Workman, *A Primer for Infrared Spectroscopy: What the Trial Attorney Must Know*, NACDL CONFERENCE ON DEFENDING DUI CASES, (NACDL and NCDD, Las Vegas, Nev.), Aug. 14, 2008.

109 ROBERT SILVERSTEIN ET AL., SPECTROMETRIC IDENTIFICATION OF ORGANIC COMPOUNDS 80 (7th ed. 2005).

machines assume that the compound reacting in the machine is ethanol, ignoring this requirement.[110] Scientifically, one cannot conclude that the compound under test is ethanol, and then use this assumption to prove that the compound is in fact ethanol.[111] This is, in essence, how all breath testing machines operate. These machines evaluate at a few points on the spectrum, and then assume that the chemical is ethanol. Without knowing that you have identified all of the infrared features of the chemical, a qualitative evaluation is not possible.

The second requirement mandates that the compound being measured must be pure so measurements of how much of a compound is present are correct.[112] Without a pure sample, you cannot know if absorbed light is from ethanol, or from another chemical that coincidently absorbs light at the same frequency.[113] Human breath is known to contain hundreds of chemical compounds.[114] The frequencies employed by breath test devices are not unique to ethanol, or even to all alcohols.

The third requirement mandates that the wavelengths of the spectroscope must be periodically calibrated to ensure that the various filter values have not drifted or changed.[115] Breath test manufacturers do not promulgate processes that would verify the correct operation of their machines, they simply ignore this foundation of the science.

D. There is a Computer Inside the Machine

All modern machines that measure human breath are controlled by a microprocessor and software. Together, the microprocessor and software manage and automate the steps that the machine follows when various functions are performed.[116] The software that controls the execution of the tests define the test process, and mistakes in the software can cause problems with the measurements made by the machine. Manufacturers, and jurisdictions that use their machines, have gone to great lengths to appear to be cooperative in making the

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[110] TAYLOR & OBERMAN, *supra* note 7, at 533-39.
[111] TAYLOR & OBERMAN, *supra* note 7, at 533-39.
[112] SILVERSTEIN ET AL., *supra* note 109, at 80.
[113] SILVERSTEIN ET AL., *supra* note 109, at 80.
[114] TAYLOR & OBERMAN, *supra* note 7, at 534-35.
[115] SILVERSTEIN ET AL., *supra* note 109, at 80.
[116] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 229.

software available for inspection, but in fact they conceal information and interfere with truly understanding their software.[117]

The use of software to create an "autopilot" operation of the machine eliminates some operator errors, but injects programming problems and interferes with detection by officers of problems that used to be observable. The common claim is that the machine must have worked correctly or it would have presented an error message. Such claims are unrealistic and wishful thinking.

When software is evaluated, computer scientists study the structure and content of source code. These scientists understand the languages that instruct the machines and should have an understanding of the breath testing process. Many times, the greatest challenge is convincing the court that the source code is relevant and material. Further material on the topic is available in published treatises on DUI Defense[118], as well as a Primer on Source Code for the Trial Court Judge.[119]

E. What the Machines Look for in a Breath Sample

The requirements for a breath sample differ greatly between the classes of machines, depending on what measurement technology is present in the machine.[120] Machines that employ fuel cells are only able to measure a single part of the breath, and therefore are not able to evaluate more than the single portion that is measured.[121] Machines that employ an infrared detector are able to compare different parts of the supplied breath, and can assess the stability of the concentration of alcohol more accurately.

PBT machines and those which are self-initiated tend to use fuel cells to measure the breath. They often measure whatever breath is supplied by the subject, without regard to the volume or pressure of the supplied breath.[122] Evidentiary machines are often configured to specifications that differ from state to state with respect to the minimum breath volume required, the minimum duration of the

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[117] *See* Tim Black, Intoxilyzer 5000EN Source Code Report, (2010), http://www.meaneypatrin.com/Black2.pdf.

[118] TAYLOR & OBERMAN, DRUNK DRIVING DEFENSE (7th ed. 2010).

[119] Thomas E. Workman Jr., *Source Code in Machines Used to Test Human Breath for Alcohol: A Primer for the Trial Court Judge*, (March 30, 2009), *available at* http://www.computers-forensic-expert.com/Judges/JudgePrimer2009.pdf .

[120] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, Table 7-1, at 235.

[121] TAYLOR & OBERMAN, *supra* note 7, at 556-57.

[122] TAYLOR & OBERMAN, *supra* note 7, at 420-21.

sample, and the minimum pressure that must be maintained throughout the sample (the minimum flow).[123] Some of these parameters are influenced by manufacturer recommendations, such as breath volume[124], while NHTSA[125] has established some minimum requirements that influence both manufacturers and states.

Evidentiary machines employ infrared technology which provides the opportunity to evaluate the alcohol content of the breath as it is submitted.[126] This permits the evaluation of the sample at different phases, and machines take advantage of this opportunity to insure that the alcohol content has stabilized prior to making a measurement.

F. The "Slope Detector"

The slope detector is a feature of all evidentiary machines, and is implemented as a software routine.[127] It is sometimes called a "Mouth alcohol detector", and is often tested by having an inspector swish high purity ethanol in their mouth, and then blow into the machine.[128]

When a breath is continuously monitored and measured, the alcohol content can be displayed graphically. The alcohol content can be measured on the y-axis (up and down) against time, displayed on the x-axis (left to right). The "slope" of the connected measurements is the numeric assessment of the manner in which the line between two points goes up or down. If the line goes up, then the slope is positive, if it goes down, the slope is negative.

The slope detector assumes that the slope of the alcohol content as a function of time should always be positive.[129] If it is negative for a specified period of time, and if the magnitude of the negative slope exceeds thresholds set by the software, then the breath sample fails the slope detector test. The error message produced may be an "invalid

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[123] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 241-46.

[124] Draeger machines in New Jersey require 1.5 Liters of breath for all men and women younger than 60, Massachusetts Draeger machines require 1.5 Liters of breath for all subjects, and Alabama Draeger machines require a volume of 1.3 Liters. Intoxilyzer machines from CMI require 1.1 Liters of breath in most jurisdictions.

[125] NHTSA, or the National Highway Traffic Safety Administration, has in the past required a minimum breath sample of 1.1 Liters of breath in order to qualify for inclusion on the conforming products list.

[126] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 403.

[127] TAYLOR & OBERMAN, *supra* note 7, at 561-62.

[128] TAYLOR & OBERMAN, *supra* note 7, at 561-62.

[129] TAYLOR & OBERMAN, *supra* note 7, at 562.

sample" or a number of other messages, as the error messages are routinely customized from state to state.[130]

The slope detector is often tested by an inspector (who has no ethanol in their system). The inspector coats the mouth tissues with pure ethanol, spits out the liquid, and then blows into the machine being evaluated.[131] As the ethanol in the moist tissues of the mouth evaporates, it quickly declines in concentration, and if the breath is being measured for ethanol, the amount of ethanol declines.[132] This is precisely what the slope detector is designed to detect.

If a subject has ethanol in their system, and if the increase in the amount of ethanol as it is exhausted from the body exceeds the decrease from ethanol that is not coming from the lungs, then the slope detector will not work. Studies published in the prosecutorial oriented IACT newsletter conclude that slope detectors fail about as often as they work.[133]

G. The Observation Period

Having acknowledged that their slope detector does not work, many jurisdictions have required that the subject be continuously observed for a period of 15 or 20 minutes, in order to assure that there is no foreign material in the subject's mouth.[134] If the observer can detect all burps, belches and regurgitations – then theoretically there can be no foreign alcohol in the mouth.

Medical doctors cannot detect GERD (gastro-esophageal reflux disease) by observing a patient so it is fair to conclude that a police officer cannot detect GERD. If a GERD event occurs, then stomach contents, which contain ethanol, will be exposed to the exhaled air and corrupt the reading.

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[130] *Intoxilyzer 8000: Reference Guide 8*, FLORIDA DEPARTMENT OF LAW ENFORCEMENT ALCOHOL TESTING PROGRAM (Feb. 2006), *available at* http: //www .fdle.state.fl.us/Content/getdoc/fbb9142a-1702-4fc8-8569-3a465e858520/I8000ReferenceGuideFeb2006-1-.aspx.

[131] TAYLOR & OBERMAN, *supra* note 7, at 562.

[132] TAYLOR & OBERMAN, *supra* note 7, at 562.

[133] TAYLOR & OBERMAN, *supra* note 7, at 435.

[134] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 232.

V. HOW IS AN INTERFERENT DETECTED?

Fuel cell machines cannot detect interferents.[135] To be an interferent, a compound must be measured by some part of the measurement system. Fuel cells simply do not respond to compounds that do not react, but this does not mean that fuel cells only react to ethanol. In fact, they do not.[136] They react to at least all members of the alcohol family which includes thousands of compounds.[137] The burden of showing correct operation lies with the government and since there are no studies to show that other compounds do not register on the fuel cell, the machines cannot qualify as reliable to report alcohol.

Infrared machine that read multiple frequencies of infrared light can sometimes compare the absorption at the various frequencies, and compare the absorption profile to other compounds that the machine has been calibrated to detect.[138] For example, an Intoxilyzer 5000 is calibrated to recognize acetone by presenting acetone to the machine and informing the machine that the compound presented is acetone.[139] The machine can then measure how much infrared light is absorbed at all frequencies measured, and can recognize acetone if it is presented to the machine again.[140] From a scientific perspective, the ability to recognize an interfering compound (such as acetone) does not qualify a machine to recognize all interfering compounds. The latter claim is often advanced by manufacturers.[141]

A. Radio Frequency Interference

Modern machines utilize electronic circuits to: automate the measurement process, to generate the light needed to shine through the chambers, to control and measure the flow of breath, to detect how much light reaches the detectors in the machines, to amplify the electrical signal, and to accept inputs from the keyboard and print the

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[135] *See* A. Wayne Jones &Lars Andersson *What Interfering Substances Are There in Breath of Apprehended Drivers? Experience Using a 5-Filter Infrared Analyzer (the Evidenzer)*, INT'L CONF. ON ALCOHOL AND DRUG TRAFFIC SAFETY, (August 2007 Symposium).

[136] Draeger 7110 MK III-C User Manual-Technical, Part #MPTECHMAN71-NJv1.2 16 (2008).

[137] TAYLOR & OBERMAN, *supra* note 7, at 625-26.

[138] *See generally* TAYLOR & OBERMAN, *supra* note 7, at 622.

[139] TAYLOR & OBERMAN, *supra* note 7, at 623.

[140] TAYLOR & OBERMAN, *supra* note 7, at 623.

[141] Manufacturers of evidentiary machines claim that their machines can distinguish alcohol from other substances.

results.[142] All of these electrical processes require an environment that is free of electromagnetic fields, in order to accurately and reliably measure and report the alcohol content in the subject's breath.[143] If interference is present when an electrical component is actively engaged in one of the functions necessary to a breath test, then a malfunction of that electrical component can cause an error in the machine's performance.[144]

Interference can come from a radio, a cell phone, or any electronic device that is powered on. The location of a breath test machine should be selected so that it is free of interference from electrical devices and transmitting towers. There should be procedures in place to ensure that police radios and cell phones are powered off when subjects and officers enter a testing area. These safeguards are seldom in place, and when they exist, they are rarely observed.

Some machines are equipped with a circuit that is intended to detect radio frequency interference.[145] Some jurisdictions have removed the circuit, by ordering equipment without the detectors.[146] The detectors are designed to detect electronic signals in one of the police radio bands.[147] The RFI detectors incorporate an antenna, which normally is located in the breath hose. The antenna detects only a narrow band of frequencies, and is blind to frequencies for which the antenna is not tuned.[148] To be effective, the RFI circuits must be calibrated to detect signals that are slightly above an RFI free environment.[149] Law enforcement facilities often do not provide the ability to perform this kind of calibration, largely because police departments have a number of transmitting radios within the building. For example, the photo that follows is of a Massachusetts police department, where breath testing is routinely performed.

[142] TAYLOR & OBERMAN, *supra* note 7, at 588-89.
[143] TAYLOR & OBERMAN, *supra* note 7, at 588-89.
[144] TAYLOR & OBERMAN, *supra* note 7, at 588-89.
[145] TAYLOR & OBERMAN, *supra* note 7, at 625-26.
[146] TAYLOR & OBERMAN, *supra* note 7, at 507.
[147] *See* TAYLOR & OBERMAN, *supra* note 7, at 622.
[148] TAYLOR & OBERMAN, *supra* note 7, at 623.
[149] TAYLOR & OBERMAN, *supra* note 7, at 588-89.

B. Power Fluctuations Matter

Electrical circuits can only operate effectively when they are supplied with electrical energy that is properly regulated.[150] Regulated power is required so that the microprocessor can function, and so that the measurement components can properly do their job.

Battery-operated equipment requires fresh batteries to permit machines to operate correctly.[151] Extracting power from a vehicle's battery or alternator is not an effective method of obtaining regulated power. An automobile regulator does not supply quality power that is suitable for operating a breath test machine.[152]

Electricity obtained from an outlet in the testing room should be conditioned by a power conditioner. A power conditioner is a device designed to deliver clean power to computers or other devices that

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[150] DRANETZ-BMI, THE DRANETZ-BMI FIELD HANDBOOK FOR POWER QUALITY ANALYSIS 17 (1998).

[151] The author has observed that procedures vary from department to department, with disposable batteries used and changed on a set schedule in some departments, and rechargeable batteries used in other departments.

[152] The author has measured the output of an automobile battery with an oscilloscope, and found that significant variations in the power level occur, which if used to power sensitive electronic equipment, could either damage the equipment or cause it to malfunction.

require clean power.[153] Surge protectors, which cost on the order of $10 to $40, are not sufficient to condition power. A surge protector does not regulate power, it simply removes large fluctuations that would otherwise damage the equipment.[154]

Some geographical areas are more vulnerable to problems caused by the transmission of power from generation to consumption. These areas feature long distances, severe weather, or both. The power grid provides a greater reliability of power availability, but presents problems with power quality if neighboring areas inject power problems from lightening, or from large power consuming devices.

VI. CALIBRATION AND CERTIFICATION

The terms calibration and certification are often used interchangeably in the breath testing community, but they have very different meanings. A measuring machine is certified when it is presented with a known stimulus, allowed to measure and report the quantity of that sample, and the result agrees with the expected measurement, within some degree of tolerance.[155] For a breath-test machine, certification measures a known concentration of ethanol, and the certification is said to succeed when the value measured, agrees to the expected value within a preset tolerance.[156] The concentration of the stimulus provided and the tolerance of allowed error vary from state to state.

Calibration is the process of presenting a known sample to a machine, and instructing the machine to reset itself so that if the identical stimulus is observed in the future, the machine will report the measurement that is communicated as part of the calibration.[157] A calibration changes the way the machine operates for all future uses, whereas a certification does not.

Certification is often incorporated within the protocol for a subject breath test, and when incorporated, the subject test is said to be invalid when the certification fails to measure within the permitted error range.[158] In Massachusetts, for example, a .15 concentration of ethanol must be measured in the range of .140 up to but not including .170, or

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153 DRANETZ-BMI, *supra* note 150, at 75-84.
154 DRANETZ-BMI, *supra* note 150, at 75.
155 GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 232.
156 *Id.*
157 *Id.* at 231.
158 *See* 501 MASS. CODE REGS. 2.11 (LexisNexis 2012).

a range of .03 error. This specifies a 20% range, or an acceptable error of 10%.[159]

A. Breath Testing Measurement Assumptions

For testing devices to function, there must be scientific principles that translate the measurements made by the machine into how much ethanol is present in the sample. If the machines respond in a linear manner, that is to say, when the machines measure a number twice as large, then there is twice as much ethanol present, then the computation of ethanol is greatly simplified.[160]

The Beer-Lambert law states that in an infrared machine, the amount of light absorbed in a chamber of the subject's breath is directly proportional to the concentration of ethanol in the breath, assuming that the length of the path of light is fixed.[161] The amount of infrared light that reaches the detector of the machine is linear, but is the electrical energy generated by the sensor directly proportional to the amount of light that reaches the sensor? Fortunately for the theory of breath testing, the answer is yes.

The Beer-Lambert law does not apply in a fuel cell machine, since the mechanism of measurement is an electro-chemical fuel cell.[162] The amount of electrical current generated by the fuel cell is proportional to the number of molecules present in the fuel cell, and if the volume of breath that is sampled is managed so that the sample size is consistent from sample to sample, then the electrical signal will be proportional to the amount of ethanol.[163]

Given that the amount of electricity that is generated in response to a sample containing ethanol behaves in a linear manner, depending upon the concentration of ethanol in the sample, machines can be either certified or calibrated by measuring representative values in the range of acceptable measurements for the machine. The assumption that the machine can properly compute results for values that lie between the values tested, is a valid scientific principle. This assumes that the points measured are properly quantified and measured.

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159 *Id.*

160 TAYLOR & OBERMAN, *supra* note 7, at 573.

161 *See supra* Part IV.B.

162 *See supra* Part IV.B.

163 GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 241.

B. Types of Calibrations—Single Point

A single point calibration is performed when a machine is presented a single known stimulus, and the reading from the machine is set to the known expected value.[164] We perform this kind of single point calibration when we set a bathroom scale to zero, when there is nothing on the surface of the scale.

It is believed that many of the breath-test machines perform a single point calibration for their zero point, after a measurement is made of an "Air Blank".[165] Most machines "mask" the reading of an air blank, basically deleting the amount of alcohol that is measured for an air blank that is less than a preset threshold, usually .005. Thus a reading of .005 will be reported as a .000 for the air blank[166], and in some cases, the machine may reduce subsequent measurements by the true reading for the air blank[167].

The traditional single point calibration utilizes a standard solution of ethanol and water, and communicates to the machine the value of the standard while presenting the standard to the machine for evaluation.[168] The machine accepts the standard that is presented, and resets its internal computational constants so that if the machine sees this concentration of ethanol in the future, it will report exactly the value that was communicated to it. The calibration changes the manner in which the machine will measure for all uses of the machine after the process has been performed.

A strategy of setting the zero point is effective only if the machine responds with correct measurements inflated by or reduced by an amount that is referred to as calibration drift. Traditional bathroom

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[164] NATIONAL INSTITUTE OF SCIENCE AND TECHNOLOGY, *What is artifact (single-point) calibration?*, *in* ENGINEERING STATISTICS HANDBOOK, *available at* http://www.itl.nist.gov/div898/handbook/mpc/section3/mpc32.htm.

[165] TAYLOR & OBERMAN, *supra* note 7, at 581.

[166] TAYLOR & OBERMAN, *supra* note 7, at 580-84.

[167] TAYLOR & OBERMAN, *supra* note 7, at 580-84 (In the example of an air blank measuring .005, a subsequent reading of .085 would report a value of .080 after subtracting the amount that was measured in error. This adjustment assumes that the error on the air blank is consistently present on all subsequent measurements, a phenomenon that is not likely.).

[168] ALCO SENSOR III OPERATIONS MANUAL, http: //www.bobkeeferlaw.com /library/Alco_Sensor_III_Breath_Testing_Manual.pdf ("The fuel cell sensor is specific to alcohol and it is a linear sensing device giving a simple one- point calibration ensuring stable calibration across the full range of its sensing capabilities.).

scales behave in this fashion, so that it is an effective strategy to adjust the scale to read "0" when nothing is placed on the scale.

C. Types of Calibration—Multiple Point

A multiple point calibration teaches a machine how to respond to different concentrations of ethanol, and assumes that the points selected respond in a linear fashion to the measured substance.[169] Since we cannot calibrate at every possible concentration, the machine must be able to determine that the concentrations supplied, have a proportional relationship when measured. Thus, the machine will be able to extrapolate readings between two measured points, with some confidence that the measured value is proportional to the distance from the closest two known and measured standards.

For example, if a machine is calibrated with standards of .20 and .30, and the subject under test, exhibits ethanol at a concentration of .25, then we should see the machine measure a value halfway between the .20 and .30 standards. If the machine measures one tenth of the way between the .20 and the .30, the machine will report a .21 result.

It is not necessary to include a measurement point that is larger than any expected measurement, as well as a point smaller than any expected measurement—yet such a practice is considered a good idea.[170] Most multi-point certifications do not incorporate a measurement at the high end of the range of accepted values.[171] Most multi-point certification schemes do incorporate a standard that is ethanol free, or the lowest possible measurement value.[172]

To confirm that the machine is responding in a linear fashion to the standards measured, at least three standard values must be

[169] T.L. Martin, *An Evolution of the Intoxilyzer® 8000C Evidential Breath Alcohol Analyzer*, 44 Can. Soc. Forensic Sci. J.1, 22-30, *available at* http: //www .csfs.ca/uploads/CSFSJApr%20Article3%20FINAL.pdf.

[170] Referred to as "Boundary Value Analysis.", *see* Software Testing Glossary, APTEST, http://www.aptest.com/glossary.html#bvatesting (last visited May 31, 2011, 16:15:24 PDT) ("Boundary Value Analysis: In boundary value analysis, test cases are generated using the extremes of the input domain, e.g. maximum, minimum, just inside/outside boundaries, typical values, and error values.").

[171] The "high end" for an Intoxilyzer is the value that does not exceed a "Range Exceeded" error message, normally a result that exceeds a .50 reading. This would indicate that a standard of .50 or something just below that upper range be incorporated into a multiple standard calibration.

[172] The Intoxilyzer 5000 calibration utilizes several different concentrations of ethanol, including a zero concentration that is plain deionized water.

measured.[173] The measurement of the linearity of response, considered crucial if the mechanism of extrapolation of measurement of values between the standards values recorded, depends on the linear response of the machine to ethanol values.[174]

Since the two mechanisms for measuring the ethanol content in evidentiary machines produce a linear response to the ethanol content[175], the machines are able to convert measurements made of standard levels and extrapolate a result.

D. Types of Calibrations—Interferent

A machine that uses an electro chemical fuel cell to measure the ethanol does not benefit from a calibration step that presents an interferent.[176] Such machines either respond to an interferent in a way that mimics ethanol, or do not respond to ethanol and thus provide no meaningful information if presented during calibration.

A machine that employs infrared measurement must be taught how to detect an interferent, such as toluene or acetone.[177] These machines learn how to detect specific interferents by observing the interferents as part of the calibration process. When an interferent is presented to the machine, the various infrared light frequencies are measured and the responses are contrasted with those of ethanol.[178] By observing the different responses to the infrared frequencies that are measured, the machine "learns" how to detect specific interferents.

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[173] *See* REFERENCE MANUAL ON SCIENTIFIC EVIDENCE, FEDERAL JUDICIAL CENTER 133-42 (2d. ed. 2000).

[174] *Id.*

[175] The Beer Lambert law insures this for infrared machines, and the measurement of the chemical reaction in an electro chemical fuel cell is proportion to the ethanol content.

[176] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 241-46 (note the absence of any discussion of interferents for any of the fuel cell devices. This is because the fuel cells are not able to detect and measure compounds traditionally thought of as interferents).

[177] The Florida data for all Inspections can be found on the FDLE website, http://www.fdle.state.fl.us/Content/Alcohol-Testing-Program/Menu/Public-Records/Electronic-Data.aspx, and then click on any Inspection Test Data link to view the tests of Acetone and Ethanol presented to the machines.

[178] MASS. GEN. LAWS. ch. 9 § 24 ("Section 24. (1) (a) (1) Whoever, . . .operates a motor vehicle with a percentage, by weight, of alcohol in their blood of eight one-hundredths or greater.") http://www.malegislature.gov/Laws/GeneralLaws/PartI/TitleXIV/Chapter90/Section24 (Massachusetts statutes used to prohibit "intoxicating liquor" exclusively.).

The growing trend in breath testing is to consider any compound in the alcohol family as a compound of interest.[179] The chemical family of compounds that are alcohol includes thousands of compounds, and are measured and reported to varying degrees by both infrared and by electrochemical detection methods.[180] These members of the alcohol family are not considered to be interferents in many jurisdictions, and are not part of the protocol used to teach machines how to recognize interferents.[181]

E. Multiple Measurements with Multiple Concentrations

Most machines employ multiple measurements because machines that test simulated human breath produce results that vary when multiple measurements are made of the same stimulus.[182] When human breath is measured, many jurisdictions require just a single measurement of a human breath, others require two measurements that agree within a specified tolerance.[183] When calibrating or certifying a calibration, the author knows of no jurisdiction that requires fewer than 4 measurements of each concentration.

Calibrations, and certifications of calibration are performed in a very similar fashion in many jurisdictions.[184] Both procedures tend to require the same number of measurements of each concentration of ethanol presented to the machine.[185] Both procedures require that the answers relate to an arithmetic average of the measurements made, and that the variation of the measured values shall not exceed some fixed percentage.[186] When the measurements fail to behave in a predictable manner, because the variation is too large, the certification or calibration is not valid.

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[179] The Florida data for all Inspections can be found on the FDLE website, http://www.fdle.state.fl.us/Content/Alcohol-Testing-Program/Menu/Public-Records/Electronic-Data.aspx, and then click on any Inspection Test Data link to view the tests of Acetone and Ethanol presented to the machines.

[180] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 241.

[181] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 241.

[182] A study by the author revealed that in Florida, presenting the identical stimulus to the machine from a tank of gas dosed with ethanol resulted in a different measured value the second time in 62.6% of the 183,424 subject tests evaluated between 2006 and 2011.

[183] Study of Dr Marley, *supra* note 47.

[184] The author has in fact found many instances where the two terms are used interchangeably, when they in fact refer to different procedures.

[185] *See* Florida Form 39, FDLE, http://www.fdle.state.fl.us/Content/Alcohol-Testing-Program/Public-Records-(1)/Forms.aspx.

[186] *Id.*

In calibration logs evaluated for the CMI Intoxilyzer 5000 from several jurisdictions,[187] the machines discard the first measured value for each concentration level. In reviewing the discarded measurements, in each instance the variation of these measurements from the average of the other measurements demonstrated an unexplained amount of error.[188] For a human sample, the first and only provided sample is measured, which appears to be the one which is least reliable when the machine has an opportunity to select one of several identical samples.[189]

For measurements of pure water in a wet bath simulator (representing zero ethanol), the results often show a negative amount of ethanol present.[190] For infrared machines, a negative measurement results from the machine detecting more light reaching the sensor when the cylinder contains the sample of air with no ethanol from a simulator, when compared to an "air blank".[191] While it is impossible for the light to be amplified by the air from a simulator, which would result in the calculation of a negative ethanol content, it is possible that the machine error results in a negative measurement of ethanol.

The optical bench of the breath machine is configured to provide linear results over the expected range of results. The greater the variation of the response by the machine over the expected range, the more accurate the machine's results.[192] While science would dictate that no result should be reported that is above the highest value that

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[187] From Texas courtesy of Troy McKinney (attorney McKinney can be contacted through his firm's website, http://www.crimedefensehouston.com/) and from Virginia courtesy of Bob Keefer (attorney Keefer can be contacted through his firm's website, http://www.bobkeeferlaw.com/).

[188] Observations of the author.

[189] A wet bath simulator is often used to supply multiple identical samples to a machine, so that the machine can either evaluate a prior calibration, or so that it can calibrate the machine.

[190] Observations of the author.

[191] If machines report the true measurement of the sampled, and there is a margin of error that causes the reported result to vary from the true concentration by either a positive or negative amount, then we should see some readings that report a negative concentration. The lack of such readings indicates that the machines are manipulating these readings, and likely reporting them as zero. It is a common practice to report measurements for air blanks that are less than a .007 as a .000 result.

[192] The greater the signal variation, the greater the signal to noise ratio, which is an electronic device phenomenon that limits the accuracy of all electronic machines. *See* Signal to Noise Ratio, SNR, RADIO-ELECTRONICS.COM, http://www.radio-electronics.com/info/rf-technology-design/rf-noise-sensitivity/receiver-signal-to-noise-ratio.php (last visited April 29, 2012).

has been measured, it is common for machines to report values that are higher than the greatest values tested on the machine during a certification of calibration, or under a calibration procedure.[193] The machines measure the amount of infrared light that is absorbed, so the electrical response is the maximum value when no ethanol is present, and is the smallest when the maximum amount of ethanol that can be recognized is present.

For a multiple point calibration, the electrical response for each calibration standard is usually averaged, and the multiple electrical measurements are tested to insure that the electrical results are linearly related to the concentrations.[194] This is done with a calculation of the R Squared regression of the data points.[195]

If calibrations and certifications of calibrations are being monitored to insure that they are being performed correctly, then some of the procedures should be identified as incorrectly performed, and should be re-done. If you ask the government for the production of documentation relating to failures of calibration or certification of calibration, the answer may be given that none exist. If so, it is highly probable that the government is not checking the results, and is unaware of failed procedures.

F. Using the Calibrated Measurements to Compute BrAC

Most breath-test machines utilize one of the measured infrared light frequency responses as the electronic signal that computes the amount of ethanol in the sample.[196] The companies often refer to this as the "ethanol channel", or the "Ethanol frequency" for measurement.[197] This does not mean that ethanol only absorbs infrared light at this selected frequency, but rather, that after the machine is done examining the measurements from all of the frequencies provided, the machine will simply compute the amount of ethanol using a simple algebraic equation.

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[193] Referred to as "Boundary Value Analysis."*See* Software Testing Glossary, APTEST http://www.aptest.com/glossary.html#bvatesting (last visited May 31, 2011, 16:15:24 PDT) ("Boundary Value Analysis: In boundary value analysis, test cases are generated using the extremes of the input domain, e.g. maximum, minimum, just inside/outside boundaries, typical values, and error values.").

[194] A calibration of an Intoxilyzer 5000 operates in this fashion.

[195] The log produced by an Intoxilyzer 5000 calibration includes a linearity check, and incorporates an R squared evaluation of linearity.

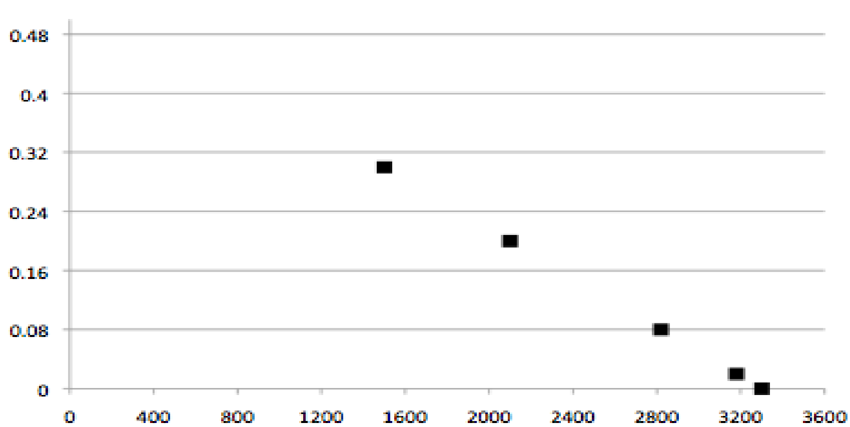
[196] *But see* TAYLOR & OBERMAN, *supra* note 7, at 496.

[197] *Id.*

To make the calculation of BrAC from the measurement of electricity from the sensor that detects light, the machine first constructs a logical graph of the values measured during calibration.[198] The machine is provided the concentration of each of several different standards, and the machine then measures the amount of electricity generated by the sensor.[199] The machine recognizes that more ethanol will result in a smaller electrical signal, since the ethanol absorbs more of the infrared light. For the purposes of this example, assume that the following standard values were presented to the machine, and the following values were measured from the light sensor:

Ethanol Content	IR Sensor Reading
0.01	3300
0.08	2820
0.20	2100
0.30	1500

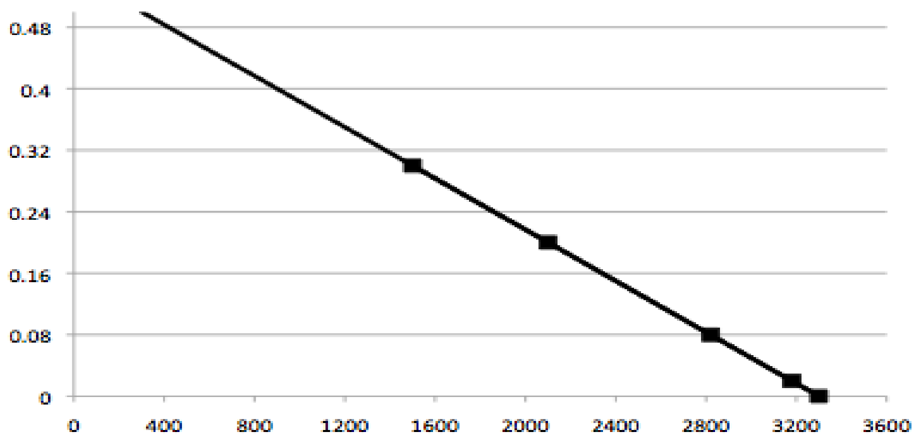
These four points can be represented on a graph, by plotting the expected ethanol content on the Y axis, and the electrical reading from the sensor on the X axis. The resulting plot of the values measured in calibration would appear as follows:



[198] An Intoxilyzer 5000 Calibration Log presents the constants for the slope of an equation, which when solved produces the ethanol content for a subject breath test.

[199] *Id.*

The calibration process measures the linearity of the points measured which is the tendency they have to form a straight line when plotted. By placing a straight line through these points, the machine derives the following graph.



The graph extends to the maximum BrAC value that can be reported, a .50, and the graph demonstrates that the electrical reading from the sensor cannot measure much beyond a .50, because the electrical signal cannot become a negative value. During calibration, the machine derives the solution to the classical formula for a straight line, that being:

> *Y = M * X + B, or in this case: BrAC = a Constant times Sensor Reading + a Constant*

Using traditional algebra, the constants are computed for use in measurements made after the calibration. In this instance, the first constant is –(1/6000) and the second constant is .55, which can be confirmed from the graph as the offset for the zero measurement. Thus, the formula used by the machine to convert the sensor reading to a BrAC is:

> *BrAC = -(1/6000) * Sensor Reading + .55*

This simple relationship is the mechanism that the machines employ, after their checks to insure that the breath is a valid sample, to compute the amount of ethanol in the breath.

Here is an example. The machine computes that the electrical signal value is 3000. The formula to convert to BrAC is employed, and the 3000 is divided by 6000 and the sign is changed to minus. That results in a -.5 result, which is adjusted by adding .55, resulting in a BrAC of .05, the reported result.

The calculation of the two calibration constants is critical to the computation of the BrAC, and they are dependent upon the calibration. The calibration checks insure that the machine is still performing in a reasonable manner, based upon the constants computed during the last calibration. Other constants are computed during calibration in order to detect specific interferents, but with respect to the computation of the BrAC, only the linearity of response of the machine and these two constants are required.

G. Wet Bath Simulators and Dry Gas Simulators

The government's theory of breath test devices operates on the assumption that since the body is a closed system (it is not) and that only deep lung air is exhaled at the end of an exhalation (not true), then a human breath can be "simulated" by an apparatus that is referred to as a "simulator".[200] The government's claim is that the simulator produces something that appears to be like a human breath.[201]

There are two ways to accomplish this. The first is to take a glass jar, place water with ethanol dissolved at a known concentration, and then bubble air through that solution.[202] The air that has bubbled through the ethanol-laden water then goes into the machine. This is called a "wet bath" simulator.[203] The second is to manufacture a tank, similar to a scuba-breathing tank, which contains ethanol in suspension with compressed air or gas.[204] It is not uncommon for jurisdictions to use pure nitrogen or even argon as the gas carrier.[205]

Wet bath simulators must have solutions that are mixed to take into account the volume of solids present in blood.[206] For blood to be at a concentration of .08 g/100 ml, the serum in the blood must be at a

[200] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 408; Swartz, *supra* note 86, at 8.

[201] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 408.

[202] Swartz, *supra* note 86, at 8.

[203] Swartz, *supra* note 86, at 8.

[204] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 408.

[205] Kurt Dubowski, *Quality Assurance and Breath Alcohol Analysis*, 18 J. OF ANALYTIC TOXICOLOGY 306, 309 (Oct. 1994).

[206] A.W. Jones, *Determination of Liquid/Air Partition Coefficients for Dilute Solutions of Ethanol in Water, Whole Blood, and Plasma*, 7 J. OF ANALYTIC TOXICOLOGY 193, 196 (July 1983).

higher concentration.[207] DUI attorneys know that one must convert serum levels to whole blood, and that there is not a conversion factor that works for all subjects. Serum is roughly 20% more concentrated than whole blood, and therefore, the standard solutions must be mixed to be 20% more concentrated than the value sought to be detected on the machine. If you fail to elevate the concentration to take this factor into account, the machines calibrated with the dilute solutions will systematically read 20% too high for all subjects tested. This is precisely what is believed to have happened in Washington DC, and made front-page news in the Washington Post[208].

1. What Does a "Wet bath" Simulator "Simulate"?

The simple answer is: a human breath with a known concentration of ethanol. The simulator accomplishes this feat by mimicking the way that ethanol is exchanged in the alveolae of the lungs.[209] To accept the scientific basis of the simulator, one must accept the government's theory of how ethanol enters the human breath. Recent studies, and the medical community[210], understand that the theory that all of the ethanol in a human breath is exchanged into the human breath in the deep part of the lungs – is incorrect. Yet the government's theory is embodied in the process in the design of the wet bath simulator.

The wet bath simulator simulates the exchange of ethanol between human blood, which flows through the membranes of the alveolae in the lungs, and the inhaled air, as represented by the incoming air that bubbles through the solution.[211] The temperature of the liquid must match the temperature of human blood, and the temperature of the air exchanging with the blood must be at the room temperature that will enter the human subject.[212]

The temperature of the wet bath liquid is maintained at 34 degrees Centigrade.[213] This is the wrong temperature, as 34 degrees Centigrade converts[214] to 93.2 degrees Fahrenheit. Blood in the body is

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[207] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 408.

[208] Mary Pat Flaherty, 400 Drunken-Driving Convictions in D.C. Based on Flawed Test, Official Says, WASH. POST, June 10, 2010, at 1.

[209] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 408; Swartz, *supra* note 86, at 6.

[210] *See* Hlastala, *supra* note 79, at 454.

[211] *Id.*

[212] Kurt Dubowski, *Breath-Alcohol Simulators: Scientific Basis and Actual Performance*, 3 J. OF ANALYTIC TOXICOLOGY 177, 181 (1979).

[213] *Id.*; *see also* Swartz, *supra* note 86, at 8.

[214] To convert Centigrade to Fahrenheit, multiply by 9/5 and add 32 degrees.

maintained at an average of 98.6 degrees Fahrenheit, which converts[215] to 37 degrees Centigrade. A three degree error in the temperature selected[216] will result in a 20% mistake in the reporting of ethanol concentration, and the 20% temperature error will cause a human breath to report a value that is 20% too high. The simulator will set the machine to read 20% too high if used in a calibration of the machine, and will cause a certification of calibration to appear to read correctly, since both the calibration and the certification are being performed at the wrong temperature.

The temperature of the air passing through the liquid is set to room temperature, at the time of calibration or certification.[217] In the event of calibration, the temperature is seldom recorded, and is likely different from the temperature at the time a test is administered or that a certification of a machine is performed.

The breath component of the exchange process is drawn from the room, at room temperature, and passed through the metal tube before it is bubbled through the water solution. As the bubbles form in the metal tube, the air has been warmed as it passed through the metal tube, which tube passes through the solution heated to 93.2 degrees Fahrenheit (or 34 degrees Centigrade). The degree to which the air has warmed is not known, nor is the exchange of ethanol from the solution that occurs when the bubbles pass through the liquid, as compared to the exchange from the surface of the liquid in the simulator with the air above the liquid.

Without validation studies that demonstrate that the simulator method is equivalent to the exchange of ethanol into human breath in a human body, the machines are being calibrated, and their calibration is being checked, using a concentration of ethanol that is speculative and perhaps incorrect.

2. Concentration of Ethanol in the Wet bath Solutions

When the solution of water and ethanol is mixed for a wet bath simulator, the concentration of ethanol is not equal to the value that the breath-test machine is intended to report. Early experiments performed

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[215] To convert Fahrenheit to Centigrade, subtract 32 degrees and multiply that value by 5/9.

[216] Telephone interview with breath test expert Mary McMurray. Mary McMurray recounted a conversation with Dr. Borkenstein, when he commented to Mary that if he could change one thing about breath testing it would be to use 37 degrees for simulators instead of 34 degrees.

[217] Kurt Dubowski, *Breath-Alcohol Simulators: Scientific Basis and Actual Performance,* 3 J. OF ANALYTIC TOXICOLOGY 177, 181 (1979).

by A.W. Jones and Kurt Dubowski utilized human blood from subjects who had been dosed to known values of ethanol.[218] By calibrating a breath-test machine so that it reported a value that was equal to the value of ethanol that was known to be present in human blood in a simulator, and then replacing the human blood with water mixed with ethanol that reported the same results, the correct amount of ethanol to be mixed with water can be computed. The value must be different because whole blood contains solids that do not absorb ethanol, so that the concentration of ethanol in the liquid portion of blood must be stronger than the concentration in whole blood.[219]

Dubowski calculated the increased portion of ethanol as 0.1226 g/100 ml[220] to simulate a result of 0.100 on a breath-test machine. Jones calculated the correct ratio as 0.1232 g/100 ml[221] to simulate a result of 0.100 on a breath-test machine. According to a compilation of conversion factors employed by 25 state laboratories, compiled February 2, 1995 by Minnesota BCA Lab chemist Robert Mooney (provided courtesy of Mary McMurray), conversion values of various states varied as follows:

Concentration	**States**
0.1209	California
0.121	Alabama, Arkansas, Colorado, Connecticut, Delaware, Hawaii, Idaho, Illinois, Iowa, Kansas, Kentucky, Michigan, Nebraska, Nevada (Las Vegas), Montana, New Jersey, South Dakota, Vermont.
0.1215	Arizona
0.1226	New York (Suffolk County), Texas, Wisconsin
0.123	Georgia, Nevada (Reno), Washington

While the data provided here is old, the jurisdictions have either retained the same value over the years or they have changed the value used in their state. In either event, the reason for adopting a value different from other states, or the reason for changing the value

[218] Kurt M. Dubowski, *Absorption, Distribution and Elimination of Alcohol: Highway Safety Aspects*, 10 J. STUD. ALCOHOL 98, 99 (1985); Dominick A. Labianca, *The Flawed Nature of the Calibration Factor in Breath-Alcohol Analysis*, 79 J. CHEM. EDUC. 1237, 1238 (2002).

[219] Letter from Minnesota BCA Lab chemist Robert Mooney to Robert Zettl, National Safety Council member (Feb. 2, 1995) (provided by Mary McMurray).

[220] Kurt Dubowski, *Breath-Alcohol Simulators: Scientific Basis and Actual Performance*, 3 J. OF ANALYTIC TOXICOLOGY 177 (1979).

[221] JAT V7, July/Aug 1983, pg 83.

adopted (and the required re-calibration of the machines to accomplish a change to a new solution concentration) must be set forth.

Robert Mooney's correspondence[222] also pointed out the error introduced by the specification of ethanol by weight per measure of water by volume: recognizing that the volume of water is different at 34 degrees Centigrade when contrasted with 20 degrees Centigrade (68 degrees Fahrenheit, or room temperature). Mooney demonstrated that the change in volume must either be taken into account when manufacturing the standard solution, or else the solution will be incorrectly constituted when the solution is heated to 34 degrees Centigrade.[223] Any official response to Mr. Mooney's letter of concern is unknown to either the author or to Mary McMurray at the time this paper is written.

3. Depletion of Ethanol in the Wet bath Solutions

Wet bath solutions are manufactured for use as certification solutions, where the measured values must agree within a tolerance that varies up to 10%[224] depending upon the jurisdiction. The amount of ethanol in the solution will vary with use, as each time air is bubbled through the wet bath standard solution, some ethanol is removed from the water, rendering the liquid in the simulator just a bit weaker than before the test was conducted.[225]

Some jurisdictions re-circulate the air that would be exhausted from the machine, so that ethanol laden air is returned through the machine, reducing the amount of ethanol that is lost with each use of the wet bath simulator. A re-circulation scheme has the disadvantage that any contaminants contained in the cylinder will be forced through the simulator, thereby contaminating the wet bath solution for all future uses (until the simulator solution is discarded and replaced with a new solution). To account for the weakening of the simulator solution, some jurisdictions establish a limit to the number of uses of the simulator solution before the solution must be replaced. Some

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[222] Letter from Minnesota BCA Lab chemist Robert Mooney to Robert Zettl, National Safety Council member (Feb. 2, 1995) (provided by Mary McMurray).

[223] *Id.*

[224] In Massachusetts, the wet bath solution used to check the machine's calibration is mixed at a concentration of 0.155 so that when measured and the reading is truncated to two digits, the result must be a 0.14, 0.15 or a 0.16. Since the upper limit is a 0.169, the results must be plus or minus 0.015, or 10% of the target value.

[225] TAYLOR & OBERMAN, *supra* note 7, at 571–72.

jurisdictions specify both a maximum duration of time, as well as a maximum number of uses of the simulator solution.[226]

When a standard solution is used to calibrate a machine, the use of a fresh solution, and the specification of the solution concentration to the authenticated concentration are essential. While it may be sufficient to check the calibration of a machine knowing that there is an error in the concentration of a standard solution (e.g. the .100 solution actually has a concentration that should measure .102), when using a solution that does not measure exactly, the standard value is not acceptable when calibrating a machine.[227]

When a calibration log is observed that specifies the various standard values at exactly their target values, it is fairly safe to assume that the target values, and not the actual values of the standards, have been entered to the machines in error. Alternatively, the standard solutions employed may be measured to a precision that specifies exactly the value procured, a very expensive proposition.

4. What if the Concentrations of Ethanol are Wrong?

The concentration of ethanol can be wrong if the incorrect value is entered (e.g. a concentration of .200 is communicated during a calibration when in fact the concentration is .100). In such an instance, if a single point calibration is performed, the resulting machine will produce results that are always double the true value.[228] If the same lot of solution is used to perform certifications of the calibration, then both calibration and certification will produce incorrect results, and the machine will appear to be operating properly.

Concentrations can be incorrectly communicated if the actual concentration is entered, instead of the expected reading on a breath-test machine. In this instance, results will be reported at levels that are systematically 25% too high.[229]

If the subject's blood contains solids in a proportion that is different from the laboratory's makeup of standard solution, then the machine will be improperly calibrated for that subject.[230] The conversion factor used in order to compute the value in whole blood to convert ethanol content in blood serum to whole blood is complicated.

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[226] 250 uses is a common limitation. Some machines incorporate a counter that enforces the number of uses, forcing a replacement of the wet bath solution when the limit of uses has been reached, or the duration of use has been reached.

[227] TAYLOR & OBERMAN, *supra* note 7, at 573.

[228] *Id.* at 572.

[229] TAYLOR & OBERMAN, *supra* note 7, at 445 (citing Hlastala, *supra* note 79).

[230] *See* Workman, *supra* note 12.

The conversion factor must be selected not for the average conversion rate, but rather a conversion rate that is two or three standard deviations from the mean.[231] Two or three standard deviations is selected so that an inference can be made that the subject's ethanol content is at least the reported value, after the conversion is performed.[232]

Finally, the concentration of the standard could have been correct when the standard was first used, but is now depleted through excessive use. The depletion of the ethanol in the standard can occur through repeated use, or through the evaporation of the ethanol in a simulator that is left powered on.[233]

H. What is a "Dry gas" Standard?

Dry gas standards are tanks of gas with a measured amount of ethanol mixed with a gas, so that the combination of gas and ethanol is expelled from the tank because the tank is pressurized.[234] When the ethanol and gas are mixed and placed into the tank under pressure, there is no moisture added or present in the gas that dilutes the ethanol.[235] The name "dry" gas is derived from the absence of moisture, which distinguishes the standard from a human breath (a human breath will always contain moisture).[236]

The amount of ethanol in a dry gas standard must be correct at the time the standard is mixed because the concentration is not generated mechanically as it is in a wet bath simulator. It must be consistent throughout the discharge of the gas from the tank, at least over a range of pressure specified for the tank.[237] If you can hear a liquid sloshing around inside the tank, as is often reported, then the ethanol content is too low in the gas that is forced from the tank, meaning that if the tank is used to calibrate a machine, the machine will systematically read too

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[231] Working Group 1, Evaluation of Measurement Data—Guide to the Expression of Uncertainty in Measurement, JOINT COMMITTEE FOR GUIDES IN METROLOGY, *available at* www.blpm.org/en/publications/guides/gum.html.

[232] *Id.*

[233] TAYLOR & OBERMAN, *supra* note 7, at 572.

[234] *See generally* GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 408.

[235] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 231.

[236] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 231.

[237] *Intoxilyzer 8000: Reference Guide 8*, FLORIDA DEPARTMENT OF LAW ENFORCEMENT ALCOHOL TESTING PROGRAM (Feb. 2006), *available at* http://www .fdle.state.fl.us/Content/getdoc/fbb9142a-1702-4fc8-8569-3a465e858520/I8000ReferenceGuideFeb2006-1-.aspx.

high[238]. The remedy of "rolling the tank" in order to dissolve the liquid ethanol is only effective if done with consistency and if it effectively transfers all of the liquid ethanol into a gaseous form.[239] An example of a certification analysis for a 105 liter tank is shown here:

CONTAINER TYPE:105

LOT CERTIFIED VALUE

CONCENTRATION

COMPONENTS	ppm (BrAC)	ACCURACY
Ethanol	208.4 (0.080)	+/- 2%
Nitrogen	Balance	

The 208.4 ppm designator refers to the concentration, which is 208.4 parts per million, a measure of volume not weight. Converted to a fraction, this equates to .0002084 proportion by volume. How this volume relates to the standard of .08 g per 210 dl is an exercise that the government expert will likely struggle with, if they are to be honest (transcripts make a dishonest expert vulnerable for future testimony). The derivation of this concentration is not well researched, and the suspicion is that the concentration is that value that required to cause a machine to confirm the readings derived from a wet bath simulator, which as previously discussed are not founded on science.[240]

The amount of ethanol placed into the tanks should be a straightforward calculation that is consistent for all manufacturers and all breath-test machines. Unfortunately, this is not the case. Intoximeters Corporation believes that they have calculated the correct amount of ethanol to add to a tank that contains 105 liters of air[241] under pressure, and is not the same as what other manufacturers use. The Intoximeter tanks are referred to as "compensated" tanks. When queried about the concentration difference, Intoximeters has been known to claim that the rest of the breath testing community is wrong, and their tanks are correct.

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[238] Calibrating with a standard that is too weak will always result in a machine that systematically reads too high.

[239] Telephone conversation between the author and Mary McMurray. Ms. McMurray can be contacted at her office, 3523 County Road JG, Blue Mounds, WI 53517-9690, telephone 608 437-5344.

[240] *See supra* Part VI.G.

[241] A 105 liter tank, when filled to capacity, is selected because the assumption is made that the partition ratio is parts per 2100, and 105 is half of 210.

1. Ethanol is Mixed With What Gas?

Dry gas standards contain ethanol mixed with a gas.[242] The Volpe Labs test machines for the National Highway Traffic Safety Administration (NHTSA), in order to establish a conforming products list.[243] The specific contents of "air" are established and mixed, so that the simulators provide ethanol laden "air" to the machines under evaluation.[244] In this way, the presentation of standards does not vary from day to day, as the makeup of air in the atmosphere will in fact vary.

The breath testing community has reached another solution in defining the standards used to calibrate and to certify machines with a tank of ethanol laden standard. Most jurisdictions utilize either nitrogen or argon as a carrier for the ethanol.[245] If the machine under test uses infrared spectroscopy as a measuring technique, then the use of nitrogen or argon as a carrier gas is significant. Both nitrogen and argon are inert in an infrared scheme of measuring. Air is not inert, and will absorb light at most frequencies.

Calibrating a machine with ethanol and an inert gas without any moisture, so that the calculated constants can be used to compute the amount of ethanol in a human breath that contains air and moisture, without a comprehensive validation study to confirm that the appropriate adjustments are both established and incorporated in the formulas within the software of the machine, is simply bad science. The infrared spectra for an air sample, as contrasted with light passing through a vacuum (with no absorbance whatsoever), is shown here:

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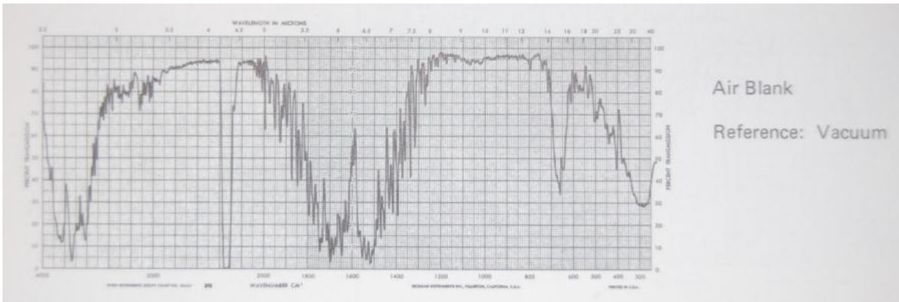
[242] *Intoxilyzer 8000: Reference Guide 8*, FLORIDA DEPARTMENT OF LAW ENFORCEMENT ALCOHOL TESTING PROGRAM (Feb. 2006), *available at* http://www.fdle.state.fl.us/Content/getdoc/fbb9142a-1702-4fc8-8569-3a465e858520/I8000ReferenceGuideFeb2006-1-.aspx.

[243] Highway Safety Programs, Model Specifications for Devices to Measure Breath Alcohol, 58 Fed. Reg. 48705 (Sept. 17, 1993).

[244] *Id.*

[245] Kurt Dubowski, *Quality Assurance and Breath Alcohol Analysis*, 18 J. OF ANAL. TOXICOLOGY 306, 309-310 (1994).



Air Blank Control Compared to a Reference that is a Vacuum.[246]

Since additional light is absorbed by air in the human sample, and infrared machines determine ethanol concentration based on the amount of light absorbed, the use of inert carrier gasses for standards can only result in the calibration of machines that read inflated values for human subjects. The degree of the inflated results has not been studied, to the author's knowledge.

2. Barometric Pressure or Altitude—Which is Used to Compensate and Why

Early breath test machines employing a dry gas canister required that the operator enter a value that was used to compensate for the variation in barometric pressure.[247] Many dry gas canisters have printed on their tanks a list of altitudes and the corresponding constants that can be used to adjust within the machine for variations when the gas in the canister is used by the machine.[248]

Unlike the wet bath process, a dry gas calibration or certification must take into account the barometric pressure when the machine measures the concentration of ethanol.[249] The concentration of ethanol is governed by Boyle's gas law, which holds that as the barometric pressure increases, more suspended molecules of ethanol will be contained within the chamber.[250] This increased concentration, attributed to barometric pressure, must be compensated for when computing the ethanol concentration.

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[246] BRIAN THOMPSON, HAZARDOUS GASES AND VAPORS: INFRARED SPECTRA AND PHYSICAL CONSTANTS 1 (1974).

[247] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 231.

[248] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 409.

[249] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 409.

[250] NASA, http://www.grc.nasa.gov/WWW/k-12/airplane/boyle.html (last visited Apr. 12, 2012).

Entering the altitude is a crude way of communicating the barometric pressure. It is certainly true that at higher altitudes, the barometric pressure tends to be lower. For machines that do not incorporate a method of measuring the barometric pressure, knowing the altitude or the factor for adjusting based upon approximate barometric pressure as a function of altitude, may be the only adjustments he machine can make.

a. Defective Certification with a Dry Gas Standard: The Alaska Experience

In February 2006, an Alaska crime lab employee decided that the state manufacturing of dry gas standard tanks was being done incorrectly.[251] The lab decided that the tanks it manufactured and subsequently tested on a Datamaster machine in the laboratory where the tanks were fabricated, needed to have the measurements adjusted in a different manner from the way that the measurements had historically been adjusted.[252]

Consider the fact that the Datamaster contains a facility for independent measurement of the barometric pressure.[253] The machine reports the barometric pressure when it makes a measurement of a sample provided to it. The state of Alaska ignored the barometric pressure value the machine reported and decided to adjust the value independently from the value reported by the Datamaster.[254] In essence, Alaska modified the Datamaster to eliminate the adjustment, so that the Alaska crime lab could manually adjust its external reading of the barometric pressure.[255]

It is highly unlikely that the software in Alaska has been modified to disable the adjustment for barometric pressure.[256] Assuming that the Alaska Datamaster machine was modified to disable the adjustment for barometric pressure when measuring a sample of air from a dry gas tank, then the state made a mistake when they decided to invert the fraction that they had been applying to the calculation of the tank

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[251] Memorandum from Orin Dym, Forensic Lab. Manager, Ala. Scientific Crime Detection Lab., to Robert Gorder, Deputy Comm'r, State of Alaska Dep't of Pub. Safety (July 9, 2010) (on file with U. MASS. L. REV.).

[252] *Id.*

[253] *Id.*

[254] Transcript of Alco Bottle/OUI Status Hearing at 3212-14, Alaska v. Tou Yang, et al., No. 3AN-10-618 CR (3rd D. Alaska Nov. 30, 2011).

[255] *Id.*

[256] Transcript of Alco Bottle/OUI Status Hearing at 3086-88, Alaska v. Tou Yang, et al., No. 3AN-10-618 CR (3rd D. Alaska Nov. 29, 2011).

values.[257] One would expect notification of the judicial system of the error that had been made in prior years of manufacture of standard tanks, but the change was made quietly, and nothing appeared to have been done to retrieve tanks that had been manufactured "incorrectly".

When Alaska finally discovered that the changed standards were incorrect and manufactured products were being labeled with concentrations of ethanol that were wrong as a result of the mistake, the process of manufacturing the tanks was changed back to the old "correct" way of doing things.[258] It is likely that the initial way of adjusting barometric pressure had problems (or the change would not have been made), yet Alaska has been reluctant to disclose this information, even though they are under court order to disclose it.[259] It is also likely that the changed method was also incorrect (someone must have seen a problem, and in fact, there is reference to a machine that could not effectively be certified when the barometric pressure was outside of normal range for weather in Alaska).[260]

The author is retained to study the data in Alaska; data that will disclose whether or not the adjustment by the state is an incorrect scientific step. It is believed to be the likely outcome, but the data will establish the correct scientific answer. The state of Alaska has tried to repair the defective manufacture of the bottles, in order to save the certifications that were fraudulently or negligently manufactured.[261]

b. State Manufacturing of the Dry gas Standard

The correct production of tanks of dry gas standards is a complex manufacturing problem. Companies that sell tanks that are dosed with ethanol have major manufacturing processes established that incorporate quality assurance and evaluation with accurate and calibrated instruments designed to accurately measure the contents of samples selected for verification.[262]

States often do not utilize such procedures, and often (as in Alaska), use a breath test machine to verify the concentration of their manufactured standards. Using a machine which lacks accuracy to

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[257] *Id.* at 2927.

[258] Transcript of Alco Bottle/OUI Status Hearing at 3084-88, Alaska v. Tou Yang, et al., No. 3AN-10-618 CR (3rd D. Alaska Nov. 29, 2011).

[259] *Id.* at 3169-74.

[260] *Id.* at 3011-14.

[261] Memorandum from Orin Dym, Forensic Lab. Manager, Ala. Scientific Crime Detection Lab., to Robert Gorder, Deputy Comm'r, State of Alaska Dep't of Pub. Safety (July 9, 2010) (on file with UMASS. L. REV.).

[262] U.S. Patent No. 5,495,875 (filed Dec. 1, 1994).

establish the accuracy of the state's program is scientifically problematic. It is also problematic to utilize a process that loads a number of tanks, when the manufacturing process must load each tank consistently. The process of mixing tanks with standard concentrations is performed, using a patented process when the manufacturer is Scott Gas, under a process they refer to as "Flexblend".[263] Duplication of that process is not legal if a state simply copies the process, as that is patent infringement.

c. The Philadelphia Calibration Problem

The March 23, 2011 news reports of 1,147 defective breath-tests in Philadelphia, Pennsylvania attributed the problem to "mis-calibrated" machines.[264] In discussions with the Philadelphia public defender's office, the problem was defined as the certification of calibration tests exhibiting measurements that exceeded the allowable range of measurement. In essence, the machines could not or were not certified as required by regulation or law. When a required certification is not performed or is not successfully completed, the consequence is that the prior calibration is invalid. An un-calibrated machine should not be used to generate evidence used in any court proceeding.

Philadelphia performed approximately 10,000 tests on 8 machines. The 1,147 number appears to relate to a single machine. According to Justin McShane[265], and confirmed by the public defender's office, four of the machines in Philadelphia appear to have been confirmed to have similar issues in regard to exceeding acceptable ranges of measurement in the certification of calibration. The problem may in fact be present for all of the current machines, and may extend to the predecessor machines used in Philadelphia.

In Philadelphia, the problems were discovered by an attorney who simply asked for the raw data. What he got in response were the certification reports. The attorney holds himself out as a DUI "dabbler" (his term) in discussions with attorney McShane. The important lesson for all is to always ask for the raw data on the machine.

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[263] *Id.*

[264] *1,147 Drunk Driving Cases Could be in Jeopardy in Philadelphia*, PHILADELPHIA CBS LOCAL, http://philadelphia.cbslocal.com/2011/03/23/i-team-1147-drunk-driving-cases-could-be-in-jeopardy/ (last visited Apr. 12, 2012).

[265] Attorney Justin McShane may be contacted through his firm's website: http: //www.themcshanefirm.com/attorneys/mcshane/.

d. The San Francisco Certification Problem

On March 5, 2012 the San Francisco mainstream press reported that hundreds to thousands of drunk driving convictions could be in doubt because of a recently discovered irregularity in the periodic testing of 20 breath testing devices used in San Francisco.[266] The problem has apparently existed for at least six years.[267] The San Francisco District Attorney reports that there did not appear to be any malicious intent behind the police officer's actions, and that they were apparently "just too lazy" to perform the test required every 10 days.[268]

The problem was discovered by San Francisco attorney Peter Fitzpatrick, according to television reports, when he defended a client whose breath test results showed a five point difference (a difference of .05 from one reading to the next), which attorney Fitzpatrick explained was a variance that could only be explained by an incorrect machine reading.[269] Upon closer examination, the log books that recorded that the tests had been performed, also reported an identical reading of .082 in every instance, leading to the conclusion that the police officer responsible for the testing was simply writing down the same number, instead of doing the required tests[270], a process referred to as "dry labbing."[271] That the situation existed for between six and ten years, undiscovered, is particularly disturbing.

VII. ACCURACY OF THE RESULTS

PBTs and self-initiated machines collect a single sample, analyze it, and produce a result.[272] Some evidentiary machines only draw one sample, by design, although all of the evidentiary machines in use today have the ability to be programmed to collect two breath

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[266] , *SFPD Breathalyzer Error Puts Hundreds of DUI Convictions in Doubt*, SAN FRANCISCO CBS LOCAL, http://sanfrancisco.cbslocal.com/2012/03/05/sfpd-breathalyzer-error-puts-hundreds-of-dui-convictions-in-doubt/ (last visited Apr. 12, 2012).

[267] *Id.*

[268] *Id.*

[269] *Id.* (Video embedded within webpage).

[270] *Id.*

[271] *See* Stephanie Drier, *Ethics & Data Integrity*, 7 (2010), *available at* http://www.health.state.mn.us/divs/phl/accreditation/docs/ethics.pdf.

[272] GARRIOTT'S MEDICOLEGAL ASPECTS OF ALCOHOL, *supra* note 18, at 231.

samples.[273] The analysis of two separate samples is referred to as "duplicate" testing[274].

In Minnesota, the Intoxilyzer 5000EN is programmed so that both the master microprocessor and the slave microprocessor (the machine has two microprocessors in it) analyze each breath sample, and both computers calculate an alcohol concentration, using data collected from the single set of sensors and optical bench contained in the machine.[275] The calculation of alcohol twice for a single breath is referred to as "replicate" testing. Unfortunately, the manufacturer did not program the 5000EN correctly, as the replicate sample is higher than the measured sample in every one of the tests that collected two breaths from January 2005 to March 2010.[276] The certification performed with each subject test was able to measure a smaller replicate value for the simulator solution in 28,631 of the subject tests.

While a majority of jurisdictions perform duplicate testing, a very small minority perform replicate testing.[277] Minnesota currently does both.[278]

Jurisdictions that require two breath samples usually require that the two samples agree, within .02, to be considered reliable.[279] Such a range is not arbitrary, but reflects the accuracy of the machines that measure breath. Even if the machine requires only a single sample, that measurement cannot be scientifically stated as a number without also specifying the range of error associated with the measurement.

Metrology, the science of measuring things, requires the specification of the uncertainty of measurement before one uses a result that is a quantity.[280] Even if the machine produces exactly the

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[273] 501 MASS. CODE REGS. 2.14 (LexisNexis 2012).

[274] 23,671 of the certification tests read higher for the replicate test, and 104,373 values matched. The distribution of deviations both positive and negative is one indication that the calculations are being made independently.

[275] TAYLOR & OBERMAN, *supra* note 7, at 623.

[276] Minnesota conducted 156,675 tests on 262 machines between January 1, 2005 and March 25, 2010.

[277] The author defines a replicate test to be the analysis of the same breath sample by more than one computer within a breath-test machine. The author defines a duplicate test as the acquisition of multiple breath exemplars from the same human subject. The literature often uses the two terms interchangeably.

[278] Minnesota is changing machines, after attorneys there studied and investigated the Intoxilyzer 5000EN, the state responded by purchasing a different machine for use throughout the state.

[279] *See* 501 MASS. CODE REGS. 2.14(4) (LexisNexis 2012).

[280] *See* NAT'L INSTITUTE OF STANDARDS AND TECH., http://www.nist.gov /traceability/suppl_matls_for_nist_policy_rev.cfm (last visited Dec. 9, 2011).

same number twice, the results are still not more precise than the uncertainty associated with the results.

In many states, including Florida, the breath testing process requires that a citizen submit two breath samples.[281] The Florida machines require a two minute delay between the two submitted breath samples.[282] During this two minute interval, the machine flushes air through the machine to clear out the first breath sample.[283] The science of breath testing assumes that this two–minute time interval is insignificant as to the degree of change in the amount of alcohol in the blood of the citizen.[284] Theoretically, each citizen tested should supply two breath samples with the same amount of alcohol, yet in reality this is not the case.

One variable that is both measured and reported is the volume of breath supplied for both breath samples. The author tested the hypothesis that the volume difference for a given citizen correlated to the amount of alcohol reported, and found that there was a very high statistical correlation between a difference in volume, and a difference in the amount of alcohol reported.

The police officer controls when the citizen stops blowing into the machine, so volume is a parameter that is directly controlled by the police officer. Since the police officer controls the volume of each sample, and the volume is highly correlated to the reported amount of alcohol, then the breath testing process is a subjective process, and not an objective process.[285]It is posited that if the process is subjective, and not objective, then it is not scientific and should not be admissible as evidence in a criminal trial. In Florida, the degree of subjectivity may be measured by determining the portion of the allowed .02 variation between the two samples that is attributed to the difference in volume. Approximately half of the permitted difference between the two samples is attributed to differences in volume.

Other influences, besides volume, are relevant to the measurement of alcohol. These other factors may present a test in which the second volume is higher, yet the alcohol reading is lower. This should be expected, statistically, for a small number of instances, and reflects

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[281] FLA. ADMIN. CODE ANN. 11D-8.002(12) (2006).

[282] *Id.*

[283] TAYLOR & OBERMAN, *supra* note 7, at 623.

[284] In testing a large number of citizens, alcohol will be increasing in the bloodstream of some citizens, and will be decreasing in others. The effect of the time delay is considered to be statistically negligible.

[285] *See* 501 MASS. CODE REGS. 2.14 (LexisNexis 2012).

other influences that present greater influences on the test in question. Though other influences are present, the influence of volume is still present; it simply has been overshadowed by some other factor in such a subject test record which shows less alcohol and more volume.

The Florida Department of Law Enforcement website is supposed to contain Subject Test results for every evidentiary breath test administered.[286] Data is organized for a series of Intoxilyzer 8000 machines, with a single PDF file set aside for a range of serial numbered machines, for a given calendar month.[287] An example of a segment of the website is presented in Figure 1.

Intoxilyzer 8000 Electronic Records					
SUBJECT TESTS DATA					
March 2006 **(Posted September 4, 2007)**					
200 to 867	868 to 997	998 to 1131	1132 to 1274	1275 to 1720	

Figure 1: Segment of FDLE Webpage, Links to Subject Test Data

By clicking on the web link for "200 to 867" in Figure 1, a single PDF document will be provided by the FDLE website. The FDLE document contains all breath testing subject pages for machines which have a serial number of 80-000200 through 80-000867 inclusive, administered on March 1, 2006 to March 31, 2006 inclusive. On December 10, 2007 the author clicked on each link provided, and by highlighting all of the data in Adobe Acrobat, copied the data from each page and pasted that data into an Excel spreadsheet. Each spreadsheet was processed by a Filemaker Pro[288] script which

[286] There is evidence that some of the Subject Test records which were supplied to a Florida Attorney in July of 2007, under a Freedom of Information request, are absent in the set of data on the FDLE website. It is posited that these records were "Deleted" from the data set, when in fact they should not have been. See Florida Department of Law Enforcement, fdle.state.fl.us (follow "alcohol testing program hyperlink; then search for Intoxilyzer 8000 Records; then follow Subject test statistics).

[287] FLORIDA DEPARTMENT OF LAW ENFORCEMENT, http://www.fdle.state.fl.us /Content/home.aspx (last visited Mar. 22, 2012) (follow "For criminal Justice" hyperlink; then follow "Alcohol Testing Program" hyperlink; then follow Intoxilyzer 8000 Records hyperlink; then follow "Subject Test Electronic Data" hyperlink).

[288] FILEMAKER, http://www.filemaker.com/products/compare/ (last visited Mar. 22, 2012) (Filemaker Pro is a cross platform database program, commercially available for purchase from the website, filemaker.com, or at many stores such as Circuit City and Staples, either at brick-and-mortar stores or from internet website presence.).

extracted the data from the spreadsheet and loaded that data into a Filemaker Pro database, where it could be processed by standard database inquiries.

Filemaker Pro provides an ability to create supplemental variables that relate to a breath test record.[289] For example, the difference in volume between the first and second sample is a computed variable. In addition, the difference in measured alcohol between the first and second breath sample is also a computed variable. The database constructed with Florida data features two variables, Volume1 and Volume2, which respectively contain the volume of air, in liters, associated with the first and second breath samples.[290] The database also features two variables, Subject1 and Subject2, which contain the measured alcohol content for the first and second breath samples. Both the volume and breath alcohol content for both breath samples are presented on the Subject Test record.

To define a field which is the difference between two fields, in this case SubjDif1, the database designer provides the information in Figure 2 to Filemaker Pro.

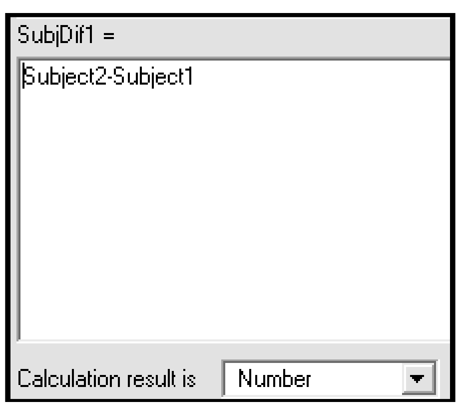

Figure 2: Filemaker Pro Definition of Calculated Variable SubjDef1.

In the Subject Test record below, the fields Subject1 and Subject2 are displayed on the top of the record display, as 0.122 and 0.118 respectively. The difference in the alcohol content is shown as the

[289] *Id.*

[290] FLORIDA DEPARTMENT OF LAW ENFORCEMENT, http://www.fdle.state.fl.us/Content/home.aspx (last visited Mar. 22, 2012) (follow “For criminal Justice” hyperlink; then follow “Alcohol Testing Program” hyperlink; then follow “Intoxilyzer 8000 Records” hyperlink; then follow “Subject Test Electronic Data” hyperlink).

computed variable SubjDif1, and is computed as the difference between these two variables for the two breath tests, as “Subject2 minus Subject1” (as defined in the figure 2), and is displayed as -0.004.

TestSerial	72885	SourceFile	133
IntoxSerial	80-000948	PageinSource	750
NumberSamples	2		
Owner	GLADES COUNTY SO		
Software	8100.27		
Test Time	7/15/2007	0:53:49	
Last Inspection	6/14/2007		
Subject	REGISTER, BENJAMIN, A		
SubjectDOB	4/12/1982		
SubjectGender	Male		
SubjectDL	FL/R223061821320		
SubjectAge	25		
Operator	CARDONA, FRANCISCO,		
Operator Agency	Glades County SO		
Solution Lot	701201G		
Solution Expire	1/15/2009	DaysSimLeft	550

Subject1	0.122	Subject2	0.118
Volume1	3.734	Volume2	3.343
SubjDif1	-0.004		
SubjVol1a	M.4	SubjVol2	M.39

Diagnostics Check OK	0:47:00	
Air Blank	0:48:00	0.000
Control Test	0:48:00	0.076
Air Blank	0:48:00	0.000
Subject Sample #1	0:49:00	0.122
Breath Volume	0:49:00	3.734
Air Blank	0:49:00	0.000
Air Blank	0:51:00	0.000
Subject Sample #2	0:52:00	0.118
Breath Volume	0:52:00	3.343
Air Blank	0:52:00	0.000
Control Test	0:53:00	0.075
Air Blank	0:53:00	0.000
Diagnostics Check OK	0:53:00	

Figure 3:Filemaker Pro Database of Subject Test Data.

Note that the breath test in Figure 3 presents information on the same citizen’s breath test as that in the FDLE webpage shown in Figure 4. The page in Figure 4 is from the FDLE website, and displays the data captured by the state of Florida on their website.[291] Some data in Figure 3 is not present on the Florida website, but is directly calculated from the data on the Florida website.[292]

For example, the age of the subject at the time of the breath test can be calculated from the subject’s date of birth and the date of the administration of the breath test, even though this calculation is not present on the Florida state website. In Figure 3, the SubjectAge field is the calculated age of the subject on the date that the breath test was administered. On July 15, 2007, when the breath test was administered, the subject was 25 years old, because their last birthday was April 12, 2007, and on that date they became 25 years of age.

The field “PageinSource” is the page number in the PDF file where the Subject Test data is found.[293] It allows for the quick retrieval in the FDLE PDF file of the data for the subject displayed. In a similar

[291] FLORIDA DEPARTMENT OF LAW ENFORCEMENT, http://www.fdle.state.fl.us/Content/home.aspx (last visited Mar. 22, 2012) (follow “For criminal Justice” hyperlink; then follow “Alcohol Testing Program” hyperlink; then follow “Intoxilyzer 8000 Records” hyperlink; then follow “Subject Test Electronic Data” hyperlink; follow “868-997” hyperlink under “ 2007” and “July”).

[292] *Id.*

[293] *Id.*

fashion, the field "NumberSamples" shows the number of breath samples provided by the subject, and permits the location of all tests with exactly 2 samples.[294]

Subject Tests

Intoxilyzer 8000 Serial # 80-000948

Instrument Registered To	Software	Date/Time of Test	Date of Last Agency Inspection
Subject Name	**DOB**	**Sex**	**Driver License**
Operator	**Agency**	**Dry Gas Lot #**	**Expiration**
Arresting Officer	**Agency**	**Arrest Time**	**Observation Time**
			Violation Code
GLADES COUNTY SO	8100.27	07/15/2007 00:53:49	06/14/2007
REGISTER, BENJAMIN, A	04/12/1982	Male	FL/R223061821320
CARDONA, FRANCISCO,	Glades County SO	701201G	01/15/2009
MORGAN, JACK	Glades County SO	23:57	00:25
			DUI

Type	Result	Time
Diagnostics Check	OK	00:47
Air Blank	0.000	00:48
Control Test	0.076	00:48
Air Blank	0.000	00:48
Subject Sample #1	0.122	00:49
Breath Volume	3.734	00:49
Air Blank	0.000	00:49
Air Blank	0.000	00:51
Subject Sample #2	0.118	00:52
Breath Volume	3.343	00:52
Air Blank	0.000	00:52
Control Test	0.075	00:53
Air Blank	0.000	00:53
Diagnostics Check	OK	00:53

Result: 0.118

Figure 4: FDLE Webpage of "Official" Subject Test Data.

A. Aggregating the Data for Analysis to Two Digits

To group together similar data from multiple tests for analysis, the records to be grouped together are assigned an identical value in a field that is designed to identify similar records.[295] In this study, that grouping is done based on tests which share a common attribute: the difference in volume between the first and second submitted sample for the same subject.

[294] *Id.*

[295] Database programs refer to a field that is used to locate similar records as a "key" field. Using an indexing structure, all of the records with a common key can be quickly found and manipulated.

While volume is reported to three decimal places, the Intoxilyzer 8000 cannot truly measure volume to three decimal places. The third decimal place contains a value that increases by more than a single digit when the next possible data value is measured and reported. For example, the value most frequently reported for Breath Volume is 1.867 Liters, at 179 samples. Yet there are no reports of volume at 1.864, 1.865, 1.866, or at 1.868, 1.869, and 1.87 (See Figure 5 below). Since the third digit to the right of the decimal point cannot be relied upon to be accurate, only two digits of information to the right of the decimal should be relied upon in calculations that use volume data.

Measured Volume	# of Occurrances
1.863	171
1.864	
1.865	
1.866	
1.867	179
1.868	
1.869	
1.87	
1.871	154

Figure 5: Measurement of Volume Returns "Sparse" Data

In order to group records which share a common difference in volume (keeping differences that are larger, separate from differences where the second sample is smaller) the first measured breath volume was subtracted from the second measured breath volume. The mathematical result was formatted into a variable which contains the same information for any two breath volumes which differ by the same amount. Since the difference in volume can be expressed as thousandths of liters, hundredths of liters, or tenths of liters, an initial strategy of measuring the difference in hundredths of liters was established.[296]

The data for two decimal digits was plotted first, and the difference in volume was created as a "key" in the database, with the difference in volume "rounded" to two significant digits. To exclude records

[296] In selecting a resolution for measuring and reporting volume difference, we consider the limitation of the machine to measure the third digit to the right of the decimal, and then select the most resolution that is reasonable, which for the Intoxilyzer 8000 is two fractional digits. We evaluate the data in this form, checking to see if we have enough data to produce results that are statistically significant.

which should not be considered, the key was formed in this fashion, only if there were exactly two breath samples provided and if the breath test produced a numeric result.[297] For each breath test with two breath samples (and excluding those tests with three samples), for which the machine produced a numeric result, a variable named "SubjVol2" was calculated with the calculation key in Figure 6.

A value of "0.00" is calculated if the difference between the two breath sample volumes (rounded to two decimal places) is zero. For citizens who supplied a smaller second breath sample volume, a value of "M" (for "minus") and the numeric value were stored to "SubjVol2." Finally, for citizens who supplied a larger second breath sample volume, a value of "P" (for "plus") and the numeric value were stored to "SubjVol2." The Filemaker Pro computation is shown in Figure 6.

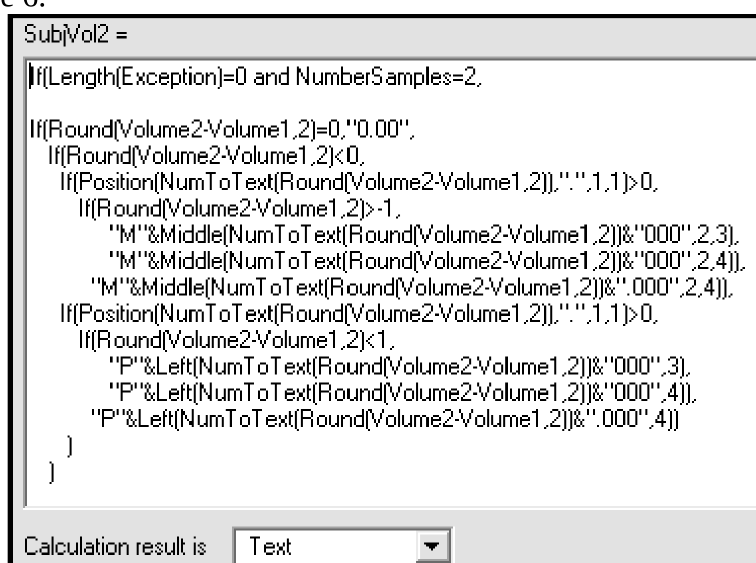

Figure 6: Filemaker Pro Assignment of Calculated Text Key for SubjVol2.

A second database was created which linked to this key "SubjVol2." The Filemaker Pro feature that permits a "Relationship" to be established was employed, causing all of the related breath test

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[297] By only including tests that produce a numeric result, we exclude tests that are excluded because they fail to agree within .02 of one another. In excluding these records, we produce a smaller error amount, and produce correlations that conservatively state the amount of error attributed to volume differences. If these tests were included in the studies, it is expected that the difference in alcohol would be greater at any given level of difference in volume.

records to average the difference in the reported alcohol amount for these breath test records.[298] The database which forms this index is called “VolumeDifference2,” and the database with the data for each breath test is called “TestMaster Old.” They are related by the Filemaker Relationship feature depicted in Figure 7, on the next page, which links all records in the database with Subject Test, which share a common difference in breath volume, to an indexing record in the database VolumeDifference2.

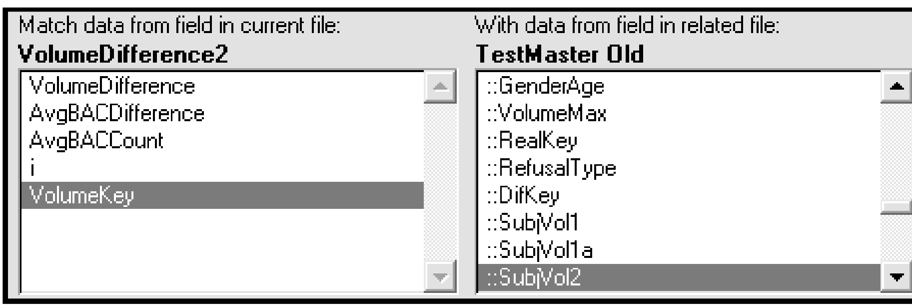

Figure 7: Filemaker Pro – Defining a Relationship for Aggregated Test Records

A variable named “AvgBACDifference” is created, which computes the average of every breath test record that is related because they share two breath test volumes that differ by the same measured difference between sample 2 and sample 1. The averaging is performed automatically by the Filemaker Pro database, and is defined when Filemaker is informed of the variable’s contents, as the averaging of another variable to define the new variable, as depicted in Figure 8 below.

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[298] FILEMAKER, http://www.filemaker.com/products/compare/ (last visited Mar. 22, 2012) (Filemaker Pro is a cross platform database program, commercially available for purchase from the website, filemaker.com, or at many stores such as Circuit City and Staples, either at brick-and-mortar stores or from internet website presence.).

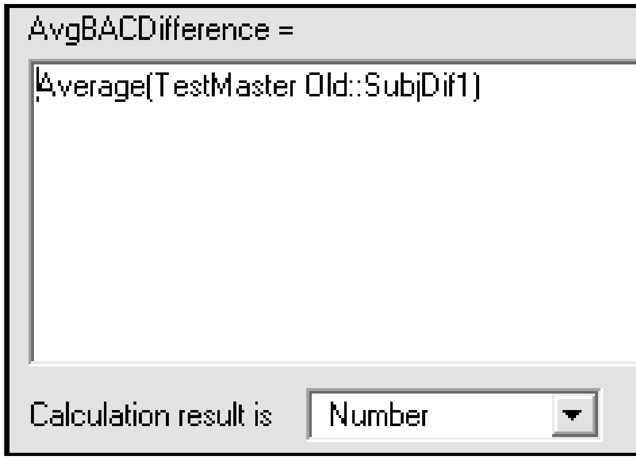

Figure 8: Filemaker Pro—Averaging BAC Difference Data with AVERAGE Function.

To create keys that range from -4.00 liters to +4.00 liters of difference between the two breath samples, there are 400 negative sample values possible, and 400 positive sample values possible, plus the zero difference possibility. A script was employed to create the 801 records with each possible difference value, to two decimal places. The most frequently occurring values for the difference between the two breath samples are those that are the smallest differences between the two breath sample volumes, and these are shown in Figure 9.

VolumeKey	VolumeDifference	AvgBACDifference	AvgBACCount
M.08	-.08	-0.00157210	423
M.07	-.07	-0.00273563	609
M.06	-.06	-0.00135255	451
M.05	-.05	-0.00147167	600
M.04	-.04	-0.00209228	531
M.03	-.03	-0.00229362	470
M.02	-.02	-0.00272105	570
M.01	-.01	-0.00058370	454
0.00	0	-0.00121486	1306
P.01	.01	-0.00060143	419
P.02	.02	-0.00015873	567
P.03	.03	0.00073499	483
P.04	.04	0.00028000	525
P.05	.05	0.00134291	557
P.06	.06	-0.00022068	503
P.07	.07	0.00146287	579
P.08	.08	0.00020267	375

Figure 9; Partial List of Records in Database – Listing the Key, Difference, Average BAC Difference, and Test Count

To plot the data, the data points are exported from Filemaker into a tab-delimited file, using the "Export" command in Filemaker Pro. Excel opens the tab delimited file, and saves the data into an Excel Worksheet. Once the data is in a worksheet, Excel creates plots of the data, plotting the volume difference along the X axis and the Average BAC difference along the Y axis. The result of this process can be viewed in Figure 10.

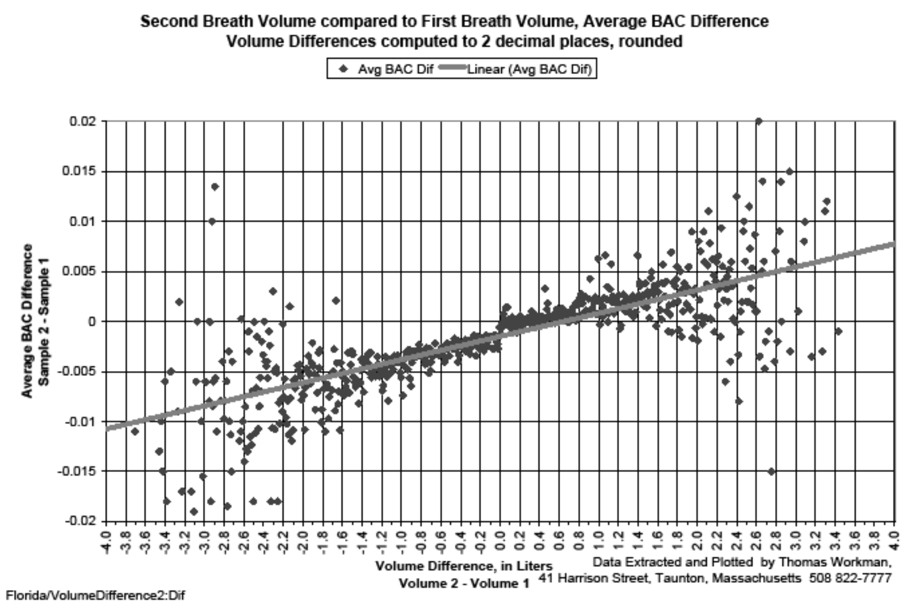

Figure 10: Volume Difference Reported to Two Digits to Right of Decimal, All Data Plotted.

A linear relationship between volume and breath alcohol is detected by Excel, and the regression relationship is computed and plotted by Excel.[299] Each data point is equally weighted by Excel when the linear relationship is calculated.

The table of data upon which Figure 10 is based is sparsely populated. Of approximately 800 possible legal values, only 311 contain at least 25 breath tests. The 0.924 correlation for establishing a

[299] Excel permits the analyst to click on a data point within a chart, and to specify that a "Trendline" should be plotted. The analyst can select a moving average, a linear regression, a polynomial, or one of several other types of curve fit. The analyst should select the appropriate based upon experience with data, and should evaluate the correlation functions to confirm that a regression selected is appropriate.

linear relationship between the two variables: Volume Difference and Measured Alcohol Difference, indicates that there is a very good correlation between the data and the linear regression computed by Excel for that data.

The correlation coefficient, which ranges from a -1 to a +1 (where a -1 indicates a negative correlation,[300] a zero means no correlation whatsoever, and a +1 means all the data lies upon the curve fit to the data) for the second graph which depicts points with at least 25 occurrences, is a 0.924. The correlation coefficient is computed based upon the following computation of the variable "r":

$$r = \frac{N\Sigma xy - (\Sigma x)(\Sigma y)}{\sqrt{[N\Sigma x^2 - (\Sigma x)^2][N\Sigma y^2 - (\Sigma y)^2]}}$$

Where:

N	=	number of pairs of scores
Σxy	=	sum of the products of paired scores
Σx	=	sum of x scores
Σy	=	sum of y scores
Σx^2	=	sum of squared x scores
Σy^2	=	sum of squared y scores

Figure 12: Standard Formula for Calculating the Correlation Coefficient for Linear Correlation

Some of the data plotted is based upon a small number of measurements, which do not form the foundation for a statistically significant set of data. These data points should be eliminated from the analysis. To refine the data fit, first we eliminate those data points which have fewer than 25 occurrences, to create Figure 11 on the next page.

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[300] A negative correlation indicates that the selected fit of data is an inverse relationship, that is to say, an increase in one variable results in a decrease in the related variable. A set of data with points randomly distributed in space would generate a coefficient of zero for a prospective fit of data. A coefficient that is near one indicates a strong correlation between the two variables. A coefficient of one indicates that one variable can be computed from the other.

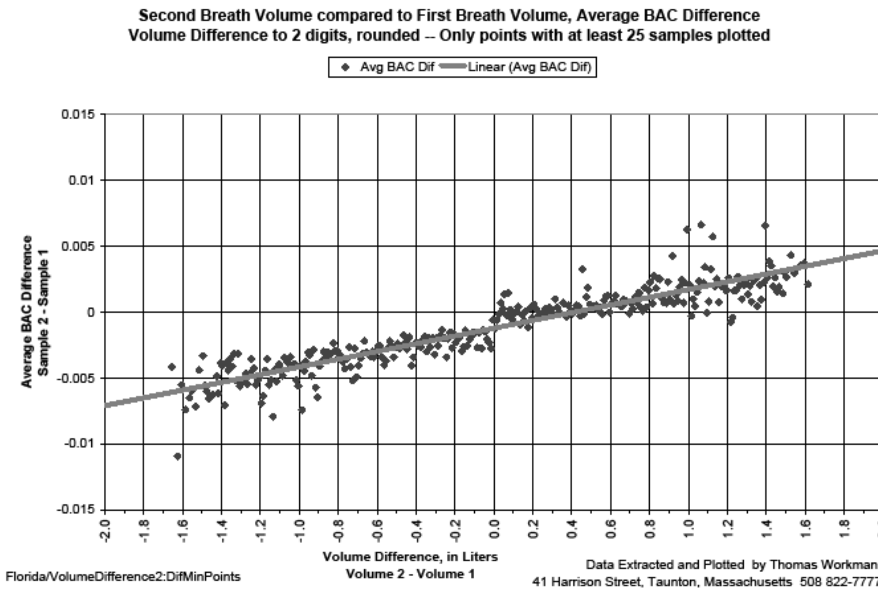
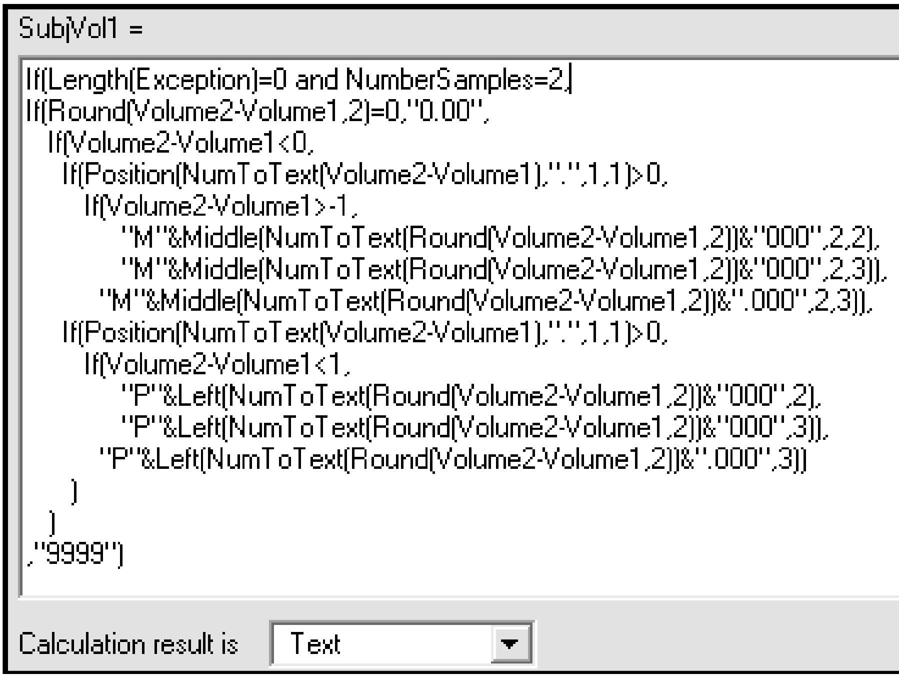


Figure 11: Volume Difference to Two Digits, Reporting Data with at Least 25 Breath Test.

In an attempt to refine the data, and develop a better correlation between the data and the relationship we are attempting to measure, the data is evaluated with the volume difference evaluated to one digit to the right of the decimal, depicting the difference in breath volume in tenths of a liter.

B. Aggregating the Data for Analysis to One Digit

The first analytical step was to truncate the key and report the data to one digit of accuracy. In doing so, the original data is rounded to two digits of accuracy, and one digit is selected to place in the key. The truncation to one digit was selected to conform to the reporting mechanism of the breath testing machines, which compute to more digits, and finally truncates to a single digit. The truncation of the key by eliminating the last digit was the only change made in the next step of the analysis and the computation of the key, which is in the main database of each Subject Test record. The computation in Filemaker Pro is depicted in Figure 13 on the next page.



```
SubjVol1 =
If(Length(Exception)=0 and NumberSamples=2,
If(Round(Volume2-Volume1,2)=0,"0.00",
  If(Volume2-Volume1<0,
    If(Position(NumToText(Volume2-Volume1),".",1,1)>0,
      If(Volume2-Volume1>-1,
          "M"&Middle(NumToText(Round(Volume2-Volume1,2))&"000",2,2),
          "M"&Middle(NumToText(Round(Volume2-Volume1,2))&"000",2,3)),
        "M"&Middle(NumToText(Round(Volume2-Volume1,2))&".000",2,3)),
    If(Position(NumToText(Volume2-Volume1),".",1,1)>0,
      If(Volume2-Volume1<1,
          "P"&Left(NumToText(Round(Volume2-Volume1,2))&"000",2),
          "P"&Left(NumToText(Round(Volume2-Volume1,2))&"000",3)),
        "P"&Left(NumToText(Round(Volume2-Volume1,2))&".000",3))
    )
  )
,"9999")

Calculation result is  Text
```

Figure 13: Filemaker Pro calculation for One Digit Key, Truncated

The database which contained the keys and variables which averaged the data in the master database was replicated, and keys with a single digit to the right of the decimal were loaded. The resulting data was exported to a tab-delimited file, and that data was again loaded into Excel. The Excel spreadsheet was a clone of the earlier analysis, and the X axis was modified to present only 81 points of data, instead of 801 possible values.[301]

[301] The range of -4.00 to +4.00 liters requires 800 values plus a value of zero, when the data is expressed to two digits to the right of the decimal. When only one digit to the right of the decimal is used, 80 values, plus one for zero, are required.

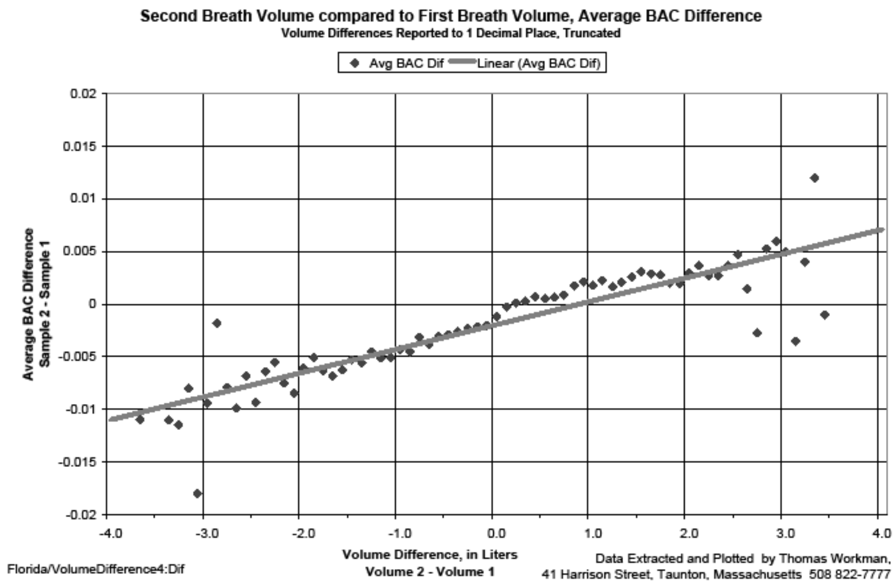


Figure 14: Volume Difference Computed to One Digit, Truncated.

The data points that contain fewer than 200 breath tests deviate from the linear relationship, and eliminating all volume differences that have fewer than 200 breath tests results in the chart shown in Figure 15. The range on the Y axis was selected because a 0.02 variation between the two samples is the maximum that is permitted under Florida regulations. The variation caused by volume, accounts for half of the acceptable deviation from the first sample to the second sample.

The correlation coefficient improved to 0.988, which indicates an excellent correlation from a statistical perspective. The fit of the data to the linear relationship can be observed by viewing the data on Figure 15.

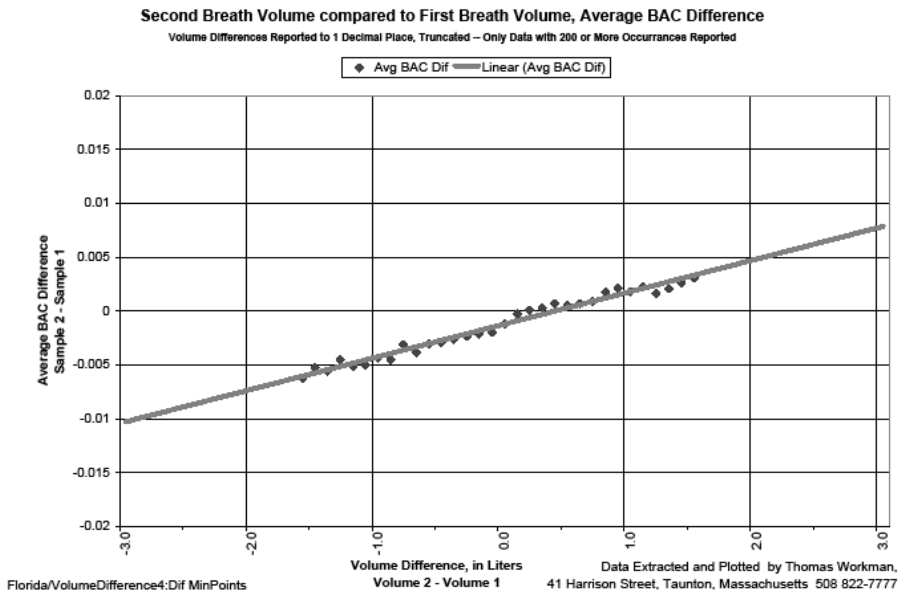


Figure 15: Volume Difference Expressed to One Digit beyond Decimal, Only 200 or More Tests

C. Refining the Data for Analysis to One Digit

By building the keys for aggregation with a truncation scheme, there exists a possibility of presenting the data in a fashion that overstates the slope[302] by a half of an increment at each end of the data. This results in 1/20th of a liter at each end of the data, or a total of 1/10 of a liter over the range of approximately 3 liters, or one part in 30. This could result in overstating the slope by approximately 3%.

A study of the data that makes up the aggregated values indicates that there are several classes of data that were incorrectly included in the data. The inclusion of tests which reported no alcohol in the breath on both samples, tended to cause the true deviation to be understated. There were also records which incorrectly reported results with samples that were insufficient (less than the regulatory 1.1 required breath sample). The final refining step in the analysis eliminated both of these categories from the data (that is, subjects with no alcohol in their system and breath tests which reported results when both samples did not have a 1.1 liter volume).

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[302] Upward or downward slant or inclination or degree of slant. MERRIAM-WEBSTER'S COLLEGIATE DICTIONARY 1174 (11th ed. 2004).

These adjustments can be seen in Figure 16, on the second line, which requires a 1.1 liter sample for both samples, and which requires a non-zero reading on at least one of the alcohol readings.

```
SubjVol1a =

If(Length(Exception)=0 and NumberSamples=2 and
(Volume2>=1.1 and Volume1>=1.1) and (Subject1>0 or Subject2>0),

If(Round(Volume2-Volume1,1)=0,"0.0",
  If(Round(Volume2-Volume1,1)<0,
    If(Position(NumToText(Round(Volume2-Volume1,1)),".",1,1)>0,
      If(Round(Volume2-Volume1,1)>-1,
          "M"&Middle(NumToText(Round(Volume2-Volume1,1))&"000",2,2),
          "M"&Middle(NumToText(Round(Volume2-Volume1,1))&"000",2,3)),
        "M"&Middle(NumToText(Round(Volume2-Volume1,1))&".000",2,3)),
    If(Position(NumToText(Round(Volume2-Volume1,1)),".",1,1)>0,
      If(Round(Volume2-Volume1,1)<1,
          "P"&Left(NumToText(Round(Volume2-Volume1,1))&"000",2),
          "P"&Left(NumToText(Round(Volume2-Volume1,1))&"000",3)),
        "P"&Left(NumToText(Round(Volume2-Volume1,1))&".000",3))
    )
  )
,"9999")

Calculation result is   Text
```

Figure 16: Filemaker Pro Calculation for One Digit Volume Difference, Rounded, Eliminating Zero Tests

When the new key is created in the master database and the database containing the keys is replicated and connected to the Master database through this newly created key, the data is exported to a tab delimited file, loaded into an Excel spreadsheet, and the graphs are updated with refreshed data based upon the refinements in the key, stated to one digit to the right of the decimal. The tests that are displayed belong to 53,579 subjects out of a total 91,098, or approximately 60% of the tests in the Florida dataset.

The first chart of the data presents all of the data points, as Figure 17, with a linear curve fitted to the total set of data points. The second graph, Figure 18, shows only those volume differences that have at least 200 breath tests of data. The linear fit is displayed, as computed by Excel. This second chart displays an extremely high correlation, with a statistical correlation of .995. Viewing the data in the chart confirms that the data points follow the curve computed by Excel, with extremely small deviations from that line. This means that the linear curve fits extremely well, and that variations in volume from the first to the second sample do in fact predict a larger or smaller measurement of alcohol in the larger or smaller volume breath sample.

Finally, a chart which displays breath test volume differences represented by fewer than 200 breath tests, but which do not utilize this sparse data in calculating the curve that fits an equation to the data, is shown as Figure 19.

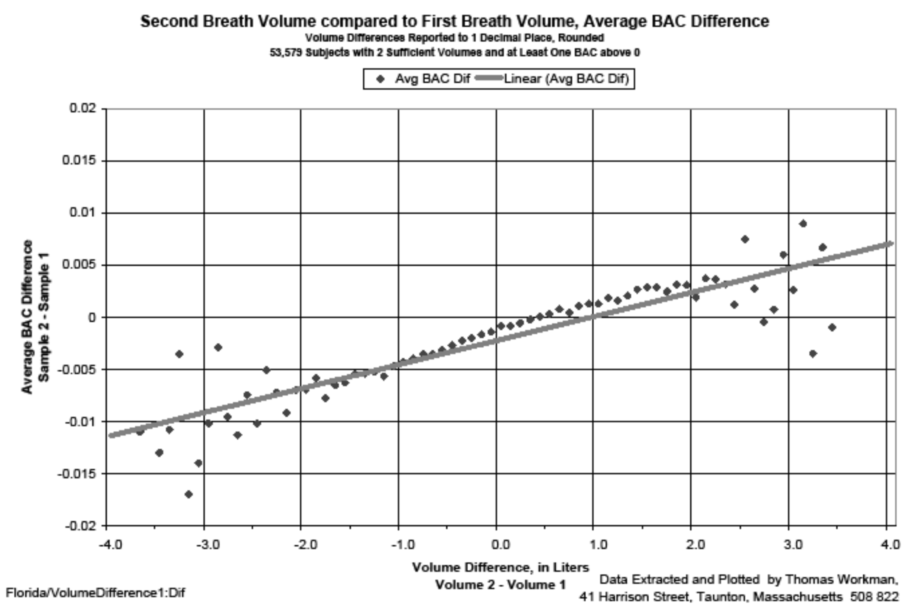

Figure 17: Volume Difference Expressed One Digit to Right of Decimal, Rounded, Eliminating Zero Tests.

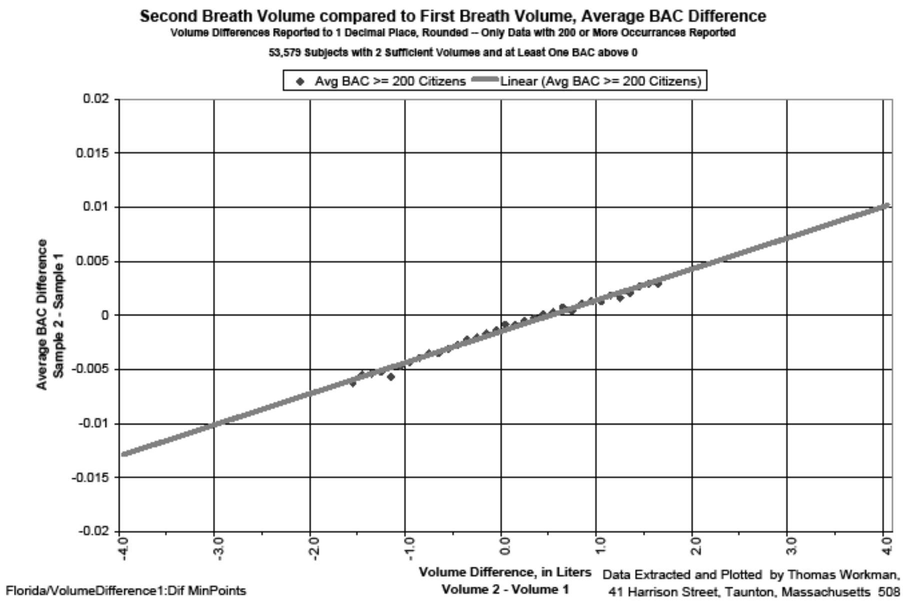

Figure 18: Best Fit of Data: Volume Difference to One Digit, Eliminating Zero tests, Only 200+ Tests.

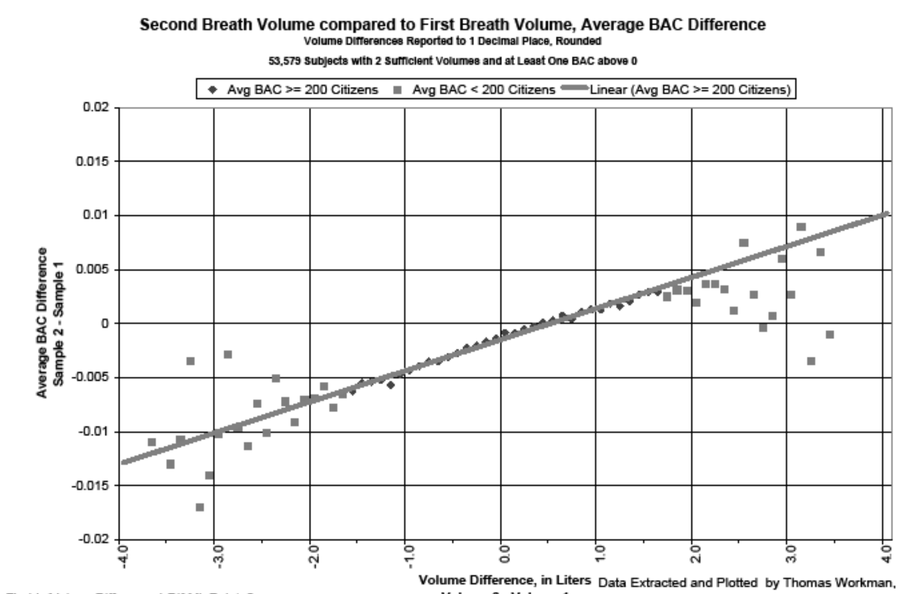

Figure 19: Linear Curve Fit to One Digit, Rounded, 200+ Tests – Showing <200 Test Data.

The range of volume deviations, from low to high, represents over seven liters of deviation (from -3.5 liters to +3.5 liters). Over that range, a 0.02 variation in the results, as directly correlated to the volume deviation, is demonstrated. That 0.02 variation represents half of the allowed deviation from a first sample to a final sample, as set forth in the Florida regulations (the second sample is said to be "good" if it is within plus or minus 0.02 of the first sample value).[303] Should a state set forth regulations that require the two samples to compute within 0.01, then the deviation based on volume differences, accounts for the entire variable space. Even at half of the allowed deviation, a significant portion of the variation is tied to volume, and that volume is directly controlled by the police officer administering the test.

The level of agreement in the relationship between volume and alcohol content is of significant importance. Whether the measurements were calculated to two decimal places, one decimal place with truncation, or with one digit utilizing rounding and eliminating zero tests – in all of these cases the results were virtually identical. From a statistical viewpoint, the data rounded to one digit has the best correlation, at 0.994; the single digit truncated data has the second best correlation at .988, and the least correlated, is the two digit data (though still exhibiting an excellent statistical correlation), which results in a correlation of .923.

D. How Does Breath Temperature Affect the Results

If the temperature of the subject is higher than the temperature assumed by the machine, then the results will be incorrectly elevated.[304] The Draeger 7110 and 9510 provide an option to measure the breath temperature and to correct the results by 6.5% for each degree Centigrade that the temperature of the subject exceeds 34 degrees Centigrade.[305] In Alabama, where the Draeger machines have the temperature option installed, 90% of the subjects tested had their results adjusted downward to account for higher temperature.[306] The average adjustment was in excess of 10%.[307]

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[303] FLA. ADMIN. CODE ANN. 11D-8.002(12) (2006).

[304] TAYLOR & OBERMAN, *supra* note 7, at 567-77 quoting Michael Hlastala, *Psychological Errors Associated with Alcohol Breath Testing*, THE CHAMPION 18 (1985).

[305] Alcotest 7110 Mk V Evidential, ttp://www.draeger.com/AU/en/products /alcohol_drug_detection/evidential/search.action (follow "Products Benefit"; follow "Measuring Breath Temperature").

[306] Dale A. Carpenter & James M. Buttram, *Breath Temperature: An Alabama Perspective,* 9 IACT NEWSLETTER 16, 16 (July 1998).

[307] *Id.*

Training for law enforcement officers does not teach the issue of temperature variation, nor are law enforcement officers trained to inquire whether a subject has a fever.[308] Some DRE examinations may take a body temperature as part of the evaluation, but such is rare for a straight DUI case.[309]

For cases that are close to the margin, that is a 0.08 to 0.09 as compared to the statutory limit for an adult, breath temperature can be the factor that adjusts the result so that it falls below the legal limit. In states that have aggravated offenses, with thresholds of 0.15 or 0.20, the same may apply. Those with a commercial driver's license may have statutory thresholds that are even lower.

VIII. CONCLUSION

The trial lawyer confronted with a motor vehicle-related alcohol offense that is associated with a breath test should understand the science of breath testing. Failing to recognize problems could result in the introduction of flawed and corrupted evidence that juries tend to rely upon in support of convictions. Knowing how a machine can go wrong is an important first step for the trial attorney.

This paper provides a foundation in the various areas of science that explain the operation of machines that measure alcohol in the human breath. When the science is wrong, or the process fails to follow proper steps, the results can be invalid, and thus not reliable.

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[308] *See e.g.*, Alcotest 7110 Mk V Evidential, http://www.draeger.com/AU/en/products/alcohol_drug_detection/evidential/search.action (follow "Products Benefit"; follow "Measuring Breath Temperature").

[309] Dominick A. Labianca, *The Flawed Nature of the Calibration Factor in Breath-Alcohol Analysis*, 79 J. OF CHEM. EDUC. 1237, 1239 (2002).