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Breath Alcohol Testers - Prevents Road Accidents

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Abstract

Four types of Breath Alcohol devices: Semiconductor Models (Breathalyzer), Fuel Cell Models (alcosensors), Infrared (IR) Spectroscopy Models (intoxilyzers), and Gas Chromatography (GC) Models (intoximeters) are described. Their function and work are examined and their effectiveness and possibility of error in DWI and DUI evaluations is discussed.

Keywords: *Alcosensors, BAC, BrAC, DUI, DWI, intoximeters, intoxilyzers.*

Introduction

Absorption of alcohol into the blood stream affects people by making them intoxicated. Alcohol intoxication in drivers can cause road accidents. When is the driver drunk? When is the driver under the influence of alcohol? Technically it is determined by the driver's blood alcohol level called the '*blood alcohol concentration*' *(BAC),* which indicates the degree of intoxication. In most countries 0.08 grams of alcohol per 100 mL of blood (BAC 0.08) is set as the legal limit beyond which the driver is considered to be legally drunk. Any driver with BAC > 0.08 can be considered to be driving under the influence of alcohol (DUI) or driving while intoxicated (DWI) and should not be allowed to drive.

Blood alcohol levels may be evaluated by using the Breathalyzer (DUI Attorney Lawyer 2005; Craig Medical Distribution Inc. 2005). There are two ways of measuring BAC (1) invasively by drawing a blood sample, and (2) non-invasively via breath, salvia, or urine samples. The latter is used mainly by law enforcement officials, and the former is generally performed by specialists at health care institutions.

Breath testing being quick and inexpensive is the most common non-invasive test.

How does a person's breath reveal the amount of alcohol consumed? When a person blows air into a breathalyzer the *breath alcohol content* (*BrAC*) is measured and converted into the corresponding BAC. In other words, BrAC is correlated with BAC. Continuous mixing of inhaled and exhaled air occurs in the lungs. Exchange of chemicals and air occur in the air-sacs called alveoli, which are surrounded by a fine network of capillary blood vessels. This is the path via which alcohol enters the blood stream.

Various types of electronic devices with alcohol specific sensors, such as lead selenide sensor (Hungler & Stevens 1997), can measure BAC. They commonly consist of a mouth piece and a sample chamber. The four basic types of instruments are described and their effectiveness is discussed.

The Breath Alcohol Testers

Breath alcohol testing devices were first developed for use by police in the 1940s. The Breathalyzer was invented by Dr. Robert Borkenstein of the Indiana State Police in 1954. An older model of the breathalyzer is shown in Fig. 1. (Breathalyzer.net 2005). Some prefer to classify breathalyzers based on color change due to alcohol chemical reaction.

The Models

There are four types of breathalyzers (Camping Survival 2005).

1. Semiconductor Models (breathalyzer)
2. Fuel Cell Models (alcosensors)

3. Infrared (IR) Spectroscopy Models (intoxilyzers)
4. Gas Chromatography (GC) Models (intoximeter)

Semiconductor Models (Breathalyzer): These types of units have the main advantage of being relatively inexpensive. Many semiconductor models are available and their use has increased rapidly. Classification involves three levels - Level I: Novelty Grade, Level II: Intermediate Grade, and Level III: Professional Grade. Some examples are shown in Fig. 2.

Breathalyzer process is based on the chemistry of alcohol **(**Craig Medical Distribution Inc. 2005)**.** The –OH group made up of one atom each of oxygen and hydrogen is an alcohol functional group. It is what makes compounds have alcoholic properties. Compounds that contain –OH in their molecule are all classed as alcohols. The alcohol in alcoholic beverages is ethyl alcohol (ethanol) with this molecular structure CH_3-CH_2-OH, which is often abbreviated as C_2H_5OH or EtOH (where Et = C_2H_5 ethyl group).

The Breathalyzer consists of a breath sampling system, two glass vials containing two identical chemical mixtures (sulfuric acid, potassium dichromate, silver nitrate and water) and a photocell system hooked to a meter for measuring the color change due to the chemical reaction.

The breath sample is bubbled through one vial, in which the chemical reaction, shown in Fig. 7 occurs.

1. Sulfuric acid absorbs the alcohol from the air.
2. Alcohol CH_3-CH_2-OH reacts with potassium dichromate KCr_2O_7 producing chromium (III) sulfate $Cr_2[SO_4]_3$, potassium sulfate K_2SO_4, acetic acid CH_3COOH and water H_2O.
3. The silver nitrate $AgNO_3$ is a catalyst that accelerates the reaction.

Color wise, the reddish-orange dichromate ion $Cr_2O_7^-$(where chromium oxidation state is 7+) changes to green chromium ion Cr^{3+}(where chromium oxidation state is 3+). The degree of this color change (caused by the change in chromium oxidation state from 7+ to 3+) is directly related to alcohol amount in expired air. For alcohol determination in exhaled air, the reacted mixture in the first vial is compared (using the photocell system) to the other vial containing the un-reacted mixture.

Fuel Cell Models (Alcosensors): Among handheld breathalyzers, fuel cell units are the top standard. People such as police officers, employers, and substance-abuse counselors use fuel cell units. The units are more specific towards alcohol detection and their accuracy is comparable to a professional semiconductor unit. Consequently there is less chance of false readings from interfering non-alcohol substances.

The sensor consists of a porous acid-electrolyte material sandwiched between two platinum electrodes. The platinum oxidizes alcohol molecules in exhaled air flowing past one side of the fuel cell producing acetic acid, protons and electrons.

Two free protons and two free electrons are released from the ethanol molecule when it is oxidized to acetic acid. The two electrons flow through a wire connected to the platinum electrode of the sensor, into an electrical-current meter and then to the platinum electrode on the other side of the cell.

The two protons move through the lower portion of the fuel cell and combine with oxygen and the above electrons, to form water. The electrical current produced depends on the number of free electrons, which in turn depends on the amount of breath alcohol oxidized. A microprocessor measures this electrical current, computes the total BrAC and converts it to equivalent BAC.

An example of a Professional Grade Fuel Cell unit is shown in Fig. 3. Some are designed as evidential testers and results can be used as evidence in a court of law.

Infrared (IR) Spectroscopy Models (Intoxilyzer): These units are extremely accurate and specific. They are often used as evidential testers in police stations. An example of an IR model is shown in Fig. 4.

It consists of a lamp that generates a broadband IR beam containing many wavelengths. The IR beam passes through the sample chamber and a lens focuses it onto a spinning filter wheel made of narrow-band filters that are specific for the alcohol wavelengths. The photocell detects the light passing through each filter and converts to an electrical pulse, which is relayed to the microprocessor that interprets the pulses and gives the BAC, based on the IR absorption.

Gas Chromatography Models (Intoximeter): These are based on the chromatographic separation principle. Alcohol peak is detected and its intensity is determined (Gomley 2004). They are called intoximeters.

What Is the Function?

The sole function is to monitor a person's breath and indicate the amount of alcohol that person has taken. It provides a quick rough quantitative measurement that allows setting of a legal limit for drunkenness. In most countries blood alcohol legal limit is 0.08, which translates to 0.08 grams of alcohol per 100 mL of blood.

In order to obtain an accurate correlation between blood and breath alcohol levels (typically 2100:1), the alcohol tester must be able to capture a deep lung-air sample. A person's vital capacity (volume of air that can be expelled without collapsing the lung) can range from 7L to 1L, depending on factors such as age, gender, physical condition, and disease status. If a digital readout is produced by the breathalyzer only after taking a very long breath sample, then there is a risk that the person won't be able to provide a breath sample. On the other hand, if the breathalyzer requires just a minimum amount of air before providing a digital readout, then the correlation between BrAC and BAC will be poor, the estimated BAC will appear to be lower than the true BAC (Craig Medical Distribution Inc. 2005).

BrAC and BAC Correlation

Alcohol is instantly absorbed into the blood capillaries of body tissues and organs, which are directly exposed. This rapid alcohol absorption occurs in the mouth tissues, the esophagus, the stomach and the small intestine. It is not metabolized (broken up), the chemical structure remains intact. Thus alcohol remains as a separate component of blood. As blood flows through the air sacs (alveoli) in the lung membranes, carbon dioxide molecules CO_2 (g) are exchanged for oxygen molecules O_2 (g). During this gas exchange alcohol, being highly volatile is released with the carbon dioxide molecules. Hence the amount of alcohol in expelled breath and the amount of blood alcohol is related.

This molecular exchange in the lung tissues allows the correlation between blood stream alcohol concentrations and the expelled breath. It can be established by measuring the alcohol evaporation rate in solution. This rate is then expressed as a constant ratio of blood alcohol concentration (BAC) to breath alcohol concentration (BrAC). Equivalent BAC can readily be estimated by calibration with a standard BrAC. The breath alcohol to blood alcohol ratio is 2,100:1. Thus 2,100 mL of alveolar air contains the same alcohol amount as 1 mL of blood. If 100 mL of blood contains 0.08 grams of alcohol the BAC is 0.08 (Craig Medical Distribution Inc. 2005).

Calibration

During the final production and assembly process electronic breath analyzers are individually pre-calibrated, using a laboratory simulator device flow meter such as GUTH34C and standard alcohol solutions of specific concentrations.

Each new test procedure is preceded by a microchip recycle and zero balancing, hence re-calibration is not necessary under normal use. Accuracies are determined by comparing simultaneous measurements of BrAC by the electronic device and a gas mass spectrometry BAC of a blood sample.

Many independent variables are present at any instant of testing. Hence conclusions cannot be drawn, and correlations between successive tests cannot be made. Each test result is specific to the test conditions and the sample analyzed; and is independent of other test results.

Some of these test specific variables include volume of breath sample, presence and amount of other gases in the sample, concentration of alcohol molecules in the mouth, presence and amount of other gases detected in the immediate environment and others.

Therefore each test result can only be interpreted independently and exclusively of other test results. This produces a common misconception and false assumption that the devices can be "tested" by repeated tests, or worse still by erroneously anticipating a value for any given test.

Discussion

How Effective Are They?

The effectiveness depends on the accuracy of measured data. The desired accuracy is dictated by the purpose for which the device is to be used. Equipment for personnel, commercial, or law requires different accuracies.

Accuracy expectations are related to the cost of models. Models at the high price range use high quality components and can provide accurate test results. On the other hand, lower cost models do not yield laboratory accuracy or specificity. But they are more cost effective for certain cases like personnel detection. They produce qualitative dependable results for such usage. For evidentiary purpose more accurate equipment that matches laboratory accuracy is demanded. Choice of equipment thus depends on the intended purpose.

But overall these devices are effective enough to detect dangerous drunk drivers and prevent accidents on the road. However there are chances of mistakes from instrument errors.

The alcohol sensor is highly sensitive and will not function correctly when wet or damaged. Its response can also be affected by temperature and humidity. Therefore a margin of error is always present. This need to be considered and an allowable margin is required. The unit must be kept in a secure, clean, dry place at room temperature. Regular calibration check against standards is essential.

Accurate readings of blood alcohol levels cannot be obtained until at least thirty minutes after the most recent alcoholic drink. If measured earlier, the breath sampling is more from the mouth rather than the lungs, and a higher reading may result. Truly accurate BAC is only obtained from blood sample measurements.

A worrying fact is the possibility of mistaken identification of all compounds that contain CH_3 - methyl groups as ethyl alcohol [Note ethyl alcohol contains a methyl group CH_3CH_2OH]. Examples of such compounds are shown in Table 1. Acetone CH_3COCH_3 and acetaldehyde CH_3CHO both contain methyl groups and can be found in the human breath. Out of the one hundred chemicals in the breath 70-80% contains methyl groups. Infrared breath machines will detect each of these as ethyl alcohol.

The effect is *additive* and the more non-alcohol methyl groups detected the higher will be the blood-alcohol reading. Thus all the non-alcoholic compounds in the breath will have a cumulative effect and a magnified error will result. Hence there is always a probability of a person being mistakenly charged with DWI or DUI, especially diabetics who tend to have acetone breath (San Diego DUI 2002).

Anyone who drives a car under the influence of alcohol is a public menace. The seriousness of DWI (driving while intoxicated) has made law enforcement authorities resort to strict enforcement of DWI statutes (San Diego DUI 2002). Many physical methods of breath-alcohol analysis to evaluate suspected OUIA (operating under the influence of alcohol) drivers are currently used. But the *Breathalyzer*, developed by Borkenstein and based on alcohol chemistry, remains the tester of choice (Craig Medical Distribution Inc. 2005). It is an enforcement instrument that serves as a reliable, noninvasive tool of forensic alcohol analysis.

Suggestions for Improvement

- Make sensors more specific to alcohol and more accurate.
- Promote better understanding of device reliability.
- Make the device record data like age, weight, body size. Different weight indicates different body water, which can affect reading accuracy.

Conclusion

While keeping roads safe by preventing DWIs or DUIs authorized users should be aware that field device accuracies cannot match those of precisely controlled laboratory results obtained from gas flow meter or mass spectrometry; that abnormal readings are mostly due to user carelessness; and that all field test results are approximate. Hence borderline readings have to be considered carefully.

It must be kept in mind that there is always a probability for wrongly enhanced BAC readings, especially when diabetics who tend to have acetone breath are involved. Health condition of suspect DWI needs to be considered (San Diego DUI 2002).

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Fig. 1. An Older Breathalyzer.

a) Novelty Grade. b) Professional Grade.
Fig. 2. Semiconductor Models.

Fig. 3. Professional Fuel Cell Model.

Fig. 4. IR Model.

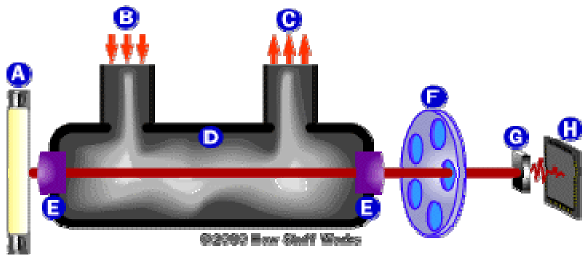

Fig. 5. Schematic Diagram of an Intoxilyzer.

Fig. 6. Fuel Cell Detectors.

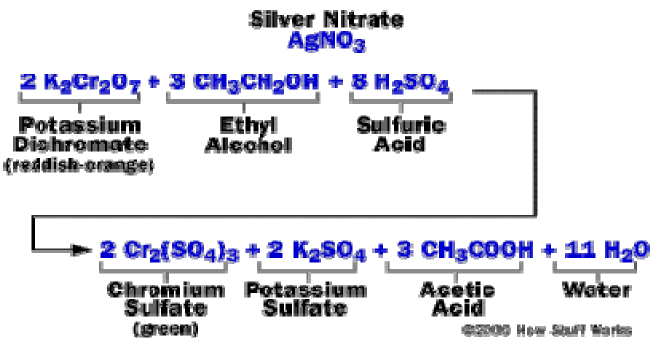

Fig. 7. Chemical Reactions in Breathalyzers.

Table 1. Compounds with CH_3 – can be misread as ethanol (San Diego DUI 2002)

• Isopropyl Alcohol	• Ethyl chloride
• Propane	• Acetic Acid
• Butane	• Butadiene
• Propylene	• Dimethylether
• Methane	• Dimethylamine
• Ethane	• Dimethylhydrazine