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THE FORENSIC TOXICOLOGY OF ALCOHOL AND BEST PRACTICES FOR ALCOHOL TESTING IN THE WORKPLACE

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Preface

This report was commissioned by the Canadian Nuclear Safety Commission in order to provide the forensic toxicological aspects of alcohol and recommendations for best practices for alcohol testing in the workplace.

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The Forensic Toxicology of Alcohol and Best Practices for Alcohol Testing in the Workplace

Executive Summary

Alcohol is currently the most common and serious drug that can affect safety in the workplace. The forensic toxicology of alcohol, including its absorption, distribution and elimination and blood alcohol concentration (BAC) calculations, is briefly discussed in this report. Alcohol is a depressant drug and can impair human performance at BACs as low as 20 mg/100mL. This impairment increases with increasing BAC.

The extensive scientific literature confirms that the proposed BAC limits for the workplace of 20 to 39 mg/100mL (resulting in temporary removal of a safety sensitive worker from duties) and 40 mg/100mL or greater (resulting in a policy violation and removal of the worker from duties) are scientifically valid. As shown by BAC calculations these BACs (20 mg/100mL or greater) will not affect social drinkers who have several glasses of wine with dinner or several bottles of beer in the evening and go to work the next morning.

The best and most objective method of determining impairment of human performance due to alcohol is by determining the BAC. The best method and practice of determining BACs in the workplace is by evidential breath alcohol testing. Initial screening for alcohol may be conducted rapidly and efficiently using a passive alcohol sensor.

Breath alcohol testing using an evidential breath testing instrument, operated by a qualified breath alcohol technician using the proper procedure, will provide the most reliable, rapid and noninvasive results and is the best practice for alcohol testing in the workplace. Urine alcohol testing and standardized field sobriety tests are not recommended.

1.0 Absorption, Distribution and Elimination of Alcohol

Alcohol is a unique drug. It is a simple, small molecule (CH_3CH_2OH), volatile, and is water soluble. Its pharmacokinetics (what the body does to the drug) are also relatively simple, especially when compared to drugs like tetrahydrocannabinol (THC). Alcohol is relatively non-toxic and can appear in the blood in high concentrations relative to other drugs. For example the blood alcohol concentration (BAC) is measured in milligrams ($1/1{,}000^{th}$ of a gram), whereas the blood THC concentration is measure in nanograms ($1/1{,}000{,}000{,}000^{th}$ of a gram). This makes the detection of alcohol much easier compared to many other drugs. The forensic aspects of absorption, distribution and elimination of alcohol will be discussed briefly.

1.1 Absorption

Alcohol is usually consumed orally and since it is such a small water soluble molecule, it is able to pass through the stomach and intestinal walls and appear within minutes in the blood stream. Alcohol requires no digestion and passes through the various membranes of the body by simple diffusion (1). No significant blood alcohol concentrations can be obtained through the skin by frequent use of an alcohol-based hand sanitizer (2), or from inhalation of alcohol fumes or paints through the lungs (3).

1.2 Distribution

As soon as alcohol is absorbed it readily mixes into the blood. The heart pumps the blood which contains alcohol to all areas of the body. Alcohol is distributed into the various tissues according to the water content. Tissues that contain a high water content (such as the brain, liver, kidneys) will absorb more alcohol than tissues such as bone or fat which have a low water content and will contain virtually no alcohol. The pathway that alcohol follows for distribution is:

Mouth ⇨Stomach/Small Intestines ⇨ Liver ⇨ Right side of heart ⇨ Lungs ⇨ Left side of heart ⇨ All tissues of the body ⇨ Right side of heart

Alcohol is therefore distributed by the blood supply into the total body water (TBW) (4). In general, men consist of about 70% body water distribution and women are approximately 60% (5). Larger persons in general will also contain more body water than lighter individuals. The greater the TBW of a person the more the alcohol that has been consumed will be diluted. Hence as seen in Table 2 of the section 1.5 on BAC calculations, a 200 pound male will have a BAC of 14 milligrams of alcohol in 100 millilitres of blood (mg/100mL) if 1 oz of liquor is distributed instantly throughout the TBW, whereas a 90 pound woman (Table 1) will have an equivalent BAC of 37 mg/100mL, more than double that of the larger man for the same 1 oz of liquor. Tables 1 and 2 list these instantly distributed BACs as a Blood Alcohol Equivalent (BAE) for various body weights of women and men based on one oz of liquor (40%).

1.3 Elimination

Once alcohol has been absorbed into the bloodstream, it will be eliminated at a fixed constant rate by the liver. Approximately 95% of the alcohol dose will be eliminated by the liver by a series of enzymatic reactions as follows:

Alcohol → Acetaldehyde → Acetate → Carbon Dioxide (CO_2) + Water (H_2O)

Only about 5% of the alcohol is eliminated unchanged into the breath, sweat and urine. Hence physical exercise (6) or sweating (7) will not significantly increase the rate of alcohol elimination.

The BAC obtained and whether it is increasing or decreasing depends on the interaction of elimination and absorption. When the absorption of alcohol into the bloodstream is greater than the elimination by the liver, the BAC will increase. When absorption is slowed as with food, the elimination and absorption are in balance and a plateau may occur. When drinking of alcohol ceases and the absorption of alcohol becomes less than the elimination the BAC will decrease. This process is illustrated below.

Absorption > Elimination; BAC↑
Absorption = Elimination; BAC→
Absorption < Elimination; BAC ↓

The range of elimination of alcohol varies from individual to individual but generally ranges between 10 and 20 mg/100mL/h (8). Light drinkers tend to have a lower rate of elimination than heavier drinkers as the liver becomes more efficient in metabolizing alcohol with chronic use (9). The average rate of elimination of alcohol for social drinkers is 15 mg/100mL/h and this rate will be used in the BAC calculations section 1.5.

1.4 Alcoholic Beverages

All alcoholic beverages are produced by the conversion of sugars into alcohol by yeast. Alcohol, which is also known as ethanol, grain alcohol or neutral spirits, is the principal psychoactive component of alcoholic beverages. The other components (known as congeners) give the alcoholic beverage its unique taste, odour and colour. The three main types of alcoholic beverages are beer, wine and liquor.

Beer is typically produced from barley or cereal grains which first have to be malted in order to break down the starch into sugars so that the yeast can produce alcohol. Hops are usually added to beer for flavouring and as a stabilizing agent. The alcoholic content of beer is usually between 4 and 6% alcohol by volume (v/v).

Wine is fermented fruit juice but is commonly made from grapes. Red wines are made from grapes, which has their skins attached during pressing. White wine can be made from red grapes when their skin is removed before pressing but red wine cannot be made from white grapes. The alcohol content of wine usually ranges from 10 to 15% v/v.

Spirits or liquors have a much higher alcohol concentration than beer or wine and are made by distilling the alcohol produced by the yeast. Distillation takes into account the differences in the boiling points of alcohol (79ºC) and water (100ºC) to produce an alcohol concentration of approximately 40% v/v.

No matter what the alcoholic beverage, a drink is a drink is a drink, when the alcohol contents are compared.

Figure 1: A drink is a drink is a drink, all of these volumes (in mL) of alcoholic beverages contain the same amount of alcohol

All of the above beverages, displayed in Figure 1, have the same amount of alcohol and will result in the same BAC when consumed over the same period of time. The amount of alcohol is based on a simple ratio. So for example, 3 glasses of wine contain the same amount of alcohol as 4.5 oz of liquor (3 X 1.5). Likewise, 4 bottles of beer contains the same amount of alcohol as 6 oz of liquor (4 X 1.5).

1.5 BAC Calculations

Simple blood alcohol concentration calculations can be conducted by combining the knowledge of the water content or the TBW of an individual, the rate of elimination and the amount of alcohol consumed over a period of time. Two examples will illustrate the principles of estimating the BAC of an individual.

Table 1: Blood Alcohol Equivalent for Women

Weight in pounds (kg)	BAE for 1 oz of liquor (mg/100mL)
90 (41)	37
110 (50)	30
130 (59)	26
150 (68)	22
170 (77)	20

Table 2: Blood Alcohol Equivalent for Men

Weight in pounds (kg)	BAE for 1 oz of liquor (mg/100mL)
120 (55)	24
140 (64)	20
160 (73)	18
180 (82)	16
200 (91)	14
220 (100)	13

Example 1:

Between 6:00 p.m. and 8:00 p.m. a 130 pound woman and a 200 pound man consume 2 glasses of wine each, with dinner. What would their BACs be at 8:00 a.m. when they started work? This example shows how several glasses of wine with a meal in the evening will not cause a positive BAC at work in the morning.

2 glass of wine = 3 oz of liquor

From Table 1, the BAE for the woman is 26 mg/100mL for one oz of liquor. Thus, for 3 oz it is 78 mg/100mL. Using an average rate of elimination of 15 mg/100mL/h, she would have a zero BAC in approximately 5 hours after the **start** of drinking (i.e. 78÷15) or at 11:00 p.m.

From Table 2, the BAE for the man is 14 mg/100mL for one oz and thus for 3 oz, it is 42 mg/100mL. Using an average rate of elimination of 15 mg/100mL/h he would have a zero BAC in 3 hours after the start of drinking (i.e. 42÷15) or at 9:00 pm.

In order for the woman to have a BAC of 20 mg/100mL at 8:00 a.m. she would have to consume approximately **6 glasses of wine**. In order for the man to have a BAC of 20 mg/100mL at 8:00 a.m. he would have to consume approximately **11 glasses of wine**.

Example 2:

At 6:00 p.m. after work, a 160 pound man goes to a sports bar and consumed 6 bottles of beer while watching the hockey game and finishes drinking at 11:00 p.m. What would his BAC be at 8:00 a.m. when he started work the next morning? This example also shows that even the consumption of relatively large amount of beer would not result in a positive BAC the next morning.

6 bottles of beer = 9 oz of liquor

From Table 2, the BAE for a 160 pound man is 18 mg/100mL for each oz of liquor consumed. Thus for 6 bottles of beer (9 oz), it is 162 mg/100mL (9 X 18). He would have a zero BAC in approximately 11 hours after the start of drinking or 5:00 a.m. In order for the man to have a BAC of 20 mg/100mL at 8:00 a.m., he would have to consume approximately **13 bottles of beer**.

Automatic BAC calculators which do not involve manual calculations as shown in this report can be obtained online by googling ***"BAC Calculators"***. I would recommend using the Alberta government website at the Alberta Gaming and Liquor Commission (AGLC) and The Police Notebook. BAC Calculators may also be obtained by downloading various apps. No matter how you calculate the BAC, it will only be an approximation. The only method to determine your exact BAC at any given time is by using an evidential breath testing instrument (EBTI).

2.0 Breath Alcohol Testing

Breath alcohol testing is one of the oldest areas of forensic science and was first described by the famous English Victorian physician and researcher, F.E. Anstie in the year of the Confederation of Canada (10). Breath alcohol testing of drivers by the police in Canada has been routinely conducted since 1956 and was enshrined as the method of choice for evidential alcohol analysis in the Criminal Code in 1969 (11). There are numerous advantages of breath alcohol testing compared to blood or urine as follows (12):

- **Breath alcohol testing is noninvasive, no needles are required as for blood samples, hence there is no possibility of injury or transmission of disease**
- **No privacy or human dignity issues, as in the collection of urine samples**
- **Breath samples cannot be tampered with, unlike urine samples[1]**

[1] A merchant ship was grounded in a harbour in Croatia. The breath alcohol concentration of the master of the ship was determined and was 165 mg/100mL. The urine alcohol concentration was only 20 mg/100mL and was found to have been doctored by the master(13)

- **Breath test results are known immediately, rather than days or weeks for blood and/or urine alcohol testing and so the appropriate action can be made immediately**

- **No continuity (chain of custody) or storage or transportation issues. No special tubes, biohazard refrigeration, or identity seals are required, as the subject blows directly into the breath testing instrument**

- **No special medical staff or phlebotomists are required for breath testing compared to blood**

- **No problem with real or alleged blood or needle phobia of the person who is breath tested**

- **Urine is a pooled sample stored in the bladder and can remain positive for alcohol even when the BAC is zero (i.e. false positive)(14)**

For these reasons, several tens of millions of breath alcohol tests are conducted globally each year, primarily by the police for enforcement of traffic safety but increasingly for testing of alcohol in the workplace. Therefore, this report recommends that breath alcohol testing should be the method and best practice for testing for alcohol in the workplace.

2.1 Principles of Breath Alcohol Testing

When blood containing the volatile drug, alcohol, passes through the lungs, the amount of alcohol in the blood is in a fixed ratio with the amount of alcohol in the breath (i.e. equilibrium). Hence, by analysis of deep lung air, the BAC can be determined. The lungs are especially adapted for rapid and efficient gas exchange between the blood and breath. They contain approximately 250 million small sacs known as alveoli and the lungs have a large surface area of more than 55 m^2 which allow a rapid exchange of volatile gases such a carbon dioxide, oxygen and volatile drugs such as alcohol.

The diffusion of alcohol from the blood to the breath is based on Henry's Law (1803) which states that

> *"When the water solution of a volatile compound is brought into equilibrium with air, there is a fixed ratio between the concentration of the compound in the air and its concentration in water. This ratio is constant at a given temperature." (15)*

The blood: breath ratio (BBR) for alcohol, which has been employed in evidential breath alcohol testing in Canada and the United States and many other countries, is 2100:1. That is 2100 mL (2.1 L) of breath contains the same amount of alcohol as 1 mL of blood. It has been known for over 50 years that using the BBR of 2100:1 will underestimate the

BAC by about 10% and the BBR for alcohol in humans is closer to 2300:1(16). Hence breath alcohol testing will tend to underestimate the BAC and give a “benefit of the doubt” to the person being tested.

There are 2 main limitations to breath alcohol testing, the mouth alcohol effect (MAE) and poor breath samples (or cooperation of the subject).

a) Mouth Alcohol Effect

Alcohol in the oral cavity from a recent drink or use of an alcohol-containing compound can falsely elevate the breath alcohol test results as the residual alcohol in the mouth is added to the alcohol exhaled from the lungs. This effect lasts for approximately 10 minutes and thus can be avoided by ensuring the subject does not consume any alcoholic beverage for approximately 10 minutes before breath alcohol testing and conducting a second breath test approximately 10 minutes later (17). In addition, EBTI that use infrared light to measure breath alcohol also have a mouth alcohol detector (18).

Besides alcoholic beverages, alcohol is also found in mouthwashes (19), cough medicine (20), asthma inhalers (21), energy drinks (22), and bread (23). But the mouth alcohol effect of these products cause only a slight elevation of the breath test results and last for only 2 to 4 minutes. This is in agreement with the conclusion of a detailed study on the mouth alcohol effect (MAE) which stated:

> *“In our view the incidence and effects of mouth alcohol on breath testing have been exaggerated. Even if it does occur its effect is small and short-lived. We do not believe that mouth alcohol results in unjust prosecutions.” (24)*

b) Poor Breath Samples (Cooperation of the Subject)

Another limitation of breath alcohol testing is that the co-operation of the subject is required to obtain a proper breath sample. If the subject does not provide a full exhalation as requested by the breath alcohol technician (BAT), then the measured BAC result can be lower by 20 to 40% (25). In addition most EBTIs have systems to ensure a proper breath sample is obtained. Good coaching and encouragement by the BAT to the subject can also assist is obtaining a proper breath sample.

2.2 Methods for Measuring Breath Alcohol Concentrations

The main detectors for measuring breath alcohol concentrations in evidential breath testing instruments used by the police in Canada are infra-red (IR), fuel cell (electrochemical detectors) or a combination of both IR and fuel cell. The Taguchi cell (n-type semiconductor) detector found in numerous inexpensive “keychain” testing devices is not recommended as it produces unstable and inaccurate results (26).

a) Infrared Detectors

Infrared light is light which cannot be seen by humans as it is at a wavelength longer than visible red light. The alcohol molecule (C_2H_5OH) will absorb IR light maximally at wavelengths of approximately 3.4 and 9.4 micrometers (um). The basic design of these instruments consists of a sample chamber which the subject exhales into via a mouthpiece. As IR light is passed across the sample chamber, any alcohol in the breath of the subject will absorb the IR light causing a decrease in the intensity or brightness of the IR light. This decrease in brightness is measured electronically and converted into an alcohol concentration. A simple schematic of the Intoxilyzer 5000 is shown in Figure 2:

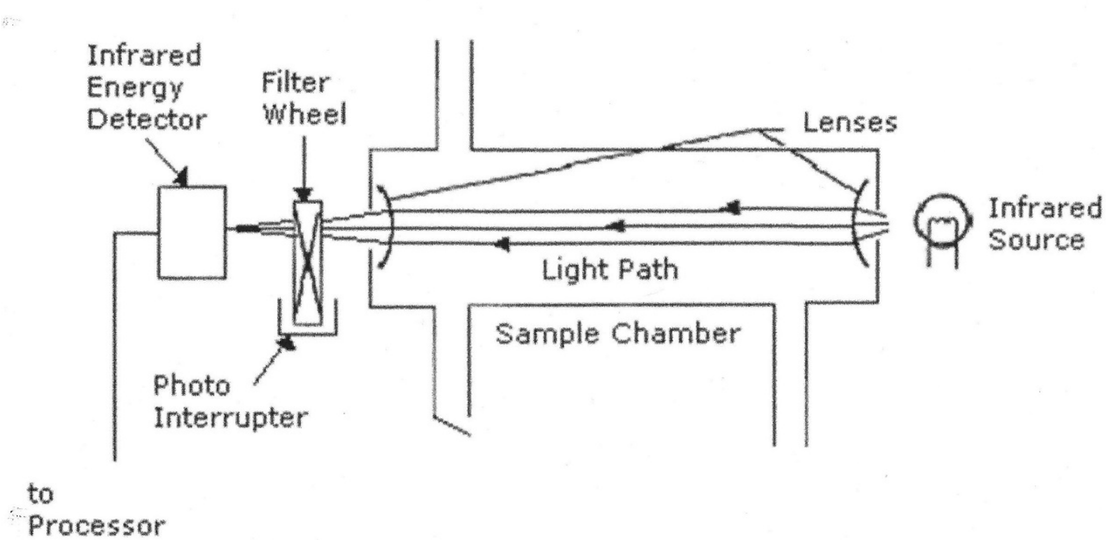

Figure 2: Schematic of the Intoxilyzer 5000 (an example of an EBTI)

The absorption of IR light by alcohol can be expressed by the Lambert-Beer Law, which relates the exponential decrease in the intensity of IR light to the concentration of alcohol in the exhaled breath as it is introduced into the sample chamber as follows (18):

$$\mathbf{I = I_o\, e^{-abc}}$$

Where: **I** = the final intensity of IR light (after breath sample is introduced into the sample chamber
I_o = initial intensity of IR light (only ambient air in the sample chamber)
e = mathematical constant (2.71)
a = absorption coefficient of alcohol

b = path length (the distance the IR light travels through the sample chamber
c = concentration of alcohol in the sample chamber after a forced exhalation

Modern evidential breath alcohol testing instruments utilized by the police in Canada rely on multiple wavelengths of IR light to detect mouth alcohol, assist in obtaining a deep-lung breath sample, and allow for specificity of the analysis. EBTIs used by the police that use multiple IR wavelengths include, the Intoxilyzer 5000C, the Intoxilyzer 8000C, the BAC Datamaster C and the BAC DMT.

b) Fuel Cell

Another detection technique used by EBTI is the fuel cell or electrochemical detector. The basic principle of the fuel cell is that it oxidizes volatile compounds such as alcohol in the breath and produces a direct electrical current which is directly proportional to the alcohol concentration as follows:

$$\mathbf{CH_3CH_2OH \quad + \quad 3H_2O \rightarrow \quad 2CO_2 \quad + \quad 12H+ \quad + \quad 12e^-}$$

The alcohol is oxidized eventually to carbon dioxide, hydrogen and electrons respectively. The hydrogen combines with oxygen in the air to form water.

The disadvantage of the electrochemical detector is that it only analyses alcohol at a single point in the exhalation, and not the entire exhalation curve as IR permits. Thus the fuel cell cannot detect mouth alcohol. The Alco-Sensor IV RBT/IV and Breathalyzer 7410 CDN with Printer are examples of this type of evidential breath testing instruments used by the police in Canada.

c) Dual EC/IR

This type of EBTI incorporates both the IR and fuel cell methods. Typically the IR is used to monitor the breath sample, to determine the uniformity of the breath sample ,and to check for mouth alcohol. The last part of a forced exhalation is then analysed by the fuel cell to determine the alcohol concentration. Examples of EBTI that are approved for use by the police in Canada include Alcotest 7110 Mk III Dual C and Intox EC/IR.

2.3 Types of Breath Testing Instruments

The four major types of breath alcohol testing devices which could be considered for improving workplace safety by alcohol testing are, as follows:

a) Passive alcohol sensors

Passive alcohol sensors (PASs) are portable, simple devices that determine the presence of alcohol in the ambient air, such as when a person is talking. They have been used successfully by the police as a screener in the US and increase the detection of drinking drivers (27). They may be considered as a rapid screen for alcohol in the workplace and if positive can provide reasonable suspicion for an evidential breath alcohol test. Training on the use of these devices would be much shorter and easier than for EBTI or standardized field sobriety tests (SFSTs) and represent a more objective method of screening for alcohol.

A wall mounted, voice activated PAS- the Lion Alcosentry- has been used to screen persons for alcohol prior to entering a factory, prison, or soccer stadium (28).

b) Automobile ignition interlock devices

The use of automobile ignition interlock devices (AIIDs) has been proven to be an effective countermeasure against drinking and driving and these devices have been installed in the motor vehicles of thousands and thousands of drivers across Canada (29). Before the motor vehicle will start, a breath test is required by the driver using the AIID. The BAC cutoffs are usually the same as those recommended in this report. A “Warn” (i.e. warning) occurs at BACs of 20 mg/100mL and a “Fail” at BACs of 40 mg/100mL and above. The installations of AIIDs in motor vehicles used in the workplace may increase safety. There are numerous companies that install and maintain AIIDs across Canada and therefore no trained personnel would be required at the workplace.

c) Approved Screening Devices

Approved Screening Devices (ASDs) are used by the police on the road to conduct roadside breath tests to determine if the driver has a BAC > 49 mg/100mL (WARN) or of > 99 mg/100mL (FAIL). The ASDs are listed in the Approved Screening Devices Order and include the Intoxilyzer 400D, the Alco-Sensor FST and Drager Alcotest 6810.

All ASDs are small portable, battery operated devices which can be operated with minimal training and as such can be operated by security personnel if desired.

d) Evidential breath testing instruments

The Alcohol Test Committee (ATC) of the Canadian Society of Forensic Sciences has provided Recommendations, Standards and Procedures for Evidential Breath Alcohol Instruments for the Federal Justice Ministry since 1967 (30). The ATC publishes and updates its policies regularly and evaluates and recommends which breath alcohol testing instruments are reliable and can be used by the police for the enforcement of the impaired driving laws (31). The best practice for workplace breath alcohol testing would be to use an instrument that has been evaluated, tested and recommended by the ATC as Approved Instruments and published in the Canada Gazette.

The most recent Approved Instruments are:

Table 3: Approved Instruments Listed in the Criminal Code of Canada

Intoxilyzer 5000C
BAC Datamaster C
Alco-Sensor IV/RBT IV
Breathalyzer 7410 CDN with printer
Alco-Sensor IV/RBT IV-K
Alcotest 7110 MKIII Dual C
Intoxilyzer 8000C
DataMaster DMT-C
Intox EC/IR

It is recommended that these evidential breath alcohol testing instruments be used for workplace alcohol testing (32).

2.4 Training of the Breath Alcohol Technician

The training course of the breath alcohol technician (BAT) should be conducted under the auspices of the manufacturer of the evidential breath testing instrument (EBTI). The majority of the training and course material, however, should be prepared by a forensic alcohol toxicologist, preferably one with extensive forensic experience in Canada and one who has taught police officers on breath alcohol testing. The BAT should be trained on specific model of EBTI.

The course should be of at least 3–day in duration (20 hours) and should include both theoretical and practical training, as follows:

Theoretical training should include:

- appropriate aspects of chemistry, physics, physiology, and pharmacology of alcohol
- principles of breath alcohol tests
- principles of the instrument technology
- design and theory of operation of the EBTI
- operational procedures of the EBTI
- instrument maintenance and service (if applicable)
- record keeping and quality assurance procedures
- appropriate aspects of workplace safety and alcohol testing

Practical training should include:

- testing with alcohol standards and other volatile substances
- conducting at least 15 breath tests on nondrinking subjects
- conducting at least 15 breath tests on 3 drinking subjects

There should also be written and practical examinations.

2.5 Annual training/testing of the BAT

There should be regular annual training and testing of the BAT, which could be web based.

2.6 Conversion Training

If the BAT is required to operate another model of EBTI, a one day (8 hour) conversion training course should be conducted, which includes training specific to the particular model of EBTI. Practical training should include at least 15 breath tests of non-drinking subjects and at least 5 breath tests of one drinking subject.

2.7 Breath Testing Procedure

The evidential breath testing instrument should be placed in an indoor room that has adequate light, ventilation and sufficient stable counter space for the instrument and accessories. No unauthorized persons should have access to the EBTI. No alcohol based hand sanitizers, or other solvents should be used in the room.

1. The subject shall have consumed only water for at least 10 minutes prior to the test. Bread, asthma inhalers, mouth sprays, and energy drinks may cause a false positive breath test result (mouth alcohol effect) for several minutes after use and should be avoided.

2. A blank test shall be conducted and shall not give a result greater than 10 mg/100mL.

3. A calibration check should be conducted (either wet bath or dry gas) and the result of the EBTI should be within ± 5% or 5 mg/100mL (whichever is greater) of the target value of the alcohol standard.

4. A new unopened mouthpiece should be inserted into the EBTI and the BAT should explain to the testing subject what is required and how to provide a proper breath sample. If the EBTI result of the test subject is less than 20 mg/100mL, the testing sequence is terminated.

5. If the EBTI result of the test subject is 20 mg/100mL or greater a second breath test at least 10 minutes later must be conducted to confirm the first breath result.

6. During the 10 minutes wait between breath tests, the test subject must be in the presence of the BAT. The subject may only consume tap water or bottled water from a bottle opened by the BAT.

7. The difference between the first and second breath tests should not exceed 20 mg/100mL. If the difference is greater than ±20 mg/100mL a third test should be conducted at least 10 minutes later and the discrepant result as determined by the BAT be discarded.

8. The lowest of the 2 valid breath test results should be used for the determination of appropriate action.

9. No other confirmatory test such as blood, oral fluid or urine alcohol testing should be required.

10. If a person fails to provide 2 proper breath samples into the EBTI without just cause (such as a severe lung disease), it shall be deemed a policy violation and the person should be removed from duties.

2.8 Maintenance and Record Keeping

Annual maintenance should be conducted on the EBTI by either the manufacturer or its agent. A maintenance log should be kept for each EBTI and should include documentation of parts replaced and problems that were fixed. During the annual maintenance all the stored data should be downloaded and kept with the instrument. A printed record of all positive breath tests (BAC of 10 mg/100mL or more) should also be kept with the maintenance log.

3.0 Blood Alcohol Concentrations and Impairment of Human Performance

Alcohol is the most readily available depressant drug globally and is currently the most common drug detected in workplace accidents and fatalities (33, 34). Thousands of studies have been conducted for over one hundred years on the effect of alcohol on human behavior and abilities, such that there is a well-established relationship between BAC and impairment of human performance. As one study reported:

> *"A major characteristic of the acute effects of ethanol ingestion is a good correlation between ethanol-induced disruption in behavior and the BAC. For the most part, an effect occurs as the BAC rises and dissipates as ethanol is eliminated from the body. Consequently the BAC can be a predictor of behavioral disruption and this predictability is the basis for the validity of using BACs in alcohol testing programs. (35)"*

Another forensic issue of importance is the distinction between impairment of human abilities and skills, and intoxication. Impairment is a decreased ability to perform a task compared to a zero BAC, whereas intoxication refers to the obvious physical effects of alcohol such as slurred speech, diminished co-ordination, and staggered gait and is commonly referred to as being "drunk". Impairment of human performance by alcohol occurs well before the intoxication due to alcohol is visible. Thus while an intoxicated person is definitely impaired, a person impaired by alcohol (which would cause an increased risk of an accident), may not seem intoxicated (36).

3.1 BAC Ranges and Actions

The following is a tabulation of increasing ranges of BACs and the associated actions that are taken by various organizations or countries. Actions at the BAC ranges proposed for workplace testing in this report have been bolded.

Table 4: BAC Ranges and Actions Taken by Various Jurisdictions

BAC Range	Action
0 to 9 mg/100mL	**Alcohol not detected**
10 mg/100mL+	Removal of license from Graduated Licensed drivers in Ontario and other provinces
10 to 19 mg/100mL	**Traces of alcohol detected**
20 mg/100mL	The BAC limit for driving in Sweden and other Scandinavian countries US Department of Transportation requires employers to remove safety-sensitive employees from duty at this BAC
20 to 39 mg/100mL	**Temporary removal of safety- sensitive worker from duties recommended** A “warn” occurs on AIIDs in most provinces and many US states and the car is unable to start
40 mg/100mL +	**Policy violation and removal of worker from duties is recommended** A “fail” occurs on AIIDs and the car is unable to start Temporary removal of a driver’s license in Saskatchewan
50 mg/100mL+	Temporary removal of all drivers’ licenses in other provinces in Canada US National Transportation Safety Board in 2013 recommends the illegal BAC for driving in the US be decreased from 80 mg/100mL to 50 mg/100mL BAC limit for drivers in most EU countries
80 mg/100mL+	Criminal code BAC for operation of a motor vehicle in Canada and the BAC limit in the US and the UK
160 mg/100mL+	Increased penalties for driving at this BAC in Canada and many other countries

3.2 Impairment in the BAC Range of 20 to 39 mg/100mL

Various laboratory studies have been conducted and impairment has been observed at BACs of **20 mg/100mL** such as

- pursuit tracking (37),
- detection of peripheral stimuli under both noise and quiet conditions (38),
- recovery of the eyes from glare (39),
- reaction time to onset of motion (40), and
- coordination (41).

At a BAC of **30 mg/100mL** various studies have demonstrated impairment of faculties such as

- frequency of eye movements and field of view (42),
- choice reaction time (43),
- eye-hand coordination (44), and
- distance judgment (45).

A recent study on the effect of BACs of between **20 and 40 mg/100mL** on auditory and visual reaction time concluded that:

> *"Increasing the alcohol dose from zero to moderate resulted in an increase of the mean total response time for auditory stimuli of about 0.2 seconds in comparison to about 0.1 seconds for visual stimuli. Under moderate alcohol doses, workers such as visual display terminal operators, motor vehicle drivers or operators of dangerous machinery who must respond quickly to visual and particularly to auditory alarms may experience increased probability of accident owing to alcohol-induced slowed response and increase probability of erroneous judgments. (46)"*

All of these studies are consistent that workers in safety-sensitive positions should be suspended or temporarily relieved at BACs of between **20 and 39 mg/100mL**.

3.3 Impairment in the BAC Range of 40 to 49 mg/100mL

Greater impairment occurs at higher BACs. Hence, more aspects of human faculties are impaired, in addition to those that occur at BACs of 20 to 39 mg/100mL. At a BAC of **40 to 49 mg/100mL,** impairment has been shown of faculties such as:

- standing steadiness (47, 48),
- simple reaction time (49),
- visual acuity at a distance (50), and
- time perception (51).

3.4 Impairment in the BAC range of 50 mg/100mL+

More abilities are impaired as the BAC increases to 50 mg/100mL and greater, such as

- smooth oculomotor tracking (52),
- nystagmatic eye movements (53),
- simple visual and auditory reaction time (54), and
- visual motor coordination (55).

A detailed review of studies related to the effect of low doses of alcohol on driving related skills concluded that:

> *"The evidence reviewed here indicates that alcohol does not uniformly impair all aspects of performance. Areas such as oculomotor function and divided attention performance demonstrate that impairment can occur at BACs as low as 0.02% [20 mg/100mL]. It is clear moreover that BACs of 0.05% [50 mg/100mL] or more impair nearly all of the important components of driver performance. There is sufficient evidence however to demonstrate that BACs of 0.05% [50 mg/100mL] and more produce impairment of the major component of driver performance; reaction time, tracking, divided attention performance, information processing, oculomotor functions, perception and other aspects of psychomotor performance.(56)"*

The increasing safety risk with increasing BAC can be best illustrated by the following Table 5 which shows the relative percent decreased performance (57).

Table 5: Relative Decrease in Human Performance Based on a Review of Laboratory Studies

Blood Alcohol Concentration (mg/100mL)	Mean Percent Relative Decrease In Human Performance
0	0
20	45%
40	68%
60	85%
80	95%
100	98%

The equation used in this tabulation was performance (+)/performance (0) -1 X 100.

4.0 Alcohol Impairment, Physical Observations and Standardized Field Sobriety Tests

In contrast to the scientific, reliable, accurate and objective method of determining impairment due to alcohol by measuring BACs using an EBTI, physical observations of the individual to determine impairment tend to be a subjective method of determining whether someone is under the influence of alcohol. Physical observation is prone to false negatives (due to alcohol tolerance) and false positives (due to medical conditions).

4.1 Alcohol Tolerance

It is difficult to detect drivers with a BAC of greater than 80 mg/100mL by physical observations alone. In one study in Alberta, police officers were only able to detect 8% of the drivers who had a BAC > 80 mg/100mL (58). In another study, 18 trained police officers assessed the alcohol impairment of 36 students who had either a low BAC (44 to 53 mg/100mL) or a high BAC (58 to 65 mg/100mL). The police officer's judgment of the students' BACs ranged from 0 to 134 mg/100mL in the low BAC group and 0 to 150 mg/100mL in the high BAC group (59). The study concluded that police judgments of alcohol intoxication are "highly subjective" and "potentially unreliable".

The main problem with relying on physical observations alone to determine alcohol impairment is that heavy, chronic drinkers and alcohol-dependent individuals develop a "tolerance" to the obvious physical effects of alcohol. At high BACs that would cause a social drinker to manifest obvious drunkenness, whereas, the alcohol-tolerant individual may show only slight physical effects, although both types of individuals would still be impaired by alcohol.

In order to correct this deficiency in Canada, police officers can conduct breath alcohol screening at the roadside, using an ASD, for "reasonable suspicion" that the driver had been drinking. The use of approved screening devices have greatly improved the detection of drivers with BACs as high as 310 mg/100mL who would normally have not been arrested (60). Once the driver fails the roadside alcohol screening test an EBTI test is then conducted and it is the result of EBTI that determines the charge. The screening tests results were confirmed by the EBTI result in 99.8% of the drivers tested at the roadside by police in Toronto (60).

Not only do police have difficulty in determining whether a driver is intoxicated by alcohol, even medical doctors may also have difficulty with determining alcohol intoxication in alcohol-dependent patients with a high tolerance to alcohol (61). In this study by Perper et al. (1986), 110 alcoholics who voluntarily entered a detoxification centre were examined clinically by medical doctors who formed an opinion as to the degree of alcohol intoxication of the patient. A blood sample was then collected from the patient and the BAC was determined. The BACs of the patients ranged between 0 and 440 mg/100mL. It was observed that of the 54 patients with a BAC of over 200 mg/100mL, 35% showed no signs of clinical intoxication. The authors concluded:

> *"From a medico-legal point of view, the interpretation of a high blood alcohol concentration as an indicator or incapacitation, manifest drunkenness, or as an exclusive cause of death is unreliable. Therefore, for example, a bartender who serves a "chemically intoxicated" person (that is, having ipso facto a high BAC) should not be accused of serving alcohol to an obviously "clinically intoxicated" individual. One should not, however, conclude that apparent clinical sobriety in a chemically intoxicated alcoholic reflect safe or acceptable driving capabilities. Driving combines a complex array of physical and mental activities that require anticipatory judgments, estimated of distance, peripheral vision and short reaction time to unexpected hazards, all of which are known to be adversely affected by alcohol. (61)"*

4.2 Diseases/Medical Conditions which May Mimic Alcohol Intoxication

In addition to the false negative cases caused by alcohol tolerance in alcohol-dependent individuals (i.e. a person with a high BAC and no obvious signs of intoxication), physical tests are also prone to false positives, in which the apparently alcohol-intoxicated individual is suffering from a medical condition that mimic alcohol intoxication and actually is alcohol-free.

Some of these conditions include (62):

- **Hypoglycemia**
- **Diabetic ketoacidosis**
- **Cerebrovascular accidents**
- **Seizure disorders**
- **Subdural hematoma**
- **Concussion Syndrome**
- **Hypoxia**
- **Hypotension**
- **Hyper/Hypo-thermia**

Of course the results of the EBTI will help distinguish these conditions from alcohol intoxication and prevent false positive results of apparent alcohol intoxication.

4.3 Standardized Field Sobriety Tests

Standardized field sobriety tests (SFSTs) were first developed by the police in the US in the 1970s to enhance the detection of drinking drivers since their laws did not allow for preliminary roadside breath alcohol screening of suspected drivers using an ASD, as in Canada. SFSTs consist of 3 sets of physical tests (63):

- **Horizontal Gaze Nystagmus (HGN)**
- **Walk and Turn (WAT)**
- **One-Leg Stand (OLS)**

These tests were originally designed to detect drivers with a BAC of over 100 mg/100mL, which was the BAC limit for driving in the US until it was lowered recently to 80 mg/100mL. The accuracy of SFSTs decreases at BACs 80 mg/100mL and lower and are not effective at BACs of 20 to 50 mg/100mL, which are an important BAC range for workplace alcohol testing.

One criticism of field sobriety tests is that they are difficult to perform and almost seem designed for failure. For example, 14 police officers who watched videotapes of 10 male and 11 female sober subjects (i.e. their BACs were 0) performing OLS, WAT and other tests determined that 46% of these alcohol-free subjects were impaired by alcohol (64).

In addition, SFSTs require at least 5 to 10 minutes to conduct properly whereas the passive alcohol screener breath test only requires about 15 seconds to conduct (65). There are also issues of training and maintaining the more complex and difficult skills required to conduct a SFST. Training for SFSTs requires approximately 3 days for the police and they can maintain their skill level by conducting numerous tests on drinking drivers. Whereas in the workplace it would be more difficult to maintain the skill level of conducting SFSTs as the incidence of drinking is so much lower in the workplace than in driving.

One researcher concludes for SFSTs that:

> *"Abandon all such tests, because even the best of them (HGN) produces substantial numbers of false positive (and negative) results and move more in the direction of chemical-based[i.e. breath tests] enforcement. (66)"*

This report agrees with that conclusion and recommends that the best practice for workplace screening for alcohol is by determining the BAC of the employee by use of EBTI.

4.4 Non-expert opinion of alcohol intoxication (Graat vs R.)

The Supreme Court of Canada has answered the question of whether a person needs specialized training or to be an expert to determine whether someone is intoxicated by alcohol and thus unfit to drive a motor vehicle (67). In an appeal of the conviction of Anthony Graat of his ability to drive impaired by alcohol, presented by the famous defence lawyer Edward Greenspan, the court ruled that:

> *"Nor is this a case for the exclusion of non-expert testimony because the matter calls for a specialist. It has long been accepted in our law that intoxication is not such an exceptional condition was would require a medical expert to diagnose it. An ordinary witness may give evidence of his opinion as to whether a person is drunk. This is not a matter where scientific, technical or specialized testimony is necessary in order that the tribunal properly understands the relevant facts. Intoxication and impairment and impairment of driving ability are matters which the modern jury can intelligently resolve on the basis of common ordinary knowledge and experience. The guidance of an expert is unnecessary (67)"*.

Thus anyone in a workplace should be able to identify without additional training or expertise that a person is intoxicated or drunk due to alcohol. Such an intoxicated person should then be required to have an EBTI instrument to determine the BAC and objectively show whether the intoxicated condition was due to alcohol.

5.0 Conclusions

The various forensic toxicology aspects of alcohol as applied to the workplace have been presented in this report. An extensive literature review validates the proposed BAC limits for the workplace of 20 to 39 mg/100mL (temporary removal of a safety sensitive worker from duties) and 40 mg/100mL or greater (as a policy violation and the removal of the worker from duties). Evidence was presented to justify employer actions at these BACs where impairment of human performance is deemed to pose a safety risk.

The best method from a forensic toxicology perspective, to determine impairment of human abilities by alcohol, is to determine the BAC. The best method to determine the BAC in the workplace is by conducting a breath alcohol test using an EBTI, operated by a trained BAT. Urine testing for alcohol is not recommended as urine is a pooled sample and may produce a false positive result. Also there are privacy and tampering issues with urine testing that do not occur with breath analysis.

Standardized field sobriety tests are not recommended as they have a high false positive and negative rate compared to breath alcohol testing. SFSTs also require greater skill and training than breath alcohol testing and SFSTs require more time to conduct than breath testing.

In conclusion, this report recommends breath alcohol testing as the best practice for workplace alcohol testing.

Recommendations

1) Breath alcohol screening should be conducted upon arrival to the workplace. This screening may be incorporated into current procedures or by using an independent passive alcohol screener.

2) If alcohol is detected in the initial screening, a portable ASD test should be conducted at the scene, and if a BAC of 20 mg/100mL or greater is detected then an EBTI test at the nursing/first aid station should be conducted by trained medical personnel. Appropriate action should be taken according to the BAC determined by the EBTI.

3) Since breath alcohol screening is recommended to be conducted upon arrival, different cutoff BACs would not be required for varying lengths of time the worker has been at work (which is the approach taken by the US NRC, Part 26 103). In the event that testing does occur partway through a workers shift (e.g., post-incident or for cause testing), it is recommended that the uncorrected EBTI result be employed.

Abbreviations and Explanations

>	greater than
<	less than
=	equals to
AGLC	Alberta Gaming and Liquor Commission
AIID	automobile ignition interlock device
ATC	Alcohol Test Committee
BAC	blood alcohol concentration
BAE	blood alcohol equivalent- instantly obtained BAC per oz of liquor consumed distributed through TBW
BAT	breath alcohol technician
ºC	degrees Celsius the metric measure of temperature
CO_2	carbon dioxide
EBTI	evidential breath testing instrument
EC	electrochemical a type of detector for alcohol also known as the fuel cell detector
EC/IR	electrochemical/infrared dual detection system for breath alcohol testing
g/100mL	grams of alcohol in 100 millilitres of blood (the unit for measurement of alcohol in the US)
h	hour
H_2O	water
HGN	Horizontal Gaze Nystagmus- one of the tests of SFST

IR	infra-red light which is used for the detection of alcohol
m^2	square metres
MAE	mouth alcohol effect
mg/100mL	milligrams of alcohol in 100 millilitres of blood (the unit for measurement of BAC in the Criminal Code of Canada). It can be converted into BAC units used in the US (g/100mL) by dividing by 1,000
mg/100mL/h	milligrams of alcohol in 100 millilitres of blood per hour (used for measuring the rate of alcohol elimination)
mL	millilitres
ng	nanogram
OLS	One Leg Stand- one of the tests in the SFST
oz	ounce
PAS	passive alcohol sensor
RT	reaction time
SFST	Standardized Field Sobriety Tests
TBW	total body water
THC	tetrahydrocannabinol, the psychoactive drug in marihuana
UAC	urine alcohol concentration
um	micrometers
v/v	volume in volume, a unit to determine the volume of alcohol in the volume of an alcoholic beverage
WAT	Walk And Turn- one of tests in SFST

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