



# PERFORMANCE CHARACTERISTICS OF THE INTOXILYZER® 9000

– AN INDEPENDENT ASSESSMENT AND REVIEW

*In support of a poster presentation for the 21<sup>st</sup> International  
Association of Forensic Sciences (IAFS 2017) Triennial Meeting  
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## AN IMPORTANT CAVEAT

This assessment on an individual Intoxilyzer 9000 was done under circumstances of complete access to the device, but with limited time constraints. Simply put, we did not have the time necessary to run exhaustive testing on the 9000 to generate the raw data necessary to ensure a proper statistical analysis. Over a ten-hour period, we were able to run about 60 individual tests on the 9000, and inspect its interior and component parts. We need further access to these devices to draw meaningful conclusions.

*As an editorial position, Counterpoint, calls on the manufacturers of ALL breath test instruments, and all government agencies that operate and control them, to make these devices, used in criminal proceedings as evidentiary collection devices, available for independent review and analysis. Transparency regarding both the physical and software design, their manufacture, and the maintenance and operation of the devices is critical in maintaining a degree of openness and trust towards the numerical BrAC results generated.*



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## INTRODUCTION

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The opportunity to conduct an independent analysis and performance review of a new breath alcohol testing device is rare, particularly the higher-end, evidentiary-level units. Access to these technologies is stringently controlled by both their manufacturers and the police and government agencies that control them. Additionally, state agencies are often reluctant to publish the results of their official assessments and analysis of the devices<sup>1</sup>.

When given the opportunity to perform such a review on a new Intoxilyzer 9000, I designed a series of experiments to quickly analyze the overall performance of the device. I attended the device's location with a colleague to determine its suitability and reliability in a number of key areas, including:

- Overall design and ease of use
- Accuracy in determining *in vitro*<sup>2</sup> BrAC<sup>3</sup> levels using a simulator
- The ability of the device to determine the presence of Fresh Mouth Alcohol using a Residual Alcohol Detection System (RADS) or the so-called “*slope detector*”
- Reliability in reporting BrAC readings that are highly specific to ethanol
- The effect of Radio Frequency Interference on the device



Figure 1 - The Intoxilyzer Model 9000 and optional USB keyboard

This article will provide a general overview of the operational characteristics of the Intoxilyzer 9000. We will assess the apparent accuracy of the device using simulator readings, and examine the ability of the device to “flag” false positive reading caused by fresh mouth alcohol contamination. We will also examine the unit's specificity towards ethanol detection and its ability to identify the presence of various interferent chemicals. Finally, we will assess the capacity of the device to detect *Radio Frequency Interference* (RFI), and what, if any, effects on a breath alcohol reading are created by RFI.

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<sup>1</sup> Regarding the Intoxilyzer 9000, only the Georgia Bureau of Investigation - Division of Forensic Sciences has publically released their sanctioned assessment on the device. You may wish to run the search parameters “Georgia replaces Intoxilyzer 5000” or “Georgia Intoxilyzer 9000” into your favorite search engine... Other agencies have performed reviews and assessments on the Intoxilyzer 9000, some even going so far as to destroy their own raw data rather than allowing the information into the public domain (the Colorado Department of Public Health and Environment).

<sup>2</sup> A Latin term used in medical and scientific literature, *in vitro* means “in the glass” and refers to biochemical testing done outside the normal biological setting, as in a test tube, or otherwise artificially in a lab setting. Using a Simulator to artificially recreate a biological Breath Alcohol Concentration (BrAC) is considered an *in vitro* test.

<sup>3</sup> I will use the term **BrAC** to denote a *Breath Alcohol Concentration*, and **BAC** to refer to a *Blood Alcohol Concentration*.

# THE INTOXILYZER® 9000 – AN OVERVIEW

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## REFERENCE MATERIALS:

### Counterpoint Article:

*The New Intoxilyzer 9000*  
*The Intoxilyzer 9000 & the Unknown*

### Author:

Mark Thiessen  
 Jan Semenov

### Reference:

Volume 1, Issue 1  
 Volume 1, Issue 3

The Intoxilyzer 9000 uses a Windows™ Mobile platform touchscreen interface for operator input, and control of the breath test sequence. Additionally, the unit we had access to offered a generic computer USB keyboard. Our unit also had an external laser printer that provided a printout of breath test results. Both the external keyboard and printer are optional – the unit can be operated without them using the onscreen touch keyboard, and an optional internal printer.

The 9000 can also incorporate an optional barcode reader or magnetic swipe scanner to allow automatic input of both operator certification and test-subject driver's license information. The 9000 also can run portably on external battery power using a DC adapter (12V DC @ 8 Amps).

Upon initiating the testing process, the operator is prompted to enter information: Name of test subject and operator, driver's license number, occurrence number, etc. The entered options are user configured. The unit then performs an internal diagnostic check, and begins the largely automated breath test sequence.

## INTERNAL DIAGNOSTIC CHECK

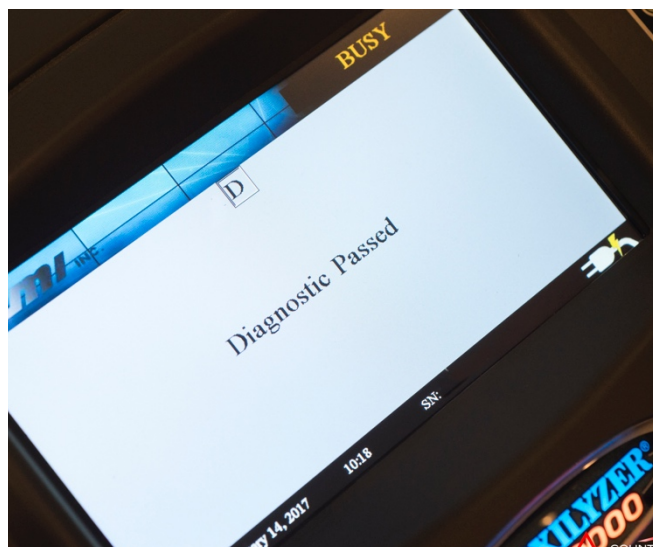


Figure 2 - When the 9000 is powered up, it performs an internal diagnostic test.

I have no information on what specific internal measurements are taken and standards compared to in order to determine the pass or fail parameters of this diagnostic, nor do I know what factors are necessary for the diagnostic to either “pass” or “fail”. As such, I cannot comment on the overall reliability of the Internal Diagnostic Check algorithm. It was established that the internal diagnostic checks on both the 5000, and to a lesser extent, the 8000 could be compromised by disconnecting various internal components and circuitry, and still generate a “DIAGNOSTIC PASS” message.

## AIR BLANKS

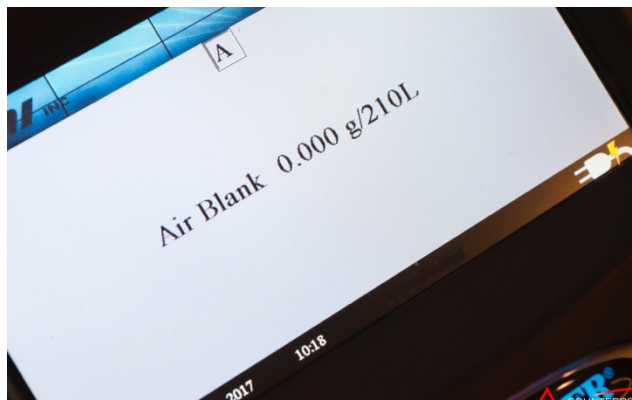


Figure 3 - When a test is initiated, the 9000 performs an initial Air Blank to establish a Zero reference point, and to determine the suitability of the ambient room air.

Similarly, the *Air Blanks* performed at the beginning and throughout the breath test sequence may well be “floating Zero” air blanks.

See Counterpoint Volume 2, Issue 1, Article 6, “*Best Practice in Breath Alcohol Testing, Part 1 – Environmental Conditions*” for a discussion on the implementation of “floating zero” air blanks in a breath test.

Regardless, the unit seemed to perform as one would otherwise expect. We encountered no *Ambient Fail* errors (none that we did not try and generate, in any case), and we didn’t experience any diagnostic failures from this brand-new Model 9000.

## THE TOUCHSCREEN



Figure 4 - The touchscreen interface in the test unit had calibration issues and proved to be a frustrating interface to the instrument's operational sequencing.

One thing that we discovered with the calibration and performance of the touchscreen interface was the difficulty in making contact with the desired points on the screen. One had to push very forcefully to get the touch screen to respond, or respond correctly. Its calibration was off, often enabling the function of a button *beside* the one pressed instead of the *intended* button pushed. This led to many tests being user-aborted due to incorrect function choices. In a few instances, the touchscreen locked up entirely, requiring a complete reboot of the instrument.

The performance of the touchscreen proved frustrating, and I think if this problem is systemic and not the aberration of an individual instrument, will result in a lot of operator angst, particularly as we often had to re-enter an entire sequence of pre-test questions before the unit would accept a breath sample. The inadequacy of the touchscreen severely impeded our ability

to assess the 9000, as it slowed down the process to probably half the speed it could have been. If this is a systemic issue, I foresee units with damaged touch screens being returned for repair by frustrated operators (particularly after entering the same information over and over again, at three in the morning).

## BREATH SAMPLING

Providing the actual breath sample was comparable to most other similar evidentiary instruments. The exhalation force to provide the breath sample, and the length of sample duration were about the same. Remember that breath alcohol testing devices typically use four parameters to determine the suitability of a breath sample:

- The pressure by which the test subject exhales
- The length of time of the exhalation
- The volume of the exhaled sample, and
- The “slope” of the readings obtained from one second to the next

## IN VITRO ACCURACY

Using a known alcohol concentration and a simulator, I was able to get a series of readings on the Intoxilyzer 9000 that closely corresponded to the anticipated results of the simulator solution. This was as expected.

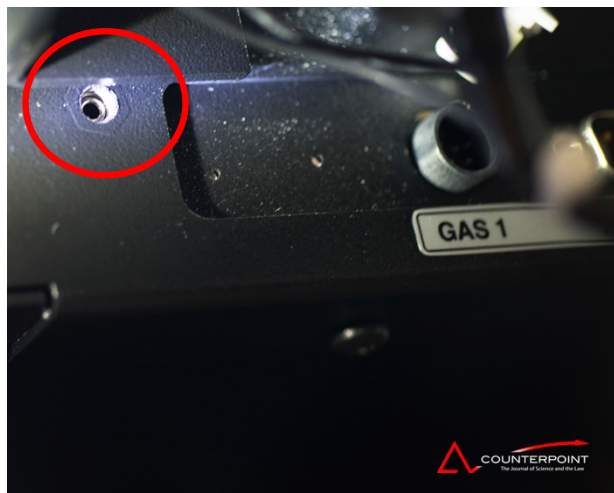


Figure 5 - The exhaust port (top left, in red circle for emphasis) was shielded and could not be accidentally blocked.

Additionally, it does not seem possible to cover the exhaust port of the device in order to prevent exhaust escape. The Intoxilyzer models 5000, 5000EN, 8000 and the 9000 utilize a “flow through” design – the exhaled breath sample is not “captured” as it is on some other devices. It has been demonstrated in the past with the 5000 and 8000 models that any blockage of the breath sample’s exhaust port, intentional or otherwise, has the net effect of artificially raising the reported BrAC reading, with the over-reporting dependent upon the degree of blockage of the exhaled sample, and its level of contamination.

The design of the exhaust port prevents either accidental or intentional blockage of the port itself. The port is shielded by a plate with an exhaust hole itself, and blocking the port seems difficult, and unlikely to occur accidentally. Time will tell...

# ASSESSMENT OF THE INTOXILYZER 9000'S *RESIDUAL ALCOHOL DETECTION SYSTEM*

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## REFERENCE MATERIALS:

**Counterpoint Article :**  
*Breath Sampling Criteria*  
*Establishing Reliability*

**Reference:**  
Volume 1, Issue 4, Page 302  
Volume 1, Issue 4, Page 309

It is unknown and unreported in the available literature what specific algorithm is used by the Intoxilyzer 9000 to determine the suitability of a breath sample in terms of what is commonly referred to as the “slope” detector, more correctly called the Residual Alcohol Detection System (hereafter – RADS)<sup>4</sup>. It may be helpful to look at the articles listed above as a means of review:

In general, RADS are designed to determine the presence of fresh-mouth alcohol. A subject who may have recently introduced alcohol into their mouth and respiratory tract by:

- Vomiting or stomach content regurgitation, including stomach gases
- Burping or belching, however slight
- A medical condition such as *Acid Reflux Disease*, or *GERD*,

will have an initial rapid rise in BAC that also falls off sharply as the false-high alcohol reading dissipates and is replaced by a “true” near-level slope.

Let’s pretend that the subject above has contaminated their oral pathway with “fresh mouth alcohol” immediately prior to or while providing a sample, as shown in red in Figure 7 on the next page:

*Continued on the next page*

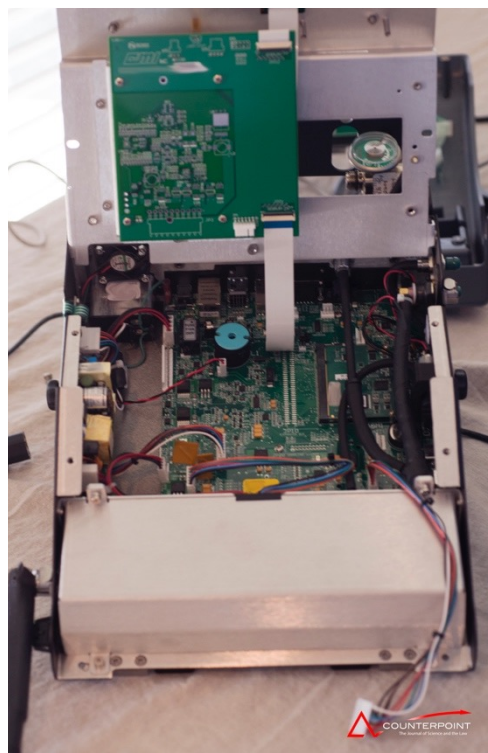


Figure 6 - The interior of the Intoxilyzer Model 9000

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<sup>4</sup> I prefer the term *Residual Alcohol Detection System* (RADS) to the commonly used term “*slope detector*”, as I feel the latter implies an actual physical component within the breath testing device itself, rather than the mathematical algorithm that the systems actually employ. As such, I will use the term RADS to refer to what most people call the “*slope detector*”.



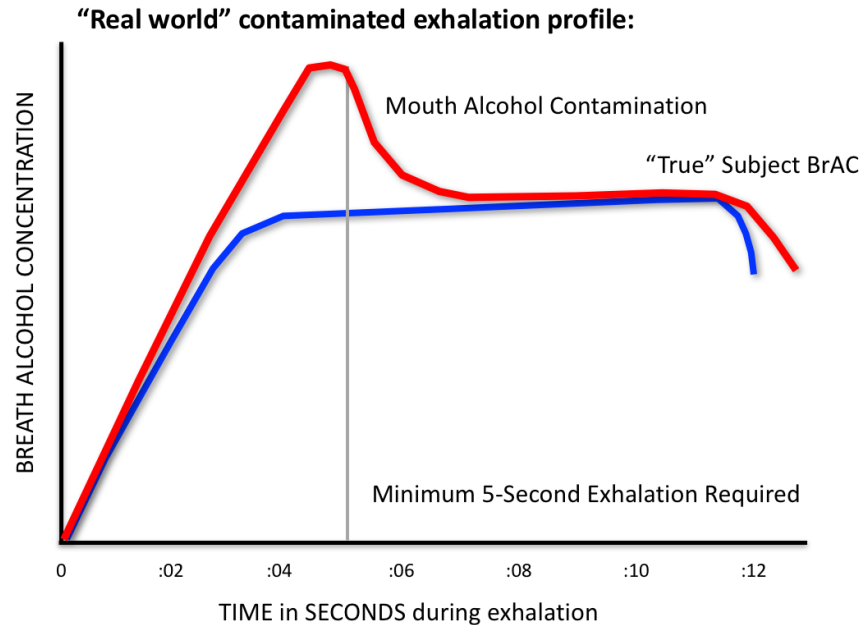


Figure 7 – Sample exhalation curve showing a breath alcohol reading caused by the introduction of fresh mouth alcohol contamination (shown in red) in comparison to the "true" BAC (shown in blue).

Ideally, the unit is able to determine the rise and subsequent fall in BrAC readings from one second to the next during the actual exhalation of the test subject. Any sudden or sharp drop in BrAC reading should be used to determine that the sample itself is contaminated. It is believed that the “true” BrAC level should not spike in this manner with the sudden drop in reading.

The Intoxilyzer 9000 has specific requirements in determining the suitability of a breath sample:

- First, it requires a minimum flow rate of 0.15 litres per second, with a minimum breath time of five seconds.
- The sample provided must be a minimum of 1.1 litres in volume.
- The sample exhalation length must be a minimum of five-seconds, uninterrupted, in duration.
- The IR source on the Intoxilyzer 9000 pulses at only 10 cycles per second (Hz). With four filters, a breath sample reading is obtained every 1/10 of a second (100 milliseconds) on each of the four-filtered points, for a total of 40 discrete pulses per second. As the pulses are analyzed, consecutive BrAC readings that do not differ by a pre-determined margin will indicate a level slope.

Once the four criteria (flow rate, volume, exhalation time, and slope) are met, a ZERO appears in front of the preliminary breath test results, indicating the sample obtained is suitable for analysis.

The 9000 can also display a histogram of the breath test results that shows:

- The subject's breath flow curve (profile of exhaled breath) and
- The subject's flow rate in litres/second
- The subject's BrAC curve (the peak BrAC, and a profile of the BrAC from second to second during exhalation)
- The subject's exhalation duration in seconds

*It should be noted that the histogram display is a user-configurable option. A number of jurisdictions have elected to eliminate this component from the final printout of results.*

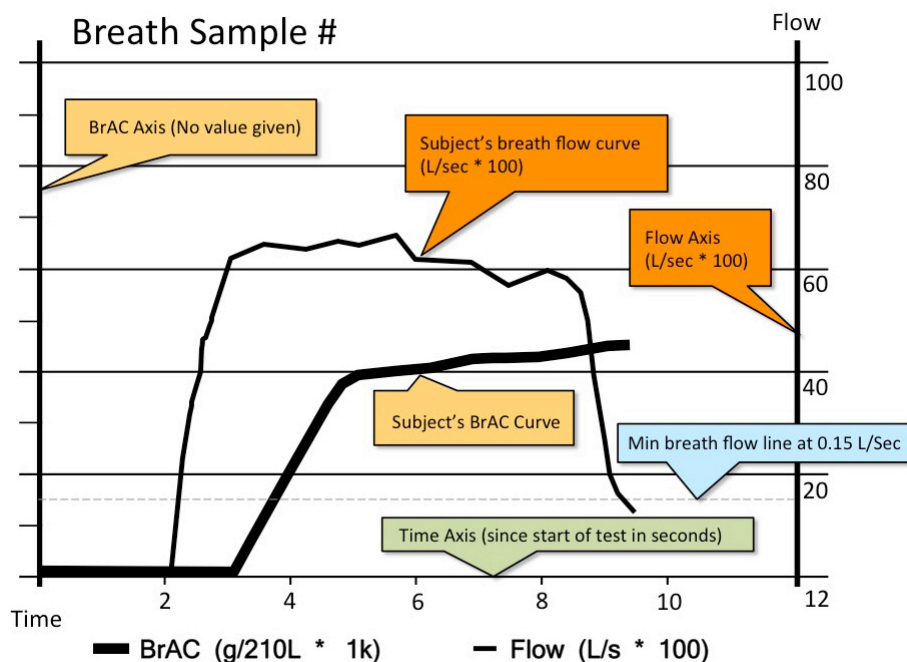


Figure 8 - The optional histogram printout on the 9000 shows the exhalation profile indicating the flow rate and BrAC curve.

The forensically acceptable standard of obtaining two readings within 0.02 grams/100ml of each another, coupled with a correctly conducted observation period before and between the two readings merely *assists* in obtaining suitable samples. The RADS adds only a certain degree of validity to the testing process. Many jurisdictions around the world do not obtain two readings, so the RADS become even more valuable to them. Unfortunately, RADS systems in general do not seem to warrant that degree of trust.<sup>5</sup>

<sup>5</sup> Gullberg, R.G., *The Inadequacy of Instrumental "Mouth Alcohol" Detection Systems in Forensic Breath Alcohol Measurement*, Northwest Association of Forensic Sciences, Oct., 2000.

## A PROBLEMATIC MEANS OF ASSESSING THE RESIDUAL ALCOHOL DETECTION SYSTEM

I have often heard forensic criminalists and state crime lab chemists or technicians describe in court how they assess the reliability of RADS during routine annual inspection or maintenance. Typically, an alcohol-free subject (as in the technicians themselves) swish and spit out an alcohol-laden solution (often, a simple mouthwash containing ethanol), then immediately provide a breath sample. There is a sudden spike in BrAC reading on the breath testing device that rapidly declines to a “true” BrAC reading of zero, setting off the RADS error message. See Figure 9:

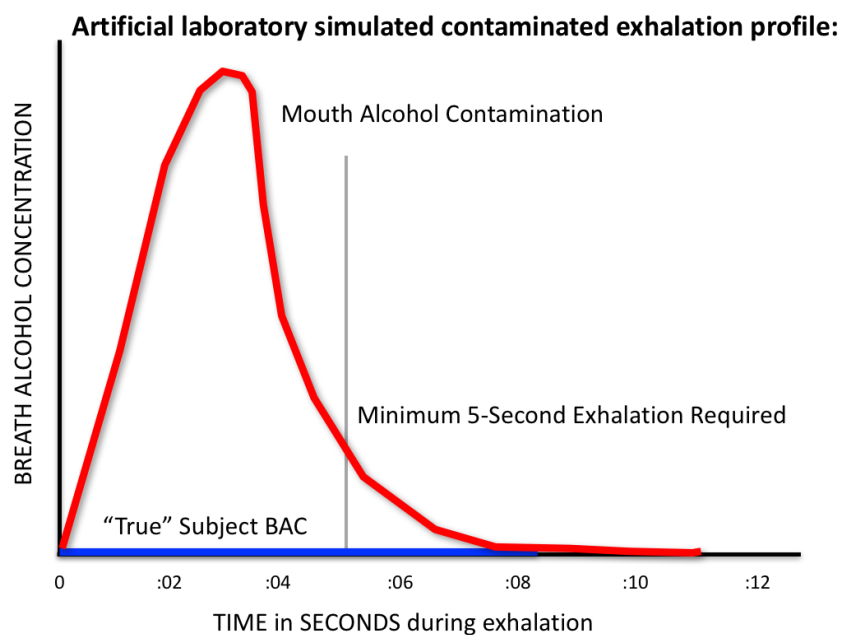


Figure 9 - Laboratory testing of the RADS, with a Zero-BAC test subject (Blue) and an artificially inflated mouth alcohol contamination (Red).

This is, in my opinion, an improper way of assessing the reliability of the RADS. In the real world, under actual operating conditions, the test subject has probably consumed alcohol, perhaps even a considerable amount. Compare the BrAC exhalation curves in Figures 7 and 9. The exhalation profiles are markedly different. The difference between the “true” baseline BrAC reading, and the falsely-elevated reported reading due to the alcohol contamination is often not enough for the “rise and fall” algorithm to identify the presence of contamination. Testing as per Figure 9, in my opinion, artificially creates the situation upon which the breath testing device easily passes this criterion, and in no way, reflects the conditions experienced by the units in the field, as shown previously in Figure 7.

When I tested the Intoxilyzer 9000 on a test subject that had an actual BAC concentration, and provided some sort of very minor levels of oral contaminate (a small drop of ethanol introduced by pipette to the tip of the tongue that was swirled and dissipated in the mouth for 30 seconds prior to providing a breath sample), the 9000 often reported falsely-inflated readings, as shown in Figure 10:

Intoxilyzer 9000 Results			
"True" BrAC Reading	Reported BrAC	False Positive Amount	Error Message Generated by 9000
.010	.030	.020	-
.010	.025	.015	-
.010	.024	.014	-
.010	.068	.058	-
.010	.038	.028	-
.008	.060	.052	-
.008	.076	.068	-
.008	.038	.030	-
.008	<b>.245</b>	.237	<i>Invalid Sample</i>
.008	<b>.135</b>	.127	<i>Invalid Sample</i>

Figure 10 – The Breath Alcohol Concentration (BrAC) results generated by an Intoxilyzer 9000 with a contaminated oral pathway from a test subject with a low-level Blood Alcohol Concentration (BAC).

I'm concerned about the last two results, shown in bold. The RADS seems to properly report Invalid Sample readings only at very high levels of contamination. I have often heard police breath test operators describe, in court, that they "saw a reading on the screen" before an error message was generated, and attempt to have that preliminary result entered as evidence of an actual measured BAC reading. We see two readings here that are well beyond the *per se* level, that were properly identified by the 9000 as Invalid Samples, yet a numerical result was also displayed. It must be stressed to qualified technicians during training that the preliminary results can never be relied upon, especially so when an error message is indicated.

## A COMPARISON TO OTHER BREATH TEST DEVICES

If this procedure to assess the RADS on the 9000 seems inappropriate, consider that I applied the same methodology to the following breath test devices:

- Intoxilyzer 8000
- DataMaster DMT

*In ALL instances, the DataMaster DMT correctly identified the presence of fresh mouth alcohol contaminate and aborted the breath testing process without generating a numerical result.*

To varying degrees, the Intoxilyzer 8000 provided, on more than one occasion, numerical results that were falsely elevated:

Breath Test Device	"True" BAC	Reported BrAC	Error Message
Intoxilyzer 8000	.009	.062	-
	.010	.047	-
	.010	.066	-
DataMaster DMT	.015	-	Invalid
	.010	-	Invalid
	.010	-	Invalid

Figure 11 – The Breath Alcohol Concentration (BrAC) results generated by an Intoxilyzer 8000 and a DataMaster DMT with a contaminated oral pathway from a test subject with a low-level Blood Alcohol Concentration (BAC).

This is also my general experience with the older Intoxilyzer 5000 and 5000EN models. I have generated falsely-elevated readings during training program demonstrations consistent with the 8000 readings above.

## OBTAINING PROPER SAMPLES & OPERATIONAL IMPLICATIONS

Relying upon the pressure / time / volume / RADS to automatically determine the suitability of the sample is insufficient. It must still be the responsibility of the qualified technician to ensure that a suitable sample is properly obtained. The Model 5000, 8000 or 9000 sets *minimum* standards for a suitable sample, based on an average subject. The qualified operator is the one who must ensure that a given subject has provided *their own unique suitable sample*. This necessitates a proper deprivation, wait and observation period for the test subject prior to, and between, the taking of suitable samples.

## THE NECESSITY OF A PROPER DEPRIVATION AND WAIT / OBSERVATION PERIOD

There is no override on the Model 5000, 8000 or 9000 as there are on some roadside screeners that are capable of manually drawing a breath sample into the test chamber. The Model 5000, 8000 and 9000 will continue to receive the sample as long as its parameters don't fall outside the residual alcohol detection system's threshold values. As long as the subject continues to provide exhaled breath sufficient to keep the pressure transducer open, the sample will be analyzed either 4, 10 or 30 times per second, per each instrument's design. The RADS, coupled with an observation period of a reasonable length of time, may provide a degree of reliability in the breath testing results. But remember, an observation period is exactly that – observation. The operator should be paying attention with their eyes, ears, and in some cases their noses to detect the smell of the fresh burp, or unnoticed "micro-burp".

## OVERALL IMPRESSION ON THE INTOXILYZER 9000 RADS

As stated before, this assessment on the Intoxilyzer 9000 was done under circumstances of complete access, but was time limited. Simply put, we did not have the time necessary to run exhaustive testing on the device to generate the raw data necessary to make a proper statistical analysis. We need further inquiry to draw meaningful conclusions.

It has been my experience that, in general, the RADS can, and often are, fooled under a variety of circumstances, most notably, recent introduction of a small quantity of alcohol, similar to what would occur during a burp or “micro-burp”. This circumstance is precisely what the RADS was designed to detect, yet fails to do so. I have routinely observed the RADS fail to register mouth alcohol that is a few minutes old, often allowing the unit to register an abnormally high reading given a simple swish of alcohol, or even a small drop of alcohol on the tip of the tongue that is allowed to dissipate for a few minutes. I can only conclude that the RADS is merely an investigative aid, and is a highly inaccurate detector of mouth alcohol, with most evidentiary breath test devices, with the notable exception of the DataMaster DMT.

What is concerning is the apparent inability of the Intoxilyzer 9000 to accurately determine this contamination. My testing shows, albeit with limited data, that the 9000 routinely gave false positive readings with minimum mouth alcohol contamination. In every instance but two where we contaminated a “true” reading with a minute quantity of ethanol, a falsely-inflated reading was obtained and reported as a true value. Our limited data shows that the true BrAC reading could be added to by as much as 0.014 to 0.068 without identifying the mouth alcohol contamination.

The only two instances that reported an INVALID sample error message was when extremely high levels of contaminate were introduced (adding .127 to .237 grams to the true amount). Even then, a numerical result was displayed as a preliminary reading that was subsequently reported as INVALID.

Simply put RADS or *slope detectors*, in general, are suspect at best, and in the Intoxilyzer 9000, do not provide a reliable means of identifying fresh mouth alcohol contamination. This points to the necessity of a properly observed and conducted deprivation and observation period prior to and between receiving evidentiary breath alcohol samples for forensic or court purposes, and for the continued use of replicate or duplicate breath alcohol testing that must fall within acceptable parameters of congruency.

# THE SPECIFICITY OF THE INTOXILYZER 9000 TOWARDS ETHANOL

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## REFERENCE MATERIALS:

### Counterpoint Article:

*Infrared Spectroscopy*  
*An Introduction to Specificity*  
 The Intoxilyzer 9000

### Reference:

Free Issue, Page 19  
 Volume 1, Issue 4, Page 293  
 Volume 1, issue 3, Page 195

First, we should agree on the definition of some terms:

- For our purposes, *specificity* refers to the ability to analyze for a specific substance, and to isolate that specific substance from any other substances with similar physical or chemical characteristics. In breath alcohol testing, the compound we are looking for is ethanol. Specificity towards ethanol detection is highly desirous.
- An *interfering compound* Any other chemical compound that appears to the breath testing device as ethanol.
- Should that interfering compound add or even multiply the apparent ethanol readings obtained, the results would be considered a *false-positive reading*.
- Should that interfering compound reduce the apparent ethanol readings obtained, the results would be considered a *false-negative reading*. To date, no false-negative compounds have been identified.

## CREATING A BREATH ALCOHOL CONCENTRATION (BRAC) READING

### THE BREATH SAMPLING SYSTEM

The breath sampling system consists of a series of tubes, both external and internal, that draw in room air, breath samples, and calibration solution vapors or dry gas into the optical chamber (or bench). Additionally, this sub-assembly requires opening and closing of valves in sequence, and a means to measure the flow rate of the exhaled test subject's breath sample.

The Intoxilyzer 9000 has specific requirements<sup>6</sup> in determining the suitability of a breath sample. First, it requires a minimum flow rate of 0.15 litres per second, with a minimum breath time of five seconds. The sample provided must be a minimum of 1.1 litres in volume.

In most breath alcohol testing devices, the volume determination is usually a calculated value, created by multiplying the flow rate, in litres per second, by the number of seconds the flow meets the minimum criteria to determine the calculated volume of exhaled breath. I have no information on how the Intoxilyzer 9000 creates this reported volume value.

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<sup>6</sup> As reported in the "Evaluation of Breath Alcohol Testing Instruments to Replace the Intoxilyzer 5000", Georgia Bureau of Investigation Crime Laboratory, Sept 2012, (author unknown).

## THE OPTICAL CHAMBER (ALSO CALLED: SAMPLE CHAMBER, OR OPTICAL BENCH)

The optical chamber, often referred to as an optical bench or simply “sample chamber”, consists of a chamber, tube or pathway in which both a room air, wet-bath solution vapor or dry-gas calibration standard, or exhaled breath sample are analyzed. Light or heat energy will also pass through the air, gas, or breath sample to determine the presence and concentration of ethanol in the sample.

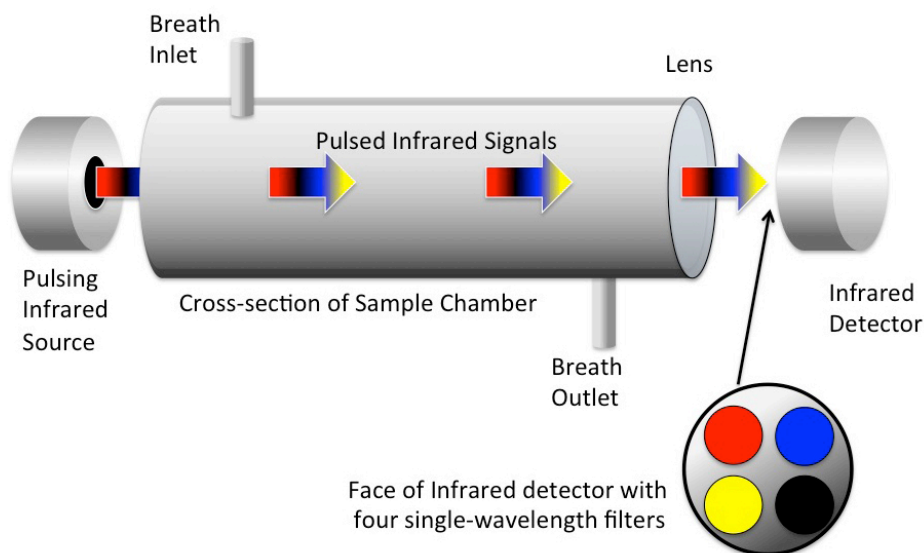


Figure 12 - A representative diagram of the optical chamber on the Intoxilyzer 9000

We do not know the internal volume of the actual sample chamber on the 9000. Externally, it measures about 10" x 2" x ¾". This internal volume is critical, in that larger optical chambers require a larger exhalation volume. A larger sample is also thought to deliver a more *analytically precise* measurement. Folded-path chambers are often utilized to deliver a more precise measurement as well. We know the 9000 does not utilize a folded pathway. Although we don't know its precise internal volume, or physical specifications, the external dimensions give rise to an internal volume about 240 mL. This is perhaps an over-estimate of its internal volume, given that the Intoxilyzer Model 5000 had a sample chamber of around 80 mL, and the Model 8000 a volume of only about 29 mL. Older units employed aluminum chambers that were sensitive to pitting and corrosion, or that promoted the growth of mold over time. Some devices use polished stainless-steel chambers that minimize this contamination or corruption. What are the 9000's characteristics in this regard?



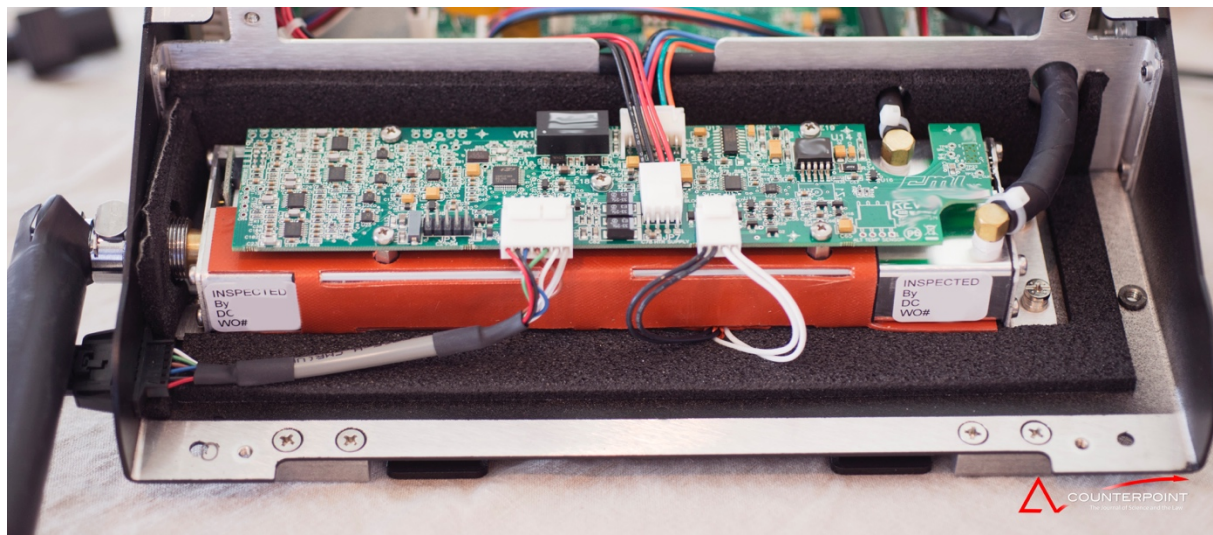


Figure 13 - The optical bench of the Intoxilyzer 9000 showing the breath sample inlet tube (left) and outlet port (right). The chamber is wrapped by a thermal blanket that was measured at 47.0° Celsius.

The sample chamber is also heated by an external warming blanket. We measured the temperature of the interior of the chamber at 47.0°C, exactly at its stated value.

## THE INFRARED SOURCE

Another component of the Optical Bench is its infrared source. The Intoxilyzer 5000 used a halogen light bulb as its infrared source. The 8000 used a pulsed infrared source, as apparently does the 9000, now incorporating pulsing LEDs (Light Emitting Diodes).

This is important in assessing the reliability of the Residual Alcohol Detection System. In the older 5000, the filter wheel component spun at around 1800 RPM. This meant that, for a ten second exhaled breath sample, about 300 readings were obtained from EACH filter. For the Model 5000EN, with five filters, this meant that 1500 discrete readings were obtained, analyzed and compared.

The Model 8000 moved from a Halogen light bulb and spinning filter wheel to a wire that was heated and cooled 2 times per second (4 Hz pulse). Only two filter points were utilized. That meant that the same ten second exhaled breath sample, only 80 discrete readings were obtained, analyzed, and compared. As such, the so-called slope detector was less precise. Third-party testing indicated that the Residual Alcohol Detection System on the Model 8000 was less reliable than on the older 5000.

It has been reported <sup>7</sup> that the IR source on the Intoxilyzer 9000 pulses at only 10 cycles per second (Hz). With four filters, a breath sample reading is obtained every 1/10 of a second (100 milliseconds) on each of the four-filtered points, for a total of 40 discrete pulses per second. As the pulses are analyzed, consecutive BrAC readings that do not differ by a pre-determined margin will indicate a level slope. Once the four criteria (flow rate, time, volume and slope) are met, a ZERO appears in front of the preliminary breath test results, indicating the sample obtained is suitable for analysis.

## THE INFRARED FILTERS

In addition to the infrared source, the infrared filters provide a precise way to measure the ethanol concentration within the test chamber. The older Model 5000 had reported filter specification of 3.39 $\mu$  (micron), 3.48 $\mu$ , and 3.80 $\mu$ , etc. The Model 8000 did not report the specific wavelengths used, but we came to know that they were at 3.40 $\mu$  and 9.36 $\mu$ .

The 9000 filters are apparently somewhere  $\geq 8\mu$  but,  $\leq 9\mu$ . Four discrete filters are used, with specific wavelengths and resolution (or programmed instrument tolerance) undisclosed.

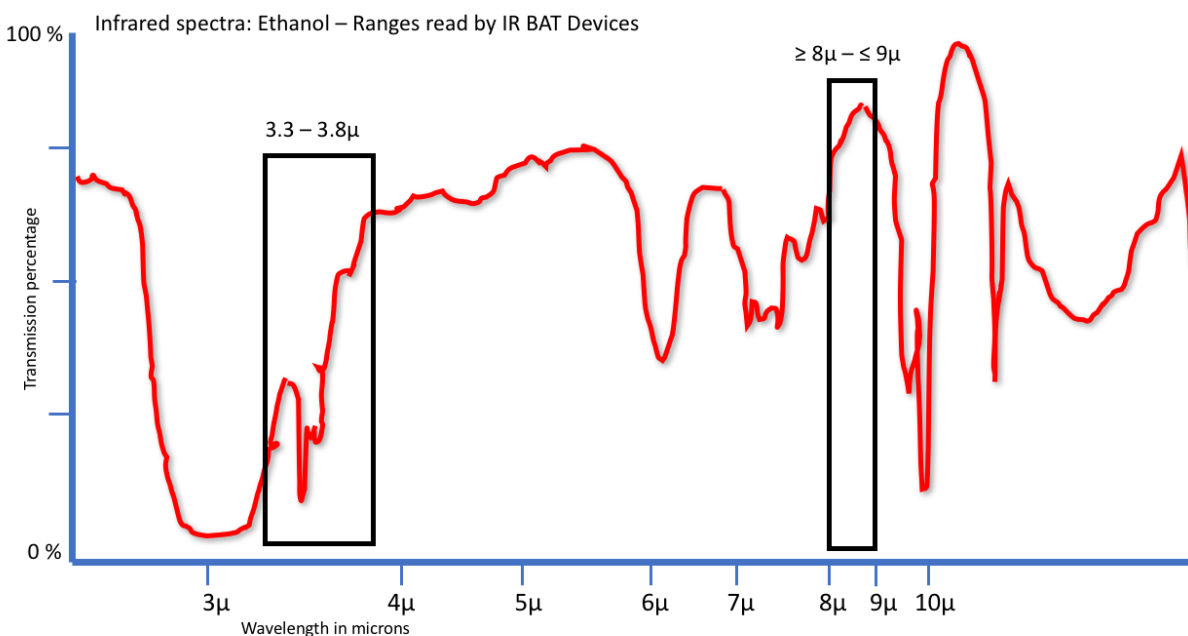


Figure 14 - The infrared spectra of ethanol, with the range of detection in the 3.3 - 3.8  $\mu$  (micron) range from the previous Intoxilyzer Model 5000 indicated in the black box (left) and the range utilized by the Model 9000 between  $\geq 8\mu - \leq 9\mu$  in the black box (right).

<sup>7</sup> Unknown Author(s), "Evaluation of Breath Alcohol Testing Instruments to Replace the Intoxilyzer 5000", Georgia Bureau of Investigation Crime Laboratory, Sept 2012.

The resolution of the filters is also important. IR filters are either narrow-bandwidth or wide-bandwidth. Think of this as narrow versus wide resolution. The wider a filter, the more IR light it absorbs. The narrower a filter, the more specific and precise it is at absorbing an IR energy bandwidth. This is important, as it speaks to the unit's specificity towards ethanol. The Model 8000 apparently had a tolerance to the filter of +/- .5 micron from target. This is too large, implies inherent measurement uncertainty, and can lead to false-positive readings when interfering chemicals are present. How does the Intoxilyzer 9000 compare in this regard?

## MEASUREMENT OF INTERFERING CHEMICALS

### METHODOLOGY & FINDINGS

Due to time constraints, we tested acetone and isopropanol in various small measures to simulate the effects of a diabetic test subject, or a person who was fasting or on severe dietary restrictions. Methanol and d-limonene are also well-established interfering substances used in occupational settings, so low levels of these chemicals were introduced as well. In order to assess the ability of the Intoxilyzer 9000 to determine the presence and concentration of ethanol, and its ability to identify and discern the presence of an interfering chemical, we used the following methodology:

A simulator, heated to 34.0°C, containing a 500-mL solution of ethanol in distilled water, had its vapor introduced into the Intoxilyzer 9000 through the external sample hose. The solution was allowed to come to equilibrium through agitation prior to being introduced. A baseline reading was obtained that indicated an equivalent BrAC reading in grams of ethanol per 100 mL of blood (210 L of breath).

To this baseline solution, interfering chemicals were added in small *aliquots*<sup>8</sup>, and also allowed to come to equilibrium through agitation and mixing. Laboratory-grade isopropanol, acetone, methanol and d-Limonene were utilized, in combination with one another and fresh ethanol mixtures. This compound solution of ethanol and the interfering chemicals had their vapor introduced into the Intoxilyzer 9000, again through the external sample hose.

The reading produced by the combination of ethanol and interfering compound were compared to the true value of the baseline solution on the preliminary results displayed on the instrument. Additionally, the results of any error or status message were recorded, along with the final displayed apparent BrAC reading.

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<sup>8</sup> An *aliquot* is a portion of a larger whole, especially a sample taken for chemical analysis or other treatment.

## DATA OBTAINED

The following table summarizes the data obtained:

Baseline ethanol solution (g/dL)	Interferent chemicals added	Error message or final display
.094	0.25 mL acetone	INTERFERENT
	0.50 mL acetone	INTERFERENT
.096	1.0 mL acetone	INTERFERENT
.090	0.125 mL acetone	INTERFERENT
	0.125 mL isopropanol	
	0.125 mL acetone	INTERFERENT
	0.125 mL acetone 0.250 mL isopropanol	INTERFERENT
.045	0.5 mL isopropanol	INTERFERENT
	1.0 mL isopropanol	INTERFERENT
.032	0.5 mL methanol	INTERFERENT
	1.0 mL methanol	INTERFERENT
0.0	d-limonene vapor	0 reading
	d-limonene vapor	0 reading

Figure 15 – Data obtained through the introduction of infrared interfering chemicals into an ethanol solution with a known concentration.

## DISCUSSION

Preliminary results indicate that the Intoxilyzer Model 9000 is capable of identifying the presence of even extremely small levels of isopropanol, acetone (and various combinations of these two chemicals), and methanol, all in the presence of ethanol at different concentrations.

The introduction of d-limonene was unique in that it did NOT provide a numerical BrAC reading other than Zero, but also did NOT indicate its presence as an infrared interfering compound. It should be tested in the future with a corresponding BrAC ethanol reading.

I have performed similar testing on other instruments, including the Intoxilyzer 5000, 5000EN, 8000, and the DataMaster DMT. Only the DataMaster DMT has been equally successful in identifying interfering chemicals and aborting the BrAC testing process. The older Intoxilyzer 5000 and 5000EN often produced false-positive readings, as did earlier versions of the Intoxilyzer 8000. Later versions of the 8000 more correctly identified these specific interferent chemicals. In short, specificity of readings seems to be increasing in the Intoxilyzer line of evidentiary breath test products.

However, there are a wide variety of other chemicals (MEK, or methyl ethyl ketone; toluene; diethyl ether; dimethyl sulfone; xylene, etc.) that have been shown by various researchers to provide false-positive readings on different evidentiary breath test devices. Each of these, in combination with different ethanol readings, should also be tested to determine their response, if any, on the Intoxilyzer 9000.

It has been long established among OSHA (Occupational Health & Safety) professionals that long-term, chronic exposure to various chemicals presents a health hazard. Simply put, a low-level of exposure to a specific substance can build up in the worker's tissues over time, developing fairly high levels, often well beyond what a non-exposed person can develop. Simulating chronic exposure to chemicals in combination with ethanol becomes problematic, as it is often very difficult, or even impossible, to determine what the baseline interferent levels are present.

The idea of plumbers with their heads under the sink cabinet, gluing pipes together all day long, then stopping on the way home for a beer or two is not out of the ordinary. Similarly, a hair stylist who works long hours dealing with straightening, coloring, bleaching chemicals, and hairspray<sup>9</sup> can develop significant chronic exposure levels to these inhaled chemicals. What effect these chemicals have, in concert with a low level of ethanol, needs to be examined in the Intoxilyzer 9000, and indeed, all other evidentiary infrared breath testing devices.

## **CONCLUSION REGARDING ETHANOL SPECIFICITY IN THE INTOXILYZER 9000**

In ALL instances, the Intoxilyzer 9000 correctly identified the presence of the interfering chemical and produced the error message "INTERFERENT DETECTED". In no instance did the preliminary digital display indicate a BrAC reading beyond the true baseline value. Our testing indicated that the Intoxilyzer 9000 performed better than most other devices in this regard, identifying the presence of interferent chemicals on par with the DataMaster DMT. Later versions of the Intoxilyzer 8000 also correctly identified interferent chemicals the majority of times. However, a wide variety of other known or potential infrared interfering chemicals should be tested in the Intoxilyzer Model 9000 to determine what, if any, effects they have on a true ethanol reading, and to discover the ability of the Intoxilyzer 9000 to identify their presence.

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<sup>9</sup> Hair spray products are often a blend of industrial polymers to provide structural support for the hair. These frequently include chemicals used to achieve the desired physical properties (adhesive strength, foaming, etc.), often using plasticizers, surfactants, and other agents. These active ingredients make up only a small portion of a hairspray (aerosol can). The majority of a canister is filled with volatile solvents necessary to solubilize and aerosolize the copolymer mixture. These include simple alcohols like ethanol or tert-butanol to solubilize the active ingredients, and dimethyl ether or mixed hydrocarbons as propellants.

# ***THE EFFECT OF RADIO FREQUENCY INTERFERENCE ON THE INTOXILYZER 9000***

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## ***WHAT IS RADIO FREQUENCY INTERFERENCE (RFI)?***

Radio Frequency Interference (RFI), also called Electromagnetic Interference (EMI), occurs when an electrical disturbance is generated on an electronic device by an external electrical source. This source may affect electronic or electrical circuitry, and degrade or otherwise impede the performance of the circuit affected. The effects can include data corruption, an increase in error rate, total or partial data loss, and may even go so far as to stop the affected device from functioning altogether<sup>10</sup>.

In our modern and increasingly connected world, the use of radio transmission and receiving devices is ubiquitous, and today certainly more so than just a few years ago. When modern police breath alcohol testing devices were invented, no one conceived of high speed, Wi-Fi enabled, 5G devices used regularly to access a continuous stream of Internet data, text messages and voice communications. Few could have foreseen a world where powerful, interconnected electronic devices were so small, that not only do they easily fit in the palm of your hand, but we lose them in our own homes (along with our car keys).

A quick peek at the Wi-Fi networks available locally to my computer indicates that about 20 different signal sources are in my immediate vicinity. Additionally, cellular phones, smart devices such as tablets or other Wi-Fi enabled devices (now including everything from Blu-Ray players to “smart” refrigerators), and other Bluetooth devices are all emanating their digital transmissions, regardless of whether they are on an active call or not. This background “noise” can create the situation generally associated with RFI and EMI emissions.

To compound the problem in police evidentiary breath testing, we have such sources as the cellphones of the people in the vicinity, police portable radios, and now, police body-worn cameras and wireless laptop computers, all transmitting notification signals back to their respective sources, telling the electronic infrastructure (and local intranet) world, “*I am here...*”

## ***A PROBLEMATIC MEANS OF ASSESSING THE RADIO FREQUENCY INTERFERENCE DETECT CIRCUITRY***

I have frequently heard forensic criminalists and state crime lab chemists or technicians describe in court how they assess the reliability of the RFI detect during routine annual maintenance of breath alcohol testing devices. Typically, a police radio, or similar transmitter, is placed near the

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<sup>10</sup> In an extreme example, EMI pulses are used in electronic warfare to interrupt communications and computer technology of enemy combatants.

device in question during its “active phase”<sup>11</sup> of breath sampling. The radio is then “keyed” into the active transmission mode, and the response of the breath test device recorded. However, this assessment is different from the Internet, cell phone, Wi-Fi, Bluetooth enabled world I’ve just described.

The problem with assessing the impact of RFI is that it is generated in an intermittent fashion, producing random and potentially irreproducible results. Indeed, the simple act of detecting the presence of RFI is a considerable challenge. As such, it has been frequently suggested that the prudent course of action is to limit exposure of RFI to devices that must deliver precise measurements with a high degree of reliability, or in critical-application situations.

That is why we are required to turn our cellphones off, or into “airplane” mode, when we board a commercial flight, enter the ICU to visit a sick relative, or are in the vicinity of sensitive medical monitors and scientific measuring devices.

It should be noted that the RFI detector built into the Intoxilyzer 5000 and 8000 series of breath alcohol testing devices is based on technology of circa 1980-2000. Although the Intoxilyzer line itself has undergone various upgrades in their capabilities, the RFI detector circuitry they employ have remained essentially the same for these earlier devices since their creation about thirty years ago. They were designed to detect the presence of radio frequencies in the 10-300 Megahertz (MHz) range, as was commonly found in police radios of that era. Due to the increased performance of newer communication technologies, most of those radio devices have long been abandoned.

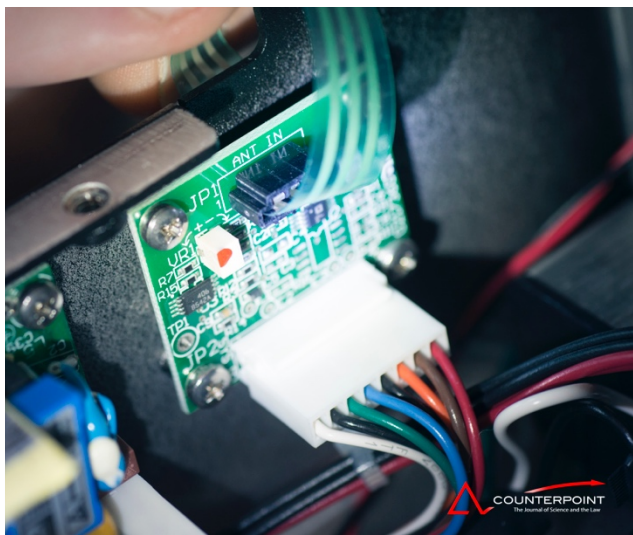


Figure 16 - The antennae circuitry on the 9000 employs a 3-lead flexible circuit that connects to the physical antennae located under the CMI label on the exterior of the instrument.

The detectors have not recognized the presence of either upper-band analog or more modern digital transmissions that may be present and interfering with the internal circuitry of the Intoxilyzers. As well, the type of RCA plug used to connect the rudimentary antennae of the Intoxilyzer 5000 and 8000 is only suitable for detecting radio frequencies in the much lower 5-6 MHz range. Simply put, the detectors utilized by the Intoxilyzers are “blind” to modern portable transceivers, used by both civilians and police agencies.

<sup>11</sup> I’m separating here the idea of an *active* mode in the breath testing device (it is ready to receive, or has been activated to receive breath samples) as opposed to its *passive* mode (where it is in the “stand-by” position, waiting for some activity to occur – i.e.; *Push the START button*).

Modern police radios commonly transmit and receive within frequencies between 400 MHz to 3 Gigahertz (GHz). Cellular telephone voice and data technology used in the United States and Canada utilizes radio frequencies in the 800 MHz through 1.9 GHz range. Additionally, voice and data transceivers utilizing technology commonly known as “Bluetooth devices” operate in the 2.4 GHz range. Modern commercially available “walkie-talkies” operating in the FCC Licensed *Family Radio Service* bands operate in the 462-467 MHz range.

The effect of these radio frequencies on the internal operation of breath test devices that use electronic circuitry similar to that of early computers is in debate. Accordingly, standard police procedures have been established in most jurisdictions in North America that prohibit the presence of active police radios, cellular telephones, and similar devices in breath test facilities.

This prohibition amongst police agencies is not unique. Most hospitals have policies prohibiting the use of similar radio or other electronic devices in patient care areas, where critical life-support or patient monitoring equipment is in operation<sup>12</sup>. RFI interference to devices such as ventilators, patient monitors, pacemakers, neonatal incubators, motorized wheelchairs, and anesthesia delivery equipment has been reported and documented.

Additionally, although there has only been one reported case of an air crash where the use of cellular telephones has been *alternately* purported as responsible<sup>13</sup>, the United States Federal Communication Commission bans the use of cellular phones in aircraft entirely (*per 47 C.F.R. § 22.925*). Similar bans are enforced in many other jurisdictions worldwide. It should be noted that newer cellular telephones transmit intermittent digital identification signals, whether an active call is in progress or not, so that local cellular transceiver sites recognize the mere presence of the phone for reception of incoming calls. As this function is beyond the control of the operator of the device, deactivating the device to the off position or “airplane” mode is warranted.

Shortly after the introduction of the types of technology used by the Intoxilyzer and similar breath test devices into general police service, the National Bureau of Standards conducted a study (*“Effects of Electromagnetic Fields on Evidential Breath Testers”*, 1983) and concluded that the possibility of erroneous Blood Alcohol Concentration (BAC) readings, influenced by various radio frequencies, was “severe”. There are numerous reported, albeit anecdotal, instances where elevated BAC readings have been observed due to the presence of known radio transmissions. The problem, frankly, in extrapolating from these observed instances, is the unpredictability and

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<sup>12</sup> I have served as both a Police Constable and Emergency Medical Technician in my community in the last 35 years. Under both police and ambulance protocols, I was required to turn my portable radio off before entering local emergency departments, as a proactive measure against the unintentional interference with critical patient care and monitoring equipment.

<sup>13</sup> Crossair Flight LX498, January 10, 2000 (flight from Switzerland to Germany). The official crash report does not mention cell phone activity as a primary cause of the crash, and instead attributes it to pilot error. However, a separate investigation into the cause of the crash documented that the autopilot system malfunctioned at the same time that a passenger's cell phone on board the plane received an SMS message and another cellular phone received a call. After this information was made public, a number of countries that had previously been reluctant to do so outlawed cell phones on flights. The bans remain in effect to this day.



lack of reproducibility of the circumstances that apparently gave rise to elevated BrAC readings. As such, the cautious and prudent approach is to absolutely eliminate the possibility of RFI altogether.

So, ultimately, the question is, *“How does the Intoxilyzer 9000 radio frequency detection circuitry identify the presence, if any, of interfering electromagnetic signals?”*

## TESTING RFI ON THE INTOXILYZER® 9000

### TESTING PROTOCOL

In order to test the effects, if any, of radio frequency interference from cellular phone calls during an active breath test, we utilized two cellphones, calling one another in the general vicinity of the Intoxilyzer 9000, to create an active cellular transmission in progress. Both were Apple iPhone 6 phones, one operating on the Verizon network, the other roaming on the AT&T network. Breath tests were conducted with a zero BrAC test subject, and tests on a test subject with a known BrAC of 0.012 grams/dL.

### RESULTS OBTAINED

The results are as follows:

“True” BAC	Reported BrAC	Error Message
0.0	0.0	RFI DETECTED
0.0	0.0	-
0.0	0.0	-
0.0	0.0	RFI DETECTED
0.0	0.0	-
0.012	<b>0.0</b>	-
0.012	<b>0.026</b>	-

Figure 17 – Data obtained through the introduction of radio frequency interferences into a known solution with a measured ethanol concentration.

With a zero BAC test subject, the 9000 correctly reported a zero BrAC reading, but only identified the presence of the active cellular calls on 2/5 occasions. In order to generate the RFI message, one of the cellular phones, on an active call, had to be placed within 2 inches (6 cm) of the external antennae. Any distance further than 2” would not generate an RFI DETECTED message.

In the next tests, the active cellular phone was placed within a 5-inch radius of the antennae while a test subject with a “true” BrAC of 0.012 grams/dL provided breath samples. The BrAC level was measured, initially from the Intoxilyzer 9000 itself, and verified using a recently calibrated handheld device (an Intoximeter FST). With the active cellular calls under way, the

9000 provided two back-to-back readings of Zero and 0.026 g/dL, all without indicating the presence of any RFI. Limited time prevented us from obtaining further results.

## OVERALL IMPRESSION ON THE INTOXILYZER 9000'S RFI DETECTION

### OBTAINING PROPER SAMPLES & OPERATIONAL IMPLICATIONS

Relying upon the RFI detect circuitry to determine the presence of stray radio waves may be insufficient. It appears that the source of any potential interference had to be within a radius of about two inches from the external antennae to be detected. It also appears that with an actual BrAC measurement (0.012 g/dL), the readings obtained may have been affected by RFI, both generating *false-negative* and *false-positive* readings, without reporting the detection of any RFI present.

As previously stated, this assessment on the Intoxilyzer 9000 was done under circumstances of complete access, but was time limited. Simply put, we did not have the time necessary to run exhaustive testing on the device to generate the raw data necessary to make a proper statistical analysis. We need further inquiry to draw meaningful conclusions.

With albeit limited tests (seven) we see preliminary indications that the Intoxilyzer 9000 does not adequately detect the presence of RFI, and additionally, that the RFI may adversely affect the reported BrAC results. Therefore, the only prudent course of action is to eliminate all potential sources of RFI. This means turning off police radios, cell phones of both officers and test subjects, police body cams, laptops that are transmitting, and any Wi-Fi devices, etc. The intermittent nature of RFI, and its potential effects, dictates the need to remove any potential source of EMI and RFI altogether. Furthermore, a proper deprivation and observation period, both before and between the breath samples, coupled with the use of replicate testing (with close sample agreement) will help to establish the reliability of breath alcohol testing results.

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# THE IAFS POSTER:



**COUNTERPOINT**  
The Journal of Science and the Law

Jan Semenov, BA, EMA  
Editor: Counterpoint Journal

## Performance Characteristics of the Intoxilyzer® 9000: An Independent Assessment & Review

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### Abstract:

Evidential Breath Alcohol Testing (EBT) instruments are typically evaluated to determine their accuracy, precision, specificity towards ethanol detection, and overall reliability by government agencies, and state run or sponsored forensic crime labs. Independent testing and analysis by individuals in private practice is rare, due in part to controlled access to EBT instrumentation. The author had an opportunity to conduct an independent inspection of an Intoxilyzer® Model 9000, recently introduced by CMI, Inc. as the most advanced EBT in their product line, and now used in a few jurisdictions in the United States and worldwide.

### Assessment areas:

The instrument was assessed in its performance in the following areas:

- Specificity towards the detection of ethanol in combination with interfering Volatile Organic Compounds (VOCs) including acetone, isopropanol, methanol and d-limonene;
- Susceptibility regarding Radio Frequency Interference (RFI);
- The ability of the instrument to identify the presence of oral pathway contamination by the Residual Alcohol Detection System algorithm, and;
- The ability of the instrument to report accurate and precise Breath Alcohol Concentrations (BrAC) in testing the vapors of simulation solutions having a known ethanol concentration.

### Conclusions:

The findings support the notion that the Intoxilyzer® 9000 can reliably detect the presence of VOCs and report that the breath sample is contaminated by a substance other than ethanol. However, the preliminary electronic display on the instrument often indicated a substantially higher reported BrAC that was subsequently not reported on the printed results. There is a concern that a breath test operator may misinterpret the preliminary display results and attempt to report them to the courts as an accurate representation of the BrAC of the test subject.

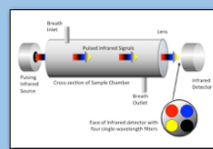
The RFI detect process was observed to generate both intermittent *false-negative* and *false-positive* results without indicating the presence of the cellular RFI.

The Residual Alcohol Detection System does not appear to reliably detect the presence of mouth alcohol contamination, thereby reinforcing the necessity of correctly performing a deprivation and observation period of at least 15-20 minutes prior to, and between, receiving replicate breath samples suitable for analysis.

### Response to Infrared Absorbing Substances (Specificity)


1

Baseline ethanol solution (g/dL)	Interferent chemicals added to baseline	Error message generated
0.094	0.25 mL acetone	INTERFERENT
0.096	0.5 mL acetone	INTERFERENT
0.090	1.0 mL acetone	INTERFERENT
	0.125 mL acetone	INTERFERENT
	0.125 mL acetone	INTERFERENT
	0.125 mL acetone	INTERFERENT
	0.250 mL isopropanol	INTERFERENT
0.045	0.5 mL isopropanol	INTERFERENT
	1.0 mL isopropanol	INTERFERENT
0.032	0.5 mL methanol	INTERFERENT
	1.0 mL methanol	INTERFERENT
0.0	d-limonene vapor	0 reading
0.0	d-limonene vapor	0 reading



**Figure 1:** The Intoxilyzer® 9000 optical bench. Four discrete IR wavelengths, pulsed @ 10kHz. Unreported IR Filter wavelengths ( $\geq 8\mu - \leq 9\mu$ )

**Chart 1:** Reported interferent chemical contamination



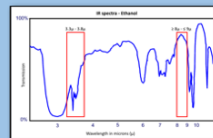
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- There were no instances where an interfering substance generated a *final* false-positive BrAC reading on the Intoxilyzer® 9000
- All instances generated the **INTERFERENT DETECTED** error message (with periodic falsely-inflated *preliminary* BrAC results indicated)
- Further testing is required on a wide variety of known infrared interferents, in combination with ethanol

### Radio Frequency Interference Susceptibility (RFI Detector)


2

Baseline ethanol solution (g/dL)	Reading produced	Error message generated
0.0	0	RFI DETECTED
0.0	0	-
0.0	0	-
0.0	0	-
0.0	0	RFI DETECTED
0.0	0	-
0.012	0	-
0.012	.026	-




**Figure 2:** IR spectra ethanol with instrument measurement areas indicated. Intoxilyzer® 5000iEN (red-left) and 9000 (red-right)

**Chart 2:** Readings obtained with active cellular calls adjacent instrument at 850/1900 MHz frequencies



**Figure 3:** Intoxilyzer® 9000 RFI circuitry



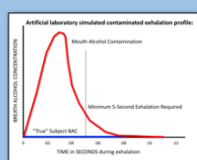
**Figure 4:** Intoxilyzer® 9000 label covering antenna

- Active cellular calls created intermittent *false-negative* & *false-positive* readings with 29% RFI detection
- Recommend that ALL adjacent **radio sources are eliminated** prior to evidentiary breath testing

### The Residual Alcohol Detection System (Slope Detector)

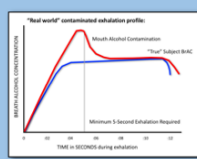
3

Intoxilyzer 9000 Results			
True® BrAC Reading	Reported BrAC	False Positive Amount	Error Message Generated by 9000
.010	.030	+ .020	-
.010	.025	+ .015	-
.010	.024	+ .014	-
.010	.068	+ .058	-
.010	.038	+ .028	-
.008	.060	+ .052	-
.008	.076	+ .068	-
.008	.038	+ .030	-
.008	.245	+ .237	Invalid Sample
.008	.135	+ .127	Invalid Sample



**Figure 5:** "Lab" mouth alcohol contamination testing profile

**Chart 3:** Mouth alcohol contamination results




**Figure 6:** "Real world" mouth alcohol exhalation profile

- There were only two instances (20%) where mouth alcohol contamination was identified as an **INVALID SAMPLE** (Contamination in excess of 0.120 g/dL)
- *Unreported* contamination ranged from + 0.014 to 0.068 g/dL
- Results identify need for minimum **deprivation and observation** period prior to, and between, evidentiary breath tests, and;
- Need for **duplicate breath testing** with results in agreement.

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01. International Association of Forensic Sciences (IAFS)  
02. New Forensic Technologies, Digital Evidence & Cybercrime

Figure 18 - The poster presented at the IAFS 2017 Conference. Reprints available upon request.

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