INTOX EC/IR II

BREATH TEST OPERATOR
INSTRUCTIONAL MANUAL

DEPARTMENT OF FORENSIC SCIENCE
BREATH ALCOHOL SECTION
EFFECTIVE JULY 7, 2008

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HISTORY OF THE BREATH ALCOHOL SECTION

The Division of Consolidated Laboratory Services, Bureau of Forensic Science, deriving its authority from §18.2-267 and §18.2-268 of the Code of Virginia, was responsible for the administration of the Virginia Breath Test Program from the program's inception in 1972 until 1990. In 1990 the Bureau of Forensic Science became the Division of Forensic Science, and in 2005 became the Department of Forensic Science (DFS). The Department's Breath Alcohol Section ensures that statewide quality assurance and operational standards are followed by the Commonwealth's law enforcement agencies when administering breath tests. To accomplish its goals, the Department of Forensic Science provides training, equipment, supplies, and laboratory support to local, state, and federal authorities. In addition to its responsibility for training and licensing operators, the Department maintains all evidential breath test instruments and provides records and expert testimony to the legal community.

Currently there are over 4,500 officers who are authorized by the Department to conduct breath tests in Virginia. From an initial ~13,500 tests in 1973, the first full year of operation, there has been an almost three-fold increase in the number of breath tests administered annually.

The rules and regulations that are promulgated by the Department establish specific requirements for administering breath tests. Only those individuals who have been trained and licensed by the Department of Forensic Science may conduct breath tests; furthermore, these tests must be administered only in the prescribed manner and only on approved and certified instruments.

To accomplish the task of training, the Department of Forensic Science supplements its staff by using police instructors to assist during training. All police instructors must successfully complete a Breath Alcohol Instructor Course conducted by DFS in addition to an initial certification course. The Department and the Breath Alcohol Section staff are extremely grateful to these professional volunteer instructors for their dedicated service to the program.

The Breath Alcohol Section of the Department of Forensic Science encourages inquiries.

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TYPES OF BREATH TEST EQUIPMENT

The continuing problem of the drinking driver has necessitated the advancement of detection and testing devices for alcohol since the early years of the automobile. Breath, because of the noninvasive nature of obtaining a sample, has been an obvious medium for which testing methods have been developed.

Instrument based breath testing began in 1972 in Virginia with the Breathalyzer®. This instrument relied upon a chemical reaction resulting in a color change. In the early to mid 1990's the Intoxilyzer 5000® was placed on the approved list of devices for Virginia and thereafter was the approved evidential device to be used for breath testing in Virginia. This instrument utilizes infrared (IR) analysis to calculate a result. In 2008, Virginia placed the Intox EC/IR II on the approved list for evidential testing. This instrument utilizes both IR and electrochemical (EC) analysis to derive a result. As an important note, the evolution of instrumentation through the years comes not from their accuracy and precision, but from their level of automation, data retention capabilities, and ease of operation.

PRELIMINARY BREATH TEST DEVICES (PBTs)

These test devices are portable and used primarily in the field prior to arrest. They are electrochemical solid-state devices with pass/fail indicator lights or a digital readout. In Virginia they are approved for use after testing and evaluation by DFS. They are not maintained by DFS. The list of approved devices is published in the Virginia Register of Regulations and may also be found on the DFS website.

EVIDENTIAL TEST DEVICE

Evidential test devices perform a quantitative analysis of alcohol in the breath. The Intox EC/IR II, manufactured by Intoximeters, Inc. is listed on the National Highway Traffic Safety Administration's (NHTSA) Conforming Products List (CPL) and has been approved for use by law enforcement personnel in Virginia.

> Intox EC/IR II**-** The instrument collects a sample of breath through which an infrared energy beam is passed. At the designated time a portion of the breath is introduced to the fuel cell and a result is calculated. The result appears on the digital display and is printed on a Certificate of Analysis.
>
> > Infrared**-** The IR sensor continuously monitors the breath sample to determine the exact moment to introduce the sample to the electrochemical portion of the instrument. The IR sensor is also used to detect residual alcohol in the mouth.
> >
> > Electrochemical**-** The use of a fuel cell, specific for alcohol, facilitates a chemical reaction that results in an electrical current. This current is then used to calculate the blood alcohol content present in each breath sample analyzed.

OVERVIEW OF VIRGINIA'S BREATH TESTING INSTRUMENT AND PERIPHERALS

INTOX EC/IR II

The Intox EC/IR II used in Virginia for evidential analysis has strict specifications that are identical in all evidential instruments maintained by the Department. Each instrument follows an automated process to analyze breath samples and report values. Operators should be familiar with each component associated with the instrument and it's peripherals to aid in discussion of the instrument and troubleshooting.

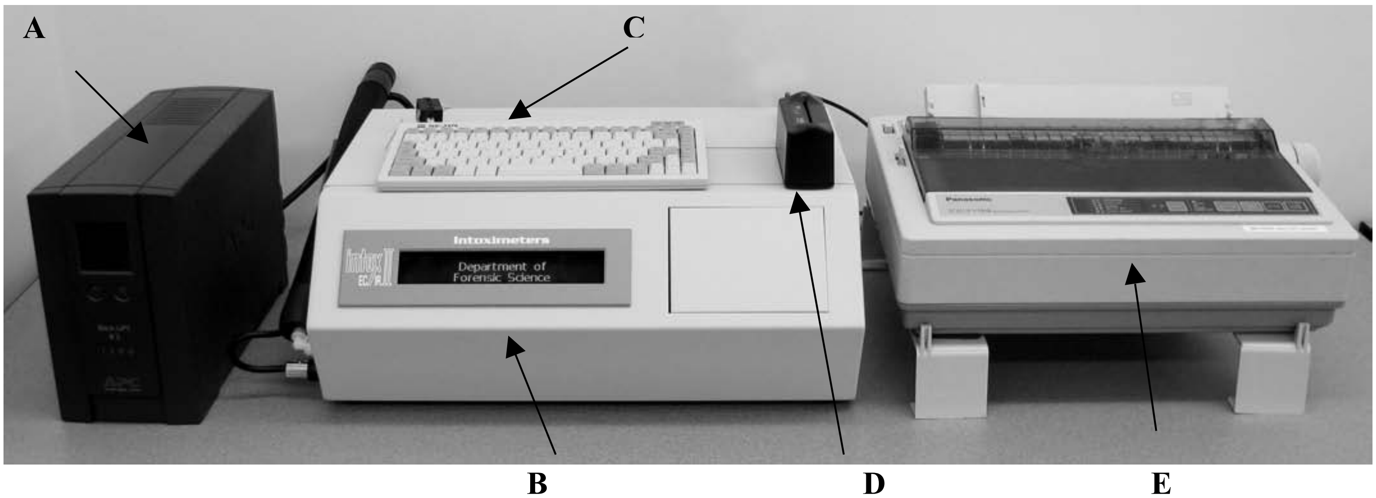


Figure 1 Virginia's Evidential Breath Testing System

A. Uninterruptible power supply (UPS). Used to condition the electricity powering the instrument and allow completion of a test if power is lost.

B. INTOX EC/IR II

Breath Tube — A heated, reinforced plastic tube through which the subject provides a breath sample to the instrument. A sterile mouthpiece is provided to each subject.

Display — A 2 line alphanumeric display. Indicates status of instrument and shows final result of subject test.

C. Keyboard — Standard keyboard, used to navigate the instrument prompts. Function keys also used to perform specific commands.

F1 Prints a copy of the last test.

F5 Resets the instrument back to scrolling DFS, date, and time.

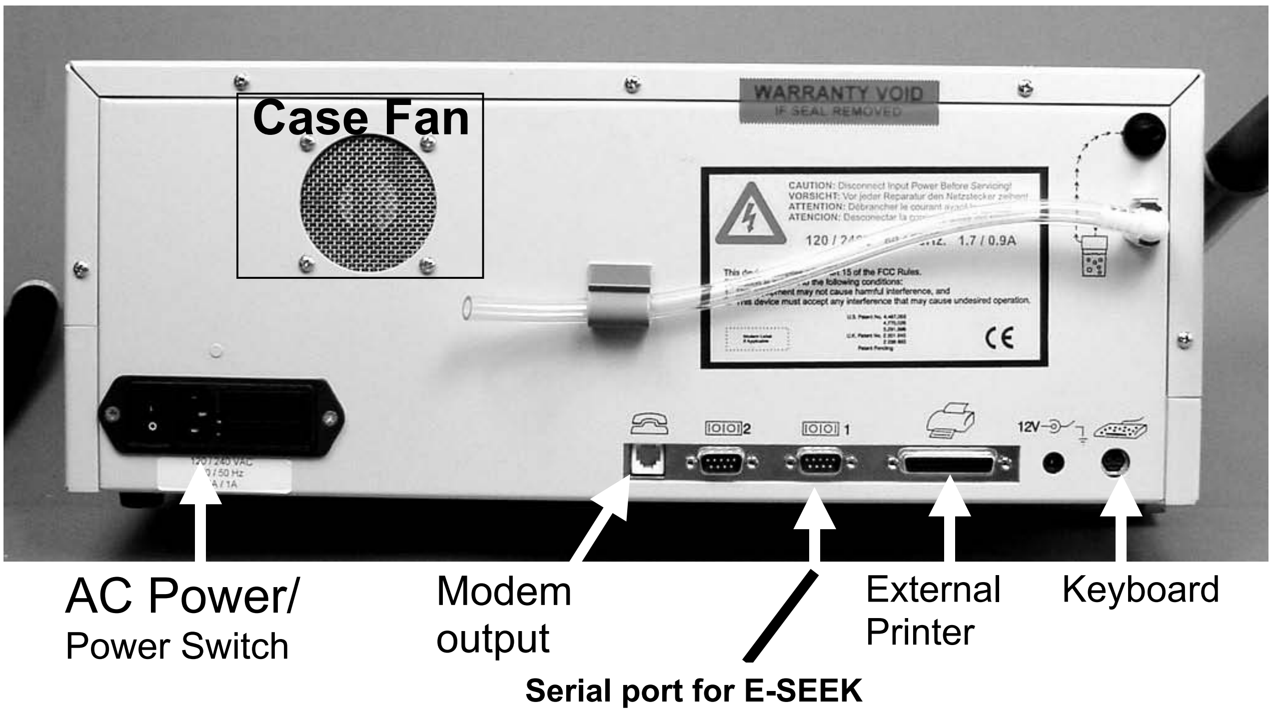
F7 Runs a **Purge/Blank** cycle.

D. Barcode Scanner

E-SEEK 200 barcode scanner. Used to read 2D barcodes on licenses.

E. Dot Matrix Printer — Refer to pages 6-9 for more information.

Rear Panel Connectors and Controls (Figure 2)



Case Fan	Cools the instrument.
AC Power	The power cord connects to this port.
Power Switch	A rocker type switch which turns the instrument on and off. To be used by, or at the direction of, DFS personnel.
Modem Output	Used to connect phone line to internal modem; used by DFS for collecting data.
Serial Port 1	Connection port for the E-SEEK 200 bar code scanner.
External Printer Port	Standard CENTRONICS interface for external printer.
Keyboard Connector	The keyboard of the instrument plugs into this port.

PRINTER

The Printer used is a Panasonic KX-P1150 dot matrix printer (Figures 3 and 4). The following pages list some of the parts and operations of the printer and its control panel (Figure 5). The printer is controlled by the control panel with the exception of loading paper.

A: TOP COVER – This is used to protect the printer tractors and certificates. It is removed when loading certificates.

B: CONTROL PANEL – Used to control printer operations. See Figure 5.

C: HEAD GAP LEVER – This lever should be positioned between the D and G. It is used to vary the pressure of the print head.

D: PAPER FEED SELECTOR – Indications the type of paper being used, should always be pulled towards the front of the printer

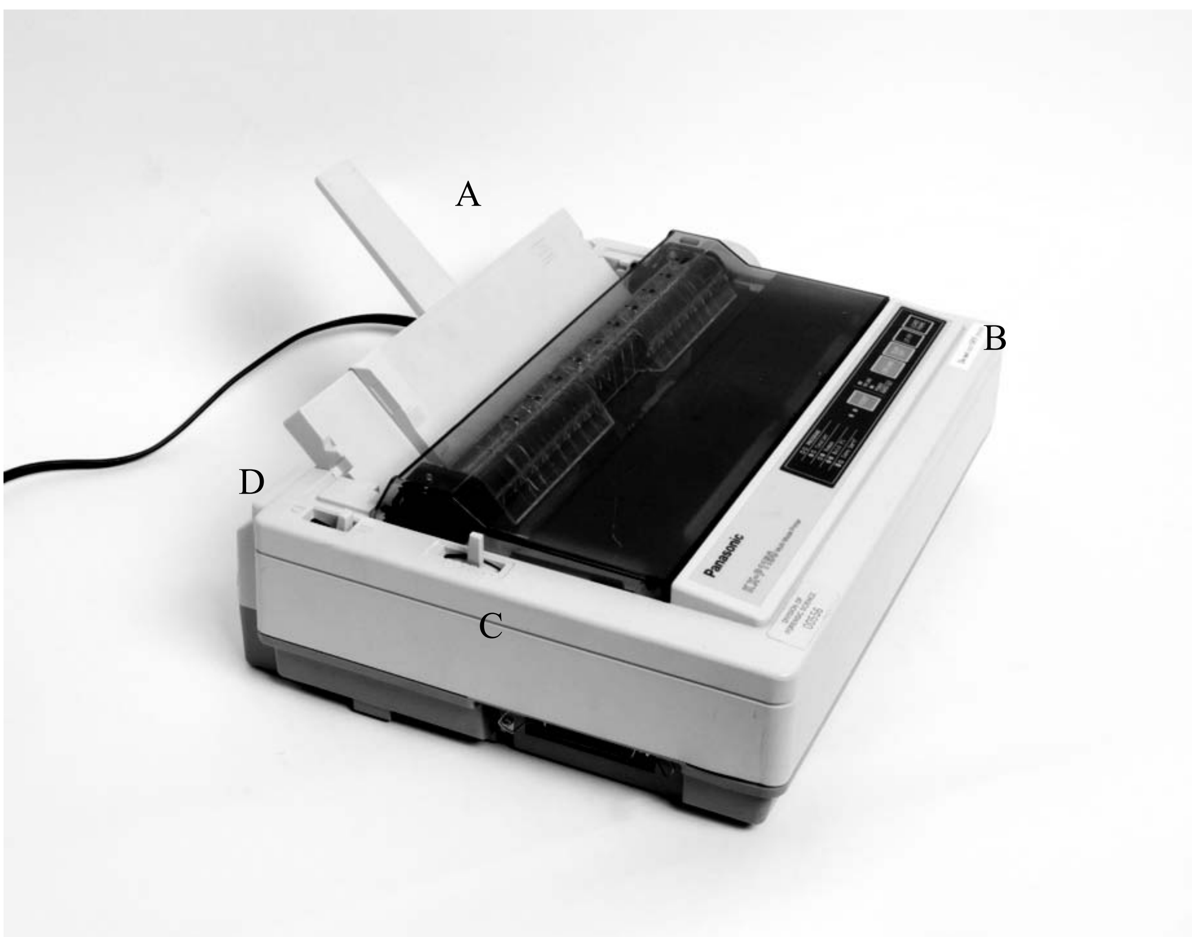


Figure 3

E: Power Switch – Used to turn the printer on and off

F: Platen Knob – DO NOT USE UNLESS REMOVING MISALIGNED FORM

G: Tractors – These are used to feed certificates into the printer.

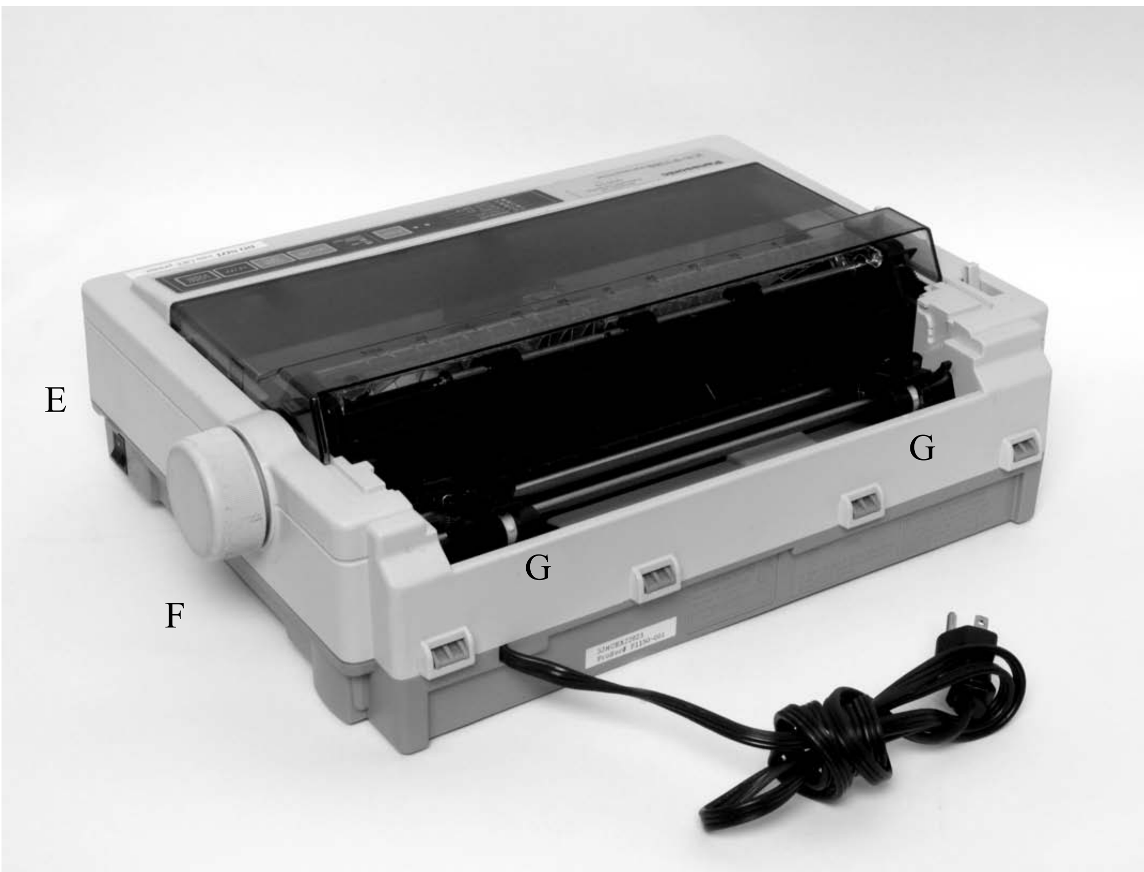


Figure 4

PRINTER CONTROL PANEL

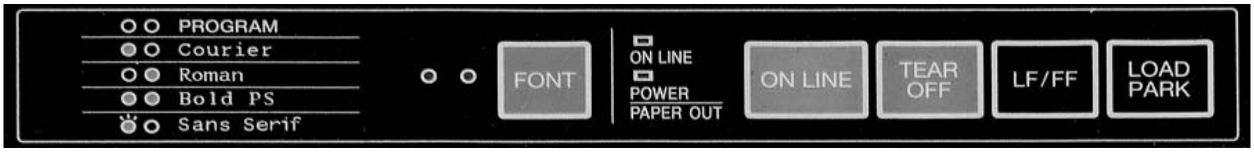


Figure 5

FONT INDICATORS – Both indicators should be unlit which indicates the PROGRAM font is being used.

FONT BUTTON – Changes the font selected.

ONLINE INDICATOR – This indicator must be lit for the printer to generate a certificate.

POWER / PAPER OUT INDICATOR – This indicator must be lit, if it is flashing load paper into printer.

ONLINE BUTTON – Used to bring the printer online.

TEAR OFF BUTTON – This button is pressed after the certificate is printed to remove it from the printer.

LF / FF BUTTON – This button should not be pressed.

LOAD PARK BUTTON – This button is used to load certificates into the printer or to realign certificates.

ALIGNING CERTIFICATES

1. Press the **LOAD PARK BUTTON** (the certificates will retract).

2. Press the **LOAD PARK BUTTON** again (the certificates will advance).

3. Make sure the **ONLINE INDICATOR** is lit.

The certificates are now properly aligned. F1 can be pressed to reprint the certificate of analysis if the next test has not been started.

LOADING CERTIFICATES

1. Remove printer **TOP COVER** to expose the tractor and tractor covers.

2. Open tractor covers (see figure 6).

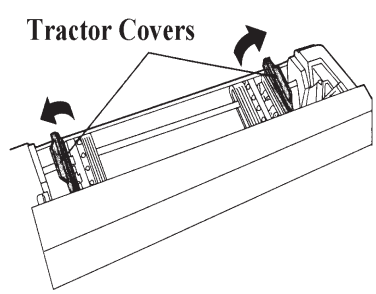


Figure 6

3. Align 2-3 holes of the top form on **TRACTORS** and close the tractor covers.

4. Replace the **TOP COVER**.

5. Press the **LOAD PARK BUTTON** (the certificates will advance).

6. Make sure the **ONLINE INDICATOR** is lit.

The certificates are now properly aligned. F1 can be pressed to reprint the certificate of analysis if the next test has not been started.

OPERATION

HOW TO RUN A SUBJECT TEST

The subject protocol requires a 20 minute observation period (minimum) followed by a licensed operator performing a subject test. The Department of Forensic Science supplies a worksheet that the operator may follow to perform the test. The subject must provide a minimum of 2 breath samples that meet all requirements for an evidential result to be given. A Certificate of Analysis is generated upon completing an evidential test. The following section outlines the steps an operator will take to perform a test.

(Visual commands that appear on the instrument display appear in **bold** typeface and are indented for ease of identification in this section)

While in ready mode, the following will scroll (display continuously):

> **Department of**
> **Forensic Science**
> **EC IR-II S/N XXXXX**
> **FRI Apr 4, 2008 13:16 EDT** (examples given)
> **Press ENTER to Start**
> **Subject Test**

Upon completion of a minimum 20 minute observation period, the operator will press the ENTER key to begin a test sequence.

> **Initializing…**
> **Swipe Operator card:**

Operator should swipe their operator license. The 2D barcode should face the green light on the barcode reader.

> **Reading**

The following prompts along with the appropriate operator information will be displayed; no changes may be made to the information. Press F5 to return to scrolling if incorrect information is displayed.

> **Operator's Last Name:**
> **Operator's First Name:**
> **Operator's Middle Initial:**
> **Agency:**
> **License Number:**
> **Card Serial Number:**
> **Effective Date:**
> **Expiration Date:**
> **Enter operator pin:**

Operator must type in his/her assigned pin number to continue the sequence. If an incorrect number is entered the display will highlight the (*) symbols and allow re-entry of pin.

Enter operator pin:
****

Swipe Subject DL/ID Card:
or press enter

Swipe the driver's license or ID card using the barcode reader. The following prompts will appear with the corresponding subject information. The subject's information will appear highlighted, indicating that the information may be edited. If no editing is necessary depress the ENTER key to advance to the next screen.

Reading

Subject's Last Name:
LastName

If Applicable, add suffix after Last Name (e.g. Smith JR).

Subject's First Name:
FirstName

Subject's Middle Initial:

Subject's Date of Birth:
MM/DD/YYYY

Subject's Sex:
M

Use space bar to toggle between M and F

Driver's License Number:

Driver's Expiration Date:

Driver's License State:
VA

Court Name:

_

Operator manually enters appropriate jurisdiction and court (e.g. Henrico Co. General District Ct.)

Starting Test Sequence:
SPACE = Cont. ENTER = Review

If any subject information has been changed, a review should be initiated by pressing the ENTER key.

If a physical license or ID card is unavailable, the operator should manually enter the subject's information following the instrument's displayed prompts. Editing may be done by using the backspace key. If subject information is manually entered, the operator should perform a review of that information by pressing the ENTER key before continuing the test sequence.

Depress the Space bar to continue the test sequence.

Test # XXX

Diagnostic Test
Diagnostic Test Passed

As a note: although the diagnostics message is displayed at this point, the diagnostic checks are run continuously on the instrument. Any deviation beyond defined values will result in the testing process being aborted.

Purging
Remove Mouthpiece

Blank Check
Blank Check Passed

Please Wait

Taking Standard Sample

Evaluating Sample
Check: Passed

Purging
Remove Mouthpiece

Blank Check

Blank Check Passed

Please Wait
Please blow until
the tone stops

Please Blow

Please Blow flashes on the display until the subject begins to blow. It will flash for a total of three (3) minutes if the subject does not provide a sample. The **Please Blow** prompt remains steady on the display once the subject begins to blow into the instrument.

Prior to allowing the subject to blow into the instrument, the operator should ensure that the subject has not burped, vomited, etc. or placed anything in their mouth during the 20 minute minimum observation period. The operator will remove a new mouthpiece from its bag, put it on the breath tube, and instruct the subject to provide a sample. After the subject begins to blow, a drop in pressure from the subject detected by the instrument prior to meeting the minimum parameters, will interrupt the sampling cycle. The instrument will purge the sampling system and allow the subject to begin again. This cycle of blow/drop in pressure/ **Purge/blank** can continue until the 3 minute time allotment of **Please Blow** has expired. Once the breath meets the required parameters, a portion of the sample will be introduced to the fuel cell for analysis. The following will be displayed:

Evaluating Sample

Sample Accepted

Purging
Remove Mouthpiece

Operator will remove mouthpiece and retain for the next sample(s).

Blank Check
Blank Check Passed

Please Wait
XX:XX

A countdown of time left between samples is displayed. The instrument has an automated two minute interval before the next **Please Blow** prompt.

Please Wait

Please blow until
the tone stops

Please Blow

As before, the operator should ensure that the subject has not burped, vomited, etc. or placed anything in their mouth during the observation period, then place the mouthpiece back on breath tube and instruct subject to provide sample.

Evaluating Sample
Sample Accepted

Purging
Remove Mouthpiece

Blank Check
Blank Check Passed

If subject samples were within 0.02 g/210 L of each other, the following will display and then return to scrolling.

Subject: 0.XX g/210L

Database Update: Success

FINAL RESULT

If the difference between sample 1 and sample 2 is greater than 0.02 g/210L, the instrument will require another 2 minute wait, and then prompt Please Blow. Again the operator will ensure that the subject has not burped, vomited, etc. or placed anything in their mouth during the observation period, then place the mouthpiece back on the breath tube and instruct subject to provide sample.

The final result is the lowest of the 2 or 3 samples provided by the subject, truncated to 2 digits past the decimal point.

PRACTICE TEST

To run a practice test, swipe your operator license and enter corresponding pin number. When prompted for subject's last name, enter "**Practice**". When prompted for subject's first name enter "**Test**". Skip other entries except court (enter your normal court with jurisdiction). Certificate may be discarded upon completion.

OPERATOR INSTRUMENT MESSAGES

AMBIENT/RFI DETECTED – Radio Frequency Interference or High Ambient conditions detected in the purge cycle of the subject test and the subject test sequence is aborted. **"Check Ambient Conditions, Ambient/RFI detected"** is displayed on digital display. A certificate of analysis is printed. Identify and eliminate source, restart subject test.

DEFICIENT SAMPLE – Subject did not meet the minimum requirements for a proper breath sample. Subject did not provide a complete breath sample during the 3 minute **"Please Blow"** prompt. A certificate of analysis is printed and **RETEST [Y/N]?** is displayed on the instrument.

EXPIRED BADGE – Operator's License is expired. Check license, contact DFS.

INSTRUMENT DISABLED; CERTIFICATION REQUIRED – Contact DFS

INTERFERENT DETECTED – A chemical other than ethanol was detected on the subject's breath, seek medical attention for the subject.

INVALID SAMPLE – Mouth Alcohol detected while subject was providing a breath sample. If retesting the subject, an additional 20 minutes will be observed. A Certificate of Analysis with **INVALID SAMPLE** is printed and **RETEST [Y/N]?** is displayed on the instrument.

NO SAMPLE GIVEN – No pressure detected by the instrument during the 3 minute **"Please Blow"** prompt. Subject did not provide a sample. A Certificate of Analysis with **NO SAMPLE GIVEN** is printed and **RETEST [Y/N]?** is displayed on the instrument.

OPERATOR ABORT – Operator stopped subject test. If aborted after the diagnostics were complete, the instrument will not allow another test to be run on that subject for 20 minutes.

OUT OF TOLERANCE – Dry gas standard out of range (greater than ± 5% of the target). Restart the subject test. After the second **OUT OF TOLERANCE** the instrument will disable itself and will contact DFS.

PRINTER OFFLINE – Printer attached to instrument is offline, check the printer.

Paper Out – Check printer to make sure it has Certificates loaded.

Remote Access – DFS is in contact with instrument

Retest [Y/N]? - This message is displayed for 25 minutes after the **Deficient Sample**, **No Sample Given**, and **Invalid Sample** instrument messages. If 'Y' is pressed, the instrument will go through diagnostics and prompt the subject to **"Please Blow"**. If 'N' is pressed the instrument returns to Scroll Mode. After an **Invalid Sample** message, an additional 20 minute observation period will be required for the subject. If neither 'Y' nor 'N' is chosen during the 25 minute prompt, the instrument automatically resets to Scroll Mode.

Sample Parameters Not Met – There was no 0.02 agreement between the 3 breath samples provided by the subject. Restart the subject test.

Sequence – Incorrect sequence during the subject test. Restart the subject test.

Test Result over range/Sample Result over Range – Results exceed upper limit of the instrument (0.000-0.500 g/210L.) Seek medical attention for the subject.

SCIENTIFIC PRINCIPLES

Operators are not expected to have total mastery of all material contained within the scientific portions of the manual. The initial class is designed to give an overview of these principles and operators will be tested on broad understanding of the principles. This manual includes more in-depth information for those who wish to gain a greater understanding of the scientific principles governing breath testing and the Intox EC/IR II.

The Use of Breath as a Sample

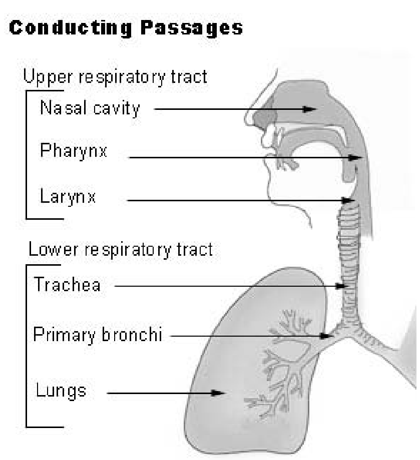
OVERVIEW

Breath testing as a means of determining alcohol content has been utilized since the 1940's. The use of breath as a sample has been proven to be both accurate and reliable. As compared to a blood test it is non-invasive to the subject and relatively quick.

Breath alcohol analysis is possible because alcohol is eliminated through human lungs in a small but measurable amount.

THE RESPIRATORY SYSTEM

The respiratory system appears as an inverted tree. The trunk is the windpipe (trachea) which then separates into 2 branches (bronchus). Figure 7 shows the upper and lower respiratory systems. The branches are inside the lungs and continue to branch out until they end in microscopic sacs (alveolus). This alveolar region is where gas exchange takes place. Figure 8 shows a cutaway section of an alveolus. Where blood vessels come in contact with the alveolar sacs there is an exchange of oxygen from the deep lung air into the blood and an exchange of carbon dioxide from the blood into deep lung air. Likewise, any alcohol present in the blood will also transfer into deep lung air. When this occurs, the deep lung air will contain approximately 1/2100th as much alcohol as the blood. This relationship of breath to blood is measurable due to Henry's Law.



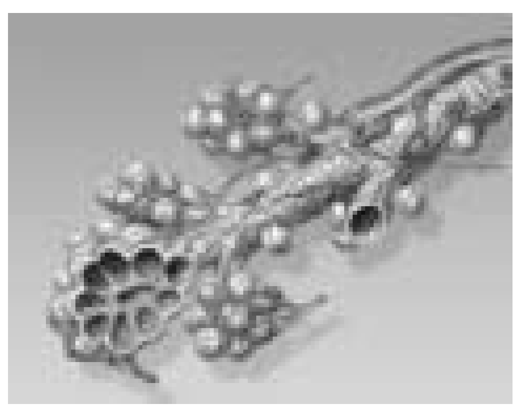


Figure 7 (Wikipedia) **Figure 8**

HENRY'S LAW

> "The weight of any gas that dissolves in a definite volume of liquid is directly proportional to the vapor pressure that the gas exerts above the liquid. This proportion differs at varying temperatures, pressures, and volumes."

Henry's Law is a scientific law that governs the interaction of a gas and a liquid. In our application the alcohol is a gas and blood is the liquid portion. A relationship exists between the concentration of alcohol in the blood and the concentration of alcohol in the alveolar air. The relationship currently used evidentially in the United States is 2100:1; that is, the amount of alcohol in 2100 mL of breath is comparable to that in 1mL of blood.

BREATH SAMPLING IN THE INTOX EC/IR II

The unique pressure sensing system in the Intox EC/IR II requires that fuel cell sampling takes place near the end of an exhalation once sample parameters have been met. Any reduction or cessation of flow rate (if it is detected prior to reaching the required parameters) causes the instrument to interrupt the sample collection. The instrument performs a purge/air blank cycle and the subject may then attempt another breath sample. After reaching the minimum volume, the instrument will take a portion of the breath sample for analysis by the fuel cell.

MOUTH ALCOHOL AND BREATH TESTING

Residual mouth alcohol must be considered when conducting a breath test. After drinking an alcoholic beverage, some alcohol (liquid or vapor) is temporarily retained in the mucous lining (the moist secreting tissues) of the mouth and the nasal passages. This is known as residual mouth alcohol. When deep lung air is exhaled, the vapor from any residual alcohol could be picked up by the deep lung air as it passes out of the mouth. Under these circumstances, mouth alcohol can cause a potentially greater concentration of alcohol in the breath sample, which in turn can cause a falsely higher BAC reading.

The effect of residual mouth alcohol is dependent upon: (1) the concentration of alcohol originally in the mouth, (2) the time the alcohol stayed in the mouth, and (3) the time elapsed since the alcohol was in the mouth. Experiments have shown that residual mouth alcohol will be eliminated by normal body processes well within 20 minutes. For this reason, the subject must be observed for 20 minutes prior to providing a breath sample.

Residual mouth alcohol contamination of a breath sample could occur in several ways other than from drinking an alcoholic beverage. First, the subject, who has alcohol in his/her stomach, could vomit and thus bring alcohol-bearing solids and liquid into the mouth cavity, producing residual alcohol. Second, a subject, who has alcohol in his/her stomach, could belch, bringing alcoholic vapor into the mouth.

Rinsing the mouth with water is not effective in eliminating mouth alcohol. When a drinking-driving subject has recently taken a drink, vomited, belched, or otherwise come in contact with alcohol, another 20-minute observation must be performed for the effects of any residual mouth alcohol to dissipate before a valid breath sample can be taken.

On occasion, a subject may have used a mouthwash in an attempt to mask the odor of an alcoholic beverage. Many mouthwashes have a significant alcohol concentration (up to 20% by volume) and should be regarded in the same manner as an alcoholic beverage. The breath test operator should be alert to the possibility of residual mouth alcohol contamination when he/she detects the characteristic odor of a mouthwash or sees the subject attempting to use a mouthwash. The foregoing also applies to cough medicines that contain alcohol. Another source of residual mouth alcohol could be an alcohol-saturated cotton wad used to relieve dental pain. The operator should always inspect the subject's mouth for any foreign objects. If found, they should be removed, and the subject must be observed for 20 minutes prior to providing a breath sample.

The Department of Forensic Science operator and instrument protocols, along with the Intox EC/IR II have several safeguards in place to prevent an inaccurate analysis and to ensure a valid test.

> <u>Visual inspection of the mouth</u>: Inspecting the mouth prior to conducting the observation period ensures that no foreign object(s) are within the mouth. If found, the foreign object(s) should be removed and a 20 minute observation period observed. As a note, based on the results of published, peer reviewed articles and DFS laboratory experimentation, the Department of Forensic Science does not require a subject to remove dental appliances or mouth piercings because of the lack of effect on breath alcohol results.
>
> <u>A minimum 20 minute observation period</u>: Experiments have shown that residual mouth alcohol will be eliminated by normal body processes well within 20 minutes. As a reminder, the operator should also ensure the subject has not belched, burped, or regurgitated during the observation time. An additional 20 minute minimum observation period should be observed if the subject does belch, etc. during the observation period. Comments can be noted on the operator worksheet.
>
> <u>Sampling protocol</u>: The Department of Forensic Science protocol requires a minimum of 2 breath samples, 2 minutes apart, with a minimum 0.02 sample agreement. If no 0.02 sample agreement is reached with 3 breath samples, the final result will be SAMPLE PARAMETERS NOT MET.
>
> <u>Intox EC/IR II safeguards</u>: The analytical portion of the instrument utilizes 2 different methods for detecting mouth alcohol. If mouth alcohol is detected, the instrument will abort the test and report INVALID SAMPLE. If this occurs and the operator decides to retest that subject, they must perform an additional 20 minute observation. The instrument will not allow another test to be run on that subject until 20 minutes has elapsed.

OPERATING PRINCIPLES

OVERVIEW OF THE INTOX EC/IR II

The Intox EC/IR II employs two distinct analytical techniques to achieve an alcohol concentration result. Both an electrochemical sensor (i.e. fuel cell) and infrared (IR) analyses are utilized. These techniques each offer a different advantage to the sampling process.

The IR system continuously monitors a breath sample. This process analyzes the quality of the sample and in conjunction with the pressure sensor determines the correct moment to draw the sample into the fuel cell. The fuel cell is specific to alcohols and provides a stable, linear response to ethanol.

In combination, these two analytical systems provide all the necessary information to make determinations of breath alcohol concentration and ensure that the instrument takes a sample representative of the blood alcohol content. Figure 9 shows a simplified diagram of the breath sampling system that contains both analytical systems.

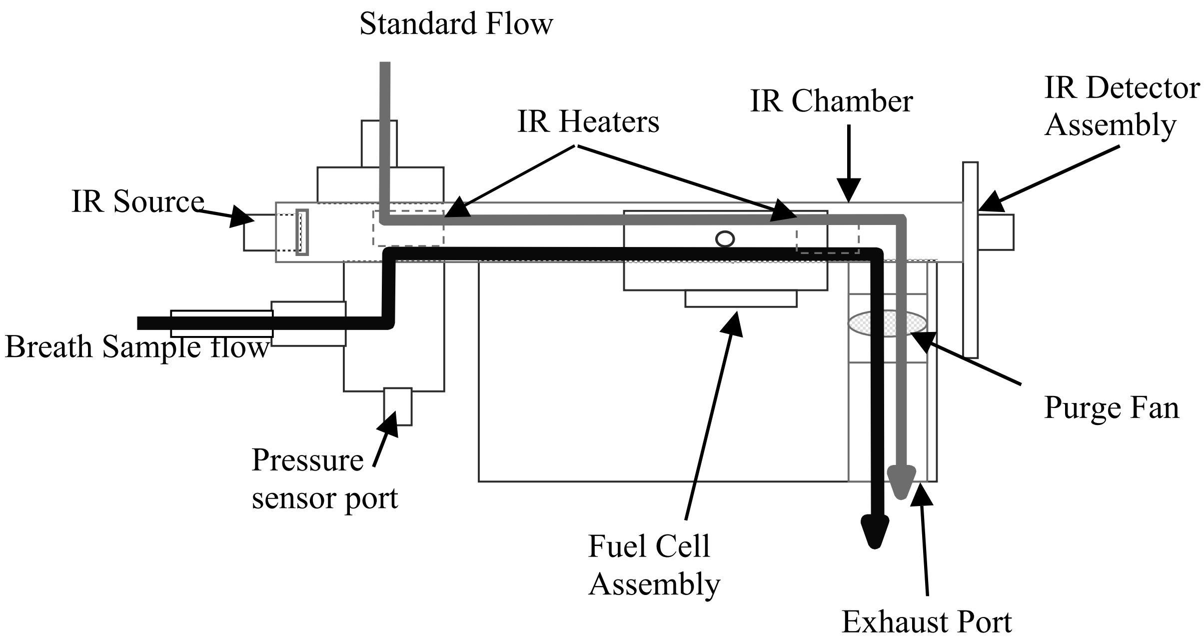


Figure 9

DUAL MICROPROCESSOR CONTROL

The Intox EC/IR II provides a user interface that can be easily customized without affecting the reliability and stability of the analytical functions. This system is comprised of two separate microprocessor-controlled modules that are connected by a secure communication link. The advantage of this system is that changes in hardware or software for one module do not affect the stability and reliability of the other module.

BREATH SAMPLE VOLUME

The breath sensing system in the Intox EC/IR-II requires that sampling takes place near the end of an exhalation. A pressure sensor continuously monitors the flow rate of the breath as it enters the instrument. Before reaching the required minimum volume, any reduction or cessation of breath flow by the subject causes the instrument to interrupt the sampling and perform a **PURGE / BLANK** cycle. The subject may then attempt to provide another breath sample. Once the pressure sensor detects the minimum volume, it monitors the flow for a reduction in breath flow, which signifies the approaching end of expiration. The pressure sensor, in conjunction with the IR system, determines when the instrument will take a portion of the breath sample for analysis via the fuel cell.

THE INFRARED ANALYSIS SYSTEM

Historically, infrared light has been used to identify chemical compounds. When infrared light is passed through a substance, some of the infrared light (energy) will be absorbed. Absorption occurs at different wavelengths and is dependent upon the molecular structure of the compound being tested.

The absorption of light can be explained by the Beer-Lambert Law. Which states: “if a light is directed through a container, the amount of light detected on the other side of the container is decreased by any substances in the container in proportion to their absorption coefficients and concentrations, and is also decreased in proportion to the distance across the container.”

Therefore, the greater the concentration of ethanol in the sample, the more infrared light it will absorb. Because the Beer-Lambert Law is independent of volume, the infrared analysis system instantaneously and continuously analyzes the sample. This feature allows the instrument to monitor the sample for mouth alcohol and determine the appropriate time to introduce a sample into the fuel cell.

INFRARED OPTICAL BENCH SCHEMATIC (FIGURE 10)

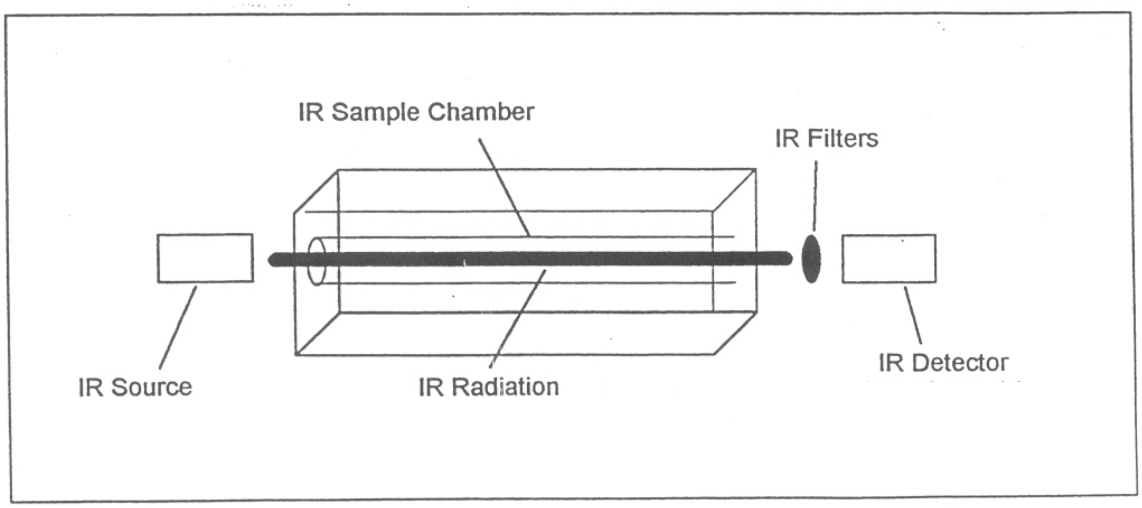


Figure 10: IR Bench Schematic

Infrared Source

The source of energy is a tungsten heater mounted in a parabolic reflector. The heater radiates energy over a wide range of wavelengths in the infrared portion of the spectrum.

Infrared Sample Chamber

The infrared sample chamber is constructed of nickel-plated aluminum. The chamber length is 5 inches. The chamber is heated to a temperature of 40^{o} C +/- 1^{o} C to eliminate water condensation.

Infrared Filters

There are three filters: two to detect ethanol and one to detect carbon dioxide (CO_2).

Infrared Detector

The detector measures the amount of infrared energy passing through the filters.

MOUTH ALCOHOL DETECTION

Two different methods are utilized during the test sequence. Gross (abundant) mouth alcohol is detected via the ethanol channel. A second method using both the ethanol and CO_2 channel is used to detect more discrete mouth alcohol.

AMBIENT/ RFI DETECTED

The Intox EC/IR II was designed and certified by an independent laboratory to meet radio frequency interference (RFI) immunity requirements. Although the instrument is certified as immune to RFI, it is recommended that no transmitting devices be used in the testing room during the testing sequence. This recommendation is intended to effectively eliminate defense claims that a test was tainted by frequency interference. However, if the instrument is subjected to a strong source of chemical vapor or RFI, the instrument would abort the test and display **Ambient/RFI Detected**.

THE FUEL CELL ANALYSIS SYSTEM

In simplest form, the alcohol fuel cell consists of a porous, chemically inert disk coated on both side with finely divided platinum (called platinum black). An acidic electrolyte solution is applied to the porous disk, with platinum wire electrical connections applied to the surfaces. The entire assembly mounts in a plastic case, which allows a fixed volume of breath to be introduced to the upper surface. See figure 11.

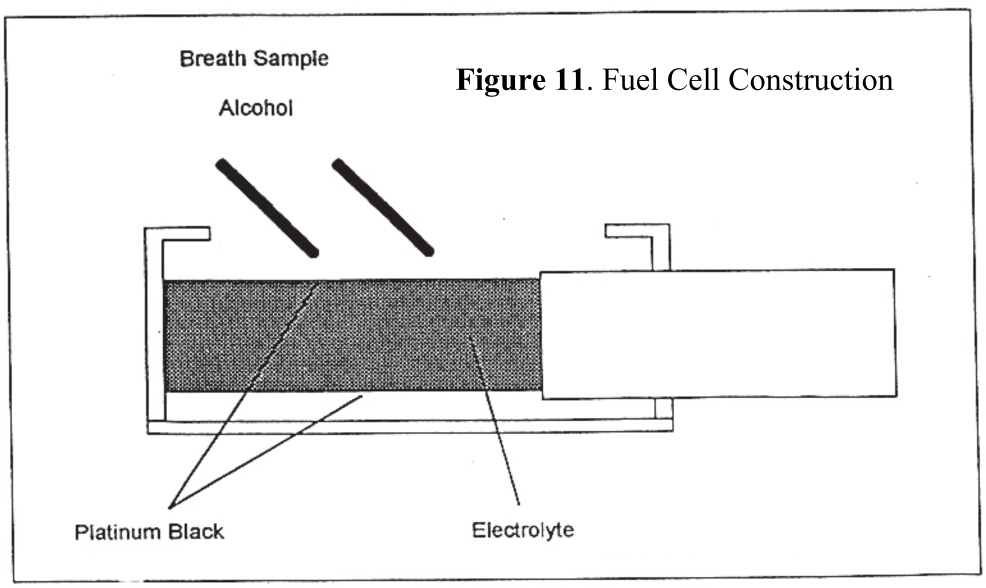


Figure 11. Fuel Cell Construction

OXIDATION

The chemical reaction that occurs is called oxidation: alcohol is broken down to acetic acid and in the process, produces free electrons and hydrogen ions. This reaction takes place on the upper surface of the fuel cell. The hydrogen ions freed in the process migrate to the lower surface of the cell, where they combine with atmospheric oxygen to form water, consuming one electron per ion in the process. This results in the upper surface having an excess of electrons, and the lower surface having a corresponding deficiency of electrons. If the two surfaces are electrically connected, a current flows through this external circuit to neutralize the charge. This current is measured and indicates the amount of alcohol oxidized by the fuel cell.

INTERFERING SUBSTANCES

One of the advantages of fuel cells is their lack of cross-sensitivity to substances other than alcohol. The fuel cell simply does not react or see those compounds. Other alcohols such as methanol and isopropyl alcohol have a small cross sensitivity on the fuel cell. However, these alcohols exhibit different characteristics when analyzed by the fuel cell. Upon detection of these alcohols the instrument will abort the subject test and display INTERFERENT DETECTED. It is recommended that medical attention is sought for the subject upon receipt of this message.

DRY GAS AS A STANDARD

OVERVIEW OF DRY GAS

Simply defined, "dry gas" is a gas or mixture of gases that contains virtually no water vapor. The standards used in evidential breath testing are a mixture of ethanol and nitrogen that are mixed to produce a known ethanol gas concentration. (Figure 12) Dry gas standards are stable over an extended period of time. When this gas is introduced into the sample system of an instrument, it is analyzed in the same way as a subject breath sample. (Figure 13)

Figure 12: Ethanol Standard Dry Gas Cylinder (left)

Figure 13: Standard connected to Inlet Port (below)

DRY GAS STANDARDS IN VIRGINIA

The dry gas used by the Department of Forensic Science is certified for accuracy and traceable to National Institute of Standards and Technology. It is used to verify the instrument is functioning properly. Each subject test requires that an accuracy check (verification test) be performed prior to the subject providing breath samples. The dry gas vapor must be within ±5% of the target value to continue the testing sequence. If the vapor results are higher or lower than the 5% limit, the instrument will abort the test and display **Out of Tolerance**. A second consecutive, **Out of Tolerance** instrument message will result in the instrument becoming disabled and will require DFS assistance to remedy.

GAS LAW THEORY

The Ideal Gas Law is used to explain the relationship between concentration, temperature and volume of a gas. The equation that governs the relationship is:

$PV = nRT$ where P is the absolute pressure of the gas,
V is the volume of the gas,
n is the number of moles of gas,
R is the universal gas constant, and
T is temperature (in Kelvin)

Removing the constant, you have PV =nT. As pressure rises, volume will decrease if the temperature and moles (molecules) of gas are held constant.

TEMPERATURE

According to the Ideal Gas Law, an increase in the temperature of gas, results in an increase in volume if it is allowed to expand. This is not the case when confined in a rigid container such as a metal gas cylinder. The analytical system in the Intox EC/IR II is heated, which provides a stable, consistent operating temperature for the analysis to take place. With temperature as a constant, the equation simplifies to PV = n.

BAROMETRIC PRESSURE

Barometric pressure is the force exerted on an object due to altitude and/or changing weather conditions. Altitude is compared to sea level. The greater the altitude (a mountain top vs. a seaside beach), the lower the barometric pressure that exists. Much of Virginia resides close to sea level. The highest point in Virginia is Mt. Rogers, which is 5,729 feet above sea level.

Returning to the equation (PV = n), a simple algebraic rearrangement gives you P = n/V. The n/V portion of the equation is analogous to concentration. The volume of the gas tank remains constant because it is rigid. Hence, a decrease in pressure will result in a decrease in concentration.

For example, a change in altitude of 333 feet results in a change of .001 ethanol concentration. At sea level a gas tank labeled at 0.100 g/210 L will read 0.100 g/210 L. On Mt. Rogers (5,729 feet above sea level) that same tank will read 0.082 g/210 L on the instrument.

The Intox EC/IR II is designed to measure the barometric pressure when analyzing the dry gas standard. Once the gas is analyzed, the result is compared to the expected (target) value which has had the barometric pressure taken into consideration. No change is made to the measured concentration. The dry gas vapor must be within $\pm$5%

of the target value to continue the testing sequence. This process is inherent to the Virginia testing protocol and requires no input from the operator.

ALCOHOL

NOMENCLATURE, TYPES AND PRODUCTION OF ALCOHOL

Alcohol is an organic compound containing carbon and hydrogen atoms and a hydroxyl (-OH) group. The most frequently encountered alcohols are infinitely soluble in water, weak acids, and are clear and colorless. Various types of alcohols have their own respective properties and toxicities, and as such, death will result if a sufficient quantity is consumed or otherwise introduced into the body. Different alcohols have varying levels of toxicity because metabolism by the body forms different products as seen in the table below.

Table 1:

COMMON ALCOHOLS				
NAME	FORMULA	BOILING POINT	USES	TOXICITY & METABOLITE
Methanol methyl alcohol wood alcohol	CH_3OH	64.5° C	Denaturant Solvent Paint Remover Fuel	~ 75 ml Formaldehyde
Ethanol ethyl alcohol grain alcohol	C_2H_5OH	78.3° C	Beverage Solvent Medicinal Veh. Fuel	~ 400 - 500 ml Acetaldehyde
Isopropanol isopropyl alcohol rubbing alcohol	C_3H_7OH	82.3° C	Denaturant Antiseptic	~ 250 ml Acetone
Butanol butyl alcohol	C_4H_9OH	117° C	Perfume and Aftershave Base	~ 100 ml

PROPERTIES OF ALCOHOLS

Alcohols are clear, colorless liquids with odors which tend to increase in complexity and intensity proportionally with their formula. Other properties of alcohols are:

> **Antiseptic**. Alcohols can be used as antiseptics. Since they are freely miscible with water, they tend to "dry out" the "germs" in the areas treated with the alcohol.
>
> **Diuretic**. Alcohol increases urine production.
>
> **Drug**. Alcohols, especially ethyl alcohol, are classified as drugs and act as central nervous system (CNS) depressants. Therefore, they are often classified as anesthetics.
>
> **Food**. Alcohol can be classified as a food since it produces heat (calories) during metabolism; however, alcohol and its metabolites have no nutritional value.
>
> **Miscible**. Alcohols are infinitely soluble in water. Alcohols will not settle out of solution, even upon sitting because of this affinity for water.
>
> **Poison**. Alcohols are poisons, whether by acting on the CNS or by producing toxic metabolites as the body oxidizes them.
>
> **Vasodilator**. Alcohol tends to dilate (make larger) the blood vessels in the body. This dilation can be especially noticeable in the surface blood vessels in the nose and face.

ETHYL ALCOHOL

Ethyl alcohol (ethanol) is the specific alcohol present in alcohol beverages.

In its pure state, ethyl alcohol is a colorless liquid with a slight odor. Because the odor is delicate, it will often go unnoticed. Ethanol also produces a burning sensation.

Simply stated: Ethyl alcohol is a clear, colorless, essentially odorless liquid that has a burning taste.

PRODUCTION OF ETHYL ALCOHOL

Ethyl alcohol can be produced both naturally by fermentation and synthetically. Synthetic production is usually accomplished by breaking down petroleum products during the refining process. This alcohol is used for industrial purposes and it is not sold for human consumption. Thus, synthetically produced ethanol is denatured (poisoned) to discourage consumption. Methanol and isopropanol are frequently used to denature industrially produced ethanol. Consumption of denatured ethanol can be very unpleasant and possibly lethal.

By law, all ethanol produced for human consumption must be produced by fermentation. Any plant matter such as grains, fruits, or vegetables containing 12 - 15% sugar can be used as a source for ethanol production. Yeast, either naturally occurring or added as a pure culture, ferments the sugar and produces ethanol and carbon dioxide.

THREE MAJOR TYPES OF ALCOHOLIC BEVERAGES

Fermented. Beer and wine are the most commonly fermented beverages. These beverages are produced by allowing the fermentation process to take place, filtering the beverage, and then packaging it for use. In the U.S., beer typically has an alcohol content of approximately 4%, whereas wine usually has an alcohol content of 10 - 12.5%. If conditions are optimal, then the maximum alcohol content attained by fermentation is approximately 15%.

Distilled. Whisky, rum, vodka, etc. are distilled beverages produced by fermenting their respective raw materials (grains, molasses, potatoes, beets, etc.). Next, the resultant mixture is distilled, a process where the mash, wine, or other alcohol-containing mixture is heated. When a solution of alcohol and water is heated, the alcohol will boil first, since it boils at 78.3° C. As the alcohol boils, the vapors are collected and condensed. This alcohol is then used to produce a distilled beverage, which contains a higher alcohol content than a fermented beverage.

Fortified. Fortified wines are the most common beverages of this type. Fortified wines typically contain 18 - 20% alcohol and can be even higher in alcohol content, which is achieved by either adding alcohol from another source or by distillation. Wine is distilled to separate the alcohol from the fruit juice. A portion of the fruit juice is removed for use in other food products, and the distilled alcohol is mixed with the remaining fruit juice to produce a fortified wine.

CONGENERS

In addition to alcohol and water, alcoholic beverages contain numerous compounds or impurities known as congeners. These typically impart a characteristic color, flavor, and odor to the beverage. They constitute a very small portion (1% or less) of the total volume of the beverage.

PROOF SYSTEM

In the United States, the proof of an alcoholic beverage is twice the percentage of alcohol by volume. Thus, an 86 proof (also written 86°) bottle of whiskey contains 43% alcohol by volume. Most alcoholic beverages have a maximum of approximately 50% alcohol by volume. The remainder consists of water and congeners.

PHYSIOLOGY

When consumed, alcohol follows a path through the esophagus and into the stomach. While in the stomach, some of the alcohol will be absorbed unchanged into the bloodstream before passing to the small intestine. Most of the remaining alcohol will be absorbed from the small intestine into the blood and carried to all parts of the body.

Since alcohol has an affinity or attraction for water, alcohol will accumulate in the body tissues in proportion to their water content. Once absorbed into the bloodstream, the body immediately starts to metabolize the alcohol. This metabolism is largely accomplished in the liver where the alcohol is ultimately oxidized to carbon dioxide and water.

The following discusses the absorption, distribution, and elimination of alcohol in the body.

ROUTES OF ABSORPTION

Absorption for the Gastrointestinal Tract. Alcohol is absorbed by various parts of the gastrointestinal tract as follows:

> -- Alcohol can be absorbed through the mouth lining: however, the amount is normally insignificant since fluid leaves the mouth rapidly. A mouth rinsed with liquor will be free of residual alcohol in less than 20 minutes.
>
> -- Approximately 25% of ingested alcohol is absorbed directly into the bloodstream through the stomach wall. The exact amount is variable and influenced by the emptying time of the stomach. The emptying of alcohol from the stomach to the small intestine is controlled by the pyloric valve which opens and closes at the base of the stomach.
>
> -- The remaining ingested alcohol (~75%) is absorbed unchanged from the small intestine into the hepatic portal vein. Most of this absorption occurs in the duodenum (the first 8- 12 inches of the small intestine).

Inhalation. Ethyl alcohol is readily absorbed by lung tissue. Animals have become severely intoxicated by breathing alcohol fumes in confined spaces; nevertheless, in humans, a concentration of alcohol high enough to produce a significant rise in blood levels would irritate the tissue lining the esophagus.

Injection. Alcohol is detectable in the blood almost immediately after injection into a muscle, or instantaneously when administered intravenously.

Insertion. When given as an enema, alcohol is readily absorbed by the large intestine (colon).

Skin Contact. Experiments have shown that no detectable blood levels have been obtained from alcohol rubs when the subject could not inhale the alcohol.

RATE OF ABSORPTION

Absorption rates vary somewhat from person to person. Individual absorption rates can also vary depending on the condition of the body. Alcohol begins to pass into the bloodstream within one to two minutes after it is consumed. Nearly all of the ingested alcohol is absorbed within 45 minutes. During normal social drinking conditions, alcohol is often absorbed in less than 30 minutes.

FACTORS THAT AFFECT THE RATE OF ABSORPTION.

Dilution. The concentration of alcohol in the beverage can affect absorption. Strong solutions irritate the gastrointestinal walls and often inhibit absorption.

Pattern of Consumption. The period of time over which one ingests the alcohol can affect the time it takes to reach the peak (highest) alcohol concentration.

DISTRIBUTION

Route. Alcohol is absorbed into the blood through the walls of the stomach and small intestine. Alcohol travels via the hepatic portal vein to the liver and then travels via the circulatory system to the heart, lungs and then back to the heart. The heart then pumps alcohol to all parts of the body.

Equilibrium. Alcohol has an affinity for water and distributes itself through the body organs and tissues in proportion to their water content. Blood circulates through the body at a rate of 3 to 4.5 liters per minute. Some organs such as the brain, liver, and kidneys have large blood supplies. Because of this large blood circulation, the alcohol content of the brain elevates quickly, resulting in rapid impairment. When absorption and distribution are complete, equilibrium occurs. Alcohol distribution is proportional to water content.

The Human Digestive System and the Route of Alcohol.

When alcohol is taken by mouth, it passes down the esophagus to the stomach, through the pyloric valve and into the duodenum where it is absorbed by the hepatic portal vein and into the blood supply. The blood then distributes the alcohol to all parts of the body including the liver. Alcohol is oxidized in the liver to acetaldehyde, then to acetic acid, and is eventually converted to carbon dioxide and water.

Widmark's Formula. E. M. P. Widmark, a Swedish scientist and pioneer in alcohol research, developed a formula for estimating the amount of alcohol needed to produce a given BAC. This formula is based on the distribution of alcohol in the body as a whole to blood. This formula, although an estimate, is the basis for many of the BAC charts.

ELIMINATION.

Ethyl alcohol is eliminated from the body both by metabolism and by direct excretion.

Metabolism. Most alcohol (between 90% and 98%) is oxidized in the liver by an enzyme, alcohol dehydrogenase. Since oxidation provides the body with calories (a form of heat), alcohol can be considered a food. In this case, however, it provides no nutritional value.

Excretion. A small amount of alcohol is excreted directly through the breath, urine, tears, saliva, perspiration, etc. The amount excreted varies between 2% and 10% of the quantity absorbed.

Rate of Elimination. As soon as alcohol is absorbed into the blood system and travels to the liver, the body immediately starts to eliminate it. The average rate of elimination ranges from 0.015 to 0.018 g/210L breath per hour. For any given person at a given time, the rate of alcohol elimination per hour will be essentially constant.

Factors Affecting Rate of Elimination. In general, the rate of elimination is not affected by stimulants, diseases and/or exercise. When rate changes have been noted, they are too small to be of any practical value. Any attempts aimed at eliminating alcohol through increased breathing rate, urination, and/or perspiration have little or no effect because the quantity excreted is so small.

PHARMACOLOGY

Pharmacologically, ethyl alcohol is the intoxicating compound in alcoholic beverages and produces those effects commonly associated with drinking. The effect of alcohol on the brain causes physical changes within the drinker.)

PHYSICAL EFFECTS

Effects on the Central Nervous System. Alcohol is a depressant and not a stimulant. While alcohol appears to have a stimulant effect on the central nervous system because it decreases one's inhibitions, it is actually a depressant at all doses. Alcohol influences the most recently developed portion of the brain first, the part controlling a person's judgment and inhibitions. The last area of influence is on the oldest and most developed portion of the brain, that which controls the automatic body functions. Large doses of alcohol over a short period of time may result in coma and eventually death due to respiratory failure.

Effects on Reaction Time and Coordination. Alcohol causes an impairment in muscular coordination. The threshold of impairment has been demonstrated to be as low as a BAC of 0.02 g/210 liters of breath. Reaction time is increased. Small additional doses of alcohol produce large losses in coordination. Motor tasks which require coordination and complex discrimination are impaired at a BAC as low as 0.05 g/210 liters of breath.

Effects on Vision. Visual acuity is generally not affected until the BAC exceeds 0.10 g/210 liters of breath. Nevertheless, glare recovery can be delayed for seconds at a BAC above 0.08 g/210 liters of breath, while peripheral vision and perception of objects in motion can deteriorate at even lower concentrations.

Effects on Skin. Alcohol is used on the skin as an antiseptic and topical rub. It imparts a cool feeling when rubbed on the skin due to dissipation of heat during evaporation. Absorption of alcohol through the skin is considered negligible. Alcohol that has been introduced into the blood causes the blood vessels of the skin to enlarge, allowing an increased amount of blood to circulate in the skin. This accounts for the "flushed face" characteristic of the habitual drinker.

Effects on Circulation. Low BAC levels have little effect on circulation except to enlarge the blood vessels of the skin, permitting an increase in the amount of blood circulating in the skin. No evidence exists that alcohol improves circulation. On the contrary, alcohol appears to impair circulation.

Effects on Kidneys. Alcohol is a mild diuretic increasing urine output. Moderate use of alcohol does not appear to cause any kidney damage.

Effects on Liver. Alcohol causes an accumulation of fat in the liver, a condition referred to as fatty liver. Cirrhosis of the liver, a fibrous scarring and shrinking of the liver, is often associated with alcohol consumption. However, the cause of cirrhosis is an indirect result of alcoholism due to poor diet and is found in less than 10% of chronic drinkers. Moderate use of alcohol does not appear to have a harmful effect on the liver as long as a healthy, nourishing diet is eaten.

SYMPTOMS OF ALCOHOLIC INFLUENCE

Consumption of an alcohol may cause one or more of the symptoms listed below:

Odor of alcoholic beverages on the breath
Speech impairment, slurred and confused speech, "thick tongue"
Poor muscular coordination
Dizziness
Swaying or unsteadiness
Nausea
Confusion
Unusual actions, such as being very talkative
Sleepiness
Visual disorders, fixed stare, glassy eyes
Disorderly appearance
Flushed skin

This list is not all-inclusive nor does any one symptom or combination of symptoms mean that a person is intoxicated. Numerous illnesses/injuries can produce the same symptoms as alcoholic influence. The operator should, therefore, examine and question the subject carefully in order to ascertain whether or not medical attention is needed.

Abnormal behavior, coupled with a low BAC, may be indicative of illness and/or injury. Under these circumstances, the subject should receive appropriate medical attention. An unusually high BAC also indicates the need for medical attention to prevent possible respiratory or cardiac failure.

ACTION WITH OTHER DRUGS

Alcohol combined with other drugs can cause special problems. As stated previously, medical care should be obtained for any individual who has a low BAC but appears to be markedly under the influence.

Stimulants. Stimulants (amphetamines, caffeine, cocaine, etc.) do not counteract the depressing affect of alcohol. They may be used for temporary arousal in severe intoxication; however, their effect is brief.

Depressants. When alcohol is ingested with other depressant drugs, either non-narcotic depressants (tranquilizers, antihistamines, etc.) or narcotic depressants (heroin, morphine, etc.), the effects are usually additive. Prescribed doses of depressant drugs, when taken with alcohol, sometime result in an overdose and/or death because of respiratory failure.

Tolerance. People react differently to the consumption of alcohol. Some are better able to "hold" their liquor than others. Tolerance is the ability of a person to adapt to alcohol so that larger quantities are needed to produce a given effect. Most investigators have observed that tolerance to ethanol is limited to low BAC levels. Some factors that may influence tolerance are increased elimination and decreased penetration in the central nervous system. However, it should be noted that all studies show that impairment exists in performing complex tasks such as driving at BACs of 0.05 g/210L and greater.

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