Introduction to the Intoximeters EC/IR II Machine
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Principles of EC/IR Detection

• One of the basic principles of analytical chemistry is that the analysis of a substance should be confirmed by an independent, alternative method.
• For example, the analysis of a suspected drug of abuse in a blood or urine sample is initially detected using a drug screening methodology and if positive, the test result must be confirmed typically using GC/MS analysis.

Principles of EC/IR Detection

• Another example is the analysis of a blood alcohol sample by a forensic laboratory. The blood sample is analyzed using gas chromatography (GC) with two different GC columns which have different affinities for volatile organic compounds. Ethanol will have different retention times on the two columns. Agreement between the two columns with respect to the unknown’s retention times and quantitation assures the reliability of the results.
Principles of EC/IR Detection

The manufacturer (Intoximeters, Inc.) has given their machines the name:

• INTOX EC/IR and INTOX EC/IR II

• This nomenclature implies that the machine will measure the alcohol concentration in two ways: EC and IR

Principles of EC/IR Detection

• The impression one gets from the nomenclature of these machines is that the breath sample will be measured using two alternate technologies at the same time: the electrochemical (EC/fuel cell) technology and the infrared technology.

• If so, then EC/IR machines would be superior to any other breath alcohol measuring device using only one method.

Principles of EC/IR Detection

• However, the nomenclature of these machines is misleading. These machines do not measure the alcohol concentration in a person’s breath using two independent, alternate methods. These machines quantitatively measure the alcohol concentration in a person’s breath using only the electrochemical (EC/fuel cell) technology.
Principles of EC/IR Detection

- The infrared (IR) detector is used only to monitor breath sample quality (end-expiratory lung air) and to detect mouth alcohol.
- Infrared (IR) detector: measures two wavelengths, 3.46 (3.45) microns (for alcohol detection) using two optical filters and 4.25 (4.26) microns (for carbon dioxide detection) using one optical filter.

Theory of IR Detection of Alcohol

In order to better understand infrared (IR) detection of alcohol, it is necessary to obtain a basic understanding of electromagnetic radiation. Both visible and infrared light are parts of what is known as the electromagnetic spectrum.

Waves in the electromagnetic spectrum vary in size from very long radio waves, the size of buildings, to very short gamma-rays, smaller than the size of the nucleus of an atom.
Wavelengths of the *Electromagnetic Spectrum*

Theory of IR Detection of Alcohol

Electromagnetic waves are generally measured in term of microns (one millionth of a meter). One meter is about 3 feet (3.2808... feet). The wavelength of visible light is from 0.4 microns (blue light) to 0.7 microns (red light).

Theory of IR Detection of Alcohol

In order to better understand the magnitude of waves, assume one meter (~ 3 feet) is equal to one million dollars.

With such an assumption, the wavelength of light would be the equivalent to $0.40 (forty cents – blue light) to $0.70 (seventy cents – red light) out of $1,000,000.00.
Theory of IR Detection of Alcohol

**Wavelength** (1 micron \(10^{-6}\) meter) = 3.927 x 10^{-5} inch:
- Radio waves = greater than 10^3 microns
- Microwaves = 25 to 10^3 microns
- Far Infrared = 15 to 50 microns
- **Mid Infrared** = 2.5 to 15 microns
- Near Infrared = 0.7 to 2.5 microns
- Visible Light = 0.4 (blue) to 0.7 (red) microns
- Ultraviolet = 10^{-3} to 4 x 10^{-1} microns
- X-Rays = 10^{-6} to 10^{-3} micron
- Gamma Rays = less than 10^{-6} microns

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Theory of IR Detection of Alcohol

- IR light is absorbed and converted by an organic molecule into energy of molecular vibration.
- Certain groups of atoms give rise to absorption bands of IR light at or near characteristic wavelengths regardless of the structure of the rest of the molecule.

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Theory of IR Detection of Alcohol

- Absorption band positions in the IR range are presented either as wave numbers or wavelengths.
- The wave number unit is cm^{-1} (reciprocal centimeters).
- Wave numbers are reciprocally related to wavelengths: \(\text{cm}^{-1} = 10^4 \times (1/\text{micron})\)
Theory of IR Detection of Alcohol

Intoxilyzer 5000 – 3 Filters:
3.39 (acetone), 3.48 (EtOH), and 3.80 (ref.) microns

Intoxilyzer 5000 – 5 Filters:
3.36 (acetaldehyde), 3.40 (acetone), 3.47 (EtOH), 3.52 (toluene), and 3.80 (ref.) microns

Intoxilyzer 8000 – 2 Filters:
3.4 (acetone) and 9.36 (alcohol) microns

BAC DataMaster – 2 Filters:
3.37 (acetone) and 3.44 (alcohol) microns

Intox EC/IR – 2 Filters:
3.45 (alcohol) and 4.26 (carbon dioxide) microns

Theory of IR Detection of Alcohol

• Chemical Structure of Ethyl Alcohol:

\[
\begin{array}{ccc}
\text{H} & \text{H} \\
\backslash & \text{
\ } \\
\text{H} & \text{C} & \text{C} & \text{O} & \text{H} \\
\text{
\ } & \text{
\ } & \text{
\ } & \text{
\ } & \text{
\ } \\
\text{H} & \text{H} \\
\end{array}
\]

H = Hydrogen atom  C = Carbon atom  O = Oxygen atom

Theory of IR Detection of Alcohol

• Chemical subgroups of atoms in alcohol:

\[
\begin{array}{ccc}
\text{H} & \text{H} \\
\backslash & \text{
\ } \\
\text{H} & \text{C} & \text{C} & \text{O} & \text{H} & \text{H} \\
\text{
\ } & \text{
\ } & \text{
\ } & \text{
\ } & \text{
\ } & \text{
\ } \\
\text{Methyl} & \text{Methylene} & \text{Alcohol Group} & \text{Group} & \text{Group} & \text{OH}
\end{array}
\]
Theory of IR Detection of Alcohol

• Characteristic vibrational absorption band wavelengths associated with methyl groups:

\[\begin{array}{c}
\text{H} \\
\text{H} - \text{C} - \\
\text{H} \\
\hline
\text{C} \ - \text{H stretch:} \ 3.38 \text{ microns} \\
\text{3.48 microns} \\
\text{C} - \text{H bending:} \ 6.90 \text{ microns} \\
\text{7.28 microns}
\end{array}\]

Theory of IR Detection of Alcohol

• Characteristic vibrational absorption band wavelengths associated with methylene groups:

\[\begin{array}{c}
\text{H} \\
\text{H} - \text{C} - \\
\text{H} \\
\hline
\text{C} \ - \text{H stretch:} \ 3.43 \text{ microns} \\
\text{3.51 microns} \\
\text{C} - \text{H bending:} \ 6.83 \text{ microns} \\
\text{C} - \text{H rocking:} \ 13.9 \text{ microns}
\end{array}\]

Theory of IR Detection of Alcohol

• Characteristic vibrational absorption band wavelengths associated with alcohol groups:

\[\begin{array}{c}
\text{C} - \text{O stretching:} \\
\text{7.93 to 10.0 microns} \\
\text{C} - \text{O} - \text{H} \\
\text{O} - \text{H stretching:} \\
\text{2.74 to 2.79 microns} \\
\text{O} - \text{H bending:} \\
\text{7.04 to 7.52 microns}
\end{array}\]
Theory of IR Detection of Alcohol

- The EC/IR machines monitor the 3.45 micron wavelength, which is detecting the absorption of infrared light by the methyl and methylene groups of alcohol and other volatile hydrocarbon molecules if present in the breath sample. The absorption of this wavelength of infrared light results in stretching vibrational energy in the carbon-hydrogen (C-H) bonds of these groups.

Theory of IR Detection of Alcohol

- A reduction in the amount of the 3.46 (3.45) micron wavelength of infrared light reaching the IR detector is an indication of the presence of methyl and methylene groups in the person's breath sample.

Principles of EC/IR Detection

- The infrared (IR) detector is used only to monitor breath sample quality (end-expiratory lung air) and to detect mouth alcohol.
- Infrared (IR) detector: measures two wavelengths, 3.46 (3.45) microns (for alcohol detection) using two optical filters and 4.25 (4.26) microns (for carbon dioxide detection) using one optical filter.
Principles of EC/IR Detection

• There are dual thermopile detectors for each of the three optical filters.

Principles of EC/IR Detection

• Dual thermopile detectors provide temperature compensation. Temperature measurement and control is important because IR energy hitting the detector’s surface depends on the average temperature of everything within the detector’s field of vision.

Principles of EC/IR Detection

• A thermopile is a number of thermocouples connected in series. A thermocouple is a junction of dissimilar metals which produce voltage when one side of the junction has a different temperature to the other. The so-called cold side of the junction is kept close to ambient temperature by bonding it to a temperature stable mass. The hot side of the junction is exposed to the IR radiation.
Principles of EC/IR Detection

Thermopile detectors differ from pyroelectric (a type of thermal) detectors:
1. Thermopile detector output is proportional to incident radiation while the pyroelectric detectors output is proportional to rate of change of incident radiation. In other words, the thermopile detector is DC coupled while the pyroelectric detector is AC coupled (e.g., Intoxilyzer 8000).

Principles of EC/IR Detection

2. Thermopile detectors have low impedance while pyroelectric detectors have very high impedance requiring an internal impedance converting buffer to make them useable. Low impedance is an advantage in that associated circuitry is less susceptible to disturbance from extraneous radiation and electrical noise.

Principles of EC/IR Detection

According to Pat Harding (page 242, Chapter 7, Garriott’s Medical-Legal Aspects of Alcohol 5th Edition, Edited by James C. Garriott):

Infrared source = coiled nichrome wire
What is coiled nichrome wire?
• Nichrome wire is an alloy of two metals, nickel and chromium. This alloy is used in heating elements in a number of household products, from curling irons to hair dryers to toasters.
While Pat Harding reports that the infrared source is a coiled nichrome wire, the Intoximeters EC/IR Operator’s Manual from Illinois and the Intox EC/IR Administrator’s Manual from Wyoming both state that the infrared source is a tungsten heater mounted in a parabolic reflector.

In contrast, the Virginia Department of Forensic Sciences Training Manual for the Intoximeters EC/IR II says that the IR Source is a “thermopile source” mounted in a parabolic reflector with plated quartz window at the source to reduce water sensitivity. However, the Virginia version does not identify the “thermopile source”.

The path length of the IR sample chamber is much shorter (5”, 12.5 cm) in the Intoximeters EC/IR II than in the DataMaster cdm (34.3”, 87 cm) or in the Intoxilyzer 5000 (11.4”, 28.9 cm). Intoximeters claim that their shorter path length “enhances real time tracking of the instantaneous ethanol concentration”.
Principles of EC/IR Detection

- However, the shorter path length decreases the sensitivity to accurately quantitate ethanol concentration.
- The IR detection system in the Intoximeters EC/IR II is not used to quantitate ethanol but is used in combination with the CO₂ IR detector to determine the presence of mouth alcohol.

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Principles of EC/IR Detection

Virginia's Mouth Alcohol Detection System
1. "Gross Mouth Alcohol" Detection System - uses only the EtOH Detector
2. Carbon Dioxide (CO₂) Mouth Alcohol Detection System - uses both the EtOH and CO₂ detectors

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Principles of EC/IR Detection

The Gross Mouth Alcohol Detection System:
- When alcohol molecules are present inside the sample chamber, some of the IR light is absorbed by the alcohol molecules. The absorption of some of the IR light results in less IR light reaching the IR detector. A reduction in the IR light reaching the detector results in a smaller electric signal (voltage) being produced.
Principles of EC/IR Detection

- Therefore, as the alcohol concentration increases, the detector signal decreases.
- For the mouth alcohol detector to detect "gross mouth alcohol", the ethanol signal must be the equivalent of at least 0.150 g/210 L with a signal increase (ethanol concentration decrease) of at least the equivalent of 0.030 g/210L.

Principles of EC/IR Detection

The Carbon Dioxide (CO₂) Mouth Alcohol Detection System:
- The signal from the ethanol IR detector is normalized by the signal from the CO₂ detector.
- If mouth alcohol is present, the normalized ethanol signal will show a distinct variance from the unnormalized ethanol signal.
Principles of EC/IR Detection

- The degree of variance is calculated via area integration of the difference between the two signals.
- Once the area integral exceeds a certain threshold value, the machine will declare a “mouth alcohol” message and will abort the test sequence.
Principles of EC/IR Detection

- The EC/IR machines monitor the amount of 3.46 (3.45) micron infrared light to monitor the alcohol profile as a person is blowing into the machine.
- Detection of a negative slope in alcohol concentration as a person is blowing into the machine would be an indication of the presence of mouth alcohol contamination.

Principles of EC/IR Detection

- However, the presence of some lung alcohol concentration will produce a positive slope in the alcohol concentration as a person blows into the machine.
- Because the detector is unable to distinguish between a molecule of alcohol coming from the lung versus coming from the mouth, the total concentration from both sources will be measured.

Principles of EC/IR Detection

- Consequently, if both mouth alcohol contamination (negative slope) and lung air alcohol (positive slope) are both present, the IR detector is likely not to see the negative slope from the mouth alcohol contamination.
- Result: With the presence of some lung air alcohol, the IR mouth alcohol detection mechanisms will often fail to do its job.
Theory of EC Detection of Alcohol

Electrochemical fuel cell technology:
• A fuel cell converts fuel and an oxidant into direct current.

For breath alcohol testing:
• The fuel is alcohol
• The oxidant is oxygen from the atmosphere

Theory of EC Detection of Alcohol

• The alcohol fuel cell consists of a porous, chemically inert layer coated on both sides with finely divided platinum (called platinum black).

• The porous layer is impregnated with an acidic electrolyte solution.

Theory of EC Detection of Alcohol

• Electrical connections are applied to the upper and lower platinum black surfaces.
• The fuel cell components are enclosed within a plastic case which includes an inlet that allows a breath sample to be introduced.
• Only a 1 cc breath sample is captured by the EC detector from the IR sample chamber at the end of the blowing.
Theory of EC Detection of Alcohol

• Alcohol molecules on the upper surface of the platinum black are oxidized with the removal of hydrogen ions (H+) which migrate to the lower surface of the fuel cell where they combine with atmospheric oxygen to form water with the removal of one electron for each hydrogen ion (H+).

• This oxidation process creates an excess of electrons on the upper surface and deficiency of electrons on the lower surface of the fuel cell.
• Because the upper and lower surfaces are electrically connected, a current of electrons flows through the external electrical circuit to neutralize the charge.

• Using platinum black as a catalyst, alcohol is oxidized into acetic acid (vinegar) with a net production of two electrons per alcohol molecule. These electrons produce the current that determines the amount of alcohol in the sample. The greater the alcohol concentration, the greater is the amount of current produced.
Fuel Cell Output as a Function of Alcohol Concentration

Theory of EC Detection of Alcohol
- Ethanol + Oxygen \Rightarrow \text{Acetic Acid} + \text{Water} + 2 \text{ electrons}
- Acetic acid further reacts at a slower rate to form oxygen, carbon dioxide, and water.
- Acetic acid builds up on the fuel cell after several consecutive positive tests, prolonging the time necessary to return to a zero baseline.

Fuel Cell Configuration
Theory of EC Detection of Alcohol

- Fuel cells are relatively, but not solely, specific for ethyl alcohol.
- Fuel cells can potentially respond to other alcohols, such as methyl alcohol (wood alcohol), isopropyl alcohol (rubbing alcohol), n-propyl alcohol, and to acetaldehyde.

Theory of EC Detection of Alcohol

- Fuel cells by themselves have no mechanism for detection of mouth alcohol contamination.
- Fuel cells by themselves will measure total concentration of alcohol present, both lung air alcohol and mouth alcohol.

Theory of EC Detection of Alcohol

- Because the EC detector cannot detect mouth alcohol contamination, the machine uses the IR detector for mouth alcohol detection.
- Different methods can be used. The actual method used to detect mouth alcohol is user (state) specified.
Measurement of Breath Flow Rate in the Intoximeters EC/IR II

- The breath flow rate is measured using a pressure sensor located at the pressure port between the breath tube connector and the IR sample chamber.
- The breath tube connector has an internal diameter of 0.25” but the opening to the IR sample chamber has a diameter of 0.156”.
- This restriction causes a pressure in the breath tube connector.

Measurement of Breath Flow Rate in the Intoximeters EC/IR II

- The greater the breath flow rate, the greater will be the pressure at this pressure port.
- The pressure (which is produced by the breath flow passing through the restriction of the smaller diameter opening of the IR sample chamber) is proportional to the flow rate of the subject’s breath.

Measurement of Breath Flow Rate in the Intoximeters EC/IR II

- The Intoximeters EC/IR II requires the subject to provide a minimum of 0.2 L/sec.
- Integration of the breath flow rate as a function of time as the subject blows into the machine yields the subject’s breath volume.
- As required by NHTSA, the minimum acceptable breath volume for evidential breath testing devices is 1.1 liters.
Measurement of Breath Flow Rate in the Intoximeters EC/IR II

- States can set their minimum acceptable breath volumes higher, but not lower than 1.1 liters.
- In the state of TN, the Intoximeters EC/IR II requires the subject to provide a minimum breath volume of 1.5 liters.
- The breath sample capture for EC detector quantification occurs when the breath flow rate drops by -5% from the highest flow after the minimum breath volume has been obtained.

Measurement of Breath Volume in the FL Intoxilyzer 8000 Machines

Limitations of EC Detection of Alcohol

- Fuel cells change in sensitivity as they age, requiring more frequent recalibration than other types of detectors.
- Changes of the electrode microstructure leads to drifting of the sensor baseline.
- Baseline drift of EC detector becomes out of sync with baseline of the IR detector.
- Result: requires frequent recalibrations.
Limitations of EC Detection of Alcohol

• Consequently, it is necessary to perform accuracy (calibration) checks (F3) with known external controls (dry gas and/or wet bath simulators). If an accuracy check is outside acceptance limits, then must perform a calibration (F4) of the machine. Following a calibration of the machine, should perform an accuracy check to determine if calibration is maintained.

Limitations of EC Detection of Alcohol

• MUST NOT perform ONLY a calibration (F4) and then an accuracy check (F3).
• Doing so prevents operator from determining if machine when out of calibration since last calibration.
• Wyoming got caught with performing accuracy checks only immediately after machine was recalibrated.

Limitations of EC Detection of Alcohol

The solution to avoiding performing frequent recalibrations when the EC detector drifts out of sync with the IR detector is the Wyoming solution:

Disable the IR detector

• And to perform only periodic calibrations followed by accuracy checks.
Limitations of EC Detection of Alcohol

• The DOT version of the Intoximeters EC/IR II has the IR function **totally disabled** - DOT workplace testing depends upon a 15 minute waiting/observation period between the initial screening and the subsequent confirmation testing.

Limitations of EC Detection of Alcohol

• If the IR part of the EC/IR is disabled, so that the slope detection and the deep lung air monitoring mechanisms no longer function, then the machine is no better than any hand-held EC preliminary breath alcohol testing (PBT) device.

Limitations of EC Detection of Alcohol

• Without the IR part providing at least the potential for mouth alcohol detection and monitoring of the end-expiratory lung air, the modified EC/IR machine should not be considered an evidential breath alcohol testing (EBT) machine.
Limitations of EC Detection of Alcohol

- As the fuel cell ages, it will take longer for the sensor to produce the information to calculate the result.
- If a machine will not consistently maintain calibration even after recalibration, the fuel cell should be replaced.
- It has been reported that, on the average, the fuel cell will last 3 to 5 years.

Limitation of EC/IR Detection of Alcohol

- Criteria for detection of mouth alcohol contamination, interference detection, breath sample acceptance requirements, and quantitation of breath alcohol concentration are all software dependent.
- Changes in software code can alter a machine’s ability to perform these functions.

Limitation of EC/IR Detection of Alcohol

- Summary:
  - Alcohol quantitation occurs only by the EC (fuel cell) detector using a 1 cc sample - - same as with a PBT handheld device.
  - Potential mouth-alcohol detection may or may not exist depending upon your state’s preferences (IR detector may be disabled).
  - Machines may not be in calibration.
Limitation of EC/IR Detection of Alcohol

- Intoximeters EC/IR II machines have IntoxNet communications and data management software – need to closely examine IntoxNet downloads.