FTIR Gas/Vapor Identification: Filling a Capability Gap in Industrial Hygiene

AIHA Webinar

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GTS
GayleTraining Solutions

LinkedIn

- Fire service for 30 years 1997 -2024
- 27 yrs Raleigh Fire Department
- 25 yrs Hazmat Response Team
- 19 yrs Fire Service Instructor
- 14 yrs teaching for manufacturers
- GTS, LLC opened in 2012

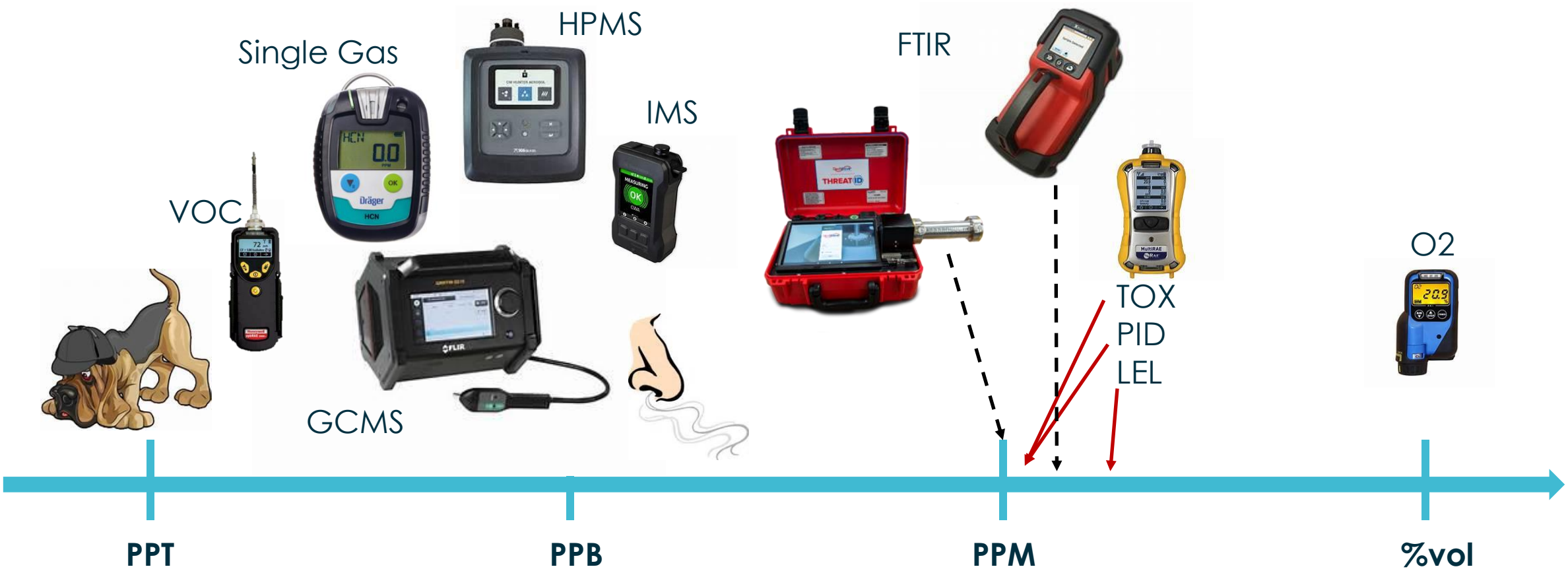
- **Training experience ~300 organizations**
  - Fire & Hazmat Teams
  - Military and Federal Agencies
  - Foreign Governments
  - Corporations/Colleges/Universities

- **Technologies with OEM Qualification:**
  - E-Chem, CGI, PID, MOx, NDIR, MPS
  - FTIR + Raman
  - IMS, HPMS, GCMS
  - RIID, Rad
  - PCR, Bioassay

Gaps in Detection Technology

- Sensor Selection
- Sensor Cross Sensitivities
- Accuracy Variance
- Correction Factor Determination
- Gas Mixtures
- Reaction Byproduct

Commonly deployed Items in HazMat Response



Then to Now: Field Portable FTIR for Gases & Vapors

2005

2007

2009

2018

2022

2024

2025

Advancements in Handheld FTIR Tech

What Fire / Mil / Hazmat teams wanted:

- Operate like an air monitor – Continuous Mode
- Identify >5,000 gases/vapors
- Quantify > 5,000 gases/vapors
- Continuously monitor CO_2
- Low PPM operational range
- Compensate for atmospheric conditions
- Reduce dependence on colorimetric tubes and electrochemical sensors
- No calibration or sensor replacement
- Cloud connectivity

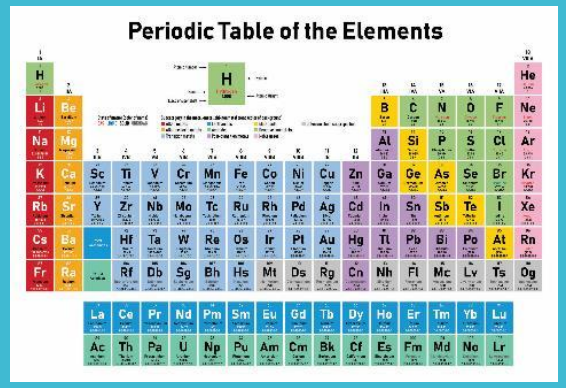
Handheld Gas FTIR

Handheld
5.5lbs / 2.49kg

Portable
20.7 lbs / 9.4kg

FTIR Gas & Vapor Library Capabilities

- TICs, TIMs, VOCs, CWAs
- Petroleum products, refrigerants, industrial chemicals, solvents, common gases
- Acetylene, ammonia, cyanide, phosphine, diborane, CO, CO2
- HCl, HF, HNO_3, acetic acid
- 20 Most Commonly Released Chemicals
  - 14 gas/vapor entries, 93%
- ITF – 40
  - 25 gas/vapor entries, 74%
- OSHA 1910:119 Highly Hazardous Chemicals, Toxics and Reactives
  - 63 gas/vapor entries
- DHS Acutely Toxic Chemicals
  - 38 gas/vapor entries, 82%



Limitations of handheld FTIR for Gas/Vapor

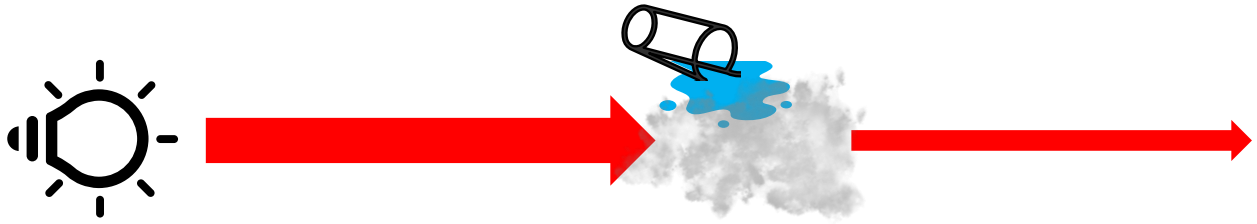
- Not a trace identification technique
  - LOI is 10 to 30ppm for most gases
- Water vapor can limit identification of certain materials
  - XplorIR has advanced algorithms to limit water vapor interference
- Two types of materials have no IR spectra
  - Nobel Gases (Helium, Neon, Argon, etc.)
    - Homonuclear Diatomic molecules
    - Have No Fear Of Ice Cold Beer

    Hydrogen, Nitrogen, Fluorine, Oxygen, Chlorine, Iodine & Bromine
  - Hydrogen Sulfide (Sewer Gas)
    - **LOI ~ 1500ppm**
    - IDLH H_2S = 100ppm

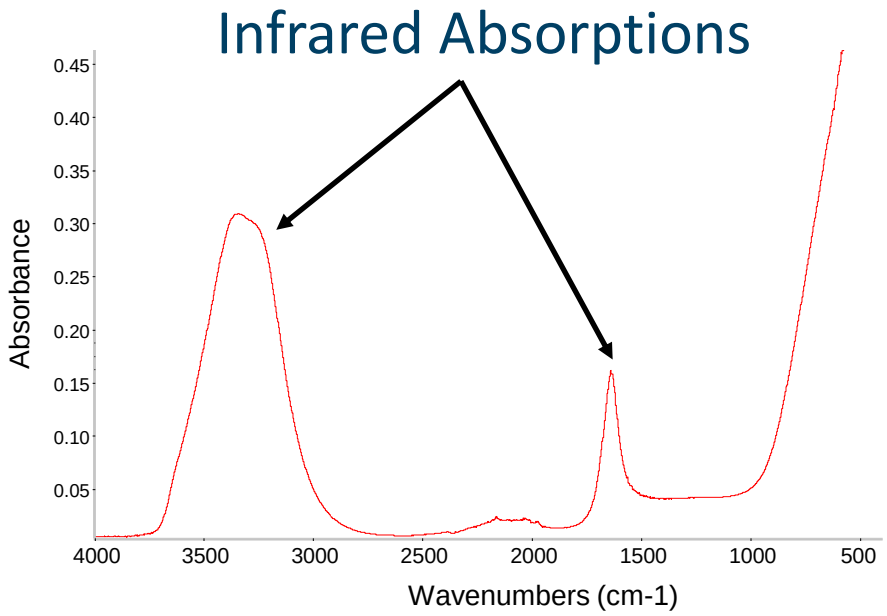
Challenges for FTIR in Air Monitoring

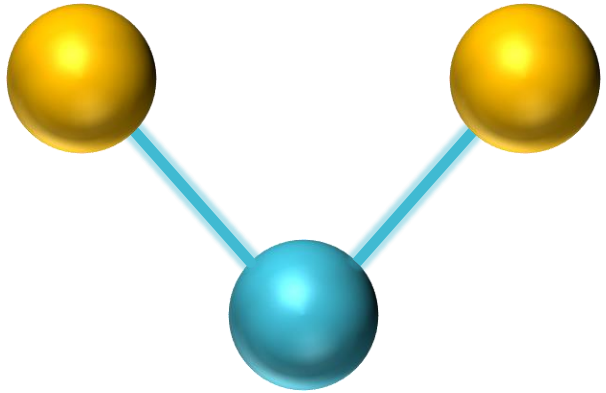
- Ambient interference from H_2O and CO_2
- Signal Optimization and Saturation
- Identification at Operationally Relevant Levels

An infrared spectrum is a graph showing the amount of infrared energy that is absorbed by a sample.

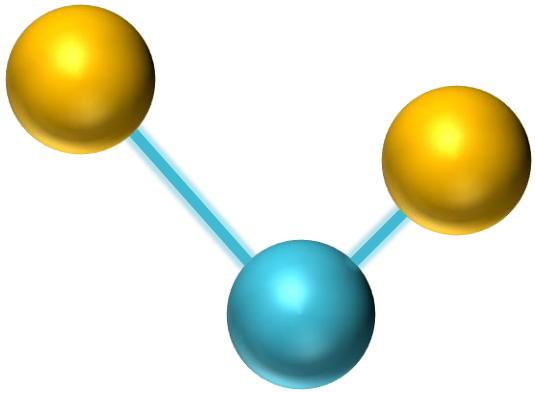


Infrared Source

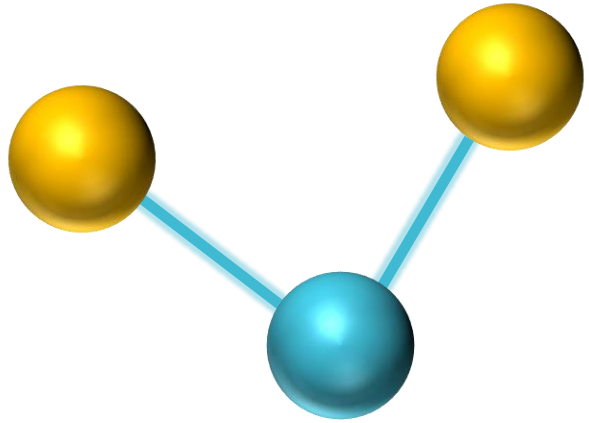




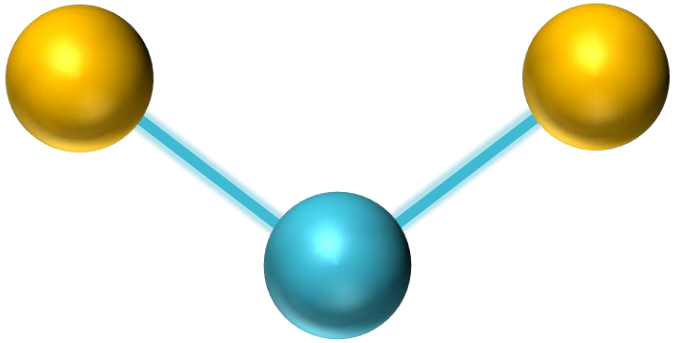
Symmetric Stretching



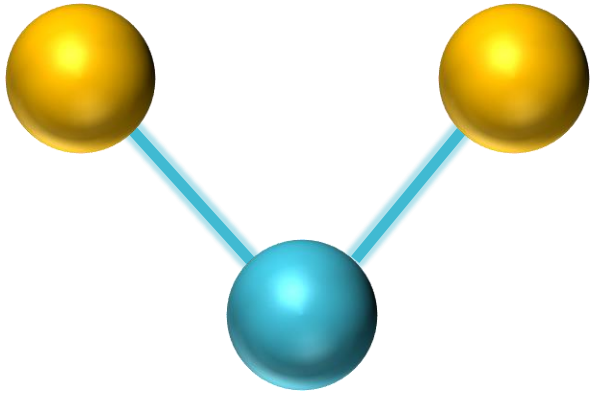
Asymmetric Stretching



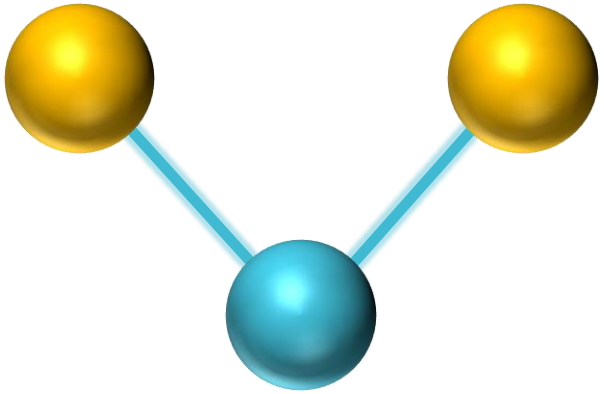
Rocking



Scissoring



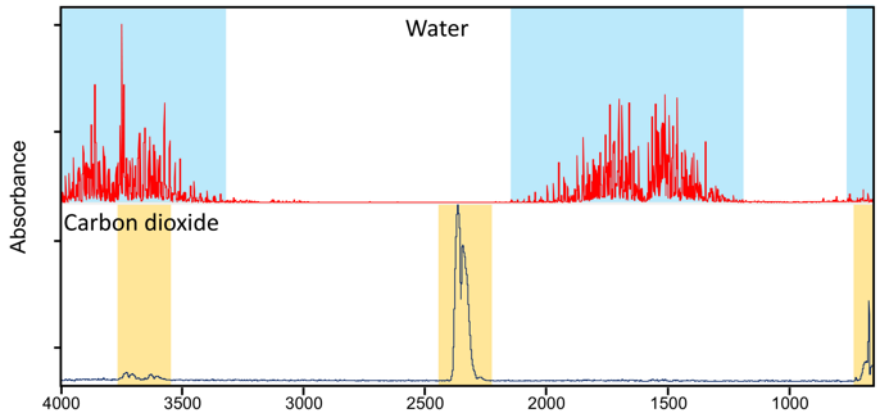
Wagging



Twisting

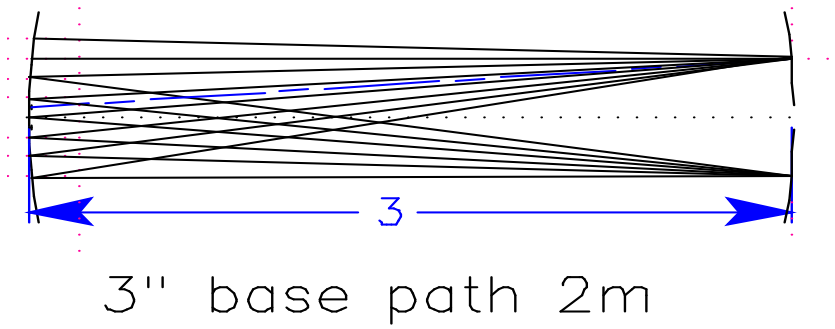
Adaptive Atmospheric Correction (AAC)

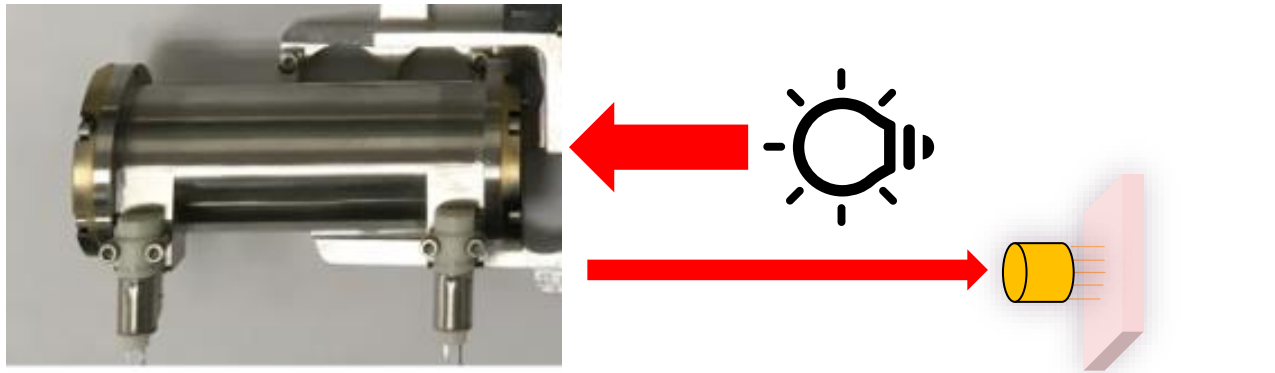
1. Build statistical model for background environment (primarily H_2O and CO_2)
2. Begin monitoring for any spectral features above background while continuously reporting CO_2 concentration
3. As background changes, adjust model in real time
4. Monitor until mode is exited or battery dies without collecting another background sm



The Primary Enabling Technology FTIR Gas & Vapor Analysis in the Field

- Long Pass, multireflection gas cell
  - Hollow tube with IR reflective mirrors on each end
  - No bulb or sensor contacting the gas
    - No damage from too much sample
  - Saturation is really too much signal and results in mismatch with library





$$A = \varepsilon c l$$

Absorbance

(What We Measure)

Extinction

(Absorption Strength)

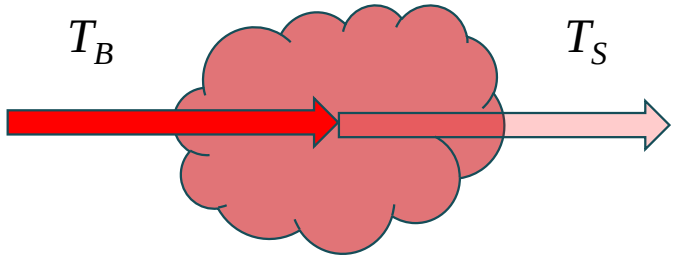
Pathlength

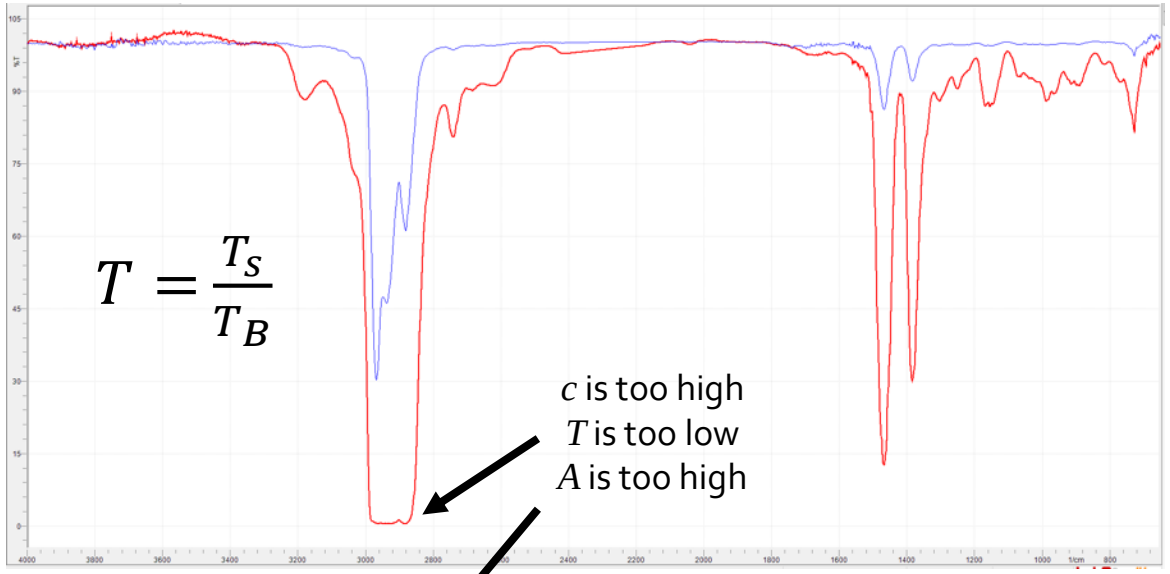
(Fixed for Device)

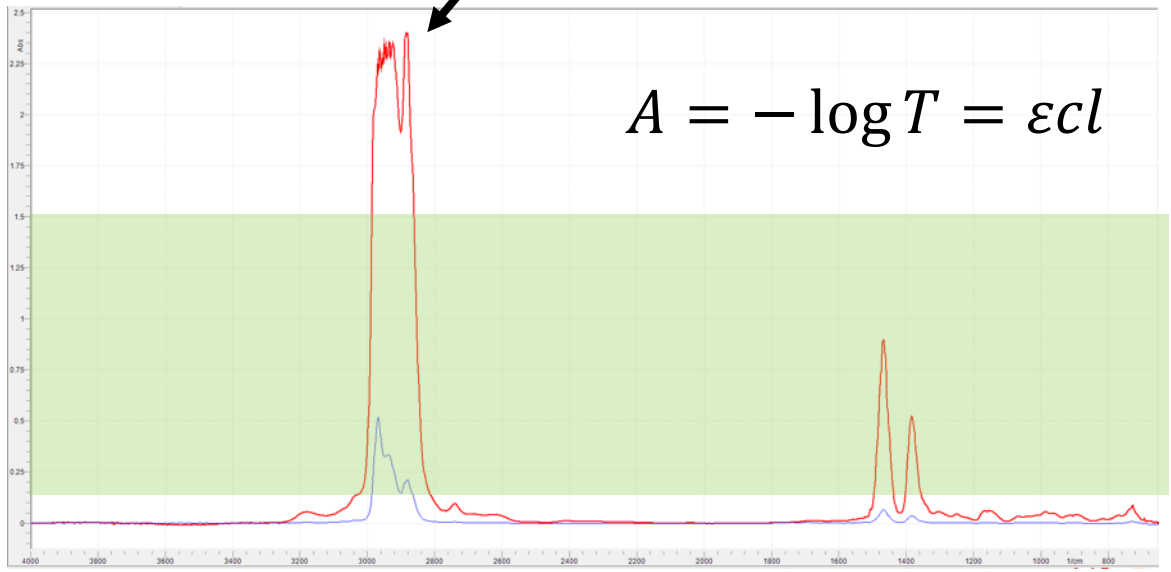
Concentration

(Vapor Pressure)

Signal Optimization

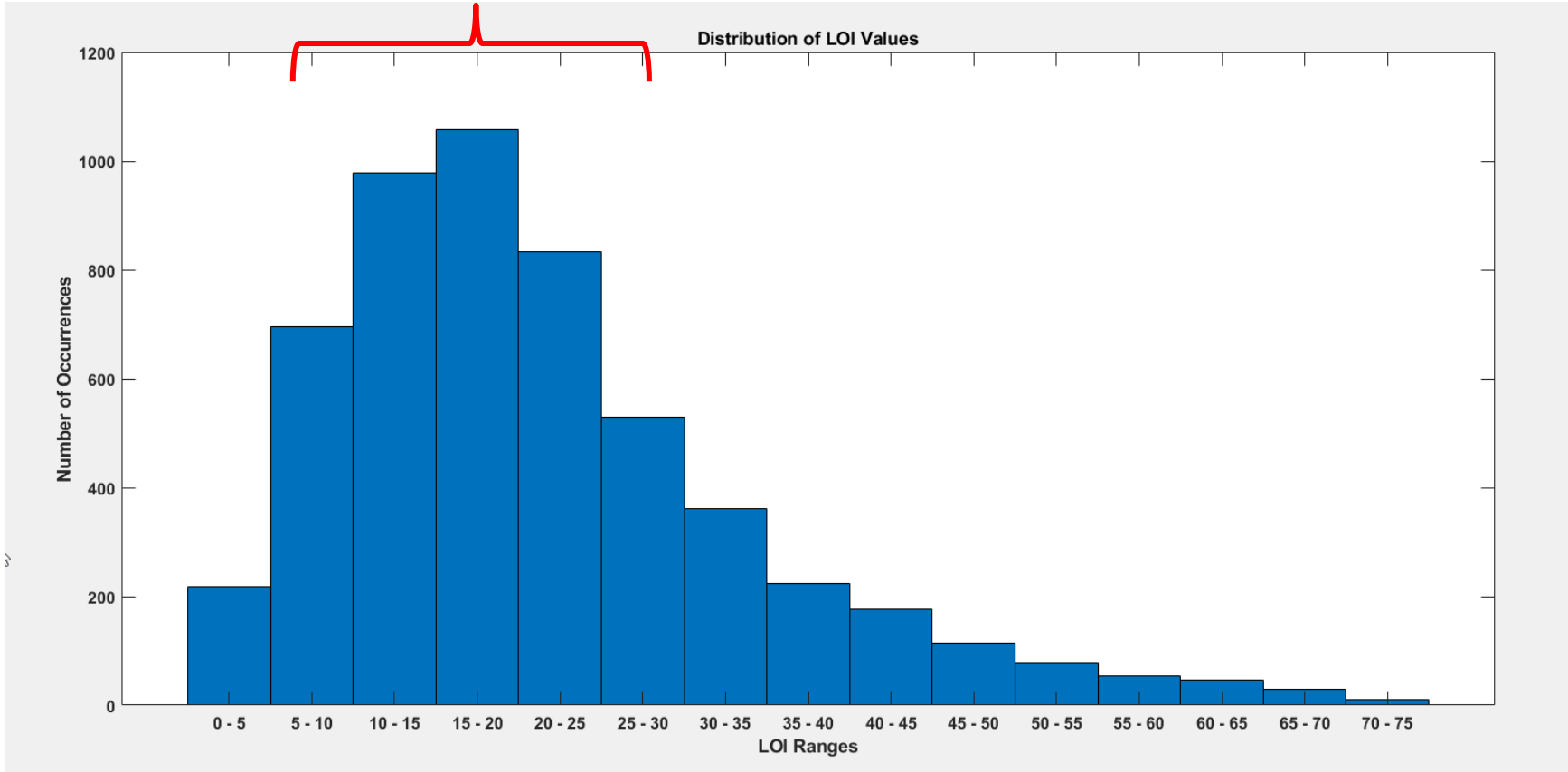






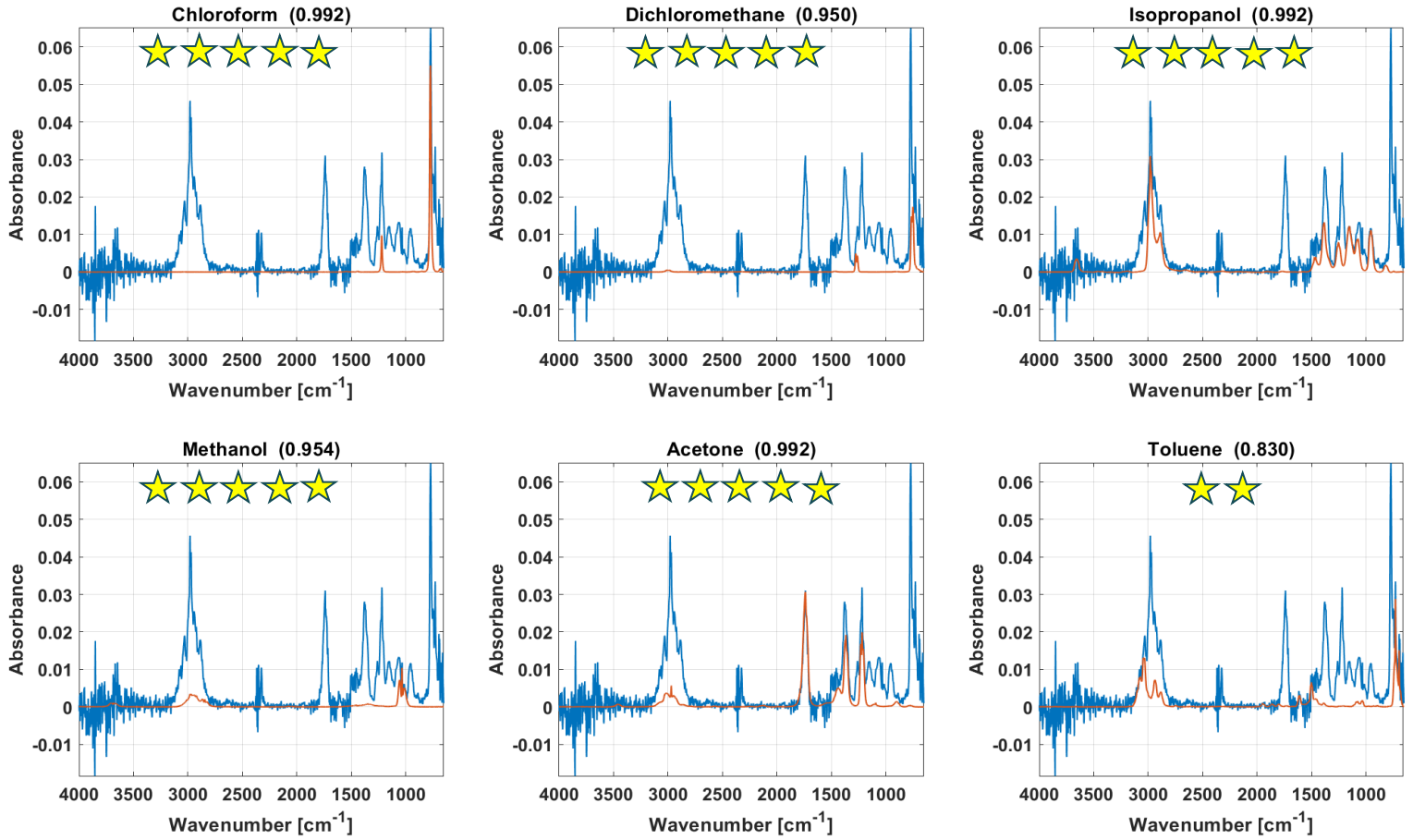
Limits of Identification (LOI) | Handheld FTIR with 2 m Gas Cell

10 – 30 ppm



FTIR of 6-Component Mixture | Contaminated Paint Stripper

Toluene	Methanol
Isopropanol	Acetone
Methylene chloride	Chloroform

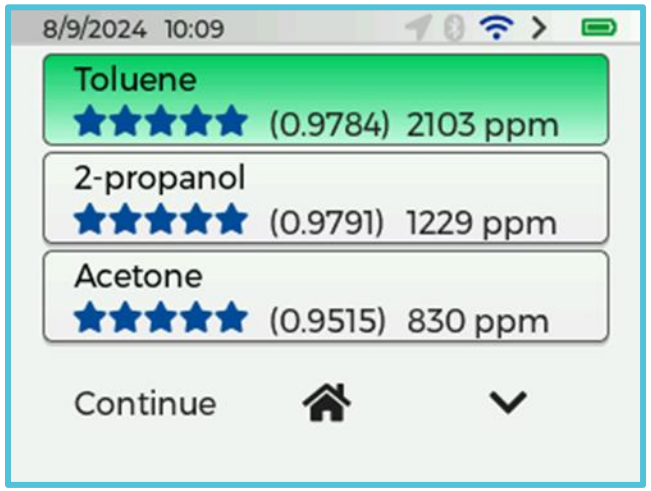


Handheld FTIR Quantification

$$A = \varepsilon c l$$

$$c = \frac{A}{\varepsilon l}$$

- l is constant (2 meters)
- For 385 gases, ε is known ($ppm^{-1} \cdot m^{-1}$)
  - Accuracy +/- 10%
- For additional gases (up to 5,000), ε is estimated
  - Accuracy +/- 20%
- Performance is comparable to PID technology



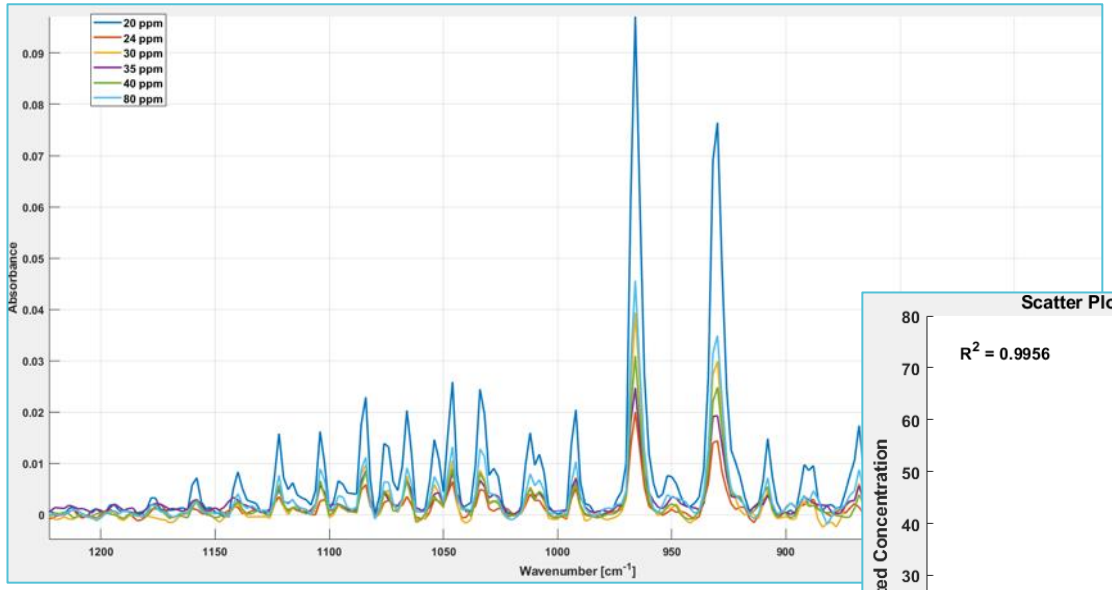
✓ *No Calibration*

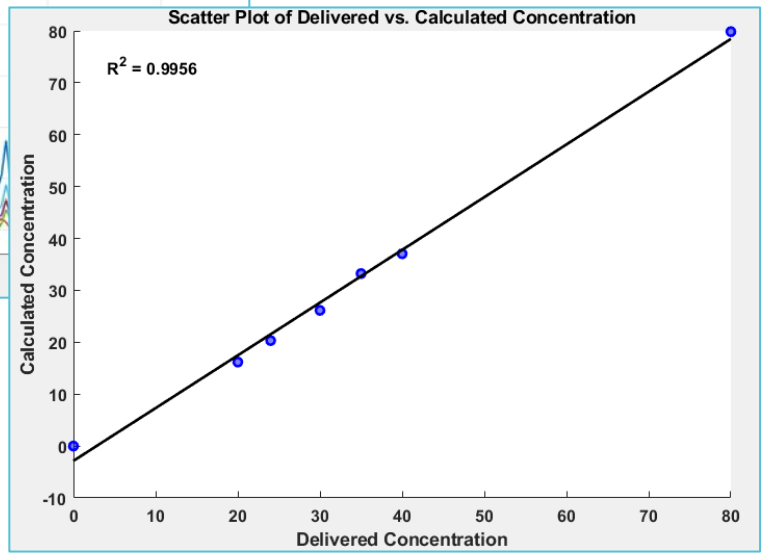
✓ *No Correction Factors*

FTIR Quantification | Ammonia

- Quantitative library with CLS analysis
- Identify then quantify
- After identification, monitor in real-time

Delivered	Calculated
20	16.18
24	20.32
30	26.14
35	33.24
40	37.05
80	79.85





Applications for Industrial Hygiene

- Handheld identification of fugitive emissions
- Broader range of on-site identification
- Quantification of gases and vapors below IDLH
- Efficacy of engineered controls
- Less dependance on presumptive colorimetric tests
- More accurate calculation of Correction Factors for FID and PID for lower concentration sampling due to the identification of mixtures and the ability to account for mixture interference
- Identification of fuming acids (i.e. Nitric, HCL, HF, Acetic, etc.)

Questions?