

Innovative Monitoring Solutions using Cavity Ring-Down Spectroscopy:

*Real-time CEMS, Fence-line, Multipoint, and
Mobile Applications*



Dave Miller
Picarro, Inc.

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PRESENTATION OVERVIEW

1. Introduction to Cavity Ring-Down Spectroscopy (CRDS)
2. Monitoring systems & applications
3. Results from the field
4. Method development & validation

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ARE WE?

- **Leading provider of solutions** to measure greenhouse gas concentrations, trace gases and stable isotopes in **industrial monitoring**, air quality, **energy and utilities** markets.
- Over 45 patents owned by Picarro or exclusively licensed from Stanford University
- ISO 9001:2015 Certified Corporate Headquarters, including R & D, Engineering and Manufacturing/Operations in Santa Clara, California
- 220+ employees including 35+ STEM PhDs
- Thousands of Picarro instruments in 95 countries world-wide



Cities



Ships



Laboratory



Forests



Towers



Aircraft



Winter



Deserts



Mountains



Mules



Glaciers

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WHAT MAKES CRDS SO SPECIAL?

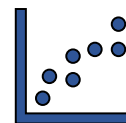
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Real-Time, continuous measurements



No sample pretreatment, chromatographic separation, or complex peripherals



Specific & sensitive to a wide variety of compounds and applications



Turn-key, low operating costs, long-term stability

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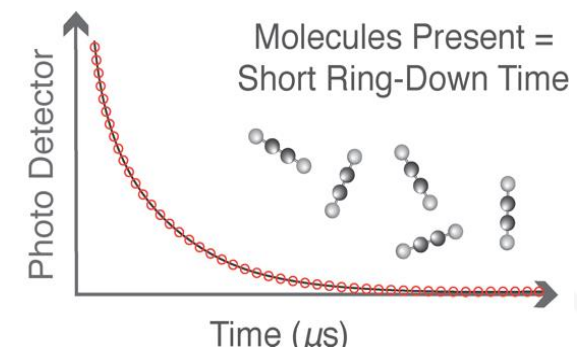
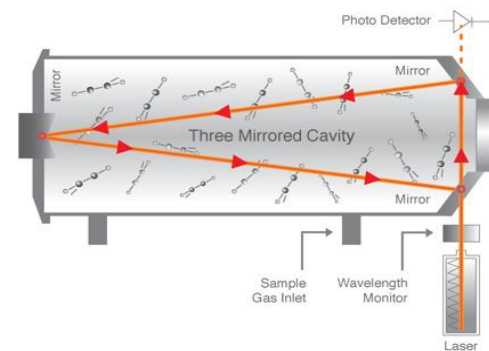
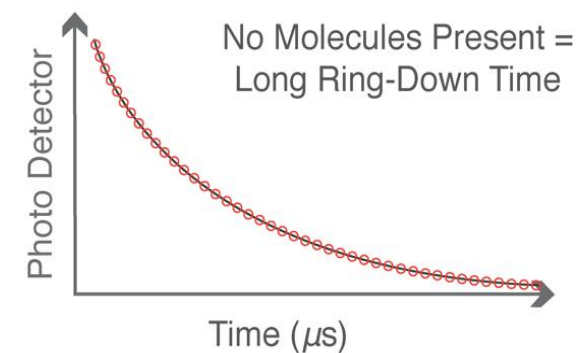
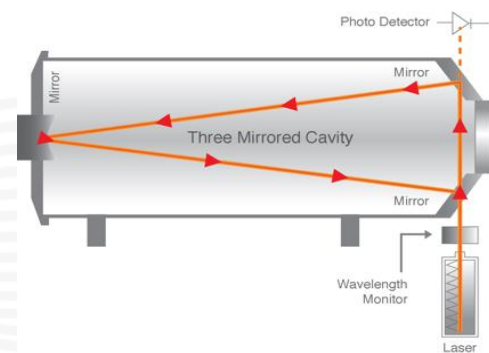
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TECHNOLOGY OVERVIEW

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- Cavity Ring-Down Spectroscopy (CRDS) utilizes the unique infrared absorption spectrum of gas-phase molecules to quantify the concentration of target analytes
- Measurement of decay rate (time-based), rather than absolute absorbance results in self referencing, low drift measurements
- Continuous flow design with small cavity (~35 cc) allows for extremely fast response and recovery to rapidly changing concentrations and fast switching for multi-point systems
- Long effective path-length (> 10 km) means higher precision and lower detection limits
- Laser tuned for target analytes also quantifies interfering compounds to provide precise and corrected data in real-time



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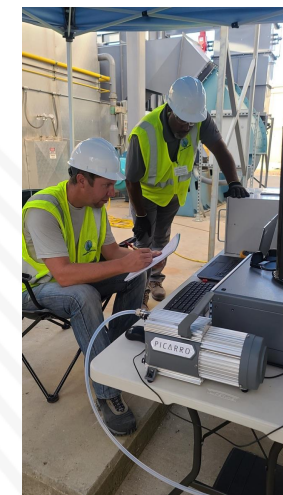
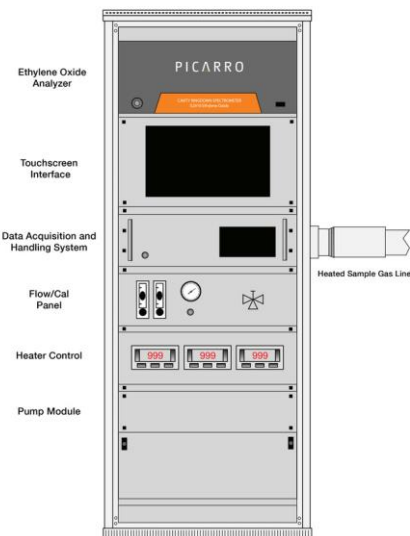
CEMS

Indoor Air Quality

Leak Detection and
Repair (LDAR)

Fenceline

Stack Testing

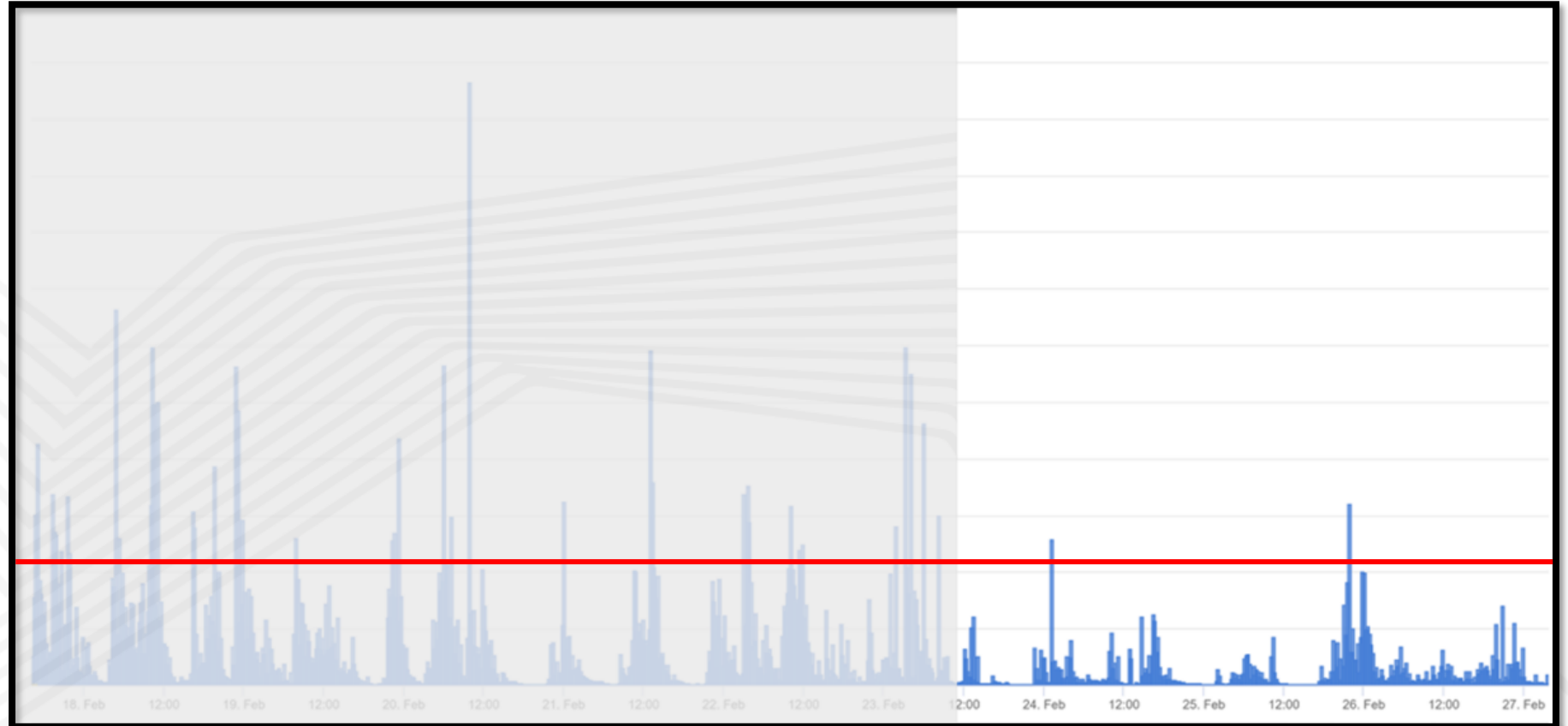


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CONTINUOUS EMISSIONS MONITORING SYSTEMS (CEMS)

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STACK TESTING

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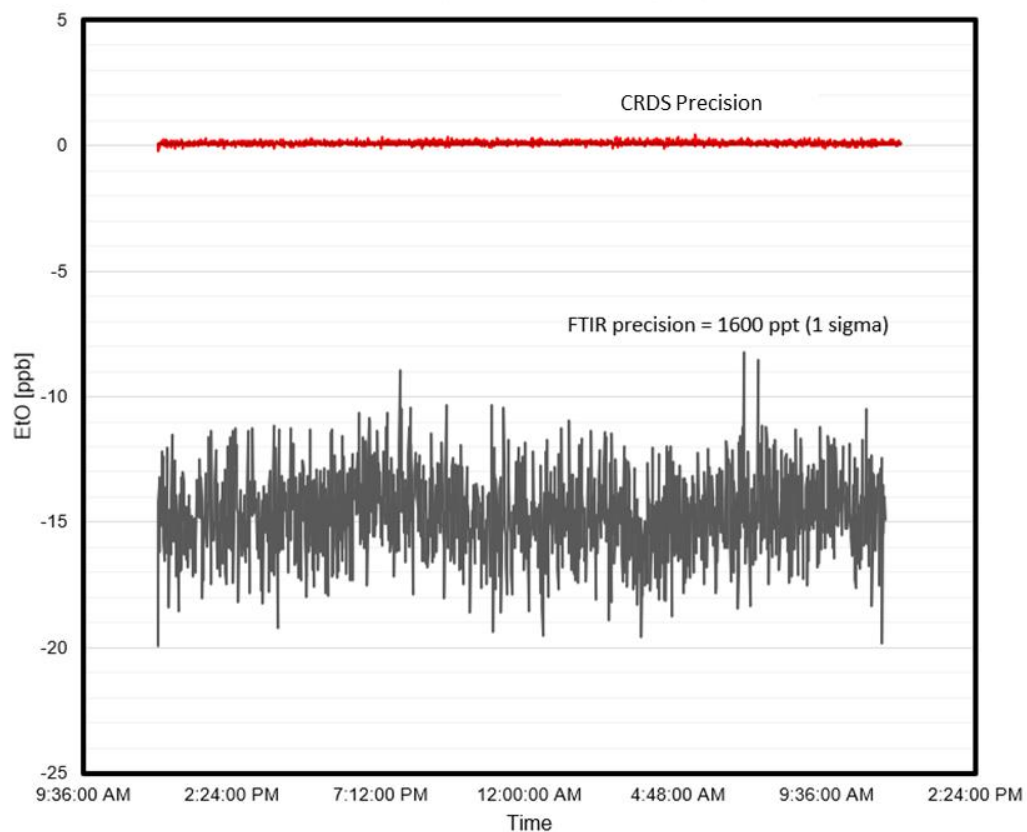
- Portable, easy deployment
- Instantaneous results
- No sample pre-treatment
- Proven to endure industrial site conditions
- Multicomponent capability

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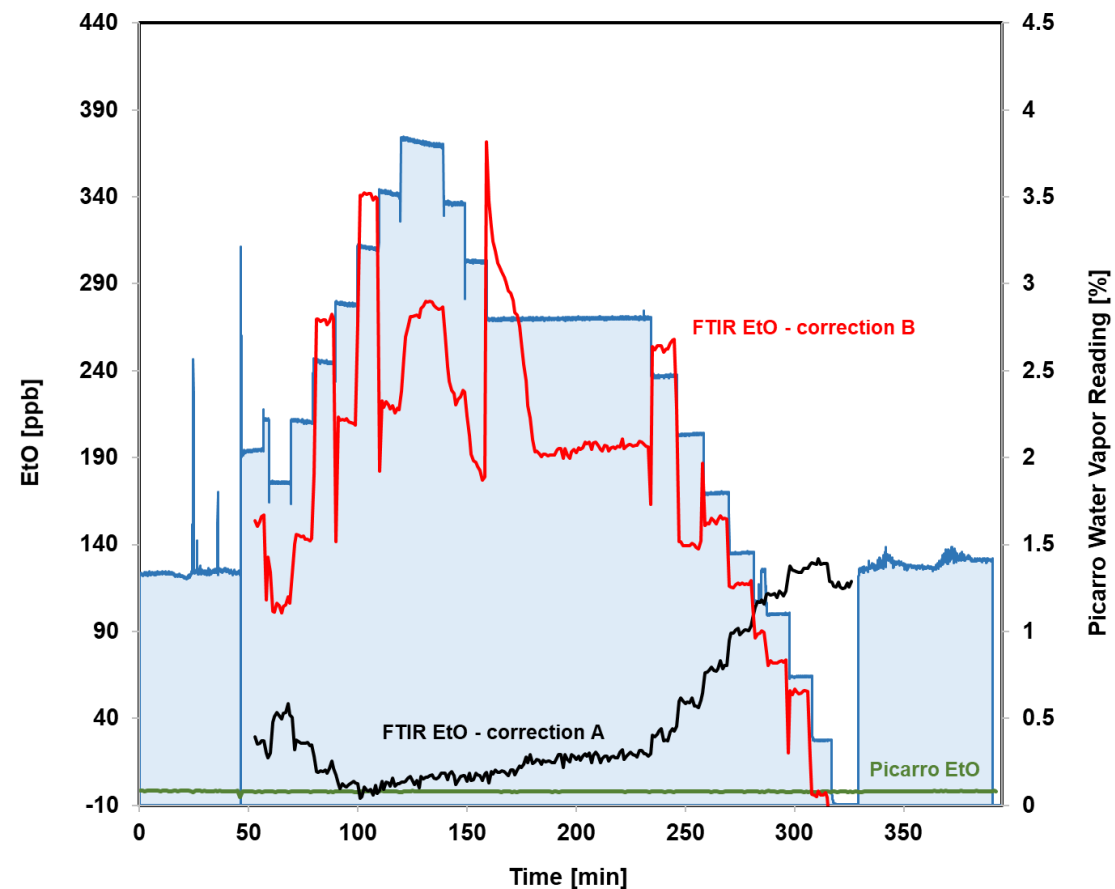


Precision

24h Drift (1 min box averages)



Interference



— CRDS EtO — FTIR EtO (200 scans) — CRDS EtO

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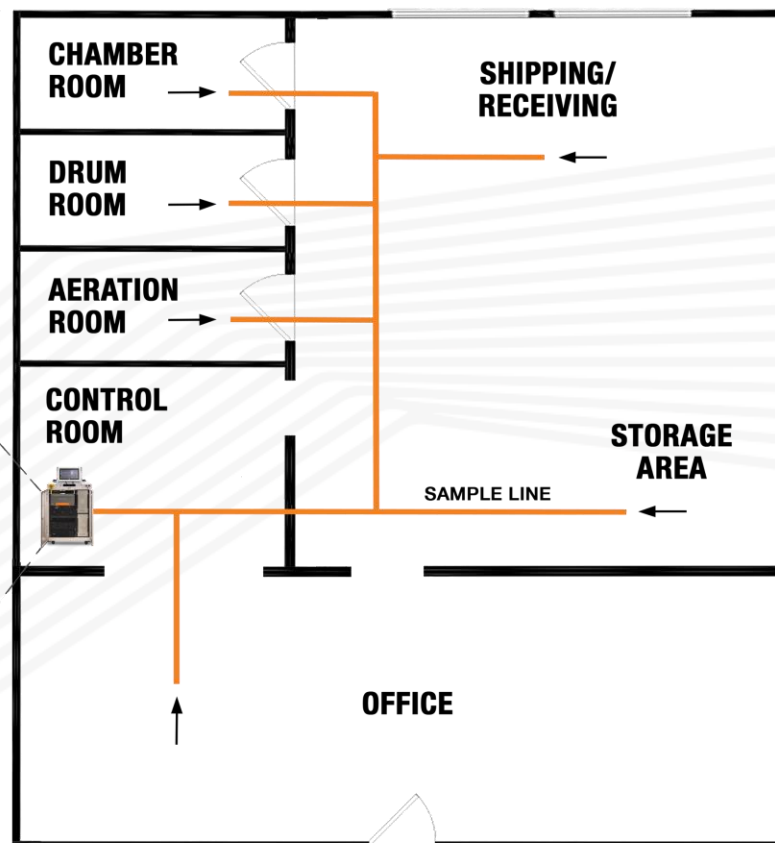
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MULTIPOINT MONITORING APPLICATIONS

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- Replacing biased technologies such as GC, PID, FID, E-Cell, FTIR
- Rapid response for maximum spatial coverage
- Analyte specific – eliminating false alarms
- Improved process safety
- Integration with visual/audial alarms and existing PI historians

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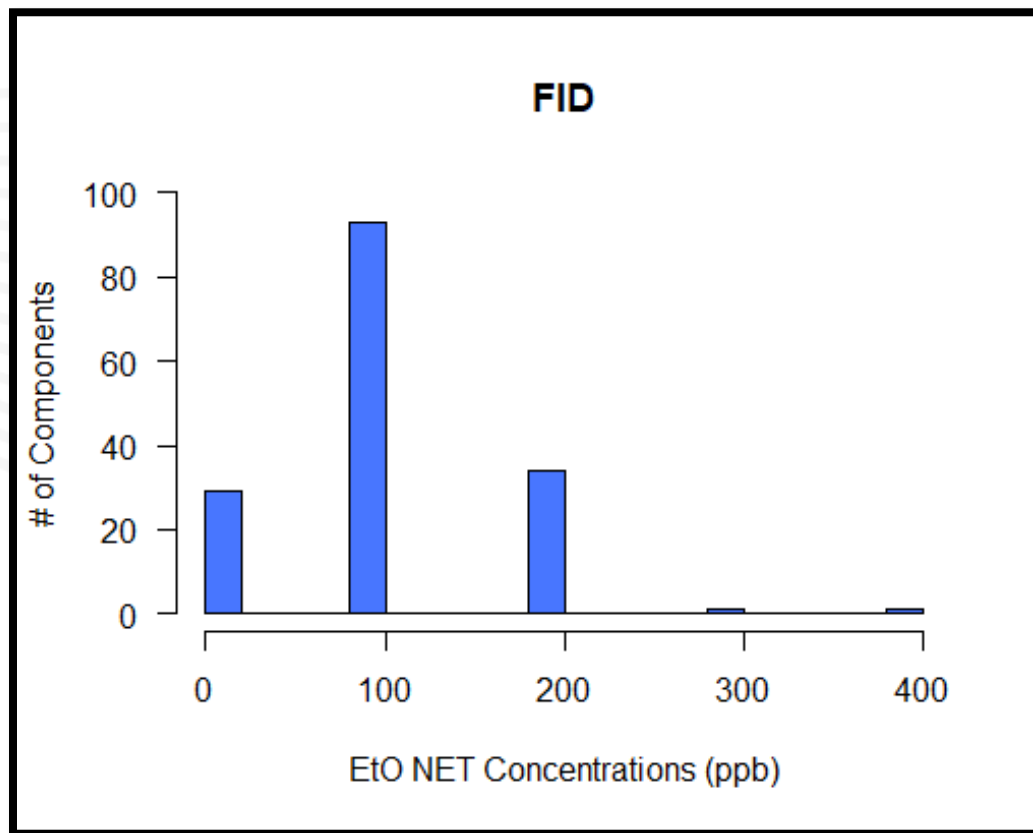
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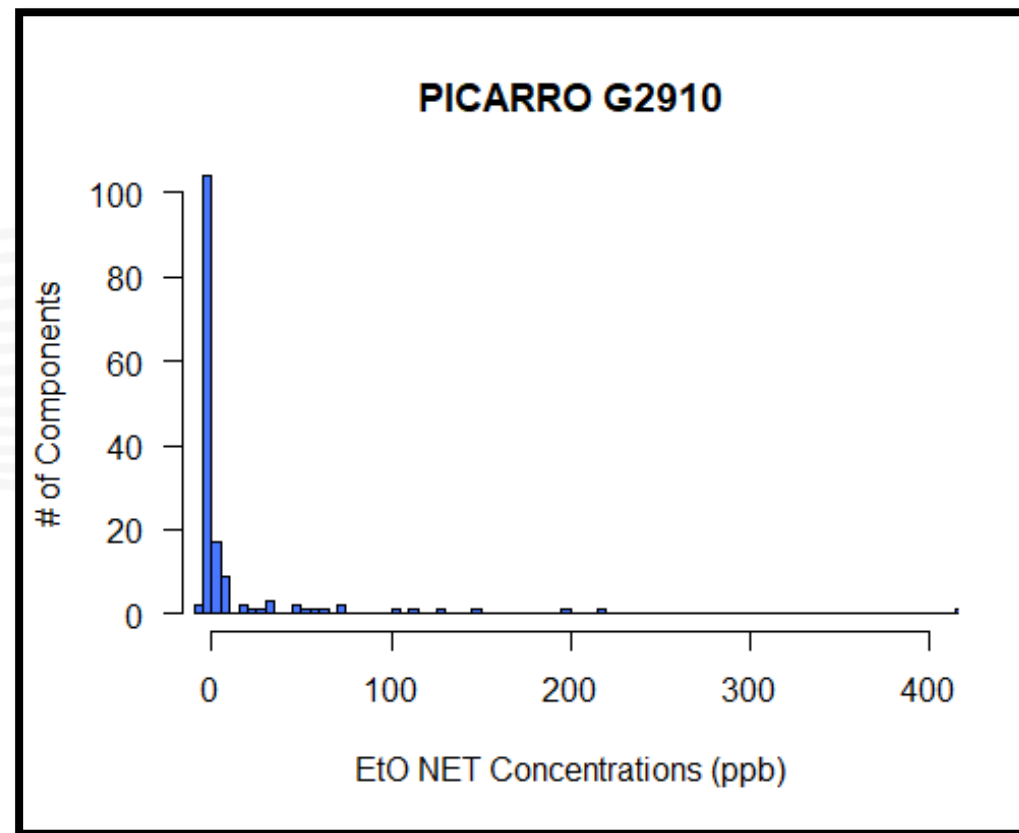
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LEAK DETECTION AND REPAIR (LDAR)

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Median: 100 ppb



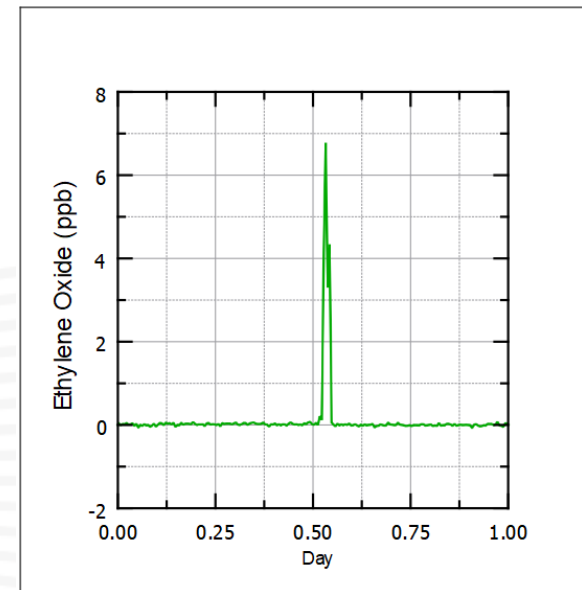
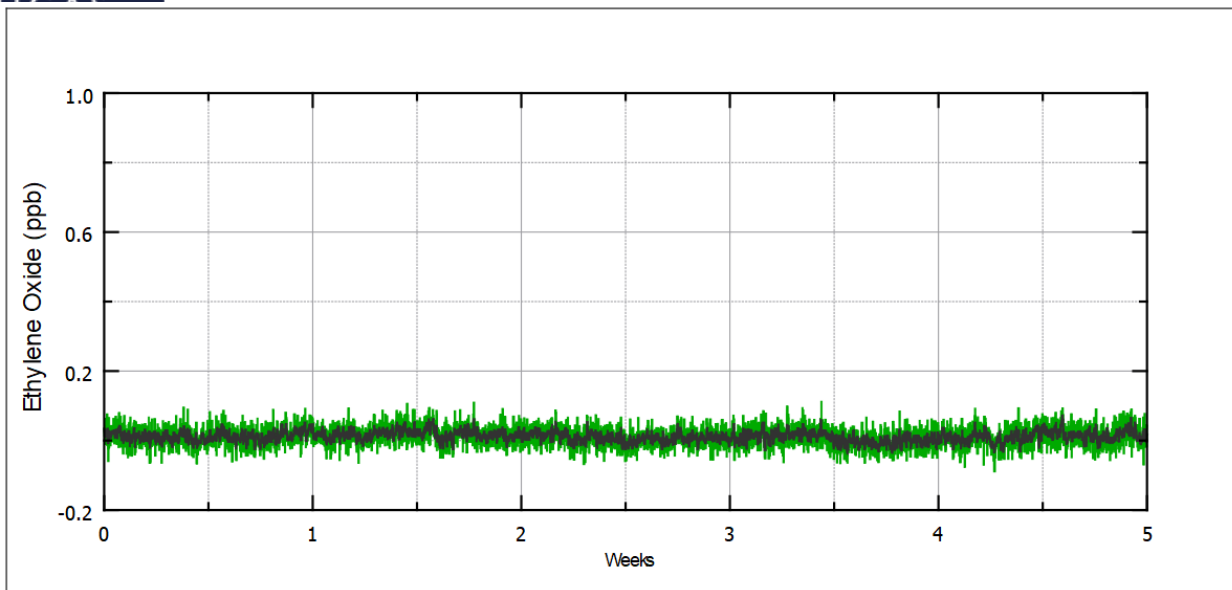
Median: 0.9 ppb

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STATIONARY FENCELINE MONITORING

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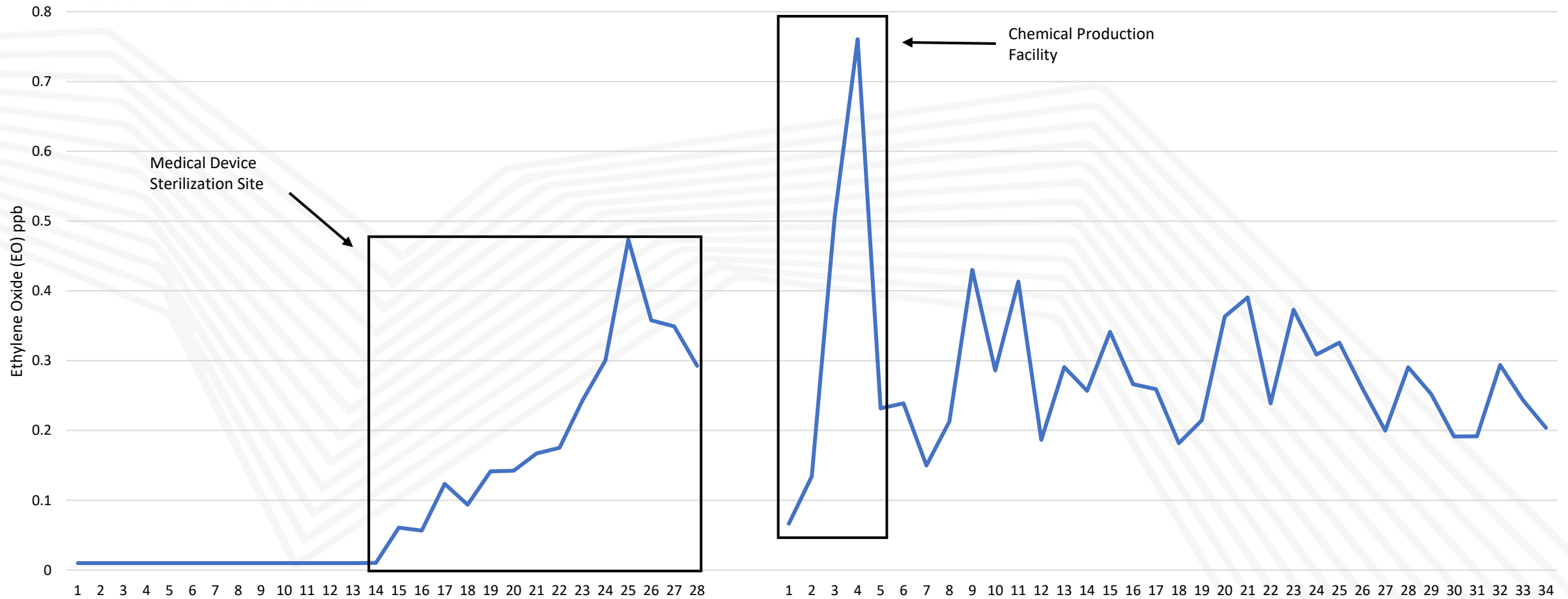
- Industry leading MDL's
- Real-time event detection
- Up to 1 year of maintenance free operation
- Parts per trillion (ppt) lower detection limits
- Turn-Key, interference free operation

MOBILE MONITORING

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Mobile Monitoring of Ethylene Oxide



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VALIDATION WITH SURROGATE GASES

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PROBLEM:

- HAPS = hazardous gases
- Standards are challenging
- Hard to procure

SOLUTION:

- SURROGATE gases = safer alternative
- Absorption spectra adjacent to original gas
- Commercially available gases



Model	Primary Gas	Surrogate Gas	Recommended Gas Concentrations
G2103	NH ₃	CO ₂	0, 200, 1000, 10000 ppm
G2108	HCl	CH ₄	0, 7, 50, 100 ppm
G2205	HF	O ₂	0, 20.94% (ambient)
G2307	H ₂ CO	CH ₄	0, 7, 50, 100 ppm

Surrogate Gas Validation: A Safer, Easier Way to Validate Measurements of Hazardous, Corrosive, and Reactive Trace Gases | Picarro

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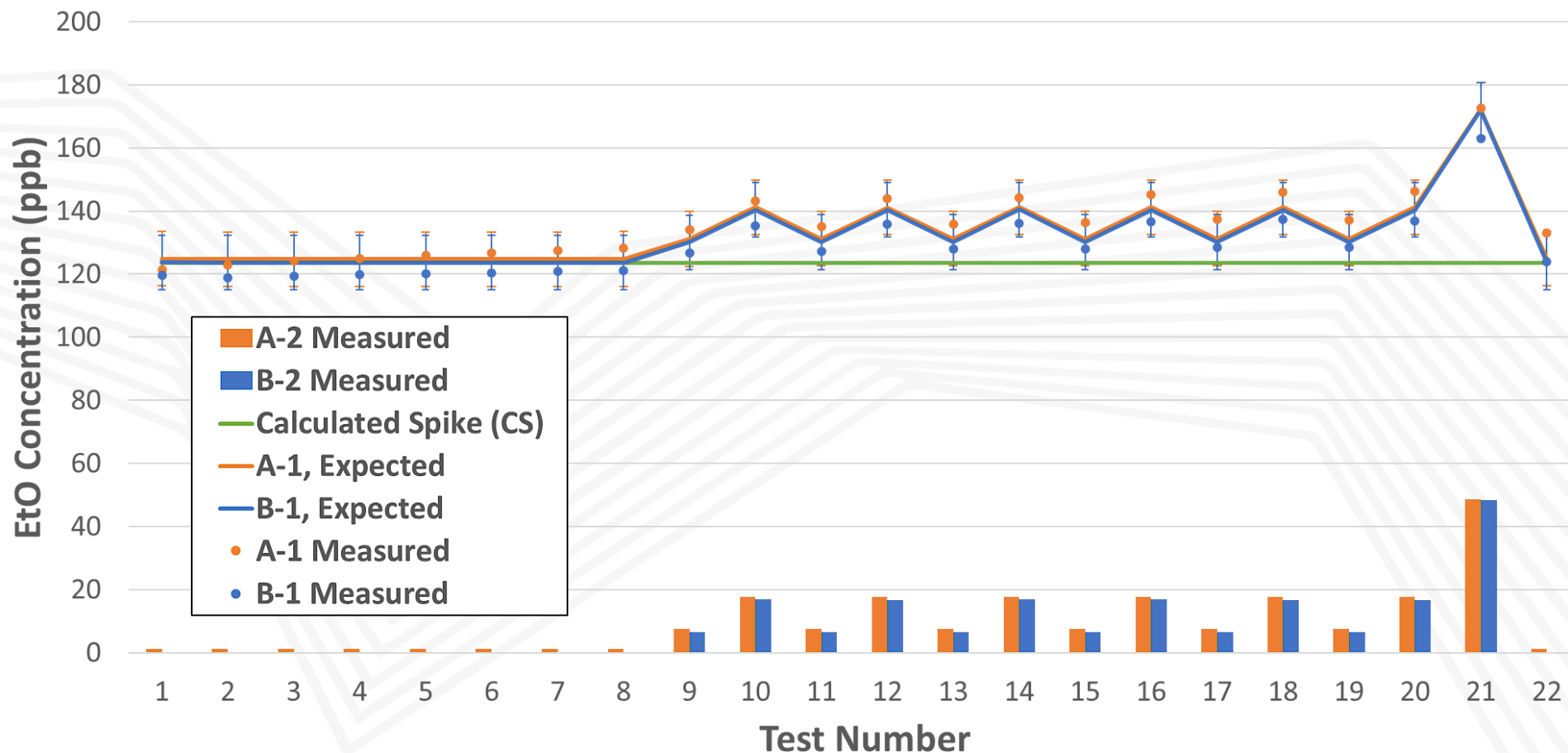
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US EPA VALIDATION TESTING RESULTS

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EPA Method 301
Validation Testing



Bias Analysis
($<10\%$)
 $B_R = 0.24\%$



T Test $<$ T-Crit
 $0.678 < 2.080$



$0.7 < CF < 1.3$
 $CF = 1.002$



RSD $<$ 20%
RSD = 1.56%

Sources: CleanAir Engineering & Picarro G2910 EPA Other Test Method (OTM) Development Testing

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How is Picarro CRDS being utilized?

Fenceline monitoring stations

Mobile monitoring surveys

Leak Detection & Repair (LDAR)

Continuous Emissions Monitoring Systems (CEMS)

Indoor air quality

Fixed multi-point leak detection



Real-Time Analyzers



Turnkey Systems



Mobile Solutions

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THANK YOU – QUESTIONS?

Dave Miller

Business Development Manager

dmiller@picarro.com

+1 870-847-3213

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