

FALL 2024

PICARRO ETO CONFERENCE

Streamlining Emissions Compliance
in the Sterilization Industry

PICARRO

Workshop C(1): On- hand Demonstration with Picarro Workplace Monitoring System

Jonathan Bent – Sr. Program Manager - Picarro



Workplace monitoring system

EtO Workplace Monitoring System

WORKPLACE



WORKPLACE Mobile



1 ppb LOD/Precision



25-point sampling w/ T95 ~5 sec



1 second sampling for 15-60 sec/position



High flow active line purging (6 SLPM)



Active self-calibration and zeroing



Active Data Quality Indicators

-Interferences, latency, fits

-Comms errors

-Flow drops



Beacon and horn high and high-high alarms

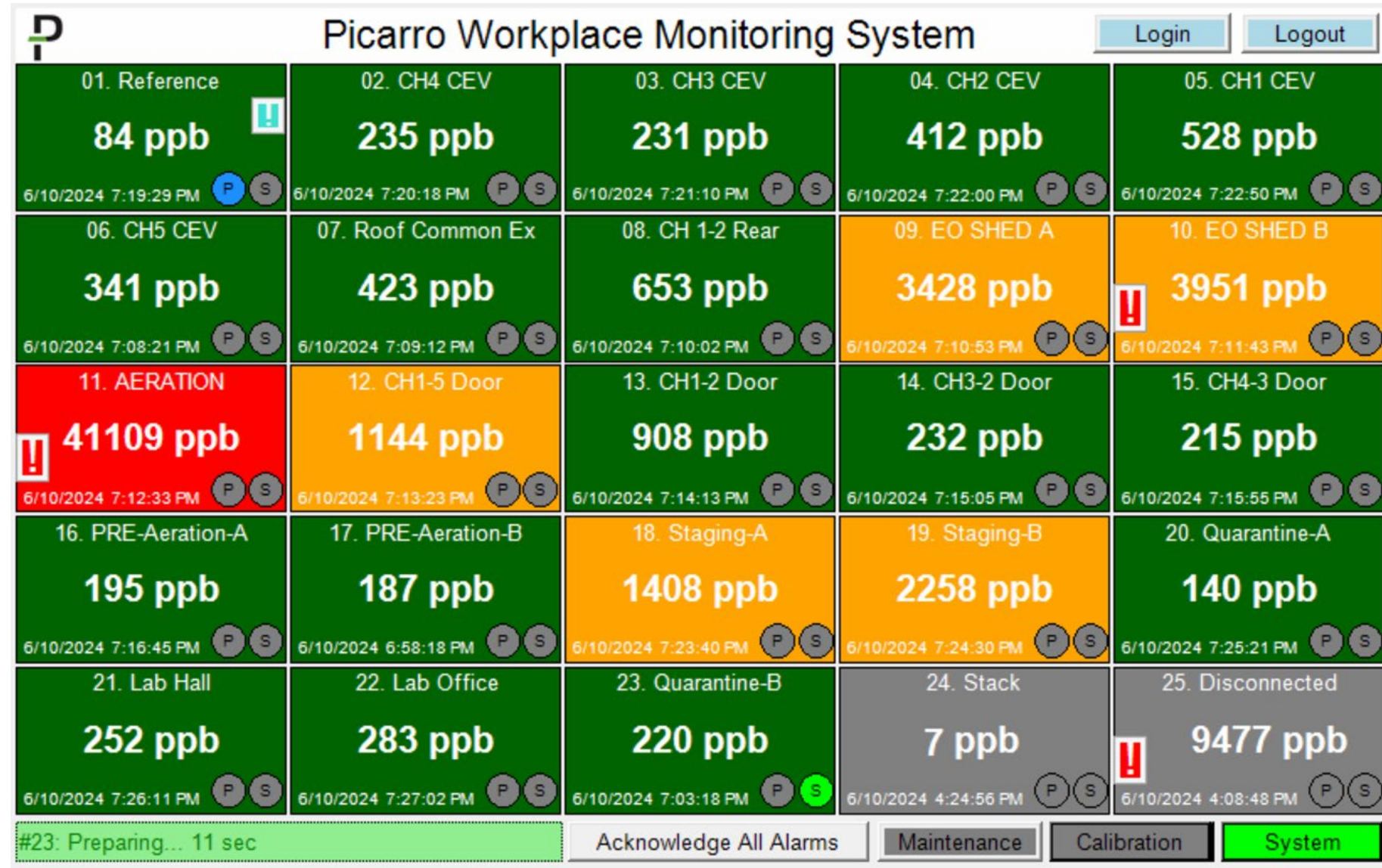


"Mobile" var. has 1 hour battery life

A clear color-based display shows all 25 points at once, displaying alarm and error states, current sample position, and time of last measurement.

Persist alarms shown as color-coded exclamation marks provide a lasting record so that operators don't miss upset states.

Persist alarms are recorded to an audit log, and can be cleared and commented on by administrators.

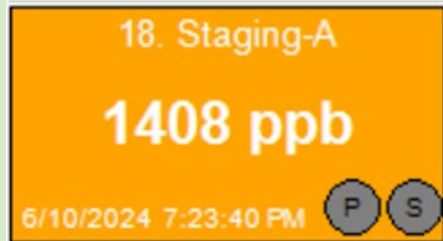


Concentration Alarming

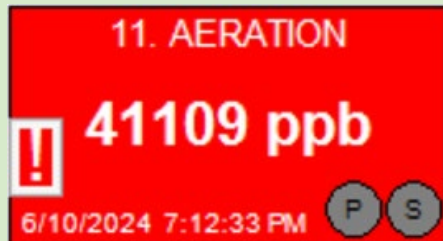
(set points fully customizable)



Normal reading below
alarm State
(< 1000 ppb)

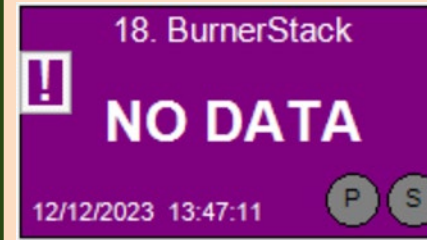


High Alarm State
($5000 > X > 1000$ ppb)

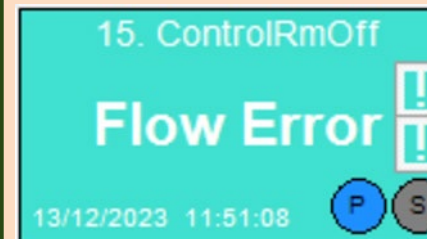


High-high Alarm State
w/ persist icon
(> 5000 ppb)

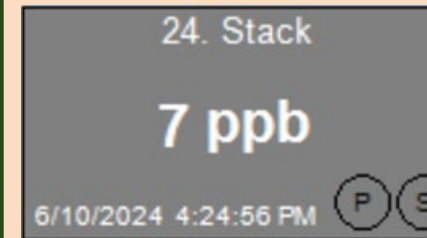
Error, Status States



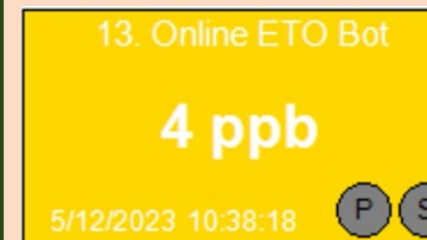
Flagged by Data
Quality Indicator,
w/ persist icon



Flagged for Low Flow,
w/ persist icon for
sample and prime lines



Position
Disabled



Communications
Error (all positions)

Sampling sequence and order can be defined by user (e.g. 1,2,3,1,4,5,1,6,7...)

Sampling, dead, and purge times can be defined by user based on lengths of tubing and dynamic range of EtO in facility.

“Dead Band”—value below which a 0 is shown on screen—can be defined to simplify interpretation of risk by operators.

Alarm thresholds can be defined to match individual need or local regulatory requirements.

Flow alarm threshold can be set based on expected flows and tubing lengths.

ENABLE ALL

ENABLE / DISABLE SPs

DISABLE ALL

| | | | | |
|------------|------------|------------|------------|------------|
| C01 C01 | C02 C02 | C03 C03 | C04 C04 | C05 C05 |
| C06 C06 | C07 C07 | C08 C08 | C09 C09 | C10 C10 |
| C11 C11 | C12 C12 | C13 C13 | C14 C14 | C15 C15 |
| C16 C16 | C17 C17 | C18 C18 | C19 C19 | C20 C20 |
| C21 C21 | C22 C22 | C23 C23 | C24 C24 | C25 C25 |

ORDER

1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25

PARAMETERS

Meas. Time: 15 sec

Dead Time: 15 sec

Purge Time: 0 sec

Total Sample Time: 30 sec

Dead Band: 100 ppb

ALARMS

High: 100 ppb

High-High: 4000 ppb

Minimal Flow: 3 l/min

FLOW & TEMP

Sample Pump Flow 4.68 l/min

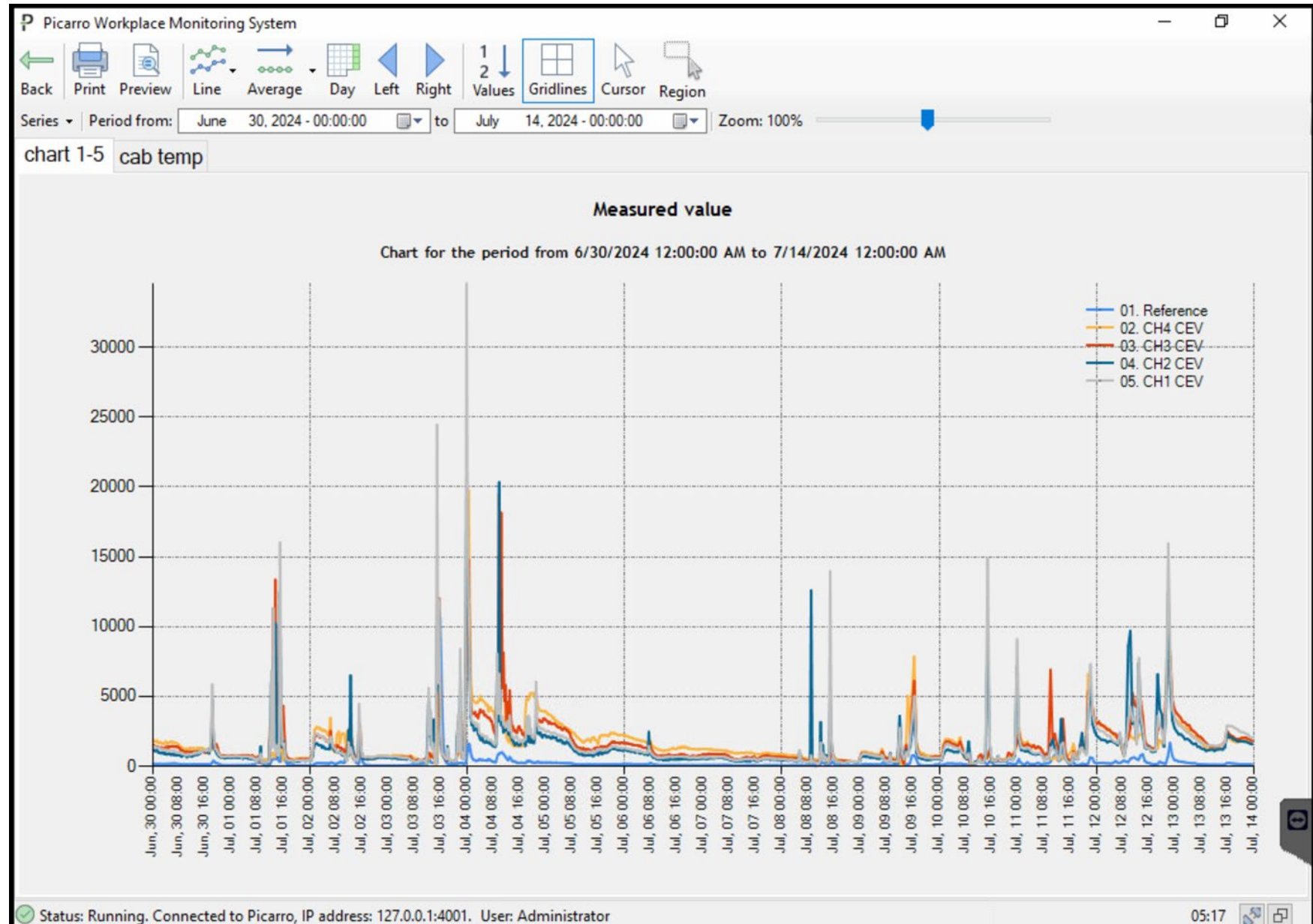
Prime Pump Flow 5.54 l/min

Cabinet Temp 30.0 °C

Multiposition graphing for individual 1Hz components or averaged sample data (seen here over 2 weeks)

Flexible time range, zooming, dynamic Y axis scaling

Additional map interface superimposes values on site map.



Reports for sample data, calibration, events, audit logs, alarm states, and other details

User selects # of positions to output

User specifies date range, with flexibility to output months of data at a time producing small (KBs-MBs) report XLS files

Automatic generation and email alerting options

Picarro Workplace Monitoring System

Back Print Preview Setup Export First Prev Next Last Zoom In Zoom Out

Report name:
Sample Data

Locations

- 01. Reference
- 02. CH4 CEV
- 03. CH3 CEV
- 04. CH2 CEV
- 05. CH1 CEV
- 06. CH5 CEV
- 07. Roof Common Ex
- 08. CH 1-2 Rear
- 09. EO SHED A
- 10. EO SHED B
- 11. AERATION
- 12. CH1-5 Door
- 13. CH1-2 Door
- 14. CH3-2 Door
- 15. CH4-3 Door
- 16. PRE-Aeration-A
- 17. PRE-Aeration-B
- 18. Staging-A
- 19. Staging-B
- 20. Quarantine-A
- 21. Lab Hall
- 22. Lab Office
- 23. Quarantine-B
- 24. Stack
- 25. Disconnected

Start time:
Jun 11 2024, 12:00 AM

End time:
Jun 17 2024, 11:59 PM

Generate

Status: Running. Connected to Picarro, IP address: 127.0.0.1:4001. User: Administrator

WMS Report Format

Reports are produced as .xls files with a tab for each sample position, over a user-specified period

Each position reports numerous timestamp parameters, concentration, Time-weighted Averages, Alarm and Error states

| | A | B | C | D | E | F | G | H | I |
|---|------------|----------|--------------------|------------|-----------------|-------------------|-----------------|--------|---|
| 1 | Date | Time | Fractional Yearday | Epoch Time | EtO Value (ppb) | EtO 8hr TWA (ppb) | Alarm State | Errors | |
| 193 | 2024-07-03 | 13:30:27 | 185.5628 | 15946227 | 645.43 | 555.30 | Normal | NA | |
| 194 | 2024-07-03 | 13:49:44 | 185.5762 | 15947384 | 696.13 | 555.30 | Normal | NA | |
| 195 | 2024-07-03 | 14:09:02 | 185.5896 | 15948542 | 493.05 | 564.37 | Normal | NA | |
| 196 | 2024-07-03 | 14:28:20 | 185.6030 | 15949700 | 459.47 | 564.37 | Normal | NA | |
| 197 | 2024-07-03 | 14:47:38 | 185.6164 | 15950858 | 6024.34 | 564.37 | High, High-High | NA | |
| 198 | 2024-07-03 | 15:06:55 | 185.6298 | 15952015 | 6610.03 | 773.60 | High, High-High | NA | |
| 199 | 2024-07-03 | 15:26:12 | 185.6432 | 15953172 | 12003.34 | 773.60 | High, High-High | NA | |
| 200 | 2024-07-03 | 15:45:31 | 185.6566 | 15954331 | 5594.59 | 773.60 | High, High-High | NA | |
| 201 | 2024-07-03 | 16:04:48 | 185.6700 | 15955488 | 2354.60 | 1723.79 | High | NA | |
| 202 | 2024-07-03 | 16:24:07 | 185.6834 | 15956647 | 992.14 | 1723.79 | Normal | NA | |
| 203 | 2024-07-03 | 16:43:24 | 185.6968 | 15957804 | 714.53 | 1723.79 | Normal | NA | |
| 204 | 2024-07-03 | 17:02:41 | 185.7102 | 15958961 | 599.37 | 1845.23 | Normal | NA | |
| 205 | 2024-07-03 | 17:21:59 | 185.7236 | 15960119 | 502.56 | 1845.23 | Normal | NA | |
| 206 | 2024-07-03 | 17:41:16 | 185.7370 | 15961276 | 456.90 | 1845.23 | Normal | NA | |
| 207 | 2024-07-03 | 18:00:35 | 185.7504 | 15962435 | 443.19 | 1856.07 | Normal | NA | |
| 208 | 2024-07-03 | 18:19:51 | 185.7638 | 15963591 | 439.46 | 1856.07 | Normal | NA | |
| 209 | 2024-07-03 | 18:39:09 | 185.7772 | 15964749 | 411.64 | 1856.07 | Normal | NA | |
| 210 | 2024-07-03 | 18:58:26 | 185.7906 | 15965906 | 421.42 | 1856.07 | Normal | NA | |
| 211 | 2024-07-03 | 19:17:44 | 185.8040 | 15967064 | 370.07 | 1851.86 | Normal | NA | |
| 212 | 2024-07-03 | 19:37:02 | 185.8174 | 15968222 | 347.20 | 1851.86 | Normal | NA | |
| 213 | 2024-07-03 | 19:56:19 | 185.8308 | 15969379 | 345.38 | 1851.86 | Normal | NA | |
| <div> 01. Reference 02. CH4 CEV 03. CH3 CEV 04. CH2 CEV 05. CH1 CEV 06. CH5 CEV 07. Roof Common Ex </div> | | | | | | | | | |

Reports for calibration
for zero, span, or both

Auto-adjustment of zero
and span state

Superb repeatable zero
check performance over
time

Report generation in
PDF, XLS, Word formats

Picarro Workplace Monitoring System

Back Print Preview Setup Export First Prev Next Last Zoom In Zoom Out

Report name: Calibration

Components: Ethylene oxide (30 sec)

Calibration point: Zero

Start time: Jun 1 2024, 5:25

End time: Jun 25 2024, 5:55

Generate

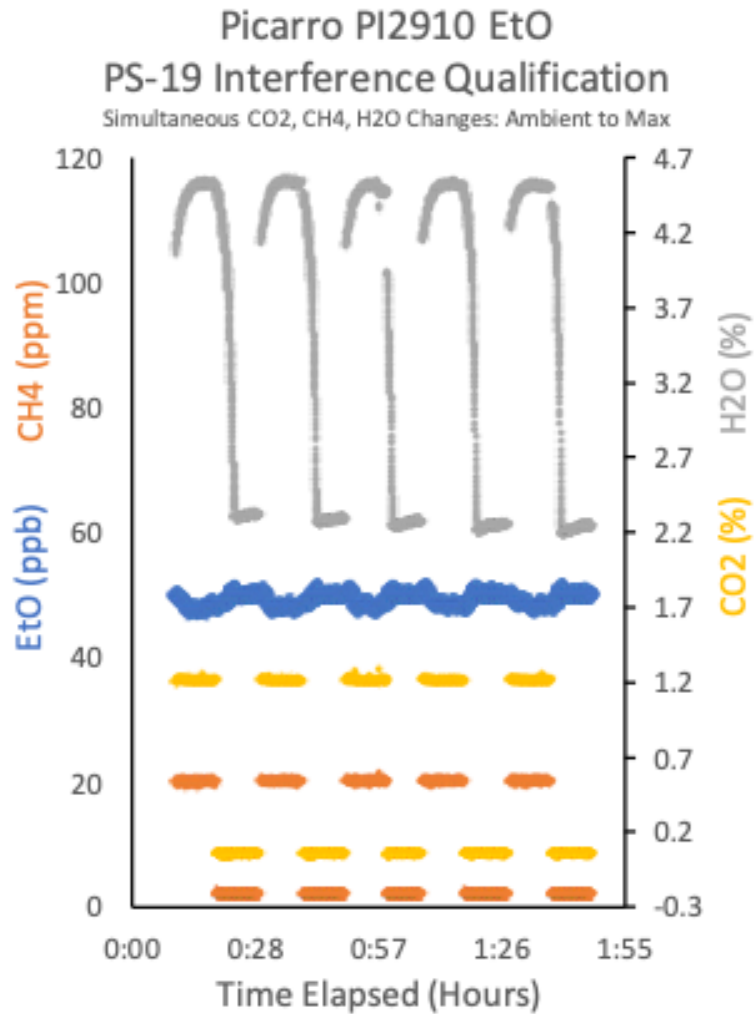
Calibration Results:

| Check Time | Reference Value (ppb) | Actual Value (ppb) | Calibrated Range (ppb) | Calibration Drift (ppb) | Calibration Drift (% FS) | Excessive Calibration Drift |
|-------------------|-----------------------|--------------------|------------------------|-------------------------|--------------------------|-----------------------------|
| 2/6/2024 0:00:47 | 0.0 | -1.3 | 0 - 1000 | -1.3 | -0.13 | Pass |
| 3/6/2024 0:00:41 | 0.0 | -1.2 | 0 - 1000 | -1.2 | -0.12 | Pass |
| 4/6/2024 0:00:39 | 0.0 | -1.8 | 0 - 1000 | -1.8 | -0.18 | Pass |
| 5/6/2024 0:00:48 | 0.0 | -1.9 | 0 - 1000 | -1.9 | -0.19 | Pass |
| 6/6/2024 0:00:46 | 0.0 | -1.7 | 0 - 1000 | -1.7 | -0.17 | Pass |
| 7/6/2024 0:00:38 | 0.0 | -1.1 | 0 - 1000 | -1.1 | -0.11 | Pass |
| 8/6/2024 0:00:39 | 0.0 | -1.6 | 0 - 1000 | -1.6 | -0.16 | Pass |
| 9/6/2024 0:00:42 | 0.0 | -1.5 | 0 - 1000 | -1.5 | -0.15 | Pass |
| 10/6/2024 0:00:40 | 0.0 | -1.4 | 0 - 1000 | -1.4 | -0.14 | Pass |
| 11/6/2024 0:00:40 | 0.0 | -1.6 | 0 - 1000 | -1.6 | -0.16 | Pass |
| 12/6/2024 0:00:37 | 0.0 | -1.3 | 0 - 1000 | -1.3 | -0.13 | Pass |
| 13/6/2024 0:00:38 | 0.0 | -1.3 | 0 - 1000 | -1.3 | -0.13 | Pass |
| 14/6/2024 0:00:45 | 0.0 | -1.3 | 0 - 1000 | -1.3 | -0.13 | Pass |
| 15/6/2024 0:00:39 | 0.0 | -1.5 | 0 - 1000 | -1.5 | -0.15 | Pass |
| 16/6/2024 0:00:44 | 0.0 | -0.9 | 0 - 1000 | -0.9 | -0.09 | Pass |
| 17/6/2024 0:00:47 | 0.0 | -0.9 | 0 - 1000 | -0.9 | -0.09 | Pass |
| 18/6/2024 0:00:48 | 0.0 | -1.1 | 0 - 1000 | -1.1 | -0.11 | Pass |
| 19/6/2024 0:00:46 | 0.0 | -1.7 | 0 - 1000 | -1.7 | -0.17 | Pass |
| 20/6/2024 0:00:41 | 0.0 | -0.3 | 0 - 1000 | -0.3 | -0.03 | Pass |
| 21/6/2024 0:00:47 | 0.0 | -1.7 | 0 - 1000 | -1.7 | -0.17 | Pass |
| 22/6/2024 0:00:49 | 0.0 | -0.3 | 0 - 1000 | -0.3 | -0.03 | Pass |

Status: Running. Connected to Picarro, IP address: 127.0.0.1:4001. User: Administrator

Stability, Selectivity, and Sensitivity

We're concerned about the accuracy of EtO measurements if concentrations of other gases change in the facility—higher CO₂ near trucks or people, higher humidity at different times of year—because we've seen that with other sensors we've used.§



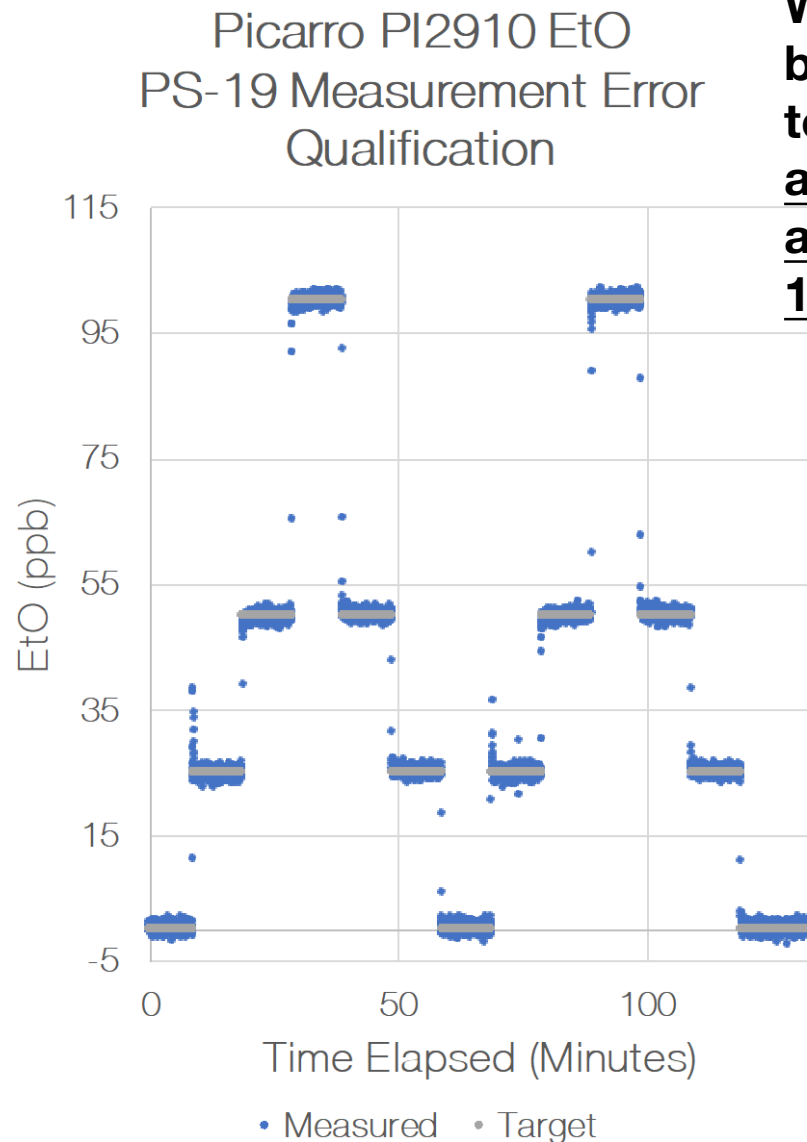
As part of PS-19 qualification required by United States EPA for the EtO NESHAP CEMS requirement, Picarro injected roughly 50 ppb EtO into a sample stream, then changed the H₂O, CO₂, CH₄ concentrations significantly to demonstrate the EtO response. Though no official requirement was provided, the response broadly had to be <30 ppb.

Average difference = 1.44 ppb

| Step | Max | Amb | Diff (Amb-Max) | Max | Amb | Max | Amb | Max | Amb |
|----------------------|--------|--------|-------------------|--------|-------|-------|-------|-------|-----|
| | EtO | EtO | EtO | CH4 | CH4 | H2O | H2O | CO2 | CO2 |
| | ppb | ppb | ppb | ppm | ppm | % | % | ppm | ppm |
| 1 | 47.978 | 49.500 | -1.522 | 19.930 | 2.008 | 4.443 | 2.926 | 12080 | 484 |
| 2 | 48.145 | 49.660 | -1.515 | 20.000 | 2.012 | 4.471 | 2.772 | 12082 | 484 |
| 3 | 48.512 | 49.913 | -1.401 | 20.006 | 2.019 | 4.437 | 2.408 | 12089 | 484 |
| 4 | 48.582 | 49.836 | -1.254 | 20.029 | 2.017 | 4.454 | 2.666 | 12080 | 485 |
| 5 | 48.337 | 49.847 | -1.509 | 20.026 | 2.016 | 4.465 | 2.565 | 12085 | 485 |
| Mean of Abs(Diff) | | | 1.440 | | | | | | |

PS-19: Measurement Error

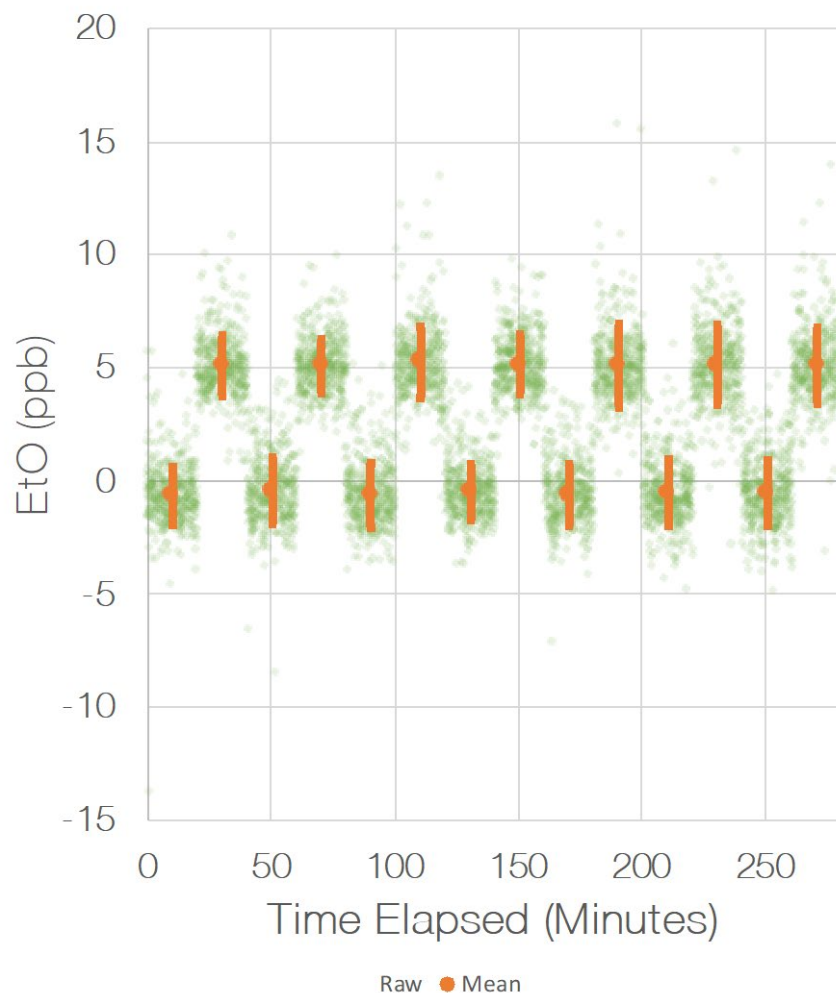
We assess the measurement error of the system as the average difference between expected and observed reading calculated as a percentage of the total span range. The mean absolute difference is 0.154 ppb, and the mean absolute error is 0.154% because the span is defined (very conservatively) as 0-100 ppb. This is successfully well below either 5% of span (5 ppb) or 10 ppb (PS-19 Section 13.3), so the Picarro CEMS passes.



| Reference Gas Value | CEMS Response | (Ref-Obs) | Meas. Err. (Ref-Obs)/Span |
|---------------------|---------------|----------------------|---------------------------|
| ppb | ppb | ppb | % |
| 0.0 | 0.18 | -0.18 | -0.18 |
| 25.0 | 24.75 | 0.24 | 0.24 |
| 50.0 | 49.67 | 0.33 | 0.33 |
| 100.0 | 100.08 | -0.08 | -0.08 |
| 50.0 | 50.07 | -0.07 | -0.07 |
| 25.0 | 25.09 | -0.09 | -0.09 |
| 0.0 | 0.16 | -0.16 | -0.16 |
| 25.0 | 24.87 | 0.13 | 0.13 |
| 50.0 | 49.81 | 0.19 | 0.19 |
| 100.0 | 100.19 | -0.19 | -0.19 |
| 50.0 | 50.09 | -0.09 | -0.09 |
| 25.0 | 25.08 | -0.08 | -0.08 |
| 0.0 | 0.16 | -0.16 | -0.16 |
| | | Mean Abs. Diff (ppb) | Mean Abs. Error (%) |
| | | 0.154 | 0.154 |

PS-19: Limit of Detection

Picarro PI2910 EtO
PS-19 Limit of Detection
Qualification



We assess the Limit (Level) of Detection by varying EtO between 0 and 6 ppb (estimated 10x LOD) while the matrix is maintained at maximum interferent levels. This is repeated 7 times. The LOD is defined as three times the standard deviation of the mean of the zero steps.

Here, the LOD was 0.239 ppb. Though the regulatory limit is not clearly stated in PS-19, a number like 30 ppb is possible; 0.239 ppb is well below 20% of 30 (6 ppb), so the Picarro CEMS passes.

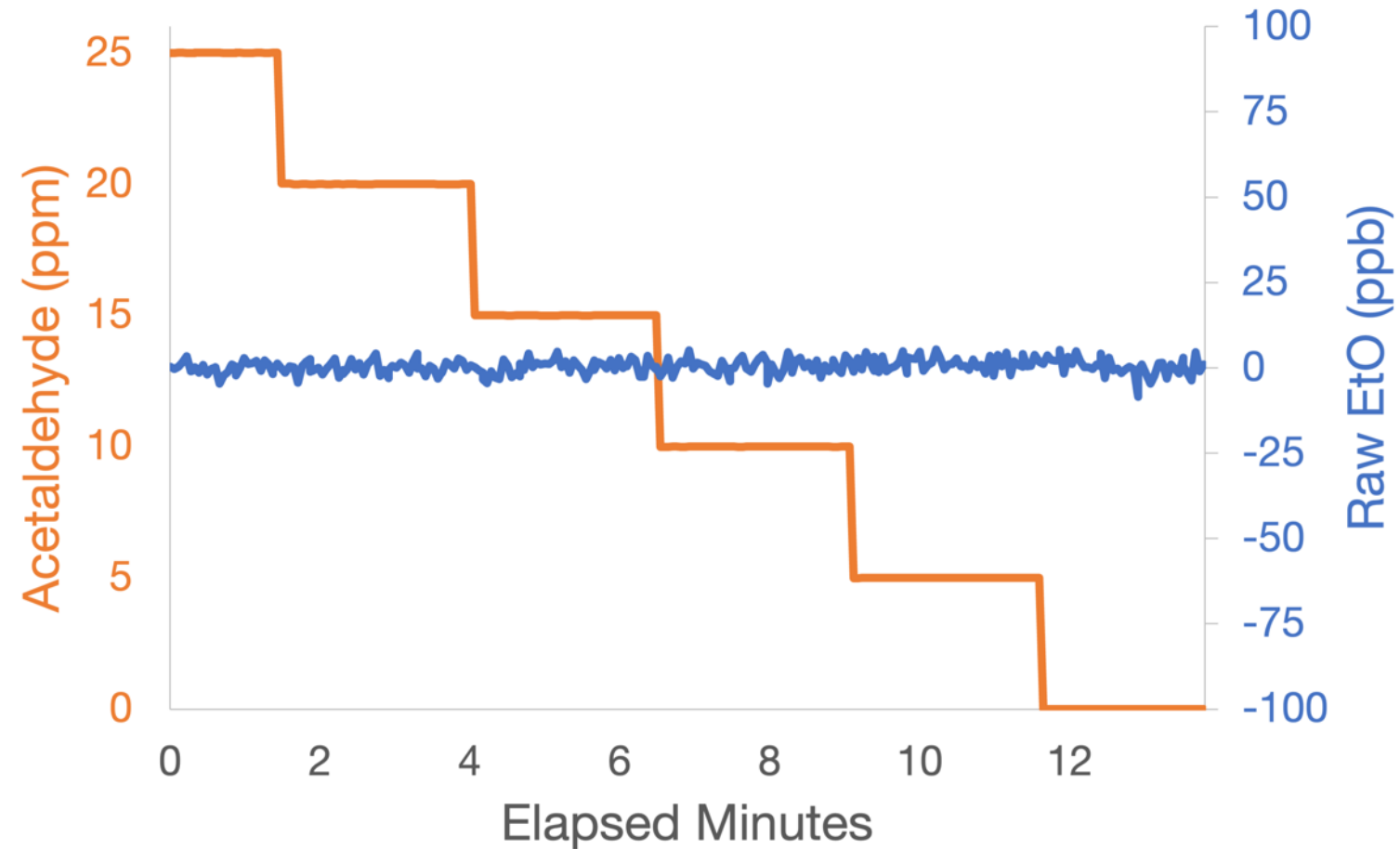
| Step | Zero Step | Span Step | Zero Step | Span Step | Zero Step | Span Step | Zero Step | Span Step |
|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| | EtO | EtO | H2O | H2O | CO2 | CO2 | CH4 | CH4 |
| | ppb | ppb | % | % | ppm | ppm | ppm | ppm |
| 1 | -0.637 | 5.109 | 4.02 | 4.00 | 12067 | 12075 | 20.00 | 19.99 |
| 2 | -0.423 | 5.085 | 3.98 | 3.99 | 12070 | 12075 | 19.98 | 19.99 |
| 3 | -0.623 | 5.243 | 3.98 | 3.96 | 12068 | 12077 | 19.99 | 20.00 |
| 4 | -0.488 | 5.156 | 3.95 | 3.94 | 12070 | 12078 | 19.97 | 19.98 |
| 5 | -0.613 | 5.107 | 3.98 | 4.16 | 12065 | 12050 | 19.97 | 19.95 |
| 6 | -0.522 | 5.140 | 4.15 | 4.13 | 12044 | 12053 | 19.95 | 19.96 |
| 7 | -0.532 | 5.114 | 4.14 | 4.10 | 12045 | 12056 | 19.94 | 19.98 |
| Mean | -0.548 | 5.136 | | | | | | |
| StDev | 0.080 | 0.053 | | | | | | |
| 3x StDev | 0.239 | 0.158 | | | | | | |

Acetaldehyde is an isomer of EtO, present at levels <0.5% in drum EtO.

It also co-elutes in Gas Chromatographs, and isn't removed by many scrubbing media, so it biases GC measurements. Here we show that concentrations of 0-25 ppm Acetaldehyde don't change the concentration of EtO detectably.

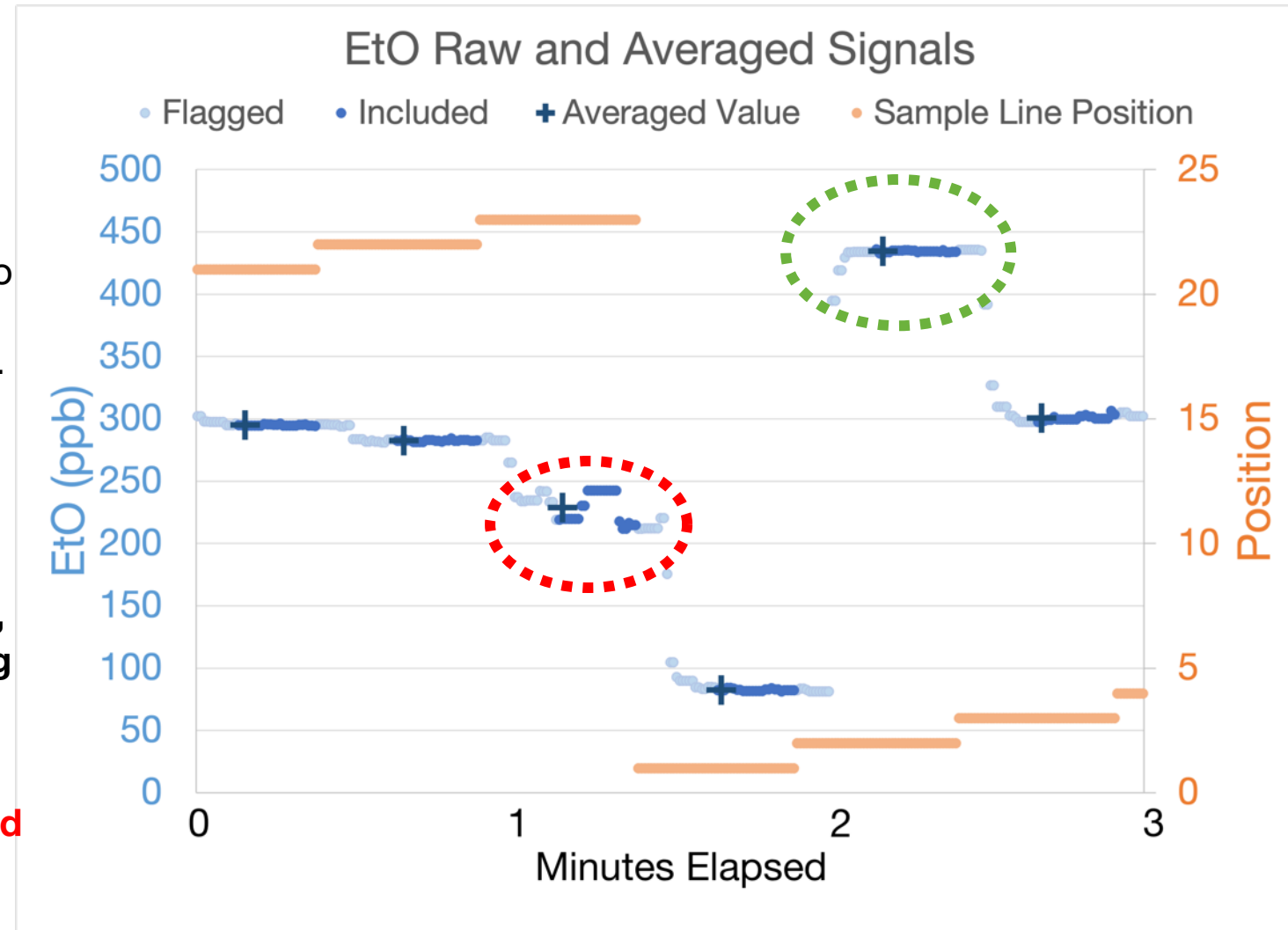
CRDS lacks the bias issues of most incumbent technologies from GCs to Electrochemical Sensors to FTIR.

Picarro PI2910 EtO
Acetaldehyde Interference Test



I've used multipoint samplers in the past, but I find that they have “memory” effects where high concentrations affect the next positions badly. These systems sometimes wrongly suggest we have a problem in an area where there isn't any product or EO use. §

- **Picarro's Workplace Monitoring System is designed specifically to address carryover in multiple ways:**
 - Pre-priming each line individually ensures sample air is fresh from the source.
 - Fast-selecting manifold with overflow: ~1 sec to reach the analyzer, ~4 seconds to flush out the cavity, resulting in a **~5 seconds T95 turnover**.
 - Transition period data flagged automatically so that average is not affected by prior position.
- **Light blue data show transition time**
Dark blue data is included for average
Dark blue cross shows the computed average, time-stamped to the beginning of the sampling period.
- **Most samples are highly stable while others show evidence of active movement of sterilized product in the sample area.**



Thank you!

Questions?