FALL 2024

PICARRO ETO CONFERENCE

Streamlining Emissions Compliance in the Sterilization Industry

OCTOBER 28-30 // ATLANTA, GEORGIA

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Streamlining Emissions Compliance in the Sterilization Industry

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Presentation 5

Innovative Monitoring Technologies and Applications

Sean Cronin
CEMS Program Manager, Picarro

Agenda

Innovative Monitoring Technologies and Applications

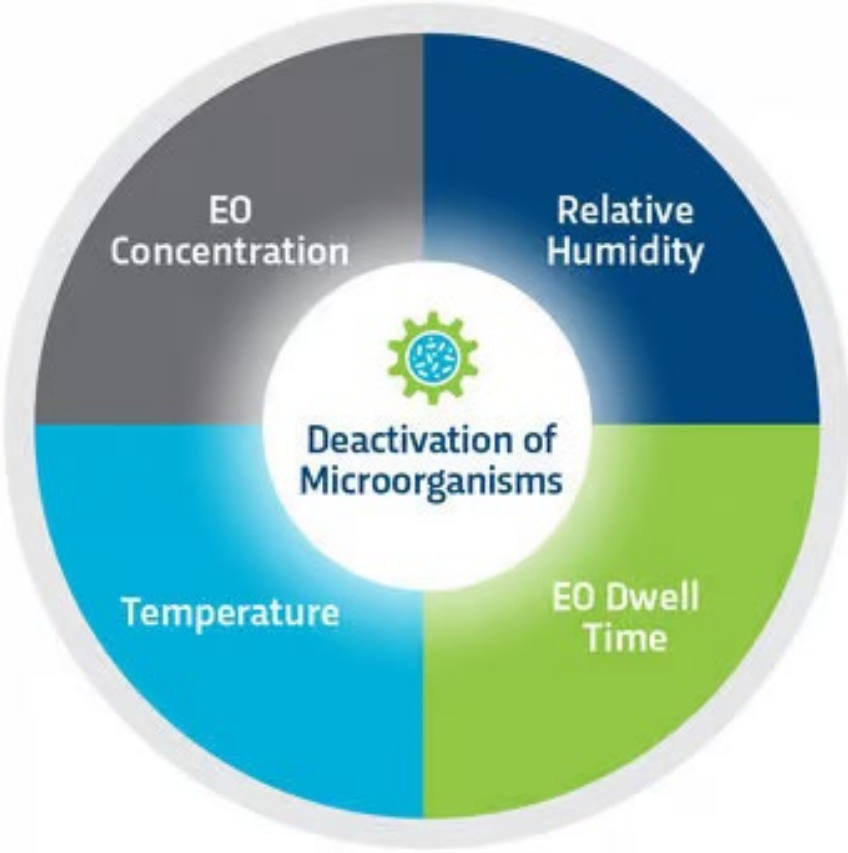
1	Introduction	Review of different CRDS applications for commercial sterilizers and chemical manufacturing facilities.
2	Reporting Innovations	Innovations for EHS staff with DRE/SWEL, including inlet measurements, and PTE reports.
3	Process Optimization	Overview of system hardware and software specializing in faster, more reliable readings with additional process optimization settings.
4	Configurable Systems	Rapidly deployed configurable systems with the ability to identify additional species and their concentrations – making new installations or certification following process changes a breeze.
5	FIFRA and Future Needs	Innovations needed to meet FIFRA requirements and any future regulations or other EtO community needs.

Introduction

Ethylene Oxide Regulations

Ethylene oxide (EtO) is carcinogenic gas that has fallen into the cross-hairs of federal and state regulatory bodies.

- Facilities that emit EtO are normally split into two categories:
  - Commercial sterilizers (medical device and/or food products)
  - Chemical production industry (HON & MON)
- Across the United States and the rest of the world, regulators have set forth restrictive emission limits for the following:
  - Continuous Emissions Monitoring Systems (CEMS)
  - Workplace Monitoring Systems (WMS)
  - Fenceline Monitoring Systems (FMS)
  - Mobile Monitoring



Introduction

Today's Technological Industry Standard

Cavity Ring Down Spectroscopy (CRDS) is widely considered the gold standard for EtO monitoring.

- Rapid response times (seconds)
- Minimal interference
- Extremely low detection limits (< 0.2 ppbv)
- Time-share capabilities (4 streams CEMS, 25 pt WMS)
- Wide instrument range (0.2 ppbv – 10,000 ppmv)
- Minimal maintenance requirements (annual preventative)
- Drift free calibrations
- Indoor or outdoor

CEMS WMS FMS

Reporting Innovations

Overview

Federal, state, and local regulatory bodies are moving towards real-time emissions monitoring that submits reports electronically for public record. Due to this, facilities need to make sure every piece of data submitted is accurate.

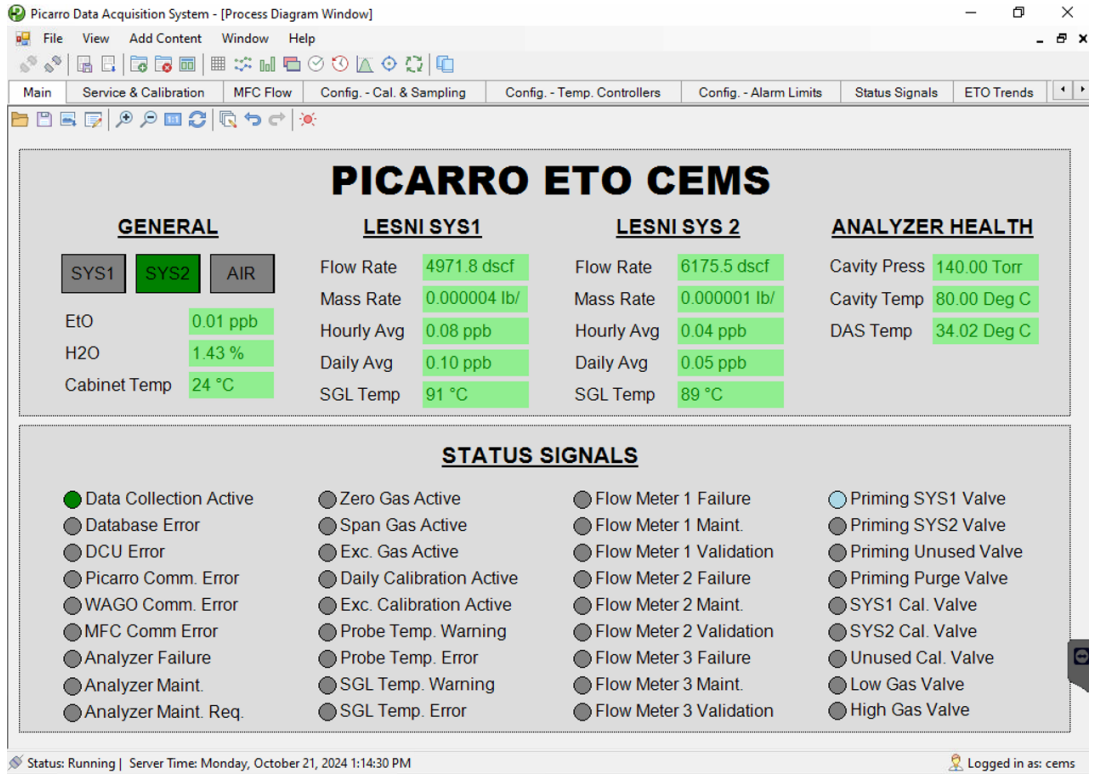
- Reports should contain:
  - Percent of data availability
  - Maximum, minimum, and average emissions
  - Detailed list of all exceedances
  - Process operating states
  - Calibration and other quality assurance data
  - All certified standards used during time interval
- Historically, this has required extensive data review by EHS staff.
- The future of emissions reports is fully integrated, intelligent multi-systems report generation

Reporting Innovations

CEMS Reporting

40 CFR 63 Subpart O requires commercial sterilizers to demonstrate compliance based on destruction removal efficiency (DRE) or site wide emission limits (SWEL).

- Process conditions must be known and correlated to quality-controlled intervals:
  - Scale/Drum weights
  - Outlet mass emissions
  - Inlet mass emissions
- Data is reduced into 30-day rolling averages
  - Constantly updated and reduced
  - Pulling multiple data streams in real-time
- Gone are the days of a DAS only capable of measuring a concentration and flow rate



Reporting Innovations

CEMS Reporting – Scale Weights

Scale/drum weights are needed to calculate facility EtO usage and are usually manually logged into workbooks to calculate DRE/SWEL.

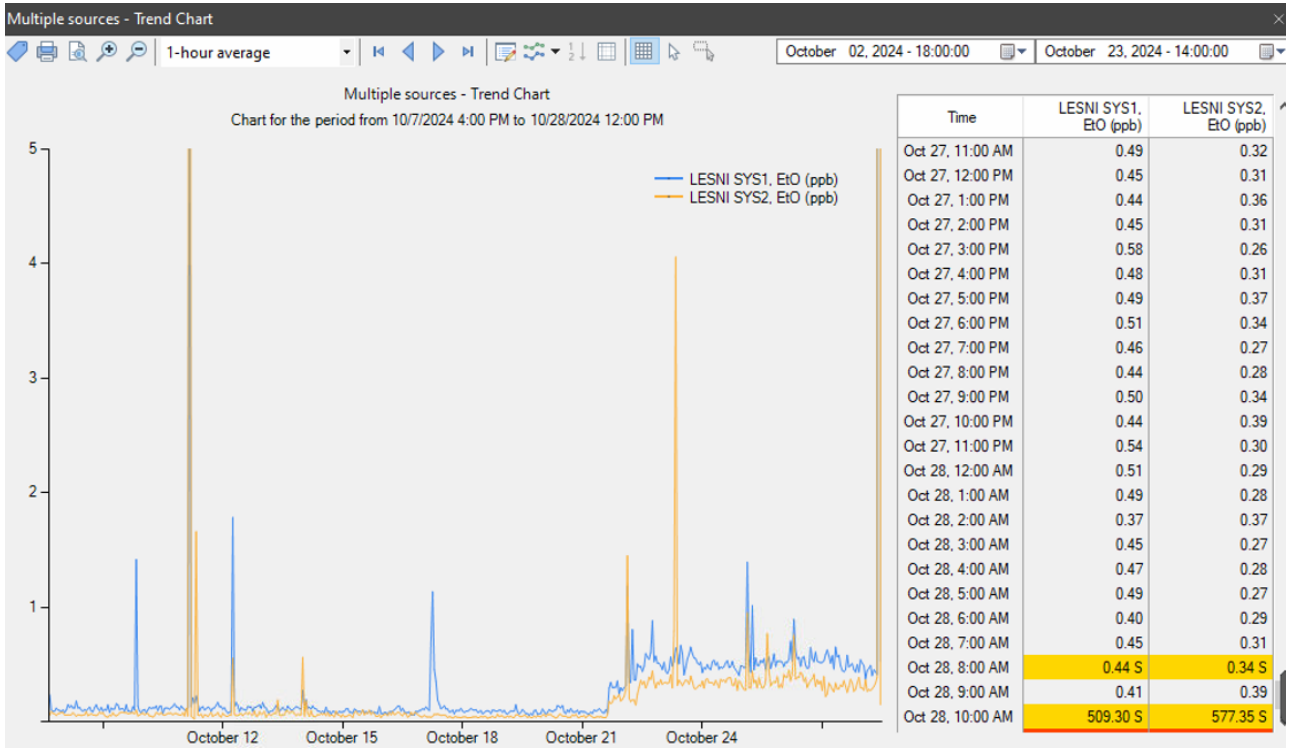
- Scale weights can be tied into the Data Acquisition System (DAS) through multiple communication protocols:
  - Modbus
  - EtherNet/IP
  - Open Platform Communication (OPC)
- Updated each cycle with a sum taken at the end of each day
- Intelligently identify when a drum has been changed
- Facility can manually adjust scale weights through an audit trailed process
- Historic data table of scale weights going back the lifetime of the DAS

Reporting Innovations

CEMS Reporting – Inlet Monitoring

US EPA left an option open for commercial sterilizers to monitor their inlet mass emission rates.

- Inlet monitoring offers some different challenges for a facility:
  - Oftentimes utilizes a time-shared system
  - Different ranges/spans amongst measurement points
  - High range analyzers and/or dilution probes
- Inlet measurements are quality assured and automatically calculated and recorded within the DAS in process related calculations
- Common for a facility calculating SWEL by emission stream
  - “Blended” site wide limit
  - Allows a higher DRE requirement, oftentimes adding double digit ppbv allowances for facilities



Time	LESNI SYS1, EtO (ppb)	LESNI SYS2, EtO (ppb)
Oct 27, 11:00 AM	0.49	0.32
Oct 27, 12:00 PM	0.45	0.31
Oct 27, 1:00 PM	0.44	0.36
Oct 27, 2:00 PM	0.45	0.31
Oct 27, 3:00 PM	0.58	0.26
Oct 27, 4:00 PM	0.48	0.31
Oct 27, 5:00 PM	0.49	0.37
Oct 27, 6:00 PM	0.51	0.34
Oct 27, 7:00 PM	0.46	0.27
Oct 27, 8:00 PM	0.44	0.28
Oct 27, 9:00 PM	0.50	0.34
Oct 27, 10:00 PM	0.44	0.39
Oct 27, 11:00 PM	0.54	0.30
Oct 28, 12:00 AM	0.51	0.29
Oct 28, 1:00 AM	0.49	0.28
Oct 28, 2:00 AM	0.37	0.37
Oct 28, 3:00 AM	0.45	0.27
Oct 28, 4:00 AM	0.47	0.28
Oct 28, 5:00 AM	0.49	0.27
Oct 28, 6:00 AM	0.40	0.29
Oct 28, 7:00 AM	0.45	0.31
Oct 28, 8:00 AM	0.44 S	0.34 S
Oct 28, 9:00 AM	0.41	0.39
Oct 28, 10:00 AM	509.30 S	577.35 S

Reporting Innovations

CEMS Reporting – Simplicity by Automation

Innovation with monitoring solutions has allowed for complex calculations to become simple tasks.

- Environmental staff can now sleep easy knowing that their compliance is automated
- Quarterly reporting windows are no longer a stressful, nightmare situation
- Each piece of data is independently tracked, logged, and quality assured
- Any updates or configuration changes are audit tracked – allowing you to always know when a change was made

Component	EtO (ppb)	EtO Mass Rate (lb/hr)	Norm Stack Flow Dry (dscfm)
10/25/2024	0.38	0.000014	5372.6
10/26/2024	0.39	0.000015	5357.3
10/27/2024	0.31	0.000012	5400.1
Minimum	0.31	0.000012	5357.3
Maximum	0.39	0.000015	5400.1
Average	0.36	0.000013	5376.7
Valid Records	3	3	3
Operating Time	3.00:00:00	3.00:00:00	3.00:00:00
Data Availability	100.00 %	100.00 %	100.00 %

Reporting Innovations

Permanent Total Enclosure Reports

40 CFR 63, Subpart O 63.364(g) specifies monitoring requirements for facilities subject to PTE requirements.

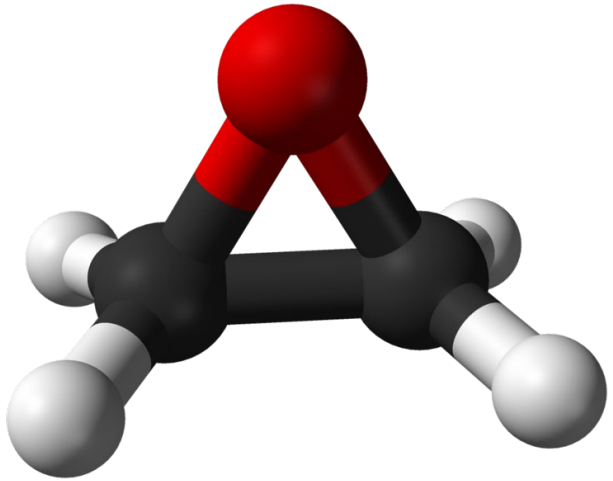
- Two primary options, each requiring data to be recorded and reported:
  - Continuous flow monitoring
  - Pressure differential monitoring
- Either option can be tied into CEMS or WMS systems
  - Data reduced to 3-hour rolling averages
  - Set up “exceedances” where data points outside of specified requirements are flagged
  - Reporting module integrates this data into a specific report that is easily generated and printed while generating other emissions reports
  - Data is easily trended with CEMS, WMS, and process operating events to better understand your facility

Reporting Innovations

Individual Exposure Reports

The highly anticipated Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) update is expected to set strict concentration limits for EtO emissions in a workplace setting.

- Multipoint workplace monitoring systems will provide facilities a means to meet this regulation
- What about companies that want to take a step further in protecting their workers from EtO exposure?
  - Location based tracking for employees that opt in
  - Log exposure based on time and duration in each area
  - Provide employees with a total exposure notification at the end of each shift
  - Generate alarms/thresholds to alert employees if they have heightened exposure



Process Optimization

Introduction

Technology is always advancing and so should your monitoring equipment.

- Regulations may be the driver behind emissions monitoring equipment, but that doesn't mean it can't also help your production
- Systems should be configured to assist a facility in understanding their process and saving money where they can

Process Optimization

Dry Bed Optimization

Dry bed media manufacturers have a recommendation for their lifetime, but what if you could make sure you're getting the most out of your investment?

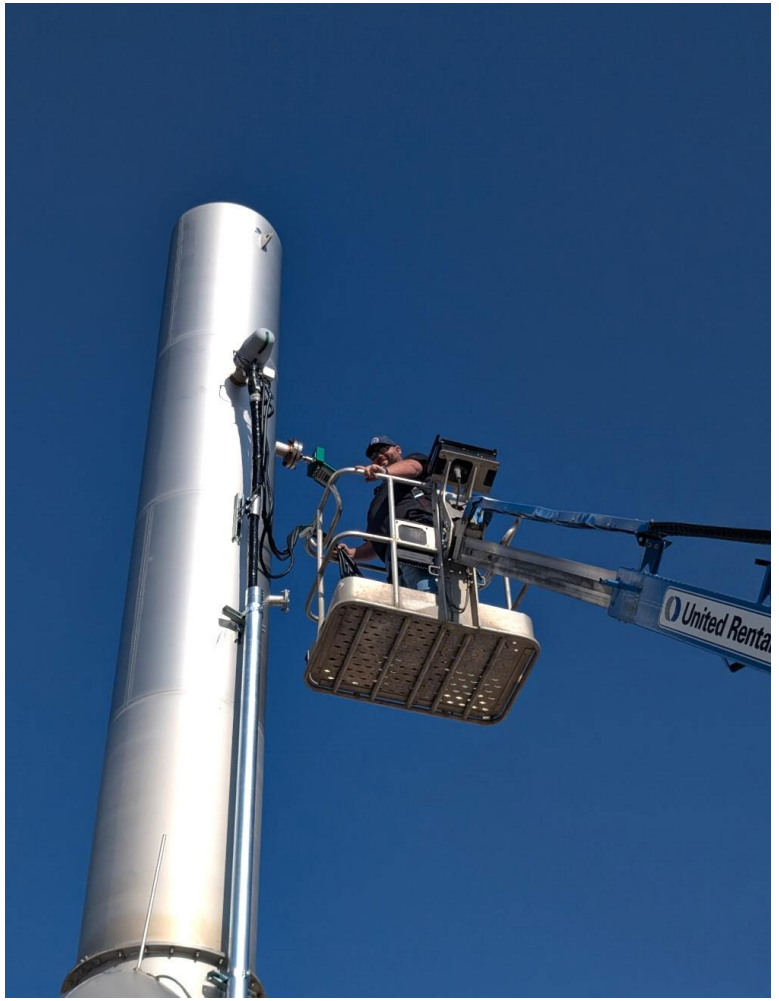
- By utilizing DRE tools within a multi-point system with additional monitoring points, facilities can monitor the overall health of their dry beds
- This can save facilities a significant volume of capital over the lifetime of those systems
- At regular time intervals, multi-point systems can be installed in outlets quickly and efficiently
  - Results in minutes
  - No fancy equipment needed, just tubing and a wrench

Process Optimization

Facility Abatement Optimization

Previous stack tests were just not as accurate as we'd like to think because the requirements then do not correlate with what the NESHAP requires today. Nor were the detection limits low enough.

- By utilizing new technologies polling in multiple process parameters and measuring emissions, facilities can make crucial choices on the designs of their facility
- It is entirely possible to "future-proof" your facility from any updated regulations
- It is common to see 20 - 40x lower emissions than what was previously understood, massively changing the design for a facility abatement
  - No longer need to "polish" EtO
  - Less dry beds needed for Group 1 and Group 2 emissions



Process Optimization

Process Liability Management

Large cities tend to have facilities with a competitor who also uses EtO right at their fenceline.

- By utilizing real-time monitoring and an anemometer, one can detect when an exceedance event came from a neighboring facility
  - Beneficial for legal matters
- Facilities can be alerted in real-time if their process is causing an exceedance and take corrective action quickly
  - Allows for understanding what caused the issue and how to mitigate the issue in the future

Configurable Systems

Introduction

Up until recently, emissions monitoring systems could only measure the pollutant/diluent they were designed to measure.

- This isn't always ideal for facilities – especially those working with chemicals who need to identify other species of interest
  - High interest in fenceline sector
  - Helpful for emissions inventories
- A configurable system can be easily changed to assist with major process changes or whenever a site/unit is being initially characterized
- Configurations can be made in the field with no need for a PhD to most optimally configure a system
  - Changes would be "locked" and only accessible via secured credentials

Configurable Systems

Overview

- **Built to leverage a library of 500+ compounds**
  - Greenhouse Gases/ Trace Gases/ Hazardous Air Pollutants/ Volatile Organic Compounds/ and others

- **Designed for continuous and automated deployments**
  - Turn-key setup, configuration, and use
  - Tracking of system operation and health metrics

- **Access to Local Analytical Toolkits**
  - Real-time data re-analysis and QA/QC
  - Automated interference detection, filtering, and correction
  - Integration of additional sensor data for advanced analytics

FIFRA and Future Needs

FIFRA Innovations

The expectation is shortly after the 2024 United States election, a final decision and ruling will be published under FIFRA.

- The expectation for FIFRA is that facilities will be required to monitor their workplace for EtO to ensure health risks are kept to a minimum
- Being as the rule has not yet been finalized, the EtO community is still unaware as to what facilities will need to do to meet this future requirement
- It is expected that facilities will have concentration-based limits for their workplace environment, requiring real-time monitoring technologies
  - The proposed rule had exposure limits as low as 10 ppbv, however, it is expected the final rule will be less strict with facilities having multiple years to meet the final exposure limit

FIFRA and Future Needs

FIFRA Innovations Cont.

Full Facility Coverage

Innovations have been made with manifold design, pump usage, technology, and system configuration to allow multi-point systems to measure an entire facility in 15 minutes or less – with 25+ locations being monitored in that window.

Data Quality Indicator (DQI)

Facilities use other chemicals on site that have historically caused interference issues when monitoring EtO. An intelligent DQI can alert a facility when a reading may not be accurate due to an unexpected chemical in the matrices and flag that data point.

Customizable Reporting

Be it a concentration limit, a time weighted average, etc. FIFRA is expected to require some form of intelligent reporting. This report function should be easily configured to record the selected data points and site wide averages for whatever limits/intervals are required.

Facility Integration

Facilities will need these systems to easily integrate into their network and any other form of alerting system that is used. This integration should be seamless and universal – allowing quick integrations for multiple deployments.

FIFRA and Future Needs

Future FIFRA Updates

Similarly to the NESHAP, it is possible that FIFRA will come out with requirements that were not in the draft/interim resources provided to facilities.

- Manufacturers should be developing robust and dependable systems capable of handling any requirement necessary:
  - Detection limit
  - Reporting requirements
  - Response time
  - Uptime
  - Notification
- Facilities will have suggestions to make life easier for them and those suggestions are a driving force behind innovation
- Trust in your vendor that you will always be supported for any future needs

FIFRA and Future Needs

Driving Future Innovations

The EtO community will play the largest part in monitoring innovations.

- The community is always adapting, and by communicating with one another, listening, and sharing information, future needs will be met quickly and effectively
- Regular meetings and touchpoints allow for vendors to quickly key in on where to make updates next
- An open dialogue within the community will allow for knowledge sharing that ultimately impacts everyone in a positive manner

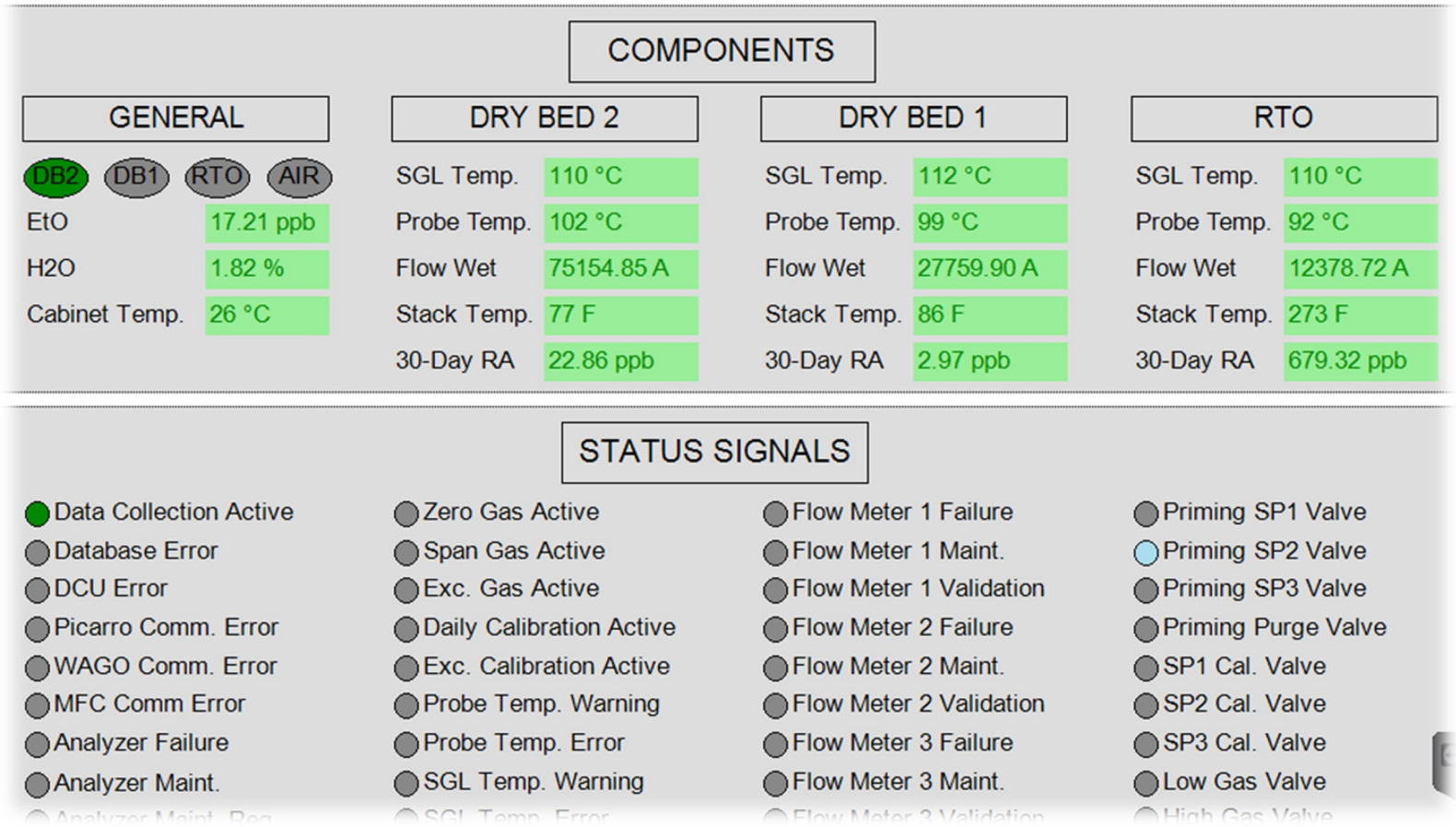
FIFRA and Future Needs

Community Impact

Facility + Abatement System Manufacturer + Monitoring System Vendor = Innovation

- When facilities discuss needs with abatement system manufacturers, better abatement systems are designed (i.e. more efficient, smaller/sleeker, cheaper)
- When abatement system manufacturers discuss with monitoring system vendors, new forms of system integration are created, allowing seamless installations
- When facilities discuss their needs with monitoring system vendors, software updates are created that allow for more streamlined work and peace of mind
- When all three of these groups work together, innovation occurs quickly

Open Discussion



Thank You!

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BREAK!

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Presentation 6

Determination of Optimal Parameters for Ethylene Oxide Destruction Using CARULITE® 500 catalyst

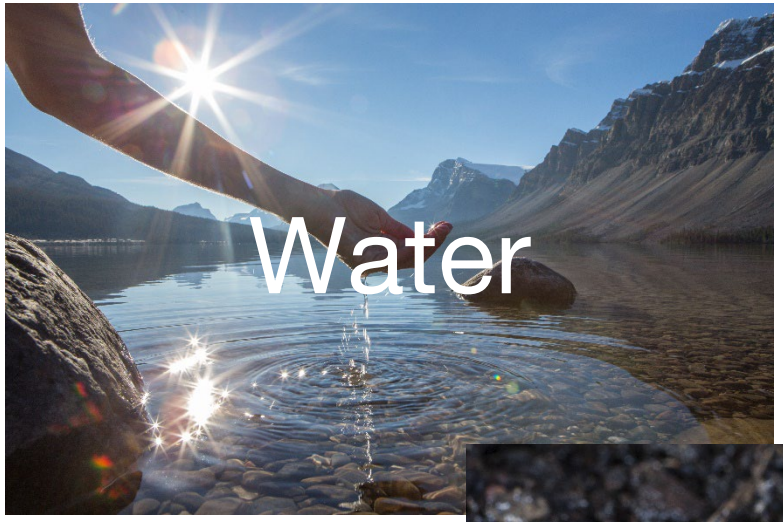
Joseph Sigmund
North American Sales Manager, Carus LLC

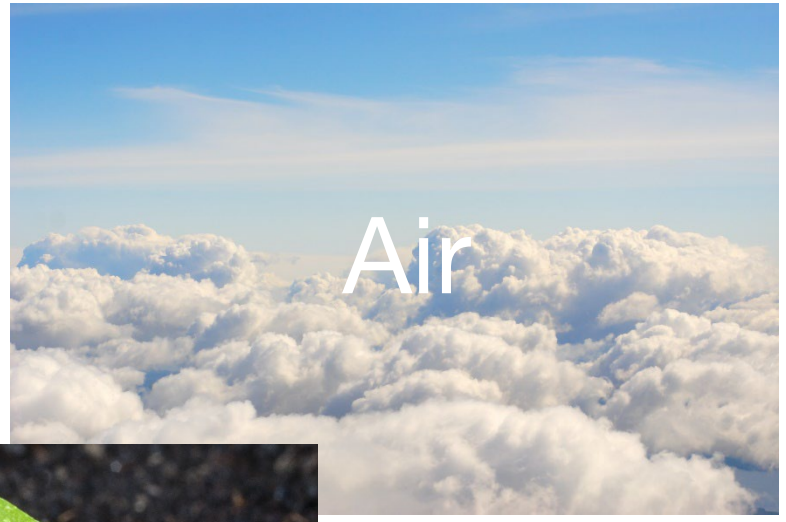
Data Disclaimer

The following presentation and data sets were generated solely and are owned by Carus LLC.

Any questions regarding the data sets and testing methodology should be directed to a Carus LLC representative.

What We Do





Key Locations

Corporate Headquarters

Peru, IL

European Headquarters

Oviedo, Spain

Manufacturing

LaSalle, IL

- Permanganates
- Manganese catalysts
- Phosphates

Belmont, NC

- Phosphates

Distribution

Global

Air Treatment

Product Applications

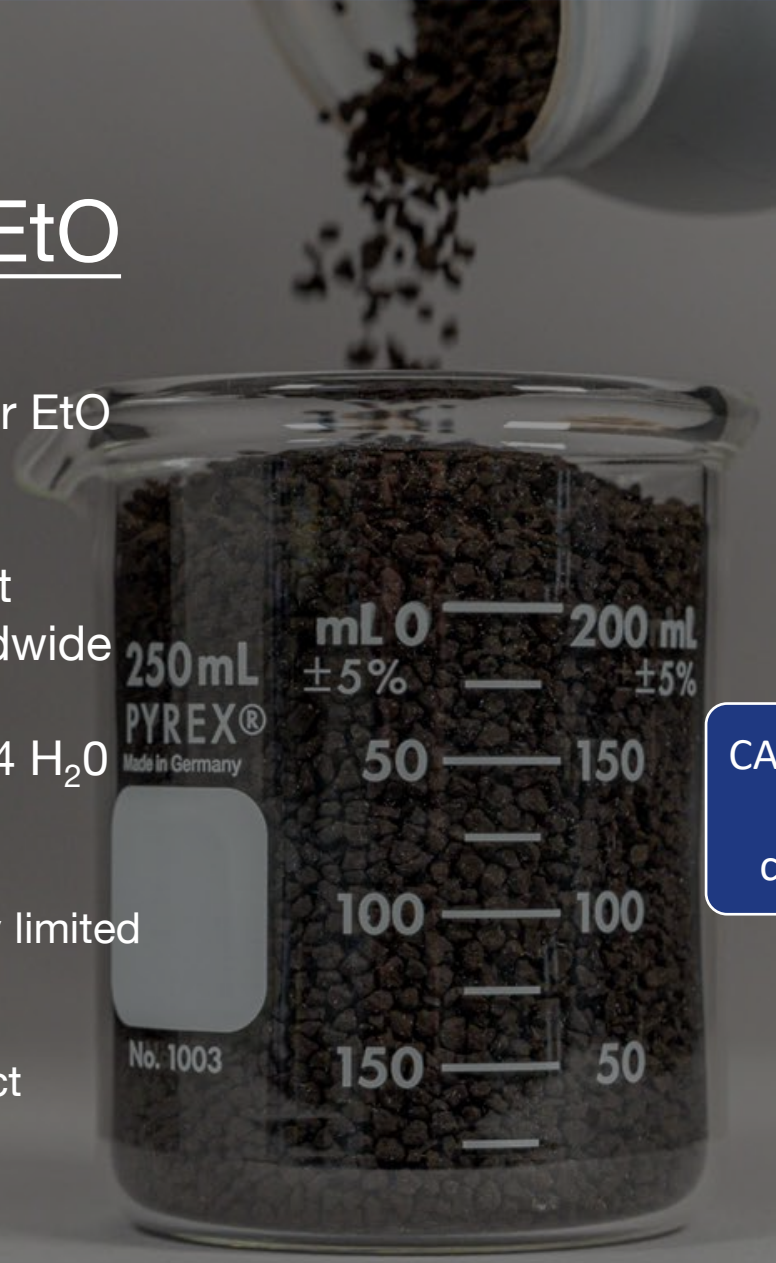
- CO Oxidation
- Ozone Destruction
- VOC Oxidation
- Ethylene Oxide Oxidation
- SCR / De-NOx

Brands

- CARULITE® 200 catalyst
- CARULITE® 300 catalyst
- CARULITE® 400 catalyst
- CARULITE® 500 catalyst

Carus History w/ EtO

- 30+ Years supplying catalyst for EtO destruction
- Used by leading EtO abatement equipment manufacturers worldwide
- $2\ C_2H_4O + 5\ O_2 \rightarrow 4\ CO_2 + 4\ H_20$
- Knowledge Gaps
  - Ultimate destruction efficiency limited by test equipment
  - How working parameters affect destruction efficiency
- Associate Member EOSA



Medical Sterilization Supply Chain

CARULITE® 500 catalyst → EtO Abatement Equipment → Medical Device Sterilizers

Carus & Picarro Testing Partnership

2024 EtO Test Program

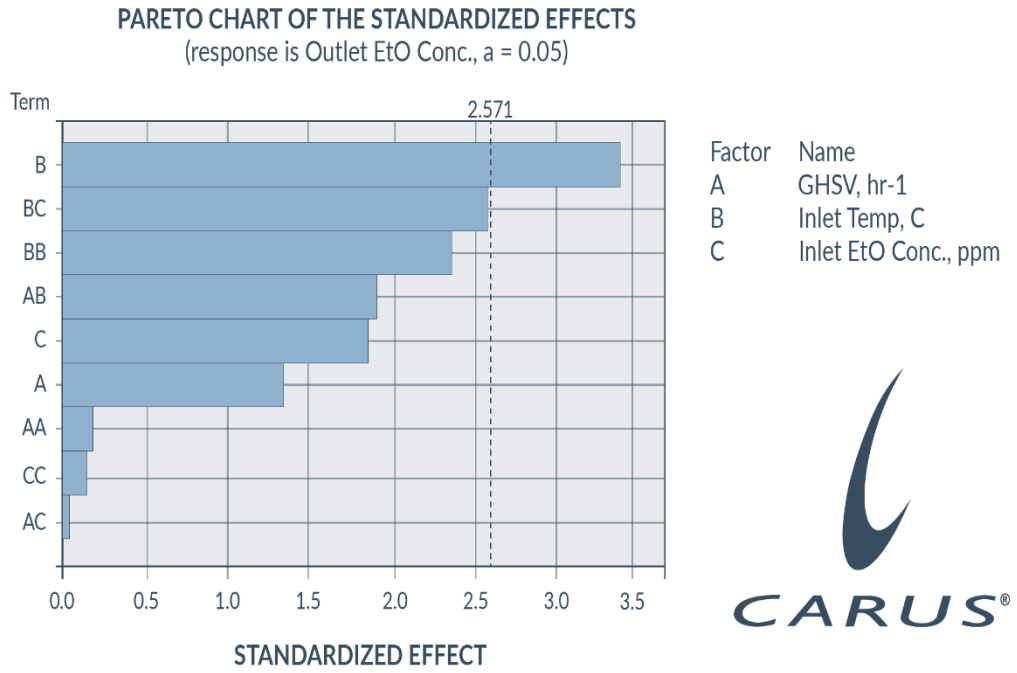
- A Box-Behnken design was used to create a response surface plot
- Three factors were tested at two levels:
  - Gas Hourly Space Velocity (GHSV) (8,000 hr-1 and 10,000 hr-1)
  - Inlet Temperature (120°C and 150°C)
  - Inlet EtO Concentration (50 and 3000 ppm)
- All tests conducted on new samples of CARULITE®500, 8x14 mesh catalyst
- EtO gas feed was 10% EtO in nitrogen, diluted to appropriate concentration using dry, compressed, heated air.
- Response measured after 8hr stabilization period
- Inlet concentrations measured using Thermo Environmental Instruments TVA-1000
- Outlet concentrations measured using Picarro G2920

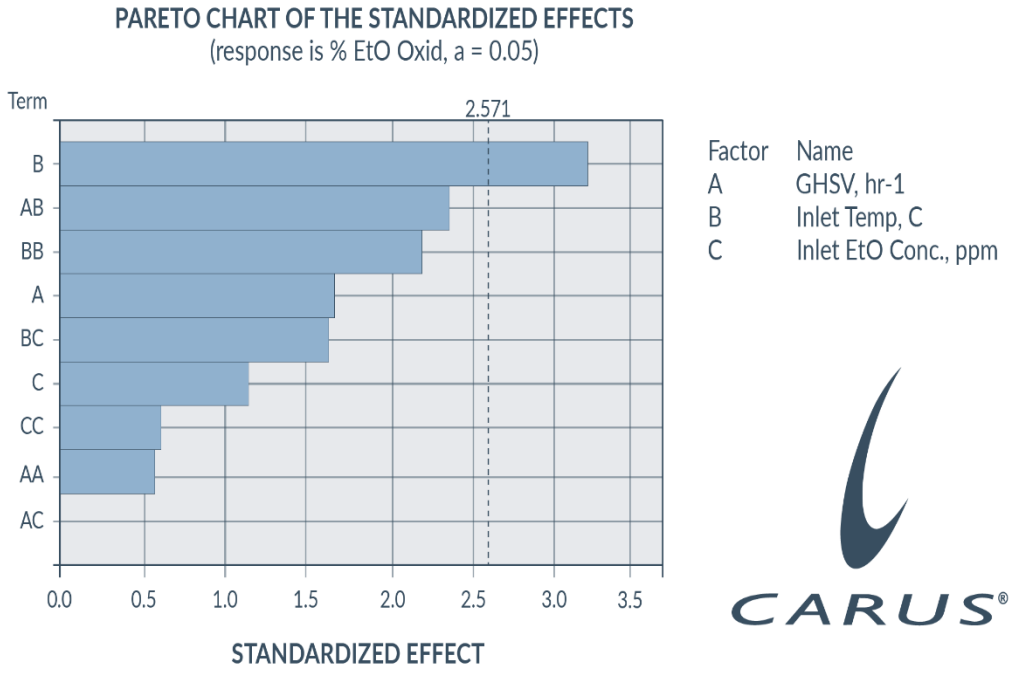
G2920 Cavity Ring Down Spectrometer (CRDS)

Complete Design With Responses

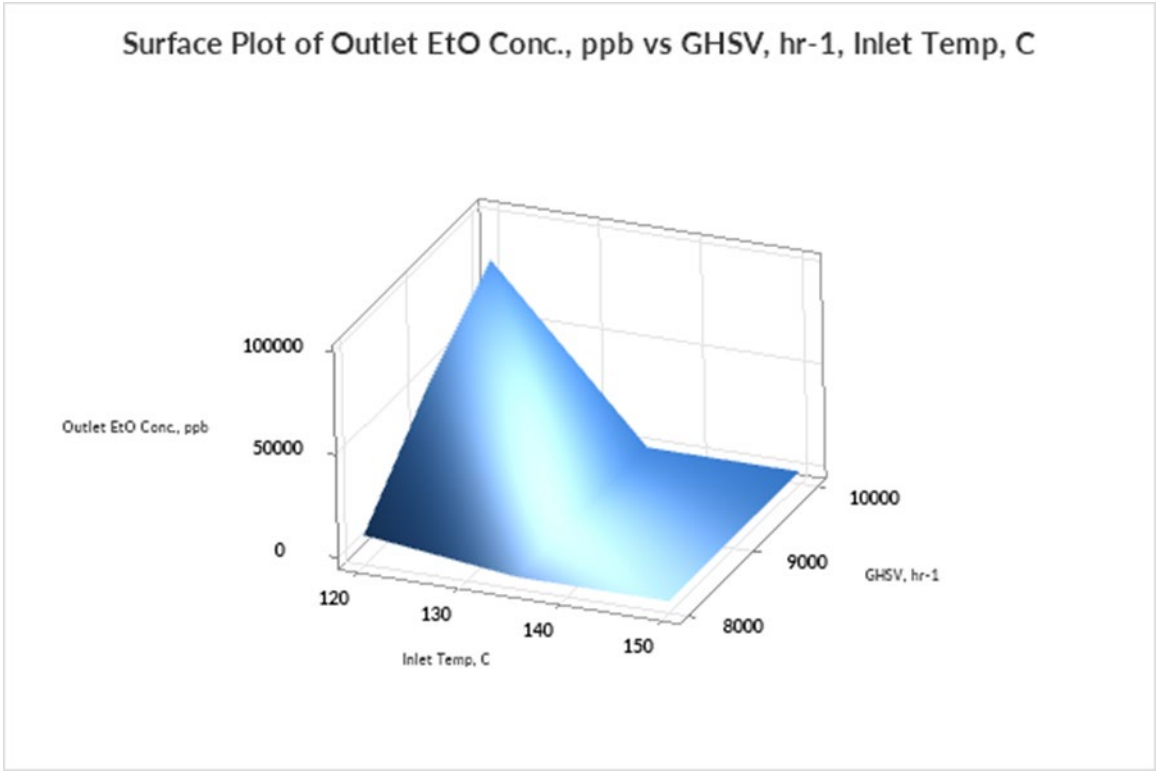
Inlet Temp, C	GHSV, hr-1	Inlet EtO Conc., ppm	EtO Outlet Conc., ppb	% EtO Oxidation
150	10000	1525	1.12	99.99993
150	9000	3000	0.83	99.99997
150	9000	50	1.68	99.99663
150	8000	1525	1.38	99.99991
135	10000	3000	1.00	99.99997
135	10000	50	1.48	99.99704
135	9000	1525	1.25	99.99992
135	9000	1525	1.54	99.99990
135	9000	1525	208	99.98637
135	8000	3000	1.22	99.99996
135	8000	50	1.37	99.99727
120	10000	1525	79500	94.78689
120	9000	50	1.33	99.99734
120	9000	3000	97987	96.73375
120	8000	1525	8567	99.43823

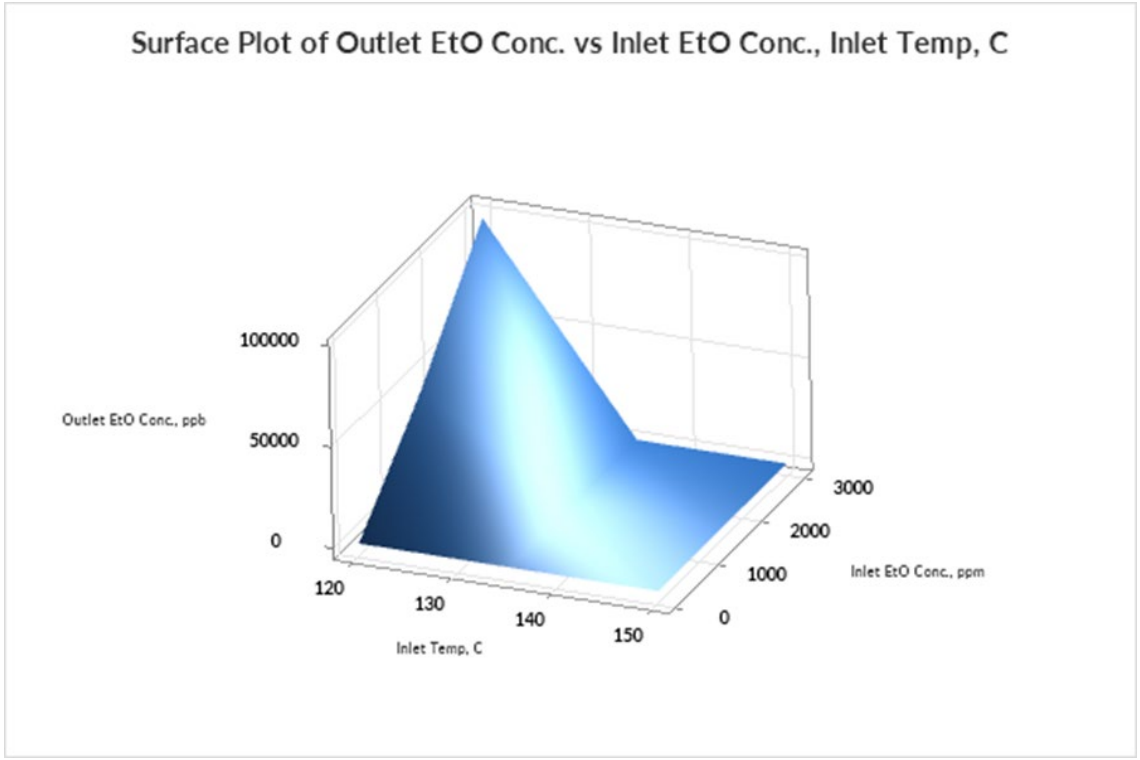
Data Summary





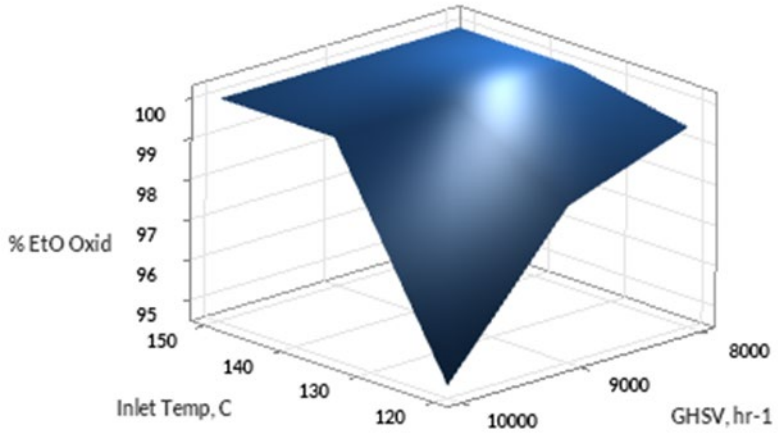
When using both outlet EtO concentration and % EtO Oxidation as the response, the variable of most significance is inlet temperature.

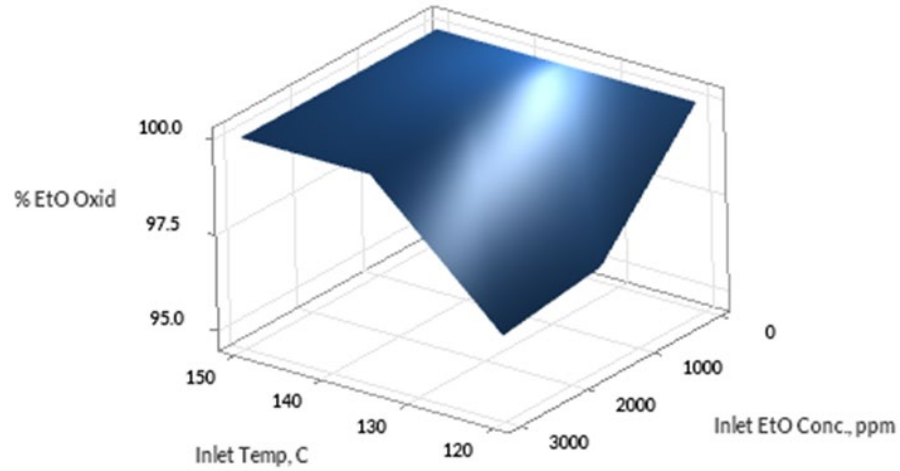




- This is the response surface using the outlet EtO concentration as a response while varying inlet temperature and GHSV.
- A great deal of curvature in the response surface seen at the approximately the mid-point temperature of 135°C.
- Excellent performance consistently found at the inlet temperature of 150°C regardless of GHSV.
- Carbon dioxide outlets at temperatures less than 150°C indicate that partial oxidation or adsorption of EtO may be occurring.

- This is the response surface using the outlet EtO concentration as a response while varying the inlet temperature and the inlet EtO concentration.
- It is interesting to see an almost identical shape between this and the previous slide. This confirms the strong dependency on the inlet temperature.





- This is the response surface using the % EtO oxidation as a function of GHSV and inlet temperature. Destruction Efficiency as a response curve while varying inlet temperature and GHSV
- This also shows the importance of the inlet temperature.

- This is the response surface using % EtO oxidation as a function of inlet EtO concentration and inlet temperature.
- Once again this shows the importance of the inlet temperature.

Conclusions

- Inlet temperature has the most profound impact on the performance of the CARULITE 500 catalyst to destroy EtO.
- Using an inlet temperature of 150°C, coupled with a GHSV ranging from 8,000-10,000 hr-1, will ensure 99.99% EtO destruction efficiency.
- Using a minimum 150°C inlet temperature will ensure complete oxidation of the EtO to carbon dioxide and water.

Future Planned Testing

- Evaluate lower inlet EtO concentrations from 1-50 ppm.
- Evaluate the treatment of EtO gas streams with oxygen levels as low as 10%.

Carus Future EtO R&D

Room Temperature Catalytic oxidation of EtO for fugitive emission capture

Stay tuned for more!!!

What challenges do you face with EtO destruction?

Carus wants to be your chemical technical solution partner!

Contact Us at: carulite@carusllc.com

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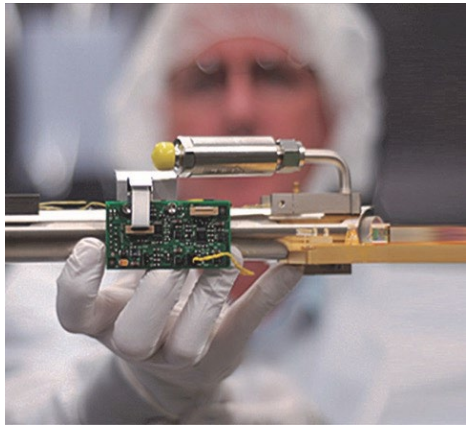
From Innovation to Impact:

Picarro's Journey in EtO Sterilization

Dave Miller
Vice President Marketing Strategy, Picarro

Our History Delivering Solutions

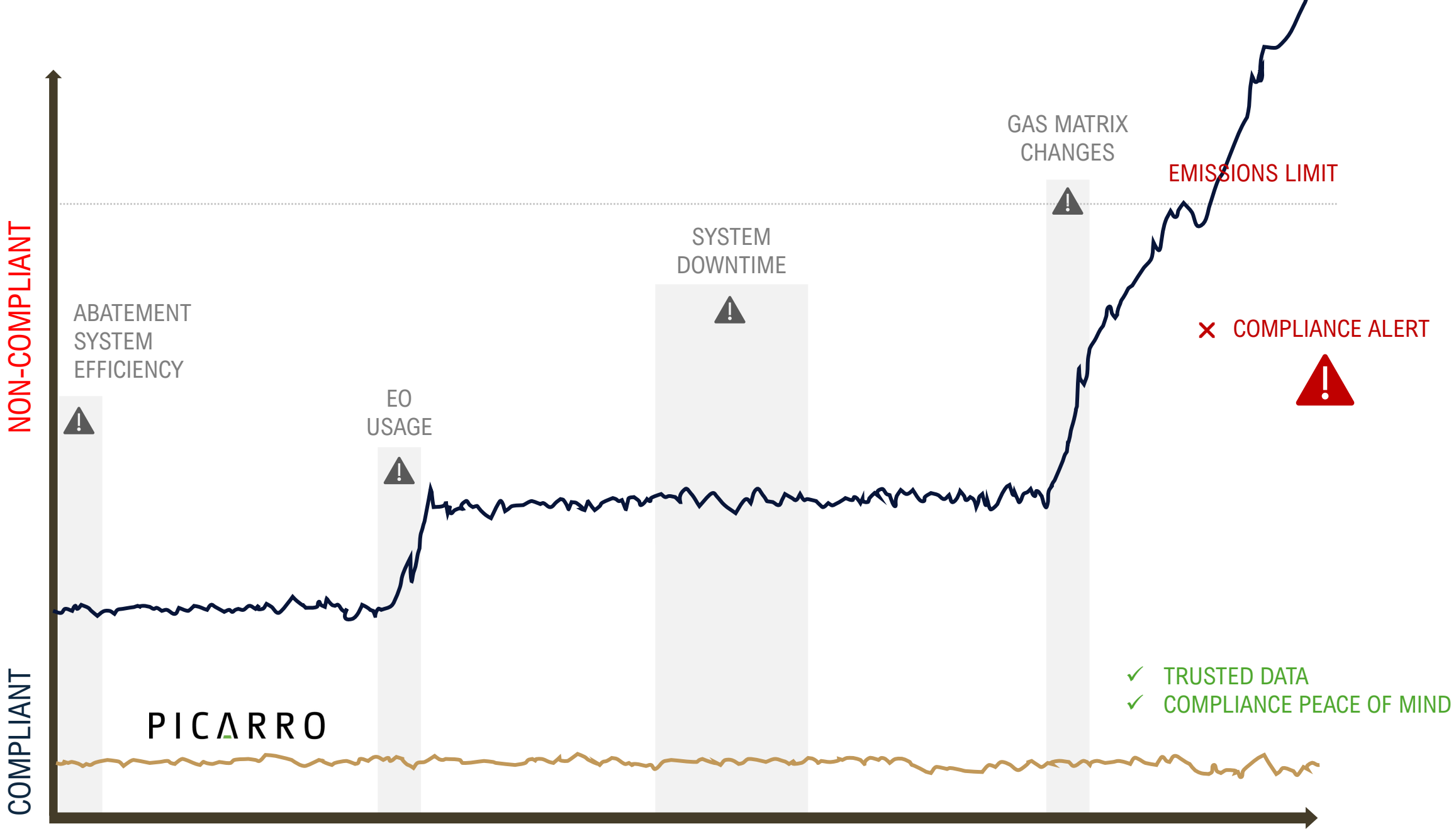
1990s — **Cavity-Ring-Down Spectroscopy Introduction**



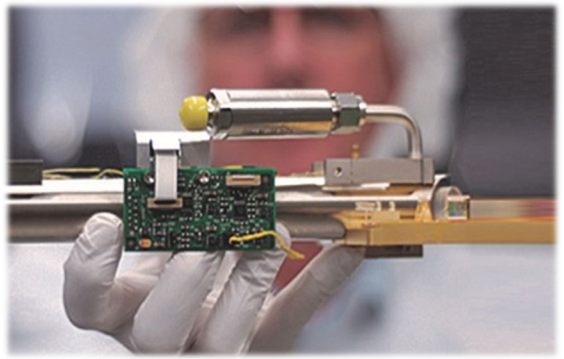
2000s — **Global Adoption & Commercialization**

2010s — **Natural Gas Utility Industry**

2020s — **Ethylene Oxide Sterilization**


NON-COMPLIANT
COMPLIANT
ABATEMENT SYSTEM EFFICIENCY
EO USAGE
SYSTEM DOWNTIME
GAS MATRIX CHANGES
EMISSIONS LIMIT
COMPLIANCE ALERT
PICARRO
TRUSTED DATA
COMPLIANCE PEACE OF MIND

End-to-End Solution



Technology

Compliance

through **trusted data**

Solutions

Thank you

86

Participants

28

Companies

7

Countries

Please join us for the 2nd EtO User Conference: October 21-23, 2025

Closing Panel

Picarro Environmental Solutions Team Leads

Dave Miller

Vice President

Gregor Lucic, PhD.

Sr. Product Manager

Jonathan Bent, PhD.

Sr. Program Manager-Workplace

Sean Cronin

Program Manager-CEMS

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Workshops

Workshop C: Hands-On Demos	**Chattahoochee C**
Workshop B: Measuring & Calc	**Chattahoochee A/B**
Workshop A: Reporting	**Chattahoochee A/B**


LUNCH!