ICAC

Measurement and Monitoring Technologies

ICAC Series on Data Centers
and Emissions Control

Considerations for Developers
and Equipment Suppliers

Who is ICAC?

Our members are clean technology innovators and provide clean air solutions

For over 60 years, our members have been providing air quality monitoring and control technologies to every industry:

- ✓ Industrial Heat
- ✓ Power Generation
- ✓ Oil and Gas
- ✓ Maritime and Port
- ✓ Cement
- ✓ Ceramics and Glass
- ✓ Metal
- ✓ Manufacturing
- ✓ **Data Centers**

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U.S. Growth in Data Center Development

Unprecedented demand

Cloud computing and AI workloads are fueling a historic data center construction boom across the U.S.

Massive investment ahead

Global data center capital expenditures could surpass **$1.7 trillion by 2030**, with over **40% in the United States** (McKinsey).

Soaring energy demand

The DOE projects U.S. data centers could consume **7–12% of national electricity by 2030**, up from just 4.4% in 2023.

Strategic implications

Data centers are becoming **critical energy infrastructure**, influencing grid planning, emissions policy, and local permitting nationwide.

Opportunity and challenge

The same digital expansion driving innovation also raises urgent questions about sustainability and energy resilience.

Environmental Considerations for Data Centers

Rising regulatory complexity

Developers face an expanding web of federal, state, and local requirements governing emissions, air quality, water use, and energy systems.

Integrated compliance challenge

Successful projects must align air, water, and energy strategies early in design to avoid permitting conflicts and costly redesigns.

Emissions control under pressure

Stricter emission limits demand advanced technologies, clean fuels, and operational constraints that affect cost and reliability.

Uncertain regulatory landscape

Ongoing rule changes and evolving GHG policies create planning and investment risk for new and expanding facilities.

Design-stage decision impact

Site layout, equipment selection, and power strategy all determine long-term environmental footprint and permit viability.

Sustainability as a differentiator

Projects that optimize energy efficiency and minimize emissions can gain community support, regulatory goodwill, and brand advantage.

Key Takeaways of Webinar #1

- Growth in data center power consumption and **the need to generate power onsite is creating major implications** related to air permitting and emission controls.
- Air quality permitting for data centers is **highly complex and varies** by federal, state, and local jurisdictions.
- **Early engagement** with regulators is essential to avoid surprises in the permitting process
- **Air permitting is not the only consideration at data centers.** Attention must be paid to water rights, noise, fuel storage, and public opposition, all of which can further delay projects.

Featuring:

BURNS McDONNELL

BISON ENGINEERING 45 Years 1980-2025

If you missed session 1, you can access it via the ICAC website

Key Takeaways of Webinar #2

- Emissions controls are now part of the core design of data center power solutions—not optional add-ons.
- Major emissions control technologies are **commercially proven and widely deployed.**
- Natural gas engines and gas turbines are gaining ground versus diesel due to cleaner emissions and operational advantages, but diesel remains essential for fast-start reliability, but requires more complex aftertreatment.
- Future advances should focus on efficiency and emerging pollutants, such as formaldehyde.
- Collaboration among developers, OEMs, regulators, and technology providers is essential for successful, compliant data center projects.

Featuring:

MITSUBISHI POWER

JM Johnson Matthey

If you missed session 2, you can access it via the ICAC website

Drivers for Emissions Measurement & Monitoring

Clean Air Act (CAA): The federal CAA, enforced by the Environmental Protection Agency (EPA), regulates emissions from large stationary sources. This is relevant to data centers with on-site power generation, which must meet certain emissions standards and obtain air permits.

State-level Mandates (e.g., California): California has enacted regulations that directly impact large data center operators.

- **SB 253 (Climate Corporate Data Accountability Act):** Requires large companies operating in California with annual revenues over $1 billion to publicly disclose their Scope 1, 2, and 3 greenhouse gas (GHG) emissions. This includes emissions from data center operations and their value chain.
- **Title 24 Energy Code:** Mandates specific energy efficiency measures for all new and expanded facilities, including data centers.

Local requirements for fenceline monitoring.

ESG reporting frameworks: In addition to government regulations, many data centers are driven by demand from investors and stakeholders for greater transparency, adhering to environmental, social, and governance (ESG) reporting frameworks.

Drivers for Emissions Measurement & Monitoring

State/Local Authority Air Quality Permit To Construct and/or Operate -
Minor Sources

Title V Operating Permit Program –
Sources over 100 tons/year potential to emit.

PSD/NSR Permitting for Major Sources
Over 250 (unlisted)/100 (listed) tons per year potential to emit

NNSR Permitting in non-attainment areas
Depends on area severity

New Source Performance Standards (NSPS) for new or modified sources of 40 CFR Part 60

National Emissions Standards for Hazardous Air Pollutants (NESHAPS) of 40 CFR Part 61-63

Title IV Acid Rain Program of 40 CFR Part 72-78

Emissions Measurement and Monitoring Technologies

Primary pollutants

- NOx
- CO
- HC/VOC
- PM
- NH_3 (ammonia slip)
- Greenhouse gases (CO_2, CH_4, N_2O)

Other Important Parameters

- O_2

Measurement and Monitoring Technologies

- **Predictive Emissions Monitoring Systems (PEMS)**
- **Continuous Emissions Monitoring Systems (CEMS)**
  - Multiple Single-Gas Analyzer CEMS
  - Multi-Gas Analyzer CEMS
- **Periodic Source Emissions Testing**
  - Multi-Gas FTIR

Typical Data Center Equipment and Emissions Potential

	NOx	SO_2	PM	CO	CO_2	VOC	PFAS
IT Halls (servers, PDUs, etc.)	-	-	-	-	-	-	-
On-site power generation (primary)	✓	✓	✓	✓	✓	✓	-
On-site backup power generation (e.g., diesel/natural gas generators)	✓	✓	✓	✓	✓	✓	-
Uninterruptible Power Supply (UPS) and Battery Energy Storage Systems	-	-	-	-	-	-	-
Cooling systems (e.g., chillers, towers, CRAH/CRAC)	-	-	✓	-	-	✓	✓

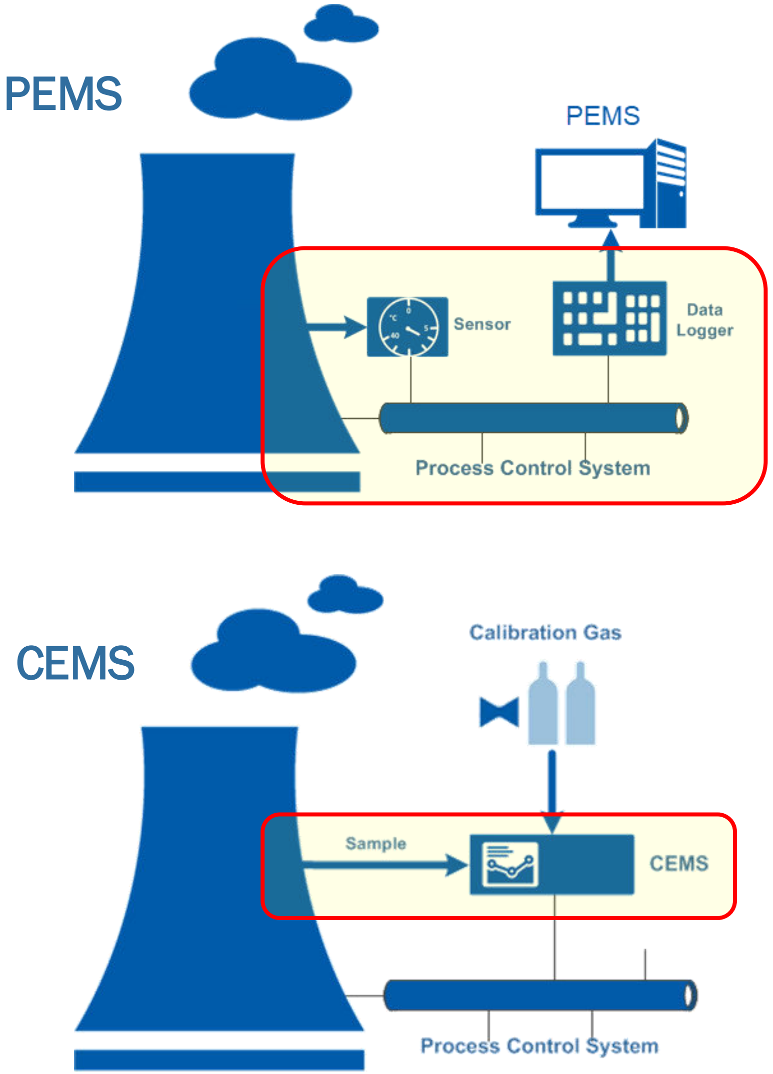
*Water and chemical treatment systems also have the potential to release biocides, corrosion inhibitors, heavy metals, and high dissolved solids

PEMS
Predictive Emissions Monitoring Systems

Predictive Emissions Monitoring System (PEMS)

Software-based system that delivers **real-time, compliant emissions data by modeling correlations in operational data,** predicting pollutant (NOx, SO_2, CO, and CO_2) emissions rather than measuring them with physical analyzer hardware:

- Process parameters
- Operating conditions
- Advanced mathematical models, including use of AI today



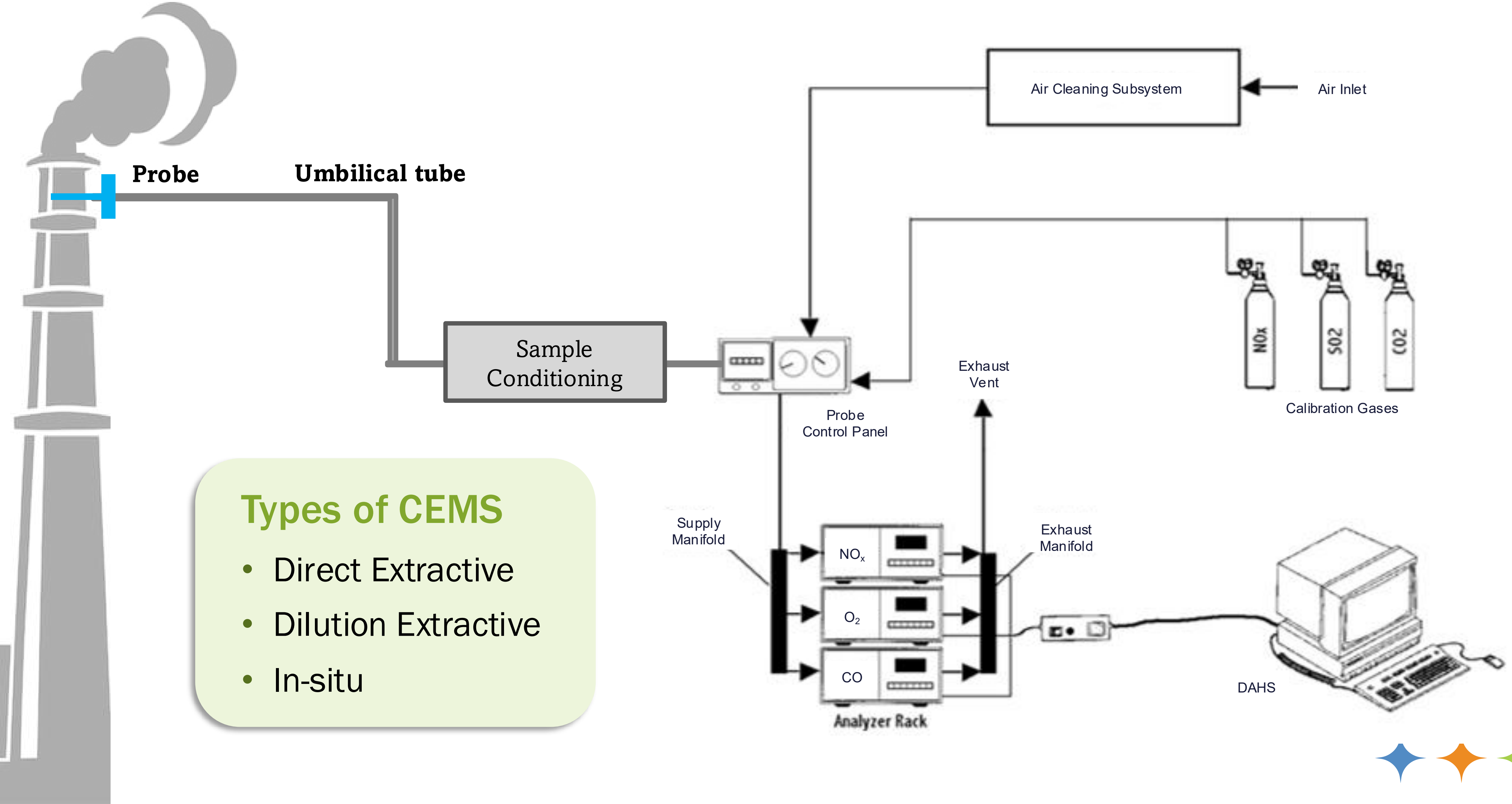
- PEMS **first approved by the U.S. EPA for use in 1993**, with continued development and wider adoption following in the early 2000s, officially finalized with **Performance Specification 16 (PS-16) in 2009.**
- **Best suited for combustion processes using consistent, cleaner-burning fuels**, notably natural gas, refinery gas, fuel oils, and light process gases.
- **Performance Specification 16** (PS-16) defines:
  - Model development
  - Validation & Accuracy
  - Quality Assurance
  - Ongoing Performance
- Sources subject to 40 CFR Part 75 and 40 CFR Part 60 regulations are **generally required to submit a petition or receive approval from the EPA to use** PEMS in lieu of or as an alternate to traditional CEMS.

Predictive Emissions Monitoring System (PEMS)

- Must **pass certification before use in the field** → RATA (Relative Accuracy Test Audit)
  - 27 measurement series of 21 min each, often conducted as 9 runs at each of three different operating levels (low, medium, high)
- Like Traditional CEMS, **Periodic Source Emissions Testing of a PEMS is required** to verify on-going accuracy and compliance to regulations
  - **RATA** must be repeated **annually**
  - **RAA (Relative Accuracy Audit)** are carried out **quarterly**
    - 3-run test (minimum) comparing the PEMS output **against a portable analyzer or reference method (RM)**
    - Frequency of RAA can be reduced if the PEMS demonstrates high performance in the first year.
    - If an RAA fails during the reduced frequency period, the requirement typically reverts to quarterly RAAs.
- **SVS (Sensor Validation Systems) are required** to be available to continuously evaluate the validity and accuracy of the process variables (input parameters) when using PEMS under 40 CFR Part 60 (specifically Performance Specification 16) and 40 CFR Part 75.
  - Statistical methods and algorithms are used to check if input sensors (e.g., fuel flow, temperatures, pressures) are within valid operating ranges.
  - If a sensor fails, the system uses mathematical models or redundant sensors to "reconstruct" (calculate) the missing data, allowing the PEMS to continue providing accurate, uninterrupted data.
  - In the event several sensors fail, the system is generally designated as being in a "failure" state, and the Data Acquisition and Handling System (DAHS) must manage this status according to applicable regulatory requirements.

CEMS
Continuous Emissions Monitoring Systems

Continuous Emissions Monitoring System (CEMS)



Types of CEMS

- Direct Extractive
- Dilution Extractive
- In-situ

Parameters Measured By CEMS

Parameter	Type	40 CFR Part 60 NSPS for Stationary Sources	40 CFR Part 75 Grid Connected EGU	Comments
NOx	Pollutant	Required	Required	Primary regulated pollutant for gas turbines
O_2	Diluent Gas	Required for direct extractive CEMS	Required for direct extractive CEMS	Diluent correction (ppm @ 15% O_2)
CO	Pollutant	Often required	Rarely	Often permit-required
CO_2	Reporting Parameter	Rarely	Required for dilution CEMS	GHG, State & heat input determination
SO_2	Pollutant	Rarely	Sometimes	Required depending on fuel

Common parameters measured for Gas Turbine

CEMS – Single-Gas Analyzer Design

Description

A traditional North American CEMS configuration using dedicated single-gas analyzers, each measuring one regulated pollutant (NO_x, CO, SO_2, O_2 etc.)

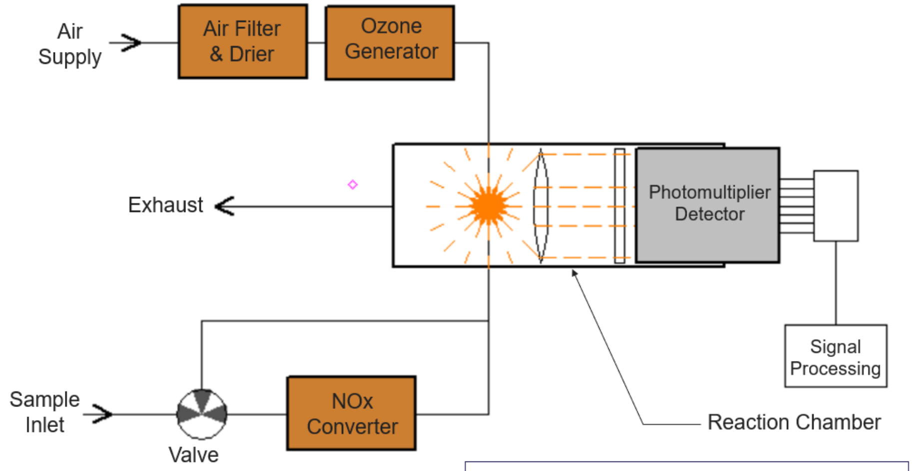
Commonly Used in:

- **Coal & Gas Power Plants**
- Refineries
- Cement Plants
- Waste Incineration
- Chemical Plants
- Pulp and Paper Mills

Single-Gas Analyzer Technologies

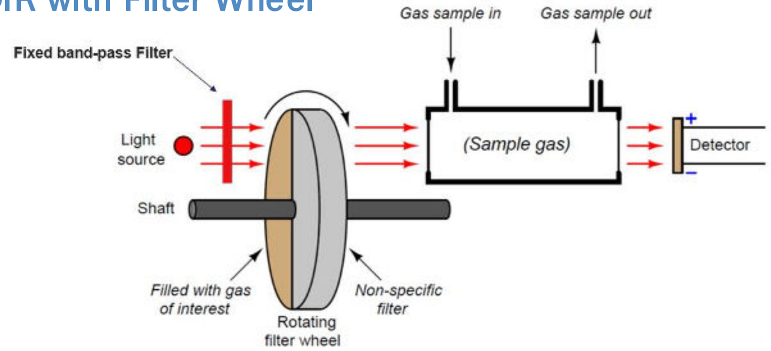
Pollutant	EPA Method	Typical Technology	Technology Description
NOx	EPA Method 7E	Chemiluminescence	• Total NOx measured by converting $NO_2 \rightarrow NO$ using thermal/catalytic converter • NO reacts with ozone (O_3) producing NO_2, O_2, and light • Light emission proportional to NO concentration
O_2	EPA Method 3A	Paramagnetic	• Oxygen is strongly paramagnetic • Magnetic field creates measurable force proportional to O_2 concentration • Creates a highly stable reading for extractive CEMS
CO	EPA Method 10	Non-Dispersive Infrared (NDIR) with Gas Filter Correlation	• Infrared source emits broadband IR radiation. • IR passes through rotating filter wheel delineating between reference and sample • CO absorb IR energy and a detector measures the reduction in IR intensity after passing through gas cell • The decrease in signal is proportional to CO concentration (Beer-Lambert Law).
CO_2	EPA Method 3A	Non-Dispersive Infrared (NDIR) with Optical Filter Correlation	• Similar to CO but for CO_2

Chemiluminescence



$$NO + O_3 \rightarrow NO_2 + O_2 + Light$$

NDIR with Filter Wheel



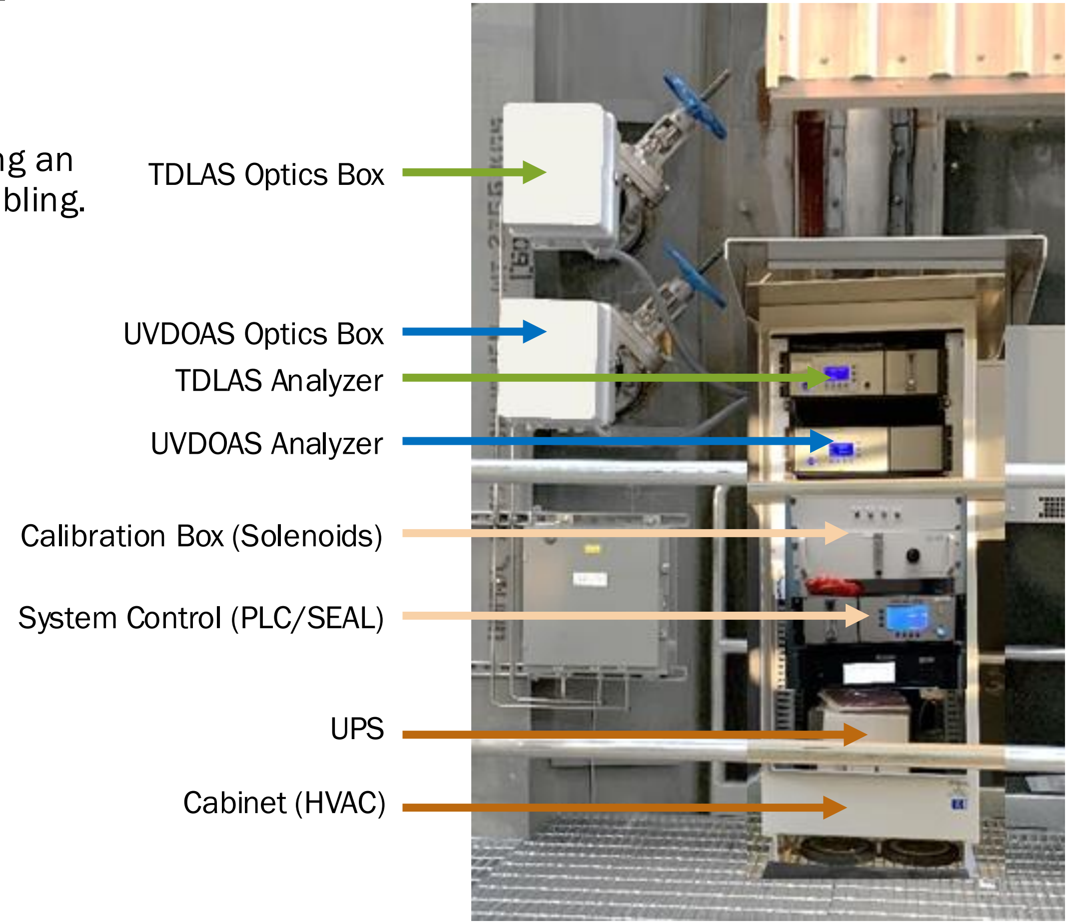
Multi-Gas Analyzer CEMS

Types of system architecture / design that challenge the cost and complexity of traditional CEMS and comply with regulatory requirements:

Integrated Path CEMS (IP-CEMS)

- Measures the gas concentrations across/within the stack (in-situ), bringing an electronic signal from the stack to the analyzer via fiber optic and coax cabling.
- Typically relies on **1 of 2 technologies, sometimes both** depending on the permitted gases measured and the sensitivities required.
- No sample transport or conditioning.
- Targets efficiency improvements.
- Calibration protocols **differ** from traditional CEMS techniques.

IP-CEMS



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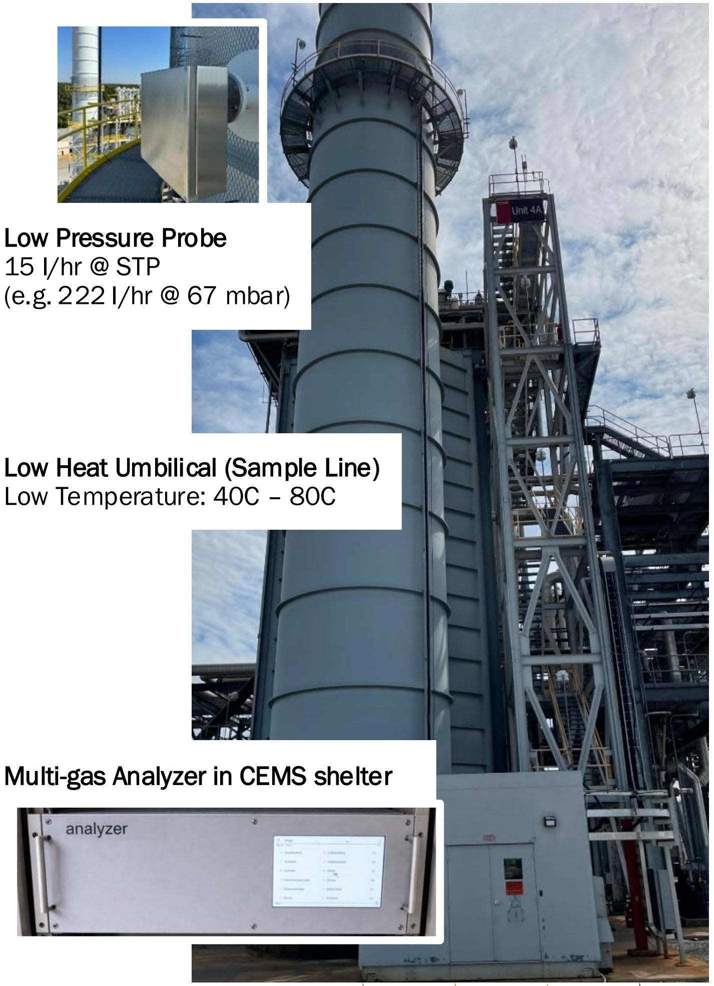
Laser CEMS

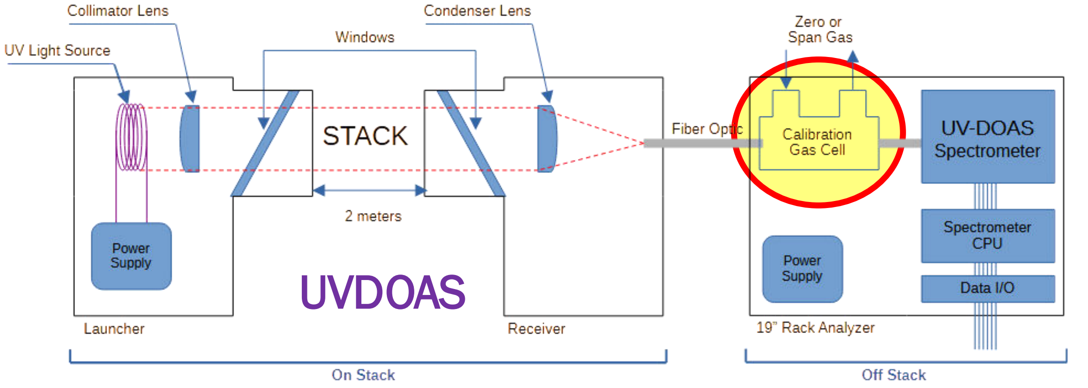
- Like traditional CEMS, this system uses an extractive probe to transport stack gas and calibration gas through an umbilical to the analyzer, where direct measurement of the sample occurs
- **One technology** to measure all regulated pollutants in one analyzer.
- No sample conditioning.
- Targets efficiency improvements.
- Calibration protocols are the **same as** traditional CEMS techniques.

Laser CEMS



Multi-Gas IP-CEMS for Part 60/75 applications

- **In-situ** measurement using one or two technologies to measure emission pollutants:
  - **UVDOAS** – single broadband light source measuring **NO, NO_2, SO_2** and other (NH3, HCHO, etc.)
  - **TDLAS** – multiple TDL narrow-band light source measuring **CO, CO_2, O_2, H_2O** and other (HCl, H_2S, etc.).
- IP-CEMS architecture requires use of **calibration gas cell** that is outside of the stack and inline with the optical path (i.e., light beam) to comply with regulatory requirements for daily Zero/Span gas calibration check.
  - **Performance Specification 2** (PS-2) under 40 CFR Part 60, Appendix B outlines requirements for optical path calibration for **NO_X and SO_2 CEMS.**
    - IP-CEMS **may** fall under these guidelines.
  - **Performance Specification 4** (PS-4) under 40 CFR Part 60 refers to same criteria listed in PS-2 for **CO CEMS**.
    - IP-CEMS **may** fall under these guidelines.
  - **Performance Specification 18** (PS-18) specially addresses optical path calibration in IP-CEMS for **HCl CEMS**.
    - Calibration check calculations differ significantly from those used for extractive traditional CEMS techniques. **Calculations and Data Analysis are outlined in PS-18 paragraph 12.0.**
  - Part 75 **may** not provide provisions for correcting pathlength differentials between the stack and calibration gas cell as found in PS-18, which can result in a "Critical Error" when the Electronic Data Report (EDR) is evaluated in the Emissions Collection and Monitoring Plan System (ECMPS)



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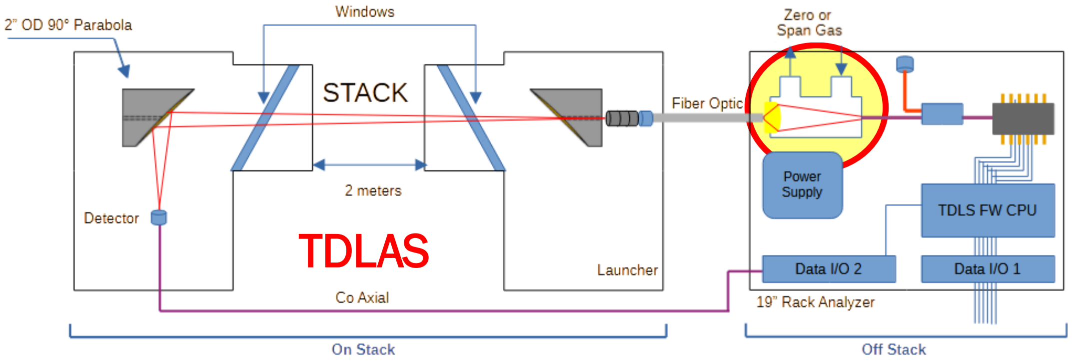
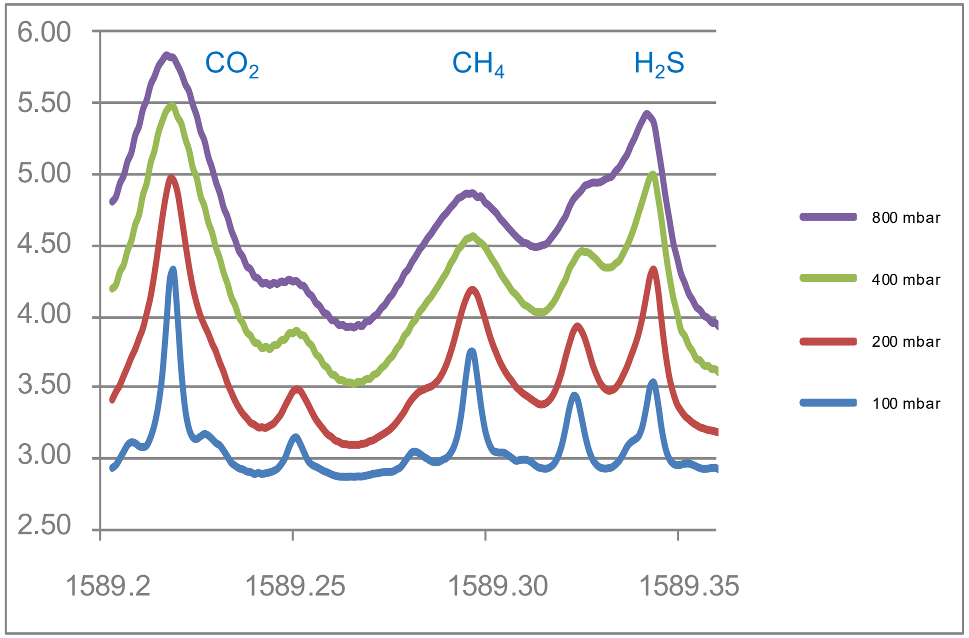


Verify with / Obtain approval from regulators that IP-CEMS can be used for your application!

Multi-Gas Laser CEMS for Part 60/75 applications

- **Direct** measurement using **one technology** to measure emission pollutants.
    - **High-resolution laser absorption spectroscopy** measuring **NO, NO_2, CO, CO_2, O_2, H_2O, SO_2** and other (NH_3, HCHO, H_2S, CH_4, etc.).
- **Same as traditional CEMS**, stack gas and calibration gas concentrations are **measured in the analyzer** (i.e., not in-situ).
    - Highly reflective mirrors in optical cell can acehive **10-50 km pathlengths** enabling ppt and ppb detection.
    - Limit of Detection (LOD) is **10 to 100 times greater** than traditional NDIR, FTIR and TDLAS technologies.
    - Built-in **auto-calibration and internal QA checks** ensure data accuracy.
- **Low-pressure transport of sample** (stack and calibration gases).
    - **Enhanced Accuracy**: Thinner spectral peaks significantly reduce cross-interference between gas species.
    - **Simplified Infrastructure**: Lowers dew point, eliminating the need for high-heat umbilical and sample conditioning.
    - **Faster Response Time**: Higher gas velocity results in faster sample transport and measurement.
    - **Reduced Maintenance**: Minimizes calibration requirements and chemical adsorption/desorption on umbilical tubing walls.
    - **Lower Operating Costs**: Very low sample consumption (e.g., 15 L/h @ STP) reduces calibration gas consumption by 80–90%.



Low pressure sampling from 800 mbar abs to 100 mbar abs

Complies with Part 60/75 regulations and QAQC requirements.

Periodic Source Emissions Testing

What is Periodic Source Emissions Testing?

Periodic Source Emissions Testing

(also called stack testing or performance testing) is the scheduled measurement of air pollutant emissions **directly at the exhaust stack** using EPA reference test methods.

- Uses portable testing equipment
- Is conducted by 3rd party certified stack testing firms
- Measures pollutant concentrations under defined operating conditions
- Demonstrates compliance with federal, state and permit emission limits

Regulatory Drivers for Stack Testing

- 40 CFR Part 60
- 40 CFR Part 75
- State permits
- Title V operating permits

Measurement Technologies for Stack Testing

- Single Analyzers
  - Method 7E (NOx), 10 (CO), 6C (SO_2)
- FTIR Multi-gas Analyzer
  - Method 320

Why is Periodic Emissions Testing Performed?

Operational & Optimization Benefits

- Identify combustion tuning opportunities
- Confirm low-NOx burner performance
- Evaluate catalyst effectiveness (if SCR installed)

Initial Compliance Demonstration

- Hand off from turbine manufacturer
- Performance guarantees from turbine manufacturer
- Permit & BACT Requirements

Ongoing Compliance Verification (No CEMS)

- Verification of compliance and permit limits
- Confirmation of combustion tuning

CEMS Validation & Quality

- RATA (Relative Accuracy Test Audit) required annually (Part 75)

Key Takeaways for Success

1. Plan for air permitting early
2. Integrate emissions control and monitoring into plant design
3. Deploy the right monitoring strategy (CEMS, PEMS, stack testing)
4. Use proven measurement technologies to ensure compliance and transparency
5. Collaboration across developers, regulators, integrators, and technology providers enables faster, cleaner project deployment
6. Clean air technologies can accelerate project approvals and community acceptance while enabling reliable power for next-generation data centers
7. Obtain approval from regulators early in the air permitting process that technologies, like IP-CEMS or PEMS, can be used for your application
8. Successful projects plan beyond installation – ensuring long-term compliance via maintenance, calibration, data quality management, and periodic testing

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Q & A

Please submit questions via the ‘Q&A’ feature on Zoom

The Institute of Clean Air Companies

Market Insight

Engagement with Decision-Makers

Technical Expertise

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Thank you

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All our webinars are available on the ICAC website

- Webinar 1:
  Permitting
- Webinar 2:
  Control Technologies
- Webinar 3:
  Measurement and Monitoring Technologies

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Thank you

Additional Information

Helpful Resources

- **Performance Specifications (Installation/Certification):** 40 CFR Part 60 Appendix B – Contains PS-1 through PS-18 for certifying monitoring systems.
- **Quality Assurance Procedures (Ongoing Operation):** 40 CFR Part 60 Appendix F – Contains Procedures 1-6 for QA/QC requirements.
- **U.S. EPA Part 75 Emissions Monitoring Technical Q&A document**
  - https://www.epa.gov/power-sector/part-75-emissions-monitoring-technical-questions-and-answers
  - Question 1.3 Optical In-situ Monitoring (**updated October 23, 2025, for IP-CEMS**)
  - Question 1.4 PEMS

Today’s Presenters

Daniel Mullen

Sr. Mgr. Product Management, Environmental Monitoring

Thermo Fisher Scientific is committed to enabling our customers to create a healthier, cleaner, and safer future through our innovative technologies. We provide advanced gas analysis solutions that support emissions monitoring for compliance reporting industries such as power generation. Our high-performance gas analyzers, integrated into CEMS, deliver precise, real-time data to help operators meet regulatory requirements, maintain uptime, and optimize operational efficiency. By supporting accurate and reliable emissions tracking, we help data centers and power generation companies balance environmental responsibility with the growing demand for digital infrastructure. Learn more at www.thermofisher.com/DataCentersEmissions

Ralph Henderer

President/Managing Director, DURAG INC

Driven by *technologies for a clean and safe environment*, DURAG GROUP delivers advanced gas analysis, emissions monitoring, combustion, predictive emissions monitoring systems, and data acquisition handling systems (DAHS) solutions for industrial and environmental applications. Supporting OEMs, system integrators, and end users, its technologies provide the real-time accuracy needed to ensure compliance, optimize operations, and maintain reliable performance. www.durag.com

Today's Presenters

Clare Schulzki
Executive Director

Since before the Clean Air Act was enacted, **ICAC, the Institute of Clean Air Companies**, member companies have represented providers of a diverse array of air pollution control technologies, measuring and monitoring systems, and equipment and services in the U.S. and abroad. ICAC provides a needed voice for the technologies that achieve practical and measurable emissions reductions for stationary sources. ICAC website

Ted Michaels
Partner

For over 20 years, innovative start-ups, Fortune 500 enterprises, and environmental stakeholders have maximized their business goals by leveraging **AJW's** unique coast-to-coast, international, and bipartisan expertise in how markets and governments work. **AJW** works closely with clients to develop sophisticated business strategies and advocate for policies and regulations that support innovators in both domestic and international markets. AJW website