# Flue Gas Desulfurization CEMS Design Lessons Learned and Monitoring Technologies to Meet the New Mercury and Air Toxics (MATS) Rule

Cemtek Environmental,
Interactive CEMS Workshop

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# Flue Gas Desulfurization CEMS Design Lessons Learned

## *Presentation Overview & Agenda*

- ***General CEMS Design Considerations***
  - ***Wet & Dry Scrubber CEMS Design***
- ***CEMS FGD Scrubber Design Experience & Lessons Learned***
  - ***Examples of over a dozen installed & certified FGD CEMS systems***
  - ***Lessons learned from projects***
- ***Mercury and Air Toxics (MATS) Additional Monitoring Requirements***
  - ***Mercury***
  - ***Particulate***
  - ***Acid Gases (HCl)***

# Flue Gas Desulfurization CEMS Design Lessons Learned

## *Presentation Overview & Agenda*

- ***General CEMS Design Considerations***
  - ***Wet & Dry Scrubber CEMS Design***

# Coal Fired Boiler FGD Scrubber General CEMS Design

*Wet & Dry FGD CEMS Application*

- ***CEMS Design Considerations***
  - **Probe Design and Accessories**
    - **Corrosion resistant materials for probe tube construction to prevent attack from acid gases (Hastelloy, Inconel, etc.)**
    - **Heated probe tube in wet stack (saturated) conditions to help prevent corrosion**
    - **Impingement shield on probe inlet to prevent clogging from wet particulate**
    - **Demisters to knock down entrained water in sample prior to entering dilution orifice**
    - **Probe accessibility for maintenance and service**
    - **Stack clearances for probe installation and removal**
    - **Temperature effects on the density of the flue gas minimized by the use of a heated orifice**

# Coal Fired Boiler FGD Scrubber General CEMS Design

*Wet & Dry FGD CEMS Application*

- ***CEMS Design Considerations***
  - **Sample Umbilical Design**
    - **Sample line routing and access. Keep in mind access for stack testers and maintenance personnel.**

*Test Port*

- **Heated umbilical for low dilution ratios (higher moisture concentrations)**
- **Heated umbilical for low CO measurement applications in conjunction with stainless steel tubing**

# Coal Fired Boiler FGD Scrubber General CEMS Design

*Wet & Dry FGD CEMS Application*

- ***CEMS Design Considerations***
  - **Dilution Air Cleanup Design**
    - **Plant air cleanup panel to condition air to instrument grade may be required**
    - **Redundant dilution air cleanup for added system availability**
    - **CO and trace gas scrubbers for removal of measured gases**

*CO2 Adsorbers & Trace Gas Scrubbers*


*CO Scrubbers*

# Flue Gas Desulfurization CEMS Design Lessons Learned

## *Presentation Overview & Agenda*

- ***CEMS FGD Scrubber Design Experience & Lessons Learned***
  - ***Examples of over a dozen installed & certified FGD CEMS systems***
  - ***Lessons learned from projects***

# Coal Fired Boiler
# Nebraska Power Plant

## *Dry FGD CEMS Application*

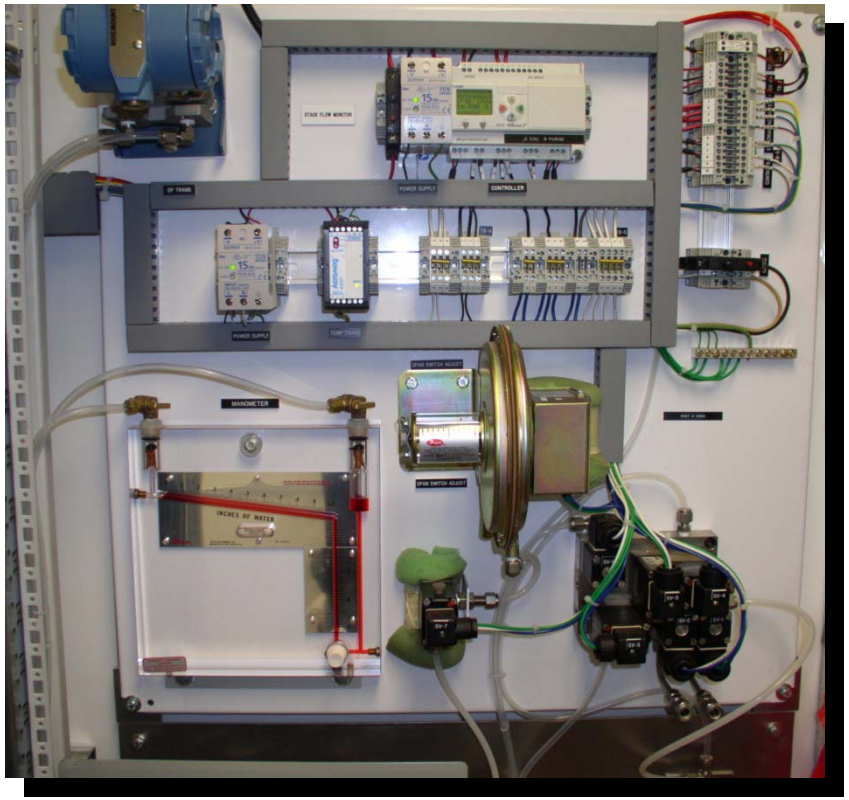
- ***Application Summary***
  - **Unit 2 retrofit with DFGD scrubber technology**
  - **Unit 2: 682 MW**

  - ***CEMS Configuration***
  - **Dilution Extractive CEMS (25:1 dilution ratio)**
  - **Out-of-stack dilution probe**
  - **Redundant dilution air cleanup panel**
  - **FGD Inlet CEMS measuring $SO_2$ & $CO_2$**
  - **Stack CEMS measuring $NO_X$, $SO_2$, CO & $CO_2$**
  - **Stack measurement of moisture and $O_2$ for process control using in-situ monitors**
  - **Stack pitot tube flow monitor**
  - **Stack opacity monitor**
  - **Stack continuous mercury monitoring system added to CEMS shelter a year after CEMS startup**

# Coal Fired Boiler
# Nebraska Power Plant

*Dry FGD CEMS Application*

- ***Lessons Learned***
  - **In-situ $O_2$ monitor integrated into probe head experienced premature failure.**
  - **Pressure compensation after startup required a software change.**



# Coal Fired Boiler
# Kentucky Power Plant

## *Wet FGD CEMS Application*

- ***Application Summary***
  - **Unit 1 & 4 retrofit with WFGD scrubber technology**
  - **Unit 1: 550 MW**
  - **Unit 4: 560 MW**

  - ***CEMS Configuration***
  - **Dilution Extractive CEMS (100:1 dilution ratio)**
  - **In-stack dilution probe**
  - **Air compressor utilized as primary source of dilution air**
  - **Redundant dilution air cleanup panel**
  - **FGD Inlet CEMS measuring $SO_2$ & $CO_2$**
  - **Stack CEMS measuring $NO_X$, $SO_2$ & $CO_2$**
  - **Stack ultrasonic flow monitor**
  - **Stack particulate CEMS using forward scattering light technology**

# Coal Fired Boiler
# Kentucky Power Plant

*Wet FGD CEMS Application*

- ***Lessons Learned***
  - **Lightning protection modules essential to protecting critical equipment.**
  - **Blown permeation tube in the stack $SO_2$ analyzer lead to extremely slow, low level response times during system startup.**

# Coal Fired Boiler
# Kentucky Power Plant

## *Wet & Dry FGD CEMS Application*

- ***Application Summary***
  - **Unit 1, 2, 3 & 4 retrofit with WFGD & DFGD scrubber technology**
    - **Unit 1: 300 MW**
    - **Unit 2: 510 MW**
    - **Unit 3: 268 MW**
    - **Unit 4: 268 MW**
  - ***CEMS Configuration***
  - **Dilution Extractive CEMS (100:1 dilution ratio)**
  - **Out-of-stack dilution probe**
  - **Dilution air cleanup panel**
  - **Heated stack sample umbilical**
  - **FGD Inlet CEMS measuring $SO_2$ & $CO_2$ for Units 1 & 2**
  - **Stack CEMS measuring $NO_X$, $SO_2$ & $CO_2$ for Units 1 & 2**
  - **Stack CEMS measuring $NO_X$, $SO_2$ CO & $CO_2$ for Unit 4**
  - **Stack ultrasonic flow monitors for Units 1, 2 & 4**
  - **Stack opacity monitor for Unit 4**
  - **Sorbent trap mercury monitoring systems for Units 1, 2, 3 & 4**
  - **Continuous mercury monitoring system for Unit 2**

# Coal Fired Boiler
# Kentucky Power Plant

*Wet FGD CEMS Application*

- ***Lessons Learned***
  - **Site personnel prefer the sorbent trap mercury system to the continuous mercury monitoring system due to maintenance time and cost.**
  - **Secure umbilical support while hanging the sample line is critical.**


# Coal Fired Boiler
# West Virginia Power Plant

## *Wet FGD CEMS Application*

- ***Application Summary***
  - **Unit 1, 2 & 3 in-field CEMS rebuild on WFGD application**
  - **Unit 1: 713 MW**
  - **Unit 2: 710 MW**
  - **Unit 3: 711 MW**

  - ***CEMS Configuration***
  - **Dilution Extractive CEMS (100:1 dilution ratio)**
  - **Out-of-stack dilution probe**
  - **Redundant dilution air cleanup panel**
  - **Stack CEMS measuring $NO_X$, $SO_2$ & $CO_2$**
  - **Stack ultrasonic flow monitor**
  - **In-field rebuild utilizing existing CEMS shelter**
  - **Integrated with existing CEMS data logger and DAHS**

# Coal Fired Boiler
# West Virginia Power Plant

*Wet FGD CEMS Application*

- ***Lessons Learned***
  - **Close communication essential from project planning stage for an in-field rebuild to ensure that the placement pieces will mate with existing infrastructure.**
  - **Complete data for flow monitor manufacturer review important to identify correct transducer for the application.**

*Before*

*After*

# Coal Fired Boiler
# Illinois Power Plant

## *Wet FGD CEMS Application*

- ***Application Summary***
  - **Unit 1 & 2 retrofit with WFGD scrubber technology**
  - **Unit 1: 360 MW**
  - **Unit 2: 590 MW**

  - ***CEMS Configuration***
  - **Dilution Extractive CEMS (125:1 dilution ratio)**
  - **Out-of-stack dilution probe**
  - **Dilution air cleanup panel**
  - **Heated stack sample umbilical**
  - **FGD Inlet CEMS measuring $SO_2$ & $CO_2$**
  - **Stack CEMS measuring $NO_X$, $SO_2$ & $CO_2$**
  - **Stack ultrasonic flow monitor**
  - **Inlet opacity monitor**

# Coal Fired Boiler
# Illinois Power Plant

*Wet FGD CEMS Application*

- ***Lessons Learned***
  - **$NO_X$ analyzer linearity issues from using a span range significantly smaller than analyzer full scale range.**
  - **Dilution ratio of 125:1 can be cumbersome in doing quick calculations.**

# Coal Fired Boiler
# New Hampshire Power Plant

## *Wet FGD CEMS Application*

- ***Application Summary***
  - **Unit 1 & 2 retrofit with WFGD scrubber technology**
  - **Unit 1: 113 MW**
  - **Unit 2: 320 MW**
  - **Common stack for Unit 1 & 2**

  - ***CEMS Configuration***
  - **Dilution Extractive CEMS (100:1 dilution ratio)**
  - **Out-of-stack dilution probe**
  - **Redundant dilution air cleanup panel**
  - **Heated stack sample umbilical**
  - **FGD Inlet CEMS measuring $NO_X$, $SO_2$ & $CO_2$ on each inlet duct**
  - **Stack CEMS measuring $NO_X$, $SO_2$ & $CO_2$ on common stack**
  - **Inlet duct pitot tube flow monitors**
  - **Stack ultrasonic flow monitor**
  - **Inlet duct opacity monitors**

# Coal Fired Boiler
# New Hampshire Power Plant

*Wet FGD CEMS Application*

- ***Lessons Learned***
  - **CEMS startup scheduled for Spring 2012**
  - **State environmental agency required revisions to monitoring plan. Important to submit early for inclusion of revisions.**

# Coal Fired Boiler
# Arizona Power Plant

## *Wet FGD CEMS Application*

- ***Application Summary***
  - **Unit 1 & 2 retrofit with WFGD scrubber technology**
  - **Unit 1: 389 MW**
  - **Unit 2: 384 MW**

  - ***CEMS Configuration***
  - **Dilution Extractive CEMS (50:1 dilution ratio)**
  - **Out-of-stack dilution probe**
  - **Redundant dilution air cleanup panel**
  - **FGD Inlet CEMS measuring $SO_2$ & $CO_2$**
  - **Stack CEMS measuring $NO_X$, $SO_2$, CO & $CO_2$**
  - **Stack multi-point pitot tube flow monitor**
  - **Stack opacity monitor**
  - **Stack particulate CEMS using forward scattering light technology**
  - **Integration of existing sorbent trap mercury monitoring system**

# Coal Fired Boiler
# Arizona Power Plant

*Wet FGD CEMS Application*

- ***Lessons Learned***
  - **Two-part shelter used to fit through access door for installation in base of stack.**
  - **Site provided particulate monitor required an adapter flange to mate with new stack ports.**

# Coal Fired Boiler
# Kentucky Power Plant

## *Wet FGD & SCR CEMS Application*

- ***Application Summary***
  - **Unit 2 retrofit with WFGD scrubber technology & SCR $NO_X$ control**
  - **Unit 2: 225 MW**

  - ***CEMS Configuration***
  - **Dilution Extractive CEMS (100:1 dilution ratio)**
  - **Out-of-stack dilution probe**
  - **Dilution air cleanup panel**
  - **Heated stack sample umbilical**
  - **FGD Inlet CEMS measuring $SO_2$ & $CO_2$**
  - **SCR Inlet CEMS measuring $NO_X$ & $CO_2$**
  - **ID Fan Outlet CEMS measuring $NO_X$, $SO_2$ & $CO_2$**
  - **ID Fan Outlet ultrasonic flow monitor**
  - **ID Fan Outlet particulate CEMS using forward scattering light tech**
  - **3 point TDL monitor used for measuring SCR ammonia slip**

# Coal Fired Boiler
# Kentucky Power Plant

*Wet FGD & SCR CEMS Application*

- ***Lessons Learned***
  - **No issues encountered during system manufacturing, startup, and certification.**
  - **Result of multiple projects between Cemtek, the project EPC contractor, and the plant Owner.**


# New Regulations Monitoring Requirements

## *Presentation Overview & Agenda*

- ***Mercury and Air Toxics (MATS) Additional Monitoring Requirements***
  - ***Mercury***
  - ***Particulate***
  - ***Acid Gases (HCl)***

# Mercury Monitoring Technologies and Detection Principles

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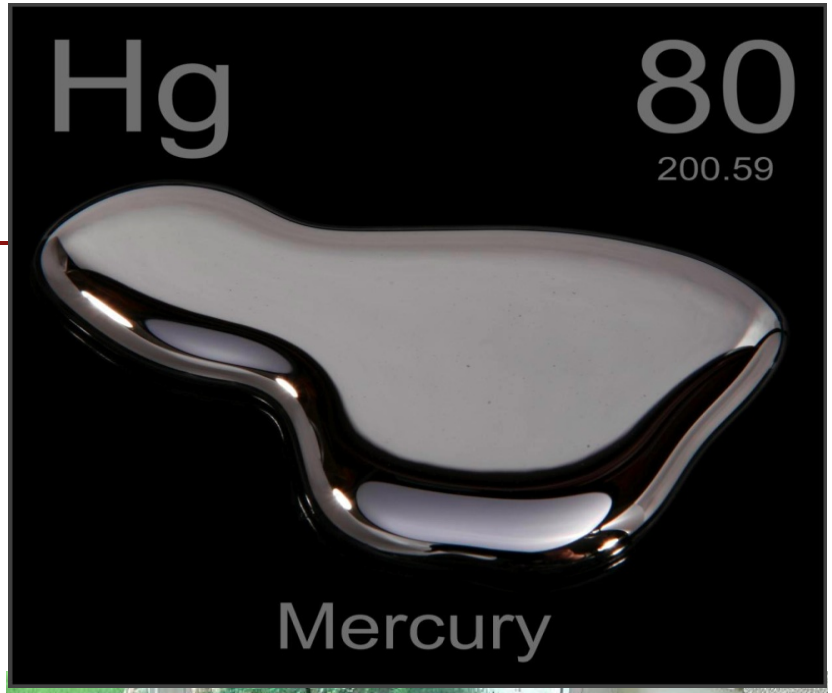


Mercury Fountain by Alexander Calder
Joan Miro Museum in Barcelona, Spain
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# Mercury Monitoring Technologies & Detection Principles

***Regulations, where do we stand?***

- **Since vacating the Clean Air Mercury Rule (CAMR), the implementation of mercury monitoring has primarily fallen on the state and local regulators.**
- **The EPA often uses Consent Decrees to mandate mercury monitoring.**
- **Cement MACT requires plants to monitor mercury emissions in kiln exhaust.**
- **More industry monitoring on the horizon.**
  - **Mercury and Air Toxics (MATS) Rule**

# Mercury Monitoring Technologies & Detection Principles

- Detection Technologies
  - Continuous Monitoring

    Cold Vapor Atomic Fluorescence

    Example: Thermo Freedom Mercury Series
  - Continuous Batch Measurement

    Pre-Concentration on Gold Filter, Thermal Desorbtion, Atomic Fluorescence

    Example: Tekran Series 3300
  - Long Term Batch Measurement

    Sorbent Trap or Appendix K

    Example: Apex Instruments

# Mercury Monitoring Technologies & Detection Principles

- Dilution based measurement
- Inertial Filter Sample Conditioning
- Conversion at the Stack
- Direct Measurement CVAF
- High sensitivity
- True real-time monitoring
- Modular design
- *i*Series platform

# Mercury Monitoring Technologies & Detection Principles


Model 3330 Inertial Probe


Model 3320 Sample Conditioner


Model 2537A AF Analyzer


Model 3310 Calibration Unit

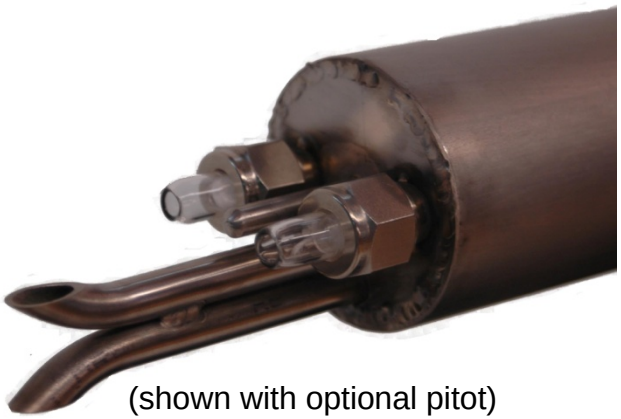
# Mercury Monitoring Technologies & Detection Principles

## Principles of Operation

- Mercury in sample gas is pre-concentrated onto (pat'd) pure gold cartridge
- Adsorbed mercury is thermally desorbed
- Detected by atomic fluorescence detector
- Two cartridges are used to alternately sample and desorb allowing continuous operation
  - No gaps in data stream

# Mercury Monitoring Technologies & Detection Principles

## HGP Dual Trap Sampling Probe



(shown with optional pitot)

Configuration:

- Heated Sample Probe –Dual Probe Heaters
  - Length (4,6,9,12ft Standard)
  - Material –C276 Hastelloy or 316 SS
  - Enclosure – Insulated SS Junction Box
  - Trap Sizes – 10mm Large Standard
  - Optional 6mm Small Trap Adapter
    - Paired trap holders
  - Pitot Tube – Optional S Type Pitot

# Mercury Monitoring Technologies & Detection Principles

## Sorbent Trap

Configuration:

- Section 1: Sample Collection Section
- Section 2: Breakthrough Indicator Section
- Section 3: Vapor-Spike Section to Measure Recovery

# Method Comparison

| Detection Method | Advantages | Disadvantages |
|---|---|---|
| **Continuous Monitoring** | ▪ True real time feedback for process control. | ▪ Large upfront investment costs<br>▪ Maintenance intensive system<br>▪ NIST traceable calibration gases/sources issue<br>▪ Consumable chlorine gas for mercuric chloride generator |
| **Continuous Batch Measurement** | ▪ Lower detection levels possible due to time integration of sample. | ▪ Large upfront investment costs<br>▪ Maintenance intensive system<br>▪ NIST traceable calibration gases/sources issue |
| **Long Term Batch Measurement** | ▪ Lesser initial investment for system startup. | ▪ Labor intensive process requiring post installation maintenance and analysis costs<br>▪ Must climb stack on daily/weekly basis for sample collection<br>▪ Glass trap breakage - loss of data<br>▪ Sample breakthrough - loss of data<br>▪ Chain of custody sample issues |

# Particulate Matter Monitoring Technologies and Detection Principles

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# PM CEMS

## *Why are PM CEMS Important?*

- **Opacity correlates poorly to PM emissions**
  - **PM CEMs can address the shortfalls of continuous opacity monitors (COMs)**
  - **With the onset of continuously decreasing limits of $SO_2$ and the concern of $SO_3$ from SCR installations, wet scrubbers have proven to be a highly efficient means of reducing $SO_2$, $SO_3$ and fine particulates; however a wet gas effluent is a result. This result is in the form of wet particulate and water droplets.**
  - **The Mercury and Air Toxic Standards (MATS) sets new standards for PM as a surrogate for non-Mercury metals.**

## *Where are PM CEMS Being Installed?*

- **Proposed Boiler MACT applications (Industrial and Utility)**
- **Scrubbed stack PM monitoring**
- **New coal-fired power plant permits**
- **EPA consent decrees**

# PM CEMS

*40CFR60 Appendix B Performance Specification 11*

- **The purpose of PS-11 is to establish the initial installation and performance procedures required for the evaluating the acceptability of a PM CEMS.**
- **PS-11 applies to any PM CEMS that is required by Title 40 of the Code of Federal Regulations (CFR) to install and operate a PM CEMS.**
- **PS-11 requires a site to perform initial installation and calibration procedures that confirm the acceptability of the PM CEMS.**
- **A site specific correlation of the PM CEMS must be developed to establish response against manual gravimetric reference method measurements including Method 5 and 5I and Method 17.**

*PS-11 provides:*

- **Guidelines for selecting a PM CEMS**
- **Installation location guidance**
- **Procedures for certifying a PM CEM**
- **Minimum performance limits**
- **Example calculations**

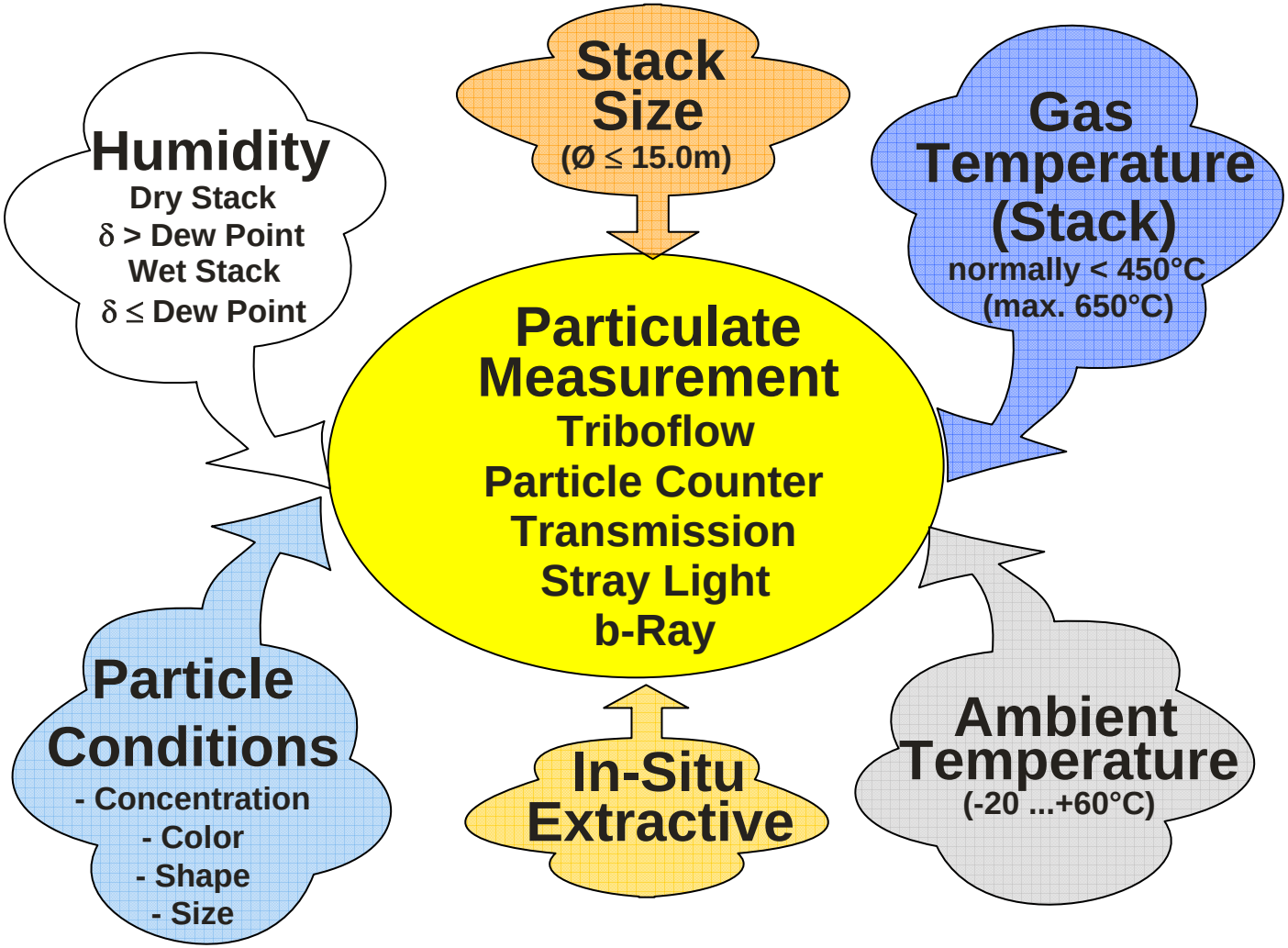
# PM CEMS

***Principal Technologies used***

- **Light Scattering**
  - **Can measure very low dust levels.**
  - **Some practical problems.**
- **Beta Attenuation**
- **Uses continuous paper tape filter.**
- **Dust particles adhering to the filter absorb beta-particles emitted by radioactive source. This absorption gives a measure of dust density.**
- **Probe Electrification (Triboelectric)**
  - **Sensitive**
  - **High accuracy**
  - **Requires compensation for flow, temperature, etc.**

# PM CEMS

*Design Considerations and Selection Parameters*



# Tunable Diode Laser Spectroscopy Detection Principles For Monitoring $NH_3$, HCl & HF

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# $NH_3$ & HCl Monitoring

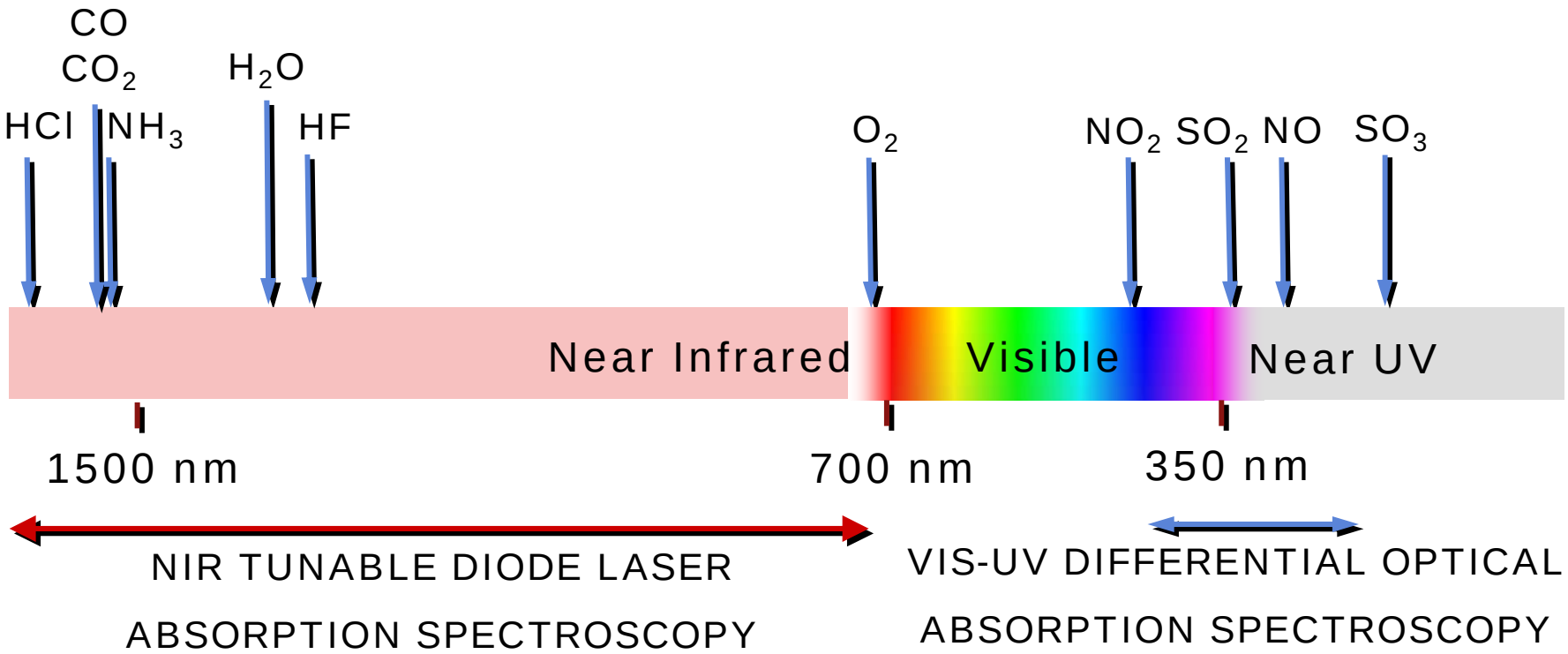
*Purpose for monitoring Ammonia ($NH_3$) Slip*

- **Regulatory emissions limits for both $NO_X$ and $NH_3$ slip**
- **Overall process efficiency**
- **Corrosion and maintenance of equipment (air preheater, etc.)**
- **Economic Considerations:**
  - **$NO_X$ emission trading credit maximization**
  - **Contamination of fly ash**
  - **Cost of consumable ammonia/urea**

*Purpose for monitoring HCl*

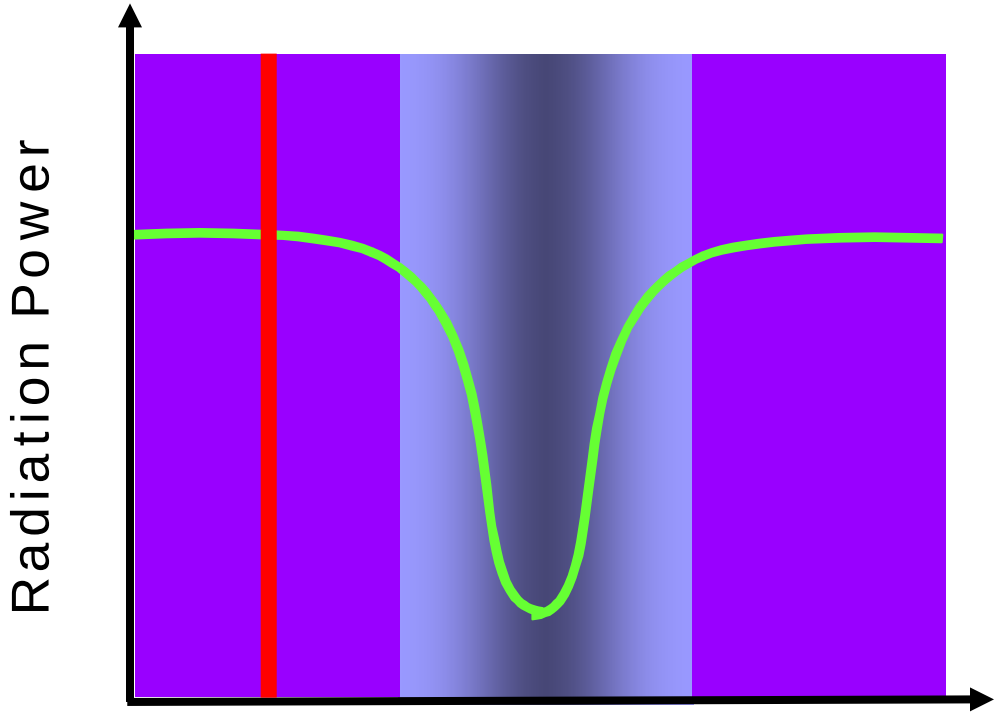
- **Regulatory emissions limits becoming more common requirements in air permits**
- **New rules call for continuous monitoring (MATS, Cement MACT)**

# Tunable Diode Laser Measurement Technique



# Tunable Diode Laser Measurement Technique

*In the Region of Wavelength Absorption*

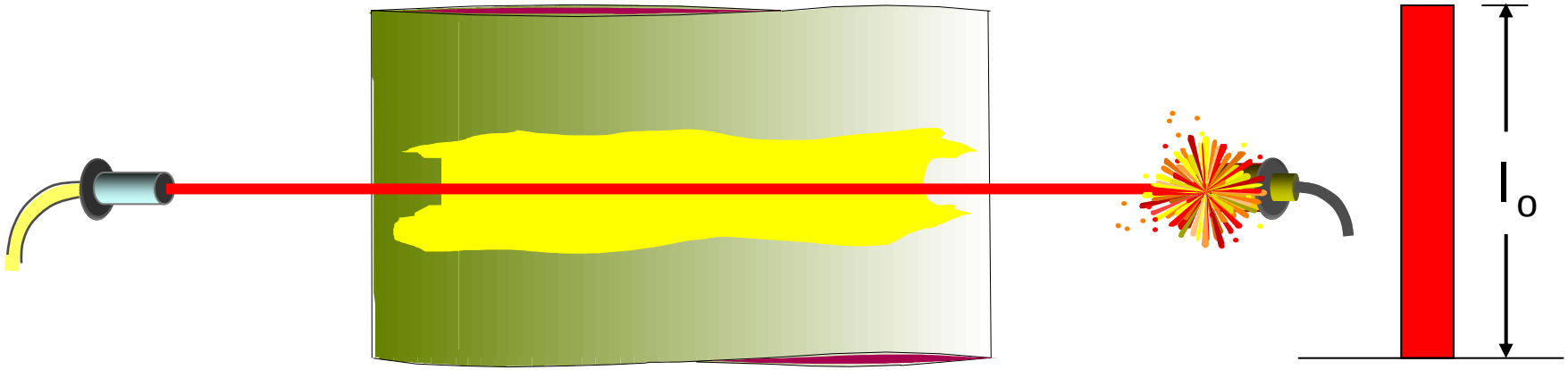



Absorption region

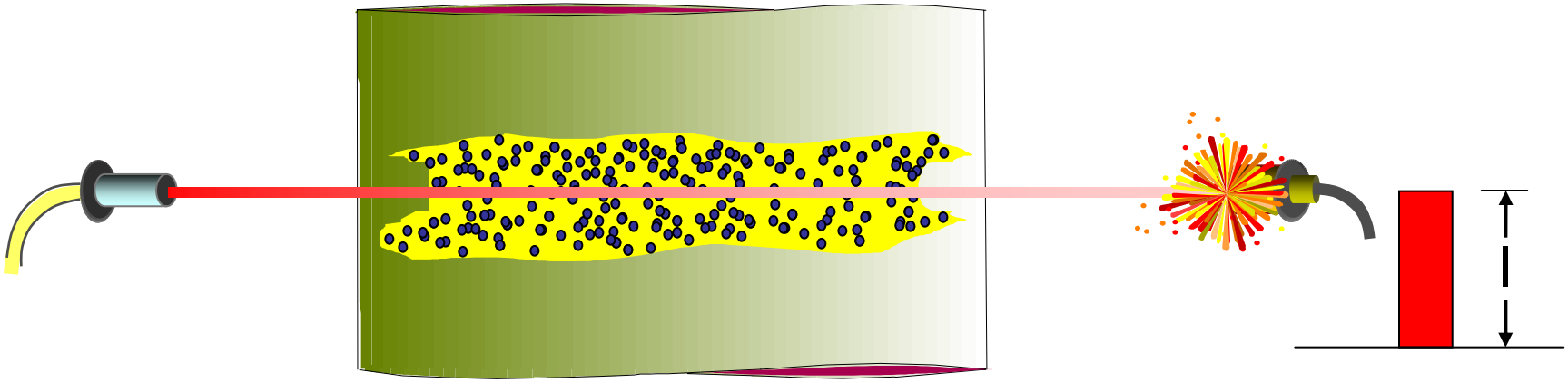
Side wavelengths, without absorption

# Tunable Diode Laser Measurement Technique

When no gas present...

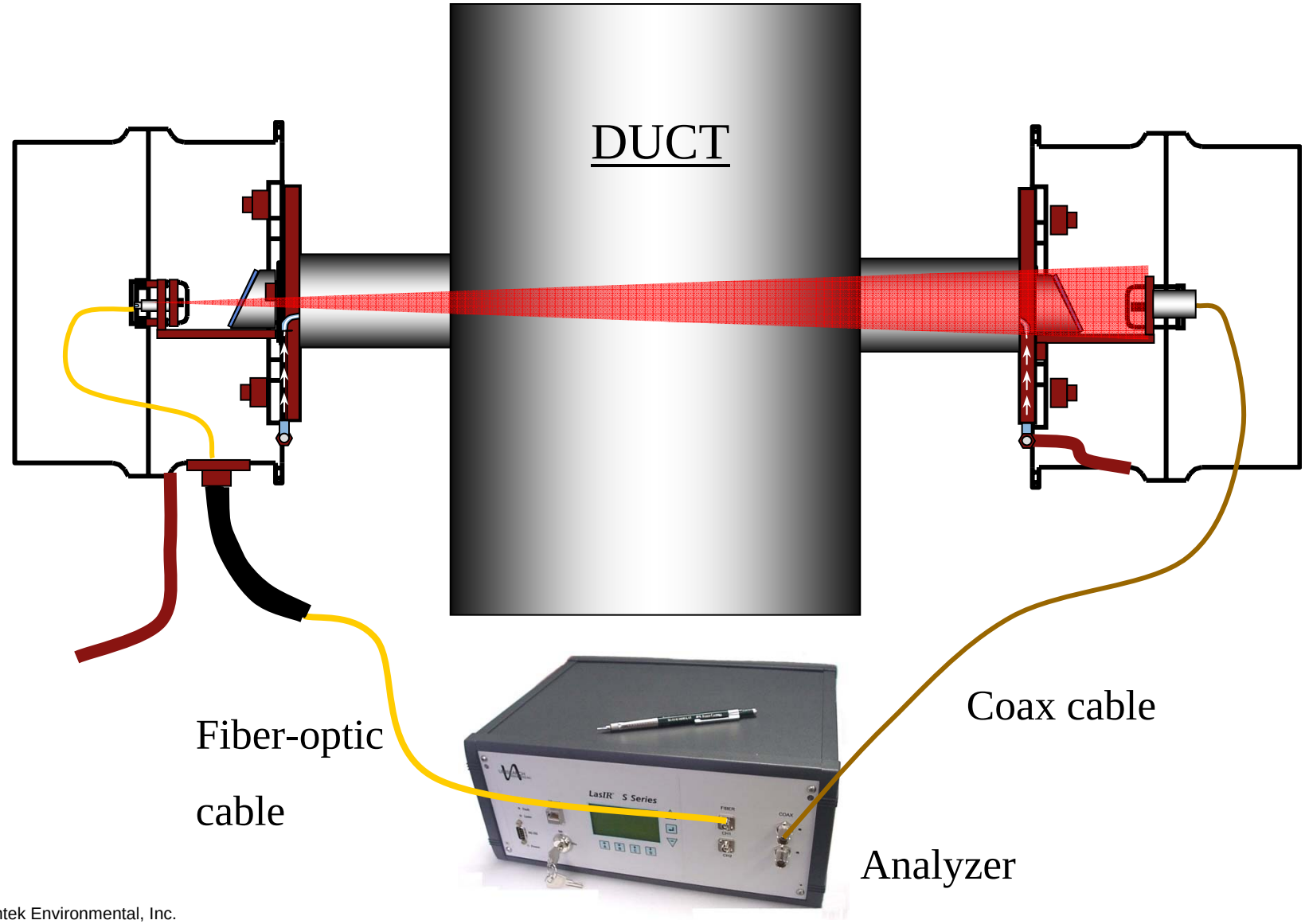



When gas present...



Absorbed intensity, $\delta I = I_o - I$

# Single Pass Stack Configuration



# Tunable Diode Lasers

*Practical Applications for the TDL*

- **HCl Monitoring**
  - **Coal Fired Power Plants**
    - **HCl injection for mercury control by promoting formation of mercuric chloride**
  - **Waste-to-Energy Applications**
    - **Plastics in fuel stock form HCl during combustion process**
  - **Wood-fired Boiler Applications**
    - **Logs transported to lumber mill Cogen and power plant facilities can absorb salt (NaCl) when in contact with salt water during transport and form HCl during combustion process**
  - **Cement Plants (HCl monitoring requirements in Cement MACT)**

# Coal Fired Boiler-
# Dry FGD HCl Application

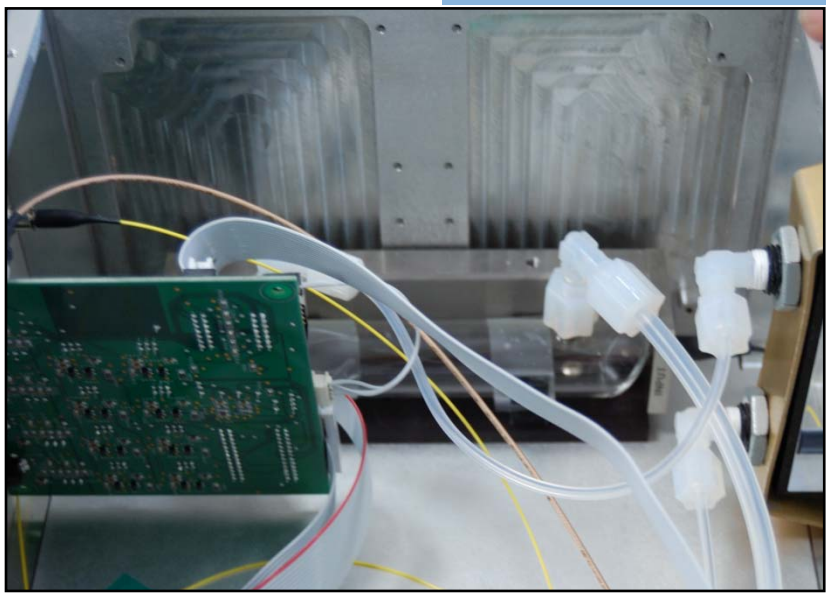
*HCl Measurement*

- ***Application Summary***
  - **Coal fired boiler with dry FGD scrubber**
  - **15 foot detection path with 0.2 ppm detection limit**
  - **478 foot distance between analyzer and stack optics**
  - **On-stack blowers to keep optic windows clean**
  - **System configured with flow-through audit cell using best quality HCl calibration gas cylinder available**
  - ***Lessons Learned***
  - **Anti-reflective coating added to optics window to limit optical noise**
  - **Pushing the analyzer detection limit, typically measuring nearly zero amount of HCl in stack flue gas**
  - **Zero drift issue that required a software change**
  - **Original bench alignment of flow-through cell introduced optical noise. Changed to cell integrated with optical bench to eliminate**
  - **Wet stacks may require heated optics windows**

# Tunable Diode Laser Audit Method

*Flow-Through Audit Cell*

- **Dynamic spiking audit**
- **HCl application with 1 - 1 ½ minute response time with 15 foot calibration cylinder distance**
- **Short recovery time**
- **Temperature correction factor used to account for difference between flow through cell and flue gas temperatures**



# Questions?

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