REINHOLD ENVIRONMENTAL Ltd.

2012 APC Round Table
& Expo Presentation

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Flue Gas Desulfurization CEMS Design Lessons Learned and New Regulations Monitoring Requirements

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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

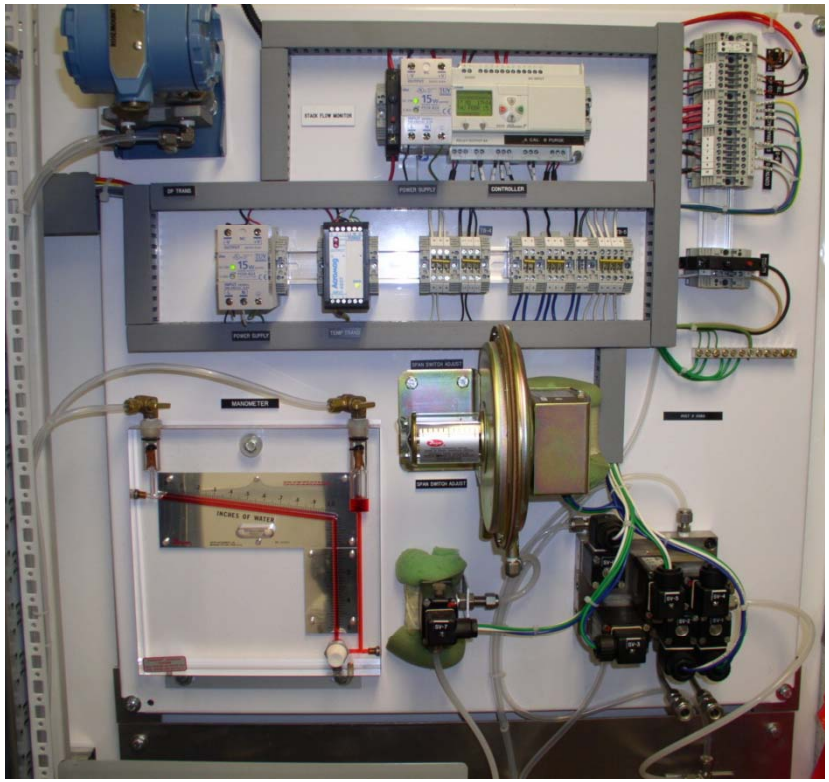
- ***Application Summary***
  - **Unit 2 retrofit with DFGD scrubber technology**
  - **Unit 2: 682 MW**

- ***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

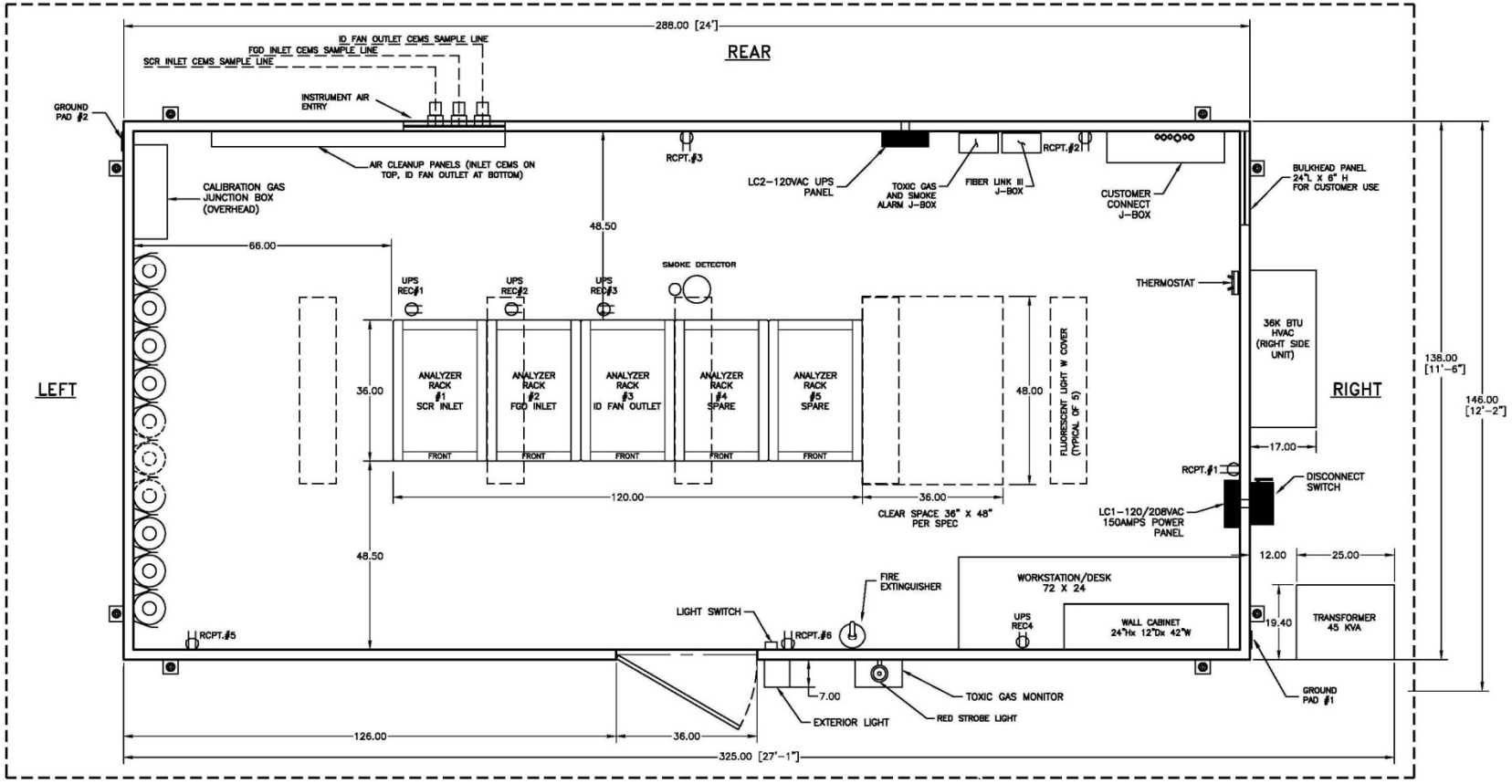
- ***Application Summary***
  - **Unit 2 retrofit with WFGD scrubber technology & SCR NO_X control**
  - **Unit 2: 225 MW**

- ***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***
  - **System currently in manufacturing**
  - **Unit operation scheduled for Summer 2012**



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 ▪ Maintenance intensive system ▪ NIST traceable calibration gases/sources issue ▪ Consumable chlorine gas for mercuric chloride generator
Continuous Batch Measurement	▪ Lower detection levels possible due to time integration of sample.	▪ Large upfront investment costs ▪ Maintenance intensive system ▪ 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 ▪ Must climb stack on daily/weekly basis for sample collection ▪ Glass trap breakage - loss of data ▪ Sample breakthrough - loss of data ▪ 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**

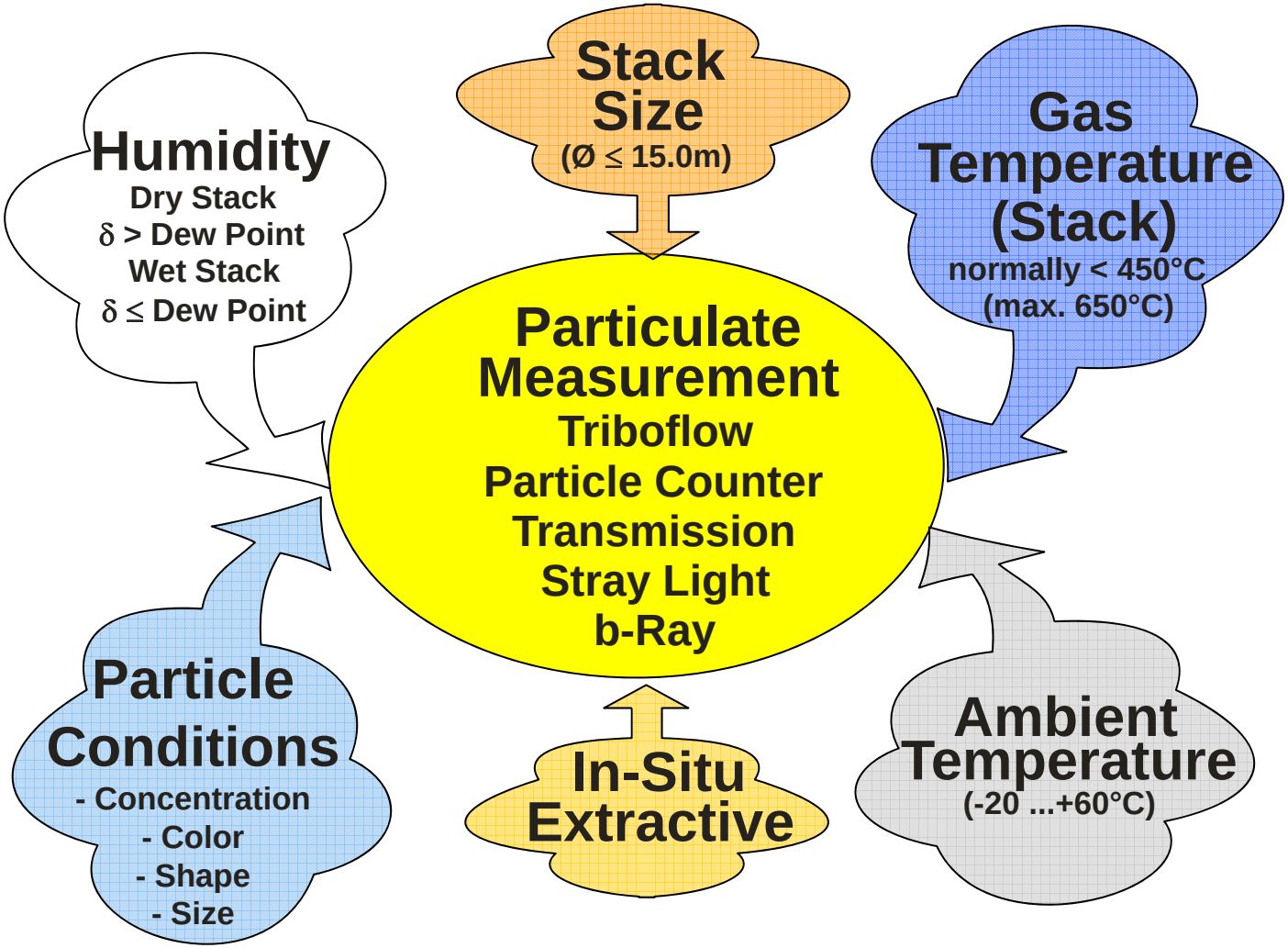
PM CEMS

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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www.cemteks.com

NH_3 & HCl Monitoring

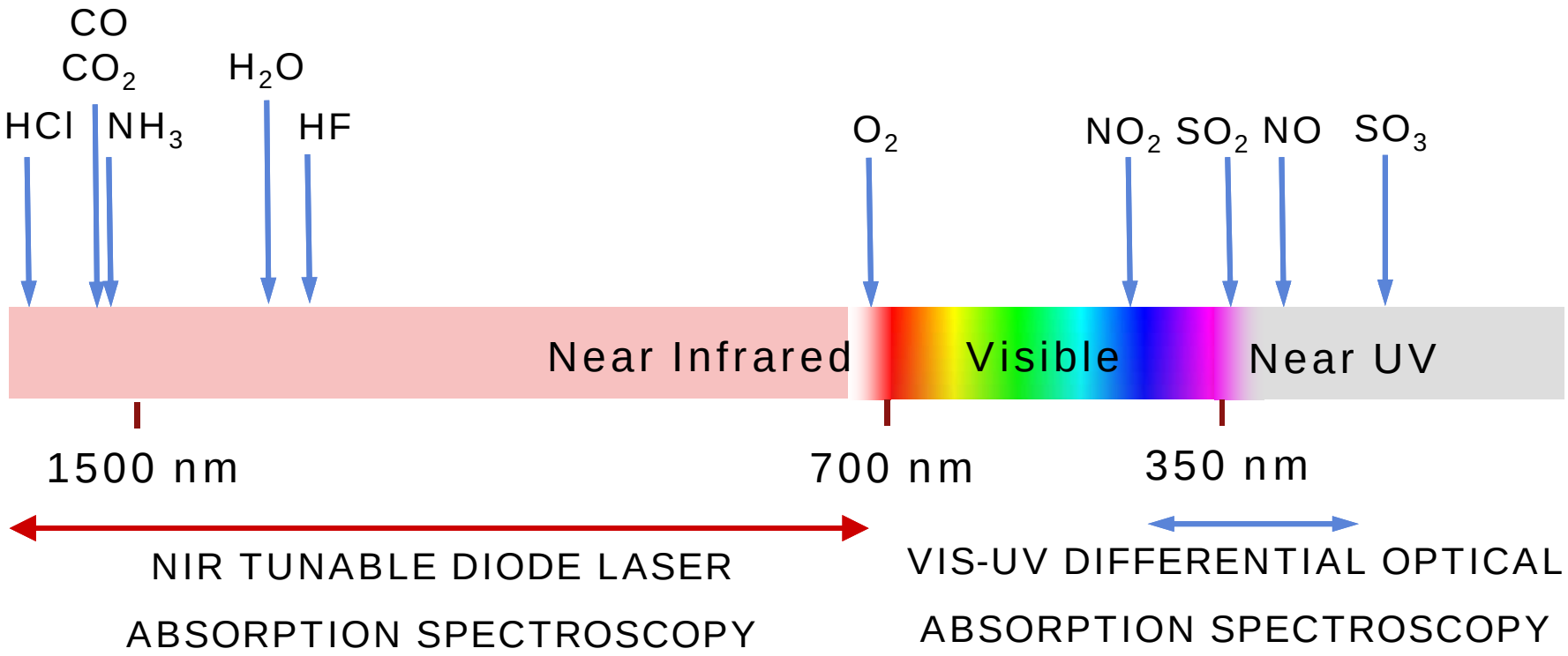
Purpose for monitoring Ammonia (NH_3) Slip

- **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

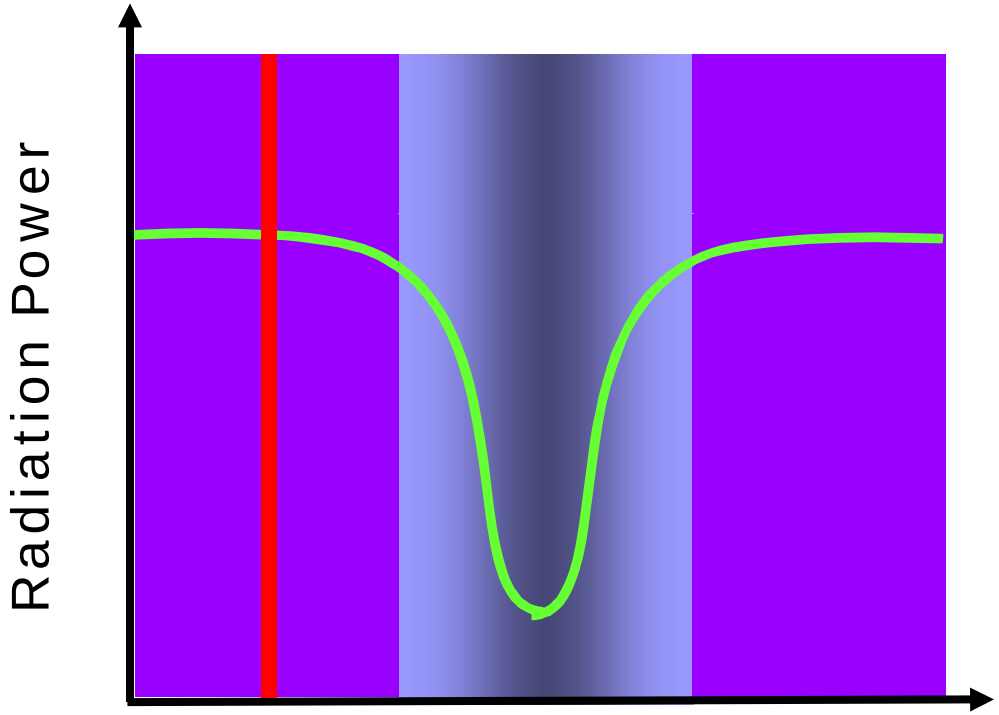
- **Regulatory emissions limits becoming more common requirements in air permits**
- **New rules call for continuous monitoring (MATS, Cement MACT)**

Tunable Diode Laser Measurement Technique



Tunable Diode Laser Measurement Technique

In the Region of Wavelength Absorption

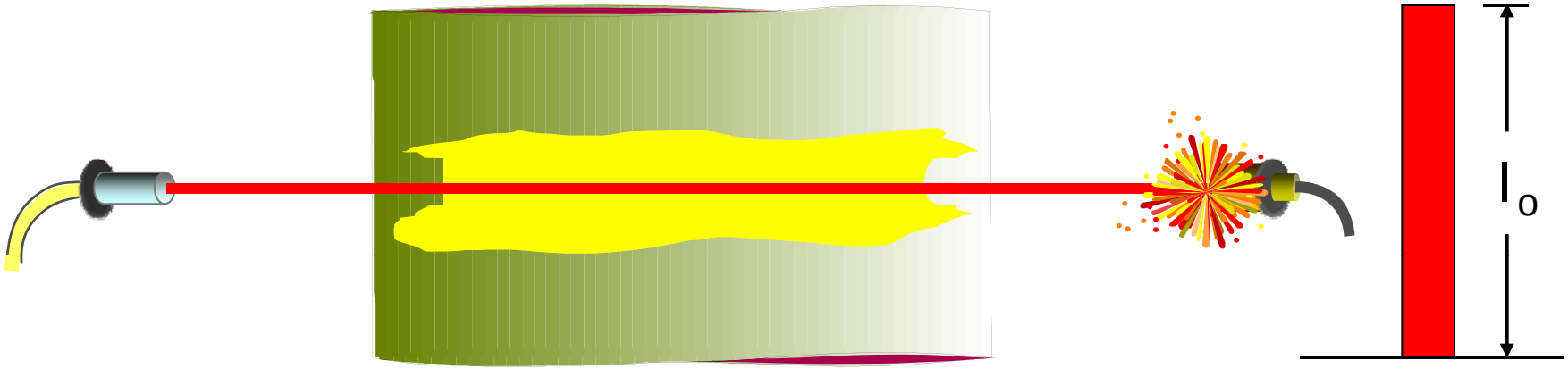


Absorption region

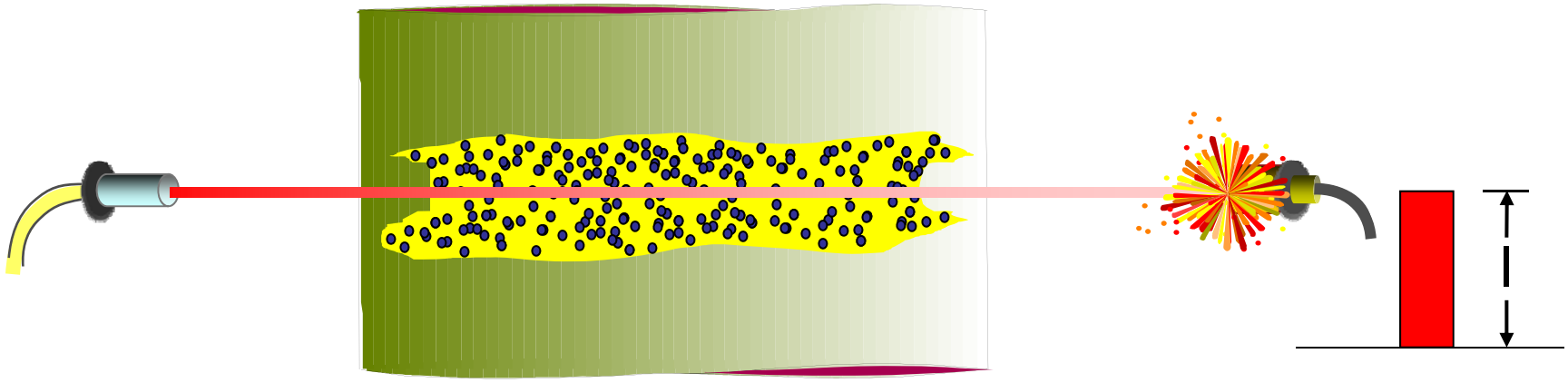
Side wavelengths, without absorption

Tunable Diode Laser Measurement Technique

When no gas present...

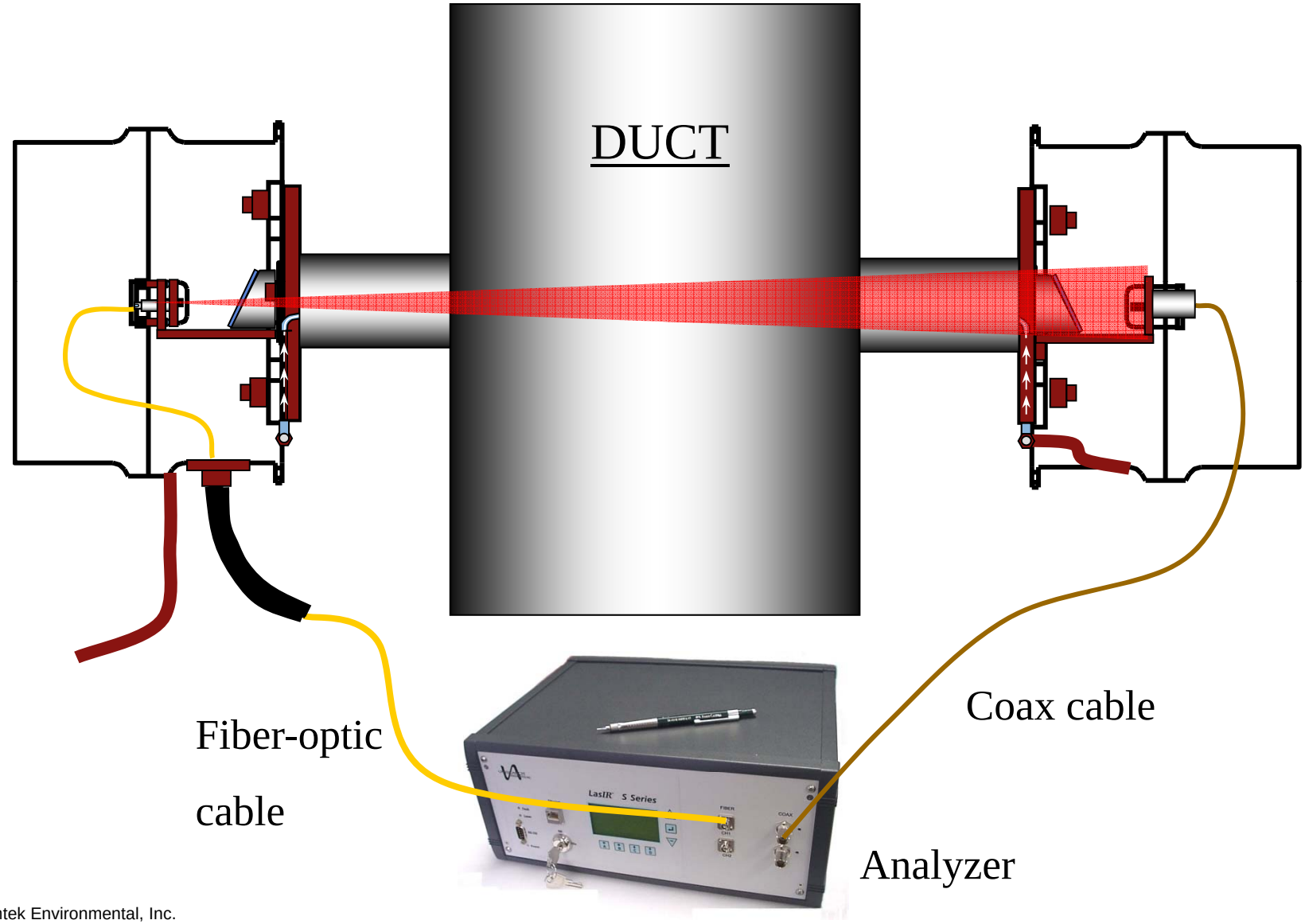


When gas present...



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

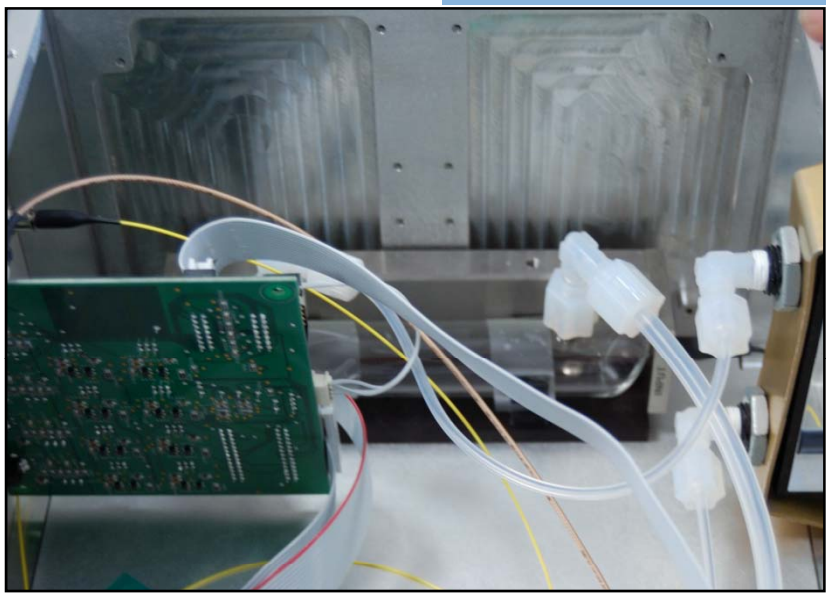
HCl Measurement

- ***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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