

REINHOLD ENVIRONMENTAL Ltd.



2011 APC Round Table & Expo Presentation

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Monitoring Challenges Related with New Regulations

Reinhold Environmental
2011 APC Round Table

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Monitoring Challenges Related with New Regulations

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**
- **Proposed Utility MACT Additional Monitoring Requirements**
 - **Mercury**
 - **Particulate**
 - **Acid Gases (HCl)**



Monitoring Challenges Related with New Regulations

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**

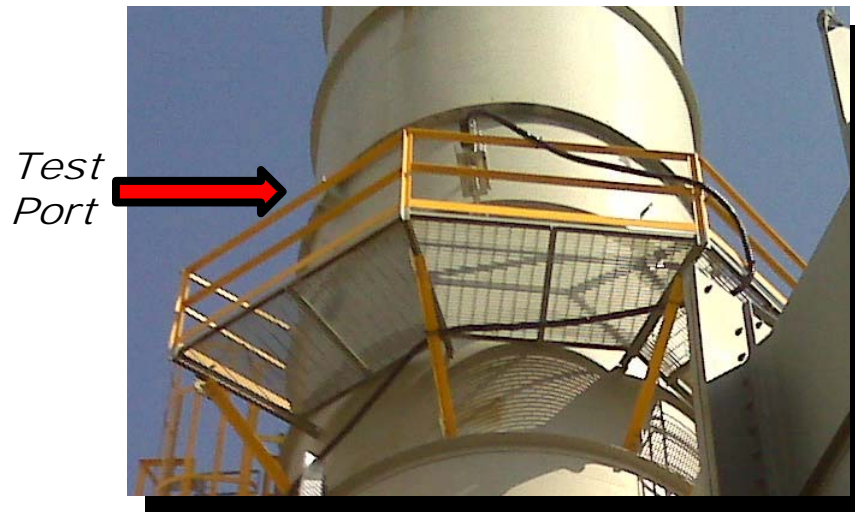
- **Corrosion resistant materials for probe tube construction to prevent attack from acid gases (Hastelloy, Inconel, etc.)**
 - **Heated probe tube in wet stack (saturated) conditions to help prevent corrosion**
 - **Impingement shield on probe inlet to prevent clogging from wet particulate**
 - **Demisters 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.**



- **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



Monitoring Challenges Related with New Regulations

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 SO₂ & CO₂**
- **Stack CEMS measuring NO_x, SO₂, CO & CO₂**
- **Stack measurement of moisture and O₂ 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**

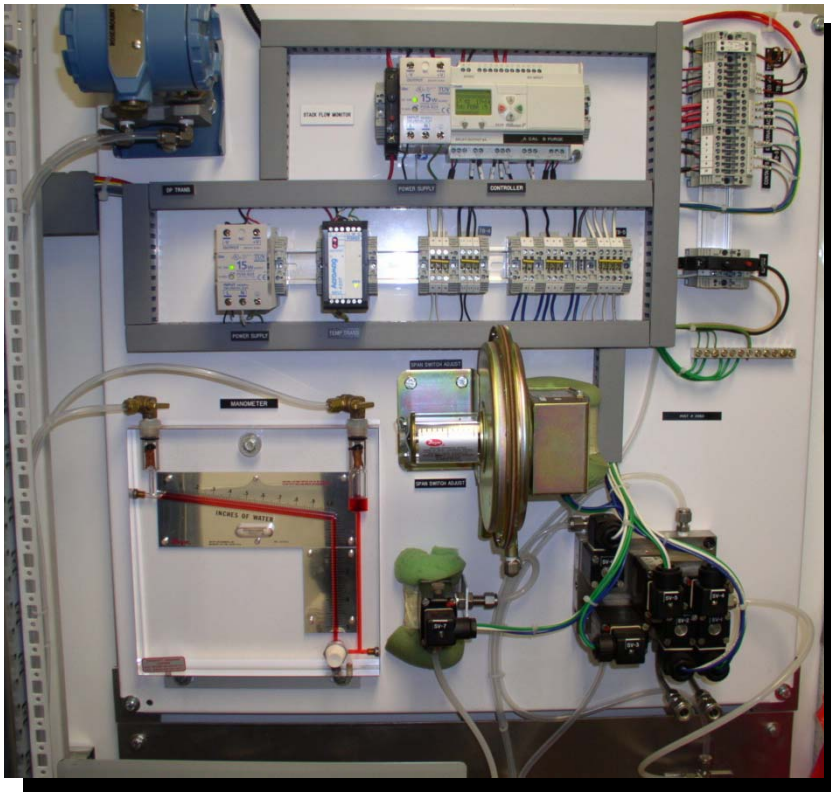


Coal Fired Boiler Nebraska Power Plant

Dry FGD CEMS Application

■ **Lessons Learned**

- **In-situ O₂ 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 SO₂ & CO₂**
- **Stack CEMS measuring NO_x, SO₂ & CO₂**
- **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 SO₂ 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 SO₂ & CO₂ for Units 1 & 2**
 - **Stack CEMS measuring NO_x, SO₂ & CO₂ for Units 1 & 2**
 - **Stack CEMS measuring NO_x, SO₂ CO & CO₂ 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, SO₂ & CO₂**
 - **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 SO₂ & CO₂**
 - **Stack CEMS measuring NO_x, SO₂ & CO₂**
 - **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, SO₂ & CO₂ on each inlet duct**
- **Stack CEMS measuring NO_x, SO₂ & CO₂ 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 Fall 2011**
 - **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 SO₂ & CO₂**
- **Stack CEMS measuring NO_x, SO₂, CO & CO₂**
- **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**

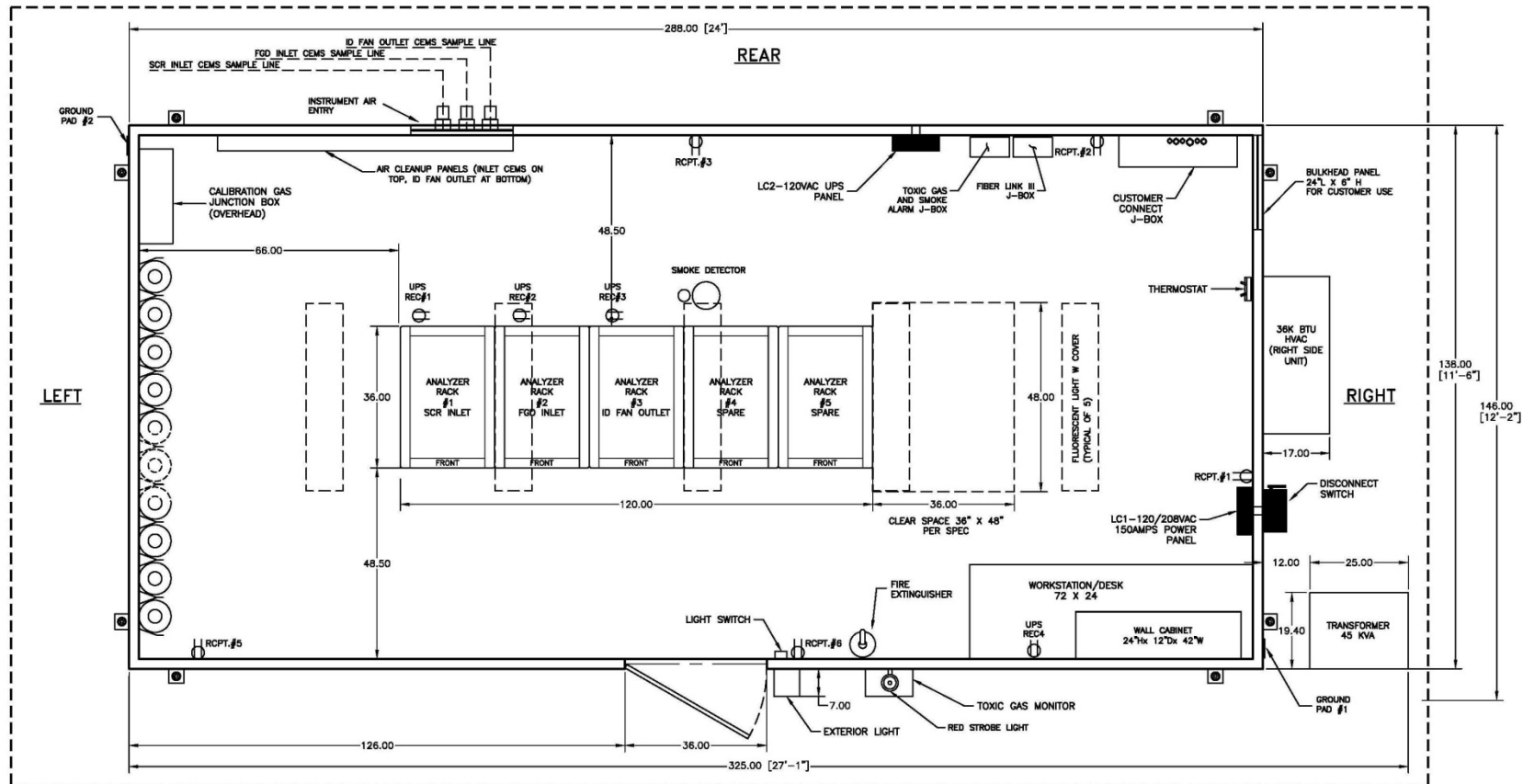
- **Dilution Extractive CEMS (100:1 dilution ratio)**
- **Out-of-stack dilution probe**
- **Dilution air cleanup panel**
- **Heated stack sample umbilical**
- **FGD Inlet CEMS measuring SO₂ & CO₂**
- **SCR Inlet CEMS measuring NO_x & CO₂**
- **ID Fan Outlet CEMS measuring NO_x, SO₂ & CO₂**
- **ID Fan 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**





Monitoring Challenges Related with New Regulations

Presentation Overview & Agenda

- ***Proposed Utility MACT Additional Monitoring Requirements***
 - ***Mercury***
 - ***Particulate***
 - ***Acid Gases (HCl)***

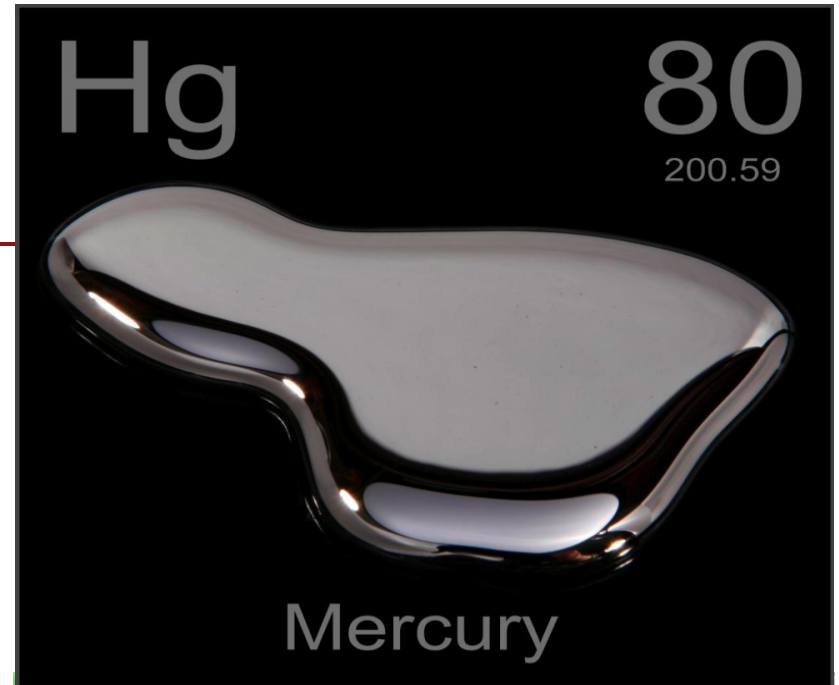


Mercury Monitoring Technologies and Detection Principles

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Mercury Fountain by Alexander Calder
Joan Miro Museum in Barcelona, Spain
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Mercury Monitoring

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.
 - Utility Boiler MACT



Mercury

- Detection Technologies
 - Continuous Monitoring
Cold Vapor Atomic Fluorescence
Example: Thermo Freedom Mercury Series
 - Continuous Batch Measurement
Pre-Concentration on Gold Filter, Thermal Desorption, Atomic Fluorescence
Example: Tekran Series 3300
 - Long Term Batch Measurement
Sorbent Trap or Appendix K
Example: Apex Instruments



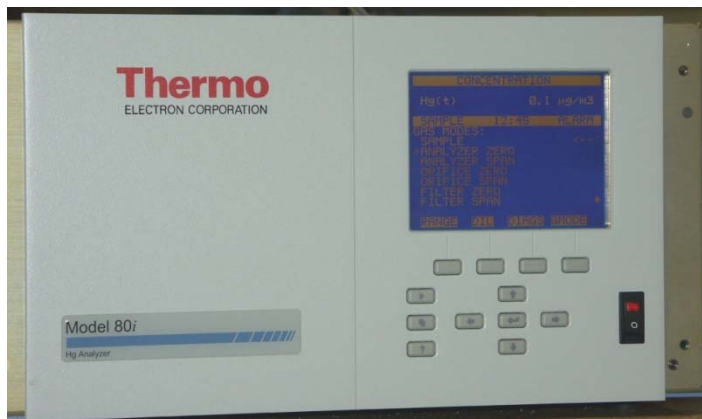
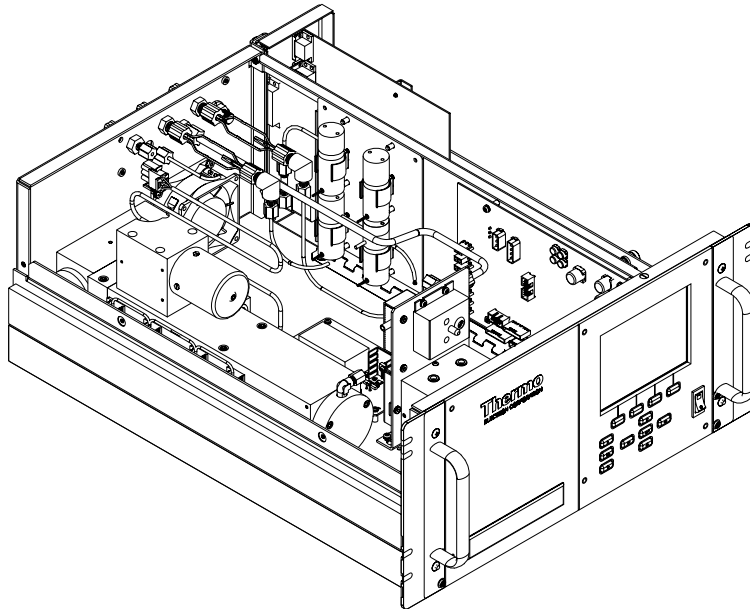
Continuous Monitoring



- 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



Continuous Monitoring

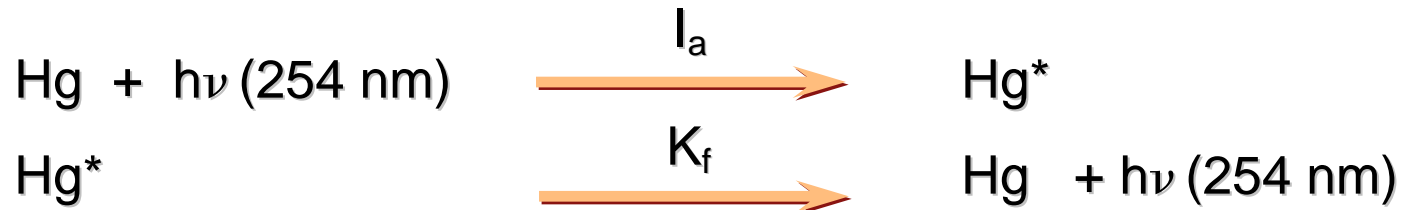


- Direct Measurement CVAF
 - Continuous measurement
 - No additional gasses required
- Diluted Sample
 - Lower moisture, less reactive
- Speciating
 - Measures either Hg^{T} or Hg^0
- Analyzer Detection Limit:
Currently $\sim 1 \text{ ng/m}^3$ ($\sim 0.1 \text{ ppt}$)
- No cross interference with SO_2



Continuous Monitoring

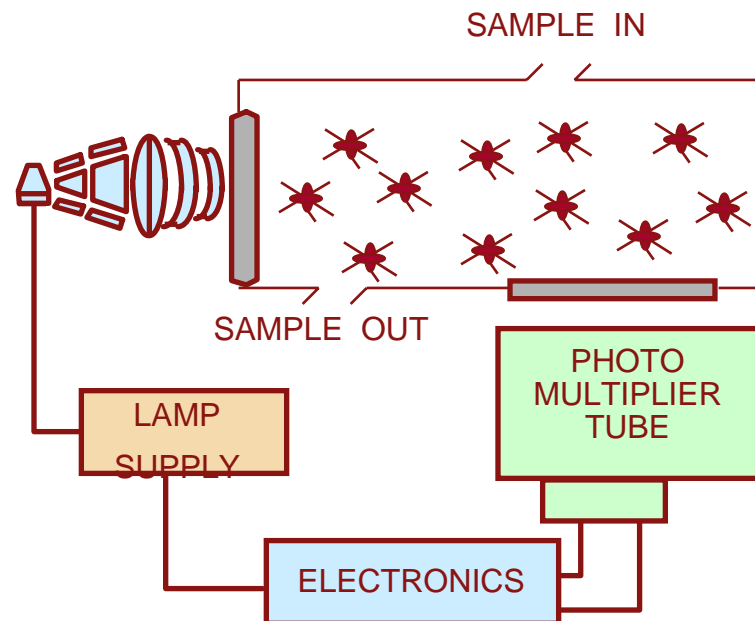
Hg Fluorescence



$$I_a = I_0[1 - e^{-ax(\text{Hg})}]$$

$$I_f \propto I_0 ax(\text{Hg}) \text{ or } K(\text{Hg})$$

- High Intensity Hg Lamp
- Reflective Filtering
- Enhanced Light Baffling
- Bandpass Filter





Continuous Batch Measurement



Model 3330 Inertial Probe



Model 3320 Sample Conditioner



Model 2537A AF
Analyzer



Model 3310 Calibration Unit



Continuous Batch Measurement

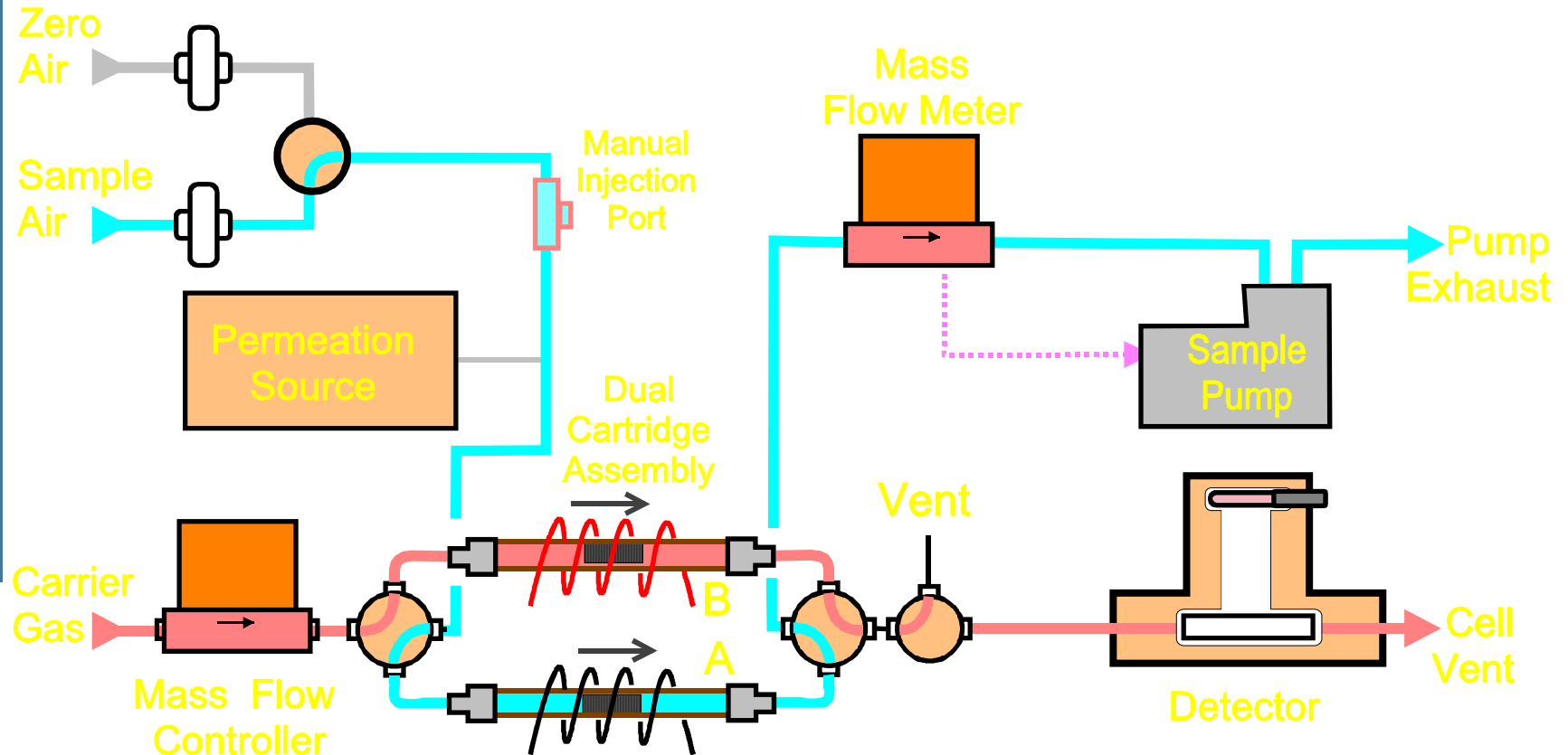
Principles of Operation

- 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



Continuous Batch Measurement

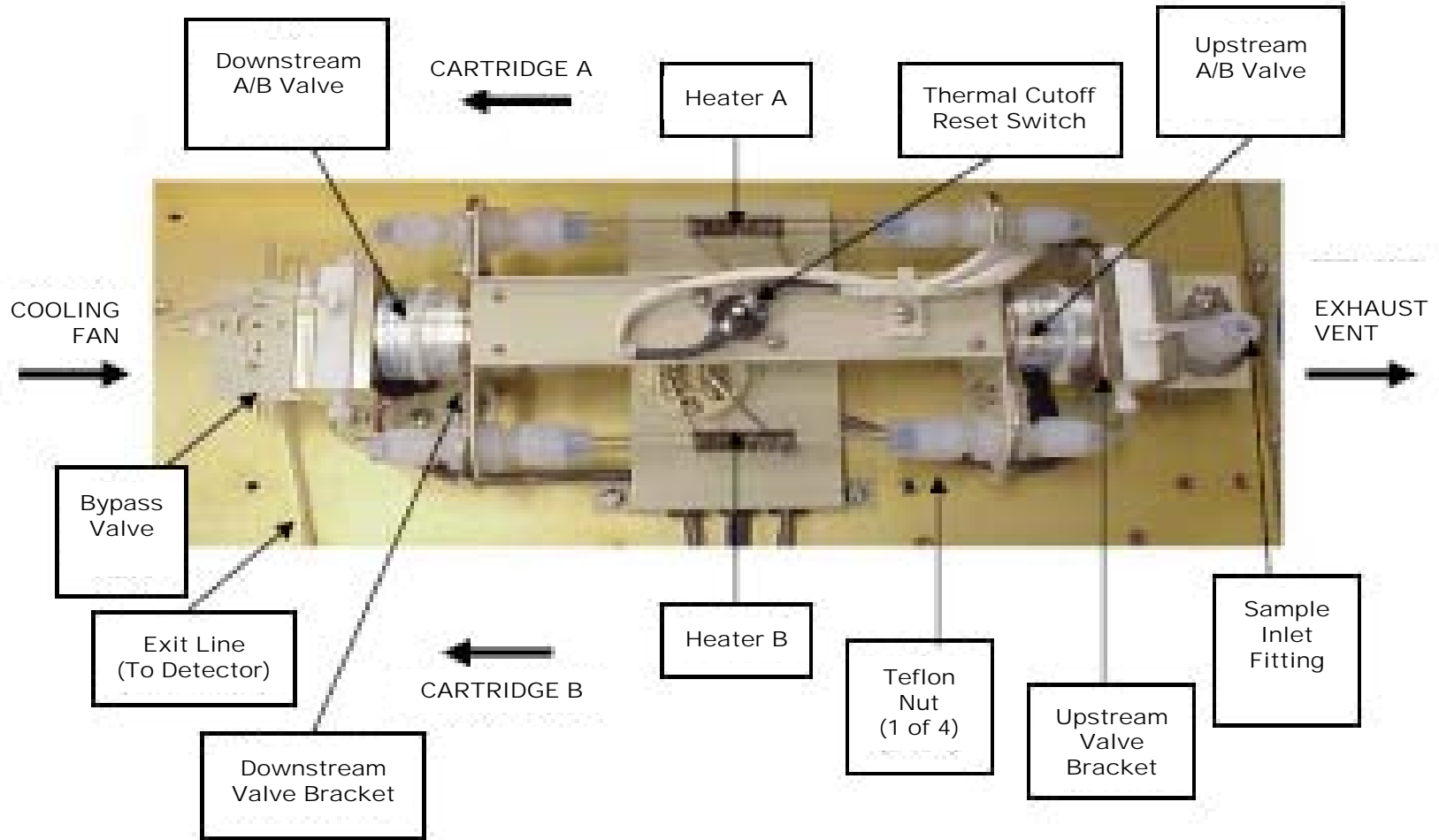
Flow Diagram of Mercury Analyzer (Pat'd)





Continuous Batch Measurement

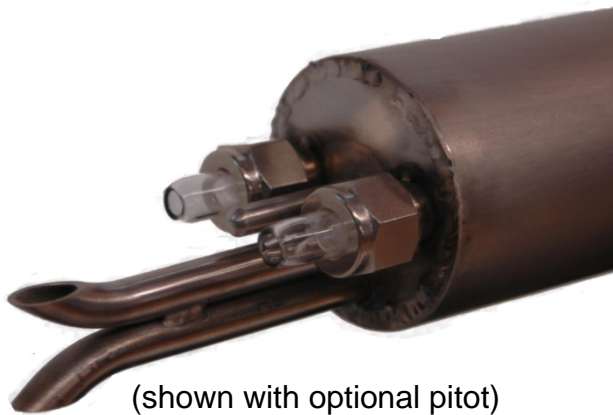
Valve Assembly





Long Term Batch Measurement

HGP Dual Trap Sampling Probe

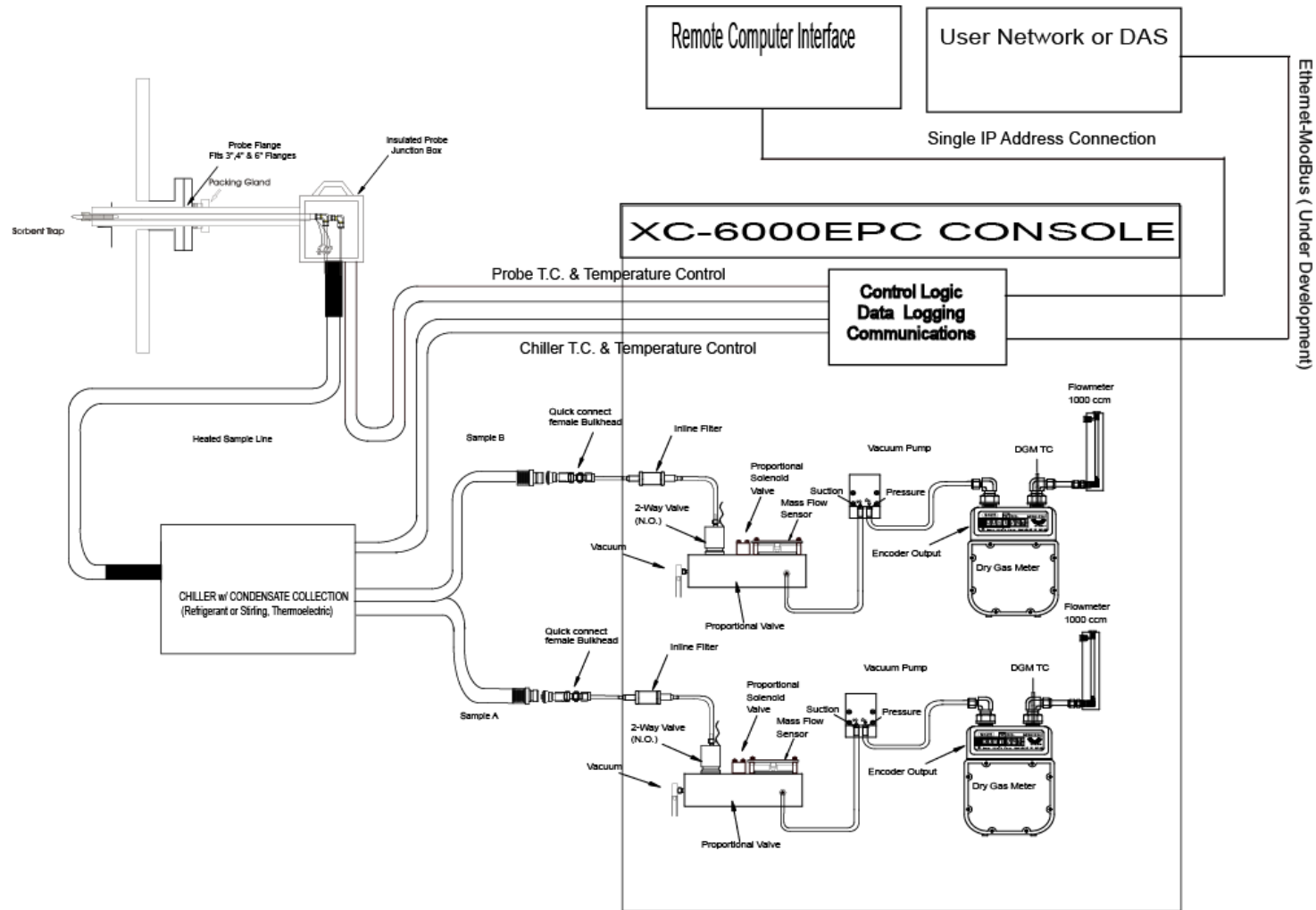


Configuration:

- 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



Long Term Batch Measurement





Long Term Batch Measurement

Sorbent Trap



Configuration:

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



Method Comparison: Detection Levels

| Detection Method | Range | Detection Limit | Sample Cycle Time |
|-------------------------------------|-------------------------------------|-----------------------------------|--|
| Continuous Monitoring | 0-50 $\mu\text{g}/\text{m}^3$ | 2 ng/m^3 | Continuous (60 - 300 sec Rolling Average Time) |
| Continuous Batch Measurement | 0.1 - 10,000 ng/m^3 | < 0.1 ng/m^3 | 2 ½ - 60 minutes |
| Long Term Batch Measurement | N/A | Dependent upon analysis technique | Several hours - several weeks (Dependent upon concentration present in process) |



Method Comparison: System Costs

| Detection Method | Budgetary System Cost | Budgetary Maintenance |
|-------------------------------------|--|---|
| Continuous Monitoring | \$200,000 <ul style="list-style-type: none"> ▪ NEMA 12 Rack Mounted ▪ 250 feet Umbilical ▪ DAHS Integration Not Incl ▪ Installation Services Incl | <ul style="list-style-type: none"> ▪ Quarterly Maintenance Contract: \$10,000* ▪ Spare Parts: \$25,000 (Consumable & Recommended) |
| Continuous Batch Measurement | \$200,000 <ul style="list-style-type: none"> ▪ NEMA 12 Rack Mounted ▪ 250 feet Umbilical ▪ DAHS Integration Not Incl ▪ Installation Services Incl | <ul style="list-style-type: none"> ▪ Quarterly Maintenance Contract: \$10,000* ▪ Spare Parts: \$25,000 (Consumable & Recommended) |
| Long Term Batch Measurement | \$100,000 <ul style="list-style-type: none"> ▪ NEMA 12 Rack Mounted ▪ 250 feet Umbilical ▪ DAHS Integration Not Incl ▪ Installation Services Incl | <ul style="list-style-type: none"> ▪ Site Labor: TBD** ▪ Ohio Lumex Analysis System: \$75,000*** ▪ Spare Parts: \$5,000 (Consumable & Recommended) |

*Cost for a third party quarterly maintenance contract. Additionally, a site technician will be required to perform daily/weekly/monthly system checks according to the Quality Assurance Program.

**Site technician will be required to climb the stack to the sampling point on a daily/weekly basis to change the sorbent traps as well as perform daily/weekly/monthly system checks according to the Quality Assurance Program.

***Sorbent traps may be sent to offsite laboratory for analysis in lieu of purchasing a site dedicated analysis system.



Method Comparison

| Detection Method | Advantages | Disadvantages |
|-------------------------------------|--|--|
| Continuous Monitoring | <ul style="list-style-type: none"> ▪ True real time feedback for process control. | <ul style="list-style-type: none"> ▪ Large upfront investment costs ▪ Maintenance intensive system <ul style="list-style-type: none"> ▪ NIST traceable calibration gases/sources issue ▪ Consumable chlorine gas for mercuric chloride generator |
| Continuous Batch Measurement | <ul style="list-style-type: none"> ▪ Lower detection levels possible due to time integration of sample. | <ul style="list-style-type: none"> ▪ Large upfront investment costs ▪ Maintenance intensive system ▪ NIST traceable calibration gases/sources issue |
| Long Term Batch Measurement | <ul style="list-style-type: none"> ▪ Lesser initial investment for system startup. | <ul style="list-style-type: none"> ▪ 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 <ul style="list-style-type: none"> ▪ Chain of custody sample issues |



Particulate Matter Monitoring Technologies and Detection Principles

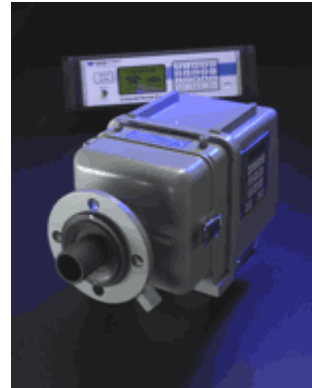
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Conventional Opacity/Particulate Matter Measurement Techniques



Principle of Detection

- Double pass systems for the dust loaded measuring path with light in the visible range.

Compliance for 10-20% Opacity

- To meet EPA Performance Standard PS-1
- Traditional Optical designs are used
- Traditional Accuracy and Drift are Acceptable

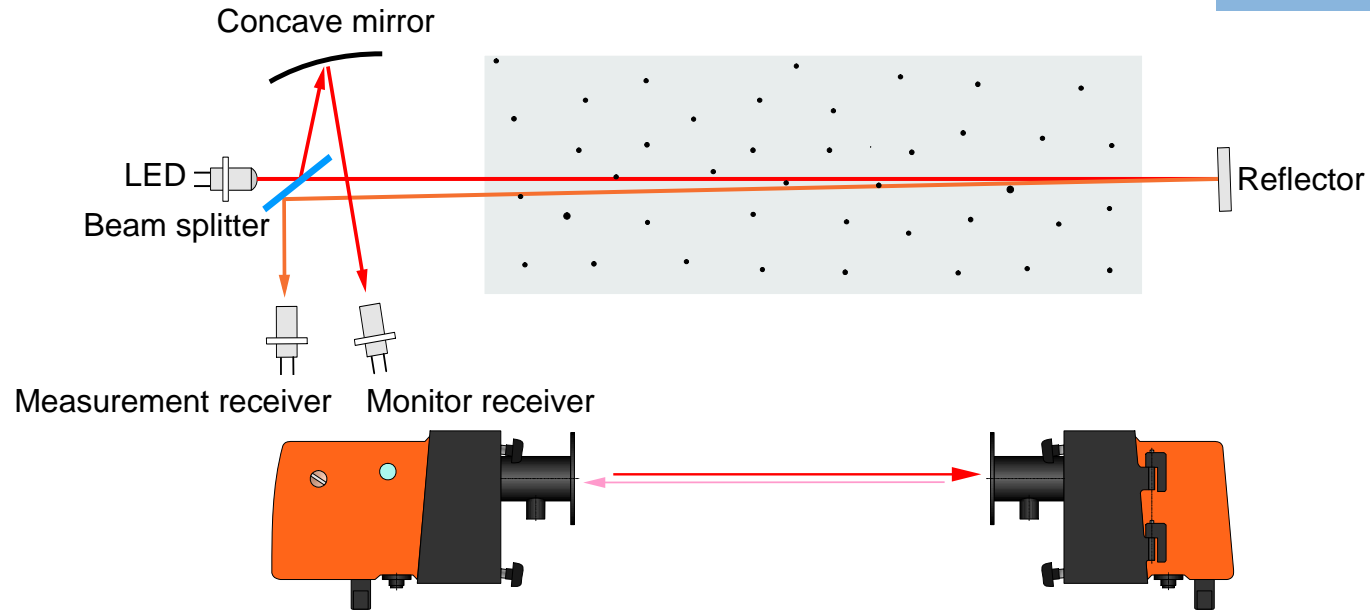
Compliance for 0-10% Opacity

- New design platforms to meet PS-11
- Traditional Drift removed
- Improved Optical Design

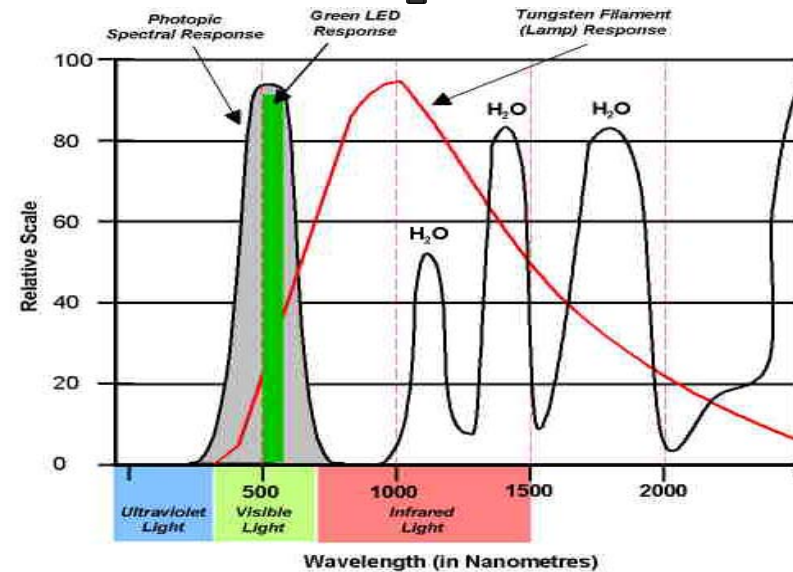




Conventional Opacity/Particulate Matter Measurement Techniques



- **Green LED**
 - Inside Regulation Wavelength
 - No Optical filters required
 - Long Life
 - Electronic Modulation





Conventional Opacity/Particulate Matter Measurement Techniques

Advantages

- 10,000+ already installed

Disadvantages

- Measures attenuation of light
- Adversely affected by particle size, shape, density change
- Measures liquid drops as PM
- Not sensitive to low PM concentration
- Costs more than a light scatter PM CEM
- Correlation to mass concentration not linear



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 SO₂ and the concern of SO₃ from SCR installations, wet scrubbers have proven to be a highly efficient means of reducing SO₂, SO₃ and fine particulates; however a wet gas effluent is a result. This result is in the form of wet particulate and water droplets.**
 - **The proposed Utility MACT 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

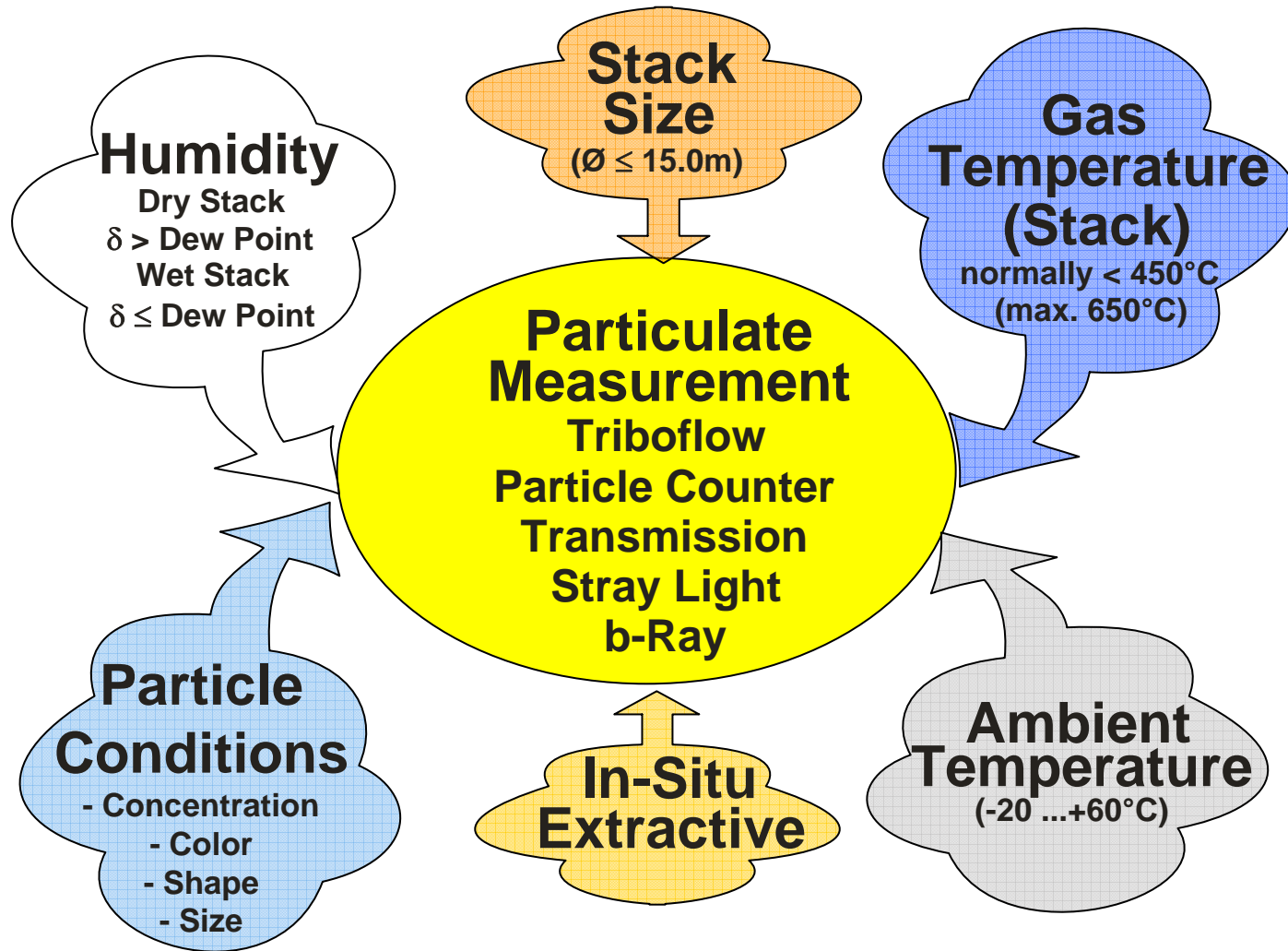
Principal Technologies used

- **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





Light Scatter Measurement Technique



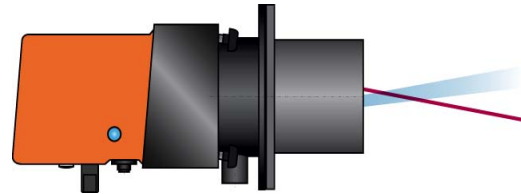
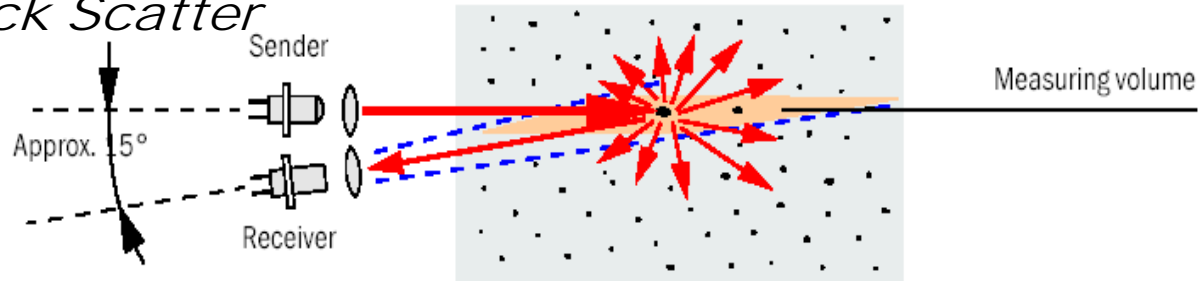
Principle of Detection

- Singular beaming of the dust loaded measuring path with laser light inside the visible range will cause light to scatter
- The scattered light measured on a different plane than the incident light is proportional to the particulate present in the flue gas stream.



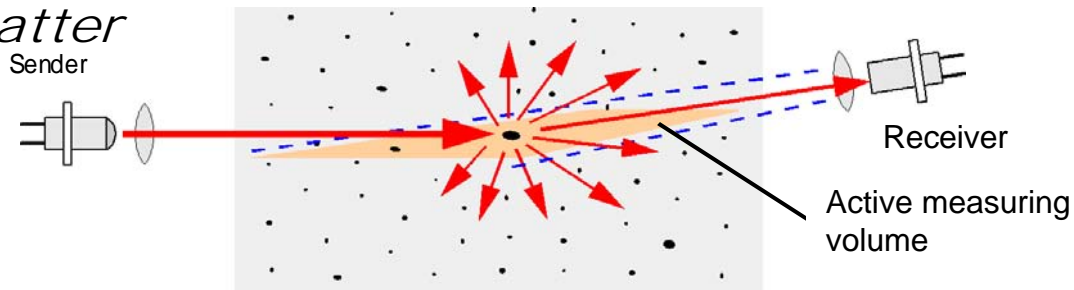
Light Scatter Measurement Technique

Back Scatter



The receiver is situated at the side of the sender

Forward Scatter



The receiver is situated on the opposite side of the sender



Light Scatter Measurement Technique

Advantages

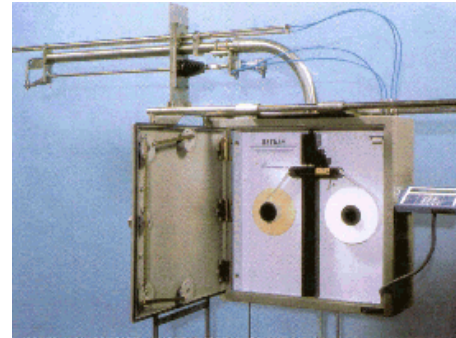
- **Low price \$15-25,000**
- **Easy to install**
- **Low maintenance**
- **Sensitive to low PM concentration**
- **Effective after fabric filter or multi-stage APC**
- **New Models Operate on Wet Gas Streams**

Disadvantages

- **Measures secondary properties of PM**
- **Adversely affected by particle size, shape, density change**
- **IR light better than visible light**
- **Measures liquid drops as PM if sample is not heated.**



Beta Attenuation Measurement Technique

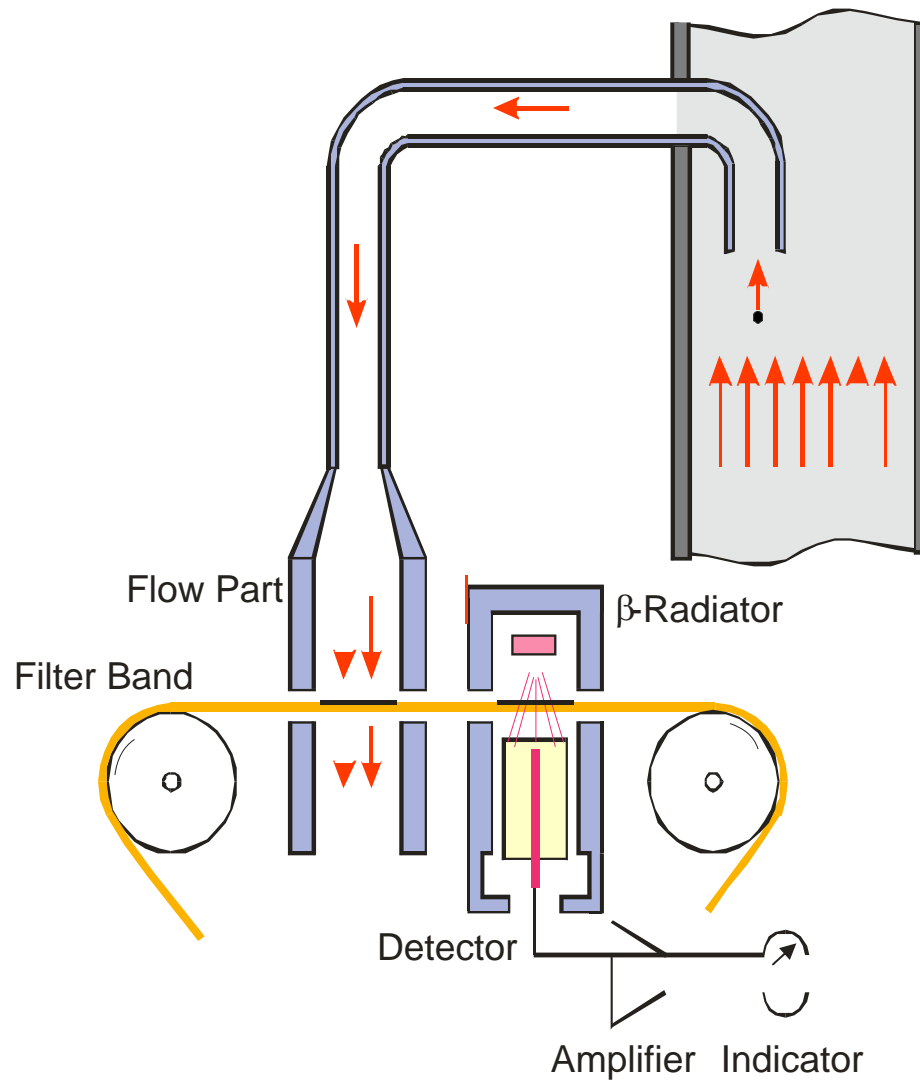


Principle of Detection

- A low energy Carbon-14 source furnishes a constant supply of beta electrons detected by a Geiger Müller tube or photodiode array.
- The particulate measurement cycle begins by measuring a clean area (spot) on the tape for a fixed time period to determine a zero value. This clean spot is then moved under a collection apparatus for sample extraction from the stack.
- A sample of stack gas deposits particulate on the filter tape. Once a sufficient amount of sample is collected on the filter tape, the tape is moved back under the beta source and re-measured.
- The difference in beta emissions measured from the original clear spot to the collected sample is directly proportional to the mass on the tape. Direct measurement of PM concentration.



Beta Attenuation Measurement Technique





Beta Attenuation Measurement Technique

Advantages

- **Direct measure of PM concentration**
- **Not affected by particle characteristic changes**
- **Designed to work in wet stack applications**

Disadvantages

- **More difficult to install**
- **Expensive \$60-90,000**
- **Higher cost of ownership**
- **Sample extraction and transport**



Probe Electrification Measurement Technique



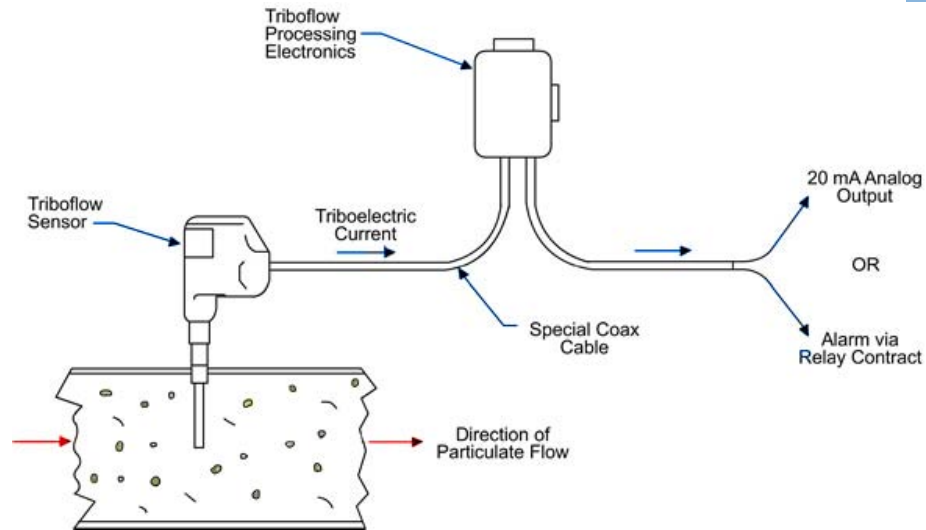
Principle of Detection

- If two bodies are contacted by friction or touch charge transfer occurs. The charge difference arises when atoms on the surfaces exchange electrons and by that a border layer with a positive and negative surface charge arises.
- This charge difference also called charge fluctuation is the basis for the dust measurement by the triboelectric principle where the charge exchange between measuring probe and nearby streaming as well as colliding particles is used.
- The measuring method is suitable for in-situ measurement as well as for the extractive registration of dust contents. Qualitative or quantitative measuring values can be achieved.

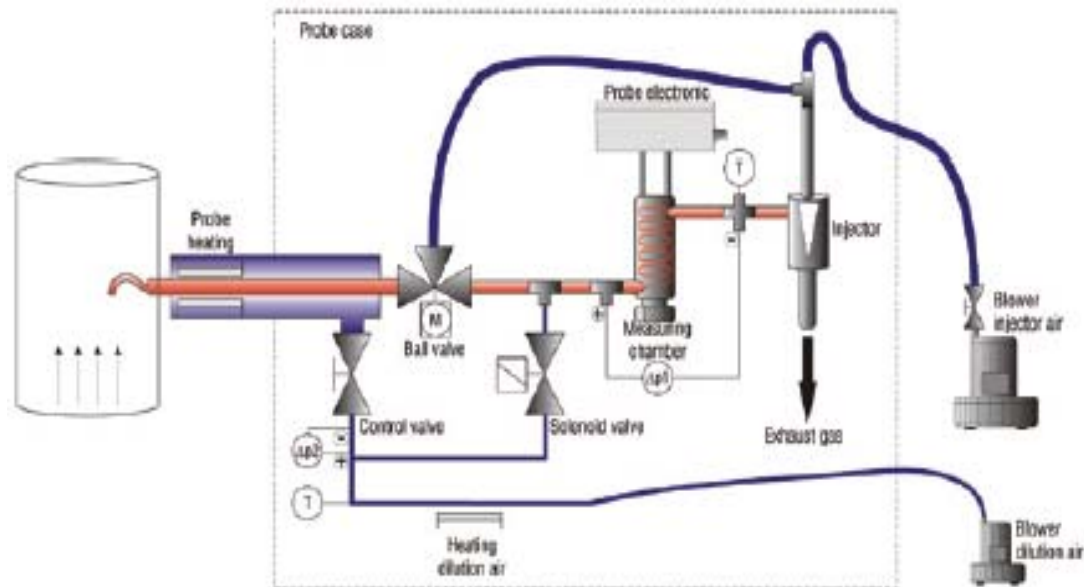


Probe Electrification Measurement Technique

Dry Stack Configuration



Wet Stack Configuration





Probe Electrification Measurement Technique

Advantages

- **Inexpensive: \$5,000 – 10,000 for bag leak detection**
- **Simple to install**
- **Sensitive to low PM concentration**
- **Effective as bag leak detectors**

Disadvantages

- **Adversely affected by:**
 - **Particle charge (not after an ESP)**
 - **Particle size and velocity changes**
- **Measures liquid drops as PM so must be heated for wet stacks**



Tunable Diode Laser Spectroscopy Detection Principles For Monitoring NH₃, HCl & HF

*a technical solution to
meet every need...*

**CEMTEK Environmental Inc.
3041 S. Orange Ave.
Santa Ana, CA 92707
800-400-0200**

www.cemteks.com





NH₃ & HCl Monitoring

Purpose for monitoring Ammonia (NH₃) Slip

- **Regulatory emissions limits for both NO_x and NH₃ 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 (Utility MACT, Cement MACT)**



Tunable Diode Laser Measurement Technique

What are Tunable Diode Lasers (TDL)?

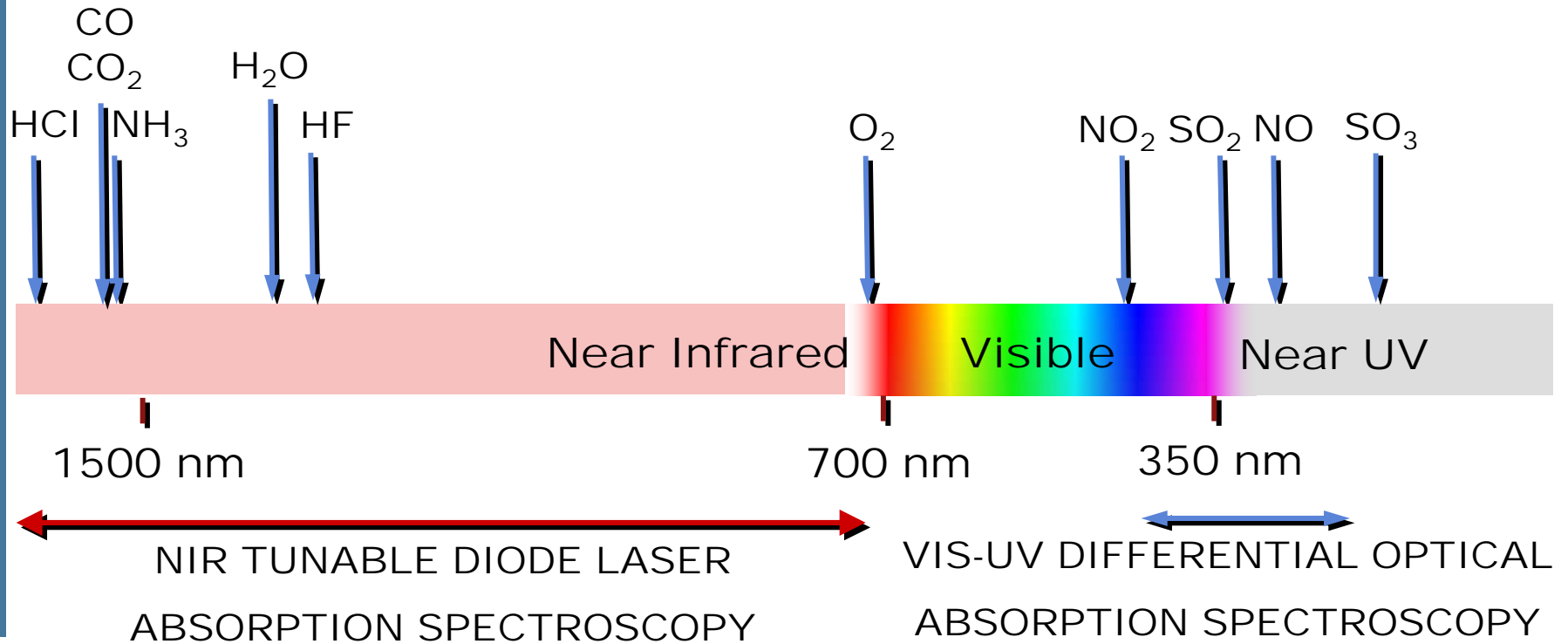
- **Lasers made of small crystals of Ga, As, Sb, P**

- **Lasers similar to those used in telecommunication, CD players and Laser Printers**
 - **Rugged construction**
 - **Commercially available at low cost**

- **Emits laser radiation in near infrared region when an electric current is applied**



Tunable Diode Laser Measurement Technique





Tunable Diode Laser Measurement Technique

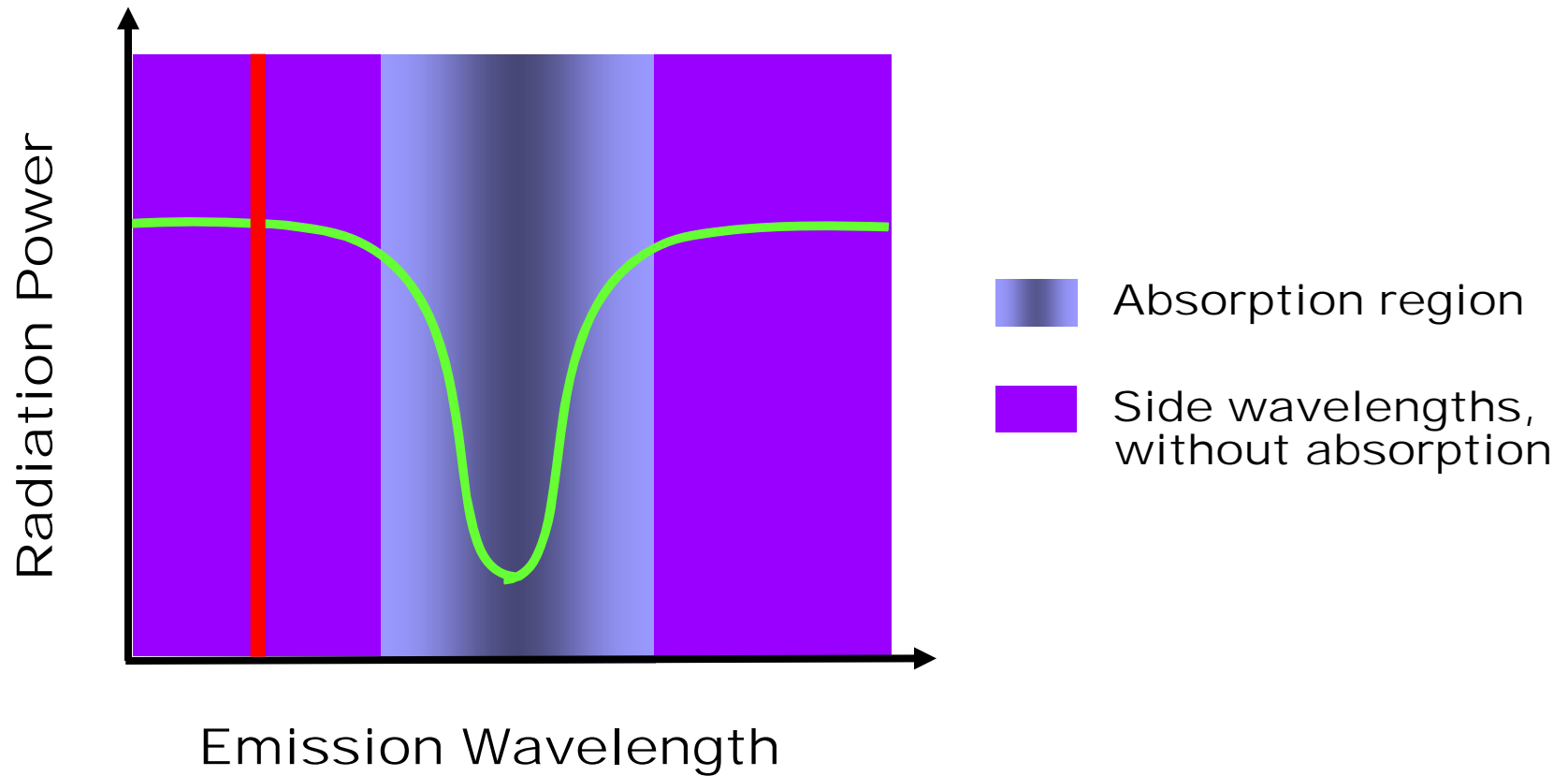
*How do Tunable Diode Lasers (TDL)
Operate?*

- **Laser center wavelength depends on composition of crystal**
- **Laser wavelength can be changed over narrow range by changing current or over a wider range by changing laser operating temperature**
- **By temperature controlling the laser, changing the electric current permits scanning over entire absorption feature**
- **By scanning the entire absorption feature, interference from dust is eliminated as the laser signal power is continuously measured.**



Tunable Diode Laser Measurement Technique

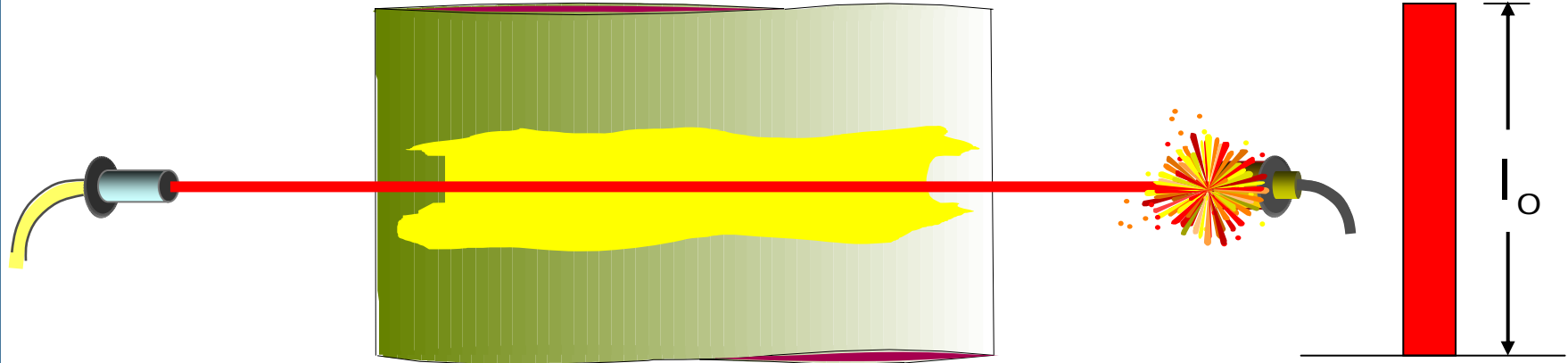
In the Region of Wavelength Absorption



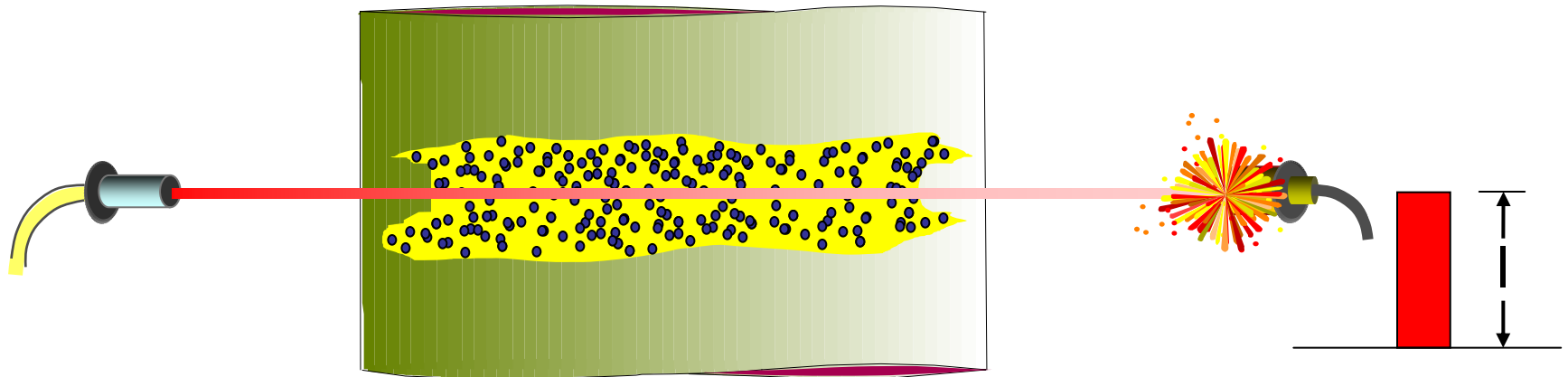


Tunable Diode Laser Measurement Technique

When no gas present...



When gas present...



Absorbed intensity, $\delta I = I_0 - I$



Tunable Diode Laser Measurement Technique

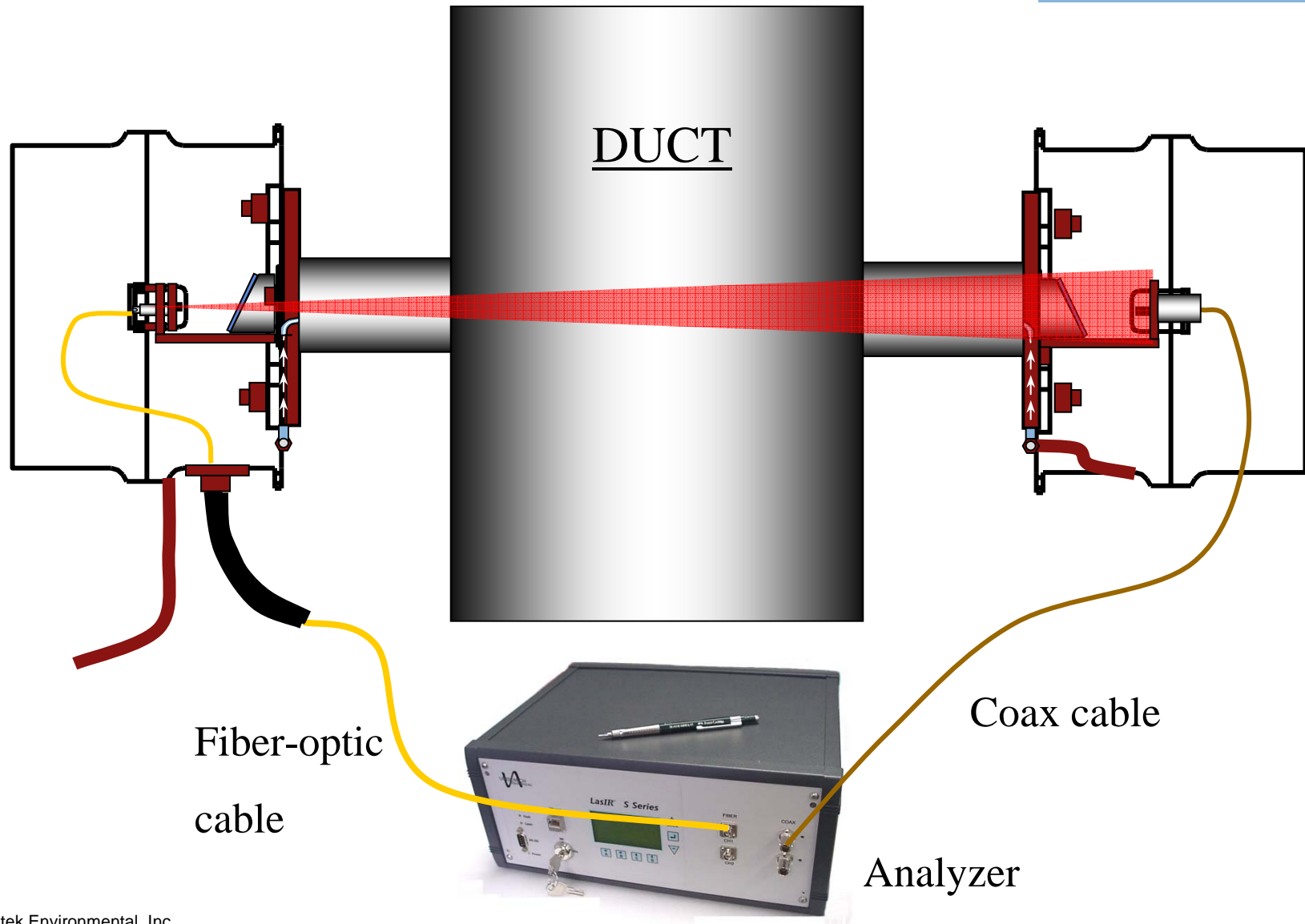
Tunable Diode Laser (TDL) Detection Limits

- **Detection limits are a factor of both path length and path measurement time and the molecule being measured.**
- **For tunable diode lasers operating in the spectral band, the detection limit is in the range of 0.1 to 5 ppm-meters.**
- **Path Length**
 - **The longer the path length, the higher the absorption and the better the sensitivity and the lower the detection limit. Therefore, longer path lengths result in better detection of low concentrations.**
- **Measurement Time**
 - **Detection limit scales approximately as the square root of the measurement time.**
 - **For example:**

**Increasing the time from one-second to one-minute
enhances the detection limit approximately seven fold**

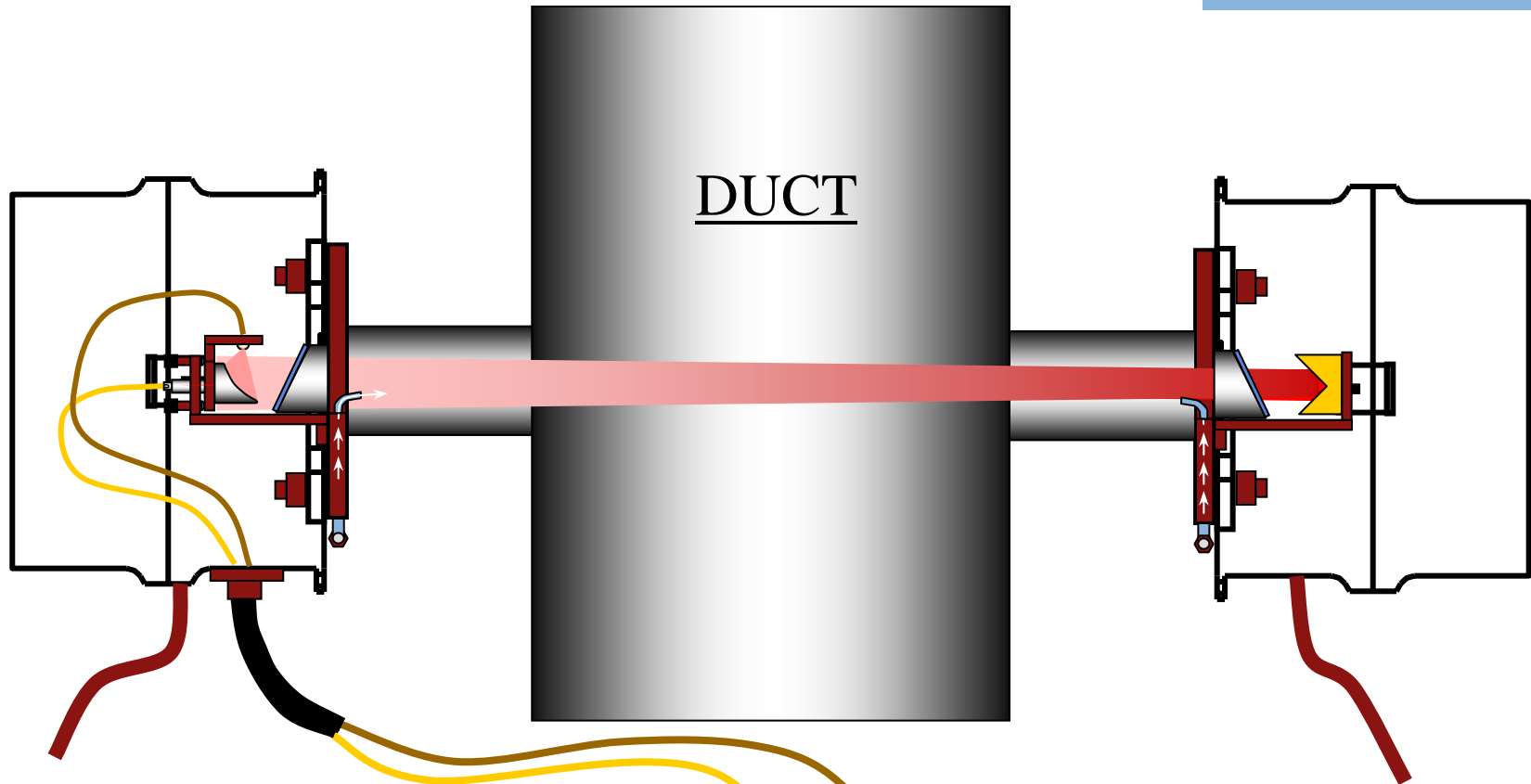


Single Pass Stack Configuration





Dual Pass Stack Configuration



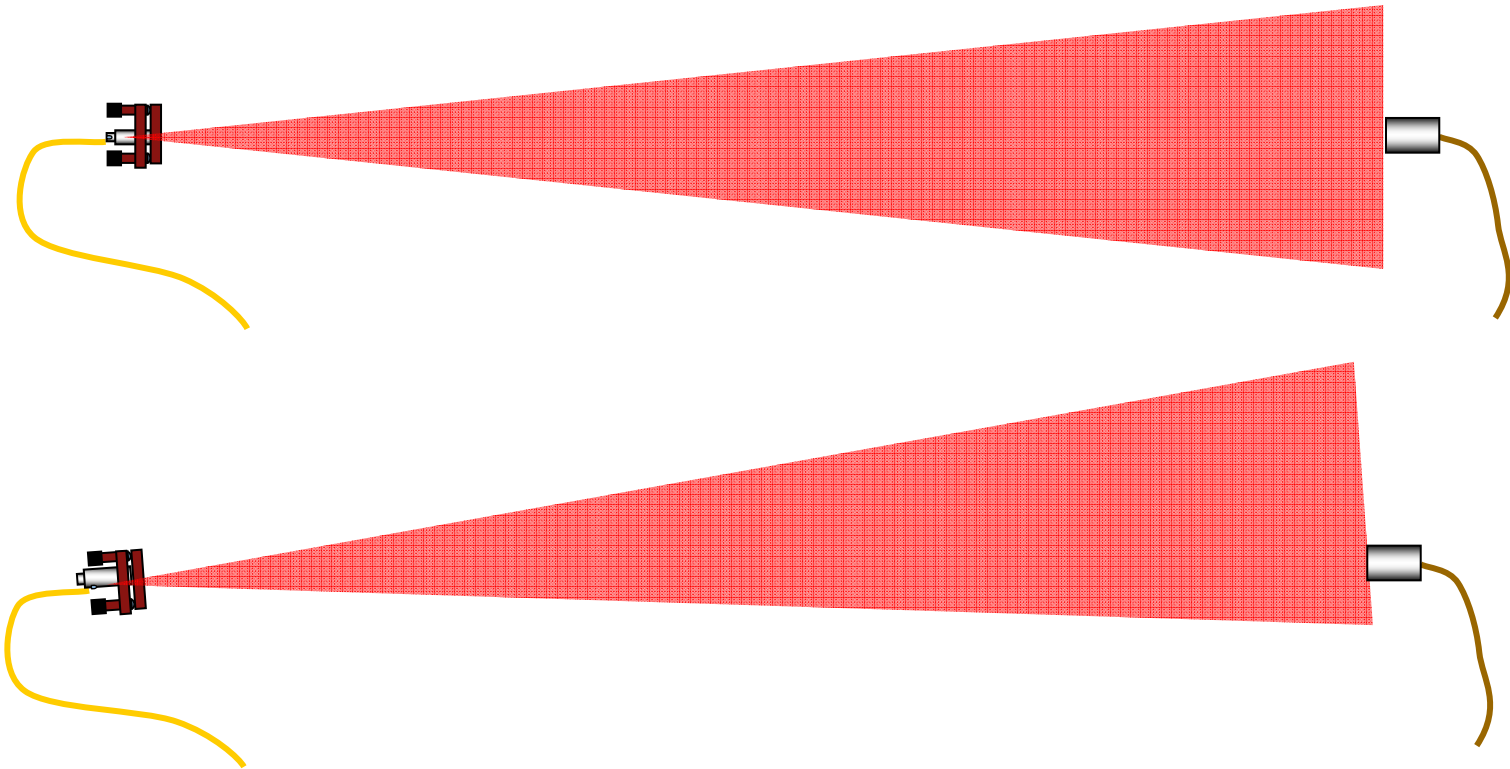
Fiber-optic
& coax cables



Analyzer



Tunable Diode Laser Measurement Technique



- Higher laser powers allow beam expansion to attain alignment stability
- By de-focusing the beam, overfill of the detector optics allows for alignment changes



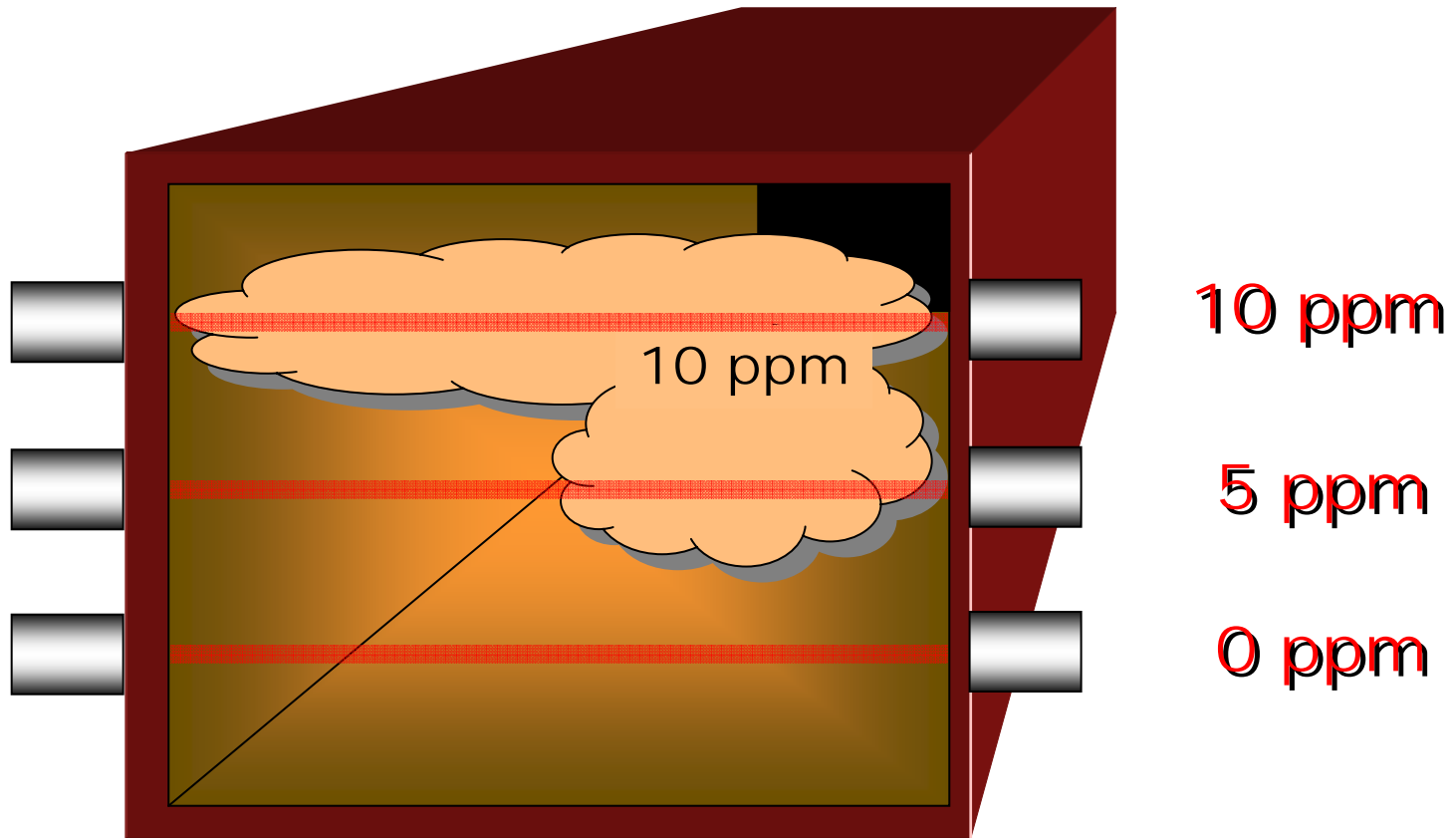
Tunable Diode Laser Measurement Technique

Multiplexed Optical Signal

- **The TDL used has a unique feature of being able to multiplex the optical signal for a multi-path array configuration**
- **Multiplexing splits the signal by time instead of power**
 - **Multiplexing sends approximately 90% of signal power to each measurement path**
 - **Beam splitting sends approximately 25% of signal power to each measurement path (4 path array)**
- **Multiplexed optical signal allows for use in heavy dust laden applications with longer path lengths**



Multi-Path Array Configuration



Measurement is integrated over path length



Tunable Diode Laser Measurement Technique

TDL Measurement Techniques

Advantages

- **Real Time Process Feedback**
- **In-situ Measurement Integrated Across Path Length**
- **Multi-Path Grid Array**
 - **Stratified applications**
 - **No Sample System Bias from Gas Transport**

Disadvantages

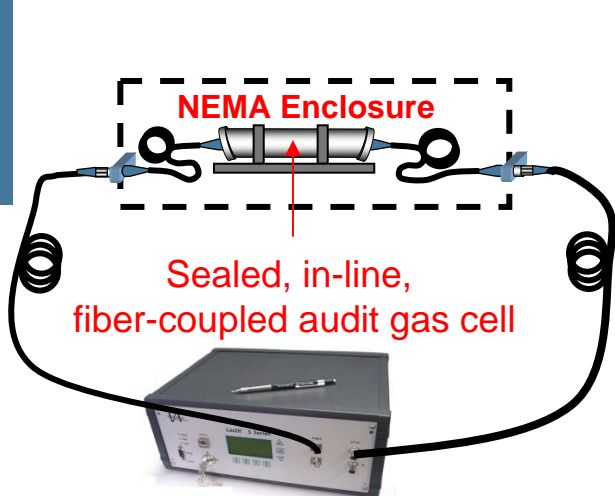
- **Alignment of Optics**
 - **Deformations in ducting due to heating and cooling can lead to misalignment.**
- **Heavy Dust Loading Applications**
 - **Must be able to transmit light across path. Multiplexed signal allows for stronger signal transmittal across path.**



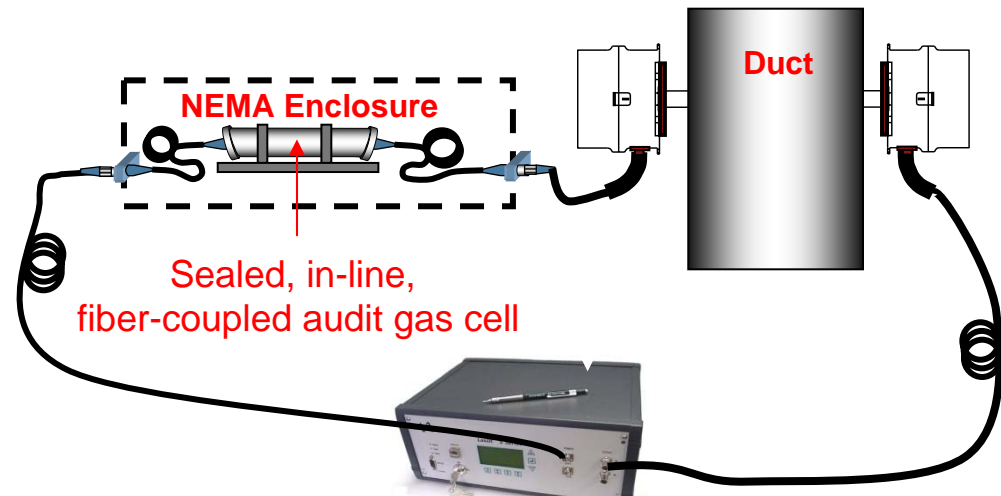
Tunable Diode Laser Audit Method

Portable External Audit Module

- Diagnostic Tool
- Dynamic Spiking
- Analyzer Isolation



Analyzer Isolation Configuration



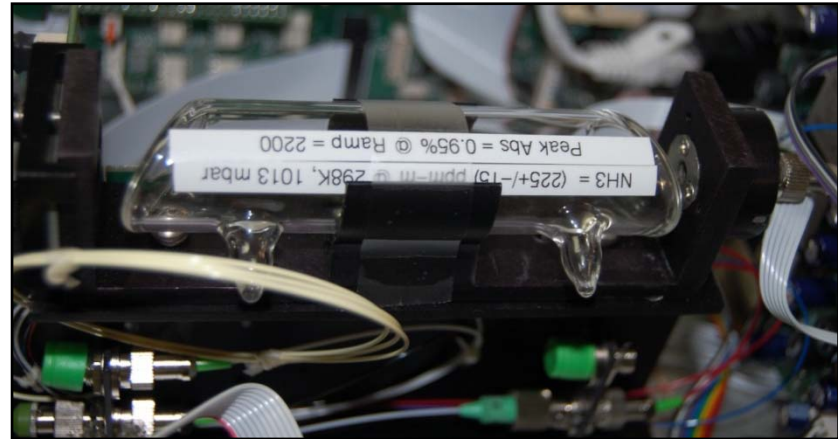
Dynamic Spiking Configuration



Tunable Diode Laser Audit Method

Internal Audit Module

- **Module spiked with known amount of target gas**
- **Isolated cell measurement**



Internal Audit Module

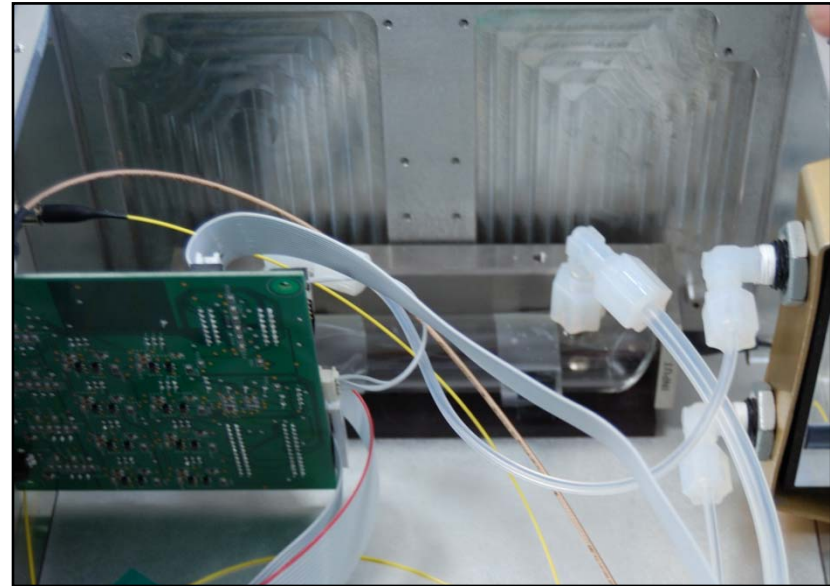




Tunable Diode Laser Audit Method

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 to difference between flow through cell and flue gas temperatures**





Tunable Diode Lasers

Case Examples of TDL Installations

- **SCR/SNCR Ammonia Slip Monitoring**
- **HCl Monitoring**

- **TDL Installations:**
 - **Coal Fired Boiler HCl Measurement on Dry FGD Scrubber Stack**
 - **Brick Manufacturer HCL Stack Measurement**
 - **Incinerator HCl Measurement**
 - **Digester Gas H₂S Measurement in Fuel Stream**
 - **Aluminum Smelter HF Measurement**
 - **Coal Fired Boiler SNCR NH₃ Measurement**



Tunable Diode Lasers

Practical Applications for the TDL

- **SCR/SNCR Ammonia Slip Monitoring**
 - **Compliance**
 - **Single Point Monitor**
 - **Internal Audit Cell**
 - **Daily span checks meet regulatory requirements**
 - **Flow-through Audit Cell**
 - **Meets requirements of Preliminary Performance Specification 1 (PPS001)**
 - **Process Control/Feedback**
 - **Multi-point arrays with single analyzer**
 - **Multiplexed signal allows for multiple monitoring points in dust laden processes**
 - **Useful for SCR tuning and monitoring catalyst bed degradation over time**



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**



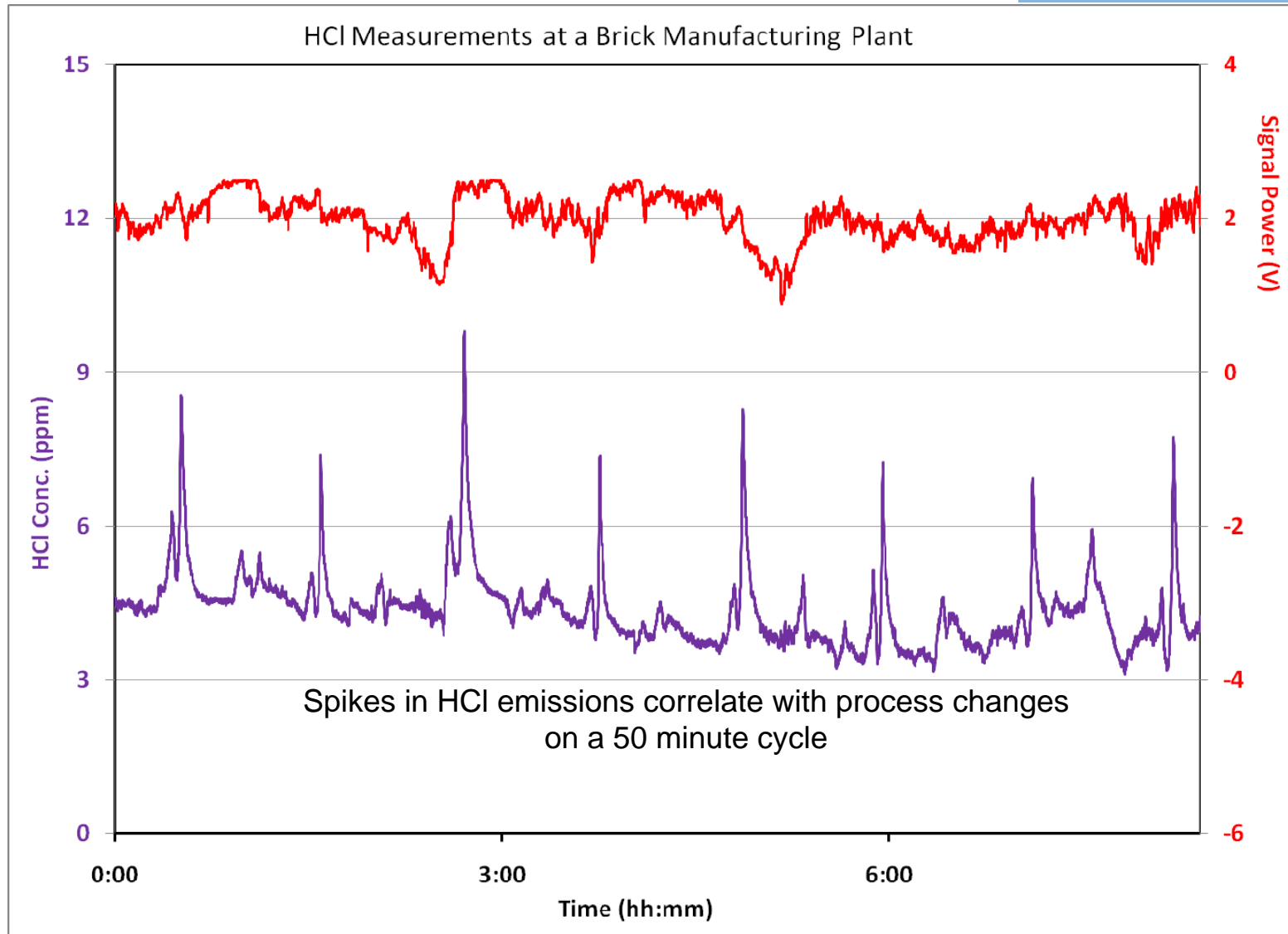
Brick Manufacturer - HCl Application

Process HCl Measurement for Brick Manufacturer in Georgia

- ***Application Summary***
 - **Process control measurement**
 - **Ammonia injection into process for brick coloring. SO₂ also present**
 - **5 ¾ foot detection path with dual pass optics for 11 ½ foot effective detection path**
 - **70 foot stack elevation of optics**
 - **Constant process background of 4 ppm HCl with spike up to 10 ppm**
 - **Blower ports left open to draw ambient air past windows**
 - **Permanent installation and operation since January 2011**
 - ***Lessons Learned***
 - **Initial installation issues with ammonia bisulfate coating windows in 20 minutes. Change to heated optics windows allows for two week operation before cleaning windows**
 - **HCl spikes track with opening of kiln door every 50 minutes**
 - **Since background level is present, auto background subtraction can't be used**



Brick Manufacturer - HCl Application





Additional Applications

Digester Gas H₂S Measurement - Denver, CO

- **Application Summary**
- **Measurement of H₂S in methane (digester gas)**
- **Original system utilized in-situ analyzer configuration - multiple year operation**
- **Original extractive system with a 12 meter path length, being replaced with extractive system - pairing TDL with and extractive Harriot multi-pass cell with effective path length of 0.8 meters**
- **Dual range with 0-600 ppm low range and 0-3000 ppm high range**
- **Class 1, Div 2 application**
- **35% moisture**

**Applicability to Utility HCl Applications*

- **WFGD Stack Moisture**
 - **Full or dilution extractive sampling can be utilized**
 - **Extractive cell can be operated at reduced pressure**

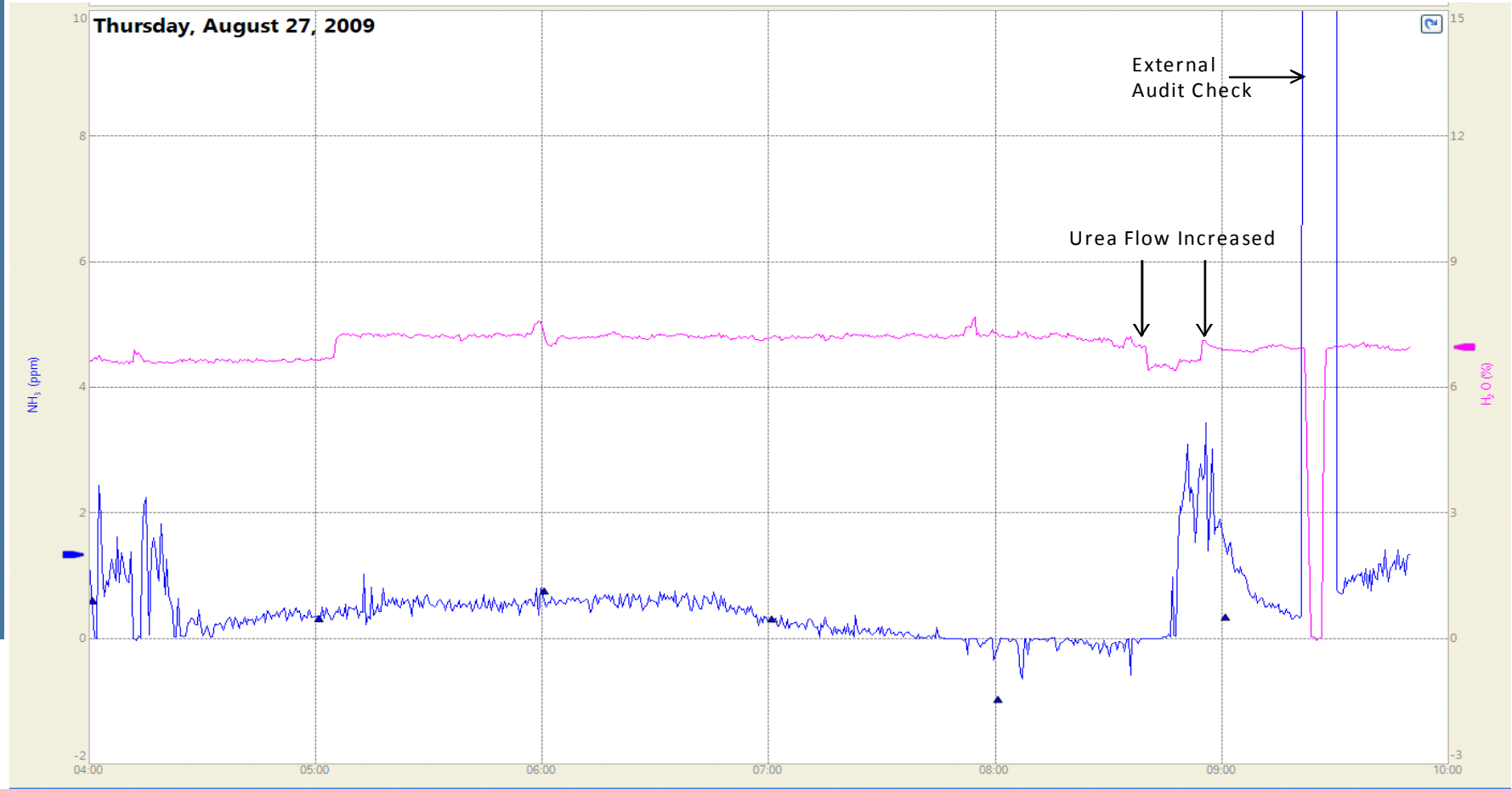


Coal Fired Boiler- SNCR Ammonia Slip Application





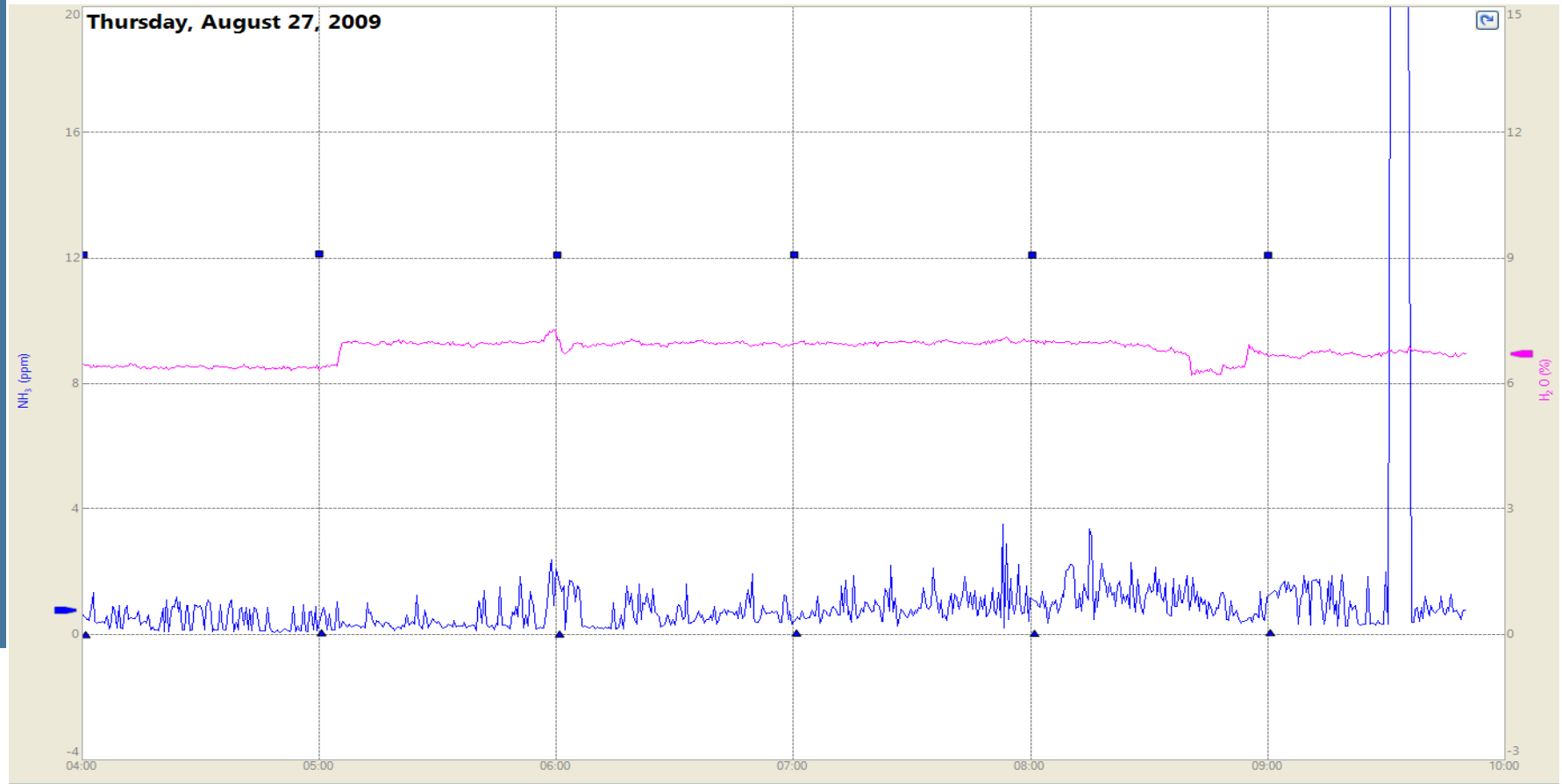
Coal Fired Boiler- SNCR Ammonia Slip Application



Unit 1, TDL Channel 1 Ammonia Slip Measurement



Coal Fired Boiler- SNCR Ammonia Slip Application

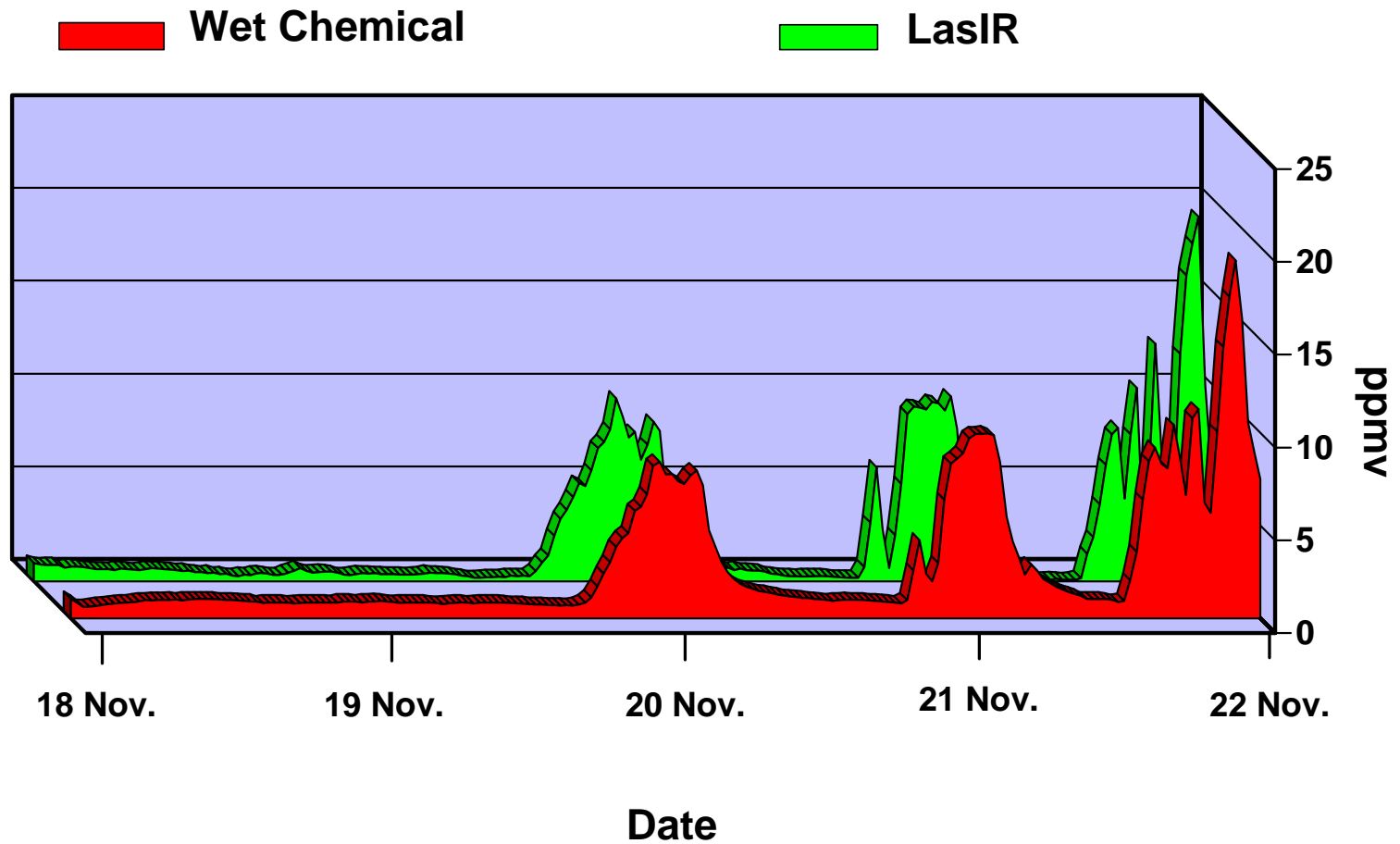


Unit 1, TDL Channel 2 Ammonia Slip Measurement



Aluminum Smelter - HF Application

HF Stack Measurements taken at an Aluminium Smelter





Questions?

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