REINHOLD ENVIRONMENTAL Ltd.

2012 NOx-Combustion Round Table & Expo Presentation

February 13-14, 2012, in Columbus, OH / Hosted by AEP

Instrumentation for Optimizing Combustion & SCR Performance

a technical solution to meet every need…

CEMTEK Instruments Inc.
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908-474-9630
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PERFORMANCE OPTIMIZATION

With the latest round of EPA sanctioned reductions in SO2 & NOx the reduction systems require tighter control utilizing continuous monitoring.

The need to reduce CO2 & Particulate matter also bring further requirements for more stringent operating procedures.

Over the last two decades we have seen a cycle of emissions reduction followed by Efficiency improvements in the various process components.

Currently we see a need for both the implementation of process additions for meeting the regulated limits and the need to improve process monitoring currently in operation.

PERFORMANCE OPTIMIZATION

What operations personnel are looking for is cost effective measurement techniques that provide good accurate data in real time.

There are a number of manufacturers providing a variety of techniques that fill some of the niches, while some remain unfulfilled.

New technologies are on the cusp of making some of these measurements a reality.

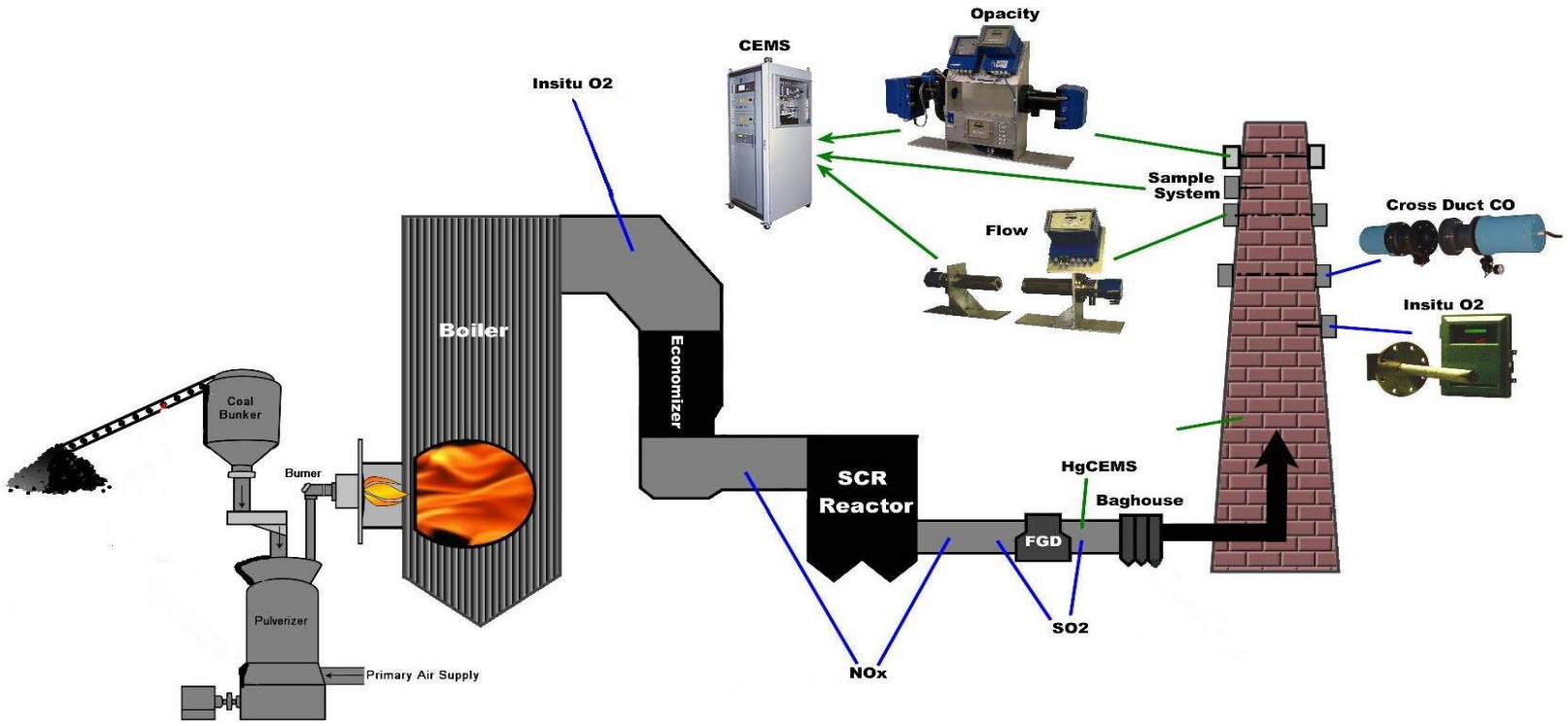
PERFORMANCE OPTIMIZATION

INCREASE EFFICIENCY & REDUCE EMISSIONS

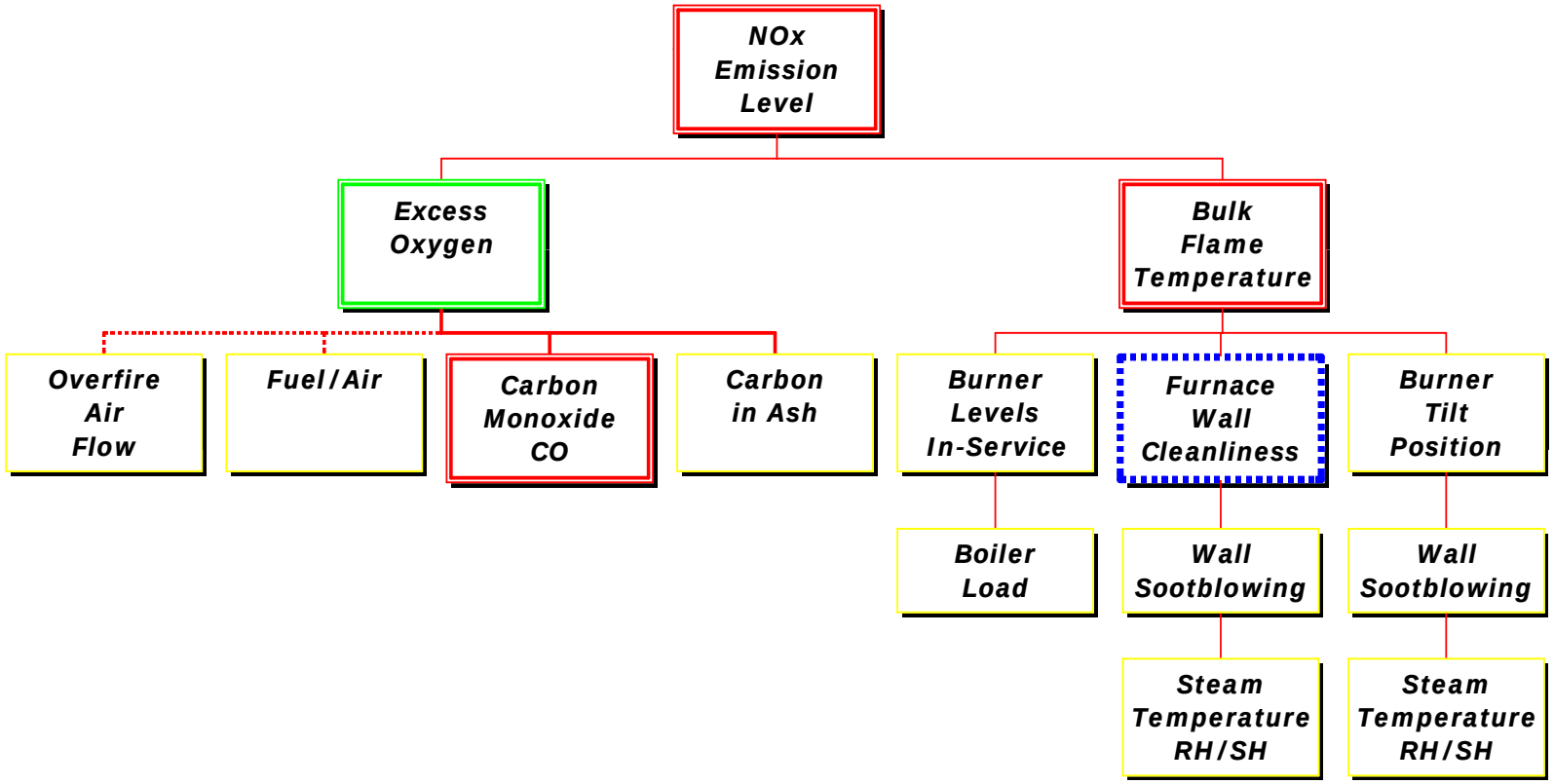
MEASUREMENTS:	LOCATIONS:
➢ FEGT, CO, NO, O2 CO2	Furnace Exit,
➢ O2, CO, NO, SO3	Economizer Inlet,
➢ CO2, NO, CO, O2	SCR Inlet/Outlet,
➢ NOx, NH3, SO3	Air Heater Inlet,
➢ SO2, SO3, HCL	Scrubber Inlet/Outlet.

PERFORMANCE OPTIMIZATION

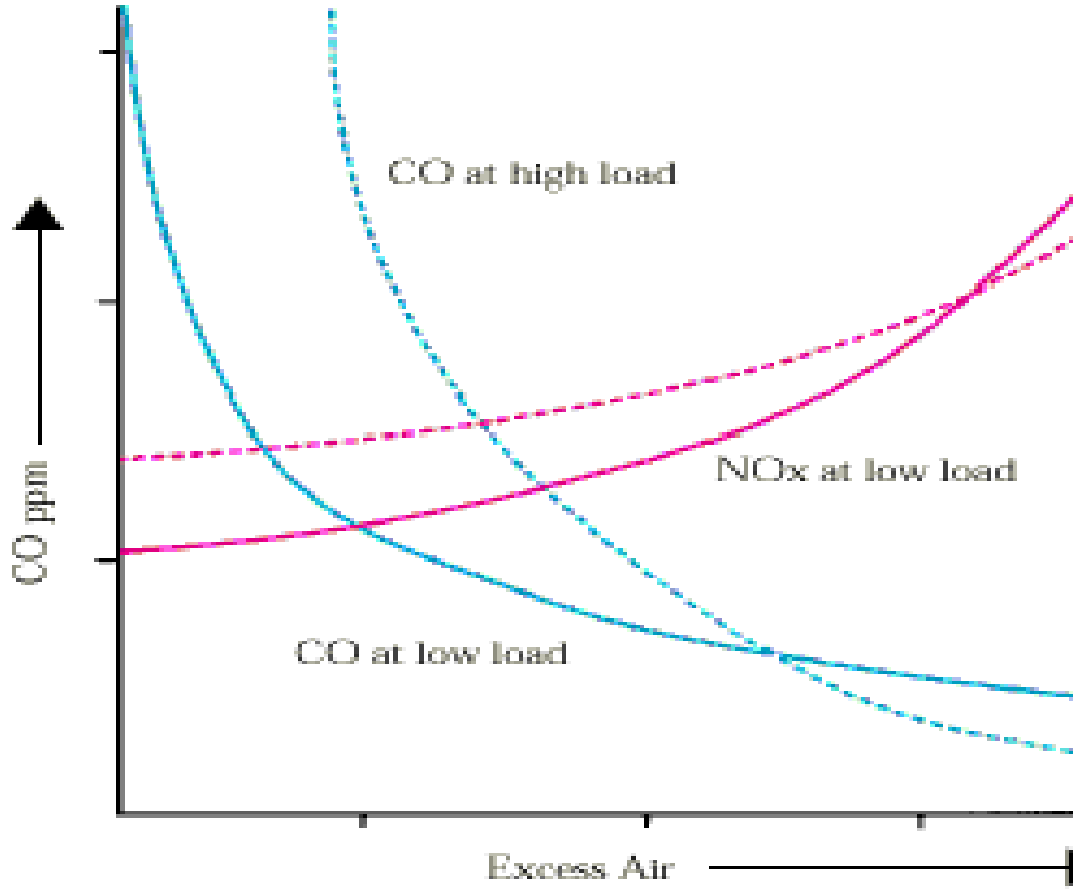
Basic Plant Design and Equipment



NOx Contributing Factors
Areas for Reduction of Excess Air



CO versus NOx



Post Combustion NO_x Reduction

- Selective non-catalytic reduction (SNCR)
- Selective catalytic reduction (SCR)
- Common requirement: introduction of NH_3

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$$

$$2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O$$

Analyzer Techniques

Chemiluminescence (Chemical Light) a measurement technique for NO/NOx that measures the light given off as a result of the reaction between NO and Ozone. The light output is proportional to the concentration of NO. NO_2 is converted to NO using a high temperature catalytic converter. NO_2 does not react with Ozone so it must be converted to NO.

UV Absorption a measurement technique that uses a UV spectrometer to measure a particular wavelength where the gas of interest absorbs (measurement) and a wavelength where the gas of interest does not absorb (reference). Most often used for SO_2 measurement in high concentrations.

Analyzer Techniques (cont)

NDIR non-dispersive Infrared, a measurement technique that compares a reference cell and measurement cell. The reference cell is sometimes filled with N2 or another compound that is present in the sample gas mixture that is known to interfere with the gas of interest i.e. CO2/N2 in the reference cell when measuring CO. Uses optical band-pass filters to isolate the area of the spectrum for measurement of a specific compound. Can measure many IR absorbing compounds.

TDL Tunable Diode Laser technology operating in the near infrared region utilizes the ability for gas species to be isolated by a single wavelength and measured accurately to very low concentrations by tuning a single diode to that specific wavelength

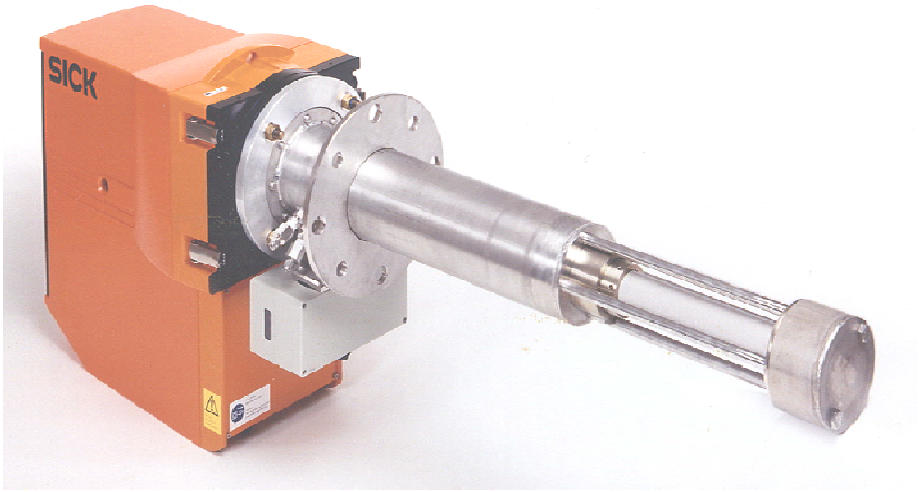
IN-SITU PROBE

- MEASURES A SINGLE POINT
- MEASUREMENT: CHEMI ,UV, NIDR, GFC, TDL, ,ZiO_2 ,
- EASY TO CALIBRATE
- POOR SENSITIVITY AT LOW CONCENTRATIONS
- CAN BE MAINTENANCE INTENSIVE IN VARIOUS APPLICATIONS
- CAN BE SUBJECT TO CROSS-SENSITIVITY

CO MONITORING WITH CATALYTIC SENSORS

- Insitu O2 & COe has had various levels of success in coal fired applications

UV ABSORPTION TECHNOLOGY

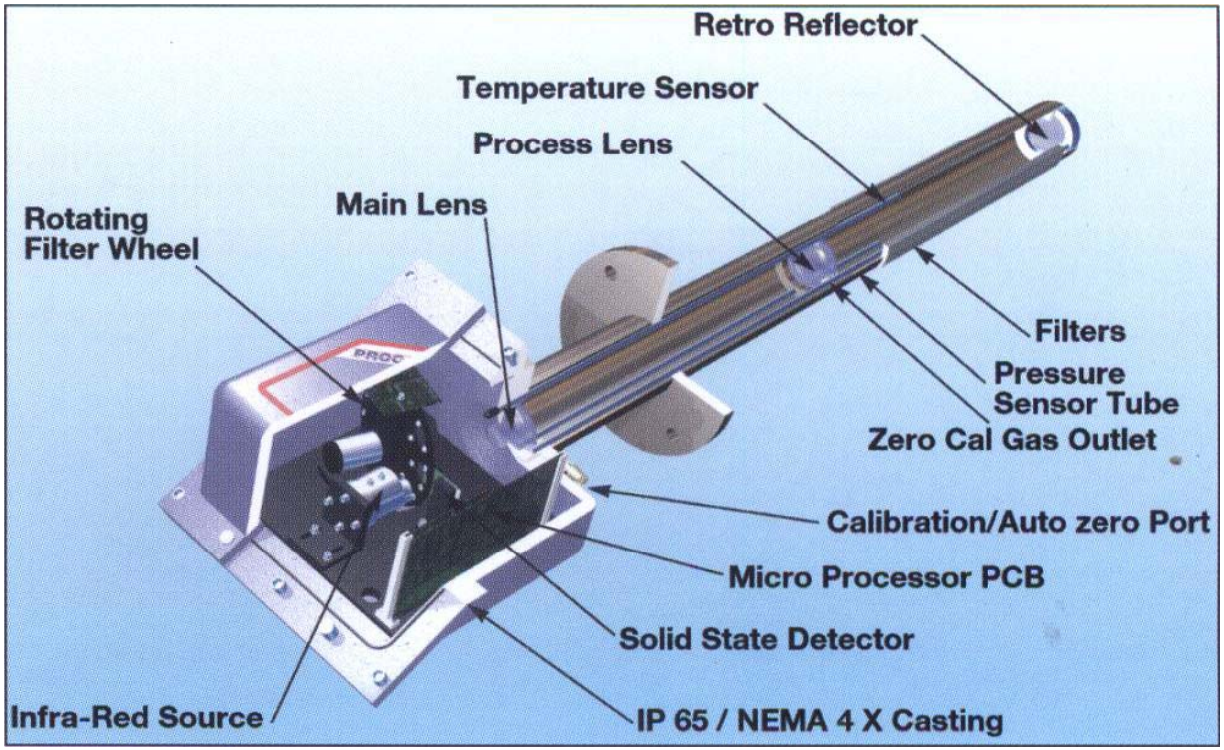


Measurement for NO, SO2, NH3

Maintenance and cross sensitivity have to be taken into account with UV type analyzers

NDIR Gas Cell Correlation Method

Multi Gas Analysis CO,CO2,H2O,NO, SO2



EX-SITU - CLOSE COUPLED

- CLOSE COUPLED DILUTION EXTRACTIVE
- ELECTRO-CHEMICAL/CATALYTIC
- HOT WET EXTRACTIVE
- NDIR/GFC/DOAS/FTIR
- HOT WET EXTRACTIVE
- USEFUL IN UNUSUAL SAMPLING CONDITIONS
- EASY TO CALIBRATE

HOT WET CLOSE COUPLED EXTRACTIVE

- Typically utilizes Chemiluminescense for NOx & NH3 if being used for SCR monitoring
- NDIR Gas Filter Correlation is used for multiple gas measurements such as NO, SO2, CO, CO2, HCL, H2O

CLOSE COUPLED NOx ANALYZER

- This analyzer is specifically designed for use in combustion process applications:
- SCR inlet/outlet monitoring applications.
- Low NO_x burner tuning,

Consisting of 3 Components

1. The Analyzer Controller which houses the electronics and the NO Sensor.

2. The Probe which contains the dilution block and optional Oxygen Sensor along with the NO2 converter if required.

3. The self-limiting heated interconnect umbilical which contains the sample line, calibration gas line, thermocouple cables and power cables.

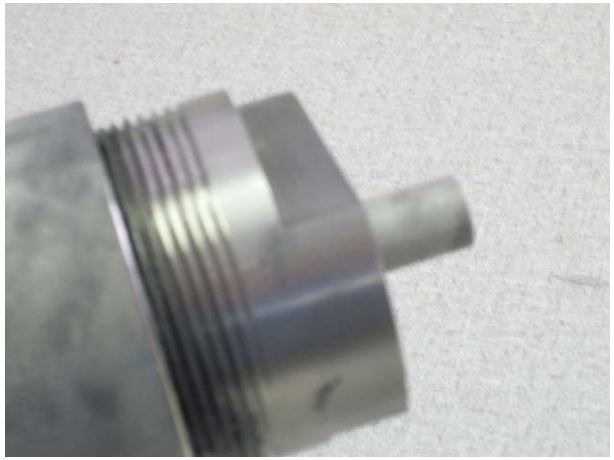
CLOSE COUPLED NOx ANALYZER

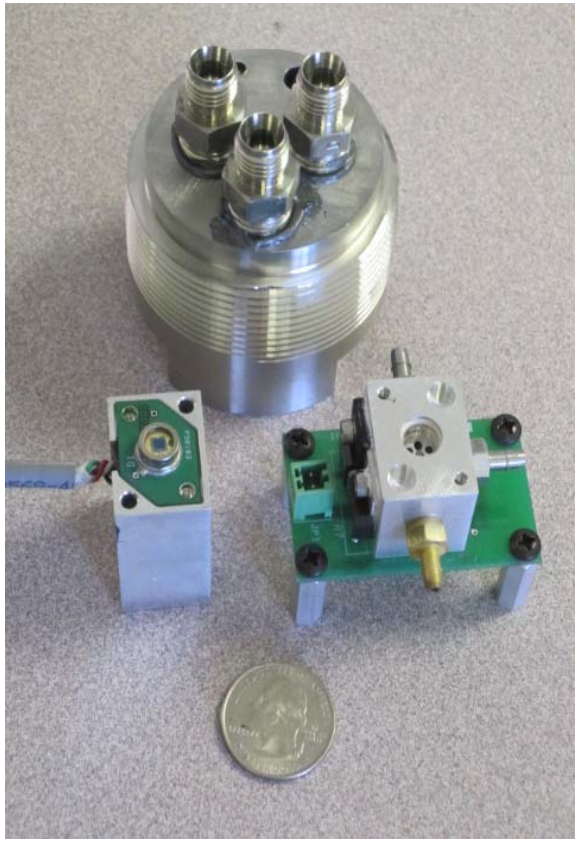
In Stack Dilution block/probe design

- Highly integrated pneumatics combines analyzer and low flow / low dilution probe into a single instrument.
- Heated to ~350 C to avoid condensation of acid gases before dilution, also provides orifice temperature control
- Heated dual-stage filtration and low flow avoids pluggage.
- Through Probe Calibration for full system integrity.

CLOSE COUPLED NOx ANALYZER

- Fully immersed, temperature controlled sample orifice
- Located at tip of probe for very fast response and virtually no time lag
- Less than 10 seconds combined
- Solid state detector for fast accurate measurement in harsh conditions.

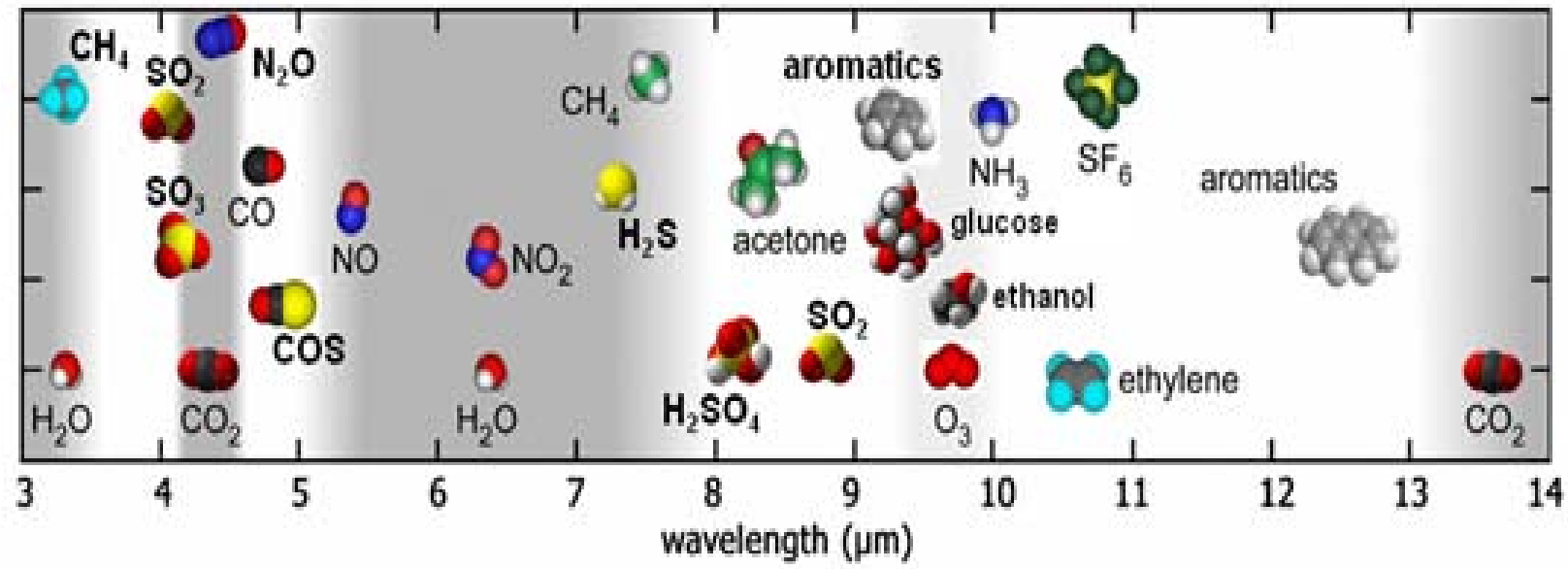




IN-SITU ACROSS DUCT

- CROSS-DUCT (SINGLE OR DOUBLE PASS)
- SAMPLES ACROSS ENTIRE DUCT
- MEASUREMENT: NDUV/NDIR/GFC/TDL/DOAS
- APPLICATION DEPENDENT ON PERFORMANCE IN WET OR DUSTY LOCATIONS
- LOW CONCENTRATION MEASUREMENTS GAS DEPENDENT

GAS SPECIES OF INTEREST



LASER SPECTROSCOPY

LASER ABSORPTION SPECTROSCOPY

- EPRI STUDIES FOR NEW GAS SPECIES SUCH AS CO, NO, NO2,HCL ARE ON GOING.
- INDUSTRY HAS BEEN SEARCHING FOR THE BEST MEASUREMENT TECHNOLOGY TO OVERCOME THE DIFFICULTIES OF MEASUREMENTS IN THE HARSH CONDITIONS ASSOCIATED WITH COAL FIRED BOILERS.
- BREAKTHROUGH WITH TDL & CASCADE LASERS ARE LOOKING PROMISING FOR CO, NO, NO2,SO2, SO3.
- FOLLOWING THE RELATIVE SUCCESS OF THESE TECHNIQUES FOR NH3 & HCL MEASUREMENTS.

Improving SCR/SNCR Performance with the Latest Continuous Monitoring Techniques

Ammonia Slip Monitoring Using Tunable Diode Laser Spectroscopy Detection Principles

a technical solution to meet every need...

CEMTEK Environmental Inc.
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www.cemteks.com

NH_3 & HCl Monitoring

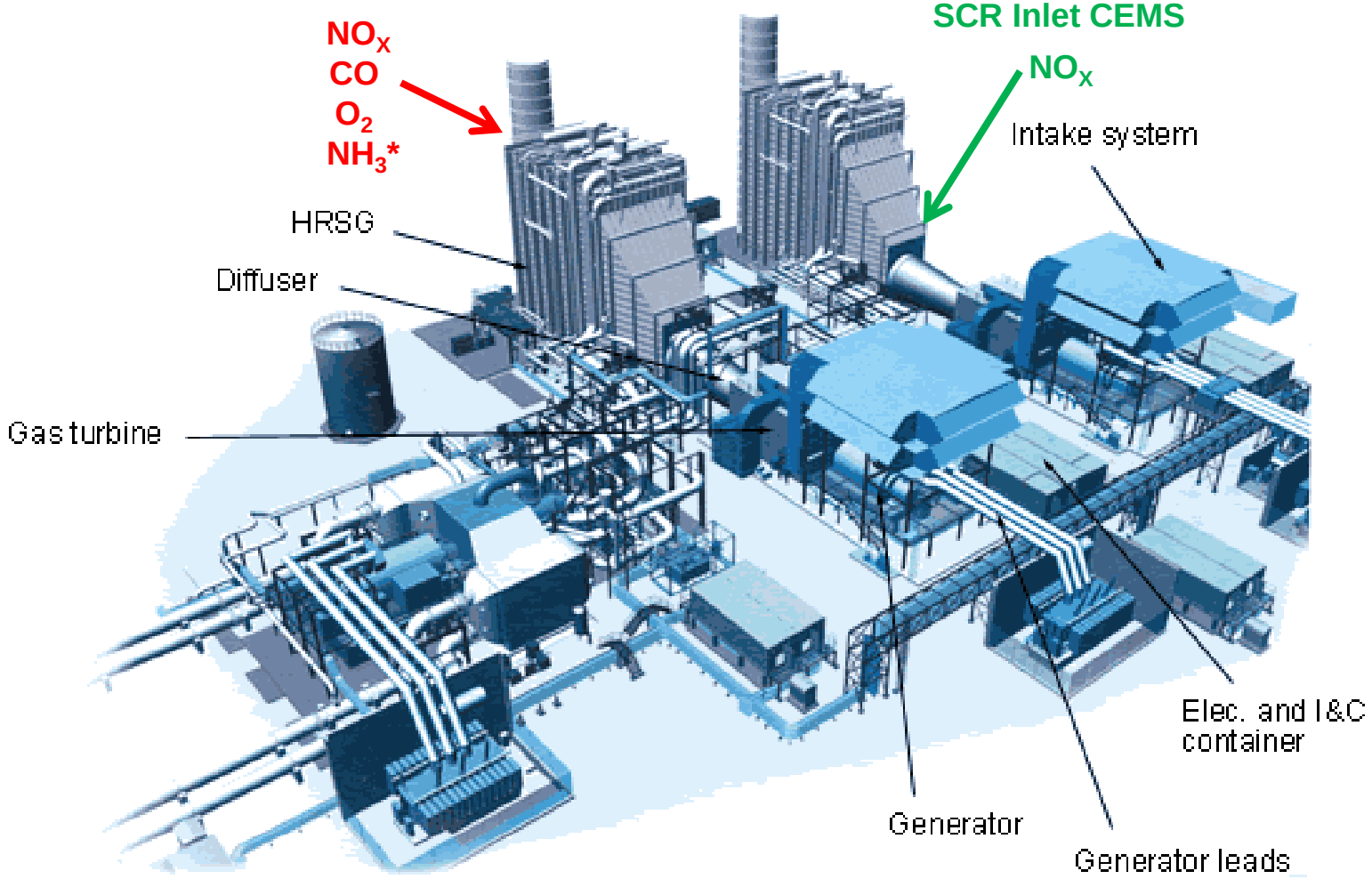
Purpose for monitoring Ammonia (NH_3) Slip

- **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

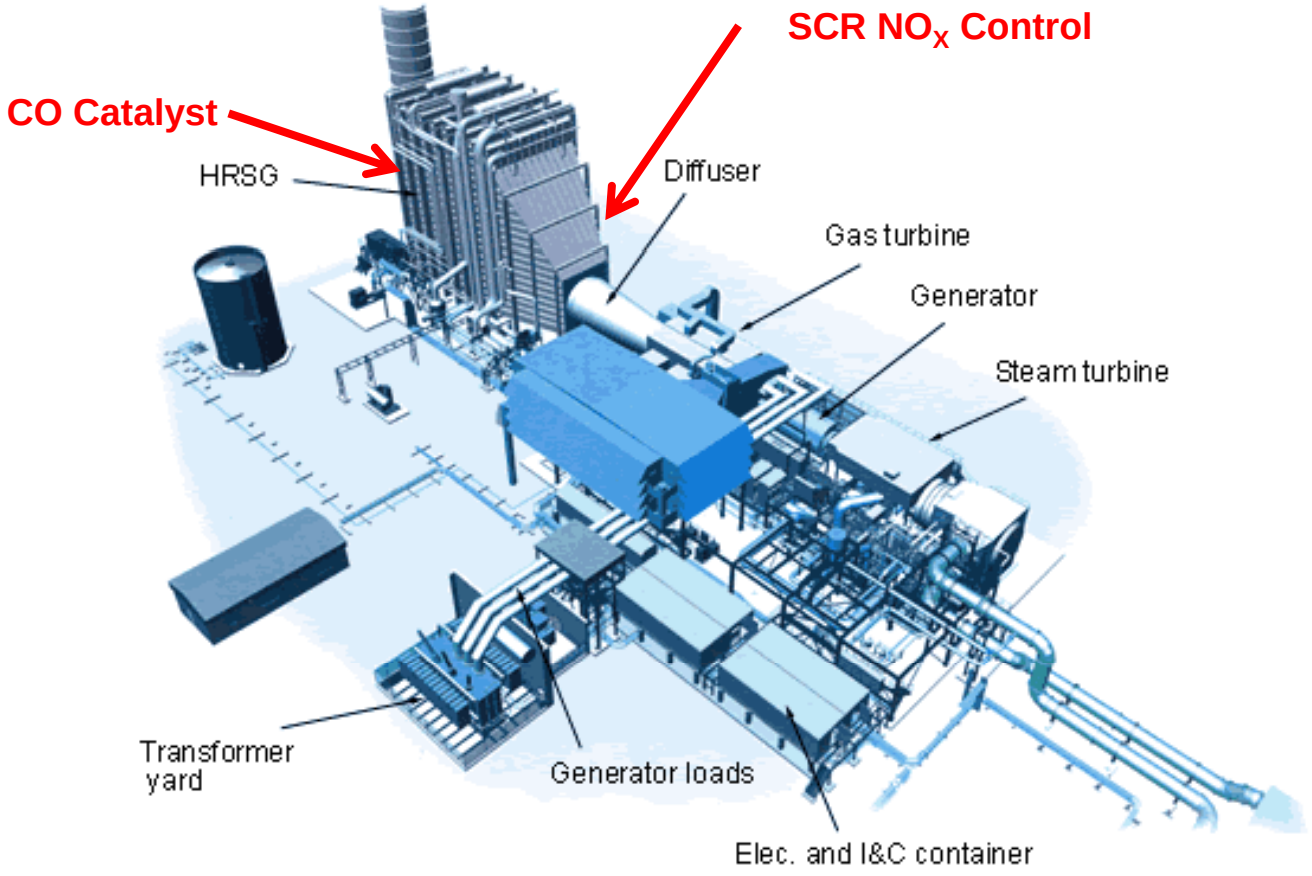
- **Regulatory emissions limits becoming more common requirements in air permits**
- **New rules call for continuous monitoring (MATS, Cement MACT)**

Gas Turbine Process Diagram



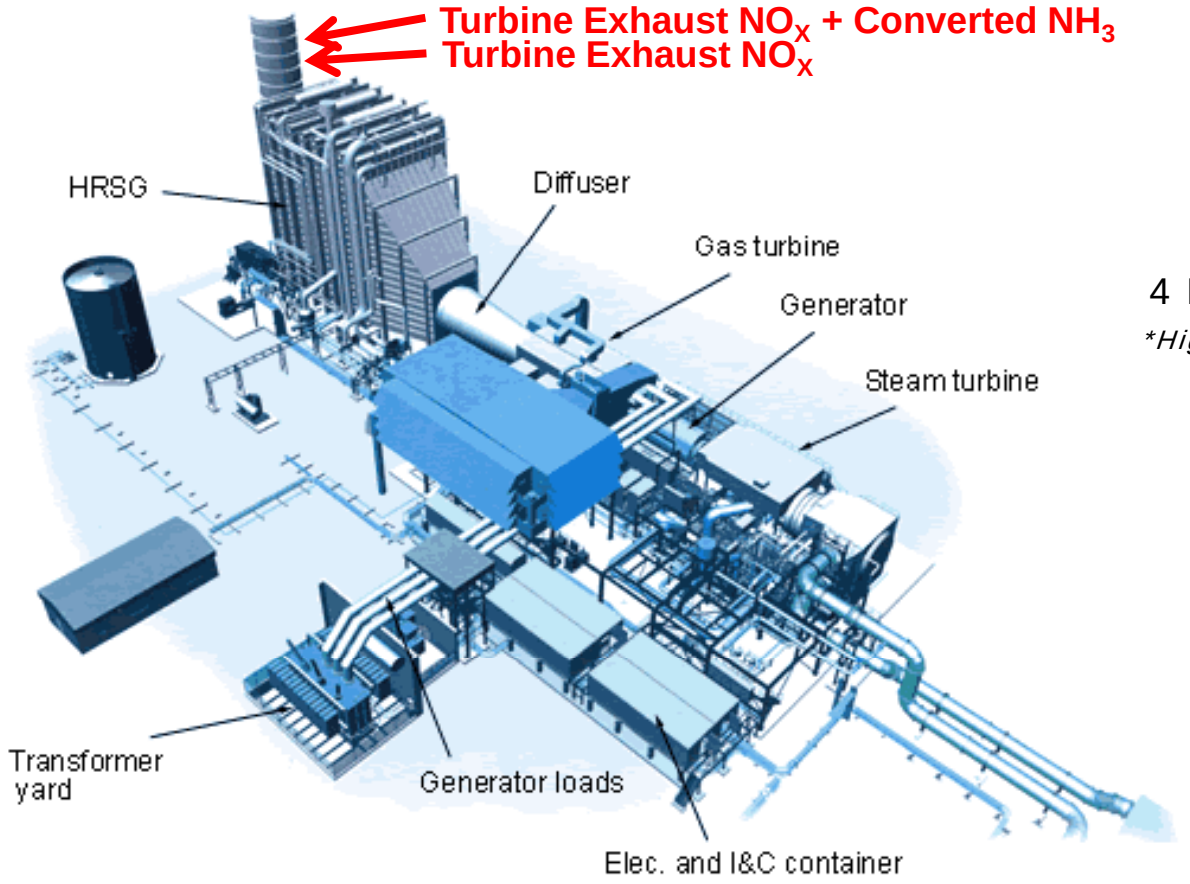
Gas Turbine
Air Quality Control Systems

Natural Gas Fired Turbine



Conventional CEMS Ammonia Slip Measurement Techniques

Differential NO_X/NH_3 Converter Method



On Stack Converter

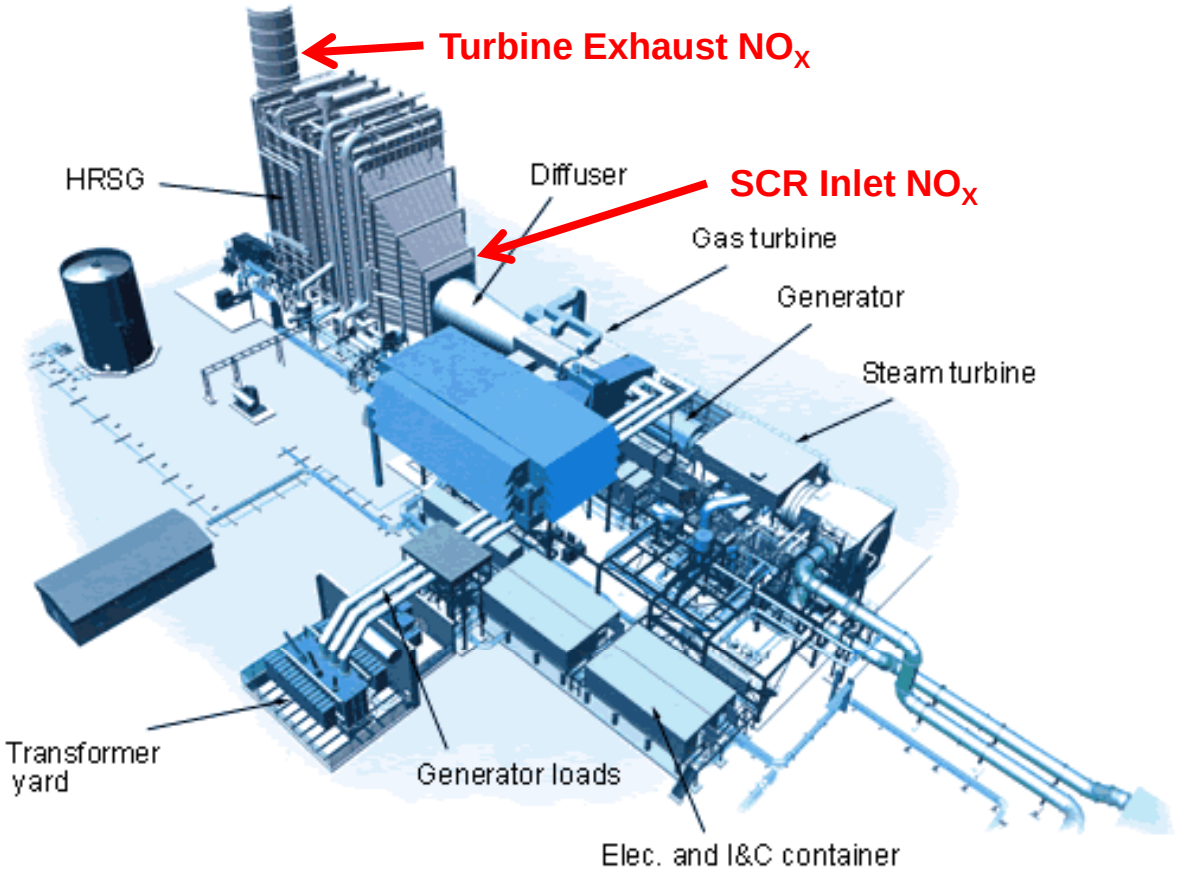
$4\ NH_3 + 5\ O_2 = 4\ NO + 6\ H_2O$

**High temperature catalyst*

NH_3 slip (ppm) = NO_X (ppm) (total converted) – NO_X (ppm) (unconverted)

Conventional CEMS Ammonia Slip Measurement Techniques

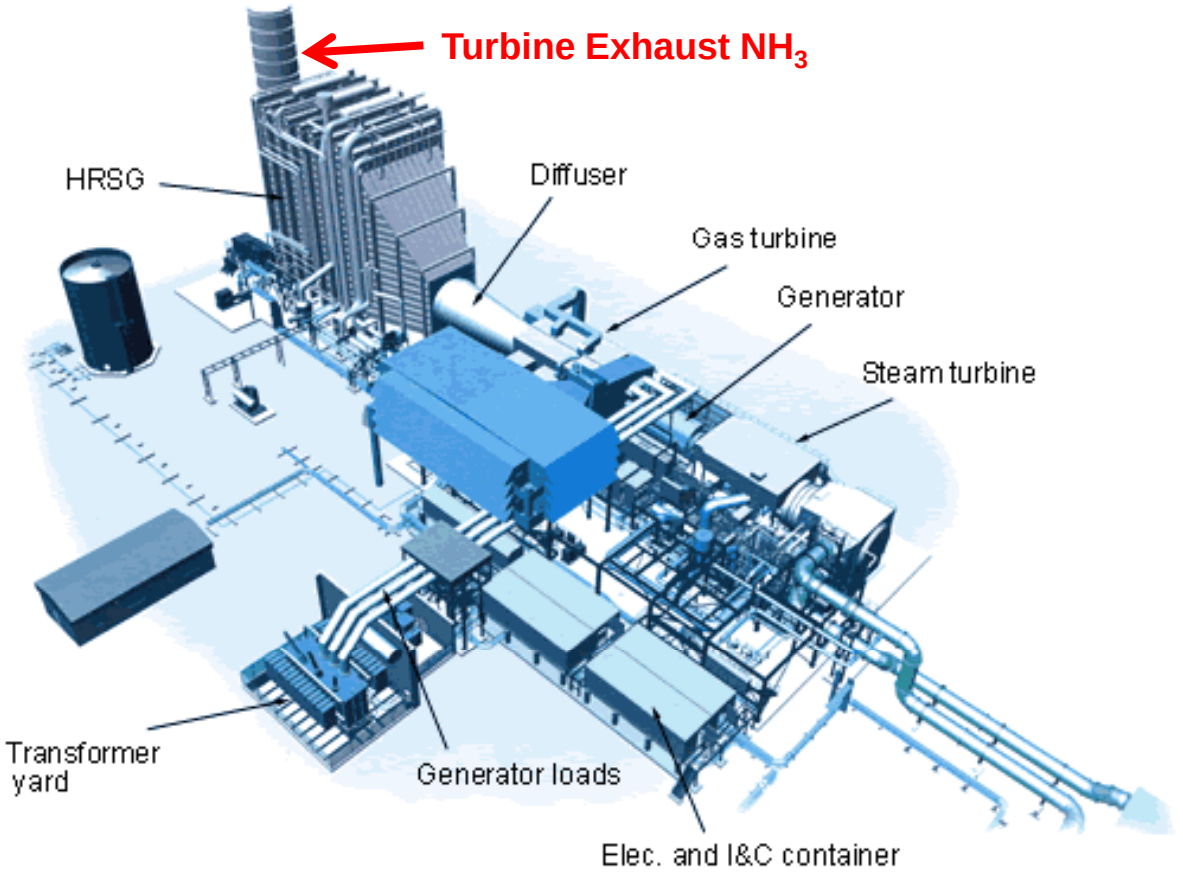
Inlet/Outlet Differential NO_X Method



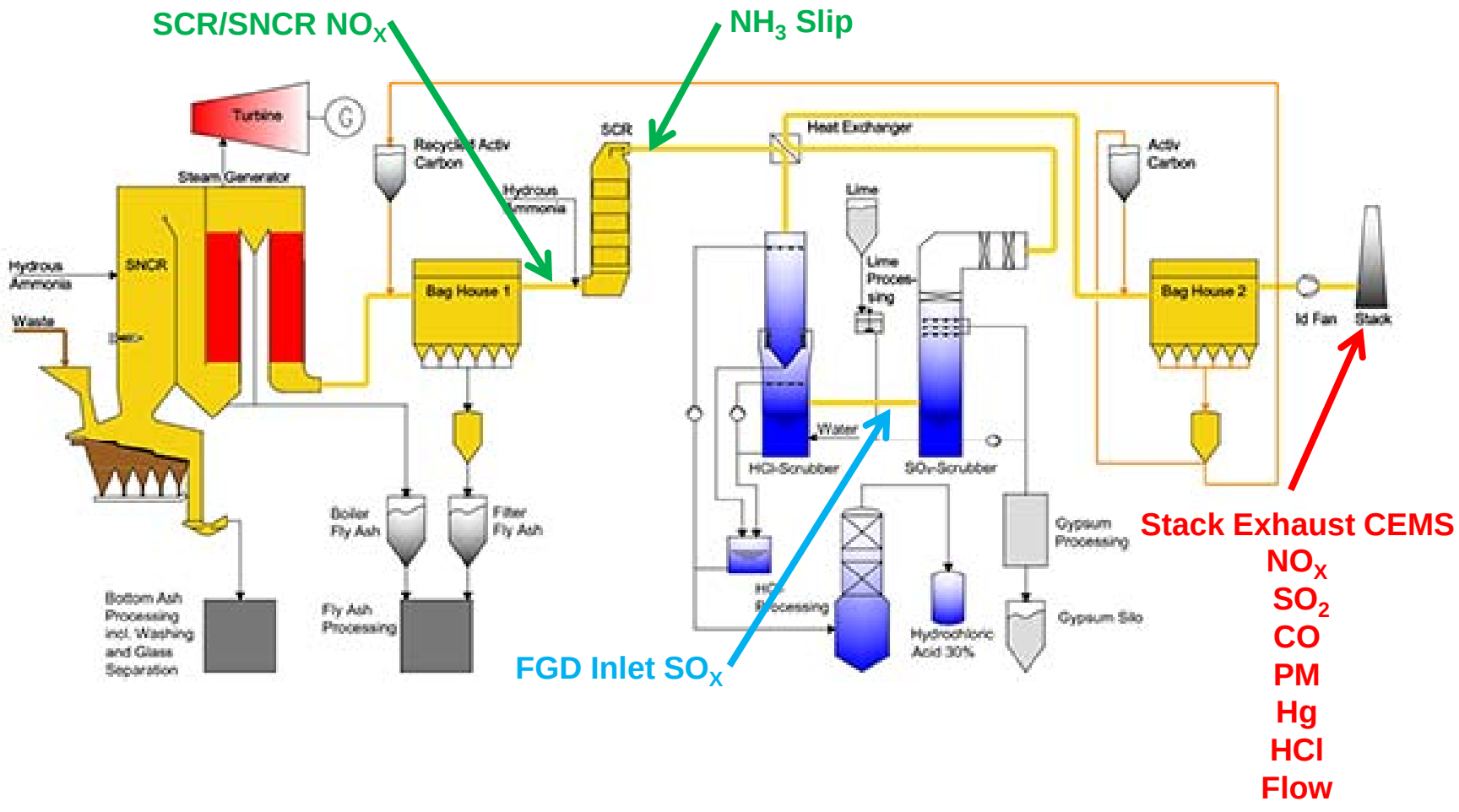
NH_3 slip = NH_3 fed – (NO_X in – NO_X out)

Conventional CEMS Ammonia Slip Measurement Techniques

Direct NH_3 Measurement Method

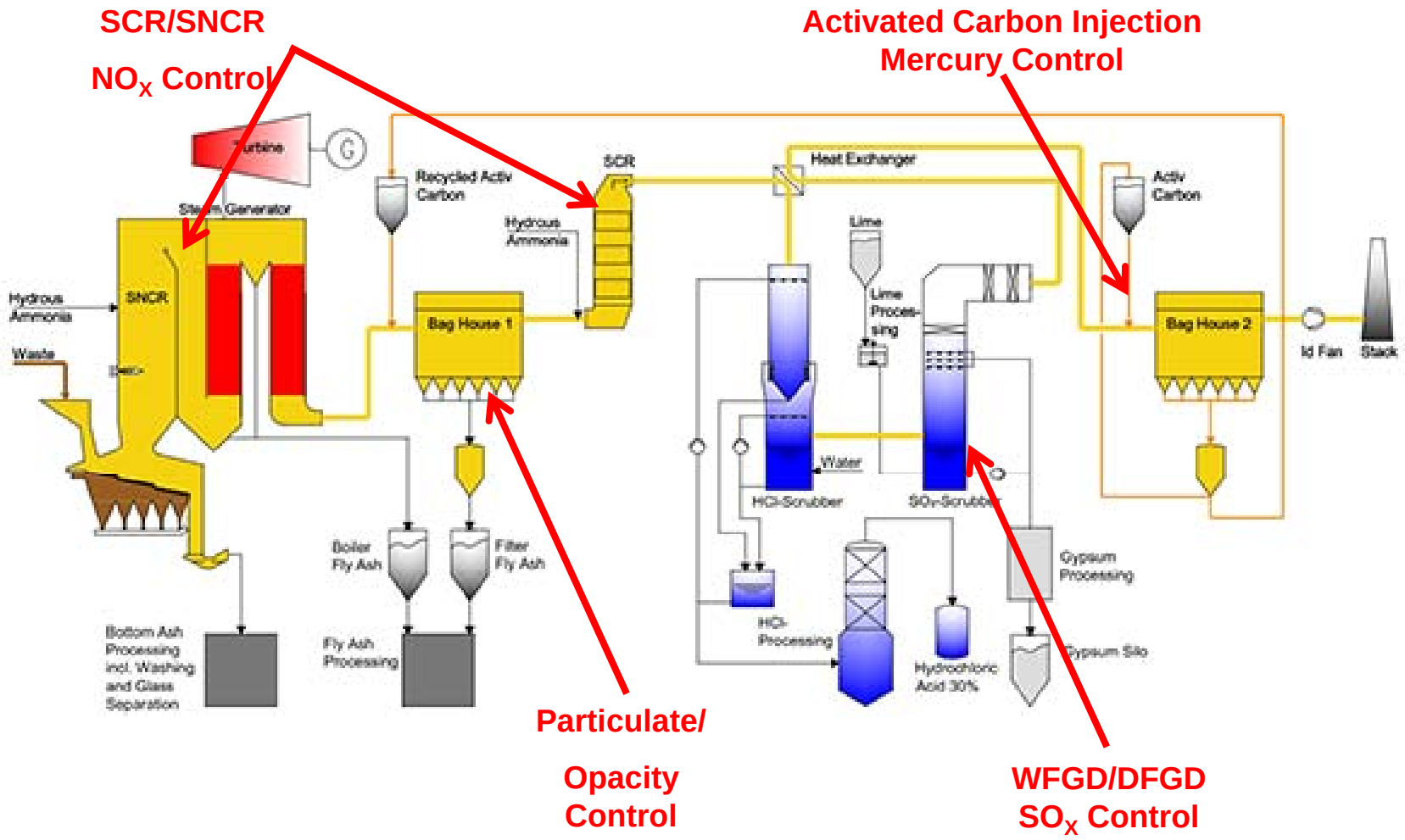


Coal Fired Utility Boiler Process Diagram



Regulatory Compliance CEMS **Compliance/Process CEMS** **Process CEMS**

Coal Fired Utility Boiler Air Quality Control Systems

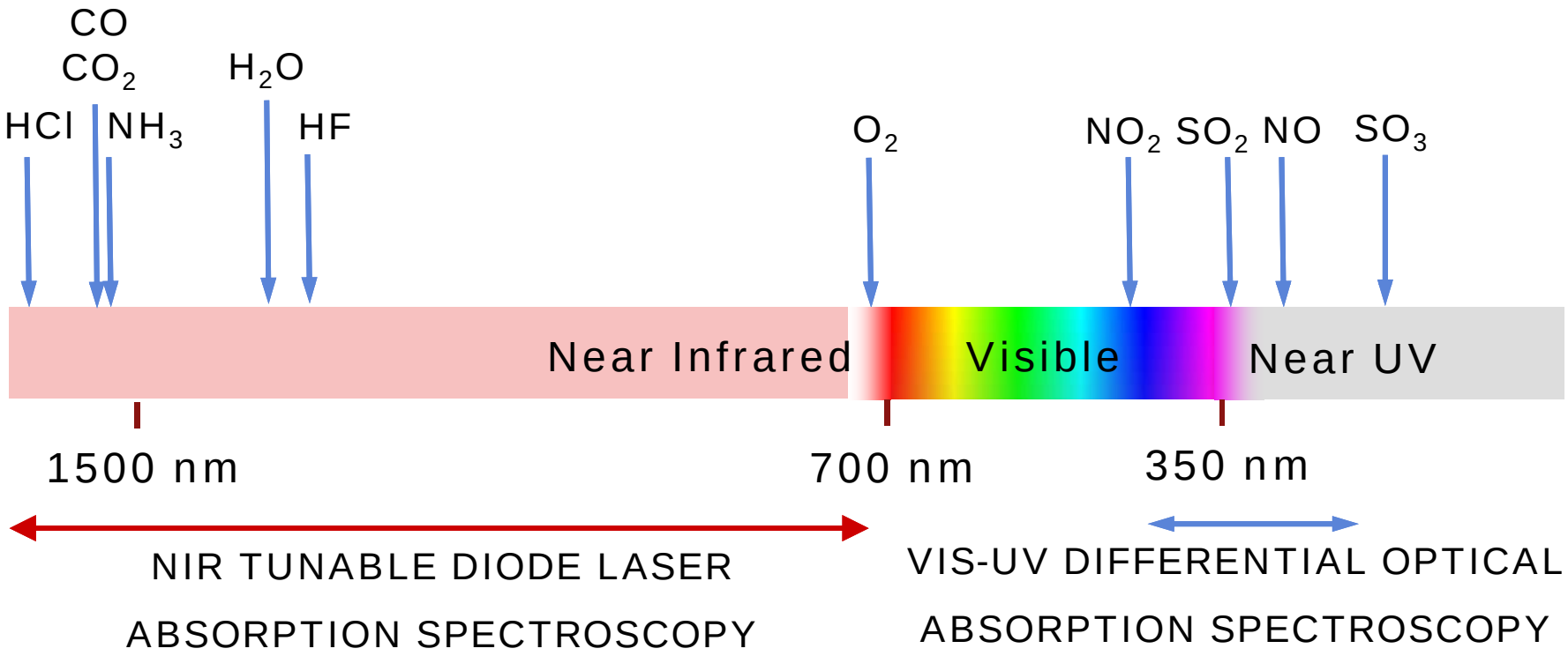


Tunable Diode Laser Measurement Technique

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



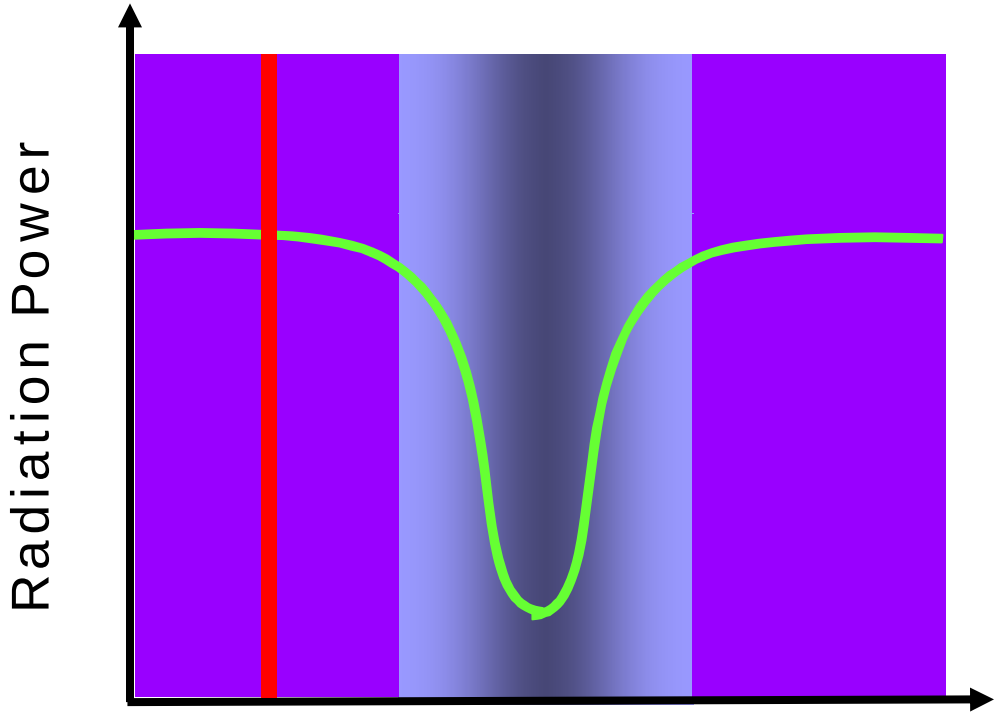
Tunable Diode Laser Measurement Technique

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

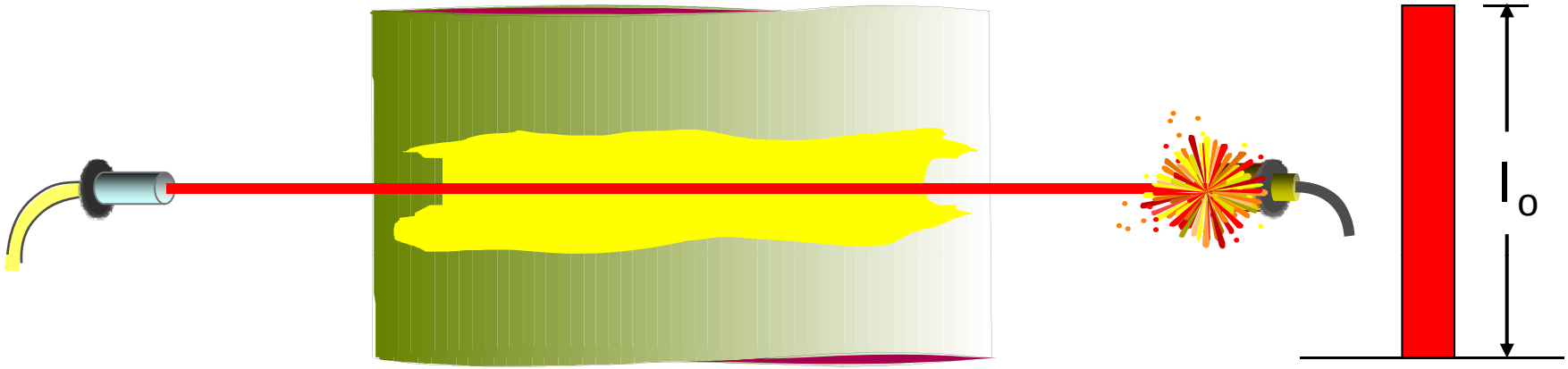


Absorption region

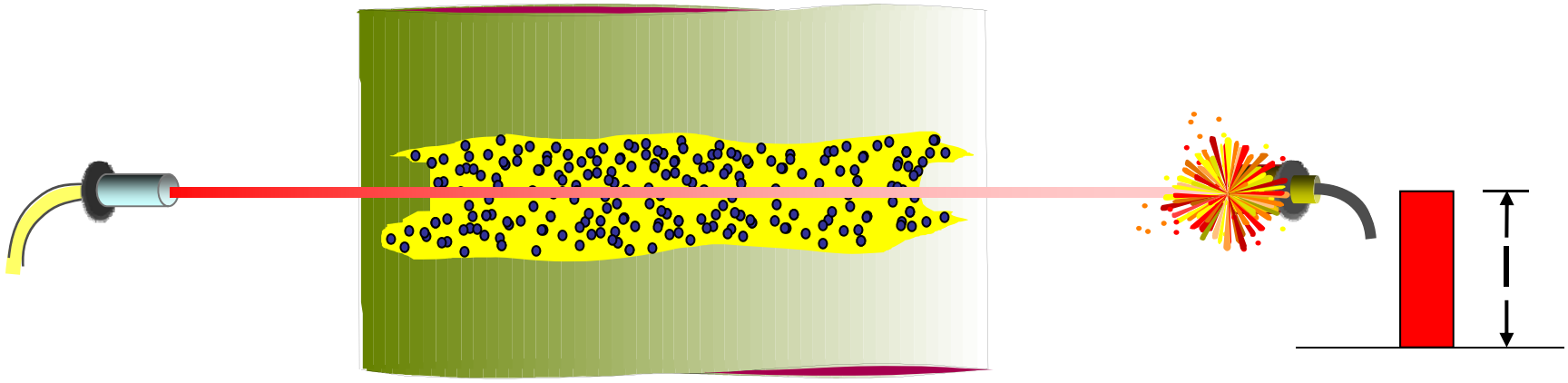
Side wavelengths, without absorption

Tunable Diode Laser Measurement Technique

When no gas present...



When gas present...



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

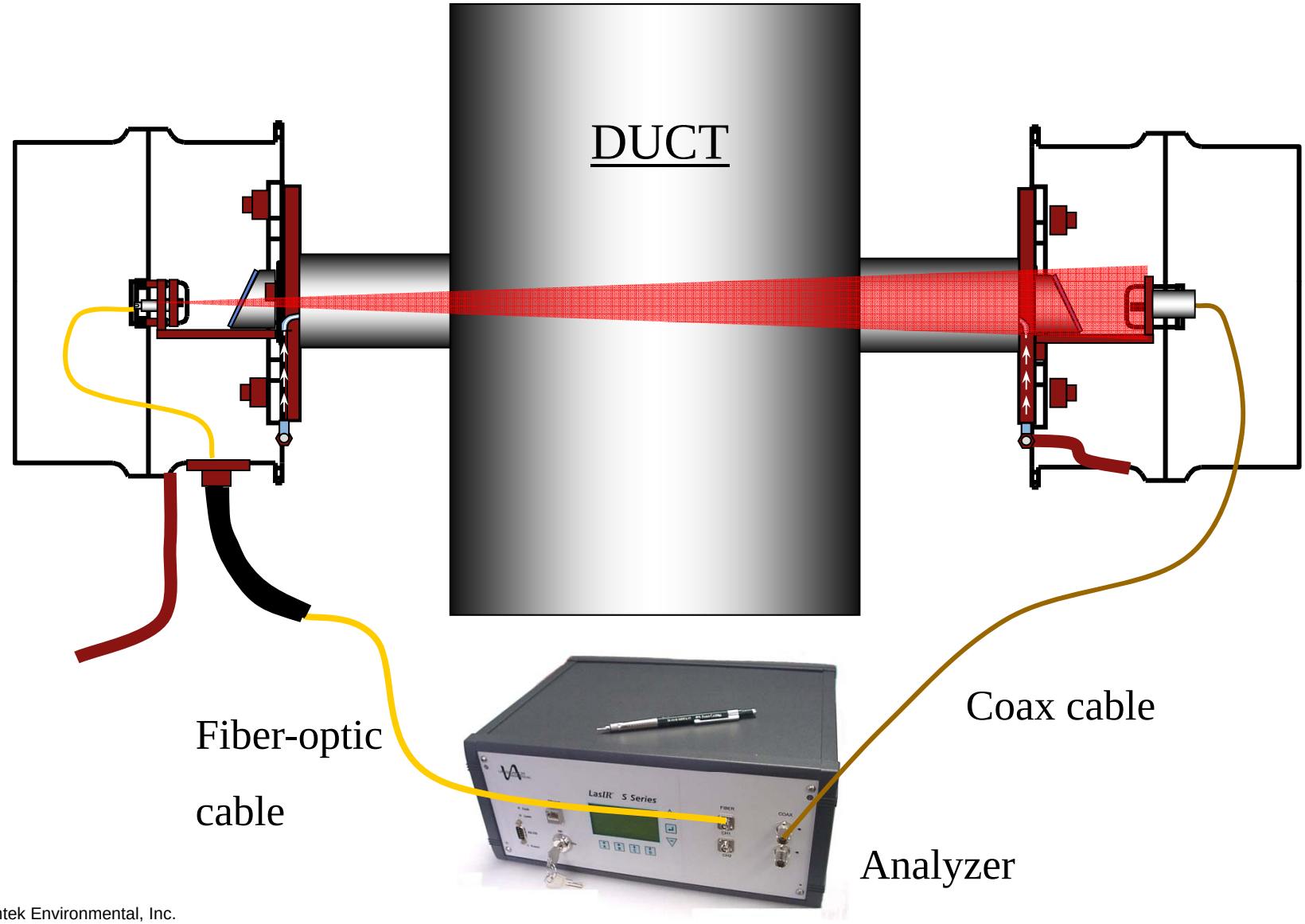
Tunable Diode Laser Measurement Technique

Tunable Diode Laser (TDL) Detection Limits

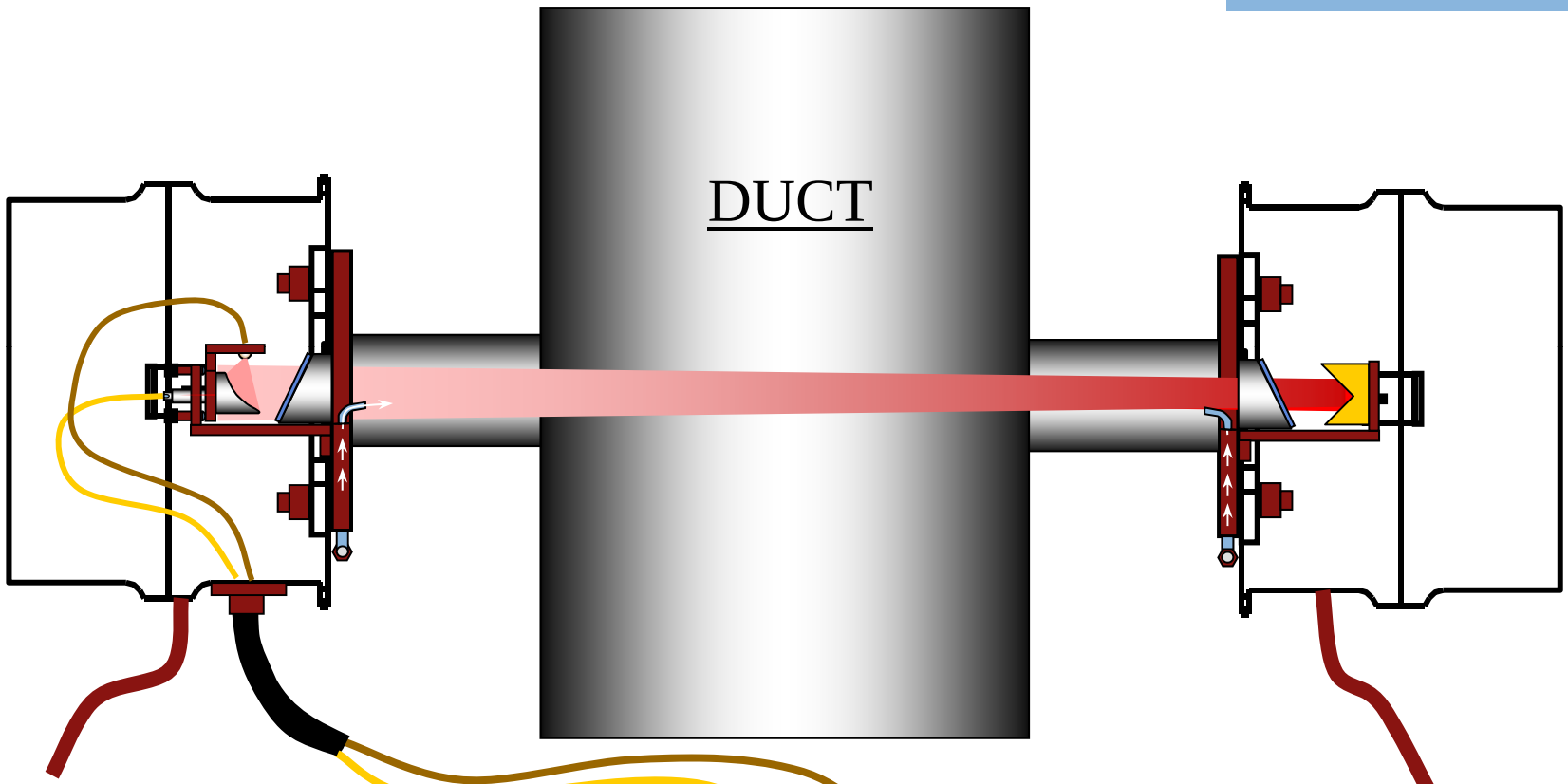
- **Detection limits are a factor of both path length and path measurement time and the molecule being measured.**
- **For tunable diode lasers operating in the spectral band, the detection limit is in the range of 0.1 to 5 ppm-meters.**
- **Path Length**
  - **The longer the path length, the higher 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

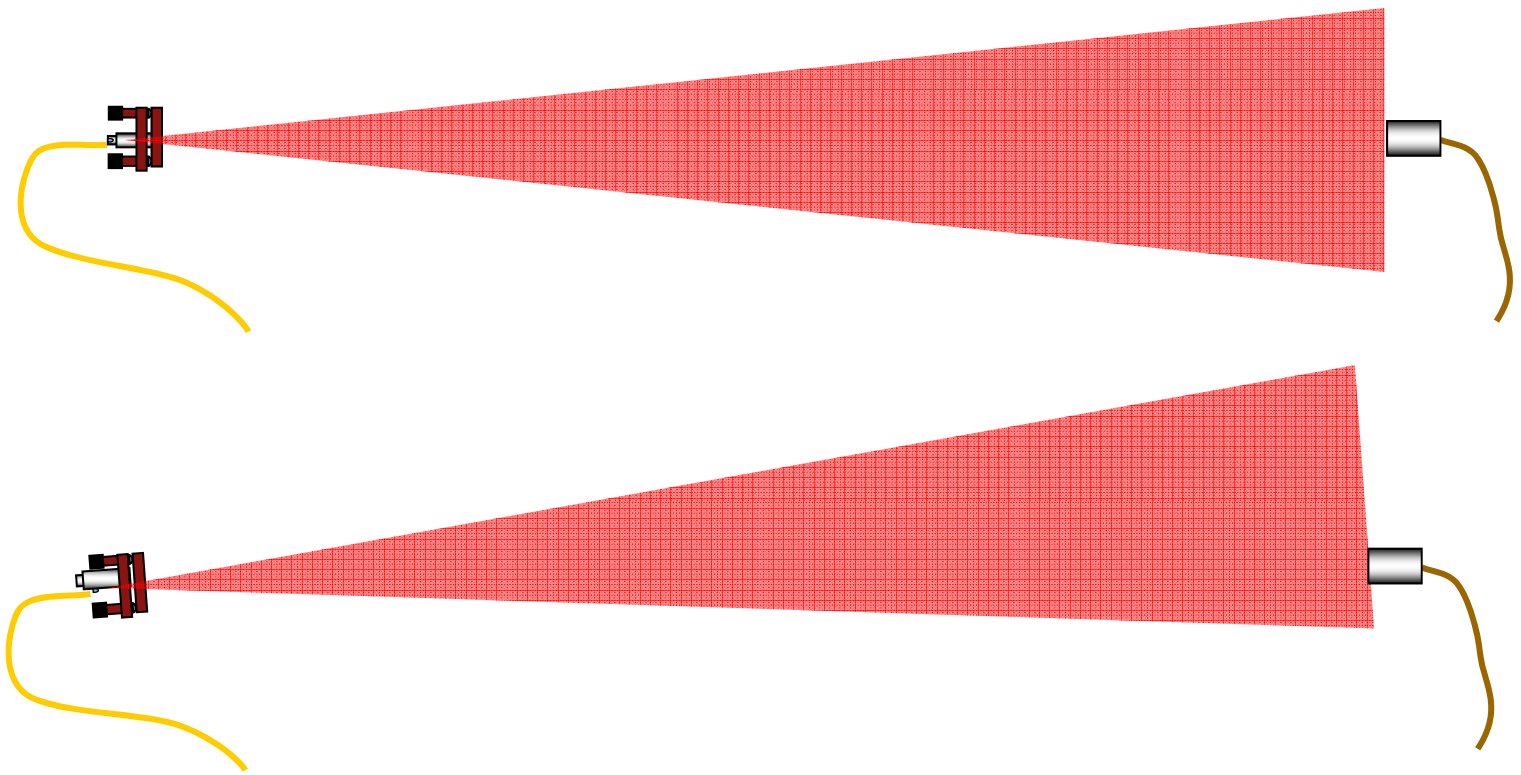


Fiber-optic

& coax cables

Analyzer

Tunable Diode Laser Measurement Technique



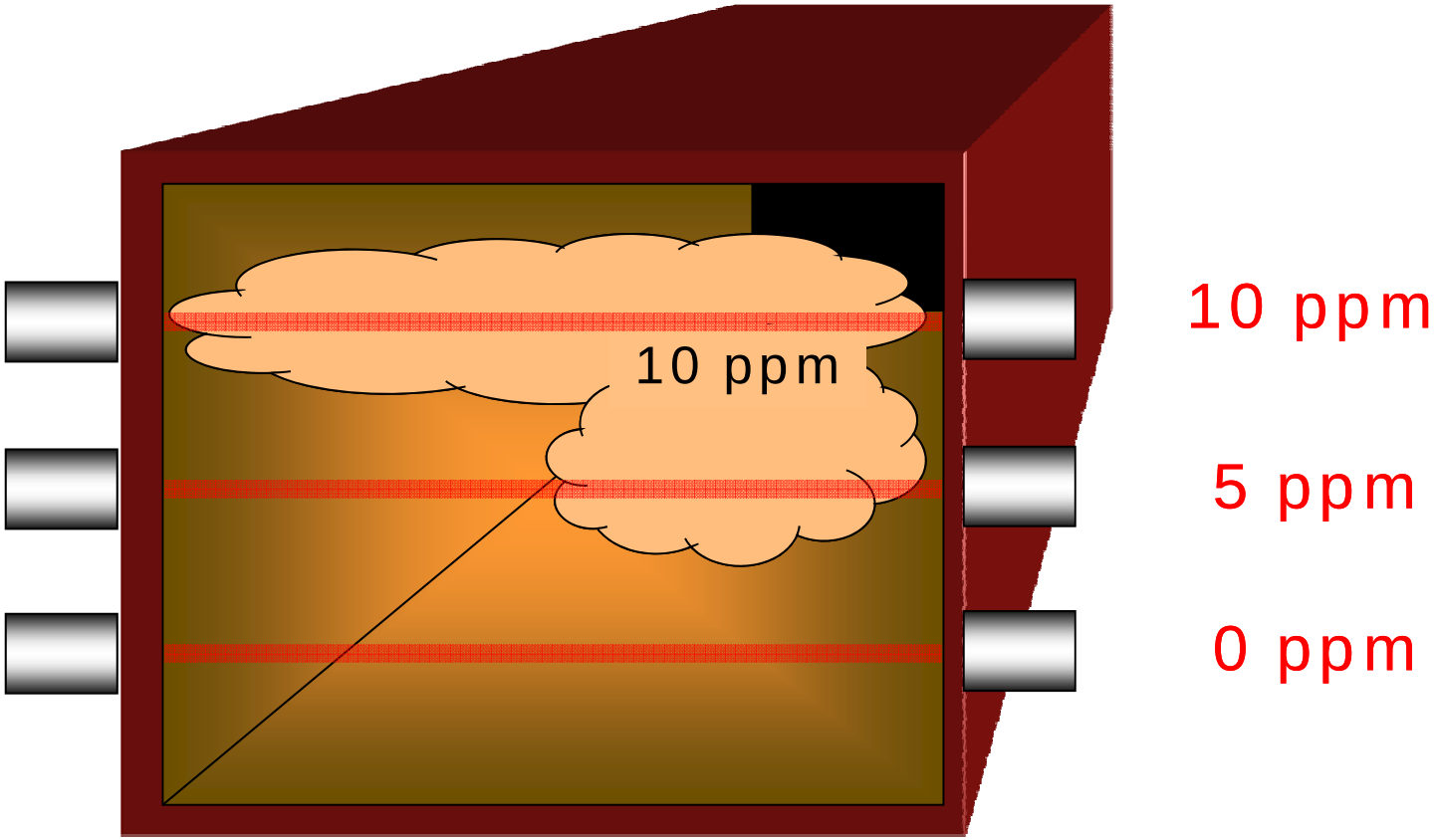
- **Higher laser powers allow beam expansion to attain alignment stability**
- **By de-focusing the beam, overfill of the detector optics allows for alignment changes**

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**

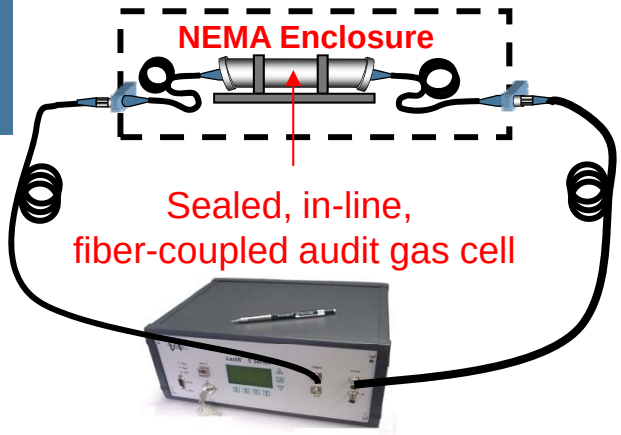
Disadvantages

- **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.**

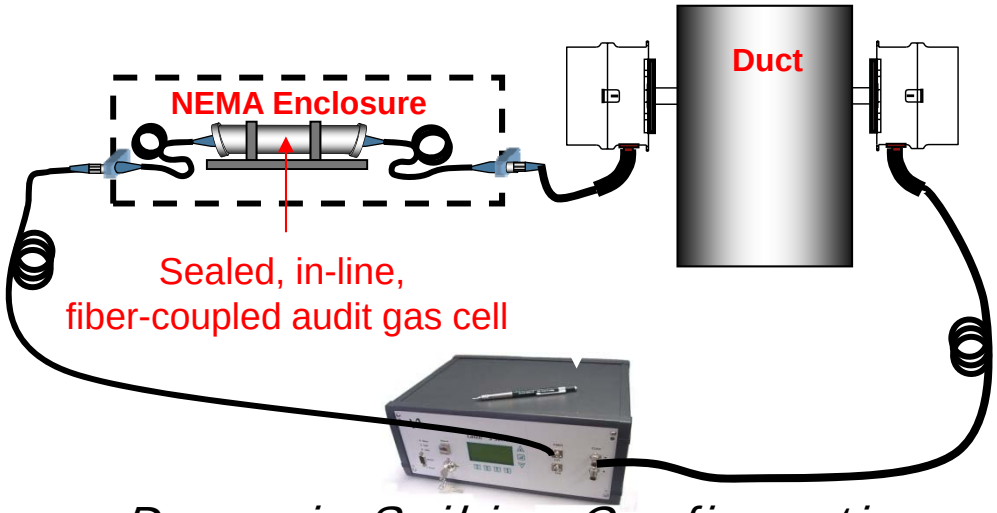
Tunable Diode Laser Audit Method

Portable External Audit Module

- **Diagnostic Tool**
- **Dynamic Spiking**
- **Analyzer Isolation**



Analyzer Isolation Configuration

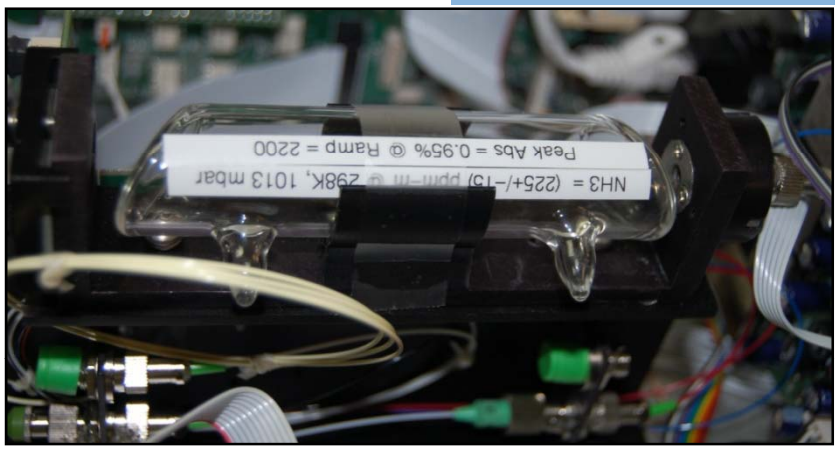


Dynamic Spiking Configuration

Tunable Diode Laser Audit Method

Internal Audit Module

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

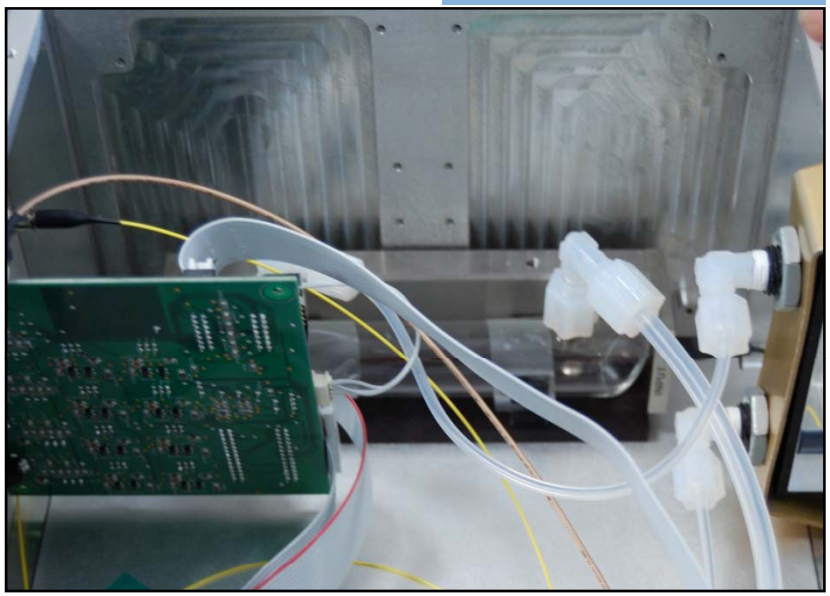


Internal Audit Module

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**
  - **Coal Fired Boiler SNCR NH_3 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)**

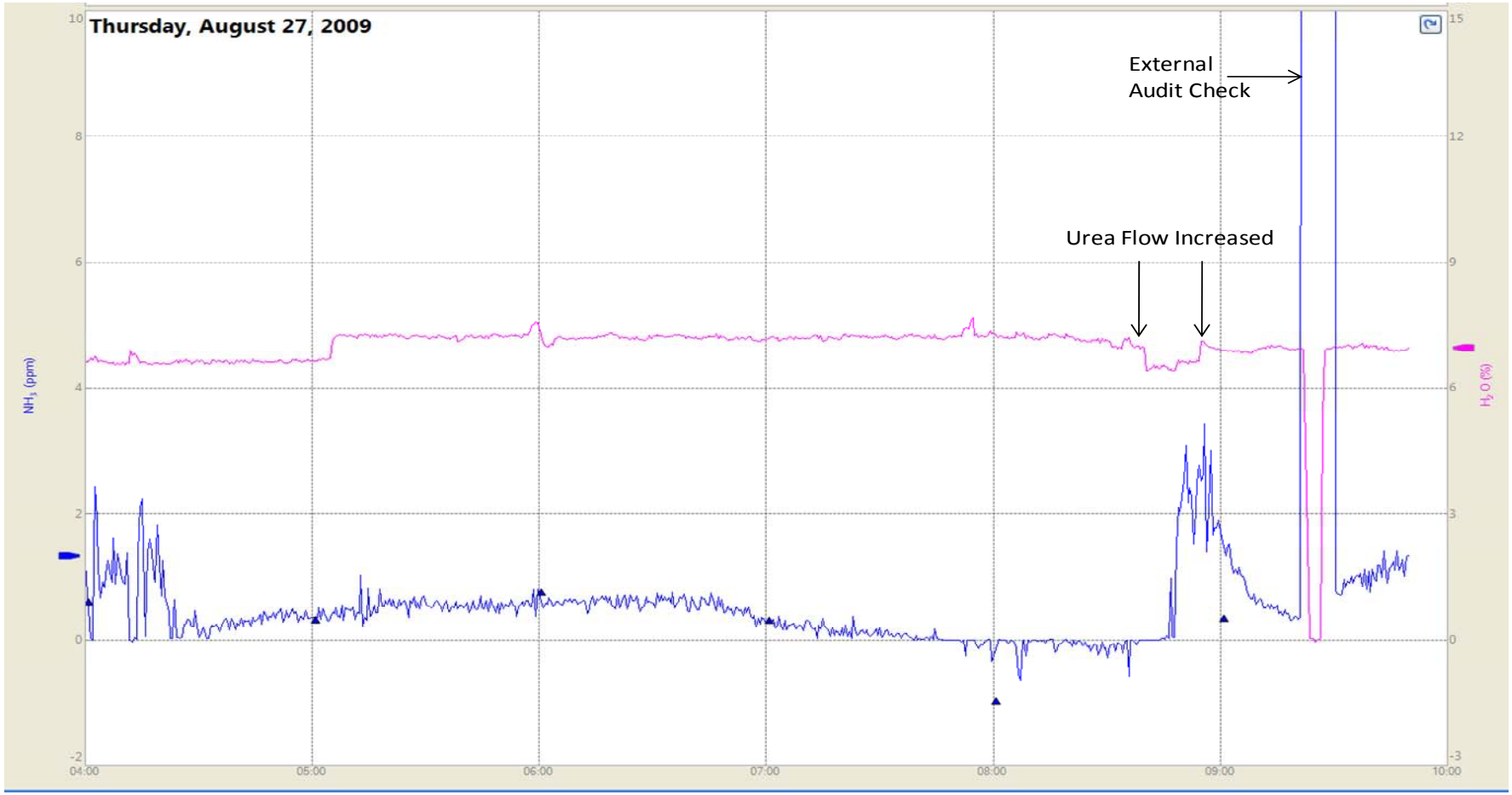
Coal Fired Boiler-
Dry FGD HCl Application

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**

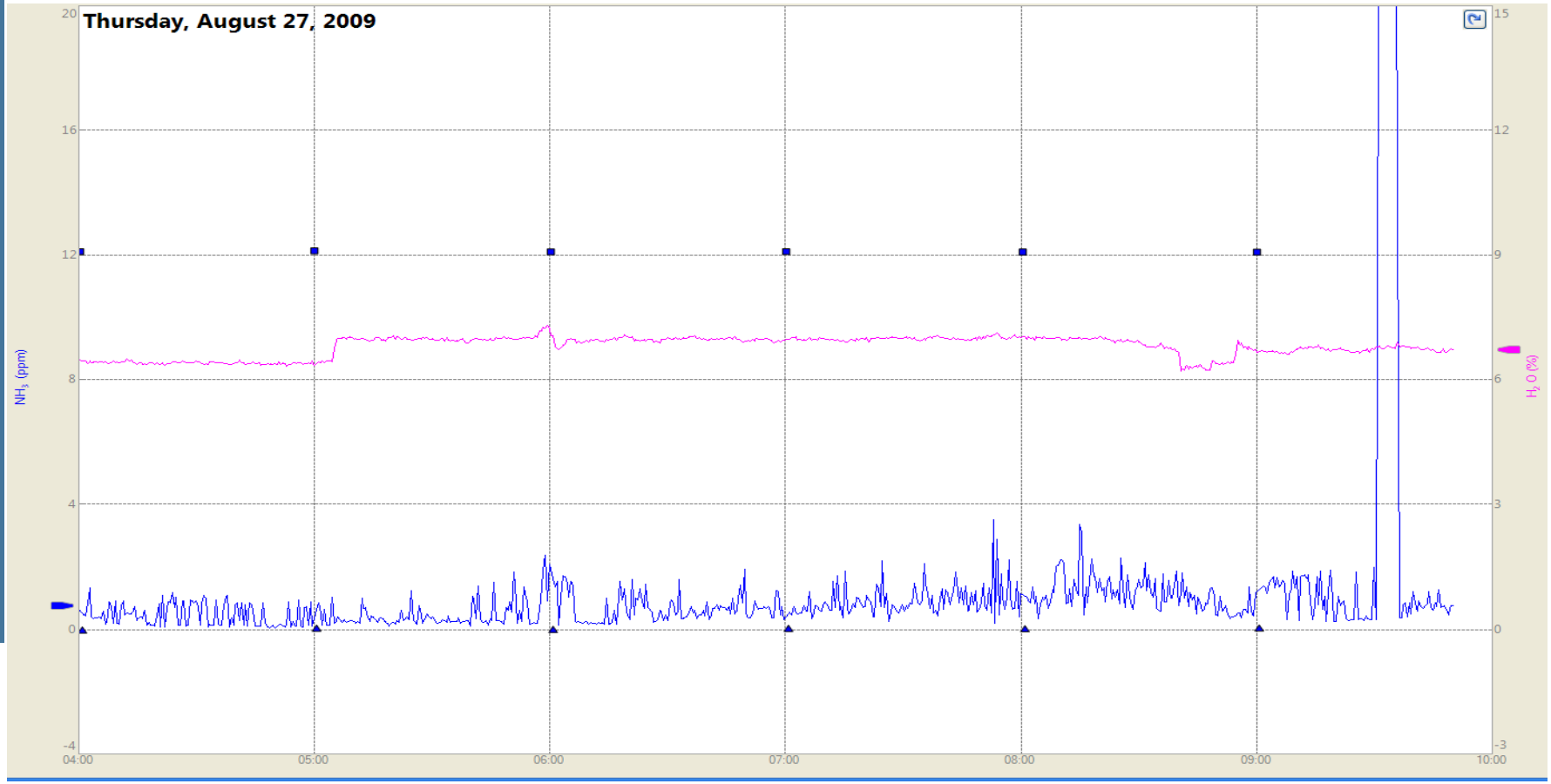
Coal Fired Boiler-
SNCR Ammonia Slip Application

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

Questions?

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