New Developments in TDLAS NH3 Monitoring

Presented by John Pisano

CEMTEK Environmental

UCR (University of California at Riverside)

Unisearch Associates Inc

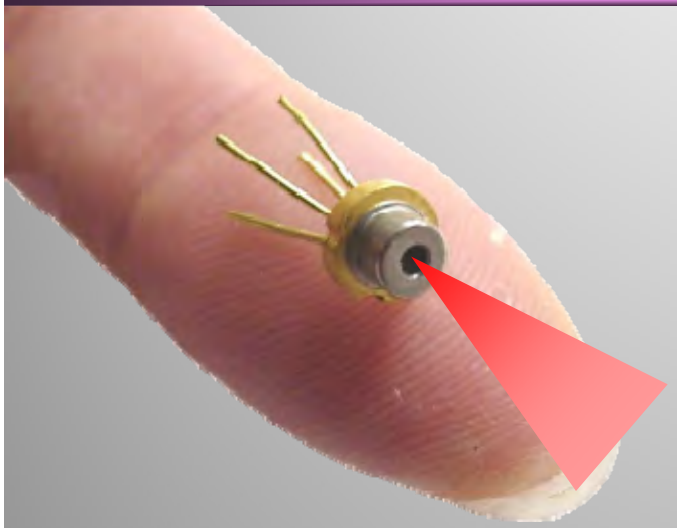
Outline

- What is a tunable diode laser (TDL)
- The theory
- General overview of a TDL system
- Navigating LasIRView software
  - General overview
  - Accessing and Parsing data

What are Tunable Diode Lasers (TDL)?

- Lasers made from Ga, As, Sb, P
- Telecommunications grade
  - Long life
  - Rugged construction
  - Commercially available at low cost
- Emits in near infrared region when power is applied.

Tunable Diode Lasers (TDL) ?



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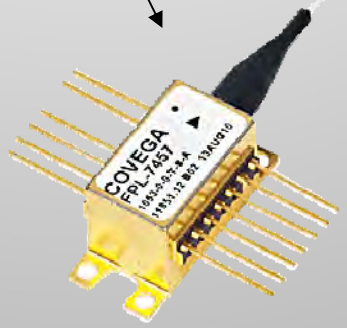

TO-CAN PACKAGE

Analyzer must be located at the measurement location

OR

14-PIN BUTTERFLY PACKAGE

Analyzer can be located far away from the measurement location

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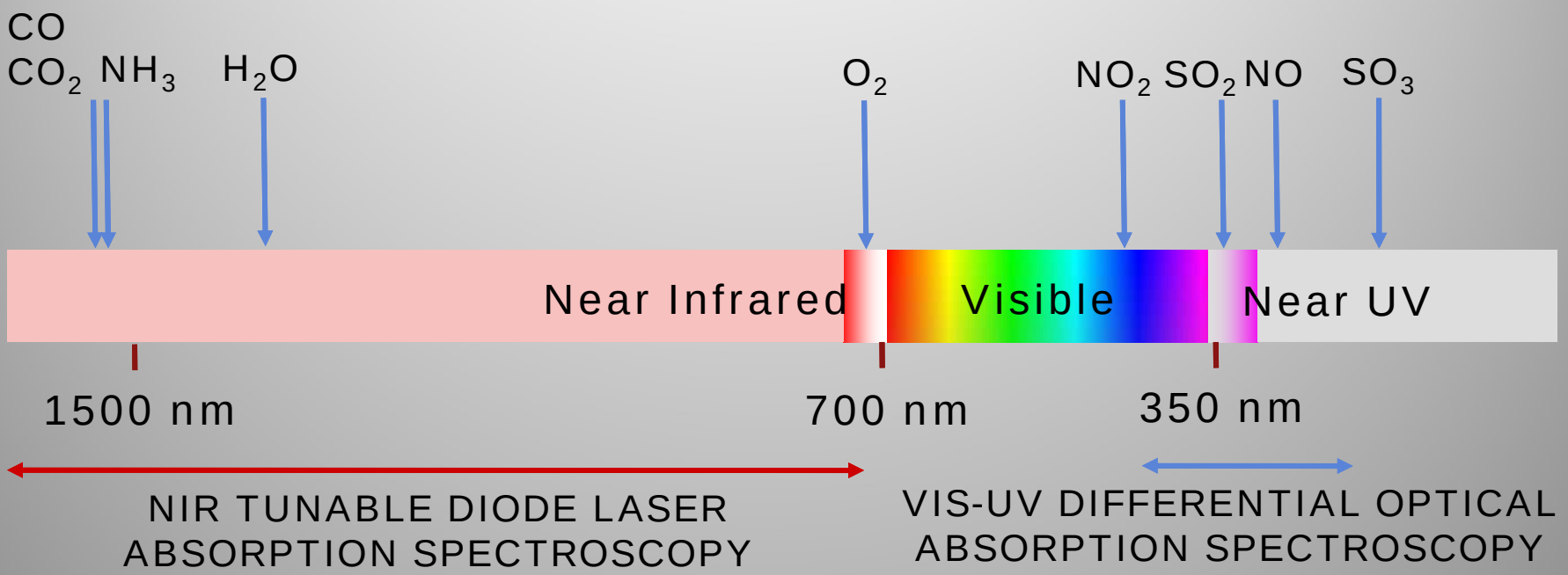
Wavelength Scale



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How do Tunable Diode Lasers (TDL) Operate?

- Laser center wavelength depends on material composition
- Wavelength can vary based on laser temperature and current
  - Current: fine tune changes in wavelength (fast)
  - Temperature: coarse tune changes in wavelength (slow)
- Laser current can be ramped rapidly
  - Permits the ability to rapidly scan over entire absorption spectrum
- Scans the entire absorption feature
  - Removes interference from dust via continuous power level monitoring

Determination of Concentration

- Beer's Law

$$I = I_0 e^{(-\sigma C L)}$$

  - I = Energy Transmitted
  - I_0 = Energy Emitted
  - σ = molecular cross-section,
  - C = Concentration [ppm]
  - L = Pathlength [m]

- All parameters known except for I, I_0, and C.
  - σ unique for each molecule. Experimentally determined.
  - I and I_0 measured
- Ideal Gas Law for temperature and pressure correction

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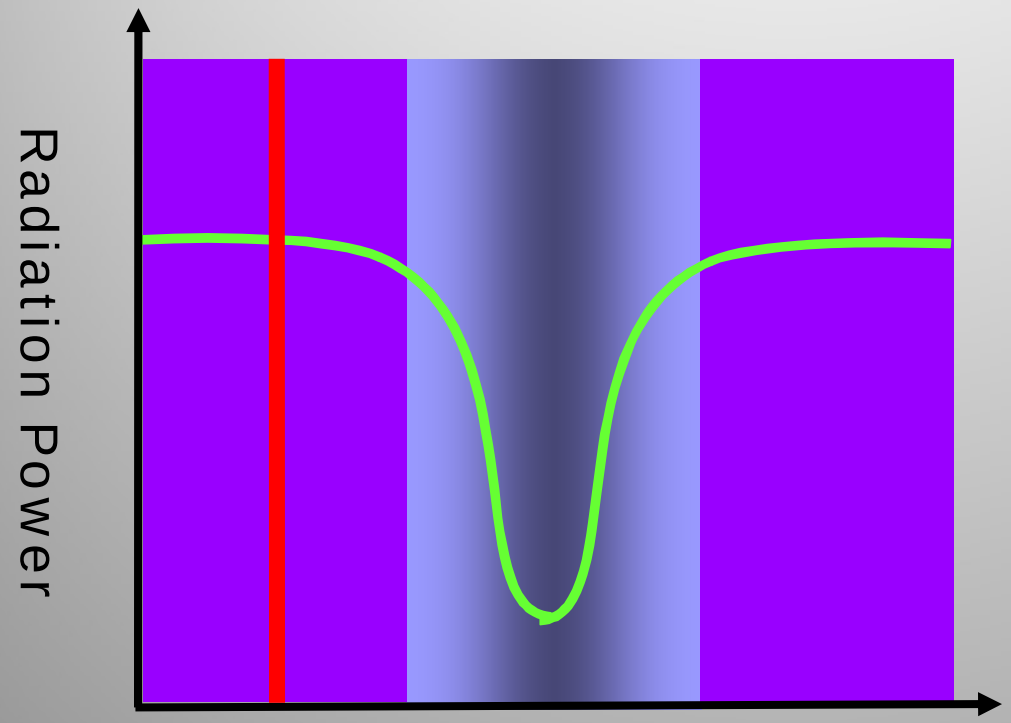
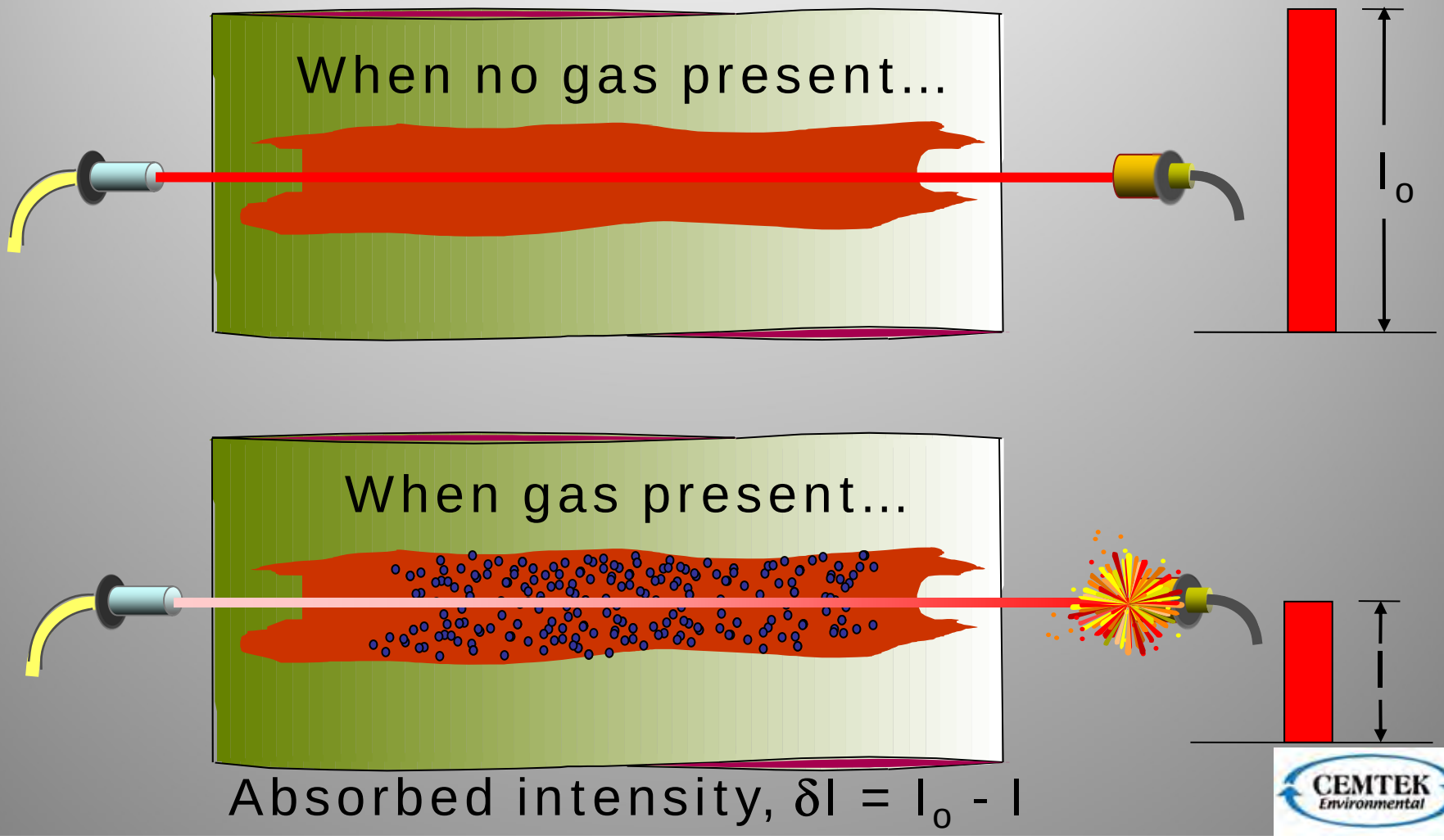
Wavelength Scan (5 kHz)



NIR Light Absorption



Species Specificity with TDLs

- Comes from unique molecular structure of monitored specifies
- Each species has a group of wavelengths at which light is readily absorbed.
  - Ammonia: 1514 nm
  - HCl: ~1800 nm
- Certain absorption peaks selected
  - Minimizes/eliminates interference due to other compounds

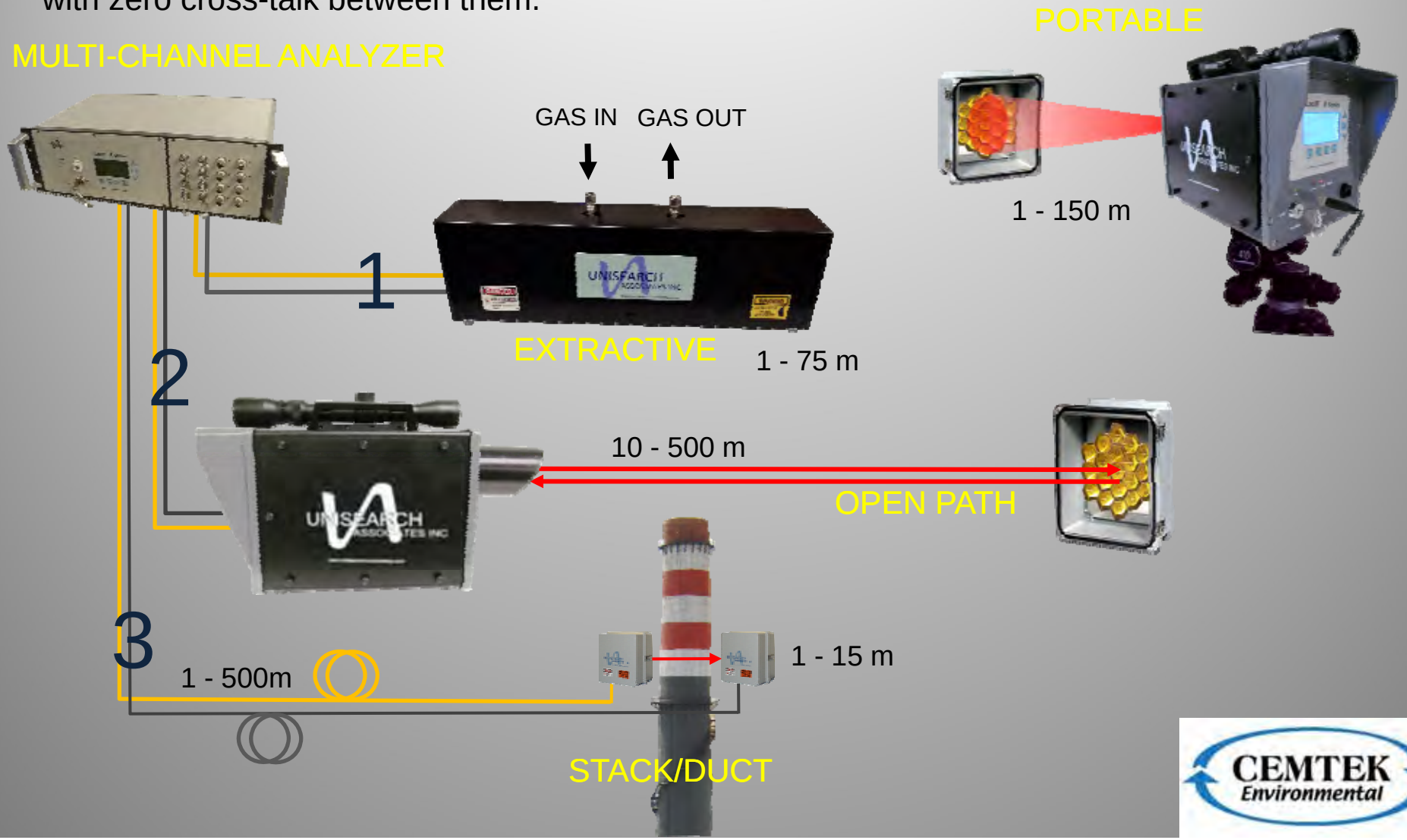
Detection Limits

- Factor of both path length and path measurement time
- Typical detection limit for ammonia:0.5 ppmv
- Path Length
  - Longer path lengths yield higher absorption, increased sensitivity and lower detection limit.
  - Thus longer path lengths result in better delectability of low concentrations.

Detection Limits

- Measurement Time
  - Scales approximately to the square root of the measurement time.
  - Example: Increasing the time from 1-second to 1-min enhances the detection limit approximately seven fold.

Multi-channel capability – single analyzer to measure multiple locations. They can be extractive, open path, in-situ stack or duct or any combination. Channels are independent with zero cross-talk between them.



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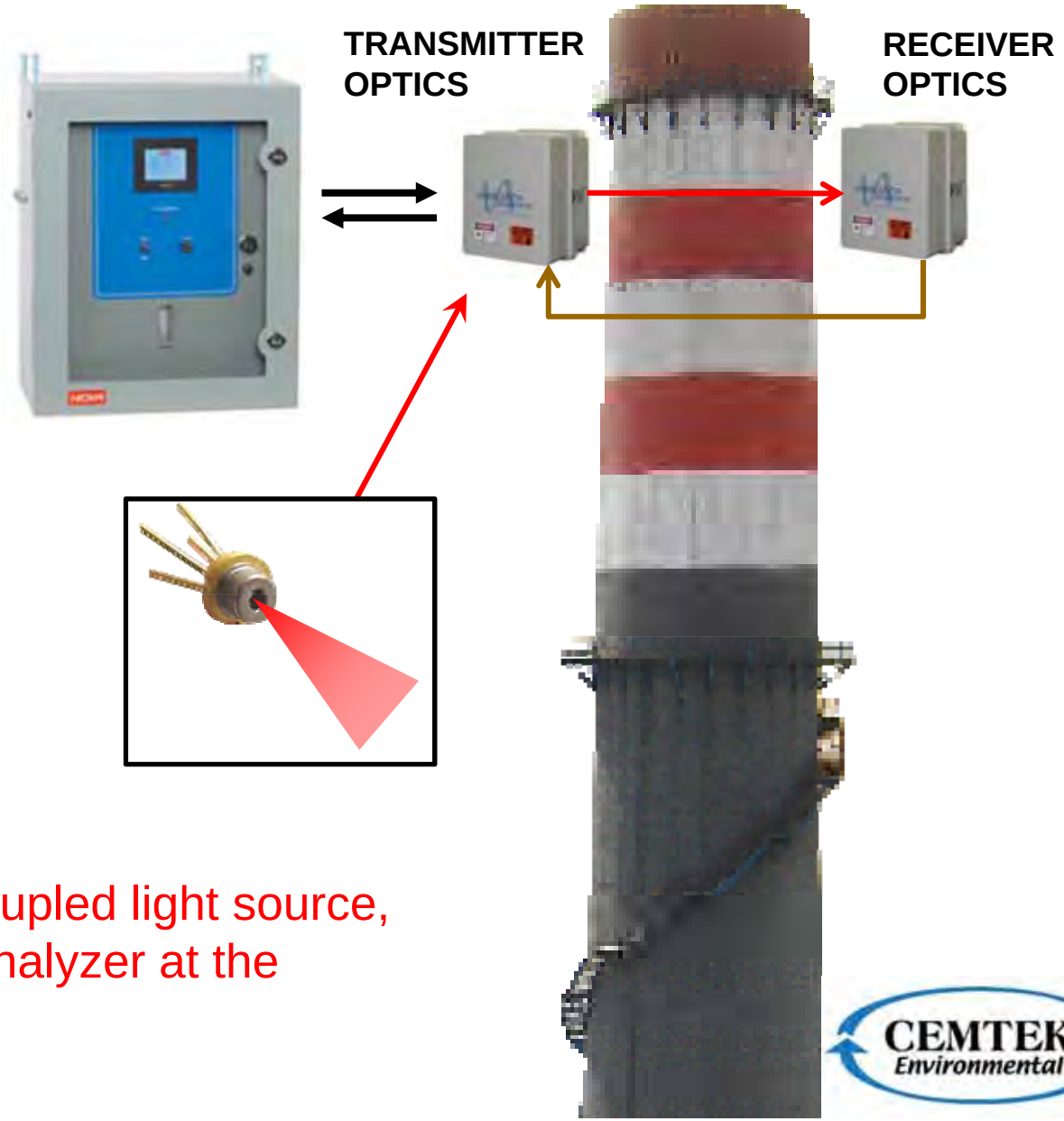

When using non fiber-coupled light source, need to locate the gas analyzer at the measurement location

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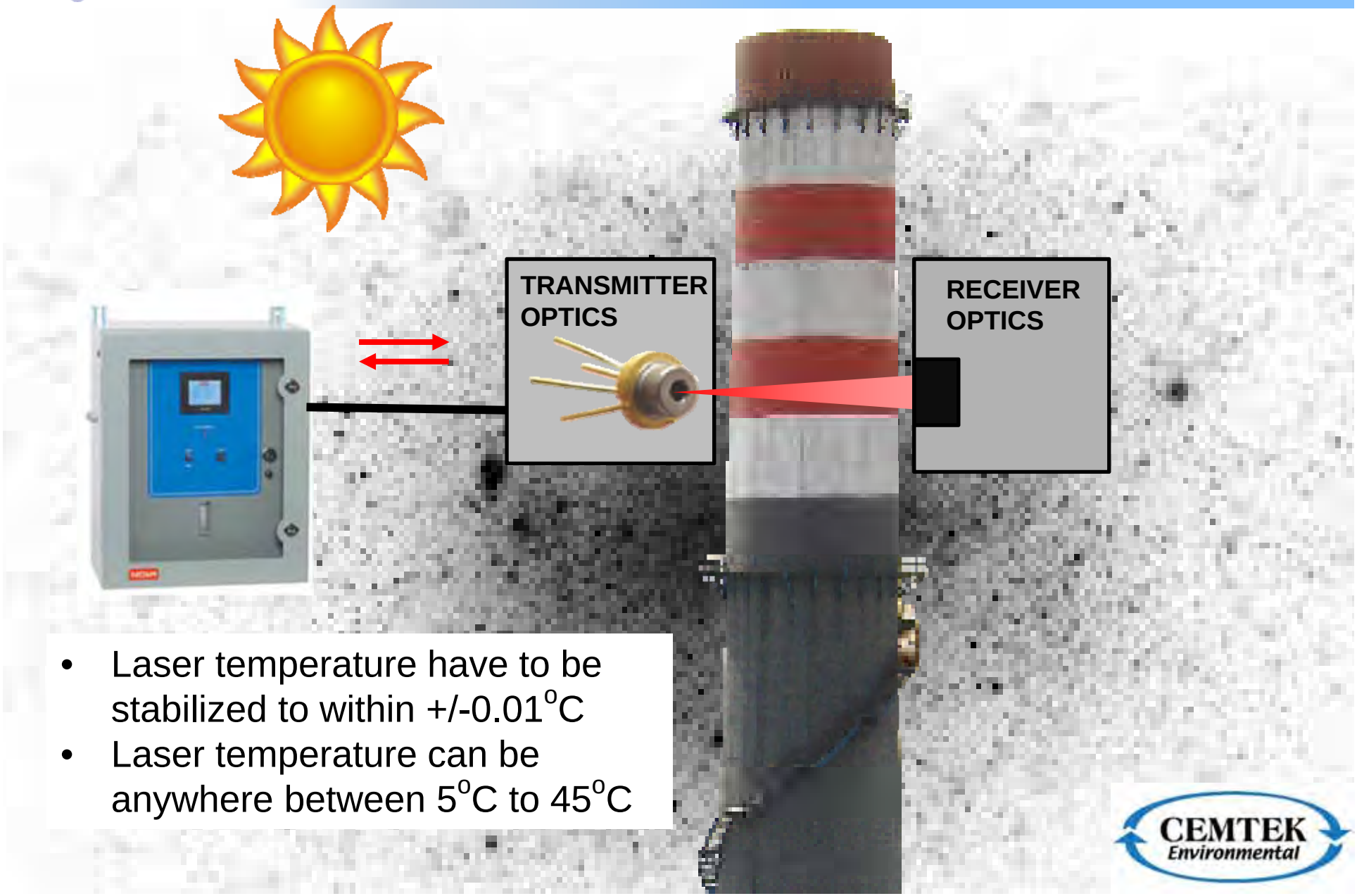

- Laser temperature have to be stabilized to within +/-0.01^{o}C
- Laser temperature can be anywhere between 5^{o}C to 45^{o}C

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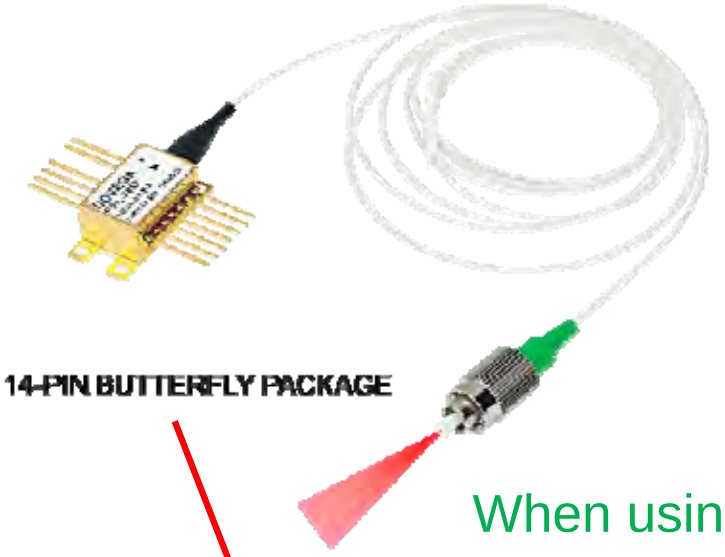

14-PIN BUTTERFLY PACKAGE

TRANSMITTER OPTICS

RECEIVER OPTICS

Purge Air

Purge Air

When using fiber-coupled light source, the analyzer can be located inside the a control room

Armored Fiber Cable

Coax Cable

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NH_3 Slip Measurements in Coal-fired Power Plants

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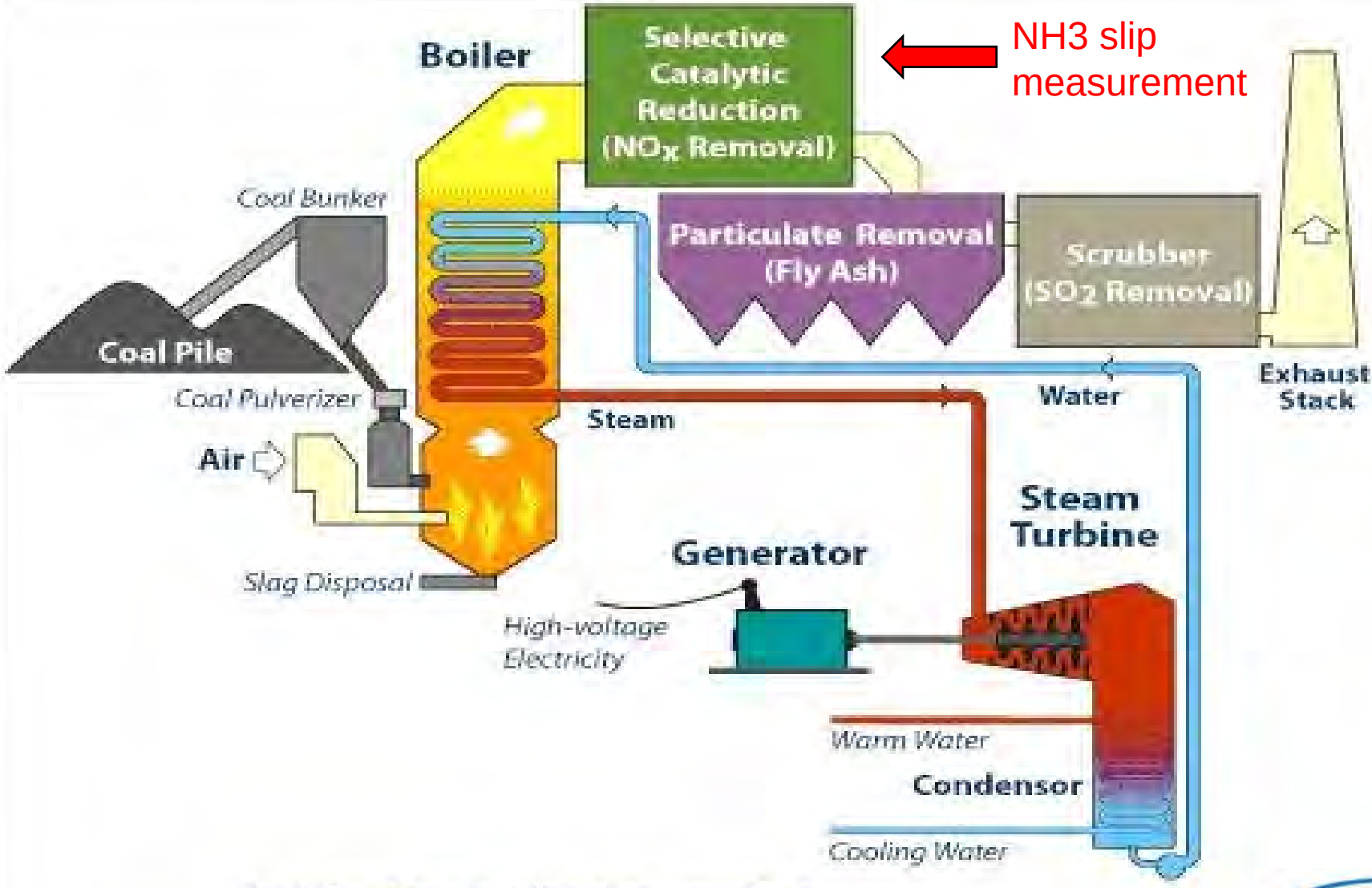

Coal-fired Supercritical Power plant

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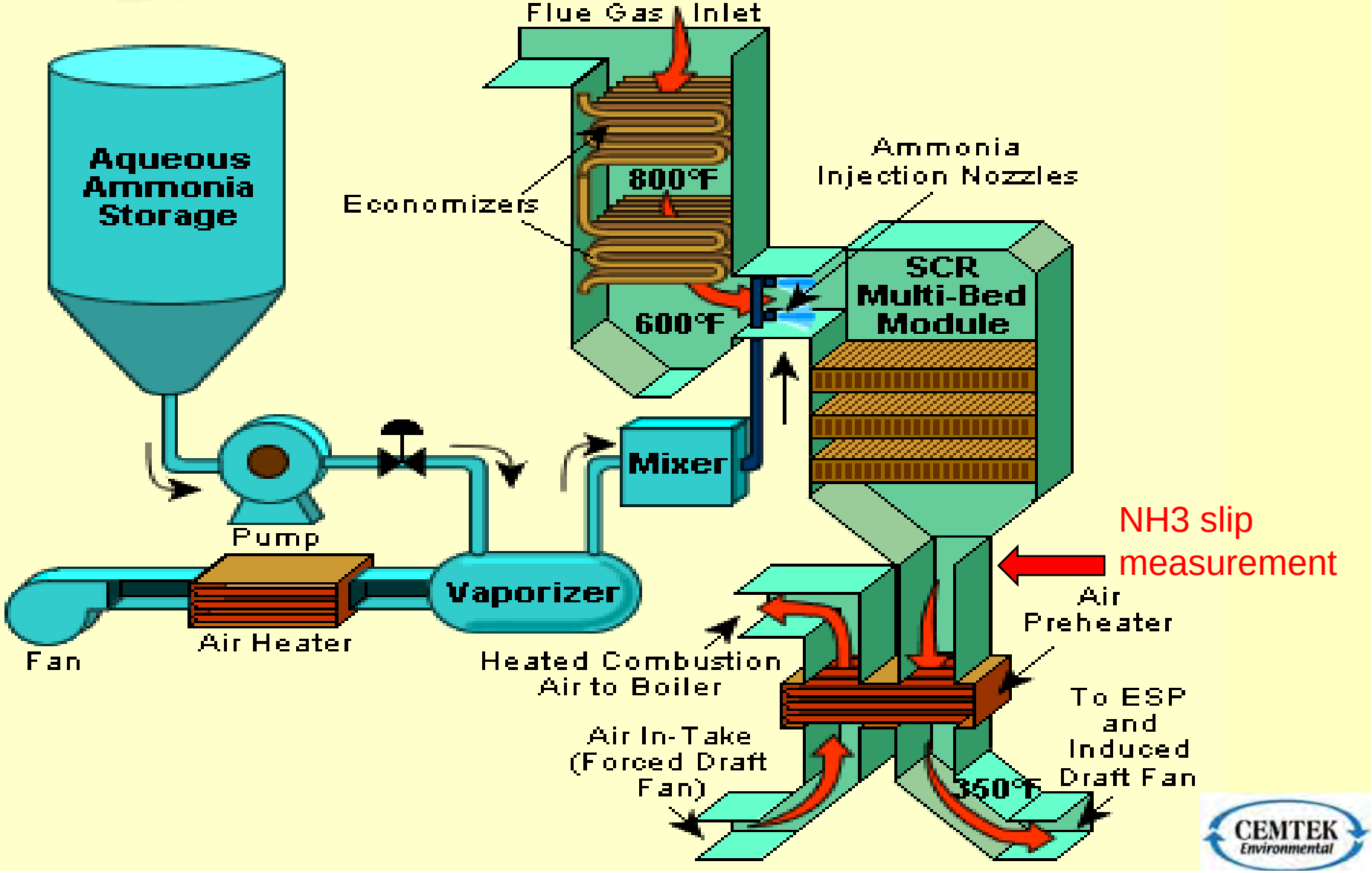
Example SCR System for NO_x Control in a Boiler



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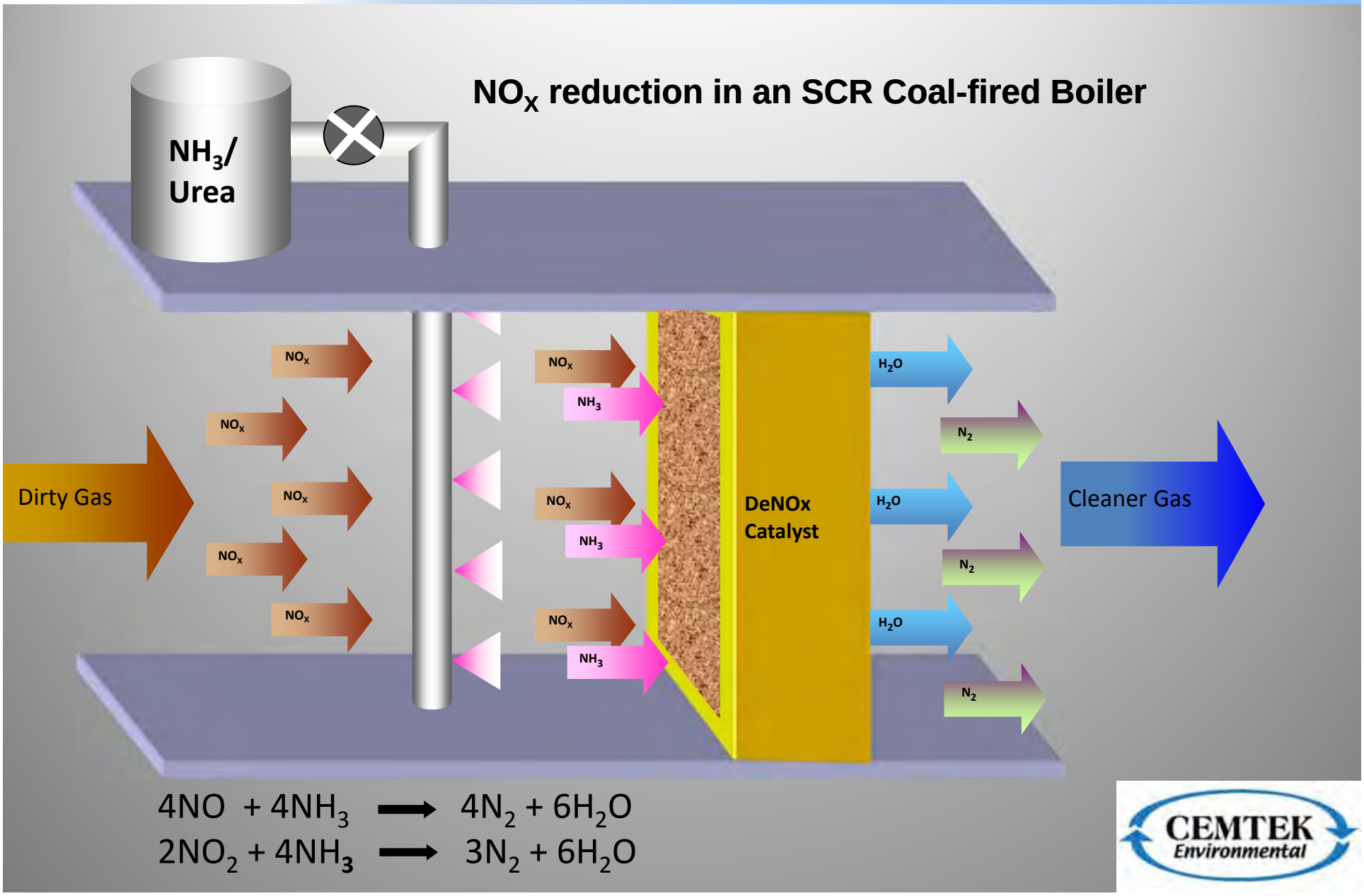

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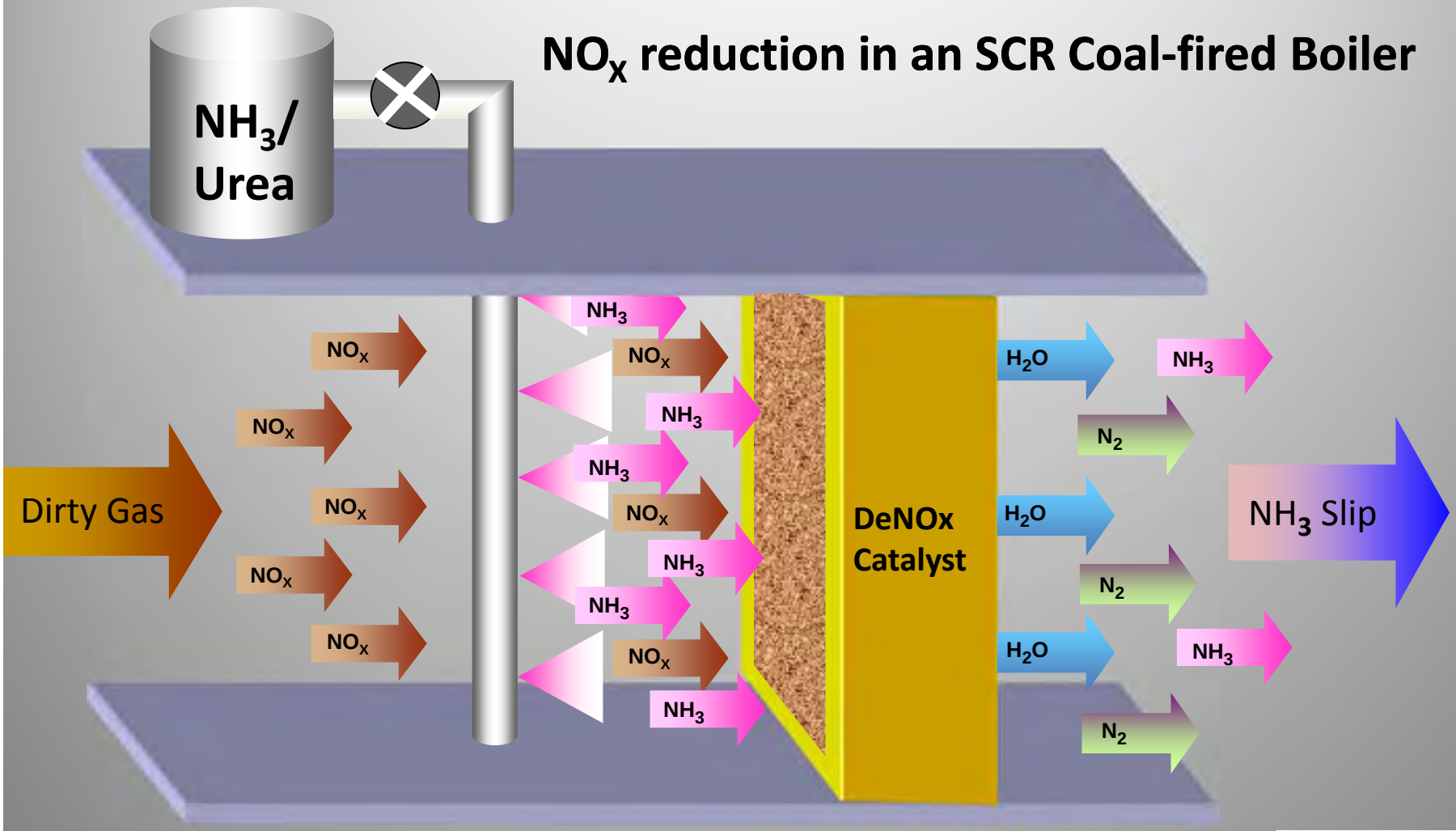
NO_x reduction in an SCR Coal-fired Boiler



$$4NO + 4NH_3 \rightarrow 4N_2 + 6H_2O$$
$$2NO_2 + 4NH_3 \rightarrow 3N_2 + 6H_2O$$

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In-situ NH3 measurement
(Lowest Detection Limit ~0.5 ppm
for a 5 meter duct diameter)

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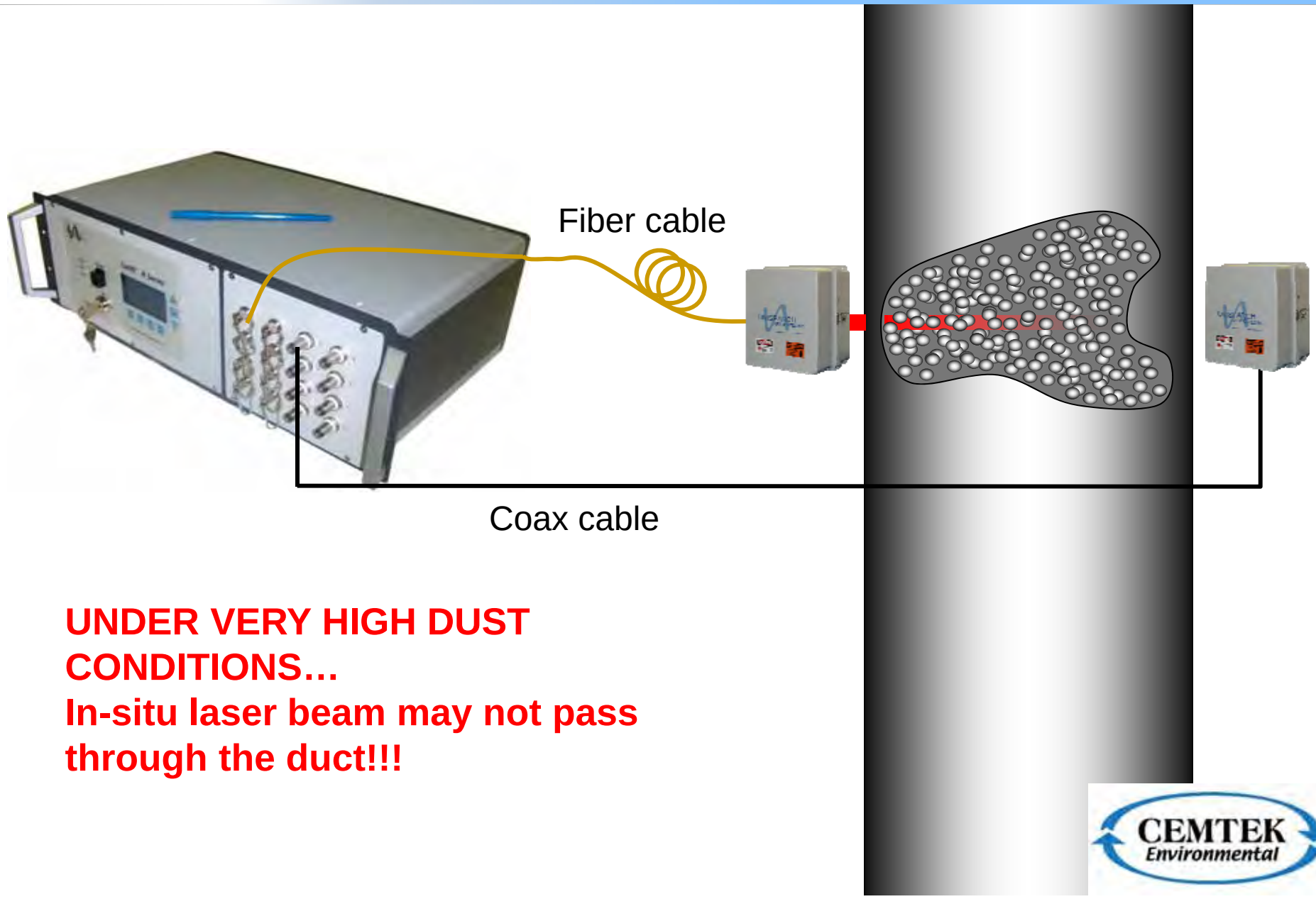

UNDER VERY HIGH DUST CONDITIONS…
In-situ laser beam may not pass through the duct!!!

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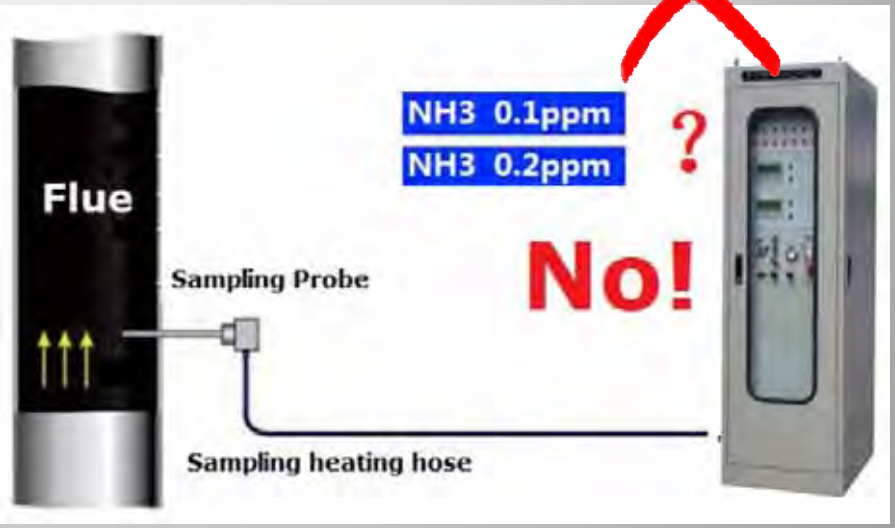
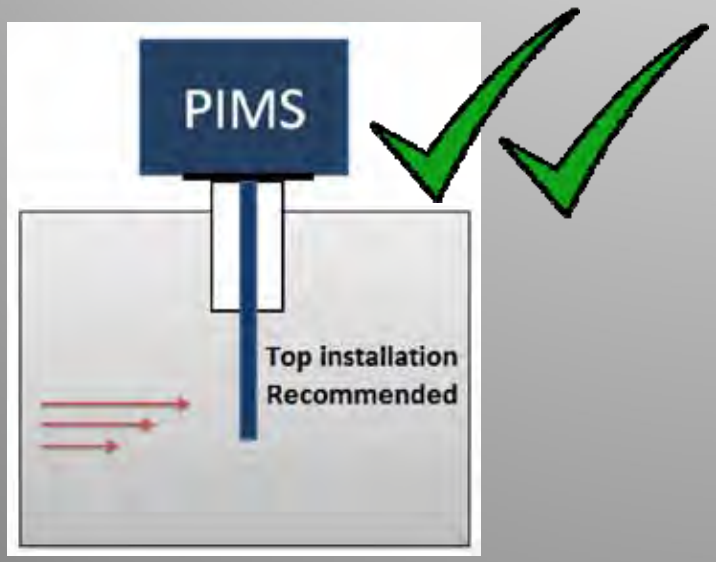
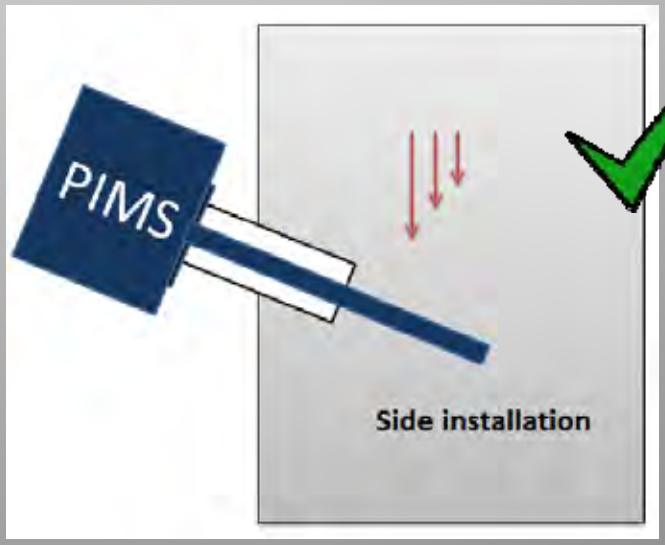
PIMS (Pseudo In-situ Measurement System)







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NH3 Extractive System
(Lowest Detection Limit ~0.1 ppm)

Optical & Extraction assembly located at the duct

Fiber cable (10-200m)

Purge Control cable

Coax cable

Analyzer located in control room

Patent-pending extractive head

Particulate filter

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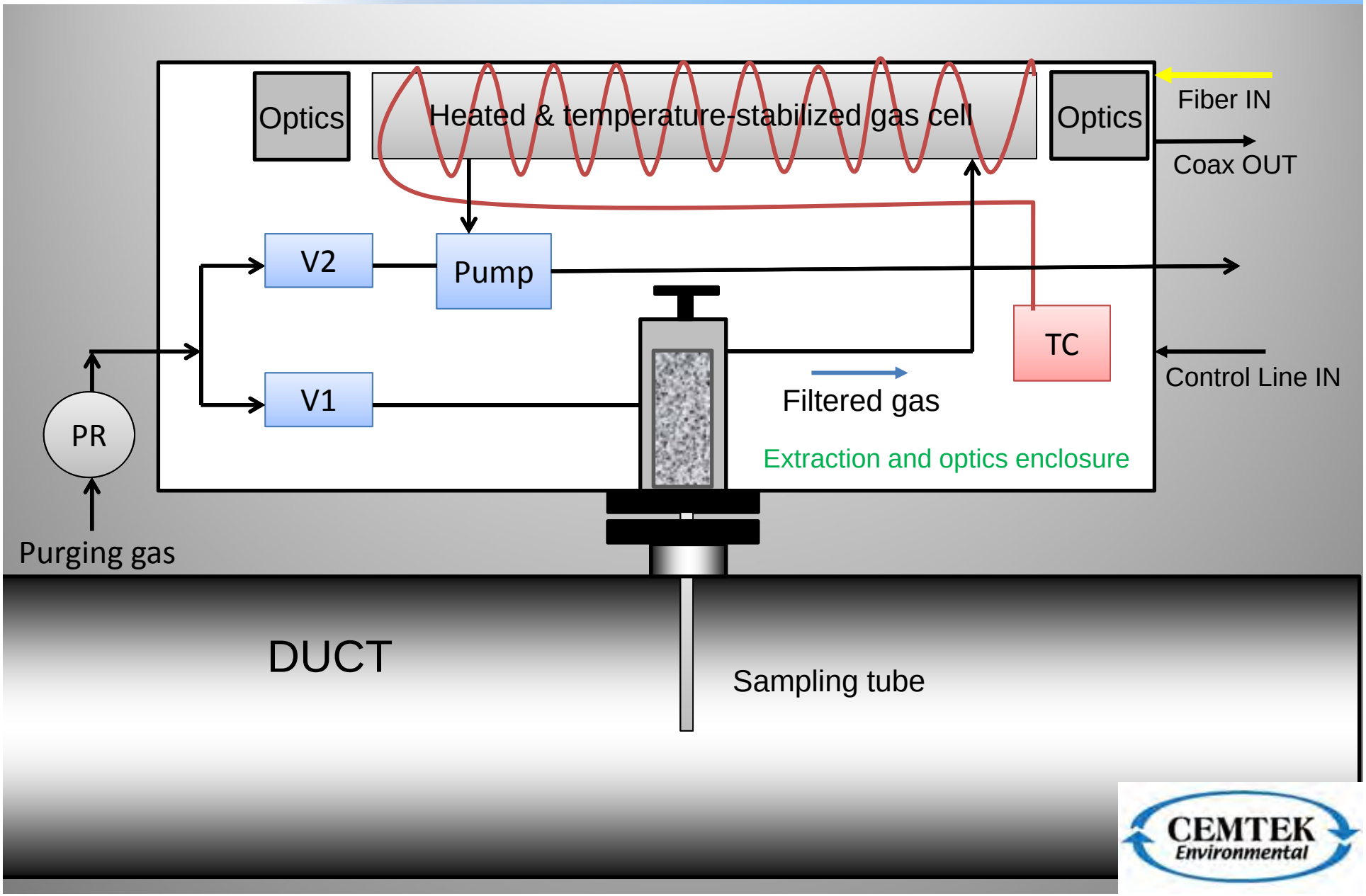
Optics
Heated & temperature-stabilized gas cell
Optics
Fiber IN
Coax OUT
V2
Pump
TC
Control Line IN
V1
Filtered gas
PR
Extraction and optics enclosure
Purging gas
DUCT
Sampling tube

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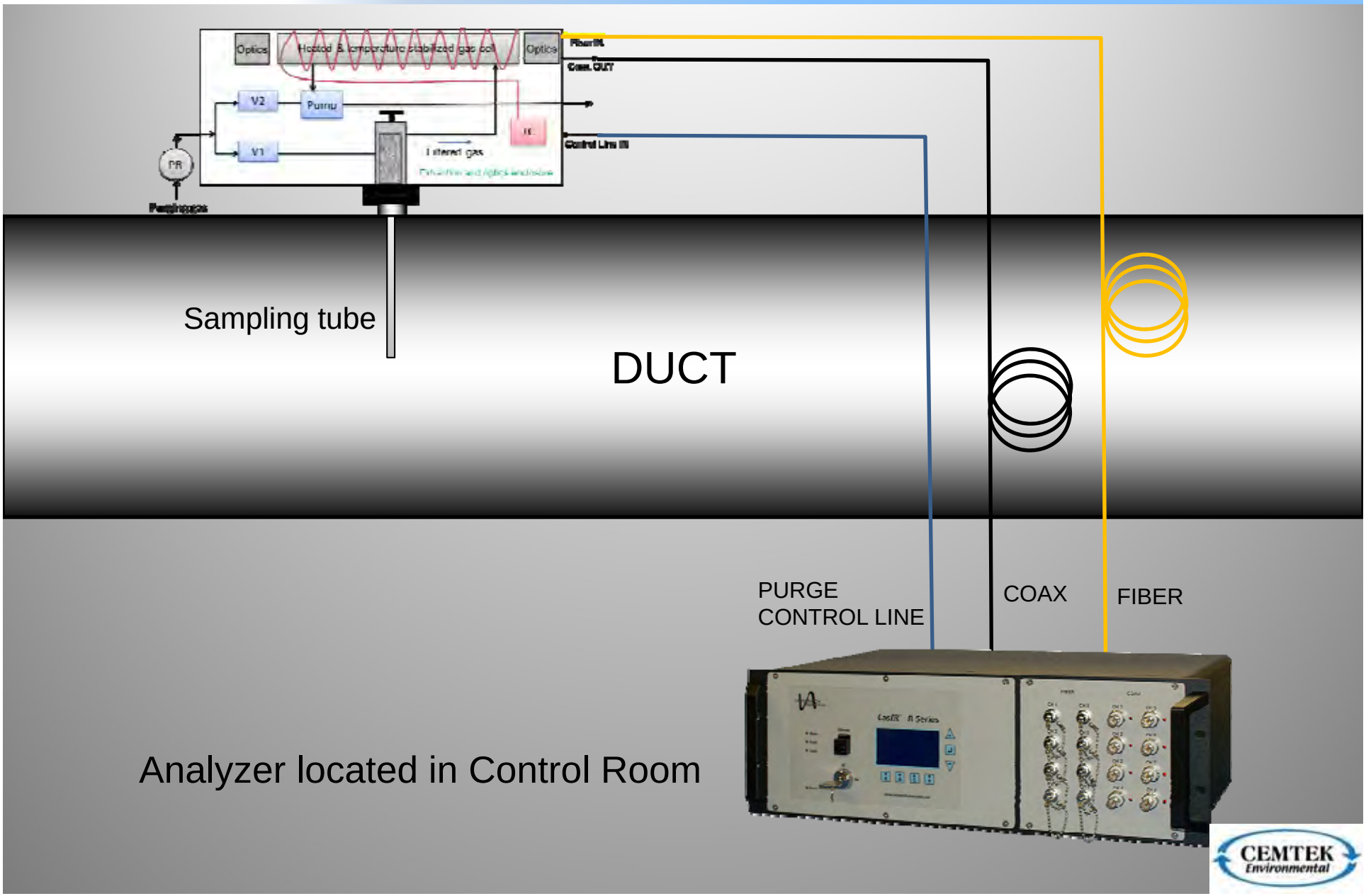
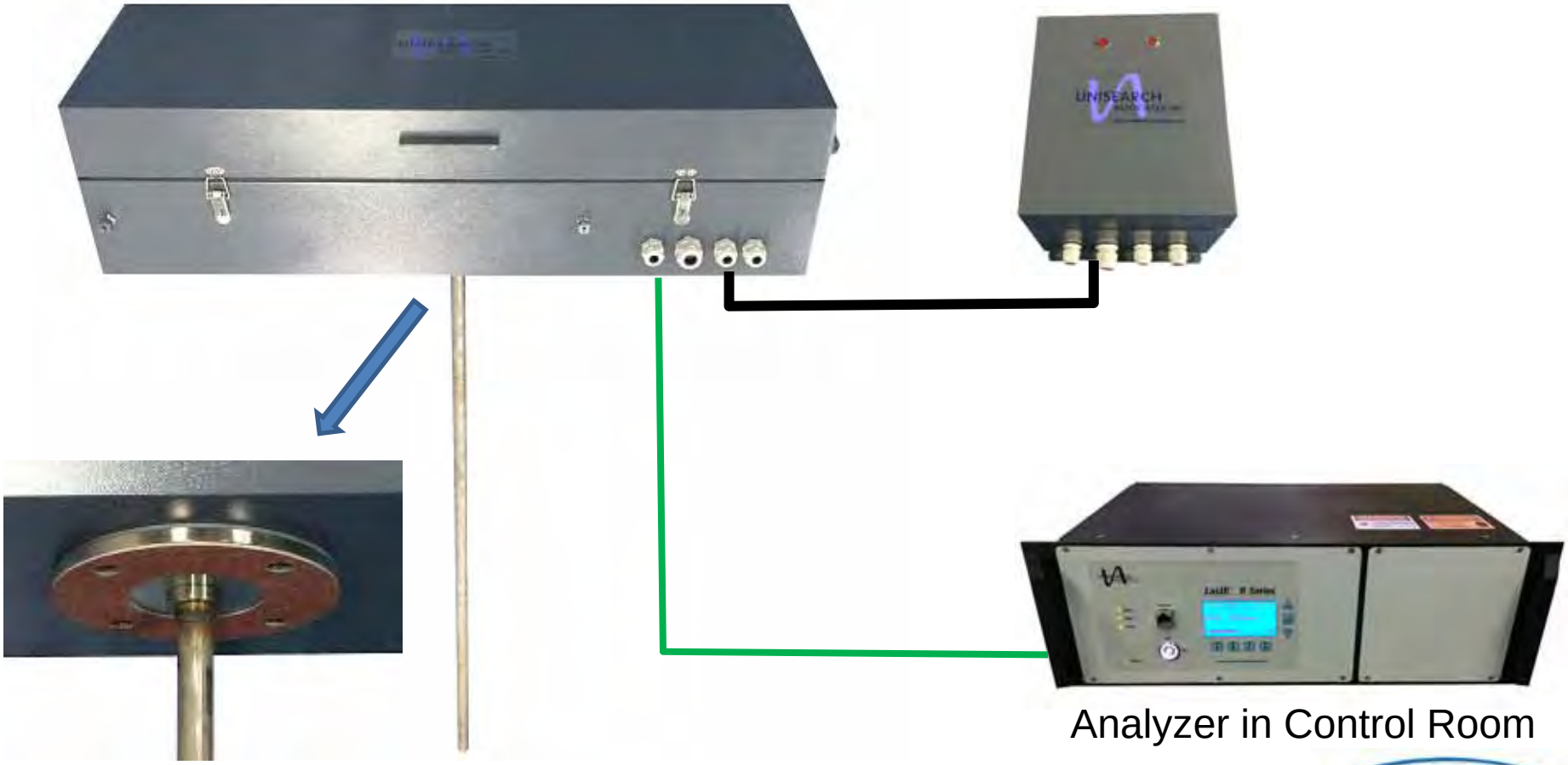


NH3 Measurement in Power Plants with High Dust Loading

PIMS installed in Duct



Analyzer in Control Room

PIMS (Pseudo In-situ Measurement System)

(China, USA, Canada, Europe, International patent pending)

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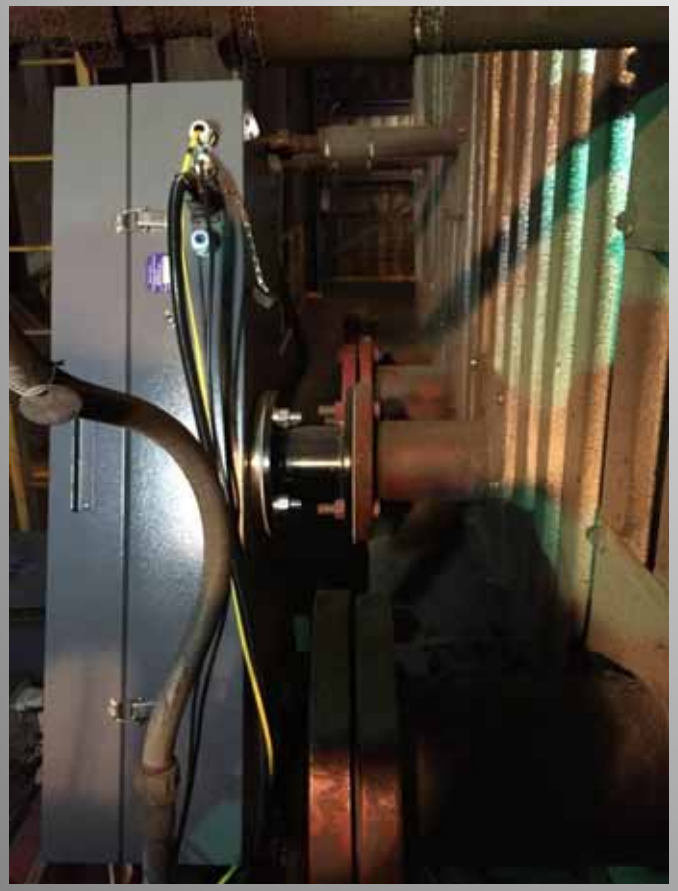
EPRI PIMS Measurement at First Energy coal-fired Power Plant in US



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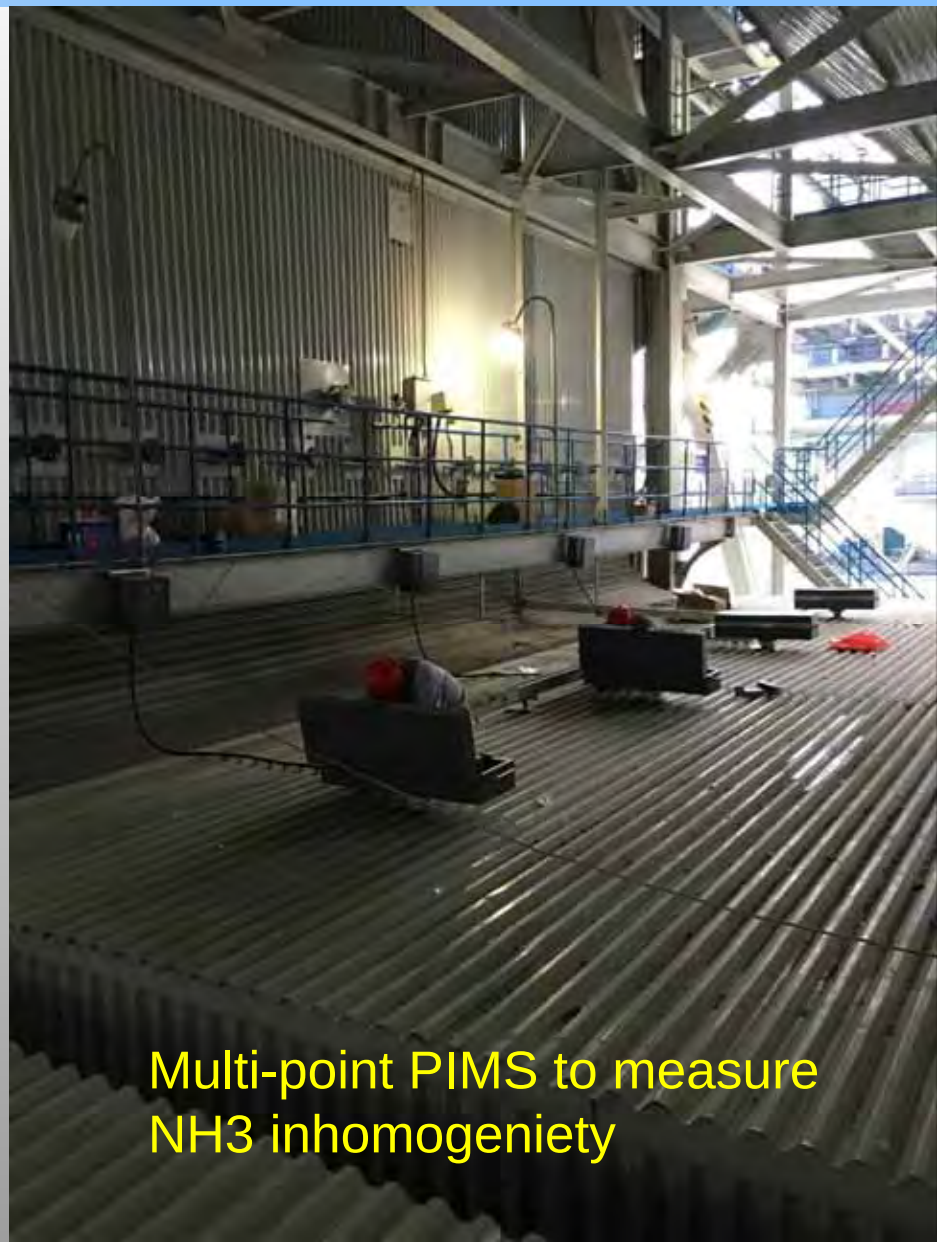

Multi-point PIMS to measure NH3 inhomogeniety

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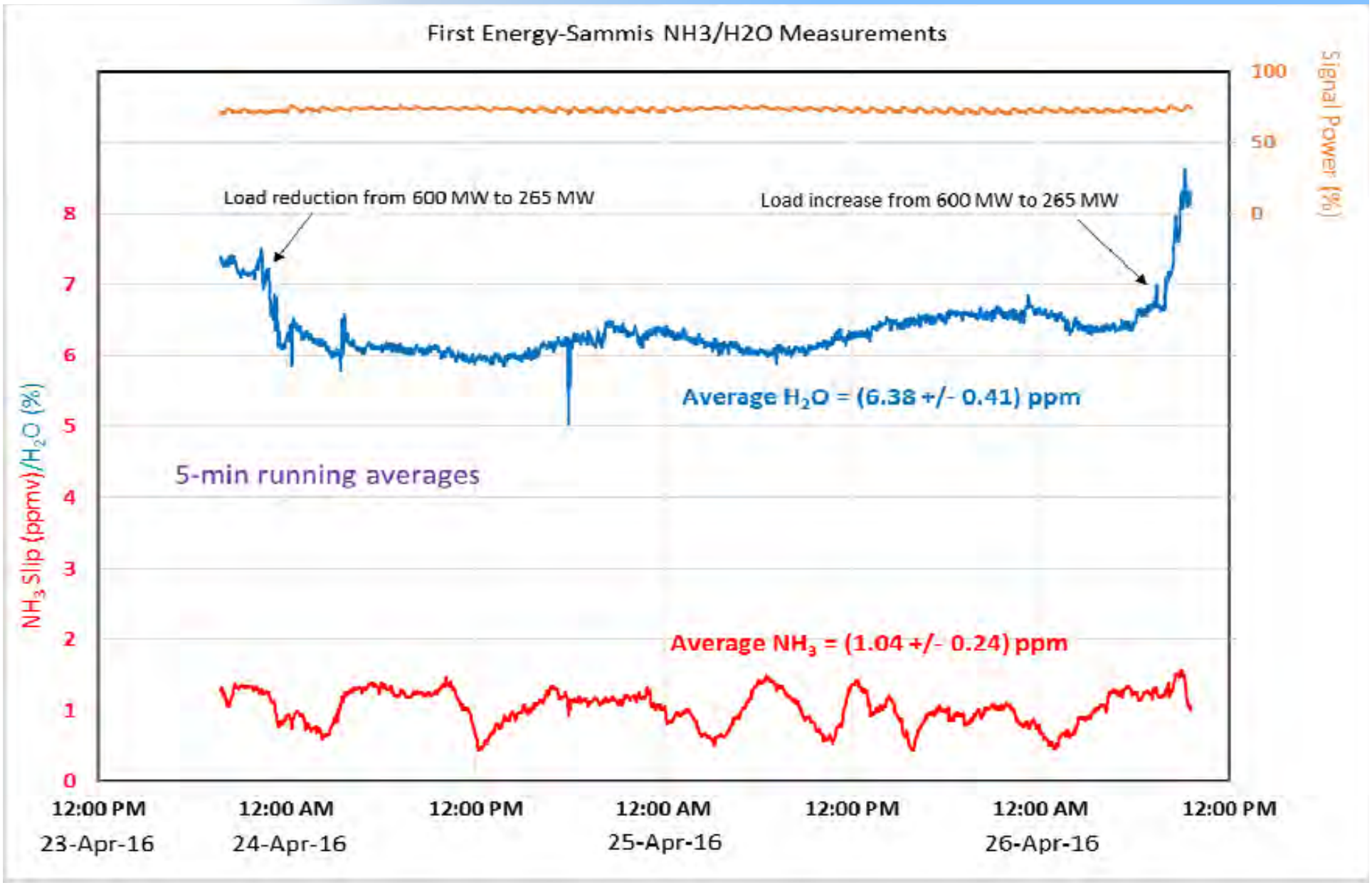

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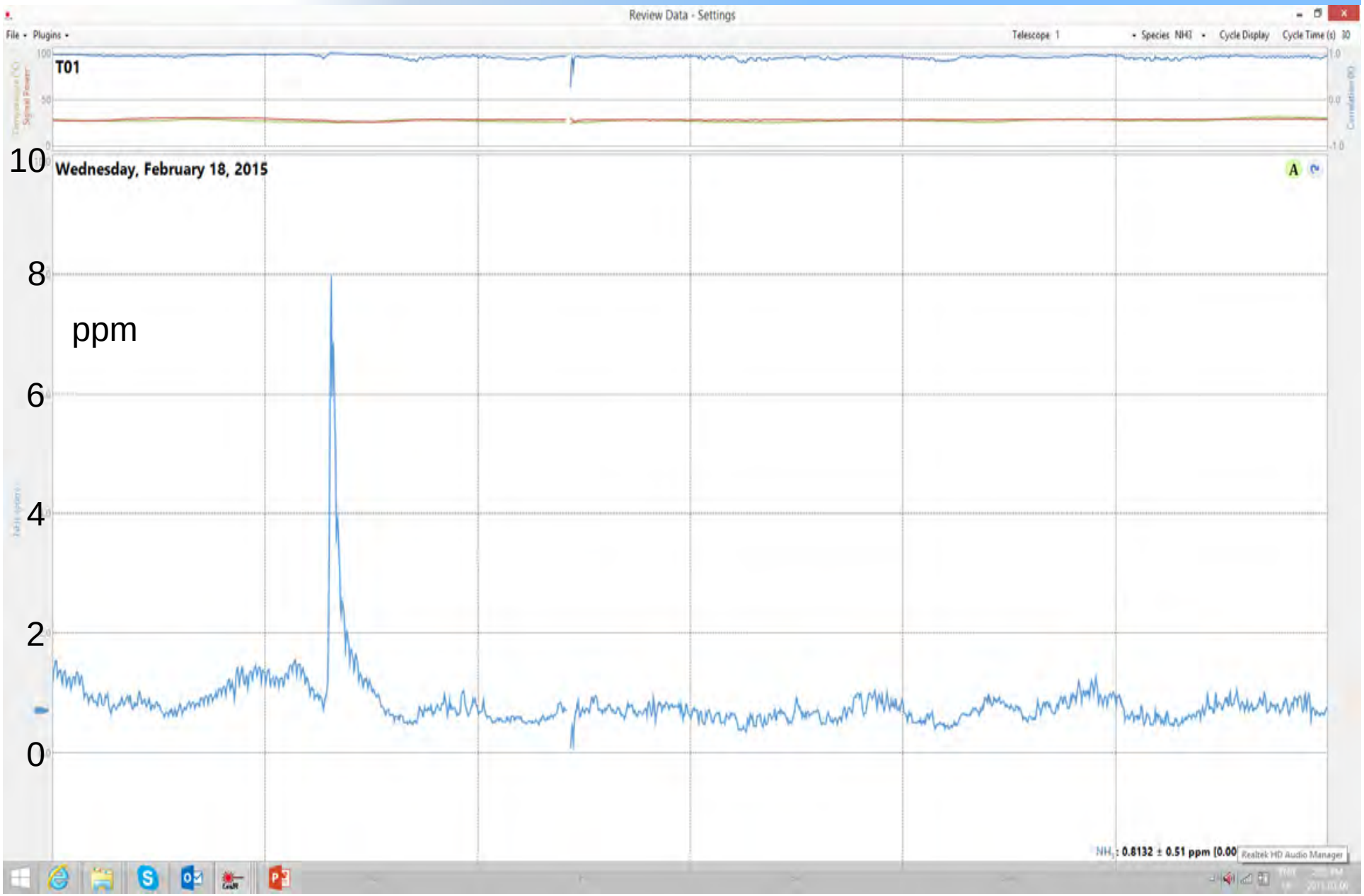
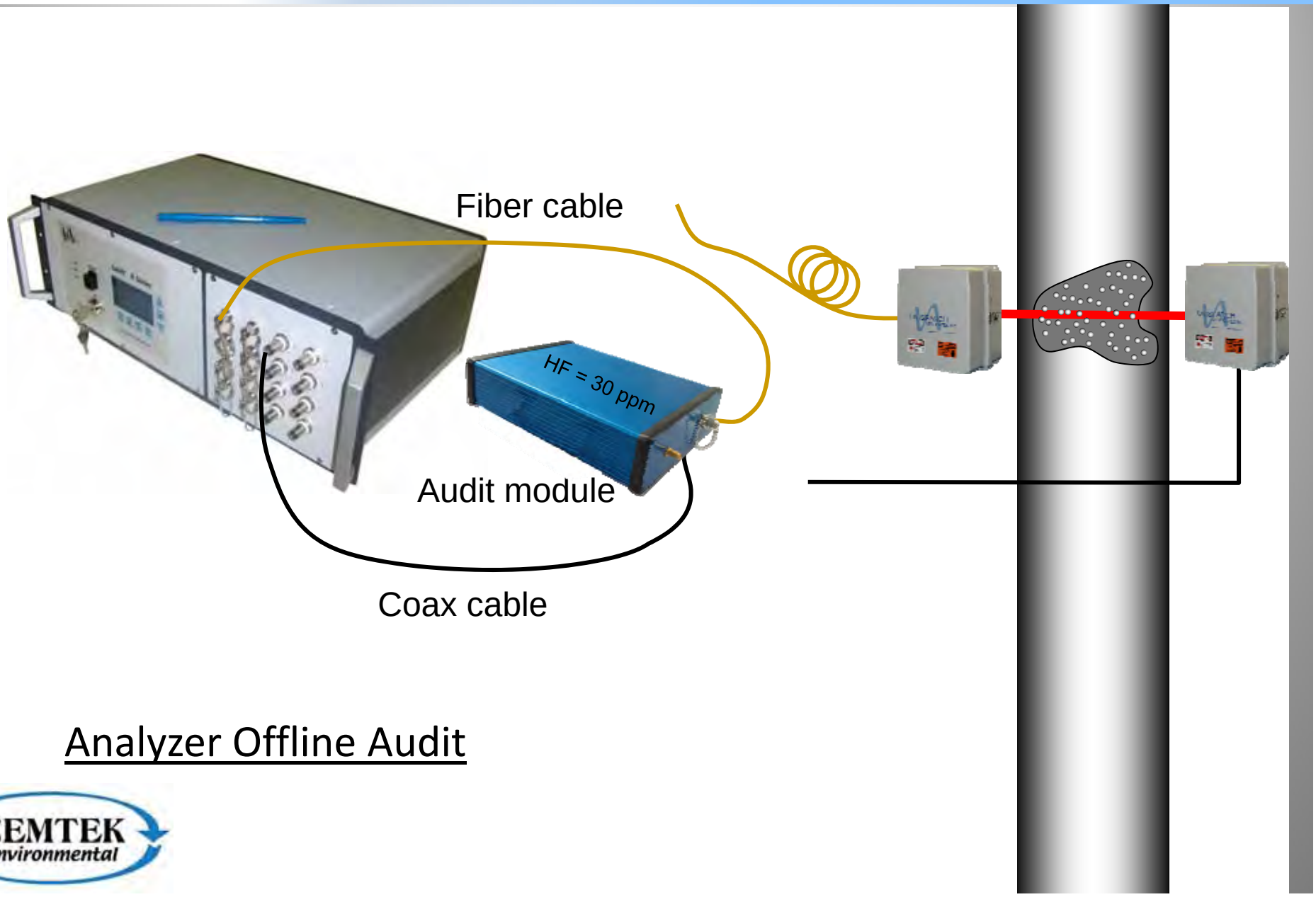


Unisearch gas analyzer do not require field calibration.

Audit Modules containing permanently sealed gas cells are available to check the validity of the measurements. Therefore, compressed gas cylinders are not required to check the performance or validity of the analyzer.



Analyzer Offline Audit

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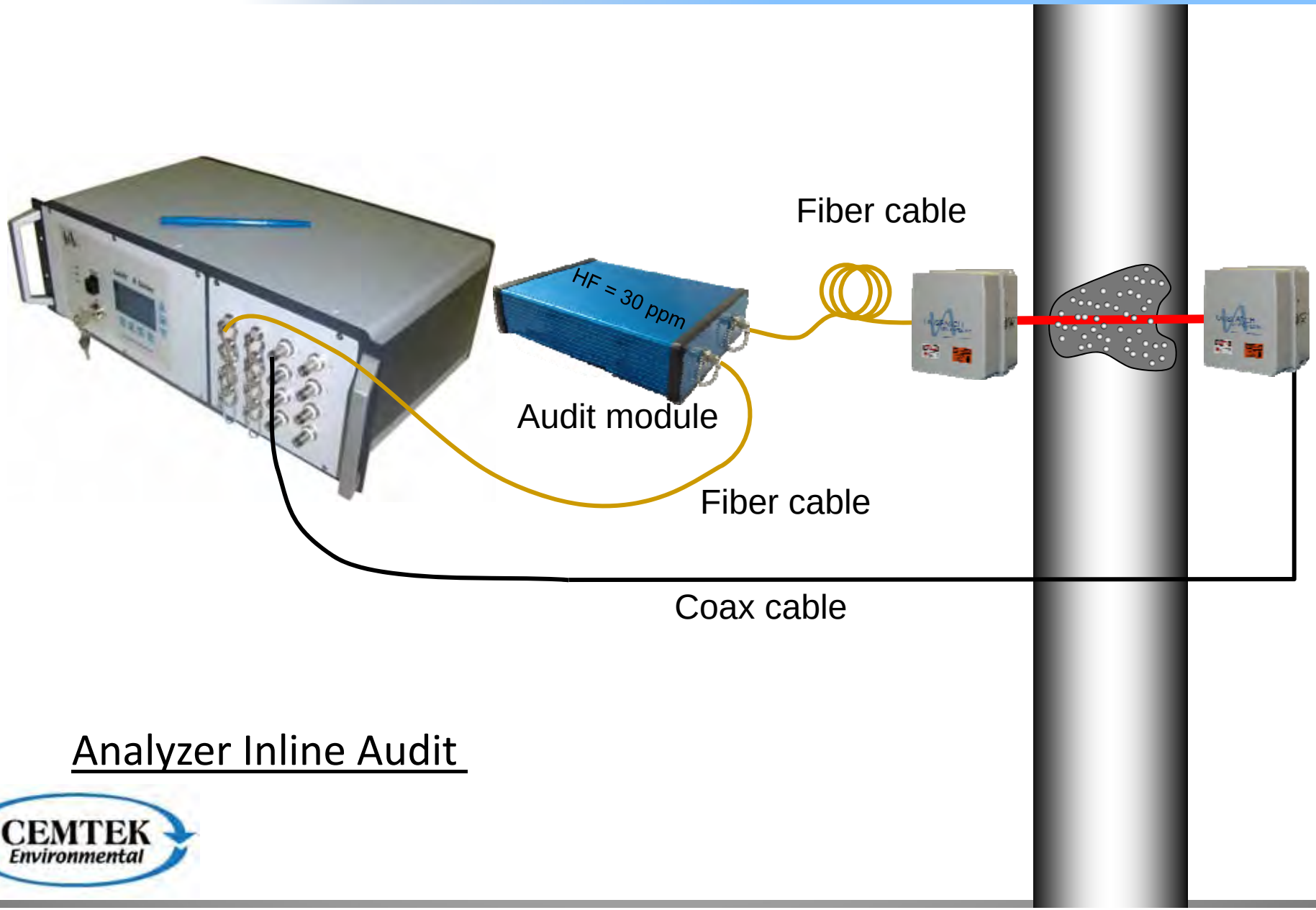

Analyzer Inline Audit

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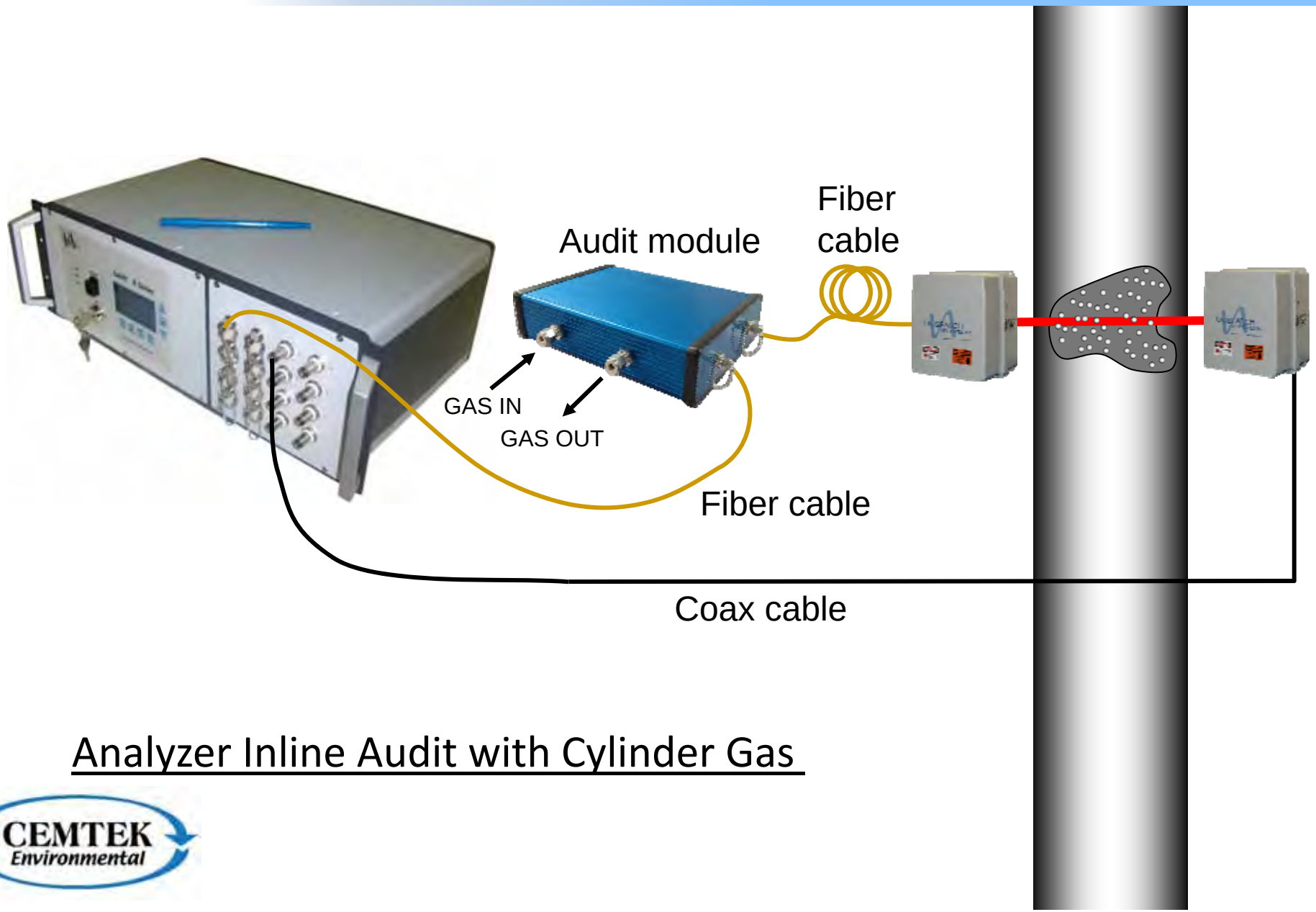

Analyzer Inline Audit with Cylinder Gas

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Data logging:

Internal compact flash card (4 GB) – can store ~5 years of data
Analog: 4-20 mA outputs (for gas level and signal power)
Digital: RS232 (ASCII), Ethernet, Modbus (TCP/IP)

Alarms:

6 dry-contact relays (5 configurable by user)

Examples:

- Analyzer main power (fixed)
- Software operation
- Gas level alarm (low and high)
- Instrument fault alarm