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# **Mercury Removal in a Multi-Pollutant Control Technology for Utility Boilers**

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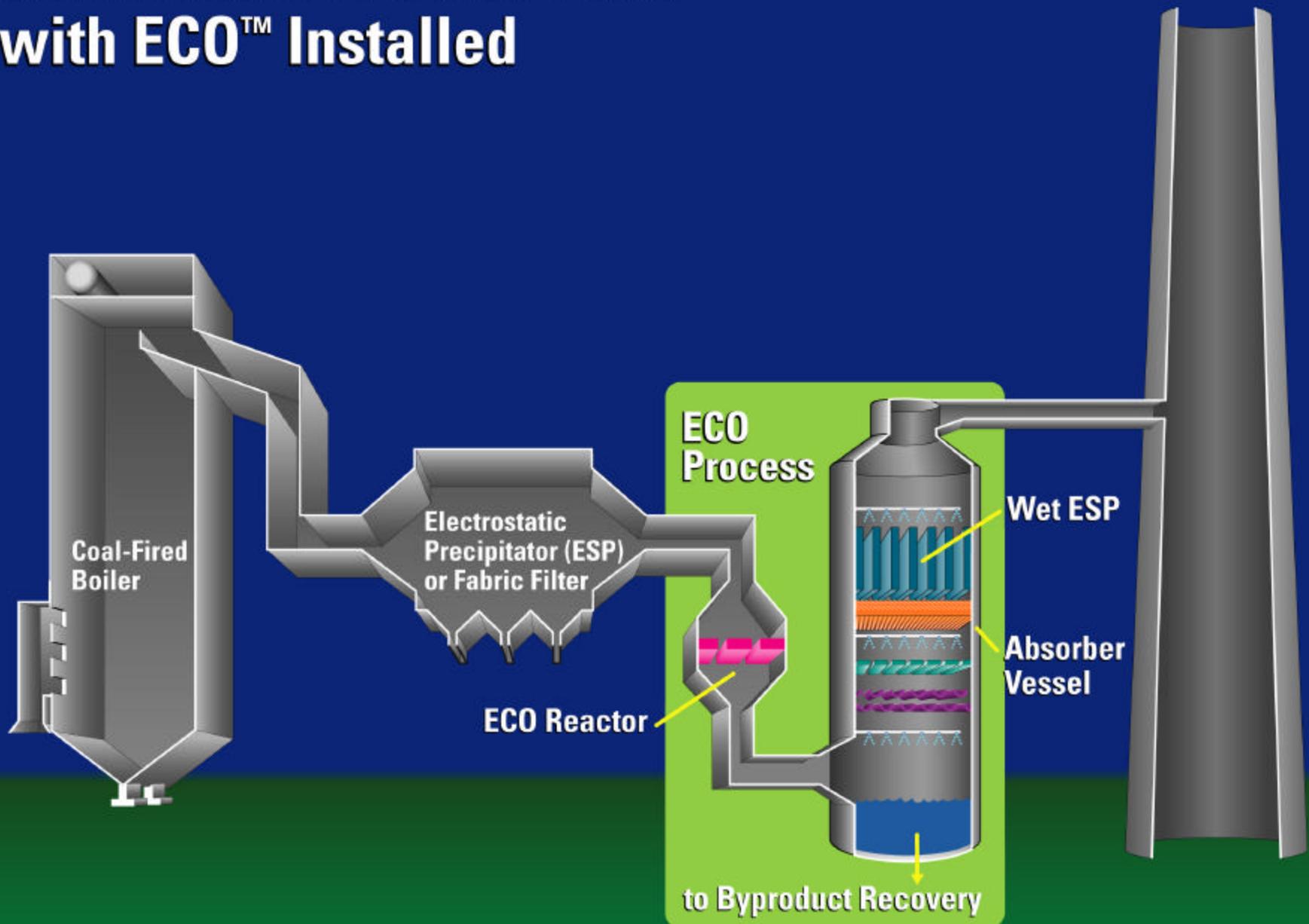
## **ECO Technology**

- **Technology Need**
- **Overview**
- **Pilot Testing and Results**
- **Benefits and Cost**

## Framework for Mercury Control

- **Federal**
  - U.S. EPA MACT standard
  - S. 556 Clean Power Act of 2002
  - Clear Skies Act of 2002
- **States/Regional**
  - Several states targeting mercury reductions from power plants
  - New England Governors and Eastern Canadian Premiers adopted a Mercury Action Plan

# Conventional Power Plant with ECO™ Installed



## Technology Overview

- **Improvements to ECO Technology**
- **Barrier Discharge Reactor**
- **Ammonia Scrubber**
- **Wet ESP**
- **Byproduct Recovery**

## Improvements to ECO Technology

- **Ammonia scrubbing of SO<sub>2</sub> and NO<sub>2</sub> (2001)**
  - Increases NO<sub>x</sub> and SO<sub>2</sub> removal to greater than 90 and 95%, respectively
  - Produces ammonium nitrate/sulfate fertilizer, offsetting reagent cost
  - Scrubber added to ECO pilot in early 2002
- **Vertical configuration**

## Barrier Discharge Reactor

- Creates radicals (O, OH) from O<sub>2</sub> and H<sub>2</sub>O
- Radicals create
  - HgO from Hg
  - NO<sub>2</sub> and HNO<sub>3</sub> from NO<sub>x</sub>
  - H<sub>2</sub>SO<sub>4</sub> from SO<sub>2</sub>
- 5eV electrons ideal for radical creation
- 80 to 90% oxidation of Hg demonstrated

## Ammonia Scrubber

- Follows gas discharge reactor
- Ammonia based scrubbing process
  - Produces ammonium sulfate and nitrate from pollutants exiting barrier discharge reactor
- Consists of two sections:
  - Gas cooling and saturation section
  - Scrubbing section

## NO<sub>x</sub>/SO<sub>2</sub> Scrubbing

- SO<sub>2</sub> scrubbing creates sulfite (SO<sub>3</sub><sup>-2</sup>, HSO<sub>3</sub><sup>-</sup>) and sulfate (SO<sub>4</sub><sup>2-</sup>, HSO<sub>4</sub><sup>-</sup>) compounds
- Sulfite reacts with NO<sub>2</sub> at high rate
  - NO<sub>2</sub> + 2SO<sub>3</sub><sup>2-</sup> ® ½N<sub>2</sub> + 2SO<sub>4</sub><sup>2-</sup>
- SO<sub>2</sub> of 3 times the NO<sub>x</sub> concentration needed for adequate NO<sub>2</sub> scrubbing

## Hg in Scrubber Solutions

- $\text{Hg}^{2+}$  can be captured in scrubber
- $\text{Hg}^0$  is not soluble
- Compounds in liquid (e.g.  $\text{SO}_3^{2-}$ ) may reduce  $\text{Hg}^{2+}$  to  $\text{Hg}^0$
- Means to limit rate of  $\text{Hg}^{2+}$  reduction
  - Alteration of scrubbing process to reduce rate of reaction
  - Treatment of scrubbing solution to keep Hg concentration low

## Wet ESP

- **Collects**
  - Aerosols ( $\text{NH}_4\text{HSO}_4$ ,  $\text{NH}_4\text{NO}_3$ ,  $\text{NH}_4\text{Cl}$ ) produced in the scrubbing process
  - Fine particulate matter ( $\text{PM}_{2.5}$ )
  - $\text{Hg}^{2+}$  not captured in scrubber
  - Air toxic compounds

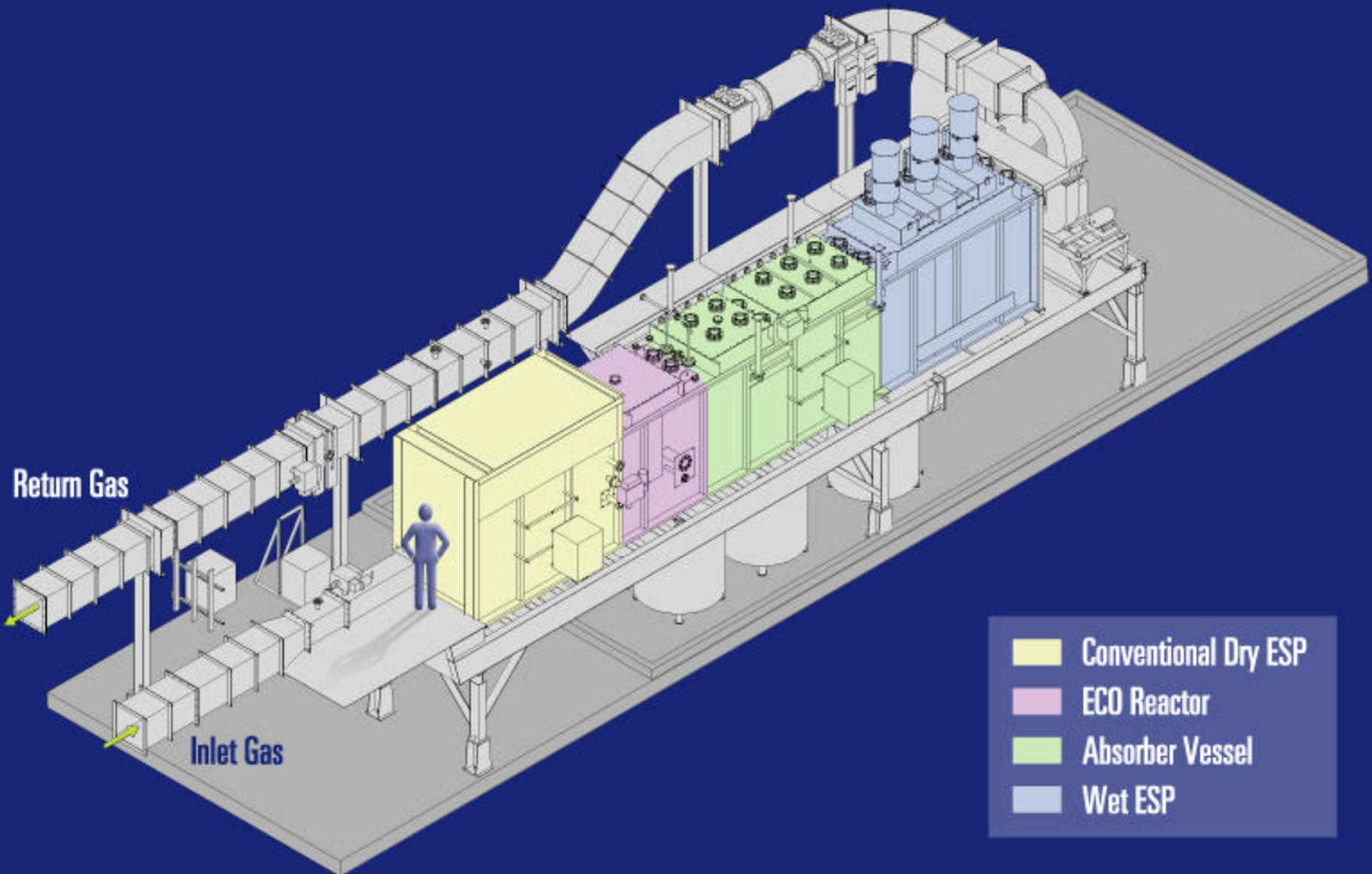
## Byproduct Recovery

- **Filtration removes ash and insoluble metal compounds**
- **Activated carbon captures soluble Hg**
  - Commercially used in wastewater and industrial waste treatment
- **Ammonium sulfate/nitrate fertilizer produced from effluent in various forms**
  - Liquid
  - Crystals
  - Granules

## DOE Funded Pilot Test Program

- **\$2.8 million cooperative agreement with U.S. DOE (NETL) for optimizing mercury removal in ECO**
- **30 month program**
- **Semi-continuous monitoring of mercury (total, elemental)**
- **Ontario-Hydro method testing to verify instrumentation and pilot performance**

# ECO™ Pilot Unit at FirstEnergy's R.E. Burger Plant



## Pilot Unit - Configuration

- Cyclone Separator and Dry ESP
- Barrier Discharge Reactor
- Horizontal Scrubber
- Wet ESP
- Instrumentation
  - Inlet and outlet CEMS for NO<sub>x</sub>, SO<sub>2</sub>, H<sub>2</sub>O, CO<sub>2</sub>, CO, O<sub>2</sub>
  - On-site analysis of liquids for NO<sub>3</sub><sup>-</sup>, SO<sub>3</sub><sup>-2</sup>, SO<sub>4</sub><sup>-2</sup>
  - Automated Data Logging

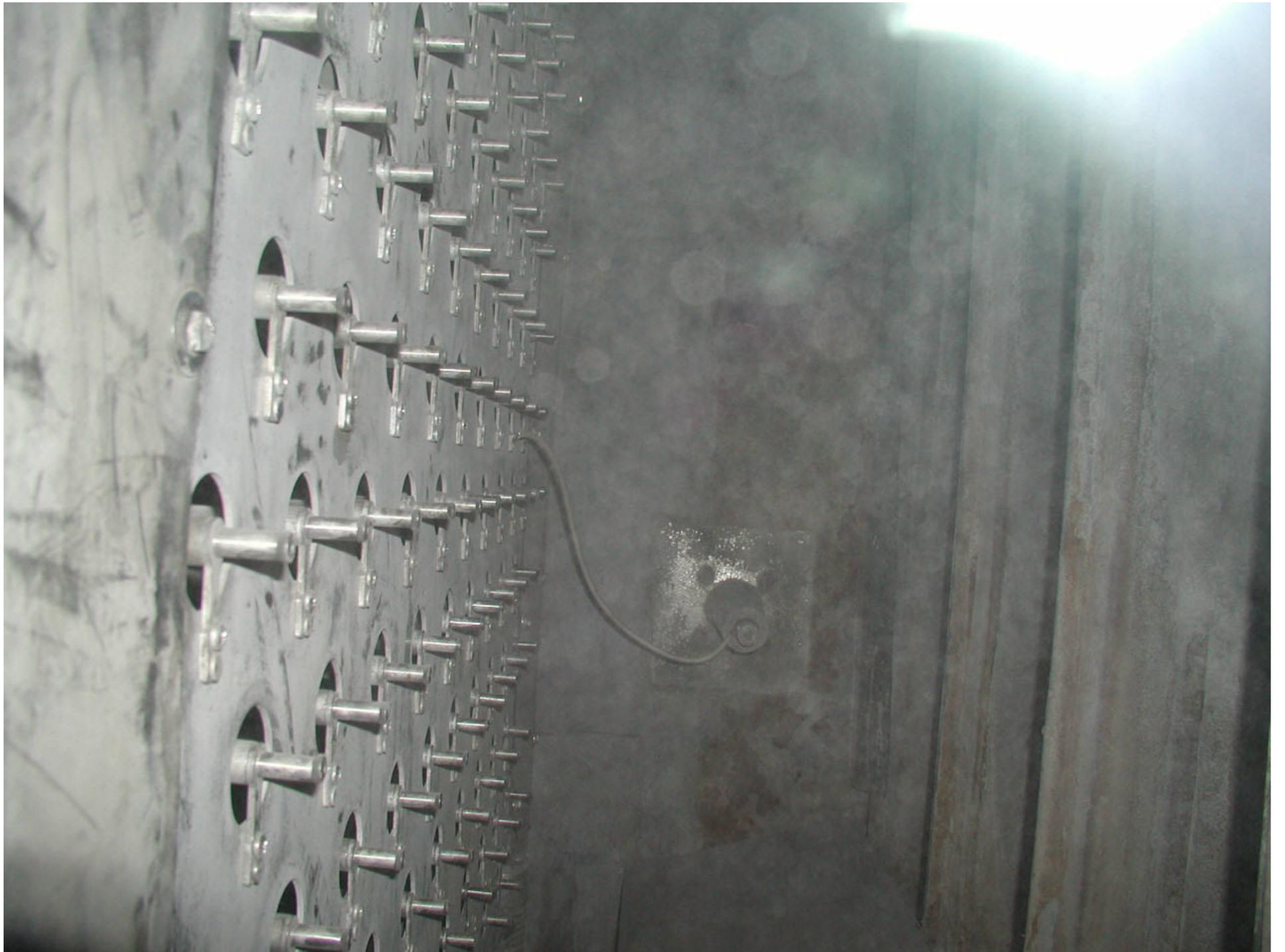


Photo - Pilot Scrubber Top





## Mercury Measurement in Gas Streams

- **Sir Galahad Hg CEMS (PS Analytical)**
  - Measurement of elemental and total Hg
  - Probes located in the inlet and return gas streams, and after individual process units
  - Reliable operation not yet demonstrated
- **Ontario-Hydro testing for particle bound, elemental and total mercury**
  - Performed by Air Compliance Testing (Cleveland, OH)

## Pilot Data – Hg Removal

- **Ontario-Hydro test results**
  - All concentrations in micrograms per dry standard cubic meter

Hg Fraction	ECO Inlet Conc.	ECO Outlet Conc.	Removal
Particle Bound Hg	0.62	.016	97.4%
Oxidized Hg	5.81	0.022	99.6%
Elemental Hg	0.16	0.75	
<b>Total</b>	<b>6.59</b>	<b>0.79</b>	<b>88.0%</b>

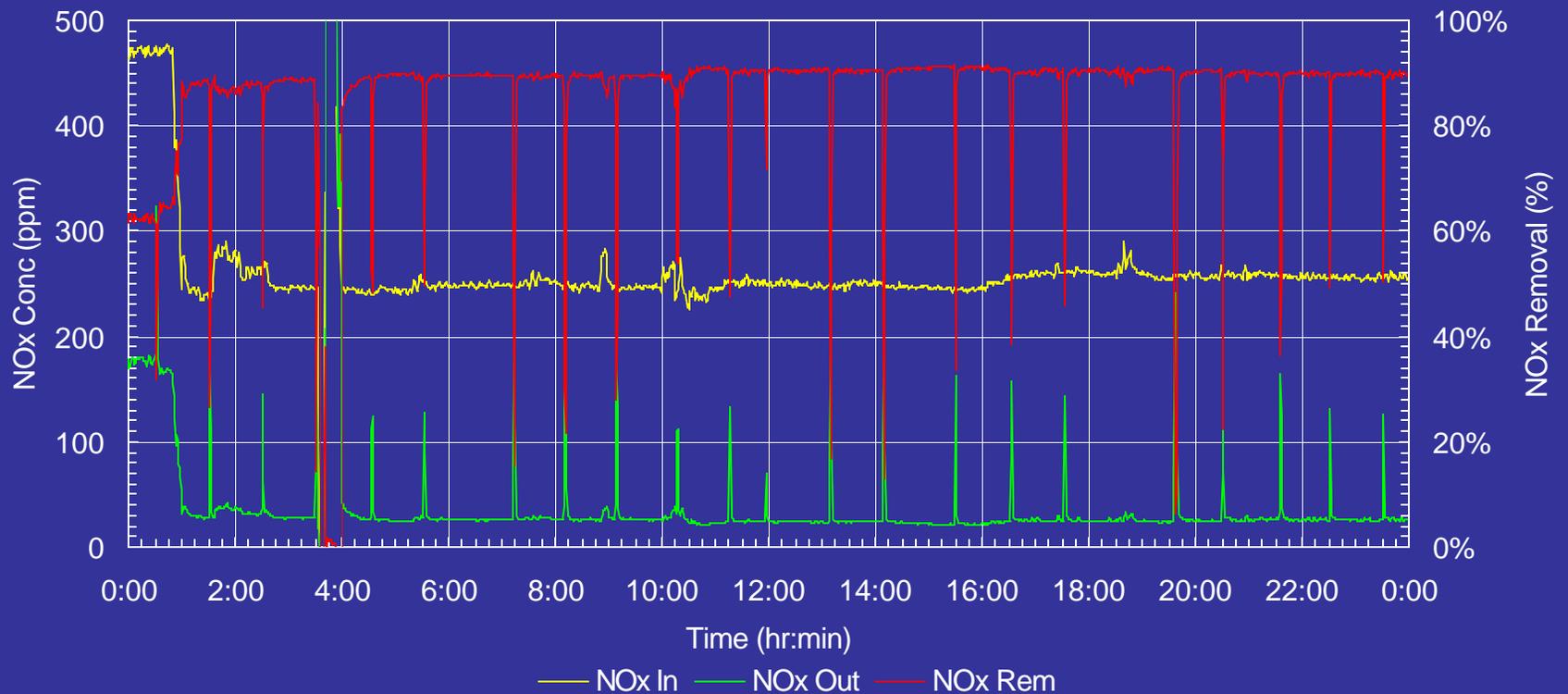
## Previous Pilot Test Results

- Testing in 2000 prior to addition of ammonia scrubber
- 81.6% removal of Hg (method 29)
- >99% capture of As, Ba, Cr, Cu, Pb, Mn, Ni, and P
- 99.6% capture of total particulate matter
- 96.7% capture of particles less than 3 microns

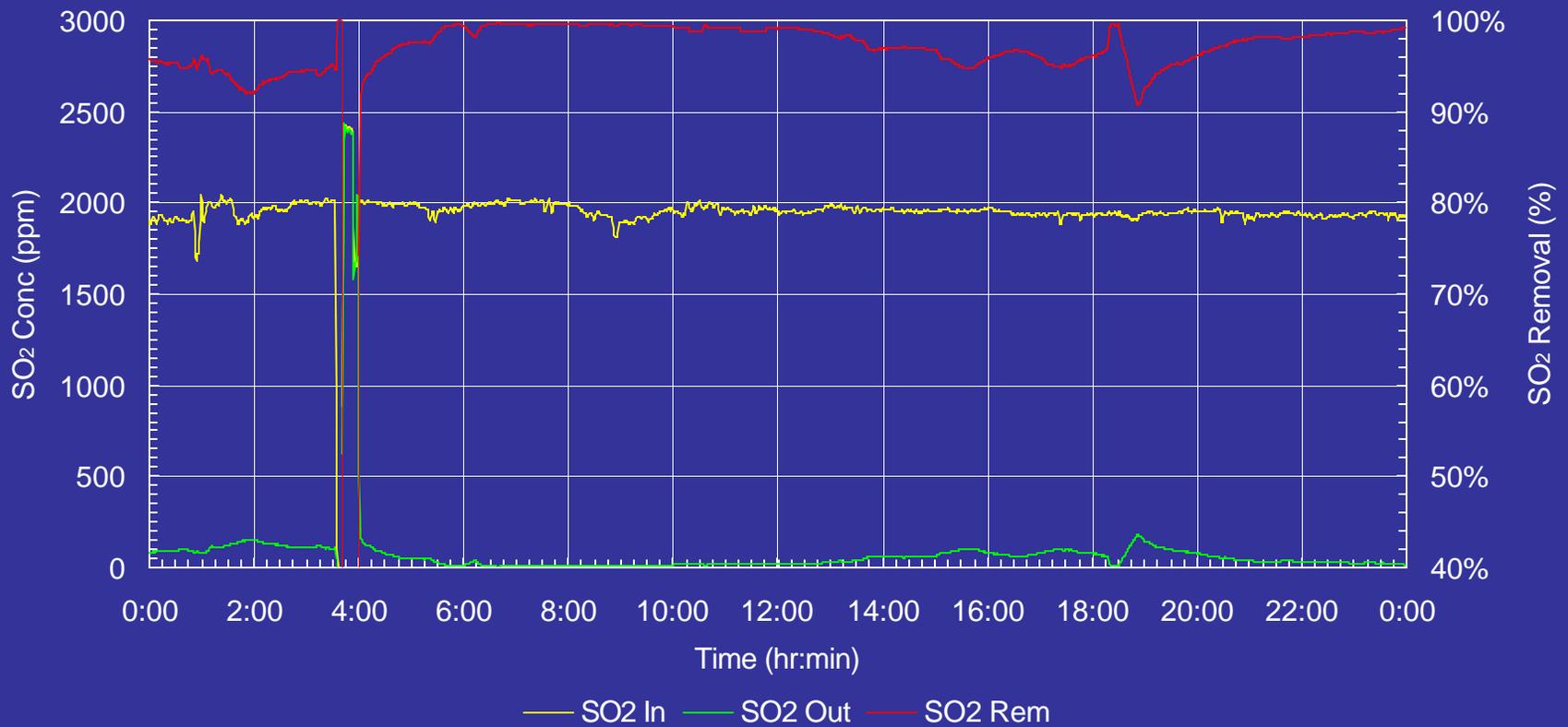
## Hg Capture from Scrubber Solution

- **Pilot liquid effluent treated with Mersorb<sup>®</sup> LW**
  - Sulfur impregnated, activated carbon
  - Manufactured by Nucon International (Columbus, OH)
- **Reduced Hg concentration in effluent from 197 ppb to <20 ppb**
- **Estimated variable cost for Hg capture is \$733 per pound of Hg**
  - includes adsorbent and disposal

# Pilot Data – NO<sub>x</sub> Removal



# Pilot Data – SO<sub>2</sub> Removal



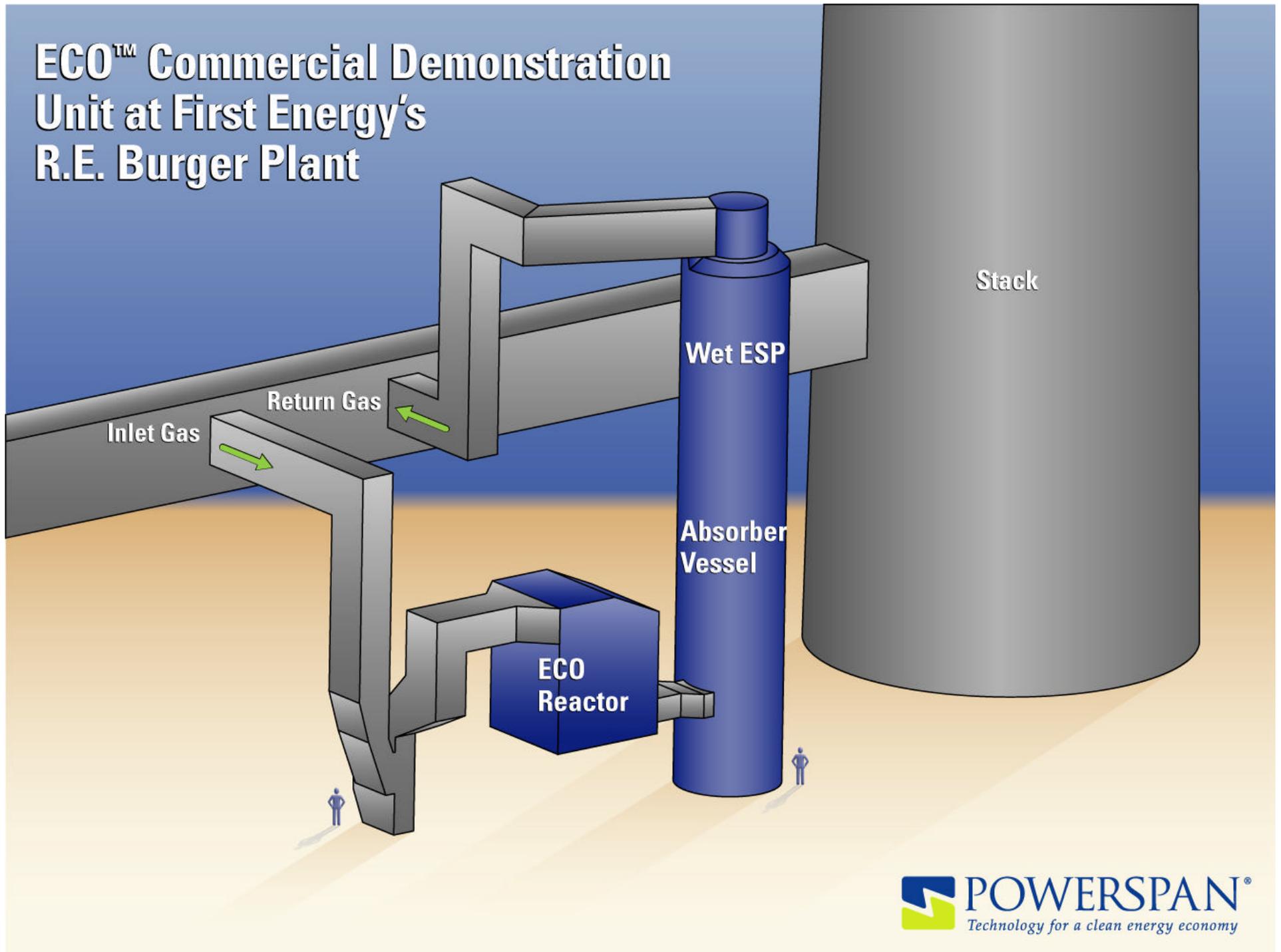
## Future Testing

- **Addition of elemental Hg to gas stream**
  - Demonstrate oxidation and capture of elemental Hg
- **Hg material balances on process streams**
  - Testing to determine fate of Hg throughout ECO process
- **Measurement of Hg (Ontario-Hydro), metals (method 29), and particle size distribution**
  - Next test event in September 2002

## **Commercial Demonstration Unit**

- **Installation at FirstEnergy's R.E. Burger Plant**
- **50 MWe slipstream from a 156 MW boiler**
- **Vertical scrubber and wet ESP in a single vessel**
- **Operation in second quarter 2003**

# ECO™ Commercial Demonstration Unit at First Energy's R.E. Burger Plant



## Benefits and Cost of ECO

- High removal levels: >80% Hg, >90% NO<sub>x</sub>, >95% SO<sub>2</sub>, >95% PM<sub>2.5</sub>
- Lower Capital Cost than FGD, SCR, ACI - ~\$150/kW for 500 MW plant
- Lower O&M Costs - ~1.5 mils per kWh
- Fertilizer byproduct versus landfill waste
- Reduces all emissions with single installation
- Avoids ammonia fouling of ash, ammonia bisulfate fouling of air heater/ESP, and associated maintenance

## For Further Information

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