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# **Mercury Program Review**

## **Novel Techniques for Mercury Control**

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# Project Objectives

## Develop Cost Effective Sorbents

- **Alternatives to Activated Carbon**
- **Identify Novel Sorbent Candidates**
- **Commercialization of Thief Process**
- **Test in Pilot-Scale Facility**

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# Project Objectives

## Develop Mercury Oxidation Catalysts

- **Identify Candidates, Reports of Invention**
- **Demonstrate Oxidation at Bench-Scale**
- **Enhance Model of Mercury in 500-lb/hr**

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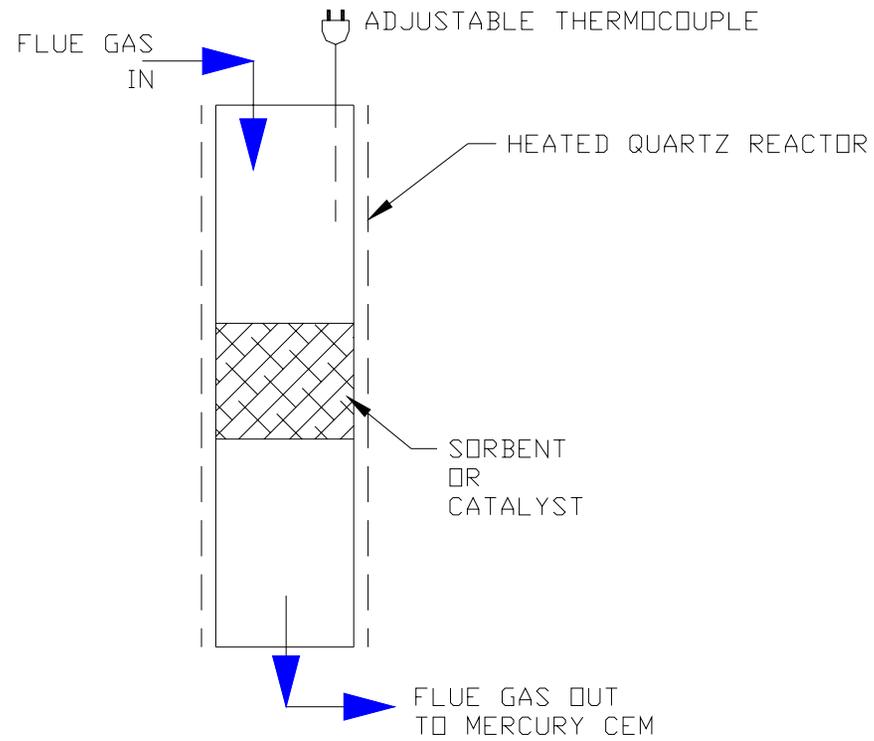
# Project Objectives

## Photochemical Removal: GP-254 Process

- **Commercialization of GP-254 Process**
- **Consultant for Powerspan**



# NETL BENCH-SCALE PACKED BED REACTOR



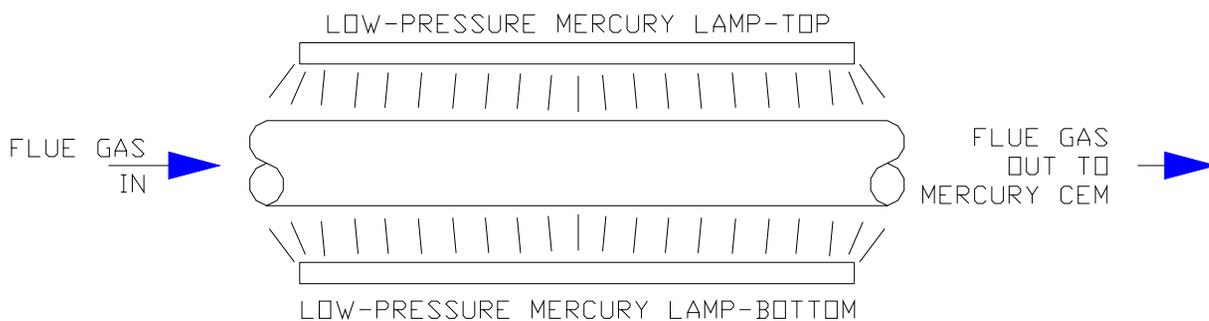
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# **Bench-Scale Packed Bed Reactor**

- **½-Inch OD by 12-Inch Long Quartz Tube**
- **100 mg of Sorbent or Catalyst**
- **Temperature: 280°F - 320°F**
- **Gas Composition: Slipstream of PRB or 90:10 PRB:Bituminous Particulate-Free Flue Gas**
- **Flow-Rate: 8 liters/min**
- **Sir Galahad CEM : Inlet/Outlet Mercury**



# NETL BENCH-SCALE PHOTOREACTOR

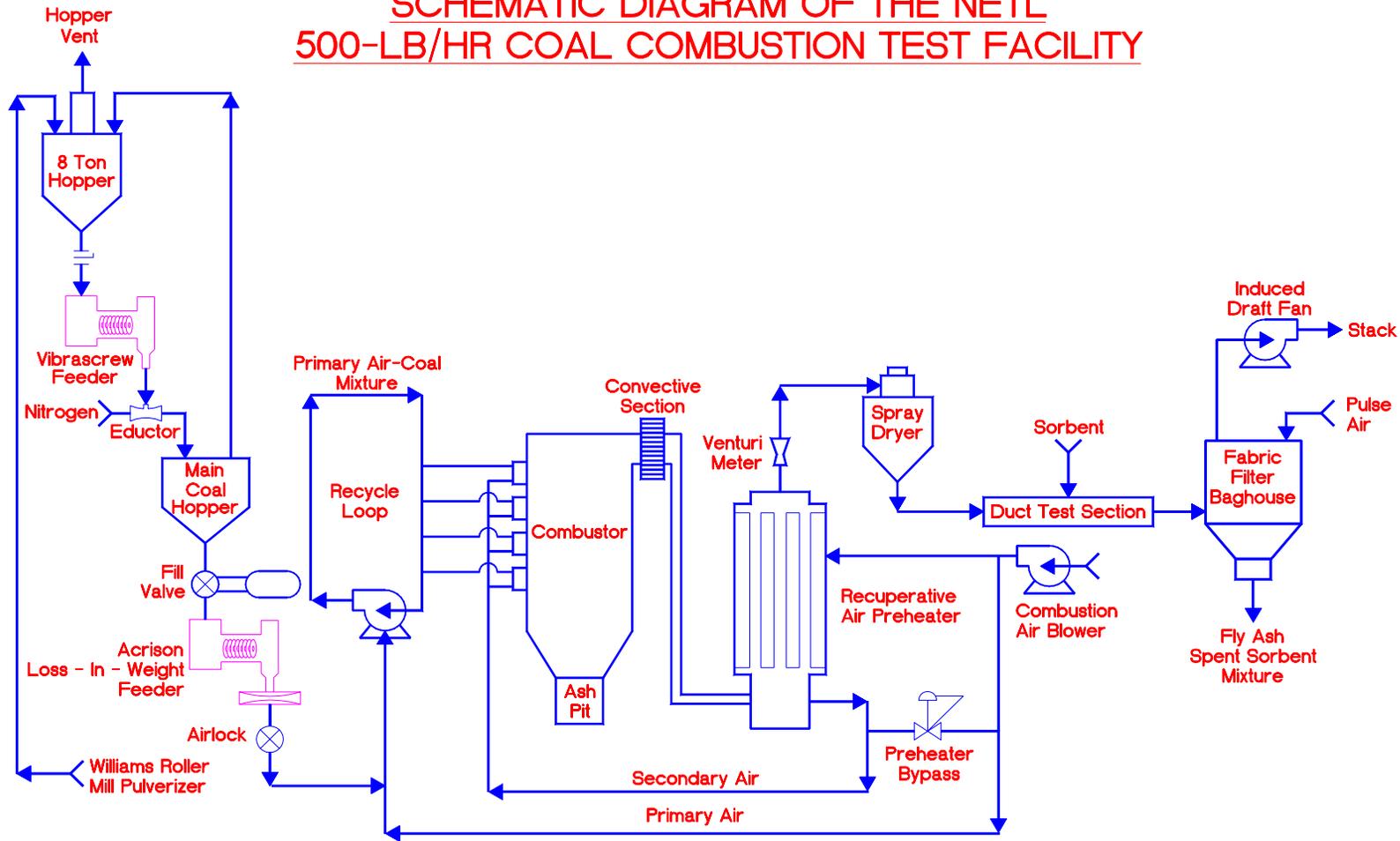


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# Bench-Scale Photoreactor

- **1/2-inch by 33-inch Quartz Tube**
- **Two 30-W Low Pressure Mercury Lamps**
- **254-nm Intensity: 20 mw/cm<sup>2</sup>**
- **Gas Composition: PRB Flue Gas**
- **Temperature: 120°F - 280°F**
- **Flow-Rate: 8 liters/min**
- **Sir Galahad CEM Monitor Inlet/Outlet  
Mercury**

## SCHEMATIC DIAGRAM OF THE NETL 500-LB/HR COAL COMBUSTION TEST FACILITY



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# Thief Process

- **Alternative to ACI Developed**
- **Process Involves Extracting Partially Combusted Coal From The Combustor and Re-injecting Downstream of the Air Preheater**
- **Recent Results Show Similar Removals to ACI**
- **Patent Issued February 2003**



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## **GP-254 Process**

- **Alternative to ACI Developed**
- **Oxidation of Mercury**
- **Irradiation of Flue Gas with 254-nm Light**
- **90% Oxidation Attained at Bench-Scale**
- **Patent Issued June 2003**
- **Licensed for Application to Coal-Burning Power Plants (Powerspan Corporation)**



# Bench-Scale Results: GP-254 Process

## Significant Level of Mercury Oxidation

- Slipstream of Particulate-Free PRB Flue Gas
- 6 – 50  $\mu\text{g}/\text{Nm}^3$  Elemental Mercury (Spiking)
- Low Power Consumption
- Typically 30-70% Removal of Mercury
- Extremely Low UV Intensity Applied
- Non-Optimized Bench-Scale Apparatus
- Higher Intensity Lamps: 90% Removal (Powerspan)



# Sorbents for Removal of Mercury in Flue Gas

<u>Sorbent</u>	<u>5% Breakthrough (min)</u>
Darco AC	120
Thief	60
Thief-HCl	90
H <sub>2</sub> SO <sub>4</sub> -AC	30
Ir	≤ 10
Ir-HCl	≤ 5
Biomass Carbon	≤ 5
Fly Ash	≤ 10
Al <sub>2</sub> O <sub>3</sub>	≤ 10

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# Catalysts for Oxidation of Mercury in Flue Gas



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# Problem & Opportunity

## EPA Regulation of Power Plants Imminent

- Many Power Plants Have Wet Scrubbers
- More Will Add Scrubbers in Near Future
- Large Fraction of Flue Gas Mercury is in Elemental Form – Hard to Capture
- Oxidized Mercury Soluble in Water
- Elemental Mercury Insoluble
- Oxidized Mercury Easily Captured on Carbon



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# Oxidation Catalysts

- **Simple Strategy**
- **Enhance Capture in Scrubbers**
- **Improve Capture in Particulate Control Device**
- **ESP**
- **Baghouse**

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# Description of Invention

## I. Catalytic Oxidation of Mercury

- Catalyst Injection, Packed Bed, or Monolith
- Oxidation of Elemental Mercury to Mercuric Chloride
- Upstream of Appropriate APCD

## II. APCD

- Wet Scrubber (Preferred)
- ESP
- Baghouse



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# Previous Work

## TVA – Gold Catalyst

- Gold is Not Inert
- Potential Degradation in Flue Gas

## URS Radian: Pd, SCR, AC, & Fly Ash

- Palladium is Not Inert
- Potential Degradation in Flue Gas

## UNDEERC: SCR Catalysts

- Fifty Percent Oxidation Levels Measured
- Not Optimized for Mercury Oxidation



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# **Iridium and Iridium Alloy Catalysts**

## **Advantages**

- **Most Corrosion Resistant Metals Known**
- **High Temperature Resistance**
- **More Resistant to Degradation than Gold, Palladium, SCR Catalyst, AC, & Fly Ash**
- **Longer Life in Flue Gas**
- **Easier to Regenerate**
- **Simple Fabrication in Low Concentrations**
- **Excellent Bench-Scale Results**



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# Thief Carbons

## Advantages

- **Far Cheaper than Activated Carbons**
- **Easy to Impregnate**
- **Cheap Enough to Be Throw-Away Catalyst**
- **Excellent Bench-Scale Results**



# Results: Iridium Catalyst

## NETL 500-lb/hr Pilot Combustion Facility

- **Catalyst: 1 wt. % Iridium on Alumina Beads**
- **Bench-Scale Packed Bed Reactor**
- **10 Inch Long by ½ Inch OD Quartz Tube**
- **Mass: 2 g Catalyst (20 mg Iridium)**
- **Flow-Rate: 7.5 l/min Slipstream of Particulate-Free Flue Gas**
- **Temperature: 280°F**



# Results: Iridium Catalyst

- **Mercury Concentration: 12  $\mu\text{g}/\text{Nm}^3$  Total**
- **Mercury Concentration: 10  $\mu\text{g}/\text{Nm}^3$  Elemental**
- **Mercury Measurements: On-Line Sir Galahad CEM**
- **2.5 hrs On-Line**
- **75% Oxidation of Mercury**
- **Level of Oxidation Increases With Time**
- **High Level of Oxidation Demonstrated**

# Results: Thief Catalyst

- **Catalyst: HCl-Treated Thief Carbon**
- **Mass: 100 mg**
- **Hg Concentration: 10 - 60  $\mu\text{g}/\text{Nm}^3$  Total**
- **Hg Concentration: 8 - 50  $\mu\text{g}/\text{Nm}^3$  Elemental**
- **Temperature: 280°F - 320°F**
- **8 hrs On-Line**
- **90% Oxidation of Mercury**
- **Level of Oxidation Increases With Time**
- **High Level of Oxidation Demonstrated**



# Results: Darco AC Catalyst

## NETL 500-lb/hr Pilot Combustion Facility

- 100 mg Darco AC
- Temperature: 280°F - 320°F
- Hg Concentration: 16 - 60  $\mu\text{g}/\text{Nm}^3$  Total
- Hg Concentration: 14 - 50  $\mu\text{g}/\text{Nm}^3$  Elemental
- 16 hrs On-Line
- 90% Oxidation of Mercury
- Level of Oxidation Increases With Time
- High Level of Oxidation Demonstrated



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# Markets

## Coal-Burning Power Plants

- **300 GW Capacity**
- **Estimated \$500 MM Market**

## Other Markets

- **Incinerators**
- **Oil-Burning Boilers & Power Plants**
- **Refuse-Derived Fuel Power Plants**
- **Gasification Systems**



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# Plans For FY05

## Sorbent Development

- **Bench-Scale Packed-Bed Reactor**

## Scale-Up To Larger Units

- **Sorbent Injection 500-lb/hr Pilot-Combustor**

## Mercury Oxidation Catalysts

- **Bench-Scale Slipstream Reactor**

