

The Thief Process for Mercury Removal from Flue Gas



Evan J. Granite, Mark C. Freeman,
Richard A. Hargis, William J. O'Dowd, and
Henry W. Pennline

**United States Department of Energy
National Energy Technology Laboratory
22nd Annual Pittsburgh Coal Conference
Pittsburgh, PA
September 13, 2005**



Thief Process

- **Alternative to activated carbon injection (ACI)**
- **Extraction of partially combusted coal from furnace & re-injection downstream of preheater**
- **Recent results show similar removals to ACI**
- **Patent issued February 2003**
- **Licensed to Mobotec USA May 2005**



Regulatory Drivers

- **EPA Announcement March 15, 2005**
- **Clean Air Mercury Rule**
- **Several States Requiring Stricter Reductions**
- **70-90% Removal Requirement**
- **Phased in Over Several Years**



Fossil Energy Program Goals

Develop more effective mercury control options

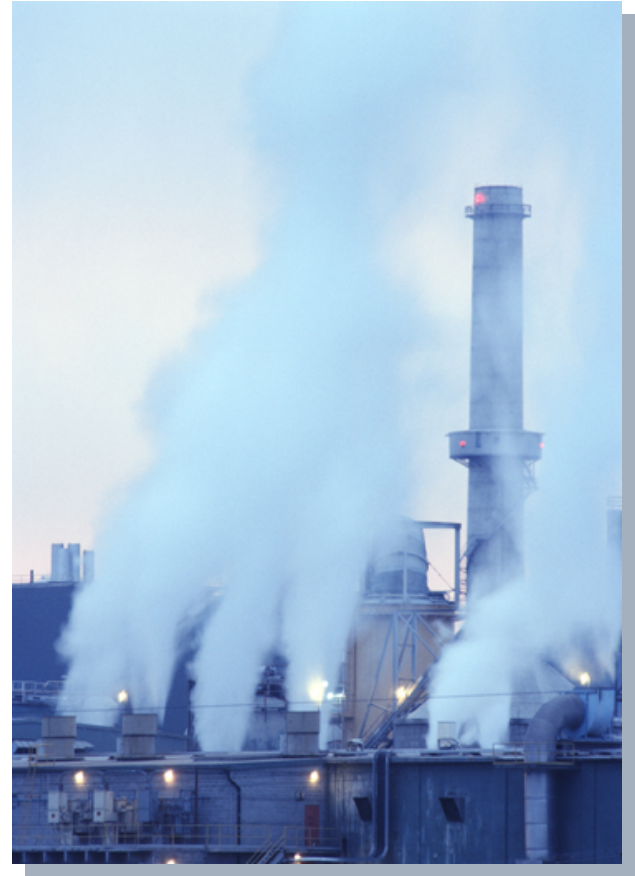
- **Cost-effective and high level of mercury removal**
- **Meet long-term IEP program goal of 90% mercury reduction at cost reduction of 25-50%**
- **Must be better than ACI**



Technical Challenges

Mercury is Difficult to Capture

- Low concentration
- Can exist as Hg^0
- Harsh conditions of coal-derived flue gas
- Competitive adsorption / poisoning
- Low sorbent reactivity
- Hg is semi-noble metal



ACI for Mercury Removal

- **Benchmark technology but has drawbacks for flue gas application**
- **General adsorbent**
- **Limited temperature range**
- **Sequestration**
- **High sorbent to Hg ratio (3,000:1 to 100,000:1)**
- **Contacting methods**
- **Expensive: \$1,000 - 3,000/ton**
- **500 MW_e power plant: \$0.5-10 MM/yr**
- **Potential market of \$10 billion/year**

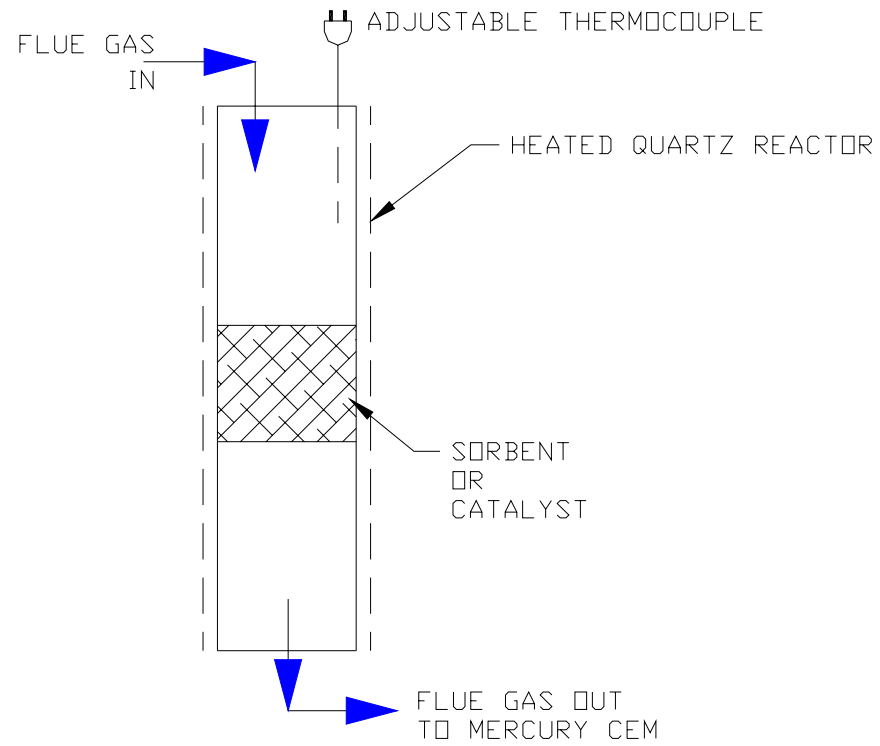
Project Objectives

Develop Cost Effective Sorbents

- **Alternatives to activated carbon**
- **Identify novel sorbent candidates**
- **Commercialization of Thief Process**



NETL BENCH-SCALE PACKED BED REACTOR

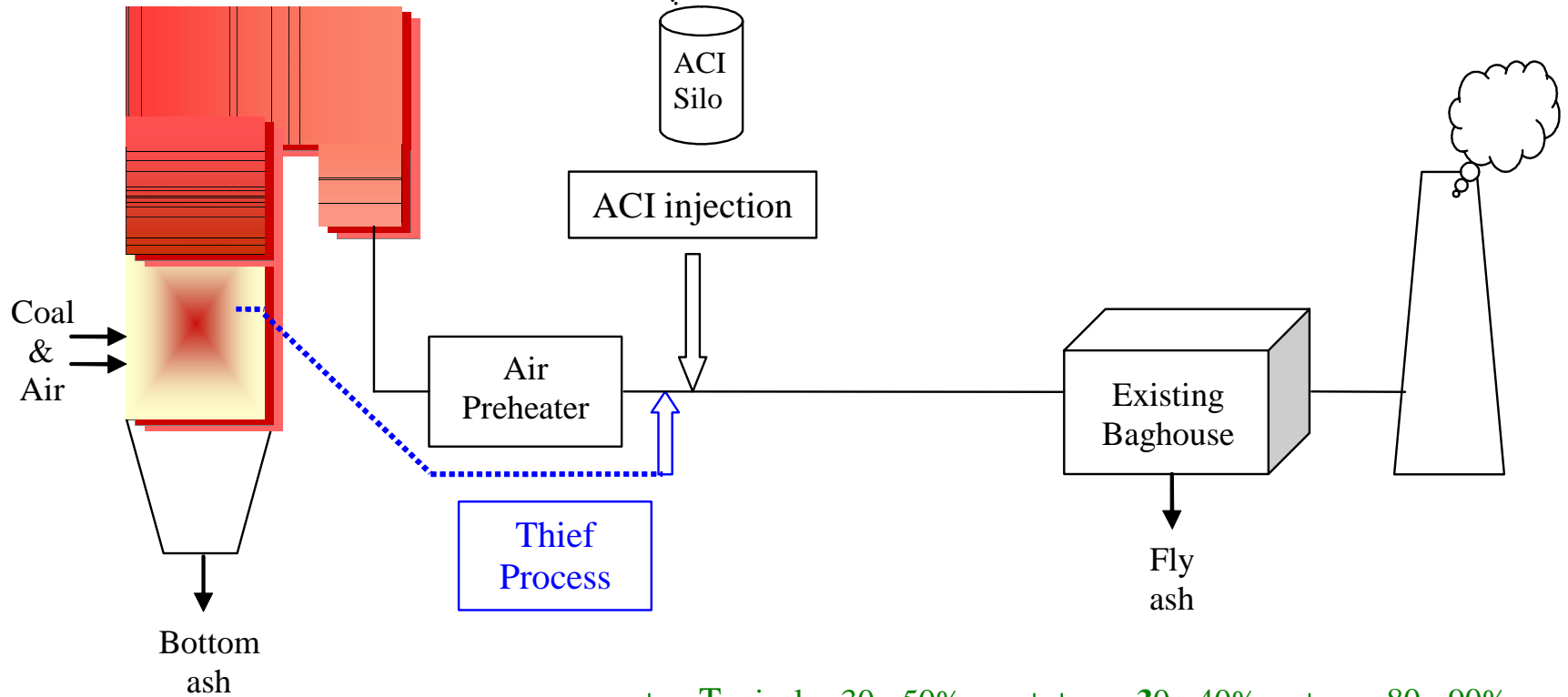


Bench-Scale Packed Bed Reactor

- **1/2-inch OD by 12-inch long quartz tube**
- **100 mg of sorbent**
- **Temperature: 280°F - 320°F**
- **Gas Composition: slipstream of PRB or PRB/Bituminous particulate-free flue gas**
- **Flow-rate: 8 liters/min**
- **Sir Galahad CEM: inlet/outlet mercury**



Thief Process and ACI Technology



Thief Process

Some general guidelines for Hg removal performance for lower levels of sorbent injection at ~ 2 - 4 lb/MMacf

Typical ~ 30 - 50%

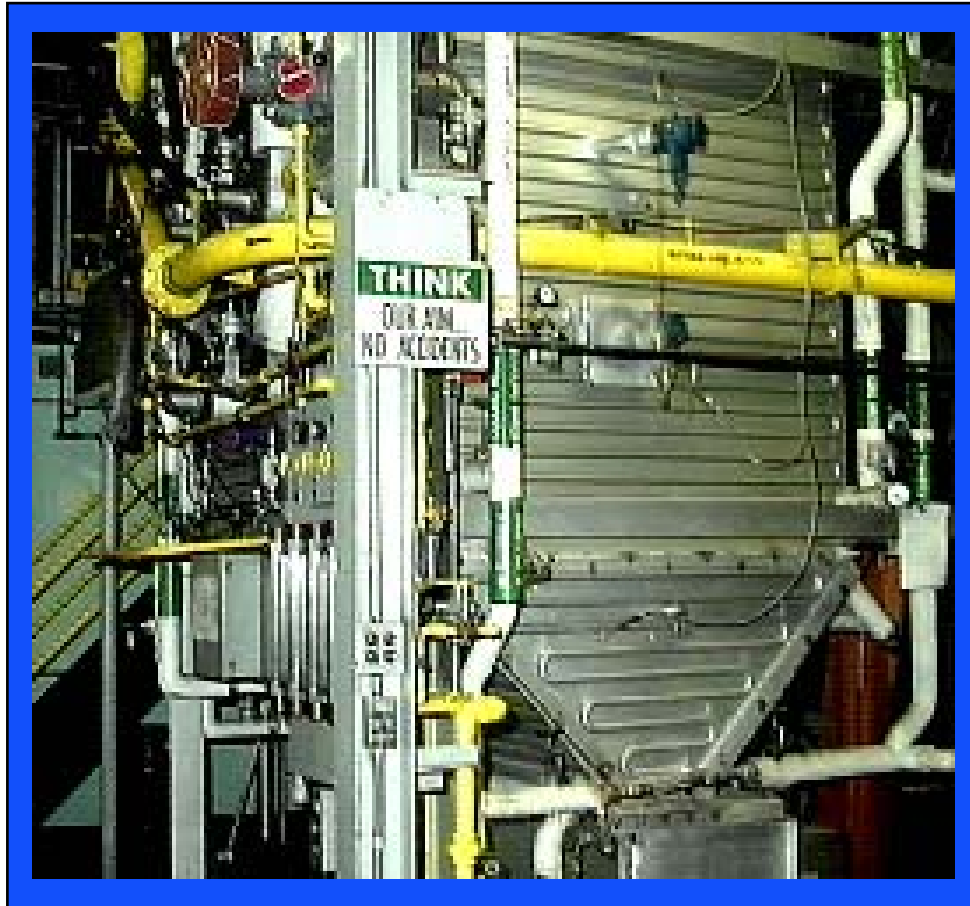
In-Duct Hg Removal

~ 30 - 40%

Hg Removal Across BH

~ 80 - 90%
Total Hg Removal Goal

500 LB/HR PILOT COMBUSTOR AND PULSE JET FABRIC FILTER









Lab Results: Commercial Carbons

<u>Sorbent</u>	<u>Capacity (mg/g)</u>	<u>Temp (°F)</u>
FluePac AC	0.89	280
Darco AC	1.60	280
Insul AC	1.96	280
Insul AC	0.19	400
S-AC-1	1.55	280
S-AC-2	1.39	280

Physical Adsorption Favored By Low Temperature

- Unpromoted carbons display good capacity
- Sulfur promotion does not increase capacity
- Cost of sulfur addition is not justified

Lab Results: Thief Sorbents

<u>Sorbent</u>	<u>Capacity (mg/g)</u>	<u>Temp (°F)</u>
Thief-1	2.19	280
Thief-2	1.80	280
Thief-3	1.38	280

Extraordinary Carbon Sorbents

- Dramatically cheaper than activated carbons
- Large removals displayed in lab and pilot tests
- Partially combusted coal, produced in-situ
- Removal from furnace via lance (“Thief”)

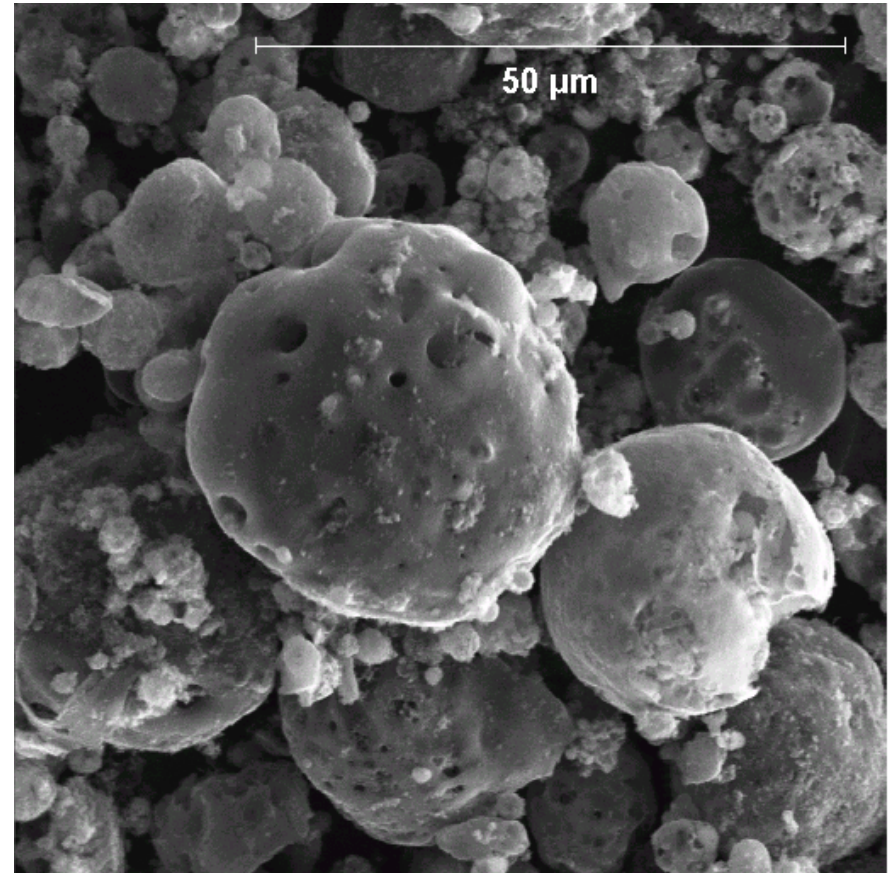
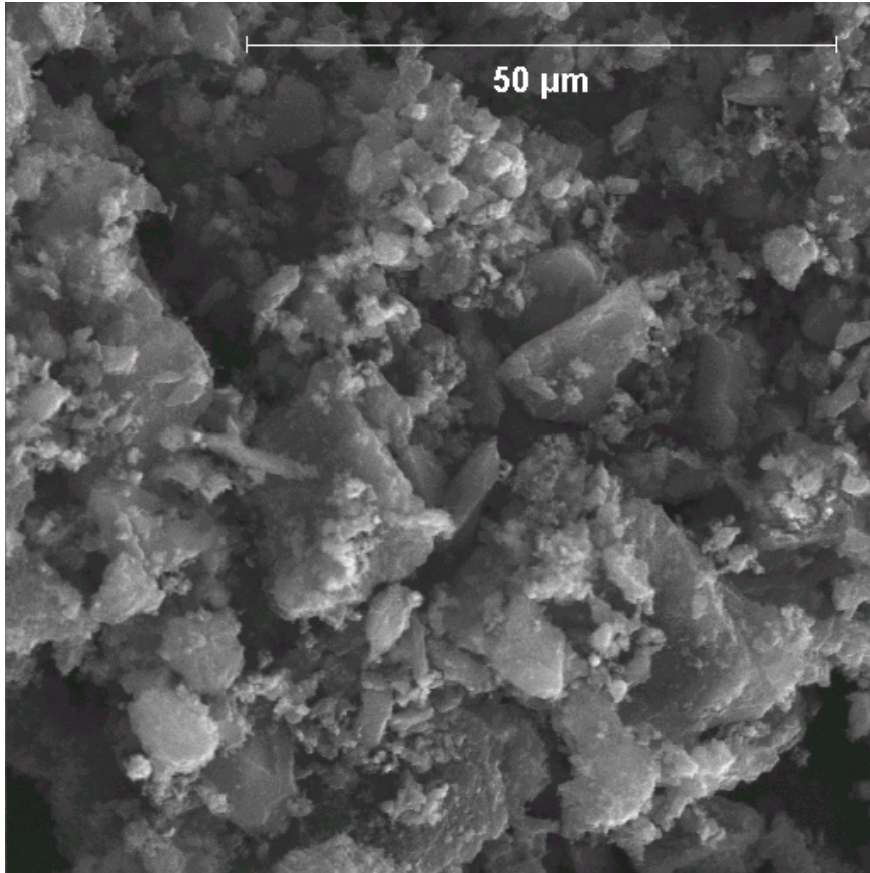
Initial Bench-Scale Results

<u>Sorbent</u>	<u>5% Breakthrough (min)</u>
Darco AC	120
Thief	60
Thief-HCl	90
Fly Ash	≤ 10

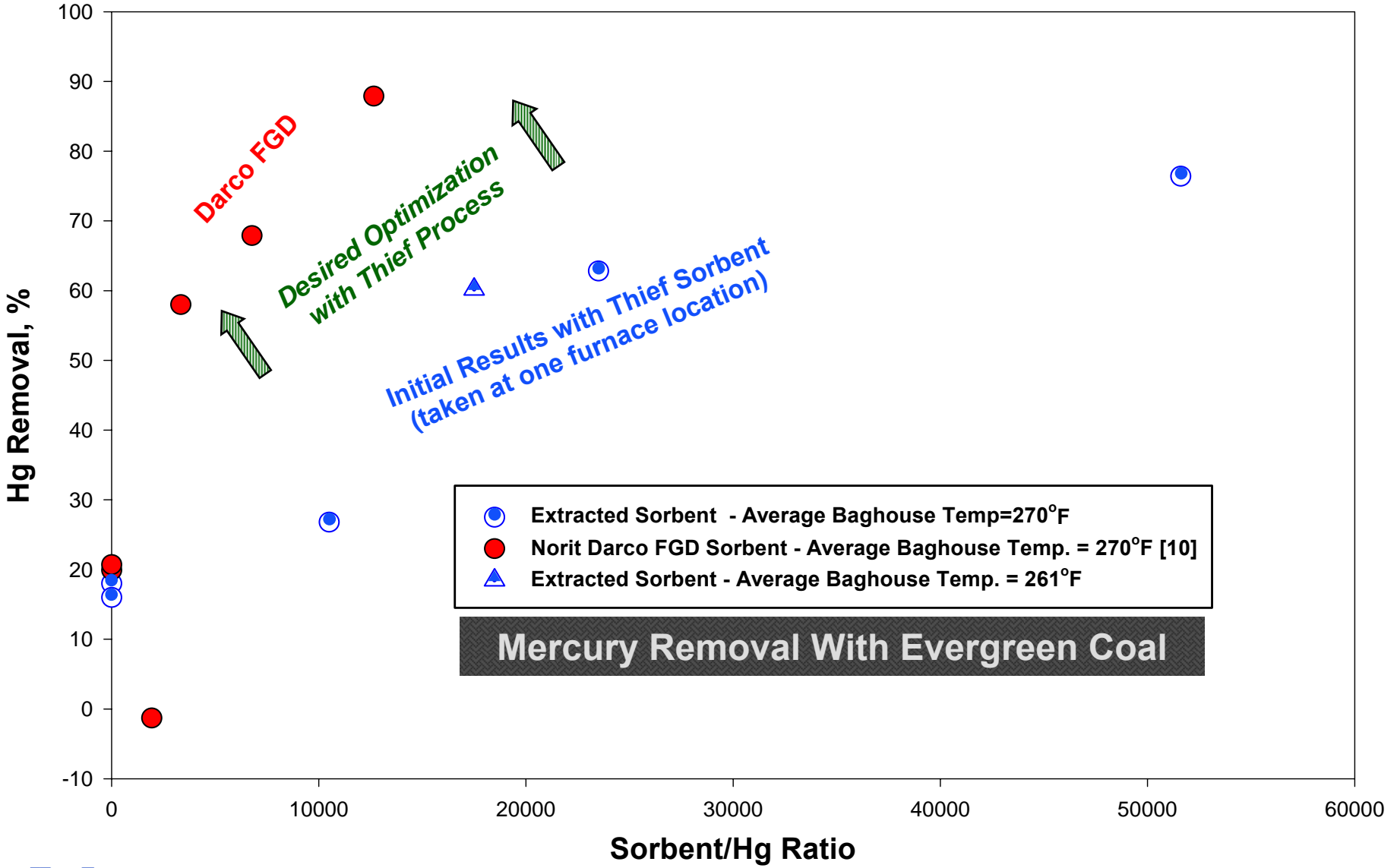
Coal: Activated Carbon Precursor

- **Contains Numerous Reactive Moieties**
- **Enormous Concentration Relative to Hg**
- **Conventional AC Manufacture Harsh**
- **High Temperature and Long Residence Time**
- **High Surface Area**
- **Lose or Passivate Reactive Species**
- **O, S, Se, Te, Cl, Br, I, and Metal Oxides**
- **Likely Retained on Surface for Thief Carbons**

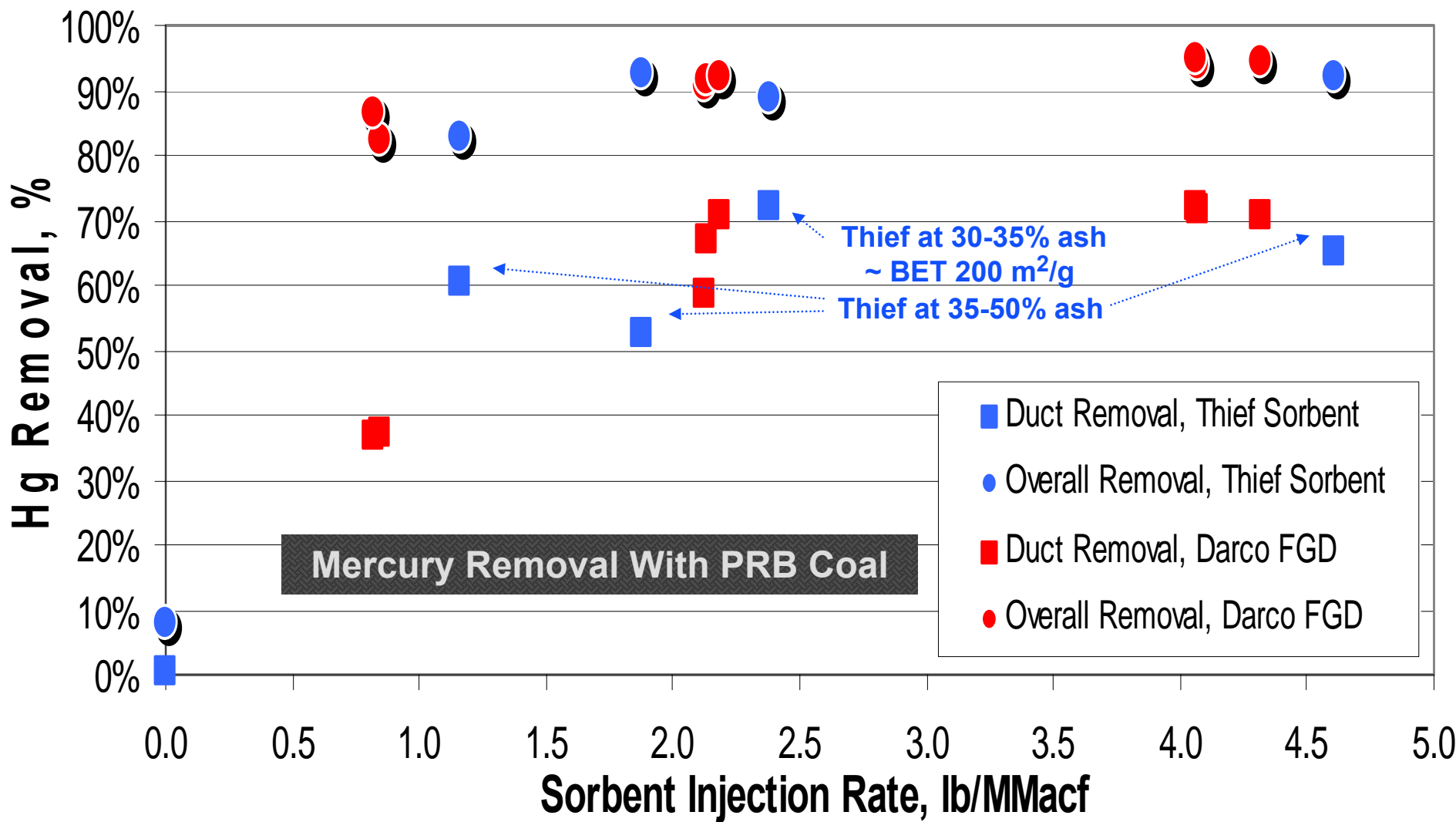
Norit Darco Versus Thief Sample (50 micron)



Initial Mercury Removal Results - Darco FGD versus Thief Sorbent



Mercury Removal Results - Darco FGD versus Thief Sorbent



Heat Rate Penalties

- **Heating Value Extracted Solids & Gas**
- **Sensible Heat Loss When Cooling Solids & Gas**
- **Heat Transfer from Furnace Gas to Small High Temperature Thief Probe**
- **Can Be Minimized by Use of Heat Exchanger**



Parasitic Power Requirements

- **Fan Power for Extraction of Sorbent & Gas**
- **Fan Power for Reinjection of Sorbent**
- **Pneumatic Injection if Thief Sorbent Stored**
- **Pulverizer Power for Make-up Coal**
- **Circulation of Any Heat Exchanger Fluids**
- **Incremental ID Fan Requirements for Additional Flue Gas Associated With Make-up Coal**

Thief Carbons

- High BET Surface Areas
- Large Iodine Numbers
- Between 80-250 m²/g
- Approaching SA of Commercial AC
- Far Cheaper than Commercial AC

Cost Estimate for Thief Carbons

- \$90-\$200/ton
- \$500-\$3000/ton for AC



Conclusions: Thief Process

Thief sorbents exhibit high capacity

- Lab, bench, & pilot-scale tests
- Capacities comparable to AC
- Lower cost carbon than AC
- Small parasitic power requirements
- Minor heat rate penalties
- Excellent commercial potential
- Further development by Mobotec USA



Acknowledgements

- **Innovations for Existing Power Plants (IEP) Program**
- **Tom Feeley**
- **Dave Wildman**
- **Bob Kleinmann**

