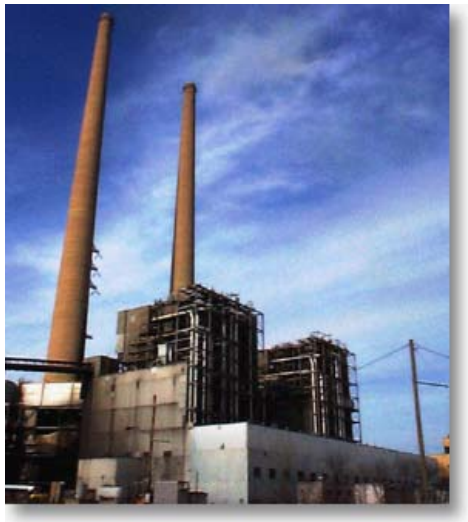
The Thief Process for Mercury Removal from Flue Gas



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National Energy Technology Laboratory
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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

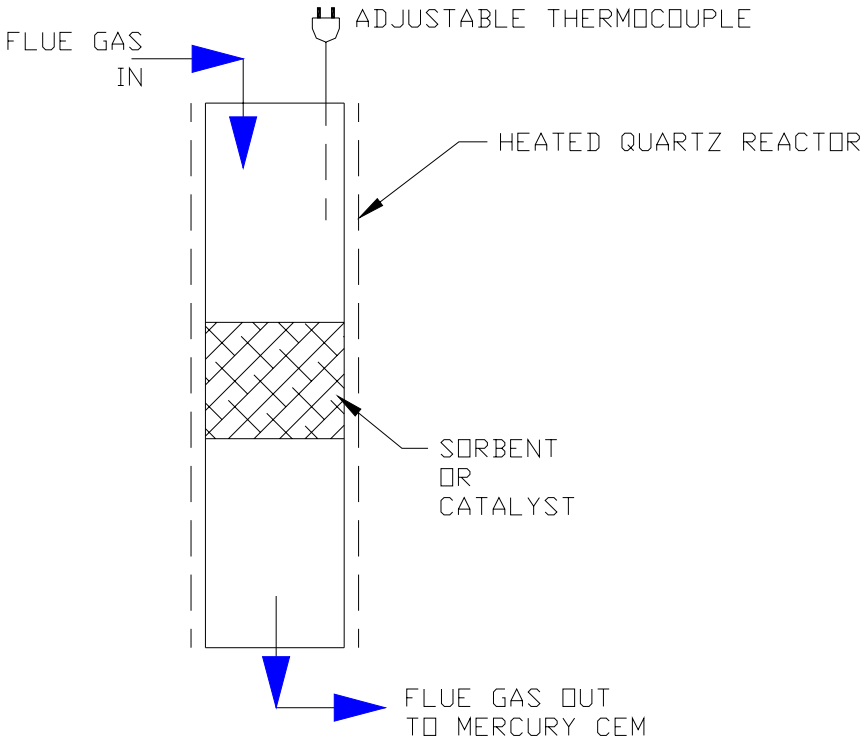
- Benchmark technology but has drawbacks for flue gas application
- General adsorbent
- Limited temperature range
- Sequestration
- High sorbent to Hg ratio (3,000:1 to 100,000:1)
- Contacting methods
- Expensive: $1,000 - 3,000/ton
- 500 MW_e power plant: $0.5-10 MM/yr
- Potential market of $10 billion/year

Project Objectives

Develop Cost Effective Sorbents

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

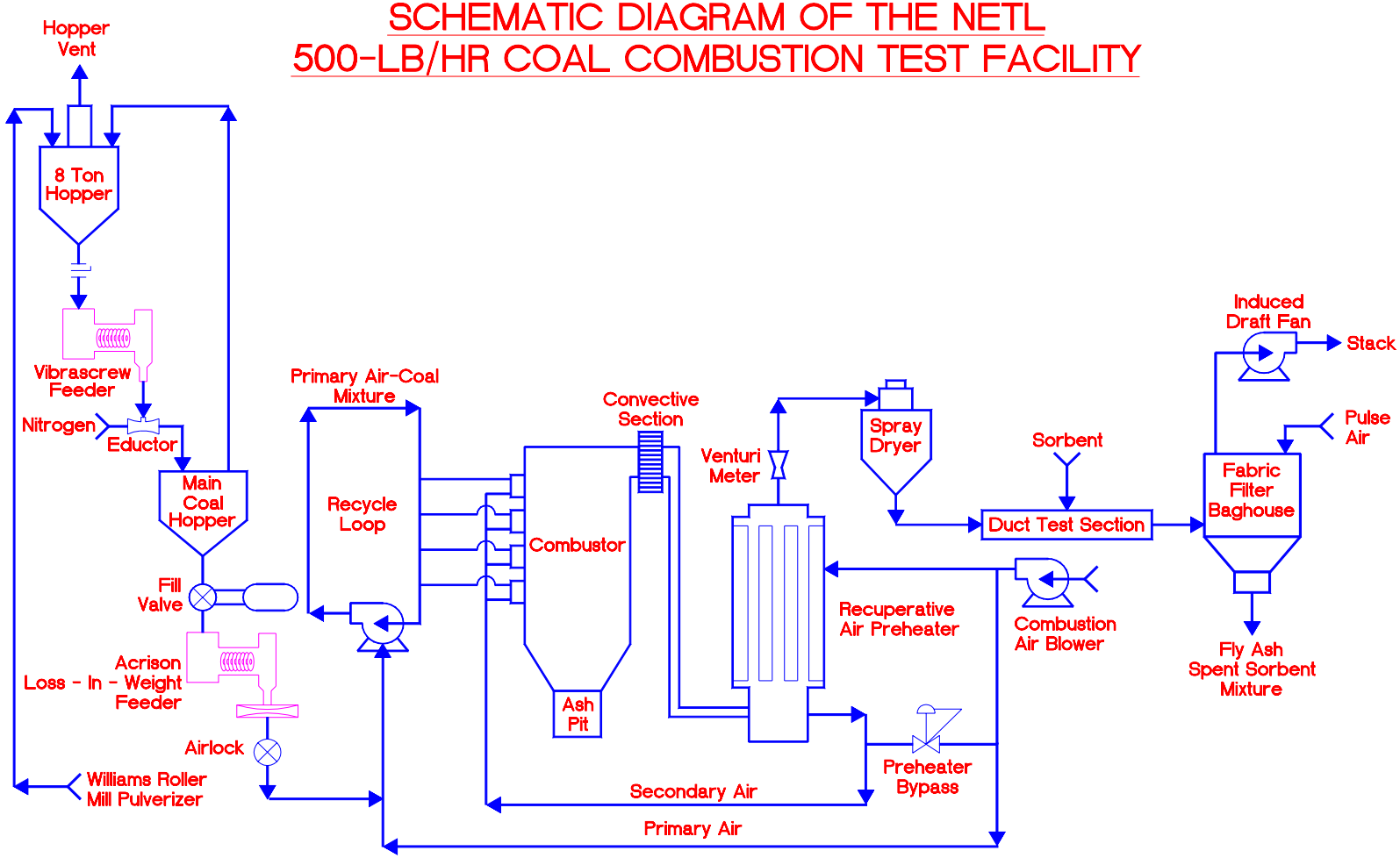
NETL BENCH-SCALE PACKED BED REACTOR



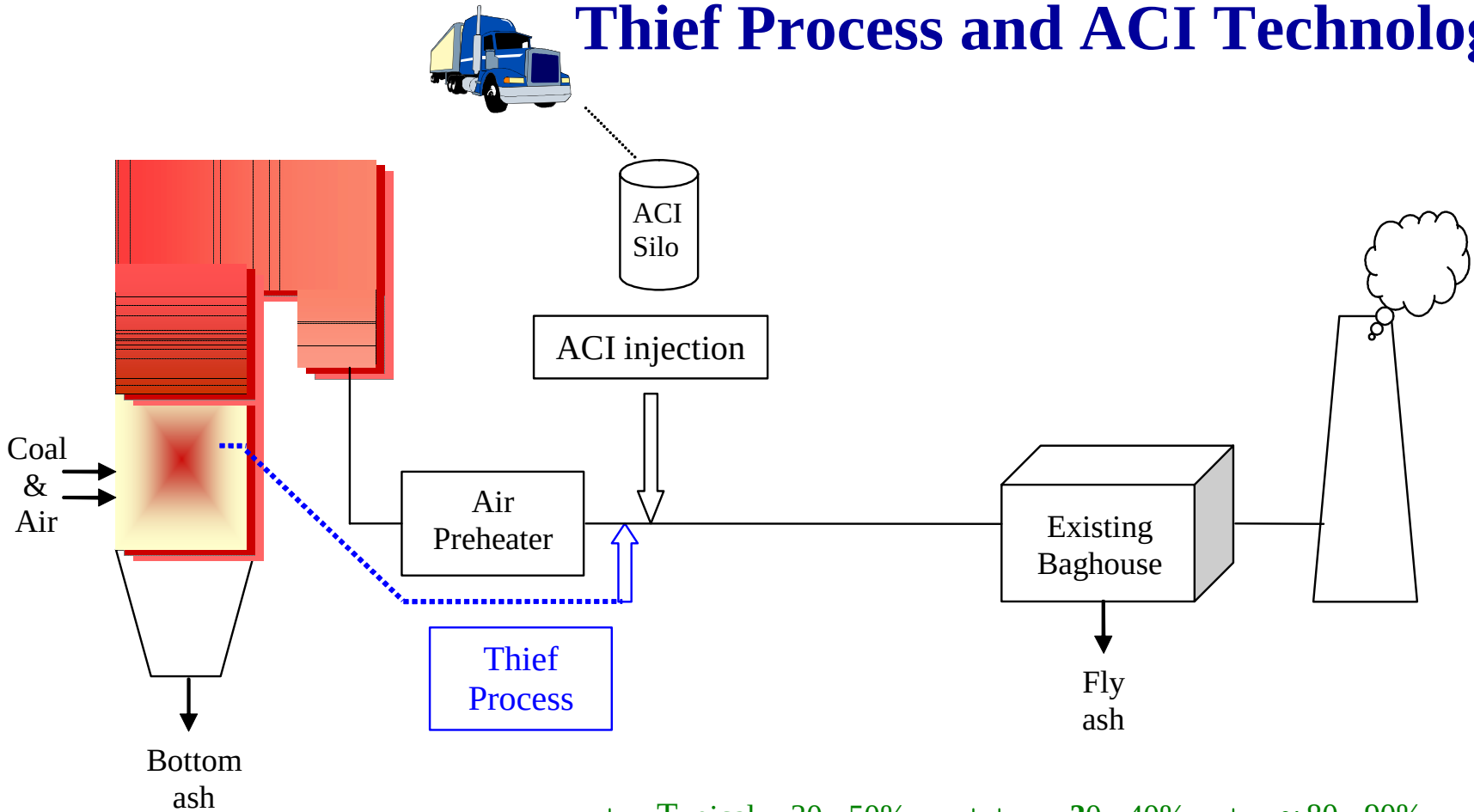
Bench-Scale Packed Bed Reactor

- ½-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

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



Thief Process and ACI Technology



Typical ~ 30 - 50%

In-Duct Hg Removal

~ 30 - 40%

Hg Removal Across BH

~ 80 - 90% Total Hg Removal Goal

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

500 LB/HR PILOT COMBUSTOR AND PULSE JET FABRIC FILTER

RETURN
CAUTION

Lab Results: Commercial Carbons

Sorbent	Capacity (mg/g)	Temp (ºF)
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

Sorbent	Capacity (mg/g)	Temp (ºF)
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")

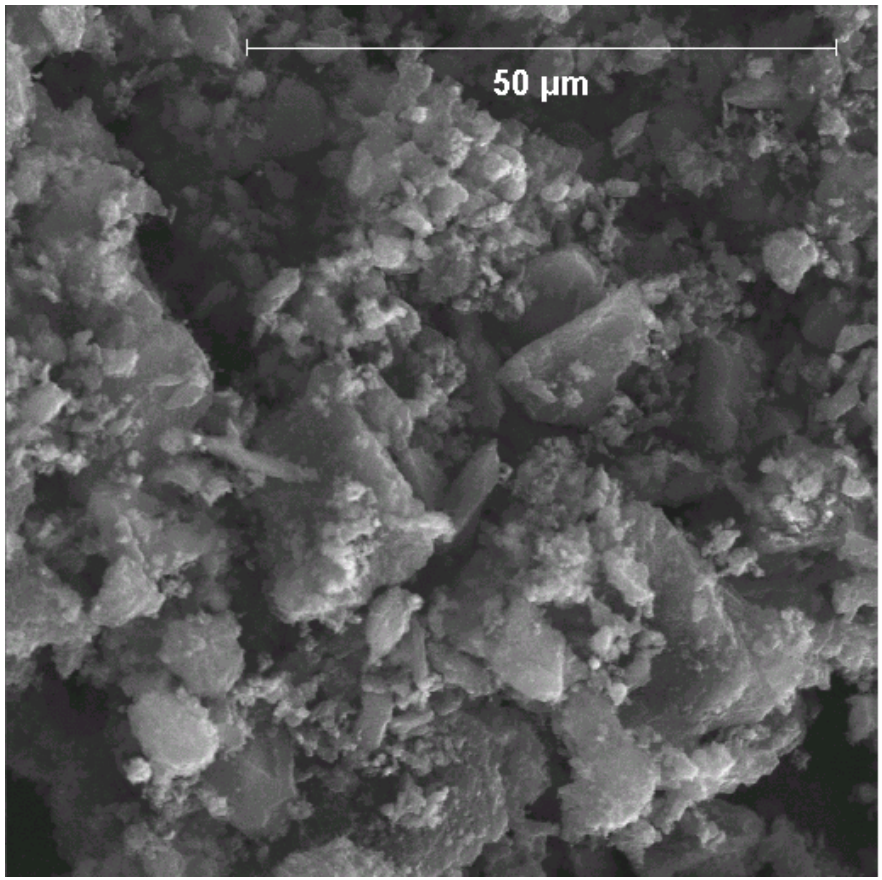
Initial Bench-Scale Results

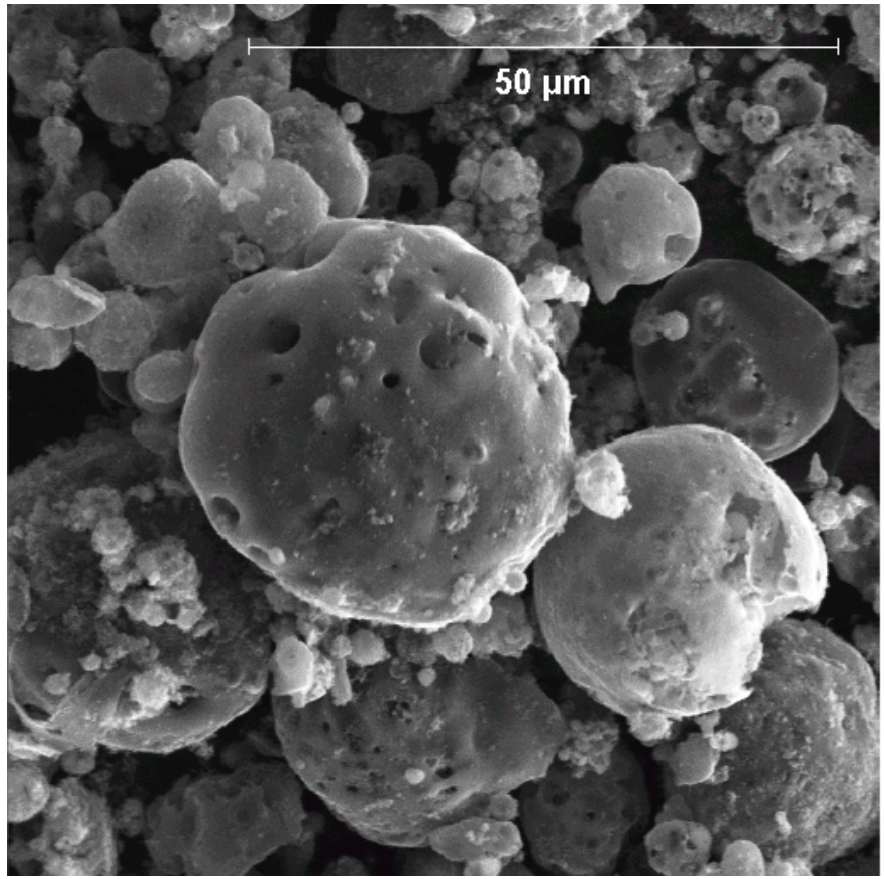
Sorbent	5% Breakthrough (min)
Darco AC	120
Thief	60
Thief-HCl	90
Fly Ash	≤ 10

Coal: Activated Carbon Precursor

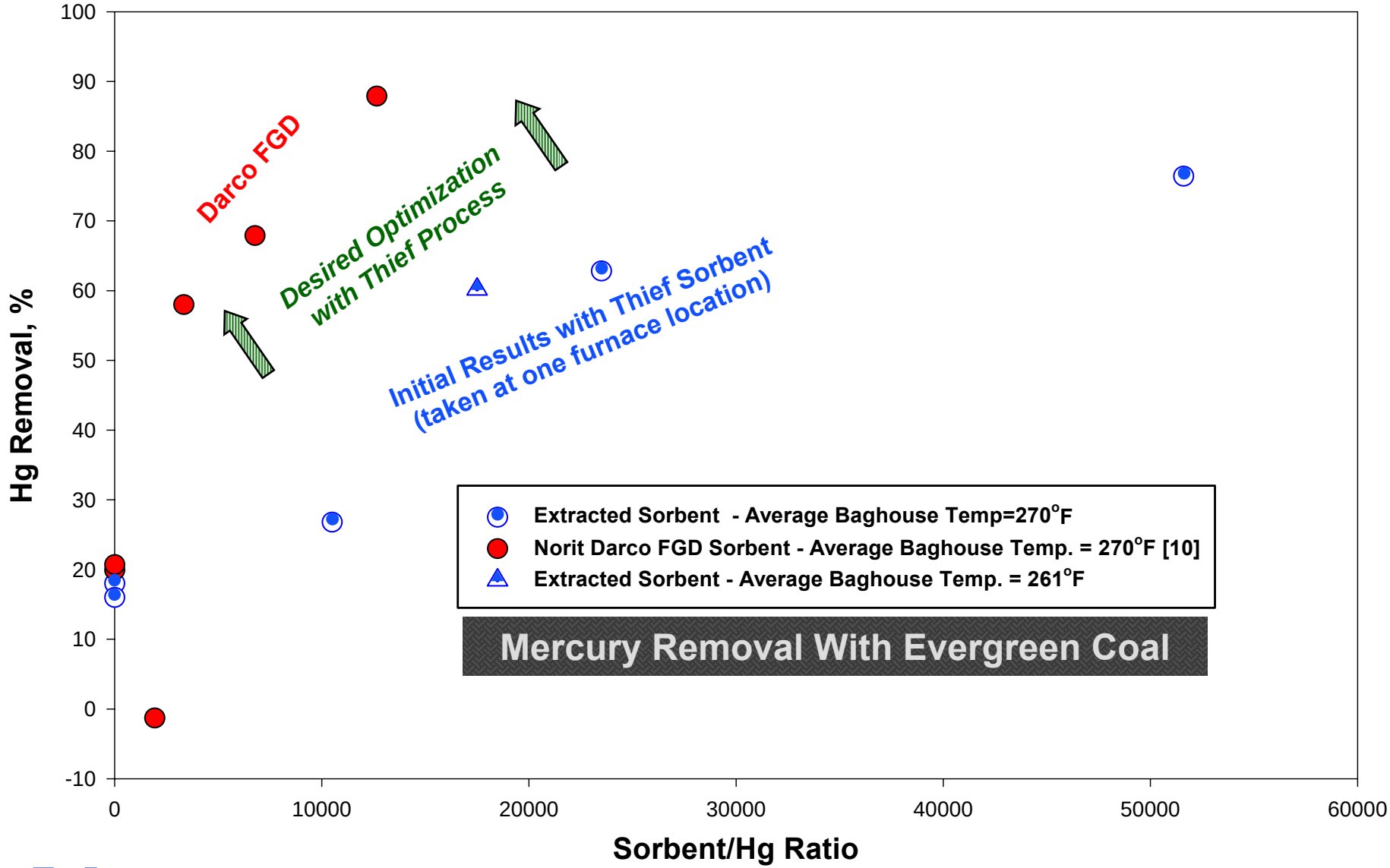
- Contains Numerous Reactive Moieties
- Enormous Concentration Relative to Hg
- Conventional AC Manufacture Harsh
- High Temperature and Long Residence Time
- High Surface Area
- Lose or Passivate Reactive Species
- O, S, Se, Te, Cl, Br, I, and Metal Oxides
- Likely Retained on Surface for Thief Carbons

Norit Darco Versus Thief Sample (50 micron)

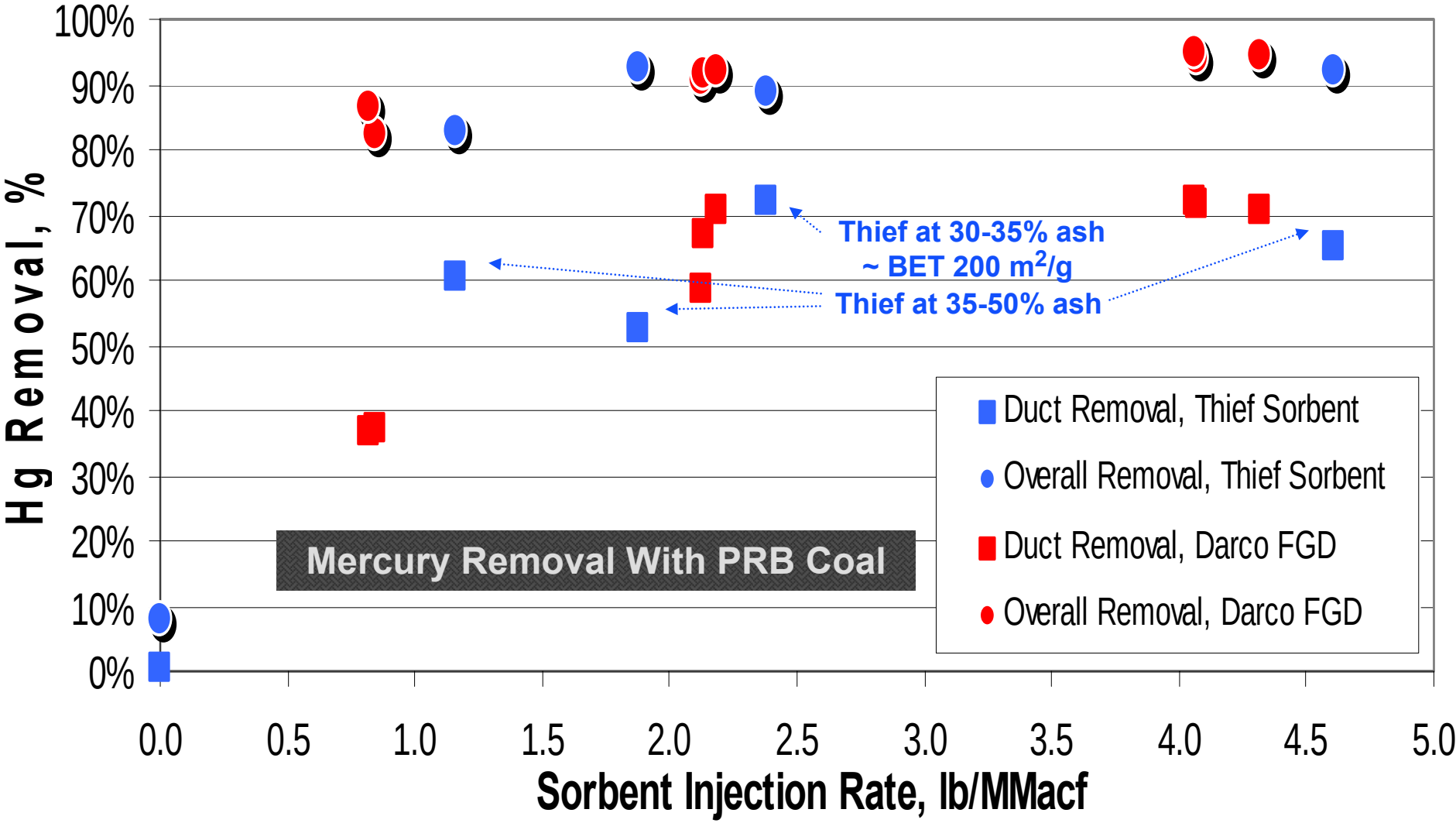




Initial Mercury Removal Results - Darco FGD versus Thief Sorbent



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 m^2/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