Oxidation of Mercury via Catalytic Barrier Filters – Phase II

University of North Dakota
Dept of Chemical Engineering
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Mercury Oxidation via Catalytic Barrier Filters

- Mercury Background
- Phase I Results
- Fabric Coating
- Performance Testing
  - Results from related work
  - Preliminary bench-scale
  - Planned pilot-scale

Mercury Background

- Coal combustion accounts for ~33 percent of Hg emitted in the United States
- Clean Air Mercury Rule: 70 percent removal when fully implemented in 2018
- Currently no single best control technology
- Estimates for control is as high as $0.004/kWh ($3-7 billion per year)

Existing Technologies

- Injection of sorbents in gas stream
  - Activated carbon with and without chlorination
- Filter capture in baghouse by fly ash
- Wet scrubbers
  - But must be in oxidized form

Mercury Oxidation

- Cl_2 and HCl reaction with mercury to form $HgCl_2$ is considered to be the dominant mechanism
- SO_2 and NO_x do not affect mercury oxidation, but inhibit it in the presence of H_2O

Previous Research

- Addition of oxidants and additives in the wet scrubber
- Addition of oxidants to sorbents
- Catalytic oxidation has been shown to produce 70-96% oxidation
  - Contacting method important variable

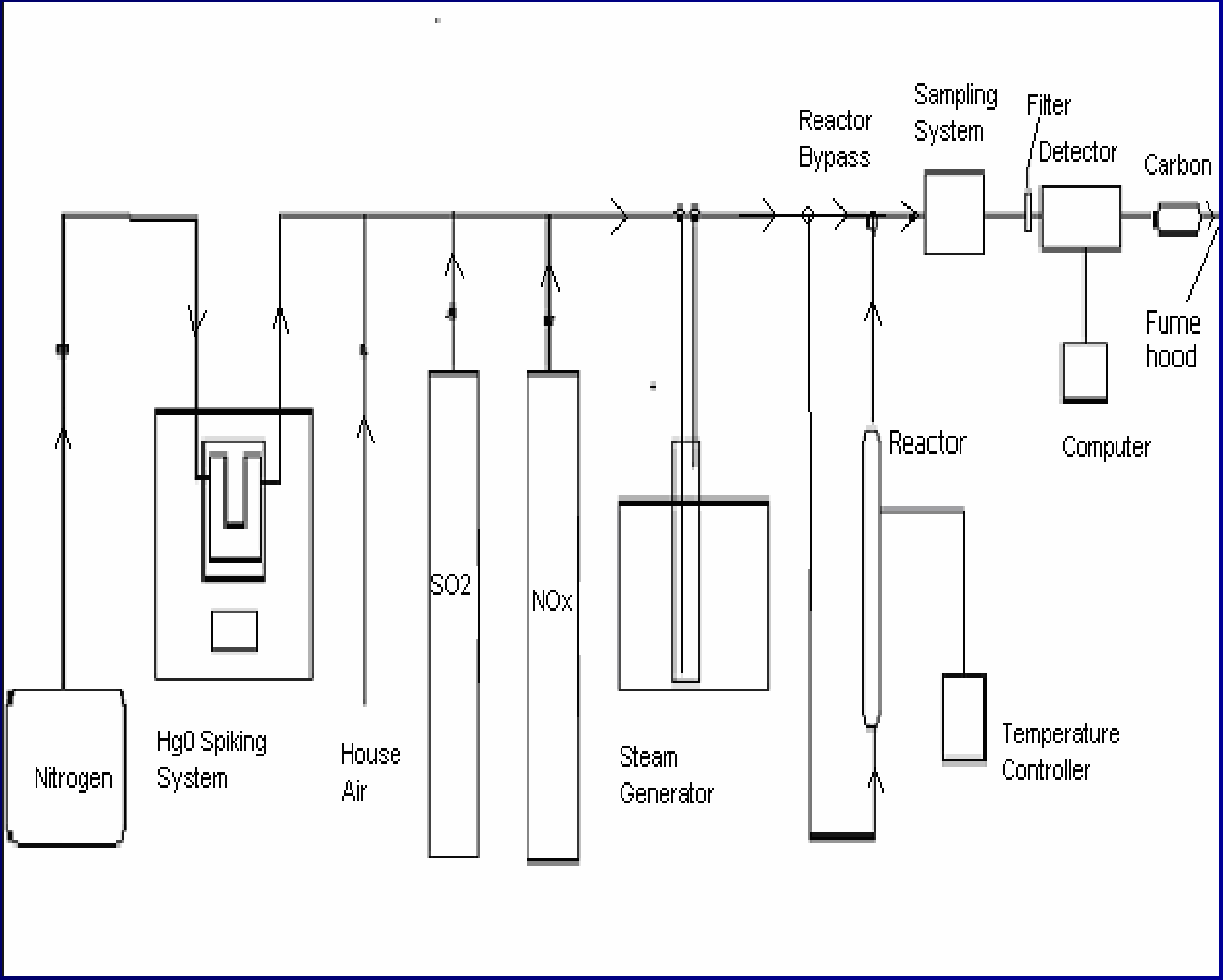
Why Barrier Filters?

- Excellent gas/catalyst contact
  - Overcome gas diffusion limitations
  - Reduce amount of catalyst required
- Virtually no additional capital expense for facilities using barrier filters

Approach

- Proof of concept studies in fixed bed reactor
- Coating tests – can we impregnate the fabric with catalyst and will it stay
- Performance testing – how effective are the catalytic filters in oxidizing mercury under “real” conditions

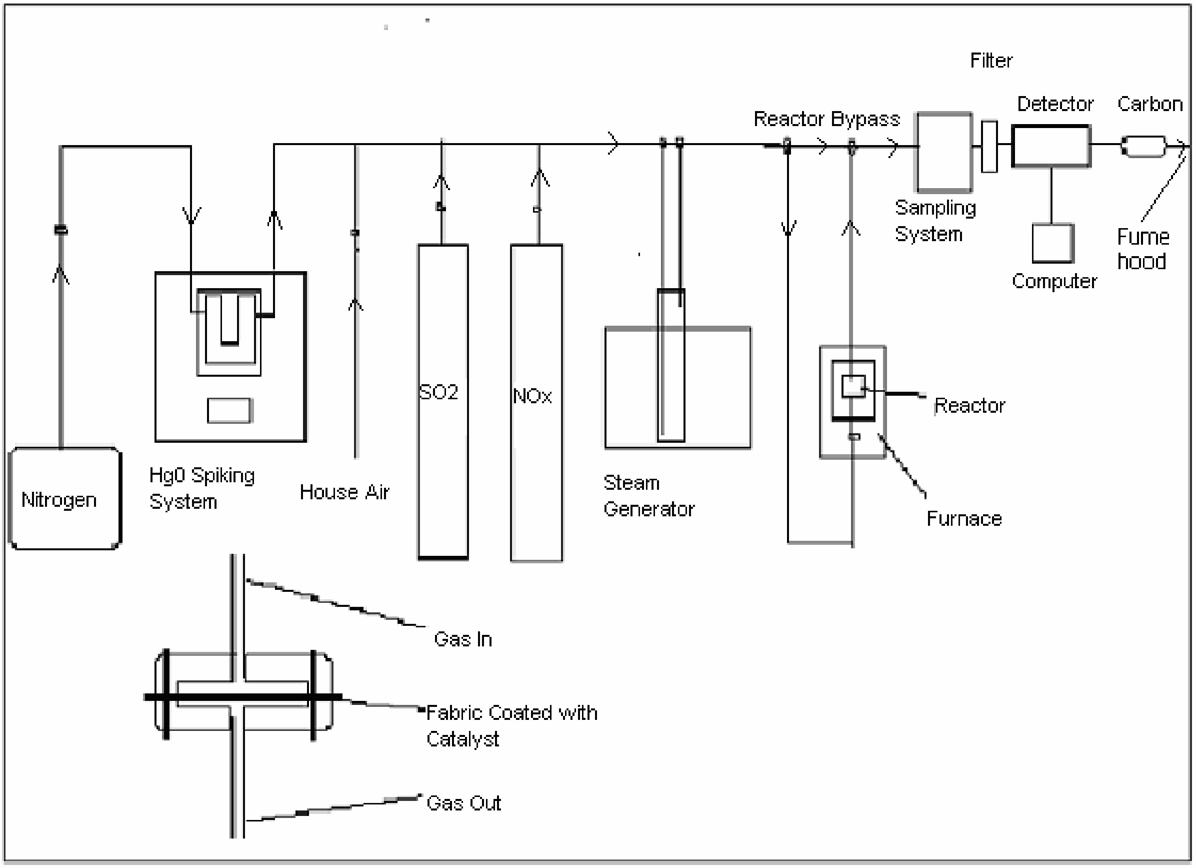
Phase I-A Experimental



Phase I-A Results

Catalyst	Al_2O_3	Pd on Alumina	TiO_2
Temp, C	Pct Hg Oxidation	Pct Hg Oxidation	Pct Hg Oxidation
150	6	98	63
250	4	97	61
350	3	97	60

Phase 1 Simulate Filter Test



Phase 1 Simulated Filter Test

Temp, C	PT001 Hg Oxidation, %
150	85
200	90
250	93

Pd on alumina

Fabric Coating

- Investigated six methods of coating on five types of fabric to determine catalyst loading
- Performed back-pulse air tests to determine amount of catalyst that stays on fabric
- TiO_2 and Al_2O_3 for coating tests
  - Au on TiO_2 and Pd on Al_2O_3 as targets

Desired Catalytic Coating Characteristics

- Maintain air flow/permeability of bags
  - Minimize pressure losses/fan electrical costs
- Catalyst penetrates the fabric/remains part of fabric
  - Minimize poisoning by ash

Commercial Coating Processes

- Dip coating
- Rod coating
- Blade or air knife coating
- Spray coating
- Curtain or slide coating
- Gravure coating
- Reverse roll coating
- Extrusion coating

Coating Considerations

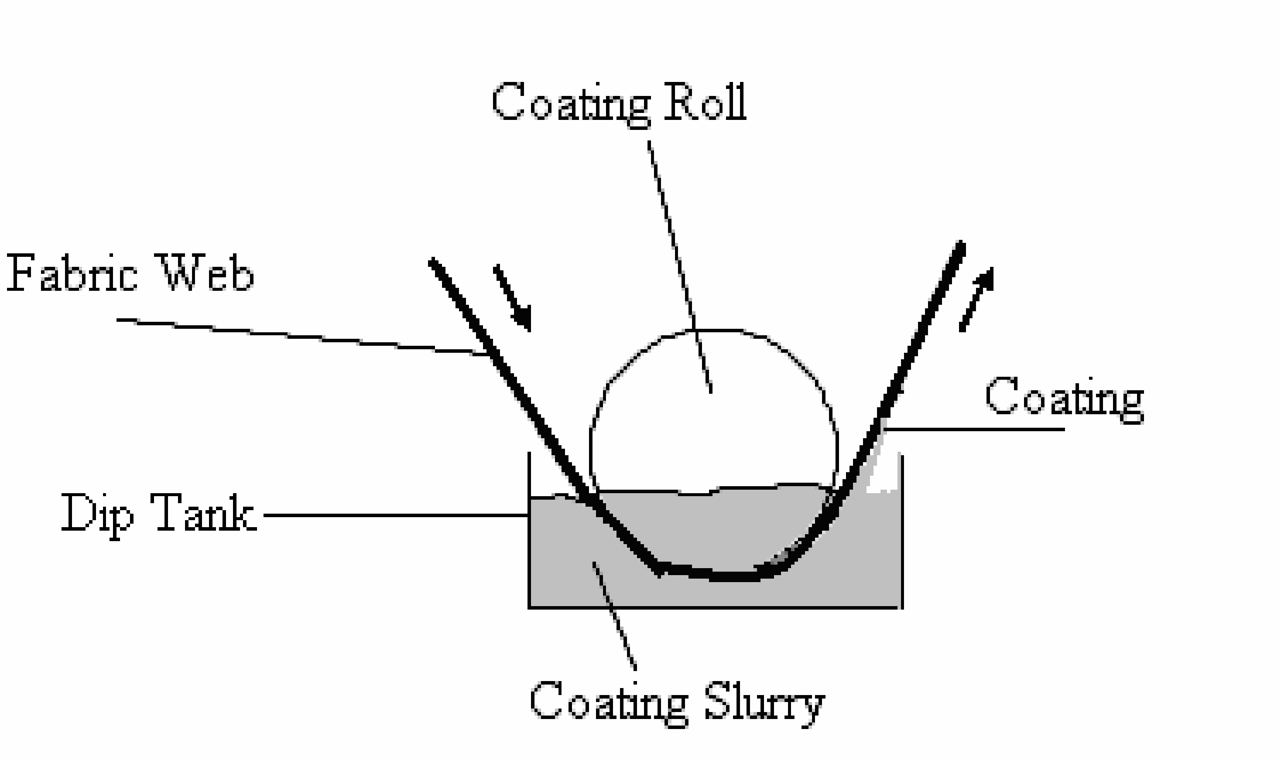
- Coating viscosity
- Surface or penetrating coating
- Substrate surface properties
- Coating uniformity
- Production speed

Penetrating Coat Methods

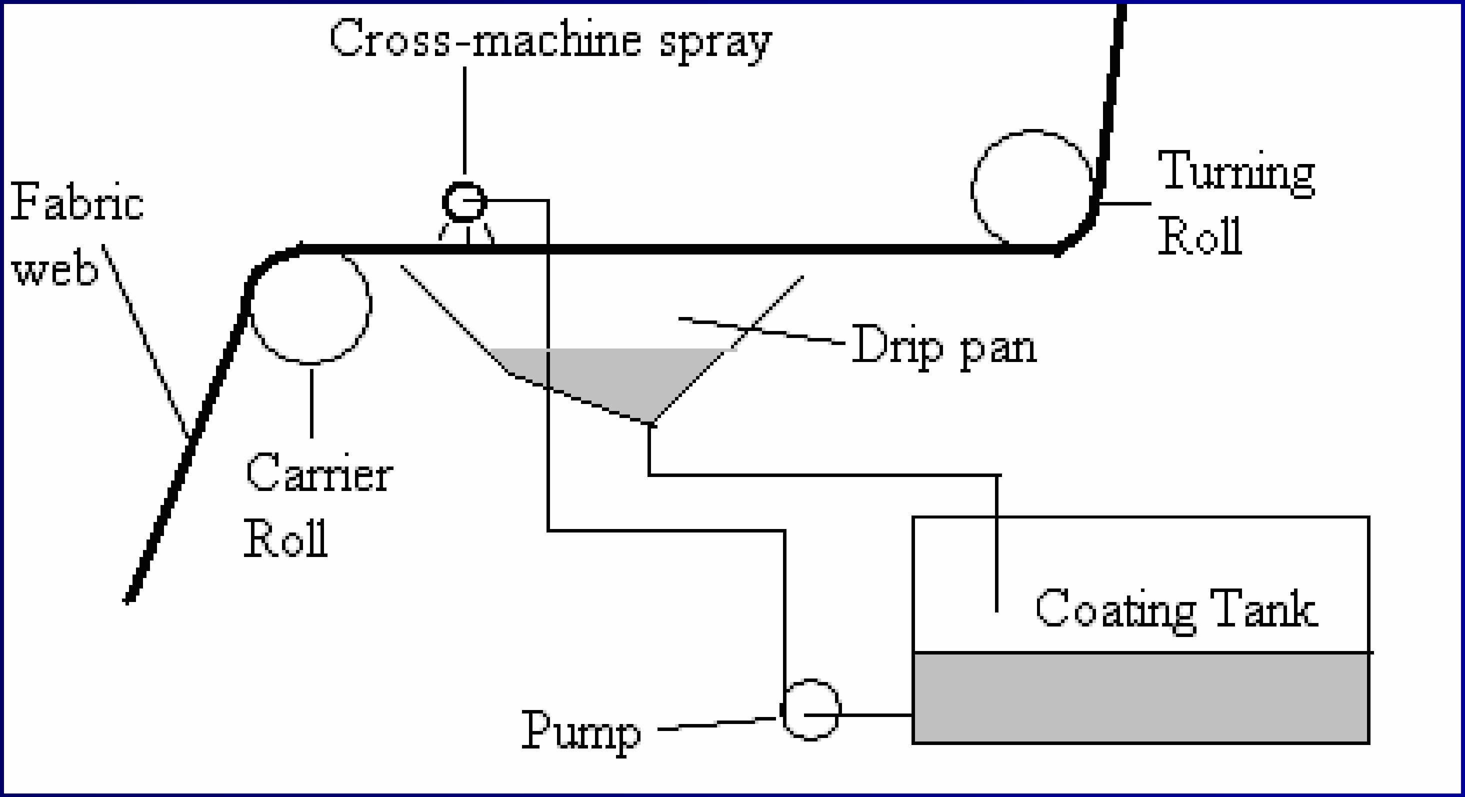
Screening tests resulted in three viable candidates

- Dip coating
- Spray coating
- Dry coating

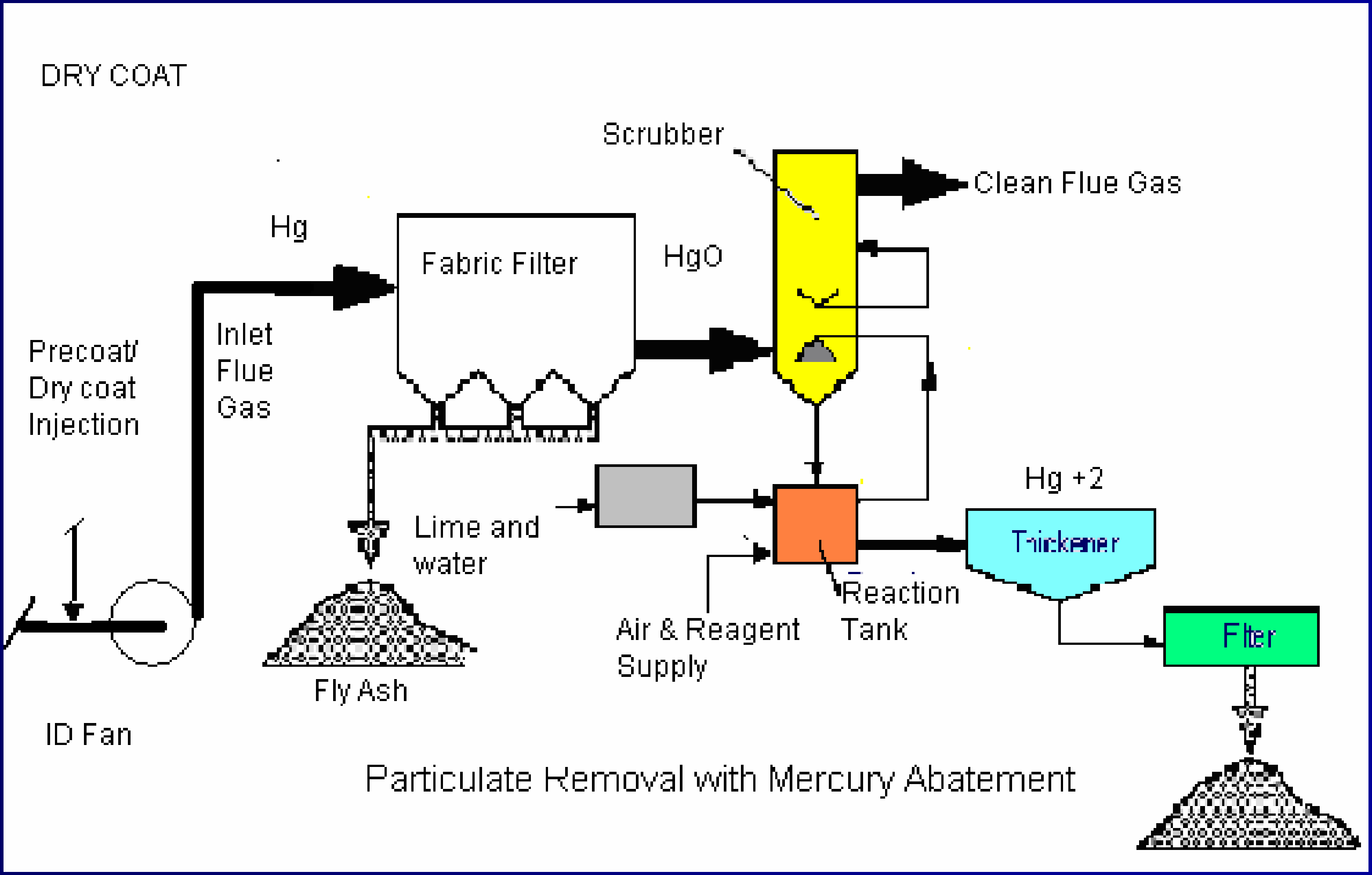
Dip Coating



Spray Coating



Dry Coat


DRY COAT
Scrubber
Clean Flue Gas
Hg
Fabric Filter
HgO
Inlet
Flue
Gas
Precoat/
Dry coat
Injection
Lime and
water
Hg +2
Thickener
Reaction
Tank
Air & Reagent
Supply
Filter
Fly Ash
ID Fan
Particulate Removal with Mercury Abatement

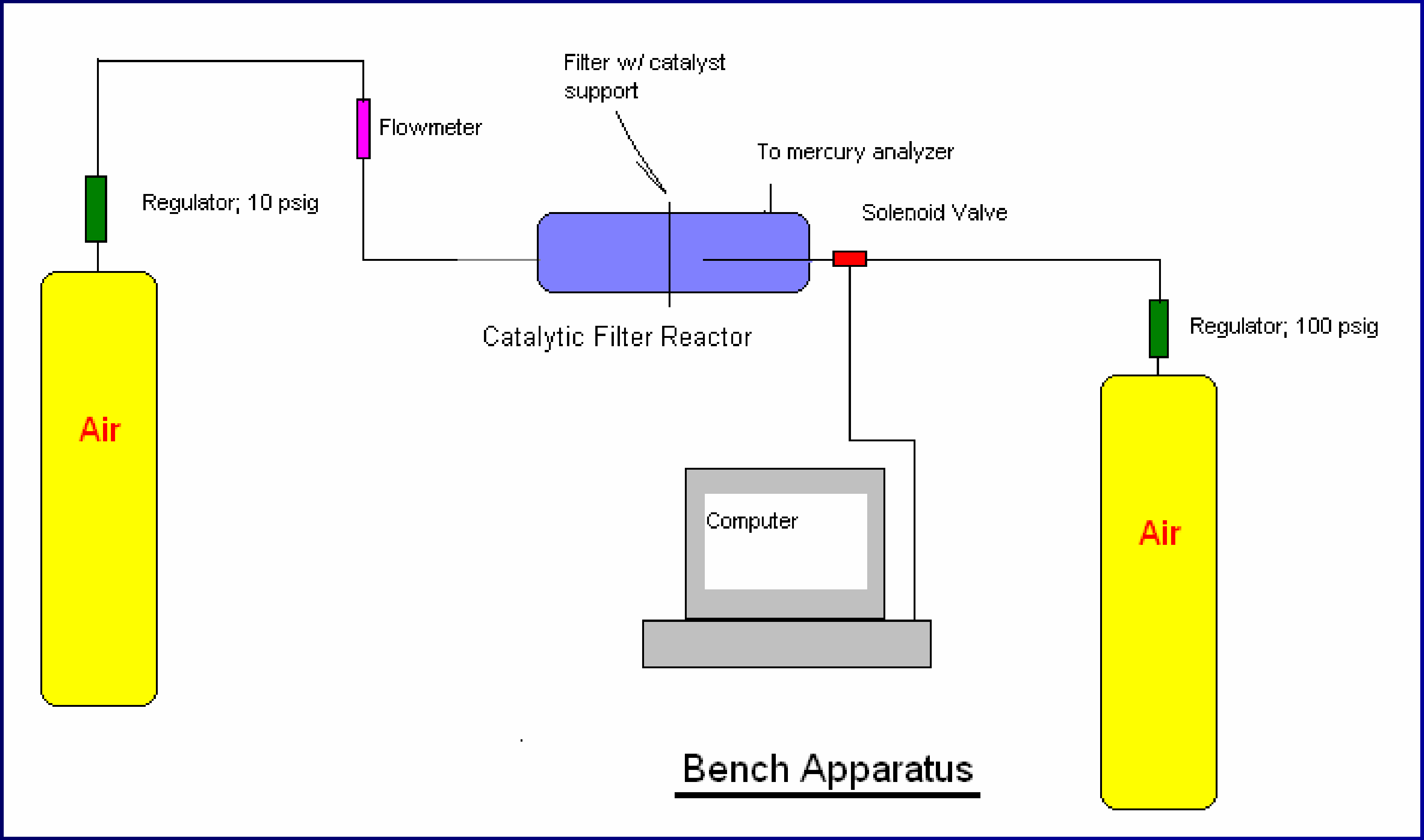
Simulating the Baghouse

- Shaker
  - Similar to shaking the rug
  - Cleaning section off-line
- Reverse air
  - Gentle reverse air flow for cleaning
  - Cleaning section off-line
- Pulse jet
  - Violent high pressure air pulse
  - Cleaning section on-line

Bench Scale Design

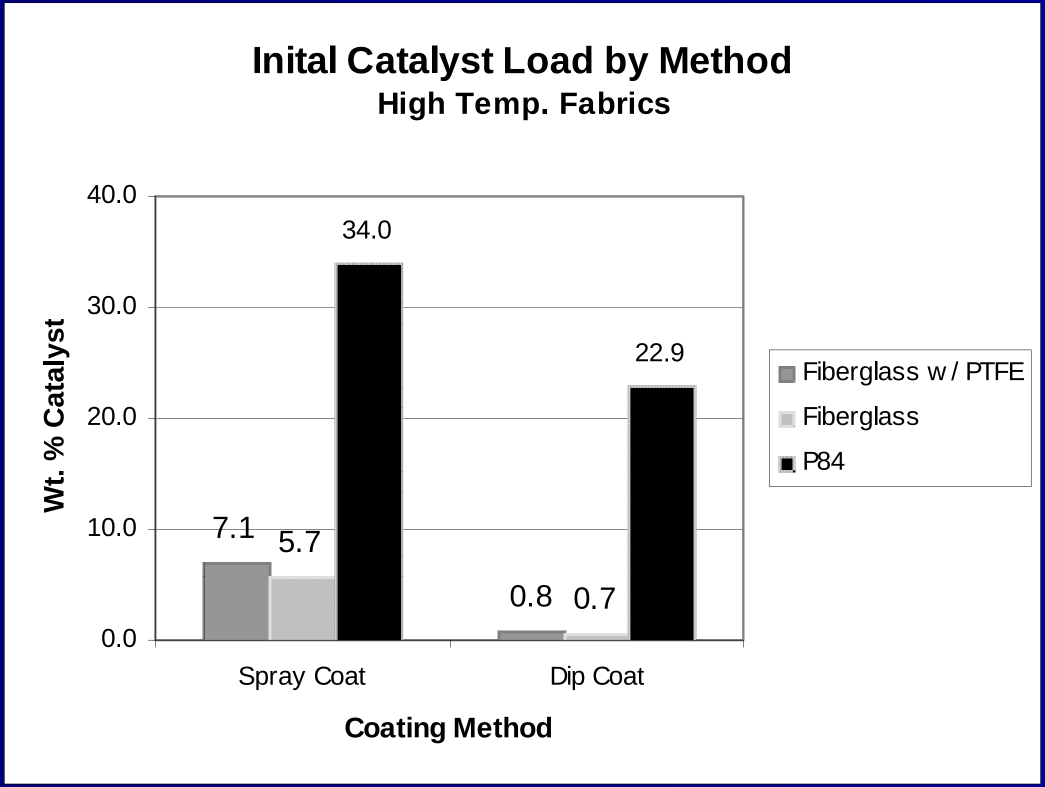
- Reactor and wetted surfaces all PTFE™ or Teflon™ coated
- Flue gas flow similar to baghouse
  1.85 m/min (6 ft/min)
- Pulse jet simulated at 250 ms 780kpa

Bench Reactor Schematic



High Temperature Fabric Trials

- Woven fiberglass fabric w/ PTFE™ laminate
- Woven fiberglass
- Felted polyimide



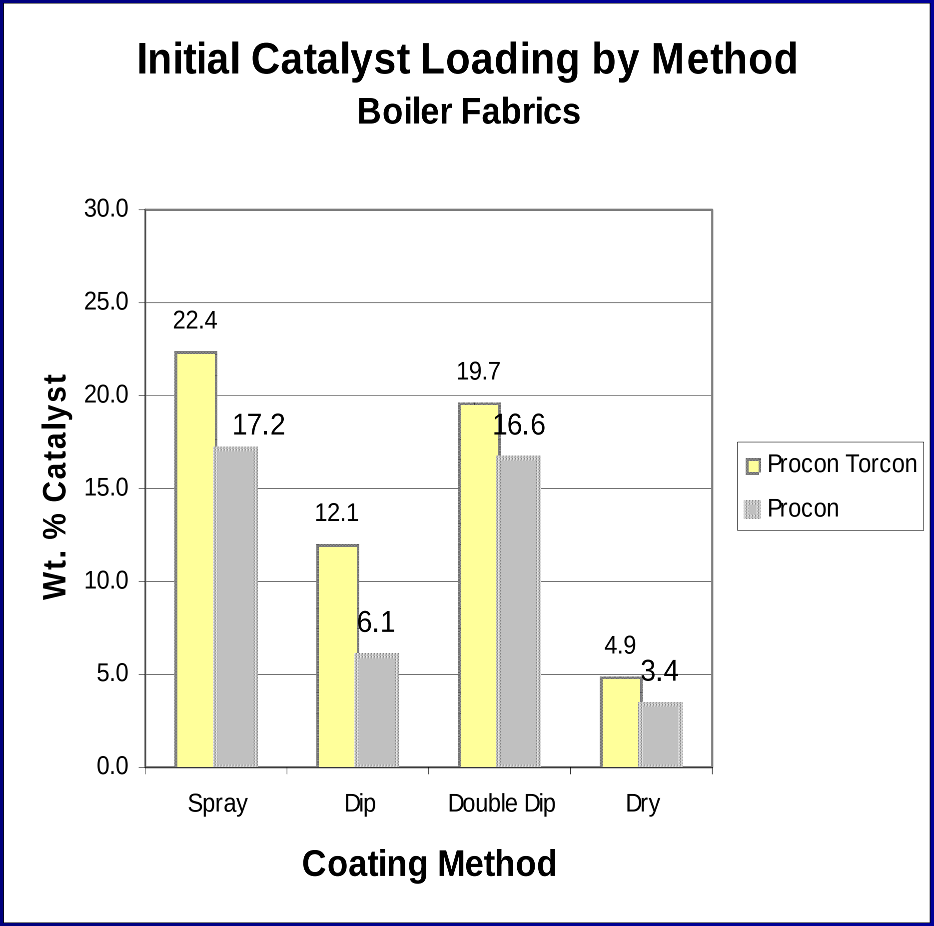
Loading of catalyst support (Al_2O_3)

Single Dip Dosing Results

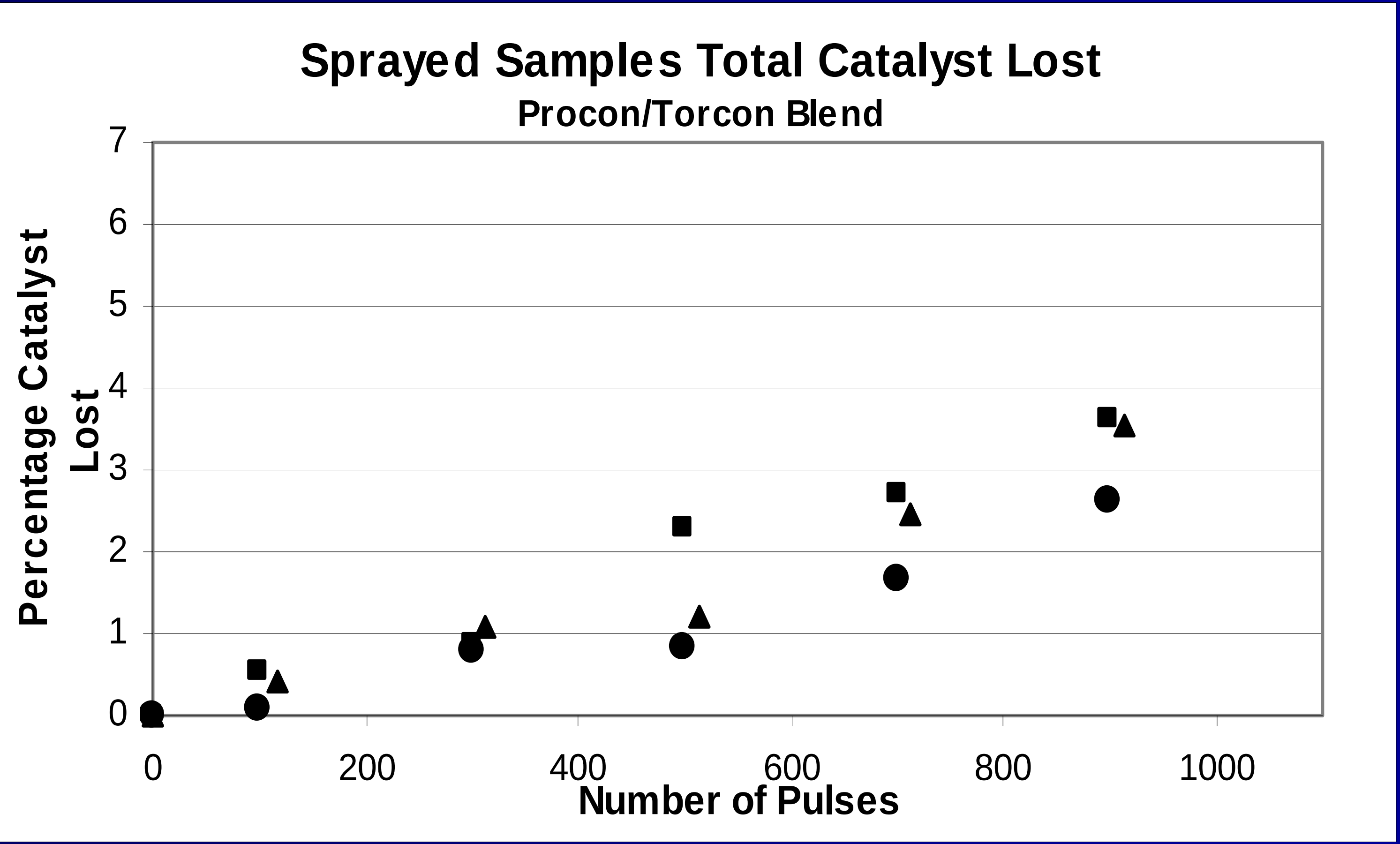
Fabrics	Weight % Catalyst Loading (%)	Air Permeability ($cm^3/cm^2/s$ @125Pa)
P84 polyimide	22.9 ± 0.9	12.5 – 22.5
Blended	12 ± 7	10.2 – 20.3
Procon™	6 ± 5	12.7 – 22.9

Boiler Fabric Trials

- Procon™/Torcon™ fabric (blended fabric)
- Procon™ fabric



Spray Coat – Durability Test



Repeat Tests - Initial Loading: 21 – 24%

Dry Coat Results

- Low Dosing
- High Losses
- Low Number of Pulses (400)

Fabric	Initial Catalyst (%)	Final Catalyst (%)	Percent Loss (%)
Blended	4.9 ± 0.5	2.7 ± 0.2	44.2
Procon™	3.4 ± 0.6	2.1 ± 0.5	39.4

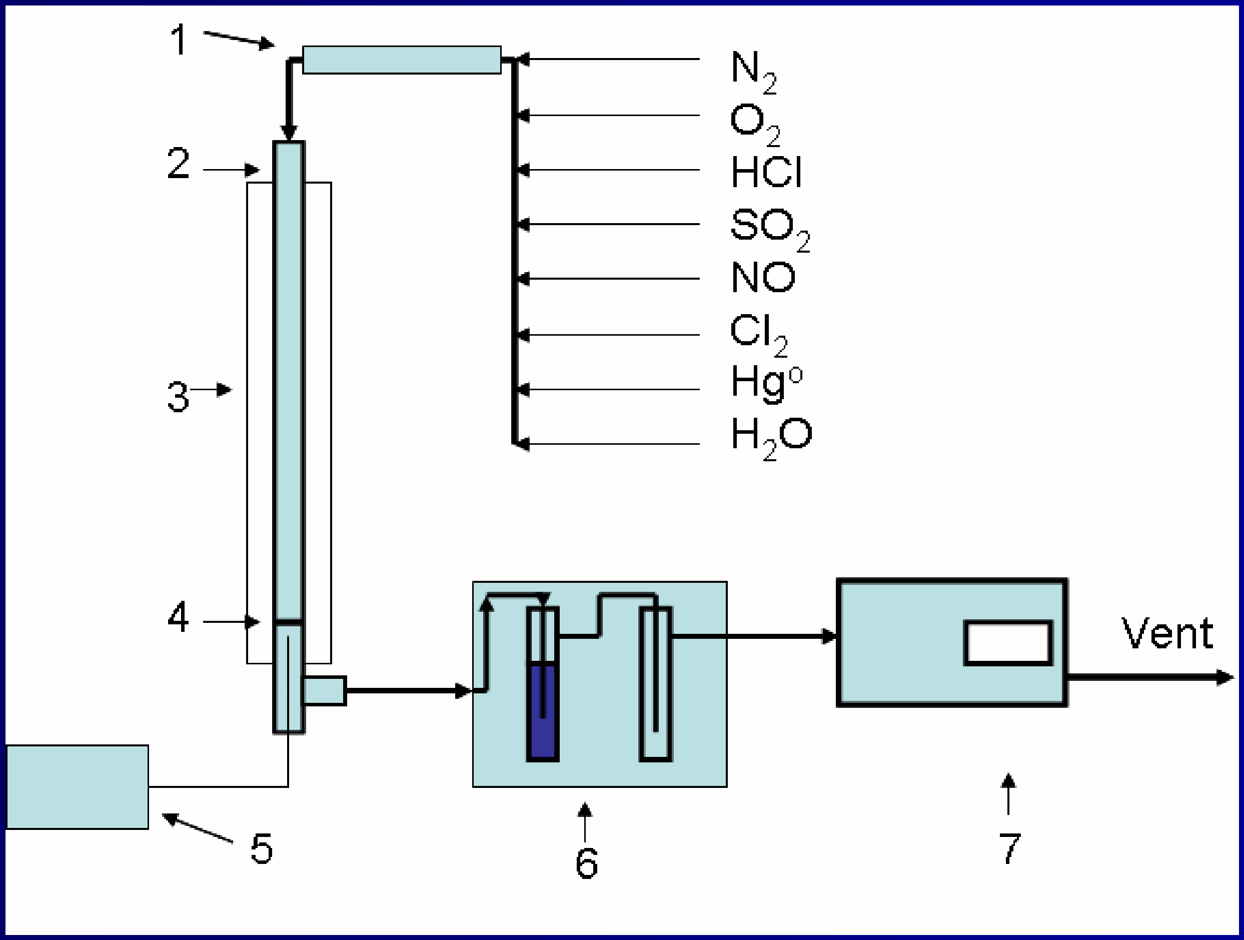
Coating Conclusions

- Felted fabrics hold catalyst better than woven fabrics
- Spray coating gives highest loading and is the easiest to control
- Single dip coating provides a low catalyst dose
- Dry coating provides low dosing and high losses
- TiO_2 dosing oxidizes the fabric

Performance Testing

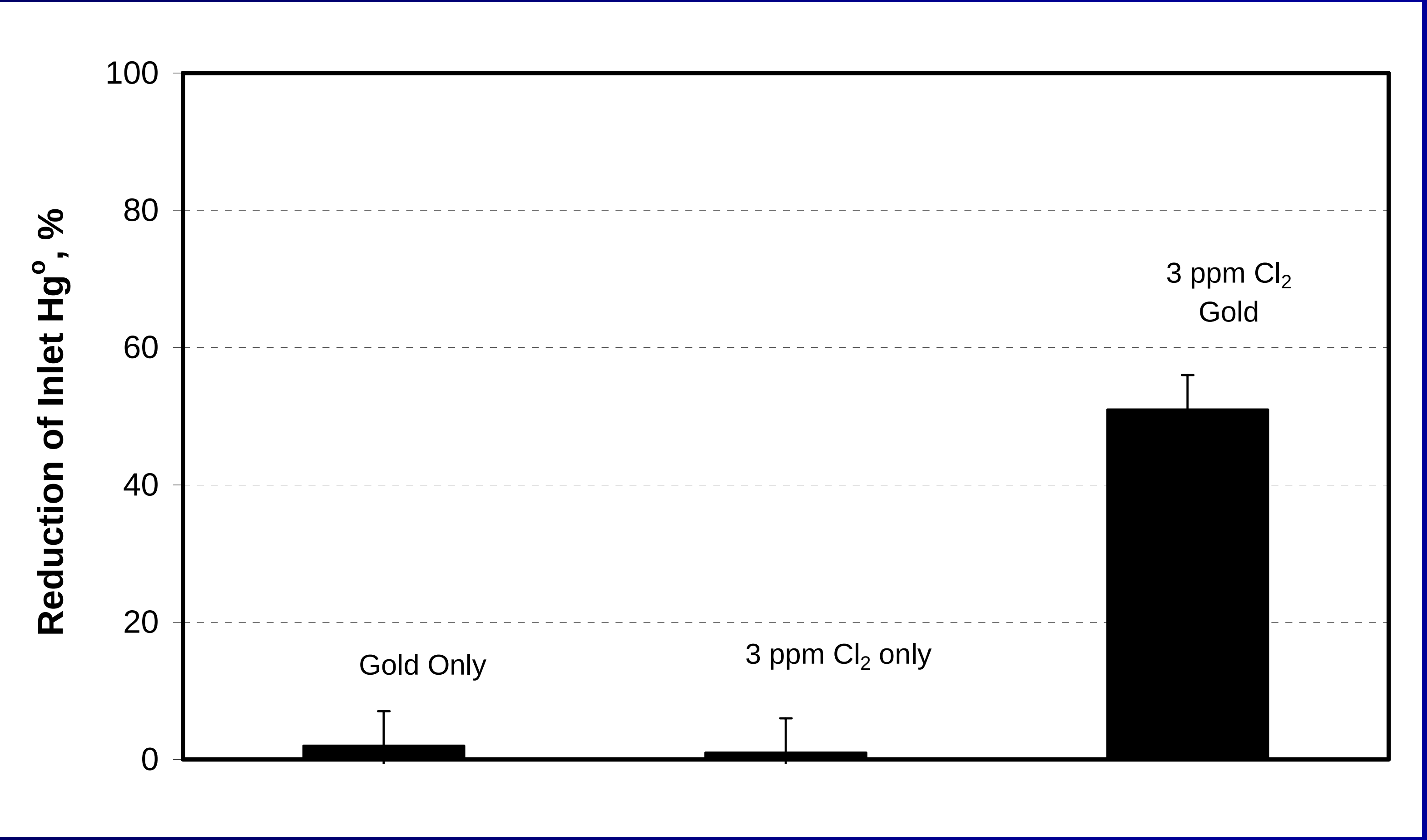
- Results from previous work
- Bench-scale
- Small pilot-scale

Previous Mechanistic Studies



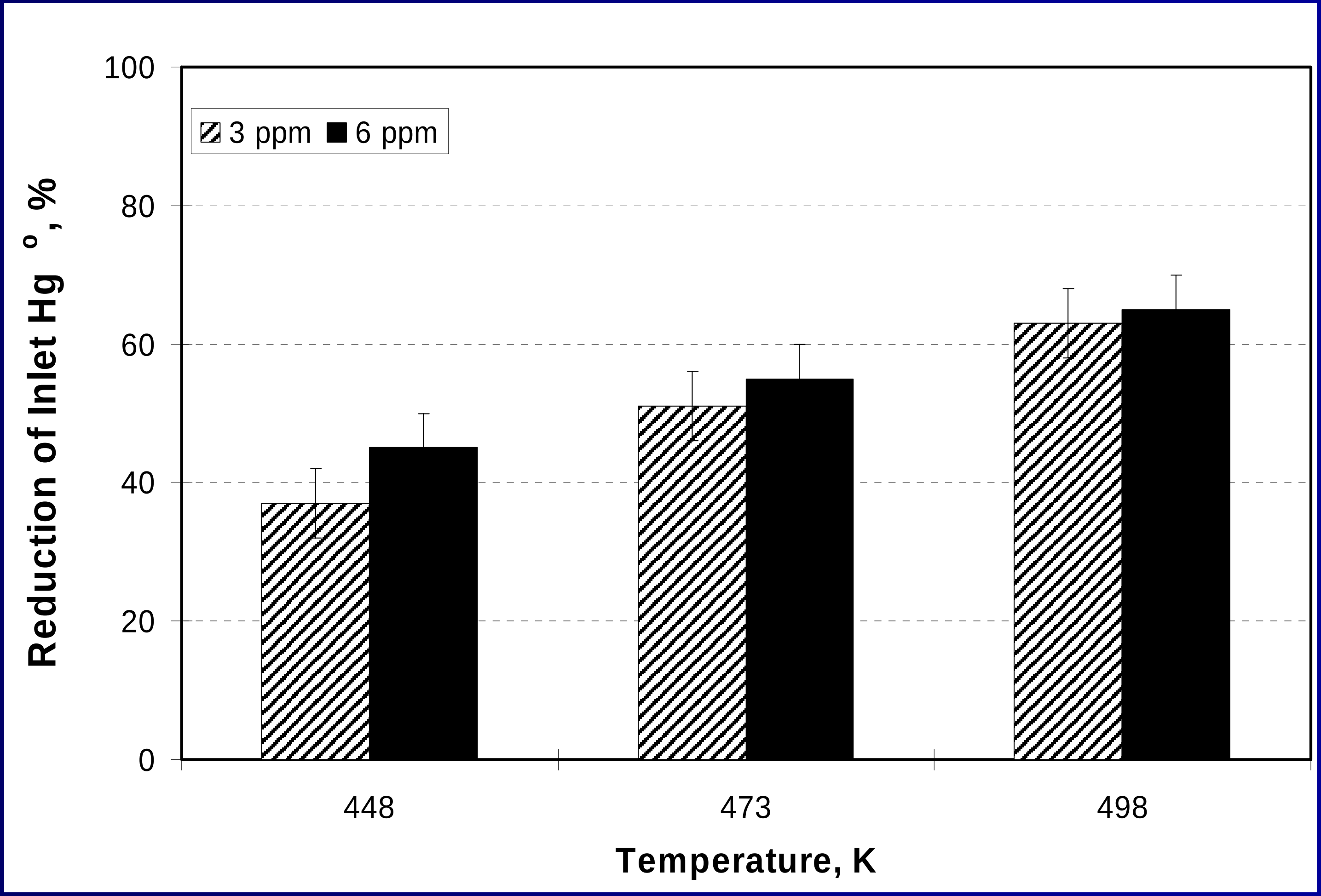
4 – Gold on Quartz

Hg Oxidation with Gold



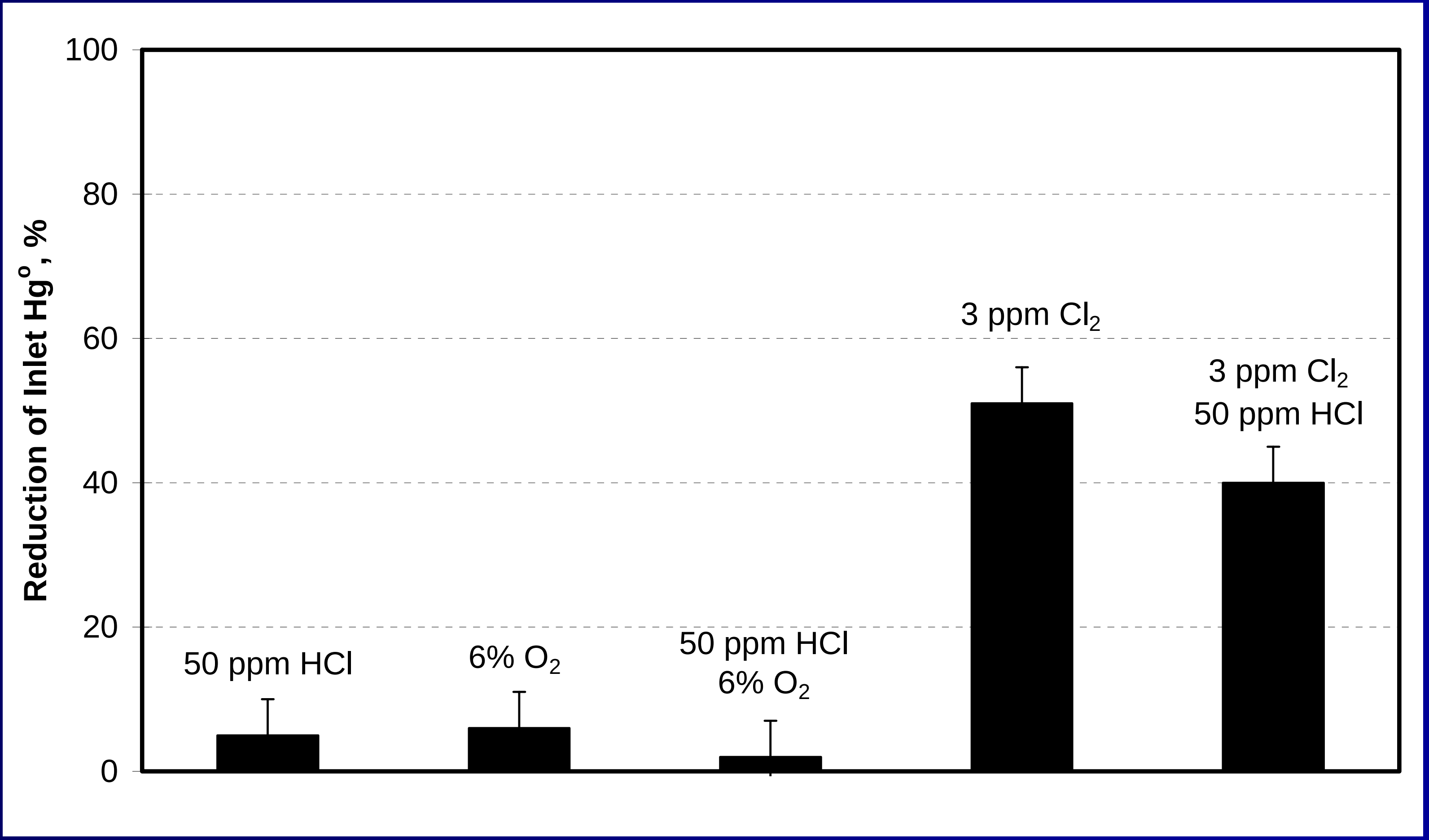
200 C

Cl_2 on Gold



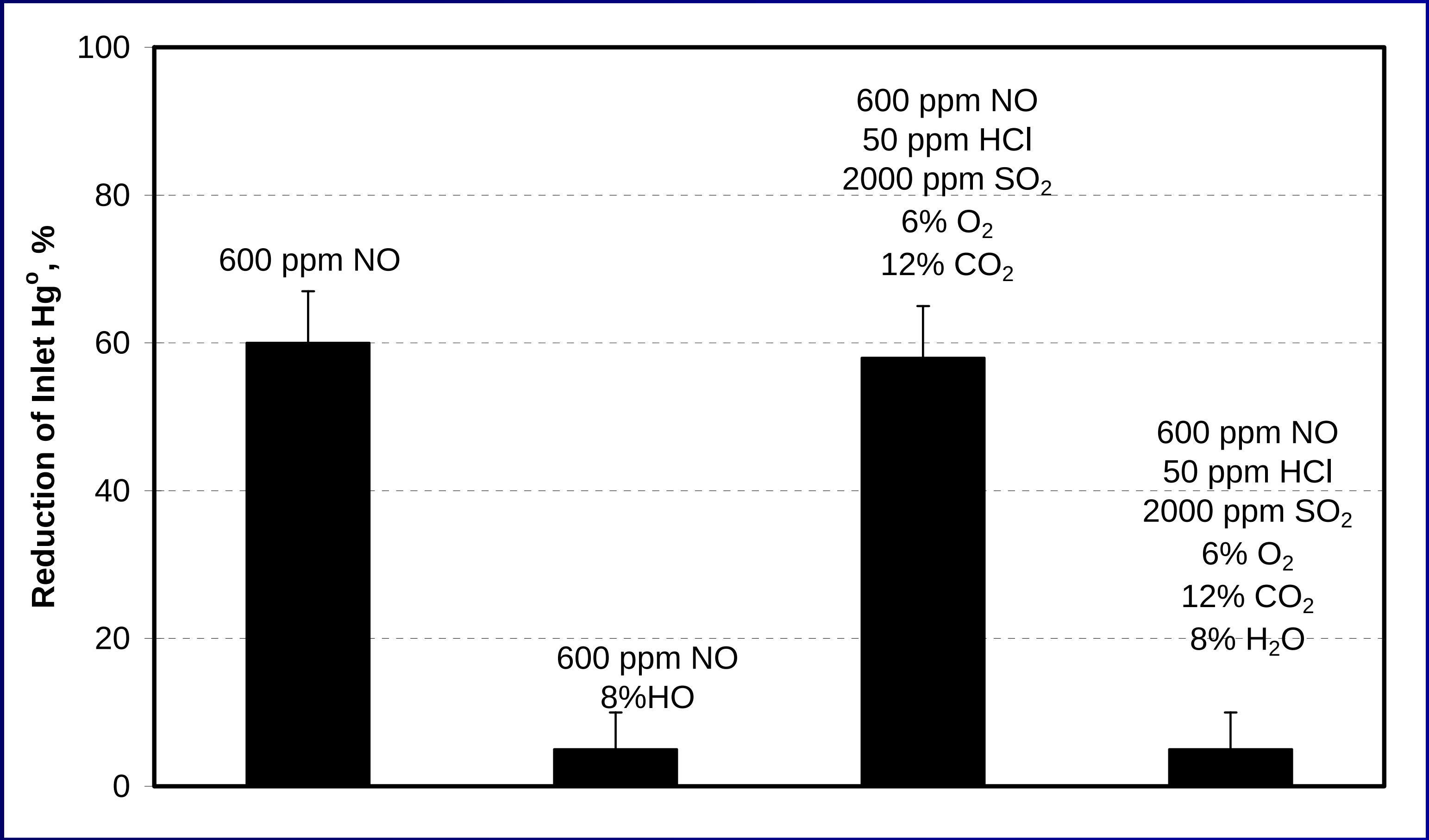
3 ppm
6 ppm
100
80
60
40
20
0
Reduction of Inlet Hg°, %
448
473
498
Temperature, K

HCl vs Cl_2



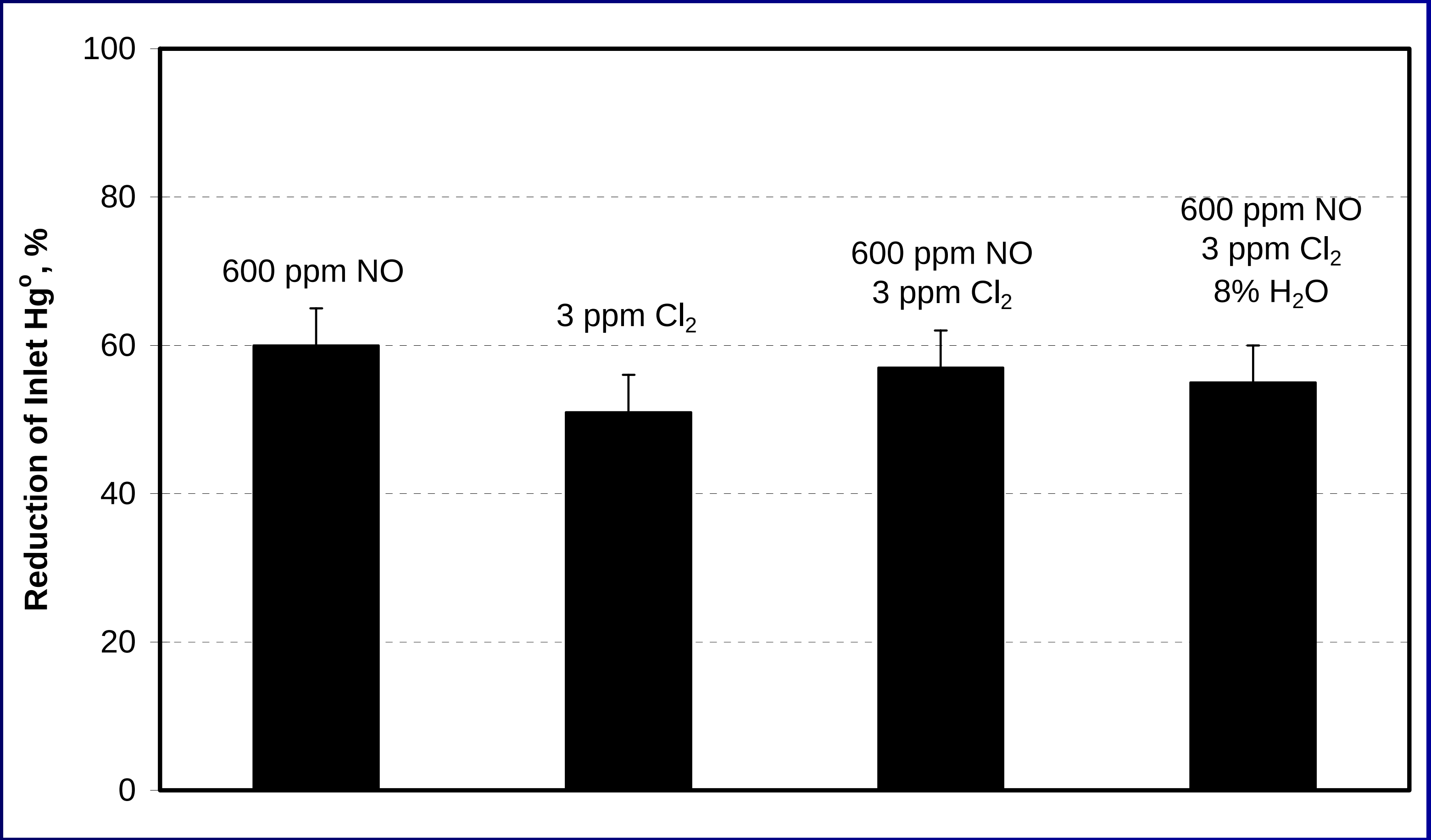
Gold on Quartz at 200 C

Impact of Acid Gas



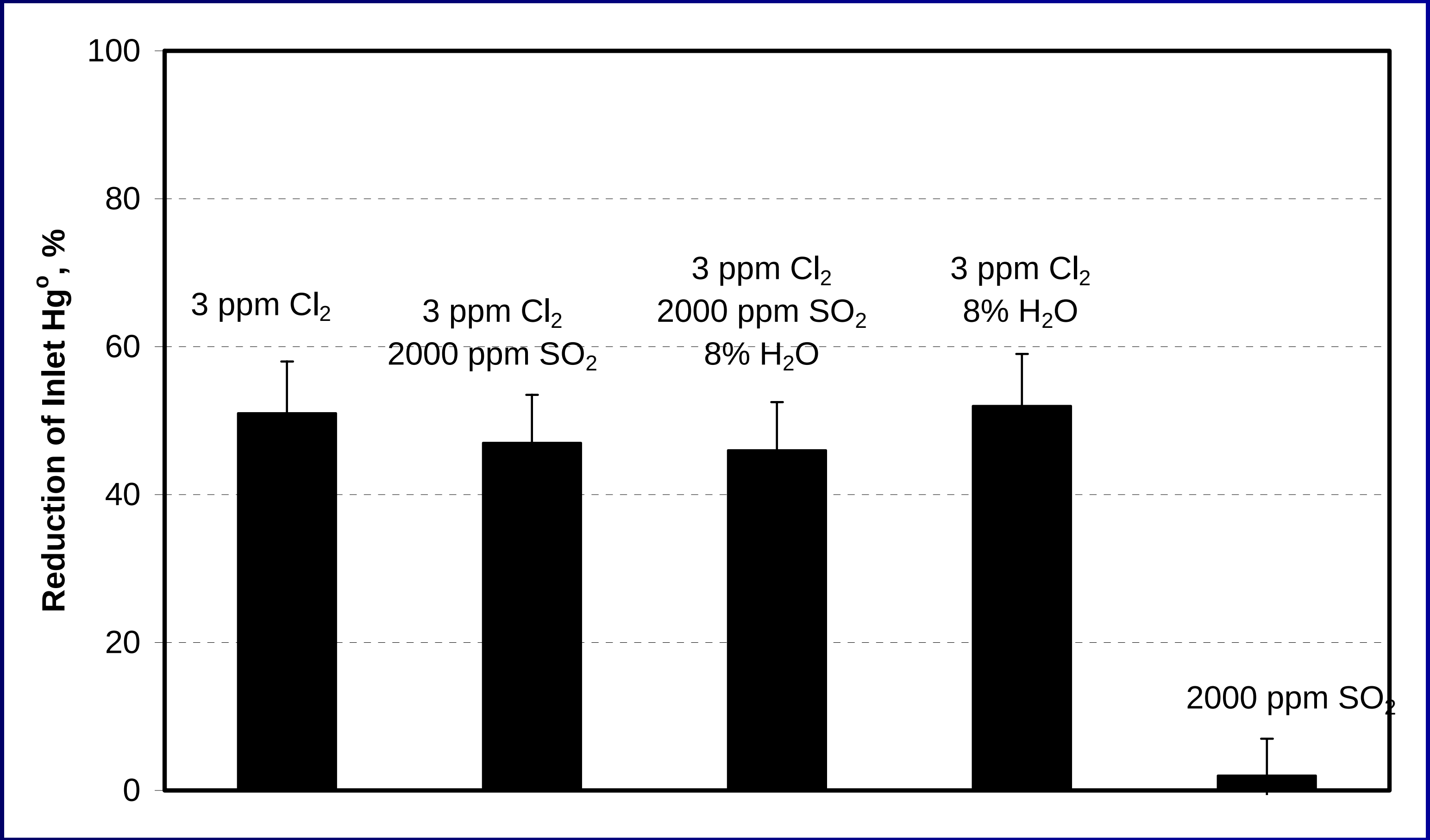
Gold on Quartz at 200 C

Impact of Acid Gas



Gold on Quartz at 200 C

Impact of Acid Gas

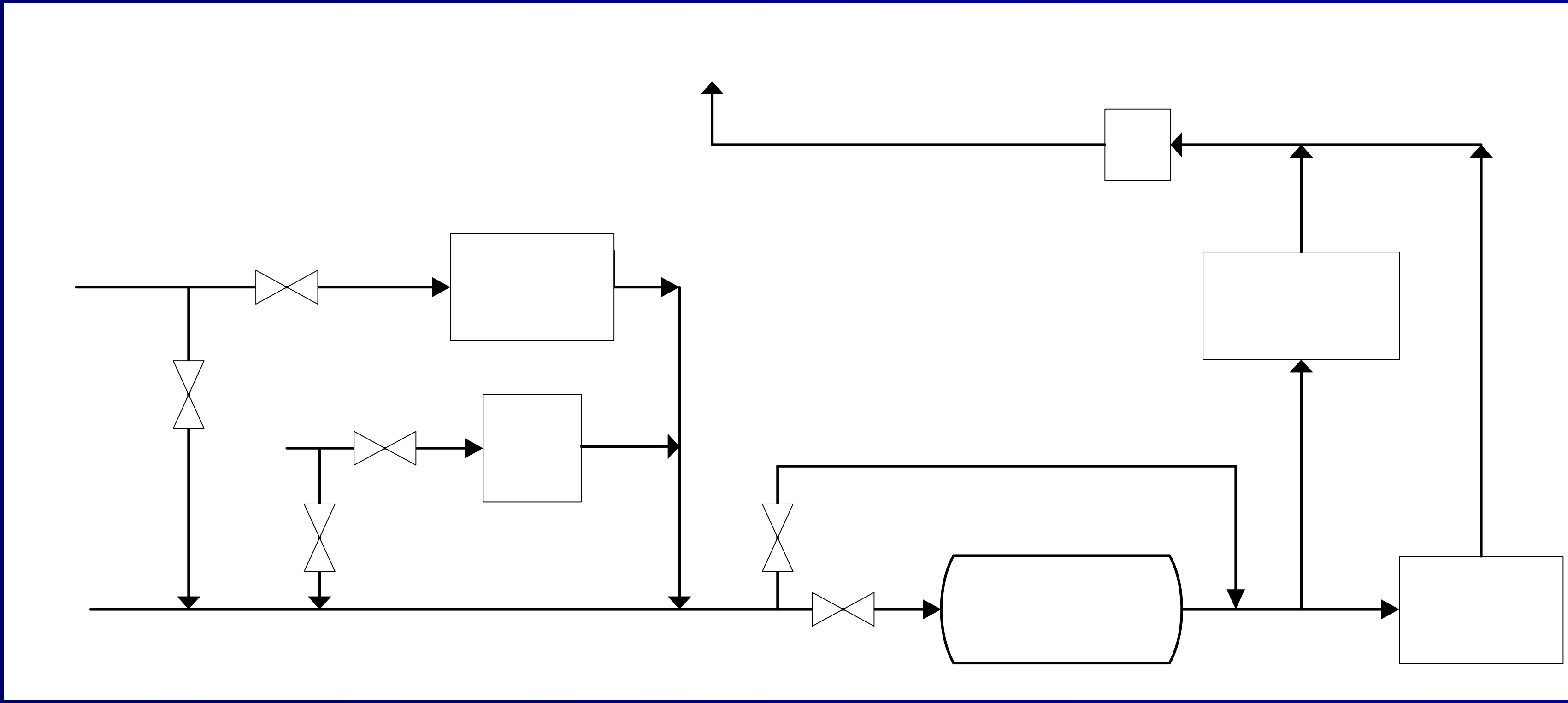


Gold on Quartz at 200 C

Phase 1: Bench-Scale Testing

- Bench-scale testing using simulated flue gas in reactor simulating baghouse conditions
- Will allow for the determination of reactivity of gases without complex combustion environment

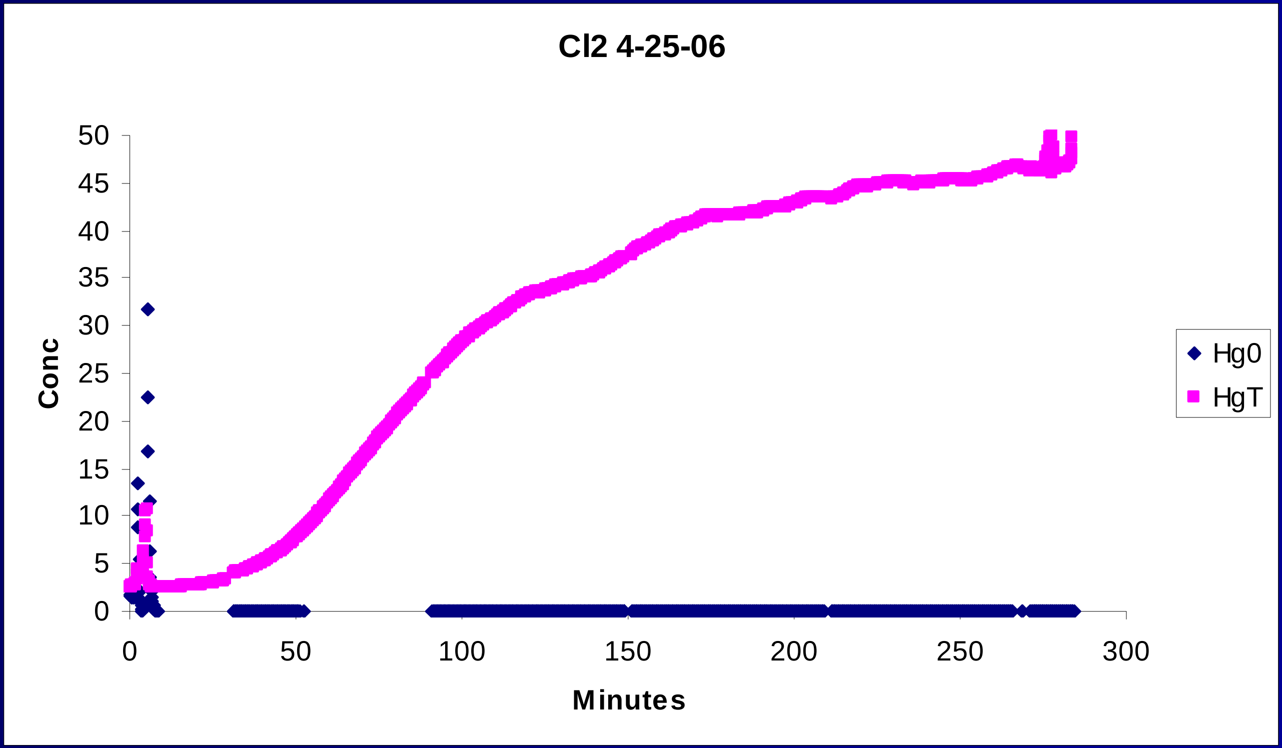
Experimental Schematic



Typical Flue Gas Composition

- Hg^0- 10 - 40 µg/m³
- O_2- 4%v
- SO_2- 1500 ppmv
- NO_x- 500 ppmv
- Cl_2- 10 ppmv
- HCl- 50 ppmv
- H_20- 6-8%v
- N_2- balance

Preliminary Bench Scale Results



Gold an Al_2O_3 – 50 ppm Cl_2 in N_2

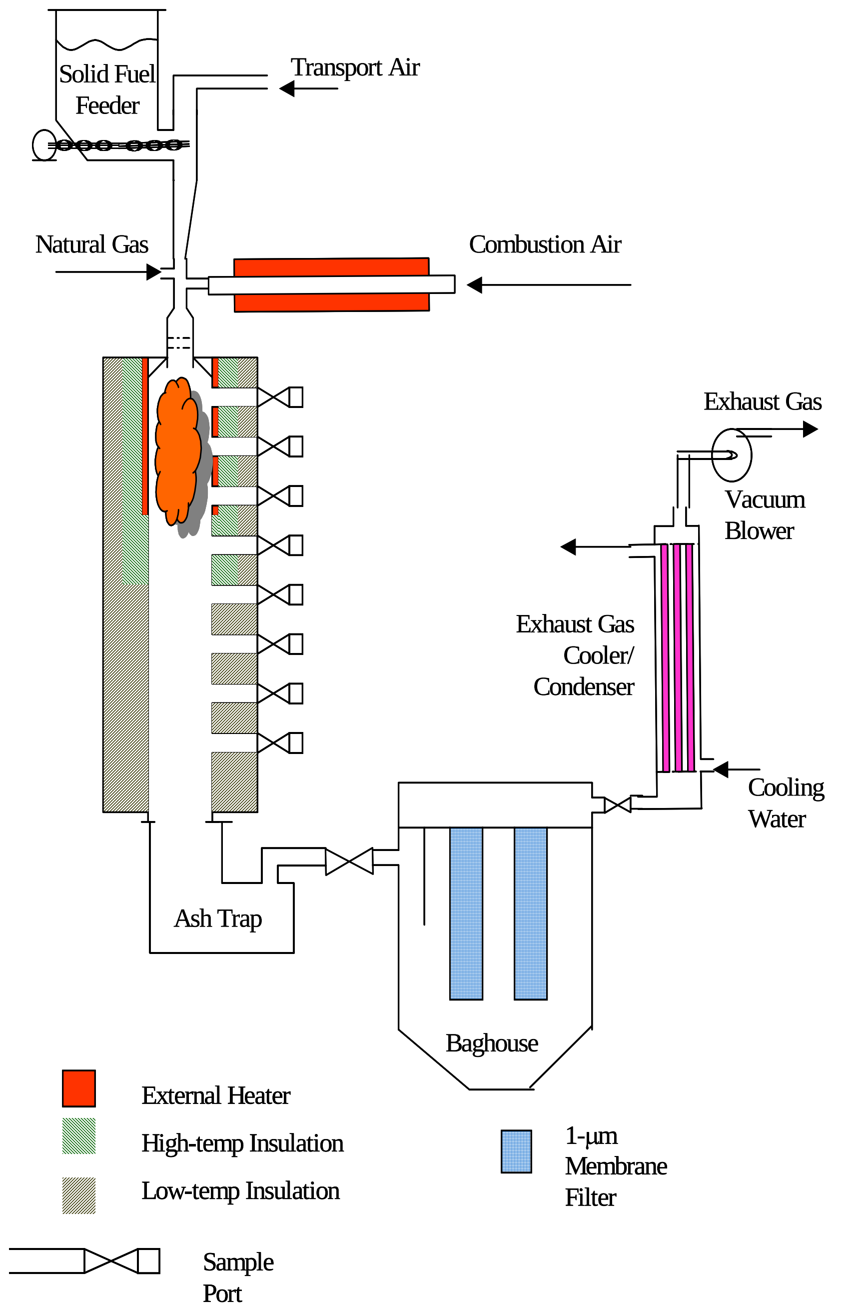
Phase 2: Small Pilot-Scale Testing

- Test Coal Characterization
- Baseline Testing
- Parametric Testing
- Verification Testing

Baseline Testing

- 19 kW combustor will be fired on the Wyoming and Pittsburgh coals
- Mercury concentrations will be measured at inlet and outlet of baghouse
- Will indicate the expected enhancement of on filter mercury capture that can be expected
- Limited testing with North Dakota lignite

17 kW Combustor



Parametric Testing

- To check oxidation performance for variations in SO_2, NO_x, Cl_2, and HCl
- The flue gas of both coals will be spiked with these acid gases to obtain similar compositions in order to determine the performance of mercury oxidation

Verification Testing

- 48 hour test for both coals to allow baghouse to operate through several cleaning cycles
- 12 hour test for lignite to determine impact of fuel/ash type on mercury capture across filter

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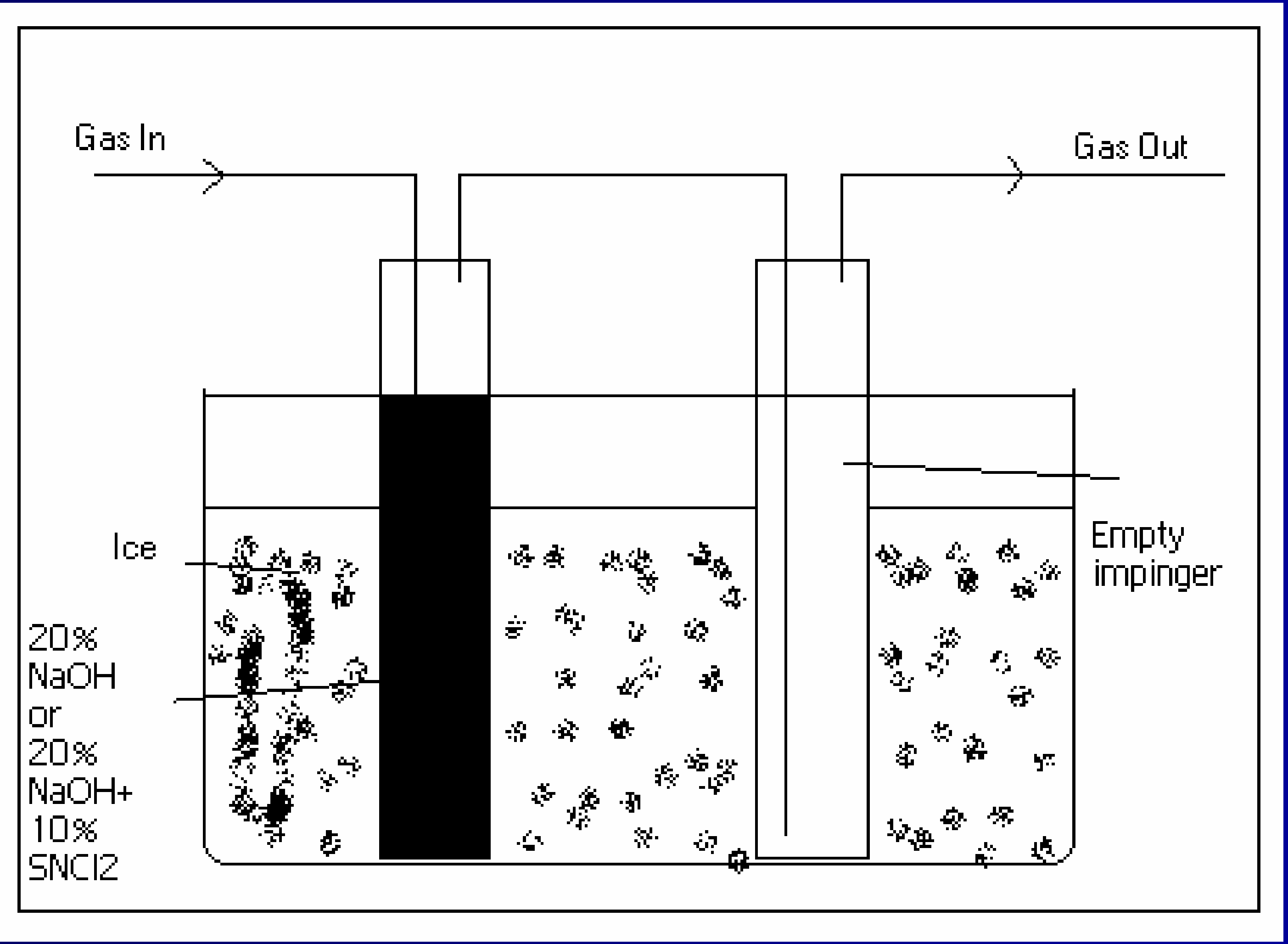
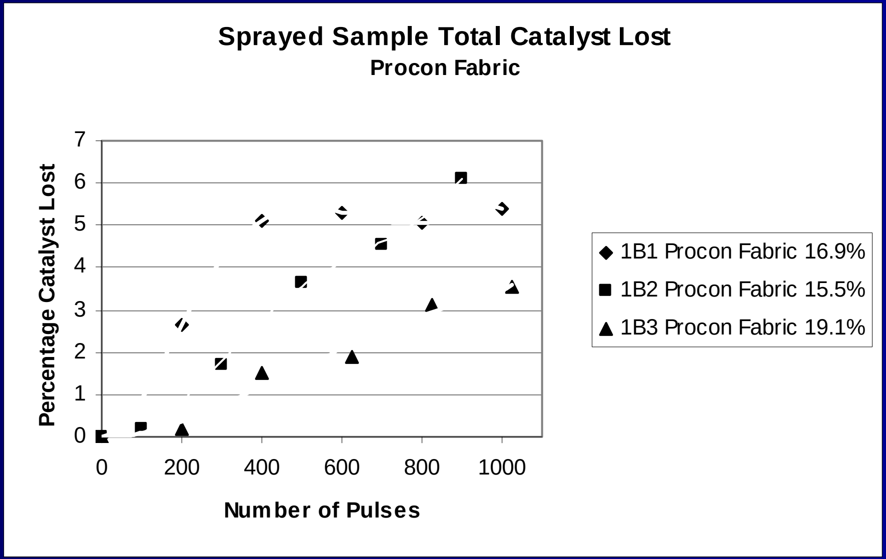
- Great River Energy
- SAS Power
- Minkota Power Cooperative
- GE Environmental Systems / BHA

Sample conditioning





Sprayed Sample Total Catalyst Lost
Procon Fabric
Percentage Catalyst Lost
0
1
2
3
4
5
6
7
0
200
400
600
800
1000
Number of Pulses
1B1 Procon Fabric 16.9%
1B2 Procon Fabric 15.5%
1B3 Procon Fabric 19.1%