Production of Powdered Activated Carbon for Mercury Capture Using Hot Oxygen

2008 Annual ACERC Meeting

Provo, UT

Introduction

- **Current focus on oxy-coal combustion is atypical of the typical use of oxygen in combustion systems**

- **Oxygen is usually used in combustion systems to 'make the process better'**
  - Improve efficiency (high stack temperature processes)
  - Increase throughput – often partial air replacement
  - Pollution control – Praxair's Oxygen Enhanced Combustion for NOx control

- **Activated carbon production is different in the oxy-coal flame *is* specifically used to create a separate product**

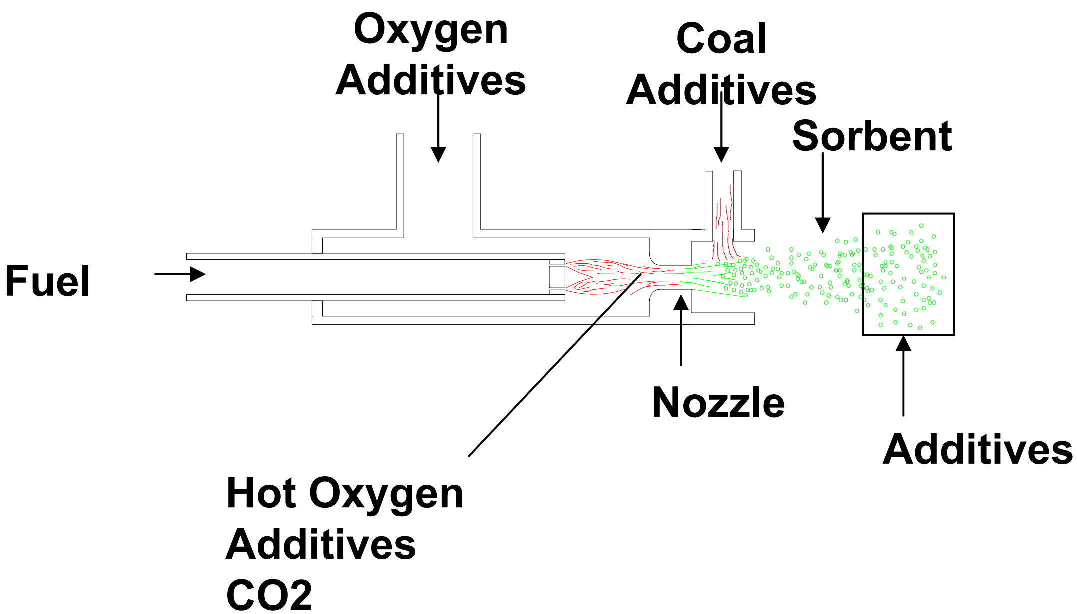
Technology Development Drivers

- **New and pending regulations will restrict mercury emissions from coal fired boilers in the U.S. and Canada**

- **Powder Activated Carbon shown to be effective for mercury capture**
  - Doped carbons may be required with some fuels
  - Currently purchased from PAC suppliers

- **Praxair process allows utilities to produce PAC onsite using the coals being fired by the plant**
  - Cost reduced by ~ 40%
  - Helps ensure security of supply

Hot Oxygen Burner



- Patented burner is the basis of the PAC production process
- Fraction of O_2 burned to heat O_2 stream
- Hot gas exits nozzle to form high velocity jet
- Turbulent hot gas jet has high shear forces and entrainment rates
- Coal entrained into jet in mixing section
- Coal-hot oxygen mixture reacts in entrained flow reactor to form PAC

Praxair's patented Hot Oxygen Burner

The Process

- **Hot, oxygen rich, gas mixes with a pulverized feedstock and reacts in an entrained flow reactor**
  - high temperature causes rapid heatup and devolatilization
  - oxidizing gas reacts with char to open pores
  - Syngas is formed
- **A quench is introduced to cool the gas and solids**
- **Cooled particles (product) and syngas separated in a cyclone**
- **Syngas returned to utility boiler as fuel**
- **Product further cooled and sent to storage silo**
  - Storage silo and injection grid is ‘standard’ equipment for activated carbon injection

PRAXAIR

Small-scale Production Rig

Small scale system includes all key process components

Syngas Flare

Baghouse

Cyclone

Loss In Weight Feeder

Mixing Section (HOB Not Shown)

Entrained Flow Reactor

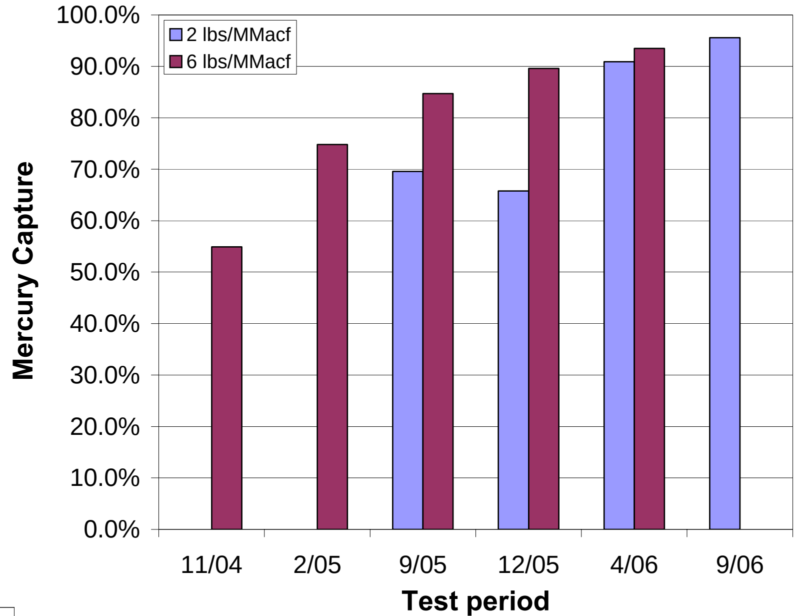
Sample Collection Drum

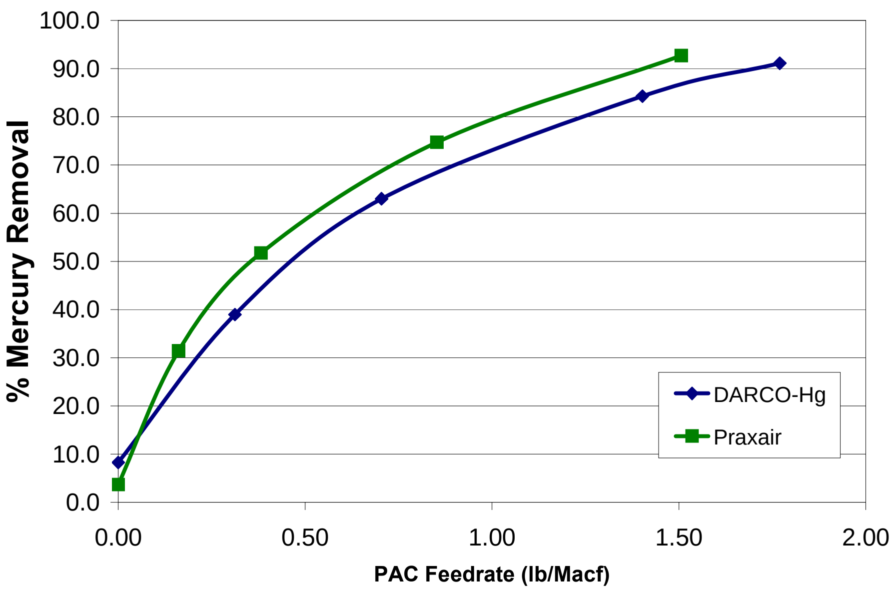
Work to Date

- **Several years of optimization effort has provided insight on process**
  - Key product qualities required for good mercury capture
  - Process parameters to control product quality and yield
- **Previous scaling work showed process is scaleable**
- **Praxair approached for large samples (~1500 lb) for use in ongoing large-scale parametric testing**
  - Led to over 200 hours of system operation on coal over approximately 6 weeks
  - Provided key information on long term operation of process and effect of coal type and variability

PAC Testing to Date

- Optimization using EPRI's PoCT slipstream rig has shown steady improvement in mercury capture
- Mercury capture >90% routinely achieved in slipstream testing with PRB-derived flue gas





- 1 MW FF testing at SaskPower's ECRF showed good capture on Lignite-derived flue gas
- 1 MW ESP testing showed mercury capture rates similar to the commercial product

Effect of Coal Type

- **Utilities in general want to use the coal they have onsite**

- **Previous work showed good product could be produced with different coals**

- **Additional work done with new coals to evaluate system flexibility**

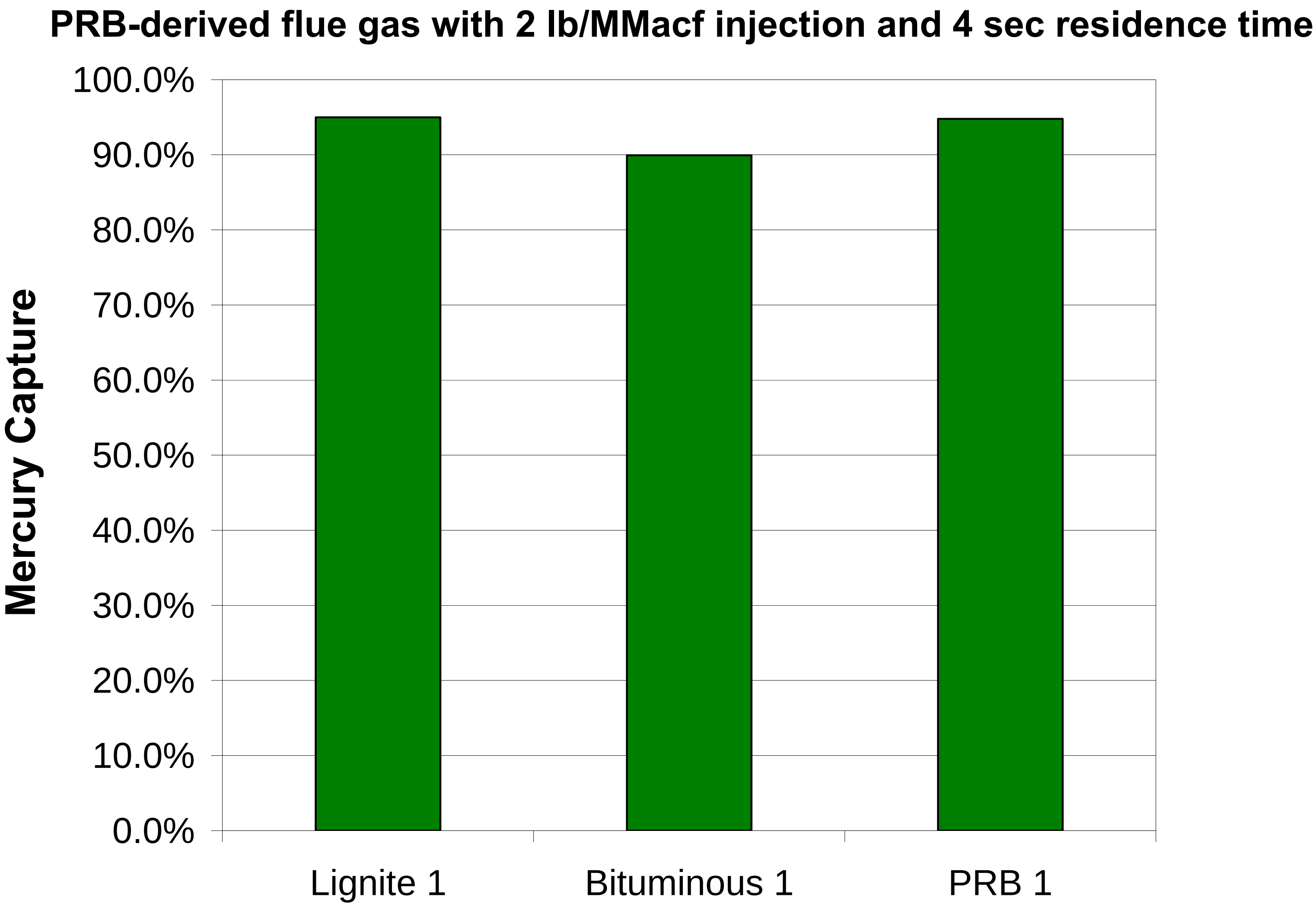
- **Recent work completed to understand how coal quality impacts process conditions required to produce good carbon**
  - Coal type
  - Ash content and composition
  - Moisture content

Coal Properties

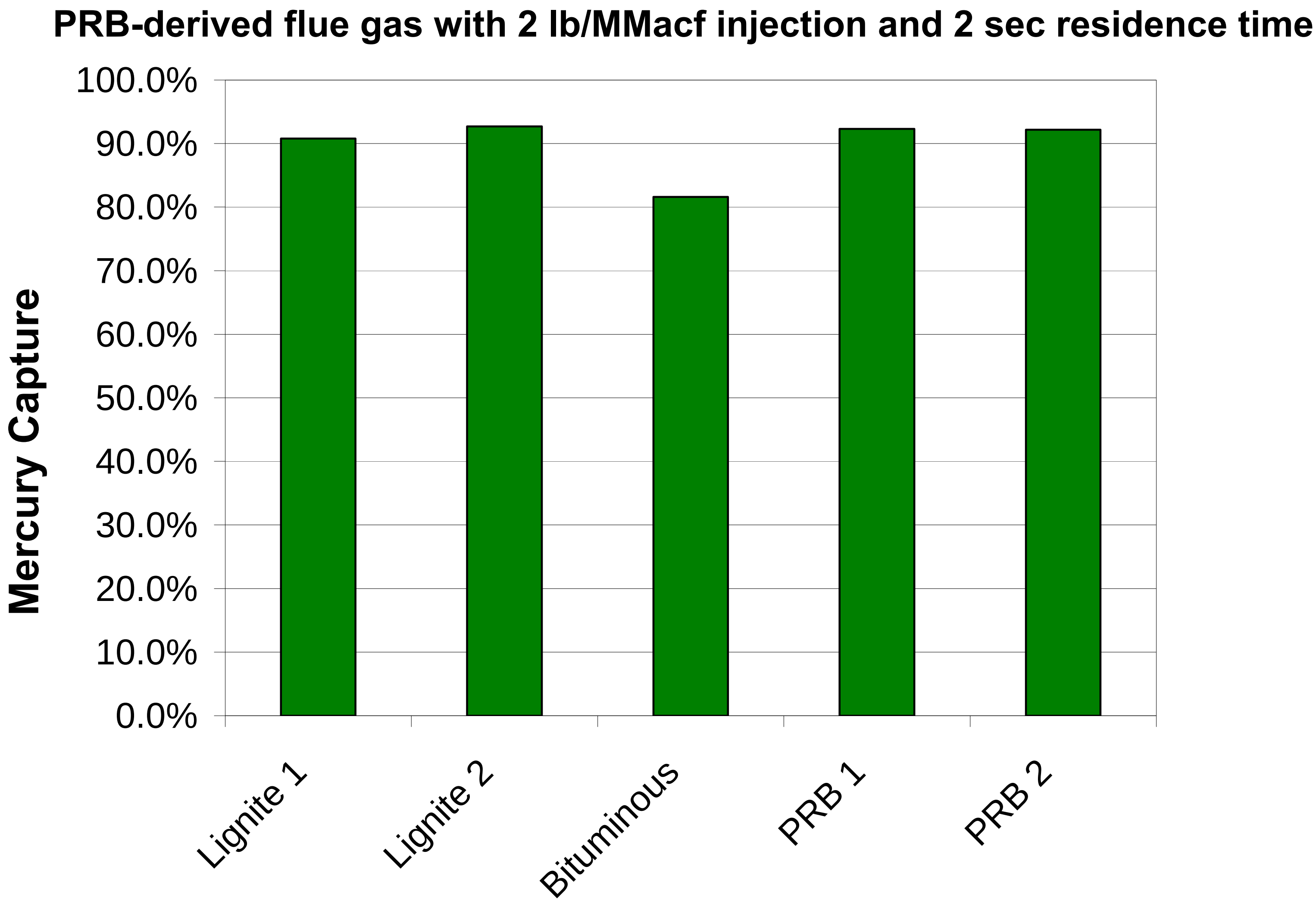
	PRB 1	PRB 2	Bit. 1	Lig. 1	Lig. 2*	Lig. 3
Ultimate Analysis						
Carbon	54.00	57.43	67.08	47.48	43.32	40.55
Hydrogen	3.90	3.97	5.03	3.38	3.07	2.52
Nitrogen	0.90	0.77	1.31	0.75	0.57	0.94
Sulfur	0.40	0.35	0.46	0.83	0.78	0.52
Oxygen	13.70	13.46	10.88	14.25	11.96	12.15
Ash	6.00	6.00	12.87	8.33	26.30	18.70
Moisture	21.10	18.00	2.35	25.00	14.00	24.61
Proximate Analysis						
Fixed carbon	39.5	41.27	44.08	32.70	29.82	29.63
Volatile matter	33.4	34.73	40.70	33.98	29.88	27.06
Ash	6.0	6.00	12.87	8.33	26.30	18.70
Moisture	21.1	18.00	2.35	25.00	14.00	24.61

* Sample ash content varied widely and much higher than normally produced at mine

Slipstream Testing Results



Slipstream Testing Results



Long Term System Operation

- **Praxair was approached for large (~1500 lb) product samples (~1500 lb) for use in ongoing large-scale parametric testing**
  - Mercury capture results to be presented by organizers/sponsers
  - Lignite 2 and PRB 2
- **Samples produced in small-scale rig (~100 lb/coal per hour)**
  - Led to over 200 hours of system operation on coal over approximately 6 weeks
  - Provided key information on long term operation of process and effect of coal type and variability
- **Addition sample production runs are ongoing**
  - Lignite 3

Learnings from Long Term Operation

- **Process optimized to maximize yield and product quality**
- **Economic yields achievable**
- **Slag/ash control is critical**
  - Primary cause of product loss
- **Mixing chamber design critical**

Data From PRB2 – Derived PAC Production

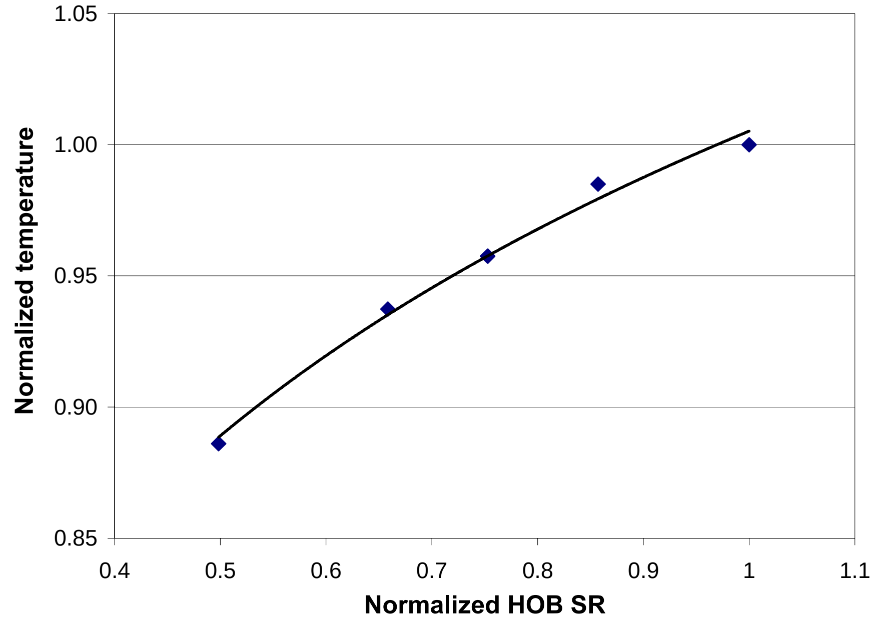
Parameter	Relative Deviation
Temperature	2.0%
Yield*	15.6%
Density	3.9%

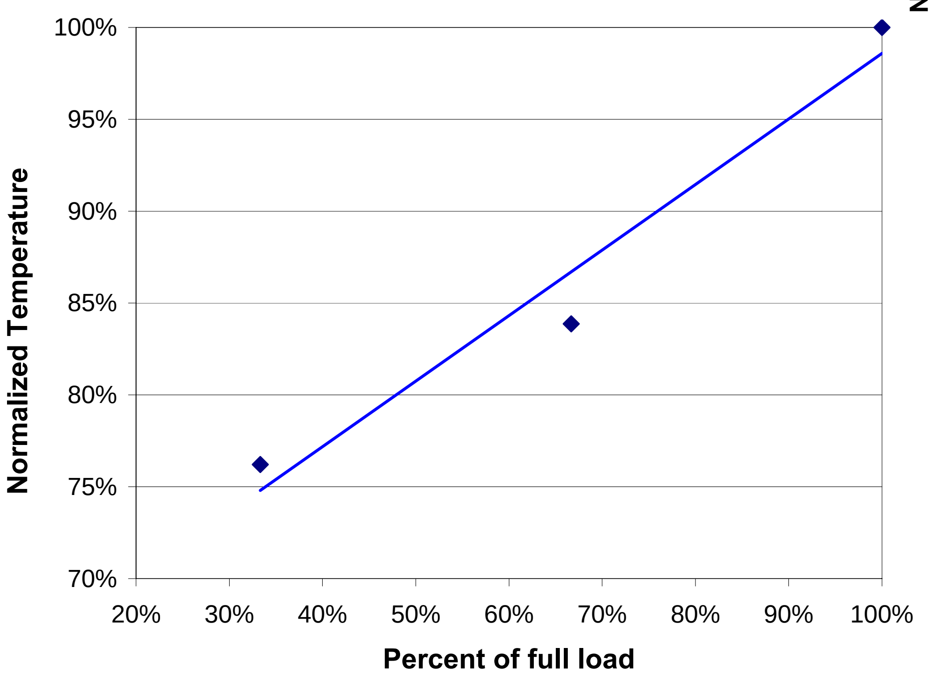
•Process conditions intentionally changed to affect yield

Long term, stable operation achievable and β site engineering requirements identified

Reactor Temperature Response

- Reactor temperature was shown to decrease as the combustion stoichiometric ratio was decreased



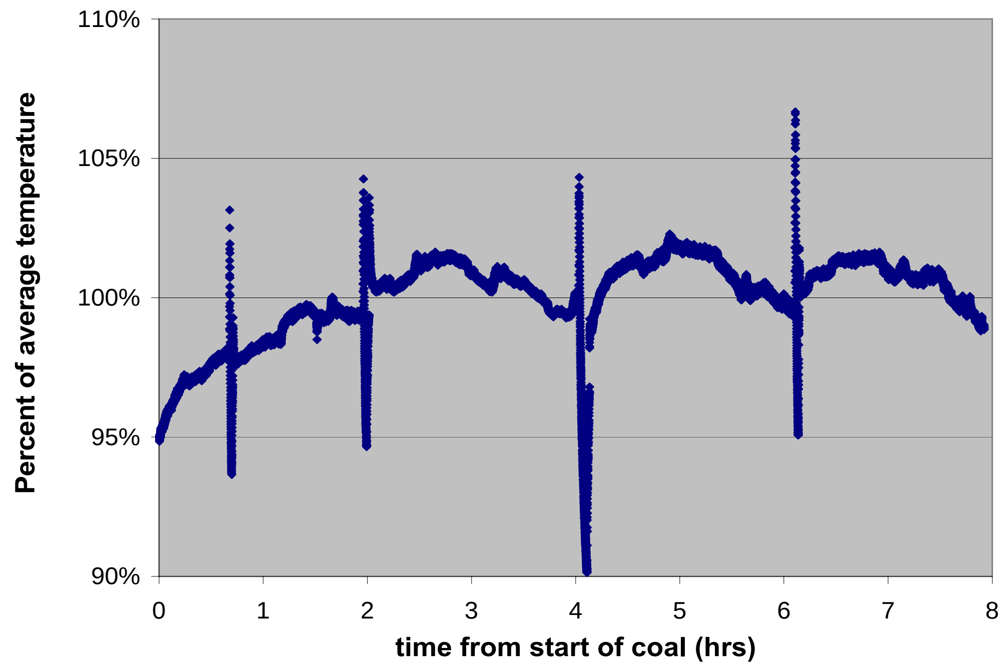


- Reactor temperature was shown to decrease as the firing rate was decreased

Temperature follows normal combustion patterns

Good Process Stability

- **Rapid change out of sample drum (show by spike in temperature) had relatively little impact on operation**
- **Slow decrease in temperatures between drum changes due to refill cycle on feeder – not a process characteristic**



Data from typical production run with the PRB fuel

Control parameters are well understood – allowing safe operation with wide range of coals

Conclusions

- **Process yields PAC with good mercury capture characteristics with a number of different coals**
  - Variability in coal quality/type could be handled by changing process conditions
- **Long term operation demonstrated**
  - Process stable even with multiple restarts to empty sample drum
  - Product quality could be controlled to optimize quality and yield
- **Engineering update underway for β-site plant**

Acknowledgements

- SaskPower
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- EERC