Fast Start Reformer Components: PrOx – CO Removal for Fast Start Fuel Processing

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Fuel Cell Program

Technical Objectives

- Investigate and develop PrOx reactor component design for integration into a fuel processor system for demonstrating the feasibility of a fast start.
- Technical Targets (2010):
  - Cold startup time to maximum power - < 30 secs.
  - CO content in product stream - <10 ppm steady-state, <100 ppm transient

Approach

- Identify PrOx catalysts for use in a PrOx reactor component
  - Measure kinetic parameters for expected operating conditions.
- Collaborate on component design for the PrOx reactor.
- Investigate PrOx options enabling rapid start of a fuel processor.
- Measure PrOx component response to simulated startup conditions and events.

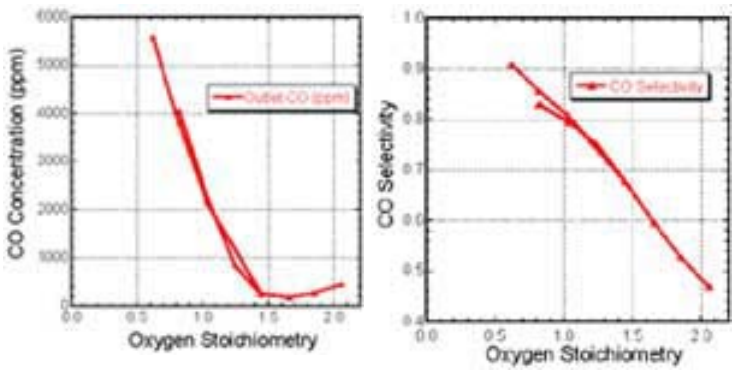
PrOx Startup Considerations

- Goal: Maintain fuel processor outlet CO concentration within fuel cell stack tolerances through the startup transient and transition to normal operation.
  - Reduce thermal mass ($m \cdot c_p$) of catalysts and components in contact with the flow
  - Low catalyst light-off temperature for CO oxidation
  - CO selectivity over a wide temperature range
  - Staged reactors for higher turndown or higher inlet CO (> 1%)
  - Oxidation of high concentrations of CO (for cases where WGS is not fully operational)

Accomplishments/Progress

- Obtained catalysts from various manufacturers on monolith, ceramic foam, and metal foam substrates.
- Identified a catalyst with low light-off temperature and good selectivity.
- Measured catalyst performance under range of expected operating conditions.
  - Data provided to ANL for fuel processor model and evaluation of kinetic parameters.
- Verified catalyst performance under similar linear face velocity as the PrOx component design
- Obtaining substrate for unique design geometry of PrOx component.

Catalyst CO Performance Measurements



- Measure outlet CO concentration and CO selectivity as a function of air stoichiometry
- Experiment – Single-Stage PrOx
  - PrOx catalyst monolith: 600 cpsi, 3 inch diameter by 5 inch long
  - 25 kW LHV Hydrogen flow
  - Inlet CO: 11700 ppm

PrOx Design and Operation Strategy

- 2-stage design may work for normal inlet CO concentrations (≈1%)
  - First stage: operate to bring outlet CO to 2000 to 1000 ppm.
  - Second stage: operate to bring outlet CO to < 10 ppm
    - Adiabatic temperature rise is small, so reverse water-gas shift reaction can be avoided, thus it can tolerate excess air.
- 3-stage design permits greater flexibility in handling higher CO concentrations (> 1%)
  - Handle higher CO concentrations with less parasitic hydrogen loss.
  - Handle higher inlet CO concentrations at startup.
  - First and second stage: operate to bring outlet CO to 2000 to 1000 ppm.
  - Third stage: operate to bring outlet CO to < 10 ppm.

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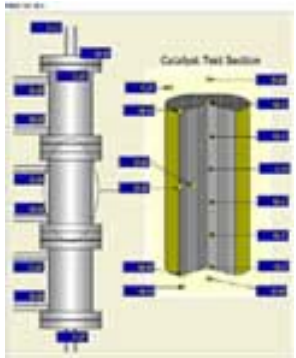
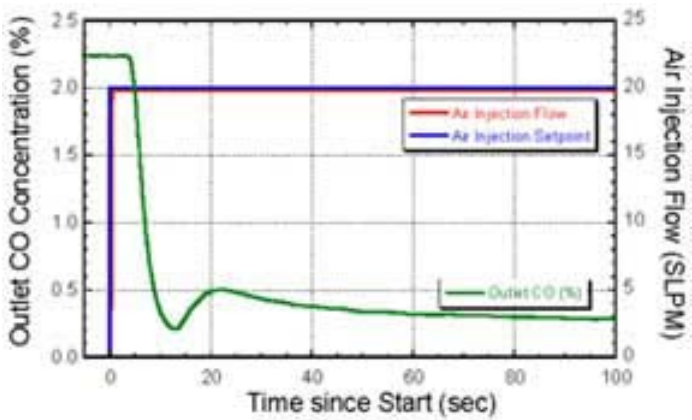
Accomplishments/Progress

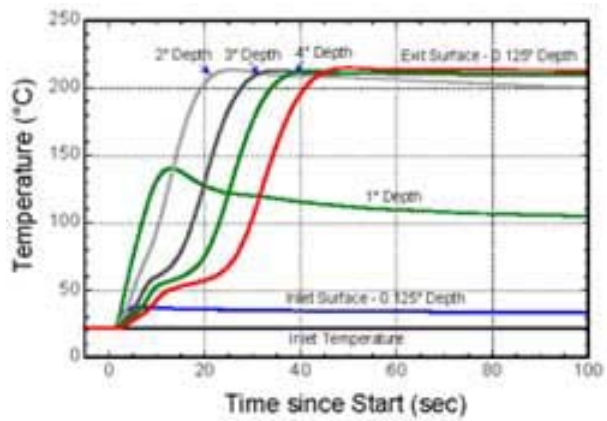
Single-Stage Startup Experiments



- Investigate startup response of a PrOx catalyst monolith from room temperature.
- Experiment – Single-Stage PrOx
  - PrOx catalyst monolith: 600 cpsi, 3 inch diameter by 5 inch long
  - Flows: 46.0% H_2, 32.9% N_2, 19.0% CO_2.
    - Dry gas temperature at inlet ≈ 20 ºC
    - GHSV ≈ 31,000 hr^{-1}
  - Primary gas flow established, then air injected at time = 0.0 s.

CO and T vs time for 2.2% CO inlet





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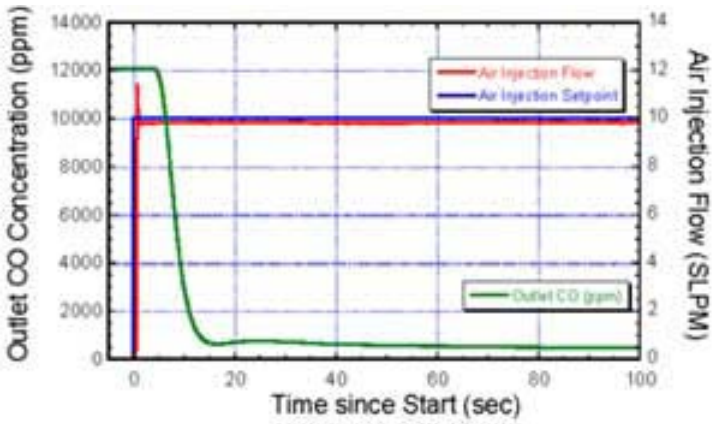
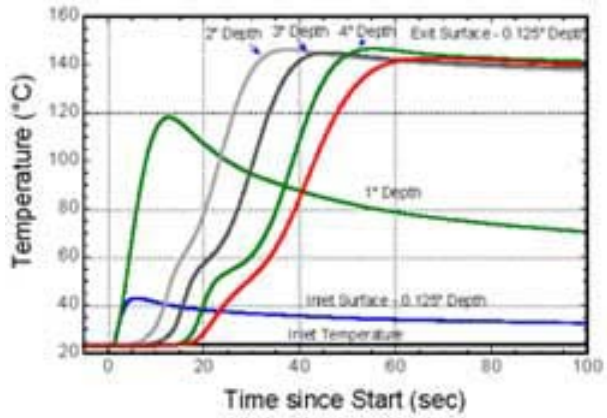
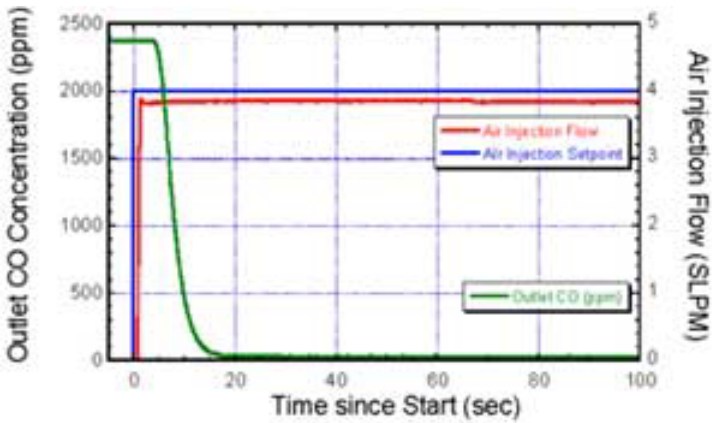
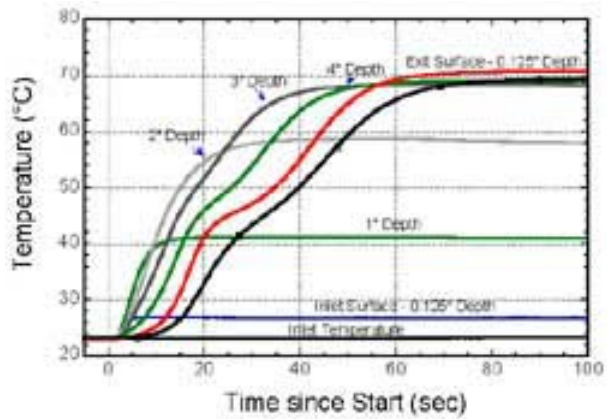
CO and T vs time for 1.2% CO inlet





CO and T vs time for 2350 ppm CO inlet





Summary – Single-stage Startup Experiments

- Outlet CO decreases rapidly to steady-state values in less than 30 s
- Low light-off temperature makes this possible.
- Temperature response takes longer to reach steady-state.
- Fast startup less than 30 s appears feasible.

Plans/Future Work

- Fabrication of PrOx reactor component – July 2003
- Multi-stage PrOx experiments
  - Verify design performance
  - Demonstrate feasibility of staged performance and control
  - Investigate limits of high CO startup option
- Fuel Processor Integration
  - Collaborate on operation and controls