Quick Start Fuel Processor

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Project Timeline

Sep. 2001: Initiate R&D for fast start FP

Jun. 2001: Transfer fuel processor integration technology

Oct. 2000: Transfer fuel processor technology to private developer

May 2000: Initiated collaboration with LANL to integrate PrOx

Dec. 1999: Compared WGS catalysts in integrated unit (ANL, CuZnO)

Aug. 1999: Demonstrated 100 ppm CO from iso-octane, in process train

Apr. 1999: Operated integrated FP with gasoline

Nov. 1998: ATR, sulfur trap, and shift reactor integrated design

Feb. 1996: Transferred methanol reforming to GM R&D

Aug. 1995: Demonstrated methanol reforming in 2” reactor - 50% H_2 in product

Reviewers' Comments

* Consider microchannel heat exchangers
* Improve collaboration or concentrate on basic science, and not development
* Project ignores interaction between FP and the fuel cell. This can significantly alter the design of the fuel processor

Objectives

- Develop strategies to enable fast start fuel processors
  - Identify fast start constraints
  - Define and demonstrate feasible strategies

- Demonstrate diesel reforming for APUs

Addresses Technical Barriers

G: Startup, transient operation

F: System integration, efficiency

H: Thermal Management

Approach: Fast Start FP

- Identify issues that limit fast start
  - Fundamental technology barrier
    - Mass of catalyst and materials
    - Efficiency penalties
- Study rapid heat-up characteristics

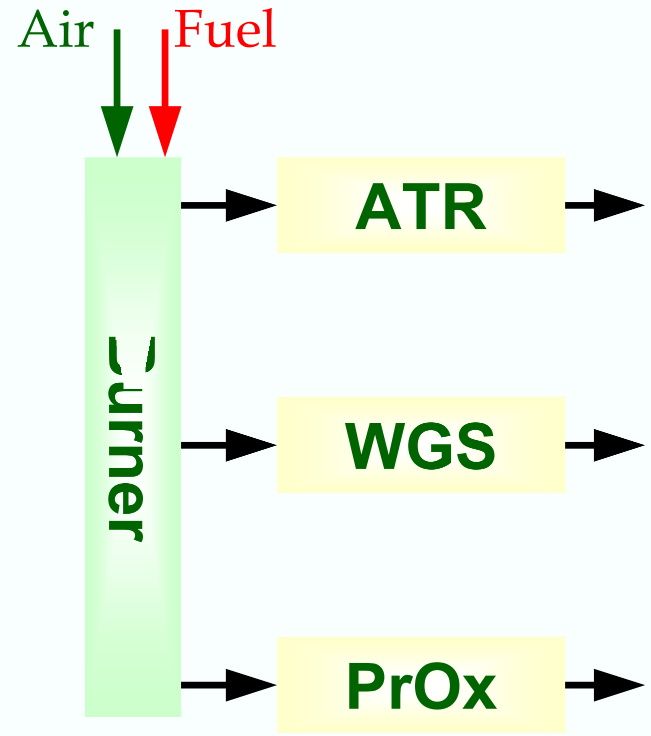
Fast start strategy will need to balance system goals, complexity, and cost

- Start-up Options
  - Heating with hot combustion gas
  - Electrical heating of critical zones
  - H_2 storage
  - CO getter
- Advances in catalysts and materials to reduce mass are key development needs

Parallel heating allows fast start at intermediate capacities

Parallel Heating

- Individual temperature control for each component
- Fuel processor can be warmed up to partial capacity
- Multiple hot gas streams increase complexity
- Higher sensible heat lost with off-gas

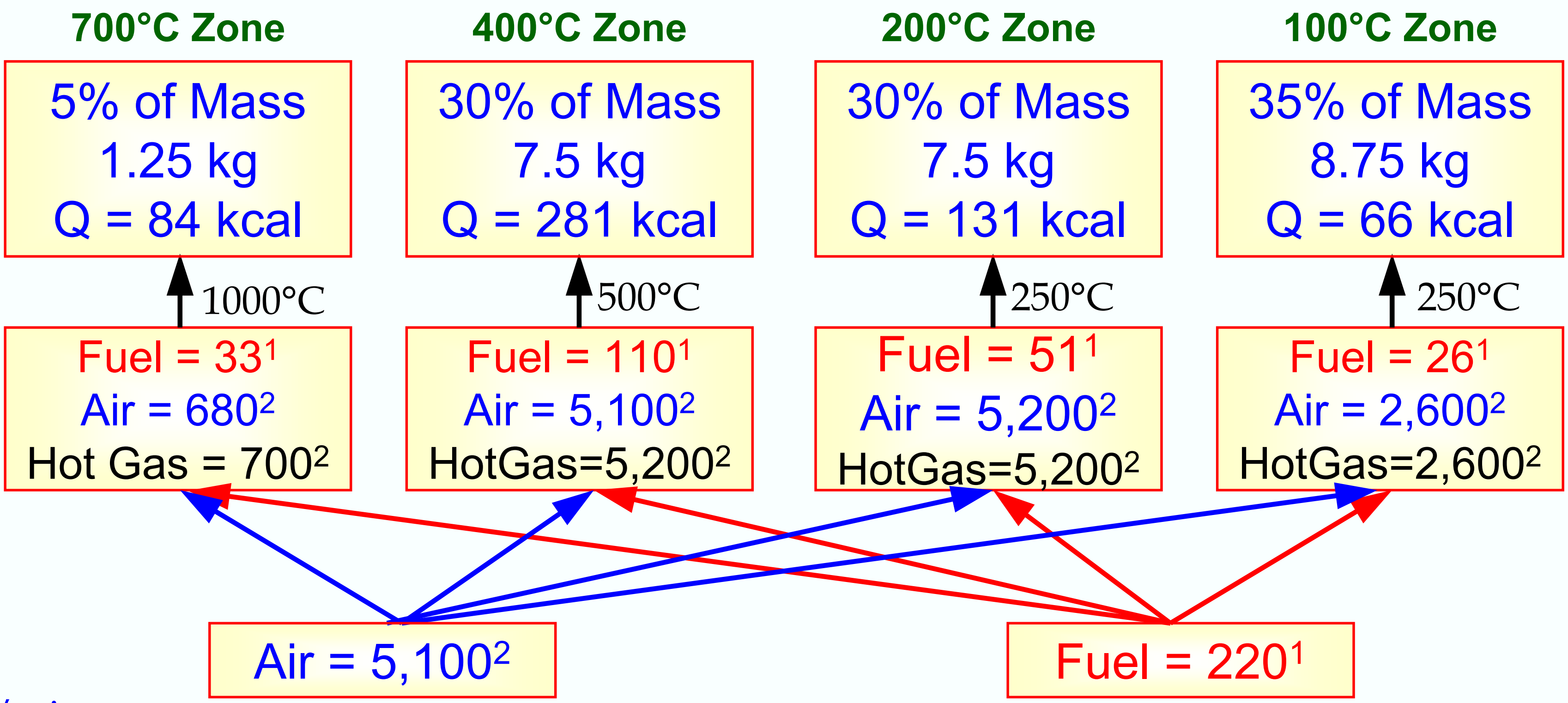


A combination of series and parallel heating may be preferable

A large volume of hot gas is necessary to achieve rapid start

(Fuel Processor + BOP) Mass = 50 kg

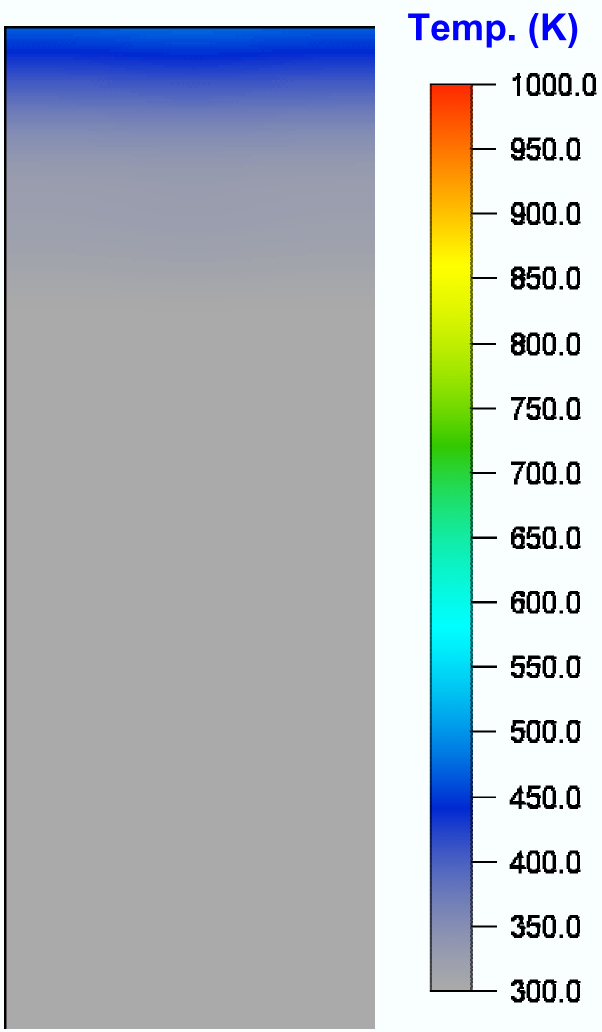
Heated Zones = 25 kg   Start-up Time = 30 sec

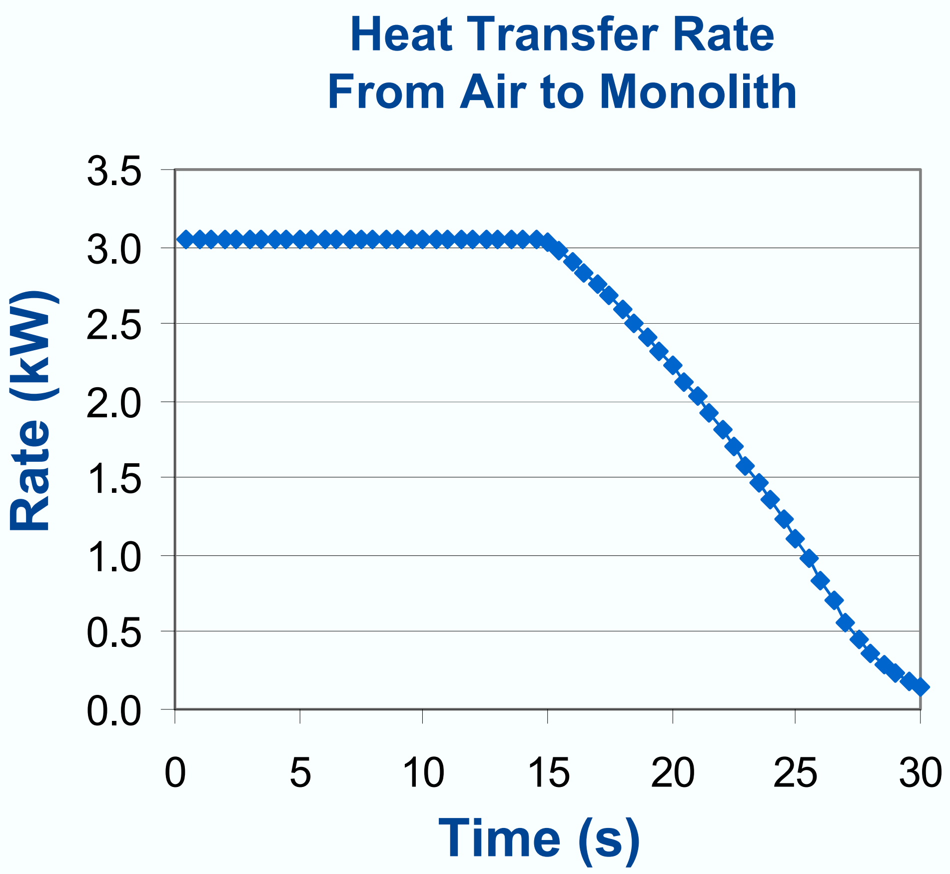


[1]mL/min

[2]SLPM

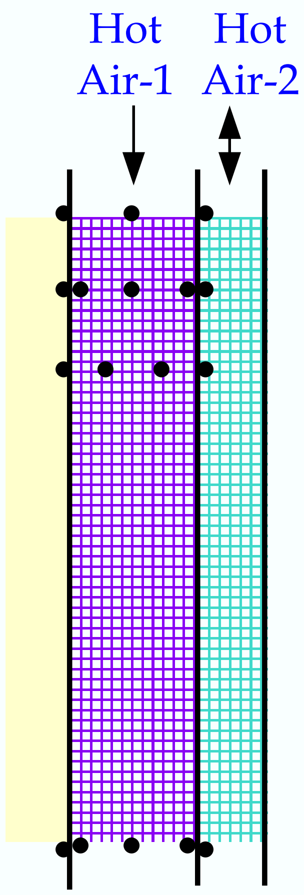
CFD Model has been developed to predict temperature and velocity patterns during startup





The heat up process is being experimentally verified

- Simulated "Reactor Zones" have been fabricated, and consist of
  - Catalyst monoliths
  - 1 or more boundaries (may be insulation or another reaction zone)
- Hot gas passed over the catalyst zone
  - Temperature rise recorded
- CFD model of reactor zone predicts transient behavior
- Validated model will be used for fast start reactor design



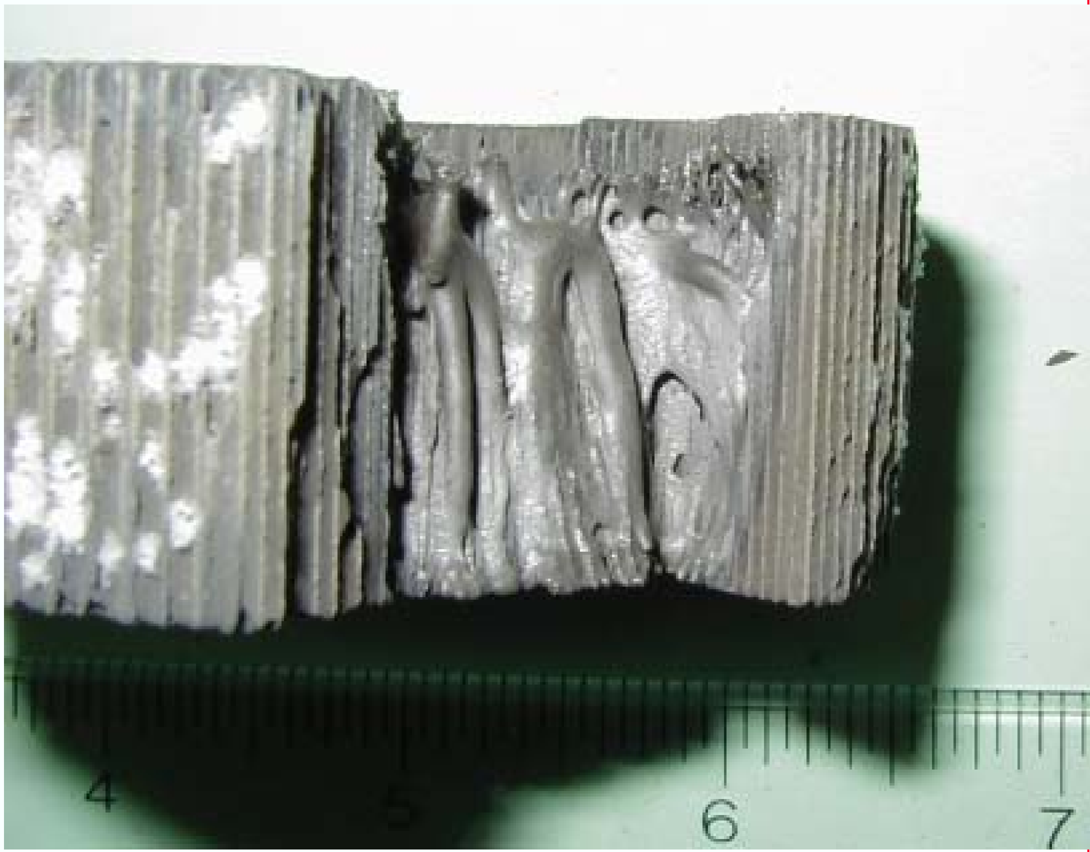
Approach: Diesel APU

- Diesel is difficult to vaporize
  - Direct injection of diesel is preferable
- Adapt commercial nozzles for reforming applications
- Evaluate reforming with direct injection of diesel in 1-3 kWe reformer

Poor fuel dispersion creates hot spots

- Fuel-rich zones coke
- Fuel-lean zones get hot

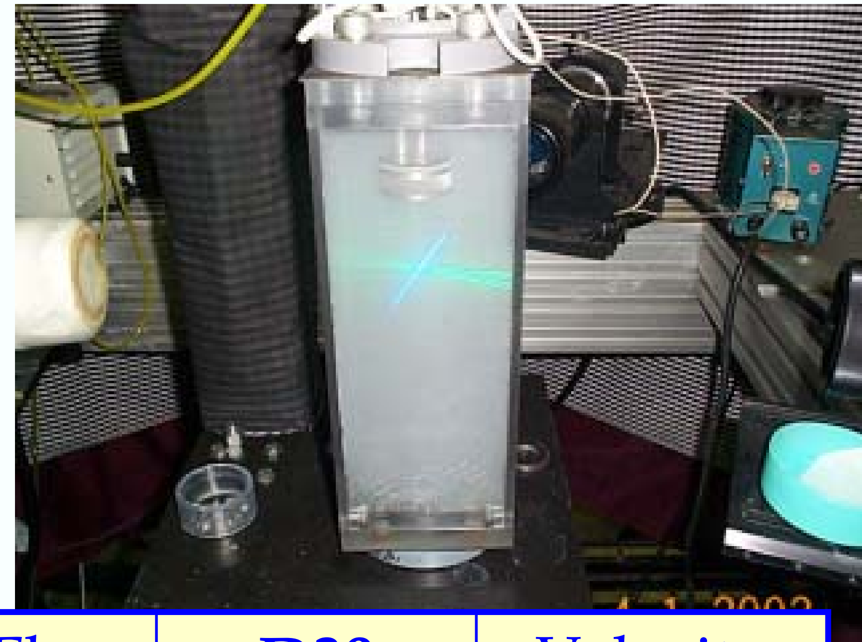
- Melting point of cordierite is 1450°C



The nozzle was designed for the diesel reformer

- **The nozzle assembly mounts to the catalytic autothermal reformer**
- **The liquid is atomized into fine droplets**

The spray was characterized using PDPA



	Liquid Flow mL/min	**D30** µm	Velocity m/sec
Design	10	8.3 ± 2.7	10.7 ± 14
Turndown	3	8.0 ± 2.3	4.3 ± 6

Reformer performance will be evaluated with direct injection of feeds

- 25-mm ID, 15-cm long
- 5 monoliths
  - 600 cpsi
- 10 thermowells
  - Up to 30 thermocouples
  - Radial, axial T profiles

- Will initially be tested at 1-3 kWe

Milestones

- ✓ Preliminary design of fast start FP (Dec.'01)
- ⇔ Demonstrate ATR operation using monolith catalyst (Feb.'02)
- ❖ Demonstrate diesel reformer operation at 3 kWe (Jun.'02)
- ❖ Model alternative FP design capable of 2-min startup (Jun.'02)
- ❖ Demonstrate 5-min startup of a 10 kW fast-start FP (Aug.'02)

Highlights

- Evaluated multiple start-up options
  - Reduction in FP thermal mass is critical
- Developed a CFD model to simulate zone heating
- Designed, fabricated, and installed a generic reactor to validate the model

- New nozzle designed for diesel reformer produces a very fine mist over range of flows
- Diesel reformer has been fabricated and installed

Accomplishments and Plans

- Demonstrated compact and efficient fuel processor
- Transferring technology to industry
- Ongoing fast-start FP R&D
  - Theoretical : Analysis of FP start-up needs leading to feasible strategies
  - Experimental
    - Validate transient model with heat-up experiments
    - Design and demonstrate fast start FP