Integrated Fuel Processor Development

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Objective: Determine reactor design, operating conditions that can meet PNGVs FP targets

- Study processing steps individually - effect of operating conditions, obtain kinetic parameters (100 W)
  - with different catalysts
  - obtain desirable temperature profile for WGS
- Study the component and thermal integration (5 kWe level)
  - identify concepts that improve performance
    - feed location, mixing, reactor size, S-removal effectiveness
  - validate models

Project Timeline

Jun. 2001: Transfer fuel processor integration technology

Oct. 2000: Transfer fuel processor technology to private developers

May 2000: Initiate collaboration with LANL to integrate PrOx

Apr. 2000: Completed evaluation of two PrOx catalysts in process train

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

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

Apr. 1999: Operate integrated FP with gasoline - 30% H_2 in product

Mar. 1999: Started experiments with process train

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

Nov. 1997: Demonstrate new ATR reforming catalyst in 3” tubular reactor

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

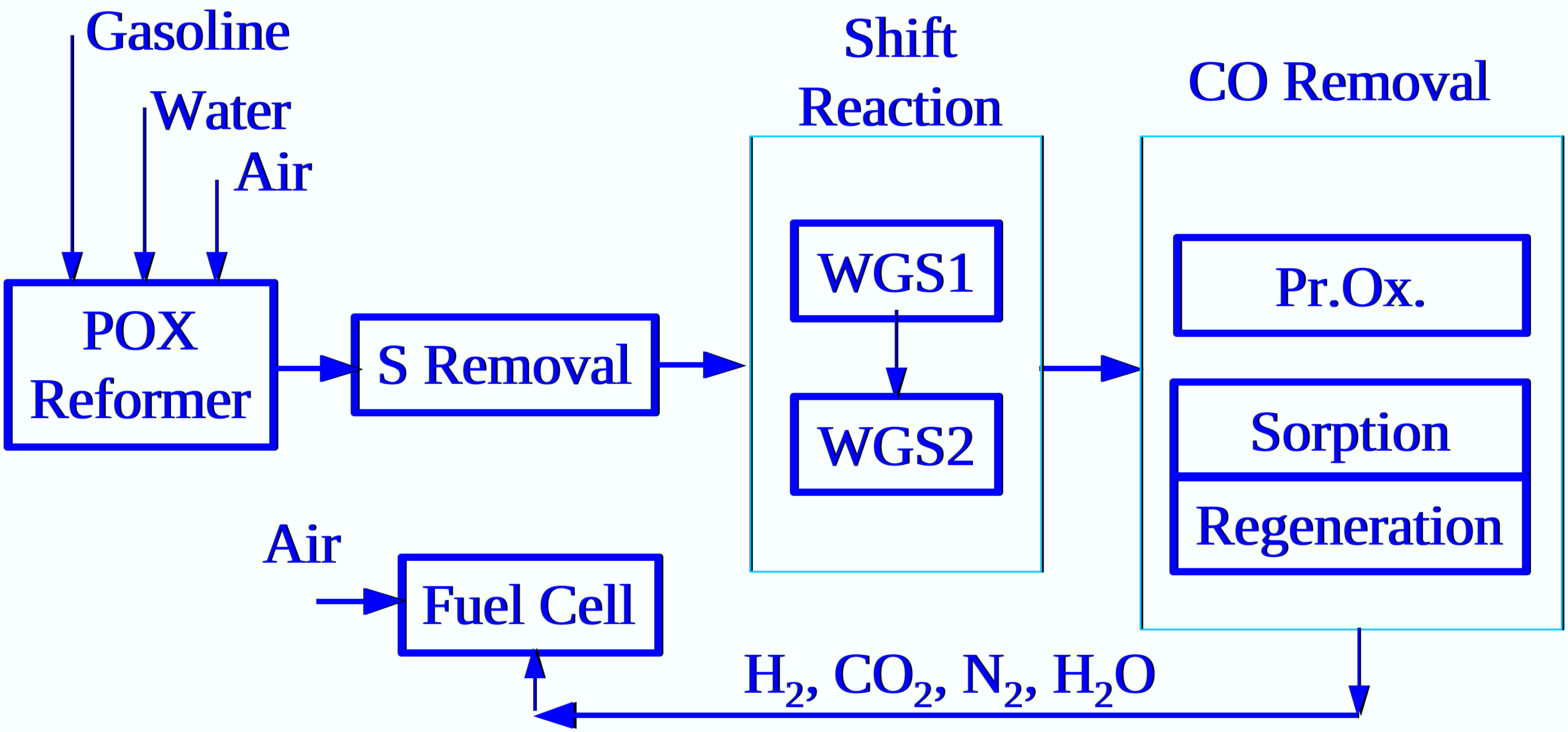
Aug. 1995: Demonstrate methanol reforming in 2” reactor - 50% H_2 in product

Milestone	***Due***	
Process Train: 1% CO after WGS from gasoline reformate	Feb.	u
Integrated FP: 75% efficiency on gasoline	May	u
Integrated FP: 1% CO from gasoline	Jun.	u
Design optimum temperature profile for shift reactor	Jun.	u
Integrated FP: Measure start-up emission	Jun.	
Partnership with industrial developer for technology transfer	Jun.	u

Reviewers commented last year...

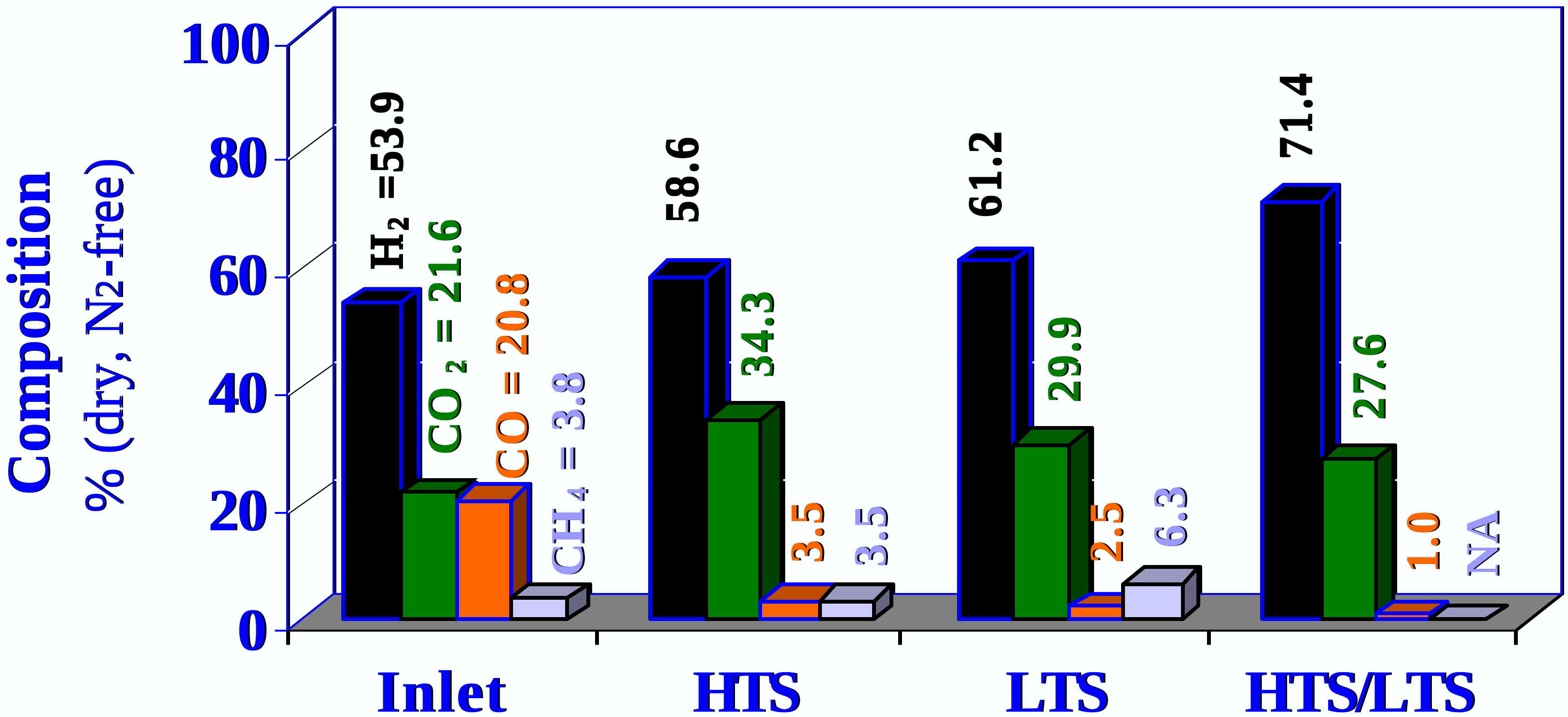
- Concentrate on fundamentals
  - Catalyst, catalyst forms, operating conditions are being studied
- Increase focus on integration, with modeling
  - Modeling effort has been increased
  - Reactor configuration with model, followed by model validation
- Work with system integrators and developers
- Address dynamic and idle conditions
- What is being learned?

The process train is used to study the components individually or in series



- The catalyst performance is verified under more realistic conditions in an engineering scale reactor.

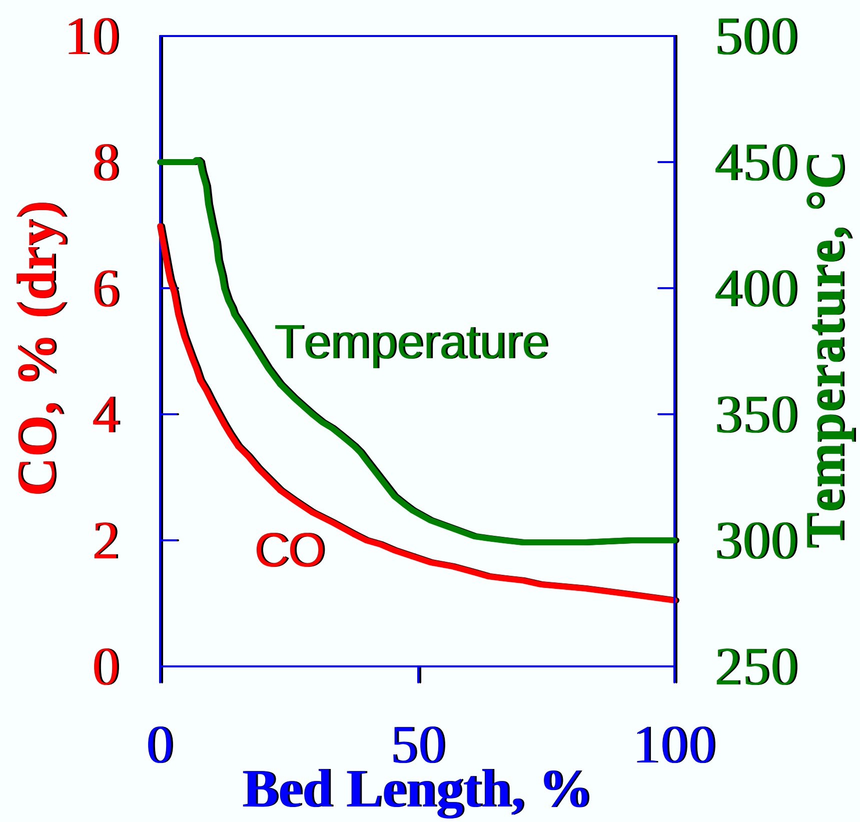
The shift reactors were configured to achieve 1% CO



HTS: Fe/Cr Oxide, T = 300°C
LTS: ANLWGS, T = 215°C

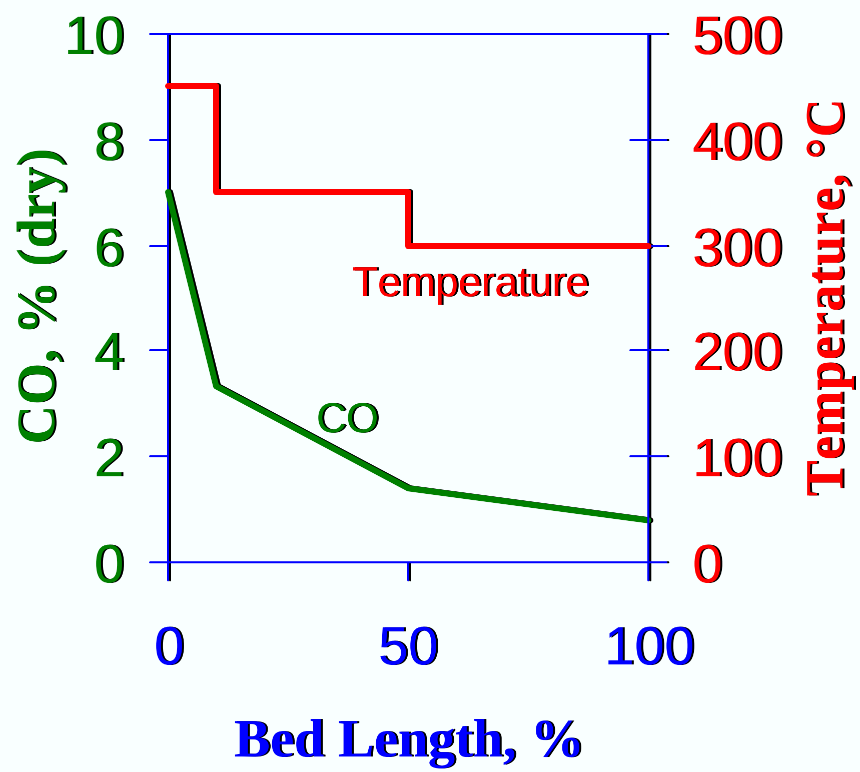
A declining temperature profile for the shift reactor was calculated

- For conversion of 85% of CO from ATR
- CO_{in} = 7%; Co_{out} = 1%; H_2O / CO = 3
- Catalyst: ANL-WGS
- A shift reactor with the determined temperature profile will require the least catalyst

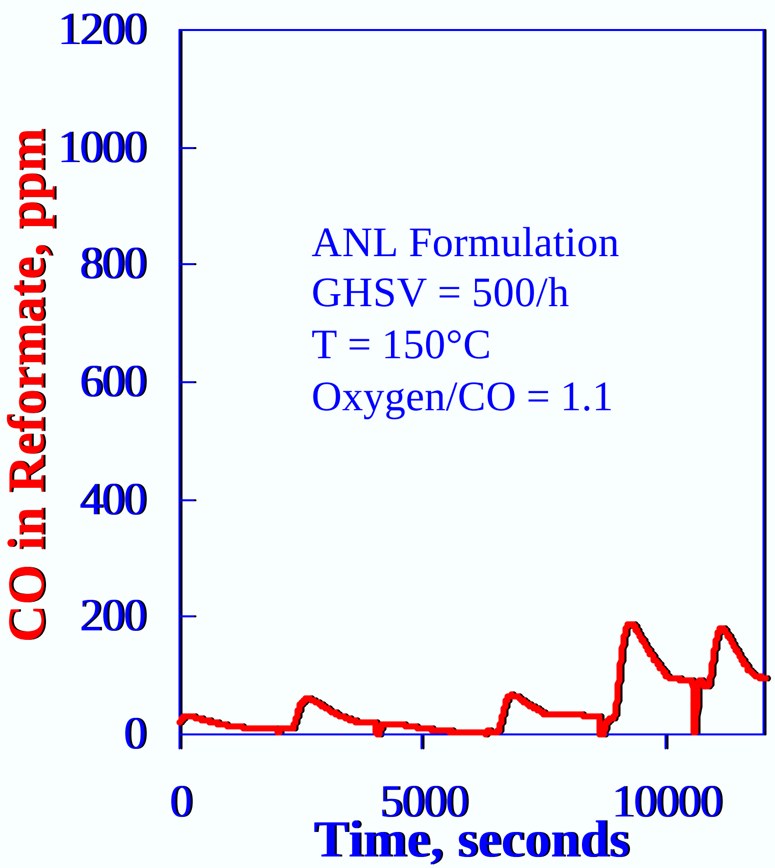


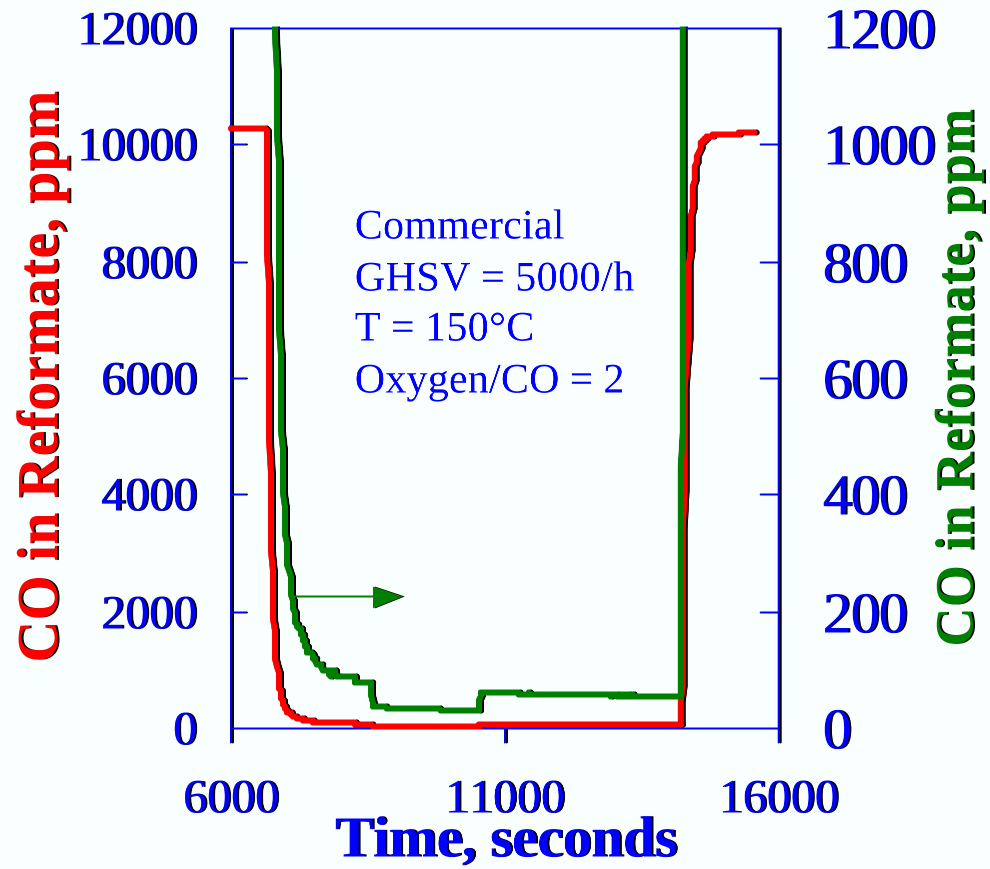
Multiple isothermal beds can be used to approach optimum-temperatures reactor

- 3 isothermal reactors will require 25% longer bed
- Multiple temperature zones can be approximated in an integrated reactor



Preferential oxidation catalysts are being evaluated

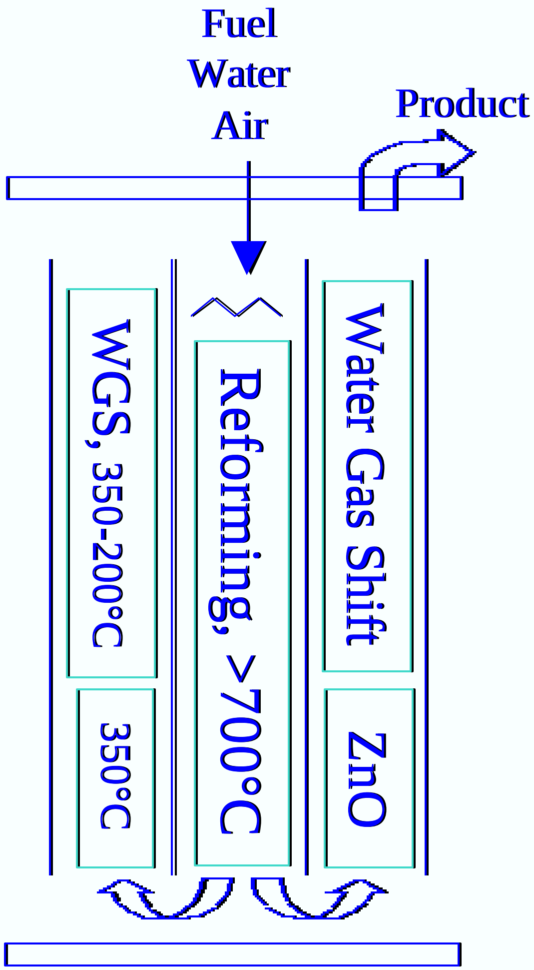




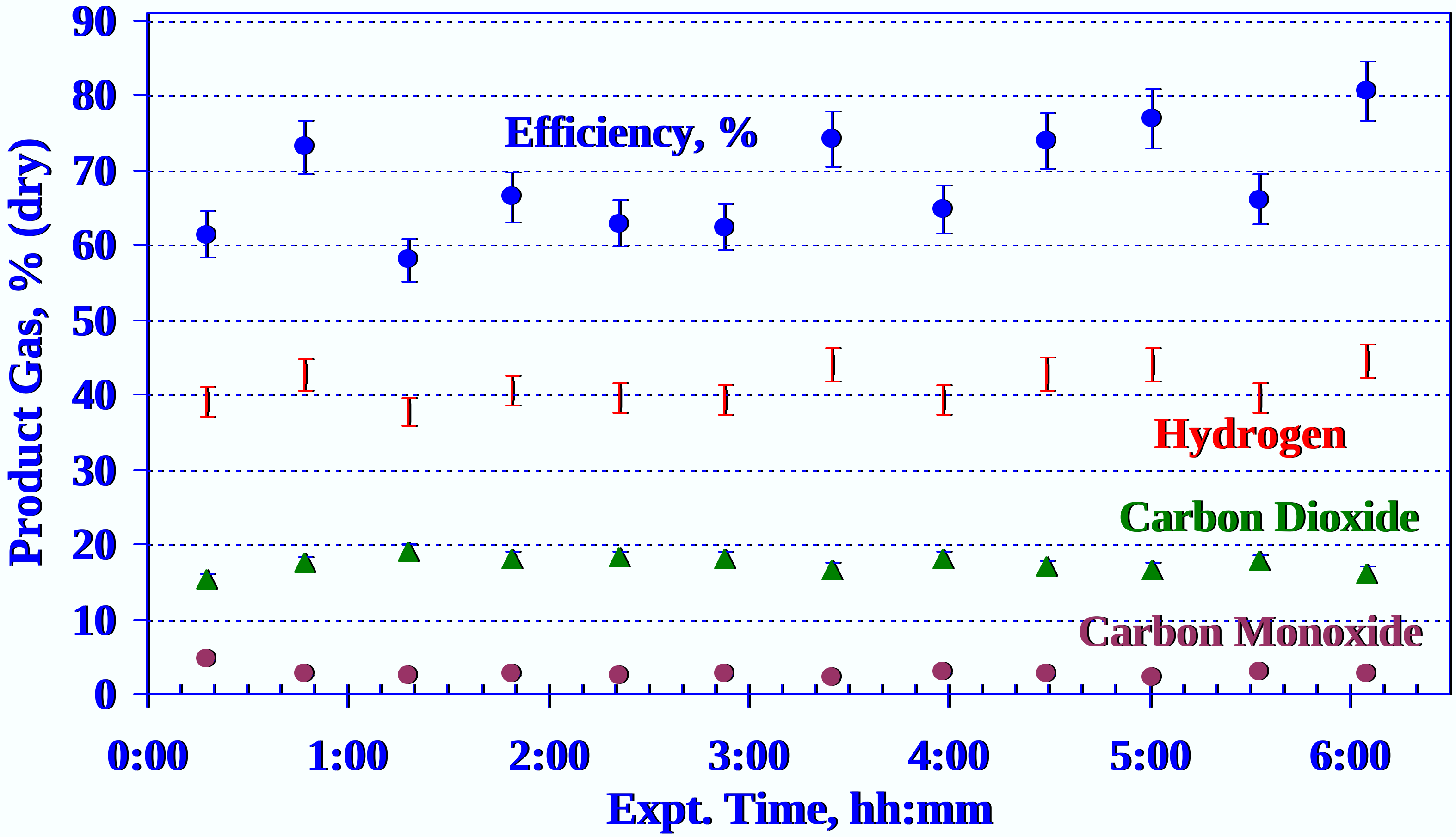
- Mn-based formulation was not stable
- Methanation activity observed at higher temperatures

The engineering unit is used to verify integration concepts, catalyst performance

- Includes:
  - fuel vaporizer
  - steam generator
  - air preheater
  - autothermal reformer
  - sulfur trap
  - shift reactor
- Capacity - 10 kWe
- Fuel: gasoline, alcohol
- 7-in. dia; 12-in long, 7-Liter



The processor achieved 88% of theoretical efficiencies, with 42% hydrogen



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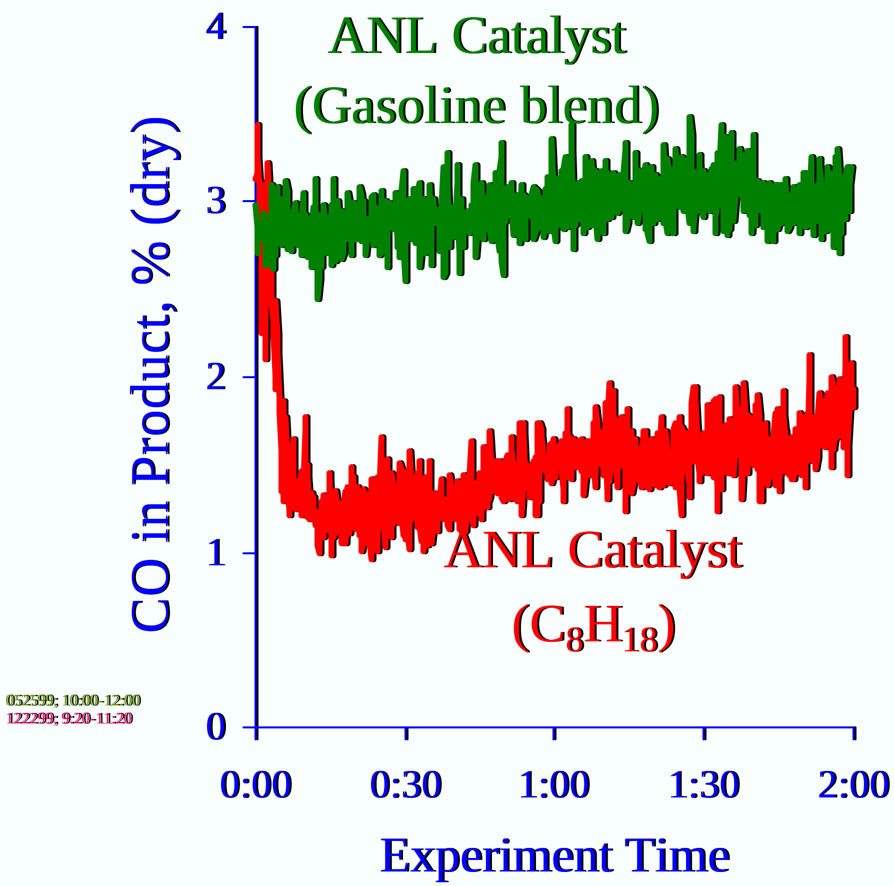
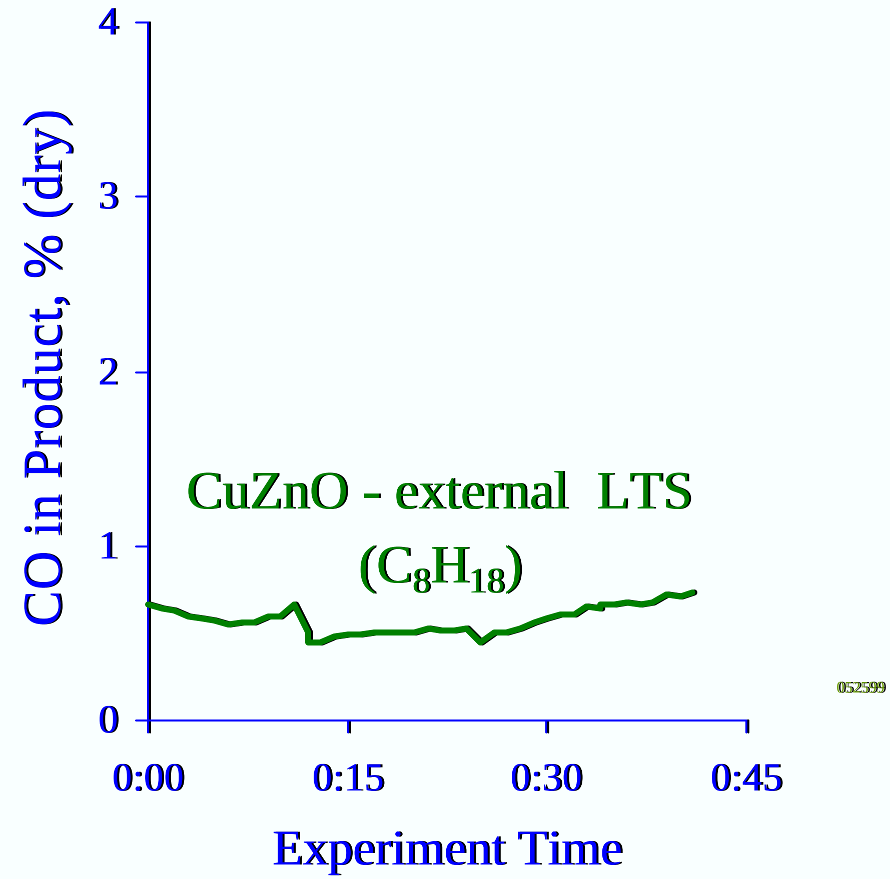
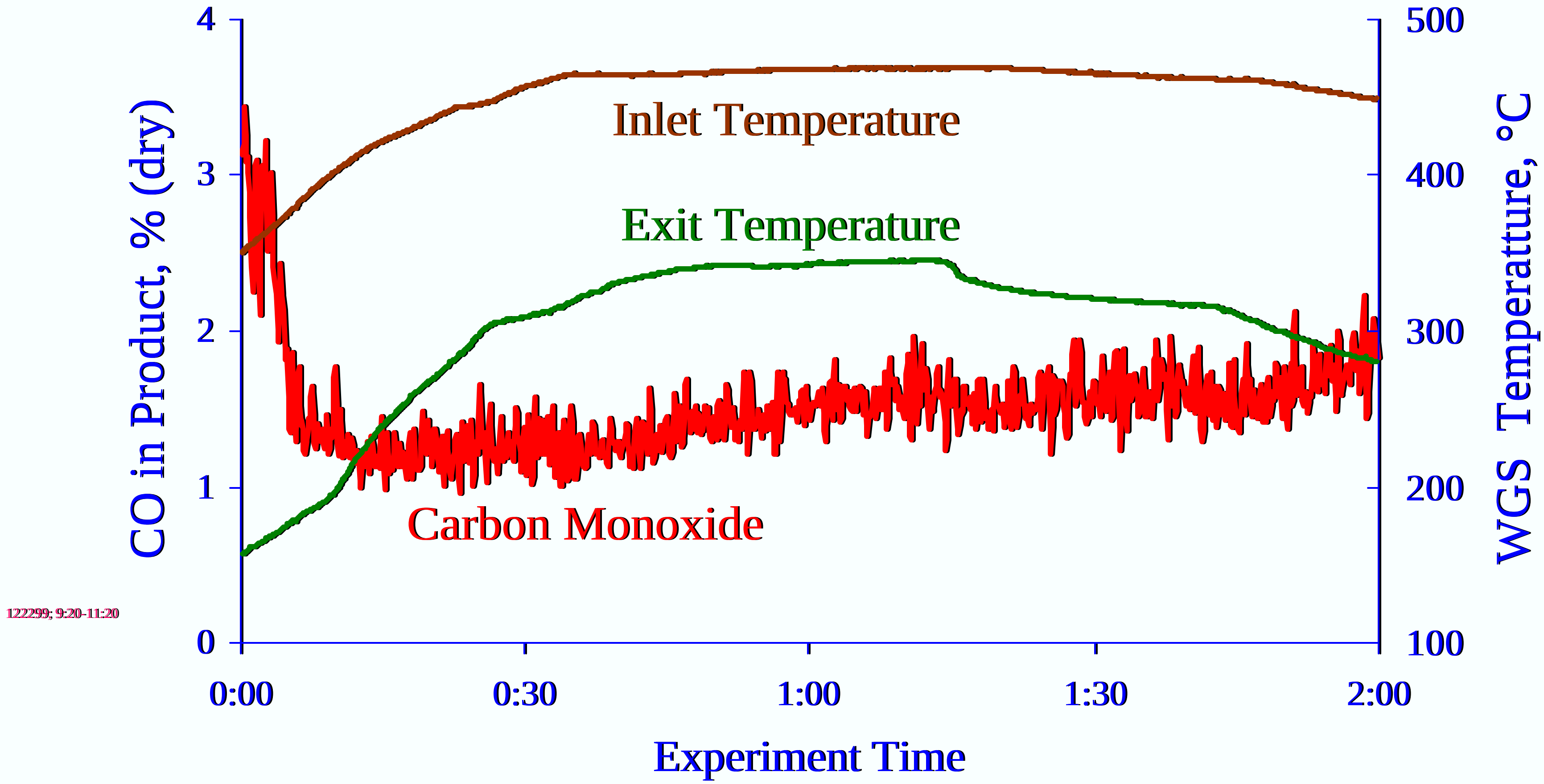
Less than 1% CO was achieved, but difficult to maintain





CO concentration is strongly dependent on WGS temperature



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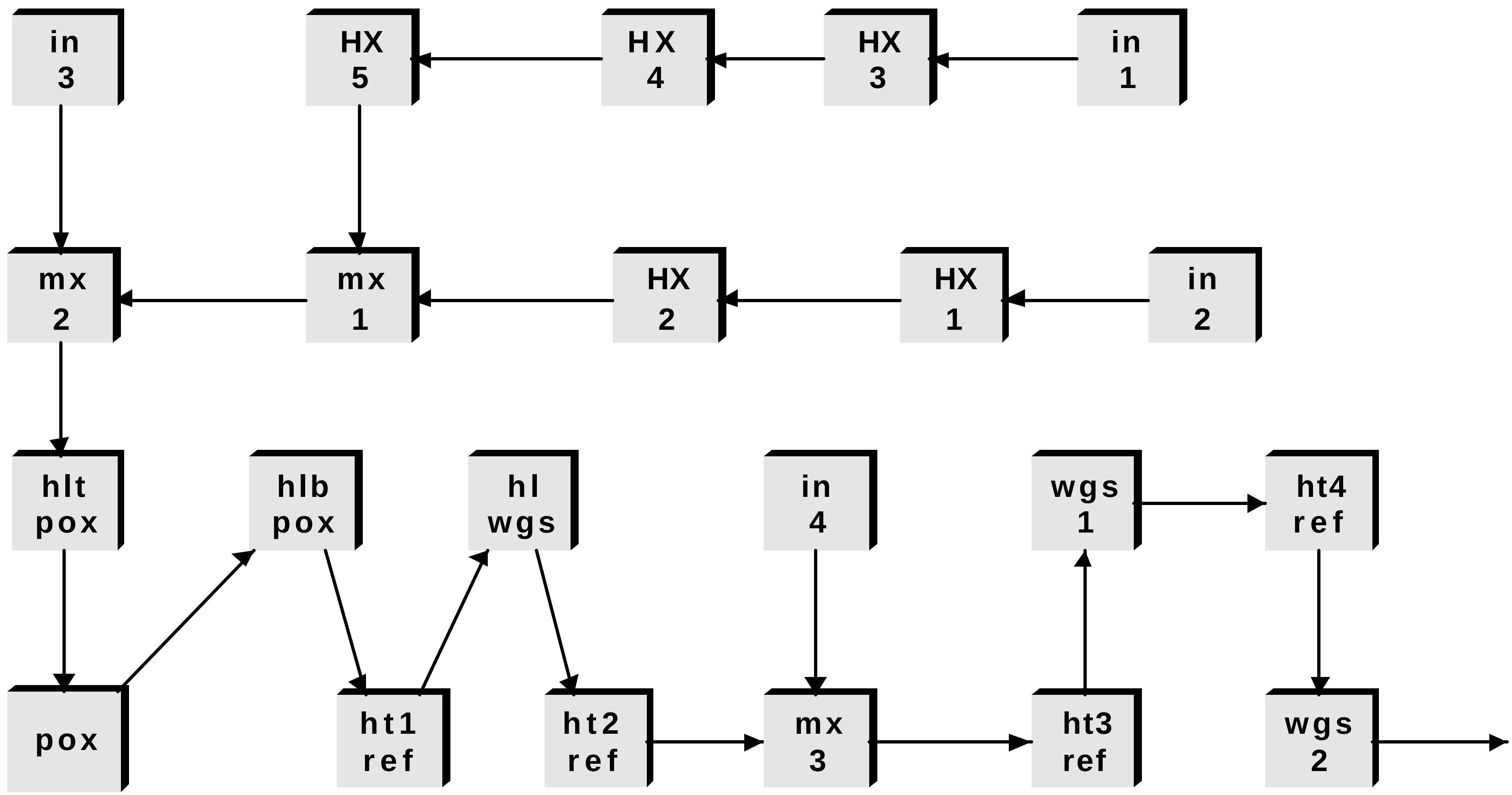
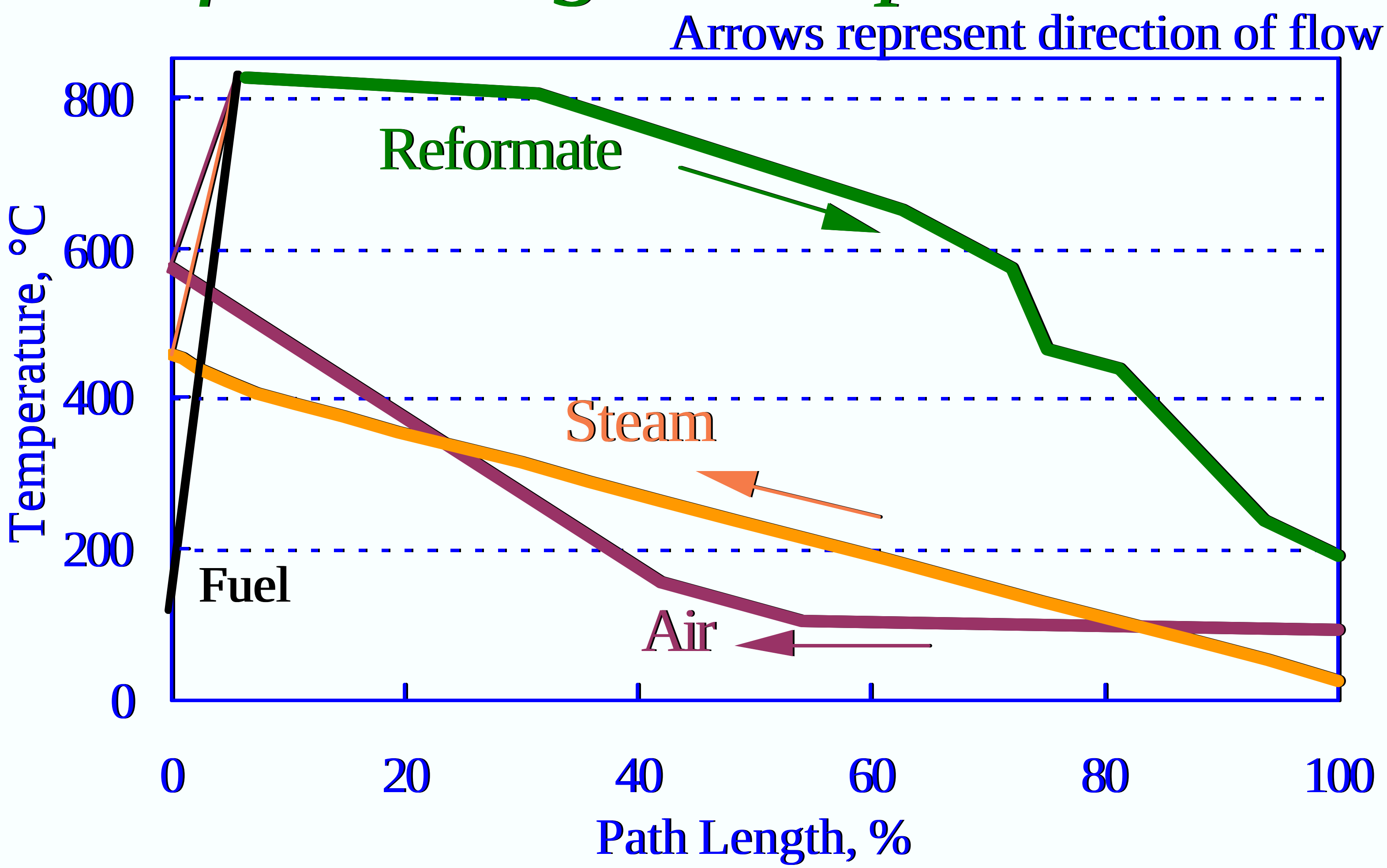
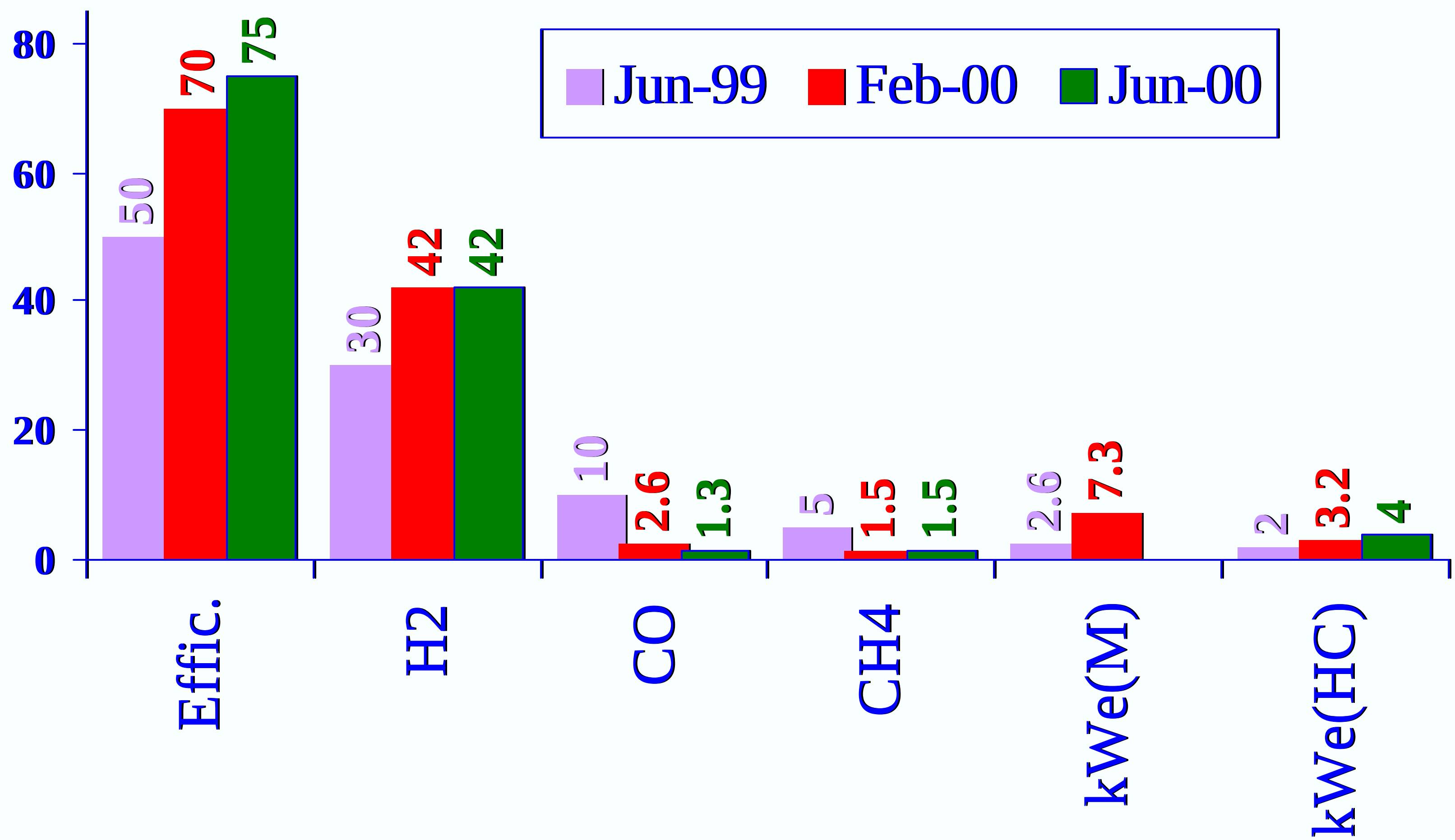
Effectiveness of reactor designs are determined with GCTool models



Reactant streams are used to control reformate gas temperature



Addressing fundamentals of integration has led to significant performance gains



Technology Transfer, External Interactions

- Autothermal reforming catalyst technology licensed to United Catalysts
- ANL will help a major system developer with fuel processor technology
  - for an automotive fuel cell system
- ANL will design a fuel processor for a start-up company (Unitel Technologies)
- Collaborating with LANL to integrate PrOx into ANL's integrated design

Future Plans

* Determine effect of operating conditions on size and performance on all processing steps
* Investigate engineering designs that reduce rapid start-up time
* Integrate PrOx with LANL collaboration
* Transfer technology to private enterprise

What have we learned?

- ANL shift catalyst performance was verified in the process train and the integrated unit
  - low temperature activity needs to be improved
- Next to catalyst activity, temperature control is the most important for the shift reactor
  - idealized temperature profiles can be calculated
  - integrated reactors can provide declining temperature profile (discretization possible)

We have verified catalyst performance, and learned integration opportunities through modeling and hardware testing

- Non-noble metal PrOx catalysts are feasible
  - need increased activity, durability
- Low temperature PrOx catalysts are more selective (for CO), prone to methanation
- Fuel processor efficiencies can approach theoretical limits with proper integration