

Microchannel Reactors for Automotive Fuel Processors

Sean Fitzgerald, Anna Lee Tonkovich, Dave VanderWiel,
Jennifer Zilka, Yong Wang, Michael Lamont, Robert Wegeng

Pacific Northwest National Laboratory
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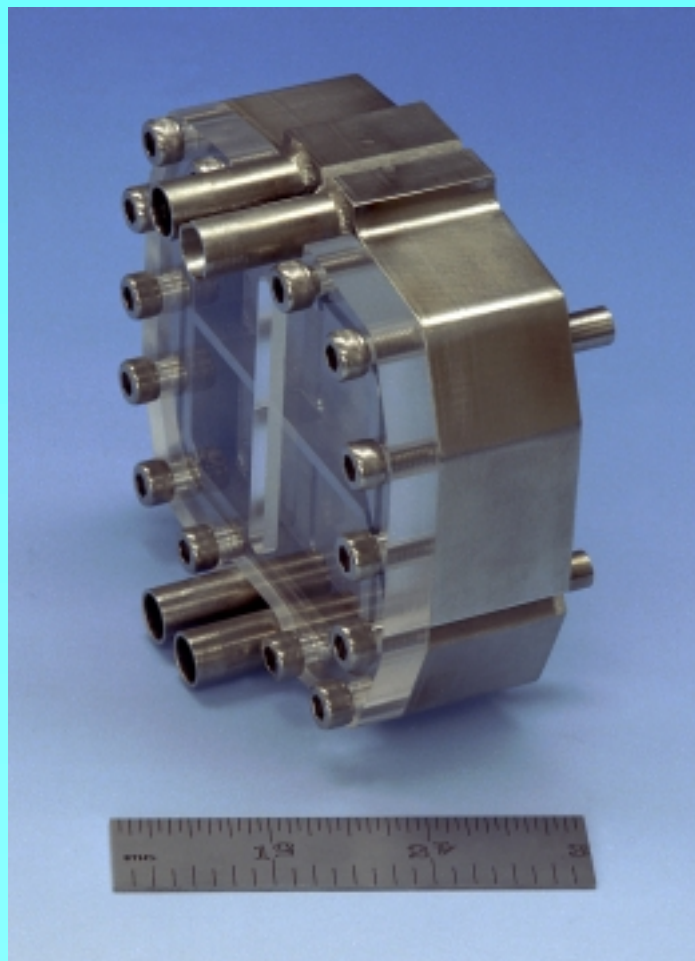
Richland, WA 99352, U.S.A.

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Presentation Synopsis

- Compact Fuel Processor
 - Gasoline Vaporizer
 - Water Gas Shift Reaction
- Compact Processes require microtechnology
- Process Commercialization

Compact Fuel Processor: Gasoline vaporizer



- Size: 8 cm by 10 cm by 4 cm
- Capacity: Vaporized gasoline for 50-kW_e fuel processing system (~ 300 mL/min)
- Implications: Complete fuel processor system = 8 Liters

Patent pending

Compact processes need microtechnology

■ Parallel processing of matter

- Reduce *heat transfer* resistance
- Reduce *mass transfer* resistance

■ Component efficiency

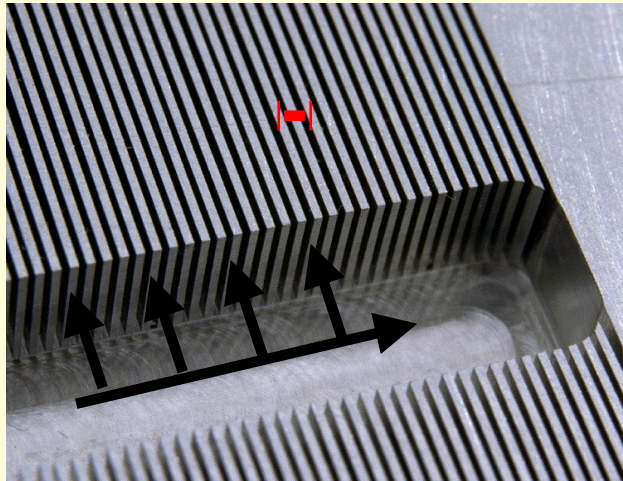
- Microtechnology ~ *90% or better*
- Conventional technology < *microtechnology*

■ Fuel Processor size (50 kW_e)

- Microchannel reactor ~ *8 Liters*
- Conventional ~ *10x to 100x larger*

Compact Processes: Highly effective Heat Transfer

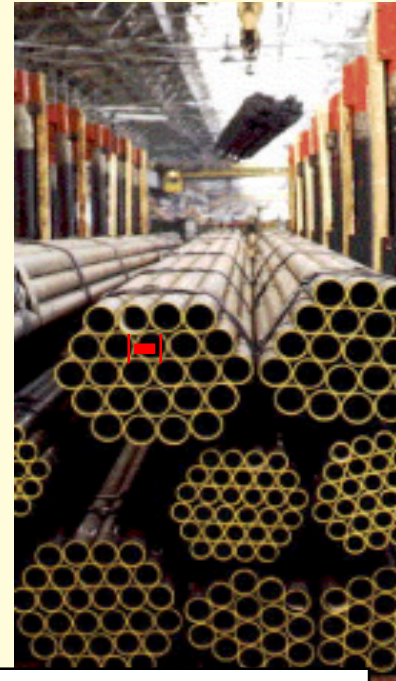
- Reduce heat transfer resistance using microchannels



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~ 0.05-0.1 cm

Vs.



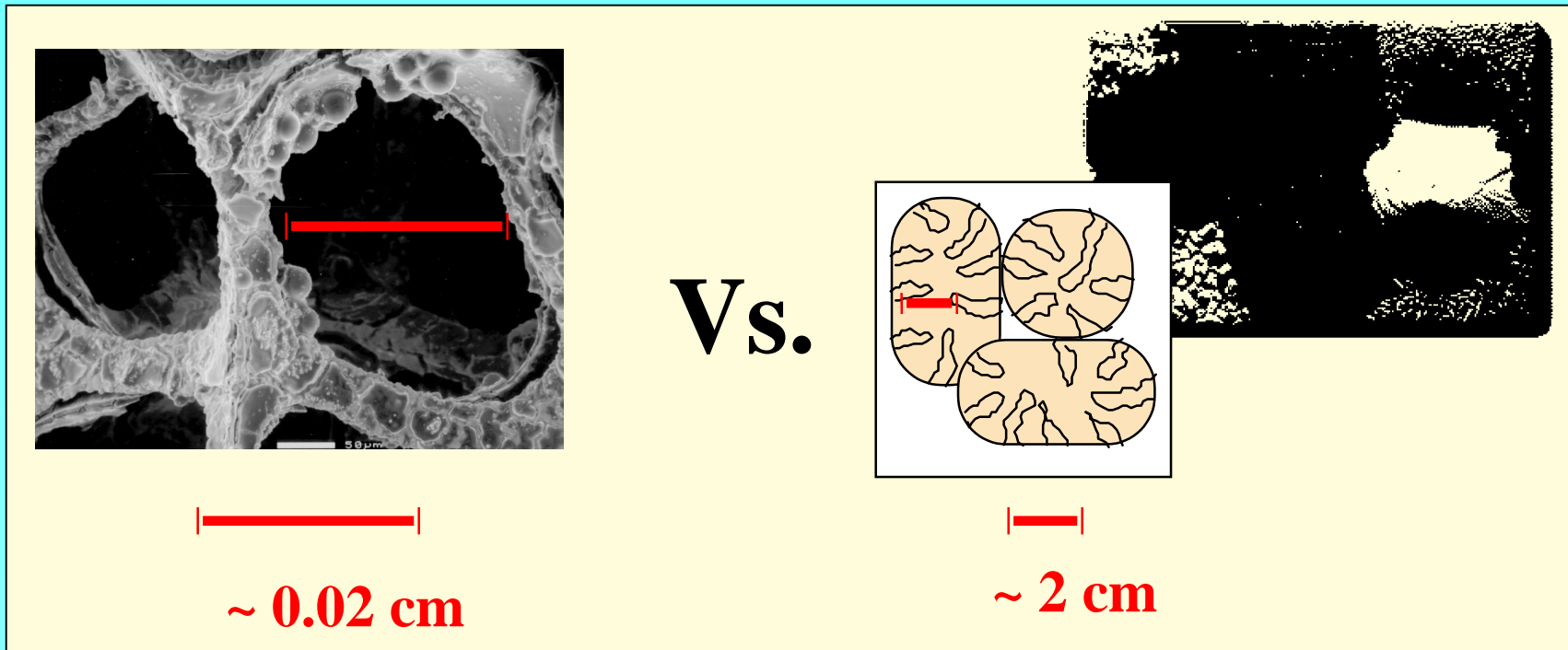
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~ 5-10 cm

- Reduce transport distance
- High surface area to volume ratio
- Low pressure drop through channels

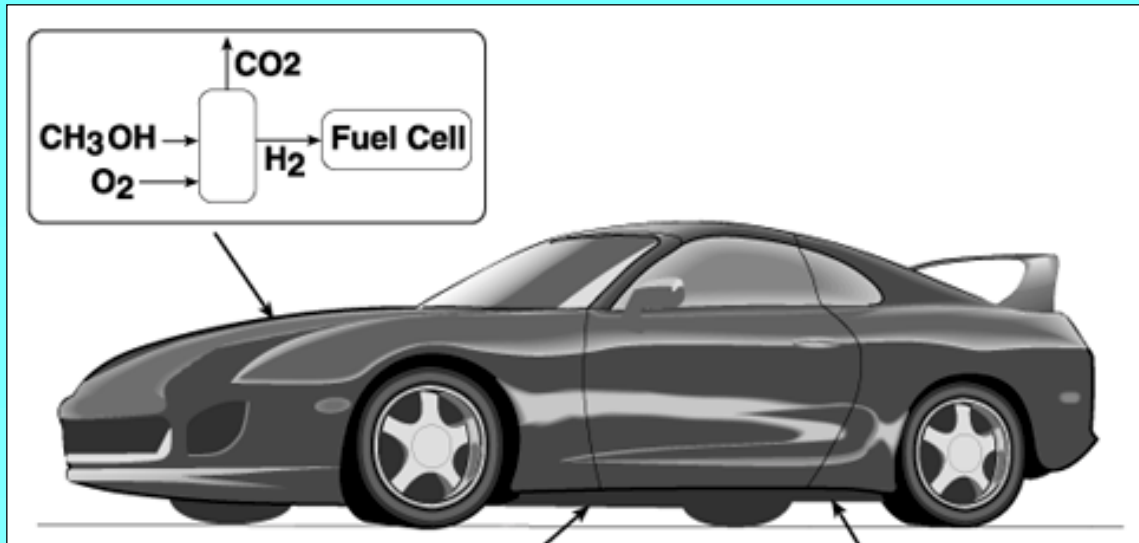
Compact Processes: Highly effective Mass Transfer

- Reduce mass transfer resistance with novel catalysts



- Reduce transport distances
- High effectiveness factor

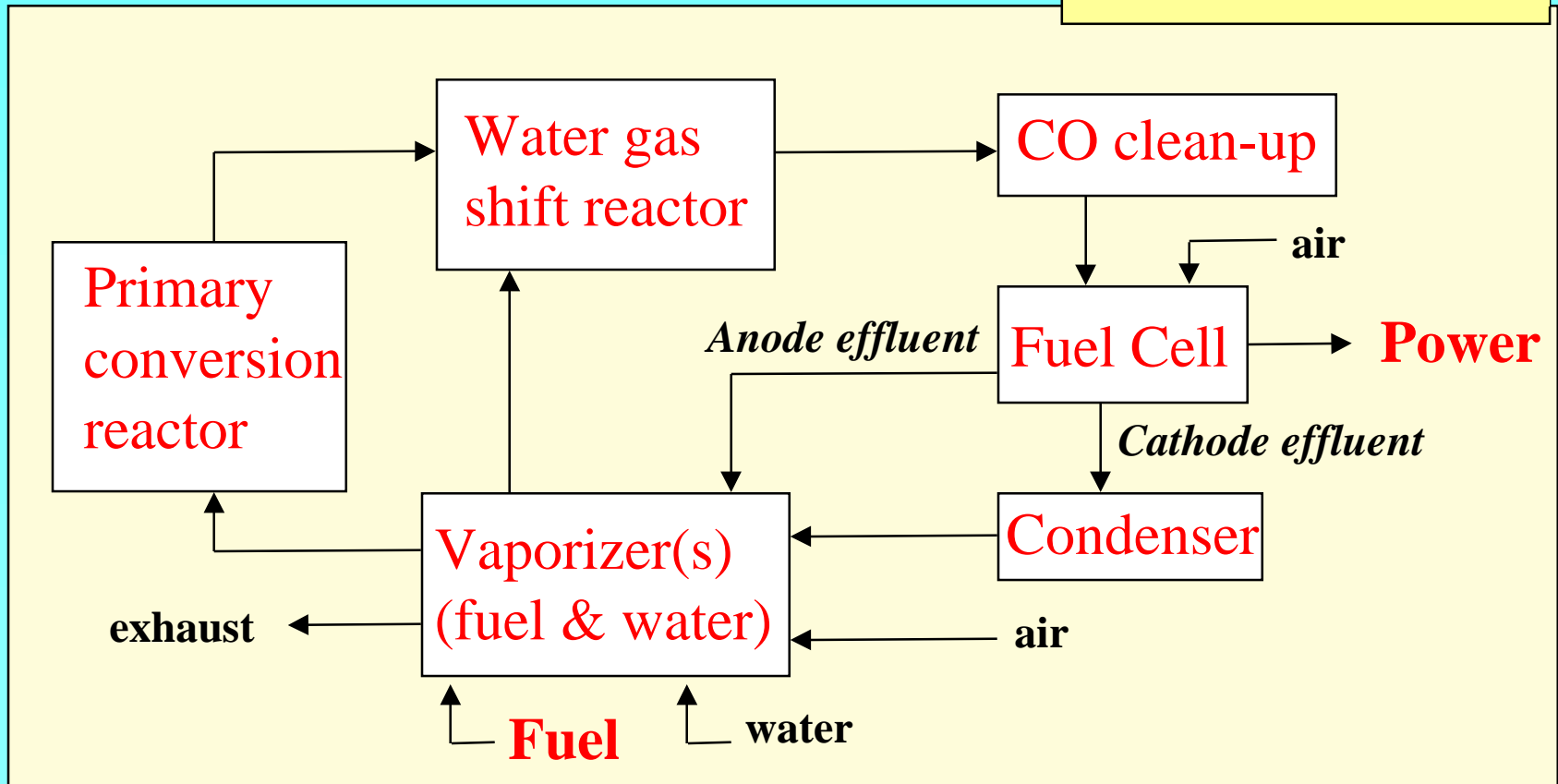
Compact fuel processor: Automotive power



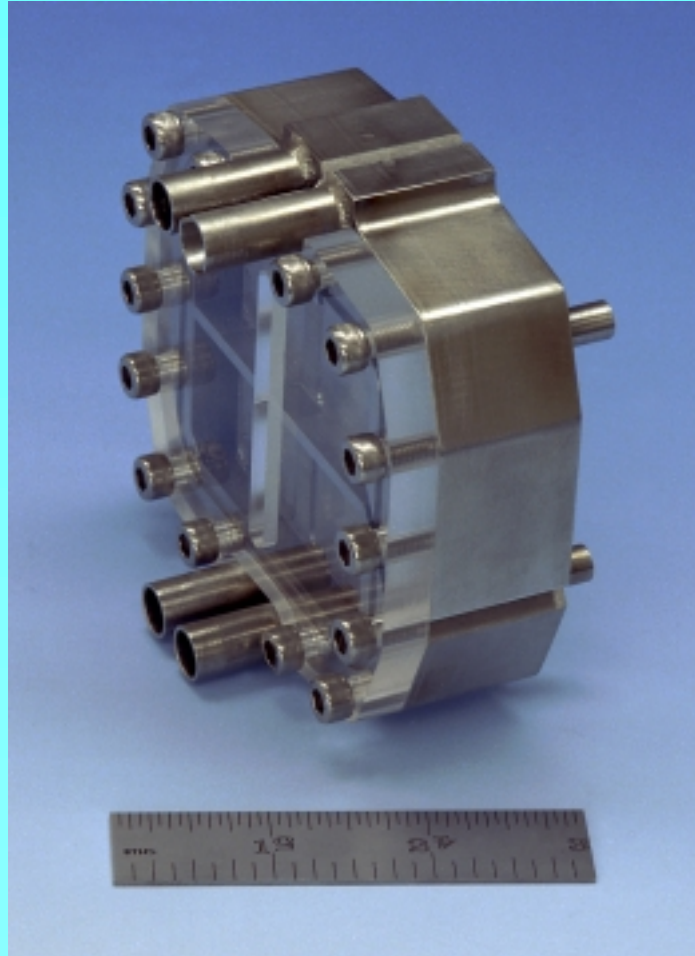
- **Efficiency**: 50% vs. 20% for IC engine
- **Issues**: Size and cost
- **Impact**: 58% reduction in CO_2 per mile traveled

Components: Compact 50kW_e fuel processor

Microtechnology:
~ 8 liters
Current technology:
> 300 liters

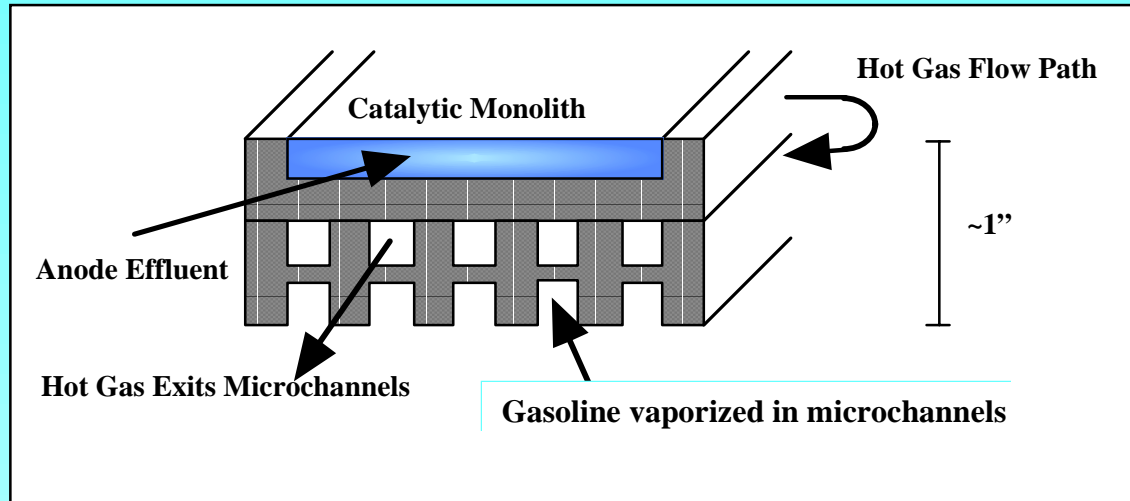


Microchannel Gasoline Vaporizer: Compact 50-kW_e Fuel Processor

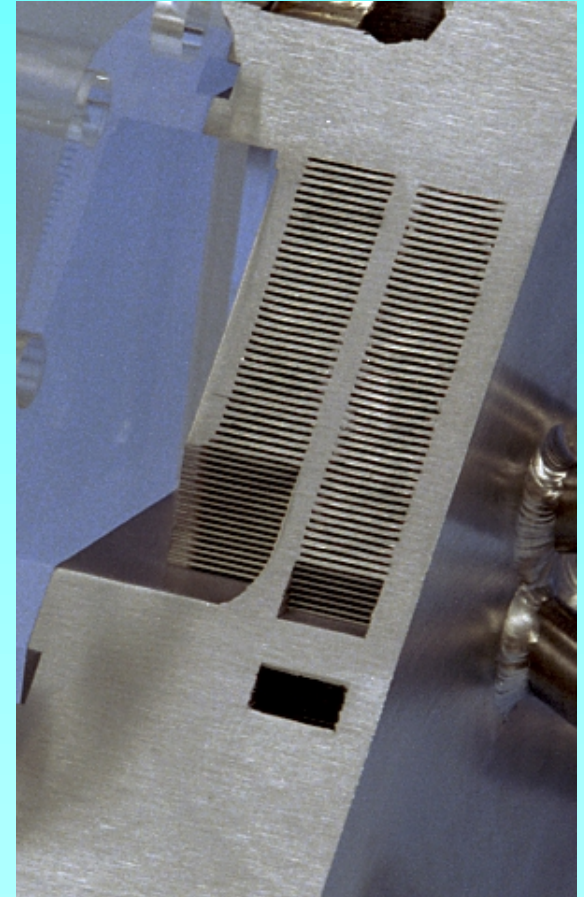


- Attributes: Four parallel cells
- Size: 8 cm by 10 cm by 4 cm
- Capacity: Gasoline (~ 300 mL/min)
- Implications: Complete fuel processor system = 8 Liters
- Fabrication: Laminate process
- Pressure drop: $\Delta P < 2\text{psi}$ (through microchannels at ~ 1400 SLPM)

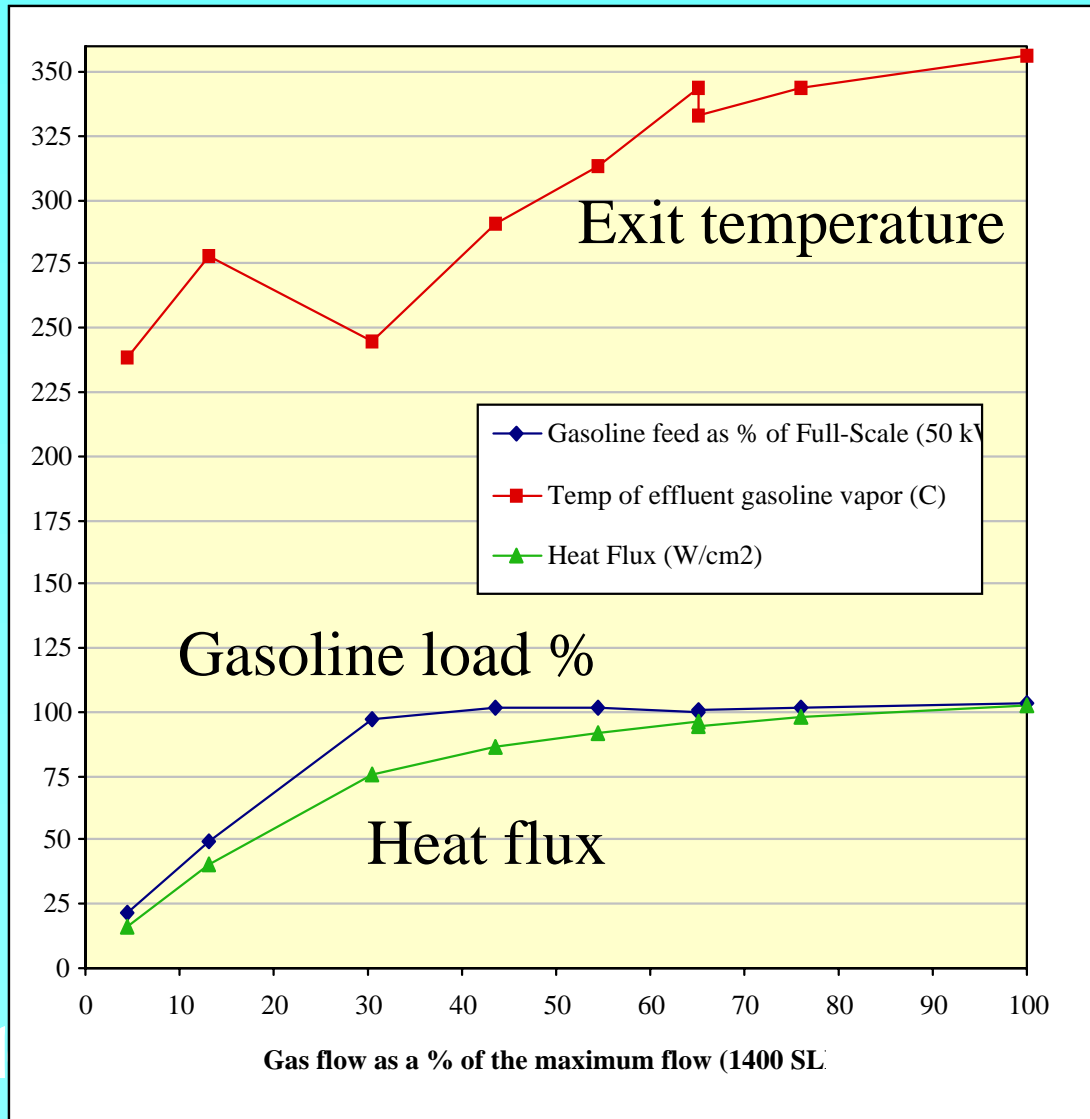
Microchannel Gasoline Vaporizer



Microchannel Vaporizer



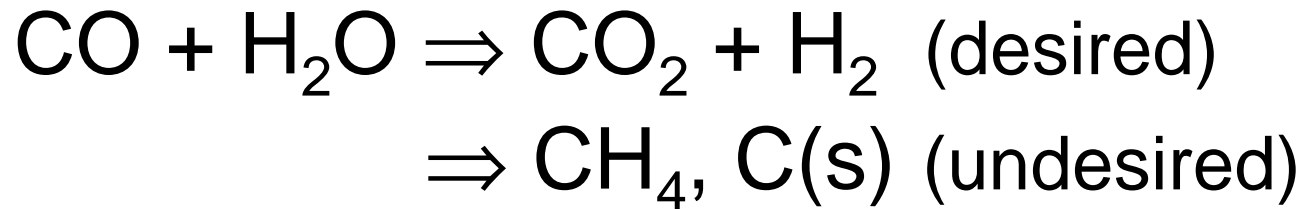
Compact Gasoline Vaporizer: Full-scale Performance



**Gasoline vaporized:
~ 300 mL/min**

**Feed gas (anode
effluent + air:
~ 1400 SLPM**

Automotive fuel processor: Compact water gas shift reactor



Conventional technology:

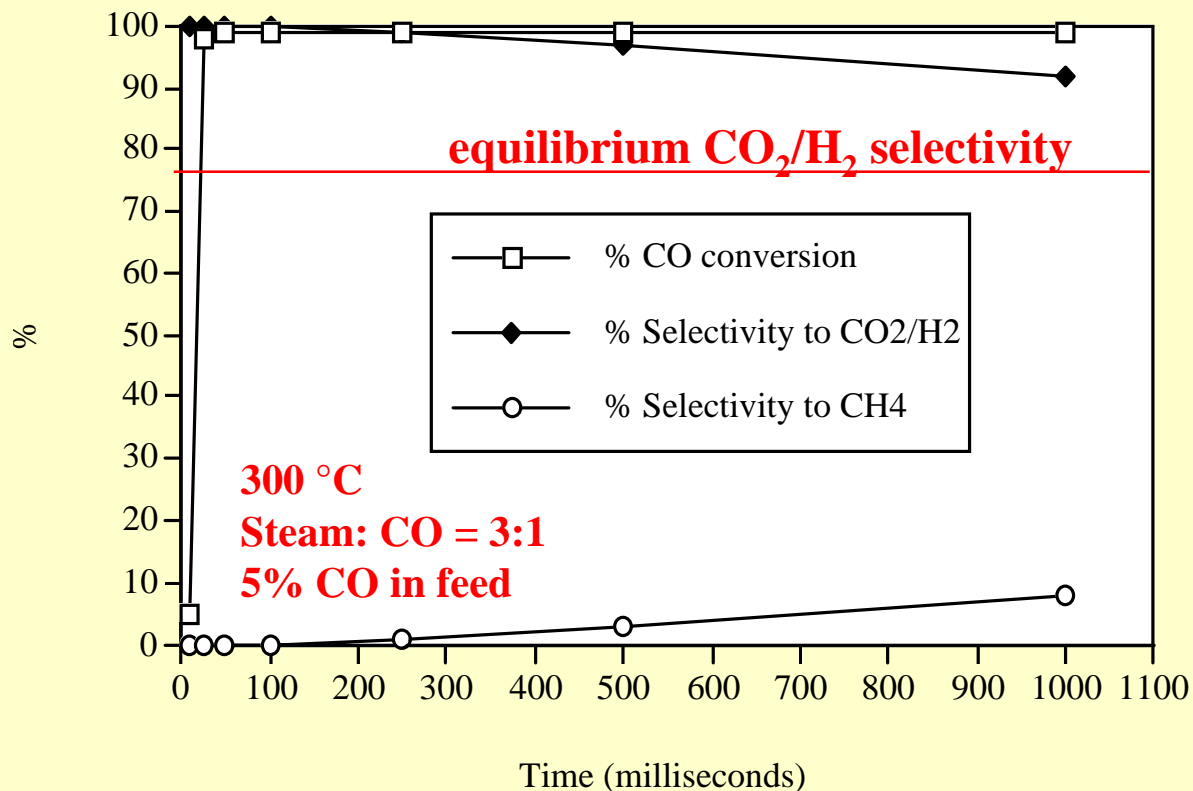
- $\tau = 1 \text{ sec}$
- 300 - 500 C

Compact microtechnology:

Patent pending

- $\tau = 25 \text{ msec}$
- 300 - 500 C

Compact Water Gas Shift Reaction Performance data

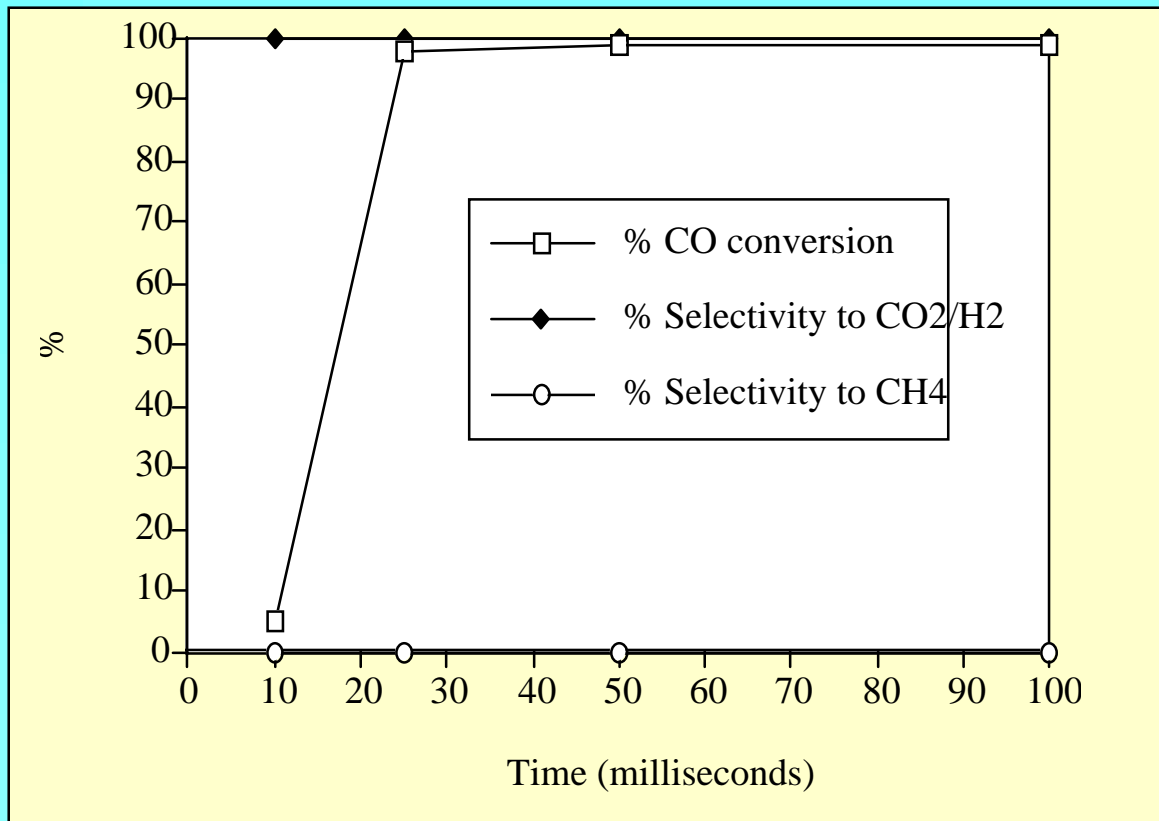


**Fast kinetics
required for
compact process**

**Non-equilibrium
products favored at
short contact times**

Compact Water Gas Shift Reaction Performance data

At 25 ms, Conversion > 99%, Selectivity ~ 100%



Compact 50-kW_e Fuel Processor

■ Components

- Vaporizer
- Primary Conversion
- WGS
- CO Cleanup

■ System

- Total ~ 8 L
- Less than 3 laptops

■ Power density

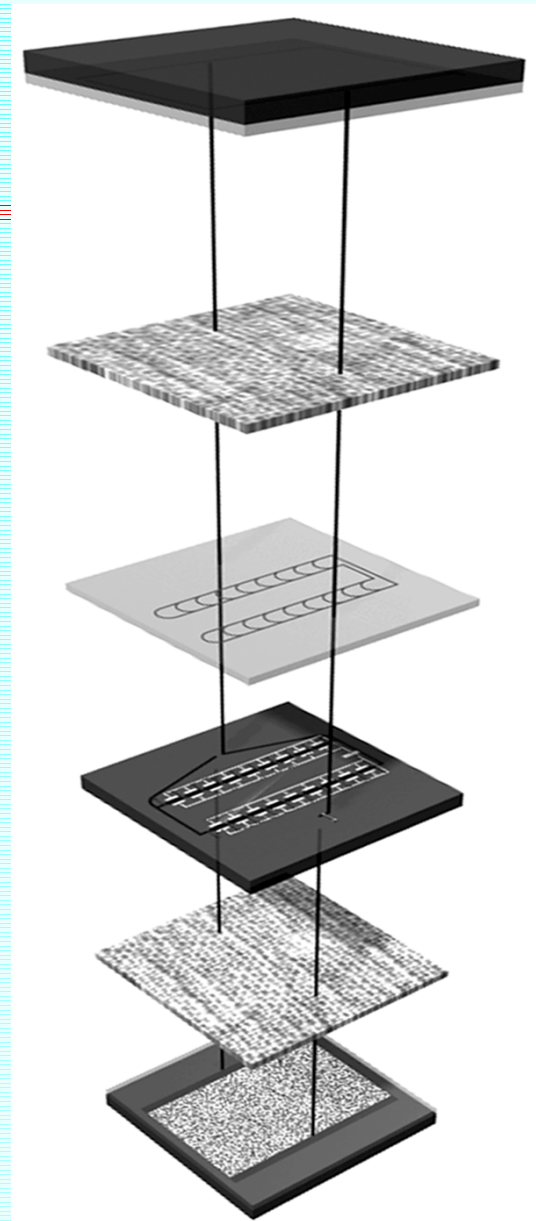
- U.S. target: 0.5 kW_e/L
- PNNL expectation: 6.5 kW_e/L



Commercializing compact processes

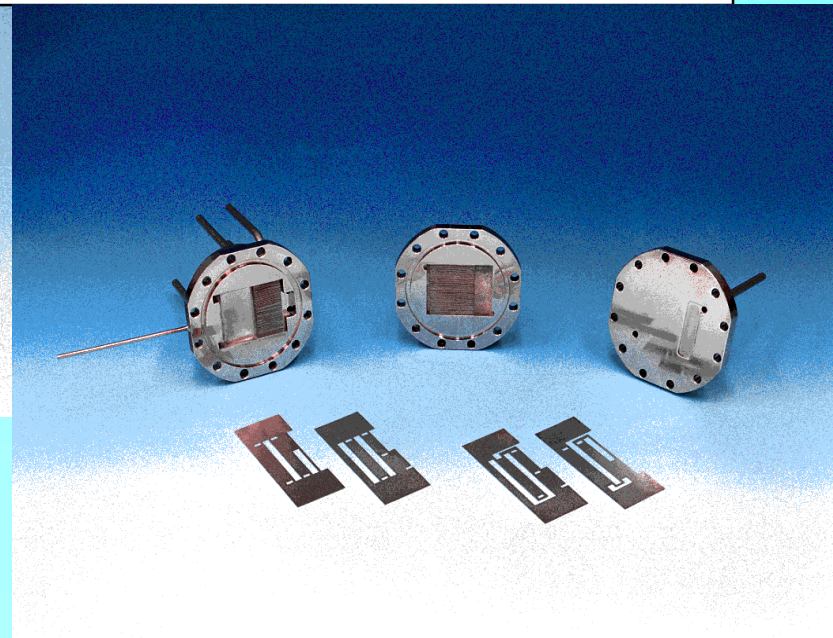
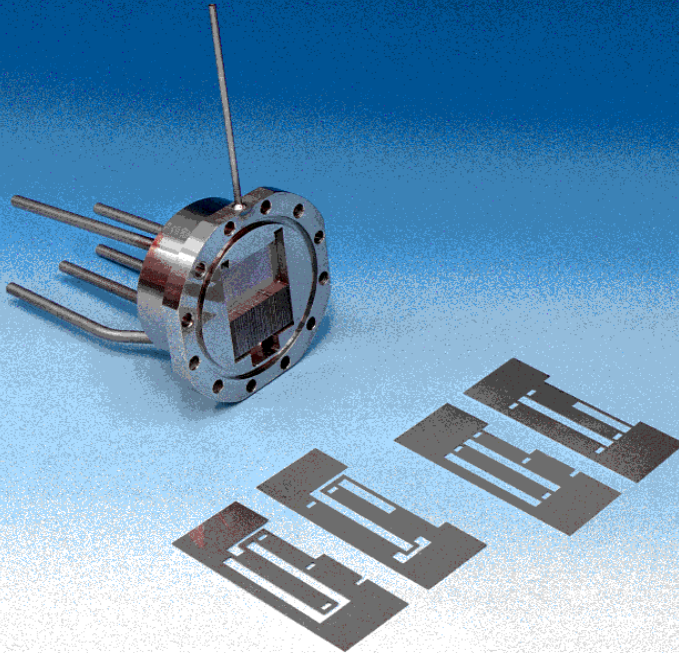
Laminate Sheet Architecture

- Multiple **microcomponents** per sheet enables scale-up
- Each sheet performs one or more unit operations
- U.S. # 5,611,214 (issued 3/18/97)
- U.S.# 5,811,062 (issued 6/11/98)
- Others pending (U.S. and foreign)



Commercializing compact processes: Laminate fabrication

Economy of
mass production,
not economy of scale



Battelle:

Leading the way in compact process development

- Demonstrated compact microreactors
- Developing other applications
- Building a portfolio of intellectual property
 - Enabling sheet architecture
 - Catalysts
 - Components & systems
 - Low cost manufacturing methods
- Interested in deploying technology with commercialization partners