Fuel Cell Reformer Emissions

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DOE Hydrogen, Fuel Cells and Infrastructure Technologies Annual Review Presentation

Philadelphia Marriot
Philadelphia, Pennsylvania
May 24-27, 2004

This presentation does not contain any proprietary or confidential information

The purpose of this study is to determine the emissions from fuel cell vehicles with on-board reformers

- Fuel cell vehicles must meet the most stringent emission standards in order to provide value to the greatest number of stakeholders
- Quantifying emissions from reformer systems needs to take into account very low detection limits in order to verify emission benefits
- Data from fuel processor systems is used to evaluate potential emissions from vehicles with on-board fuel processors

Budget

- Total funding for the project = $584,400
  - DOE = $468,300
  - TIAX = $117,100
- FY04 funding = $120,000

This project addresses the following technical barriers from the HFCIT Program Multi-Year R,D&D Plan:

- Fuel Cells: Fuel-Flexible Fuel Processor
  - K. Emissions and Environmental Issues

Data on the effects of fuel/fuel blend properties on the potential formation of toxic emissions are limited. Fuel processor and stack emissions (including evaporative emissions) are not adequately characterized. Standardized emission test procedures are lacking. Start-up emissions are not well characterized.

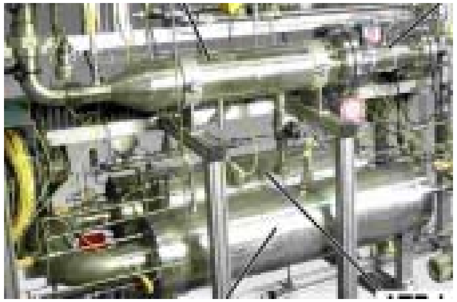
DOE Technical Targets: Integrated FC Fuel Processor System
Operating on Tier 2 Gasoline (30 ppm S)

Characteristics	Units	Calendar year		
		2003	2005	2010
Energy efficiencya @ 25% of rated power	%	34	40	45
Energy efficiency @ rated power	%	31	33	35
Transient response (time from 10 to 90% power)	sec	15	5	1
Emissions [a]	g/mi	< Tier 2 Bin 5, 0.07 NOx and 0.01 PM		

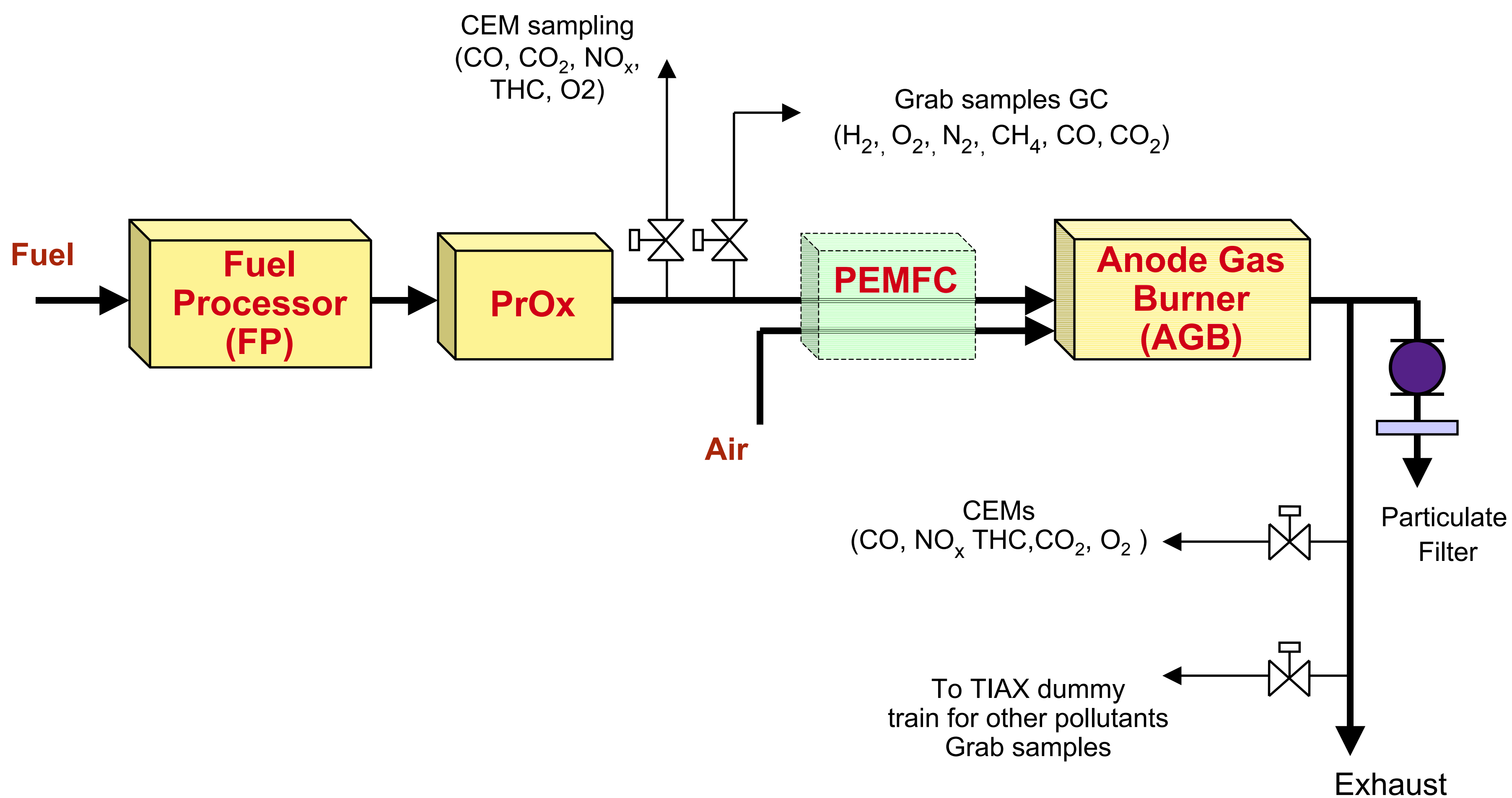
a Emissions levels will comply with emissions regulations projected to be in place when the technology is available for market introduction.

Four fuel processor systems will be tested.

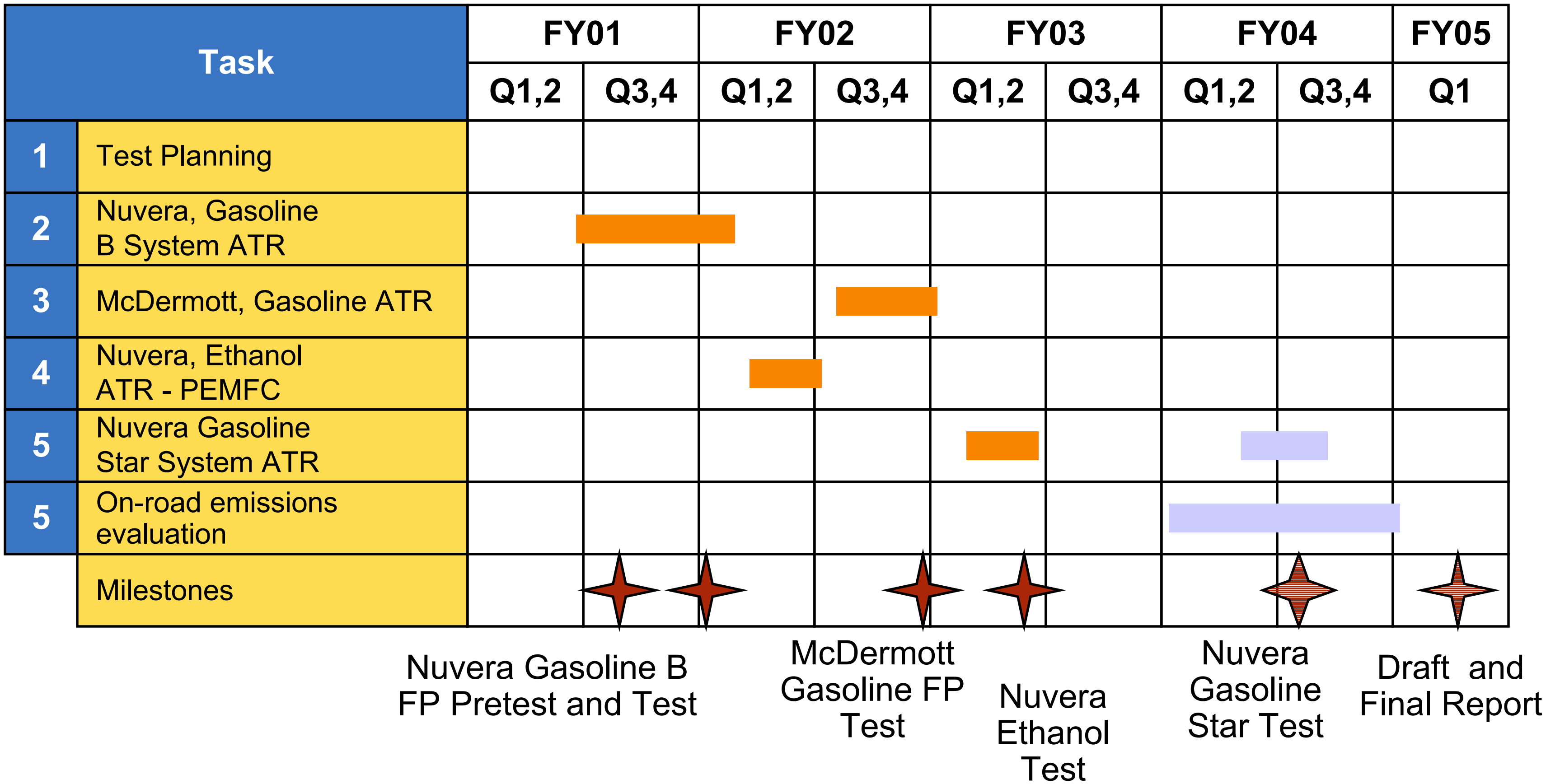
System	Date Tested	AGB Feed	Power Rating
Nuvera, Gasoline B System ATR	October 2000	Gasoline Start-up PrOx Reformate (100% output)	50 kWe
McDermott, Gasoline ATR	September 2002	Gasoline	50 kWe Tested @ 10kWe PrOx
Nuvera, Ethanol ATR - PEMFC	January 2003	Ethanol Start-up PEMFC Anode Gas	10 kWe
Nuvera Gasoline Star System ATR	June 2004	Gasoline Start-up PrOx Reformate	50 kWe



The Nuvera system was tested after the PrOx and after the AGB, without a fuel cell.



Prior to finalizing our analysis, we intend to obtain input from



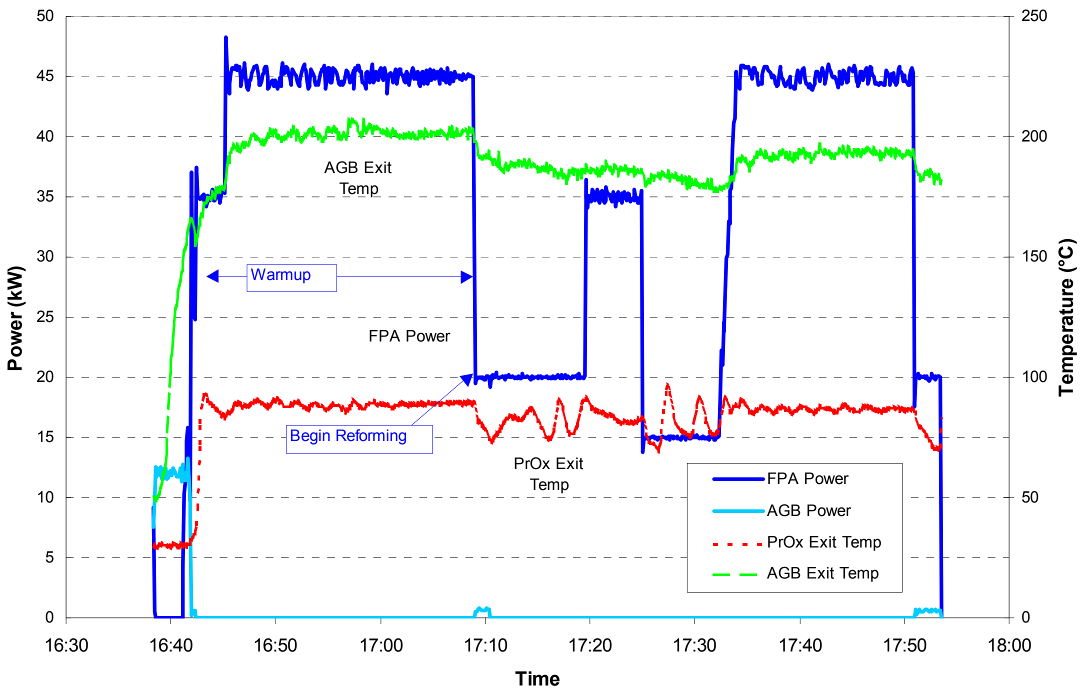
Safety

- Safety aspects of the work are covered under the safety plans for the fuel processor developers. All testing is done at their sites.

Test cycles attempted to cover operating range

Test Cycle

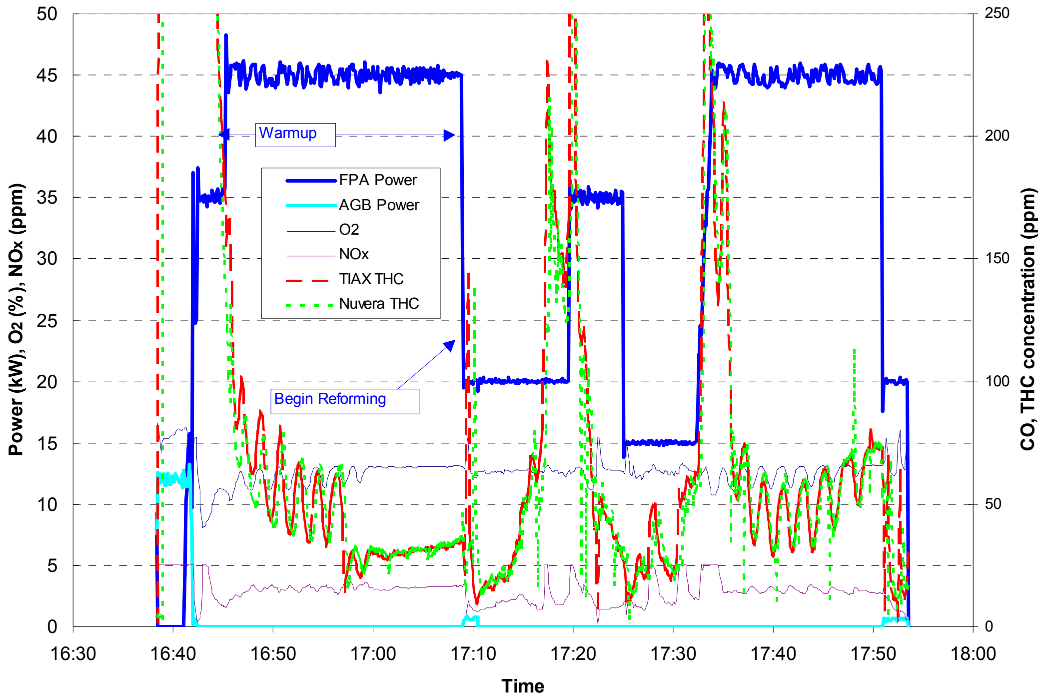
- Fuel processors were unable to simulate vehicle driving cycle
- Test start up and steady state conditions
- Collect grab samples to evaluate non methane fraction of hydrocarbons



Accomplishments/Progress Emission Testing

AGB Emissions

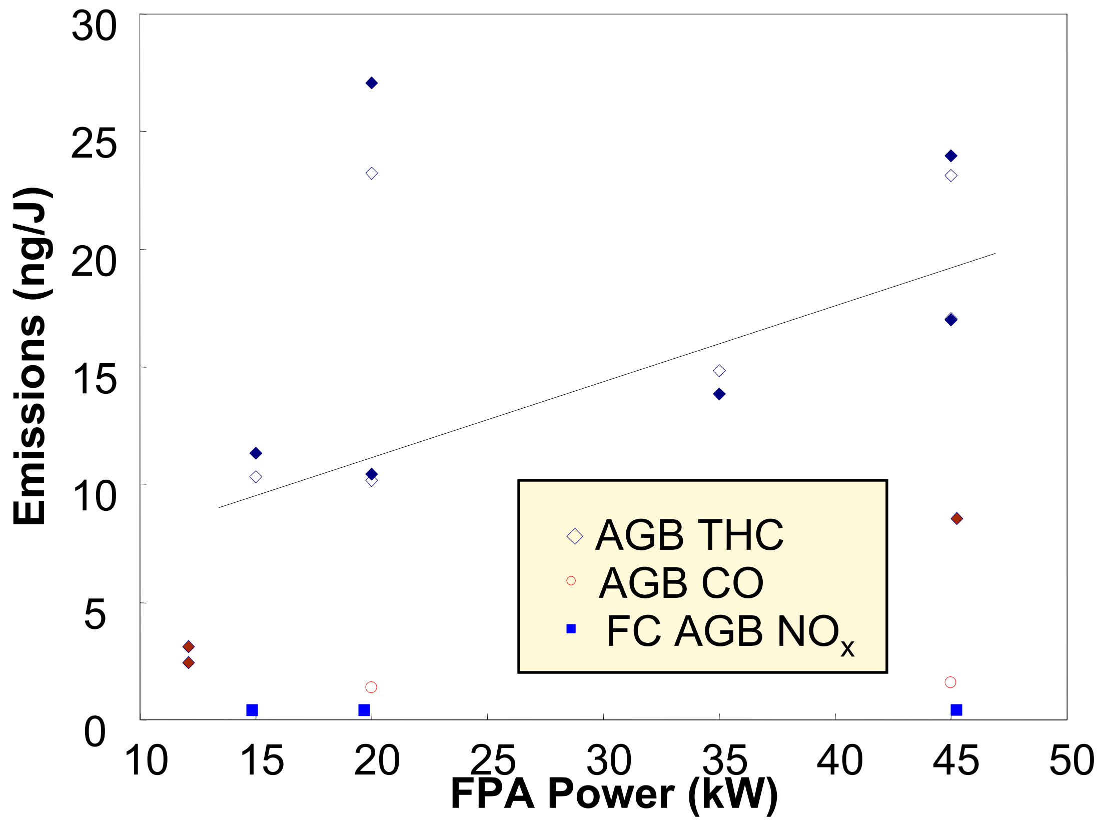
- THC and NOx emissions highest during start up
- Some NO_x still detected when burning PrOx product in air
- NO_x at or below DL for fuel cell anode gas in AGB.
- THC emissions ranged from 0.2 to 20 ppm when burning anode gas
- Attempted particulate sampling of AGB exhaust



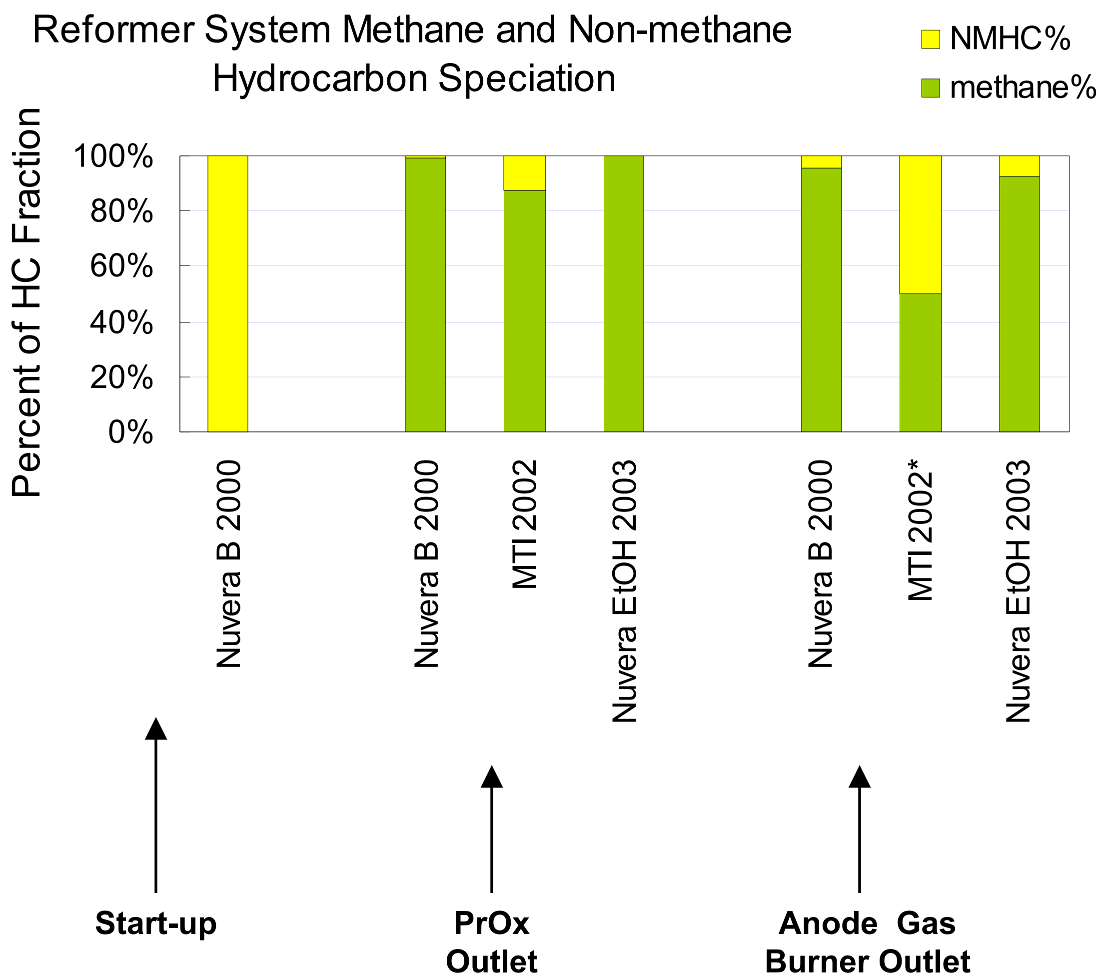
Accomplishments/Progress Emission Testing

Emission rates (ng/J)

- AGB NO_x emissions low & invariant with load, near zero for integrate FC system
- AGB CO emissions low & invariant with load, 1.5 ng/J
- AGB THC emissions vary with FCP system and load
  - Some systems less than 3 ng/J, others > 10 ng/J



Speciation of non-methane hydrocarbons for various operation modes are represented below



- Each of the testing programs is represented by an average speciated sample.
- MTI (2002) methane measurements had 1 ppm detection limit, so methane fraction of total hydrocarbons isn't known

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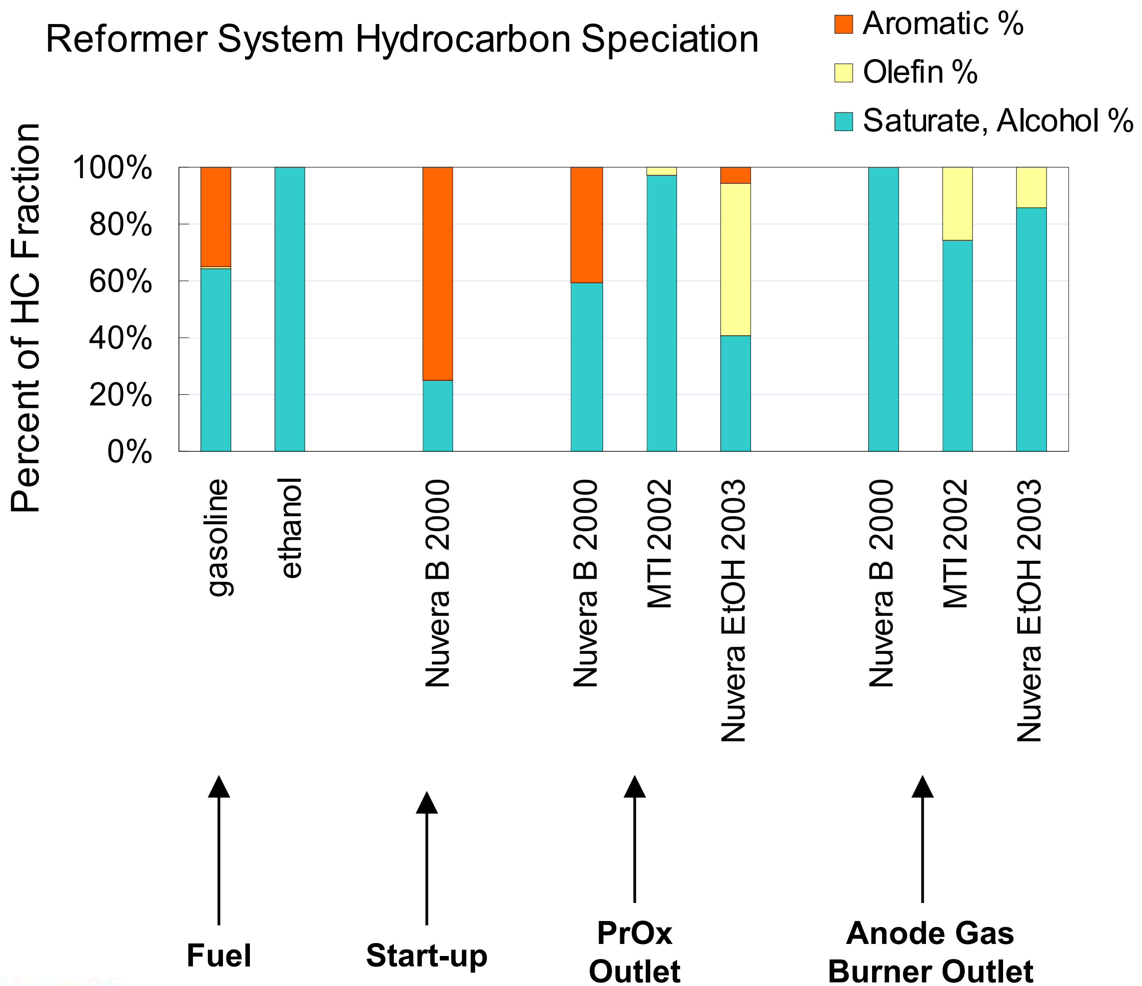


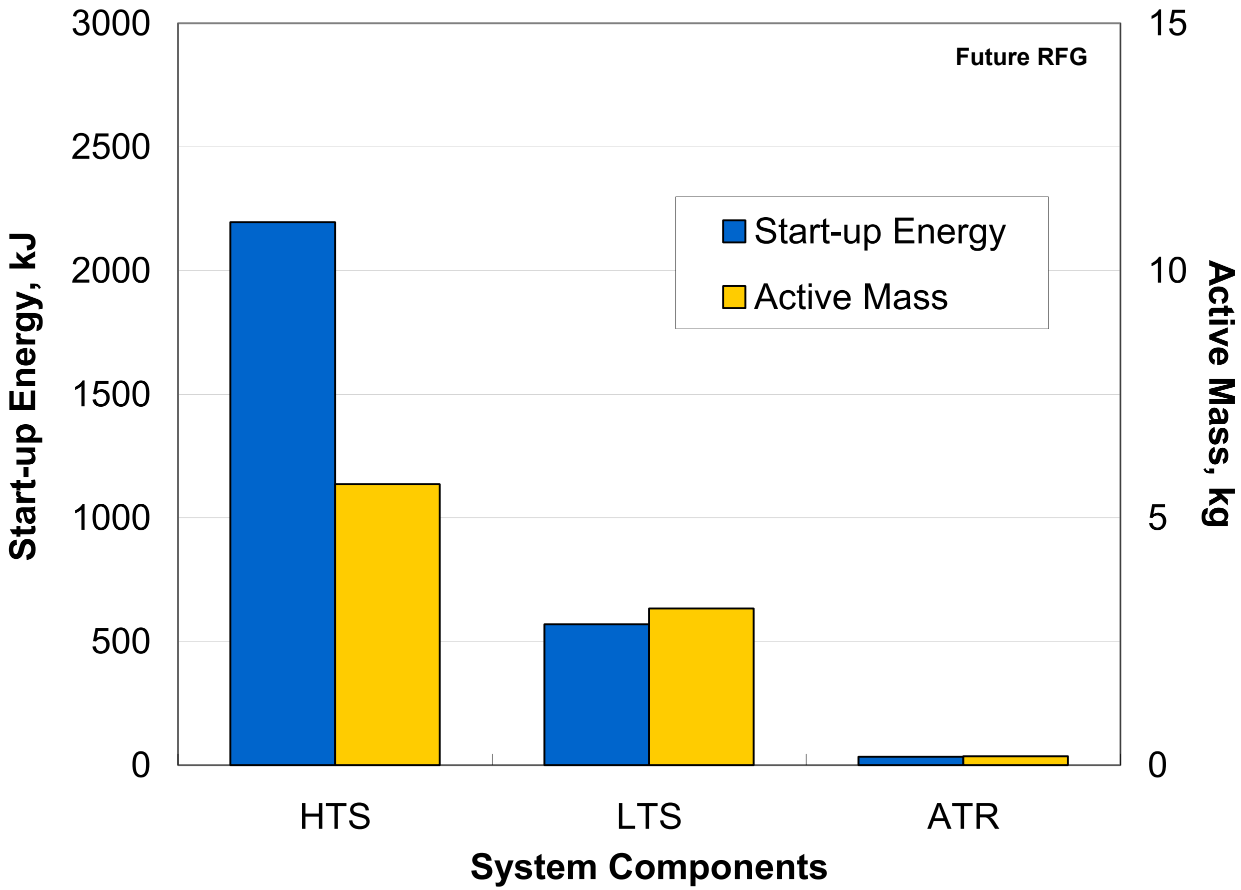
- Each of the testing programs is represented by an average speciated sample.
- Nuvera B (2000) and McDermott Technologies, Inc. (MTI2002) reformer systems were operated on gasoline
- Nuvera (2003) reformer-FC test was performed using ethanol

On-road emissions will be modeled based on driving cycle energy requirements and start up energy.

- NOx and CO should meet the lowest emission standards
- A key target should be the CA PZEV NMOG standard for NMOG of 0.01 g/mi and NOx standard of 0.02 g/mi
  - Depends on start up energy and start up emissions
  - Some emission control during reforming may also be required
- A quick emissions example
  - During reforming
  - 5 ng/J x 1,800,000 J/mi = 0.009 g/mi
  - During startup
  - 500 ng/J x 1,700,000J/25 mi = 0.03 g/mi
  - Total = 0.039 g/mi
- **Calculations are illustrative only**

The start-up energy requirement for system components decreases with active mass.

System component requirements for future 60 kW RFG FCVs



We have meet with technology developers and others outside of DOE to present our results/perspectives and solicit feedback on our progress.

Opportunity
Propose teaming with SOFC and stationary SMR developers
Initiated discussions with NREL to provide emissions data for ADVISOR runs
Present potential emission impacts from fuel cell vehicles - IEA Annex XV Nov 02, Nov 03 - CA AB 2076 Petroleum Dependency June 03

Reviewer Comments

- Incorporate particulate matter measurements
  - PM measurements have been attempted in prior tests
  - Final test series will use a new PM test method
- Try to understand NO_x >0
  - NO_x > 0 was measured when the AGB was not operating on hydrogen depleted gas. Exhaust temperatures were higher than those for an integrated fuel cell system
  - The final report will clarify operating conditions that do not reflect real integrated fuel cell systems.
- Delineate start-up emissions during burner light-off
  - THC concentrations vary from 1000 ppm during start up to 10,000 ppm from PROX product to < 100 ppm after AGB
  - A combination of grab samples and dual monitors has been used to observe range in emissions. However, matching emission ranges with gas concentrations has been challenging.

If development goals are met, next generation fuel processor/fuel cell systems should be tested. Emissions from APUs and stationary hydrogen systems should also be characterized.

Future Work	Challenges
Model on-road emissions from fuel cell vehicles	• Limited test data from a fully integrated reformer/fuel cell system
Characterize N_2O and other pollutant emissions	• Low detection levels and background emissions
Measure emissions from next generation fuel cell/fuel processor systems	• Limited availability of developed systems
Measure emissions from promising technologies	• Find developers interested in quantifying both start up and continuous emissions and assessing operational profiles