NREL
National Renewable Energy Laboratory

Hydrogen from Post-Consumer Residues

S. Czernik, R. French, R. Evans, E. Chornet

National Bioenergy Center

U.S. DOE Hydrogen and Fuel Cells Merit Review Meeting

Berkeley, CA May 19-23, 2003

Goal of the Project

This work is one of three tasks in the **Biomass to Hydrogen** project.

Goal: develop and demonstrate technology for producing hydrogen from biomass at $2.90/kg purified hydrogen by 2010. By 2015, be competitive with gasoline.

Objectives of the Task

Explore feasibility of producing hydrogen from low-cost, potentially high-hydrogen-yield renewable feedstocks that could complement biomass, increase flexibility and improve economics of Biomass to Hydrogen process.

Can help overcome a barrier of high cost and availability of feedstock.

Demonstrate efficiency of pyrolysis/reforming technology in application to readily available post-consumer wastes: plastics, trap grease, mixed biomass and synthetic polymers.

Addresses the challenge of technology improvement.

Potential for Hydrogen

Plastics wastes: 15 Mt/year; potential for producing 6 Mt/year of hydrogen (energy equivalent 0.8×10^{18} J/year) – enough to fuel 15-20 million fuel cell vehicles

Requires development of collection programs and separation technologies.

Target streams: manufacturing residues (textiles), MRF tailings.

Trap grease recovered: 6 kg/year/person - 1.5 Mt/year; potential for 0.5 Mt/year hydrogen.

Assuming that processing costs will be comparable to those for residual oil (\$0.7/kg H_2), trap grease presents a near-term market opportunity for the production of hydrogen.

Approach

Technology being developed for producing hydrogen from biomass:

- Pyrolysis or partial oxidation of biomass, plastics, and other solid organic residues.
- Catalytic steam reforming of the resulting pyrolysis gases and vapors.
- Catalytic steam reforming of biomass-derived liquid streams (trap grease).

Opportunities to co-process different feedstocks.

Process Reactions

$$\text{Polymers} \xrightarrow{500\text{-}800^{o}C} \text{Monomers and other volatile compounds}$$

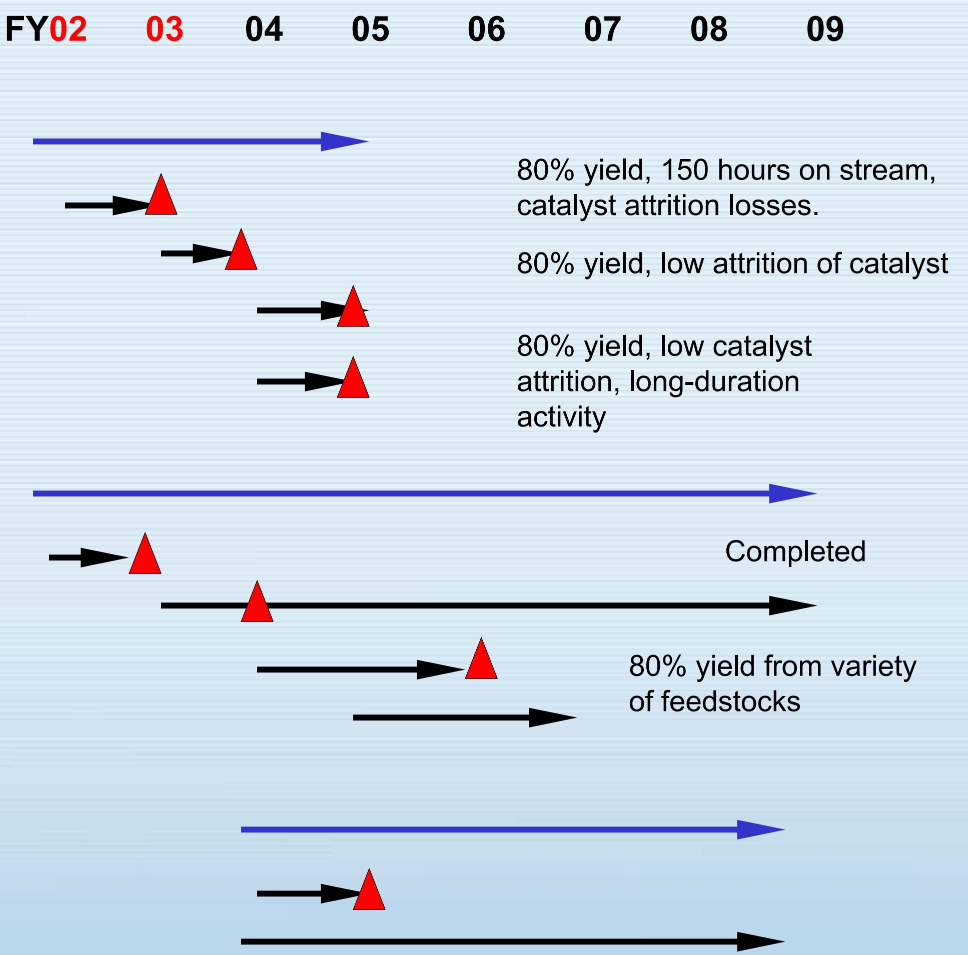
$$C_nH_mO_k + (n\text{-}k)\ H_2O \xrightarrow{800^{o}C,\ cat.} n\ CO + (m/2 + n\text{-}k)\ H_2$$

$$n\ CO + n\ H2O \longleftrightarrow n\ CO_2 + n\ H_2$$

Project Timeline

Hydrogen from Post-Consumer Residues

Timeline



Production of Hydrogen by Catalytic Steam Reforming of Trap Grease

Reforming tests using commercial catalyst

Reforming tests using NREL fluidizable catalysts

Feedstock clean up strategy and long-term catalyst performance demonstration

Co-process trap grease with other biomass-derived liquids

Production of Hydrogen by Integrated Pyrolysis/Reforming of Plastics

Proof of Concept at Micro-Reactor/MBMS scale

Bench-scale tests using integrated bubbling bed reactor system

Bench-scale tests using plastic mixtures (gas clean up)

Bench-scale co-processing of biomass and other feedstocks

Production of Hydrogen from Different Feedstocks in Support of the Scale up Effort

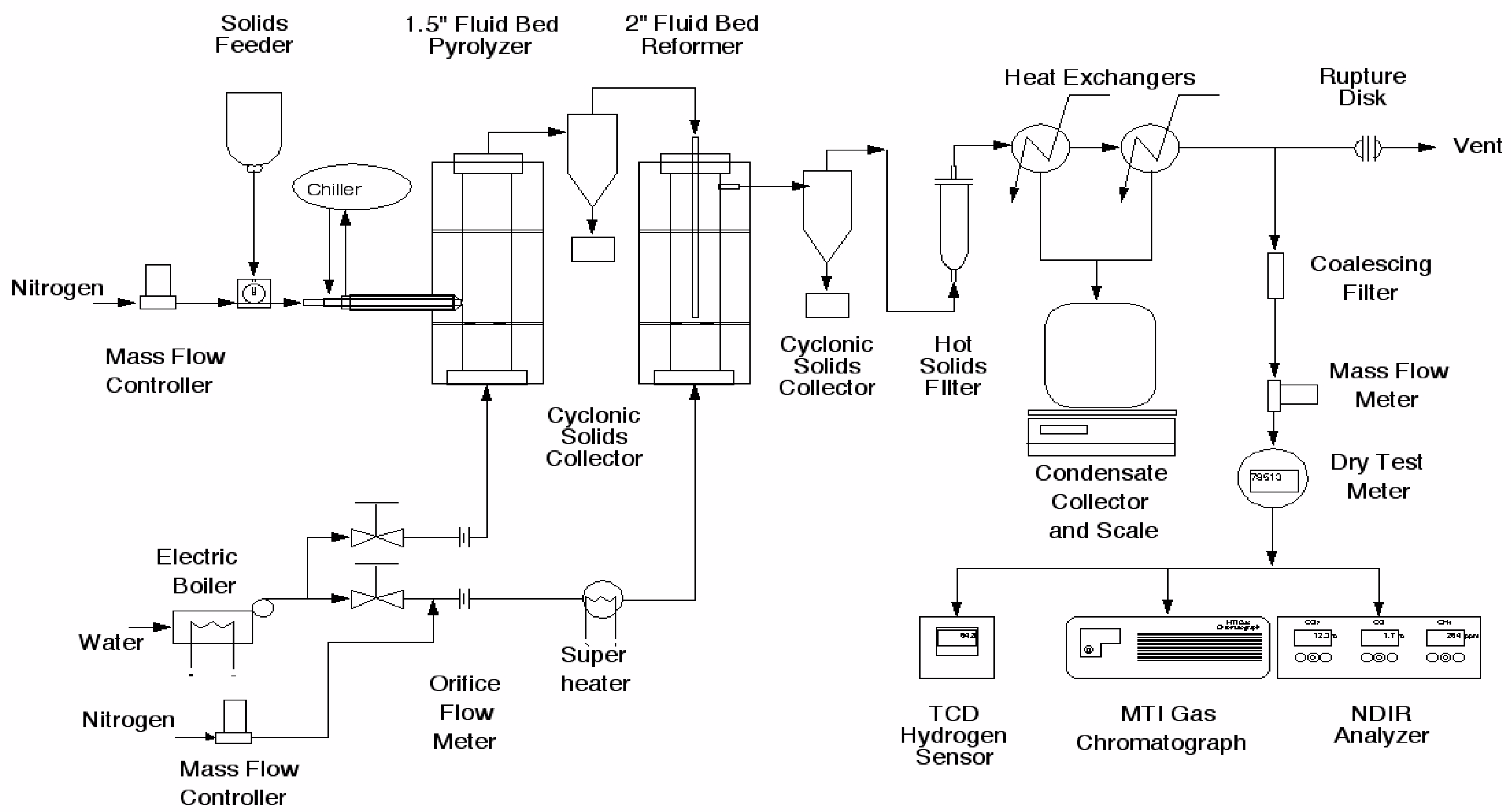
Construction of bench-scale circulating fluid bed reformer

Bubbling and circulating bed tests on flexible feedstocks

Milestones

1. Production of hydrogen from plastics by fluidized bed pyrolysis/reforming process; yield 80% of stoich. (34 g H_2/100 g PP). **September 2003.**
2. Demonstrate efficiency of fluidisable, attrition resistant catalyst developed at NREL for trap grease reforming; 80% of the stoich. yield (28 g H_2/100 g grease). **September 2003.**

Fluidized Bed Integrated Pyrolysis Reforming System

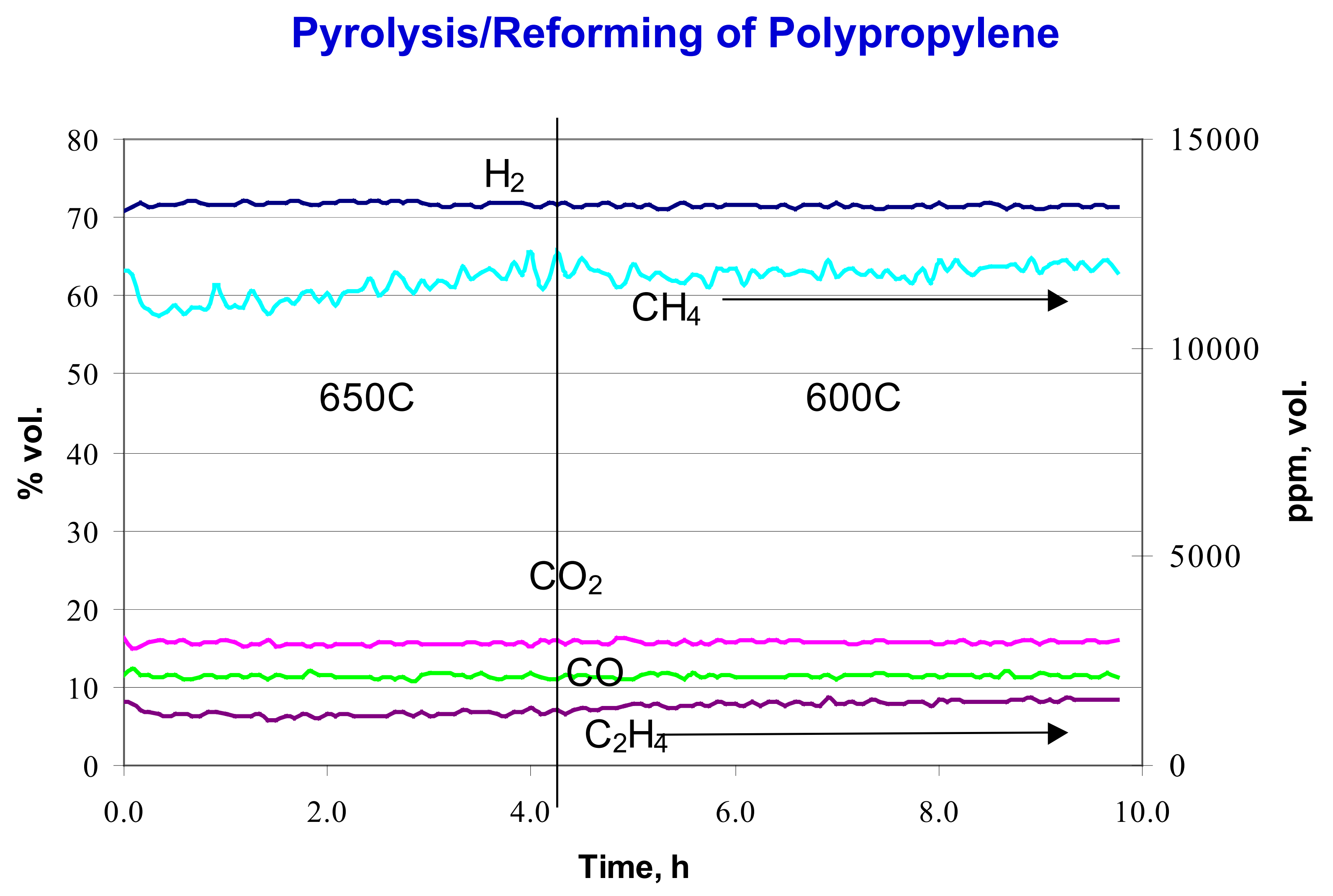


Process Conditions

Pyrolysis zone at 600 - 700°C
(Operated in both pyrolysis and POX mode)
Steam flow: 240 g/h
Feed rate: 60 g/h polypropylene

Reforming zone at 850°C
Commercial nickel-based catalyst
Molar (Steam/Carbon): 4.6
$G_{C1}HSV$: 1600 h^{-1}

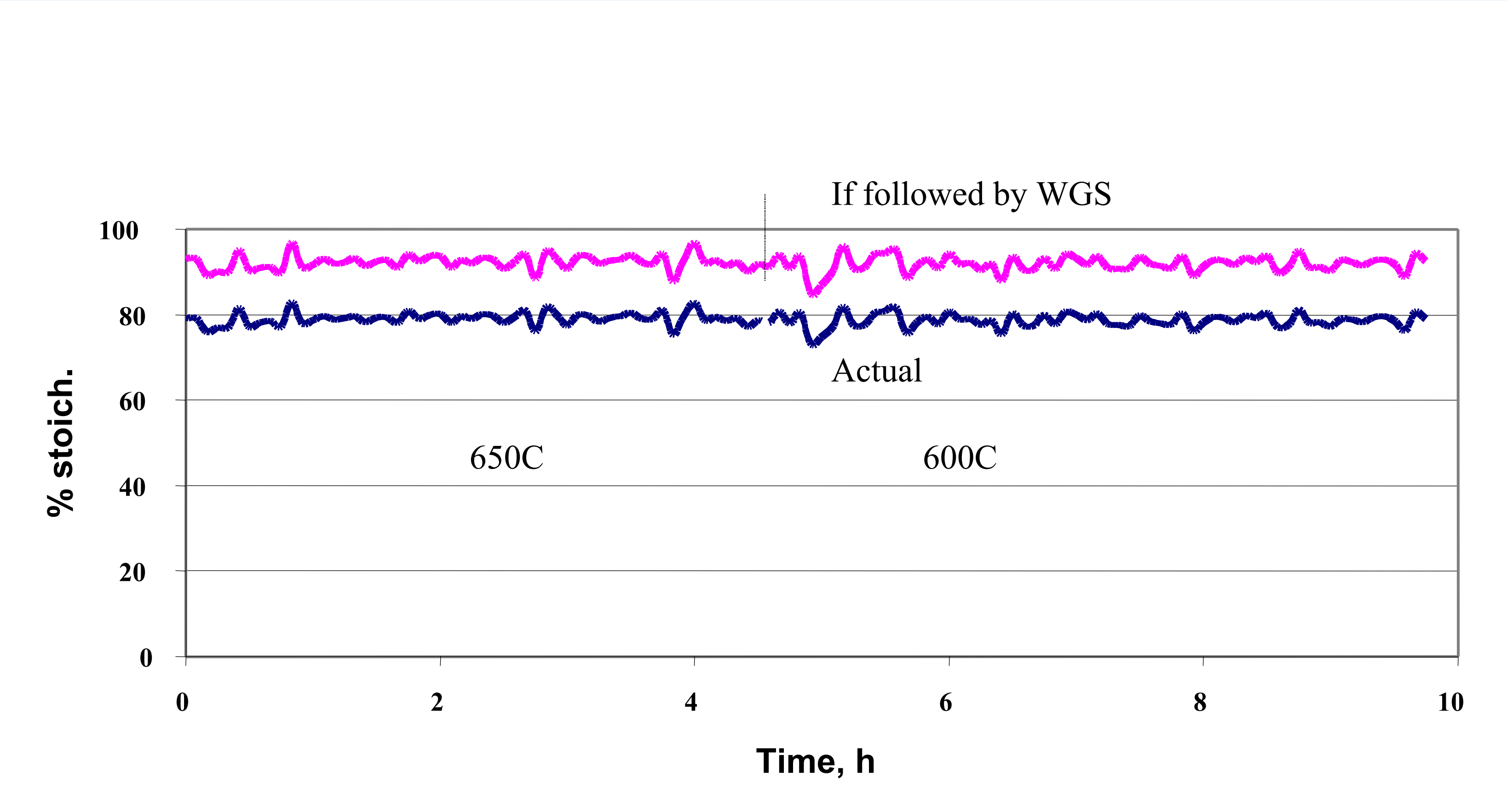
Product Gas Composition



Yield of Hydrogen

Pyrolysis/Reforming of Polypropylene

(stoich. yield: 42.9 g H_2/100 g PP)



Trap Grease

Collected from different sites in the U.S. by Pacific Biodiesel for DOE Biodiesel Program.

Mixture of C_{16} and C_{18} free fatty acids and fats;

Elemental analysis:

C: 76.2%; H: 11.8%; O: 11.9%;

N: 0.02%; S: 70 ppm; ash: 0.1%;

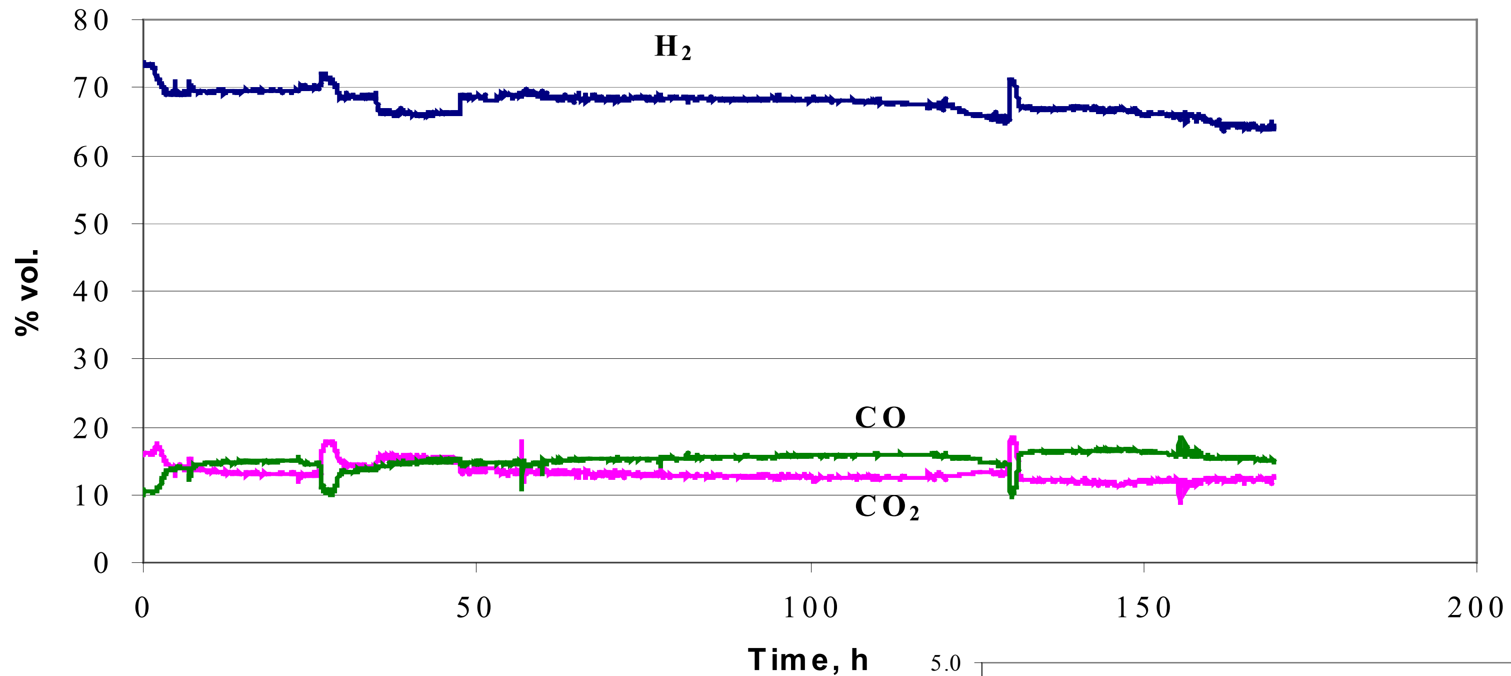
Process conditions:

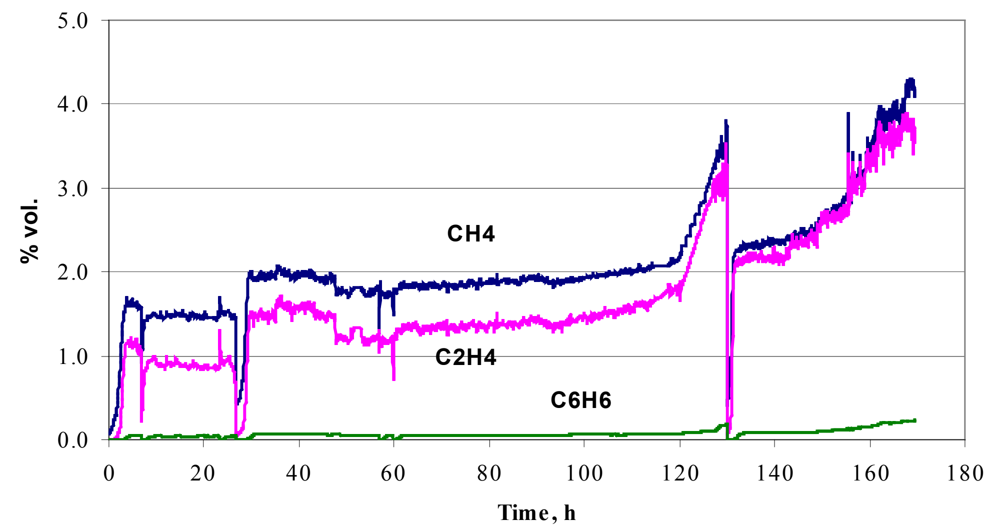
Temperature: 850°C, NREL fluidisable catalyst

Grease feed rate: 42 g/h, steam flow: 240 g/h

S/C: 5, $G_{C1}HSV$: 970 h^{-1}

Trap Grease Product Gas Composition

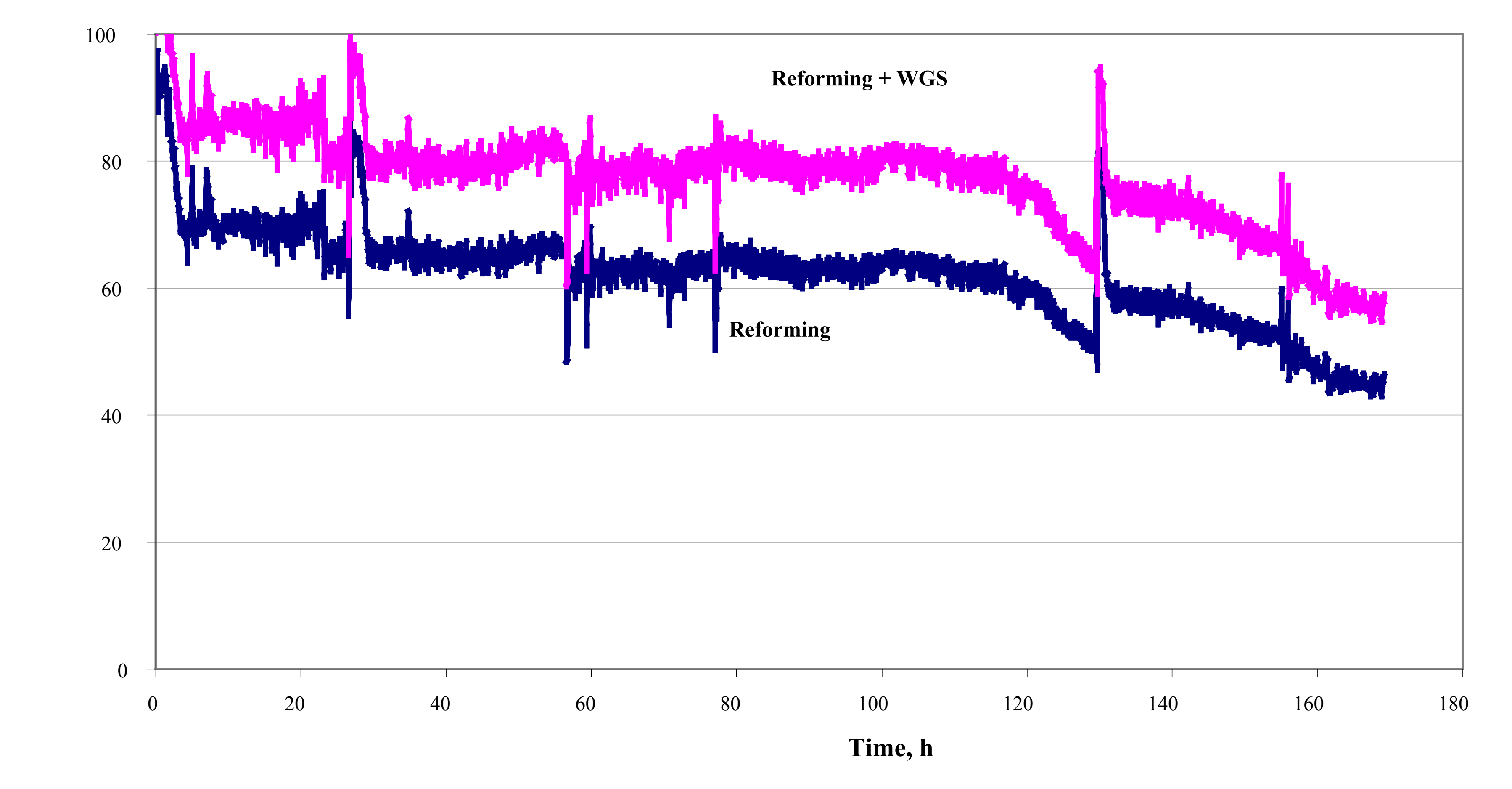




Yield of Hydrogen

Reforming Trap Grease

(Stoich. yield of H_2: 35 g/100 g grease)



Other Accomplishments

Publications:

Chornet, E. and Czernik, S., Renewable fuels: Harnessing hydrogen, **Nature 2002, 418, 928-929.**

Czernik, S., French, R., Feik, C., Chornet, E.; Hydrogen by Catalytic Steam Reforming of Liquid Byproducts from Biomass Thermoconversion Processes, **I&EC Research 2002, 41, 4209-4215.**

Record of Invention filed in U.S. DOE.

Collaboration:

Interface Research Corp., National Diesel Board, American Apparel Manufacturers Association.

Future Work

Complete milestones for FY 2003.

Demonstrate pyrolysis/reforming process for complex feedstocks (textiles, mixed plastics) using commercial and NREL developed catalysts.

Demonstrate production of hydrogen by co-processing renewable (solid and liquid biomass and wastes) and fossil (natural gas) feedstocks.