Hydrogen Production from Infrastructure and Alternative Fuels

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Fuel Cells Can Efficiently Generate Electricity and Heat

Fuel cells can efficiently generate electricity and heat. Distributed hydrogen production is needed to support those fuel cells. Hydrogen can be produced from available fuels--petroleum-derived fuels such as gasoline, natural gas, or liquefied petroleum gas (LPG)--or renewable fuels such as biomass and ethanol.

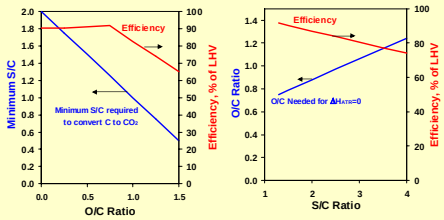
Technology to reform these fuels will broaden hydrogen production options. In this project, our objective is to develop economically viable technology to produce hydrogen from available and renewable fuels. We are working to develop solutions for the challenges involved in LPG reforming, and to define and demonstrate (proof of principle) ethanol reforming at high pressure.

The Fuel Cell Department of Argonne's Electrochemical Technology Program is the lead organization for developing fuel-cell-related fuel processing technologies for the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy.

LPG Contains More Than 90% Propane (C_3H_8)

- Includes butane and low levels of olefins, which promote coke formation during reforming
- A sulfur-containing odorant is added before distribution; sulfur poisons catalysts in fuel processor and fuel cell
- Composition of gas exiting cylinder changes with inventory due to fractionation and reformer operating conditions may require commensurate adjustment

$$C_3H_8 + O_2 + H_2O \longrightarrow CO_2 + H_2$$

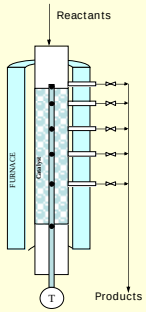


The reforming efficiency is strongly influenced by the oxygen and steam in the feed

Rationale

- Reforming catalysts and operating conditions need benchmarking correlated to product yields
- Kinetic information needed for reactor design

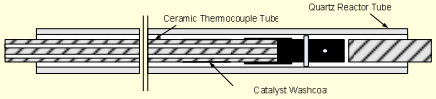
Steam Reforming Reactor



Approach

- Two micro-reactors have been designed to study
  - The steam reforming reaction and
  - Partial oxidation and autothermal reforming

Partial Oxidation Reforming Reactor



The model will use the reactor data to extract kinetic parameters

Ethanol is a Renewable Liquid Fuel

Ethanol has a high energy density, and when produced from biomass, it is a renewable fuel. It is environmentally benign. For reforming, ethanol does not have to be of high purity, which eliminates the energy penalty incurred in ethanol purification

Fuel	LHV* (MJ/Liter)
Gasoline	31
Ethanol	21
Propane (compressed liquid)	21

*G. Thomas et al., "Hydrogen Storage – Overview," BES Hydrogen Delivery and Infrastructure Workshop, May 2003.

Rationale

- Hydrogen purification and storage are favored at high pressure
- Steam reforming with liquid ethanol feed can yield pressurized hydrogen
  - Expensive gas-phase compression costs can be reduced or eliminated

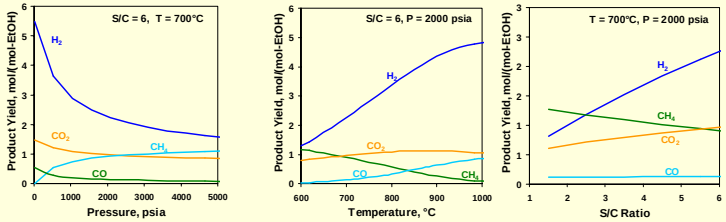
Approach

- Develop technology to reform ethanol at high pressure
  - Define suitable reforming conditions
  - Establish kinetics and product yields

$$C_2H_5OH + 3H_2O \longrightarrow 2CO_2 + 6H_2$$

High pressure reforming does not favor high hydrogen yields at equilibrium

Higher temperature and excess steam favor high hydrogen yields at equilibrium



Summary

- LPG is a widely available infrastructure fuel
- Ethanol is a renewable fuel
- Technology to reform these fuels will broaden hydrogen production options
- This project will prove principles and develop key capabilities

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