Project ID #TVP2

Chattanooga Fuel Cell Demonstration Project

a partnership of

the enterprise center

THE UNIVERSITY of TENNESSEE at CHATTANOOGA

Ion America

May 23-26, 2005

CHATTANOOGA FUEL CELL DEMONSTRATION PROJECT

introduction by

Joe Ferguson
The Enterprise Center

presented by

Jim Henry
The University of Tennessee at Chattanooga

Overview

Timeline

- Project start: Jul 2004
- Project end: Sep 2005
- 50% Complete

Barriers

- Barriers addressed

  I. Hydrogen and Electricity Coproduction

  – Production systems for coproducing hydrogen and electricity need to be statistically validated at user sites

Budget

- Total project funding
  - DOE Share: $2,485,250
  - Contractor Share: $230,217
- $0 received in FY04
- $2,485,250 for FY05

Partners

- The Enterprise Center
- The University of Tennessee at Chattanooga
- Ion America

Objectives

- Develop and demonstrate a prototype 5 kW class, grid parallel, solid oxide fuel cell (SOFC) system that coproduces hydrogen

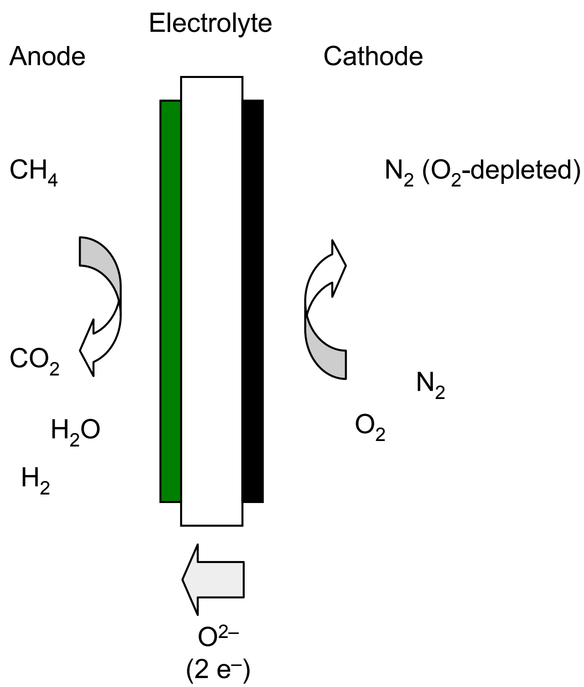
Relevance to the Hydrogen Program:

- Technology validation of a near-term economical pathway to help build out the hydrogen infrastructure
  - Equipment coproduces electricity and hydrogen
  - System operates with high capacity factor even when the demand for hydrogen is relatively low

Approach

- The Enterprise Center (Chattanooga, TN) is facilitating efforts between Ion America (Moffett Field, CA), the City of Chattanooga, and The University of Tennessee at Chattanooga (UTC) to work cooperatively to develop a 5 kW class, grid parallel, SOFC system, and to conduct a field demonstration and premarket testing
- When the working prototype is ready for testing, the UTC Applied Technology Lab will place the prototype into a regimen of testing to prove it is ready to be utilized to provide power
- The installation will be configured to simultaneously and efficiently produce hydrogen from a commercial natural gas feedstream in addition to electricity
- This ability to produce both hydrogen and electricity at the point of use provides an early and safe pathway to hydrogen production

SOFC Concept



Overall reaction using methane fuel:

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + 8e^- +$ Heat

High Quality Heat → Cooling

Premium Power

- Cheapest alternative among fuel cells; competitive with grid power and other distributed solutions
  - Inexpensive materials
  - High volume low cost manufacturing processes
- Extremely high reliability
  - No moving parts
  - Solid state energy conversion
- High efficiency energy generation (45-60% net AC)
- High temperature (800-900°C) Operation affords
  - Fast chemical kinetics
  - Very high quality waste heat
  - High cogeneration efficiency (80-90%)
- Great fuel flexibility
- Environmentally very clean at no additional cost – 50-60% reduction in GHG emissions, near-zero SO_x and NO_x

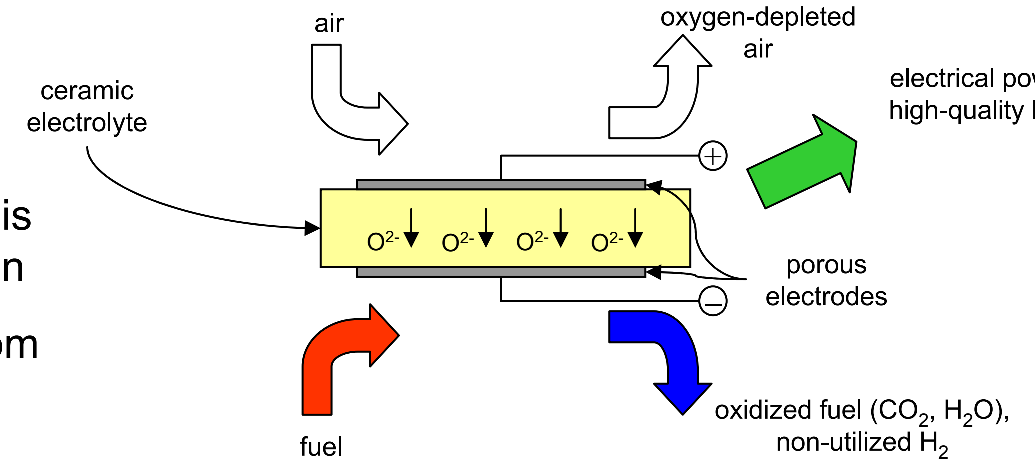
SOFC Coproduction of Hydrogen

- Solid oxide fuel cells (SOFC) coproduce hydrogen during electrical power generation
- Within an SOFC stack, we have

steam methane reforming:	$CH_4 + H_2O \rightarrow CO + 3H_2$
water-gas shift:	$CO + H_2O \rightarrow CO_2 + H_2$
CO oxidation:	$CO + {}^1/_2O_2 \rightarrow CO_2$ + electricity + heat
hydrogen oxidation:	$H_2 + {}^1/_2O_2 \rightarrow H_2O$ + electricity + heat
partial oxidation:	$CH_4 + {}^1/_2O_2 \rightarrow CO + 2H_2$ + electricity + heat

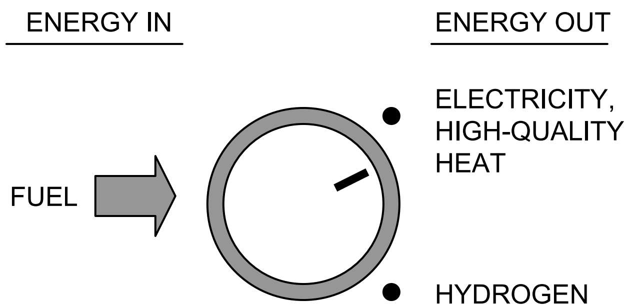
Not all hydrogen produced is utilized for power generation

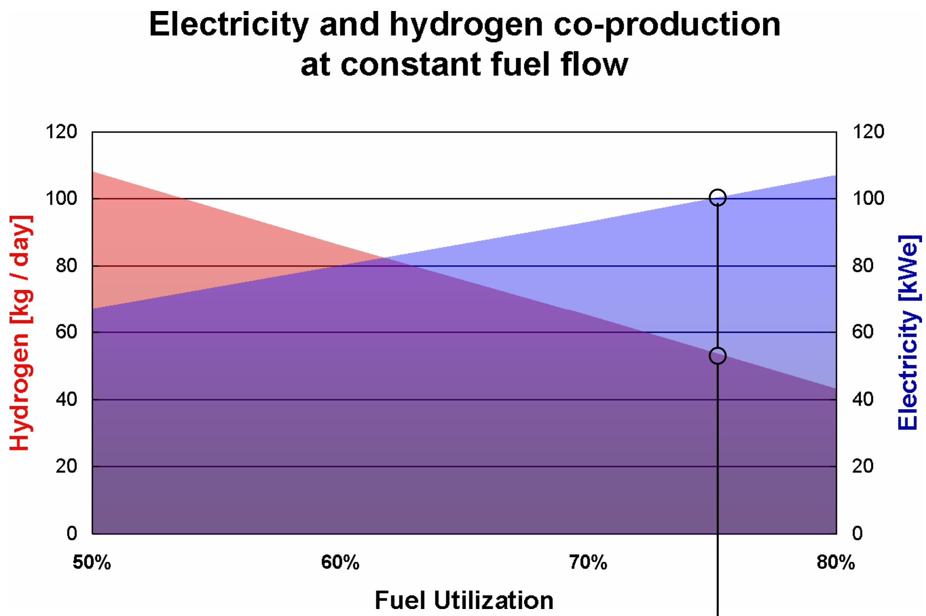
Utilization can be varied from 50% – 80%



Electricity & Hydrogen Coproduction

Rate of electricity and hydrogen production as a function of fuel (methane) utilization, total fuel flow held constant





Example: 100 kWe SOFC generator at 75% fuel utilization

A hydrogen production rate of **50 kg / day** corresponds to

- a gasoline energy equivalent of 47 gallons / day (equal energy basis)
- support for a fleet of 25 fuel cell vehicles

Progress

- Ion America established detailed design requirements for the SOFC system based on The City of Chattanooga and The Department of Energy contract requirements
  - Design requirements included system safety requirements, electrical interface requirements to the utility grid, chemical feed stream and exhaust requirements, mechanical, installation, and interface requirements from the SOFC operating site, and operating and performance requirements
- From the system requirements, the system architecture was established
  - Chemical, thermal, and electrical, Process and Instrumentation Diagram, Wiring Diagram, Communication Interface, and Power Budget were updated, and system performance projections were prepared

Accomplishments – 1

- New project – started in Jul 2004
  - Signed contracts in place for the team in Feb 2005
  - First month for deliverables (IA subcontract to UTC) in Jan 2005
- Project requirements definition completed
- System architecture design completed and validated with Aspen Plus modeling
- Piping & Instrumentation Diagram, Wiring Diagram, Communication Interface, and Power Budget completed
- System performance projections completed
- System design frozen

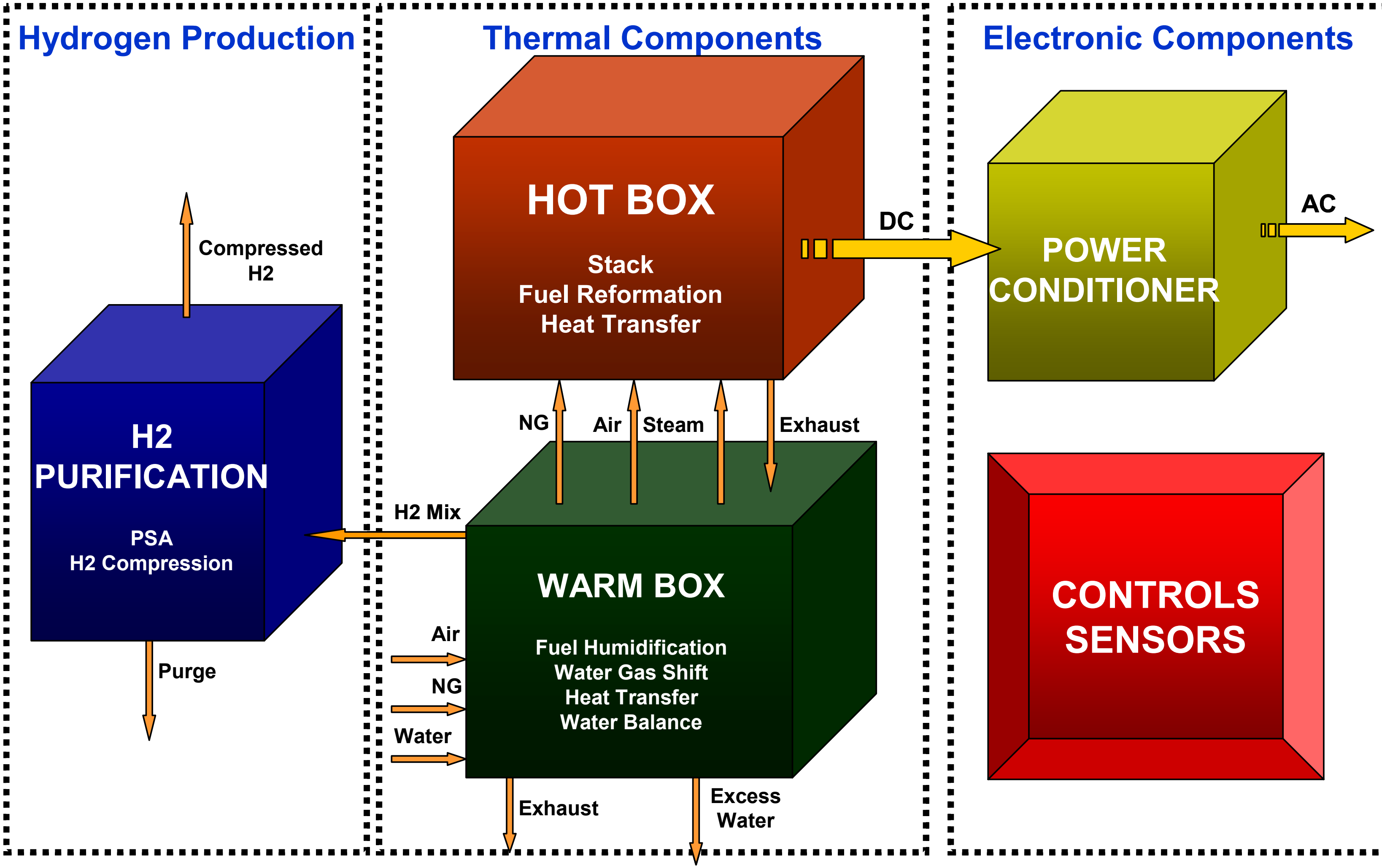
Accomplishments – 2

- Subsystem requirements defined
- Stack and Balance of Power (BoP) subsystem design completed
- Initial phase of control software completed
- Commenced FMEA and safety analysis
- Most subsystem designs frozen
- Bill of Materials (BoM) specified
- Most vendor requirements defined

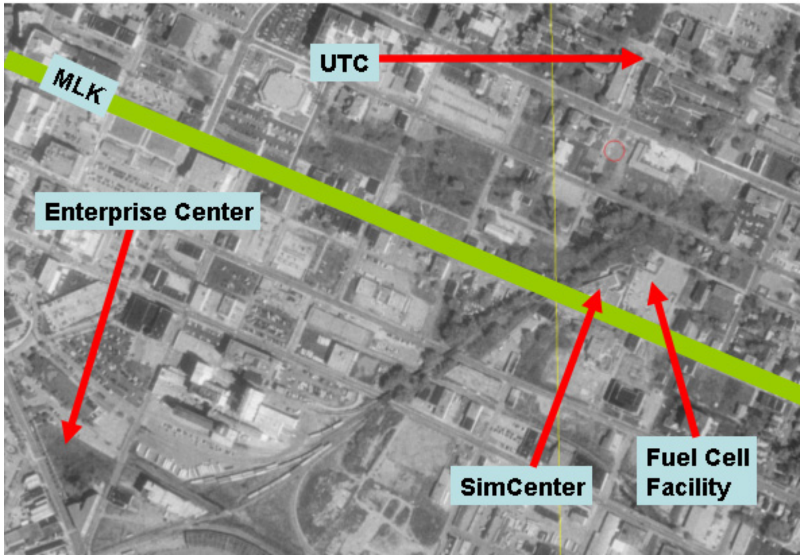
Accomplishments – 3

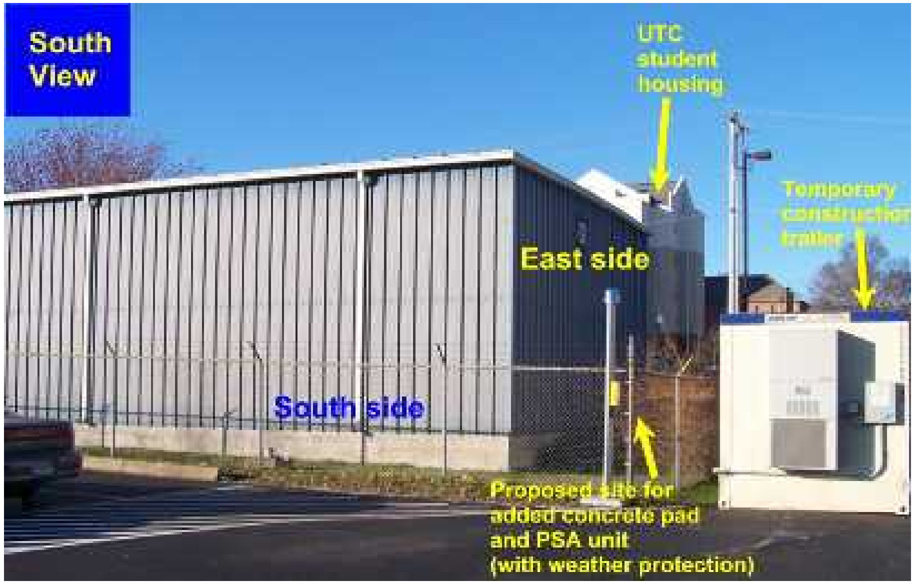
- Hydrogen purification subsystem testing commenced
- Most components and subsystem designs qualified
- Several candidate electrolytes and electrodes under test
- Cell stack qualification commenced
- BoP specified and most BoP components received
- Site for UTC Fuel Cell Facility identified
- Specified and commenced modifications to the UTC Fuel Cell Facility

System Architecture

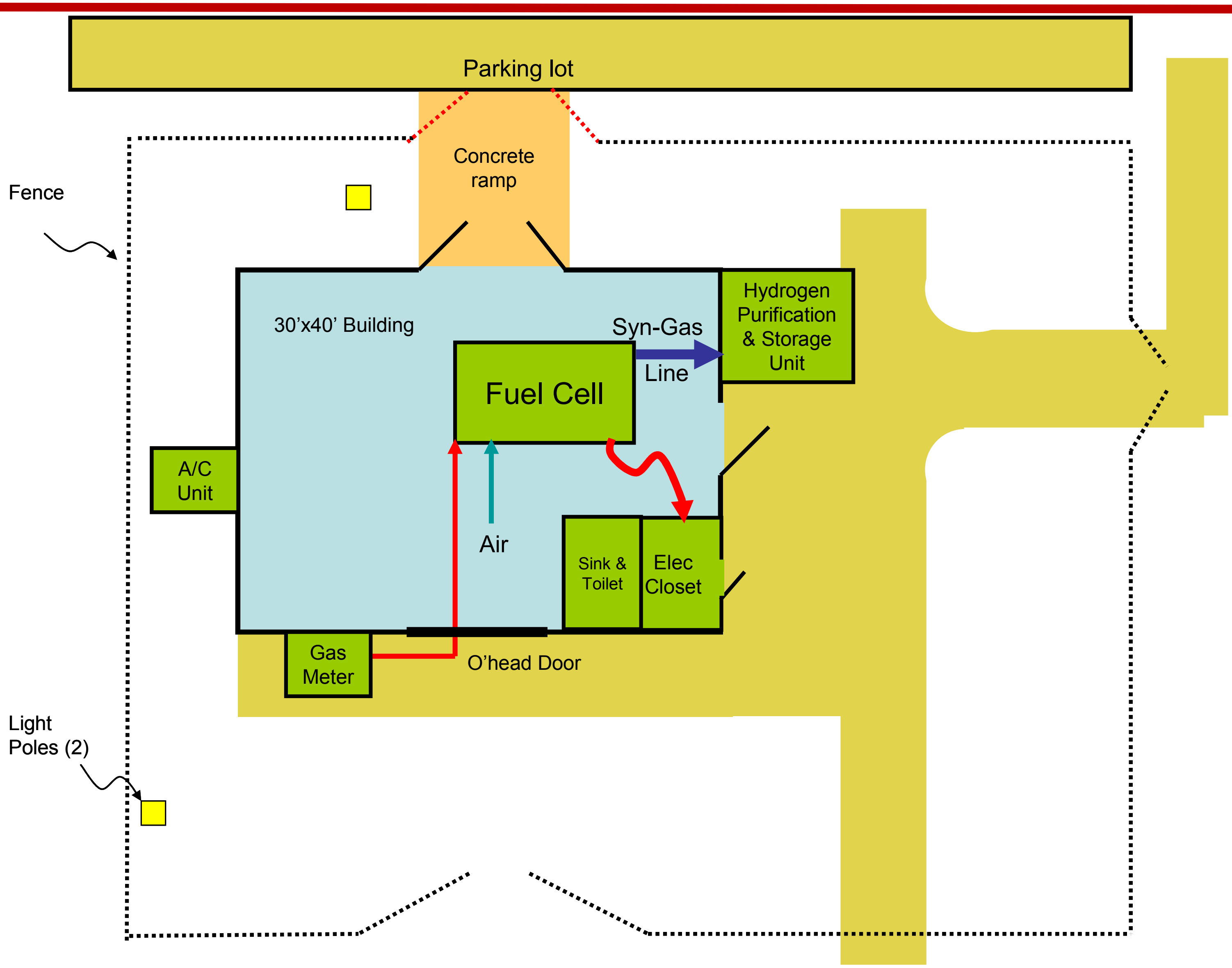


UTC Fuel Cell Facility





UTC Fuel Cell Facility



Future Work – 1

- System control software ported to a PC-based architecture and tested
- Component and subsystem tests completed
- BoP assembly completed
- SOFC stacks manufactured after qualification is completed
- SOFC stacks conditioned and start-up in system
- System stand alone tests

Future Work – 2

- System grid-tie tests
- System load step tests
- Control system fault response
- Prepare system for shipment and ship to UTC at end of FY05
- Complete Fuel Cell Facility modifications and prepare to accept delivery
- System setup, checkout, and start-up at UTC Fuel Cell Facility

Publications and Presentations

Two papers were recently accepted for publication:

- K.R. Sridhar, Jim McElroy, Fred Mitlitsky, Venkat Venkataraman, and Mark C. Williams, "Applications and Markets for Solid Oxide Regenerative Fuel Cells", 207th Meeting of The Electrochemical Society, Ninth International Symposium on Solid Oxide Fuel Cells (*SOFC-IX*), PV 2005-07, S. C. Singhal and J. Mizusaki, Editors, Quebec City, Canada, May 15-20 (2005).
- Darren Hickey, Mark Cassidy, Jim McElroy, Fred Mitlitsky, and Venkat Venkataraman, "Optimization and Demonstration of a Solid Oxide Regenerative Fuel Cell System ", 207th Meeting of The Electrochemical Society, Ninth International Symposium on Solid Oxide Fuel Cells (*SOFC-IX*), PV 2005-07, S. C. Singhal and J. Mizusaki, Editors, Quebec City, Canada, May 15-20 (2005).

Hydrogen Safety

The most significant hydrogen hazard associated with this project is:

- *A leak of pressurized hydrogen could create a jet that ignites and impinges on flammable material that could start a fire*

Hydrogen Safety

Our approach to deal with this hazard is:

- *The near-ambient pressure fuel cell anode exhaust will be piped outside to a pad before buffering, pressurizing, and purifying the hydrogen*
- *The hydrogen purification system will be sited to meet NFPA 50A/B standards*
- *The total inventory of hydrogen on the pad will be low (<0.1 kg), and the maximum pressure will be low (75 psig)*
- *The total inventory of hydrogen inside the building will be negligible*