

# ADVANCED REACTOR, FUEL CYCLE, AND ENERGY PRODUCTS WORKSHOP FOR UNIVERSITIES

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*Jim O'Brien*

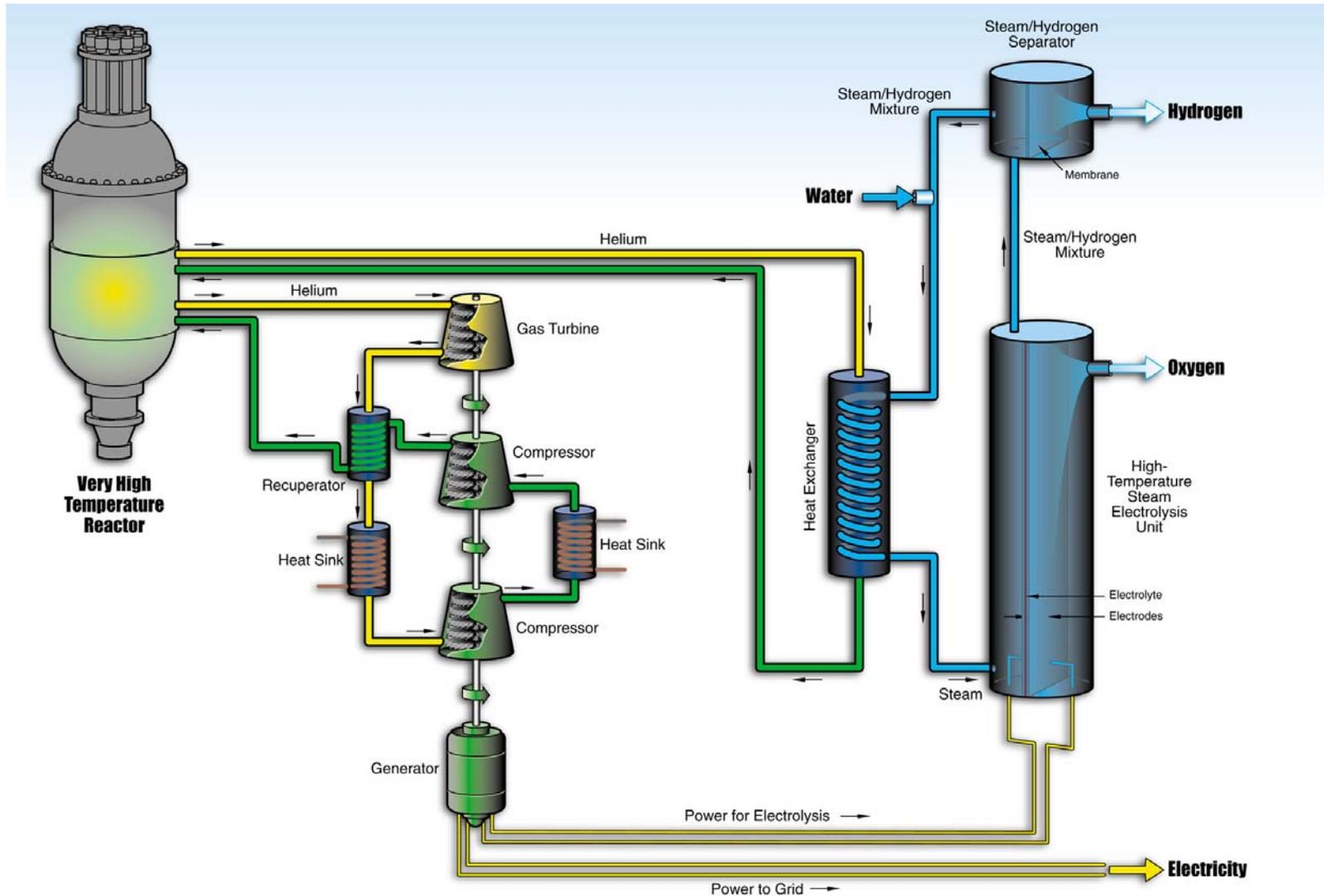
***Nuclear Hydrogen Initiative  
High Temperature Electrolysis  
Idaho National Laboratory***

*Workshop for Universities  
Hilton Hotel, Gaithersburg, MD  
March 20, 2007*



# High Temperature Electrolysis Overall Technical Objective:

Develop and demonstrate high temperature steam electrolysis for energy-efficient carbon-free hydrogen production from nuclear energy



# Specific HTE Program Objectives

- **Develop and demonstrate high-temperature solid-oxide electrolysis cells (SOECs) and stacks for hydrogen production from steam**
- **Demonstrate HTE at progressively larger scales**
- **Develop flowsheet analyses of systems-level HTE processes to support planned scale-up to Integrated Laboratory-scale, Pilot-scale and Engineering Demonstration-scale experiments.**
- **Perform detailed CFD analyses of operating SOECs; validate with experiment data**
- **Investigate alternate cell materials (e.g. alternate electrode and/or interconnect materials) and alternate cell configurations (e.g. porous-metal substrates, tubular cells, porous electrodes, large-format cells)**

## Strategy

- **Wherever possible, build on previous development of solid oxide fuel cells by DOE-EE, SECA and others.**

# HTE Program Work Structure

## WP1. HTE System Definition

- Plant conceptual design [INL]
- CFD and Systems Modeling [INL and ANL]
- Athabasca oil-sand upgrading (I-NERI, INL, ANL with AECL)

## WP2. HTE Experiments and Scale-Up

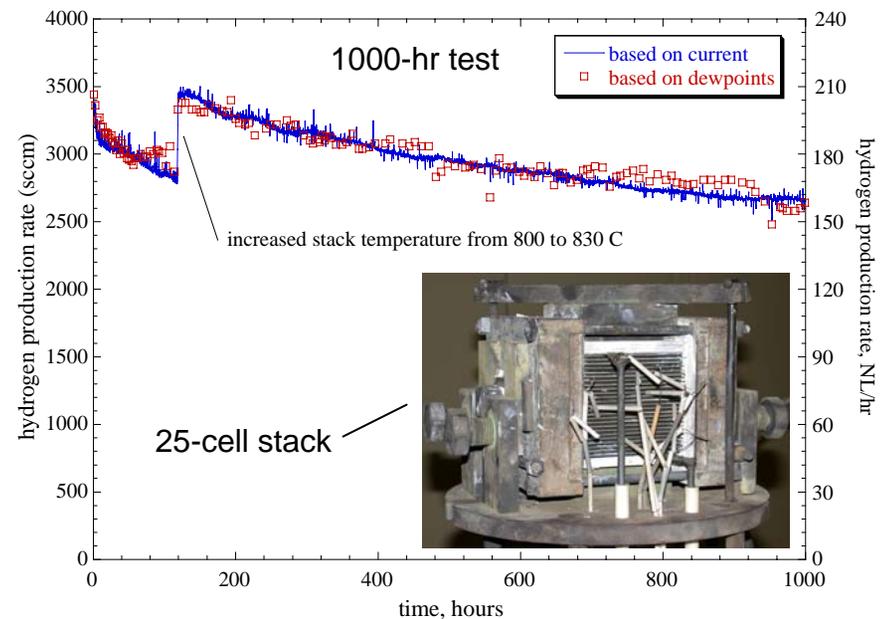
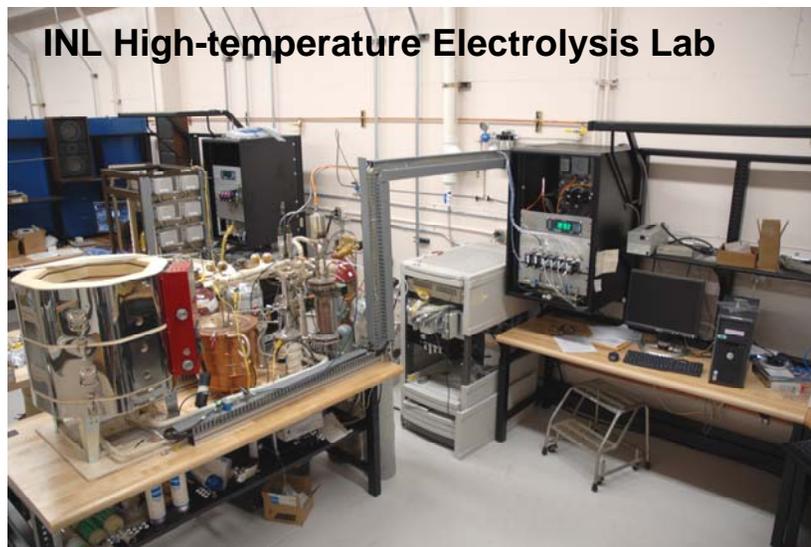
- Button Cell and Stack fabrication [Ceramatec, Inc., SLC, plus additional industrial partners]
- Advanced electrodes and electrolytes [ANL]
- HTE test stand operation [INL]
- Plasma deposition of cells [INL]
- High temperature H<sub>2</sub>/H<sub>2</sub>O membrane separations [ORNL]

# FY 2006 Major Accomplishments and Milestones

## INL HTE Program

### High-Temperature Electrolysis Experimental Development

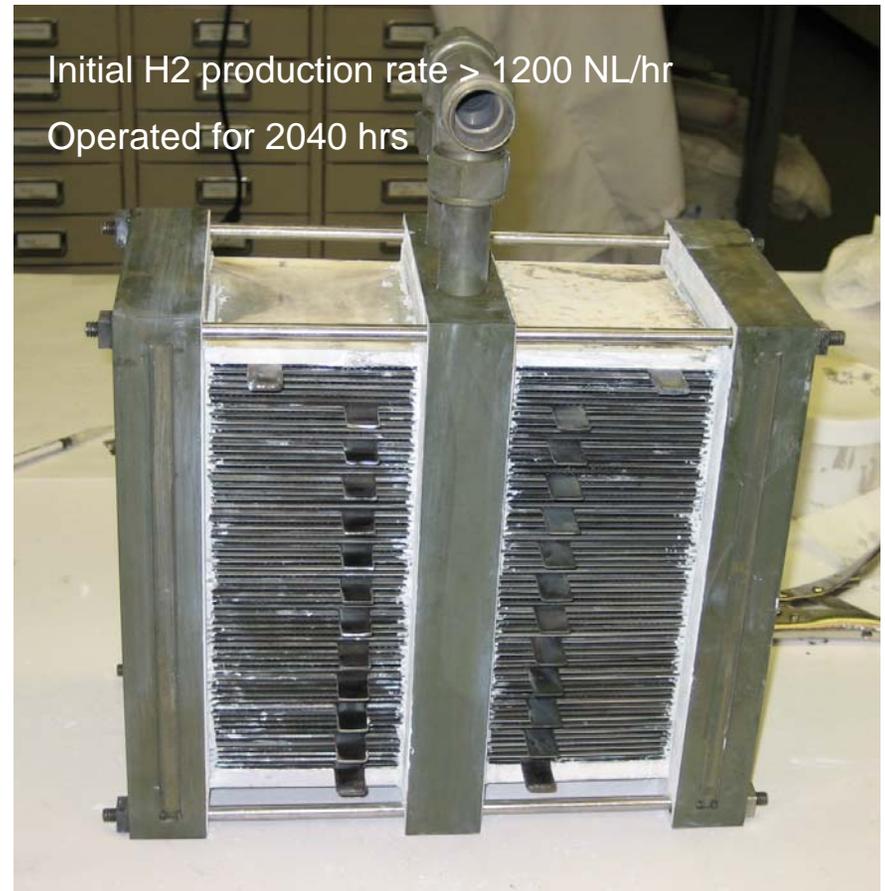
- M2.1: Complete review article on Sealing Technologies Applicable to Solid Oxide Electrolysis Cells [Level 2, 11/30/05]
- M2.2: Operate 20-25 cell stack at 100 Normal liters per hour for 1000 hours [Level 1, 3/31/06]
- M2.5: Operation of a 20-30 cell stack with an area-specific resistance (ASR) less than 2.0 Ohm-cm<sup>2</sup> after 100 hours of operation at 830 C. [Level 3; 8/15/06]



# FY 2006 Major Accomplishments and Milestones INL HTE Program

## High-Temperature Electrolysis Experimental Development

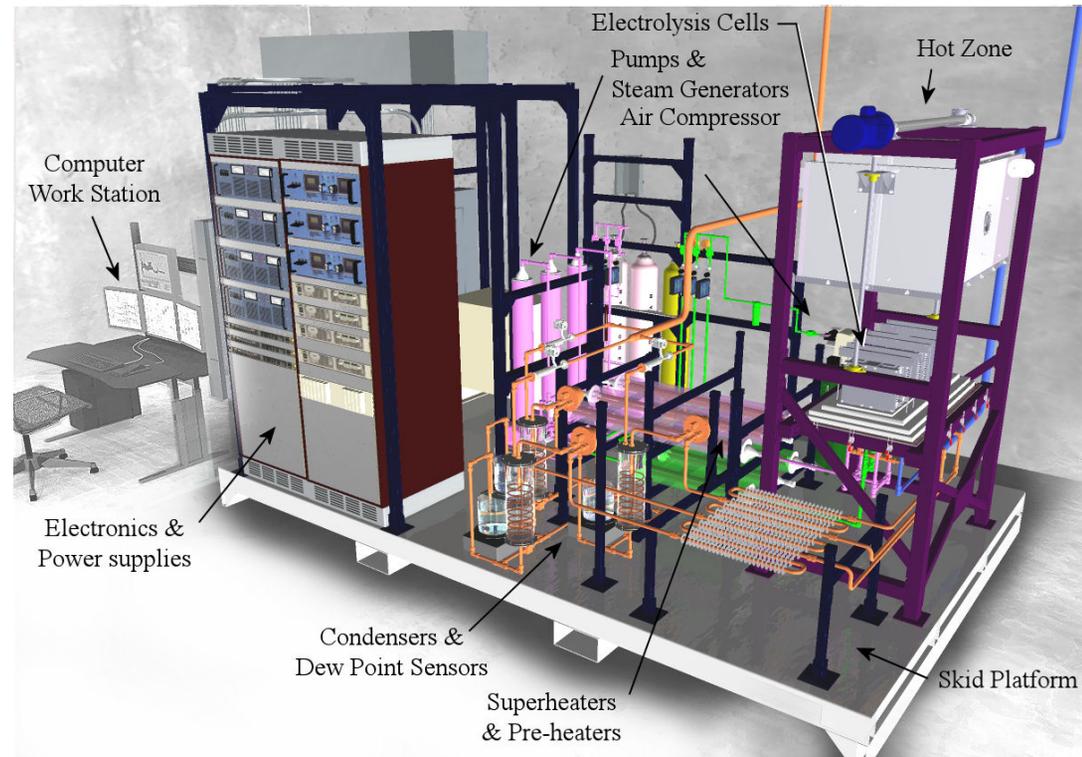
- M2.4: Initial operation of materials testing loop [Level 2; 7/31/06]
- M2.3: Begin testing of initial dual-stack integrated laboratory scale (ILS) Module at Ceramatec [Level 1; 7/14/06]



# FY 2006 Major Accomplishments and Milestones INL HTE Program

## High-Temperature Electrolysis System Definition

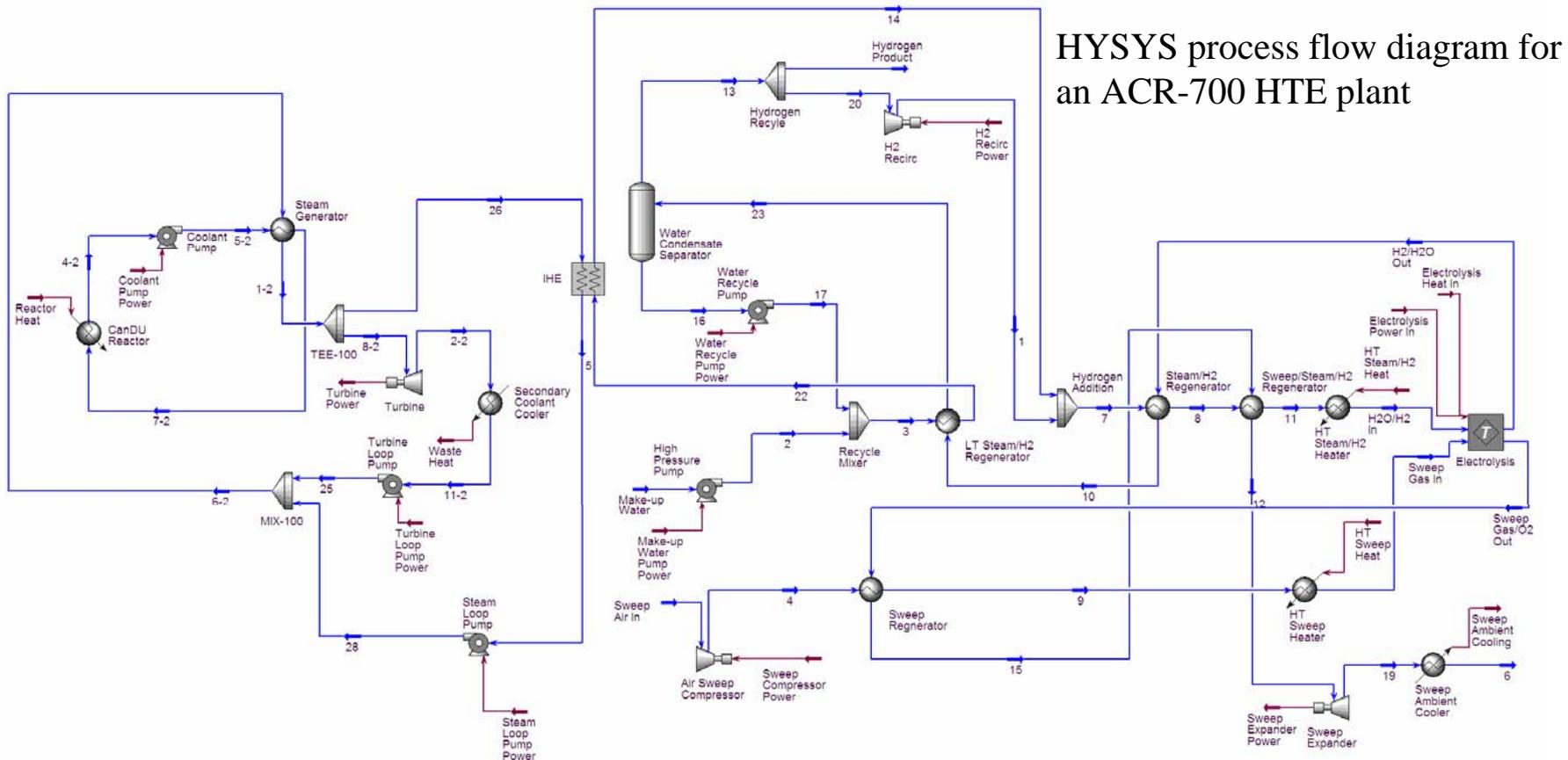
- M1.1: Finalize “Integrated Laboratory-scale Experiment Performance, Space and Power Requirements” [Level 2; 2/1/06]
- M1.2: Complete document entitled “Integrated Laboratory-scale Stack Specification and Mechanical Design.” [Level 2, 9/1/06 also PEMP]



# FY 2006 Major Accomplishments and Milestones INL HTE Program

## High-Temperature Electrolysis System Definition

- M1.3: Complete Analysis on use of HTE for Upgrading Athabasca Oilsands [Level 2; 9/15/06]



# FY 2006 Major Accomplishments and Milestones ANL and ORNL HTE Program

## ANL

- *Computational Fluid Dynamics analyses of HTE cells.*
- *Plant flowsheet analyses to thermally optimize the HTE-nuclear plant combination, particularly in the areas of heat recovery*

## ORNL

- *Complete testing of high temperature inorganic membranes for the separation of hydrogen and steam*

# HTE Work in Progress for FY07

## System Definition

- Completion of detailed ILS System Design and Safety Analysis
- CFD Simulations of Integrated Planar Design
- Completed Summary Report on “Reactor-Coupled HTE Modeling Sensitivity Studies”
- Improved Performance predictions for commercial-scale HTE Operations

## Experiment Development

- Completed Testing of “Integrated Planar Cells”
- Complete assembly of Integrated laboratory Experiment
- Completion of Corrosion test facility, plus initial test series
- Complete assessment of degradation in long-duration test cells (ANL)
- Demonstrate improved electrode materials for high-temperature steam electrolysis (ANL)
- Complete analysis of SOEC stack and cell configurations to optimize hydrogen production (ANL)

# High Temperature Electrolysis Work Scope Highlights FY08 – FY09

## FY2008

- Complete an integrated laboratory-scale module experiment at a nominal 15 kW power level
- Demonstrate Stack-level CFD Simulation capability
- Analyze cell performance degradation mechanisms
- Pilot-scale systems analysis and preliminary design
- Evaluate alternate cell/stack designs for possible ILS testing

**Extended operation target: 2500 hours at 5 Normal m<sup>3</sup>/hour by July 2008**

## FY2009

- ILS Extended Operation
- Implement cell/module technology improvements
- Incorporate improved CFD models to minimize empiricisms
- Pilot scale experiment design