High Temperature Electrolysis for Hydrogen Production

J. Stephen Herring, Carl M. Stoots, James E. O'Brien
Idaho National Laboratory

and Joseph J. Hartvigsen, Ceramatec, Inc.

Materials Innovations in
an Emerging Hydrogen Economy
Hilton Oceanfront
Cocoa Beach, Florida
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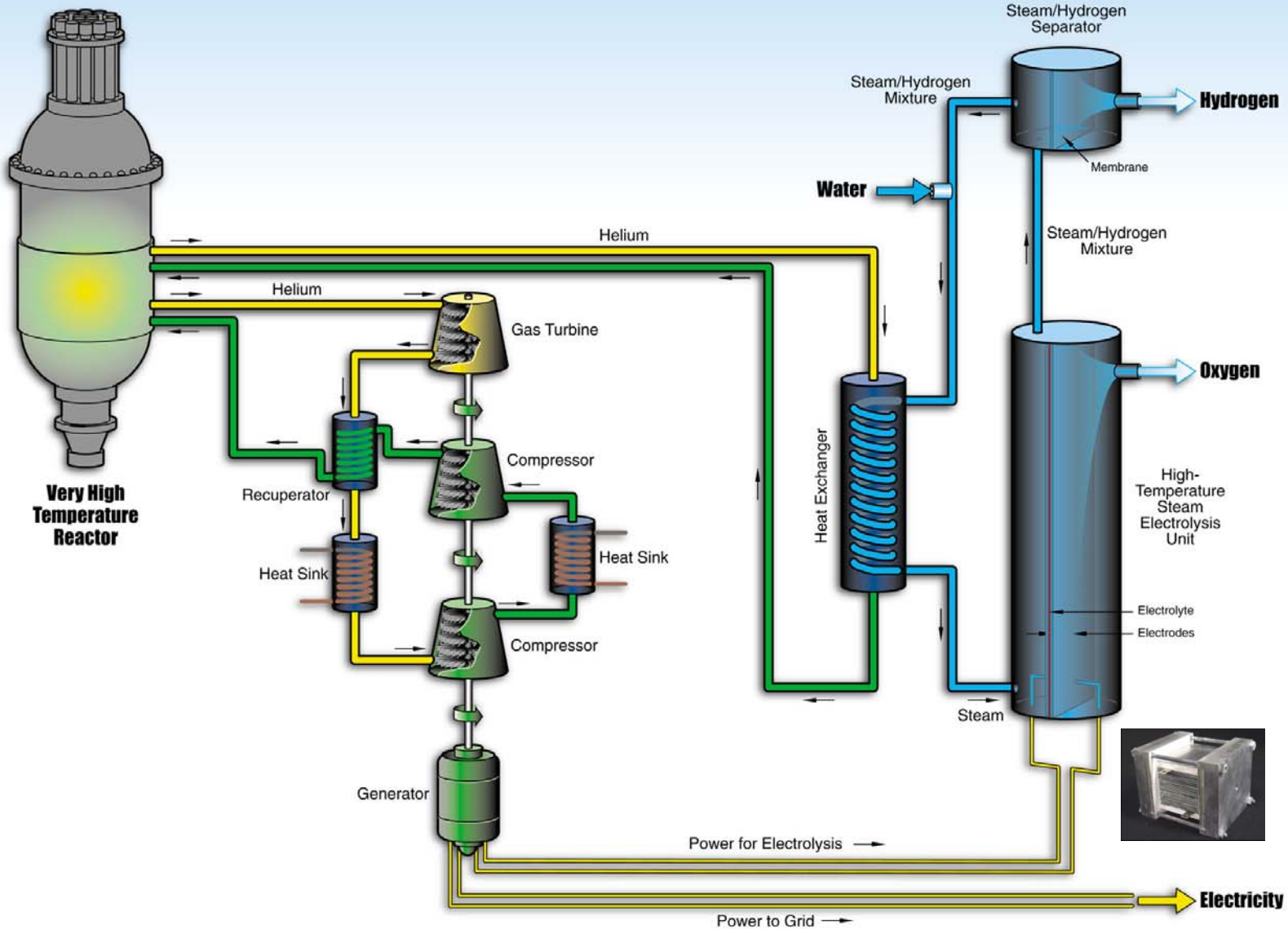
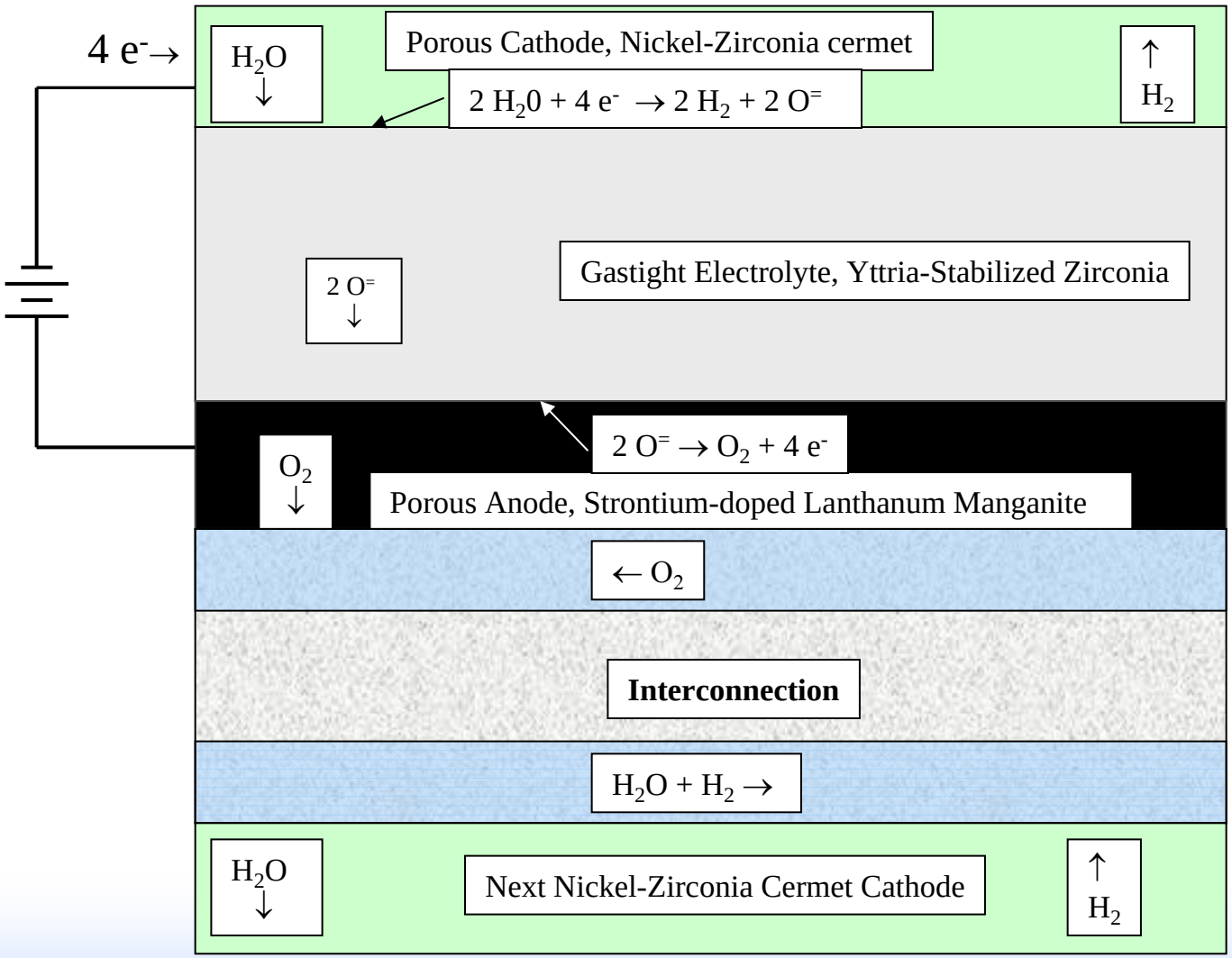
INL

High Temperature Electrolysis Plant



90 v/o H_2O + 10 v/o H_2

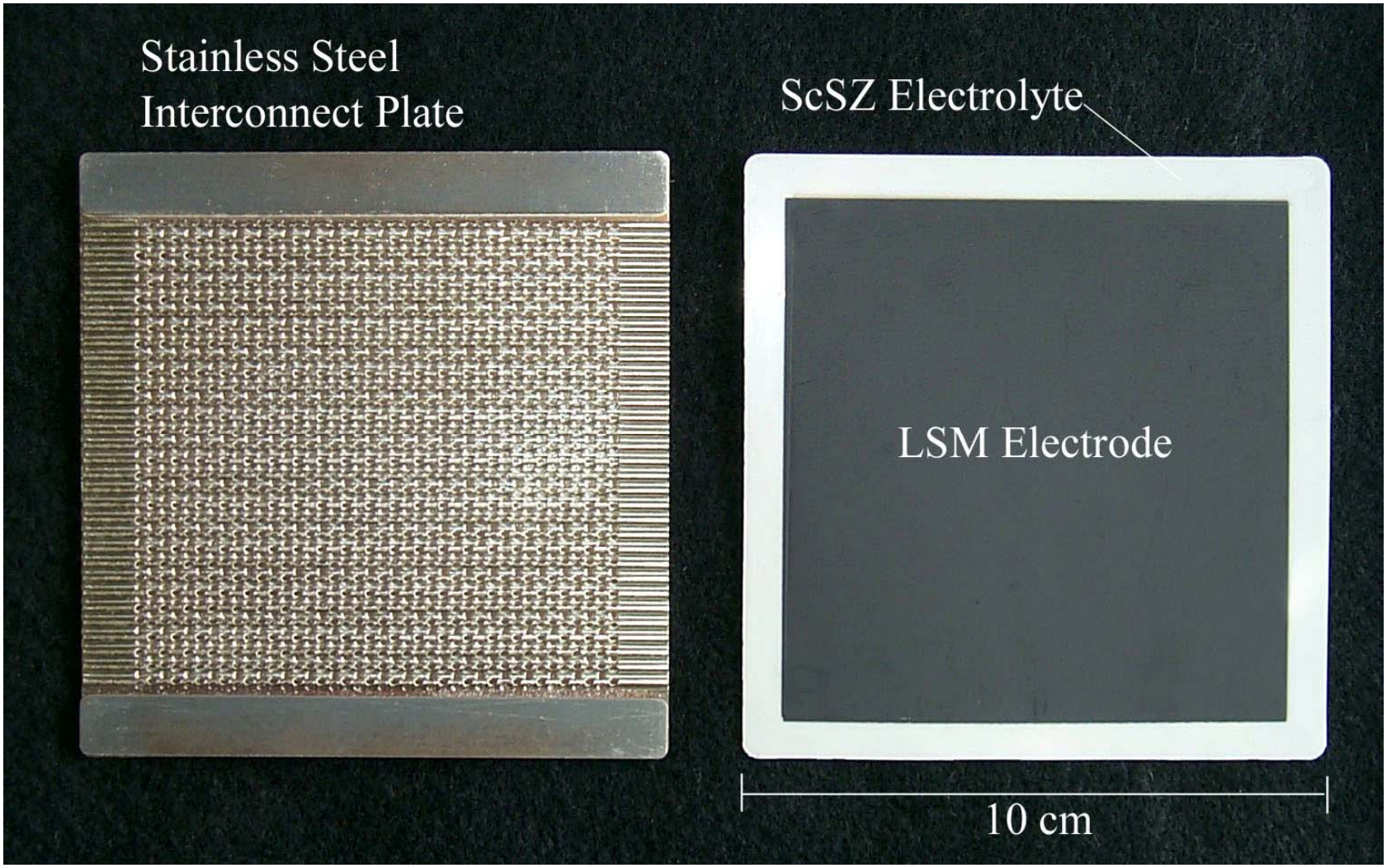
25 v/o H_2O + 75 v/o H_2

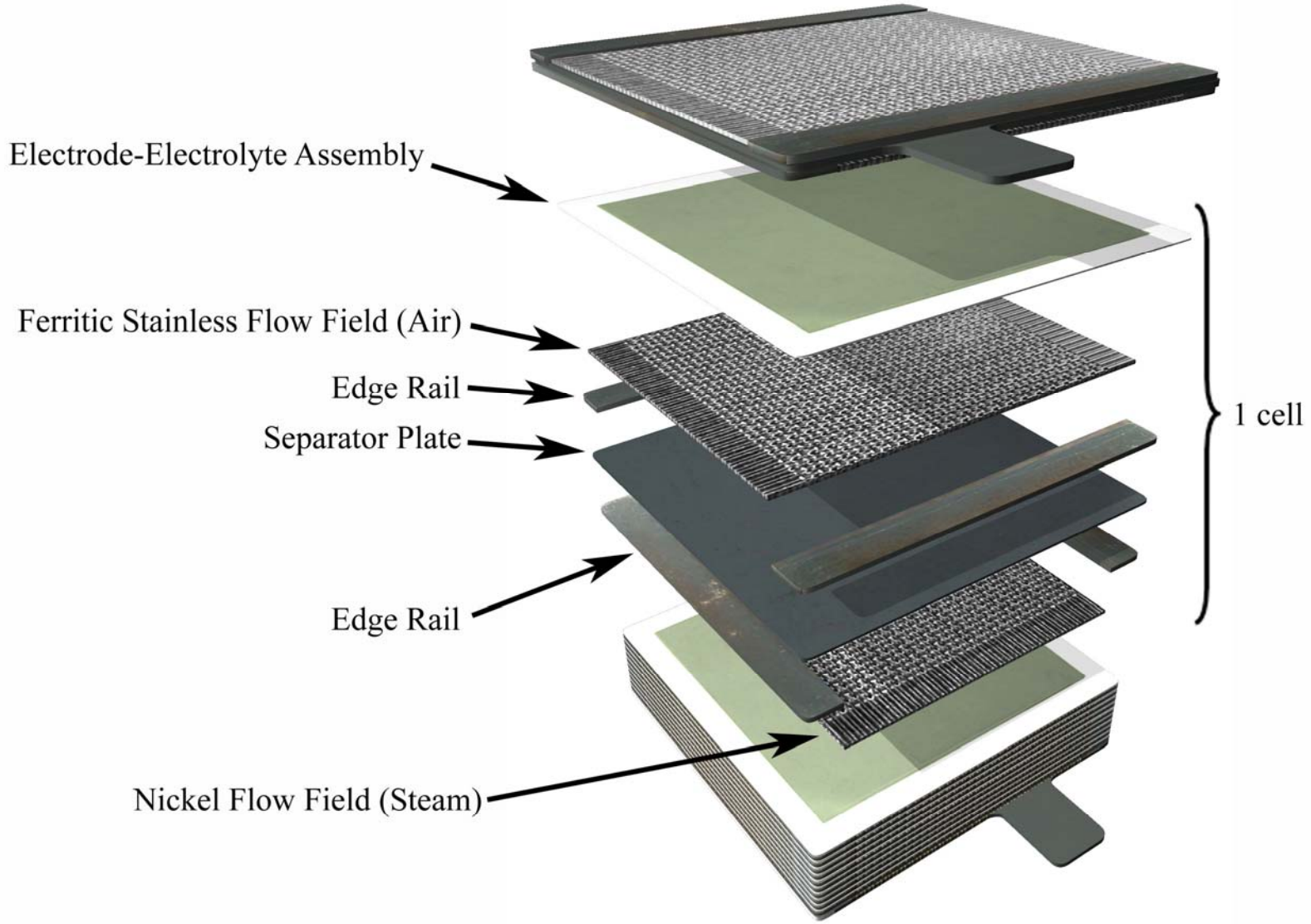


Typical thicknesses

	Electrolyte-supported	Cathode-supported
	0.05 mm	1.500 mm
	0.10 mm	0.01 mm
	0.05 mm	0.05 mm
	1 – 2.5 mm	

Stack Internal Components

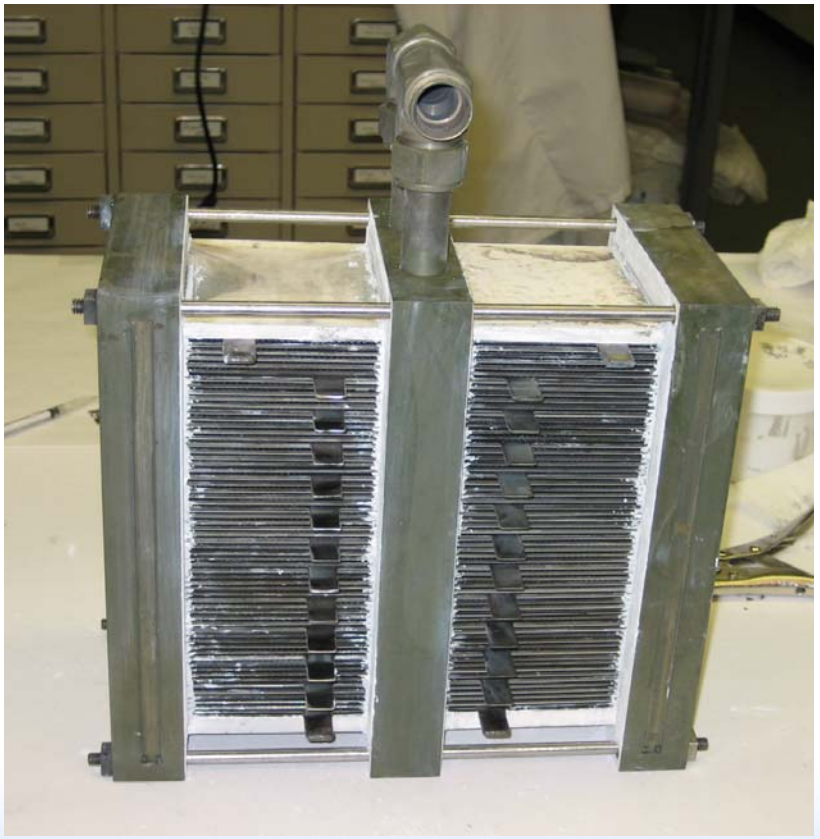



Electrode-Electrolyte Assembly
Ferritic Stainless Flow Field (Air)
Edge Rail
Separator Plate
Edge Rail
Nickel Flow Field (Steam)
1 cell

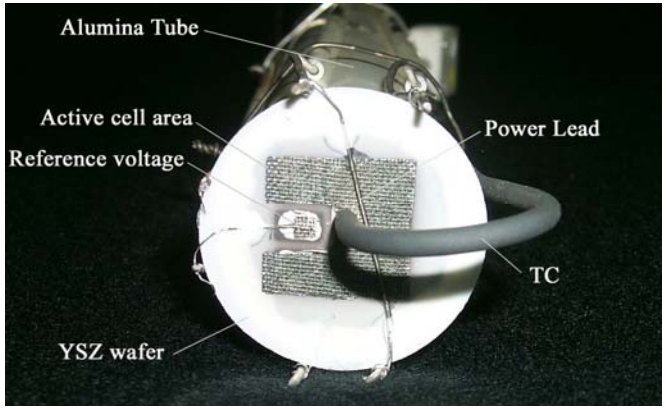
25-cell stack used in 1000-hour test Jan. 4 – Feb. 16, 2006

2 x 60-cell stacks tested at Ceramatec, SLC

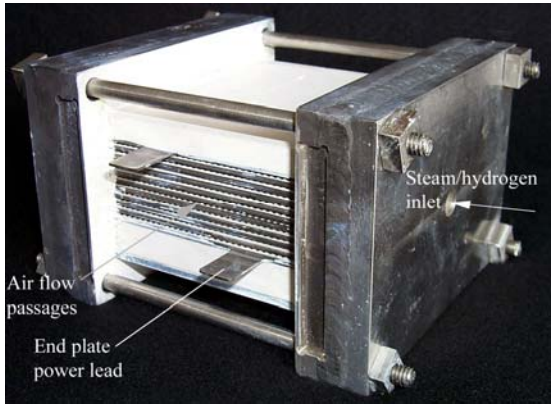
Initial rate: 1.2 Nm3 H2/hr
final: 0.65 Nm3 H2/hr
2040 hours, ended 9-22-06
>800 hrs in co-electrolysis



High Temperature Electrolysis: from Button Cells to the Integrated Laboratory Scale Experiment



Button cell (2003) 3.2 cm^2



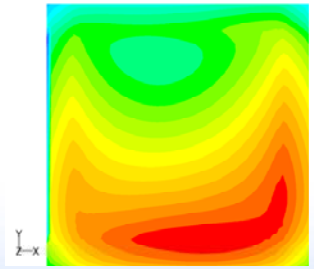
10-cell stack (2004) 640 cm^2

120-cell half-module (2006) 7,680 cm^2

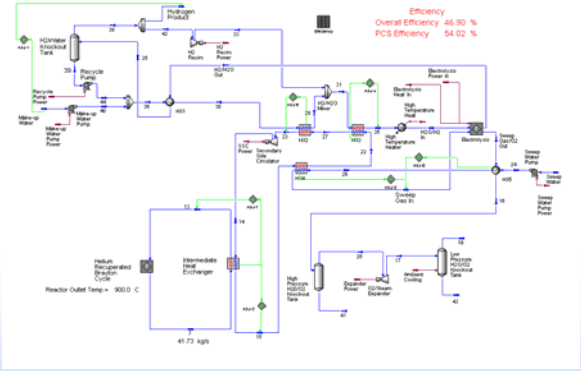
Research Goals:

- Develop efficient solid-oxide electrolysis cells, building on solid-oxide fuel cell research
- Decrease cost, increase durability
- Determine reasons for long-term cell degradation
- Optimize plant designs
- Co-electrolyze CO_2 and steam to CO and H_2
- Develop designs to apply nuclear heat and H_2 to heavy petroleum and oil sand upgrading
- Integrate nuclear energy sources and fossil/biomass carbon sources for hydrocarbon synthesis

CFD and Flowsheet Analyses



Temperature profile of cell



Process Flowsheet for Reactor-driven commercial plantl

Integrated Laboratory Scale (operational 8-22-07) 720 cells, 3 modules (2008) 46,080 cm^2

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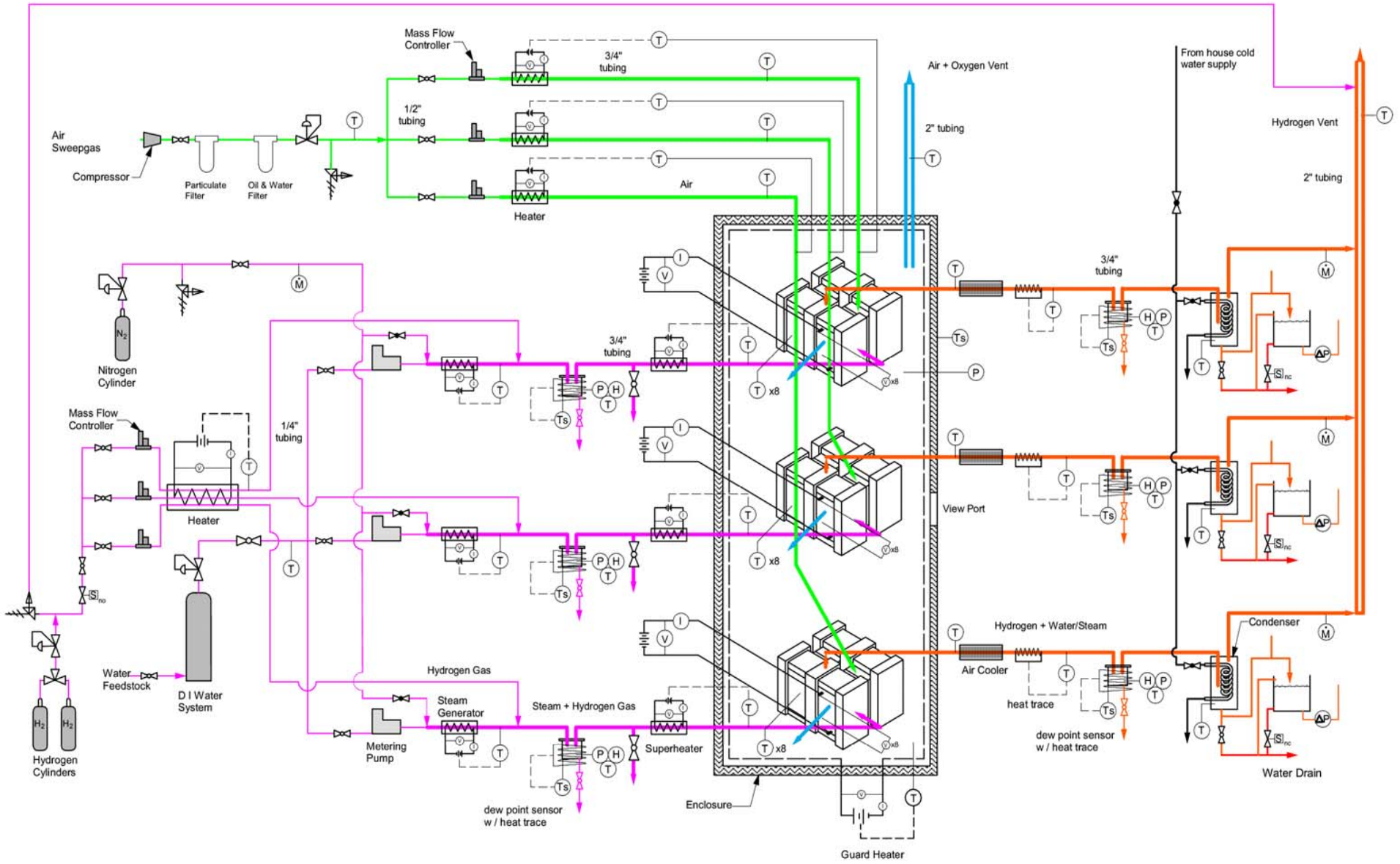
ILS Piping and Instrumentation



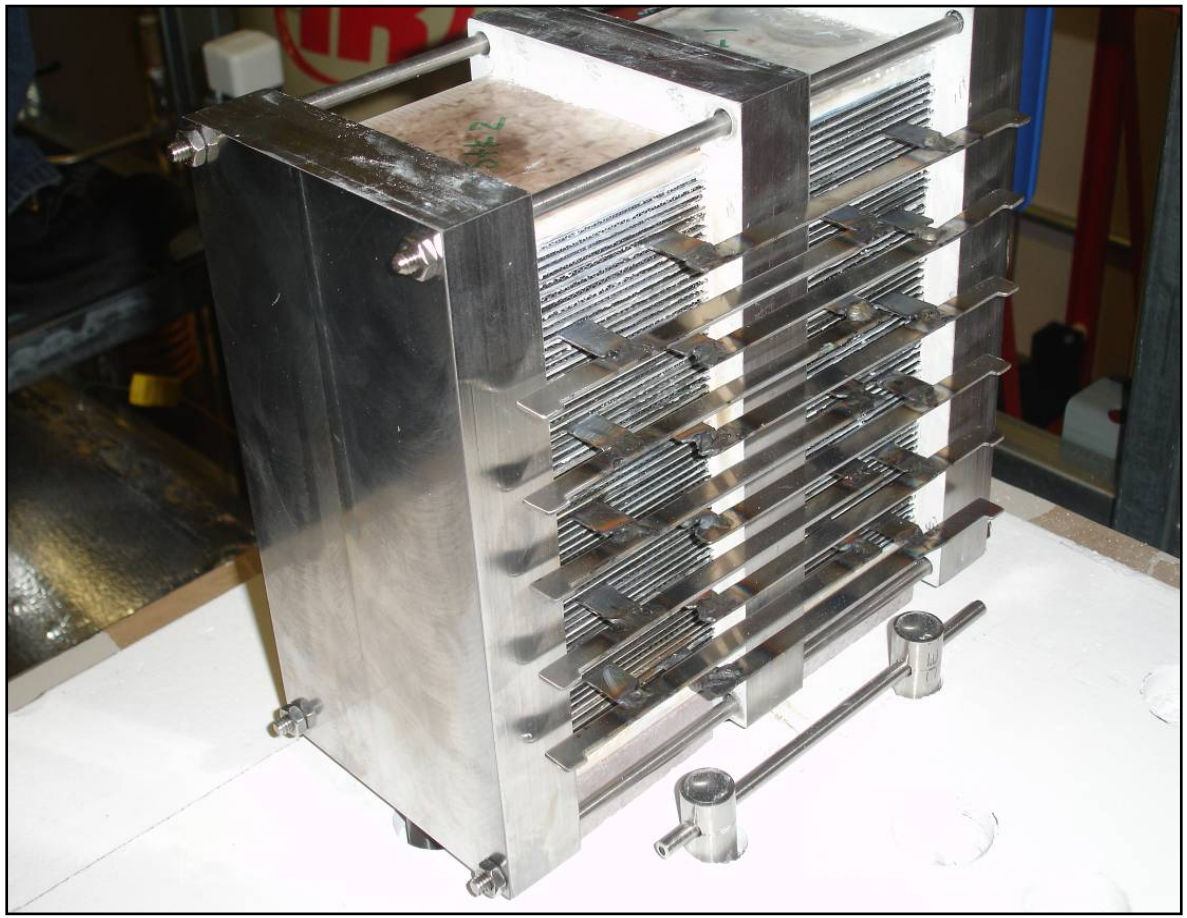
Comparison of nominal and extreme design cases.

	Nominal Case	Extreme Design Case
ASR (ohm cm^2)	1.5	1.0
Current Density (A/cm^2)	0.25	0.37
Per-cell Voltage, (V)	1.283	1.283
Electrolysis Power (kW)	14.54	21.8
Hydrogen Production Rate (NL/hr)	4735	7103

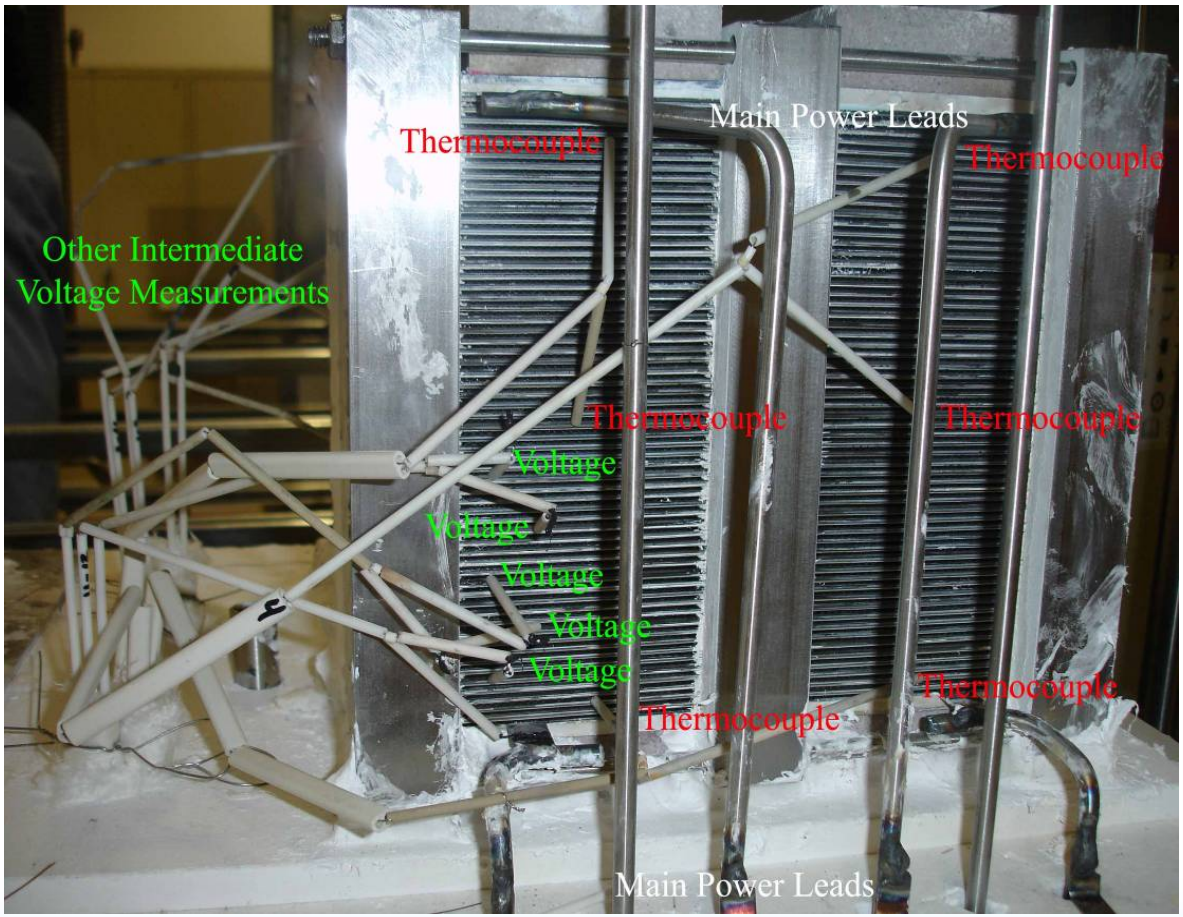
Assembled ILS Components

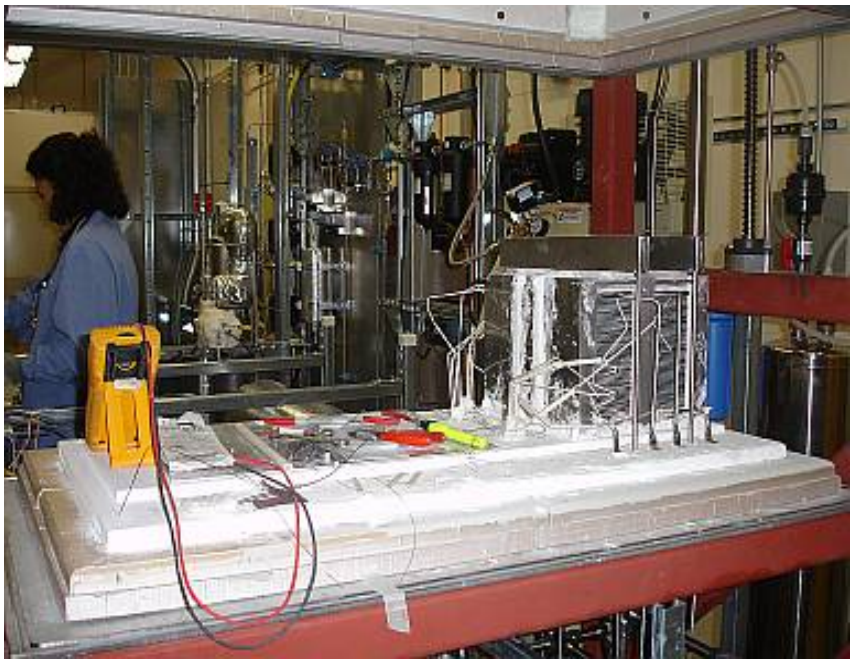
High-Temperature Electrolysis
Integrated Laboratory Scale Experiment July 16, 2007

ILS Module Installation



ILS Module Installation





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Start of Testing

Initial operations began Aug 24, 2007

Module testing began Sept 24, 2007

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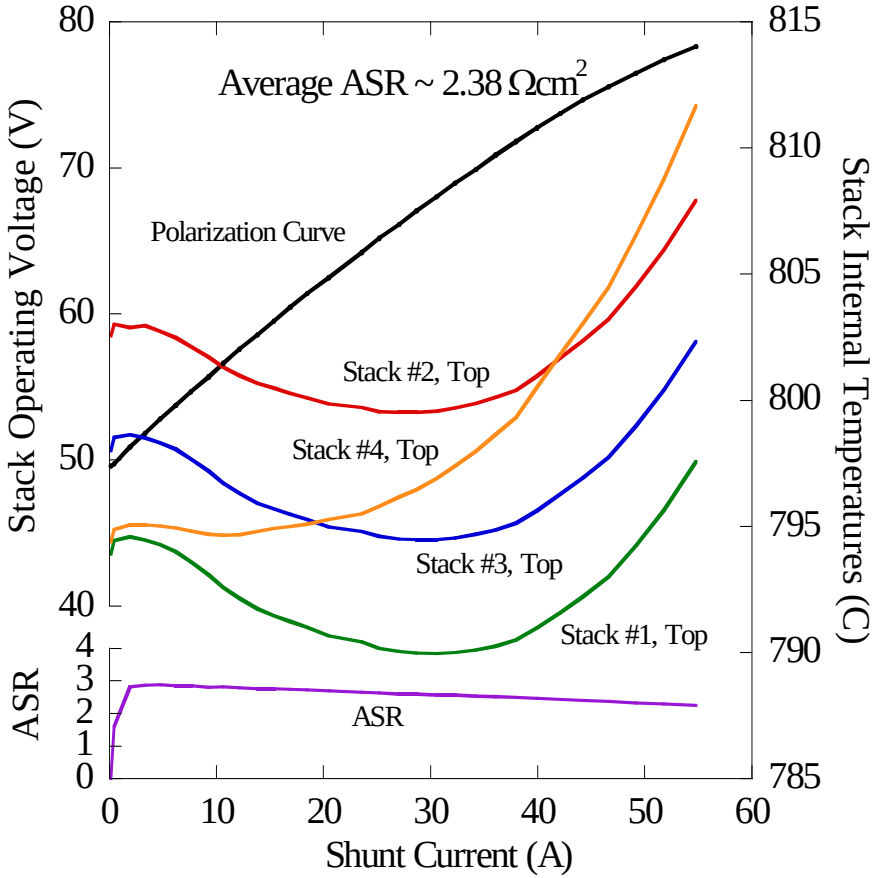
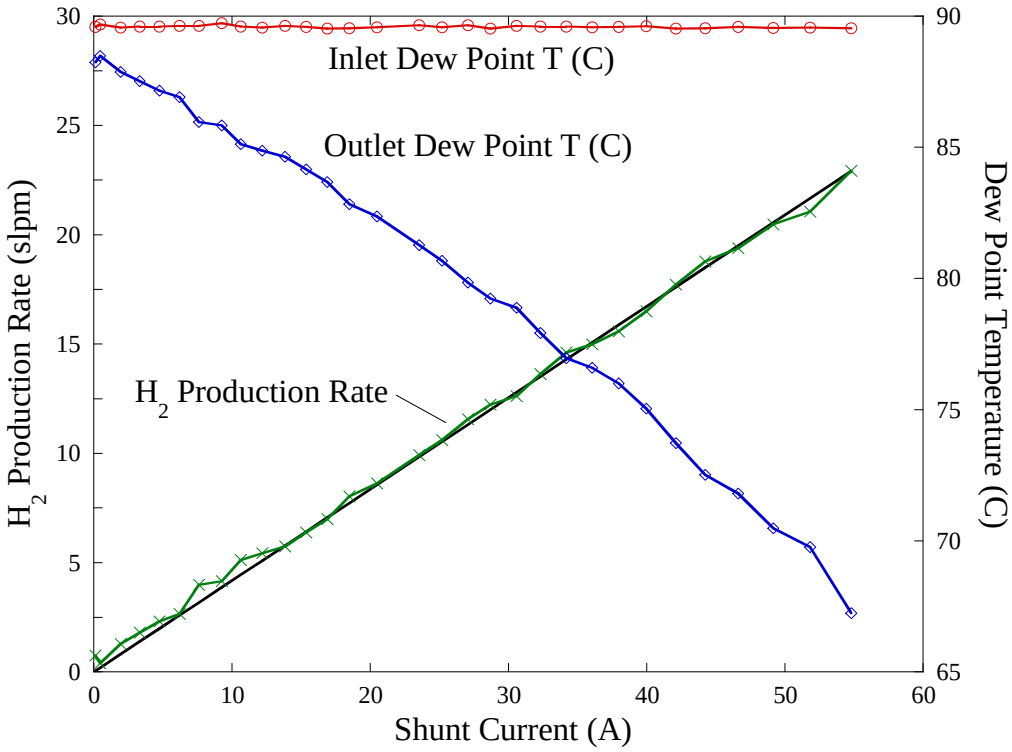
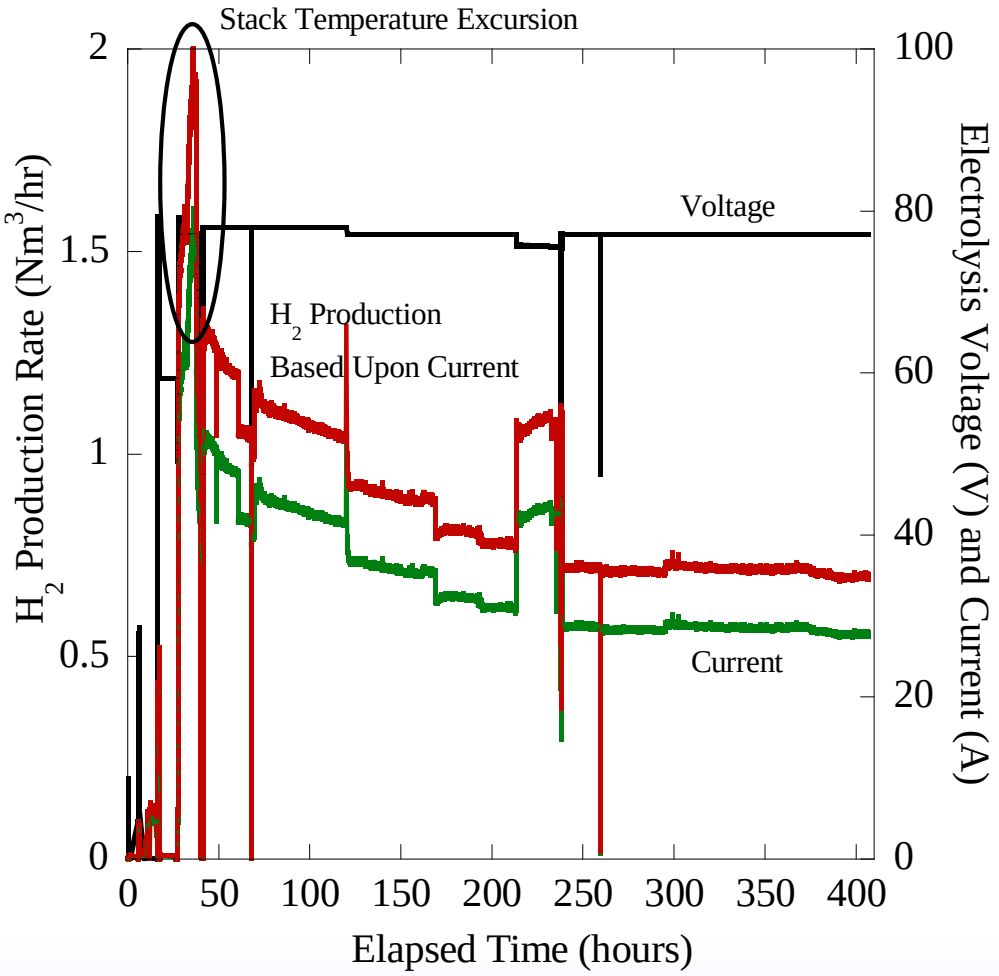
ILS Module Sweep Data





Overall ILS Data



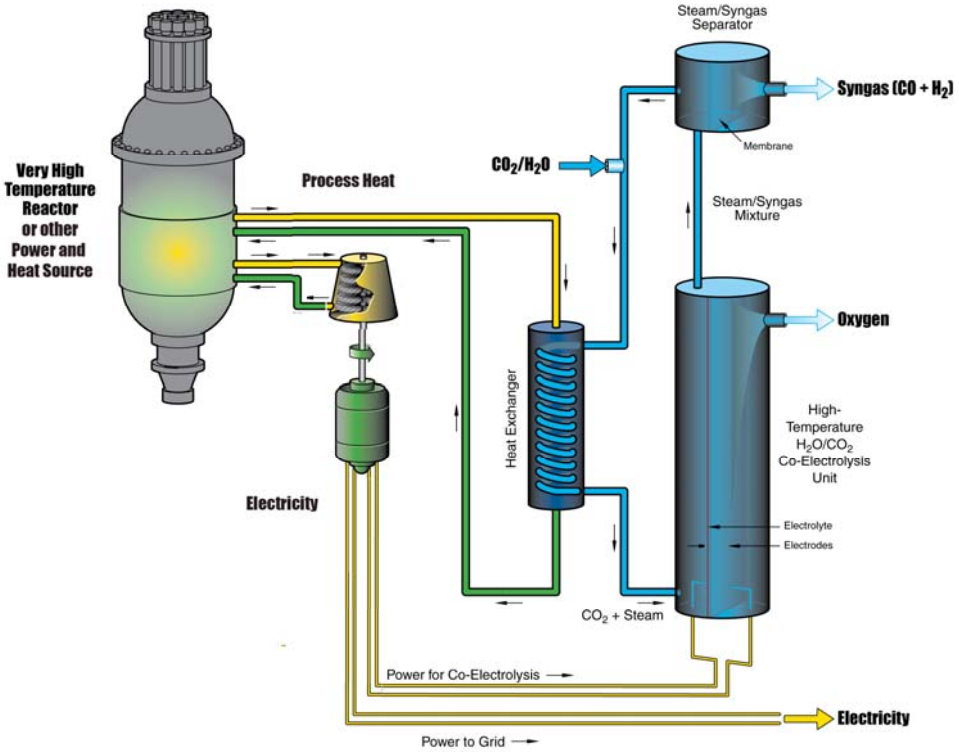
One additional experimental problem:

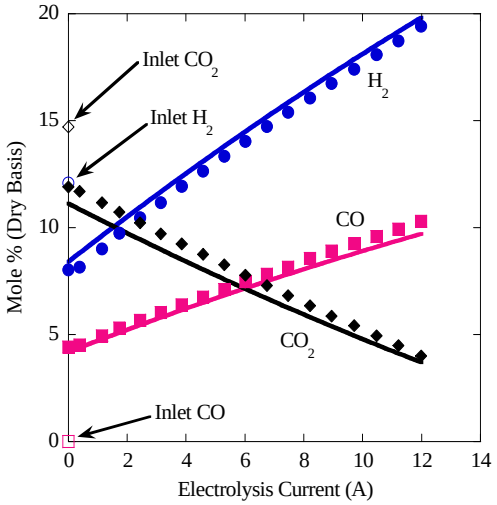
Bias voltages arising from intra-stack instrumentation

Not a problem for short stacks

Next iteration – separate DAC for intra-stack instrumentation

Syntrolysis: Co-Electrolysis of CO_2 and Steam to produce CO and H_2 (synthesis gas)





Syngas

$$2\,H_2O + CO_2 \rightarrow 2\,H_2 + CO + 1.5\,O_2$$

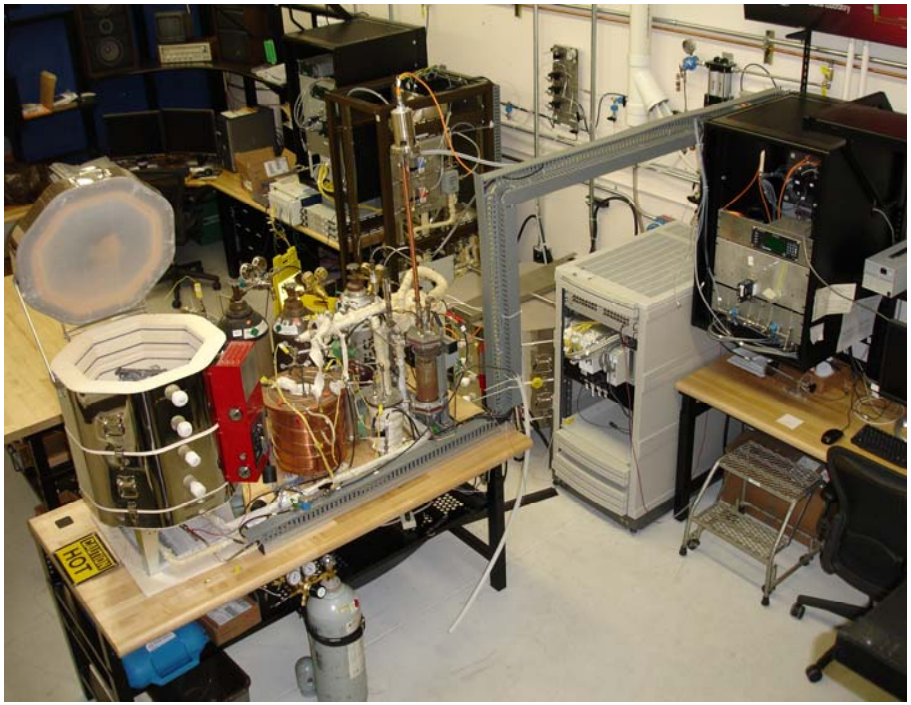
(**demonstrated 2006 and 2007 at INL and Ceramatec**)

Application: Carbon-neutral Production of Synthetic Diesel and Jet fuels via the Fischer-Tropsch process

$$n\mathrm{CO} + (2n+1)\mathrm{H_2} \rightarrow \mathrm{C_nH_{2n+2}} + n\mathrm{H_2O}$$

using CO_2 from biomass sources and nuclear heat/electricity

INL Coelectrolysis Experiment



Conclusions

- Conventional electrolysis is available today
- High temperature electrolysis is under development and will be more efficient
- HTE Experimental results from 25-cell stack, 2x60-cell half-module and 4x60-cell full module, fabricated by Ceramatec,
  - Hydrogen production greater than 800 normal liters/hour was achieved in the half-module test for 2040 hours
  - The Integrated Laboratory Scale experiment operated with one module in Sept-Oct 2007, producing a maximum of 2.0 Nm^3/hr and an average of ~0.85 Nm^3/hr for 420 hours
- In the near-term hydrogen from nuclear energy will be used to upgrade crude and later to synthesize conventional gasoline and diesel fuel from renewable carbon sources
- In the long-term pure hydrogen from nuclear energy will power vehicles directly through fuel cells