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High Temperature Electrolysis for Hydrogen Production

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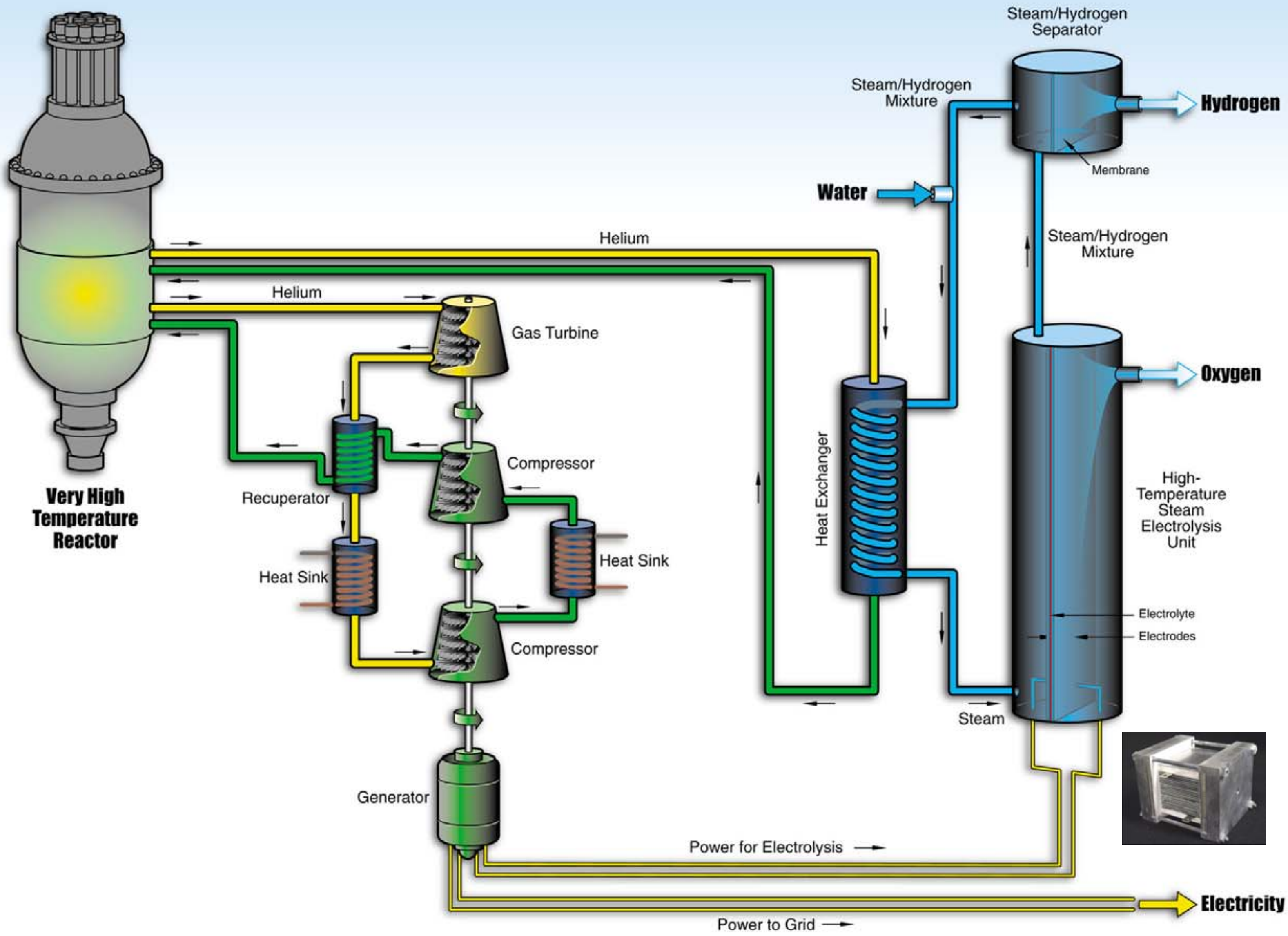
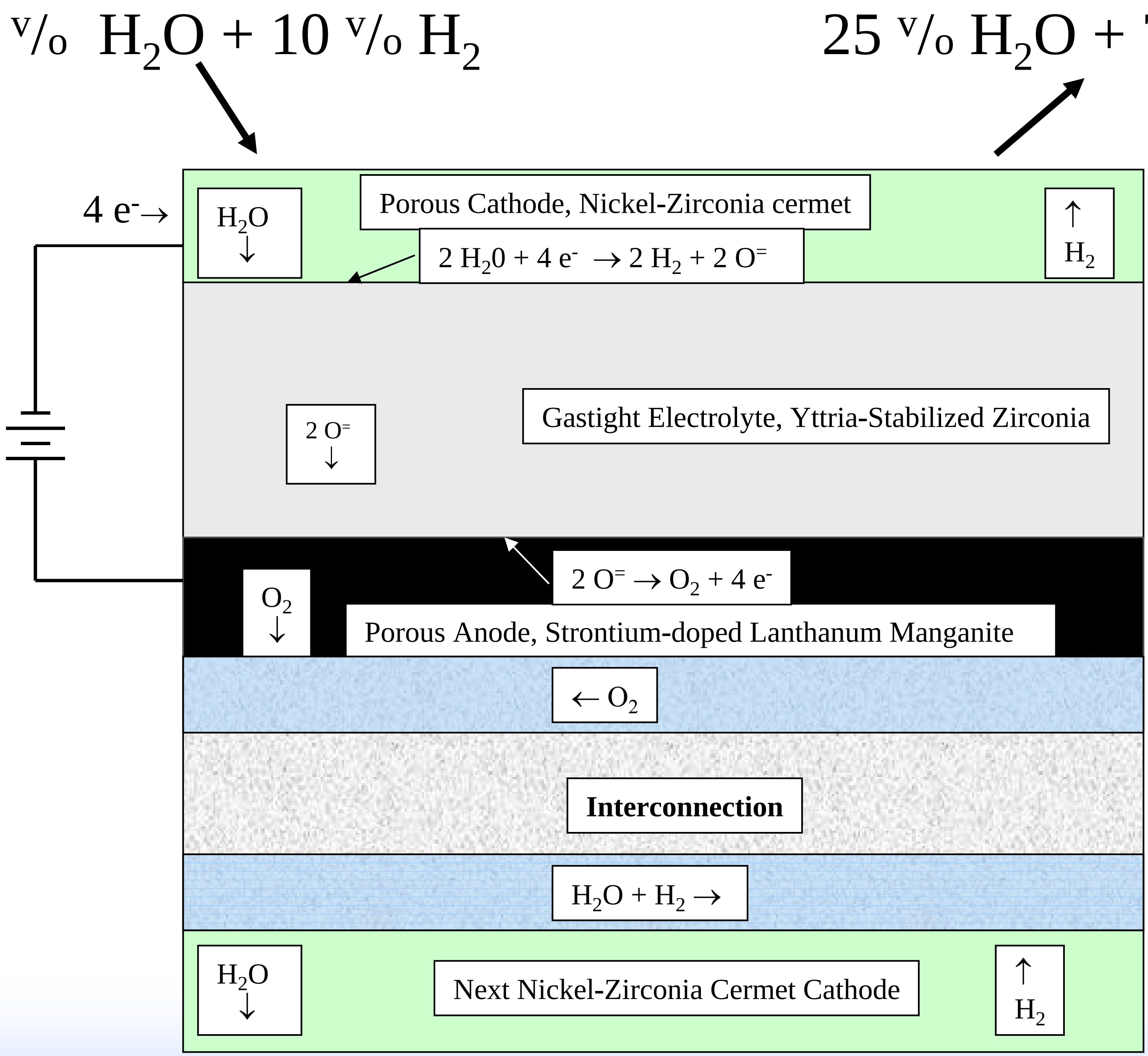
**Materials Innovations in
an Emerging Hydrogen Economy
Hilton Oceanfront
Cocoa Beach, Florida
February 26, 2008**

High Temperature Electrolysis Plant

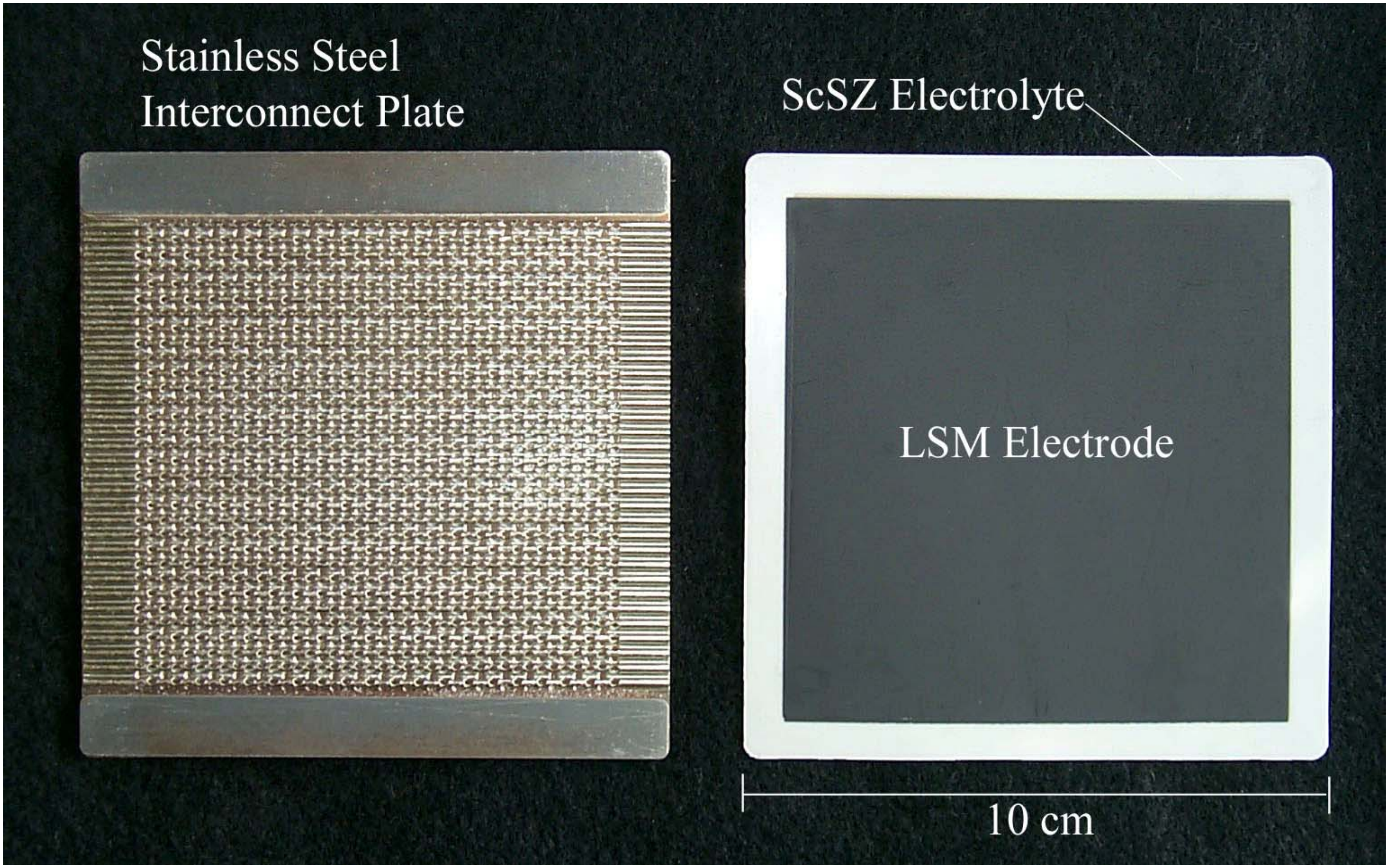


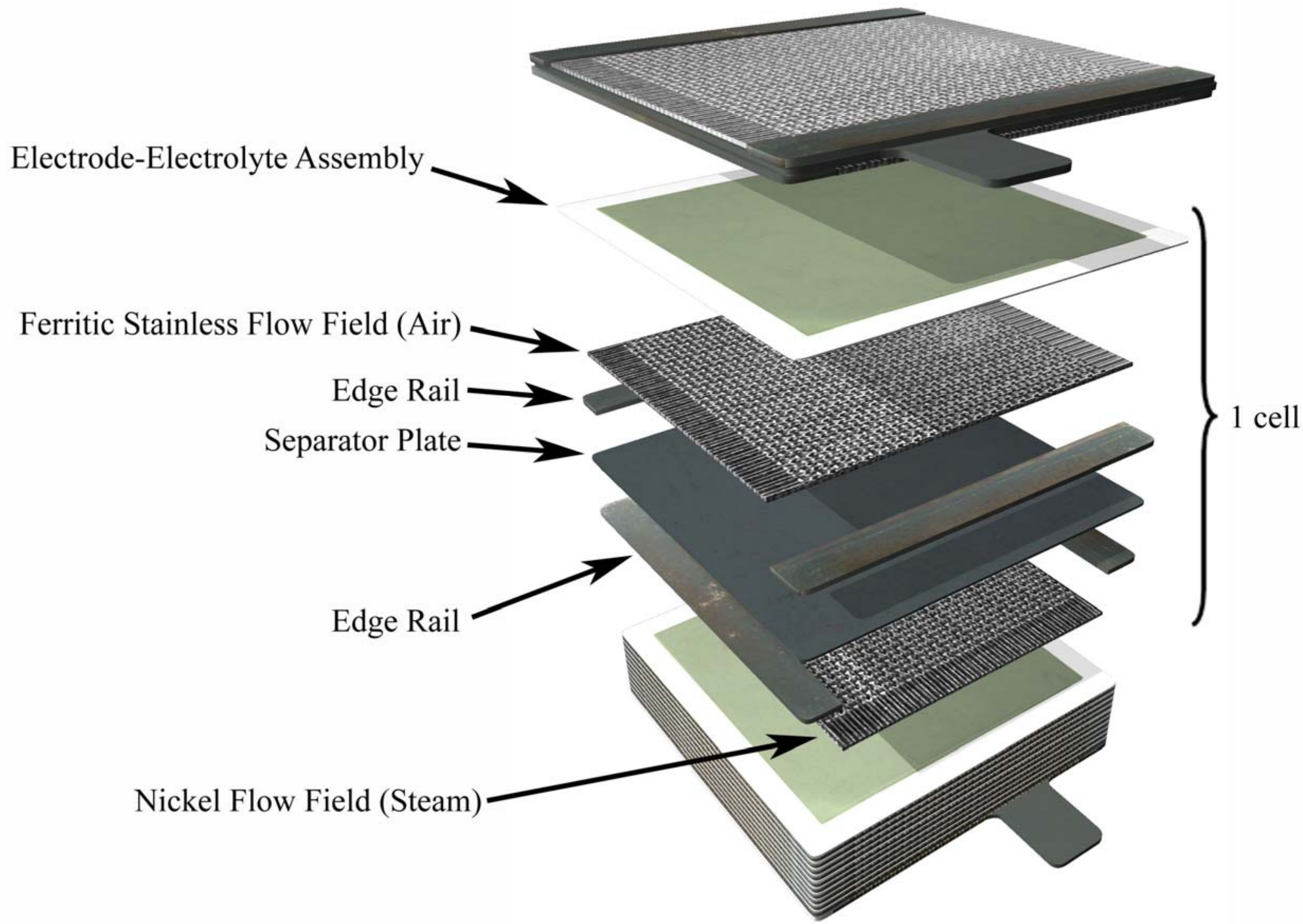


Typical thicknesses

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

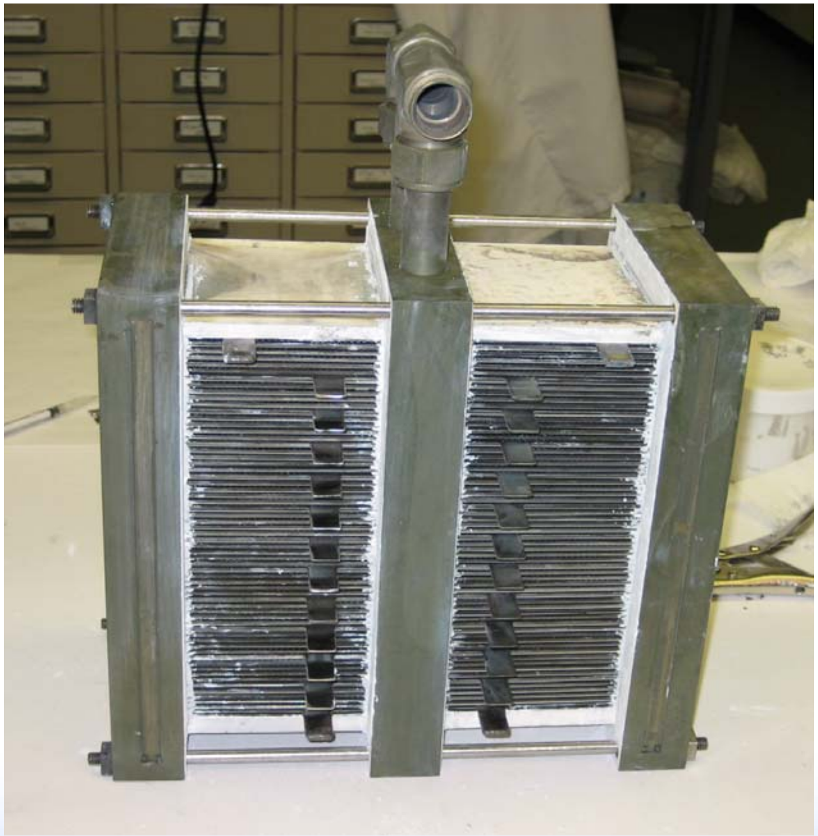



Electrode-Electrolyte Assembly
Ferritic Stainless Flow Field (Air)
Edge Rail
Separator Plate
Edge Rail
Nickel Flow Field (Steam)
1 cell

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



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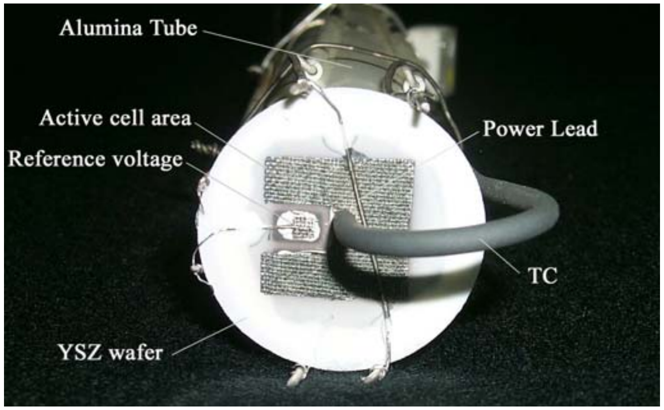
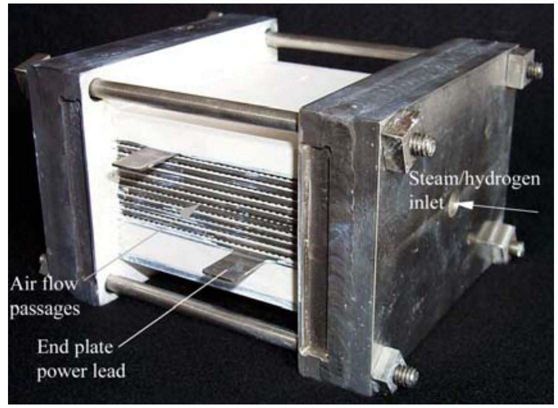
High Temperature Electrolysis: from Button Cells to the Integrated Laboratory Scale Experiment



Button cell (2003) 3.2 cm^2



10-cell stack (2004) 640 cm^2

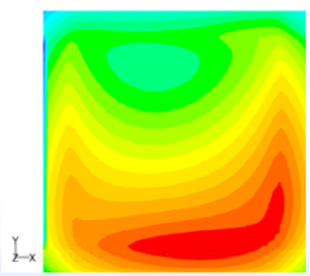
120-cell half-module (2006) 7,680 cm^2

Research Goals:

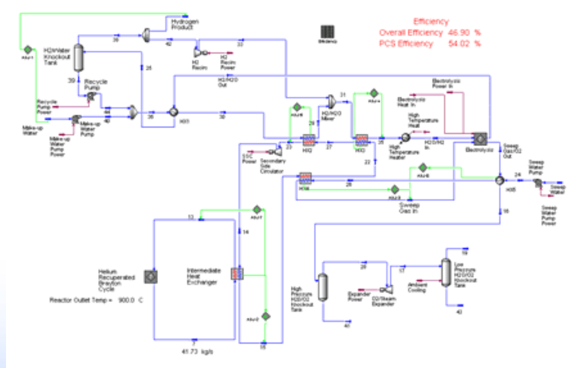
- Develop efficient solid-oxide electrolysis cells, building on solid-oxide fuel cell research
- Decrease cost, increase durability
- Determine reasons for long-term cell degradation
- Optimize plant designs
- Co-electrolyze CO_2 and steam to CO and H_2
- Develop designs to apply nuclear heat and H_2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

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

CFD and Flowsheet Analyses



Temperature profile of cell



Process Flowsheet for
Reactor-driven commercial plantl

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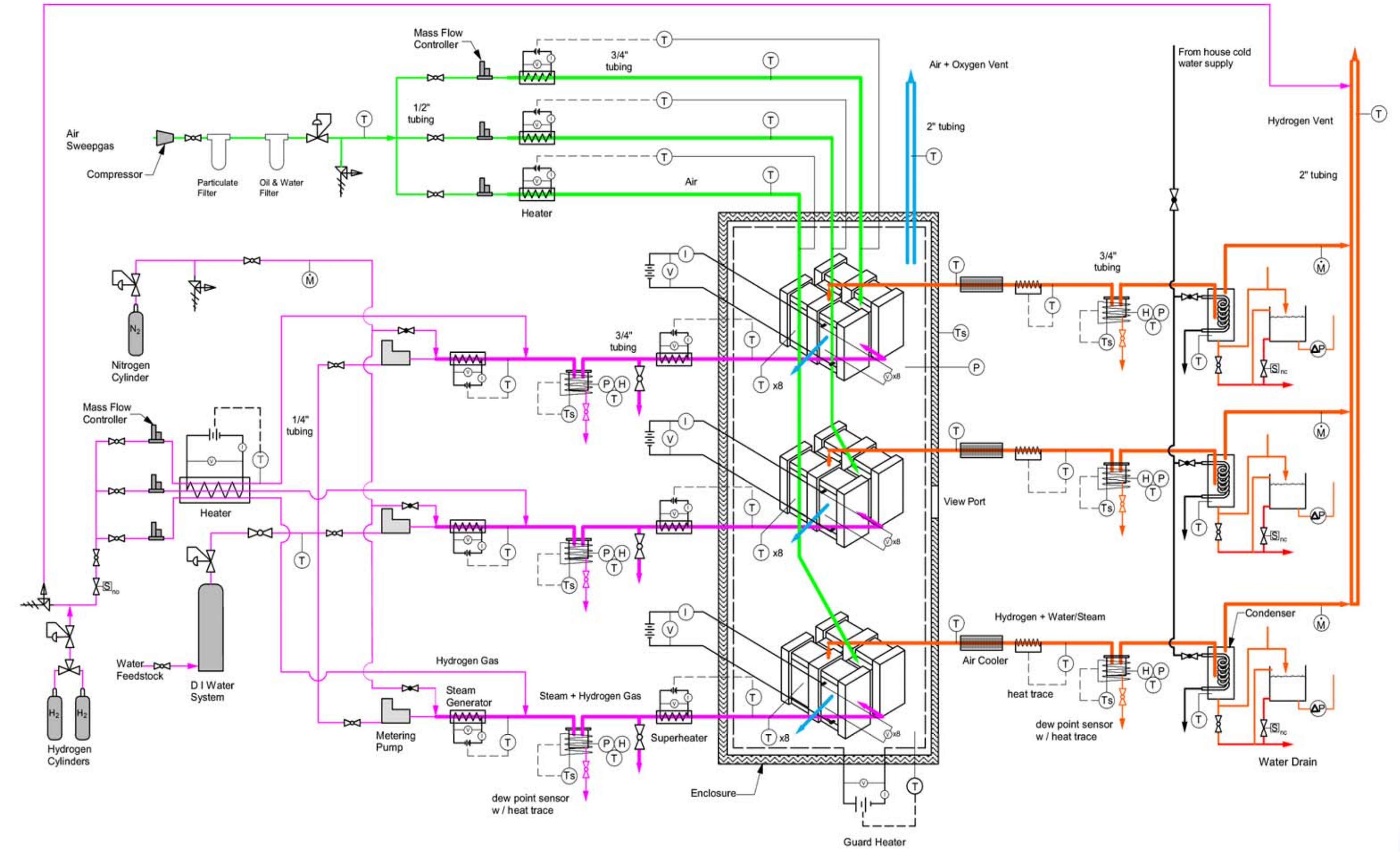
ILS Piping and Instrumentation



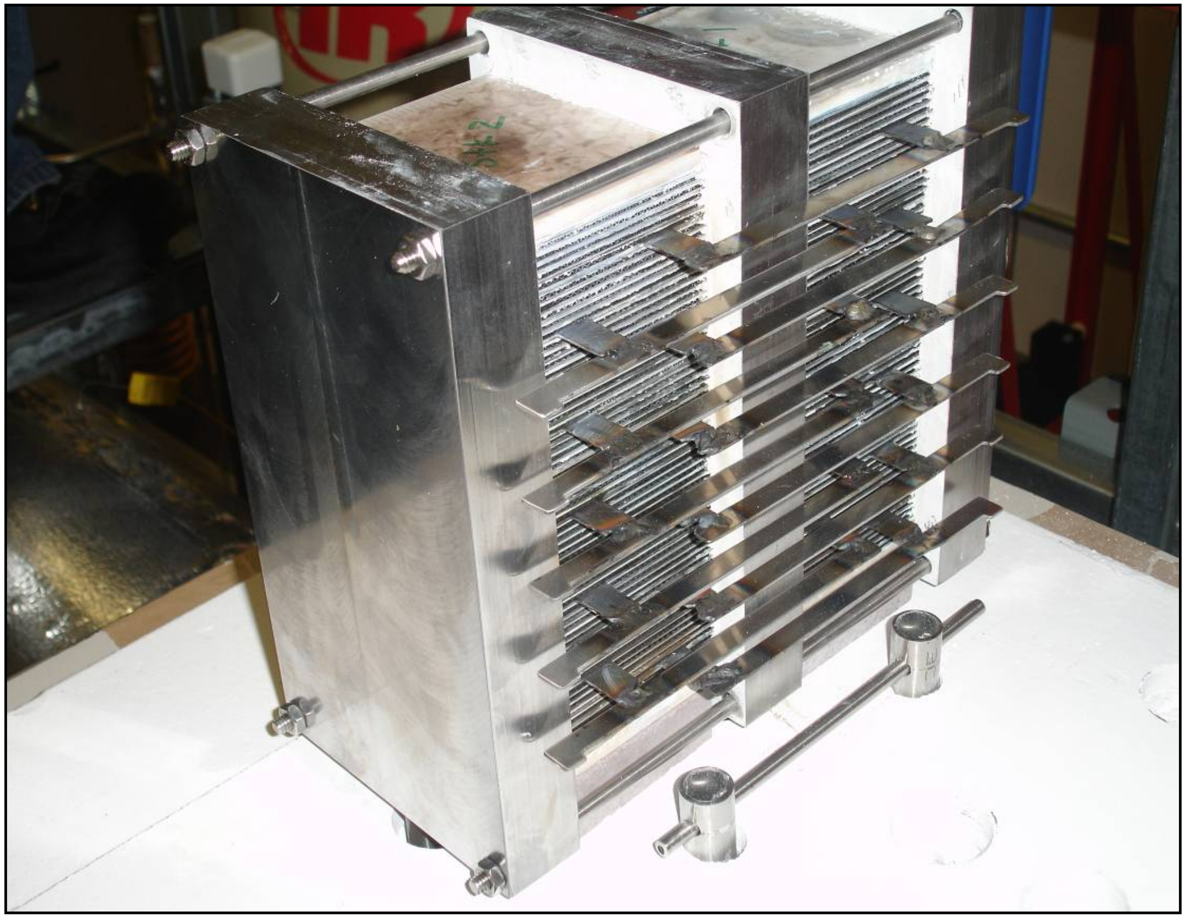
Comparison of nominal and extreme design cases.

	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

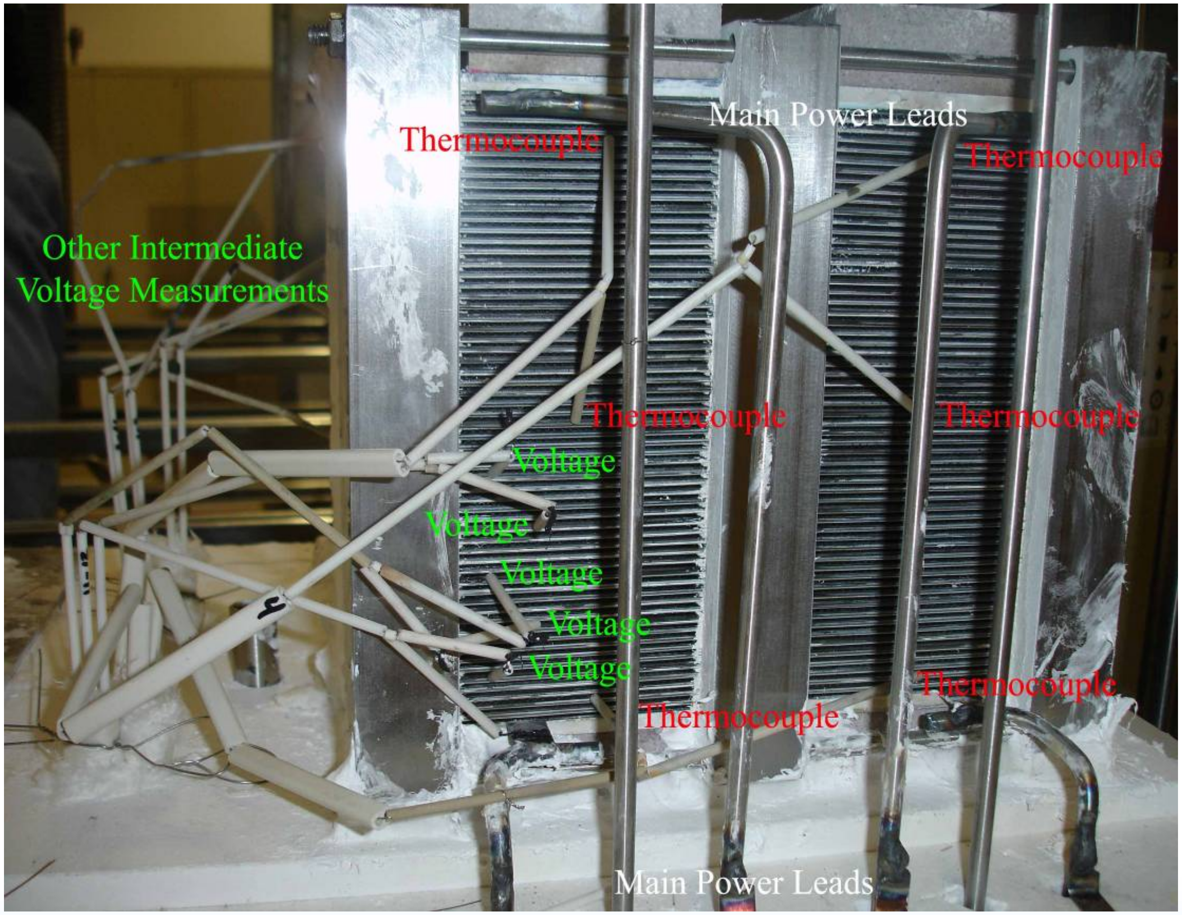
Assembled ILS Components

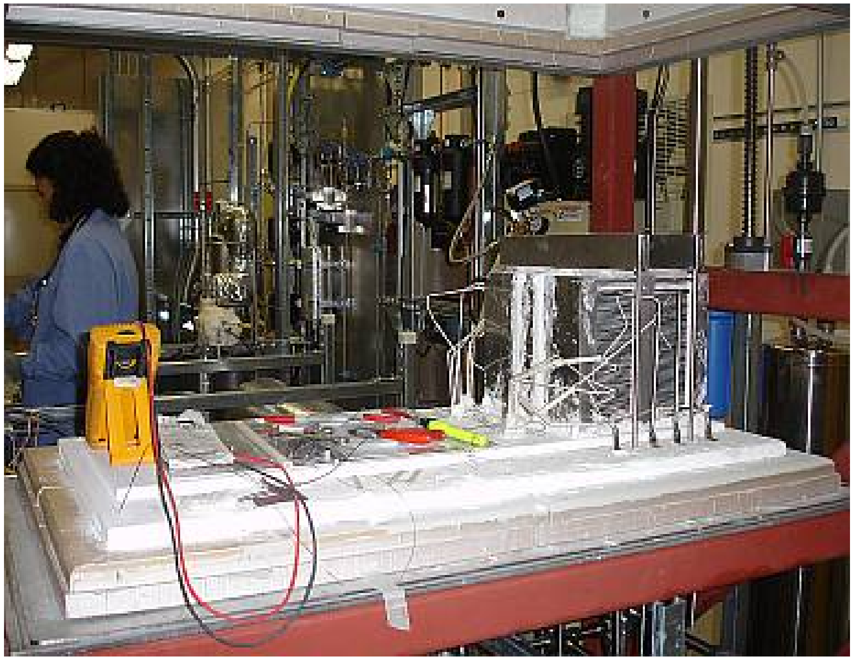
High-Temperature Electrolysis
Integrated Laboratory Scale Experiment July 16, 2007

ILS Module Installation



ILS Module Installation





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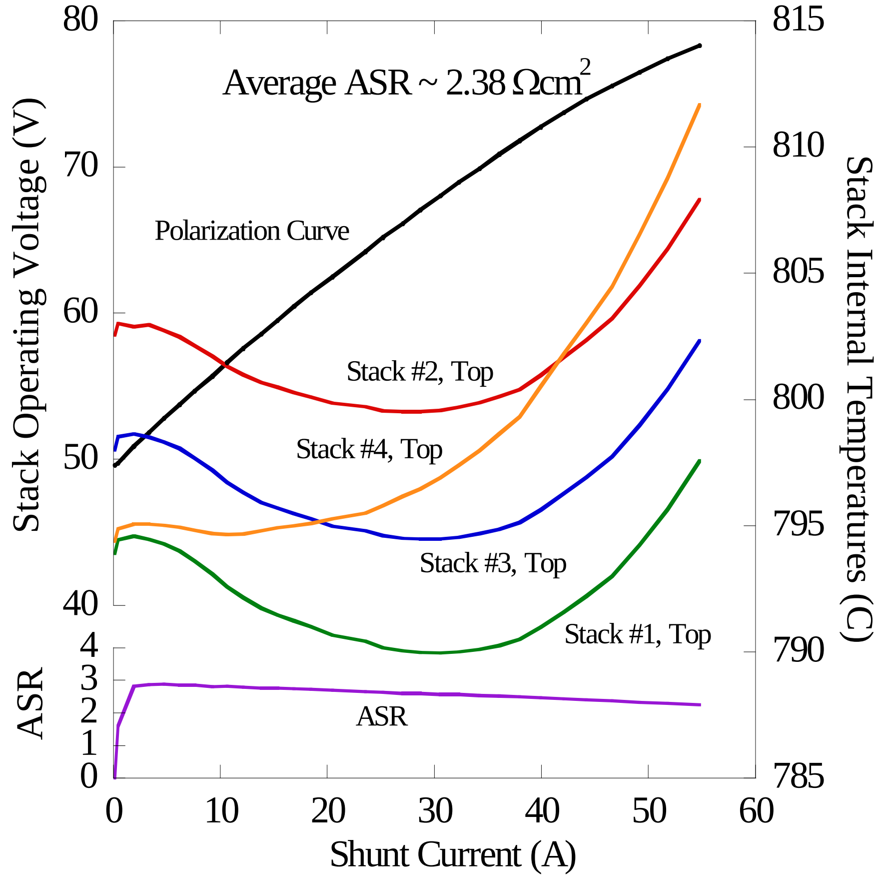
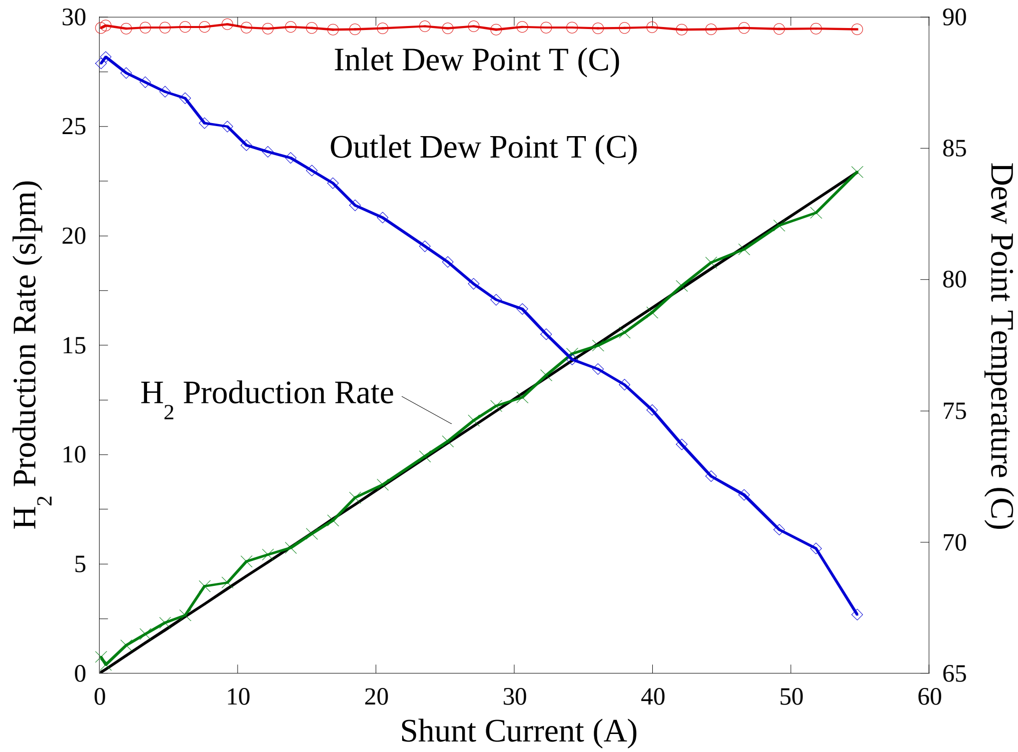
Start of Testing

Initial operations began Aug 24, 2007

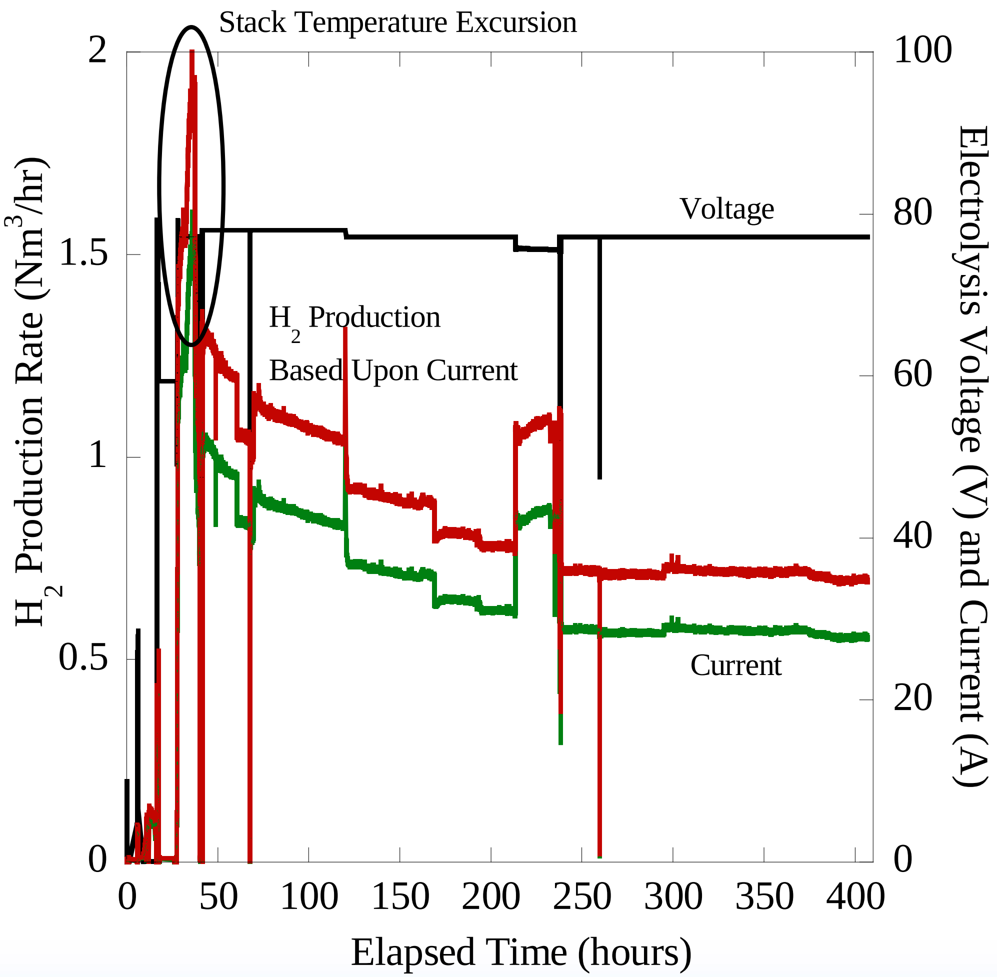
Module testing began Sept 24, 2007

ILS Module Sweep Data





Overall ILS Data



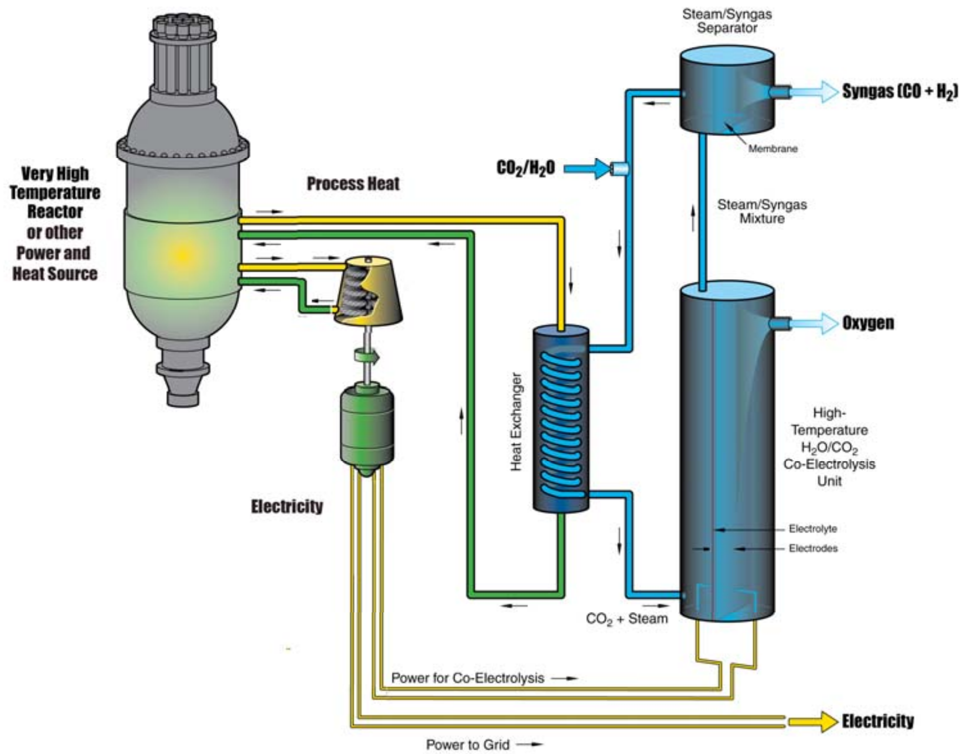
One additional experimental problem:

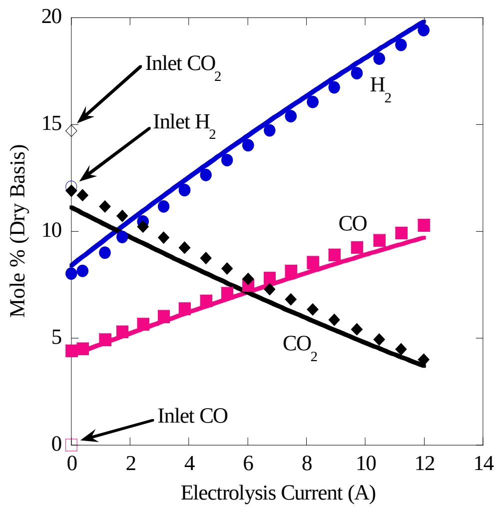
Bias voltages arising from intra-stack instrumentation

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

$$nCO + (2n+1)H_2 \rightarrow C_nH_{2n+2} + nH_2O$$

using CO_2 from biomass sources and nuclear heat/electricity

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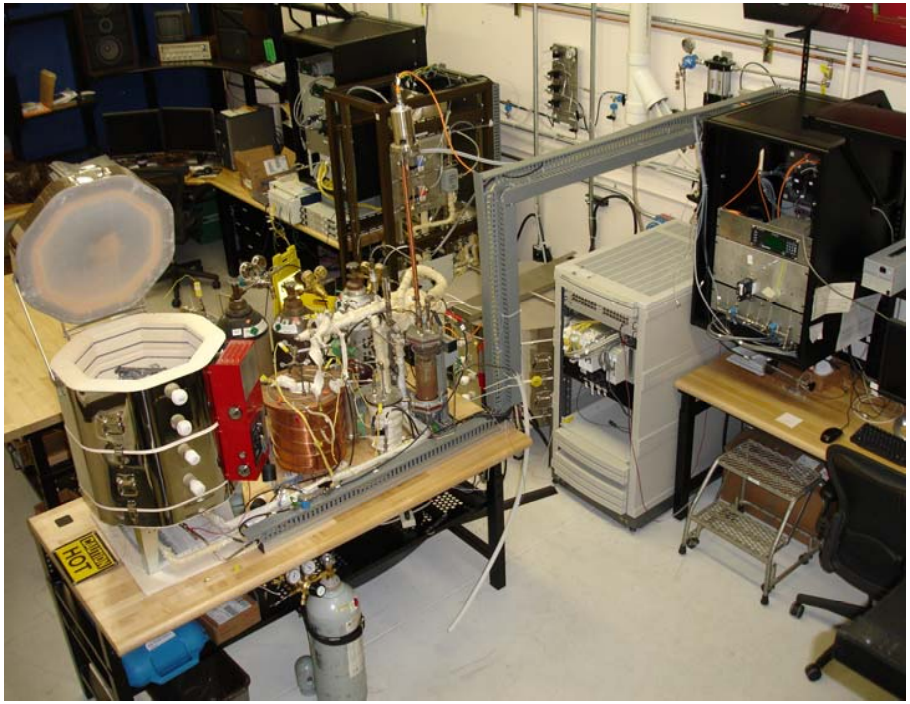
INL Coelectrolysis Experiment



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