Hawaii Hydrogen Center for Development and Deployment of Distributed Energy Systems

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TV3

Overview

Timeline

- October 2004
- June 2006
- 15% (through 3/31/05)

Budget

- Total $4.3 mm
  - DOE 3.1 mm
  - Cost share 1.2 mm
- FY05: $1.2 mm total

Barriers addressed

- See next slide

Partners

- HI Dept. of Business, Economic Development & Tourism
- City and County of Honolulu
- HELCO/HECO
- The Gas Company
- AirGas
- Sandia National Laboratory
- MVSystems
- ClearFuels Technology
- New Mexico Tech
- Hawaiian Commercial & Sugar Co.
- Center for a Sustainable Future
- PICHTR
- Sentech

Barriers

- **Hawaii Hydrogen Power Park**
  - **B, C, E, H, I: Hydrogen Infrastructure Technology Validation**
  - **G, H: Hydrogen Safety**
- **Hydrogen Fuel Quality Assessment**
  - **A, C: MEA Materials and Components – durability and performance**
- **Renewable Hydrogen Production: Photoelectrochemical**
  - **AP, AQ: Materials efficiency and durability**
  - **AS: Device configuration design**
- **Renewable Hydrogen Production: Biomass**
  - **W: Cost reduction of biomass gasification**
  - **W: Gasifier product gas cleanup**
  - **W: Basic research on advanced hydrogen purification**

Objectives

- **Hawaii Hydrogen Power Park:** Develop and operate a test bed for validation and characterization of hydrogen technologies in a real world setting which will:
  - Integrate a renewable energy source with an electrolyzer, fuel cell and hydrogen-fueled internal combustion engine to power a building
  - Collect real-world cost and engineering data
  - Outreach to local authorities and the general public
- **Hydrogen Fuel Quality Assessment:** Characterize the effect of trace level contaminants on the performance and durability of PEM fuel cells
  - Collect data suitable for use in development of fuel quality guidelines
  - Develop and validate test plan and test protocols

Objectives

- **Renewable Hydrogen Production – Photoelectrochemical:** Develop novel multi-terminal device configurations which offer potential for higher efficiency photoelectrodes for solar H_2 production than achievable with current thin film approaches
  - Develop high efficiency CIGS solar cells compatible with 4-terminal device
  - Demonstrate high efficiency 4-terminal photoelectrodes
- **Renewable Hydrogen Production – Biomass:** Investigate critical steps for H_2 production from biomass, including biomass & syngas conditioning/cleanup, optimal pathway assessment & characterization of selected biomass gasification technology
  - Evaluate H_2 production potential of the Pearson Technologies' gasification process
  - Develop processes for tar reforming and H_2 purification processes at the HNEI gasifier facility
  - Analyze H_2 yield potential of commercial gasifier facilities under development in Hawaii

Approach

- **Hawaii Hydrogen Power Park**
  - Leverage Phase I SEP Power Park experience at Hawaii Fuel Cell Test Facility which includes a Stuart Electrolyzer, high pressure hydrogen storage system, and 5kW Plug Power Fuel Cell
  - Work closely with SNL modeling group to identify appropriate data base insuring broadest applicability of results
  - Select a show-case site which contributes to outreach objectives – Hawaii Gateway Energy Center on the Big Island
- **Hydrogen Fuel Quality Assessment:**
  - Leverage DOD investment in Hawaii Fuel Cell Test Facility
  - Work in close collaboration with industry, SAE, USFCC, and DOE working groups to develop detailed test plans and test protocols
  - Use 3rd party, non-proprietary MEAs to allow post-test analysis

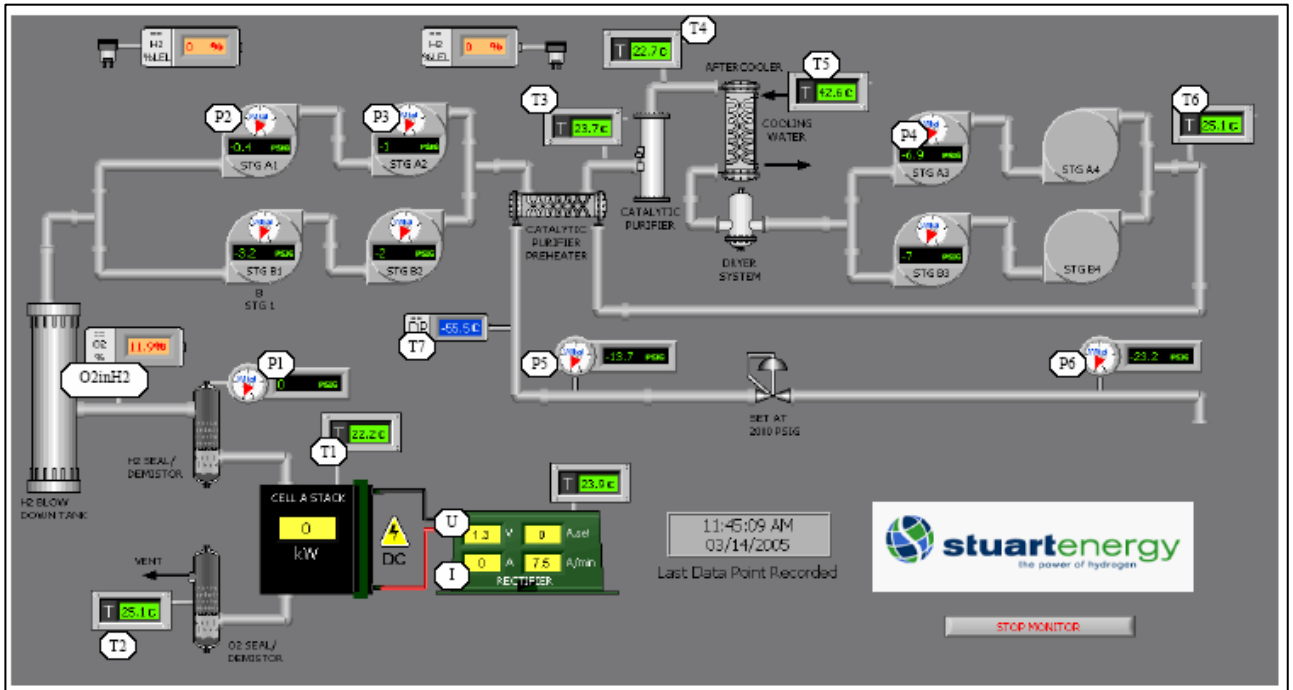
Approach

- **Renewable Hydrogen Production: Photoelectrochemical**
  - Integrate existing high-efficiency CIGS (HNEI) and a-Si (MVSystems) technologies to demonstrate high efficiency concepts
  - Utilize modeling to identify highest-performance device configurations
  - Utilize detailed optoelectronic characterization of materials and devices for component optimization and model input parameters

- **Renewable Hydrogen Production: Biomass**
  - Conduct parametric gasification tests on Pearson Technologies' pilot plant (4.5 Mg per day) in Aberdeen, Mississippi
  - Develop skid-mounted, producer-gas clean-up test bed to include tar reforming and H_2 purification unit operations
  - Use skid-mounted clean-up system at other biomass facilities in Hawaii to evaluate H_2 yield potential and cost projections

Technical Accomplishments/Progress/Results: Hydrogen Power Park

- Electrolyzer fully operational
- Fuel cell being commissioned – data acquisition to commence in May 05
- Data acquisition system designed and installed:
  - Instrumentation plan developed with SNL
  - Full characterization of electrolyzer at various power levels

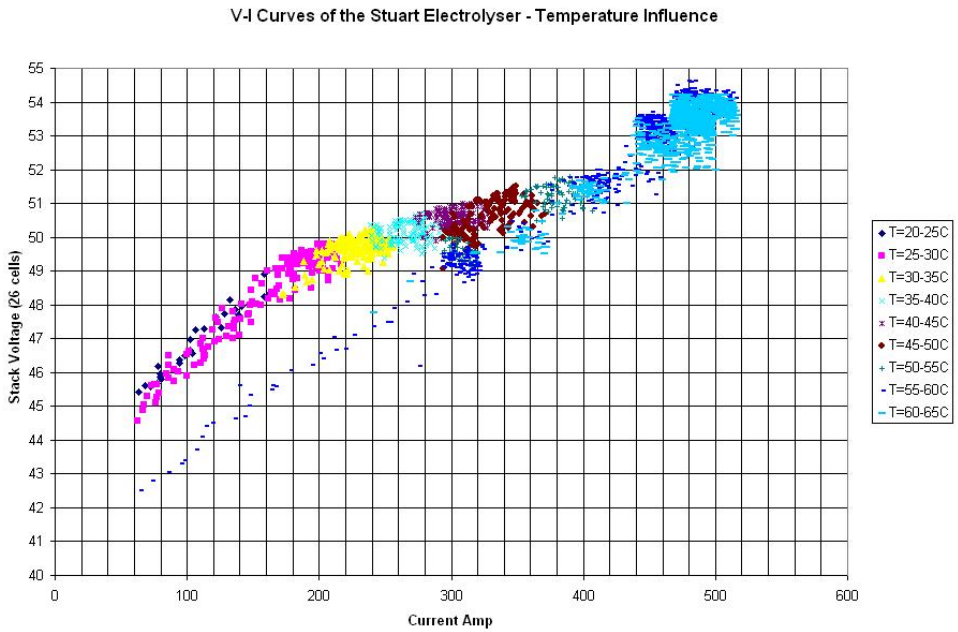


Temperatures (degree C): 1) Cell (*CellATemperature*), 2) O2 Seal (*O2SealTemperature*), 3) H2 before purifier (*PurifierInTemperature*), 4) H2 after purifier (*PurifierOutTemperature*), 5) cooling water (*CoolantTemperature*, cooling the cells, the H2 Seal and the Catalytic Water Aftercooler), 6) Discharge T (*DischargeTemperature*), 7) Dew Point Analyser output (*DewPointAnalyser*)

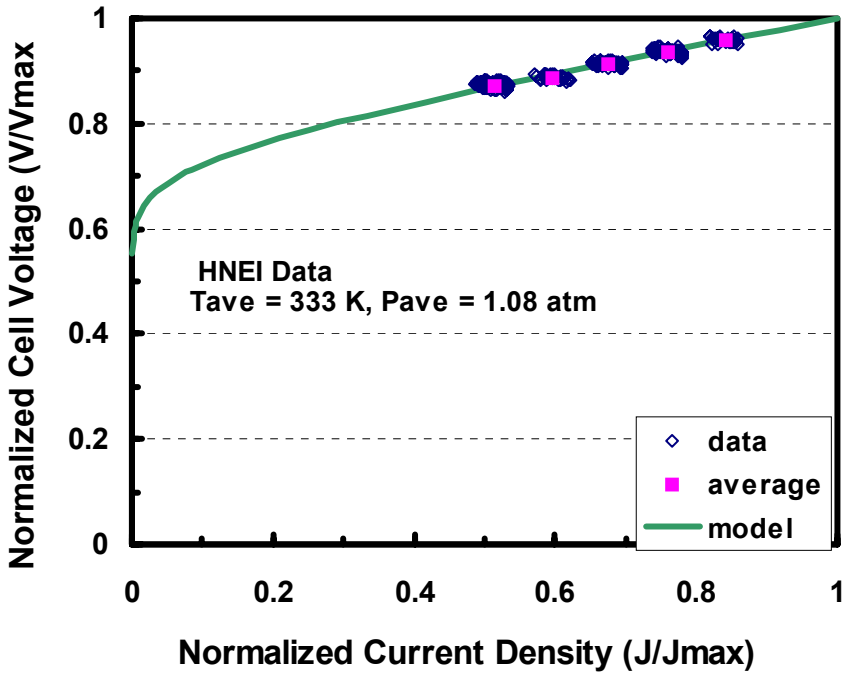
- Labview interface showing 13 data collection points on electrolyzer
- Additional sensors being added including H_2 output mass flow meter

Technical Accomplishments/Progress/Results: Hydrogen Power Park

- SNL processing initial data – see TV-P-4 for initial results
- HNEI analyzing data both “in-house” and sending to SNL for further analysis



Effect of Temp on Electrolyzer HNEI Analysis



Calibration of Electrolyzer Polarization Curve SNL Analysis

Technical Accomplishments/Progress/Results: Hydrogen Power Park

- Electrolyzer H_2 purity testing conducted
- Hydrogen quite clean

Component	Level	Component	Level
Oxygen	**<1 ppmv**	**Nitrogen**	**<1 ppmv**
Methyl Mercaptan	**<1 ppbv**	**Methane**	**<0.5 ppmv**
Ethane	**<0.5 ppmv**	**Ethene**	**< 0.5 ppmv**
Carbon Dioxide	**0.48 ppmv**	**Carbonyl Sulfide**	**<1 ppbv**
Carbon Monoxide	**<1 ppmv**	**Water**	**<1 ppmv**
Total Volatile Petroleum Hydrocarbons			**<0.017 ppmv**

Smart Chemistry Report 5 Feb 05 of H2 samples taken 21 Jan 05

Hawaii Fuel Cell Test Facility

Site of Power Park Phase I & Fuel Quality Assessment Work

Test stands

Electrolyzer

Gas storage

- Demonstrated 24/7 operation
- Full time engineering support
- Extensive safety systems
- Computerized process control and data acquisition
- Secure lines for external monitoring and data transfer

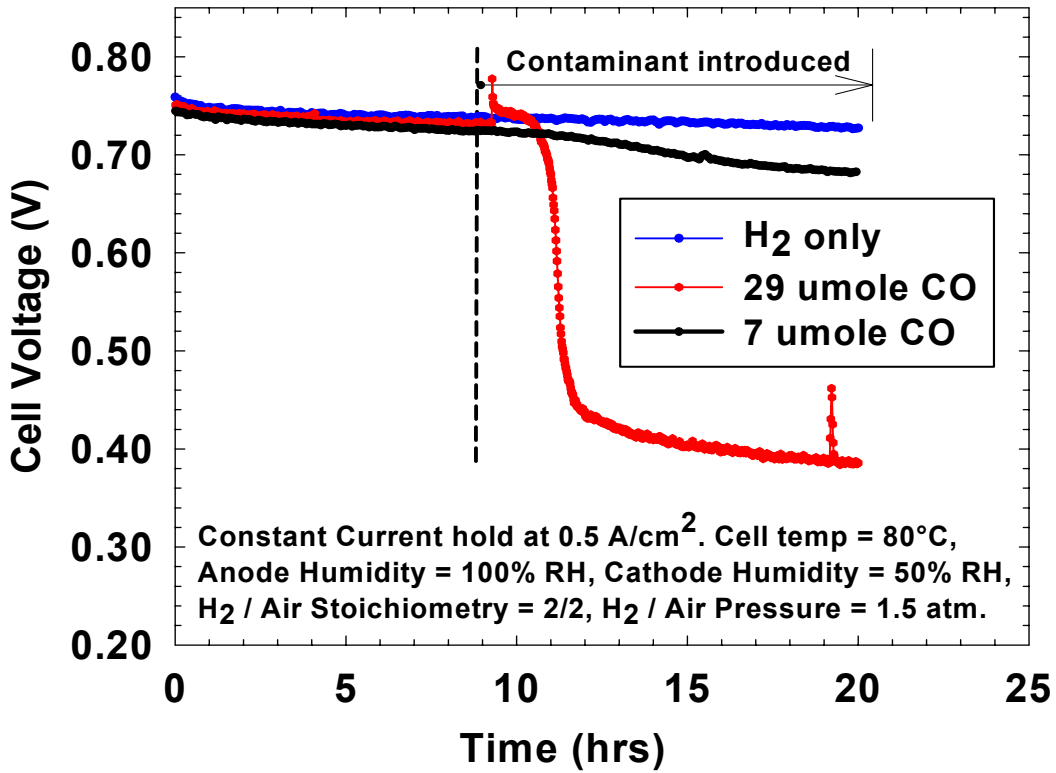
- On-site hydrogen generation
- Wide selection of gases (H_2, reformate, O_2, air, fuel contaminants)
- On-line high resolution gas analysis

Technical Accomplishments/Progress/Results: Fuel Quality Assessment

- Participating in SAE, USFCC and DOE working groups for development of test protocols and work plans
- Fuel cell hardware from General Motors(GM), Ballard Power Systems(BPS), and UTC Fuel Cells on site – reference and test cells provided
- Protocols for MEA assembly, cell build, cell conditioning and operation, and manufacturer specific test diagnostics transferred to HNEI
- Additional test stand capacity specified and orders placed

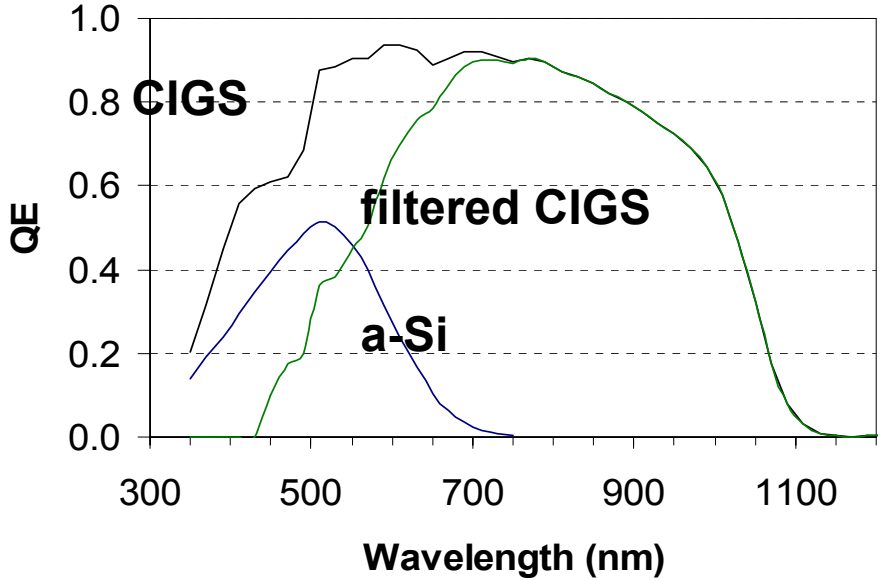
Technical Accomplishments/Progress/Results: Fuel Quality Assessment

Effect of CO Contamination on Cell Performance



- Performance of HNEI test stations verified by comparison of HNEI test results with UTC and BPS test data
- Shakedown testing on GM and BPS cells with CO ranging from 7 to 29 ppm completed

Technical Accomplishments/ Progress/Results: Photoelectrochemical H_2 Production



4-Terminal Device	V_{OC} (mV)	J_{SC} (mA/cm^2)	FF	PV Efficiency
top (thin a-Si)	933	7.09	0.75	4.96%
bottom (CIGS)	604	24.77	0.71	10.62%
total				**15.58%**

- Stand-alone CIGS solar cell: 14.04%
- >15% PV efficiency possible using currently available materials
- Reduction of reflection losses at interfaces critical for high efficiency

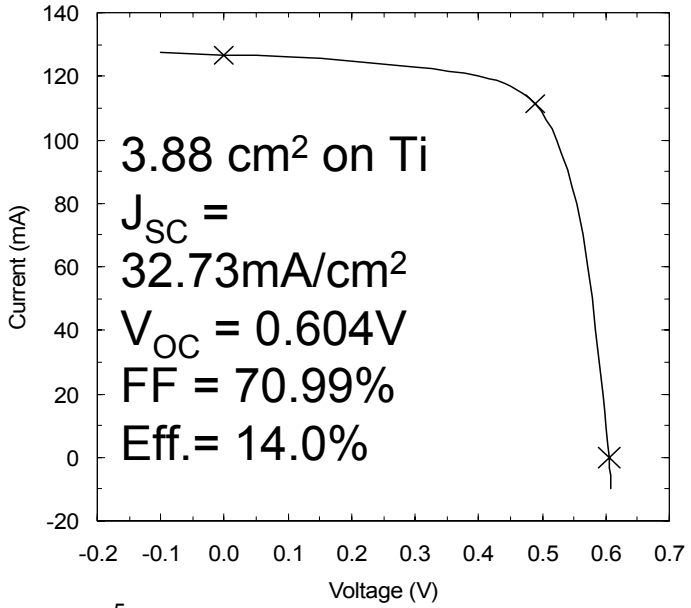
Technical Accomplishments/ Progress/Results: Photoelectrochemical H_2 Production

Process modifications to improve robustness of HNEI's high efficiency fabrication process have been implemented:

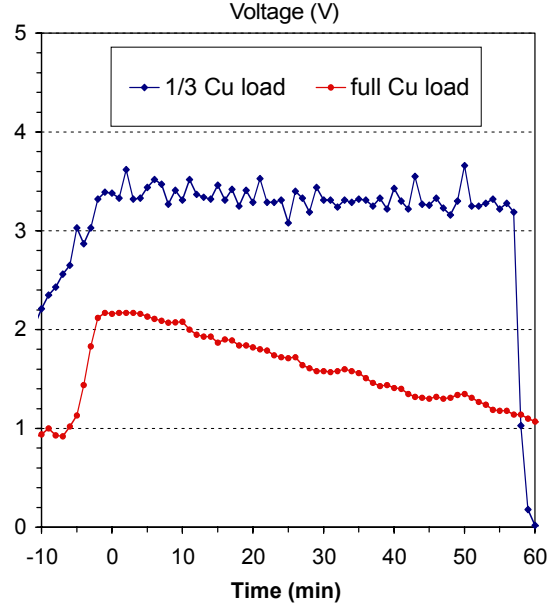
- **CIGS Process Endpoint Detection**
  - Pyrometer for substrate temperature monitoring is being installed
- **CIGS Evaporation Source Stability**
  - Cu source fill level optimized for more stable deposition rate

NREL

Daystar/HNEI



TCO by NREL

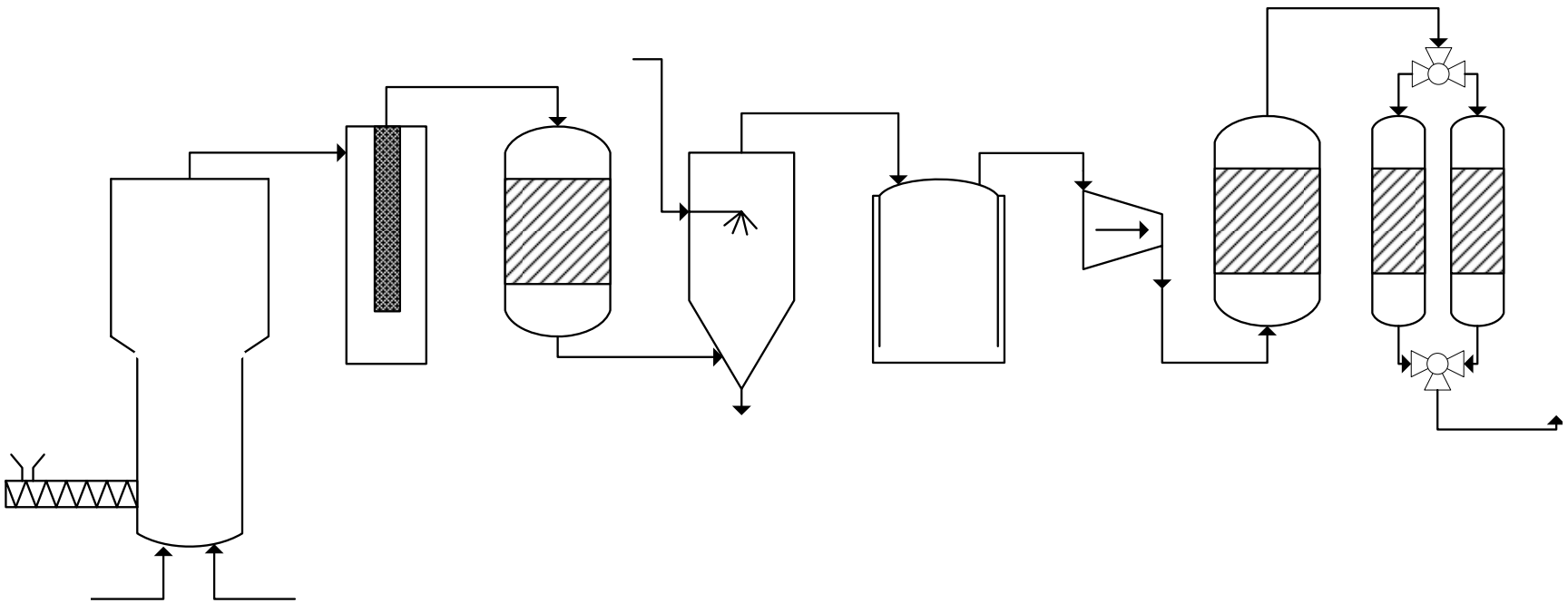


Technical Accomplishments/Progress/Results: Renewable Hydrogen – Biomass

- Five short-duration preliminary parametric tests have been conducted at Pearson Technologies' 4.5 Mg per day (5 tpd) pilot plant in Mississippi
  - Atmospheric pressure, entrained-flow reactor utilizing steam as the oxidizer
  - Reactor exit temperature 925°C
  - Average inert-free gas composition of 51% H_2, 31% CO, 6% CH_4, 12% CO_2
  - Gas yield of 1.3 m^3 gas per kg biomass (at STP)

Technical Accomplishments/Progress/Results: Renewable Hydrogen – Biomass

- Preliminary design of skid-mounted, producer-gas clean-up test bed unit completed



H_2O In

Wet

Responses to Previous Year Reviewers' Comments Hawaii Hydrogen Power Park

Narrow the technical approach. Use just renewable for H_2 production instead of using reformers with multi fuels.

- Scope reduced to use renewables to power electrolyzer.

Delay in fuel cell selection and installation.

- Fuel cell procured, installed, commissioned. Data acquisition to start in May 05.

No quantifiable Goals.

- Data provided to SNL for quantitative analysis.

Add FC manufacturer to project team.

- Supplier/Client relationship with Plug Power is strong. Plug Power is responsive to project's requirements.

Plan to install either multiple fuel cell modules or larger units.

- Current fuel cell is compatible with energy needs of Gateway Energy Center.
- Budget precludes significant increase in FC.

Future Plans

- **Hawaii Hydrogen Power Park:**
  - Relocate Power Park to Hawaii Gateway Energy Center
  - Investigate opportunities to use Big Island geothermal, wind and biomass renewable resources for H_2 production
  - Continue data acquisition task and work with SNL
  - Identify additional partners/technologies for incorporation into Power Park
    - HELCO: grid reliability issues
    - GasCo: clean energy fuel station
    - Collier technologies: hydrogen IC engine
- **Hydrogen Fuel Quality Assessment:**
  - Install additional test stands
  - Complete characterization of CO and H_2S contaminant effects
  - Initiate testing using other contaminants identified by USFCC and DOE working group

Future Plans

- **Renewable Hydrogen Production: Photoelectrochemical**
  - Continue development of high-efficiency CIGS solar cells compatible with PEC device integration
  - Design, model and fabricate 4-terminal device compatible with H_2-production requirements using best available materials
- **Renewable Hydrogen Production: Biomass**
  - Complete longer-term testing at Pearson Technologies' plant
  - Complete design, fabricate, and operate skid-mounted, producer-gas clean-up unit at the HNEI gasifier facility
  - Transport skid-mounted unit to Kauai for evaluation of 45 Mg per day gasifier under development at the Gay & Robinson Sugar factory

Publications and Presentations

Hawaii Hydrogen Power Park
Conference Presentations:

R. Rocheleau, J. Ewan – "Power Park", US DOE Workshop on Distributed Energy Resources, Honolulu, HI, 24 August 04

R. Rocheleau, E. Miller, J. Ewan, C. Jensen, M. Kaya, J. Hurwitch, T. Quinn, "Hydrogen Programs in Hawaii", 2004 NHA Conference

T. Gillen, Documentary Video "Sustainable Hawaii" featuring Power Park, August 2004

Fuel Purity Assessment
Conference Presentations:

T. Thampan, Keith Bethune, R. Rocheleau, "Impact of Hydrogen Quality on PEM Performance", submitted for 2005 Fuel Cell Seminar

R. Rocheleau, E. Miller, K. Bethune, D. Wheeler, "Full Scale PEM Testing at the Hawaii Fuel Cell Test Facility: Recent Progress", Electrochemical Society Meeting, October 2004

R. Rocheleau, Hydrogen Fuel Contaminant Tests: Status Report. Presented to the DOE Hydrogen Fuel Quality Working Group, March 2005, Washington, DC

Renewable Hydrogen Production – Photoelectrochemical
Conference Presentations:

B. Marsen, A. Madan, S. Dorn, S. Marsillac, F. Matsunaga, R. Rocheleau, and E. Miller, "Four-Terminal Solar Cell Based on High-Efficiency Cu(In,Ga)Se2 Device on Metal Foil", 206th ECS Meeting, Honolulu, 2004.

B. Marsen, S. Marsillac, S. Dorn, R. Rocheleau, "Effect of Selenium Effusion Rate on CIGS Thin Films Deposited at Low Substrate Temperature", 31st IEEE PVSC, Orlando, 2005

Hydrogen Safety

The Power Park and Fuel Quality Testing are the only projects with significant quantities of hydrogen. Other projects are lab-scale and much smaller.

- Most significant hydrogen hazard:
  - H_2 leak and fire from H_2 storage system
- Safety measures to deal with hazard:
  - "Design for Safety" as the overall design approach
  - Major storage components located outdoors
  - Automated safety monitoring and control system
  - Flash arrestors on all vents
  - Limit high pressure piping runs
  - Use of flow limiters and fail-safe shut-off valves
  - Security measures such as fencing, surveillance and signage
  - Training

Hydrogen Safety

- Most Likely H_2 Accident Scenarios:
  - Personnel error in operating the system
  - Failure of gas distribution components.
- Measures to deal with most likely accident:
  - As specified under Safety Measures
- Other serious safety concerns:
  - Vandalism and the need for a 24/7 security system
- Serious safety concerns to discuss with panel:
  - None at this time