Filling Up With Hydrogen 2000

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Technical Barriers Electrolysis

- Cost
- Siting System (emissions, codes and standards)
- Efficiency
- Grid Emissions + Connection to Renewable Power

General Goals

- Validate Stuart Fuel Appliance approach:
  - Appliances convert existing electricity infrastructure to hydrogen fuel – on-site production avoids fuel distribution costs and “scale up costs” ;ideal for fleet application
  - “Zero emission” Hydrogen Fuel Infrastructure is Near-term Option – achievable through emission mitigation at power plant
- Demonstrate superiority of Stuart electrolytic method:
  - Appliances of any size/“fill fuel needs anywhere”;
  - Compact: footprint less than 10% of vehicle;
  - Emission-free: only O_2 and H_20 vapour;
  - Can achieve hydrogen fuel cost in car of $2.50/kg.

Specific Objectives

- Prove Stuart CST cell stack technology in large scale systems (> 1 Nm3/h) – key to cost reduction strategy;
- Introduce Personal Fuel Appliance (PFA) to broad audience – “change the way people think about hydrogen”;
- Validate goals:
  - Cost: Manufacturing pathway $300/kW
  - Footprint: Less than 10% of vehicle
  - “Plug and Produce”: Automation/Reliability (8000 h service interval)

Methodology

- Prototyping development approach to product development:
  - Educate users - “change thinking”
  - Learn from customer experience and system reliability
  - Develop strategic positions for future commercialization
  - Five steps in “prototyping” product development process:
    - ✓ Design, Build, Test, Customer Evaluation and Post Mortem

1999

2003

Plan for Personal Fuel Appliance

D = Design | B = Built | T = Testing | CE = Customer Evaluation | PM = Post Mortem

Prototype	Cell Type	Capacity (SCFH)	Pressure (psig)	Test Site	D	B	T	CE	PM
Model 10	Single Stack	20	3000	Selected Demo	Q3 98	Q4 99	Q3 99	Q1 00	Q3 99
Model 25	Single Stack	40	3600	Ford Motor Co.	Q2 99	Q3 99	Q2 00	Q2 01	Q2 04
Deca	Single Stack	40	3600	Numerous Demos	Q2 00	Q2 00	Q3 00	Q3 00	Q4 02

psig: pounds per sq. in.

SCFH: std. cu. ft. per h

Plan for Fleet Fuel Appliances

D = Design | B = Built | T = Testing | CE = Customer Evaluation | PM = Post Mortem

Prototype	Cell Type	Capacity (SCFH)	Pressure (psig)	Test Site	D	B	T	CE	PM
P3-1A	Multi Stack	1500	4000 psig	SunLine Transit	Q3 98	Q1 99	Q3 99	Q1 00	Q2 03
P3-1B HP	Single Stack	400	5000 psig	Powertech Labs CFCP	Q1 00	Q2 00	Q4 00	Q2 01	Q3 03
P3-1B LP	Single Stack	400	220 psig	Factory Tested to be delivered to FCPI Q4-2002	Q2 99	Q4 99	Q1 00	Q4 02	Q2 03
P3-5	Multi Stack	10000	N/A	Design Only	Q1 01	—	—	—	—
P4-1A	Single Stack	500	6000 psig	Internal	Q2 01	Q3 01	Q2 02	—	Q3 02
P4-1B	Single Stack	1000	6000 psig	AQMD	Q3 01	Q1 02	Q2 02	Q3 03	Q1 05
Mark 1	Single Stack	400	5000 psig	Bus Transit	Q1 02	Q1 03	Q2 03	Q3 03	Q4 04

CFCP: California Fuel Cell Partnership,

FCPI: Fuel Cell Propulsion Institute

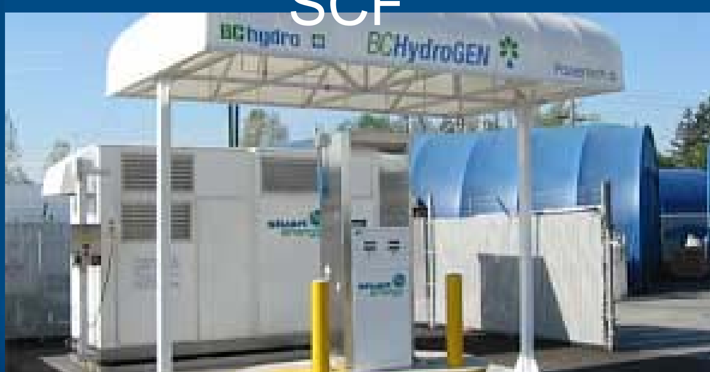
AQMD: South Coast Air Quality Management District

P3 Fleet Appliances Progress

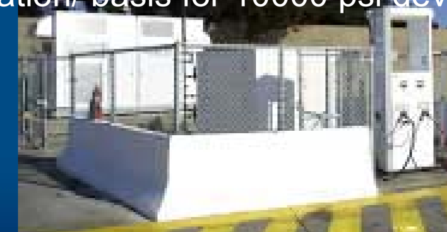
P3-1A: SunLine Transit (4,000 psig) - 3100 h over 3.5 million SCF

- Demonstrate stack performance: 49 kWh/kg
- Gas purity has been demonstrated: Unit has fueled Ballard and UTC bus engines
- Leak detected in stack (Q1 03) due to electrode connection

P3-1B HP: PowerTech Labs (5,000 psig) – 5,000 h over 2 million SCF



- Dispenses H_2 and 51% H_2/CNG mix at 6000 psig
- Demonstrate pushbutton operation/ basis for 10000 psi development
- Similar unit built for CFCP in Richmond, California

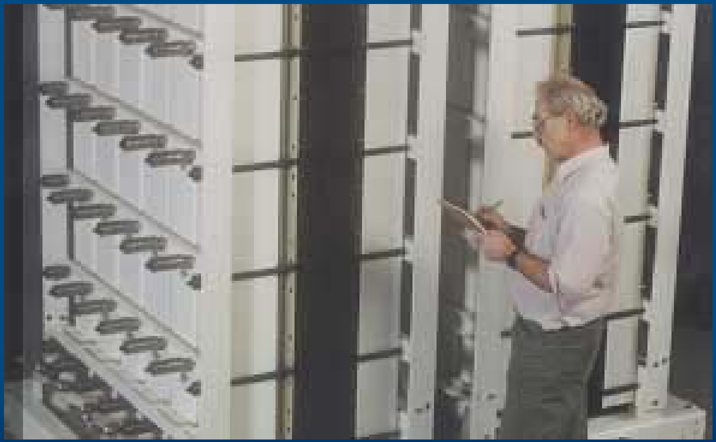


P3 Fleet Appliances Progress

P31B LP: FCPI - factory tested for 2500 h / 150 h in field

- Appliance Performance: 65 kWh/kg
- Low pressure (200 psig) fuel dispensing for metal hydride converted to high pressure for field trial
- Unit delivered on mobile fueling deck to Fuel Cell Propulsion Institute (FCPI)

P3-5: Cell Block Design & Demonstration Only - 1,250 h over 4.5 million SCF



- Stack Performance: 47.5 kWh/kg
- Cost target achieved $150/kW
- Material manufacturing quality control problems identified – quality control improved

P4 Fleet Appliances Progress

P4 - 1A: Internal Testing

- 10,000h pressurized CST cell stack test successful
- Problems with instrumentation/contamination
- Pressure insufficient to achieve economy in compression
- Design approach of pressurized CST stack abandoned in favour of acquisition of Vandenborre Hydrogen Systems

P4 – 1B: South Coast Air Quality Management District – 250 h test

- Unit deployed at South West Research Institute to supply fuel to H_2 ICE Motor/generator set (Ford Power Products)
- Unit will test CST integration with renewable power/ unit will "follow generator"

P4 Fleet Appliances Progress

Mark I : SunLine Transit

- 450 SCFH @6000 psig
- 65 kWh per kg
- Delivery June 2003

Personal Fuel Appliance Progress

White Box | 200 Series | Deca

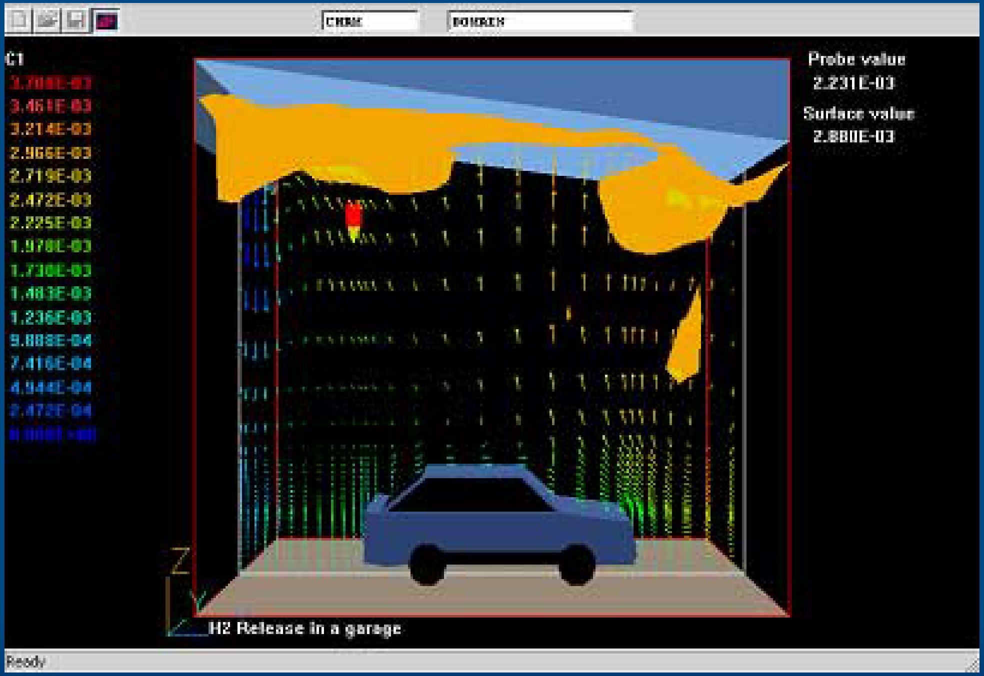
Three design Generations

- reduction in size of 80%
- U/L (Underwriters Laboratories) certification
- unit widely demonstrated
- Technical tasks complete, final report submitted for approval

Joint Evaluation with Ford Motor Company

Safety Update

- PFA received ULC Special Inspection Label;
- Larger appliance have met requirements of approval agencies; (UL,CSA, CE)
- Developing CFD mathematical models of leak scenarios



Business Plan Update

- Adjust to delays in bringing fuel cell vehicles to market & slower than expected introduction of fuel cell buses in North America:
  - Smaller fuelers for small fleet fuel applications
  - Market intro for PFA delayed (2008)
- "Energy Station" near term focus :
  - Evolve "dual role" Infrastructure backup power and vehicle refueling
  - Promote hydrogen ICE as low cost way to develop infrastructure

ICE: Internal Combustion Engines

Challenges

- Achieving Emissions:
  - Easier to deal with large sources
  - Realize regional opportunities where power is clean
  - Long-term will help finance renewable energy
- Fuel cost margins tight
  - Monetize emission benefits ($100 per ton for CO_2) results in $1 credit per kg ($3.50 per kg)
- Fuel cell gap – no cars until 2010
  - Bridge gap with ICE – building infrastructure, testing components will accelerate fuel cell commercialization

Cost Model

- Hydrogen costs of \$3.50 per kg are achievable
  - Appliance cost : \$300 per kW
  - o/m + CRF = \$60 per kW per y (20%) or .75¢/kWh (assuming 40% capacity factor)
  - Electricity cost: \$2.20 /kg @ .04¢/kWh
  - Total: \$3.14/kg

Next Steps

Commercialization:

- System available in two sizes: 450 SCFH & 1350 SCFH
- Offer "turn-key" solution:
  - complete station design including back-up power option
  - fuel appliance, storage, dispenser
  - safety analysis
  - service contract