Trains and Boats and Planes

CHBC Hydrogen and Fuel Cell Summit
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Trains
A Long History

• 1970’s
  – Fuel Cells (JPL)
  – Fuel Cells (EMD = Argonne)

• Mid-80’s
  – Hydrogen combustion for mining
  – Fuel cells (EMD, TRB)

Roger Smith (GM) committed to developing a locomotive in 1986
A Long History

Fuel Cell Technology for Railway Vehicles

Interim Report

Stella Lindeke
Economic and Environment Division
UIC

for C12 Committee, UIC

December 1998

• 1970’s Canadian Interest
• 1990’s: European Interest
• Siemens, ECN, LBST
A Long History

• SCAQMD 1991-1995 ~50 participants
  – Preliminary spec
  – Potential applications: Switch Engines, Line Haul, APU

Ballard, SAIC
A Long History

- JPL Studies, 1992-95
- 1995 conclusions:
  - LPG or clean diesel
  - NOT hydrogen
  - 45% efficiency
  - $700-$800 kW system cost
  - 2,000,000 mile durability

1994 R&D Appropriation killed by DOE
What Happened?

• Fuel cell industry
  – Small market; No market?
  – No apparent regulations driving market
  – Distraction
  – No/little research funding
  – DOE withdrawal

• Advocates
  – Technology readiness/lead time
  – Prior commitment to other technologies
  – Lack of customer interest
  – Lack of developer interest
What Happened?

• Developers
  – Technology readiness
  – Prior investment in advanced technologies
  – Lack of customer interest
  – No coercive regulation
  – Leadership moved on, retired

• Customers
  – “Radical” and new
  – Cost-benefit
  – Fuel inflexibility (remember GASRAIL?)
  – No coercive regulation
Drivers Then, Drivers Now

- Compatible hybrid electric technology
- Weight less of a barrier
- Fuel tender possible
- Potential for increased efficiency (25% - 50%)
- Superior environmental performance, quiet
- Developed and developing world expanding their systems
- China moving away from coal
Drivers Then, Drivers Now

- Potential economic case
  - Cost of electrification
  - Off-catenary expansion
  - Modular – less costly to provide different power levels
  - Permits new configurations
New Economic Pressures

- In US, diesel costs increased 4X since 1990’s
  - 40% of consumption at idle
- Security concerns: Grid failure kills the whole system
- Cost of electrification (China: $3M /km)
- Operating Flexibility
New Regulatory Pressure

• Pressure for regulation increasing
  – Rail yards
  – Diesel engines and fuels
  – Ports and related infrastructure
  – “Environmental justice”
  – Particulate regulated as carcinogen (CA)
  – New concern about “ultrafines”
  – New concern about black carbon
Technical Progress

- 60,000-80,000 durability (1.6M miles at 20 mph)
- New passenger engines configured for APU
- Costs are coming down
Studies and Demonstrations Worldwide

- Spain
- South Africa
- US
• China

Developed to protect worker health at underground construction and maintenance sites

• Korea

• Russia
Ferries and Other Boats
Aircraft and Airports
Airport Applications

- Ground support needs
- Airport infrastructure
- Mobile refueling
- Tugs and general maintenance equipment
- Back-up power
- Sustained electrical power quality
- Communications systems
- Emergency Response
Aircraft Applications

- Aircraft primary power
- Aircraft auxiliary power
- Novel on-board systems
Opportunities

German Aerospace Center (DLR) and Airbus identified potential FC applications in aircraft:

- Power
- Emissions-free ground operation, including autonomous taxiing, maintenance bus supply and cargo reloading
- Electrical main engine start
- Electrical environmental control system supply (air conditioning)
- Water generation - potable water and water for toilets
- Heat generation for icing prevention and hot water
- Explosion, fire prevention and suppression via inerting of the tanks, cargo and electrical bay compartment
- Cockpit and cabin air humidification
“Fuel cell technology applications are a key element of aviation’s longer term environmental strategy.”

-Joe Breit, Boeing Commercial Airplanes

75% Fuel Savings on the Ground From Onboard APU
Aviation Fuel Cell Pathway

Source: Boeing 2010
“Fuel cells are one of the most promising ‘step change’ technologies and Airbus sees high potential in fuel cell applications towards a further significant reduction of emissions, fuel consumption and external noise.”

http://www.airbus.com/innovation/eco-efficiency/design/fuel-cells
German project ELBASYS

- Integrated FC into an Airbus A320 to provide emergency backup power to electric motor pump, back up hydraulic circuit and ailerons

- Test flights in 2007/2008, altitudes of up to 25,000 feet - FC showed “robust behavior” under high gravity loads, turns, zero gravity aircraft maneuver
Antares Manned Fuel Cell Aircraft

- Takes off and cruises using FC power
- Twice as efficient as conventional propulsion
- H3 aims at 6,000 km, 50 flight hours
Fuel Cell Electric Nose Wheel

- Estimated reduction of up to 19% of airport emissions
- Almost all noise can be eliminated during taxiing
- First full-scale test in 2011
- Potential Frankfurt Airport savings from Airbus A320 electrically-driven nose wheels: 44 tons of fuel/day
“We really see fuel cells as one of our primary energy sources in the future. We’re hoping to remove some battery systems because they typically require lots of maintenance for engine generators.”

“The FAA tries to make sure we have power availability 99.999 percent of the time.”

- David Powers, FAA program implementation manager
Don’t Forget the Little Guys
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