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Queen's Fuel Cell Team

# CLEAN SNOWMOBILE



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## Heavy Duty Hydrogen Trucks Rolling Into Ho

By ELENA CRAFT, PHD | BIO | Published: MARCH 6, 2013



Source: www.earthtechling.org

### About This Blog

Advocating for cleaner, healthier air in Texas through public education and policy influence.

### Meet The Bloggers

- News archive
  - 2013
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- Events

Home Page | News & Events | News | 2013 | February | Boeing's Hydrogen Fuelled Phantom Eye Completes Second Flight

## Boeing's Hydrogen Fuelled Phantom Eye Completes Second Flight

27 FEB 2013



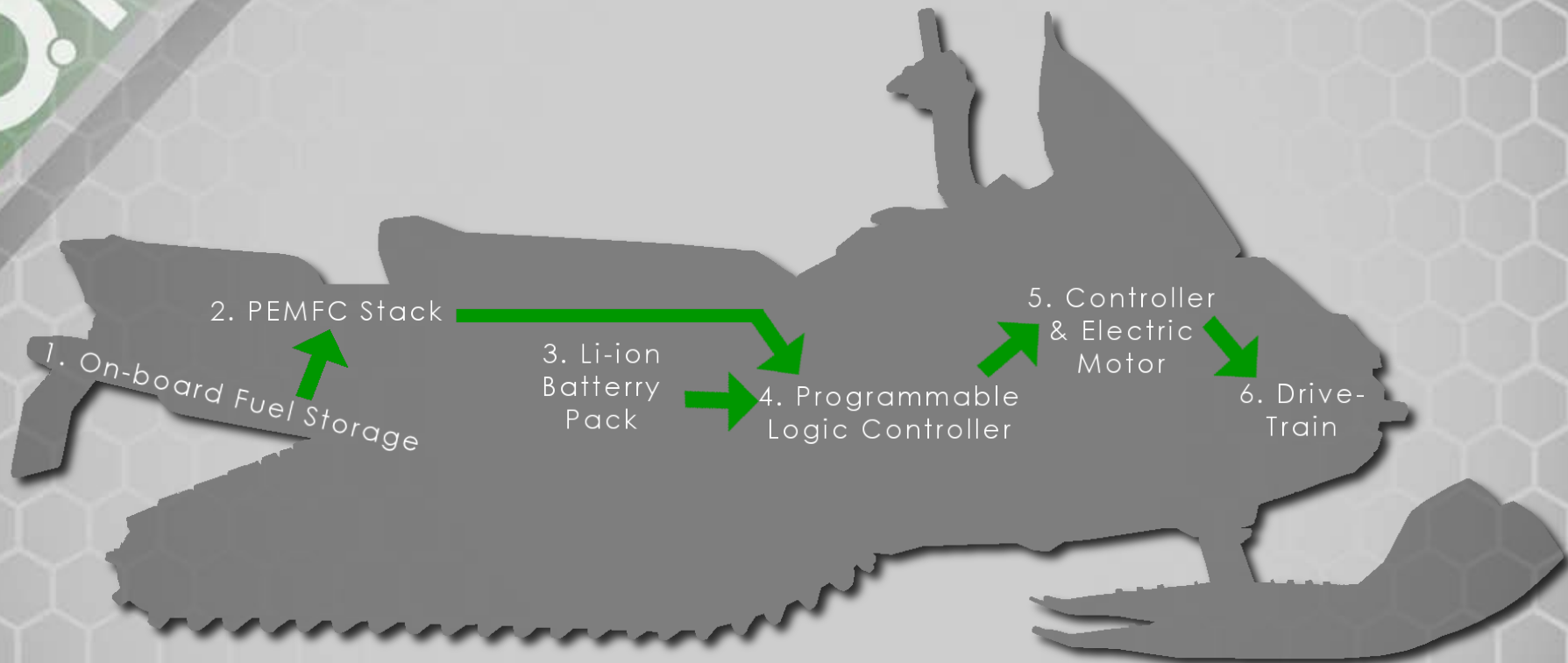
## OTHER APPLICATIONS



Image courtesy of: <http://www.autoguide.com>

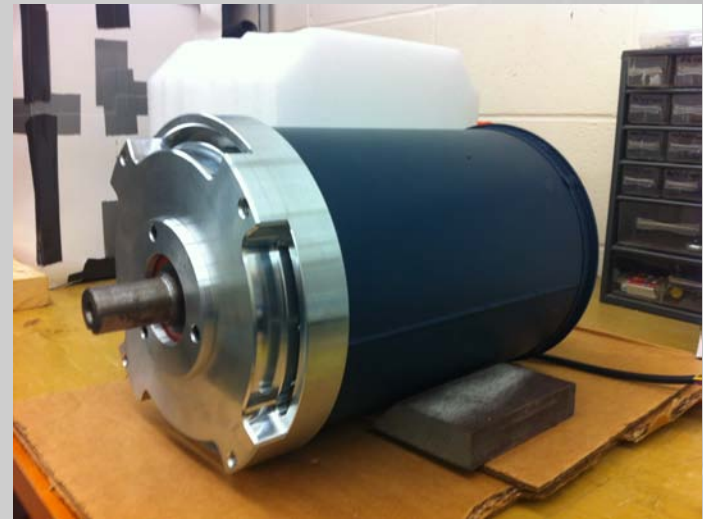
- ▶ Produces 540-hp from fuel cells
- ▶ Top Speed ~ 300km/h (~188 mph)

## THE SYSTEM



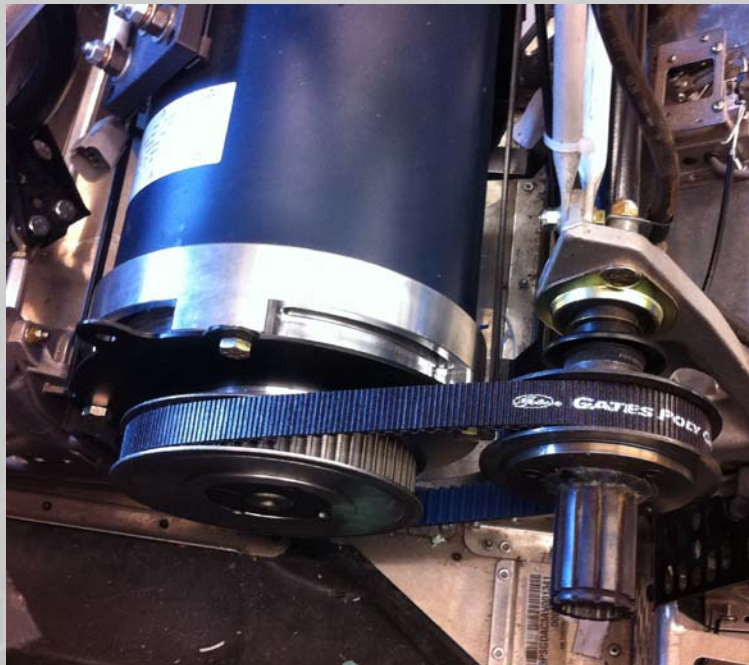
## MOTOR

- ▶ AC-35 by HPEV
- ▶ Curtis 1238 Motor Controller
- ▶ Max 35 hp, continuous 10 hp



# FIXED GEAR RATIO

- ▶ Gates Polychain GT Carbon Belt
- ▶ Chain Drive
- ▶ Total gear ratio of 1.4



# POWER REQUIREMENTS

Component	Voltage	Current	Power
Motor Controller	72 – 96 V	600 A	N/A
Battery	96 V nominal	0 – 450 A (750 pulse)	0 - 43.2 kW
FC Stack	40 – 80 V	0 – 380 A	0 – 17 kW



# BATTERY SPECIFICATIONS

- ▶ 26 Dow Kokam Cells
  - ▶ 2.7—4.2V, 3.7V Nominal
  - ▶ Max Discharge Current 450A
  - ▶ Max Charge Current 225A
- ▶ Pack Specs:
  - ▶  $\approx 96$  V nominal
  - ▶  $\approx 7.2$  kWh\*

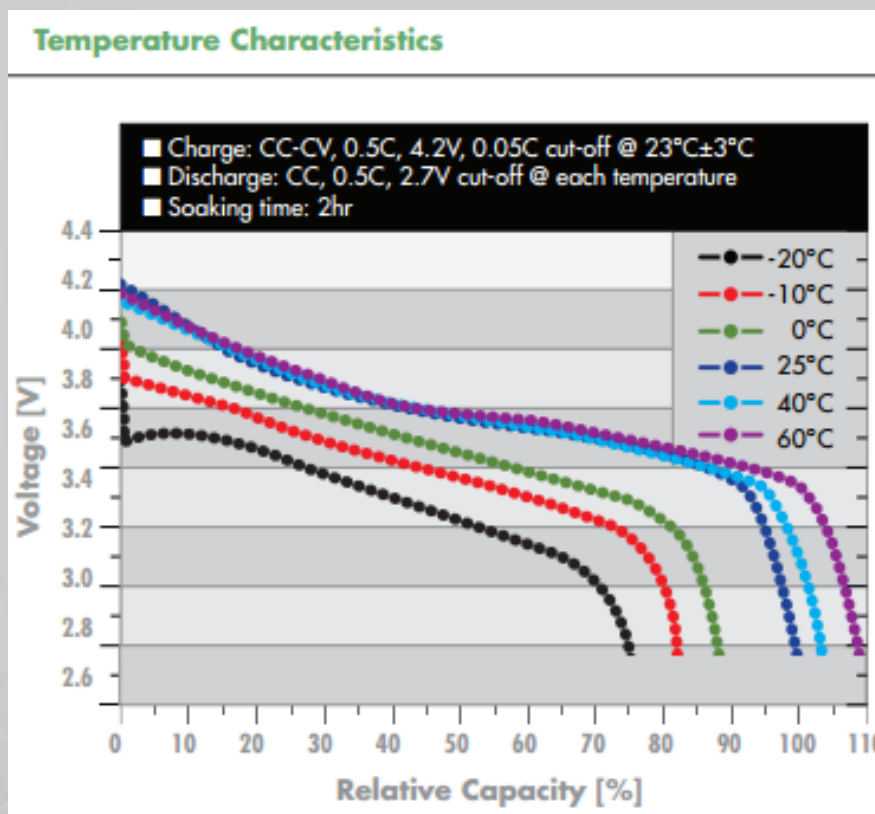


\* Dependant on operating current



## BATTERY SPECIFICATIONS

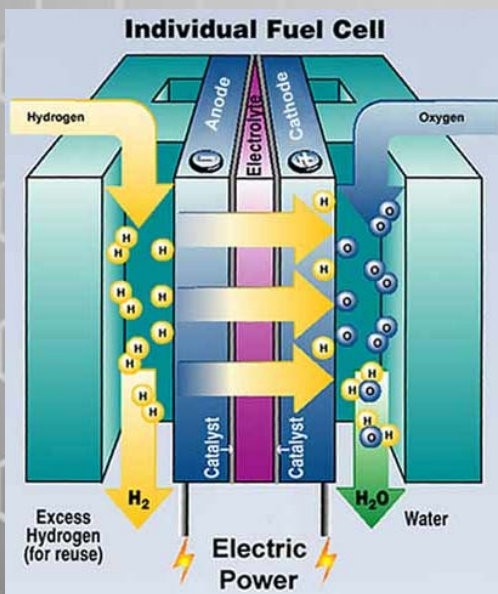
- ▶ Minimum Discharge Temperature  
-30°C/-22°F



## PEM FUEL CELL

- ▶ Uses air and compressed hydrogen as fuel source
- ▶ Hydrogen combines with oxygen to produce **only** water, heat and electricity
- ▶ Cells are combined in series to reach a desired voltage

- ▶ Clean, zero emission energy source



# HYDROGENICS HYPM 16

- ▶ 17 kW maximum output
- ▶ Max efficiency of 55%
- ▶ Internally humidified
- ▶ 240 standard Litres/min
  - ▶ At 16kW discharge
- ▶ Adds ~220 km\*
  - ▶ ~7.5 hours runtime



Image From: <http://www.directindustry.com>



# DYNETEK HYDROGEN TANKS

- ▶ 2 x 700 bar (~10 000psi)
- ▶ 1.2 x 0.31 metres (~ 47 x 12.31inches)
- ▶ Made from extruded aluminum and externally wrapped in carbon fibre
  - ▶ Carbon fibre disperses both axial and hoop forces applied
- ▶ Tank includes integrated high pressure solenoid valves



# REFUELLING COSTS

- ▶ Fuelling costs are expected to be under \$15/kg
  - ▶ <http://spectrum.ieee.org/green-tech/advanced-cars/first-commercial-hydrogen-filling-station-opens>
  - ▶ <http://www.h2carblogger.com/?p=461>
  - ▶ <http://www.caranddriver.com/features/pump-it-up-we-refuel-a-hydrogen-fuel-cell-vehicle-hydrogen-filling-stations-are-still-rare-page-3>
- ▶ Norway \$6.40 / kg



## INFRASTRUCTURE

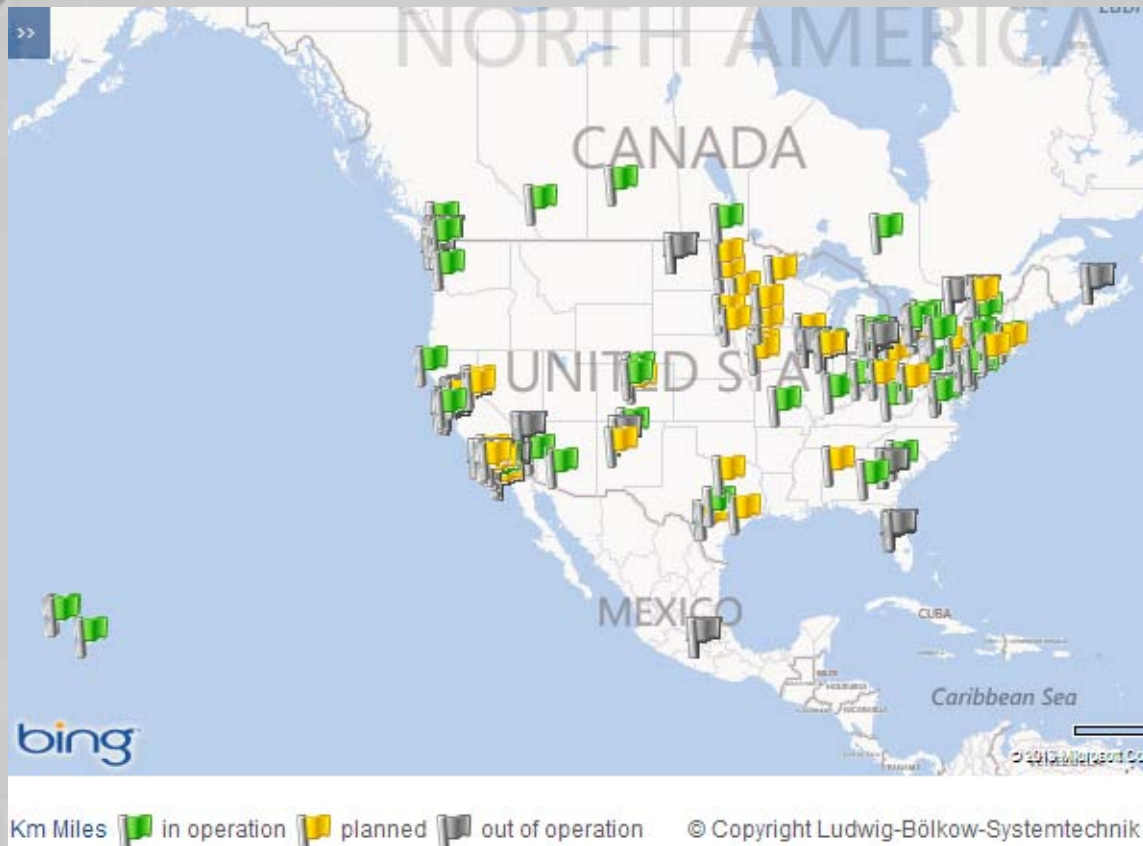
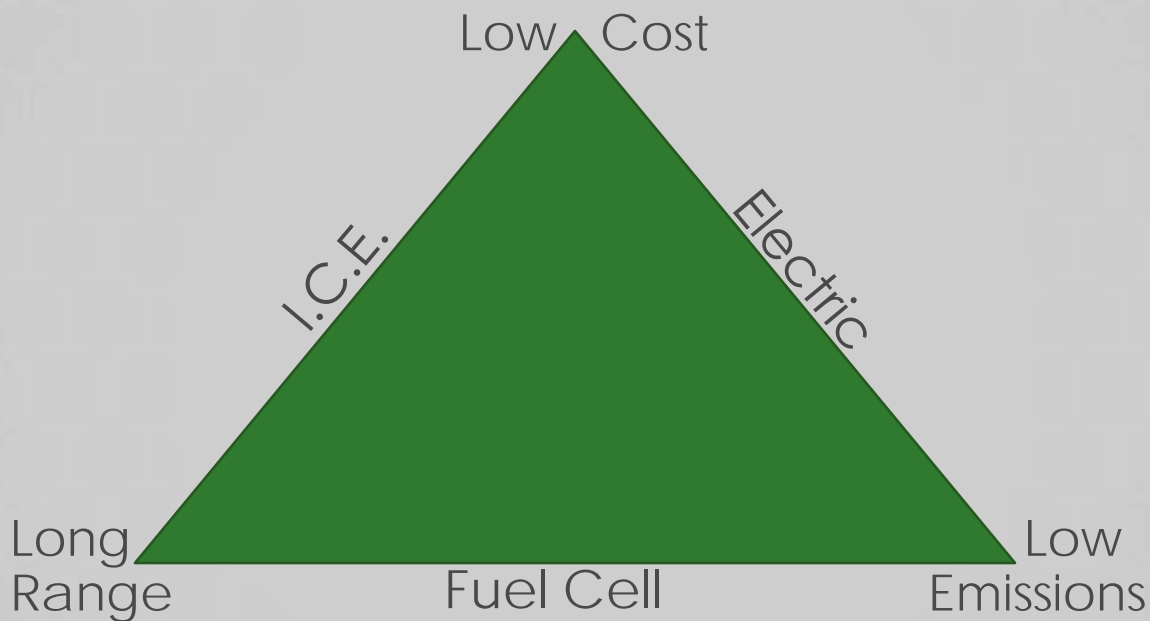


Image courtesy of: <http://www.netinform.net>

# DESIGN COMPROMISE



## MSRP & COST

Vehicle Type	Cost (CAD)
FC Snowmobile	~ \$106 000
Battery	~ \$33 000





# PERFORMANCE

	Hybrid Fuel Cell Snowmobile	Electric Snowmobile
Weight	~500 kg	~300 kg
Range	246 km	24 km <sup>1</sup>
Time at 30 km/h	8h 11min	48min <sup>2</sup>

1. Good snow conditions (Powder). Rolling resistance coefficient = 0.2
2. Based on complete battery discharge



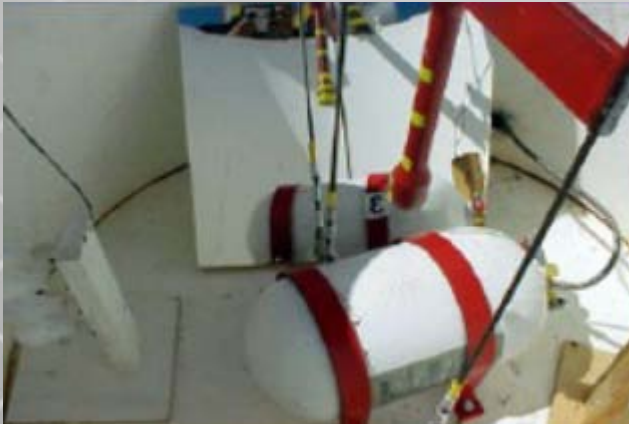
# HYDROGEN TANK SAFETY

QUANTUM  
TECHNOLOGIES

Validation: Severe Abuse Testing

## Validation Test

- ▶ Hydrostatic Burst
- ▶ Extreme Temperature
- ▶ Ambient Cycle
- ▶ Acid Environment
- ▶ Bonfire
- ▶ Gunfire Penetration
- ▶ Flaw Tolerance
- ▶ Accelerated Stress
- ▶ Drop Test
- ▶ Permeation
- ▶ Hydrogen Cycle
- ▶ Softening Temperature
- ▶ Tensile Properties
- ▶ Resin Shear
- ▶ Boss End Material



# HYDROGEN TANK SAFETY



**Photo 1 - Time: 0 min, 0 sec - Hydrogen powered vehicle on the left. Gasoline powered vehicle on the right.**



## HYDROGEN TANK SAFETY



**Photo 2 - Time 0 min, 3 seconds - Ignition of both fuels occur.  
Hydrogen flow rate 2100 SCFM. Gasoline flow rate 680 cc/min.**

# HYDROGEN TANK SAFETY



**Photo 3 - Time: 1 min, 0 sec - Hydrogen flow is subsiding, view of gasoline vehicle begins to enlarge**



## HYDROGEN TANK SAFETY



**Photo 4 - Time: 1 min, 30 sec - Hydrogen flow almost finished.  
View of gasoline powered vehicle has been expanded to nearly  
full screen**



# HYDROGEN TANK SAFETY



**Photo 5 - Time: 2 min, 20 sec - Frame prior to interior deflagration.**



## HYDROGEN TANK SAFETY



**Photo 6 - Time: 2 min, 20 sec - Deflagration in the interior, following frame shows flames exiting around edges of trunk lid.**





## HYDROGEN TANK SAFETY



**Photo 7 - Time: 2 min, 40 sec - Frame prior to driver's side rear tire rupture.**



# HYDROGEN TANK SAFETY



**Photo 8 - Time: 2 min, 40 sec - Driver's side rear tire rupture sends debris out the passenger side of the vehicle.**

Images from Fuel Leak Simulation test – University of Miami  
<http://ewworld.com/library/Swainh2vgasVideo.pdf>



# ADVANTAGES AND DISADVANTAGES

Advantages	Disadvantages
Zero Emission	High Cost
Longer Range	Complex System
Safety - Fuel	Lack of Hydrogen Infrastructure
Refill Time	Safety - Electrical
Fuel Abundance	Temperature/Start up Limitations



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