Long Term Hydrogen Vehicle Fleet Operational Assessment

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“Accelerating the infusion of commercially viable technology into military land warfare systems” and professional development.”
Project Background

• Purchased ten Hydrogen Hybrid Internal Combustion Engine (H2ICE) vehicles in 2008
  • Converted gasoline hybrid to be operated on hydrogen
  • Operated for first year at multiple locations
  • Fitted with data acquisition equipment to record vehicle performance

• Fleet consolidated to one location in July 2009 in Hawaii
Project Goals

• Project Goals:
  • To demonstrate applicability of hydrogen vehicles for non-tactical fleets at military installations
  • To investigate long-term effects of the conversion process on the performance of the vehicle

• Project tracked fleet of vehicles from July 2009 to January 2011 recording vehicle performance, driver feedback and maintenance actions performed on the vehicles.
Location and Driver Selection

- Island of Oahu, Hawaii selected as fleet deployment site
  - DoD presence on Oahu - Army, Navy, Air Force, Pacific Command, Coast Guard and National Guard
  - Organizational Interest from installations
  - Availability of Hydrogen

- Drivers were selected based on expected vehicle utilization and interest in the technology
  - Goal of 200 miles per month per vehicle
  - Require vehicle during their average workday
  - Proximity to hydrogen refueling station
Vehicle Conversion

- Standard MY 2008 Hybrid Gasoline Electric Sport Utility Vehicle converted to burn gaseous hydrogen instead of gasoline
• Conversion Process
  • Replaced 15 gallon gasoline fuel system with carbon-fiber hydrogen tanks and hydrogen fuel lines.
  • Storage of 3.8 kg hydrogen at 350 bar.
  • Standard gasoline engine with replacement fuel injectors, spark plugs and air filter.
  • Added a turbocharger to recover engine power lost from converting to gaseous fuel.
  • Installation of hydrogen sensors

• Vehicles had published range of 100 miles; actual distance driven varied depending on driver and local conditions.

• Data collected through the CANbus on the engine, hybrid battery and vehicle operation.
• Temperature and Pressure Sensors recorded the state of the hydrogen storage tanks.
Operational Issues

• Electrical Problems with Hydrogen Fuel System
  • Hydrogen Sensors
  • Fuel Gauge Module
  • Addressed through replacing the faulty equipment

• Vehicle Performance on Steep Grades
  • Hydrogen consumption on steep hills limited vehicle range
  • Addressed through Driver Training on vehicle limitations

• Driver Concern with Continuously Variable Transaxle and Turbo Lag
  • Driver reports of high engine speeds and improper shifting
  • Driver reports of lacking power from Turbolag
  • Addressed through additional training
<table>
<thead>
<tr>
<th>Vehicle Number</th>
<th>Miles Travelled (mi)</th>
<th>Hydrogen Usage (kg)</th>
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## Fuel Economy

<table>
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<tr>
<th>Vehicle Number</th>
<th>Average Fuel Economy (mi/kg)</th>
<th>Average Fuel Economy (mi/gge)</th>
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</thead>
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<tr>
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<td>27.2</td>
<td>27.1</td>
</tr>
</tbody>
</table>
• Average fuel economies varied greatly between vehicle

• Fleet Fuel Economy was 26.2 mi/kg or 26.1 mi/gge

• The fuel economy of the fleet of H2ICEs was comparable to the standard hybrid-electric gasoline SUVs
Maintenance Actions

• Effects of Water on Exhaust and Engine Lubrication
  • Muffler showed internal oxidation
    • Required earlier replacement than Gasoline vehicle
    • Replaced with Stainless Steel muffler
    • Traced back to increased water in the exhaust system
  • Water contamination in engine oil
    • Water condensed during initial warm-up, entering crankcase
    • Related to local temperatures
    • Premature oil breakdown

• Starting Battery
  • Minor parasitic draw on the battery
  • Cause traced back to vehicle electronics combined with hydrogen fuel system parasitic load
  • Consistent operation of the vehicle maintains battery life
Summary/Conclusions

- H2ICEs were an equivalent replacement to gasoline non-tactical vehicle
- H2ICE range and fueling were issues to the drivers
- Maintenance was generally equivalent, except additional effort to maintain oil quality
- Some performance issues noted by drivers were due to the other systems, not the hydrogen conversion
Any Questions?

For more information please contact Steven Eick - Steven.Eick1@us.army.mil