Super Civic
Partial Hydrogen Injection

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The Basics

Hydrogen to Engine

Electricity from Alternator

\[ 2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O} \]
Objective

• Design and build a water electrolyzer.
• Determine how partial hydrogen injection affects engine performance.

  – Effect on air fuel ratio
  – Horse power output
  – Effect on fuel economy
Results

System Testing

System Design & Construction

Background Research on Existing Systems
System Design Criteria

• Component materials MUST...

  – be resistant to corrosion in caustic electrolyte solution.
  – perform well in temperatures ranging from -4°F to 158°F (-20 to 70°C).
  – maintain structural integrity under compressive load and operating temperatures.
The Cell (Stack)
Assembly Layout

- Cell was more productive when layout was vertical.
- Allows for more compact design.
- Tall, slender design is ideal for under hood or back seat location.
Original Layout
Electrolyte Solution

• 10% Potassium Hydroxide by weight dissolved into distilled water.

• Does not break down.

• Electrodes stay clean due to KOH’s minimal reactive nature with 316L Stainless Steel and other plastic components.
Engine Effects of PHI

- Change in power output from the engine
  - Quenching distance

- Change in air fuel ratio
  - O2 issue

- Effect on fuel economy
Quenching Distance

<table>
<thead>
<tr>
<th>Property</th>
<th>Hydrogen</th>
<th>Gasoline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stoichiometric ratio for complete combustion (A/F by mass)</td>
<td>34:1</td>
<td>15:1</td>
</tr>
<tr>
<td>Auto Ignition Temp (°C)</td>
<td>585</td>
<td>260-460</td>
</tr>
<tr>
<td>Flame Temp (°C)</td>
<td>2207</td>
<td>2307</td>
</tr>
<tr>
<td>Quenching Distance (mm)</td>
<td>0.64</td>
<td>~2</td>
</tr>
<tr>
<td>Ignition Energy @ stoich (mJ)</td>
<td>0.02</td>
<td>0.24</td>
</tr>
<tr>
<td>Flame Speed @ stoich (m/s)</td>
<td>3.46</td>
<td>0.42</td>
</tr>
</tbody>
</table>
Increased Burning Efficiency

• Due to the decrease in quenching distance in the cylinder, more of the fuel injected into the cylinder is burned.
Effects on Air-Fuel Ratio

\[ AFR = \frac{m_{\text{air}}}{m_{\text{fuel}}} \]

**Oxygen Sensor Switching Voltage**
(Zirconia Type 02 Sensor)

- **RICH MIXTURE**
- **LEAN MIXTURE**

- O2 Sensor Output Voltage
- Air/Fuel Ratio

www.AA1Car.com
Solutions (for O2 problem)

• Add voltage to the $O_2$ signal; tricking the computer to believe more oxygen is present and does not add more fuel.

• Modify ECU look-up tables.
System Testing

• Cell characterization
• Vehicle dynamometer tests
• Long term fuel efficiency tests
Volumetric Flow of HHO from Cell

- Flow v Voltage (V): $R^2 = 0.97$
- Flow v Current (A): $R^2 = 0.91$
1994 Honda Civic
Installation

- Mounted on back of passenger seat.
Installation in Vehicle

• Switch controls powering of cell.

**NEED:**
1. Doesn’t run down car battery.
2. In case of need for emergency shut off during running of vehicle.
Positive and Negative leads to battery.

Mixture input into cool air filter.
Dyno Tests

Testing Conditions:
  ○ 80 °F, ambient temperature
  ○ 94 Honda Civic, DX

Cell Operating Conditions:
  ○ 13.6 Volts, 15 Amps
  ○ Flow rate of HHO (1.10 Liters / minute)
1994 Honda Civic Dynamometer Results

Power Output (HP)

AFR

Power Output without HHO
Power Output with HHO
AFR without HHO
AFR with HHO

RPM
**Fuel Economy**

12 volts @ 10 amps → 0.7 L/min of HHO

<table>
<thead>
<tr>
<th>Test</th>
<th>Miles</th>
<th>Gallons</th>
<th>MPG</th>
<th>Average MPG</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>No HHO</td>
<td>329.8</td>
<td>9.8</td>
<td>33.7</td>
<td>City</td>
<td></td>
</tr>
<tr>
<td></td>
<td>316.4</td>
<td>9.5</td>
<td>33.3</td>
<td>City</td>
<td>34.5</td>
</tr>
<tr>
<td></td>
<td>304.2</td>
<td>8.3</td>
<td>36.7</td>
<td>Highway</td>
<td></td>
</tr>
<tr>
<td>With HHO</td>
<td>321.1</td>
<td>9.1</td>
<td>35.3</td>
<td>City</td>
<td>37.0</td>
</tr>
<tr>
<td></td>
<td>212.6</td>
<td>5.5</td>
<td>38.7</td>
<td>Highway</td>
<td></td>
</tr>
</tbody>
</table>

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Conclusion

• No increase in horsepower.
• No change in air fuel ratio.
• 7% increase in fuel efficiency.
• How would these values change when more hydrogen is injected?
Special Thanks to:

- **Computron Metal Products**, Whitman, MA
  
  Donated materials and machined many components.

- **Dent Sport Garage**, Norwood, MA
  
  Donated technician time for dyno analysis.