Hydrogen Fuel Cell Vehicle Electrical System Performance

ALAMO COLLEGES
SAN ANTONIO COLLEGE

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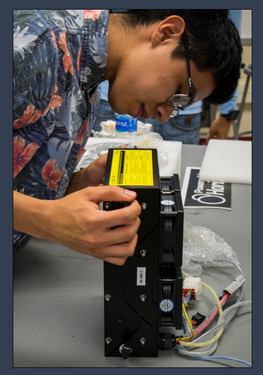
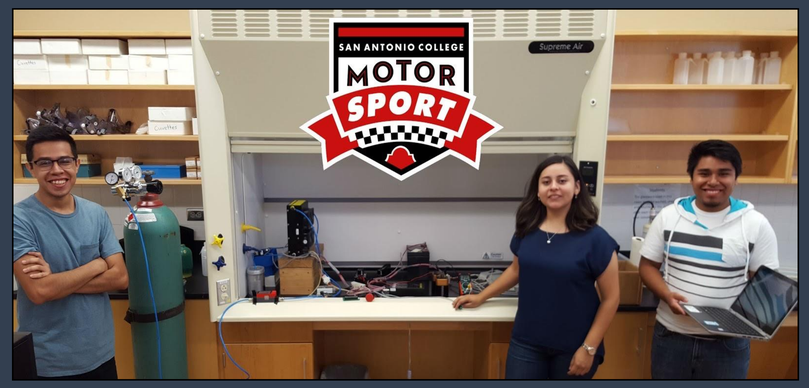
Objectives

1. Verify Hydrogen Fuel Cell Stack (HFCS) voltage, current, and wattage output specifications.
2. Determine the conditions for the HFCS to produce 48 volts and output power levels to about 750 watts.
3. Test the HFCS electrical system to optimize its performance in order find its peak fuel efficiency.
4. Incorporate the findings into the design of the electrical system for SAC's hydrogen fuel cell prototype vehicle, "The Noventa."

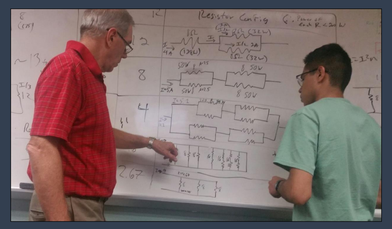




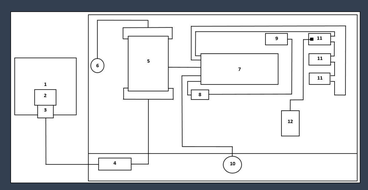
Abstract

San Antonio College (SAC) students with the assistance of SAC faculty, industry contacts, and Texas State University, are working to develop a Hydrogen Fuel Cell Vehicle (HFCV) for the prestigious Shell Eco-Marathon Americas competition in Detroit. The competition challenges students around the world to create highly fuel efficient vehicles. Twenty engineering students took on the challenge and formed the SAC Motorsport Team. In order to compete effectively in Shell Eco Marathon there was a need to better understand how the H-1000XP Hydrogen Fuel Cell Stack (HFCS) performs under different parameters to find its most efficient operational configuration. This research project addressed this need. HFCS performance was tested with two different variables being controlled; i.e., the hydrogen gas supply pressure and HFCS output load. The objectives of this research project were met; i.e., a better understanding of HFCS operation and determining its most efficient operational configuration.

Test Procedure



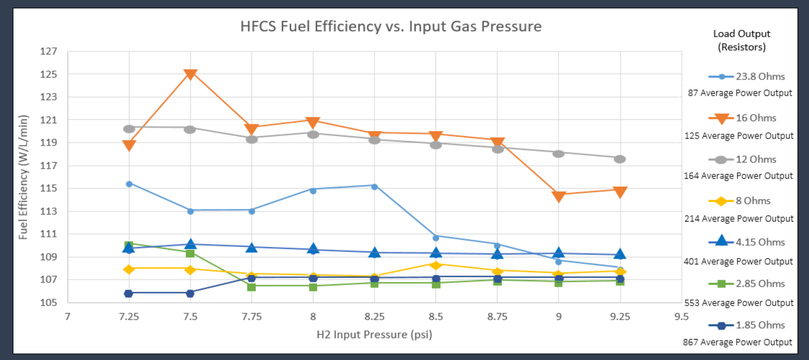
- Check resistance of the output load circuit and ensure that there was good electrical connections and set the pressure regulator at 7.25 psi.
- Turn on the flow meter, and place the temperature sensor on the load resistors to make sure they don't overheat.
- Press and hold the on/off button to start up the HFCS system.
- Record hydrogen fuel consumption in liters per minute and the HFCS output voltage (volts) and current (amps) as they appear on the flow meter's LCD screen.
- Multiply the output voltage and current to calculate output power in watts, then divide this by the fuel
- consumption to calculate the fuel efficiency of the HFCS in Watts/Liter/min.
- Record our results on a spreadsheet.
- Repeat the procedures for pressures from 7.25 to 9.25 psi in 0.25 psi increments. (*Table 2*).
- After reaching 9.25 psi, turn off the fuel cell, disconnect the load resistors.
- Setup the next test using the appropriate resistive load for the output power level desired. (see *Table 1*).

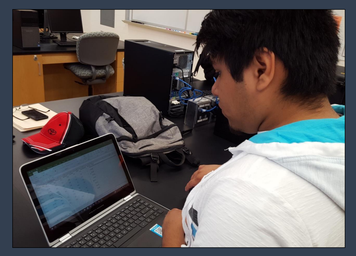


1 - Hydrogen Gas Tank	2 - Pressure Regulator	3 - Pressure Gauge
4 - Pressure Regulator	5 - HFCS	6 - H2O Collector
7 - HFCC	8 - Hydrogen Leak Sensor	9 - Accessory Battery
10 - Emergency Stop Button	11 - Load Resistors	12 - Multimeter/ Thermometer

Figure 2 - Testing Configuration

Test Results - Graph





Resistor Loads (Ω = ohm) and Average Power Output (W = watts)		
23.8 Ω = 87 W	16 Ω = 125 W	12 Ω = 164 W
8 Ω = 214	4.15 Ω = 401 W	2.85 Ω = 553 W
	1.85 Ω = 867 W	

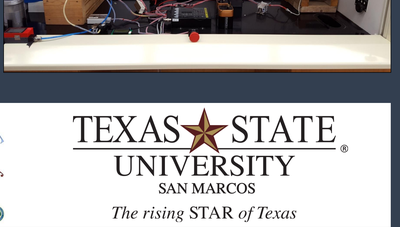
Table 1 - Hydrogen Fuel Cell Stack Average Power Output by Resistor Load

Test Gas Pressure Ratings (psi = pounds per square inch)			
7.25 psi	7.5 psi	7.75 psi	8.0 psi
8.25 psi	8.5 psi	8.75 psi	9 psi
9.25 psi			

Table 2 - Hydrogen Gas Test Pressure for Hydrogen Fuel Cell Stack

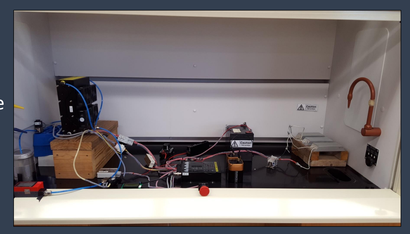
Test Results - Discussion

- **87 Watts**: Starting with 23.8 ohms load resistance produced an average of 115.36 (W/l/min) at 7.25 psi. From 7.25 to 8 psi, it decreased slightly to 114.76 (W/L/min). As the levels increased 8 to 9.25 psi, fuel efficiency dropped steadily to its lowest value of 107.888 (W/L/min).
- 125 Watts:The load resistance of 16 ohms produced an average 118.8 (W/L/min). From 7.25 psi to 8 psi, fuel efficiency increased from 118.8 to 120.8 (W/L/min). At 8 to 9.25 psi, it gradually declined from 120.8 to 114.7 (W/L/min).
- 164 Watts: At 12 ohms of resistance, the fuel efficiency was 120.1 (W/L/min) at 7.25 psi. From 7.5 to 9.25 psi, there was a downwards trend to 117.6 (W/L/min).
- 867 Watts:The final load resistance of 1.85 ohms was able to produce 105.783 (W/L/min) of fuel efficiency at 7.25 psi. Surprisingly enough, the efficiency increased then remained level at exactly 107.089 (W/L/min) from 7.5 through 9.25 psi.
- Overall testing at the smaller load resistances of 8, 4.15, 2.85, and 1.85 ohms and higher output powers (214 W to 867W) resulted in fairly constant fuel efficiency values from 7.75 to 9.25 psi.



Conclusions

- Based on the findings from testing the HFCS with different output loads and varying input hydrogen gas pressures we discovered:
- First, by increasing the load (i.e., with a smaller load resistance resulting in higher output power) the fuel efficiency of the HFCS decreased in most cases.
- Second, Increasing the pressure of the hydrogen gas supplied to the HFCS above 7.75 psi had little to no effect on its fuel efficiency at the four highest power output levels (214, 401, 553, 867 W).
- Third, for the three lowest power output levels (87, 125, 164W) increasing the gas pressure caused the efficiency of the HFCS to generally decline especially above 8.25 psi input gas pressure.
- The higher fuel efficiencies of the HFCS occurred when both the input gas pressure and power output were low. The highest fuel efficiency measured was 125.1 W/L/min at 7.5 psi input gas pressure and 129.5 watts output power.
- The lower fuel efficiencies of the HFCS occurred when the power output were high. The lowest fuel efficiency measured was 105.8 W/L/min, which occurred when the output power was 867.4 watts and the input hydrogen gas pressure was 7.25 psi or 7.5 psi.
- The test results should be beneficial in reaching optimum hydrogen fuel cell vehicle performance in the Shell Eco-Marathon competition by knowing what hydrogen gas pressure supplied to the HFCS will result in the best fuel efficiency.



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References: Horizon Fuel Cell Technologies. (2013). H-1000XP PEM Fuel Cells. *TW Horizon Fuel Cell Technologies*. Retrieved from http://www.horizonfuelcell.com/, "Alternative Energy." - *Wind, Solar, Hydro and Other Alt Energy Sources for Home Power*. N.p., n.d. Web. 11 Aug. 2016.

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