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The Impact of Driving Conditions on PHEV Battery Performance

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Technical Track 3: Electric & Hybrid Electric Vehicles

The Impact of Driving Conditions on PHEV Battery Performance

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Abstract

The battery performance of a modified Prius with a 5 kWh plug-in battery was documented for a year to determine the impact of environmental conditions and user attributes on vehicle performance. Both fuel economy and pure electrical efficiency were compared to ambient temperature. The fuel economy has a positive relationship with ambient temperature until approximately 70˚F where the efficiency begins to drop. Electrical performance has a positive linear relationship with ambient temperature. With the emergence of electric vehicles (EVs) and PHEVs from a variety of automotive manufacturers, information on EV and PHEV performance for consumers will become more important.

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Driving Conditions Impact on PHEV Battery Performance

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Introduction

Considerable improvements in the energy storage industry have allowed innovative battery technology to take the wheel in driving new electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) forward. With the emergence of newer battery powered vehicles from a variety of automotive manufactures, both the technical world and public will begin to ask questions when comparing the performance of a pure EV, hybrid electric vehicle (HEV), and PHEV.

This paper will address our data acquired through monitoring the performance of a PHEV for approximately one year. During our analysis, temperature data was examined in order to evaluate the performance of the battery and overall efficiency. In addition, we were able to compare our vehicles performance with a variety of others in the field. The goal of this project is create a better understanding of how various driving conditions affect PHEV battery performance.

PHEV Specifications

The test car, a modified 2004 Toyota Prius, uses the Hymotion A123 L5 Lithium Ion (li-ion) Battery Pack. The battery has a capacity of 5 kWh, has a maximum recharge time of 5.5 hours (at 120Vac) and can provide a nominal driving range of up to 20 to 25 miles on electricity. During our study, the Prius traveled a total of 16,762 miles, of which, 5,305 miles (33%) were in electric PHEV mode.

In addition to the standard equipment displayed on the Prius's console, we installed a Gridpoint (V2Green) data monitoring and data acquisition system. The V2Green data monitoring system allows users to collect a greater variety of driving information in addition to what the standard Prius system is able to capture.

Discussion

The following material includes information we acquired during the yearlong analysis of our PHEVs performance under normal driving conditions. The primary area we focused on involved temperature and relative percentage of time in PHEV mode.

Temperature & Fuel Economy[1]

Figure 1 shows the performance of our PHEV during a wide range of operating temperatures. As shown, lower temperatures drastically reduce the capacity and overall efficiency of the PHEV. A considerable reduction in battery efficiency took place in the colder winter months, when temperatures consistently dropped below approximately 40° F. From 40° F and above, we consistently saw MPG ratings of 80+. Temperatures between 60° F to70° F provide peak fuel economy with an average of above 100 MPG. The maximum fuel economy shown in ***Figure 1*** is 100 MPG; this is due to the display in the PHEV only measuring up to 99.9 MPG. In actuality, the V2Green system has reported fuel economy of up to 240 MPG.

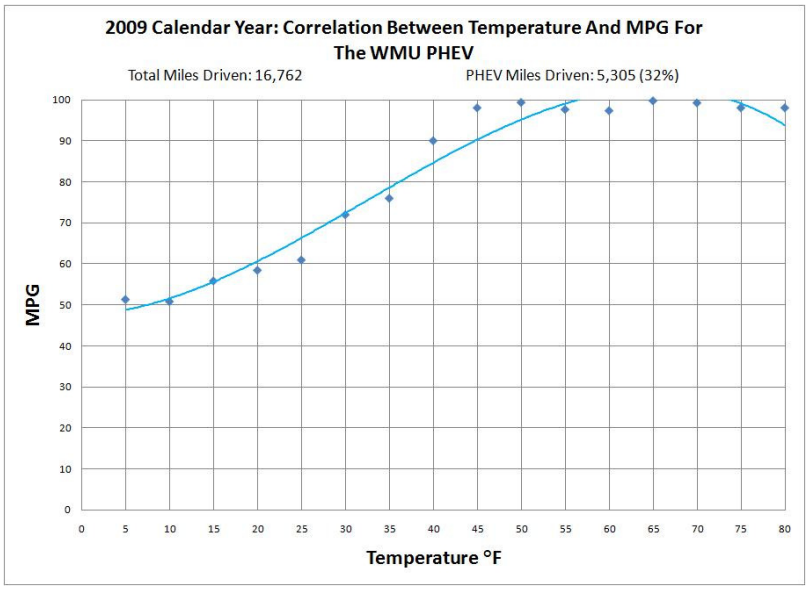

Figure 1: **Impact of Temperature on Fuel Economy**

Note: *the graph only goes to 100 MPG as these figures were taken from the Prius display, before the Gridpoint-V2Green system was operational.*

Temperature and M/kWh

Another measure used to evaluate the performance of the PHEV is a modified expression of fuel efficiency, similar to MPG, but more closely aligned with the electric nature of the PHEV. As our primary objective involved measuring the battery performance, we used miles per kilowatt-hour (M/kWh).Under ideal driving conditions, the 5 kWh battery has the potential to support the PHEV in full electric mode for up to 40 miles (according to manufactures information). This would mean that the vehicle would be capable of 8 M/kWh at maximum capacity. However, because our average driving range was closer to 20 miles in pure electric mode per charge, we were only able to achieve an average of~ 4 M/kWh (See ***figure 2***, 4 M/kWh occurs at about 40-45 °F). ***Figure 2*** shows the affect of temperature on the PHEVs M/kWh value, similar fashion to ***Figure 1***, the efficiency increases as the temperature increases. During the colder winter months, the vehicle averaged approximately 3.5 M/kWh while in the warmer summer months, the average increased to approximately 4.5 M/kWh.

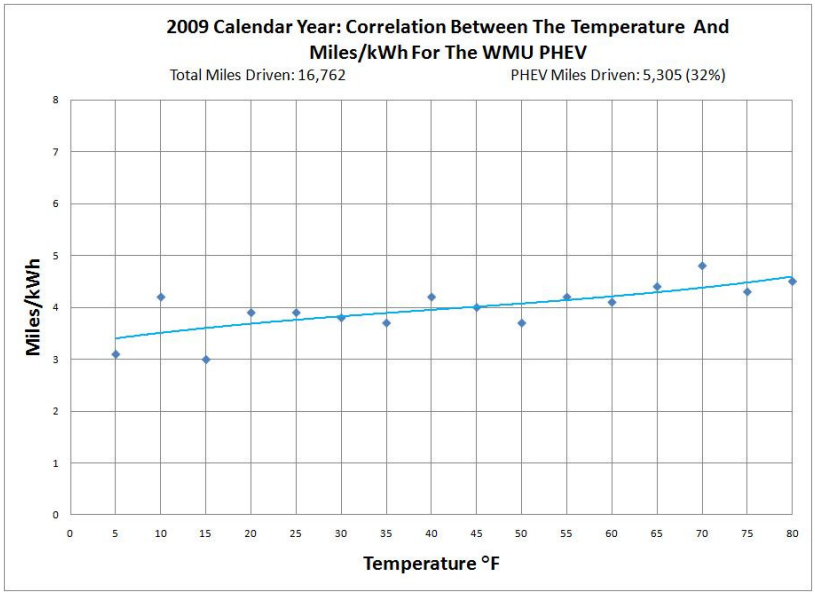

Figure 2: **Impact of Temperature on Electrical Performance**

Conclusions

PHEV performance is variable based upon temperature. The PHEV was able to achieve a fuel economy of over 100 MPG in the 60˚F to 70˚F range and performed as low as 50 MPG in sub-freezing conditions. The highest electrical performance achieved was ~4.5 miles per kWh at high temperatures and as low as 3.0 miles per kWh at low temperatures. This linear relationship indicates a direct positive relationship between electrical performance and temperature.

References

WMU Plug-In Hybrid Electric Vehicle. (2008). Retrieved March 2011 from http://www.ceas.wmich.edu/PHEVData/PHEV/index.php

Note:

[1] The graphs provided display the information in a bin method. Each increment of five (5) represents many different individually averaged trips.