Energy Efficiency Dynamometer Testing at the 1996 American Tour de Sol

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Abstract

In 1995, the U.S. Department of Energy through Argonne National Laboratory's Center for Transportation Research sponsored energy efficiency data collection from the student, private, and professional vehicles during the American Tour de Sol. The American Tour de Sol is a multiple-day road rally event run from New York City to Washington, D.C. As part of this efficiency testing, a number of vehicles were tested on a chassis dynamometer utilizing three common drive cycles: the LA-4, the New York City Cycle, and the Highway Fuel Economy Test. The results demonstrate remarkable efficiency increases over a gasoline control vehicle and significant cycle-sensitivity information. Two series hybrid electric vehicles (HEVs) were shown to have fuel efficiencies which were less sensitive to drive cycle than either a gasoline or an electric vehicle.

Introduction

Alternative transportation competitions offer an opportunity to study alternative-fueled vehicles in a low-cost setting. These competitions typically include vehicles from many levels of technology, from home-built conversions to professional-purpose-built vehicles. These competitions also afford the opportunity for increasing the education of both the public and the participants in the event in the areas of alternative fuels technology and environmental awareness.

The American Tour de Sol represents a unique opportunity to conduct emissions and fuel economy testing on a wide variety of vehicles. The 1996 event was no exception. For the first time, the American Tour de Sol included a separate category for hybrid electric vehicles. During the week leading up to the seventh running of this annual event a group of seven hybrid electric vehicles which were entered in the Tour were tested at the New York City Department of Environmental Protection's Alternative Fuels Test Laboratory. In addition, a Solectria Force NMH and a 1996 Dodge Neon were also tested. The Force was tested as an up-to-date conversion EV, and the Dodge Neon was tested for use as a reference vehicle.

Energy Efficiency Comparisons of EVs and HEVs

When comparing an electric vehicle (EV) or hybrid electric vehicle (HEV) to a conventional vehicle, it is important to consider the full fuel cycle for producing electricity. The importance of this concept lies in the fact that the processes for producing gasoline at the pump and electricity at the plug are not equally efficient. In addition, battery charge and discharge efficiencies also apply to the electrical energy measurements from EVs and HEVs. Based upon a cross section of energy-producing technology, a relative efficiency factor of 0.3727 has been applied to compare gasoline to electricity, since electricity production is less efficient than gasoline production. efficiencies are typically 90% and 80%, respectively; therefore these factors have also been applied.

Emissions and fuel economy tests for EVs and for conventional vehicles are more straightforward than for HEVs. HEVs can draw energy from two sources: the battery pack and the fuel tank. In order to correctly account for all of the energy used for the test, the results from HEV testing are state-of-charge corrected. The procedure used for testing with state-of-charge corrections varies, depending upon the energy management strategy of the HEV being tested. In general, state-of charge corrections account for the fuel economy and emissions impacts of electricity taken from the plug as well as fuel energy used to either propel the vehicle or recharge the batteries.

Dynamometer Testing

The testing was performed on a Clayton twin-roll water brake chassis dynamometer. Unfortunately, proper facilities were not available to perform reliable coastdown tests for each vehicle. Therefore, the dynamometer road load was set on the basis of published aerodynamic data for each vehicle type and the vehicle weight as measured with computerized scales.

TEST CYCLES--Three driving cycles (LA-4, Highway Fuel Economy Test, and New York City Cycle) were used to test the vehicles. The LA-4 (or FTP-73) is a test that simulates an urban drive 12.07 km long with frequent stops. The speed for this cycle ranges between 0 and 91.2 km/h, with an average speed of

Battery charge and discharge

31.5 km/h. The LA-4 test dictates that the test vehicle idle for 17.8% of the cycle, or just over four minutes. The highway fuel economy test (HWFET) simulates continuous traffic conditions on a road or expressway. The HWFET speed range is from 0 to 96.4 km/h, with an average speed of 77.4 km/h. The New York City Cycle (NYCC) simulates high-traffic urban driving. It has a much lower average speed (11.4 km/h) than either the LA-4 or the HWFET and dictates that the test vehicle idle for 40% of the test.

VEHICLES--The four vehicles of interest for this paper were as follows: a Dodge Neon gasoline reference vehicle, a Solectria Force NMH, the University of Wisconsin HEV, and the Virginia Tech HEV. The Force NMH is a production EV based upon a conversion of a Geo Metro sedan, and it uses Ovonic nickel-metal hydride batteries. The Wisconsin HEV is a conversion based upon a 1992 Ford Escort Wagon,and uses Hawker Genesis advanced lead-acid batteries. The Virginia Tech HEV is a converted 1995 Chevrolet Lumina that also uses Hawker Genesis lead-acid batteries.

RESULTS--As can be seen from Figure 1, the results show that the Force has significantly higher fuel efficiency than any of the other vehicles. The Force achieved a fuel efficiency of 47 mpg equivalent on the LA-4 cycle and an impressive 58 mpg equivalent on the NYCC cycle. Both of the HEVs shown demonstrated higher fuel efficiency on the LA-4 cycle than did the Neon. This result is especially significant since both of the HEVs are heavier and larger than the Neon. Both of the HEVs achieved a 32 mpg equivalent highway mileage. The Wisconsin entry also proved to have a higher fuel efficiency on the NYCC than the Neon, and although the Virginia Tech entry was not tested on the NYCC, the trend in the graph indicates that its performance would likely have been nearly the same as the Wisconsin vehicle.

The two HEVs demonstrated a reduced dependence of fuel economy upon driving cycle when compared to either the gasoline control vehicle or the EV. Both of the HEVs shown are series design vehicles. The Wisconsin entry used a small two-cylinder industrial engine rated at 18.6 kW and fueled with reformulated gasoline. The throttle for the engine was mechanically fixed. The Virginia Tech entry used an automotive three-cylinder engine rated at 42.5 kW and fueled with liquefied propane gas. Virginia Tech employed an electronic throttle control scheme. Both vehicles used a control strategy that turned the engine on and off to maintain the battery state-of-charge within specified limits.

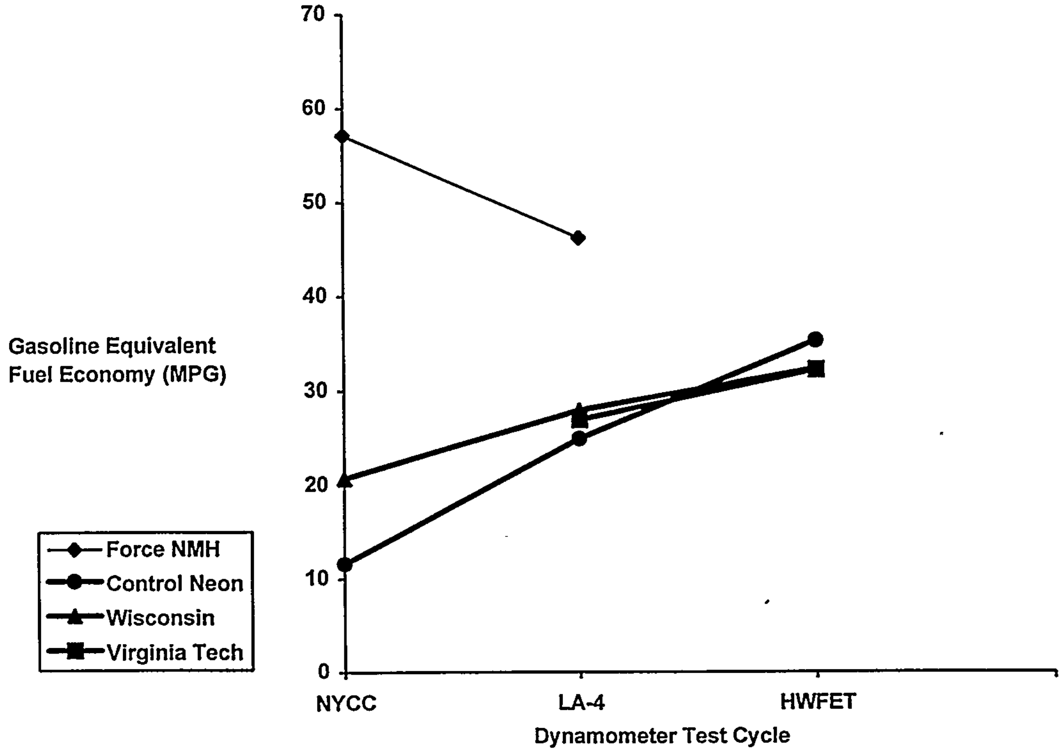

Figure 1: Fuel economy comparison of four vehicles during three dynamometer drive cycles.

Conclusions

Both electric and hybrid electric vehicle technology have been shown to provide potential improvements in energy efficiency over conventional vehicle technology. The Force demonstrated dramatically improved efficiency in crowded urban conditions represented by the NYCC. Both hybrid electric vehicles also performed well, demonstrating improvements over a Neon control vehicle on both the NYCC and the LA-4 cycle. The HEVs also demonstrated decreased sensitivity to the driving cycle than did either the EV or the Neon control vehicle.

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Acknowledgement

Work supported by the U.S. Department of Energy, Assistant Secretary for Energy Efficiency and Renewable Energy, under contract W-31-109-ENG-380.