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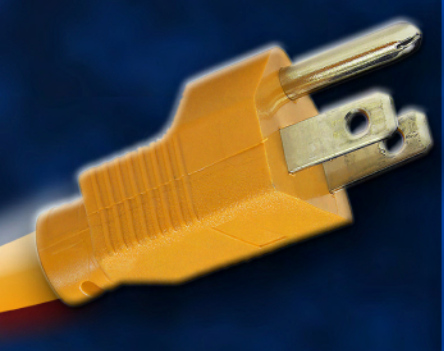


Quantifying PHEV All-Electric Range and Sensitivity of Fuel Economy in Charge-Sustaining Mode to Low State-of-Charge Operation

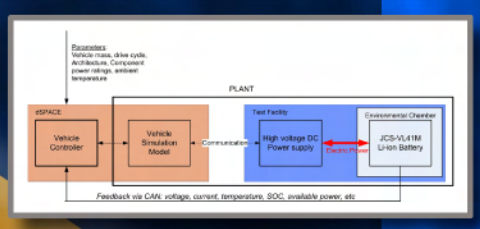
Battery Hardware-in-the-Loop Used to Test Johnson Controls-Saft-VL41M Li-ion Battery

Introduction

Argonne National Laboratory used its Battery Hardware-in-the-Loop (BHIL) to conduct an all-electric range (AER) test on a JCS-VL41M Li-ion battery. This test quantifies the electric vehicle (EV) range for different vehicle platforms.

After reaching a low state-of-charge (SOC), the plug-in hybrid (PHEV) vehicle is expected to operate in a charge-sustaining mode. From a vehicle perspective, it is important to determine the sensitivity of fuel economy to different low SOCs.

Battery Hardware-in-the-Loop



- Argonne's BHIL allows real batteries (here, the JCS-VL41M) to be evaluated in a "virtual vehicle."
- Battery performance and thermal behavior can be evaluated for multiple vehicle configurations, energy management strategies, drive cycles, and battery temperatures.
- BHIL is an ideal tool for developing vehicle energy management for extreme battery temperatures and for studying the impact of the same on vehicle petroleum displacement.

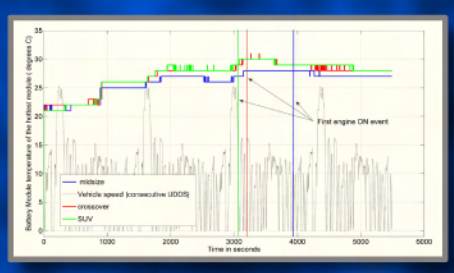
Johnson Controls-Saft-VL41M Battery Specifications

Battery Capacity	41 Ah at C/3 rate
Battery Nominal Voltage	260 V
Peak Power	60 kW at 50% SOC for 30 seconds

All-Electric Range Test at Starting Temperature of 20°C

Vehicle Class	Battery Ah Depleted in the AER Test	All-Electric Range (miles)	Wh/mile	Rise in Battery Temperature Over Initial (°C)	Energy Consumed
Midsize (1665 kg, 3663 lb)	24	21	277.01	6	5.3
Crossover (1845 kg, 4059 lb)	24	17.42	325.61	9	5.28
SUV (2049 kg, 4508 lb)	24	15.87	359.54	9	5.25

- Vehicle Type/Class: Pre-transmission parallel — midsize, crossover, and SUV.
- Vehicle Operation: Vehicle subjected to consecutive urban cycles in EV mode from an initial 90% SOC until battery capacity depleted by 24 Ah.



Sensitivity of Vehicle Fuel Economy to SOC in Charge-Sustaining Mode

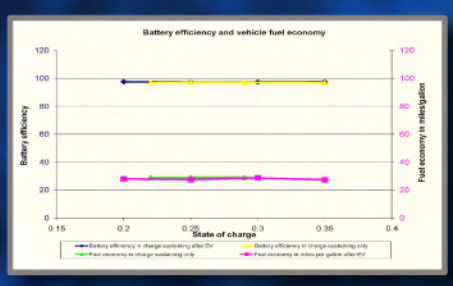
- Vehicle Type/Class: Pre-transmission parallel — SUV.
- Vehicle fuel economy in charge-sustaining mode calculated over a balanced Ah window through consecutive urban (UDDS) cycles.
- Charge-sustaining mode of operation at 35%, 30%, 25%, and 20% respectively.

Case 1: Battery in Charge-Sustaining Mode Following EV Mode of Operation from High (90%) SOC

Observations

- Battery temperature in charge-sustaining mode slightly higher at lower SOCs, due to longer EV range.
- Temperature differences or SOC do not impact battery efficiency or estimated fuel economy in charge-sustaining mode.

Case 2: No EV Mode, Battery in Charge-Sustaining Only for Consecutive UDDS



Observations

- Battery temperature is the same for charge-sustaining operation at all SOCs.
- No significant change in battery efficiency and estimated fuel economy over the differing SOCs, as well as in comparison with Case 1.

Conclusions

- **AER tests quantified the EV range of the VL41M at 20°C for three presented vehicle classes.**
- **Vehicle fuel economy is insensitive to SOC in charge-sustaining operation.**
- **SOC for charge-sustaining operation is a "battery life" decision, not a "battery performance" decision.**

Contact Information

Neeraj Shidore
Research Engineer
Argonne National Laboratory
630-252-7416
nshidore@anl.gov

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