Battery Pack Laboratory Testing Results

2013 Ford C-Max SE - VIN 5138

Vehicle Details and Battery Specifications[1,2]

Vehicle Details

Base Vehicle: 2013 Ford C-Max SE	VIN: 1FADP5AU9DL535138
Architecture: Hybrid Electric	

Battery Specifications

Manufacturer: Panasonic	Rated Pack Energy/Capacity: 1,400 Wh / 5.0 Ah
Type: Lithium-ion	Min/Max Cell Voltage: 2.75/4.20 V
Number of Cells: 76	Pack Mass/Volume[3]: 34.5 kg, 47.7 L
Nominal Cell/System Voltage: 3.7/281.2 V	Thermal Management: Active-Forced Air

[1] Vehicle details and battery specifications were either supplied by the manufacturer or derived from a literature review

[2] For full vehicle specifications, see the Baseline Performance Testing Results for this vehicle

[3] Battery pack volume is approximate and is based on the overall rectangular envelope less any significant voids

Battery Laboratory Test Results Summary

Test Number	Vehicle Odometer (Miles)	Date of Test	Measured Average Capacity (Ah)	Measured Average Energy Capacity (Wh)	10s Discharge Power Capability at 50% DOD (kW)	10s Charge Power Capability at 50% DOD (kW)
Baseline	4,053	2/13/2014	5.0	1,400.0	66.0	47.8
ICD 1	49,781	8/26/2014	4.7	1,340.0	66.8	49.3
ICD 2	105,135	5/10/2015	4.7	1,310.0	64.4	51.2
ICD 3						
End-of-Test						

HEV Battery Test Results Analysis

Battery test results include those from the Static Capacity Test and the Hybrid Pulse Power Characterization (HPPC) Test, based on test procedures from the United States Advanced Battery Consortium Battery Test Manual For Power-Assist Hybrid Electric Vehicles at the time of testing. These tests were performed for the US Department of Energy Vehicle Technology Office's Advanced Vehicle Testing Activity, which is conducted by the Idaho National Laboratory and Intertek Testing Services, North America.

Static Capacity Test Results

The Static Capacity Test measures the charge and energy capacities of the battery between maximum and minimum pack voltages when discharged at a one-hour (C_1) constant current rate, based on rated capacity.[4] Pack voltage versus capacity discharged during the Static Capacity Test is shown in Figure 1. Three iterations of the Static Capacity Test are performed at each interval, and the average results from each interval test are shown in the test results summary table on page 1.

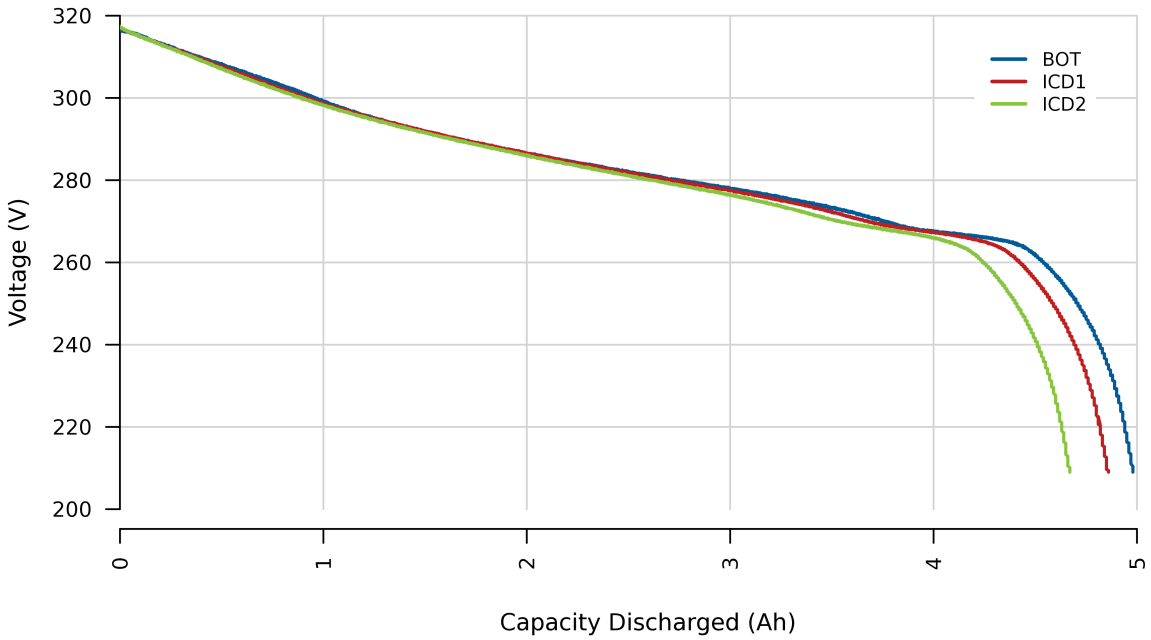

Figure 1. Voltage versus capacity discharged during the static capacity test

Hybrid Pulse Power Characterization Test Results

The HPPC test is performed to characterize the discharge and charge pulse power capabilities of the battery at each 10-percent depth-of-discharge interval. Numerical results derived from the HPPC test results are summarized in the table on page 1. The results from these tests can be compared to USABC power-assist HEV battery targets.

[4] Discharge rate is determined by dividing the rated capacity by one hour (5.0 Ah/1hr = 5.0 A).

Figures 2 and 3 illustrate the battery charge and discharge calculated pulse resistances, which indicate internal resistance at each 10-percent depth-of-discharge interval.

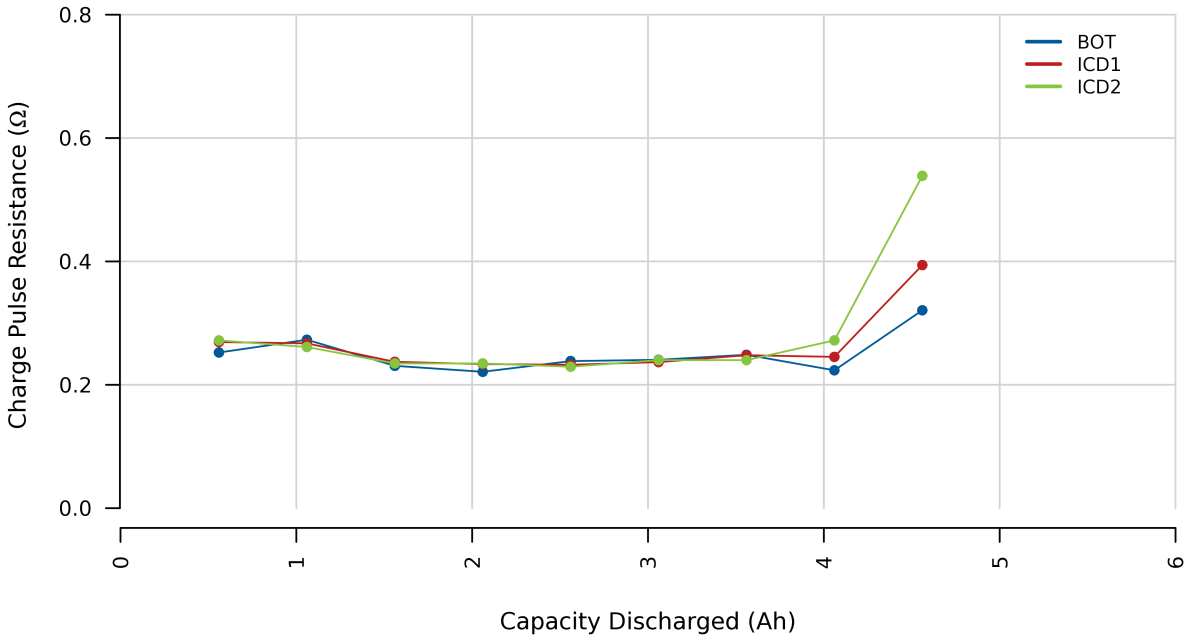

Figure 2. Ten-second charge pulse resistance versus capacity discharged

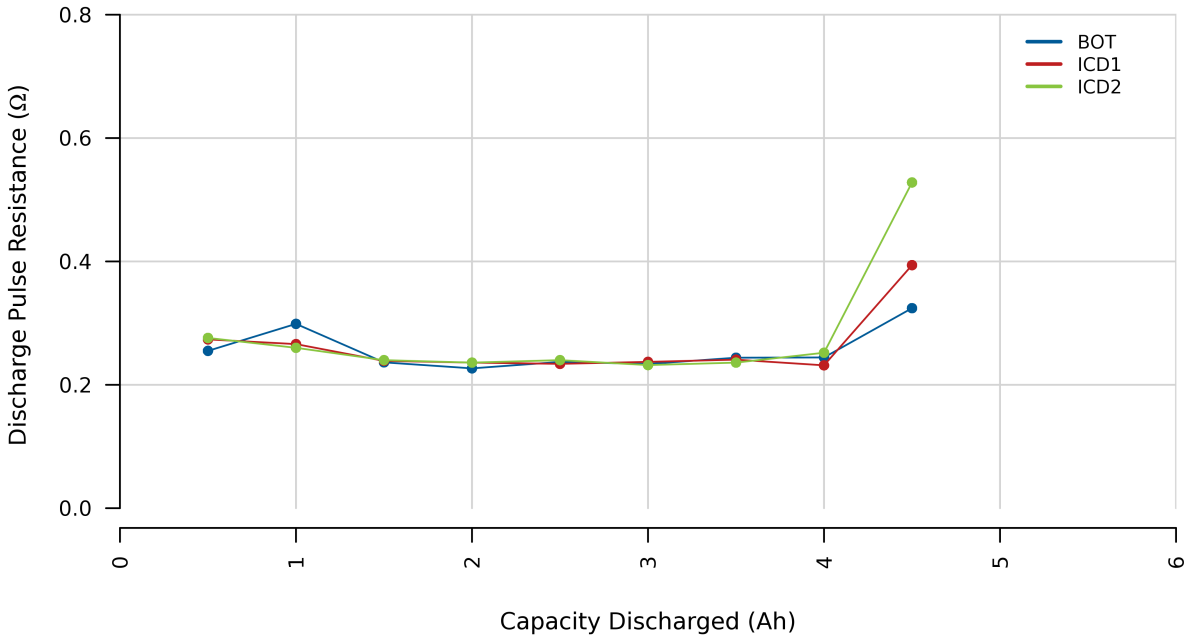

Figure 3. Ten-second discharge pulse resistance versus capacity discharged

Figure 4 shows the battery's 10-second charge and discharge pulse power capabilities as a function of energy discharged. The Minimum power-assist battery target performance goals of 25 kW discharge power and 20 kW charge power are shown as a dashed line. Note that the axes are scaled such that the charge and discharge pulse power goals align.

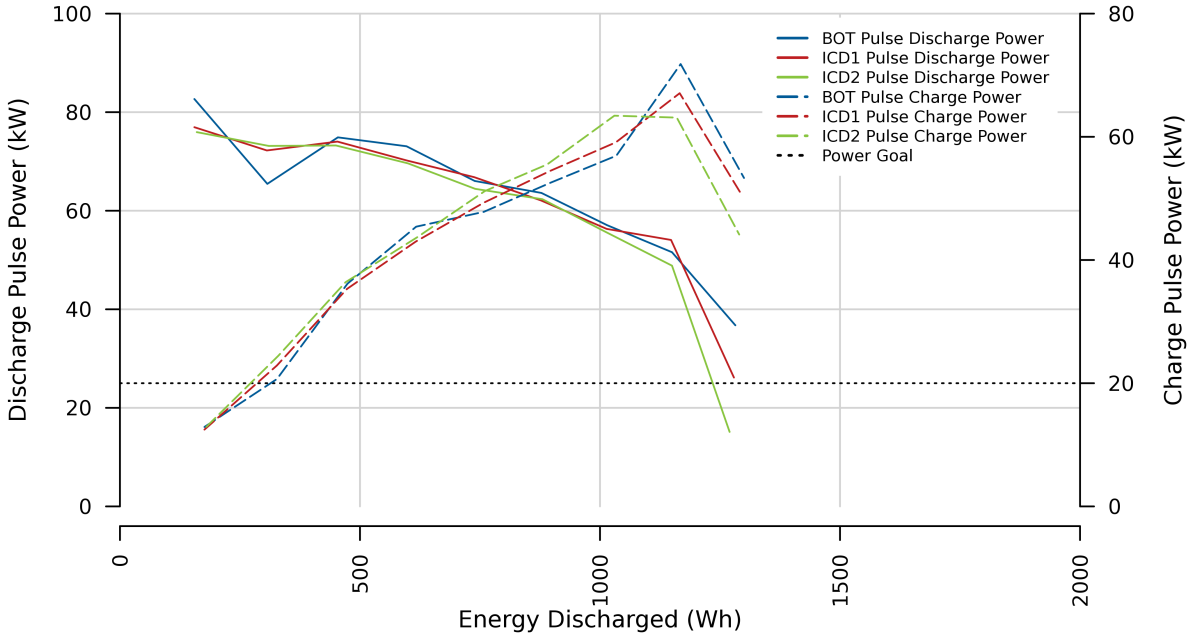

Figure 4. Discharge and charge power capabilities versus energy discharged

Figure 5 shows the Usable Energy curve, calculated using the methods from the HEV battery test manual. The curve indicates the Usable Energy as a function of discharge power. The dotted horizontal line shows the USABC Minimum power-assist HEV battery available energy goal of 300 Wh. The dotted vertical line shows the Minimum power-assist HEV battery discharge power goal of 25 kW. Available Energy is defined as the Usable Energy point, on the y-axis, where the curve crosses the discharge power goal line. Available Power is defined as the discharge power point, on the x-axis, where the curve crosses the energy goal line.

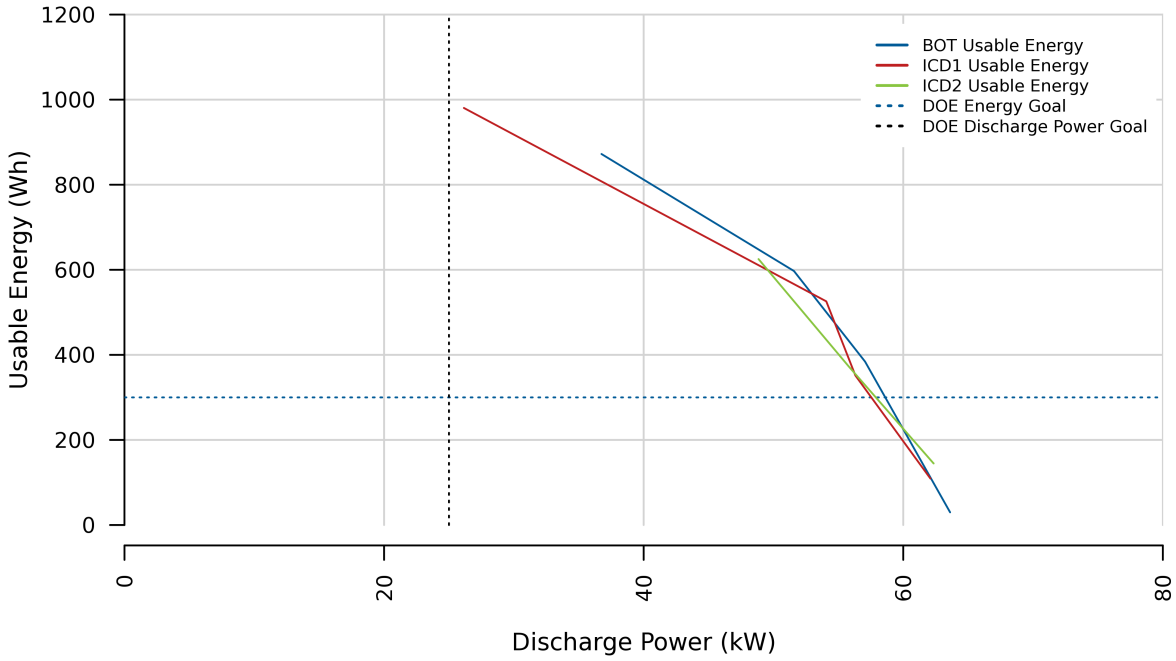

Figure 5. Usable energy versus power