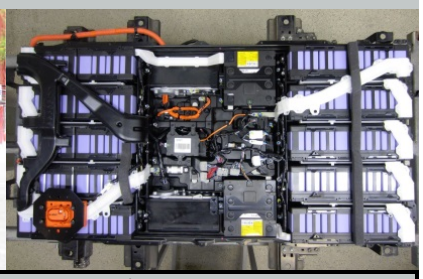
2012 Mitsubishi i-MiEV – VINs 3178 & 4550

Advanced Vehicle Testing –DC Fast Charging at Temperature Test Results



VEHICLE, ENERGY STORAGE SYSTEM, AND DCFC DETAILS[1]

Vehicle Details

Base Vehicle: 2012 Mitsubishi i-MiEV
Vehicle Type: BEV
VINs: JA3115H11CU033178; JA3215H15CU024550

DCFC Details

Manufacturer: Hasetec
Model/Type: HQC31-125-03AB/ CHAdeMO
Rated DC Charge Power: 50 kW
De-Rated DC Current[2]: 120 A

Energy Storage System Specifications

Manufacturer: Lithium Energy Japan
Type: Lithium-ion
Rated Pack Energy/Capacity: 16.0 kWh/50.0 Ah
Thermal Management: Active – Air

Test Dates by VIN

	3178	4550
0 °C	8/5/2014	6/24/2014
25 °C	8/6/2014	6/25/2014
50 °C	8/7/2014	7/1/2014

TEST RESULTS SUMMARY

Test Temp. (°C)	Total Charge Duration (hh:mm:ss)	End of Charge Range (mi)	Total DC Charge Energy (kWh)	Initial Charge Start/End SOC[3] (%)	Top-Off Charge Start/End SOC[3] (%)	Initial/Top-Off Charge Avg. Power (kW)	ESS ΔT[4] min/max (°C)	ESS Thermal Regulation Energy[5] (kWh)
VIN 3178 - Beginning-of-Test (at 7,865 miles)[6]								
0 °C	01:19:06	60	10.9	15.0 / 80.0	80.0 / 88.5	11.2 / 2.2	8 / 11	Not Activated
25 °C	00:53:16	66	12.1	15.5 / 79.5	79.5 / 96.5	26.5 / 2.6	6 / 10	0.73
50 °C	00:38:31	73	9.5	15.0 / 67.5	67.5 / 80.5	15.1 / 13.9	-10 / 0	1.95
Middle-of-Test								
0 °C								
25 °C								
50 °C								
End-of-Test								
0 °C								
25 °C								
50 °C								
VIN 4550 - Beginning-of-Test (at 13,209 miles)[6]								
0 °C	01:23:15	58	10.6	15.0 / 78.0	78.0 / 86.5	10.2 / 2.6	7 / 10	Not Activated
25 °C	00:53:47	73	12.3	14.5 / 80.5	80.5 / 96.0	25.7 / 1.9	6 / 10	0.67
50 °C	00:39:43	60	9.4	14.0 / 62.0	62.0 / 78.5	13.5 / 16.5	-12 / 0	1.98
Middle-of-Test								
0 °C								
25 °C								
50 °C								
End-of-Test								
0 °C								
25 °C								
50 °C								

Test Results Analysis

DC fast charging at temperature testing includes tests that measure the charge duration, energy transfer, and energy used to thermally regulate the energy storage system (ESS) for charge events at 0, 25 and 50 °C.[6] The objective of this testing is to provide analysis about the effects of ambient temperature on DC fast charge-capable vehicles. These tests were performed as part of the US Department of Energy Advanced Vehicle Testing Activity, which is conducted by Idaho National Laboratory and the Intertek Center for Evaluation of Clean Energy Technology (CECET).

Test Results: Energy and SOC

Figures 1a, 1b, and 1c show the energy transferred to each vehicle and the change in state of charge (SOC) over the duration of each charge event for each of the specified temperatures. Each DC fast charge event consists of an initial charge event and a top-off charge event.[8,9] The end of the initial charge is denoted by a dashed oval. Many vehicle manufacturers report the time required for a charge of the ESS to 80% SOC as being 30 minutes; for VIN 3178, the SOCs recorded at the 30-minute mark for the 0, 25 and 50 °C tests were 65.0%, 87.5%, and 67.0%, respectively. For VIN 4550, the SOCs recorded at the 30-minute mark for the 0, 25 and 50 °C tests were 62.0%, 86.5%, and 61.0% respectively.

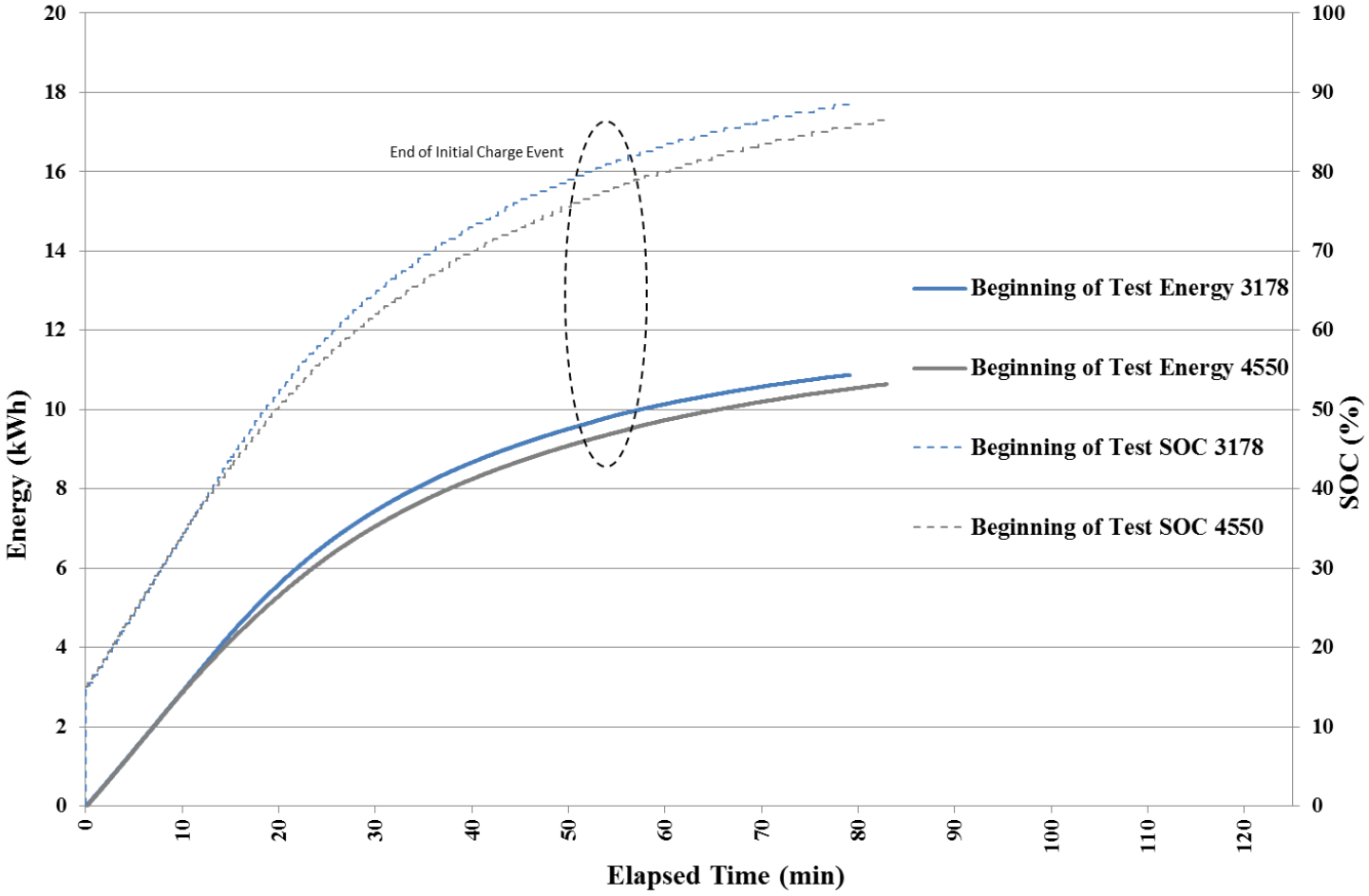


Figure 1a. 0 °C charge energy and SOC versus time

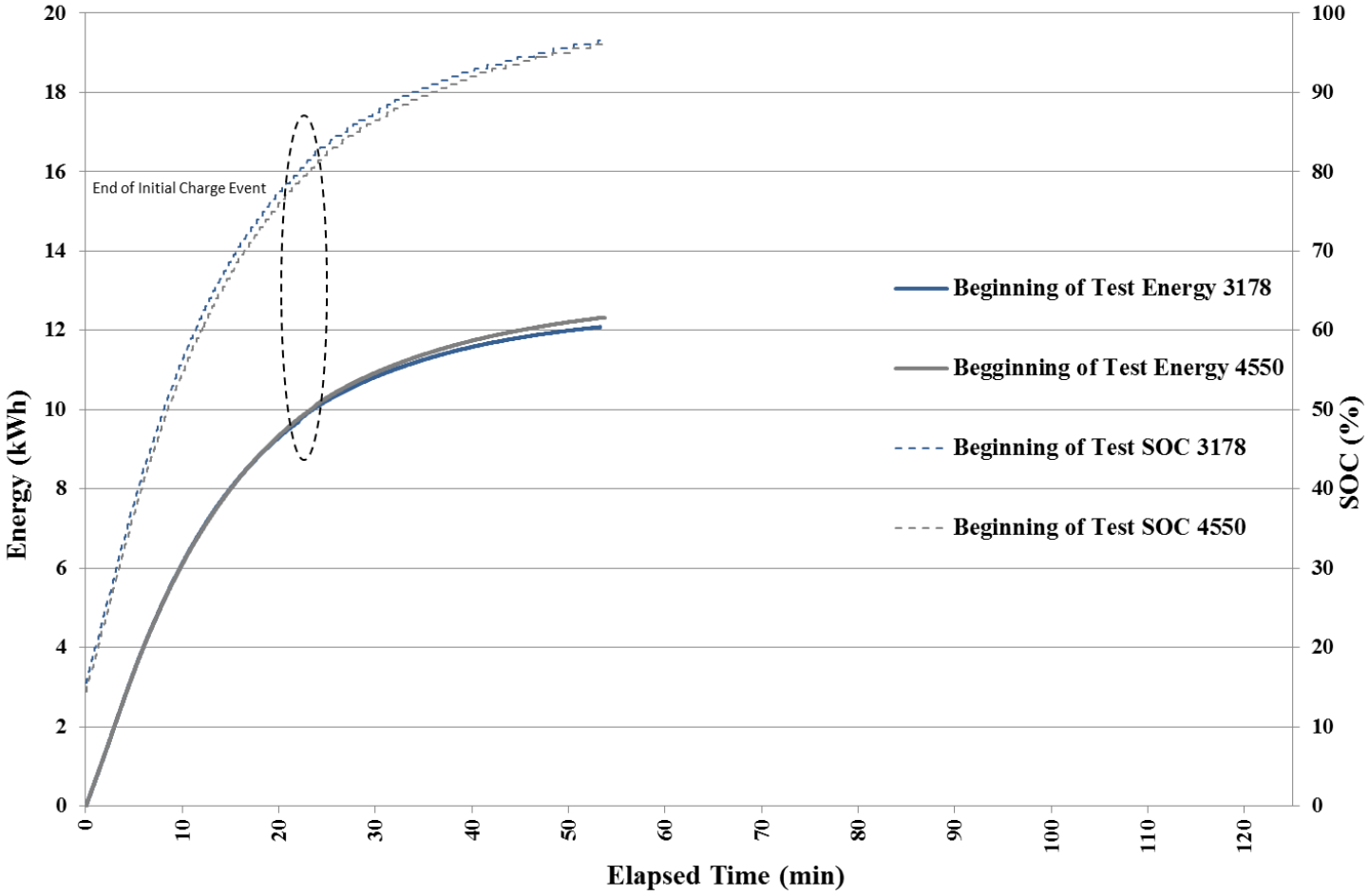


Figure 1b. 25 ºC Charge energy and SOC versus time

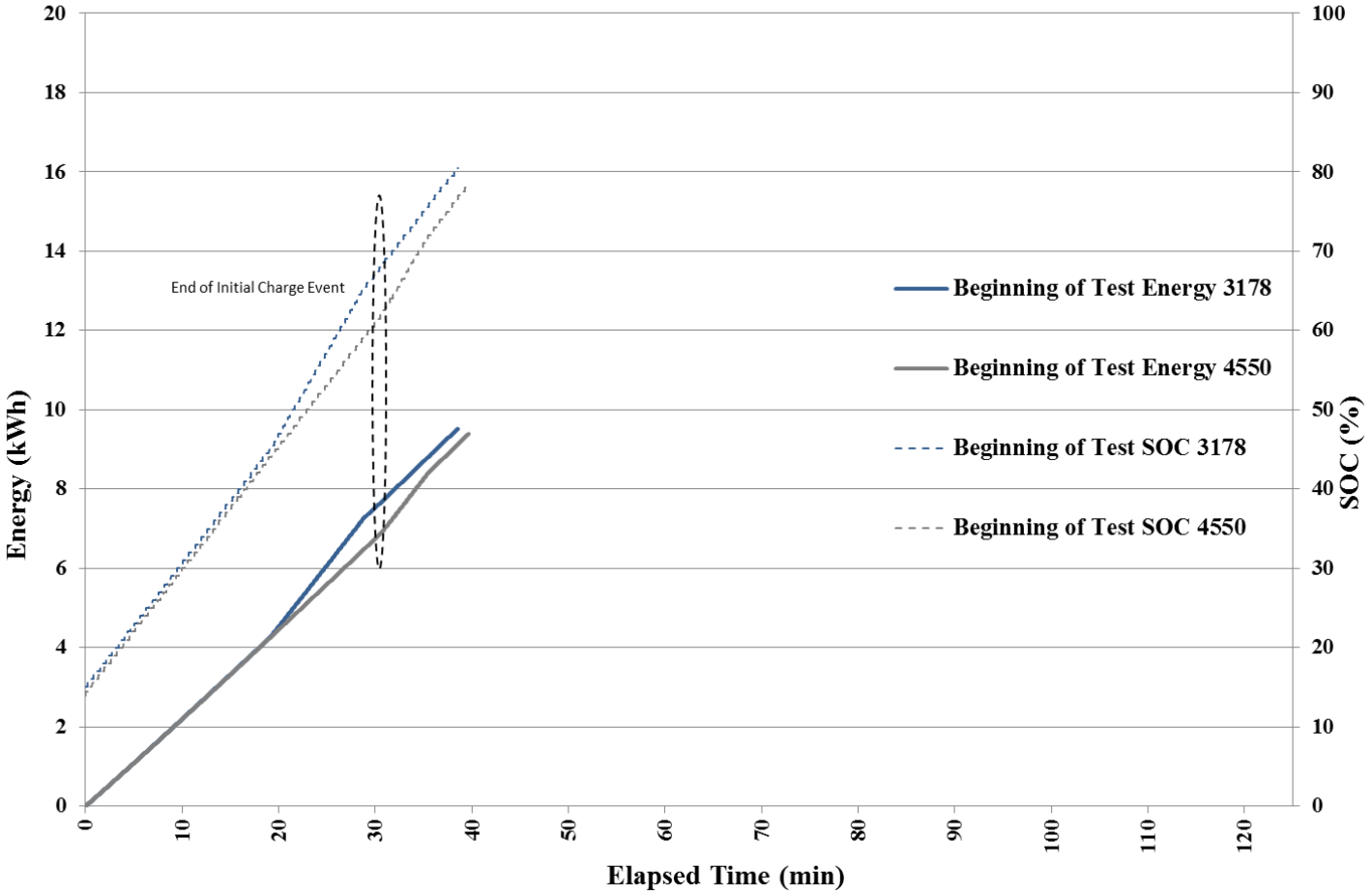


Figure 1c. 50 ºC Charge energy and SOC versus time

Test Results: Temperatures

Tables 1 and 2 show the initial, final, and maximum cell temperatures of each vehicle's ESS during charging events.

Table 1. VIN 3178 ESS cell temperature during BOT test

Test Temp. (°C)	ESS Cell Initial Temp. (°C)	ESS Cell Final Temp. (°C)	ESS Cell Maximum Temp. (°C)
0 °C	4	14	15
25 °C	26	36	36
50 °C	49	49	49

Table 2. VIN 4550 ESS cell temperature during BOT test

Test Temp. (°C)	ESS Cell Initial Temp. (°C)	ESS Cell Final Temp. (°C)	ESS Cell Maximum Temp. (°C)
0 °C	3	13	13
25 °C	27	37	37
50 °C	49	49	49

Test Results: Charge Power[10,11]

Figures 2a, 2b, and 2c show the power at which each vehicle's ESS was being charged for each of the specified temperatures. As before, the end of the initial charge event is denoted by a dashed oval.

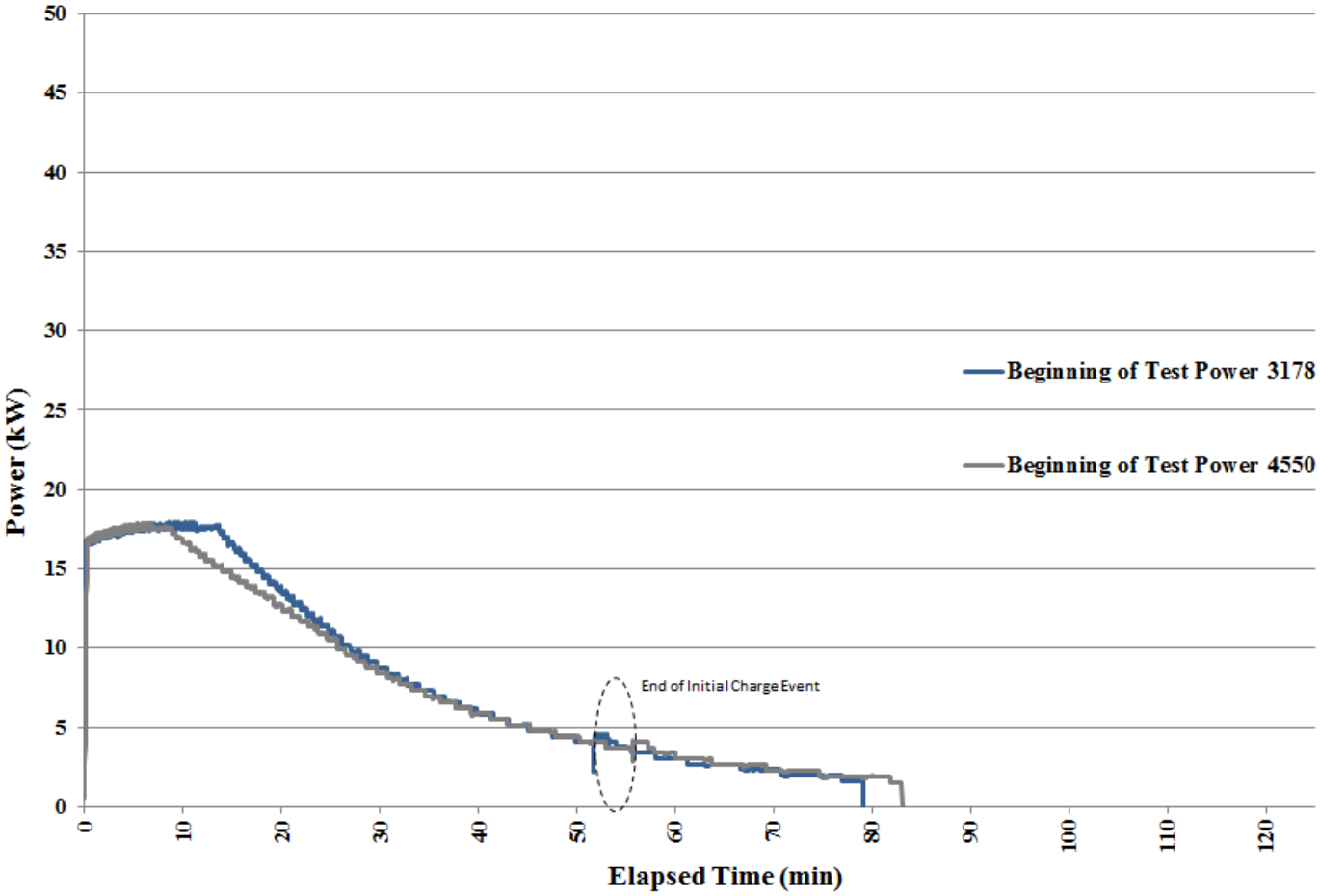


Figure 2a. 0 ºC Charge power profiles

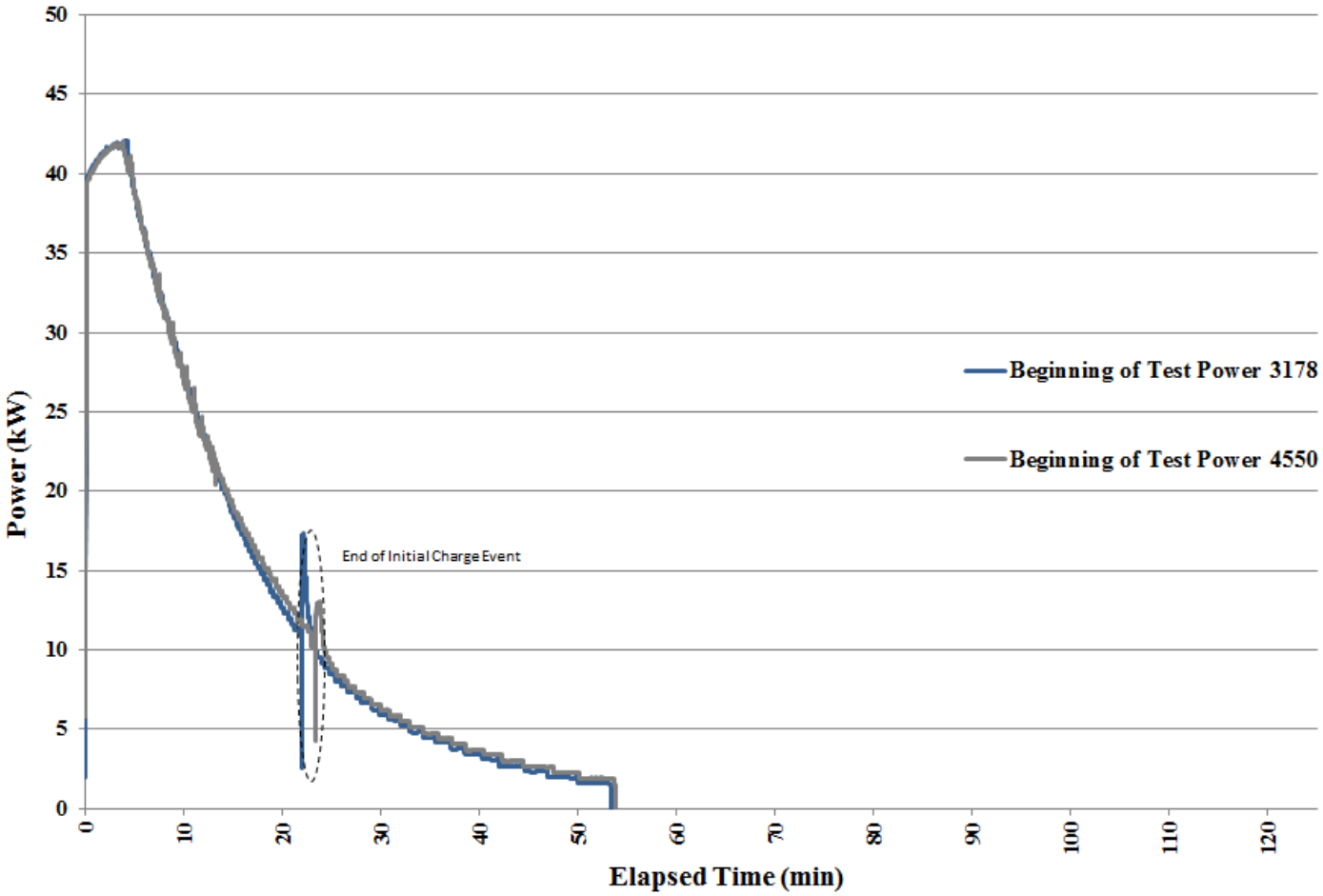


Figure 2b. 25 °C charge power profiles

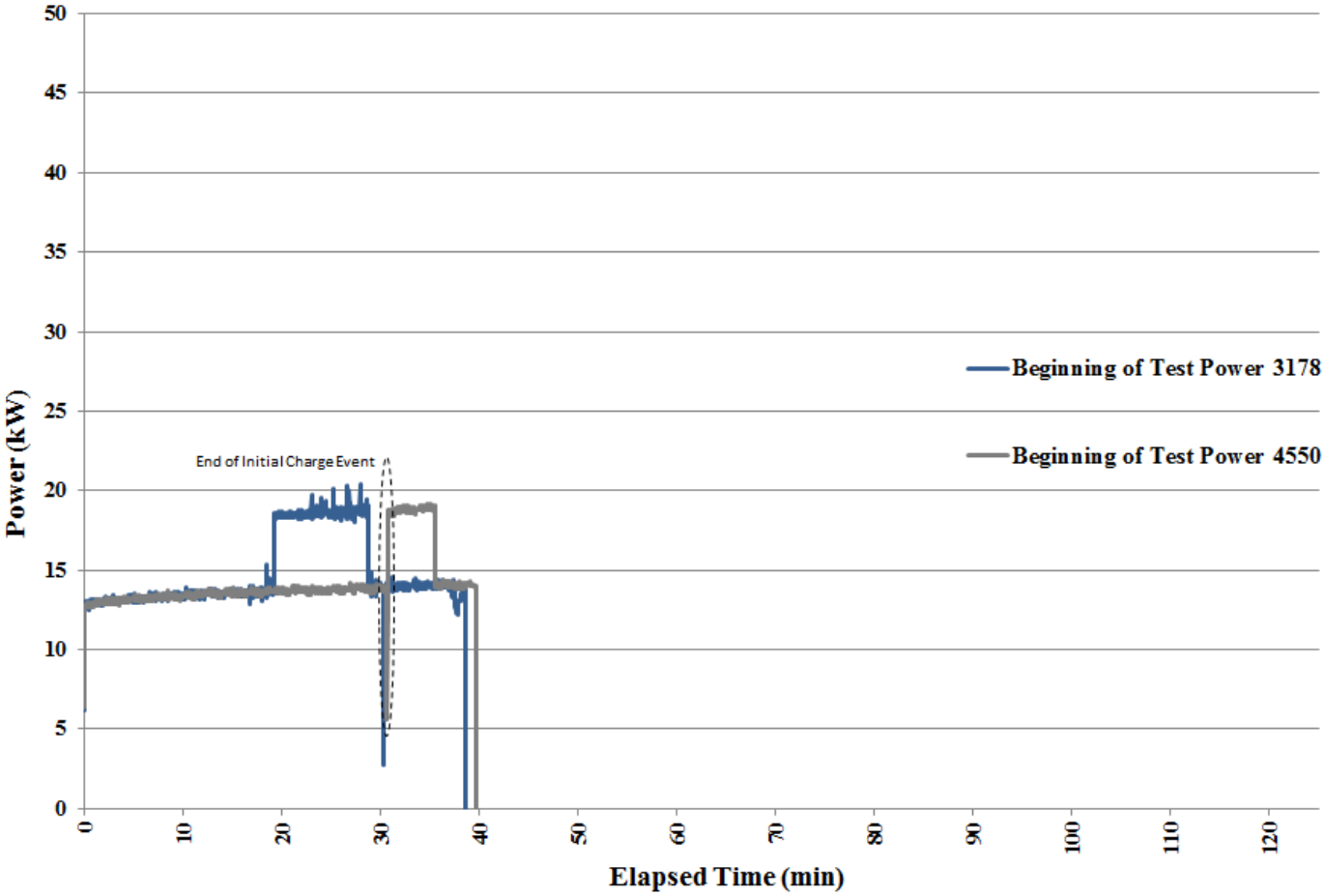


Figure 2c. 50 °C charge power profiles

NOTES:

1. Vehicle, ESS, and DCFC details were either supplied by the manufacturer or derived from a literature review.
2. The Hasetec DCFC was de-rated from 125 A to 120 A for all testing.
3. The ESS SOC is recorded from the vehicle controller area network (CAN) bus. The SOC displayed on the dashboard is also recorded for comparison and corroboration when available. In the case of the Mitsubishi i-MiEV, the CAN SOC correlates with the SOC revealed by a diagnostic scan tool. Refer to Note 8 for details concerning top-off charge events.
4. The "ESS ΔT During Test" is the difference in the temperature of the ESS between start and end of test for the cells with the minimum and maximum temperature. This parameter is calculated using the vehicle CAN message for battery temperature when available. When the CAN message is not available, the ESS enclosure temperature is measured by placing a thermocouple on the enclosure of the battery pack. In the case of the Mitsubishi i-MiEV, the minimum and maximum cell temperatures are reported via CAN.
5. The thermal regulation load is an approximate calculation of the amount of energy used by the vehicle to regulate ESS temperature, where applicable. This is calculated by subtracting the amount of energy into the ESS from the amount of energy output by the DCFC; the calculated value also includes resistive electrical losses. For comparison, the energy consumption of the AC compressor inverter as reported by the vehicle CAN bus has been included below:
   VIN 3178:
   0 °C: Not Activated | 25 °C: 0.08 kWh | 50 °C: 1.05 kWh
   VIN 4550:
   0 °C: Not Activated | 25 °C: 0.11 kWh | 50 °C: 1.24 kWh
6. Each fast charge-capable vehicle is chamber tested three times over the course of its test life. Under normal circumstances for EVs, the temperature chamber testing will take place at the same mileage target as the ESS Beginning of Test (BOT) test at 400 miles. The Middle of Test (MOT) takes place at the same mileage target as the ESS Interim Component Durability 3 (ICD3) test that is conducted at 24,000 miles. Finally, the End of Test (EOT) is conducted at the same mileage target as the ESS EOT test that is conducted at 36,000 miles. In the case of the Mitsubishi i-MiEV, the decision to run the chamber testing at the same mileage target as the ESS BOT test was made after the ESS Testing had been completed.
7. Each test consists of a soak period of a length deemed sufficiency to ensure the vehicle ESS is at the target test temperature; the soak period is a minimum of 21 hours.
8. One top-off charge is conducted per test regardless of the ESS SOC reading at the end of the initial and top-off charge events. The battery management system (BMS) determines the stopping point of the initial and top-off charge events. The dashboard Vehicle Energy Indicator (VEI) for each vehicle at the start/end of each test was as follows:
   VIN 3178:
   0 °C: 1 / 15 bars | 25 °C: 1 / 16 bars | 50 °C: 1 / 14 bars
   VIN 4550:
   0 °C: 1 / 15 bars | 25 °C: 1 / 16 bars | 50 °C: 1 / 14 bars
9. Time (in seconds) between the end of the initial charge and beginning of the top-off charge is collected for each test. This delay has not been included in the figures.
   VIN 3178:
   0 °C: 32 s | 25 °C: 31 s | 50 °C: 36 s
   VIN 4550:
   0 °C: 52 s | 25 °C: 35 s | 50 °C: 45 s
10. Maximum charge power for initial and top-off charges:
    VIN 3178:
    0 °C: 18.0 / 4.6 kW | 25 °C: 42.1 / 17.4 kW | 50 °C: 20.4/ 14.5 kW
    VIN 4550:
    0 °C: 17.9 / 4.2 kW | 25 °C: 41.9 / 13.0 kW | 50 °C: 14.2 / 19.1 kW
11. Voltage at end of initial charge / voltage at end of top-off charge / maximum charge voltage / voltage at initial current drop off:
    VIN 3178:
    0 °C: 361.0/ 360.8/ 361.1/ 360.7 V | 25 °C: 361.0 /361.2 / 361.1 / 360.3 V | 50 °C: 354.4 / 360.2 / 356.6 / 356.6 V
    VIN 4550:
    0 °C: 360.8 / 360.7 / 361.0 / 359.7 V | 25 °C: 360.9 / 361.0 / 361.1 / 358.9 V | 50 °C: 352.6 / 358.6 / 359.7 / 359.0 V

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