2015 Chevrolet Spark EV – VINs 4878, 8065, 8708 & 9952

Advanced Vehicle Testing –DC Fast Charging at Temperature Test Results




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

Vehicle Details

Base Vehicle: 2015 Chevrolet Spark EV
Vehicle Type: BEV
VINs: KL8CK6S05FC704878; KL8CL6S05FC718065; KL8CL6S0XFC718708; KL8CL6S09FC709952

DCFC Details

Manufacturer: BTC Power
Model/Type: EVFC-5-1-B-1-1-480/SAE CCS+CHAdeMO
Rated DC Charge Power: 50 kW
Rated DC Current[2]: 100 A

Energy Storage System Specifications

Manufacturer: LG Chem
Type: Lithium-ion
Rated Pack Energy/Capacity: 19.0 kWh/52.0 Ah
Thermal Management: Active Cooling – Liquid (Dex-Cool), Active Heating – Resistive

Test Dates by VIN

	4878	8065	8708	9952
0 °C	10/13/2015	9/24/2015	10/14/2015	9/25/2015
25 °C	10/15/2015	9/26/2015	10/16/2015	9/27/2015
50 °C	10/21/2015	9/28/2015	10/20/2015	9/30/2015

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] (°C)	ESS Thermal Regulation Energy[5] (kWh)
VIN 4878 - Beginning-of-Test (at 5,509 miles)[6]								
0 °C	00:46:57	74	18.27	3.2 / 97.0	N/A	23.3 / 0.0	20.5	0.83
25 °C	00:42:49	79	18.36	2.4 / 96.9	N/A	25.7 / 0.0	0.0	1.03
50 °C	00:42:07	76	18.25	1.5 / 96.9	N/A	26.0 / 0.0	-9.0	1.96
Middle-of-Test								
0 °C								
25 °C								
50 °C								
End-of-Test								
0 °C								
25 °C								
50 °C								
VIN 8065- Beginning-of-Test (at 5,231 miles)[6]								
0 °C	00:49:25	75	18.75	1.2 / 96.8	N/A	22.8 / 0.0	21.0	0.66
25 °C	00:44:29	76	18.50	2.0 / 96.8	N/A	24.9 / 0.0	-2.0	1.08
50 °C	01:00:39	72	18.37	2.0 / 96.8	N/A	18.2 / 0.0	-11.0	2.35
Middle-of-Test								
0 °C								
25 °C								
50 °C								
End-of-Test								
0 °C								
25 °C								
50 °C								

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] (°C)	ESS Thermal Regulation Energy[5] (kWh)
VIN 8708 - Beginning-of-Test (at 5,262 miles)[6]								
0 °C	00:49:33	75	18.52	2.1 / 97.0	N/A	22.4 / 0.0	22.5	0.90
25 °C	00:42:51	74	18.64	1.4 / 96.9	N/A	26.1 / 0.0	-0.5	0.77
50 °C	02:01:20	72	18.33	2.0 / 15.1	15.1 / 97.1	2.2 / 15.9	-12.5	1.45
Middle-of-Test								
0 °C								
25 °C								
50 °C								
End-of-Test								
0 °C								
25 °C								
50 °C								
VIN 9952 - Beginning-of-Test (at 6,022 miles)[6]								
0 °C	00:47:01	77	18.70	2.0 / 97.0	N/A	23.9 / 0.0	20.0	0.51
25 °C	00:44:26	76	18.38	2.0 / 96.0	N/A	24.8 / 0.0	-1.0	1.11
50 °C	01:58:00	65	17.99	2.5 / 15.6	15.6 / 95.7	2.2 / 16.5	-9.0	1.73
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.[7] 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. Most DC fast charge events consist of an initial charge event and a top-off charge event.[8,9] Only VIN 8708 and VIN 9952 accepted a top-off charge, and only during the 50 °C tests. The end of the initial charge is denoted by a dashed oval, where a top-off charge was allowed by the vehicle. Many vehicle manufacturers report the time required for a charge of the ESS to 80% SOC as being 30 minutes. For VIN 4878, the SOCs recorded at the 30-minute mark for the 0, 25, and 50 °C tests were 76.4%, 89.2%, and 72.9%, respectively. For VIN 8065, the SOCs recorded at the 30-minute mark for the 0, 25, and 50 °C tests were 73.9%, 87.9%, and 73.0%, respectively. For VIN 8708, the SOCs recorded at the 30-minute mark for the 0, 25, and 50 °C tests were 71.4%, 88.5%, and 7.4%, respectively. For VIN 9952, the SOCs recorded at the 30-minute mark for the 0, 25, and 50°C tests were 74.9%, 86.6%, and 7.2%, respectively. During the 50 °C tests, VINs 8708 and 9952 limited their charging current to less than 10 A. This continued through the first hour and into the top-off segment. The current appeared to be limited until the SOC reached a level sufficient for active cooling to begin, after which the charging current increased to levels observed at other test temperatures.

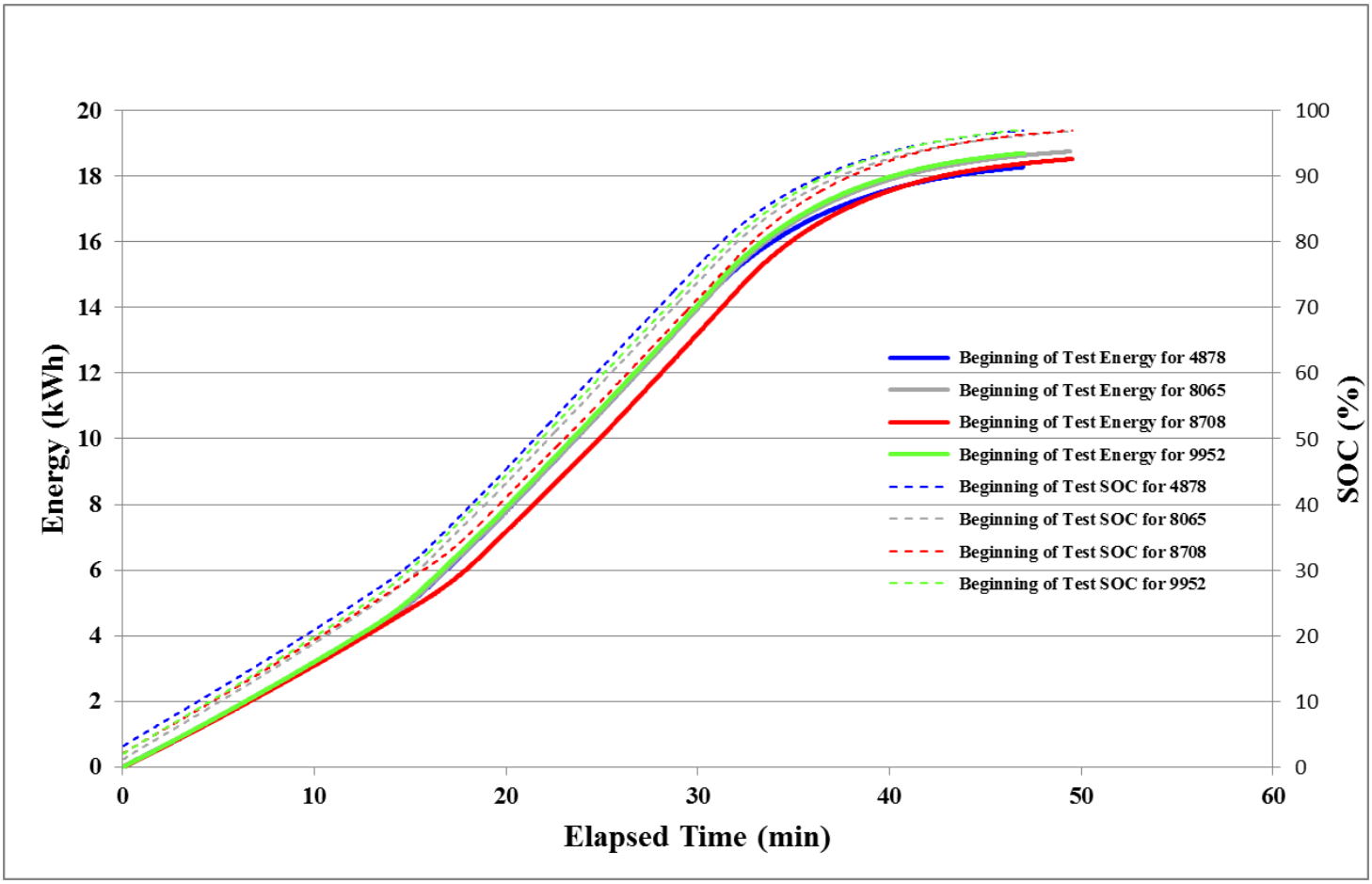

Figure 1a. 0 °C charge energy and SOC versus time

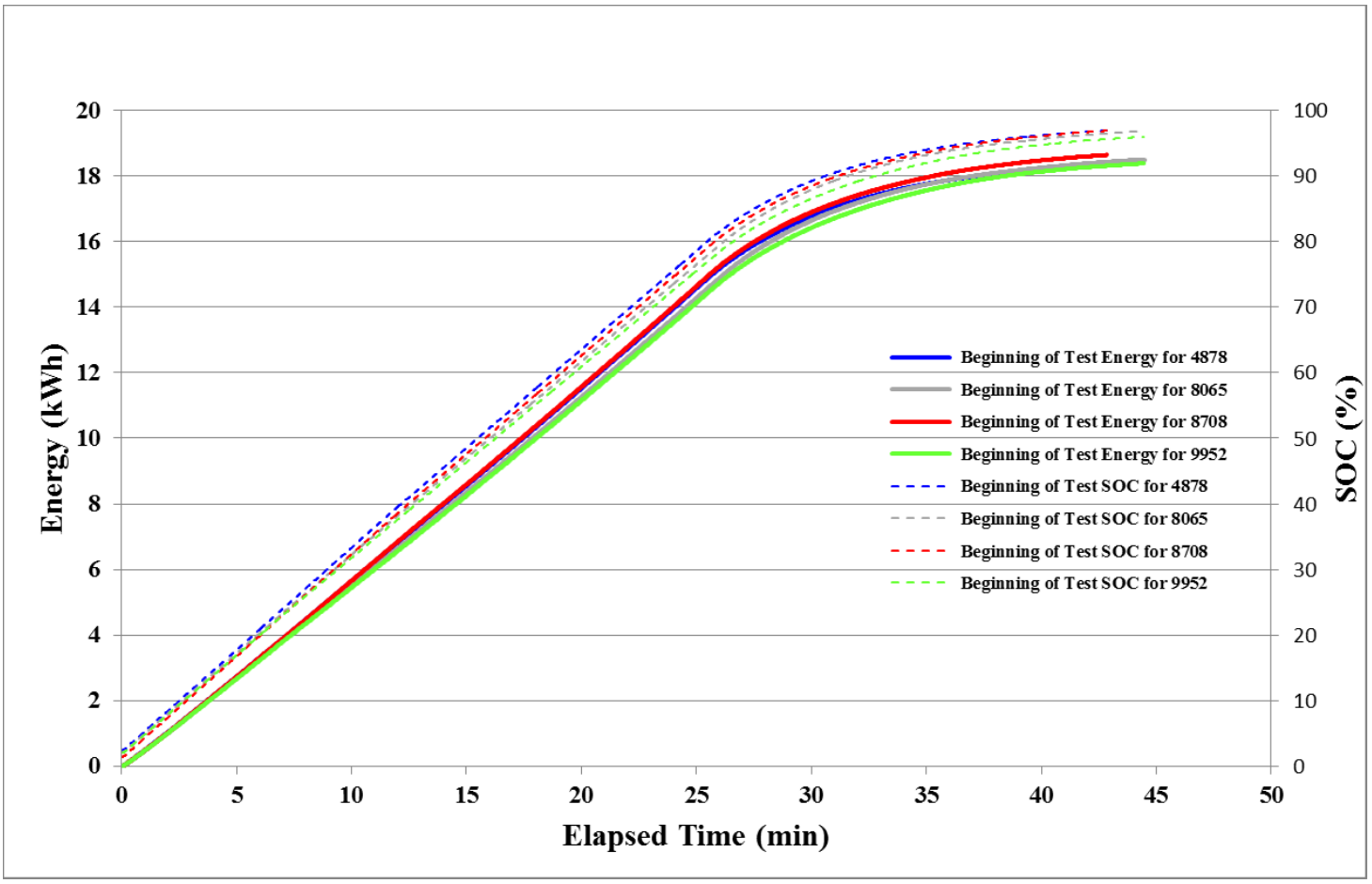

Figure 1b. 25 °C charge energy and SOC versus time

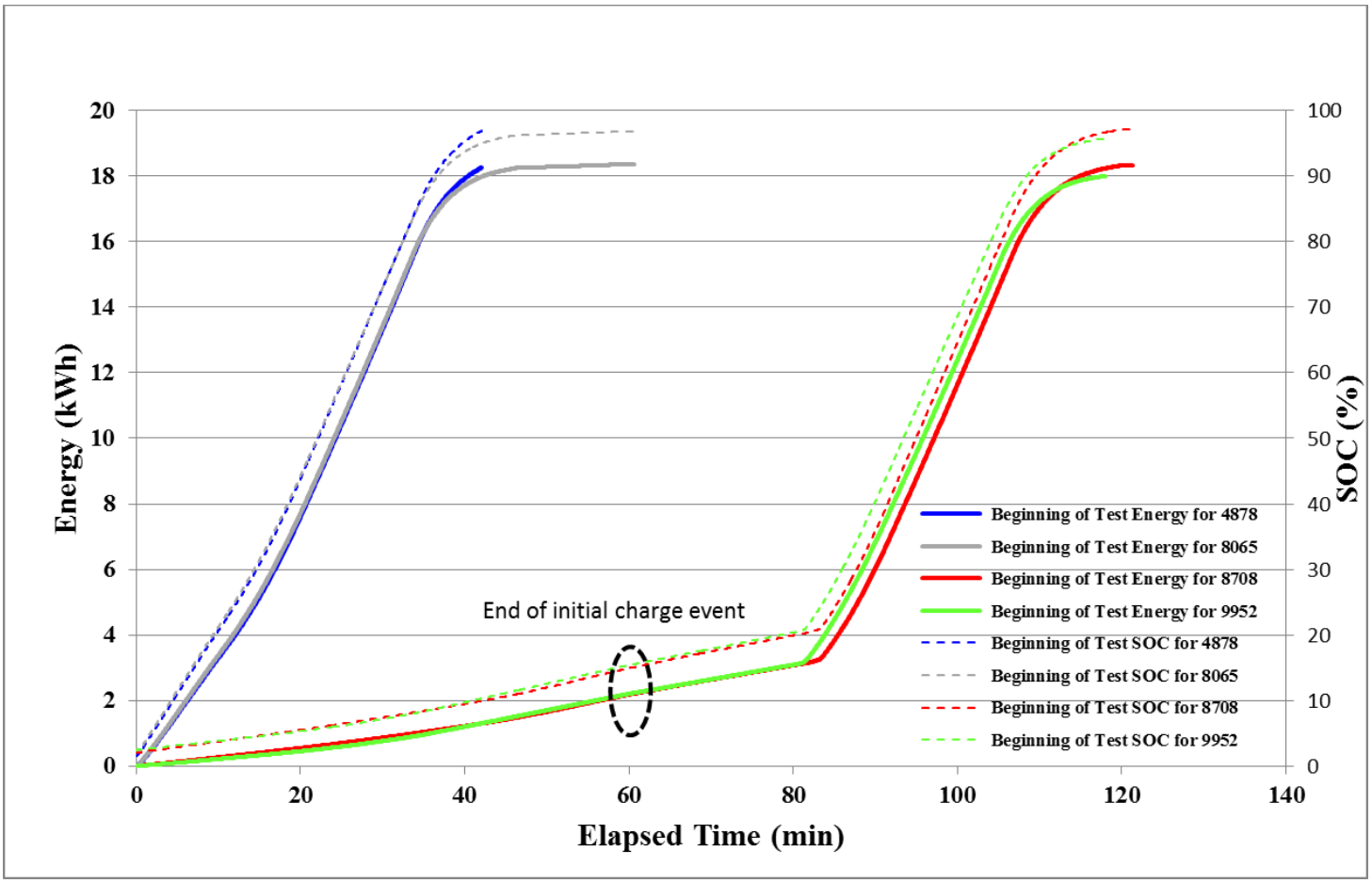

Figure 1c. 50 °C charge energy and SOC versus time

Test Results: Temperatures

Tables 1, 2, 3, and 4 show the initial, final, and maximum cell temperatures of each vehicle's ESS during charging events.

Table 1. VIN 4878 ESS cell temperature during BOT test

Test Temperature (°C)	ESS Initial Temp. (°C)	ESS Final Temp. (°C)	ESS Maximum Temp. (°C)
0 °C	3.5	24.0	24.0
25 °C	24.5	24.5	29.0
50 °C	48.5	39.5	49.0

Table 2. VIN 8065 ESS cell temperature during BOT test

Test Temperature (°C)	ESS Initial Temp. (°C)	ESS Final Temp. (°C)	ESS Maximum Temp. (°C)
0 °C	3.5	24.5	24.5
25 °C	26.5	24.5	28.5
50 °C	48.5	37.5	48.5

Table 3. VIN 8708 ESS cell temperature during BOT test

Test Temperature (°C)	ESS Initial Temp. (°C)	ESS Final Temp. (°C)	ESS Maximum Temp. (°C)
0 °C	2.5	25.0	25.5
25 °C	25.0	24.5	29.0
50 °C	50.0	37.5	50.0

Table 4. VIN 9952 ESS cell temperature during BOT test

Test Temperature (°C)	ESS Initial Temp. (°C)	ESS Final Temp. (°C)	ESS Maximum Temp. (°C)
0 °C	4.5	24.5	24.5
25 °C	26.5	25.5	28.5
50 °C	50.0	41.0	50.0

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 in Figure 2c.

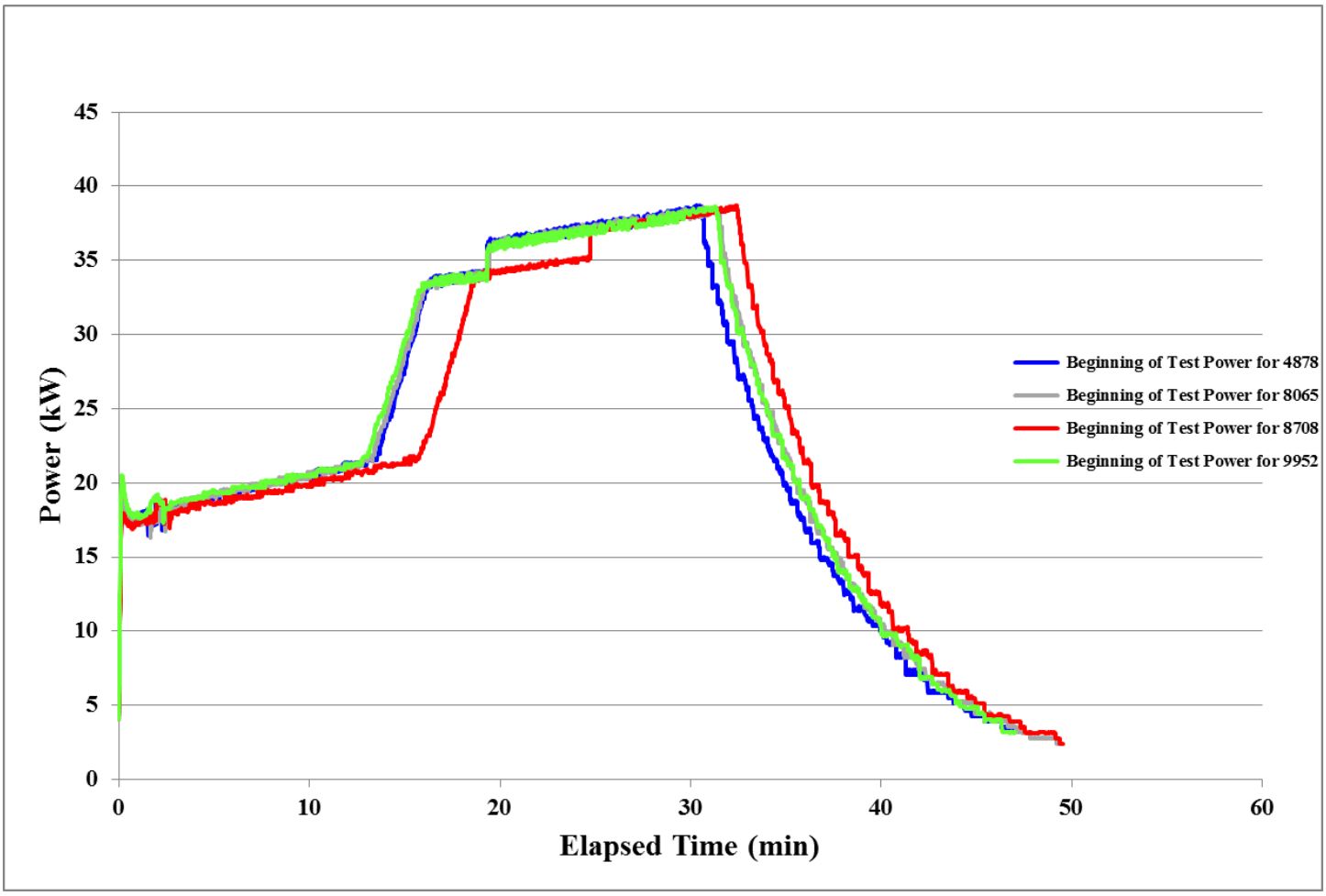

Figure 2a. 0 °C charge power profiles

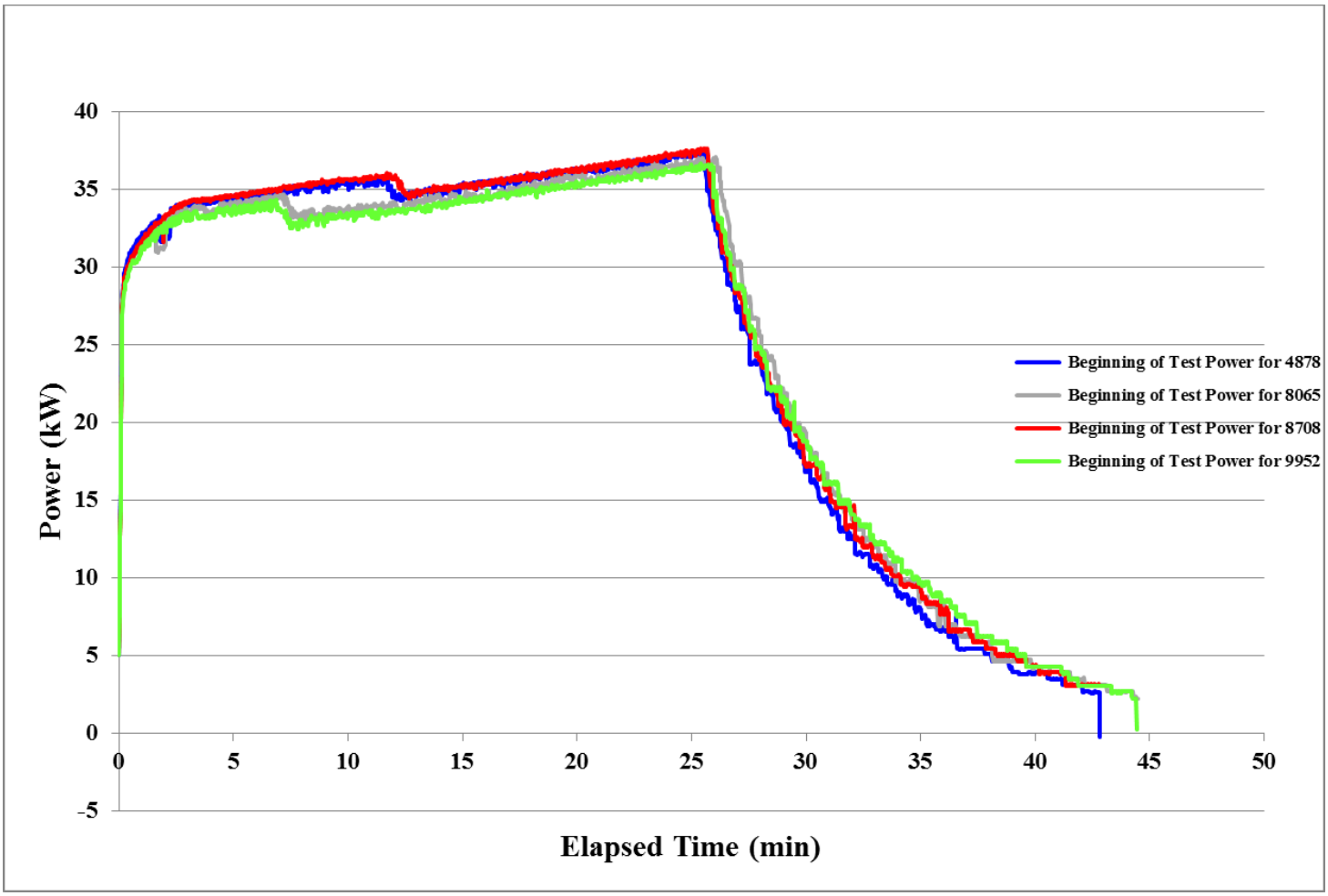

Figure 2b. 25 °C charge power profiles

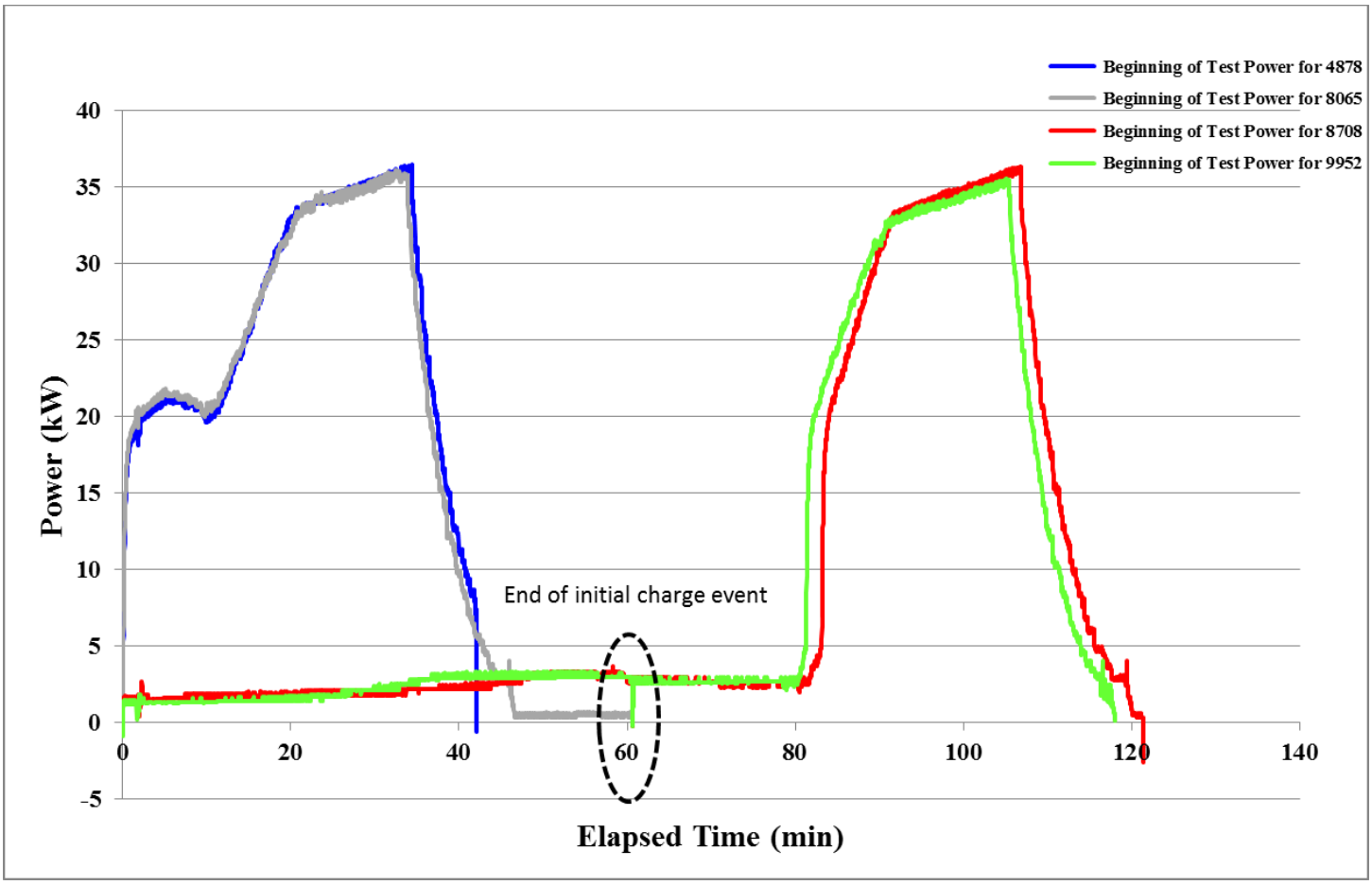

Figure 2c. 50 °C charge power profiles

NOTES:

1. Vehicle, ESS, and DCFC details were either supplied by the manufacturer or derived from a literature review.
2. The BTC DCFC has a maximum current output of 100 A. The BTC DCFC shuts down after 60 minutes regardless of the presence of a stop signal from the vehicle.
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 Chevrolet Spark EV, 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" is the difference in the maximum cell temperature of the ESS between start and end of test. 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 top of the battery pack enclosure. In the case of the Chevrolet Spark EV, ESS maximum cell temperature is 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 and conversion electrical losses. It is possible that some of the energy values noted for tests are due to parasitic losses or powering of the vehicle fast charging system. There are three possibilities for how the onboard vehicle electronics receive power during a fast charge: 1) 12 V interface on the CCS charger, 2) DC-to-DC converter steps high voltage down to 12 V, or 3) the system could be powered directly from the 12 V battery of the vehicle.
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 Chevrolet Spark EV, the procurement of an SAE CCS fast charger was made after the vehicles had reached BOT mileage.
7. Each test consists of a soak period deemed sufficient 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, assuming the charge takes less than 1 hour. Only VIN 8708 and VIN 9952 accepted a top-off charge, and only during the 50 °C tests. The dashboard Vehicle Energy Indicator (VEI) for each vehicle at the start/end of each test was as follows:

   VIN 4878:
   - 0 °C: 0 / 10 bars
   - 25 °C: 0 / 10 bars
   - 50 °C: 0 / 10 bars

   VIN 8065:
   - 0 °C: 0 / 10 bars
   - 25 °C: 1 / 10 bars
   - 50 °C: 1 / 10 bars

   VIN 8708:
   - 0 °C: 0 / 10 bars
   - 25 °C: 0 / 10 bars
   - 50 °C: 0 / 10 bars

   VIN 9952:
   - 0 °C: 0 / 10 bars
   - 50 C: 0 / 10 bars
   - 50 °C: 0 / 10 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 4878:
   - 0 °C: N/A
   - 25 °C: N/A
   - 50 °C: N/A

   VIN 8065:
   - 0 °C: N/A
   - 25 °C: N/A
   - 50 °C: N/A

   VIN 8708:
   - 0 °C: N/A
   - 25 °C: N/A
   - 50 °C: 68 s

   VIN 9952:
   - 0 °C: N/A
   - 50 C: N/A
   - 50 °C: 175 s

10. Maximum charge power for initial and top-off charges:

    VIN 4878:
    - 0 °C: 38.7 / 0.0 kW
    - 25 °C: 37.5 / 0.0 kW
    - 50 °C: 36.4 / 0.0 kW

    VIN 8065:
    - 0 °C: 38.6 / 0.0 kW
    - 25 °C: 37.0 / 0.0 kW
    - 50 °C: 36.1 / 0.0 kW

    VIN 8708:
    - 0 °C: 38.7 / 0.0 kW
    - 25 °C: 37.6 / 0.0 kW
    - 50 °C: 3.7 / 36.3 kW

    VIN 9952:
    - 0 °C: 38.6 / 0.0 kW
    - 50 C: 36.7 / 0.0 kW
    - 50 °C: 3.4 / 36.3 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 4878:
    - 0 °C: 397.3 / N/A / 397.8 / 397.3 V
    - 25 °C: 397.3 / N/A / 398.3 / 397.8 V
    - 50 °C: 396.8 / N/A / 398.3 / 397.8 V

    VIN 8065:
    - 0 °C: 397.3 / N/A / 397.3 / 397.3 V
    - 25 °C: 397.8 / N/A / 398.8 / 398.3 V
    - 50 °C: 397.3 / N/A / 398.8 / 398.3 V

    VIN 8708:
    - 0 °C: 396.8 / N/A / 397.3 / 396.8 V
    - 25 °C: 397.3 / N/A / 398.3 / 398.3 V
    - 50 °C: 339.6 / 396.8 / 398.3 / 398.3 V

    VIN 9952:
    - 0 °C: 396.2 / N/A / 396.8 / 396.2 V
    - 25 °C: 396.8 / N/A / 397.8 / 397.3 V
    - 50 °C: 339.0 / 396.8 / 397.8 / 397.8 V

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