



Powertrain Cooling and Thermal Performance for Alternative Propulsion Passenger Vehicles

1 Scope

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. To determine the powertrain cooling temperatures (coolant, engine oil, and transmission oil), thermal temperatures (underhood and underbody components affected by powertrain generated heat), power electronics temperatures (inverters and converters), motors and Energy Storage System (ESS)/Rechargeable Energy Storage System (RESS) temperatures for the conditions specified in the Vehicle Technical Specifications (VTS), Subsystem Technical Specifications (SSTS), Component Technical Specifications (CTS) and Interface Control Documents (ICD).

1.2 Foreword. This test procedure is intended to be a supplement to GMW14555 for alternative propulsion programs and used along with procedure GMW14555 to validate the powertrain cooling, thermal, power electronics, motor, and ESS/RESS capability for an alternative propulsion vehicle program. This procedure shall be run in addition to the applicable GMW14555 conditions as specified in the VTS for all regions where the Alternative Propulsion vehicle will be sold. The temperatures measured are compared against the limits defined in the VTS, SSTS, CTS, and ICD documents.

1.3 Applicability. For all alternative propulsion (belt alternator starter (BAS), hybrid electric vehicle (HEV), plug-in hybrid electric vehicle (PHEV), extended range electric vehicle (EREV), fuel cell electric vehicle (FCEV), battery electric vehicle (BEV), etc.) passenger vehicles and multipurpose vehicles.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

40 CFR Part 86 ^{Note 1}

Note 1: CFR 86 Federal Schedule (FTP, HWFE, US06, Cold CO, SC03) CFR Part 86. These are the United States Federal tests located at the following link: <http://www.epa.gov/nvfel/testing/dynamometer.htm>. An external link to the drive profiles is established at <http://www.dieselnet.com/standards/cycles/> All programs/tunnels should review this link on a quarterly basis (January, April, July, and October) to ensure that the drive profile has not been updated.

2.2 GM Standards/Specifications.

GMW3202

GMW8697

GMW14555

GMW15845

2.3 Additional References.

- Electric Safety – General Awareness course
- Vehicle Technical Specifications (VTS) – 3.2.1.5.4.

3 Resources

This procedure is intended to be a supplement for GMW14555 for alternative propulsion vehicle programs. All resource information unless otherwise listed is common with GMW14555. Refer to GMW14555 for detailed resource information.

3.1 Facilities. Refer to GMW14555.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.2 Equipment.

3.2.1 General. Refer to GMW14555.

3.2.2 Hybrid Specific. Not applicable.

3.3 Test Vehicle/Test Piece. Alternative propulsion passenger vehicles equipped with ESS/RESS battery pack and configured with appropriate vehicle content.

3.4 Test Time.

Calendar time: 60 days

Test hours: 512 hours

Coordination hours: 250 hours

3.5 Test Required Information. Refer to GMW14555 and Appendix B of this document "Required Data".

3.6 Personnel/Skills. Refer to GMW14555 for basic requirements. All personnel shall be trained in high voltage safety and alternative propulsion vehicle safety protocol. This includes the alternative propulsion Electric Safety – General Awareness course and Electric Safety procedure for the particular vehicle. These courses can be found by searching General Motors University (GMU) for Hybrids or contacting a Subject Matter Team (SMT) manager of alternative propulsion systems.

4 Procedure

4.1 Preparation. Refer to GMW14555 for basic requirements. Set up the vehicle with the normal GMW14555 and GMW15845 measuring locations and then add the additional measuring locations listed in Appendix A.

4.1.1 Vehicle Pre-Conditioning.

4.1.1.1 Battery Temperature Setting. Unless specified otherwise by the test procedure or by the specific requirements recorded in the VTS, the vehicle shall be conditioned to ensure that the ESS/RESS battery cell skin temperatures, as read by the on board controller, shall be within 3 °C of the ambient temperature prior to the start of the vehicle tunnel test (not each test condition). The ESS/RESS can be conditioned by blowing air across the battery pack or circulating coolant using the passive cooling loop.

4.1.1.2 Vehicle Temperature Conditioning. Unless specified otherwise by the test procedure or by the specific requirements recorded in the VTS, the vehicle shall be conditioned to ensure that the temperatures of the Engine Oil (if equipped), Transmission Oil (if equipped), and Seat Rail/Vehicle Structure shall be within 3 °C of the ambient temperature prior to the start of the vehicle tunnel test (not each test condition).

4.2 Conditions. Refer to GMW14555 except as follows:

4.2.1 Environmental Conditions. The operating conditions of alternative propulsion vehicles require test in multiple ambient temperatures. Unless specified otherwise by the specific requirements recorded in the VTS, the default values for the required environmental conditions (ambient, solar, and humidity) are defined in the test conditions. To enable on-road testing, a modification to the environmental conditions can be accepted if in the judgment of the responsible engineer it would not affect the test results.

Due to vehicle calibrations and hybrid mode transitions, the additional environmental conditions for worst case testing may be required. Development testing and knowledge of the system calibrations shall be used to determine any additional environmental conditions.

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.2.2.1 ESS/RESS State of Charge (SOC) Setting. The hybrid ESS/RESS Battery State of Charge (SOC) shall be set to the starting State of Charge (SOC) as defined by the test before any Heating, Ventilation & Air Conditioning/Powertrain Cooling (HVAC/PTC)/Thermal/ESS/RESS thermal testing. The desired SOC shall be verified through the use of the vehicle electronic communications and, as necessary, a charging or depleting schedule will need to be run to attain the desired SOC (electronic commands can also be used to achieve the desired SOC).

On some vehicles it may be necessary to test at multiple SOC levels. During analysis/development, multiple SOC starting points shall be run to find the worst case for each cooling loop. If one condition is more severe

(higher temperatures) for all cooling loops, then that condition shall be used for validation; otherwise multiple conditions shall be run for validation.

In general "Min (minimum) SOC" is used for non-plug-in hybrids and Full SOC is used for plug-in vehicles. For some schedules plug-in vehicles with backup power (PHEV/EREV) will start from the Min SOC (the SOC that determines the onset of charge sustaining mode).

4.2.2.2 Rear HVAC Module Operation. For vehicles equipped with rear/auxiliary HVAC modules (including heater only, AC only and blower only systems) additional test conditions are required based on multiple rear HVAC settings. Tests shall be run with the rear/auxiliary systems in "mimic" mode to the front and also operated in "off" position.

4.3 Instructions. A vehicle program may not need to run all of the conditions of this procedure. The required conditions are dictated by the program VTS for the region and vehicle content. Check the condition paragraph to see which ones are optional based on the region and content. A reference summary of the conditions required versus content can be found in Appendix N.

4.3.1 Condition 1 – Sequence Test Shutter Closed Ice Mode Min SOC (with Shutters Only). Run GMW14555 condition 1 (Global Sequence Procedure) at the ambient and SOC condition as follows:

- Ice Mode Shutter Ambient (if unknown use 10 °C Shutters Closed), 60% humidity, 0 W/m², and no air conditioning (A/C).

Vehicle Load settings per GMW14555.

The SOC conditioning for this test shall be:

Min SOC.

Test Complete.

4.3.2 Condition 2 – Sequence Test Shutter Closed Ice Mode Full SOC (Plug-in with Shutters Only). Run GMW14555 condition 1 (Global Sequence Procedure) at the following ambient and SOC conditions:

- Ice Mode Shutter Ambient (if unknown use 10 °C Shutters Closed), 60% humidity, 0 W/m², and no A/C.

Vehicle Load settings per GMW14555.

The SOC conditioning for this test shall be:

Full SOC for plug-in vehicles (completing each section as much as possible in charge depleting mode).

For some vehicles (such as limited range Electric Vehicles, Plug-in Hybrid Vehicles, and Extended Range Electric Vehicles), it is necessary to run the Global Sequence Test parts individually (as allowed per GMW14555), without the pre-conditioning portion, and with a charging cycle between each part. The individual parts for these vehicles shall be run starting from Full SOC and then ending at Min SOC (for example the Rural Highway portion should be run back to back until the charge depletes from Full SOC to Min SOC). To minimize test time for these vehicles the recharge cycles should be run using the recharge test conditions in this document.

Test Complete.

4.3.3 Condition 3 – Sequence Test 20 °C Min SOC. Run GMW14555 condition 1 (Global Sequence Procedure) at the following ambient and SOC conditions:

- Low Ambient: 20 °C, 40% humidity, 600 W/m², and no A/C.

Vehicle Load settings per GMW14555.

The SOC conditioning for this test shall be:

Min SOC.

Test Complete.

4.3.4 Condition 4 – Sequence Test 20 °C Full SOC (Plug-in Only). Run GMW14555 condition 1 (Global Sequence Procedure) at the following ambient and SOC conditions:

- Low Ambient: 20 °C, 40% humidity, 600 W/m², and no A/C.

Vehicle Load settings per GMW14555.

The SOC conditioning for this test shall be:

Full SOC for plug-in vehicles (completing each section as much as possible in charge depleting mode). Additional Testing Required in Min SOC for plug-in vehicles such as Extended Range Electric Vehicles and Plug-in Hybrid Electric Vehicles.

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For some vehicles (such as limited range Electric Vehicles, Plug-in Hybrid Vehicles, and Extended Range Electric Vehicles), it is necessary to run the Global Sequence Test parts individually (as allowed per GMW14555), without the pre-conditioning portion, and with a charging cycle between each part. The individual parts for these vehicles shall be run starting from Full SOC and then ending at Min SOC (for example the Rural Highway portion should be run back to back until the charge depletes from Full SOC to Min SOC). To minimize test time for these vehicles the recharge cycles should be run using the recharge test conditions in this document.

Test Complete.

4.3.5 Condition 5 – Sequence Test 30 °C Min SOC. Run GMW14555 condition 1 (Global Sequence Procedure) at the following ambient and SOC conditions:

- Mid-ambient: 30 °C, 40% humidity, 600 W/m², and auto 22 °C (automatic systems) or A/C full cold, mid- (~6 V) blower (manual systems), customer selectable outside air (OSA).

Vehicle Load settings per GMW14555.

The SOC conditioning for this test shall be:

Min SOC.

Test Complete.

4.3.6 Condition 6 – Sequence Test 30 °C Full SOC (Plug-in Only). Run GMW14555 condition 1 (Global Sequence Procedure) at the following ambient and SOC conditions:

- Mid-ambient: 30 °C, 40% humidity, 600 W/m², and auto 22 °C (automatic systems) or A/C full cold, mid- (~6 V) blower (manual systems), customer selectable OSA.

Vehicle Load settings per GMW14555.

The SOC conditioning for this test shall be:

Full SOC for plug-in vehicles (completing each section as much as possible in charge depleting mode).

For some vehicles (such as limited range Electric Vehicles, Plug-in Hybrid Vehicles, and Extended Range Electric Vehicles), it is necessary to run the Global Sequence Test parts individually (as allowed per GMW14555), without the pre-conditioning portion, and with a charging cycle between each part. The individual parts for these vehicles shall be run starting from Full SOC and then ending at Min SOC (for example the Rural Highway portion should be run back to back until the charge depletes from Full SOC to Min SOC). To minimize test time for these vehicles, the recharge cycles should be run using the recharge test conditions in this document.

Test Complete.

4.3.7 Condition 7 – Sequence Test 38 °C Min SOC. Run GMW14555 condition 1 (Global Sequence Procedure) at the following ambient and SOC conditions:

- High Ambient: 38 °C, 40% humidity, 1000 W/m², A/C full cold, high (~14 V) blower, customer selectable OSA (duplication of standard GMW14555 – included here for SOC Clarification).

Vehicle Load settings per GMW14555.

The SOC conditioning for this test shall be:

Min SOC.

Test Complete.

4.3.8 Condition 8 – Sequence Test 38 °C Full SOC (Plug-in Only). Run GMW14555 condition 1 (Global Sequence Procedure) at the following ambient and SOC conditions:

- High Ambient: 38 °C, 40% humidity, 1000 W/m², A/C full cold, high (~14 V) blower, customer selectable OSA (duplication of standard GMW14555 – included here for SOC Clarification).

Vehicle Load settings per GMW14555.

The SOC conditioning for this test shall be:

Full SOC for plug-in vehicles (completing each section as much as possible in charge depleting mode).

For some vehicles (such as limited range Electric Vehicles, Plug-in Hybrid Vehicles, and Extended Range Electric Vehicles), it is necessary to run the Global Sequence Test parts individually (as allowed per GMW14555), without the pre-conditioning portion, and with a charging cycle between each part. The individual parts for these vehicles shall be run starting from Full SOC and then ending at Min SOC (for example the Rural Highway portion should be run back to back until the charge depletes from Full SOC to Min SOC). To minimize test time for these vehicles, the recharge cycles should be run using the recharge test conditions in this document.

Highway portion should be run back to back until the charge depletes from Full SOC to Min SOC). To minimize test time for these vehicles, the recharge cycles should be run using the recharge test conditions in this document.

Test Complete.

4.3.9 Condition 9 – Sequence Test 43 °C Min SOC (North America/GMIO Hot). Run GMW14555 condition 1 (Global Sequence Procedure) stopping after the Idle following City Traffic at the following ambient and SOC conditions:

- Higher Ambient: 43 °C 30% humidity, 1000 W/m², A/C full cold, high (~14 V) blower, customer selectable OSA (duplication of standard GMW14555 condition 1 through 20 minute idle– included here for SOC Clarification).

Vehicle Load settings per GMW14555.

The SOC conditioning for this test shall be:

Min SOC.

Test Complete.

4.3.10 Condition 10 – Sequence Test 43 °C Full SOC (Plug-in Only North America/GMIO Hot). Run GMW14555 condition 1 (Global Sequence Procedure) stopping after the Idle following City Traffic at the following ambient and SOC conditions:

- Higher Ambient: 43 °C 30% humidity, 1000 W/m², A/C full cold, high (~14 V) blower, customer selectable OSA (duplication of standard GMW14555 condition 1 through 20 minute idle – included here for SOC Clarification).

Vehicle Load settings per GMW14555.

The SOC conditioning for this test shall be:

Full SOC for plug-in vehicles (completing each section as much as possible in charge depleting mode).

For some vehicles (such as limited range Electric Vehicles, Plug-in Hybrid Vehicles, and Extended Range Electric Vehicles), it is necessary to run the Global Sequence Test parts individually (as allowed per GMW14555), without the pre-conditioning portion, and with a charging cycle between each part. The individual parts for these vehicles shall be run starting from Full SOC and then ending at Min SOC (for example the Rural Highway portion should be run back to back until the charge depletes from Full SOC to Min SOC). To minimize test time for these vehicles, the recharge cycles should be run using the recharge test conditions in this document.

Test Complete.

4.3.11 Condition 11 – Sequence Test 46 °C Min SOC (GMIO Middle East). Run GMW14555 Condition 1 (Global Sequence Procedure) stopping after the Idle following City Traffic at the following ambient and SOC conditions:

- Highest Ambient: 46 °C 10% humidity (depending on region per GMW14555), 1000 W/m², A/C full cold, high (~14 V) blower, customer selectable OSA (duplication of standard GMW14555 Condition 1 through 20 minute idle – included here for SOC Clarification).

Vehicle Load settings per GMW14555.

The SOC conditioning for this test shall be:

Min SOC.

Test Complete.

4.3.12 Condition 12 – Sequence Test 46 °C Full SOC (Plug-in Only North America/GMIO Middle East). Run GMW14555 Condition 1 (Global Sequence Procedure) stopping after the Idle following City Traffic at the following ambient and SOC conditions:

- Highest Ambient: 46 °C 10% humidity (depending on region per GMW14555), 1000 W/m², A/C full cold, high (~14 V) blower, customer selectable OSA (duplication of standard GMW14555 Condition 1 through 20 minute idle – included here for SOC Clarification).

Vehicle Load settings per GMW14555.

The SOC conditioning for this test shall be:

Full SOC for plug-in vehicles (completing each section as much as possible in charge depleting mode).

For some vehicles (such as limited range Electric Vehicles, Plug-in Hybrid Vehicles, and Extended Range Electric Vehicles), it is necessary to run the Global Sequence Test parts individually (as allowed per GMW14555), without the pre-conditioning portion, and with a charging cycle between each part. The individual parts for these vehicles shall be run starting from Full SOC and then ending at Min SOC (for example the Rural Highway portion should be run back to back until the charge depletes from Full SOC to Min SOC). To minimize test time for these vehicles the recharge cycles should be run using the recharge test conditions in this document.

Test Complete.

4.3.13 Condition 13 – Sequence Test 20 °C Min SOC Windows Open (Interior Air Cooled Only). This condition only applies if the ESS and/or Hybrid System Electronics cooling uses cabin air for cooling. After the vehicle pre-conditioning, open all windows 50 mm. Run GMW14555 Condition 1 at the following ambient and SOC conditions:

- Low Ambient: 20 °C, 40% humidity, 600 W/m², and no A/C.

Vehicle Load settings per GMW14555.

The SOC conditioning for this test shall be:

Min SOC.

Test Complete.

4.3.14 Condition 14 – Sequence Test 20 °C Full SOC Windows Open (Plug-in Interior Air Cooled Only). This condition only applies if the ESS and/or Hybrid System Electronics cooling uses cabin air for cooling. After the vehicle pre-conditioning, open all windows 50 mm. Run GMW14555 Condition 1 at the following ambient and SOC conditions.

- Low Ambient: 20 °C, 40% humidity, 600 W/m², and no A/C.

Vehicle Load settings per GMW14555.

The SOC conditioning for this test shall be:

Full SOC for plug-in vehicles (completing each section as much as possible in charge depleting mode). Additional Testing Required in Min SOC for plug-in vehicles such as Extended Range Electric Vehicles and Plug-in Hybrid Electric Vehicles.

For some vehicles (such as limited range Electric Vehicles, Plug-in Hybrid Vehicles, and Extended Range Electric Vehicles), it is necessary to run the Global Sequence Test parts individually (as allowed per GMW14555), without the pre-conditioning portion and with a charging cycle between each part. The individual parts for these vehicles shall be run starting from Full SOC and then ending at Min SOC (for example the Rural Highway portion should be run back to back until the charge depletes from Full SOC to Min SOC). To minimize test time for these vehicles, the recharge cycles should be run using the recharge test conditions in this document.

Test Complete.

4.3.15 Condition 15 – Sequence Test 38 °C Min SOC Windows Open (Interior Air Cooled Only). This condition only applies if the ESS and/or Hybrid System Electronics cooling uses cabin air for cooling. After the vehicle pre-conditioning, open all windows 50 mm. Run GMW14555 Condition 1 at the following ambient and SOC conditions:

- High Ambient: 38 °C, 40% humidity, 1000 W/m², auto 22 °C (automatic systems) recirculation mode or A/C full cold, mid- (~6 V) blower (manual systems), recirculation mode.

Vehicle Load settings per GMW14555.

The SOC conditioning for this test shall be:

Min SOC.

Test Complete.

4.3.16 Condition 16 – Sequence Test 38 °C Full SOC Windows Open (Plug-in Interior Air Cooled Only). This condition only applies if the ESS and/or Hybrid System Electronics cooling uses cabin air for cooling. After the vehicle pre-conditioning, open all windows 50 mm. Run GMW14555 C

ondition 1 at the following ambient and SOC conditions:

- High Ambient: 38 °C, 40% humidity, 1000 W/m², auto 22 °C (automatic systems) recirculation mode or A/C full cold, mid- (~6 V) blower (manual systems), recirculation mode.

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Vehicle Load settings per GMW14555.

The SOC conditioning for this test shall be:

Full SOC for plug-in vehicles (completing each section as much as possible in charge depleting mode).

For some vehicles (such as limited range Electric Vehicles, Plug-in Hybrid Vehicles, and Extended Range Electric Vehicles), it is necessary to run the Global Sequence Test parts individually (as allowed per GMW14555), without the pre-conditioning portion and with a charging cycle between each part. The individual parts for these vehicles shall be run starting from Full SOC and then ending at Min SOC (for example the Rural Highway portion should be run back to back until the charge depletes from Full SOC to Min SOC). To minimize test time for these vehicles, the recharge cycles should be run using the recharge test conditions in this document.

Test Complete.

4.3.17 Condition 17 – Extended Thermal US06 30 °C Min SOC. Execute the Federal US06 schedule as defined by the Code of Federal Regulations (CFR) Part 86 (shown for reference in Appendix C). Repeat the schedule 12 times for a total cumulative continuous time of 2 h. For thermal tests, the pre-conditioning can be shortened to achieve the vehicle conditioning requirements per 4.1.1. This shall be done for the following conditions:

- Mid-ambient: 30 °C, 40% humidity, 600 W/m², and auto 22 °C (automatic systems) or A/C full cold, mid- (~6 V) blower (manual systems), customer selectable OSA.

Vehicle Load settings shall be set at Gross Vehicle Mass Rating (GVMR).

During development, the ESS system temperatures and cooling loop temperatures after 4 of the Thermal US06 cycles should be compared to the Conditions 1 through 12 temperatures during the rural highway part and city traffic part to determine if extended Global Thermal Sequence rural highway (6 times for a total cumulative continuous time of 2 h) and/or extended Global Thermal City Traffic (4 times for a total cumulative continuous time of 4 h) is also required.

The SOC conditioning for this test shall be:

Min SOC.

Test complete.

4.3.18 Condition 18 – Extended Thermal US06 30 °C Full SOC (Plug-in Only). Execute the Federal US06 schedule as defined by the Code of Federal Regulations (CFR) Part 86 (shown for reference in Appendix C). Repeat the schedule 12 times for a total cumulative continuous time of 2 h. For thermal tests, the pre-conditioning can be shortened to achieve the vehicle conditioning requirements per 4.1.1. This shall be done for the following conditions:

- Mid-ambient: 30 °C, 40% humidity, 600 W/m², and auto 22 °C (automatic systems) or A/C full cold, mid- (~6 V) blower (manual systems), customer selectable OSA.

Vehicle Load settings shall be set at GVMR.

During development, the ESS system temperatures and cooling loop temperatures after 4 of the Thermal US06 cycles should be compared to the Conditions 1 through 12 temperatures during the rural highway part and city traffic part to determine if extended Global Thermal Sequence rural highway (6 times for a total cumulative continuous time of 2 h) and/or extended Global Thermal City Traffic (4 times for a total cumulative continuous time of 4 h) is also required.

The SOC conditioning for this test shall be:

Full SOC for plug-in vehicles.

Limited range vehicles will run until the charge depletes from Full SOC until Min SOC.

Test complete.

4.3.19 Condition 19 – Extended Thermal US06 38 °C Min SOC. Execute the Federal US06 schedule as defined by the Code of Federal Regulations (CFR) Part 86 (shown for reference in Appendix C). Repeat the schedule 12 times for a total cumulative continuous time of 2 h. For thermal tests the pre-conditioning can be shortened to achieve the vehicle conditioning requirements per 4.1.1. This shall be done for the following conditions:

- High Ambient: 38 °C, 40% humidity, 1000 W/m², customer selectable OSA, A/C full cold, and high (~14 V) blower.

Vehicle Load settings shall be set at GVMR.

During development, the ESS system temperatures and cooling loop temperatures after 4 of the Thermal US06 cycles should be compared to the Conditions 1 through 12 temperatures during the rural highway part and city traffic part to determine if extended Global Thermal Sequence rural highway (6 times for a total cumulative continuous time of 2 h) and/or extended Global Thermal City Traffic (4 times for a total cumulative continuous time of 4 h) is also required.

The SOC conditioning for this test shall be:

Min SOC for all non-plug-in vehicles.

Test complete.

4.3.20 Condition 20 – Extended Thermal US06 38 °C Full SOC (Plug In Only). Execute the Federal US06 schedule as defined by the Code of Federal Regulations (CFR) Part 86 (shown for reference in Appendix C). Repeat the schedule 12 times for a total cumulative continuous time of 2 h. For thermal tests the pre-conditioning can be shortened to achieve the vehicle conditioning requirements per 4.1.1. This shall be done for the following conditions:

- High Ambient: 38 °C, 40% humidity, 1000 W/m², customer selectable OSA, A/C full cold, and high (~14 V) blower.

Vehicle Load settings shall be set at GVMR.

During development, the ESS system temperatures and cooling loop temperatures after 4 of the Thermal US06 cycles should be compared to the Conditions 1 through 12 temperatures during the rural highway part and city traffic part to determine if extended Global Thermal Sequence rural highway (6 times for a total cumulative continuous time of 2 h) and/or extended Global Thermal City Traffic (4 times for a total cumulative continuous time of 4 h) is also required.

The SOC conditioning for this test shall be:

Full SOC for plug-in vehicles.

Limited range vehicles will run until the charge depletes from Full SOC until Min SOC.

Test complete.

4.3.21 Condition 21 – Extended Thermal US06 38 °C Min SOC (Interior Air Cooled Only). Execute the Federal US06 schedule as defined by the Code of Federal Regulations (CFR) Part 86 (shown for reference in Appendix C). Repeat the schedule 12 times for a total cumulative continuous time of 2 h. For thermal tests the pre-conditioning can be shortened to achieve the vehicle conditioning requirements per 4.1.1. This shall be done for the following conditions:

- High Ambient: 38 °C, 40% humidity, 1000 W/m², auto 22 °C (automatic systems) recirculation mode or A/C full cold, mid- (~6 V) blower (manual systems), recirculation mode.

Vehicle Load settings shall be set at GVMR.

During development, the ESS system temperatures and cooling loop temperatures after 4 of the Thermal US06 cycles should be compared to the Conditions 1 through 12 temperatures during the rural highway part and city traffic part to determine if extended Global Thermal Sequence rural highway (6 times for a total cumulative continuous time of 2 h) and/or extended Global Thermal City Traffic (4 times for a total cumulative continuous time of 4 h) is also required.

The SOC conditioning for this test shall be:

Min SOC.

Test complete.

4.3.22 Condition 22 – Extended Thermal US06 38 °C Full SOC (Plug-in Interior Air Cooled Only). Execute the Federal US06 schedule as defined by the Code of Federal Regulations (CFR) Part 86 (shown for reference in Appendix C). Repeat the schedule 12 times for a total cumulative continuous time of 2 h. For thermal tests the pre-conditioning can be shortened to achieve the vehicle conditioning requirements per 4.1.1. This shall be done for the following conditions:

- High Ambient: 38 °C, 40% humidity, 1000 W/m², auto 22 °C (automatic systems) recirculation mode or A/C full cold, mid- (~6 V) blower (manual systems), recirculation mode.

Vehicle Load settings shall be set at GVMR.

During development, the ESS system temperatures and cooling loop temperatures after 4 of the Thermal US06 cycles should be compared to the Conditions 1 through 12 temperatures during the rural highway part and city traffic part to determine if extended Global Thermal Sequence rural highway (6 times for a total cumulative continuous time of 2 h) and/or extended Global Thermal City Traffic (4 times for a total cumulative continuous time of 4 h) is also required.

The SOC conditioning for this test shall be:

Full SOC for plug-in vehicles.

Limited range vehicles will run until the charge depletes from Full SOC until Min SOC.

Test complete.

4.3.23 Condition 23 – Extended Thermal US06 Failure Modes. The Design Failure Mode and Effect Analysis (DFMEA) shall drive the testing required. This test may need to be repeated for each type of failure mode (for example, loss of cooling flow or loss of airflow) per cooling loop tractor power inverter module (TPIM) pump failure in addition to ESS pump failure, etc.) For Plug-in Vehicles (EREV, PHEV, BEV), an additional test in charging mode may be required.

Disable the coolant pump, kink a cooling hose, disable valve position or block the ESS air inlet. Execute the Federal US06 schedule as defined by the Code of Federal Regulations (CFR) Part 86 (shown for reference in Appendix C). Repeat the schedule 12 times for a total cumulative continuous time of 2 h or a vehicle shutdown occurs. For thermal tests, the pre-conditioning can be shortened to achieve the vehicle conditioning requirements per 4.1.1. This shall be done for the following conditions:

- High Ambient: 38 °C, 40% humidity, 1000 W/m², customer selectable OSA, A/C full cold, and high (~14 V) blower.

The SOC conditioning for this test shall be:

Min SOC for all non-plug-in vehicles.

Full SOC for plug-in vehicles.

Test complete.

4.3.24 Condition 24 – Thermal FTP/HWFE/US06. Execute 2 Federal Test Procedure (FTP) City, 2 HWFE and 2 US06 as defined by the Code of Federal Regulations (CFR) Part 86 (shown for reference in Appendix D). For thermal tests, the pre-conditioning can be shortened by running vehicle cool down procedures to achieve the vehicle conditioning requirements per 4.1.1.

This shall be done for the following conditions:

- Mid-ambient: 27 °C, 45% humidity, HVAC Off as per CFR Part 86, 0 W/m².

The SOC conditioning for this test shall be:

Nom (nominal) SOC for all non-plug-in vehicles.

Min SOC for plug-in vehicles with extended range capability (PHEV/EREV).

Full SOC for Battery Electric Vehicles.

Alternative test can be run with hood up with fixed cooling fan per CFR Part 86.

Test complete.

4.3.25 Condition 25 – All Electric Range. Plug-in Vehicles with all Electric Range Capability Only. Execute All Electric Range Testing per Energy Drive Quality Team (FTP City, FTP Highway and/or New European Drive Cycle/Motor Vehicle Emissions Group (NEDC/MVEG)) to determine all electric range. This shall be done for the following conditions:

- Mid-ambient: 27 °C, 45% humidity, HVAC Off as per CFR Part 86, 0 W/m².

The SOC conditioning for this test shall be:

Full SOC for plug in vehicles.

Test complete.

4.3.26 Condition 26 – NEDC/MVEG. Execute the NEDC/MVEG Cycle (shown for reference in Appendix E). For thermal tests, the pre-conditioning can be shortened to achieve the vehicle conditioning requirements per 4.1.1. This shall be done for the following conditions:

- Mid-ambient: 27 °C, 45% humidity, HVAC Off, 0 W/m².

The SOC conditioning for this test shall be:

Nom SOC for all non-plug-in vehicles.

Min SOC for plug-in vehicles with extended range capability (PHEV/EREV).

Full SOC for Battery Electric Vehicles.

Test complete.

4.3.27 Condition 27 – SC03 Schedule. Execute the SC03 test as defined by the Code of Federal Regulations (CFR) Part 86 (shown for reference in Appendix F). For thermal tests, the pre-conditioning can be shortened to achieve the vehicle conditioning requirements per 4.1.1. This shall be done for the following conditions:

- High Ambient: 35 °C, 40% humidity, 850 W/m².

Auto HVAC settings for this test are set for Auto 72 °F with Auto Blower Auto Mode and Auto Recirculation.

Manual HVAC settings for this test are set for Face mode, Recirc, Full Cold and Maximum Blower.

Vehicles with Rear/Auxiliary HVAC shall be in “mimic” mode for this test and repeated in off mode.

Alternative settings may be used with approval from the emissions certification team.

The SOC conditioning for this test shall be:

Nom SOC for all non-plug-in vehicles.

Min SOC for plug in vehicles with extended range capability (PHEV/EREV).

Full SOC for Battery Electric Vehicles.

Test complete.

4.3.28 Condition 28 – Cold FTP/Cold CO (Carbon Monoxide). Execute the Cold FTP (FTP 20/Cold CO) as defined by the Code of Federal Regulations (CFR) Part 86 (shown for reference in Appendix G). For thermal tests, the pre-conditioning can be shortened to achieve the vehicle conditioning requirements per 4.1.1. This shall be done for the following conditions:

- Low Ambient: -7 °C, N/A% humidity, 0 W/m².

Automatic HVAC systems shall use settings of Defrost Mode with Auto 72 °F, Auto Blower and Auto Recirc.

Manual HVAC settings for this test are initially set for Defrost mode, OSA, Full Hot and Blower off. At T = 125 s (second idle of test or first deceleration to 0 vehicle speed), the blower speed is set to maximum. Maintain defrost mode, OSA with full hot. At T = 505 s (6th idle of test), the blower speed is set to the minimum speed. Maintain defrost mode, OSA with full hot.

Vehicles with Rear/Aux HVAC shall be in “mimic” mode for this test.

Alternative settings may be used with approval from the emissions certification team.

The SOC conditioning for this test shall be:

Nominal SOC for all non-plug-in vehicles.

Min SOC for plug-in vehicles with extended range capability (PHEV/EREV).

Full SOC for Battery Electric Vehicles.

Test complete.

4.3.29 Condition 29 – 12 h Parking Lot Hot Soak Average Summer Day (Non-GMIO Middle East). At the end of Condition 24 (FTP/Hwy/US06), bring the vehicle into a Soak starting the solar/temperature time profile at 7 a.m. (Alternative methods can be used for pre-conditioning, but the internal ESS/Battery Temperature at the start of the soak shall be within 1 °C of the end temperature during Condition 24.) Soak the vehicle for 12 h.

Vehicle shall be unplugged during this soak.

Immediately following the 12 h soak, execute Condition 19 (Extended Thermal US06) while continuing to follow the soak profile until battery temperatures are below the continuous limits. The HVAC settings shall be auto 22 °C (automatic systems) recirculation mode or A/C full cold, mid- (~6 V) blower (manual systems), recirculation mode.

The test shall be performed for the following soak profiles per VTS and vehicle sales region:

- Low Ambient: Average Southwest Summer Day (Appendix H).

Note: On-road Testing can use the building parking lot area on blacktop pavement (must be unshaded).

Test complete.

4.3.30 Condition 30 – 12 h Parking Lot Hot Soak Hot Summer Day (Non-GMIO Middle East). At the end of Condition 24 (FTP/Hwy/US06), bring the vehicle into a Soak starting the solar/temperature time profile at 7 a.m. (Alternative methods can be used for pre-conditioning, but the internal ESS/Battery Temperature at the start of the soak shall be within 1 °C of the end temperature during Condition 24.) Soak the vehicle for 12 h.

Vehicle shall be unplugged during this soak.

Immediately following the 12 h soak, execute Condition 19 (Extended Thermal US06) while continuing to follow the soak profile until battery temperatures are below the continuous limits. The HVAC settings shall be auto 22 °C (automatic systems) recirculation mode or A/C full cold, mid- (~6 V) blower (manual systems), recirculation mode.

The test shall be performed for the following soak profiles per VTS and vehicle sales region:

- Mid-ambient: Hot Southwest Summer Day (Average Middle East Summer Day) (Appendix J).

Note: On-road Testing can use the building parking lot area on blacktop pavement (must be unshaded).

Test complete.

4.3.31 Condition 31 – 12 h Parking Lot Hot Soak Average Middle East Summer Day (GMIO Middle East). At the end of Condition 24 (FTP/Hwy/US06), bring the vehicle into a Soak starting the solar/temperature time profile at 7 a.m. (Alternative methods can be used for pre-conditioning, but the internal ESS/Battery Temperature at the start of the soak shall be within 1 °C of the end temperature during Condition 24.) Soak the vehicle for 12 h.

Vehicle shall be unplugged during this soak.

Immediately following the 12 h soak, execute Condition 19 (Extended Thermal US06) while continuing to follow the soak profile until battery temperatures are below the continuous limits. The HVAC settings shall be auto 22 °C (automatic systems) recirculation mode or A/C full cold, mid- (~6 V) blower (manual systems), recirculation mode.

The test shall be performed for the following soak profiles per VTS and vehicle sales region:

- Mid-ambient: Average Middle East Summer Day (Hot Southwest Summer Day) (Appendix J).

Note: On-road Testing can use the building parking lot area on blacktop pavement (must be unshaded).

Test complete.

4.3.32 Condition 32 – 12 h Parking Lot Hot Soak Hot Middle East Summer Day (GMIO Middle East). At the end of Condition 24 (FTP/Hwy/US06), bring the vehicle into a Soak starting the solar/temperature time profile at 7 a.m. (Alternative methods can be used for pre-conditioning, but the internal ESS/Battery Temperature at the start of the soak shall be within 1 °C of the end temperature during Condition 24.) Soak the vehicle for 12 h.

Vehicle shall be unplugged during this soak.

Immediately following the 12 h soak, execute Condition 19 (Extended Thermal US06) while continuing to follow the soak profile until battery temperatures are below the continuous limits. The HVAC settings shall be auto 22 °C (automatic systems) recirculation mode or A/C full cold, mid- (~6 V) blower (manual systems), recirculation mode.

The test shall be performed for the following soak profiles per VTS and vehicle sales region:

- High Ambient: Hot Middle East Summer Day (Appendix K).

Note: On-road Testing can use the building parking lot area on blacktop pavement (must be unshaded).

Test complete.

4.3.33 Condition 33 – Extended Parking Lot Hot Soak Average Summer Day (Non-GMIO Middle East). At the end of Condition 24 (FTP/Hwy/US06), bring the vehicle into a Soak starting the solar/temperature time profile at 7 a.m. (Alternative methods can be used for pre-conditioning, but the internal ESS/Battery Temperature at the start of the soak shall be within 1 °C of the end temperature during Condition 24.) Soak the vehicle for 108 h. This time can be shortened based on achieving stabilized maximum internal ESS/Battery temperatures (maximum temperatures from day to day are within 0.5 °C).

Vehicle shall be unplugged during this soak.