AVTE Interoperability Project, Phase 1: AC Conductive Charging

Final Report Submitted to

Idaho National Laboratory

Prepared by:

Jeffrey Wishart, Ph.D.
Engineering Team Lead

INTERTEK – Center for the Evaluation of Clean Energy Technology

430 S. 2nd Avenue
Phoenix, Arizona 85003-2418

Phone: (480) 525-5890

www.intertek.com/automotive

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1 Introduction

This final report provides the details of Phase 1 of the Interoperability Project, which was conducted by the Center for the Evaluation of Clean Energy Technology (CECET) division of Intertek Testing Services, North America, under the U.S. Department of Energy's Advanced Vehicle Testing and Evaluation (AVTE) Program, and managed by Idaho National Laboratory (INL). Phase 1 (i.e., ACL2-ITP) involved alternating current (AC) conductive charging, where Phase 2 (i.e., DCFC-ITP) involves direct current (DC) conductive charging. The first objectives of the Interoperability Project were to conduct a series of tests as part of an evaluation of the Society of Automotive Engineers (SAE) International J2953™ standard and to assist the SAE J2953™ committee in finalizing the standard. The standard will be used to determine the interoperability of plug-in electric vehicles (PEVs) and electric vehicle supply equipment (EVSE) unit pairs that are SAE J1772™ compliant. By testing different combinations of PEVs and EVSE units, insights can be gained into how potential inconsistencies in adherence to the SAE J1772™ standard by either the PEV or EVSE can affect vehicle charging. Other objectives were to assist the PEV and EVSE original equipment manufacturers (OEMs) in product development and to evaluate software developed by Argonne National Laboratory (ANL) that partially automates SAE J2953™ standard testing procedures.

Participants in the ACL2-ITP, including both EVSE and PEV OEMs, were solicited by SAE International. Project solicitation elicited participation from 12 EVSE OEMs, providing 14 EVSE units, and from 11 PEV OEMs, providing 14 PEVs. The list of PEVs and EVSE units is shown in Table 1. These EVSE and PEVs yielded a total test combination of up to 169 interoperability test pairs for ACL2-ITP. OEMs delivered their products to the Intertek facility in Plymouth, Michigan for testing purposes. This facility specializes in testing and certifying EVSE and is in close proximity to many PEV and EVSE OEMs. The overall project was managed by the Phoenix office of Intertek, with the SAE organization serving as a liaison with project participants. EVSE were installed per manufacturer's instructions and were kept for the duration of the ACL2-ITP. PEVs were scheduled in advance for testing with EVSE units and kept only for the three-week duration of their individual testing. Testing was conducted primarily using proprietary software developed by ANL.

During the project, monthly updates were provided to the SAE J2953™ committee. The committee is currently developing the SAE J2953™ standard; the AC conductive charging portion of the SAE J2953/2™ standard has been published and the DC conductive charging portion is in development. Results from this project and this final report may influence refinement of the SAE J2953™ standard, which vehicle and EVSE OEMs use to design and evaluate their products.

This final report is submitted to INL as a deliverable for the AVTE Project. This document includes a summary of the tests conducted and the results produced; however, the results have been

anonymized in accordance with the original solicitation agreement made with project participants.

Table 1. PEV and EVSE participants

PEV Make and Model	EVSE Units Make and Model
BMW i3	AddEnergie CoRe+
Chevrolet Volt	AddEnergie Smart Two
Fiat 500e	Aerovironment EVSE-RSW30B15CXXW-0001
Ford Focus EV	Bosch AWU70217BEN-B
Ford Fusion Energi	ChargePoint CT 4020-HD-GW
Honda Accord PHEV	Clipper Creek CS-100
Honda Fit EV	Clipper Creek LCS-25
Kia Soul EV	Eaton Marina EVSE L230CNBW
Mitsubishi i-MiEV	EVSE LLC Watt Point
Nissan Leaf	GE WattStation
Smart fortwo ED	Merit Charge ergl-01
Toyota Prius Plug-in	Schneider-Electric EV230WS
Toyota RAV4 EV	Siemens VersiCharge
VW e-Golf	Telefonix L1x2

2 Test Protocols

The SAE J2953/1™ and SAE J2953/2™ standards were used to conduct interoperability testing of PEV-EVSE pairs. Setup for the tests is discussed in the following subsections and equipment used for the tests is listed in Table 2.

2.1 Mechanical Test Setup

The mechanical test used a handheld Omega DFG35-50 push-pull force gauge, which was affixed to the SAE J1772™ EVSE plug to measure the insertion and removal force required between the combination of EVSE plug and PEV inlet. The gauge was affixed to the EVSE plug so it was in-line with the center of the connection, thereby giving a force measurement along the axis of the connection.

2.2 All Other Test Setup

Per the SAE J2953™ standard, a break-out test fixture consisting of a SAE J1772™ inlet making a complete pass-through of all lines to a SAE J1772™ plug was used to interface with the signal and power lines that make up the connection between the PEV and EVSE. Within the break-out test fixture was a National Instruments Compact RIO (cRIO-9004) complete with cards NI 9221,

NI 9401, NI 9225, and NI 9227 and a Tyco Electronics current transformer (M55E-80/5). The cRIO-9004 and corresponding cards measured the pilot line voltage, frequency, duty cycle and state transition times, proximity line voltage and transition times, and power line voltage and current. The breakout fixture and all related components were borrowed from ANL for use within this project.

Other components external to the break-out test fixture included the Agilent Technologies oscilloscope (MS06104A/8M), which was used to measure pilot line digital signal characteristics (e.g., rise times, fall times, and settling times). This measurement was accomplished with a voltage tap on the face of the break-out fixture. EVSE units were powered by a California Instruments AC power supply (Model MX45). This power supply was able to produce various voltage signals for grid repeatability purposes on all standard grid input tests and for all grid event simulation tests (e.g., those in Tier 2).

Software supplied by ANL was used to automate the signal measurement, data recording, SAE J2953™ standard comparisons/errors, and report generation for the following:

- Pilot and proximity state transition times
- Pilot and proximity line voltage measurements and standard tolerance comparison
- Pilot line frequency and duty-cycle measurements and standard tolerance comparison
- Power line current magnitude versus duty-cycle comparison.

The ANL software is designed to aggregate measurements produced by the Agilent Technologies oscilloscope for standard comparison and compiles these data into the generated report; however, this feature never functioned properly during testing. Further discussion on the failure of this function to operate as designed is included later in this report.

Table 2. Project equipment

Equipment Description	Function
Agilent Technologies MSO6104A/8M mixed-signal oscilloscope: 1 GHz, 4 channel, 2 GS/s, 8 Mpts	Measure frequency, timing, and voltage of Pilot waveform
Laptop computer	Host software and data collection modules
California Instruments AC power supply Model: MX45-3PI-208-HV Input: 208; VAC: 50-60; HZ: 53K VA Output: 150/300/400; VAC: 16-819 HZ: 45K VA	Vary the voltage input to the EVSE for additional tests

Equipment Description	Function
TE Connectivity / Crompton current transformer, M55E-80/5	Current sensor connected to NI 9227 current module to measure current through Line 1
Test fixture (built in-house)	Contains instrumentation for data collection
Omega DFG35-50 digital force gauge	Used in mechanical test of the SAE J2953™ standard
NI cRIO-9004 real-time embedded controller, 512 MB storage, 64 MB DRAM	Data collection module
NI 9221 8-channel, ±60 V, 800 kS/s, 12-Bit analog input module	Measure voltages of the pilot and proximity signals
NI 9401 8-channel, 5 V/TTL high-speed bidirectional digital I/O module	Component in the break-out test fixture
NI 9225 3-channel, 300 V_{rms} analog input module	Measure incoming line voltage from EVSE units
NI 9227 C Series 4-channel current module	Measure current of Line 1
ANL software	Automation of test conduct, data collection, and reporting

2.3 Test Deviations

Tests from the SAE J2953™ standard were all conducted with adherence to the standard, with the following three notable exceptions:

1. The specified number of trials for the mechanical test of Tier 1 in the SAE J2953™ standard is four connections and four disconnections. The decision was made for this project to conduct 10 trials for both the connection and disconnection tests in order to reduce statistical variation. The same test technician performed the mechanical testing throughout the project to avoid user bias. It is recommended that the SAE J2953™ committee consider adding these or other modifications to the SAE J2953™ standard to improve the repeatability and accuracy of the mechanical test.
2. In some Tier 2 tests, a test exception was implemented where the full 20-minute wait period specified by the SAE J2953™ standard to allow the charge to resume was not completed in order to expedite the test process. This was due to time constraints with certain PEVs. As discussed in Section 3.2, these instances were labeled 'Exception', and the actual wait time completed was included in the results.

3. In some charge interrupt and resume tests from Tier 3, the 30-minute wait period specified in the SAE J2953™ standard before resuming the charge event through either the PEV or EVSE interface was not adhered to during testing due to time limitations. As discussed in Section 3.2, these instances were labeled 'Pass*/Soft Pass*' if the charge event resumed or labeled 'Exception*' if the charge event did not resume. The actual wait times that were completed have been included in the results.

3 Test Results

The full set of anonymized test results are shown in Appendix A. The vehicles have been designated 'Vehicle 1' through 'Vehicle 14', and the EVSE units have been designated EVSE 'A' through 'N'. It should be noted that not all tests were conducted on all PEV-EVSE pairs. In some cases, one or both of the PEV and EVSE malfunctioned; in others, time constraints did not allow for full testing to be completed. A summary of the test results for the three tiers of the SAE J2953™ standard are presented in Section 3.3. The total number of tests conducted was 2,499.

3.1 Mechanical Test Criteria

The following criteria were used to determine the pass/fail result for the mechanical tests:

- **Pass**: All 10 values were less than 75 N.
- **Fail**: All 10 values were greater than 75 N.
- **Soft Pass**: Average value is less than 75 N, but some values can be greater than 75 N.
- **Soft Fail**: Average value is greater than 75 N, but some values can be less than 75 N.

Additional criteria were included to provide insight into test result possibilities. It is recommended that the SAE J2953™ committee consider adding these additional criteria as well.

3.2 All Other Test Criteria

Acceptance criteria for all tests outside the mechanical tests include eight possible designations: 'Pass', 'Fail', 'Soft Pass', 'Timer', 'Comm', 'Pass+/Soft Pass+', 'Exception', and 'Pass*/Soft Pass*. Descriptions of each of these criterion are outlined below. It should be noted that the SAE J2953™ standard does not explicitly list acceptance criteria other than 'Pass' and 'Fail'. Additional criteria were included to reflect various test result possibilities. It is recommended that the SAE J2953™ committee consider adding these additional criteria as well.

- **Pass**: No failed transitions or time/voltage measurement(s) were outside of the accepted criteria ranges and the charge event was able to be completed.
- **Soft Pass**: The charge event was able to be completed, but one or more failed transitions occurred or one or more time/voltage measurement(s) was/were outside of the

accepted criteria ranges. This designation is outside the current version of the SAE J2953™ standard; its inclusion in the standard will be discussed with the SAE J2953™ committee.

- **Fail**: The charge event was not able to be completed.
- **Feature:** Applies to the charge functionality test and safety feature functionality test of Tier 1 only. This designation indicates the test could not be completed due to a feature of the PEV not allowing switch S3 to be opened by the EVSE connector latch button. This designation is outside the current version of the SAE J2953™ standard; its inclusion in the standard will be discussed with the SAE J2953™ committee.
- **Incomplete:** Applies to the safety feature functionality test of Tier 1 only. This designation indicates that the charge event did not resume when the EVSE connector latch button was released and the second portion of the test could not be completed. This case is different from the fail designation because the charge event proceeded until the EVSE connector button was pressed; had the charge event resumed, the test may have resulted in a 'Pass' or 'Soft Pass' designation. This designation is outside the current version of the SAE J2953™ standard; its inclusion in the standard will be discussed with the SAE J2953™ committee.
- **Pass+**: Applies to the safety feature functionality test of Tier 1 only. This designation indicates the charge event did not resume when the EVSE connector latch button was released and the second portion of this test could not be completed initially. However, opening the driver side door did cause the charge event to restart, allowing the rest of the test to be completed. Because the action of opening the door was outside the SAE J2953™ standard, the "+" was added to the designation of 'Pass'. This designation is outside the current version of the SAE J2953™ standard; its inclusion in the standard will be discussed with the SAE J2953™ committee.
- **Timer**: Applies to Tier 2 testing only. This designation applies if (1) the charge event is disrupted by the grid event and (2) the EVSE sets a timer instead of resuming the charge event immediately. The charge event does not resume within the 20-minute window specified by the SAE J2953™ standard; however, it is possible that the charge event would have resumed at the beginning of the timer window. This designation is outside the current version of the SAE J2953™ standard; its inclusion in the standard will be discussed with the SAE J2953™ committee.
- **Comm**: Applies to Tier 2 testing only. This designation is included to accommodate commercial charging EVSE units that require authentication (e.g., reading of an radio frequency identification (RFID) card to begin a charge event). This designation applies if (1) the charge event is disrupted by the grid event and (2) the EVSE requires authentication to re-start the charge event. This designation is outside the current

version of the SAE J2953™ standard; its inclusion in the standard will be discussed with the SAE J2953™ committee.

- **Exception**: Applies to Tier 2 testing only. This designation indicates that the full 20-minute wait period specified by the SAE J2953™ standard to allow charging to resume after a grid event was not completed in order to expedite the test process. The wait duration (in seconds) before the test was terminated was noted in the results.
- **Exception***: Applies to the charge interrupt and resume test of Tier 3 only. This designation indicates that the 30-minute wait period specified in the SAE J2953 ™standard before attempting to resume the charge event through either the PEV or EVSE interface was not adhered to during testing due to time limitations. The charge event did not resume.
- **Pass*, Soft Pass***: Applies to the charge interrupt and resume test of Tier 3 only. This designation indicates that the 30-minute wait period specified in the SAE J2953™ standard before resuming the charge event through either the PEV or EVSE interface was not adhered to during testing due to time limitations; however, the charge event did resume.

3.3 Test Results Summary

The test results from Tier 1, Tier 2, and Tier 3 testing are presented in Table 3, Table 4, and Table 5, respectively. The values in the tables indicate the number of instances a result occurred for the entire collection of tests for all PEV-EVSE pairs. A brief analysis of each test follows the associated table. It should be noted that where the tables contain 'N/A', either the result designation did not apply to the particular test or, in the case of the Ampacity Test of the Tier 3 results in Table 5, no EVSE from project participants had this capability.

Table 3. Tier 1 test results summary

Tier 1 Test	Pass	Soft Pass	Pass+	Soft Fail	Fail	Incomplete	Feature
Mechanical Tests							
• Connect	113	8	N/A	3	47	N/A	N/A
• Disconnect	127	5	N/A	6	20	N/A	N/A
Charge Functionality Test	31	124	3	N/A	0	N/A	13
Safety Feature Functionality Test	22	120	N/A	N/A	0	12	13

Mechanical Test Results

Based on the modified criteria described in Section 3.1, a PEV-EVSE pair obtained a 'Fail' or 'Soft Fail' on the connect test 29% of the time and on the disconnect test 16% of the time. A full 'Pass' designation occurred 66% and 80% of the time for the connect and disconnect tests, respectively.

Charge Functionality Test Results

There were no failures of the Charge Functionality Test, although with Vehicle 1, all PEV-EVSE pair tests obtained a 'Feature' result. A full 'Pass' designation occurred 18% of the time, while there were three instances, all with Vehicle 13, that had a 'Pass+' result.

Safety Feature Functionality Test Results

There were no failures of the safety feature functionality test, although with Vehicle 1, all PEV-EVSE pair tests obtained a 'Feature' result. Further, there were results labeled 'Incomplete' results with Vehicle 3 and Vehicle 13. A full 'Pass' designation occurred 13% of the time.

Table 4. Tier 2 test results summary

Tier 2 Test	Pass	Soft Pass	Fail	Timer	Comm	Exception
Indefinite grid event tests						
• Voltage swell	53	82	28	0	0	0
• Voltage sag	59	104	0	0	0	0
• Frequency swell	58	96	0	0	0	0
• Frequency sag	51	112	0	0	0	0
Dynamic grid event tests						
• Voltage swell	25	81	1	0	0	43
• Voltage range variation	42	120	0	0	0	4
• Voltage sag	28	109	0	0	0	0
• Momentary outage	34	79	3	5	3	35
• Long-term outage	14	75	2	14	6	47
• Frequency range variation	54	103	0	0	0	0

Indefinite Grid Event Test Results

Failures only occurred during the voltage swell test. A full 'Pass' designation occurred 33%, 36%, 38%, and 31% of the time for the voltage swell, voltage sag, frequency swell, and frequency sag tests, respectively.

Definite Grid Event Test Results

Failures occurred during a single voltage swell test and during three and two momentary outage and long-term outage tests, respectively. These instances mean that failures occurred for these three tests 0.7%, 2%, and 1% of the time. A 'Timer' result was obtained 3% of the time for the momentary outage test and 9% of the time for the long-term outage test. A 'Comm' result was obtained 2% of the time for the momentary outage test and 4% of the time for the long-term outage test. Because of time constraints, a result of 'Exception' was designated for 29% of the voltage swell tests, 2% of the voltage range variation tests, 22% of momentary outage tests, and 30% of long-term outage tests. A full 'Pass' designation occurred 17%, 25%, 20%, 11%, 9%, and 34% of the time for the voltage swell, voltage range variation, voltage sag, momentary outage, long-term outage, and frequency range variation tests, respectively.

Table 5. Tier 3 test results summary

Tier 3 Test	Pass	Soft Pass	Fail	Exception*	Pass*	Soft Pass*
Scheduled Charge Tests						
• PEV Scheduled Charge	56	29	4	N/A	N/A	N/A
• EVSE Scheduled Charge	11	11	4	N/A	N/A	N/A
Staggered Schedule Charge Tests						
• PEV Scheduled First	6	6	3	N/A	N/A	N/A
• EVSE Schedule First	6	6	3	N/A	N/A	N/A
Charge Interrupt and Resume Tests						
• PEV Interrupt	4	0	0	4	34	8
• EVSE Interrupt	6	0	0	3	17	25
Ampacity Control Test	N/A	N/A	N/A	N/A	N/A	N/A

Scheduled Charge Test Results

Failures occurred for 4% of the PEV scheduled charge tests and for 15% of the EVSE scheduled charge tests. A full 'Pass' designation occurred 63% of the time for the PEV schedule charge test and 42% of the time for the EVSE schedule charge test.

Staggered Schedule Charge Test Results

Failures occurred for 20% of the PEV scheduled charge tests and for 20% of the EVSE scheduled charge tests. A full 'Pass' designation occurred 40% of the time for the PEV schedule charge test and 40% of the time for the EVSE schedule charge test.

Charge Interrupt and Resume Test Results

No outright failures occurred for the charge interrupt and resume test. Because of time constraints, the 30-minute time period from the SAE J2953™ standard was not followed for some of the test vehicles; the charge event was set to resume via either the PEV or EVSE interface in a reduced timeframe. The charge event failed to resume in 8% of the cases of the PEV interrupt test and in 6% of the EVSE interrupt test.

Ampacity Control Test Results

No EVSE units participating in this project had an ampacity control feature.

4 Observations

By conducting testing for the Interoperability Project, Intertek personnel were able to gain significant experience in execution to the SAE J2953™ standard, utilizing the recommended equipment, and using the ANL software. The sections below outline the observations that were made during project testing.

4.1 General Test Observations

The SAE J2953™ standard does not account for EVSE units that require authentication. Of the participating EVSE units, only EVSE G, EVSE I, and EVSE J required authentication. However, as more commercial EVSE units are introduced, this may become a more common test occurrence. No EVSE units had ampacity control. Some commercialized EVSE units have this capability; however, there was no opportunity to run the ampacity control tests during this project.

While the requirements of the SAE J1772™ standard dictate that a vehicle cannot drive away when an EVSE connector is plugged into the PEV port, the SAE J2953™ committee could consider adding a test to ensure this safety feature. Similarly, the committee could consider adding a test to check that the charge event will not begin with the EVSE connector not fully inserted (i.e., the pair does not transition out of State A). These two tests could be done quickly and could serve to increase confidence in adherence of the PEV-EVSE pair to the safety measures required by the SAE J1772™ standard.

One feature observed on multiple vehicles during testing is the ability to lock the SAE J1772™ connector in the PEV port. This feature is designed to assure vehicle owners that when they initiate a charge event, the charge event will continue uninterrupted (all other features, communications, and standards permitting) until they initiate a stop (or the vehicle initiates a stop because the vehicle battery is fully charged). Locking mechanisms observed during this testing take advantage of the standardized latch on top of the SAE J1772™ connector by pinning

it down with some form of electronically controlled mechanical bar, such as a locking pin actuated by a solenoid. While no locking mechanism is specifically described by the SAE J1772™ standard, the standard does mention this type of connector locking as a possibility.

The lever that is blocked in order to lock the connector is mechanically connected to a switch that controls the resistive value of the proximity signal in accordance with the SAE J1772™ standard. Therefore, by locking the connector, the proximity line cannot normally be put into a state that causes the vehicle to respond by ramping down the current to less than 500 mA to avoid interrupting the charge event at full current via connector disconnect (see Section 4.2.2 of the J1772 standard). This is, by itself, not a problem and could even be considered a feature. However, in some cases, the vehicle does not respond to a change in the proximity signal (i.e., when switch S3 opens) when the vehicle locking feature is activated. This was found when connecting to a vehicle with the dummy cable/connector from the breakout test fixture of the SAE J2953™ standard test setup, which does not contain mechanical control of the proximity signal switch. This setup allows for the EVSE connector latch mechanism and, by default, the proximity signal switch (S3) to be actuated when the vehicle setting assumes that the connector is locked and incapable of being disconnected. Thus, the vehicle does not ramp down the charge current request, which could result in a user disconnecting at full current. This possibility allows for a dangerous situation in which the connectors could be damaged or arcing could occur that ignites a fire and/or injures the user.

The setup used in testing is not the normal connection method; however, commercially available EVSE having a broken lever on the SAE J1772™ connector is a possibility, which would behave in the same manner as the test setup. With this possibility, it should be a requirement of all PEVs that the vehicle must respond to the proximity signal state change at all times. Specifically, the proximity signal state change tested in the safety feature functionality test should require a pass regardless of features enabled on the vehicle.

4.2 Argonne National Laboratory Software Observations

The ANL software was quite useful and the automation allowed for a reduction in test duration, analysis, and reporting. The software generated reports that include visual graphics displaying various electrical properties from the test; this was anecdotally observed as useful by project participants. The following list includes observations about the software made by Intertek test personnel:

- In the reports generated by the software, a result of ‘Fail’ for a specific requirement is listed incorrectly (consistently so in some cases). For example, some tests do not have time requirements, but a test result of ‘Fail’ is listed no matter what time value is listed for one or more transitions. Further, some of the generated reports include

requirements that do not match a particular test run; this could be misleading to an observer who is not intimately knowledgeable of the SAE J2953/1™ standard.

- In some tests, a failed transition that the software labels "Invalid Pilot to B – Duty" occurred with a time of 3.001. This may be coincidence, but it could be an error in the software.
- In some tests, a failed transition that the software labels "Shutdown B to No Line Voltage" occurred; however, the actual time of the transition indicated that the requirement was met.
- In some tests, a failed transition that the software labels "Startup C/D to No Line Voltage" occurred; however, the actual time of the transition indicated that the requirement was met.
- In some tests, transitions between states (B1, B2, and C) happen too slowly with some PEV-EVSE pairs, but this is recorded by the ANL software as an out-of-bounds voltage rather than a state change error.

It should be noted that although the oscilloscope used in the test was the model specified by ANL, Intertek personnel were not able to establish full communication between the oscilloscope and the ANL software. Thus, testing automation was not complete and some testing had to be conducted manually. It is believed that the software supplied by ANL for the project was a 'beta' version. In addition to addressing this compatibility issue, if ANL plans on further development, they should consider the following suggestions on additional features and options:

- Ability to edit the test number
- Ability to add comments to the report after test has finished
- Options for data export (e.g., TDMS, CSV, etc.)
- Ability to select which test is being conducted and select only the relevant requirements

4.3 SAE J2953™ Standard Observations

Observations have been made by Intertek test personnel while conducting testing for this project; feedback received from Intertek test personnel is presented here. Not all tests have observations included in this section.

4.3.1 Mechanical Test Observations

The current procedure for the mechanical testing is structured in a way that makes it difficult to produce reliable and repeatable results, especially from different users and different test apparatuses. It is suggested that the minimum number of trials specified be increased from four to 10 in order to reduce statistical variation. The criteria could also be modified to include the 'Soft pass' and 'Soft Fail' (i.e., some measurements over 75 N but average less than 75 N and some measurements under 75 N but average over 75 N, respectively) additions used in this project. Further, it is suggested that a lower force threshold be specified to avoid a situation

where the electrical pins of the EVSE connector and the PEV port are not in solid contact, which could result in arcing when a charge event is initiated.

Ideally, a test apparatus that would eliminate the human element of the measurements would be designed. Specifically, orienting the EVSE connector so the angle made with the PEV port is consistent would provide more reliable measurements; however, this test apparatus may not be worth the additional expense.

Current procedure steps could also be modified slightly. The SAE J2953™ standard instructs test personnel to perform connection and disconnection measurements consecutively. However, it was found that disconnection measurements were more consistent when conducted after the latch button had been taped in the open or depressed position and the bracket and force gauge were mounted on the EVSE connector. Thus, the consistency of the test measurements increased when the physical test setup for the connect and disconnect tests were different.

Also, repeated use of connectors can result in degradation of the connector seal. Should the test connector be degraded, the force required to secure the connection with the PEV could increase. Therefore, it is recommended that verbiage be included in J2953 to reflect that only a non-degraded connector should be used for testing.

4.3.2 Non-Mechanical Soft Pass Results

Throughout testing, there were many instances where the charge event was fully completed, but one or more failures of the SAE J2953™ standard requirements were not met (i.e., a 'Soft Pass' occurred). Examining the causes or implications of these failures is beyond the scope of this document; the summarized results are presented in Table 6 and may inform the SAE J2953™ standard committee of instances where the standard may be too restrictive. The sub-test failure messages are listed against the number of instances in which the message was received for each test of the SAE J2953™ standard.

4.3.3 Safety Feature Functionality Test Observations

The safety feature functionality test consists of two separate tests. It is possible for a PEV-EVSE pair to pass the first test, but not be able to transition to the second test. For example, a feature in either the PEV or EVSE will not allow the EVSE latch button to be pressed during a charge event and the PEV-EVSE pair would obtain a failing result in this case (as was found during this project with Vehicle 1). The SAE J2953™ standard should be modified to account for this possibility and that one or both of the PEV and EVSE OEMs might consider this behavior to be a feature of their product and not deem the situation as a failure.

The safety feature functionality test contains instructions for pressing the EVSE connector latch button and being sure to maintain connection with the plug and inlet. This could be further emphasized that failure to maintain the connection will result in a failure for the test.

When testing Vehicle 13, the charge event would not resume after the EVSE connector latch button had been pressed (and switch S3 had been opened) unless the driver door was opened. However, there is no way for the SAE J2953™ standard to account for these unusual and idiosyncratic requirements of an individual OEM, but it was deemed worth noting.

Table 6. Soft pass summarized results

Sub-Test Failure	T1 Charge Functionality	T1 Safety Systems	T2 V+	T2 V-	T2 F+	T2 F-	T2 W1 SWELL	T2 W2 VRV	T2 W3 SAG	T2 W4 FREQ	T2 W5 MOM	T2 W6 INDEF	T3 Car Schedule	T3 Car Interupt	T3 EVSE Schedule	T3 EVSE Interrupt	T3 EV Stagger	T3 EVSE Stagger
Disconnect No Line Voltage	X	30	1	1	1	1	1	X	X	2	3	X	X	X	X	X	X	X
Disconnect No PWM	3	7	3	4	3	5	4	3	5	3	3	4	1	X	X	X	X	X
Duty Cycle Response	2	1	X	1	2	X	X	1	X	1	2	3	X	X	X	8	X	X
EVSE Plugged S3 closed	X	2	10	21	23	22	19	25	24	26	20	7	2	4	X	2	1	X
EVSE Plugged S3 open	X	1	2	2	1	2	2	2	2	3	X	1	1	X	X	1	X	X
EVSE Unplugged	28	3	28	29	29	28	17	29	30	28	28	28	15	X	4	9	2	2
Invalid Pilot to B - Duty	69	5	24	42	28	33	38	37	26	32	51	67	18	6	4	38	5	3
Invalid Pilot to B - Voltage	6	2	X	7	10	7	5	10	6	4	5	12	1	3	X	6	X	X
Invalid Pilot to B2	X	X	X	X	X	X	1	X	X	X	X	1	X	X	X	2	X	X
Malfunction No Line Voltage	X	X	X	X	X	X	1	2	X	X	X	1	X	X	X	X	X	X
PEV AC Current Draw	25	26	13	21	19	22	29	53	72	22	14	14	6	1	3	5	X	X
PWM Frequency	7	4	2	4	13	9	2	1	2	4	4	2	2	2	X	3	X	X
S3 open to No Line Current	106	107	79	99	97	99	64	98	100	99	81	56	60	34	11	24	12	10
Shutdown B to No Line Voltage	8	11	8	10	7	11	8	9	11	9	8	4	1	2	2	1	1	1
Startup C/D to Line Voltage	1	X	X	1	X	1	1	2	1	3	3	10	2	1	X	X	X	X
State A Voltage	4	5	6	2	3	1	3	X	1	X	1	2	1	X	X	X	X	X
State B Voltage	1	1	7	5	3	3	4	1	2	1	4	4	2	1	X	1	X	1
State C or D to B2 Transition	7	9	8	9	7	11	8	8	9	8	6	4	X	2	1	1	1	1
State C or D to Energy Transfer	X	X	X	X	X	1	X	X	X	X	1	X	1	X	X	X	X	X
State C Voltage	X	4	2	1	1	1	X	3	1	2	7	4	2	X	X	X	X	X
State F Voltage	1	1	8	4	5	4	16	9	5	6	23	49	3	X	1	2	X	1
State X Low-side Voltage	18	16	15	21	20	20	15	17	19	20	20	11	9	9	10	17	7	8

4.3.4 Indefinite and Dynamic Grid Event Test Observations

Several commercial EVSE units on the market require authentication, such as an RFID card, before beginning a charge event. In certain instances during project testing, a grid event caused the EVSE unit to stop the charge event and, when power to the unit was restored, the EVSE unit did not re-establish the charge event without re-authentication. This case is not accounted for in the SAE J2953™ standard; it is suggested that the SAE J2953™ committee consider adding the 'Comm' test result designation (similar to what was done in this project).

Some EVSE also displayed messages that would instruct the user to perform a task after a charge event had been disrupted. For example, EVSE J would display "Return Handle Back to Unit." Once Intertek test personnel followed this instruction and re-plugged the EVSE connector into the break-out test fixture, the charge event was re-established. Similar to the above authentication requirement, the SAE J2953™ committee may want to account for these unique EVSE features.

In some grid event tests, EVSE E and EVSE F would enter a timer mode after power was restored to the units. Despite the setting, in most cases, the charge event would be re-established within the 20-minute window requirement of SAE J2953™. However, in some cases, the charge event would not occur before the schedule of the timer was met. This case is not accounted for in the SAE J2953™ standard; it is suggested that the SAE J2953™ committee consider adding the 'Timer' test result designation.

During the project, it was observed that, in several instances, the voltage swell test caused a failure in either the PEV or EVSE unit. This test was moved to the end of the testing so the rest of the tests could be conducted before creating this potential fault situation. The SAE J2953™ committee could consider whether this voltage swell is too extreme. In any case, the OEMs should be made aware that this test caused failures in several PEV-EVSE pairs. The test equipment should capture the time required for the PEV-EVSE pair to re-establish the charge event; however, as a backup, test personnel should be instructed to manually record the time required.

4.3.5 Staggered Schedule Charge Test Observations

The SAE J2953™ standard instructs test personnel to set the timer of the PEV to 1 hour and the timer of the EVSE to 2 hours and vice versa. However, some EVSE units had minimum timer settings of 2 hours or more. A small change to the language of the instructions should be made to set the pairs to the shortest possible combination to expedite testing.

4.3.6 Charge Interrupt and Resume Test Observations

The instructions of the SAE J2953™ standard state that after the EVSE or PEV interface has been used to interrupt the charge event, "The system should be in State B." However, to those not

intimately familiar with thae SAE J1772™ standard, it may not be clear what is meant by this instruction. Because there is no actual State B, but States B1 and B2 do exist, the instruction should be clarified. If the EVSE interface is used to interrupt the charge event, the pair should be in State B1. If the PEV interface is used to interrupt the charge event, the pair should be in State B2 or State C or D (in which case, the PEV has set the current allowable to 0 A).

5 Summary and Future Work

Phase 1 (i.e., ACL2-ITP) of the AVTE Interoperability Project is complete with publication of this final report. Participation from as many PEV and EVSE OEMs as possible was sought and 14 PEVs (from 12 PEV OEMs) and 14 EVSE units (from 12 EVSE OEMs) were included in testing. Overall, nearly 2,500 tests were conducted on various PEV-EVSE pairs. Some units failed during testing, and not all possible combinations (i.e., 4,116 tests is the maximum number of possible combinations) were tested. Most EVSE units do not have features that would have allowed for completion of Tier 3 testing; in fact, no EVSE unit had ampacity control such that the level of current could be modified during a charge event.

This final report provides test result summaries and anonymized results for all tests in Appendix A. Observations made during testing have been included for discussion within the SAE J2953™ committee and to provide information for those interested in more testing details.

With Phase 1 complete, attention can now be directed to Phase 2, (i.e., DCFC-ITP) of the AVTE Interoperability Project, where the PEV-EVSE pairs will be tested again, but with some differences. First, the SAE J2953™ standard is not complete for DC fast charging and no defined completion date has been set by the SAE J2953™ committee. Second, in addition to the combined charging system outlined in the SAE J1772™ and SAE J2953™ standards, there are two other competing DC fast charging standards with deployed infrastructure in the United States:

1. CHAdeMO stations (various networks)
2. Tesla Supercharger network (vehicles from other OEMs cannot currently access this network; therefore, there are no interoperability issues; however, Tesla offers adapters for its vehicles to CHAdeMO and combined charging system DC fast chargers).

The presence of three standards complicates the logistics and adds cost to Phase 2. There are no interoperability standards similar to the SAE J2953™ standard for either the Tesla adapter or the CHAdeMO standard. As a result, test procedures will have to be developed independently by AVTE personnel. Further, the AC conductive charging EVSE units of Phase 1 are relatively inexpensive to purchase and install (i.e., EVSE participants either loaned or donated their units). DCFCs are much more expensive to purchase and install. Additionally, installing all the DCFC units in one place is difficult from a logistical, space, and electrical service perspective.

Possibilities are currently being explored about whether Phase 2 should be conducted in the same manner as Phase 1 with all EVSE units installed in one place or to have all vehicles at one location and have the DC fast chargers sent sequentially.

This final report is submitted to INL as a deliverable for the AVTE Project.

Appendix A – Anonymized Test Results

Vehicle 1:

EVSE	T1 Mechanical Push	T1 Mechanical Pull	T1 Charge Functionality	T1 Safety Systems	T2 V+	T2 V-	T2 F+	T2 F-	T2 W1 SWELL	T2 W2 VRV	T2 W3 SAG	T2 W4 FREQ	T2 W5 MOM	T2 W6 INDEF	T3 Car Schedule	T3 Car Interupt	T3 EVSE Schedule	T3 EVSE Interrupt	T3 EV Stagger	T3 EVSE Stagger	T3 A
A	Fail	Pass	Feature	Feature	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈40	N/A	Pass* ≈23	N/A	N/A	N/A	N/A	N/A
B	Pass	Pass	Feature	Feature	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈55	Exception ≈40	N/A	Soft Pass* ≈27	N/A	Soft Pass* ≈44	N/A	N/A	N/A
C	Pass	Pass	Feature	Feature	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	Pass* ≈34	N/A	N/A	N/A	N/A	N/A
D	Pass	Pass	Feature	Feature	Fail	Soft Pass	Soft Pass	Soft Pass	Exception ≈50	Exception ≈60	Soft Pass	Soft Pass	Soft Pass	Exception ≈65	N/A	Soft Pass* ≈34	N/A	N/A	N/A	N/A	N/A
E	Pass	Pass	Feature	Feature	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Timer	N/A	Soft Pass* ≈26	Fail	Soft Pass* ≈31	N/A	N/A	N/A
F	Pass	Pass	Feature	Feature	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Timer	Timer	N/A	Pass* ≈28	Fail	N/A	N/A	N/A	N/A
G	Pass	Pass	Feature	Feature	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈75	Exception ≈155	N/A	Soft Pass* ≈29	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	Fail	Pass	Feature	Feature	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈120	N/A	Pass* ≈20	N/A	N/A	N/A	N/A	N/A
J	Pass	Pass	Feature	Feature	Fail	Soft Pass	Soft Pass	Soft Pass	Exception ≈75	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈55	N/A	Pass* ≈29	N/A	N/A	N/A	N/A	N/A
K	Pass	Pass	Feature	Feature	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	Pass* ≈26	N/A	Pass* ≈36	N/A	N/A	N/A
L	Pass	Pass	Feature	Feature	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈55	N/A	Pass* ≈20	N/A	N/A	N/A	N/A	N/A
M	Pass	Pass	Feature	Feature	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈60	N/A	Pass* ≈28	N/A	Pass* ≈34	N/A	N/A	N/A
N	Fail	Pass	Feature	Feature	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈55	Soft Pass	N/A	Pass* ≈24	N/A	N/A	N/A	N/A	N/A

Vehicle 2:

EVSE	T1 Mechanical Push	T1 Mechanical Pull	T1 Charge Functionality	T1 Safety Systems	T2 V+	T2 V-	T2 F+	T2 F-	T2 W1 SWELL	T2 W2 VRV	T2 W3 SAG	T2 W4 FREQ	T2 W5 MOM	T2 W6 INDEF	T3 Car Schedule	T3 Car Interupt	T3 EVSE Schedule	T3 EVSE Interrupt	T3 EV Stagger	T3 EVSE Stagger	T3 A
A	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A
B	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	Soft Pass* ≈19	N/A	N/A	N/A
C	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈1030	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A
D	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A
E	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	Soft Pass	Soft Pass* ≈25	Soft Pass	Soft Pass	N/A
F	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	Soft Pass	N/A	Soft Pass	Soft Pass	N/A
G	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	Soft Pass	Soft Pass	Soft Pass	Comm	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A
J	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Fail	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A
K	Fail	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	Soft Pass* ≈26	N/A	N/A	N/A
L	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A
M	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	Soft Pass* ≈25	N/A	N/A	N/A
N	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	Soft Pass	Soft Pass	Soft Pass	Fail	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A

Intertek

Vehicle 3:

EVSE	T1 Mechanical Push	T1 Mechanical Pull	T1 Charge Functionality	T1 Safety Systems	T2 V+	T2 V-	T2 F+	T2 F-	T2 W1 SWELL	T2 W2 VRV	T2 W3 SAG	T2 W4 FREQ	T2 W5 MOM	T2 W6 INDEF	T3 Car Schedule	T3 Car Interupt	T3 EVSE Schedule	T3 EVSE Interrupt	T3 EV Stagger	T3 EVSE Stagger	T3 A
A	Fail	Pass	Soft Pass	Incomplete	Pass	Pass	Pass	Pass	Exception ≈65	Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Pass	Pass* ≈20	N/A	N/A	N/A	N/A	N/A
B	Pass	Pass	Soft Pass	Incomplete	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈850	Soft Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Pass	Soft Pass* ≈29	N/A	Soft Pass* ≈32	N/A	N/A	N/A
C	Pass	Pass	Pass	Incomplete	Pass	Pass	Pass	Pass	Exception ≈620	Pass	Soft Pass	Pass	Soft Pass	Pass	Pass	Pass* ≈25	N/A	N/A	N/A	N/A	N/A
D	Soft Pass	Pass	Pass	Incomplete	Pass	Pass	Pass	Pass	Soft Pass	Pass	Soft Pass	Pass	Pass	Soft Pass	Pass	Pass* ≈32	N/A	N/A	N/A	N/A	N/A
E	Pass	Pass	Soft Pass	Incomplete	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈500	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Timer	Soft Pass	Soft Pass* ≈35	Soft Pass	Soft Pass* ≈34	Soft Pass	Fail	N/A
F	Fail	Pass	Pass	Incomplete	Pass	Pass	Pass	Pass	Exception ≈60	Soft Pass	Soft Pass	Pass	Timer	Timer	Pass	Pass* ≈43	Pass	N/A	Pass	Fail	N/A
G	Fail	Pass	Pass	Incomplete	Pass	Pass	Soft Pass	Soft Pass	Exception ≈310	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Pass	Pass* ≈48	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	Fail	Pass	Soft Pass	Incomplete	Pass	Pass	Pass	Pass	Exception ≈365	Soft Pass	Soft Pass	Pass	Pass	Pass	Pass	Pass* ≈42	N/A	N/A	N/A	N/A	N/A
J	Fail	Pass	Soft Pass	Incomplete	Pass	Pass	Pass	Pass	Exception ≈45	Soft Pass	Soft Pass	Pass	Pass	Exception ≈50	Pass	Pass* ≈35	N/A	N/A	N/A	N/A	N/A
K	Pass	Pass	Pass	Soft Pass	Pass	Pass	Pass	Pass	Exception ≈60	Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Pass	Pass* ≈37	N/A	Pass* ≈33	N/A	N/A	N/A
L	Pass	Pass	Pass	Soft Pass	Pass	Soft Pass	Pass	Pass	Exception ≈65	Soft Pass	Soft Pass	Pass	Pass	Pass	Pass	Pass* ≈40	N/A	N/A	N/A	N/A	N/A
M	Pass	Pass	Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Pass	Exception ≈45	Soft Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Pass	Pass* ≈37	N/A	Pass* ≈54	N/A	N/A	N/A
N	Fail	Pass	Soft Pass	Incomplete	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈40	Soft Pass	Soft Pass	Soft Pass	Exception ≈540	Soft Pass	Pass	Pass* ≈38	N/A	N/A	N/A	N/A	N/A

Vehicle 4:

EVSE	T1 Mechanical Push	T1 Mechanical Pull	T1 Charge Functionality	T1 Safety Systems	T2 V+	T2 V-	T2 F+	T2 F-	T2 W1 SWELL	T2 W2 VRV	T2 W3 SAG	T2 W4 FREQ	T2 W5 MOM	T2 W6 INDEF	T3 Car Schedule	T3 Car Interupt	T3 EVSE Schedule	T3 EVSE Interrupt	T3 EV Stagger	T3 EVSE Stagger	T3 A
A	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈65	Pass	N/A	N/A	N/A	N/A	N/A	N/A
B	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈85	Exception ≈95	Pass	N/A	N/A	Soft Pass* ≈37	N/A	N/A	N/A
C	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	N/A	N/A	N/A	N/A	N/A	N/A
D	Soft Pass	Pass	Soft Pass	Soft Pass	Fail	Soft Pass	Soft Pass	Soft Pass	Exception ≈70	Soft Pass	Soft Pass	Pass	Soft Pass	Exception ≈65	Pass	N/A	N/A	N/A	N/A	N/A	N/A
E	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Timer	Soft Pass	N/A	Soft Pass	Soft Pass* ≈75	Soft Pass	Soft Pass	N/A
F	Pass	Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Timer	Timer	Pass	N/A	Pass	N/A	Pass	Pass	N/A
G	Fail	Pass	Soft Pass	Soft Pass	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Pass	Comm	Comm	Pass	N/A	N/A	N/A	N/A	N/A	N/A
H	Fail	Fail	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	Pass	Pass	Soft Pass	Soft Pass	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Pass	Soft Pass	Pass	N/A	N/A	N/A	N/A	N/A	N/A
J	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈40	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈60	Pass	N/A	N/A	N/A	N/A	N/A	N/A
K	Fail	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	N/A	N/A	Pass* ≈40	N/A	N/A	N/A
L	Pass	Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	N/A	N/A	N/A	N/A	N/A	N/A
M	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈130	Pass	N/A	N/A	Pass* ≈35	N/A	N/A	N/A
N	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈95	Soft Pass	Pass	N/A	N/A	N/A	N/A	N/A	N/A

Vehicle 5:

EVSE	T1 Mechanical Push	T1 Mechanical Pull	T1 Charge Functionality	T1 Safety Systems	T2 V+	T2 V-	T2 F+	T2 F-	T2 W1 SWELL	T2 W2 VRV	T2 W3 SAG	T2 W4 FREQ	T2 W5 MOM	T2 W6 IND	T3 Car Schedule	T3 Car Interupt	T3 EVSE Schedule	T3 EVSE Interrupt	T3 EV Stagger	T3 EVSE Stagger	T3 A
A	Pass	Pass	Soft Pass	Pass	Pass	Pass	Pass	Pass	Pass	Soft Pass	Pass	Pass	Soft Pass	Exception ≈85	Pass	N/A	N/A	N/A	N/A	N/A	N/A
B	Fail	Soft Fail	Pass	Pass	Soft Pass	Pass	Soft Pass	Pass	Soft Pass	Pass	Pass	Soft Pass	Exception ≈80	Exception ≈60	Pass	N/A	N/A	Soft Pass* ≈50	N/A	N/A	N/A
C	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Pass	Soft Pass	Soft Pass	Pass	Pass	Pass	Pass	Pass	Pass	N/A	N/A	N/A	N/A	N/A	N/A
D	Pass	Pass	Soft Pass	Soft Pass	Fail	Pass	Pass	Pass	Exception ≈30	Exception ≈30	Pass	Soft Pass	Pass	Exception ≈50	Pass	N/A	N/A	N/A	N/A	N/A	N/A
E	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Timer	Soft Pass	N/A	Soft Pass	Soft Pass* ≈74	Soft Pass	Soft Pass	N/A
F	Fail	Pass	Soft Pass	Soft Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Exception ≈35	Exception ≈50	Soft Pass	N/A	Pass	N/A	Pass	Pass	N/A
G	Fail	Pass	Soft Pass	Pass	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Pass	Pass	Exception ≈70	Soft Pass	Pass	N/A	N/A	N/A	N/A	N/A	N/A
H	Fail	Fail	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	Fail	Pass	Soft Pass	Soft Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	N/A	N/A	N/A	N/A	N/A	N/A
J	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Pass	Soft Pass	Exception ≈30	Pass	Pass	Pass	Pass	Exception ≈65	Pass	N/A	N/A	N/A	N/A	N/A	N/A
K	Fail	Fail	Soft Pass	Soft Pass	Pass	Pass	Pass	Pass	Pass	Soft Pass	Pass	Pass	Pass	Soft Pass	Pass	N/A	N/A	Pass* ≈36	N/A	N/A	N/A
L	Pass	Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Soft Pass	Pass	N/A	N/A	N/A	N/A	N/A	N/A
M	Pass	Pass	Soft Pass	Pass	Pass	Pass	Pass	Pass	Pass	Soft Pass	Pass	Pass	Soft Pass	Exception ≈95	Soft Pass	N/A	N/A	Pass* ≈24	N/A	N/A	N/A
N	Pass	Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Pass	Pass	Soft Pass	Pass	Soft Pass	Pass	Exception ≈40	Soft Pass	Pass	N/A	N/A	N/A	N/A	N/A	N/A

Vehicle 6:

EVSE	T1 Mechanical Push	T1 Mechanical Pull	T1 Charge Functionality	T1 Safety Systems	T2 V+	T2 V-	T2 F+	T2 F-	T2 W1 SWELL	T2 W2 VRV	T2 W3 SAG	T2 W4 FREQ	T2 W5 MOM	T2 W6 INDEF	T3 Car Schedule	T3 Car Interupt	T3 EVSE Schedule	T3 EVSE Interrupt	T3 EV Stagger	T3 EVSE Stagger	T3 A
A	Pass	Pass	Pass	Soft Pass	Soft Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Soft Pass	Exception ≈85	Pass	Pass* ≈40	N/A	N/A	N/A	N/A	N/A
B	Pass	Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
C	Pass	Pass	Pass	Pass	Pass	Soft Pass	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Pass	Pass	Pass* ≈55	N/A	N/A	N/A	N/A	N/A
D	Pass	Pass	Soft Pass	Soft Pass	Pass	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Pass	Soft Pass	Pass	Pass* ≈62	N/A	N/A	N/A	N/A	N/A
E	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Timer	Pass	Pass* ≈62	Soft Pass	Soft Pass*	Pass	Pass	N/A
F	Pass	Pass	Pass	Soft Pass	Pass	Pass	Pass	Pass	Pass	Soft Pass	Soft Pass	Pass	Timer	Timer	Pass	Pass* ≈70	Pass	N/A	Pass	Pass	N/A
G	Pass	Pass	Pass	Soft Pass	Pass	Pass	Soft Pass	Pass	Pass	Soft Pass	Soft Pass	Pass	Exception ≈85	Comm	Pass	Pass* ≈97	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	Fail	Pass	Pass	Soft Pass	Pass	Pass	Pass	Pass	Pass	Soft Pass	Soft Pass	Pass	Pass	Pass	Pass	Pass* ≈91	N/A	N/A	N/A	N/A	N/A
J	Pass	Pass	Pass	Soft Pass	Pass	Pass	Pass	Pass	Exception ≈65	Soft Pass	Soft Pass	Pass	Pass	Exception ≈70	Pass	Pass* ≈96	N/A	N/A	N/A	N/A	N/A
K	Pass	Pass	Soft Pass	Soft Pass	Pass	Pass	Pass	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Pass	Pass	Pass* ≈110	N/A	Pass* ≈102	N/A	N/A	N/A
L	Pass	Pass	Pass	Soft Pass	Pass	Pass	Pass	Pass	Pass	Soft Pass	Soft Pass	Pass	Pass	Soft Pass	Pass	Pass* ≈102	N/A	N/A	N/A	N/A	N/A
M	Pass	Pass	Pass	Soft Pass	Pass	Pass	Pass	Pass	Pass	Soft Pass	Soft Pass	Pass	Pass	Exception ≈85	Pass	Pass* ≈115	N/A	Pass* ≈111	N/A	N/A	N/A
N	Pass	Pass	Pass	Soft Pass	Pass	Pass	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Exception ≈80	Soft Pass	Pass	Pass* ≈102	N/A	N/A	N/A	N/A	N/A

Vehicle 7:

EVSE	T1 Mechanical - Push	T1 Mechanical - Pull	T1 Safety Systems	T1 Charge Functionality	T2 V+	T2 V-	T2 F+	T2F-	T2 Voltage Range	T2 Voltage Swell	T2 Voltage Sag	T2 Momentary	T2 Indefinite	T2 Frequency Range	T3 Car Schedule	T3 Car Interupt	T3 EVSE Schedule	T3 EVSE Interrupt	T3 EV Stagger	T3 EVSE Stagger	T3 A
A	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈60	Soft Pass	Pass	Pass	N/A	N/A	N/A	N/A	N/A
B	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈55	Exception ≈30	Soft Pass	Soft Pass	Soft Pass* ≈1740	N/A	Pass* ≈1750	N/A	N/A	N/A
C	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Pass	Soft Pass	Pass	Pass	Pass	Pass* ≈1610	N/A	N/A	N/A	N/A	N/A
D	Soft Fail	Soft Fail	Soft Pass	Soft Pass	Soft Pass	Pass	Pass	Soft Pass	Soft Pass	Exception ≈40	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass* ≈122	N/A	Soft Pass	N/A	N/A	N/A
E	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈40	Soft Pass	Soft Pass	Exception ≈55	Soft Pass	Fail	Exception* ≈1750	Fail	Pass	Pass	Soft Pass	N/A
F	Fail	Fail	Soft Pass	Soft Pass	Pass	Pass	Soft Pass	Pass	Soft Pass	Exception ≈40	Soft Pass	Exception ≈50	Exception ≈60	Pass	Fail	Exception* ≈1750	Soft Pass	N/A	Fail	Pass	N/A
G	Soft Fail	Soft Fail	Soft Pass	Soft Pass	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈45	Exception ≈30	Soft Pass	Pass	Pass	N/A	N/A	N/A	N/A	N/A
H	Fail	Fail	Soft Pass	Soft Pass	Pass	Pass	Pass	Soft Pass	Soft Pass	Exception ≈30	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Fail	Exception* ≈1770	N/A	N/A	N/A	N/A	N/A
I	Fail	Fail	Soft Pass	Soft Pass	Pass	Pass	Soft Pass	Soft Pass	Pass	Pass	Pass	Pass	Exception ≈30	Pass	Fail	Exception* ≈1760	N/A	N/A	N/A	N/A	N/A
J	Fail	Soft Fail	Soft Pass	Soft Pass	Pass	Pass	Pass	Pass	Pass	Exception ≈25	Pass	Pass	Exception ≈55	Pass	Pass	Pass* ≈1740	N/A	N/A	N/A	N/A	N/A
K	Fail	Fail	Soft Pass	Soft Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Soft Pass	Pass	Soft Pass	Soft Pass	N/A	Pass	N/A	N/A	N/A
L	Pass	Pass	Soft Pass	Soft Pass	Pass	Pass	Pass	Soft Pass	Pass	Exception ≈85	Pass	Soft Pass	Exception ≈65	Soft Pass	Pass	Pass	N/A	N/A	N/A	N/A	N/A
M	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈15	Soft Pass	Soft Pass	Exception ≈60	Soft Pass	Pass	Pass	N/A	Pass	N/A	N/A	N/A
N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Vehicle 8:

EVSE	T1 Mechanical Push	T1 Mechanical Pull	T1 Charge Functionality	T1 Safety Systems	T2 V+	T2 V-	T2 F+	T2 F-	T2 W1 SWELL	T2 W2 VRV	T2 W3 SAG	T2 W4 FREQ	T2 W5 MOM	T2 W6 IND	T3 Car Schedule	T3 Car Interupt	T3 EVSE Schedule	T3 EVSE Interrupt	T3 EV Stagger	T3 EVSE Stagger	T3 A
A	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈80	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A
B	Pass	Pass	Pass	Pass	Pass	Soft Pass	Pass	Soft Pass	Pass	Pass	Soft Pass	Pass	Exception ≈75	Exception ≈75	Soft Pass	N/A	N/A	Soft Pass* ≈13	N/A	N/A	N/A
C	Fail	Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Pass	Pass	Soft Pass	Pass	Soft Pass	Pass	Soft Pass	Pass	Pass	N/A	N/A	N/A	N/A	N/A	N/A
D	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	Pass* ≈28	N/A	N/A	N/A
E	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Timer	Soft Pass	N/A	Pass	Soft Pass* ≈23	Soft Pass	Soft Pass	N/A
F	Fail	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Pass	Timer	Timer	Pass	N/A	Pass	N/A	Pass	Pass	N/A
G	Fail	Fail	Soft Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Pass	Comm	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A
H	Fail	Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	Fail	Fail	Soft Pass	Soft Pass	Soft Pass	Pass	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Comm	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A
J	Fail	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈55	Soft Pass	Soft Pass	Pass	Pass	Exception ≈60	Pass	N/A	N/A	N/A	N/A	N/A	N/A
K	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Exception ≈85	Soft Pass	Pass	N/A	N/A	Pass* ≈24	N/A	N/A	N/A
L	Pass	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Pass	Soft Pass	Soft Pass	Pass	Pass	Pass	Pass	N/A	N/A	N/A	N/A	N/A	N/A
M	Pass	Fail	Soft Pass	Soft Pass	Pass	Pass	Pass	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Exception ≈125	Soft Pass	N/A	N/A	Soft Pass* ≈18	N/A	N/A	N/A
N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Vehicle 9:

EVSE	T1 Mechanical Push	T1 Mechanical Pull	T1 Charge Functionality	T1 Safety Systems	T2 V+	T2 V-	T2 F+	T2 F-	T2 W1 SWELL	T2 W2 VRV	T2 W3 SAG	T2 W4 FREQ	T2 W5 MOM	T2 W6 INDEF	T3 Car Schedule	T3 Car Interupt	T3 EVSE Schedule	T3 EVSE Interrupt	T3 EV Stagger	T3 EVSE Stagger	T3 A
A	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈25	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A
B	Fail	Fail	Soft Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Pass	Exception ≈40	Exception ≈55	Soft Pass	N/A	N/A	N/A	Pass* ≈1740	N/A	N/A	N/A
C	Fail	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D	Fail	Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Pass	Pass	Soft Pass	Exception ≈50	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	Soft Pass	N/A	N/A	N/A
E	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈55	Soft Pass	N/A	N/A	Pass	Pass	N/A	N/A	N/A
F	Fail	Soft Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Pass	Soft Pass	Pass	Soft Pass	Exception ≈40	Exception ≈50	Soft Pass	N/A	N/A	Pass	N/A	N/A	N/A	N/A
G	Fail	Fail	Soft Pass	Soft Pass	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈35	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	Fail	Soft Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	Fail	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈35	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	Fail	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈30	Soft Pass	Soft Pass	Exception ≈45	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K	Fail	Fail	Soft Pass	Soft Pass	Pass	Pass	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈50	Soft Pass	N/A	N/A	N/A	Pass	N/A	N/A	N/A
L	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Exception ≈50	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A
M	Pass	Pass	Soft Pass	Soft Pass	Pass	Pass	Pass	Pass	Soft Pass	Pass	Pass	Pass	Exception ≈60	Pass	N/A	N/A	N/A	Pass	N/A	N/A	N/A
N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Vehicle 10:

EVSE	T1 Mechanical Push	T1 Mechanical Pull	T1 Safety Systems	T1 Charge Functionality	T2 V+	T2 V-	T2 F+	T2F-	T2 Voltage Range Variation	T2 Voltage Swell	T2 Voltage Sag	T2 Momentary Outage	T2 Indefinite Outage	T2 Frequency Range Variation	T3 Car Schedule	T3 Car Interupt	T3 EVSE Schedule	T3 EVSE Interrupt	T3 EV Stagger	T3 EVSE Stagger	T3 A
A	Pass	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
B	Pass	Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
C	Pass	Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D	Pass	Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Soft Pass* ≈29	N/A	N/A	N/A
E	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈45	N/A	Soft Pass	N/A	N/A	Soft Pass	Soft Pass* ≈23	N/A	N/A	N/A
F	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Soft Pass	N/A	N/A	Soft Pass	N/A	N/A	Soft Pass	N/A	N/A	N/A	N/A
G	Pass	Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	Soft Pass	Pass	Pass	Pass	Pass	Soft Pass	Pass	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	Pass	Pass	Pass	Pass	Soft Pass	Soft Pass	Pass	Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈15	Soft Pass	Exception ≈55	N/A	N/A	N/A	Soft Pass* ≈25	N/A	N/A	N/A
L	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A
M	Pass	Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Soft Pass* ≈22	N/A	N/A	N/A
N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Vehicle 11:

EVSE	T1 Mechanical Push	T1 Mechanical Pull	T1 Charge Functionality	T1 Safety Systems	T2 V+	T2 V-	T2 F+	T2 F-	T2 W1 SWELL	T2 W2 VRV	T2 W3 SAG	T2 W4 FREQ	T2 W5 MOM	T2 W6 INDEF	T3 Car Schedule	T3 Car Interupt	T3 EVSE Schedule	T3 EVSE Interrupt	T3 EV Stagger	T3 EVSE Stagger	T3 A
A	Pass	Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A
B	Pass	Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	Exception* ≈25	N/A	N/A	N/A
C	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	Pass	Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	Pass	Soft Pass* ≈34	N/A	N/A	N/A
F	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	Pass	N/A	N/A	N/A	N/A
G	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Comm	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	Pass	Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Fail	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K	Pass	Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	Soft Pass* ≈32	N/A	N/A	N/A
L	Pass	Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A
M	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	N/A	N/A	N/A	Soft Pass* ≈31	N/A	N/A	N/A
N	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Fail	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Vehicle 12:

EVSE	T1 Mechanical Push	T1 Mechanical Pull	T1 Charge Functionality	T1 Safety Systems	T2 V+	T2 V-	T2 F+	T2 F-	T2 W1 SWELL	T2 W2 VRV	T2 W3 SAG	T2 W4 FREQ	T2 W5 MOM	T2 W6 INDEF	T3 Car Schedule	T3 Car Interupt	T3 EVSE Schedule	T3 EVSE Interrupt	T3 EV Stagger	T3 EVSE Stagger	T3 A
A	Pass	Pass	Soft Pass	Soft Pass	Pass	Pass	Pass	Pass	Exception ≈85	Pass	Pass	Soft Pass	Soft Pass	Exception ≈250	Pass	N/A	N/A	N/A	N/A	N/A	N/A
B	Pass	Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
C	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Exception ≈65	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	N/A	N/A	N/A	N/A	N/A	N/A
D	Pass	Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈130	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	N/A	N/A	N/A	N/A	N/A	N/A
E	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈65	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Timer	Soft Pass	N/A	Soft Pass	Soft Pass* ≈34	Fail	Fail	N/A
F	Fail	Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈65	Soft Pass	Soft Pass	Soft Pass	Timer	Timer	Pass	N/A	Fail	N/A	Fail	Pass	N/A
G	Soft Fail	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈65	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Comm	Pass	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	Fail	Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈95	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Pass	N/A	N/A	N/A	N/A	N/A	N/A
J	Pass	Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈100	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈45	Pass	N/A	N/A	N/A	N/A	N/A	N/A
K	Pass	Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈65	Soft Pass	Soft Pass	Soft Pass	Exception ≈60	Soft Pass	Pass	N/A	N/A	Exception* ≈75	N/A	N/A	N/A
L	Pass	Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈70	Pass	N/A	N/A	N/A	N/A	N/A	N/A
M	Pass	Pass	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈65	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈75	Pass	N/A	N/A	Exception* ≈50	N/A	N/A	N/A
N	Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈65	Soft Pass	Soft Pass	Soft Pass	Exception ≈70	Soft Pass	Pass	N/A	N/A	N/A	N/A	N/A	N/A

Vehicle 13:

EVSE	T1 Mechanical Push	T1 Mechanical Pull	T1 Charge Functionality	T1 Safety Systems	T2 V+	T2 V-	T2 F+	T2 F-	T2 W1 SWELL	T2 W2 VRV	T2 W3 SAG	T2 W4 FREQ	T2 W5 MOM	T2 W6 INDEF	T3 Car Schedule	T3 Car Interupt	T3 EVSE Schedule	T3 EVSE Interrupt	T3 Car Stagger	T3 EVSE Stagger	T3 A
A	Fail	Pass	Pass	Pass	Fail	Pass	Pass	Soft Pass	Pass	Pass	Soft Pass	Pass	Soft Pass	Exception ≈55	N/A	N/A	N/A	N/A	N/A	N/A	N/A
B	Pass	Pass	Soft Pass	Pass	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈80	Exception ≈85	N/A	N/A	N/A	Pass* ≈38	N/A	N/A	N/A
C	Pass	Pass	Pass	Soft Pass	Fail	Pass	Soft Pass	Pass	Soft Pass	Pass	Pass	Pass	Pass	Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D	Pass	Pass	Pass	Soft Pass	Fail	Pass	Soft Pass	Pass	Exception ≈65	Pass	Pass	Pass	Pass	Exception ≈55	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	Pass	Pass	Soft Pass	Soft Pass	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Timer	N/A	N/A	Soft Pass	Soft Pass* ≈336	N/A	N/A	N/A
F	Pass	Pass	Pass	Pass	Fail	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈70	Exception ≈35	N/A	N/A	Pass	N/A	N/A	N/A	N/A
G	Pass	Pass	Pass	Incomplete	Fail	Pass	Soft Pass	Soft Pass	Soft Pass	Pass	Pass	Pass	Exception ≈60	Comm	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	Pass	Pass	Pass	Incomplete	Fail	Soft Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	Pass	Pass	Pass	Pass+	Fail	Pass	Pass	Pass	Exception ≈40	Pass	Pass	Pass	Pass	Exception ≈30	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K	Pass	Pass	Pass	Pass+	Fail	Soft Pass	Pass	Pass	Soft Pass	Pass	Pass	Pass	Pass	Soft Pass	N/A	N/A	N/A	Pass* ≈324	N/A	N/A	N/A
L	Pass	Pass	Pass	Pass+	Fail	Soft Pass	Pass	Pass	Pass	Soft Pass	Pass	Pass	Pass	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A
M	Pass	Pass	Pass	Soft Pass	Fail	Pass	Pass	Pass	Pass	Pass	Pass	Soft Pass	Pass	Exception ≈110	N/A	N/A	N/A	Pass* ≈343	N/A	N/A	N/A
N	Pass	Pass	Soft Pass	Soft Pass	Fail	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈65	Soft Pass	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Vehicle 14:

EVSE	T1 Mechanical Push	T1 Mechanical Pull	T1 Charge Functionality	T1 Safety Systems	T2 V+	T2 V-	T2 F+	T2 F-	T2 W1 SWELL	T2 W2 VRV	T2 W3 SAG	T2 W4 FREQ	T2 W5 MOM	T2 W6 INDEF	T3 Car Schedule	T3 Car Interupt	T3 EVSE Schedule	T3 EVSE Interrupt	T3 EV Stagger	T3 EVSE Stagger	T3 A
A	N/A	N/A	Pass	Soft Pass	Pass	Pass	Pass	Pass	Exception ≈105	Pass	Soft Pass	Pass	Soft Pass	Exception ≈65	N/A	N/A	N/A	N/A	N/A	N/A	N/A
B	N/A	N/A	Soft Pass	Soft Pass	Pass	Soft Pass	Soft Pass	Soft Pass	Exception ≈70	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
C	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
L	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
M	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A