Safety or abuse tests in standards on Li-ion batteries – detailed description

This table covers safety or abuse tests for Li-ion batteries. It is made in the European projects eCaiman, Spicy and Naiades.

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	UN38.3: 2015	IEC 62281:2016 RLV	IEC 62133-2:2017	IEC 62660-2:2010	ISO 12405-3:2014	SAE J2929-2013
Thermal	**38.3.4.2 Test T.2: Thermal test** Storage for at least six hours (12 hours for large batteries) at 75 ± 2 °C, followed by storage for at least six hours (12 hours for large batteries) at -40 ± 2 °C. The maximum time interval between test temperature extremes is 30 minutes. This procedure is to be repeated until 10 total cycles are complete.	**6.4.2 Test T-2: Thermal cycling** Similar to UN38.3 but UN 38.3 says that the open circuit voltage of each test cell or battery after testing is not less than 90% of its voltage immediately prior to this test. IEC 62281 ed.2:2012 says that there shall be no short-circuit during the test. Different ways of verifying the same thing. Storage for at least six hours (12 hours for large batteries) at 75 ± 2 °C, followed by storage for at least six hours (12 hours for large batteries) at -40 ± 2 °C. The maximum time interval between test temperature extremes is 30 minutes. This procedure is to be repeated until 10 total cycles are complete.	**7.2.2 Case stress at high ambient temperature (battery)** The battery is placed in 70 °C ± 2 °C, 7 h. Requirements: No physical distortion of the battery case resulting in exposure of internal protective components and cells.	**6.2.2 Temperature cycling** For cells only. This standard says nothing about the number of cells that shall be tested. Test without electrical operation: test duration 20 hours; operating temperature -40 °C and 85 °C or Tmin and Tmax specified by the manufacturer. Test with electrical operation: test duration 20 hours; operating temperature -20 °C and 65 °C .	**7.1 Dewing (T change):** Battery packs and battery systems only. Test profile according to IEC60068-2-30 and ISO 12405-1. During the test the DUT shall be exposed to a humidity change between 50%Rh and 98%Rh and a T change between 25 °C and 80 °C or it shall be agreed by the customer and supplier. Five test cycles. **7.2 Thermal shock cycling** Battery packs and battery systems only. During the test the DUT shall be exposed to a T change between -40 °C and 85 °C or a T change agreed by the customer and supplier. The maximum time interval between test T extremes is 30 minutes. This procedure is to be repeated until 5 total cycles are complete.	**4.2.3 Thermal Shock** Complete Battery System:As UN 38.3. Test T.2 or SAE J2464 4.4.4 Thermal shock Storage for at least six hours (12 hours for large batteries) at 75 ± 2 °C, followed by storage for at least six hours (12 hours for large batteries) at -40 ± 2 °C. The maximum time interval between test temperature extremes is 30 minutes. This procedure is to be repeated until 10 total cycles are complete.
Thermal: Abuse			**7.3.4 Thermal abuse (cells)** Purpose: An extremelyl high temperature shall not cause fire or explosion Test procedure: After putting the cells in an ambient temperature of 20°C± 5 °C for 1 h, the temperature is raised to a temperature of +130 °C at a rate of 5°C/min ± 2 °C/min . The cells remains at this temperature for 30 min before the test is terminated. Requirements: No fire or explosion.			
Thermal: Loss of thermal / cooling					**10.3 Loss of thermal control / cooling** For battery packs and battery systems only. The DUT shall be at any operational SOC and the active cooling device shall be disabled. The DUT shall be placed in a convective oven or climatic chamber and cycled with max. applicable current to the cell. The T shall be gradually increased until the DUT reaches a T up to 20 K above the DUT max. operating T or until the rated T threshold at which the protection measures would become effective, whichever is lower. The test shall be terminated if the cycling is interrupted or reduced by the protective measure, or the T change of the DUT is less than 4 K within 2 h or 2 h after the DUT reaches the maximum operating T.	**4.11 Single Point Thermal Control System Failure** Purpose: simulates the condition where the battery system temperature control is no longer operating and the failure may lead to a battery system over temperature condition. Test procedure: The battery system is to be tested in accordance with SAE J2464, Section 4.4.3.
Mechanical: Vibration	**38.3.4.3 Test T.3: Vibration** Cells and batteries are firmly secured to the platform of the vibration machine without distorting the cells in such a manner as to faithfully transmit the vibration. The vibration shall be a sinusoidal waveform with a logarithmic sweep between 7 Hz and 200 Hz and back to 7 Hz traversed in 15 minutes. This cycle shall be repeated 12 times for a total of 3 hours for each of three mutually perpendicular mounting positions of the cell.	**6.4.3 Test T-3: Vibration** Similar to UN38.3 but UN 38.3 says that the open circuit voltage of each test cell or battery after testing is not less than 90% of its voltage immediately prior to this test. IEC 62281 ed.2:2012 says that there shall be no short-circuit during the test. Different ways of verifying the same thing. Cells and batteries are firmly secured to the platform of the vibration machine without distorting the cells in such a manner as to faithfully transmit the vibration. The vibration shall be a sinusoidal waveform with a logarithmic sweep between 7 Hz and 200 Hz and back to 7 Hz traversed in 15 minutes. This cycle shall be repeated 12 times for a total of 3 hours for each of three mutually perpendicular mounting positions of the cell.	**7.3.8.1 Vibration** Similar to UN38.3. Cells and batteries are firmly secured to the platform of the vibration machine without distorting the cells in such a manner as to faithfully transmit the vibration. The vibration shall be a sinusoidal waveform with a logarithmic sweep between 7 Hz and 200 Hz and back to 7 Hz traversed in 15 minutes. This cycle shall be repeated 12 times for a total of 3 hours for each of three mutually perpendicular mounting positions of the cell.	**6.1.1 Vibration** For cells only. This standard says nothing about the number of cells that shall be tested. Test duration 8 hours. Maximum frquency 2000 Hz.	**6.1 Vibration** For battery packs and battery systems only Test profile according to IEC60068-2-64:2008. During the test the DUT shall be exposed to a temperature change between -40 °C and 75 °C or a temperature change agreed by the customer and supplier. No leakage, rupture, fire or explosion and the isolation resistance shall be higher than 100 W/V for DC-systems and 500 W/V for AC-systems	**4.2.2 Vibration** Alternative 1. Complete Battery System: UN 38.3, Test T.3 or SAE J2380 Alternative 2. Battery Subsystem: PART A: UN 38.3, Test T.3 or SAE J2380 PART B: Complete Battery system test under appropiate vibration testing profile
Mechanical: Shock	**38.3.4.4 Test T.4:Shock** Each cell or battery shall be subjected to a half-sine shock of peak acceleration of 150 gn and pulse duration of 6 milliseconds. Large cells and large batteries shall be subjected to a half-sine shock of peak acceleration of 50 gn and pulse duration of 11 milliseconds. Each cell or battery is subjected to three shocks in the positive direction followed by three shocks in the negative direction of each of three mutually perpendicular mounting positions of the cell for a total of 18 shocks.	**6.4.4 Test T-4: Shock** Similar to UN38.3 but UN 38.3 says that the open circuit voltage of each test cell or battery after testing is not less than 90% of its voltage immediately prior to this test. IEC 62281 ed.2:2012 says that there shall be no short-circuit during the test. Different ways of verifying the same thing. Each cell or battery shall be subjected to a half-sine shock of peak acceleration of 150 gn and pulse duration of 6 milliseconds. Large cells and large batteries shall be subjected to a half-sine shock of peak acceleration of 50 gn and pulse duration of 11 milliseconds. Each cell or battery is subjected to three shocks in the positive direction followed by three shocks in the negative direction of each of three mutually perpendicular mounting positions of the cell for a total of 18 shocks.	**7.3.8.2 Mechanical shock (crash hazard)** Similar to UN38.3. Each cell or battery shall be subjected to a half-sine shock of peak acceleration of 150 gn and pulse duration of 6 milliseconds. Large cells and large batteries shall be subjected to a half-sine shock of peak acceleration of 50 gn and pulse duration of 11 milliseconds. Each cell or battery is subjected to three shocks in the positive direction followed by three shocks in the negative direction of each of three mutually perpendicular mounting positions of the cell for a total of 18 shocks.	**6.1.2 Mechanical shock** For cells only. This standard says nothing about the number of cells that shall be tested. Test profile according to ISO16750-1.The cell shall be subjected to a half-sine shock of peak acceleration of 50 gn and pulse duration of 6 milliseconds. The shock shall be performed 10 times in the same direction as the acceleration of the shock occurs in the vehicle.	**6.2 Mechanical shock** For battery packs and battery systems only . Test profile according to ISO16750-1. This standard says nothing about the number of cells that shall be tested. The cell shall be subjected to a half-sine shock of peak acceleration of 50 gn and pulse duration of 6 milliseconds. The shock shall be performed 10 times in the same direction as the acceleration of the shock occurs in the vehicle. No leakage, rupture, fire or explosion and the isolation resistance shall be higher than 100 W/V for DC-systems and 500 W/V for AC-systems.	**4.5 Mechanical Shock** Purpose: Simulates intertial loads which may occur during a vehicle crash situation. Test procedure: Alternative 1: Battery System-Level Condition: UN Test Manual, Test T.4; or SAE J2464, Section 4.3.1. Alternative 2: Vehicle-Level Evaluation Condition: FMVSS 305, S6.1, 6.2, 6.3 :

	SAE J2464:2009	SAND 2005-3123	QC/T 743-2006	UL 2580:2013	DOE-INL/EXT-15-34184
Thermal	**4.4.4 Thermal Shock Cycling** (Cell level or above) Optional at cell level. DUT at max. operating SOC, contained in a closed volume, and active thermal controls disabled, thermally cycle the DUT with ambient air cycling between 70 °C to –40 °C. The time for the chamber ambient temperature to reach each temperature extreme shall be max. 15 min. The DUT shall remain at each extreme for a minimum of 1 h at the cell level, 6 h at the module level or as required to reach a uniform temperature (±5 °C) at the pack level. A total of 5 cycles shall be performed. Perform 3 C/3 discharge cycles at 25 °C ambient air temperature before and after test (using the manufacturers recharge algorithm) to determine immediate effects of the thermal cycling.	**4.3. Elevated Temperature Storage** Test on cell level or higher. DUT is stored at 100, 50 and 20% of SOC at temperatures of 40, 60 and 80°C for minimum of two months. Check capacity every week at ambient or operating temperature. Stop test when 80% of the initial capacity are reached. **4.5. Thermal Shock Cycling** Test is on cell level or higher. Similar to UN38.3, IEC62281:2016RLV, IEC62133-2:2017, SAE J2929-2013 and UL2580:2013. but upper temperature level is 80°C. All thermal controls need to be disabled.		**39 Thermal cycling** Similar to UN38.3, IEC62281:2016RLV, IEC62133-2:2017 and SAE J2929-2013. Full system. Fully charged DUT. Storage for at least 6 h (12 h for large batteries) at 75 °C, followed by storage for at least 6 h (12 h for large batteries) at -40 °C. The max time interval between test T extremes is 30 minutes. Repeat until 10 total cycles are complete.	**3.7.1 Survival Temperature Test.** Cold storage test (-40ºC): 1. From fully charged, perform a C/3 discharge-charge followed by a LHPPC. 2. From a fully charged, bring the device to Vnominal at 30°C using the C/3 CC rate. Taper the current at Vnominal following the manufacturer's recommended procedure. 3. Ramp the thermal temperature to the specified minimum survival temperature within 1 hr and then soak the device at open circuit for a 24 hr period. 4. Return to 30°C and rest for at least 4 to 16 hours. 5. From fully charged, perform a C/3 discharge-charge followed by a LHPPC. Hot storage test (66ºC): Follow the same steps defined for the cold storage by replacing the corresponding extreme temperature and reaching it in 15 min. instead of 1 hr.
Thermal: Abuse	**4.4.1 High Temperature Hazard Test** (Pack Module Level and Above) The objective of this test is to reproduce the T experienced in a fuel fire: 890ºC achieved within 90 s and held for 10 min. The DUT will be at 100% SOC. The suggested "radiant heating" test fixture is a thin cylindrical metallic fixture whose inside is coated such that it will radiate approximately like a black body. The test T is controlled by thermocouples mounted on the interior surface of the fixture, with the DUT placed in the center of the fixture such that it does not contact the fixture walls. **4.4.2 Thermal Stability Test** Fully charged cell and at normal operating T at the beginning of the test. If the T at which a major exothermic reaction occurs is known, the test may begin at 25 °C lower than this temp. Heat the cell to 300 °C above its maximum operating T. Increase the T in 5 °C increments, and hold at each T step for 30 min or until any self heating is detected. If self heating (>1.0 °C/min) is detected, hold the chamber T until the cell T stabilizes or until (a) the T reaches 300 °C above the operating T of the cell or (b) a catastrophic event occurs. This test should be repeated (heating in 2 °C increments and held for a minimum of 1 h) with cells that have been overcharged, on cells that are at mid-life and at end-of-life.	**4.1. Thermal Stability** For cell or higher level. Fully charged DUT its to be stored at 30°C, then with a heating rate between 5 and 10°C /min the cell is to be heated up till 200° with specified hold times at specified temperature levels. Observe temperatures and also detect self heating. Test is completed when, 200°C is reached, catastrophic event occurs or additional self heating is detected. **4.2. Simulated Fuel Fire** Test on module and above. DUT must be exposed to a ramp starting at 25°C going up 890^C surface temperature within 90s from a radiant source.	**6.2.12.5 Heat** On celll level. Place the fully charged DUT inside a climate chamber where the temperature is 85°C ±2°C for 120min. There shall be no fire nor an explosion. **6.3.8.4 Heat** On full system level. Place the fully charged DUT inside a climate chamber where the temperature is 85°C ±2°C for 120min. There shall be no fire nor an explosion.	**42 External fire exposure test** On full system level. Place a fully charged DUT in the centre of a fire source: 590°C within 5min on the surface. When this is reached the test lasts for 20min. **43 Internal fire exposure test** Full system. Force a thermal runaway of one centric cell in a fully charged DUT. There shall be no fire or explosion.	
Thermal: Loss of thermal / cooling	**4.4.3 Cycling without Thermal Management** (Module and Pack Level) DUT at nominal operating T, fully charged, contained in a closed volume in static air, and active thermal controls disabled, charge the DUT using the manufacturers defined charge algorithm followed by a discharge at a rate comparable to the intended application. Apply 20 full charge/discharge cycles with no rest period. **4.4.5 Passive Propagation Resistance Test** (Module or Pack Level) DUT charged to 100% SOC. All external circuits, cooling systems, or other devices are turned off or disconnected. The DUT is heated until the cells stabilize at 55 °C or the maximum operating T, whichever is greater. One cell within the DUT at a locations described is uniformly heated in-situ to a T of 400 °C (or until the cell enters thermal runaway) in less than 5 min. DUT is observed for 1 h. This above procedure shall be repeated with cells in different locations that represent various thermal environments/relationships within the pack.	**4.4. Rapid Charge/Discharge** Test on module or higher. Nominal operating temperature and fully charged DUT is subjected to 20 full cycles according to manufacturer specification without any rest period in between. Test should be performed in an enclosed volume. Thermal controls have to be disabled. Check capacity before and after test.		**28 Temperature test** On full system or functional subassembly if applicable. Charge a fully discharged DUT at maximum allowed rate at maximum allowed T for charging. After thermal stabilization, discharge the DUT under maximum allowed T. Repeat 5 times. **33 Failure of cooling / thermal stability system test** (On full system) Fully discharged DUT conditioned to maximum operational T. Then fully charged with max. rate and disabled cooling circuit until fully charged state, activation of protection circuit or catastrophic event. Fully charged DUT its then again discharged at maximum rate applying the same conditions as above. Conduct the same test at lowest operation T.	
Mechanical: Vibration			**6.3.7 Resistance to vibration** On full system. Mount fully charged DUT on table. Discharge with C/3 while subjecting to a up and down frequency sweep between 10-55Hz (max. acc. 30m/s²) for 2h.	**35 Vibration endurance test** On full system. Fully charged DUT is to be tested with the anticipated vehicle application vibration profile. If no specific vibration profile is anticipated it is to be tested according to SAE J2380. DUT is to be monitored for 1 day after testing. No catastrophic event should take place.	
Mechanical: Shock	**4.3.1 Shock Tests** Shock tests are labelled as optional at cell level. UN38.3 is to be applied to cells. For pack: Acceleration 25g, Duration 15ms, Pulse Form half sine, Total Number of Shocks 18 = 3 repeats on 3 axes in both positive and negative directions. The DUT should be observed for a minimum of 1 h after the test.	**3.6. Mechanical Shock** For module level. Different half sine amplitudes on the DUT ranging from 25G for 30ms up to 35G up to 51ms.		**36 Shock test** On full system level. Fully charged system is to be subjected to half sine shocks defined in IEC-60068-2-27. DUT shall be monitored for 1 day after the test. No catastrophic event should take place.	

Mechanical: Impact / Crush	**38.3.4.6 Test T.6.** **38.3.4.6.2 Impact** (just for cylindrical cells ≥ 18 mm in diameter). Place cell or component cell on a flat smooth surface. A 15.8mm diameter, minimum 6cm long bar is to be placed across the centre of the sample. Drop a weight of 9.1kg from a height of 61cm at the intersection of the bar and sample in a **38.3.4.6.2 Crush** A cell or component cell is to be criushed between 2 flat surfaces. Gradual crushing at 1.5 cm/s till one of these conditions is reached: applied force reached 13kN; the voltage drops 100mV;thickness decreases 50%. The DUT shall be observed for 6h after the end ot the test.	**6.4.6 Test T-6: Impact/crush** For cells only. **Impact.** (applicable to cylindrical cells greater than 18 mm in diameter). Place cell or battery on a 15.8mm diameter bar and drop a weight of 9.1kg from a height of 610mm. **Crush.** (prismatic, pouch, coin/button cells and cylindrical cells not more than 18 mm in diameter). Crush cell between two flat surfaces with a speed of around 15mm/s until the force reaches 13kN, the voltage drop is greater than 0.1V or the cell deformation is greater than 50%. There shall be no excessive T rise, no rupture, no explosion and no fire during this test and within the 6 h of observation.	**7.3.3 Free fall** Purpose: Dropping a cell or battery (for example, from a bench top) shall not cause fire or explosion. Fully charged cell or battery is dropped three times from a height of 1,0 m onto a concrete floor or metal floor. Requirements: No fire or explosion. **7.3.5 Crush (cells)** Purpose: Severe crushing of a cell shall not cause fire or explosion. There are some differences between UN38.3 and IEC62133. The number of test objects are different. Requirement: Almost the same		**8 Simulated vehicle accidents** The purpose is to simulate mechanical damage to the battery pack during a crash. The tests can be performed with the battery only and can also be performed installed in the vehicle. **8.2 Contact force at vehicle crash** Same as SAE J2464 but F=100kN	**4.3 Drop Test** SAE J2464, Section 4.3.2. **4.6 Battery Enclosure Integrity** Alternative 1: Battery System-Level Evaluation - Application-Specific Condition:SAE J2464, Section 4.3.6. Alternative 2: Battery System-Level Evaluation - Generic Condition: SAE J2464, Section 4.3.6, Alternative 3: Vehicle-Level Evaluation Condition: The complete battery system is to be assessed following vehicle tests simulating front, rear and side impacts,as defined in FMVSS 305, S6.1, 6.2, 6.3	**4.3.2 Drop Test (Pack Level Only)** Free drop from 2 meters onto a hard flat surface in the most vulnerable orientation. A horizontal impact into a hard flat surface with an equivalent velocity and deceleration on impact is acceptable. The DUT should be observed for a minimum of 1 h after the test. **4.3.6 Crush Test** DUT is to be crushed in at least two of the three axes (different RESS for each crush), Long axis of the crush surfaces should be oriented perpendicular to the cell major dimension so that the cells are deformed and not merely spread apart. For each DUT, crush to 85% of the initial dimension and hold for 5 min. After the hold period, continue the crush to 50% of the initial dimension. Crush maximum force 1000 times the weight of the DUT. Crush speed sufficiently slow to allow determination of the source of any shorting and the rate of internal heat propagation leading to possible thermal runaway (between 0.5 and 1 cm/min for packs and between 0.5 and 1 mm/min for cells). If outside, wind speed <3 mph. Hazard Severity Level, a spark source should be present.	**3.1. Controlled Crush** For module level. Crush DUT under flat plate and textured plate. Textured plate is equipped with semi-circular intrudes with a 75mm radius, 30mm apart. Control and circuitry in place and operating Press to 50% displacement or 1000 times the module's mass and hold for 5 minutes. **3.3. Drop** Drop test on pack level. Free drop from a pre-determined height not to exceed 10m on a cylindrical steel object with a radius of 150mm. Acceleration, (HF) video and pictures, temperatures, resistance and voltage between terminals among each other and casing before and after the test measured if possible.	**6.2.12.4 Fall** Drop fully charged battery cell from 1.5m to a floor of 20mm thick hard wood. Repeat until every surface hits the floor once. **6.2.12.5 Heat** Same as 6.2.12.6 but DUT at 85°C ±2K environment for 2h. **6.2.12.6 Crush** Crush the fully charged cell till the terminal voltage drops to 0V or the battery enclosure breaks. **6.3.8.5 Crush** Crush fully charged system until the size is 85% of the original pack size and remain at the level for 5min. Then crush until the size is 50% of the original pack size.	**37 Drop test** On full system level. Drop fully charged DUT from a height of min. 1m on solid concrete surface. If only one drop is made it should not be a flat drop, but 10° shifted. DUT shall be observed for 1 day after testing. No catastrophic event shall take place. **38 Crush test** On full system level. Crush a fully charged DUT according to SAE J2464 in all axes of symmetry with a maximum force of 100kN. No catastrophic event shall take place.	
Mechanical: Penetration & Roll-over							**4.3.3 Penetration Test** Penetrate the DUT with a mild steel (conductive) rod. The orientation of the penetration shall be perpendicular to the cell electrodes. Optional test for modules or packs. For cell: Diameter of Rod 3mm, Rod End Type Tapered to a sharp point, Rate of Penetration 8 cm/s or greater, Minimum Depth of Penetration Through cell. For Module/Pack: Diameter of Rod 20mm, Rod End Type Tapered to a sharp point, Rate of Penetration 8 cm/s or greater, Minimum Depth of Penetration Through 3 cells or 100 mm whichever is greater. The DUT should be observed for a minimum of 1 h after the test with the rod remaining in place. **4,3,4 Roll-over Test** (Module and Pack Level) Rotate the DUT one complete revolution in 1 min in a continuous slow roll fashion, and observe leaks. Then rotate the DUT in 90 degree increments for one full revolution. Observe the DUT for 1 h at each position and for a minimum of 1 h after the test.	**3.2. Penetration** For cells modules and packs. Same as SAE J2464:2009. **3.5. Roll-over Simulation** Test on module level. Same procedure as SAE J2464:2009 Rotate the DUT one complete revolution in 1 min in a continuous slow roll fashion, and observe leaks. Then rotate the DUT in 90 degree increments for one full revolution. Observe the DUT for 1 h at each position and for a minimum of 1 h after the test.	**6.2.12.7 Prick** Test on cell level. Penetrate fully charged cell with a steel needle which's diameter is 3 to 8mm with a speed of 10 to 40mm/s. The steel needle remains in the cell. **6.3.8.6 Prick** Cell on system level. Penetrate fully charged system with a steel needle which's diameter is 3 to 8mm with a speed of 10 to 40mm/s. At least 3 cells should be hit by the needle. The steel needle remains in the cell.	**34 Rotation test** On full system level. Rotate fully charged DUT over all 3 axes for 360° each, with a speed of 90°/15s. There shall be no fire, explosion, gassing or breakdown of the isolation.	
Electrical: External short circuit	**38.3.4.5 Test T.5: External short circuit** The cell or battery to be tested shall be temperature stabilized so that its external case temperature reaches 55 ± 2 °C and then the cell or battery shall be subjected to a short circuit condition with a total external resistance of less than 0.1 ohm at 55 ± 2 °C. This short circuit condition is continued for at least one hour after the cell or battery external case temperature has returned to 55 ± 2 °C.	**6.4.5 Test T-5: External short-circuit** Similar to UN38.3 but UN 38.3 says that cells and batteries meet this requirement if their external temperature does not exceed 170 °C and there is no disassembly, no rupture and no fire during the test and within six hours after the test. IEC 62281 ed.2:2012 says there shall be no excessive temperature rise, no rupture, no explosion and no fire during this test and within the 6 h of observation. Different ways of verifying the same thing. The cell or battery to be tested shall be temperature stabilized so that its external case temperature reaches 55 ± 2 °C and then the cell or battery shall be subjected to a short circuit condition with a total external resistance of less than 0.1 ohm at 55 ± 2 °C. This short circuit condition is continued for at least one hour after the cell or battery external case temperature has returned to 55 ± 2 °C.	**7.3.2 External short circuit** Similar to UN38.3. The cell or battery to be tested shall be temperature stabilized so that its external case temperature reaches 55 ± 2 °C and then the cell or battery shall be subjected to a short circuit condition with a total external resistance of less than 0.1 ohm at 55 ± 2 °C. This short circuit condition is continued for at least one hour after the cell or battery external case temperature has returned to 55 ± 2 °C. **7.3.1 External short circuit (cell)** Short-circuiting of the positive and negative terminals shall not cause fire or explosion. The number of test objects are different. Othervise similar to UN38.3. Requirement: Almost the same **7.3.2 External short circuit (battery)** Short-circuiting of the positive and negative terminals shall not cause fire or explosion. There are some differences between UN38.3 and IEC62133. The number of test objects are different. In UN38.3 the short circuit shall only be performed in +55 °C ± 5 °C. In IEC62133 the short circuit shall be performed in both 20 °C ± 5 °C and +55 °C ± 5 °C. Requirement: Almost the same	**6.3.1 External short circuit** For cells only. This standard says nothing about the number of cells that shall be tested. Shall be performed in room temperature with a total external resistance of less than 0.5 ohm Test results shall include cell voltage and cell current during test, cell temperature during test, total extrenal resistance and the conditions of the cell after test.	**9.1 Short circuit** For battery packs and battery systems only The purpose is to check the functionality of the overcurrent protection device. The test shall be performed under normal operating conditions. A conductor shall be used with a total external resistance of less than 0.1 ohm. No leakage, rupture, fire or explosion and the isolation resistance shall be higher than 100 W/V for DC-systems and 500 W/V for AC-systems	**4.8 Electrical Short Circuit** Purpose: simulates a hard short circuit condition across the battery terminals. Test procedure: UN Test Manual, Test T.5; the pack hard short circuit condition defined in SAE J2464, Section 4.5.1, or ISO 12405-1 or ISO 12405-2, Section 9.2	**4.5.1 Short Circuit Tests** (Cell and Module or Pack) Short in less than 1 sec for 60 min. Prior to this test, all active protective devices shall be disabled. Separate tests will be performed with passive protective devices intact and then disabled or bypassed wherever possible, as long as it does not compromise the integrity of the DUT. Continue observation for an additional period of 1 h. Hard short circuit (≤5 mOhm and <<DUT DC impedance) Soft short circuit on a separate DUT at a resistance comparable to the total DUT DC resistance but no less than 10 mOhm. Moderate short will assure that the cell response is measured rather than internal connector failure which can occur at high currents.	**5.2. Short Circuit** Test on module level or higher. DUT fully charged, hard short circuit with a resistance below 5mOhms or 1/10 of DUT resistance if it's below 5mOhms, to be established within 1s. Hold short circuit for 10 min, then release and observe for another 2h. **5.4. Partial Short Circuit** Test on module level or higher. DUT at 100% SOC. Test temperature is maximum operating temperature. Predefined adjacent units are subjected to hard short circuit below 5mOhms for 10 minutes. Passive short circuit protection is allowed.	**6.2.12.3 Short circuit** Test is on cell level. Short circuit fully charged cell for 10 min with less than 5mOhm. **6.3.8.3 Short circuit** Test on module level is similar to cell level.	**26 Short circuit test** On full system or functional subassembly if applicable. Fully charged DUT is to be short-circuited with a resistance of <=20mOhm. Test is repeated with a load drawing a current 15% under the operation of the short circuit protection. DUT its to be discharged this way to 0% SOC or SOE respectively. Test to be aborted when catastrophic event occurs.	
Electrical: Overcharge	**38.3.4.7 Test T.7: Overcharge** The charge current shall be twice the manufacturer's recommended maximum continuous charge current. Tests are to be conducted at ambient temperature. The duration of the test shall be 24 hours.	**6.5.1 Test T-7: Overcharge** Similar to UN 38.3. The charge current shall be twice the manufacturer's recommended maximum continuous charge current. Tests are to be conducted at ambient temperature. The duration of the test shall be 24 hours.	**7.2.1 Continuous charging at constant voltage (cells)** Fully charged cells are subjected for 7 days to a charge as specified by the manufacturer. Requirement: a continuous charge at constant voltage shall not cause fire or explosion. **7.3.6 Over-charging of battery** Purpose: Charging for longer periods than specified by the manufacturer shall not cause fire or explosion. Test procedure: There are some differences between UN38.3 and IEC62133. The number of test objects are different. Requirement: Almost the same	**6.3.2 Overcharge** For cells only. This standard says nothing about the number of cells that shall be tested. Continue charging the cell beyond the 100 % SOC with charging current 1 It for BEV application and 5 It for HEV application at room temperature.Charge up to 200 % SOC. Test results shall include cell voltage and cell current during test, cell temperature during test, total extrenal resistance and the conditions of the cell after test.	**10.1 Overcharge protection** For battery packs and battery systems only The purpose is to check the functionality of the overcharge protection device. The battery shall be charged with the recomended cc rate of 5C and the upper limit of the power supply shall be set not to exceed 20 % of the maximum battery system voltage. No leakage, rupture, fire or explosion and the isolation resistance shall be higher than 100 W/V for DC-systems and 500 W/V for AC-systems	**4.9 Single Point Overcharge Protection System Failure** Charge the battery system at the maximum possible charge rate for the application. Maximum voltage shall be limited to charging device output limit. Continue charging until the charge device voltage is reached or the connection interface disconnects battery from charge device.	**4.5.2 Overcharge Test** DUT should be fully charged. Two overcharge tests for cells, one overcharge test for modules or packs. All active protective devices shall be disabled prior to this test. Cells charged at two rates – a) 1 C-Rate constant current and b) High-Rate overcharge at the maximum current (if unknown, 3C) that can be supplied by the regenerative braking or charging system (scaled to cell level if parallel) - until at least 200% SOC has been reached. Modules and Packs charged at 1 C-Rate constant current until at least 200% SOC has been reached.	**5.1. Overcharge / Overvoltage** Test on module level or higher. DUT at 100 % SOC is overcharged with a constant current of 32A and a voltage not to exceed 450V for BEV or the voltage that can be delivered by the HEV energy source. Continue charging till SOC is 200%, 4 hours or the DUT fails.	**6.2.12.2 Over-charge** Test is on cell level. Charge cell with a) 3C to 5V for 90min or b) with 9C to 10V. Test is on cell level. Charge system with a) 3C until one cells reaches 5V or for 90min or b) with 9C until one cell reaches 10V. **6.3.8.2 Over-charge** Test is on system level. Charge cell with a) 3C until voltage of one cell is 5V for 90min or b) with 9C until voltage of one cell is 10V. Test is on cell level. Charge system with a) 3C until one cells reaches 5V or for 90min or b) with 9C until one cell reaches 10V.	**25 Overcharge test** On full system or functional subassembly if applicable. Fully discharged DUT is to be charged with the maximum specified rate. A single fault condition in the overcharge protection circuit is to be made. Test is passed when overcharge is terminated by the protective circuitry remaining. Test is not passed when a catastrophic event occurs or the SOC is above 110%.	
Electrical: Forced discharge	**38.3.4.8 Test T.8: Forced discharge** For cells only. Each cell shall be forced discharged at ambient temperature by connecting it in series with a 12V D.C. power supply at an initial current equal to the maximum discharge current specified by the manufacturer.	**6.5.2 Test T-8: Forced discharge** Similar to UN 38.3. For cells only. Each cell shall be forced discharged at ambient temperature by connecting it in series with a 12V D.C. power supply at an initial current equal to the maximum discharge current specified by the manufacturer.	**7.3.7 Forced discharge (cells)** Similar to UN 38.3. For cells only. Each cell shall be forced discharged at ambient temperature by connecting it in series with a 12V D.C. power supply at an initial current equal to the maximum discharge current specified by the manufacturer.	**6.3.3 Forced discharge** For cells only. This standard says nothing about the number of cells that shall be tested. Discharge a fully discharged cell at 1C for 90 min. Test results shall include cell voltage and cell current during test, cell temperature during test, total extrenal resistance and the conditions of the cell after test.	**10.2 Overdischarge protection** For battery packs and battery systems only . The purpose is to check the functionality of the overdischarge protection device. The battery shall be discharged with the standard discharge. After that continue with a 1 C discharge until the overdischarge protection device activates. No leakage, rupture, fire or explosion and the isolation resistance shall be higher than 100 W/V for DC-systems and 500 W/V for AC-systems	**4.10 Single Point Over Discharge Protection System Failure** Discharge the battery system at a 1C rate for HEV/PHEV applications or at a C/3 rate for EV applications. Continue discharging until the connection interface disconnects battery from discharge load or battery voltage reaches 0.0 V ± 0.2 V.	**4.5.3 Overdischarge (Forced Discharge) Test** Passive integrated overdischarge protection shall remain operational. All active protective devices shall be disabled prior to this test. Voltage at end of forced discharge will be maintained for 30 min.Observe cell for 60 min. after completion of test. Optional test at module or pack level. Discharge a fully charged cell at maximum recommended continuous current for duration of 2 times the cell capacity in Ah. The voltage applied to the DUT shall not exceed max. recommended voltage of cell. For multi-cell series configuration in a Module, a completely discharged cell is to be force-discharged by connecting it in series with fully charged cells of the same kind. The module will be discharged at the maximum recommended current until the module voltage reaches 0.0 ± 0.2 volts.	**5.3. Overdischarge / Voltage Reversal** Test on module level or higher. DUT at 100% SOC, with cooling system available. Fully discharge at 1C rate for 90min or until 50% of all subunits have achieved voltage reversal for 15 min. Passive overcharge protection is allowed.	**6.2.12.1 Over-discharge** Test on cell level. Discharge fully charged cell with 1C down to 0V at 20°C ±5K. **6.3.8.1 Over-discharge** Test on system level. Discharge fully charged system until one cell reaches 0V at 20°C ±5K. If system has protection circuit disable for this test.	**27 Overdischarge protection test** On full system or functional subassembly if applicable. Fully discharged DUT is to be discharged until overdischarge protection is activated or the DUT has to be discharged for another 30min after reaching the specified normal discharge limits. There shall be no fire and explosion and no uncontrolled venting.	
Electrical: Electromagnetic Susceptibility						**4.2.5 Electromagnetic Susceptibility** Purpose: Simulates an electromagnetic environment which a battery system will likely experience during its life. Test procedure: SAE J2344, Paragraph 4.8					

Electrical: Protection against High Voltage Exposure						**4.13 Protection against High Voltage Exposure** Automatic Disconnects Purpose: This condition verifies that the battery system is electrically disconnected from the vehicle high voltage system when commanded to do so. Manual Disconnects Purpose: This condition verifies that the battery system can be safely handled in the event of automatic disconnect failure. Protection against Direct High Voltage Contact Purpose: This condition verifies that the battery system does not expose users to high voltage hazard. Test procedure: The battery enclosure as installed in the vehicle shall meet the requirements of ISO 6469-3, Section 7.6.				**30 Dielectric voltage withstand test** Test is on electrical circuits above 60V. Circuits are to be subjected to a dielectric withstand voltage of 1.413 times twice rated voltage for minimum of 1min. There shall be no evidence of a dielectric breakdown. **31 Isolation resistance test** Test is on system level. DUT shall be tested as in received condition, after conditioning and also fully charged. Applicable standards are ISO-6469-1 and IEC-60068-2-30.	
Electrical: Separator Shutdown Integrity							**4.5.4 Separator Shutdown Integrity Test** This test applies only to cells that have a shutdown separator. Heat the cell to at least 5 °C above the shutdown temperature. Shutdown temperature can be determined by passing 5 mA through the cell during heating with a maximum power supply voltage less than one volt greater than the cell voltage. Shutdown has been reached when the cell current drops and the voltage increased to this maximum level. Once this temperature has stabilized for 10 min, apply the high-level over voltage (at least 20 V) with a current limit of less than 1C. Maintain the applied voltage for a minimum of 30 min or until the separator fails.				
Electrical: imbalanced charging										**29 Imbalanced charging test** On full system or functional subassembly if applicable. All internal modules should be discharged fully, except one module which is to be discharged to around SOC 50%. Then the DUT is to be charged according to specifications. There should be no catastrophic event nor should the maximum values be exceeded.	
Environmental	**38.3.4.1 Altitude simulation** Test cells and batteries shall be stored at a pressure of 11.6 kPa or less for at least six hours at ambient temperature (20 ± 5 °C).	**6.4.1 Test T-1: Altitude** Similar to UN38.3 but UN. 38.3 says that the open circuit voltage of each test cell or battery after testing is not less than 90% of its voltage immediately prior to this test. IEC 62281 ed.2.2012 says that there shall be no short-circuit during the test. Different ways of verifying the same thing. Test cells and batteries shall be stored at a pressure of 11.6 kPa or less for at least six hours at ambient temperature (20 ± 5 °C)			**6.4 Exposure to fire** For battery packs and battery systems only. The purpose is to check the ability to prevent internal overheating and also a failure of thermal control or cooling function. The battery shall be placed in a temperature chamber and the battery shall be in operation connected to an electric load.. The temperature shall be increased until the battery reaches a temperature up to 20 K higer than the maximum operating temperature or until the protective device activates. Isolation resistance shall be higher than 100 W/V for DC-systems and 500 W/V for AC-systems	**4.2.4 Humidity / Moisture Exposure** Simulate a temperature / humidity environment Test procedure: The complete battery system is to be tested in accordance with IEC 60068-2-30 with a severety of 55ºC with 6 cycles, utilizing Variant 1 during the temperature lowering period. **4.7 Exposure to Simulated Vehicle Fire** Purpose: simulates exposure to a vehicle fire condition to verify that the battery system does not pose additional risk due to explosion. Test procedure: The complete battery system is to be subjected to a high temperature heat and flame environment until the battery system is fully resolved in the fire.				
Environmental: Water immersion					**6.3 Water immersion** For battery packs and battery systems only The purpose is to simulate water immersion which can occur when a vehicle is flooded. Very unclear how to perform this test but the standard point out short circuit as a threat especcily in salty water. The standard also mention the risk that electrolysis can produce hazardous (explosive) gases.	**6.4 Immersion Test** Purpose: This condition simulates a situation in which a vehicle is flooded Test procedure: The complete battery system is to be tested in accordance with SAE J2464, Section 4.3.5	**4.3.5 Immersion Test** (Module and Pack Level) At full state of charge, completely immerse the DUT in ambient temperature salt water (5% by weight NaCl in H2O) for a minimum of 2 h or until any visible reactions have stopped.	**3.4 Immersion** For cells or higher: EESS at nominal operating temperature in its normal operating orientation, immerse the EESS fully in salt water for 2 hours or until visible reactions have stopped. Observe for minimum of a four after test. The terminal voltage, pictures, resistance between terminals and casing before and after test. Measure T of the DUT during test.		**40 Salt spray test** On full system level. Fully charged DUT is to be subjected to a salt spray test according to IEC-60068-2-52. No catastrophic event shall occur and the isolation resistance should not drop. **41 Immersion test** On full system level. Fully charged DUT shall be fully immersed with several boundary conditions in 5% weight percent NaCl in H2O solution for 1h. There shall be no fire or explosion.	

Despite our care we do not claim to cover all standards and that all test topics have been given here. The organisations that categorised the available test standards cannot be kept responsible for your decisions.

The involved institutes of this survey are: