



Verizon NEBS™ Compliance: Valve Regulated Lead Acid (VRLA) Battery Qualification Test Requirements

Verizon Technical Purchasing Requirements
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CHANGE CONTROL RECORD:

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1	6/02/2008	New	
2	8/12/2014	Reissue	Updated to reflect lessons learned from implementing program with key suppliers to Verizon. Test requirements tagged, clarified, updated and re-numbered.
* New, Add, Delete, Change, Reissue			



Trademark Acknowledgement – NEBS is a trademark of Telcordia Technologies, Inc.

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*With much appreciated technical and business contributions, guidance and assistance from key Verizon users, suppliers and other industry stakeholders.



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1.0 PURPOSE

The purpose of this Verizon Technical Purchasing Requirement (TPR) document is to specify the qualification test requirements for Ground Fixed, VRLA Batteries and Battery Strings purchased by Verizon.

2.0 SCOPE

This TPR document specifies the Verizon Physical Design, Electrical, Chemical, Environmental, Electromagnetic, Safety, Quality and Reliability requirements for VRLA batteries purchased by Verizon. These batteries are for use in either Controlled (Central Office and CEV) or Uncontrolled (OSP and RT) environment applications.

The qualification test plan (punch-list) contained herein shall be used by suppliers and Verizon accepted Independent Test Laboratories as the minimum set of tests to be used for VRLA cell, battery and battery string qualification. Additional tests may be added as needed to properly exercise manufacturer-specific materials, technology and design.

3.0 REFERENCES

In all instances of test planning and test execution, the specified version of the referenced GR document shall be used. Where no version is specified, the most recent Verizon-accepted version of the referenced GR shall be used.

GR-63-CORE	NEBS™ Requirements: Physical Protection Issue 4, April 2012
GR-78-CORE	Generic Physical Design Requirements for Telecommunications Products and Equipment Issue 1, September 1997
GR-357-CORE	Generic Requirements for Assuring the Reliability of Components Used in Telecommunications Equipment Issue 1, March 2001.
GR-1089-CORE	Electromagnetic Compatibility and Electrical Safety, Generic Criteria for Network Telecommunications Equipment Issue 6, May 2011
GR-1209-CORE	Generic Requirements for Passive Optical Components, Issue 3, March 2001
GR-1221-CORE	Generic Reliability Assurance Requirements for Passive Optical Components, Issue 2, January 1999
VZ.TPR.9306	NEBS requirements for the Physical Design and Manufacture of Telecommunication Products and Equipment
SR-4228	Special Report VRLA Battery String Certification Levels Based on Requirements for Safety and Performance Issue 1, December 1996
IEC/MIL/etc.	Various reference test methods and procedures



4.0 ACRONYMS

VRLA	Valve Regulated Lead Acid
EOD	End of Discharge
ESD	Electro Static Discharge
EUT	Equipment Under Test
ITL	Independent Testing Laboratory
CO	Central Office
CEV	Controlled Environmental Vault
OSP	Outside Plant
RT	Remote Terminal

5.0 DEFINITIONS

Charging – The conversion of electrical energy, in the form of current from an external electrical source, into chemical energy.

Float Voltage – The continuous, long-term constant voltage of the telephone plant that should maintain the cells in a fully charged condition.

Coup De Fouet – The name given to the transient voltage response of the cell (or battery) when it is taken off float and used to supply the load current.

Cell Matching – A means of assuring the capability of a group of cells so that, when they are installed, they float properly together as a string.

Re-Charge Efficiency (ampere-hour efficiency) – Is the electrochemical efficiency expressed as a ratio of the ampere-hours output to the ampere-hours input required for a recharge.

Short Circuit – A zero impedance connection, internal or external, between the positive and negative terminals of a battery causing a zero voltage across the terminals and an infinite current flowing through the short. In practice, the current is limited by the battery's internal resistance and the resistance of the shorting connection.

C-Rate – The C-rate of a battery is the constant current rate at which the battery is charged or discharged to completely charge or discharge the battery. It is expressed in amperes. For instance, a C/8 rate indicates an 8-ampere rate of charge or discharge.

End of Discharge Voltage (EOD) – The average voltage to which the cells are discharged. Telecommunications service operates at voltages above 42 V. This translates to the average EOD voltage of 1.75 V/cell in a 24-cell string.

Service Life (of a cell) – The period of time from installation to when the ampere-hour capacity of the cell has fallen to 80% of its rated capacity.

Shelf Life – The time during which a fully charged battery can be stored in a controlled environment on open circuit and not require recharging.

Oxygen Recombination Efficiency – A measure of the amount of oxygen recombined at the negative terminal to form water.



Gassing – The production of hydrogen, oxygen and other gasses during charging and overcharging.

Grid Corrosion – Oxidation of the positive grid material to lead dioxide which decreases the cross sectional area of the grid and eventually leads to collapse of the plate.

Positive Plate Growth – Conversion of the lead in the positive grid material to lead dioxide. The lead dioxide occupies more space and is stronger than the lead from which the dioxide is formed. This causes expansion of the positive grid, loss of contact with the active material pellets and eventual cell failure due to low capacity.

Active Material – Dark brown or black lead dioxide formed at the positive plate of the battery. It is continuously electrolytically produced through anodic oxidation of the positive grids.

Thermal Runaway – This is the process of catastrophic cell destruction, while on charge or discharge. It is primarily caused by the exothermic chemical reaction at the cathode, the rate of which increases with temperature. A positive feedback mechanism of heat generation and temperature rise is thus established resulting in rapid internal heat generation that soon exceeds the dissipation capability of the case. This can result in battery case melting, fire or explosion.

6.0 GENERAL REQUIREMENTS

Verizon requires that manufacturers submit samples of their VRLA cells, batteries, battery strings and associated documentation as needed to a Verizon certified/accepted ITL for testing and verification of conformance to the qualification test requirements specified in this document. For a list of Verizon certified laboratories and locations, consult the Verizon web page at: <http://www.verizonnebs.com/tcppage.html>.

7.0 VRLA BATTERY QUALIFICATION REQUIREMENTS

Qualification Requirements for VRLA Cells, Batteries and Battery Strings are detailed in the ‘Qualification Test Schedule’ (Punch List) detailed in Table 7-1 below. This schedule is designed to not only provide the required qualification tests and declarations but to also provide the required format for reporting the measured/design values and summarizing their conformance to requirements. The requirements are based on several listed Telcordia documents, the primary one of which is SR-4228, as well as on Verizon specific requirements based on field experience. The supplier/laboratory completing the report need only populate column 5 with the measured or declared value for the test item together with a reference to the report or document (with number and date) where the full information is located. Column 6 is to be left blank for use by Verizon. In addition to populating column 5 with the measured or declared parametric value of each test item, the report shall also contain a section listing the manufacturer or sub-contractor used and the designated physical location where key processes from product design thru to product disposal are executed. Finally the report shall also include a tabular listing of the product description and the manufacturer’s part number of all items covered by the qualification activity.



Table 7-1: Qualification Test Requirements for VRLA Cells, Batteries and Battery Strings

Item Ref. #	Parameter/Test Item	Item Source Ref./ Test Procedure	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA Acceptable
SR-4228: Section 7 - Physical Design and Construction Criteria					
Material Level Criteria/Declarations*					
1.	General Physical Design Requirements	78: Sections 2 and 3 4228: Section 7 [67 through to 104]	As per SR-4228 Section 7		
2.	Outer case material	78: [695, 696] DS	Shall withstand 85°C minimum. (Materials like Polypropylene, and PPO/PS have proven satisfactory in long life applications)		
3.	Outer cover material	78: [695, 696] DS	Shall withstand 85°C minimum. (Materials like Polypropylene, and PPO/PS have proven satisfactory in long life applications)		
4.	Seam between case and cover	DS 4228: [73]	Shall be a permanent leak proof bond able to withstand internal pressures without damage for life of battery		
5.	Terminal post material	DS 4228: [76 through to 79 and 172]	Shall be Lead (Pb) with threaded brass inserts		
6.	Terminal post sealing gasket material	DS 4228: [76 through to 79 and 172]	Shall be RTV Silicone rubber and/or epoxy		



Item Ref. #	Parameter/Test Item	Item Source Ref./ Test Procedure	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA Acceptable
7.	Glass transition temperature T_G of outer case and cover material	1221: R4-24	Shall be $\geq 95^\circ\text{C}$		
8.	Heat distortion/melt index T_{HDT} of outer case and cover material	DS	Shall be $\geq 150^\circ\text{C}$		
9.	Terminal post sealing gasket material T_G	1221: R24	Shall be $\geq 95^\circ\text{C}$		
10.	Glass transition temperature T_G of label attach adhesive	1221: R4-24	Shall be $\geq 95^\circ\text{C}$		
11.	Toxicity	1209: R3-16	Shall be non-toxic to personnel under normal operation		
12.	Corrosion resistance	1209: R3-17	No significant external corrosion		
13.	Dissimilar metals	1209: R3-18	There shall be no contacting dissimilar metals that could promote galvanic corrosion		
14.	Flammability: -Outer case and cover housing -Terminal sealing gasket	4228: [67, 169] 78: R3-4 357: 4.4.2.5 [86] 326: R3-24/5 1209: R3-20/1	UL 94V-0 and OI >28%		
15.	Oxidative Induction Time (OIT) of case and cover materials, if thermoplastic	20: R6-31[135] ASTM D3895 ASTM D4565	20 minutes minimum after aging at 90°C for 14 days		
16.	Operating Attitude	DS 4228: [103]	Shall operate in any orientation in frames, racks or cabinets		



Item Ref. #	Parameter/Test Item	Item Source Ref./ Test Procedure	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA Acceptable
17.	Operating Altitude	4228: [58] 63: [74, 75, 76, 136, 137]	Cells shall not be damaged and shall remain operational from 60m below sea level to 3000m above sea level		
18.	Electrolyte	1. 4228: [33] 2. 4228: [34] 3. 4228: [34]	1. Shall be immobilized. 2. Shall be within plates and separators or between gel and plates 3. No residual free or bulk liquid @ 25°C		
19.	Safety Vent	4228: [80, 81, 82, 83, 84, 85, 173]	Flame-arresting one-way, self-sealing pressure relief valve		
Metrology and Visual Examination					
20.	Visual examination	DS	As per detail spec		
21.	Dimensions (outline)	DS	As per detail spec		
22.	Labels	78: R10-1	Labels shall remain Legible and Adherent for life of product (85°C/85% RH testing for 1000 hours is sufficient to demonstrate this)		
23.	Marking	78: R10-1 4228: [98, 99, 100, 170, 182]	Each battery or cell shall be permanently marked as per 4228 Sect. 7.11		
24.	Marking Permanence	78: R10-1	Markings shall remain legible after testing to Mil Std 883, Method 2015.11		



Item Ref. #	Parameter/Test Item	Item Source Ref./ Test Procedure	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA Acceptable
25.	Container	4228: [67 through to 72 and 168 through to 170]	Shall conform to 4228: Sect. 7.2		
26.	Cell Covers	4228: [73, 74, 74, 171]	Shall conform to 4228: Sect. 7.4		
27.	Terminal Posts	4228:[76 through to 79 and 172	Shall conform to 4228: Sect. 7.4		
28.	Flame Arresters	4228: [80, 81, 173]	Shall conform to 4228: Sect. 7.5		
29.	Plates	4228: [86, 87, 88, 178]	Shall conform to 4228: Sect. 7.7		
30.	Separators	4228: [89, 90, 179]	Shall conform to 4228: Sect. 7.8		
31.	Weight	4228: [91, 180]	Shall conform to 4228: Sect. 7.9		
32.	Accessories	4228: [92, 93, 94, 95, 96, 97, 181]	Shall conform to 4228: Sect. 7.10		
33.	Packaging	4228: [101, 102, 183]	Shall conform to 4228: Sect. 7.12		
34.	Mounting Arrangements	4228: [103, 184]	Shall conform to 4228: Sect. 7.13		
35.	Handling	4228: [104, 184]	Shall conform to 4228: Sect. 7.14		



Item Ref. #	Parameter/Test Item	Item Source Ref./ Test Procedure	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA Acceptable
Other Materials/Process Test Requirements					
36.	Resistance to solvents	357: 4.4.2.4 [85] Commonly used solvents include: Deionized water, Dilute Sulfuric Acid (1.225sg), Ethylene Glycol, WD-40, 10% IGEPAL, Isopropyl Alcohol, Wasp & Hornet Spray, Sodium bicarbonate solution.	No visible degradation of physical properties		
37.	Polymer Functional Groups of case material (FTIR Analysis)	DS	FTIR spectroscopic analysis (or other means) to verify material conformity to specification		
38.	Case Material Melt Flow/Melt Volume Index	DS	ASTM D1238; Verify conformity to specification		
39.	Case Material Density	DS	ASTM D6683; Verify conformity to specification		
40.	Case Material Chemical Resistance - Stress Cracking	771: [92] Chemicals as for item #36 above.	No evidence of cracking after chemical immersion		



Item Ref. #	Parameter/Test Item	Item Source Ref./ Test Procedure	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA Acceptable
41.	Case Material Chemical Resistance - Immersion	771: [94] Chemicals as for item #36 above.	< 10% weight change after chemical immersion		
42.	Case Material Chemical Resistance - Immersion	771: [95] Chemicals as for item #36 above.	< 20% tensile strength change after chemical immersion		
43.	Case Material Chemical Resistance - Immersion	771: [95] Chemicals as for item #36 above.	< 20% change in elongation after chemical immersion		
44.	Case Material Thermal Aging	78: [32, 695, 696] 771: 6.4.1	90°C for 30 days; 1. No visible deterioration, deformation, melting or cracking. 2. < 20% degradation in mechanical properties.		
45.	Case Material Fungus Resistance	326: R3-23 1209: R3-19	Materials used shall not support fungus growth. An ASTM G-21 rating of 0 is required.		
46.	Case Material Hardness	771: 5.5.3	Rockwell Hardness > R87 or equivalent		
SR-4228: Section 8 – Quality and Reliability Criteria					
47.	Quality and Reliability Criteria	4228: Section 8	As per SR-4228 Section 8		
48.	Fail Safe Operation of Cells	4228: Section 8.2	Cells must not fail 'open'		
49.	Battery String Reliability	4228: [106]	Short circuit failure of two (2) cells shall not cause a catastrophic event		



Item Ref. #	Parameter/Test Item	Item Source Ref./ Test Procedure	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA Acceptable
50.	Fail Safe Design	4228: [107]	Battery string failure must not cause a catastrophic event		
51.	Bonding and Grounding	1089: Section 9	Cell and battery bonding, grounding and interconnections, both internal and external, shall conform to the applicable requirements of Section 9 of GR-1089. Bonding process shall produce molecular bonds.		
SR-4228: Section 9 – Documentation and Training Criteria					
52.	Documentation and Training Criteria	4228: Section 9	As per SR-4228 Section 9		
SR-4228: Section 10 – Testing Criteria					
53.	Testing Criteria	4228: Section 10	As per SR-4228 Section 10		
54.	Sample Size	4228: [113]	Three (3) smallest replaceable units minimum per test		
55.	Accuracy of Measuring Instruments Used	4228: [116]	As per SR-4228 Table 10-1		
Operating Environments					
Controlled Environments (CO & CEV)					
56.	Ambient Operating Temperature Range	78: [694] 63: [72] 1209: Table 3-1	+5°C to +40°C		
57.	Ambient Operating Humidity Range	1209: Section 3.7 & Table 3-1	5% to 85% RH		
58.	Ambient Storage Temperature Range (non-operating)	1209: Section 3.7 & Table 3-1	-40°C to +85°C		



Item Ref. #	Parameter/Test Item	Item Source Ref./ Test Procedure	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA Acceptable
Un-Controlled Environments (OSP, RT & Cabinets without Fans)					
59.	Ambient Operating Temperature Range	78: [695] 1209: Section 3.7 & Table 3-1	-40°C to +65°C		
60.	Ambient Operating Humidity Range	1209: Section 3.7 & Table 3-1	5% to 85% RH		
61.	Ambient Storage Temperature Range (non-operating)	1209: Section 3.7 & Table 3-1	-40°C to +85°C		
SR-4228: Section 4 – Electrical Criteria					
62.	Electrical Criteria	4228: Section 4	As per SR-4228 Section 4		
63.	Charging	4228: [5]	1. Designed for continuous float operation 2. Shall be re-chargeable after discharge to 1.75V/cell		
Pre-Testing: Initial Capacity Verification of all Test Modules at 25 °C					
64.	Charge	4228: [114]	Each Module. 7 days @ Float voltage		
65.	Discharge	4228: [117]	Each Module. Eight-hour rate to 1.75 V/cell		
66.	Initial Capacity Verification	4228: [114]	90% minimum rated capacity @ 25°C		



Item Ref. #	Parameter/Test Item	Item Source Ref./ Test Procedure	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA Acceptable
Single Module Electrical Tests and Criteria					
67.	Module Capacity Test	4228: [1, 2, 3, 4, 114, 117]	Discharge at C/8 rate to 1.75V/cell. Shall achieve 95% minimum of rated capacity		
68.	Recharge Efficiency Test	4228: [14, 129, 130]	Discharge at C/8 rate to 1.75V/cell. Recharge to 101%. Discharge @ C/8 to 1.75V/cell and recharge at float for 7 days; Shall achieve 90% minimum recharge efficiency		
69.	Coup De Fouet Voltage Test	4228: [8, 124, 125]	Discharge @ C/5. Recharge at C/8 rate for 7 days; Analyze discharge data. C de F @ C/5 rate shall be > 1.89 V/cell for new, 1-year old and 3-year old batteries.		
70.	One-minute External Short Circuit Test	4228: [15, 131, 132, 133, 134, 135, 136, 137]	Duration of Short = 1 minute; Discharge @ C/8 rate to 1.75 V/cell; Remaining capacity shall be > 90% of initial value		
71.	Zero Volt External Short Circuit Test	4228: [15, 131, 132, 133, 134, 138, 139]	Duration of Short = 24 hours; There shall be no fire or explosion		
72.	Charge/Discharge Cycling Test	4228: [17, 140, 141, 142]	Discharge to 1.75 V/cell @ 3, 5 and 8-hour rates; recharge for 24 hours after each discharge; Number of cycles > 10 or # of years warranted. Remaining capacity = 80% rated		



Item Ref. #	Parameter/Test Item	Item Source Ref./ Test Procedure	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA Acceptable
73.	Shelf Life and Charge Retention of Module Test	4228: [29, 31, 32, 146,]	Fully charge module. Store on open circuit at 25°C. Shelf life = 183 days minimum. After 183 days capacity @ C/8 rate > 50% and > 90% after 1 week recharge		
Full String Electrical Behavior Tests and Criteria					
74.	Float Voltage Test	4228: [7, 123]	Float Charge for 7 days. Voltage of smallest accessible group of cells shall be < 0.05 V of average volts/cell x number of cells in group		
75.	Capacity Matching of Modules in String Test	4228: [5, 9, 12, 13, 126, 128]	Capacity of all modules in string shall be > 90% rated capacity.		
76.	Voltage Matching of Modules in String Test	4228: [7, 10, 123, 127]	Difference between highest and lowest float voltage in string shall be ≤ 0.10 V and average cell voltage shall be within specified float voltage		
77.	End of Discharge Voltage of String Test	4228: [22, 23, 24, 144]	Discharge to 1.75 V/cell @ C/8-hour rate; recharge for 24 hours at limiting current = value used for C/8 discharge; All cells and modules shall reach 90% capacity in 24 hours; cell voltage range < 0.30 V; lowest cell < 0.25 V below average; weakest cell 1.5 V; no cell reversal.		



Item Ref. #	Parameter/Test Item	Item Source Ref./ Test Procedure	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA Acceptable
Service Life Test and Criteria					
78.	Accelerated Life Test <u>Activation Energy</u> GR value: E _A = 0.63eV; Default value: E _A = 0.85eV	4228: [25, 26, 27, 28, 145]	Age at 70°C and 20% RH in 28 day increments. Charge at float voltage specified for 25°C. Measure battery capacity @ 25°C 1. Life Requirement = 10 years min. @ 25°C and 2. Life Objective = 20 years min. @ 25°C.		
Pressure Relief Valve Tests and Criteria					
79.	Relief Valve Opening and Closing Test	4228: [82, 83, 84, 174, 175]	1. Opening pressure shall be ≥ 2.0psi and 2. Closing pressure shall be ≥ 1.5psi		
80.	Relief Valve Sealing Against Atmospheric Oxygen Test	4228: [83, 174, 175, 176, 177]	1. Valve shall seal in the closed position 2. Negative sealing pressure tests shall incur no damage		
SR-4228: Section 5 – Chemical Tests and Criteria					
81.	Electrolyte Leak Test	4228: [33, 34, 147]	1. 1/4 inch opening at bottom corner; 45° tilt from horizontal; 2. 1/4 inch opening in cover. 3. There shall be no loss of electrolyte in either case after 72 hours.		
82.	Specific Gravity/Open Circuit Voltage Tests	4228: [35, 36, 148]	SG before electrolyte immobilization. Verified by open circuit voltage measurement after 24 hours minimum.		



Item Ref. #	Parameter/Test Item	Item Source Ref./ Test Procedure	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA Acceptable
83.	Oxygen Recombination Efficiency	4228: [37, 149]	Recombination efficiency shall be: > 99% C/10000 to C/1000 > 95% C/1000 to C/100 > 85% C/100 to C/10 and > 75% C/10 to C/4		
84.	Gassing	4228: [38, 39, 40, 41, 150]	1. Hydrogen release shall be < 200 ppm/cell 2. Gassing rates between 25°C and 65°C shall be provided. 3. Data shall include effect of 1 thru 5 shorted cells per string. 4. Hydrogen evolution shall be: > 5% C/10000 to C/1000 > 8% C/1000 to C/100 > 17% C/100 to C/10 and > 26% C/10 to C/4		
85.	Grid Corrosion	4228: [42, 43, 151]	Average reduction of grid wire cross section at end of 70°C life test from 'as cast' value shall be: 1. ≤ 0.05 mm per year. 2. Not cause premature failure		



Item Ref. #	Parameter/Test Item	Item Source Ref./ Test Procedure	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA Acceptable
86.	Positive Plate Growth	4228: [44, 152]	Disassemble, measure, and inspect the horizontal and vertical growth of grid plates from samples after 70°C life test. Average plate growth shall be: 1. $\leq 8\%$ of area of each plate ($\leq 4\%$ per direction) 2. Cell shall not crack 3. Cell shall not fail catastrophically		
87.	Active Material Flaking	4228: [45, 153]	Disassemble and inspect cells after 70°C life test. There shall be no evidence of potential shorting from flaking of active material		
88.	Operating Internal Cell Pressure	4228: [46]	Measure internal cell pressure under normal operating conditions. Pressure shall: 1. Be sufficient for $\geq 99\%$ recombination efficiency. 2. Shall not crack case or cause excessive deformation.		
89.	Pressure Withstand	4228: [154, 168, 171]	Cells shall withstand 125% of the highest manufacturer specified pressure for 10 minutes		



Item Ref. #	Parameter/Test Item	Item Source Ref./ Test Procedure	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA Acceptable
90.	Dry-Out and Water Loss	4228: [47, 155]	Measure average weight loss during accelerated life testing at 70°C and calculate: 1. SG Increase and 2. OCV per cell Compare to specified float voltage to verify water loss rate is in range for expected cell lifetime.		
91.	Thermal Runaway of Cells and Modules	4228: [6, 48, 49, 51, 156, 158]	1. Generate Tafel Curve for each module at 25°C over manufacturer recommended float voltage range. 2. Select modules that are fully recombinant, i.e., have Tafel slopes below 90 mV/decade/cell 3. Monitor module voltage, module current temperature of cells and ambient air 4. Apply linearly increasing float voltage at rate of 0.04 mV/minute/cell 5. Determine onset of thermal runaway (T _{cell} -T _{amb} > 15°C) at 25°C, at -40°C and at +65°C		



Item Ref. #	Parameter/Test Item	Item Source Ref./ Test Procedure	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA Acceptable
92.	Thermal Runaway of String	4228: [6, 48, 49, 50, 157]	1. Generate Tafel Curve for each module in string at 25°C over manufacturer recommended float voltage range. 2. Select modules that are fully recombinant, i.e., have Tafel slopes below 90 mV/decade/cell 3. Monitor string voltage, string current temperature of four center cells and ambient air 4. Apply linearly increasing float voltage at rate of 0.04 mV/minute/cell 5. Determine onset of thermal runaway (T _{cell} -T _{amb} > 15°C) at 25°C, at -40°C and at +65°C		
SR-4228: Section 6 – Environmental Tests and Criteria					
93.	Mechanical Shock (Drop Test) – (Packaged and Un-Packaged)	63: [107, 108, 109] 4882: [60]	Cells and/or Batteries shall not be damaged and shall remain operational		
94.	Mechanical Vibration - Office (Unpackaged)	63: [122, 123, 124] 4882: [61]	Cells and/or Batteries shall not be damaged and shall remain operational		
95.	Mechanical Vibration – Transportation (Packaged)	63: [122, 123, 124] 4882: [61]	Cells and/or Batteries shall not be damaged and shall remain operational		
96.	Earthquake Resistance	63: [114, 5.4.1] 4882: [64]	Cells and/or Batteries shall not be damaged and shall remain operational at Zone 4 severity level.		



Item Ref. #	Parameter/Test Item	Item Source Ref./ Test Procedure	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA Acceptable
97.	Low Temperature Exposure and Thermal Shock	63: [5.1.1.1] 4228: [62]	Cells and/or Batteries shall remain operational and floatable -40°C to +25°C		
98.	High Relative Humidity Exposure	63: [5.1.1.2] 4228: [63]	Cells and/or Batteries shall remain operational and floatable from 10% to 95% RH		
99.	High Temperature Exposure and Thermal Shock	63: [5.1.1.3] 4228: [62]	Cells and/or Batteries shall remain operational and floatable +25°C to +70°C		
100.	Airborne Contaminants	4228: [65] 63: [127, 185]	Cells and/or Batteries shall remain operational for the intended service life		
101.	Electrostatic Discharge	78: [721, 722, 723] 1089: [3, 4] 4228: [66, 167]	<ol style="list-style-type: none"> 1. Charge for 24 hours 2. While on charge, apply 15 kV on each side, four upper corners and each terminal 3. Repeat ESD application after battery is disconnected from charger 4. Recharge battery @ C/8 for 7 days 5. Discharge battery @ 8-hour rate to 1.75V/cell and recharge with C/8 current for 7 days. <p>All cells shall remain operational</p>		



Item Ref. #	Parameter/Test Item	Item Source Ref./ Test Procedure	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA Acceptable
102.	Cell element and separator stability after Zone 4 Earthquake Testing	63: [110]	Disassemble and evaluate cell element and separator for structural stability after exposure to Zone 4 seismic waveform testing.		
<i>End-of-Life Processing, Recycling and Disposal/Environmental, Health and Safety (EH&S) Practices</i>					
103.			1. Has your company responded to the Verizon inquiry on Commitment to Environmental Stewardship? 2. Does your company publicly report on its EH&S Policies, Practices and Results? 3. Which of your manufacturing locations is certified under the Better Environmental Sustainability Target (BEST) standard?		
<i>Additional Manufacturer-Specific Tests Performed</i>					
104.	Add as available				
105.	Add as available				
106.	Add as available				

*Conformance to the tests listed at the Material Level of Table 7-1 above may be declared by the manufacturer based on manufacturer internal and/or supplier provided data.

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