Verizon NEBS™ Compliance: Qualification Requirements for Sodium-Metal-Halide Cells, Cell Strings and Batteries

Verizon Technical Purchasing Requirements
VZ.TPR.9807
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CHANGE CONTROL RECORD:

Version	Date	Action*	Reason for Revision
Draft	*03/01/2014*	New	
1	*09/01/2014*	Reissue	Updated to reflect lessons learned from implementing program with key Verizon suppliers and their subcontractors. 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 (VZTPR) document is to specify the qualification test requirements for Ground Fixed, generic Sodium-Metal-Halide Batteries that may be purchased by Verizon.

2.0 SCOPE

This VZTPR document specifies the Verizon Material, Physical Design, Electrical, Chemical, Environmental, Electromagnetic, Safety, Quality and Reliability requirements for generic Sodium-Metal-Halide batteries (including other electrode specific material compositions for Metals like Nickel, Lithium, etc. and Halides like Bromide or Fluoride) that may be purchased by Verizon. These batteries are for use in either Controlled (Central Office and CEV) or Uncontrolled (protected OSP and RT) environment applications.

The schedule of tests contained herein shall be used by suppliers and Verizon accepted Independent Test Laboratories as the minimum set of tests for Sodium-Metal-Halide batteries and associated cells and cell string qualification. Additional manufacturer-specific tests may be added as needed to properly exercise the materials, technology, design and manufacturing processes used by the manufacturer for its specific battery technology.

3.0 REFERENCES

In all cases 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 3, March 2006
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 4, June 2006
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
GR-3020-CORE	Nickel Cadmium Batteries in the Outside Plant, Issue 1, April 2000
VZ.TPR.9306	NEBS requirements for the Physical Design and Manufacture of Telecommunication Products and Equipment
IEC/MIL/etc.	Various reference test methods and procedures

4.0 ACRONYMS

Na-Ni-Cl	Sodium-Nickel-Chloride
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

Na-Ni-Cl – Cell/Battery using Sodium-Nickel-Chloride technology
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 a lead acid cell (or battery) when it is taken off float and used to supply a load current – included for completeness.
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 2.58 V/cell in a 20-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 – Corrosion 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 forming 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 QUALIFICATION TESTS AND REQUIREMENTS FOR Na-M-H BATTERIES

6.1 General

Qualification tests and requirements for Sodium-Metal-Halide batteries purchased by Verizon are detailed in Table 7-1 below. The tests and requirements in the table supplement and include the standard NEBS requirements from GR-63, GR-78 and GR-1089.

The tests specified in the table are not exhaustive. They represent a reasonable set of known state-of-the art tests and procedures that, in Verizon's view, would help assure that Sodium-Metal-Halide batteries purchased by Verizon will meet the safety, service life and reliability requirements in Verizon applications. Additionally, but not in lieu of the requirements specified herein, battery manufacturers may include in the test report the results of any other manufacturer-specific tests they consider applicable to and necessary for properly exercising the materials, technology, design and manufacturing processes used for their specific batteries. These manufacturer-specific tests and test results will supplement information in the *Sodium-Metal-Halide Battery Test Conformance Report (TCR)* provided to Verizon as a module of the NEBS testing and reporting program.

6.2 Execution of Qualification Tests

Verizon requires that manufacturers submit samples of their Na-M-H cells, batteries, strings and associated documentation to a Verizon-Certified Independent Test Laboratory (ITL) and/or other Verizon accepted laboratory as appropriate to conduct qualification testing and verification of conformance to the qualification test requirements specified in this document. To view an up-to-date listing of Verizon-Certified ITLs, along with lab locations and scope of approvals, log on to the Verizon webpage at: http://www.verizonnebs.com/tcppage.html

Conformance to the tests listed at the cell and cell string levels of these tables may be declared by the manufacturer based on the manufacturer's own internal test data, its supplier-provided test data or its subcontractor-provided test data. However, all tests in the tables at the battery and

battery string level shall be executed by the manufacturer selected, Verizon-Certified ITL and/or other Verizon accepted laboratory.

6.3 Reporting of Qualification Results

Table 7-1 is designed to not only provide the required tests and declarations but to also provide the required format for reporting the design/measured values and summarizing their conformance to requirements.

Reporting of the test results shall be done by the ITL and/or the equipment manufacturer as appropriate. The equipment manufacturer shall provide the *Sodium-Nickel-Chloride Battery Test Conformance Report* to Verizon as part of the NEBS testing and reporting program.

6.4 Test References

The test references cited in Table 7-1 are intended to outline the general test methods and procedures to be used to evaluate the applicable requirement. The test conditions specified in this Table shall be used, and where applicable, shall override those specified in the cited reference. Other test methods (IEC, IEEE, Joint Electron Device Engineering Council [JEDEC], etc.) may be acceptable alternatives to the cited references. However, the use of alternative test methods, procedures, sampling plans, etc. will require demonstration that the proposed procedure is equivalent to or is better (from a user's viewpoint) than the specified procedure.

6.5 Sample Size and Accept Criteria

6.5.1 Cell Level

At the material, component, and cell level, the sample size and accept criteria used shall be as appropriate for the specified test.

6.5.2 Battery Level

At the battery (cell string) level, the number of battery samples used shall be selected to ensure a minimum of three (3) smallest replaceable DUTs are used. Parallel or sequential testing may be used to maximize test coverage and to optimize use of test samples. Where sequential testing is used, precautions shall be observed to ensure no destructive tests are done within the test sequence.

7.0 Na-M-H BATTERY QUALIFICATION REQUIREMENTS

Qualification Requirements for Na-M-H materials, Cells, Cell Strings, and Batteries are listed in the 'Qualification Test Schedule' detailed in Table 7-1 below. This schedule is designed to not only provide the Verizon required qualification tests and declarations but to also provide the required format for reporting the measured/declared values and summarizing their conformance to the requirements. The requirements are based on several listed Telcordia GR documents, 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 shall 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 Requirements for Na-M-H Cells, Materials and Strings

Item Ref. #	Parameter/Test Item	Item Source Ref. GR/SR/DS etc.	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA/ Acceptable
GR-3020: Section 5 – Physical Design and Construction Requirements					
Material Level Design and Construction Criteria/Declarations*					
1	General Physical Design Requirements	78: Sections 2 and 3 All GR-3020 Section 5 Physical Design Requirements	As per the Physical Design Requirements of GR-3020 Sections 5		
2	Outer cell case material	GR-78: [695], [696] DS	Shall withstand 85°C minimum. (Materials like Metals, Polypropylene, and PPO+PS have proven satisfactory in long life applications)		
3	Outer cell cover material	GR-78: [695], [696] DS	Shall withstand 85°C minimum. (Materials like Metals, Polypropylene, and PPO/PS have proven satisfactory in long life applications)		
4	Seam between Cell Case and Cell top	GR-3020: [49]	Shall be a permanent, leak-proof bond able to withstand the internal pressures developed without damage for life of battery.		
5	Cell Terminal Post and Insert Material	GR-3020: [53]	All post and insert contacts shall be nickel plated or otherwise treated to avoid corrosion.		
6	Cell and Battery Terminal Post sealing Gasket Material	GR-3020: [50]	Terminal posts shall be sealed to prevent electrolyte leakage and/or gas release.		

Item Ref. #	Parameter/Test Item	Item Source Ref. GR/SR/DS etc.	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA/ Acceptable
7	Battery Management System (BMS) Terminal Post type and material	GR-3020: [50]	BMS terminal post shall be of hard drawn copper or nickel plated brass material with a two hole electrical connection and shall not rotate		
8	Glass transition temperature Tg 1. Outer case and cover material 2. BMS enclosure	GR-1221: R4-24	Shall be > 95°C		
9	Outer case and cover material heat distortion/ melt index THDT	DS	Shall be ≥ 150 °C		
10	Terminal sealing gasket material Tg	GR-1221: R4-24	Shall be ≥ 95 °C		
11	Label Attach Adhesive Tg	GR-1221: R4-24	Shall be ≥ 95 °C		
12	Toxicity	GR-1209: R3-16	Shall be non-toxic to personnel under normal operation		
13	Corrosion resistance	GR-1209: R3-17, R3-18	No significant external corrosion		
14	Dissimilar metals	GR-1209: R3-18 [18]	There shall be no contacting dissimilar metals that could promote galvanic corrosion		
15	Flammability: -Outer case and cover housing -Terminal sealing gasket - BMS enclosure	GR-3020: [39], [114] GR-63: [90], [91], [92], [92], [96]	UL 94V-0 Or UL 94V-1 and OI ≥ 28%		
16	Oxidative Induction Time (OIT) of all Thermoplastic Polymer materials used	20: R6-31[135] ASTM D3895 ASTM D4565	20 minutes minimum after aging at 90°C for 14 days		
17	Operating Attitude	GR-3020: [72]	Cells shall operate in an upright orientation in frames, racks or cabinets		

Item Ref. #	Parameter/Test Item	Item Source Ref. GR/SR/DS etc.	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA/ Acceptable
18	Operating Altitude	GR-3020: [31] GR-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		
19	Electrolyte	GR-3020: Section 3.1	An alkaline (not acidic) electrolyte is to be used		
20	Safety Vent	GR-3020: [22], [54], [55], [56]	1. Flame-arresting one-way, self sealing, safety vent shall be provided 2. Safety vent shall facilitate water addition		
Metrology and Visual Examination (including physical design criteria)					
21	Visual examination	GR-3020: [62], [63], [64], [66], [67]	As per detail specification		
22	Dimensions (outline)	GR-3020: [62], [63], [64], [66], [67]	As per detail specification		
23	Labels	GR-78: R10-1 [747] GR-3020: [68], [128]	Labels shall remain legible and adherent for life of product. (85°C/85% RH testing for 1000 hours is sufficient to demonstrate this)		
24	Marking	GR-78: R10-1 [747] GR-3020: [68], [69], [70], [128]	Each battery or cell shall be permanently marked		
25	Marking Permanence	GR-78: R10-1 [747]	Markings shall remain legible after testing to Mil Std 883, Method 2015.11		
26	Container/Cradle	GR-3020: [39], [40], [41], [42], [43], [44], [45], [46]	Container/Cradle shall conform to requirements of GR-3020 Section 5.1		
27	Cell Covers	GR-3020: [47], [48], [49]	Cell and Module covers shall conform to requirements of GR-3020 Section 5.2		
28	Terminal Posts	GR-3020: [50], [51], [52], [53]	Terminal Posts shall conform to GR-3020 Section 5.3		
29	Flame Arresters and Vent Caps	GR-3020: [54], [55]	Flame Arrestors shall Conform to GR-3020 Section 5.4 and 5.5		
30	Plates	GR-3020: [57], [58]	Plates shall conform to GR-3020 Section 5.6		

Item Ref. #	Parameter/Test Item	Item Source Ref. GR/SR/DS etc.	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA/ Acceptable
31	Separators	GR-3020: [59], [60]	Separators shall conform to GR-3020 Section 5.7		
32	Battery Weight	GR-3020: [61]	Battery weight shall conforms to GR-3020 Section 5.8		
33	Accessories	GR-3020: [62], [63], [64], [65], [66], [67]	Accessories shall conform to GR-3020 Section 5.9		
34	Packaging	GR-3020: [71]	Packaging shall conform to GR-3020 Section 5.11		
35	Mounting Arrangements	GR-3020: [72]	Mounting shall conform to GR-3020 Section 5.12		
36	Handling	GR-3020: Section 4.3	Handling shall conform to GR-3020 Section 4.3		
Other Materials/Process Test Requirements					
37	Resistance to solvents	GR-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, and Wasp & Hornet Spray.	No visible degradation of physical properties on exposure to solvents commonly present in telecommunication buildings.		
38	BMS case material Polymer Functional Groups (FT-IR) Analysis	DS	FT-IR spectroscopic analysis to verify polymer material conformity with specification		
39	BMS Material Melt Flow/ Melt Volume Index	DS	ASTM D1238; Verify conformity to specification		
40	BMS Material Density	DS	ASTM D6683; Verify conformity to specification		
41	BMS Material Chemical Resistance-Stress Cracking	GR-771: [92] Chemicals as for item #37 above.	The material used for BMS case shall show no evidence of cracking after chemical immersion		
42	BMS Material Chemical Resistance-Immersion	GR-771: [94] Chemicals as for item #37 above.	< 10% in weight change after chemical immersion		

Item Ref. #	Parameter/Test Item	Item Source Ref. GR/SR/DS etc.	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA/ Acceptable
43	BMS Material Tensile Strength	GR-771: [95] Chemicals as for item #37 above.	< 20% change after chemical immersion		
44	BMS Material Elongation	GR-771: [95] Chemicals as for item #37 above.	< 20% change after chemical immersion		
45	BMS Case Material Thermal Aging	GR-78: [32], [695], [696] GR-771: R5-11 [85]	90°C for 30 days; 1. No visible deterioration, deformation, melting or cracking. 2. < 20% degradation in mechanical properties.		
46	BMS Case Material Fungus Resistance	GR-326: R3-6 [6] GR1209: R3-19 [19]	Materials used shall not support fungus growth. An ASTM G-21 rating of 0 is required.		
47	BMS Case Material UV Resistance – 90 days	GR-487: R3-40 [19] GR-771: R5-22 [96]	Materials used shall be resistant to 90 days UV exposure		
48	BMS Case Material Hardness	GR-771: 5.5.3(5.6.2)	Rockwell Hardness > R87 or equivalent		
GR-3020: Section 6 – Quality and Reliability Requirements					
49	Quality and Reliability Criteria	As per GR-3020 Section 6	Batteries shall conform to design and manufacturing requirements of GR-3020 Section 6		
50	Fail Safe Operation of Cells	GR-3020: [73]	Cells must not fail 'open'		
51	Cell String Reliability	GR-3020: [74]	Short circuit failure of three (3) cells shall not cause a catastrophic event		
52	Fail Safe Design	GR-3020: [75]	Cell string failure must not cause a catastrophic event		
53	Bonding and Grounding	GR-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. The bonding process used shall produce molecular bonds.		
54	Grounding Provisions	GR-1089: Section 9	The battery (EUT) shall provide a means of grounding		

Item Ref. #	Parameter/Test Item	Item Source Ref. GR/SR/DS etc.	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA/ Acceptable
55	EMC Emissions and Immunity	This document	RFI/EMI emissions and immunity shall conform to the applicable requirements of Section 3 of GR-1089.		
GR-3020: Section 7 – Documentation Requirements					
56	Documentation and Training Criteria	As per GR-3020 Section 7	Documentation and Training criteria shall conform to GR-3020 Section 7		
57	Testing Criteria	GR-3020: Section 9	Testing criteria shall conform to GR-3020 Section 9		
58	Sample Size	GR-3020: [84]	Three (3) smallest replaceable units minimum per test		
59	Accuracy of Measuring Instruments Used	GR-3020: [88]	Accuracy of Measuring Instruments Used shall conform to GR-3020 table 9-1		
Operating Environments					
Controlled Environments (CO & CEV)					
60	Ambient Operating Temperature Range	GR-78: [694] GR-63: [72] GR-1209: Table 3-1(3.7) GR-3020: [34]	Batteries shall be capable of operating from +5°C to +40°C		
61	Ambient Operating Humidity Range	GR-1209: Section 3.7 & Table 3-1 GR-3020: [30] GR-63: [72]	Batteries shall be capable of operating from 5% to 85% RH		
62	Ambient Storage Temperature Range	GR-1209: Section 3.7 & Table 3-1 GR-3020: [34]	Batteries shall be capable of being stored from -40°C to +70°C		
Un-Controlled Environments (OSP, RT & Cabinets without Fans)					
63	Ambient Operating Temperature Range	GR-78: [695] GR-63: [72] GR-1209: Table 3-1 GR-3020: [34]	Batteries shall be capable of operating from -40°C to +65°C		

Item Ref. #	Parameter/Test Item	Item Source Ref. GR/SR/DS etc.	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA/ Acceptable
64	Ambient Operating Humidity Range	GR-1209: Section 3.7 & Table 3-1 GR-3020: [30] GR-63: [72]	Batteries shall be capable of operating from 5% to 85% RH		
65	Ambient Storage Temperature Range	1209: Section 3.7 & Table 3-1 GR-3020: [34]	Batteries shall be capable of being stored from -40°C to +70°C		
GR-3020: Section 2 – Electrical Requirements					
66	Electrical Criteria	As per GR-3020 section 2	Electrical criteria shall conform to GR-3020 section 2, i.e.: - Capacity - Charging - Float Voltage etc.		
67	Charging	GR-3020: [6]	Batteries shall be: 1. Designed for continuous float operation 2. Re-chargeable after discharge to 2.58 V/cell		
Pre-Testing: Initial Capacity Verification of all Test Modules at 25 °C					
68	Charge	GR-3020: [94]	Charge of each module shall conform to GR-3020 section 2.2 for 24 hours @ Float voltage		
69	Discharge	GR-3020: [89]	Discharge of each Module shall conform to GR-3020 Section 2. Eight-hour rate to 2.24 V/cell		
70	Initial Capacity Verification	GR-3020: [4]	90% minimum of rated capacity @ 25°C		
Single Module Electrical Tests and Criteria					
71	Module Capacity Test	GR-3020: [1], [2], [3], [4], [89], [90] [91], [92]	Shall conform to GR-3020 Section 2. Discharge at C/8 rate. Shall achieve 90% minimum of rated capacity.		
72	Recharge Efficiency Test	GR-3020: [9], [96], [97]	Shall conform to GR-3020 Section 2. Charge at float for 24 hours, Discharge at C/8 rate (C1). Recharge to 101%. Discharge @ C/8 (C2); A minimum recharge efficiency of C2/C1 x 100 = 90% shall be achieved		

Item Ref. #	Parameter/Test Item	Item Source Ref. GR/SR/DS etc.	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA/ Acceptable
73	One-minute External Short Circuit Test	GR-3020: [10], [11], [98], [99], [100], [101], [102]	Short circuit duration = 1 minute; Discharge @ C/8 rate to 2.24 V/cell; Remaining Capacity shall be > 90% of initial value.		
74	Zero Volt External Short Circuit Test	GR-3020: [10], [11], [98], [99], [100], [101], [102]	Short circuit duration = 24 hours; There shall be no fire or explosion		
75	Charge/Discharge Cycling Test	GR-3020: [12], [103], [104]	Discharge to 2.24 V/cell @ 3, 5 and 8-hour rates; recharge for 24 hours after each discharge; Number of cycles > 3x per year for the number of years (20 years) of operating life. Remaining capacity > 80% of rated capacity		
76	Shelf Life and Module Charge Retention Test	GR-3020: [18], [19], [20], [21], [106], [107], [108]	Discharged module: Store on open circuit at 25°C. Shelf life = 1 year minimum. Fully charged module: After 183 days capacity @ C/8 rate > 50% and > 90% after 24 hours recharge.		
Full String(48-Volts) Electrical Tests and Criteria					
77	Float Voltage Test	GR-3020: [8], [95]	Float Charge for 7 days. Voltage of smallest accessible group of cells shall be less than or equal to +0.050 V and greater than or equal to -0.100 V of average volts/cell x number of cells in group		
78	Capacity Matching of Cells in String	This document	Cells in a string shall be capacity matched such that all cells in a string have a minimum capacity of 90% of their rated capacity. The difference between the lowest and the highest cell capacities in the string shall not exceed 8% of rated capacity.		

Item Ref. #	Parameter/Test Item	Item Source Ref. GR/SR/DS etc.	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA/ Acceptable
79	Voltage Matching of Cells in String	This document	Cells in a string shall be matched such that the difference between the highest and the lowest cell float voltage shall not exceed 0.10 volts and the average float voltage for each cell shall be within the manufacturers specified float voltage		
80	End of Discharge Voltage of Cell String Test	This document	The string shall be capable of being discharged to 2.10V/cell. The EOD voltage for the string shall not be lower than this cell voltage value when discharged at the four hour rate (C4). After discharge to this EOD voltage all cells in the string shall be capable of being recharged to at least 90% of their rated capacity at the recommended float voltage in a time period not to exceed 24 hours.		
Service Life Test and Criteria					
81	Accelerated Life Test Activation Energy GR value: $E_A = 0.63eV$; Default value: $E_A = 0.85eV$	This document and GR-3020: [15], [16], [17], Section 9.2.8	Life Requirement = 20 years min. @ 25°C.		
82	BMS and Battery Failure Rate	This document	The calculated failure rate shall be less than: 1. 500 FITS for BMS and 2. 2000 FITS for Battery Estimates shall be based on the parts count method of SR-332 using field observed failure values for components used. State source of FIT rates used.		

Item Ref. #	Parameter/Test Item	Item Source Ref. GR/SR/DS etc.	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA/ Acceptable
Pressure Relief Valve Tests and Criteria					
83	Relief Valve Opening and Closing Test	GR-3020: [54], [55], [56]	1. Opening Pressure shall be ≥ 1.0 psi 2. Closing Pressure shall be ≥ 0.0 psi		
84	Relief Valve Sealing Against Atmospheric Oxygen Test	GR-3020: [54], [55], [56]	1. Valve shall seal in the closed position 2. Negative(sealing) pressure tests shall incur no damage		
SR-4228: Section 5 and GR-3020 Section 3 – Chemical Tests and Criteria					
85	Electrolyte Leak Test	4228: [33, 34, 147]	1. ¼ inch opening at bottom corner; 45° tilt from horizontal; 72 hrs. 2. ¼ inch opening at top; 3. No loss of electrolyte in either case		
86	Specific Gravity/Open Circuit Voltage Tests	4228: [35, 36, 148]	SG before electrolyte immobilization. Verified by open circuit voltage measurement after 24 hours minimum.		
87	Oxygen Recombination Efficiency	4228: [37, 149]	Recombination efficiency shall be: > 99% C/10000 to C/1000 > 95% C/1000 to9 C/100 > 85% C/100 to C/10 > 75% C/10 to C/4		
88	Gassing	GR-3020: [22], [109]	1. Total gassing rate and the rate of hydrogen release shall be reported for 25°C 35°C and 45°C and at 1.40, 1.45, 1.50, 1.55, 1.60 and 1.65 V/cell. 2. Data shall include effect of up to 5 shorted cells per string.		
89	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 pre-mature failure		

Item Ref. #	Parameter/Test Item	Item Source Ref. GR/SR/DS etc.	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA/ Acceptable
90	Positive Plate Growth	4228: [44, 152]	Disassemble measure and inspect the horizontal and vertical grid growth of plates from samples after 70°C life test. Plate growth shall be: 1. Shall be < 8% of area of each plate (≤ 4% per direction) 2. Shall not cause cell to crack 3. Shall not cause cell to fail catastrophically		
91	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		
92	Operating Internal Cell Pressure	4228: [46]	Measure internal cell pressure under normal operating conditions. Pressure shall: 1. Be sufficient for ≥ 99% recombination efficiency. 2. Shall not crack cell case or cause excessive deformation		
93	Dry-Out and Water Loss	GR-3020: [23], [24], [25], [26], [27], [110]	The rate of water loss shall be measured by weight loss. If no water is used, the maximum internal moisture shall be less than 500 ppm (-30° C dew point)		
94	Thermal Runaway of Cells and Modules	GR-3020: [28], [29], [111]	No thermal runaway: 1. When up to 5 cells are shorted to zero volts at 40° C 2. When operated normally throughout its useful life 3. When operated abnormally at 1.65 V/cell and 55° C		

Item Ref. #	Parameter/Test Item	Item Source Ref. GR/SR/DS etc.	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA/ Acceptable
95	Thermal Runaway of Cell String	GR-3020: [28], [29], [111]	No thermal runaway: 1. When up to 5 cell are shorted to zero volts at 40° C 2. When operated normally throughout its useful life 3. When operated abnormally at 1.65 V/cell and 55° C		
GR-3020: Section 4 – Environmental Requirements					
96	Mechanical Shock (Drop Test) – (Packaged and Un-Packaged)	GR-3020: [32], [115] GR-63: [108], [109]	Cells and batteries shall not be damaged and shall remain operational		
97	Mechanical Vibration - Office (Unpackaged)	GR-3020: [33] GR-63: [122], [123]	Cells and batteries shall not be damaged and shall remain operational		
98	Mechanical Vibration – Transportation (Packaged)	GR-3020: [33] GR-63: [124]	Cells and batteries shall not be damaged and shall remain operational		
99	Earthquake Resistance	GR-3020: [36], [116] GR-63: [110], [114], [115]	Cells and batteries shall not be damaged and shall remain operational when exposed to a Zone 4 Seismic event.		
100	Low Temperature Exposure and Thermal Shock	GR-3020: [30], [34], [112] GR-63: [69], [72] GR-3108: [133]	Cells and batteries shall remain operational and floatable from -40°C to +25°C		
101	High Relative Humidity Exposure	GR-3020: [35] GR-63: [71]	Cells and batteries shall remain operational and floatable from 5% to 90% RH		
102	High Temperature Exposure and Thermal Shock	GR-3020 [30], [34], [112] GR-63:[70], [72] GR-3108: [133]	Cells and batteries shall remain operational and floatable from +25°C to +70°C		
103	Airborne Contaminants	GR-3020: [37], [117] GR-63: [127]	Cells and batteries shall remain operational for the intended service life (20 yrs.)		
104	Electrostatic Discharge	GR-3020: [38], [118] GR-1089: [3], [4]	1. Apply 15 kV on surfaces likely to be touched during field operation. 2. Cells and batteries shall remain operational		

Item Ref. #	Parameter/Test Item	Item Source Ref. GR/SR/DS etc.	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA/ Acceptable
Other Tests Performed/Declared by Supplier on their Na-Ni-Cl Batteries					
105	Cell hermeticity	This document and GR-357	$1x10^{-7}$ cc/atm/sec using helium leak detector		
106	Cell residual moisture content	This document and GR-357	-30°C dew point or 500 ppm		
107	Cell wall material	This document	Nickel plated cold rolled steel		
108	Cell wall thickness	This document	0.5 mm minimum		
109	Internal operating cell pressure	This document	Shall be less than 25 psi @ 0% SOC Shall be less than 60 psi @ 100% SOC		
110	Cell case pressure withstand (burst strength)	This document	Shall withstand 100 psi or a minimum of 150% of working psi @100% SOC		
111	Cell seam sealing process	This document	Cell seam sealing process shall result in a molecular bond. Brazing, TIG or Laser welding is appropriate.		
112	Cell Rupture	This document	1. Shall fail in a safe mode 2. Shall not result in a catastrophic event 3. Shall not cause the temperature of the external battery case to rise greater than +15°C above the ambient.		
113	Electrical isolation between cells and external battery case	This document	Shall withstand 1000 V dc for 1 minute minimum		
114	Cell Electrode Seals	This document	Electrode seals shall be Glass-metal or Metal-Ceramic		
115	Cell electrical Interconnections	This document	Shall be a nickel bus-bar capable of handling at least 50 A.		
116	Cell External Short Circuit	GR-1089 –See item #73	One minute duration – Shall be recoverable 24 hours duration - Shall not explode or create a fragmentation hazard		
117	Interconnected cell enclosure (battery box) material	This document	Shall be similar to 304 SS		

Item Ref. #	Parameter/Test Item	Item Source Ref. GR/SR/DS etc.	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA/ Acceptable
118	Interconnected cell enclosure (battery box) construction	This document	Shall be of a double walled construction		
119	Interconnected cell enclosure (battery box) wall thickness	This document	1.0 mm minimum		
120	Interconnected cell enclosure (battery box) hermeticity	This document GR-357: R4-87 [91] Mil-Std 883 method 1014	Shall meet Gross leak requirements using perfluorocarbon (after helium) or equivalent test methods. No bubbles shall be seen		
121	Impact Resistance of battery box	This document	Shall meet the impact resistance requirements of UL1973		
122	Crush Resistance of battery box	This document	Shall meet the crush resistance requirements of UL1973		
123	Thickness of thermal insulation material used	This document	50 mm minimum		
124	Flammability of thermal insulation of cell enclosure	This document	UL 94V-0 Or UL 94V-1 and OI ≥ 28%		
125	Operating temperature of 1. Thermal insulating material 2. Electrical insulating material (mica)	This document	1. 950°C minimum 2. 550° C minimum		
126	Terminal voltage when battery is in the 'cold' state and fully discharged to zero energy (0% SOC)	This document	Measured voltage at output battery terminals shall be zero volts when 'cold' and at 0% SOC.		
127	Battery Management System (BMS) enclosure material	This document	Shall withstand 85°C minimum		

Item Ref. #	Parameter/Test Item	Item Source Ref. GR/SR/DS etc.	Requirement/ Required Value	Measured/Declared Value and Source Report Reference	Conforms? Y/N/NA/ Acceptable
128	BMS enclosure material flammability	This document	UL 94V-0 Or UL 94V-1 and OI ≥ 28%		
129	BMS Printed Board Assemblies (PBAs)	This document	1. Bare PBs shall be solder masked 2. PBAs shall be assembled using SAC-305 Pb-free solder alloy. 3. PBAs shall be conformal coated.		
130	Other qualification tests/declarations, if any, performed by supplier.				
Other Verizon Tests/Requirements					
OSHA Listing Requirements					
131	NRTL Safety Listing	This document and GR-1089 Section 7	Batteries shall be Listed for CPE applications		
End-of-Life Processing, Recycling and Disposal/Environmental, Health and Safety (EH&S) Practices					
132	Environmental Stewardship	This document	1. Does your company have a Commitment to Environmental Stewardship Policy? 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? 4. Does your company have a return and recycling program for customer disposal of these batteries?		

*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.

END OF Na-M-H BATTERY QUALIFICATION REQUIREMENTS