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PERFORMANCE SPECIFICATION

BATTERY CELLS AND MODULES, VALVE REGULATED LEAD-ACID, MAIN STORAGE, SUBMARINE; GENERAL SPECIFICATION FOR

This specification is approved for use by the Naval Sea Systems Command, Department of the Navy, and is available for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers valve regulated lead-acid (VRLA) main storage battery cells (see 6.6.1), modules (see 6.6.3), and installation and checkout parts (see 6.9) for submarines.

1.2 Classification. Battery cells are of the types specified below. The required electrical capacity and configuration of the cells determine type characteristics as shown on the applicable specification sheet (see 3.1 and 6.2).

1.2.1 Types. Battery cell types are as follows:

a. Type B - 2675 ampere-hour (Ah) cell, 1-hour rating

b. Type C - 2225 ampere-hour (Ah) cell, 1-hour rating

1.2.2 Battery set configurations. Battery ship sets will be configured as follows. Configurations will consist of left-hand (see 6.6.3.1), right-hand (see 6.6.3.2), dual cell, and single cell configurations for both or either Type B and Type C cells.

a. Ship Set A1 – two strings (see 6.6.6) of 127 Type C cells in spinlock style single cell modules, with 127 modules in right-hand (see 6.6.3.2) orientation and 127 single cell modules in left-hand (see 6.6.3.1) orientation.

b. Ship Set A2 – two strings (see 6.6.6) of 126 Type C cells each. Cells for this ship set type are to be shipped in Government-furnished temporary shipping trays in accordance with NAVSEA Drawing 803-7329696. Cell orientation in the shipping trays is irrelevant.

c. Ship Set B – three strings (see 6.6.6) of 132 Type C cells, arranged in dual cell modules, with 88 modules in right-hand (see 6.6.3.2) orientation and 110 modules in left-hand (see 6.6.3.1) orientation.

d. Ship Set C – one string (see 6.6.6) of 120 Type B cells and one string of 120 Type C cells, arranged in dual cell modules, with 40 modules of each type in right-hand (see 6.6.3.2) orientation and 20 modules of each type in left-hand (see 6.6.3.1) orientation.

e. Ship Set D – one string (see 6.6.6) of 126 Type B cells and one string of 126 Type C cells, arranged as follows: one single cell module and 31 dual cell modules of each type in right-hand (see 6.6.3.2) orientation, and one single cell module and 31 dual cell modules of each type in left-hand (see 6.6.3.1) orientation.

Comments, suggestions, or questions on this document should be addressed to: Commander, Naval Sea Systems Command, ATTN: SEA 05S, 1333 Isaac Hull Avenue, SE, Stop 5160, Washington Navy Yard DC 20376-5160 or emailed to CommandStandards@navy.mil, with the subject line “Document Comment”. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.daps.dla.mil/online.

AMSC N/A FSC 6140

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3, 4, or 5 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3, 4, or 5 of this specification, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-S-901	-	Shock Tests, H.I. (High-Impact); Shipboard Machinery, Equipment, and Systems, Requirements for
MIL-PRF-32273/1	-	Battery Cell, Valve Regulated Lead-Acid, Main Storage, Submarine, Classification Type B
MIL-PRF-32273/2	-	Battery Cell, Valve Regulated Lead-Acid, Main Storage, Submarine, Classification Type C

(Copies of these documents are available online at https://assist.daps.dla.mil/quicksearch/ or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

2.2.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

NAVAL SEA SYSTEMS COMMAND (NAVSEA) DRAWINGS

NAVSEA Drawing 201-7607331	-	VRLA Battery Tray Interface Control Drawing
NAVSEA Drawing 201-7666427	-	S/A SSN 4348K-SSN688 CL, VRLA Battery and Tray Assembly Interface Drawing
NAVSEA Drawing 201-8206447	-	S/A SSN 4508K-SSN688 CL Storage Battery Modular Cabinet Assembly and Details
NAVSEA Drawing 803-7329696	-	SHIPALT 4508K-688 Class Shipping Case for VRLA Battery Assembly and Details

(Copies of these documents are available from the applicable repositories listed in NAVSEA S0005-AE-PRO-010/EDM. Copies of NAVSEA S0005-AE-PRO-010/EDM are available from the Naval Logistics Library, 5450 Carlisle Pike, Mechanicsburg, PA 17055 or online at https://nll1.ahf.nmci.navy.mil.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

UNDERWRITERS LABORATORIES (UL)

UL 94 - Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

(Copies of this document are available from the Underwriters Laboratories, 333 Pfingsten Road, Northbrook, IL 60062-2096 or online at www.ul.com.)

2.4 Order of precedence. Unless otherwise noted herein or in the contract, in the event of a conflict between the text of this document and the references cited herein (except for related specification sheets), the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 Specification sheets. The individual item requirements shall be as specified herein and in accordance with the applicable specification sheet. In the event of any conflict between the requirements of this specification and the specification sheet, the latter shall govern.

3.2 Qualification. Battery cells furnished under this specification shall be products that are authorized by the qualifying activity for listing on the applicable qualified products list (QPL) before contract award (see 4.2 and 6.5).

3.2.1 Qualification sample cells. This specification shall be used when fabricating qualification sample cells for inspection as specified in 4.2.2. Manufacturer's drawings shall be made available to support inspections required in section 4.

3.3 Electrical requirements. Cells shall meet the electrical requirements as specified in 3.3.1, 3.3.2, and 3.3.3.

3.3.1 Service life. Service life (see 6.6.4) shall be as specified in the applicable specification sheet and shall be demonstrated as specified in 4.4.7.

3.3.2 Temperature-corrected capacity. In its deliverable form prior to shipment, each cell shall demonstrate a temperature-corrected capacity equal to or greater than the rated Ah capacity with the cell voltage at or above the minimum cell voltage stated in the applicable specification sheet when tested as specified in 4.4.1.

3.3.3 Insulation resistance. The cell shall be filled and charged. Each cell shall have a minimum allowable insulation resistance of 1 giga-Ohm when tested as specified in 4.4.9 for cells in production and as specified in 4.4.10 for cells delivered in trays for installation.

3.4 Physical requirements. Cells shall meet physical requirements as specified in 3.4.1 through 3.4.9. Gelled electrolyte immobilization construction is prohibited.

3.4.1 Dimensions and materials. Cell dimensions and materials shall be as specified in the applicable specification sheet and drawings. If a secondary cell cover-to-jar seal is used, the additional plastic shall not interfere with the insertion of the cell into the tray.

3.4.1.1 Cell jars and covers. Cell jars and covers shall be molded using Government-owned molds as specified (see 6.2). Reference dimensions (marked in parentheses) on specification sheets are to establish mold designs and qualification acceptance for cell covers and jars and are not a requirement for cell conformance inspection. Dimensions on specification sheets listed with tolerances shall be checked during conformance inspection for compliance. The manufacturer shall notify the Government immediately upon identification of any problems with the Government-owned molds that negatively impact product dimensions. The Government-owned molds are designed for the cover to be heat sealed to the jar. Flame retardant polypropylene plastic resin which meets the UL 94 V-0 or equivalent flammability rating shall be used for manufacture of cell jars and covers.

3.4.1.2 Cell tray. Trays shall be constructed in accordance with NAVSEA Drawings 201-7607331, 201-7666427, or 201-8206447. For Ship Set B, Ship Set C, and Ship Set D configurations, single and dual stacked installations shall be in accordance with NAVSEA Drawing 201-7607331. For Ship Set A1 single cell rack mount installations, trays shall be in accordance with NAVSEA Drawing 201-7666427. For Ship Set A2 modular cabinet installations, NAVSEA Drawing 201-8206447 shall be used. Tray masses are listed in the applicable specification sheets for information purposes only, are nominal values and include the tray, cover, screws and washers, but do not include cell masses.

3.4.1.3 Cell and tray assembly. With the cell(s) installed in the tray, the tray restraint cover shall bolt securely against the cell tray without the use of shims. Cell compression shall not be greater than 1.5-mm when the restraint cover is installed.

3.4.1.4 Cell shipping configurations. Cells shall be installed in trays, the combination of which shall be referred to as a module (see 6.6.3), for shipment and installation. Ship Set A2 configuration cells shall be shipped in Government-furnished temporary shipping trays (GFE) in accordance with NAVSEA Drawing 803-7329696 (see 6.2).

3.4.1.5 Cell manufacturing period. Each cell within a ship set (as identified in 1.2.1) shall be formed such that the formation date between the oldest and youngest cell in the ship set does not exceed one year.

3.4.2 Cell mass. In the "filled and charged" condition, maximum cell mass shall not exceed the value specified in the applicable specification sheet when measured as specified in 4.4.3.

3.4.3 Pressure relief valves and flash arrestors. Two removable pressure relief valves with attached flash arrestors shall be provided for each cell in accordance with the battery cell manufacturer's standards and practices when inspected as specified in 4.4.4.

3.4.4 Markings. Cells shall be marked with a manufacturer's unique alpha-numeric identifier used during production for quality assurance purposes. This number shall be visible when the cell is installed for use. Positive terminal posts shall be identified by either "POS" or "+" and contain red post caps or rings, and negative terminal posts shall be identified by either "NEG" or "-" and contain black post caps or rings. Inspection shall be as specified in 4.4.5.

3.4.5 Terminal screw threads. To ensure a standardized connection interface, each cell terminal shall be drilled and tapped with threads to receive bolts with M6x1-6H threads. Depth of the hole shall be a minimum of 37.46 millimeters (1.475 inches) with a minimum thread depth of 29.96 millimeters (1.180 inches) from the top. The cell terminal shall be capable of receiving a bolt torqued to a minimum of 1.27 kilogram-meters (110 inch-pounds).

3.4.6 Installation and checkout parts. When specified (see 6.2), installation and checkout parts (see 6.9) for each set shall be provided in the quantities indicated by table I.

TABLE I. Installation and checkout parts.

Part Nomenclature	Quantity
Vendor's flash arrestor/relief valve assembly with sealing mechanism	4 (All ship sets)
Vendor's vent cover	10 (All ship sets)
Vendor's pressure vent removal and installation tool	1 (All ship sets)
Cell numbering sticker sets with 20 blank spares	2 sets (Ship Sets A1, A2, C, and D) 3 sets (Ship Set B)
Spare colored terminal post caps or rings	6 red and 6 black (All ship sets)
Silicone O-ring grease, 5 oz. minimum resealable tube	1 (All ship sets)

3.4.7 Spares. Spare cells shall be provided when specified (see 6.2 for quantities, type, and orientation).

3.4.8 Mercury. Mercury shall not be used in the manufacture of the cell or any of its components. Mercury shall not be used in any test or test equipment in which there is any danger of introducing mercury into the cell through accident or otherwise.

3.4.9 Recycled, recovered, or environmentally preferable materials. Recycled, recovered, or environmentally preferable materials should be used to the maximum extent possible, provided that the material meets or exceeds the operational and maintenance requirements, and promotes economically advantageous life cycle costs.

3.5 Environmental requirements. Environmental requirements shall be as specified in 3.5.1 and 3.5.2.

3.5.1 Temperature operating environment. Battery cells shall be capable of withstanding ambient temperature extremes of 0 to 55 °C while in storage or in operation. .

3.5.2 Shock. Cells shall meet the Grade A shock acceptance requirements of MIL-S-901 when tested as specified in 4.4.6. A larger cell (Type B) which passes the shock test specified herein will provide sufficient evidence of shock capability for the smaller cell (Type C) if both cell types use identical construction techniques and similar plate dimensions, but different plate quantities. The shock test of the Type B cell in either a single or dual cell module (i.e., subsidiary component test per MIL-S-901) will not provide the objective quality evidence (OQE) required for shock qualification of the principal unit (i.e., the ship set installed in the ship). However, the test specified herein will provide reasonable assurance that the cells will pass shock testing when mounted in a principal unit and can be used to support future shock extensions. The sample cells (two if testing a single cell configuration or four if testing a dual cell configuration) must meet the following requirements when tested as specified in 4.4.6:

a. There shall be no permanent loss in cell voltage during and after each test blow. Permanent loss is defined as a complete open circuit voltage (0 Volts).

b. Type B cells shall yield at least 2700 amp-hours capacity at the 3-hour rate identified in the applicable specification sheet after shock testing. If Type C cells are used, they shall yield at least 2316 amp-hours capacity at the 3-hour rate identified in the applicable specification sheet after shock testing.

c. There shall be no evidence of contact between conductors of opposite polarity or between conductors and other metallic components following the shock test.

d. There shall be no evidence of permanent external electrical shorts.

e. There shall be no evidence of release of flame, smoke, or sparks.

f. The following cell components shall not come adrift during shock testing, but may degrade, provided they do not impact the performance of the cell and prevent it from meeting its electrical requirements: cell terminals, covers, jars, and pressure relief vents. Electrolyte and gas leakage are allowable.

4. VERIFICATION

4.1 Classification of inspections. The inspection requirements specified herein are classified as follows:

a. Qualification inspection (see 4.2).

b. Conformance inspection (see 4.3).

4.2 Qualification inspection. Qualification inspection on Type B and C cells as specified in 4.2.1 and 4.2.2 shall be performed at a Government-approved laboratory and conducted in the order shown in table II. The samples shall be representative of the items intended to be supplied under this specification. The samples shall not be produced with the use of any equipment or procedure not normally used in production of the cell. If Type B cell shock testing is successful, the Type C cell shall be qualified for shock (but not service life) by extension.

4.2.1 Qualification retention. In order to maintain qualification, each manufacturer shall submit annually a certification that the product and design previously qualified have not changed.

4.2.2 Sample cells. To qualify a cell design, a minimum of 12 sample cells are required for all qualification inspections and tests except Shock specified in table II. Two additional cells if using single cell configuration or four if using a dual cell configuration are required for shock qualification testing. Cells intended for shock testing shall be delivered in single cell modules or dual cell modules depending on the test configuration selected. Cells intended for service life tests shall be delivered in dual cell modules.

TABLE II. Qualification inspections and tests.

Inspection or Test	Sample Cell Identification No.	Requirement Paragraph	Inspection/Test Paragraph
Dimensions and materials	All	3.4.1	4.4.2
Cell mass	All	3.4.2	4.4.3
Pressure relief valve & flash arrestor	All	3.4.3	4.4.4
Markings	All	3.4.4	4.4.5
Terminal screw threads	All	3.4.5	4.4.8
Insulation resistance	All	3.3.3	4.4.9 & 4.4.10
Capacity	All	3.3.2	4.4.1
Shock	13 and 14 (if a single cell test configuration is tested) or 13 through 16 (if a dual cell test configuration is tested)	3.5.2	4.4.6
Service life	1 through 12	3.3.1	4.4.7

4.3 Conformance inspection. Each production cell for delivery shall be inspected for conformance as specified in table III. Except for changes previously approved by the Government, batteries produced under this specification shall be identical in every respect to the qualified cell. Any unapproved changes from the qualified cell shall constitute cause for rejection.

TABLE III. Conformance inspections and tests.

Inspection or Test	Requirement Paragraph	Inspection/Test Paragraph
Capacity	3.3.2	4.4.1
Cell dimensions	3.4.1	4.4.2
Cell mass	3.4.2	4.4.3
Pressure relief valve & flash arrestor	3.4.3	4.4.4
Markings	3.4.4	4.4.5
Insulation resistance	3.3.3	4.4.9 & 4.4.10

4.4 Inspection methods.

4.4.1 Temperature-corrected capacity. Testing for temperature-corrected Ah capacity shall be conducted on each cell in its deliverable form, irrespective of tray or enclosure, prior to shipment for delivery. Objective evidence of each cell's voltage at the time the required temperature-corrected Ah capacity is developed shall be provided in accordance with the following steps.

4.4.1.1 3-hour rate test discharge.

4.4.1.1.1 Average cell temperature calculation. Using a calibrated contact temperature-measuring device or other Naval Sea Systems Command, Department of the Navy-approved alternative method, measure and record the temperature of each cell in the circuit to be tested within 0.5 hour prior to commencement of the 3-hour rate test discharge. The temperature measured at the center negative terminal of a cell (either center negative terminal for a Type B cell will suffice) shall be used as a representative temperature for that cell. If a series-connected group of cells is being tested, calculate the average temperature of the cells in the string.

4.4.1.1.2 Test duration calculation. Calculate the test duration using the following formula:

Test Duration (in minutes) = 180 minutes x [1 + 0.007002 x ($T_{Cell\ Avg}$ - 25 °C)]

Where: $T_{Cell\ Avg}$ is the average temperature of the cell (or cells if connected in a series string) within 0.5 hour prior to commencement of the 3-hour rate test discharge

4.4.1.1.3 Test discharge commencement. Discharge the battery cells, either individually or in a series-connected string, at a constant current at the 3-hour discharge rate (±0.20 percent tolerance) specified in the applicable specification sheet.

4.4.1.1.4 Temperature measurement at end of test discharge. Using the methods used in 4.4.1.1.1, measure and record the temperature of each cell in the circuit within the 30 minutes preceding the conclusion of the 3-hour rate test discharge. These temperatures may provide a potential screening tool to identify cells with significant temperature deviations.

4.4.1.1.5 Test discharge conclusion. The 3-hour rate discharge shall continue, as a minimum, for the test duration calculated in 4.4.1.1.2.

4.4.1.2 Minimum cell voltage. Any cell with a voltage less than 1.70 volts at the prescribed test duration, as calculated in 4.4.1.1.2, shall not be delivered without conditioning and retest.

4.4.1.3 Recharge. For shock test (see 4.4.6) and operational cycle life test (see 4.4.7.1), the cells shall be recharged using the cell manufacturer's discharge recovery procedure intended for shipboard operations. Percent recharge (total ampere-hours of charge multiplied by 100 and divided by total ampere-hours of discharge) shall be calculated and recorded.

4.4.2 Dimensions and materials. Cell and tray dimensions shall be inspected for conformance to the applicable specification sheets and drawing requirements. Cell and tray materials shall be verified by manufacturer certificate of conformance as specified (see 6.2).

4.4.3 Mass measurement. Cells shall be weighed in the filled and charged condition. Individual cell mass shall be equal to or less than the maximum cell mass specified in the applicable specification sheet.

4.4.4 Pressure relief valves and flash arrestors. The cells shall be inspected for the presence of pressure relief valves with attached flash arrestors as specified in 3.4.3. Written certification that the valves and flash arrestors comply with manufacturer standards and practices shall be provided as specified (see 6.2).

4.4.5 Markings inspection. Cell markings shall be inspected for conformance to the requirements of 3.4.4.

4.4.6 Shock test. The cell type (see 1.2.1) being shock tested shall be subjected to a shock test in accordance with MIL-S-901 as follows:

4.4.6.1 Classification.

a. Test category – Medium weight

b. Shock grade – A

c. Equipment class – I

d. Shock test type – B

e. Mounting location – Hull

f. Mounting plane aboard ship – Face mounted, battery is installed on its side in a tray with its positive terminal posts vertically aligned

g. Mounting orientation aboard ship – Unrestricted

4.4.6.2 Test description. The intention of the shock test specified herein is to prove multidirectional survivability of the cell design. This can be accomplished by shock testing either a single cell or a dual cell configuration. For a single cell configuration, the test shall consist of a total of nine shock blows applied to two sample cells. For one sample cell, three blows shall be applied in each of two axes. For the second sample cell, three blows shall be applied in the third axis. For a dual cell configuration, the same procedure shall be used but dual cell modules shall be used in place of single cell modules.

4.4.6.2.1 Pre-test routine. Prior to initiating shock testing, the battery shall be subjected to a pre-test routine in accordance with 4.4.7.1.2.1 through 4.4.7.1.2.3. The following parameters shall be monitored and recorded: individual cell voltages and temperatures, circuit (battery) current, and cumulative circuit (battery) ampere-hours.

4.4.6.2.2 Test sequence. The shock blows shall be applied in the following sequence:

a. Sample cell #13 for a single cell configuration or #13 and #14 for a dual cell configuration (see table II) shall be mounted to the MIL-S-901, Figure 13, Standard Mounting Platform for Testing Equipment on Mediumweight Shock Testing Machine, table arrangement using the fixture that places the plane of the cell plates perpendicular to the hammer's axis of percussion (the cell face/terminals horizontal). One Group I, one Group II, and one Group III blow (as defined in MIL-S-901) shall be applied to the cell.

b. Sample cell #13 for a single cell configuration or #13 and #14 for a dual cell configuration (see table II) shall be mounted to the MIL-S-901, Figure 16, 30 Degree Mounting Fixture for Testing Base Mounted Equipment on Mediumweight Shock Testing Machine, 30-degree incline using a fixture such that the plane of the cell plates will be at a 30-degree angle to the hammer's axis of percussion (the cell face/terminals pointing up the 30-degree incline). One Group I, one Group II, and one Group III blow (as defined in MIL-S-901) shall be applied to the cell.

c. Sample cell #14 for a single cell or #15 and #16 for a dual cell configuration (see table II) shall be mounted to the MIL-S-901, Figure 17, 30 Degree Mounting Fixture for Testing Base Mounted Equipment on Mediumweight Shock Testing Machine, 30-degree incline using a new/unused fixture such that the plane of the cell plates will be at a 30-degree angle to the hammer's axis of percussion and the cell face/terminals perpendicular to the cell orientation tested in 4.4.6.2.2b. One Group I, one Group II, and one Group III blow (as defined in MIL-S-901) shall be applied to the cell.

4.4.6.2.3 Cell operation during shock blows. Except during periods of transport, shock blows, or physical inspection after the blows, the cells shall be float charged in accordance with the manufacturer's technical manual. During application of each shock blow, the cell shall be delivering current at a constant rate between the 3-hour and 10-hour discharge rates identified in the applicable specification sheet. Voltage and current shall be continuously monitored and recorded (at a rate of not less than once each millisecond) starting not less than 15 seconds prior to each shock blow and lasting until not less than 15 seconds after the blow.

4.4.6.2.4 Cell discharge capacity. At the conclusion of the nine shock blows, the sample cells shall be recharged in accordance with the manufacturer's technical manual. Each cell shall then be discharged at the 3-hour rate identified in the applicable specification sheet to a cutoff voltage of 1.00+0.00/-0.01 volts. Cell capacity measured in ampere-hours shall be temperature corrected using the following formula:

$$\text{Corrected Capacity} = \text{Measured Capacity} \div [1 + 0.007002 \times (T_{Cell} - 25\ °C)]$$

Temperature-corrected cell discharge capacities shall be recorded. The cells shall then be recharged in accordance with the manufacturer's technical manual. All cells shall meet the acceptance criteria specified in 3.5.2 after the test.

4.4.6.2.5 Shock test failure. Failure of any cell to meet the requirements specified in 3.5.2 shall constitute failure of the shock test.

4.4.7 Service life testing. Service life tests shall be conducted on two 6-cell batteries using the test regimes specified in 4.4.7.1 (operational cycle life test) and 4.4.7.2 (accelerated cycle life test). The batteries shall meet the requirements specified in 3.3.1.

Note: Follow manufacturer's instructions regarding inrush current limits used during discharge recovery procedures.

4.4.7.1 Operational cycle life test. The battery shall be subjected to the testing regime in 4.4.7.1.1 through 4.4.7.1.6 to quantify the cycle life of the battery under cyclic conditions simulating shipboard operations. Perform all steps in order listed.

4.4.7.1.1 Test battery configuration. Six cells shall be connected in a series-parallel circuit with two strings of three cells each. Temperature sensors shall be placed on the buswork as close as possible to each cell's centermost negative terminal bolt. Test monitoring equipment shall provide an alarm and stop the test when any cell reaches 1.00+0.00/-0.01 volts during any discharge event. Test monitoring equipment shall provide an alarm and suspend the test when any cell voltage reaches the maximum voltage specified by the manufacturer during any charge event. If the test is suspended, contact the cell manufacturer for a test continuance recommendation. Cell mass measurements shall be taken and recorded at the start and conclusion of the test. Unless otherwise specified, the following parameters shall be monitored and recorded during conduct of the operational cycle life test routine: circuit (battery) voltage, circuit (battery) current, cumulative circuit (battery) ampere-hours, individual cell voltages, and individual cell temperatures. Parameters shall be recorded at the following intervals:

a. During cell/circuit charge (except float charge): once every five minutes.

b. During cell/circuit discharge: once every 30 seconds.

c. During cell/circuit float charge: once every one hour.

Note: Current rates shown in table II of the applicable specification sheet apply to the circuit (battery). Both cell strings would be expected to carry one-half of the current value shown in the applicable table II specification sheet.

4.4.7.1.2 Pre-test routine. Prior to initiating life cycle testing, the battery shall be subjected to a pre-test charge, discharge, and recharge in accordance with 4.4.7.1.2.1 through 4.4.7.1.2.3.

4.4.7.1.2.1 Freshening charge procedure. The battery cells shall be boost charged at a constant potential charge (voltage) as prescribed by the manufacturer. Temperature monitoring shall not be required. The cells shall be allowed to equalize to a temperature of 21 to 30 °C before continuing.

4.4.7.1.2.2 3-hour rate capacity test discharge. The battery cells shall be discharged at a constant current at the 3-hour discharge rate (±0.20 percent tolerance) specified in the applicable specification sheet to an average cutoff voltage of 1.70±0.01 volts per cell or until any individual cell reaches 1.00+0.00/-0.01 volts. Cell capacity measured in ampere-hours shall be temperature corrected using the following formula:

$$\text{Corrected Capacity} = \text{Measured Capacity} \div [1 + 0.007002 \times (T_{Cell} - 25\ °C)]$$

4.4.7.1.2.3 Recharge. The cells shall be recharged using the cell manufacturer's discharge recovery procedure intended for shipboard operations. Percent recharge (total ampere-hours of charge multiplied by 100 and divided by total ampere-hours of discharge) shall be calculated and recorded.

4.4.7.1.3 7-day test routine. The battery shall be cycled in accordance with 4.4.7.1.3.1 and 4.4.7.1.3.2.

4.4.7.1.3.1 7-day test routine definition. The cells in the battery circuit shall be cycled using the 7-day test profile specified in table II of the applicable specification sheet.

4.4.7.1.3.2 Charge interruption. Following each discharge period, the battery shall be recharged using the discharge recovery procedure defined in 4.4.7.1.2.3 until the start of the next discharge evolution as specified in table II of the applicable specification sheet. After each constant current discharge, the recharge sequence shall be restarted per 4.4.7.1.2.3. No discharges are scheduled on the seventh day of the test sequence to allow the battery to complete the entire discharge recovery procedure and to continue on float charge for at least 12 to 18 hours. This is intended to bring the battery back to a fully charged condition at least once every 7-day period.

4.4.7.1.4 Six-week test sequence. Repeat the 7-day test routine specified in 4.4.7.1.3 five times. Upon conclusion of the sixth 7-day test profile, proceed to 4.4.7.1.5.

4.4.7.1.5 Periodic capacity test discharge. Repeat the pre-test routine specified in 4.4.7.1.2.2.

4.4.7.1.6 Test routine continuance. Repeat cyclic testing in accordance with 4.4.7.1.4 and 4.4.7.1.5 until the battery has either accumulated a minimum of 240 equivalent Navy cycles (see 6.6.2), 96 months of cyclic testing, or the battery's temperature-corrected discharge capacity falls to less than 80 percent (2700 amp-hours for Type B cells or 2316 amp-hours for Type C cells) of rated at the 3-hour rate identified in the applicable specification sheet. If 240 equivalent Navy cycles or 96 months of cyclic testing has been achieved, the operational cycle life test is complete. If the battery's temperature-corrected discharge capacity falls to less than 80 percent of rated before reaching 240 equivalent Navy cycles or 96 months of cyclic testing, then proceed to 4.4.7.1.6.1 or 4.4.7.1.6.2 depending on which is applicable.

4.4.7.1.6.1 6-cell circuit battery recovery. If six cells remain in the battery circuit and any individual cell reaches 1.00+0.00/-0.01 volts, or the battery circuit voltage is less than or equal to 5.10 volts at the end of discharge, perform the following steps:

Step 1: Attempt to correct the problem by obtaining and implementing the manufacturer's recommendations to restore battery capacity.

Step 2: Repeat the 3-hour capacity test and recharge in accordance with 4.4.7.1.2.2 and 4.4.7.1.2.3.

Step 3: Assess battery capacity. If the battery capacity recovers to greater than or equal to 80 percent of rated, return to the 7-day test routine per 4.4.7.1.3. If battery capacity does not recover to 80 percent of rated, attempt to correct the problem by obtaining and implementing the manufacturer's recommendations to restore battery capacity.

Step 4: Repeat the 3-hour capacity test and recharge in accordance with 4.4.7.1.2.2 and 4.4.7.1.2.3.

Step 5: Assess battery capacity. If the battery capacity recovers to greater than or equal to 80 percent of rated, return to the 7-day test routine in accordance with 4.4.7.1.3. If battery capacity does not recover to 80 percent of rated, jumper the two weakest cells. Shuffling cells to maintain two balanced parallel strings is allowable.

Step 6: Recharge the 4 cells and repeat the 3-hour capacity test and recharge in accordance with 4.4.7.1.2.2 and 4.4.7.1.2.3.

Step 7: Assess battery capacity after jumpering. If the battery capacity recovers to greater than or equal to 80 percent of rated, return to the 7-day test routine in accordance with 4.4.7.1.3. If battery capacity does not recover to 80 percent of rated, the battery has failed to meet the operational cycle life test requirements. Record the number of attempts at capacity restoration and the method(s) used. Prepare the battery for teardown analysis and proceed to 4.4.7.3.3.

4.4.7.1.6.2 4-cell circuit (2 cells isolated) battery recovery. If two cells were previously isolated in 4.4.7.1.6.1, perform the following steps. No more than two consecutive battery recovery attempts in accordance with 4.4.7.1.6.2 may be performed.

Step 1: Attempt to correct the problem by obtaining and implementing the manufacturer's recommendations to restore battery capacity.

Step 2: Repeat the 3-hour capacity test and recharge in accordance with 4.4.7.1.2.2 and 4.4.7.1.2.3.

Step 3: Assess battery capacity. If the battery capacity recovers to greater than or equal to 80 percent of rated, return to the 7-day test routine in accordance with 4.4.7.1.3. If battery capacity does not recover to 80 percent of rated, attempt to correct the problem by obtaining and implementing the manufacturer's recommendations to restore battery capacity.

Step 4: Repeat the 3-hour capacity test and recharge in accordance with 4.4.7.1.2.2 and 4.4.7.1.2.3.

Step 5: Assess battery capacity. If the battery capacity recovers to greater than or equal to 80 percent of rated, return to the 7-day test routine in accordance with 4.4.7.1.3. If battery capacity does not recover to 80 percent of rated, the battery has failed to meet the operational cycle life test requirements. Record the number of attempts at capacity restoration and the method(s) used. Prepare the battery for teardown analysis and proceed to 4.4.7.3.3.

4.4.7.2 Accelerated cycle life test. The battery shall be subjected to the testing regime in accordance with 4.4.7.2.1 through 4.4.7.2.3 to prove the ability of the battery cell design to deliver expected lifetime ampere-hours and cycles over a compressed period (18 months maximum).

4.4.7.2.1 Test battery configuration. Six cells shall be connected in a series-parallel circuit with two strings of three cells each. Measurements of cell mass shall be taken at the start and conclusion of the test. During conduct of the accelerated cycle life test routine (4.4.7.2) except where noted, the following parameters shall be monitored: circuit (battery) voltage, circuit (battery) current, cumulative circuit (battery) ampere-hours, individual cell voltages, and individual cell temperatures. Temperature sensors shall be placed on the buswork as close as possible to each cell's centermost negative terminal bolt. Test monitoring equipment shall provide an alarm and stop the test when any cell reaches 1.00+0.00/-0.01 volt during any discharge event. Test monitoring equipment shall provide an alarm and suspend the test when any cell voltage reaches the maximum voltage specified by the manufacturer during any charge event. If the test is suspended, contact the cell manufacturer for a test continuance recommendation. Regardless of the test sequence (4.4.7.1.2 or 4.4.7.2.3), the following data sampling rates shall apply:

a. During cell/circuit charge: once every five minutes.

b. During cell/circuit discharge: once every 30 seconds.

Note: Current rates apply to the circuit (battery). Note that each cell string would be expected to carry one-half of this current, which is the 3-hour discharge rate identified in the applicable specification sheet.

4.4.7.2.2 Pre-test routine. Prior to initiating life cycle testing, the battery shall be subjected to a pre-test charge and discharge in accordance with 4.4.7.2.2.1 through 4.4.7.2.2.3.

4.4.7.2.2.1 Freshening charge procedure. The battery cells shall be boost charged at a constant potential charge (voltage) as prescribed by the manufacturer. Temperature monitoring shall not be required. The cells shall be allowed to equalize to a temperature of 21 to 30 °C before continuing.

4.4.7.2.2.2 3-hour rate capacity test discharge. The battery cells shall be discharged at a constant current at the 3-hour discharge rate (±0.20 percent tolerance) specified in the applicable specification sheet to an average cutoff voltage of 1.70±0.01 volts per cell or until any individual cell reaches 1.00+0.00/-0.01 volts. Cell capacity measured in ampere-hours shall be temperature corrected using the following formula:

$$\text{Corrected Capacity} = \text{Measured Capacity} \div [1 + 0.007002 \times (T_{Cell} - 25\ ^\circ C)]$$

4.4.7.2.2.3 Recharge. The cells shall be recharged using the cell manufacturer's discharge recovery procedure intended for shipboard operations. Percent recharge (total ampere-hours of charge multiplied by 100 and divided by total ampere-hours of discharge) shall be calculated and recorded.

4.4.7.2.3 Test routine. The battery shall be cycled in accordance with 4.4.7.2.3.1 through 4.4.7.2.3.5.

4.4.7.2.3.1 Discharge routine. The battery shall be discharged at a constant current at the 3-hour discharge rate (±0.20 percent tolerance) specified in the applicable specification sheet for 1.75 hours.

4.4.7.2.3.2 Recharge routine. The battery shall be recharged using the cell manufacturer's discharge recovery procedure intended for Accelerated Cycle Life testing. The service life requirement specified in the applicable specification sheet (240 equivalent Navy cycles) shall be demonstrated within an 18-month period. The manufacturer's recommended recharge routine must support this requirement.

4.4.7.2.3.3 Test cycles. Repeat the routines of 4.4.7.2.3.1 and 4.4.7.2.3.2 49 times. After every 50th test cycle, calculate and record equivalent Navy cycles (see 6.6.2) and proceed to 4.4.7.2.3.4.

4.4.7.2.3.4 Capacity test discharge and recharge. Repeat the routines of 4.4.7.2.2.2 and 4.4.7.2.2.3.

4.4.7.2.3.5 Test routine continuance. Repeat cyclic testing in accordance with 4.4.7.2.3 through 4.4.7.2.3.5 until the battery has accumulated a minimum of 240 equivalent Navy cycles (see 6.6.2), or the battery's temperature-corrected discharge capacity falls to less than 80 percent (2700 amp-hours for Type B cells or 2316 amp-hours for Type C cells) of rated at the 3-hour rate identified in the applicable specification sheet. Follow the steps in 4.4.7.3 for service life test failure verification.

4.4.7.3 Service life test failure verification. When the test battery's capacity falls below 80 percent of rated 3-hour rate capacity (2700 amp-hours for Type B cells or 2316 amp-hours for Type C cells) during a routine test discharge at the 3-hour rate identified in the applicable specification sheet, follow the sequence outlined below to verify service life test failure.

4.4.7.3.1 Recharge. Recharge the battery per 4.4.7.2.2.3.

4.4.7.3.2 Conduct 3-hour rate test discharge. Repeat the 3-hour rate test discharge in accordance with 4.4.7.2.2.2.

4.4.7.3.2.1 Capacity greater than 80 percent. If battery capacity is greater than 80 percent (2700 amp-hours for Type B cells or 2316 amp-hours for Type C cells), recharge the battery in accordance with 4.4.7.2.2.3 and continue with the cycling routine.

4.4.7.3.2.2 Capacity less than 80 percent. If battery capacity is less than 80 percent (2700 amp-hours for Type B cells or 2316 amp-hours for Type C cells), recharge the battery in accordance with 4.4.7.2.2.3, jumper the weakest cell in each string of three cells in parallel. Jumpering of the weakest cell is allowed one time. Shuffling cells to maintain two balanced parallel strings is allowable. Repeat the capacity test discharge at the 3-hour rate identified in the applicable specification sheet in accordance with 4.4.7.2.2.2.

4.4.7.3.2.2.1 Retest capacity greater than 80 percent. If the capacity is greater than 80 percent (2700 amp-hours for Type B cells or 2316 amp-hours for Type C cells), recharge the battery in accordance with 4.4.7.2.2.3, and return to cycling routine.

4.4.7.3.2.2.2 Retest capacity less than 80 percent. If the capacity is less than 80 percent (2700 amp-hours for Type B cells or 2316 amp-hours for Type C cells), recharge the battery in accordance with 4.4.7.2.2.3 and cease testing, failure has been verified. Prepare the battery for teardown analysis or shipment for teardown off site.

4.4.7.3.3 Failure analysis. After the termination of the service life test, a teardown analysis shall be performed on the failed cells to determine the failure mode. The teardown analysis shall include cells that failed and were removed during the test, as well as failed cells at the end of the test.

4.4.7.3.4 Reporting methods. Battery lifetime capacity under cyclic operating conditions shall be reported as total "equivalent Navy cycles" (see 6.6.2).

4.4.8 Terminal screw threads. Terminal bolts (see 3.4.5) with M6x1-6H threads shall be inserted into terminal openings to validate thread size and depth.

4.4.9 Insulation resistance test. Each cell shall be subjected to the insulation resistance test to determine compliance with 3.3.3.

4.4.9.1 Test setup. A tank of sufficient size to hold a cell shall be filled with a dilute solution of water and ammonia (approximately 2 tablespoons of ammonia per gallon of water), where the water level comes up to the top edge of the side of the cell when lowered into the tank. Care shall be taken to submerge the cover to jar seal area while ensuring the water solution does not come over the top of the cell. If the tank is not made of metal, it shall be provided with a metallic grounding strip extending from the rim of the tank down into the water solution to the bottom of the tank. Caution should be exercised to ensure that a ground path is not developed through the cell lifting device.

4.4.9.2 Measurement. Using a 500-volt calibrated megohmmeter (Megger Brand MIT430 or equivalent), obtain a reading between a cell terminal and the metal tank or grounding strip.

4.4.9.3 Pass and fail criteria. Cleaning and repair of the cell is permitted. If the insulation resistance is below the 1 giga-ohm requirement (see 3.3.3) after three attempts to correct, the cell shall be rejected.

4.4.9.4 Cell cleanliness. Prior to inserting the cell into the tray or alternate shipping restraint, the entire exterior of the cell shall be cleaned, wiped down, and dried.

4.4.10 Final insulation resistance test. After the cell is cleaned, dried, and inserted into the tray with restraint cover or alternate shipping restraint installed, perform a final insulation resistance test. Using a 500-volt calibrated megohmmeter (Megger Brand MIT430 or equivalent), obtain a reading between a cell terminal and the tray or alternate shipping restraint. The minimum allowable insulation resistance shall comply with 4.4.9.3.

4.5 Certified test reports. Test reports for qualification and conformance testing shall be prepared as specified (see 6.2).

5. PACKAGING

5.1 Packaging. For acquisition purposes, the packaging requirements shall be as specified in the contract or order (see 6.2). When packaging of materiel is to be performed by DoD or in-house contractor personnel, these personnel need to contact the responsible packaging activity to ascertain packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activities within the Military Service or Defense Agency, or within the military service's system commands. Packaging data retrieval is available from the managing Military Department's or Defense Agency's automated packaging files, CD-ROM products, or by contacting the responsible packaging activity.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. The valve regulated lead-acid (VRLA) cells are intended for use in submarine main storage batteries to furnish power for vital loads and other power-consuming equipment when the submarine is operating under conditions when the nuclear reactor or diesel engines cannot be used to supply power.

6.2 Acquisition requirements. Acquisition documents should specify the following:

a. Title, number, and date of the specification and applicable specification sheet or sheets.

b. Number of sets (see 6.6.5) of cells by ship set configuration (see 1.2.2).

c. Quantity of Government-owned shipping trays for Ship Set A2 configuration battery sets and destination (see 1.2.2.b and 3.4.1.4).

d. Identification of Government-owned molds to be supplied to the manufacturer appropriately marked by the Government by cell type (see 3.4.1.1).

e. Required installation and checkout parts (see 3.4.6 and 6.9).

f. Quantity, type, and orientation of spare cells (see 3.4.7).

g. Certificate of conformance (see 4.4.2) that cell and tray dimensions and materials meet applicable specification sheet and drawing requirements.

h. Certification that the valves and flash arrestors comply with manufacturer standards and practices (see 4.4.4).

i. Test report requirements (see 4.5 and 6.3).

j. If partial shipments are permitted (see 5.1).

k. Module air shipment requirements (see 6.4).

6.3 Certified test reports. The test reports should contain the following information at a minimum:

a. This specification number, revision, and date (required for both qualification and conformance testing).

b. The date and serial number of the NAVSEA letter of approval authorizing qualification testing (required for qualification testing only).

c. A statement that the product was constructed only from materials listed on the manufacturer's approved detailed construction drawing (required for qualification testing only).

d. A statement that the product meets all the requirements of this specification (required for qualification testing only).

e. Results of all tests indicating actual values obtained (required for both qualification and conformance testing).

6.4 Air shipment. Modules, either single or dual cell, are to be shipped in accordance with International Air Transport Association (IATA) Dangerous Goods Regulations Packing Instruction #806 and Special Provisions A-48 and A-67.

6.5 Qualification. With respect to products requiring qualification, awards will be made only for products which are, at the time of award of contract, qualified for inclusion in Qualified Products List (QPL) No. 32273 whether or not such products have actually been so listed by that date. The attention of the contractors is called to these requirements, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. Information pertaining to qualification of products may be obtained from Commander, Naval Sea Systems Command, ATTN: SEA 05S, 1333 Isaac Hull Avenue, SE, Stop 5160, Washington Navy Yard DC 20376-5160 or emailed to CommandStandards@navy.mil. An online listing of products qualified to this specification may be found in the Qualified Products Database (QPD) at https://assist.daps.dla.mil/online.

6.6 Definitions. The definitions specified in 6.6.1 through 6.6.6 are applicable to this specification.

6.6.1 Cell. An individual cell is a unit with a nominal terminal voltage of 2 volts DC and is complete with all hardware required by this specification.

6.6.2 Equivalent Navy cycle. An equivalent Navy cycle for a cell in ampere-hours of charge is equal to 80 percent of the 3-hour rate capacity in ampere-hours (2700 amp-hours for Type B cells or 2316 amp-hours for Type C cells) multiplied by 1.08.

6.6.3 Module. A module is an assembly consisting of a steel tray with either one or two installed cells, and referred to as single or dual cell configuration, respectively. Modules facilitate battery shipment and shipboard installation.

6.6.3.1 Left-hand orientation. Cells and modules that have the positive terminals on the left side when facing the terminals.

6.6.3.2 Right-hand orientation. Cells and modules that have the positive terminals on the right side when facing the terminals.

6.6.4 Service life. Service life, expressed in months of service and equivalent Navy cycles (see 6.6.2), quantifies the life of the submarine VRLA battery under cyclic conditions encountered during submarine operation. In a cyclic application, the battery is frequently operated through a series of discharge and charge evolutions. The cyclic conditions stress the cell's positive and negative active materials.

6.6.5 Ship set. A set is the total number of cells or modules necessary to assemble one complete battery installation in a ship.

6.6.6 String. A string is a number of battery cells connected electrically in series. A battery may consist of a single or multiple strings connected in parallel.

6.7 Sub-contracted material and parts. The packaging requirements of referenced documents listed in section 2 do not apply when material and parts are acquired by the contractor for incorporation into the equipment covered by this specification and lose their separate identity when the equipment is shipped.

6.8 Intercell connectors and buswork installation information. To ensure design and installation compatibility, cell terminals will be bolted to copper interrow, crossover and intercell connectors, and buswork. The installed terminal bolt connections will be torqued to 100±10 inch-pounds. Interrow, crossover and intercell connectors, and buswork may be solid or flexible to accommodate relative motion between two connected cells and between cells and the battery compartment bulkheads. The buswork will be designed to have a current density of no more than 12,903 amperes per square centimeter (2000 amperes per square inch). Non-contact area parts of buswork and intercell connectors will be coated with plastisol and the contact areas will be silver electroplated to prevent corrosion of contact areas. Buswork and terminal contact areas will be coated with corrosion inhibiting treatment, NO-OX-ID A Special from SanChem Corporation or equivalent.

6.9 Installation and checkout parts. Installation and checkout parts include extra flash arrestor and relief valve assemblies with a sealing mechanism, cell pressure vent removal and installation tool, cell numbering sticker sets, silicone O-ring grease, vent covers, and red and black terminal polarity post rings or caps.

6.10 Subject term (key word) listing.

VRLA

6.11 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extent of the changes.

Preparing Activity:
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NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at https://assist.daps.dla.mil/online.