INCH-POUND
MIL-DTL-32529
04 September 2015

DETAIL SPECIFICATION

POWER ELECTRONIC CONVERSION EQUIPMENT, NAVAL SHIPBOARD

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.dla.mil.

AMSC N/A FSC 6150

DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND
1333 ISAAC HULL AVE SE
WASHINGTON NAVY YARD DC 20376-0001

IN REPLY REFER TO
4121
Ser 05Z/397
SEP 04 2015

From: Commander, Naval Sea Systems Command (SEA 05, CHENG)

Subj: CHENG'S INTENT FOR IMPLEMENTATION OF POWER ELECTRONIC CONVERSION EQUIPMENT

Ref: (a) MIL-DTL-32529, Power Electronic Conversion Equipment, Naval Shipboard

1. Purpose. The NAVSEA Chief Engineer's (CHENG's) intent for issuing a new defense specification for naval shipboard power electronic conversion equipment, reference (a), is to provide a common basis of requirements for future power electronic conversion equipment acquisition procurements for surface and submarine naval vessels. The current industry standards for such equipment do not cover unique requirements for Navy shipboard systems such as requirements for electrical power interface, electromagnetic interference (EMI), shock, and vibration.

2. Discussion. Reference (a) addresses requirement gaps of other electrical equipment specifications in areas such as modularity, derating factors for power electric devices, cybersecurity, and unique power quality characteristics of power electronics. Reference (a) adopts lessons learned from previous and ongoing design efforts of power electronic conversion equipment in the Navy. Power electronic conversion equipment satisfying the requirements of reference (a) will provide user loads with required power level and quality to ensure safe and reliable operation.

3. Action. NAVSEA encourages the use of reference (a) in future acquisition requirements of power electronic conversion equipment to enhance commonality of requirements and parts.

4. Point of Contact. For information pertaining to Power Electronic Conversion Equipment, please contact the Machinery - High Energy/High Power Systems - Surface Ships Technical Warrant Holder, Vincent Kane, SEA 05Z31, commercial, (202) 781-3772, email: vincent.kane@navy.mil.

L. B. FULLER
By direction

Affixed to: MIL-DTL-32529

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers naval shipboard Power Electronic Conversion Equipment (PECE) design and selection of components. PECE consists of any power converter (see 6.4.3), inverter (see 6.4.11), or rectifier (see 6.4.19) that is stand-alone or part of a power distribution system. PECE utilizes solid-state power switching devices to provide user loads with required power level and quality to ensure safe and reliable operation. Examples of applications include, but are not limited to, variable frequency drives (VFD), frequency converters (see 6.4.6), power conversion modules (PCM), power conditioners, and other specialty power supplies. In a unidirectional design, PECE provides power conversion, power conditioning, and electrical supply to the loads. In a bi-directional design, PECE provides energy conversion back to the energy source or storage device. This specification applies to PECE for surface and submarine naval vessels (see 6.2), regardless of voltage level and output type.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3 and 4 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 and 4 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-DTL-917	-	Electric Power Equipment, Basic Requirements for
MIL-DTL-2036	-	Enclosures for Electric and Electronic Equipment, Naval Shipboard
MIL-DTL-15024	-	Plates, Tags, and Bands for Identification of Equipment, General Specification for
MIL-DTL-16036	-	Switchgear, Power, Low Voltage, Naval Shipboard
MIL-T-16366	-	Terminal, Electrical Lug and Conductor Splices, Crimp Style
MIL-DTL-16878	-	Wire, Electrical, Insulated, General Specification for
MIL-PRF-19500	-	Semiconductor Devices, General Specification for
MIL-W-21965	-	Water Cooling of Shipboard Electronic Equipment, General Specification for
MIL-DTL-24640	-	Cables, Lightweight, Low Smoke, Electric, for Shipboard Use, General Specification for
MIL-DTL-24643	-	Cables, Electric, Low Smoke Halogen-Free, for Shipboard Use, General Specification for
MIL-PRF-24712	-	Coatings, Powder, Thermosetting
MIL-DTL-24749	-	Grounding Straps and Bosses, Electromagnetic
MIL-DTL-24765	-	Power Supply, Uninterruptable, Static (Naval Shipboard)

MIL-PRF-28876	-	Connectors, Fiber Optic, Circular, Plug and Receptacle Style, Multiple Removable Termini, General Specification for
MIL-DTL-32483	-	Switchgear, Power, Hard-Mounted, Medium Voltage, Naval Shipboard
MIL-DTL-83522	-	Connectors, Fiber Optic, Single Ferrule, General Specification for
MIL-PRF-87252	-	Coolant Fluid, Hydrolytically Stable, Dielectric

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-108	-	Definitions of and Basic Requirements for Enclosures for Electric and Electronic Equipment
MIL-STD-129	-	Military Marking for Shipment and Storage
MIL-STD-130	-	Identification Marking of US Military Property
MIL-STD-167-1	-	Mechanical Vibrations of Shipboard Equipment (Type I – Environmental and Type II – Internally Excited)
MIL-STD-202	-	Electronic and Electrical Component Parts
MIL-STD-461	-	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
MIL-STD-681	-	Identification Coding and Application of Hookup and Lead Wire
MIL-STD-740-2	-	Structureborne Vibratory Acceleration Measurements Acceptance Criteria of Shipboard Equipment
MIL-STD-810	-	Environmental Engineering Considerations and Laboratory Tests
MIL-STD-1310	-	Shipboard Bonding, Grounding, and Other Techniques for Electromagnetic Compatibility, Electromagnetic Pulse (EMP) Mitigation, and Safety
DOD-STD-1399-70-1	-	Interface Standard for Shipboard Systems Section 070 – Part 1 D.C. Magnetic Field Environment (Metric)
MIL-STD-1399-300	-	Electric Power, Alternating Current
DOD-STD-1399-301	-	Interface Standard for Shipboard Systems, Section 301A, Ship Motion and Attitude (Metric)
MIL-STD-1399-390	-	Interface Standard for Shipboard Systems, Section 390, Electric Power, Direct Current, (other than Ship's Battery) for Submarines (Metric)
MIL-STD-1399-680	-	High Voltage Electric Power, Alternating Current
MIL-STD-1472	-	Human Engineering
MIL-STD-1474	-	Noise Limits
MIL-STD-1627	-	Bending of Pipe or Tube for Ship Piping Systems
MIL-STD-1683	-	Connectors and Jacketed Cable, Electric, Selection Standard for Shipboard Use
MIL-STD-1686	-	Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

MIL-STD-2003-2 - Electrical Plant Installation Standard Methods for Surface Ships and Submarines (Equipment)

MIL-STD-2042 - Fiber Optic Cable Topology Installation Standard Methods for Naval Ships

DEPARTMENT OF DEFENSE HANDBOOKS

MIL-HDBK-263 - Electrostatic Discharge Control Handbook for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices) (Metric)

MIL-HDBK-338 - Electronic Reliability Design Handbook

MIL-HDBK-454 - General Guidelines for Electronic Equipment

MIL-HDBK-470 - Designing and Developing Maintainable Products and Systems, Volume I

MIL-HDBK-2164 - Environmental Stress Screening Process for Electronic Equipment

(Copies of these documents are available online at http://quicksearch.dla.mil/.)

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.

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

NIST SP 800-53 - Security and Privacy Controls for Federal Information Systems and Organizations

NIST SP 800-82 - Guide to Industrial Control Systems (ICS) Security

(Copies of these documents are available online at http://www.nist.gov.)

NAVAL SEA SYSTEMS COMMAND (NAVSEA) PUBLICATIONS

S0400-AD-URM-010/TUM - Tag-Out User's Manual

S9086-CJ-STM-010/075 - Fasteners

S9086-KC-STM-010/300 - NSTM Chapter 300, Electric Plant-General

(Copies of these documents are available online at https://nll.ahf.nmci navy mil, requested by phone at 215-697-2626, or requested by email at nllhelpdesk@navy mil. These publications can be located by searching the Navy Publications Index for the TMIN without the suffix.)

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.

ASME

ASME B18.2.1 - Square, Hex, Heavy Hex, and Askew Head Bolts and Hex, Heavy Hex, Hex Flange, Lobed Head, and Lag Screws (Inch Series)

ASME B18.2.2 - Nuts for General Applications: Machine Screw Nuts, Hex, Square, Hex Flange, and Coupling Nuts (Inch Series)

(Copies of these documents are available online at www.asme.org.)

ASTM INTERNATIONAL

ASTM D1868 - Standard Test Method for Detection and Measurement of Partial Discharge (Corona) Pulses in Evaluation of Insulation Systems

ASTM E814 - Standard Test Method for Fire Tests of Penetration Firestop Systems

(Copies of these documents are available online at www.astm.org.)

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC. (IEEE)

IEEE-STD-1012 - Standard for System and Software Verification and Validation

IEEE-STD-1413 - Standard Framework for Reliability Prediction of Hardware

IEEE-STD-1413.1 - Guide for Selecting and Using Reliability Predictions Based on IEEE 1413

IEEE-STD-1584 - Guide for Performing Arc Flash Hazard Calculation

IEEE-STD-3007.3 - Recommended Practice for Electrical Safety in Industrial and Commercial Power Systems

(Copies of these documents are available online at www.ieee.org.)

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

IEC 60529 - Degrees of Protection Provided by Enclosures (IP Code)

IEC 61000-4-5 - Electromagnetic Compatibility (EMC) – Part 4–5: Testing and Measurement Techniques – Surge Immunity Test

(Copies of these documents are available online at www.iec.ch.)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70E - Standard for Electrical Safety in the Workplace

(Copies of this document are available online at www.nfpa.org.)

SAE INTERNATIONAL

SAE-AS-85049 - Connector Accessories, Electrical General Specification for

SAE-GEIA-STD-0008 - Derating of Electronic Components

SAE-J-527 - Brazed Double Wall Low-Carbon Steel Tubing

(Copies of these documents are available online at www.sae.org.)

UNDERWRITERS LABORATORIES, INC. (UL)

UL 840 - Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment

(Copies of this document are available 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, 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 First article. When specified (see 6.2), a sample shall be subjected to first article inspection in accordance with 4.2.

3.2 Mechanical design requirements.

3.2.1 Basic design requirements. PECE basic design requirements shall be in accordance with MIL-DTL-917. PECE shall be designed such that current-carrying parts are insulated with respect to ship's hull ground (with the exception of a single connection of the system neutral to ship's hull ground). PECE installation standard methods shall be in accordance with MIL-STD-2003-2. When flexible mounts are used, they shall meet shock and vibration requirements (see 3.9.4 and 3.9.5).

3.2.2 Size and weight. PECE maximum size and weight and center of gravity shall be designed as specified (see 6.2).

3.2.3 Materials. Materials shall be capable of meeting all operational, safety, and environmental requirements specified herein and in accordance with MIL-DTL-917. PECE shall be constructed of durable, fire-resistant, and moisture-resistant materials suitable for a marine environment and temperatures to which PECE is exposed.

3.2.3.1 Recycled, recovered, environmentally preferable, or biobased materials. Recycled, recovered, environmentally preferable, or biobased 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.

3.2.3.2 Prohibited materials. Prohibited materials specified in MIL-DTL-917 shall not be used.

3.2.4 Processes. Corrosion treatment, plating, painting, soldering, brazing, and welding shall be in accordance with MIL-DTL-917.

3.2.4.1 Paint. Paint used on PECE shall be in accordance with MIL-DTL-917. Powder coatings shall be used in accordance with MIL-PRF-24712.

3.2.5 Enclosure. PECE enclosures shall have protection against the intrusion of foreign objects and liquids appropriate for the location in which it is installed.

3.2.5.1 Degree of ingress protection. PECE enclosure ratings shall be in accordance with the degree of ingress protection standards of IEC 60529 or, when specified (see 6.2), the ingress protection standards of MIL-STD-108.

3.2.5.2 Construction. PECE enclosure shall be constructed in accordance with MIL-DTL-2036.

3.2.5.3 Enclosure access. Interface requirements for operator access to energized equipment shall be in accordance with MIL-DTL-2036. Enclosure access shall be in accordance with MIL-DTL-917. PECE safe electrical access should follow the guidance of S9086-KC-STM-010/300.

3.2.5.4 Door interlocks. When specified (see 6.2), interlocking device(s) shall be installed in cover(s), door(s), or power module(s) that have access to live circuits greater than 30 volts and are not protected by guards or barriers. Automatic energy discharge capability shall be provided to bring circuit and capacitor voltages down to 30 volts or less within 2 seconds, following the guidance of MIL-HDBK-454. The interlocking device shall isolate power to the components behind the cover(s), door(s), or power module(s) inside PECE.

3.2.5.5 Grounding straps. Grounding straps shall be in accordance with MIL-DTL-24749. For all electrical equipment enclosures, a low-resistance flexible grounding strap shall connect the cover(s) or access door(s) to the enclosure. When energized parts are mounted on a cover(s) or access door(s), the strap shall have a current carrying capacity at least as great as that of the largest conductor on the cover- or access door-mounted device(s). The ground strap shall be located so that it cannot come in contact with electrical parts.

3.2.5.6 Safety information plates. Safety information plates shall be prominently displayed to remind the maintenance personnel of appropriate precautions to ensure de-energization of the guarded circuit (see 3.10.6 and 3.10.7).

3.2.6 Explosion-proof. When specified (see 6.2), enclosure shall be designed for explosion-proof capability in accordance with MIL-DTL-2036.

3.2.7 Electrical interface.

3.2.7.1 Cable entrance. Cable entrance hardware shall be in accordance with MIL-DTL-2036. When specified (see 6.2), cable entrance plates or Multi-Cable Transits (MCTs) shall be in accordance with ASTM E814.

3.2.7.2 Cable installation. Cable installation shall be in accordance with the cable entrance requirements of MIL-DTL-2036. PECE shall be designed to provide necessary space to meet cable conductor bend radius and cable support. Cable routing shall be such that final installation does not result in cable or conductor interference with any parts requiring access for inspection, adjustment, or maintenance. Cables shall be routed within the cabinet in such a manner as to prevent contact with surfaces that exceed the temperature rating of the cable as well as prevent wear and abrasion of the cable. Cable terminations shall be accessible with all cables in place in order to perform inspections and torque checks.

3.2.8 Accessibility. PECE shall be designed and arranged to provide accessibility to all parts which may require inspection, servicing, maintenance, repair, or replacement during the life of the equipment. Unless otherwise specified (see 6.2), access to these parts shall be from the front of the cabinet. MIL-HDBK-454 may be used as guidance.

3.2.8.1 Access. Parts or subassemblies shall not require unsoldering of wires in order to gain access to terminals, mounting screws, or other hardware for servicing and maintenance.

3.2.8.2 Drawers. PECE drawers with channel-guided slides shall lock in an intermediate position when necessary to provide access to the drawer components for alignment or troubleshooting without removal of the drawer from the enclosure. In the intermediate position, all test jacks and controls used for alignment shall be accessible and all indications shall be visible. In the fully extended position, all connectors and hardware associated with the drawer removal shall be visible and accessible. Drawer removal shall not be possible without deliberate action to release or remove the last mechanical stop.

3.2.8.3 Removable cover(s) and access door(s). A removable cover(s) or access door(s) shall be selected in accordance with MIL-DTL-2036. A removable cover(s) or access door(s) shall provide access to the internal components, subassemblies, bus work, and electrical connections of PECE for servicing, maintenance repair, or replacement. The number and location of removable cover(s) or access door(s) shall be as specified (see 6.2).

3.2.8.3.1 Removable cover(s). Mounting and alignment devices shall be provided to facilitate installation and removal of cover(s).

3.2.8.3.2 Access door(s). An access door(s) shall be provided with doorstops or positioning devices to stop the door in its opening swing and to hold it in the open position. The width of the access door(s) shall not exceed the maintenance envelope (see 6.4.13), as specified (see 6.2). The bottom edge of the access door(s) shall be above any sub-base of the equipment. A means of quickly disconnecting the hinges without special tools shall be provided in order to remove the door(s). Door hinge connection(s) shall be captive-type so as to prevent the loss of the hardware.

3.2.9 Equipment identification. Unless otherwise specified (see 6.2), PECE and individual modules shall be marked with the following information in accordance with MIL-STD-130, unique item identifier (UII) data set construct #2, and MIL-DTL-15024.

a. Nomenclature of PECE.

b. Manufacturer name and part number.

c. Date of manufacture.

d. Serial number.

e. Rating.

f. National stock number (when available).

g. Lot codes.

h. Issuing agency code.

3.2.10 Labeling. Labeling of all components shall be provided in accordance with MIL-DTL-917 requirements. Switches used to isolate the unit electrically shall have open and closed labels visible and clearly marked.

3.2.11 Parts selection. Parts shall be selected in accordance with MIL-DTL-917. An open architecture (see 6.4.15) design approach shall be used to achieve parts standardization and commonality to allow components to be added, modified, replaced, removed, and supported by different vendors throughout the life cycle of the PECE.

3.2.12 Fasteners. Mounting fasteners and fastening devices shall be in accordance with MIL-DTL-917.

3.2.12.1 Fastener properties. Unless otherwise specified (see 6.2), the fastener properties (material, grade, construction, and other such properties) shall be in accordance with ASME B18.2.1 and ASME B18.2.2. Locking devices shall be used for bolts and nuts for mounting electrical components.

3.2.12.2 Access fastening hardware. Access covers and doors, provided to facilitate equipment alignment or alignment checks, fuse replacement, or operation and troubleshooting of equipment with power applied, shall be secured to the equipment by captive hardware. The design and spacing of the fasteners shall be consistent with the required enclosure degree of ingress protection (see 3.2.5.1) and the frequency of required access to meet the environmental and electromagnetic interference (EMI) requirements.

3.2.12.3 Fastener hardware. Unless otherwise specified (see 6.2), high-strength alloy steel screws or bolts shall not be used. Aluminum and aluminum alloy fasteners shall not be used. Black oxide or other non-conductive coatings shall not be used where they would interfere with equipment grounding or otherwise adversely affect equipment operation. The use of black oxide-coated brass fasteners ¼-inch in diameter and larger shall be prohibited unless the provisions of S9086-CJ-STM-010/075 are met. The material of the locking device shall be of the same chemical composition to the material of the fastener, unless the fastener has a built-in nylon or similar locking feature.

3.2.12.4 Electrical connection fasteners. Electrical connection fasteners (locking devices) shall ensure a permanently tight connection under high-current and high-temperature conditions. For applications where the temperatures of high-current connections may exceed 250 °F, acceptability of locking devices shall be in accordance with MIL-DTL-16036 and MIL-DTL-32483. Fasteners securing the current carrying parts shall be provided with means to prevent loosening caused by vibration.

3.2.13 Grab rails. When specified (see 6.2), grab rails or handles in accordance with MIL-DTL-16036 shall be provided at PECE Human-Machine Interface (HMI) and local controls. Grab rails and grab bars shall be attached in such a manner that access doors or removable covers can be opened or removed without removal of the rail from the member to which it is attached.

3.2.14 Bus bars. The design of bus bars, including materials, sizes, spacing, arrangements, and joints shall be in accordance with MIL-DTL-917. Bus bar plating material shall not contain any tin. Laminated bus bars shall be encapsulated with semi-rigid epoxy and all exposed hook-up current carrying copper surfaces shall be silver coated to control corrosion. Preparation of bus bar connection surface areas shall prevent degradation from corrosion and other environmental conditions so as to minimize the resistivity and heating for no less than the expected service life of the equipment as specified (see 3.5.3). Creepage and clearance distances shall be as specified (see 3.4.13). Alternative bus bar arrangement and spacing shall be as specified (see 6.2).

3.2.15 Component location. Line replaceable units (LRUs) shall be located to allow ease of access for troubleshooting and replacement, in order to meet or exceed the mean time to repair (MTTR) requirement (see 3.5.5). Control system processors, communication interfaces, and all removable and replaceable control components which require access to verify system operation, maintenance, or any troubleshooting activities shall be located in a separate compartment with no exposed hazardous voltages (see 3.10.1).

3.2.16 Thermal management. PECE shall be designed for continuous operation within the maximum ambient and cooling medium (fluid) temperature without reduction of the equipment's rated performance criteria. The selection and design of the cooling method and cooling medium shall be in accordance with MIL-DTL-917. PECE non-LRU components that have embedded temperature sensors, such as power transformers, shall be provided with redundant temperature sensors. The cooling interface requirements shall be designed as specified (see 6.2).

3.2.16.1 Loss-of-cooling alarms. Air-cooled PECE shall be in accordance with the alarm requirements of MIL-DTL-917. Liquid-cooled PECE shall have sensing to monitor pressure and temperature to provide a loss-of-cooling alarm. All loss-of-cooling alarms shall cause audible and visual indications.

3.2.16.2 Loss-of-cooling operation. When specified (see 6.2), PECE shall continue to operate at a limited or reduced load under loss of cooling.

3.2.16.3 Leak detection. Liquid-cooled PECEs shall be equipped with leak detectors and shall alarm if a leak is detected within the PECE. Leak detection shall directly sense leakage of cooling liquid and shall not rely exclusively on secondary effects such as differential pressure or loss of pressure.

3.2.16.4 Pressure relief devices. Dangerous pressure build-up within the fluid circuit shall be prevented when liquid-cooling is used on PECE heat exchangers, transformers, inductors, and modules. Safety pressure plugs, relief valves, or other devices may be used. Each PECE liquid-cooled device with quick-disconnects shall provide pressure relief to allow for device removal and maintenance. Unless otherwise specified (see 6.2), pressures shall not exceed values in accordance with MIL-W-21965 for quick-disconnect fittings or shut off valves.

3.2.16.5 Pressure transients. PECE cooling system shall not be damaged or degraded as a result of water hammer effects (see 6.4.21) on the ship's cooling liquid supply.

3.2.16.6 Cooling medium reaction. Piping, cold plates, heat exchangers, valves, and fitting materials shall be compatible with the cooling medium and materials in accordance with MIL-DTL-917.

3.2.17 Liquid-cooled transformer or inductor. Liquid-cooled transformers or inductors used in PECE shall meet the following design requirements:

a. Fluid connection and associated piping locations, configurations, and orientations shall be such that they minimize the chance of leakage spraying or dripping onto transformer or inductor windings or electrical connections. Pipe fittings and connections shall be located below and outside the transformer or inductor compartment to the maximum extent practicable.

b. The compartment in which the windings and heat exchanger are located shall have leak detection.

c. Windings shall be separated from fluid by two metallic barriers to prevent exposure to fluid. When double-walled tubing is used, it shall be in accordance with SAE-J527.

d. Heat exchanger tube bend radii shall be in accordance with MIL-STD-1627.

e. The ability of all components to maintain integrity when subjected to vibration in accordance with MIL-STD-167-1 shall be demonstrated by testing.

f. The high temperature condition of each winding shall be alarmed.

g. Drain ports shall be provided to carry leakage and condensation outside the enclosure.

h The preferred method to insulate liquid-cooled transformers or inductors from leakage onto windings and connections shall be vacuum pressure impregnation (VPI) in accordance with MIL-DTL-917.

3.2.18 Human engineering. PECE shall be designed to human engineering standards in accordance with MIL-STD-1472.

3.3 Modularity.

3.3.1 Modular design. PECE shall be designed and constructed to minimize operational and maintenance down-time due to failed subcomponents in order to meet or exceed the MTTR requirement (see 3.5.5). Subcomponents of the PECE system shall be constructed in a building block approach using discrete, removable components with common parts to minimize repair, maintenance, and replacement time. Unless otherwise specified (see 6.2), a module failure shall isolate all interfaces from the rest of the system to maintain power quality and limit output power interruption time.

3.3.2 Module accessibility. Modules shall have effective means incorporated to ensure a safe removal process, as specified (see 3.3.4.4). All power interfaces to the modules shall connect and disconnect without requiring personnel to be exposed to or come in direct contact with the hazardous voltages. Control and communication connections shall utilize plugs or other devices which enable quick-disconnect. All connections shall be routed and configured in such a way as to allow module removal without interference after any cables and hoses are disconnected.

3.3.3 Module rating. Unless otherwise specified (see 6.2), the rating of the PECE module (see 6.4.16) shall be based on the continuous current times minimum voltage, the maximum continuous current rating, and the maximum overload and short circuit current rating. Derating of PECE module components shall be as specified (see 3.5.2).

3.3.4 Module replacement. PECE modules shall be replaced when PECE is in the off operating state (see 3.7.6). When specified (see 6.2) and approved by NAVSEA, PECE modules can be safely replaced when PECE is in the standby or online operating state (see 3.7.6). The operation of door interlocks (see 3.2.5.4), with respect to live PECE module replacement, shall be as specified (see 6.2).

3.3.4.1 PECE module key. PECE shall provide a mechanical means to prevent a module from being placed into an incompatible slot. Module keying shall be required for modules whose type, functions, or ratings are compatible with a specific location in the PECE.

3.3.4.2 PECE module warning signal. PECE shall provide a warning signal at the local HMI panel to indicate a missing or open PECE module. The state of the PECE module shall be identifiable without requiring opening doors or removing any covers.

3.3.4.3 PECE module extraction. Unless otherwise specified (see 6.2), PECE shall provide a self-contained means of fully extracting the module from the unit, without requiring special tools or equipment. The extraction hardware shall also have a locking mechanism in place to maintain the module's support in the fully extracted position without falling out of the enclosure. The fully extracted position shall be designed to permit full access to removable cover fastening hardware for troubleshooting and maintenance.

3.3.4.4 Removal of PECE module.

3.3.4.4.1 Energized PECE. Removal of a PECE module from an energized bus shall have:

a. Capability to de-energize the module output and verify that current is zero.

b. Capability to automatically discharge stored energy inside the PECE module. Automatic discharge devices shall bring circuit and capacitor voltages down to 30 volts or less within 2 seconds and should follow the guidance of MIL-HDBK-454.

c. Standoff distances between live components and personnel performing the process in accordance with the arc flash analysis requirements of NFPA 70E and IEEE-STD-1584, as specified (see 6.2).

d. Capability to safely disconnect cooling system interface, such as a quick-disconnect.

e. Capability to safely disconnect control power interface.

3.3.4.4.2 De-energized PECE. Removal of a PECE module from a de-energized bus shall have:

a. Capability to verify that the output module is de-energized (including stored energy).

b. Capability to safely disconnect cooling system interface, such as a quick-disconnect.

c. Capability to safely disconnect control power interface.

3.3.4.5 Insertion of PECE modules.

3.3.4.5.1 Energized PECE. Insertion of a PECE module onto an energized bus shall have:

a. Blind-mate type power and control connections.

b. Capability to ensure PECE module is not automatically re-energized.

c. Capability to safely reconnect cooling system interface, such as a quick-disconnect.

d. Capability to safely reconnect control power interface.

3.3.4.5.2 De-energized PECE. Insertion of a PECE module onto a de-energized bus shall have:

a. Blind-mate type power and control connections.

b. Capability to safely reconnect cooling system interface, such as a quick-disconnect.

c. Capability to safely reconnect control power interface.

3.3.5 Module cooling medium interface. PECE removable modules shall have accessible cooling hoses with quick-disconnect fittings which emit no leakage during the connect or disconnect process, or an insignificant amount of leakage as specified (see 6.2). Hoses shall be routed within the cabinet in such a manner as to prevent contact with surfaces that exceed the temperature rating of the hose as well as prevent wear and abrasion on internal components or outer doors or covers. Hoses shall not be permitted to come in contact with enclosure or module surfaces subject to removal or vibration. Hoses shall be arranged to permit module removal without requiring removal of hoses from other modules or removal of any additional components.

3.3.6 Module communication. Each module shall communicate all control, status, and alarm or fault information with the PECE central control system. Information shall be transmitted via a communications link as specified (see 6.2). The central control system shall control the online, off, and standby operating state (see 3.7.6) of each module. The PECE central control system shall also provide the capability to program any module via the central controller. Unless otherwise specified (see 6.2), each module shall be able to provide all sensor, alarm, fault, configurable parameter, state, and diagnostic information to the PECE central control system for operator troubleshooting.

3.3.7 Module control connection. Unless otherwise specified (see 6.2), the control connection of the module shall be of a quick-disconnect or blind-mate design such as pin and socket or other low insertion force-type connector. Mechanical fasteners shall be used to prevent unintentional disconnection of the module. All mechanical fasteners shall be accessible and not require exposure to hazardous voltages in order to access and disconnect.

3.3.8 Module electrical connection. The electrical connections of the module, for applications up to and including 1000 volts, shall be of a quick-disconnect or blind-mate design such as pin and socket, tulip, or other low-insertion force-type connector. Unintentional disconnection of the module and exposure to hazardous voltages shall be prevented mechanically by a jack screw, hold-down bar, circuit card rack door, or other similar method. For applications greater than 1000 volts, bus bars and cable connections that use nuts and bolts may be used as specified (see 6.2).

3.3.9 Module electrical isolation. PECE module shall provide input and output galvanic isolation in order to electrically isolate the module from the rest of the PECE in the event of an internal component failure. The input and output galvanic isolation shall be designed to enable the tag-out procedure to be followed in accordance with S0400-AE-URM-010/TUM.

3.4 Electrical design requirements.

3.4.1 Power quality requirements.

3.4.1.1 Input power quality. PECE shall meet the interface requirements of MIL-STD-1399-300, Types I, II, or III or MIL-STD-1399-680, Classes I, II, or III, as applicable. PECE with direct current (DC) input shall meet interface requirements as specified (see 6.2). PECE shall not impact power quality and shall be dynamically stable on the input power source (see 3.4.1.2.8) during any load conditions. PECE shall not be damaged by input power interruptions.

3.4.1.2 Output power quality. Unless otherwise specified (see 6.2), PECE outputs connected to fixed frequency low voltage (see 6.4.12) alternating current (AC) system loads shall be as specified (see Appendix A). Unless otherwise specified (see 6.2), PECE outputs connected to fixed frequency high voltage (see 6.4.9) AC system loads shall be as specified (see Appendix B). Unless otherwise specified (see 6.2), PECE outputs connected to DC system loads shall be as specified (see Appendix C).

3.4.1.2.1 Output voltage harmonics. Unless otherwise specified (see 6.2), PECE with AC output shall have output voltage total harmonic distortion of less than 3 percent and less than 2 percent per phase for the entire load spectrum.

3.4.1.2.2 Output voltage offset. When specified (see 6.2), PECE shall operate continuously without degraded operation with the specified voltage offset from ground (hull) at the output.

3.4.1.2.3 Output voltage characteristics. Unless otherwise specified (see 6.2), PECE shall provide output power characteristics as specified in Appendices A, B, and C for linear loads, nonlinear loads (see 6.4.14), and pulsed loads (see 6.4.18) as defined in MIL-STD-1399-300, MIL-STD-1399-680, and MIL-STD-1399-390.

3.4.1.2.3.1 Output voltage regulation. PECE output voltages listed in Appendices A, B, and C shall be stable and shall not produce resonances that result in an overvoltage or overcurrent in any load condition. PECE shall not interact with sources in a manner that causes the input or output voltage to exceed the limits of Appendices A, B, and C.

3.4.1.2.3.2 Transient output voltage and recovery. Any sudden change of load on PECE shall not cause an output deviation greater than the values listed in Appendices A, B, and C. The voltage at the PECE output terminals shall recover within time as listed in Appendices A, B, and C and stay within steady-state regulation band. Voltage transients developed within PECE shall not reflect back into the input system so that limits are within MIL-STD-1399-300 or MIL-STD-680 as applied.

3.4.1.2.3.3 Output voltage ramp-up. PECE output voltage shall ramp-up to rated voltage as specified (see 6.2).

3.4.1.2.4 Power electronic device switching frequency. Unless otherwise specified (see 6.2), PECE output power electronic (see 6.4.17) device switching frequency shall be selected to reduce passive filter size, minimize switching losses, address limitations of power electronic device high frequency switching, and meet the EMI emission limitations specified in MIL-STD-461.

3.4.1.2.5 Power electronic device switching reference. The power electronic devices that produce PECE output power shall be isolated from ship's hull and shall be isolated from PECE control power supply ground (see 6.4.8).

3.4.1.2.6 Power sharing. Unless otherwise specified (see 6.2), the PECE overall power rating shall be based on the module ratings, the number of modules, and the load sharing tolerances.

3.4.1.2.6.1 Source sharing. When specified (see 6.2), PECE with multiple input sources shall provide user adjustable input source sharing capability to carry the load and to transfer any load from one source to the other seamlessly. Source sharing set point accuracy shall be within 5 percent of calculated load while maintaining interface power quality requirements.

3.4.1.2.6.2 Module sharing. When specified (see 6.2), PECE shall be designed to share output power load equally between all paralleled modules providing the same bus power within PECE. Module sharing accuracy shall be 5 percent between modules at full-load, while maintaining interface power quality requirements.

3.4.1.2.6.3 Load sharing. When specified (see 6.2), PECE with multiple outputs shall provide user adjustable load sharing capability to carry the load and to transfer any load from one PECE output to the other seamlessly. Output power load sharing set point accuracy shall be within 5 percent of calculated load while maintaining interface power quality requirements.

3.4.1.2.6.4 Voltage and frequency interaction. Equipment supplied from two AC power sources shall meet all performance requirements with all combinations of the voltage, frequency, and worst case phase relationships within their steady state tolerances. The equipment shall operate to the requirements of MIL-STD-1399-300 with transients occurring simultaneously on both sources as well as on each source while the other is de-energized or at a steady value.

3.4.1.2.7 Overload. PECE shall provide overload capability as specified (see 6.2). The overload rating of the PECE output is the power that the bus can supply for a predetermined period of time while operating in an overload condition. The overload rating is determined based on the I^2t curve associated with the output. PECE shall detect the overload condition and provide an alarm of that condition.

3.4.1.2.8 Stability requirements. PECE shall be dynamically stable over its entire range of operations, including variations in capacity and configurations of source (see 6.2), PECE load, and transient conditions (see 3.4.1.2.3.2). The Nyquist Stability Criterion shall be used at each source and load interface to indicate the degree of system stability. The minimum Nyquist stability margin shall be 3-decibel (dB) gain margin and 30-degree phase margin at all load levels from no-load to full-load (including the allowance for future load growth) and from minimum to maximum voltage. Alternative criteria and methods may be used subject to approval of NAVSEA.

3.4.1.2.9 Variable frequency AC system loads. PECE outputs connected to variable frequency AC system loads shall be as specified (see 6.2).

3.4.2 Electromagnetic interference (EMI). PECE input and output shall be in accordance with the EMI requirements of MIL-STD-461 for surface ship, below deck, and submarine (internal to pressure hull) installations. The DC resistance measured from the conduction frame of an assembly receiving primary power and the unit electrical bond point shall not exceed 2.5 milliohms in accordance with MIL-STD-461. The emission and susceptibility requirements shall be performed in accordance with MIL-STD-461.

3.4.3 Electromagnetic pulse (EMP). When specified (see 6.2), PECE shall be designed to meet the ship's specific EMP requirements and be in accordance with MIL-STD-461.

3.4.4 DC magnetic field emission. PECE shall be in accordance with the DC magnetic field susceptibility requirements of DOD-STD-1399-70-1.

3.4.5 Magnetic field reduction. When specified (see 6.2), magnetic field reduction shall be provided in accordance with MIL-DTL-917.

3.4.6 Regenerated power. When specified (see 6.2), regenerative power (see 6.4.20) shall be controlled by PECE.

3.4.6.1 Unidirectional PECE. Unidirectional PECE that is subject to regenerated power shall provide protection to prevent backfeed via blocking diodes or by actions of the control system. A means to dissipate regenerative energy shall be provided.

3.4.6.2 Bidirectional PECE. Bidirectional PECE that is subject to regenerative power shall provide protection for overcurrent and overvoltage on both interfaces.

3.4.7 Electrical insulation. Electrical insulating materials shall be in accordance with the requirements of MIL-DTL-917.

3.4.8 Isolation means. PECE shall provide input and output galvanic isolation (see 6.4.7) in order to electrically isolate PECE in the event of an internal component failure and allow for a tag to be applied in accordance with S0400-AE-URM-010/TUM. The isolation shall provide visible indication of opened and closed status with means to tag-out the device in the open position, and shall have interlock circuit to prevent operation while a source of power is applied. For circuits where the positive voltage check is not available, a means shall be provided to perform the positive voltage check. When specified (see 6.2), input power terminals shall be galvanically isolated (such as using an isolation transformer) from output power terminals.

3.4.9 Insulation systems. PECE insulation systems shall be in accordance with MIL-DTL-917. Systems above 1000 volts shall be as specified (see 6.2).

3.4.10 Insulation resistance. The insulation resistance from conductor to conductor and conductor to ground shall be not less than 10 mega ohms at 77 °F (25 °C), in accordance with MIL-DTL-917. User equipment shall tolerate the test voltage between each power conductor and ground without equipment damage, arc-over, degradation, or abnormal operation. Systems above 1000 volts shall be as specified (see 6.2).

3.4.11 Surge voltage withstand capability. PECE shall be designed to withstand a surge voltage test in accordance with IEC 61000-4-5.

3.4.12 Dielectric withstand. The dielectric withstand voltage for each circuit shall be determined by the voltage rating of the circuit, in accordance with MIL-DTL-917. If no assigned rating, the maximum voltage of the circuit considering all conditions of the equipment operation at rated voltage shall be used. Systems above 1000 volts shall be as specified (see 6.2).

3.4.13 Creepage and clearance distances. Creepage over surface and clearance through air spacing between electrical circuits shall be in accordance with MIL-DTL-917. When commercial power electronic devices are used such as control card assemblies, active or passive components, IGBTs, diodes, and other semiconductor devices, the creepage and clearance distances shall be accordance with UL 840 considering the PECE system operating voltage, Pollution Degree (PD), and the Comparative Tracking Index (CTI) of the insulation material. Since UL 840 tables have been found to be too low for the Navy environment, a minimum PD of 3 and CTI of IIIa shall be used for all Navy applications. When the operating voltage is in between the value cited in the requirement, the higher voltage rating shall be used.

3.4.14 Grounding, bonding, and shielding. PECE electrical grounding, bonding, and shielding provisions shall be in accordance with MIL-STD-1310. The provision shall be available for terminating the cable ground shields on incoming and outgoing cables. MIL-HDBK-454 may be used for guidance for testing with Wheatstone bridge or equivalent method.

3.4.15 Chassis grounding. All external parts capable of electrical conduction shall be at ground potential at all times in accordance with MIL-STD-1310. All removable covers with indicators, controls, or any electrical device over 30 volts shall be bonded to main structure.

3.4.16 Circuit grounding. Equipment shall be designed to operate satisfactorily from an ungrounded ship's power system in accordance with MIL-STD-1399-300 or MIL-STD-1399-680. Grounding of this system shall not cause improper operation of the equipment. Input isolation transformers or blocking diodes on each phase may be considered to mitigate system level ground fault issues. Unless otherwise specified (see 6.2), the equipment circuitry shall not be electrically connected to ship's hull (ground), except for electrical and magnetic interference filters in accordance with MIL-STD-1399-300.

3.4.17 Safety leakage current. The leakage current shall be in accordance with MIL-STD-1399-300. In the event that required line filters results in ground current that exceeds this limit, NAVSEA approval shall be required along with provision of onboard monitoring of this parameter.

3.4.18 Line filter capacitors to ground. For AC systems, line-to-ground filter capacitance shall be in accordance with MIL-STD-1399-300. For high voltage AC systems, high resistance-grounding scheme shall be used in accordance with MIL-STD-1399-680.

3.4.19 Common mode current. When specified (see 6.2), PECE shall monitor common mode current on all input and output interfaces. PECE shall report alarm when it exceeds the common mode current limits as specified (see 6.2). When PECE is part of a subsystem, common mode current shall be coordinated with ground fault detection and location. When specified (see 6.2), PECE shall provide internal or external input isolation transformer or blocking diodes on each phase to isolate common mode ground current propagation when a PECE output is grounded.

3.4.20 Ground fault detection. When specified (see 6.2), PECE shall provide ground fault detection capability with adjustable threshold to continuously monitor the system and provide alarm when ground fault condition exists on any input interface, internal bus link, and output interface. PECE shall be capable of detecting impedance (both resistive and reactive) to ground as specified (see 6.2), without affecting the ground isolation of the system.

3.4.21 Ground fault location. When specified (see 6.2), PECE shall be capable of locating the ground fault upstream, internal, or downstream to an individual interface without requiring operator intervention or interruption of power to the load and report the location locally and remotely as specified (see 6.2).

3.4.22 Internal wiring. PECE internal instrumentation and control wiring shall be flame retardant and stranded type. Wiring shall be in accordance with MIL-DTL-16878.

3.4.23 Cable lug terminals. Where used, cable lug terminals shall be in accordance with MIL-T-16366 and MIL-DTL-917. Terminal lugs used for power connection shall be of the two-hole design in order to prevent lug rotation and to share the stress on the fasteners. Alternative means of anti-rotation requires NAVSEA approval prior to incorporation.

3.4.24 Wire identification. Wire identification shall be in accordance with MIL-DTL-917.

3.4.25 Wire, wiring methods, and marking. Wire, wiring methods, and marking shall be in accordance with MIL-DTL-917. Color-coded wire may be used in accordance with MIL-STD-681.

3.4.26 Semiconductor device selection. The selection, performance, and testing of semiconductor devices used in PECE shall be in accordance with MIL-PRF-19500.

3.4.27 Electrical connectors. Connectors for cables conforming to MIL-DTL-24640 and MIL-DTL-24643, as applicable, shall be selected in accordance with MIL-STD-1683. Connector backshells shall be in accordance with SAE-AS-85049.

3.4.28 Fusing. Fuses shall not be used for system fault isolation or reconfiguration. Fuses shall only be used to prevent catastrophic failure events within PECE. The location and accessibility of the fuses shall be designed to meet or exceed the MTTR requirement (see 3.5.5) of the specific PECE.

3.4.29 Endurance. Unless otherwise specified (see 6.2), PECE shall meet 100-hour burn-in test requirements as specified (see 4.29), and accelerated life requirements as specified (see 4.29.1).

3.4.30 Efficiency. Unless otherwise specified (see 6.2), input-to-output total efficiency shall be 95 percent or greater at rated load and 90 percent or greater at loads greater than 80 percent up to rated load. The partial load efficiencies shall be as specified (see 6.2). The no-load losses of PECE shall not exceed 1 percent of nominal rating. All integrated auxiliary components required for the operation of the PECE component shall be included in the efficiency calculation.

3.5 Reliability.

3.5.1 Reliability. PECE shall be designed, such as to prevent single-point failures and nuisance shutdowns, to meet the operational availability (Ao) as specified (see 6.2). For nuisance shutdowns, protective mechanisms such as door interlocks, leak detection, and over-temperature detection as well as control components such as processors and data converters may have the necessary redundancy to prevent a single occurrence from violating the required Mean Time Between Failure (MTBF) of PECE, as specified (see 3.5.4). Redundant components shall provide the full functionality of the primary component(s) without loss of control, communication, or indication when the primary component has failed.

3.5.2 Derating. The PECE parts shall be derated in accordance with Appendix D and MIL-DTL-917; where there are conflicting requirements between the two, Appendix D shall take precedence. SAE-GEIA-STD-0008 and MIL-HDBK-338 may be used for guidance, as appropriate. Unless otherwise specified (see 6.2), the more conservative values shall be applied when there is a derating conflict.

3.5.2.1 Discrete semiconductor derating and application stresses. Semiconductor devices rated 5 amperes and less are based on the absolute system in accordance with the definitions appendix of MIL-PRF-19500. Power diodes and silicon-controlled rectifiers (SCRs) above 5 amperes shall follow the application stress limits and derating factors in Appendix D. These ratings shall not be exceeded under any service or test. No two of the rated values (for example, voltage and current) shall be imposed at the same time. Semiconductor devices shall be chosen and applied in such a way that the worst stress of each type imposed on the device with any available setting of adjustable circuit parts does not exceed its rated value for that stress factor as specified by the applicable device detail specification. This shall include stresses under surge or transient conditions from clearing of grounds, shorts, or other faults on the power system that may result from operation of protective devices.

3.5.3 Service life. Unless otherwise specified (see 6.2), non-LRU component parts of PECE, such as enclosure structural members, power transformers, and other such large components that require major disassembly, shall have a minimum life of 20 years. The equipment components shall be selected such that components will be available for the life of the equipment and suitable to be upgraded to newer technologies. When specified (see 6.2), the PECE will have an obsolescence plan.

3.5.4 Failure rate. PECE shall be designed for a calculated MTBF of no less than 25,000 hours and should follow the guidance of MIL-HDBK-338. IEEE-STD-1413 shall be used for reliability prediction of hardware utilizing IEEE-STD-1413.1 for prediction methodology.

3.5.5 Repair rate. PECE shall be designed with LRUs that provide a MTTR of 1 hour or less including detection, isolation, removal, replacement, verification, and return to operation.

3.6 Protection requirements. PECE shall provide adequate protection for the function it is designed to perform. The alarm and fault data shall be available in non-volatile memory, so that it is retrievable after a unit shutdown.

3.6.1 Personnel safety. PECE shall be designed and constructed in a way that will ensure safety to operating and maintenance personnel. Guidance for design for personnel safety can be found MIL-HDBK-454.
The minimum design and construction safety criteria to ensure safety of operating and maintenance personnel are as follows:

a. PECE shall be designed to prevent operating personnel from receiving an electric shock due to an internal fault between any two circuits, between any circuit and a structural member, or between any circuit and ground.

b. The exposure of maintenance personnel to hazardous voltages (see 3.10.1) while servicing, adjusting, or inspecting the equipment shall be minimized. For access to such circuits, further positive action shall be required to remove a cover or open a portion of the guard means.

c. A warning plate shall be prominently displayed to remind the maintenance personnel of appropriate precautions to ensure de-energization of the guarded circuit.

d. External moving parts which are a potential hazard to personnel shall be avoided. When their use is unavoidable, positive protection in the form of a guard shall be provided.

e. Sharp corners and projections which may cause injury or catch on clothing shall be avoided.

f. The exposure to burn hazard shall be in accordance with MIL-STD-1472. Exposure to excessive enclosure temperature shall be avoided.

3.6.2 Overvoltage protection. PECE shall have protection from excessive output terminal voltage variation and transients. After recovery, PECE shall operate and supply the load with the same output voltage that was provided prior to the output overvoltage. PECE output voltage shall be controlled in such a way to prevent PECE component failure due to output overvoltage condition. The overvoltage protection set point, as specified (see 6.2), shall be adjustable by the user at the operator interface to permit adjustment.

3.6.3 Input overcurrent protection. PECE shall have input overcurrent protection to protect internal power electronic components from cascading failure due to short circuits internal to PECE. The input overcurrent protection set point, as specified (see 6.2), shall be adjustable by the user at the operator interface to permit adjustment. Input protection shall be as specified (see 3.6.11).

3.6.4 Output overcurrent protection. PECE shall have protection from output overcurrent so that the permissible current of the equipment cannot be exceeded during normal operation. The output overcurrent protection set point and duration, as specified (see 6.2), shall be adjustable by the user at the operator interface to permit adjustment.

3.6.5 Short-circuit current limiting function. PECE shall have a current limiting function that limits its output current for external fault protection against short circuit current. When specified (see 6.2), PECE shall be capable of managing the fault current limit duration and avoiding shutdown. PECE fault current limiting feature shall be adjustable. The equipment shall automatically shut down when the output current exceeds the specified short circuit duration.

3.6.6 Inrush current protection. PECE and PECE modules shall limit the input inrush current to a level consistent with the rating of the unit and power system operation and protection levels in accordance with MIL-STD-1399-300 or MIL-STD-1399-680, as applicable.

3.6.7 Over-temperature protection. PECE components such as, but not limited to, transformers, inductors, power modules, and control devices shall be protected from damage and shut down resulting from exceeding component maximum rated temperature.

3.6.8 High temperature warning or alarm. High-temperature audio and visual alarm shall be provided for an early warning of the high temperature fault level condition. Warnings shall not occur at or below the maximum ambient operating temperatures. Cooling mechanism failure shall not be used to secure the unit.

3.6.9 Firefighting measures. When specified (see 6.2), PECE enclosures shall be designed to provide fixed fire suppression interface or means to self-extinguish. Provisions shall be made to minimize fire propagation inside compartments and outside the PECE enclosure via fire-stopping means.

3.6.10 Electrostatic discharge (ESD) protection requirements. Electronic parts and assemblies that are subject to electrostatic discharge (ESD) damage shall be handled and packaged in accordance with MIL-STD-1686 and using the guidance provided in MIL-HDBK-263. Electrostatic discharge sensitive (ESDS) parts shall be marked in accordance with MIL-STD-129. The symbol shall be located in a position readily visible to personnel when that assembly is incorporated into its next higher assembly.

3.6.11 Input protection. PECE shall support coordination of system protection and shall shut down automatically when a potentially catastrophic internal fault condition occurs. Disconnecting means via contactor, fuse, or circuit breaker shall be provided locally within the unit as specified (see 6.2). The local disconnecting means shall be rated to interrupt the full fault current and shall only be activated when overcurrent, short circuit, and catastrophic fault protection have not cleared the fault. The disconnecting means shall be in a separate compartment or have barrier provisions in order to prevent exposure to any live surfaces when in the open or disconnected position. In addition to the local means of isolation, when the unit is rated greater than 100A nominal current, a shunt trip signal shall be sent to the input source(s) for isolation upon detection. For units rated less than 100A nominal current, an internal circuit breaker may be utilized for this protection. The input protection shall be coordinated so that there are no nuisance trips. The input circuit breaker shall be accessible to the operator for reset without breaking the electrical plane. Common mode ground current isolation requirements are specified in 3.4.19.

3.6.12 Emergency stop or output disable. PECE shall provide local operator control to shut down the equipment and de-energize the output(s). When specified (see 6.2), the emergency stop or output disable interface shall provide remote shutdown functionality. The local emergency stop/output disable operator shall be colored red and shall be covered or guarded. The operator control shall also act to disable PECE output(s) to electrically isolate the output(s) of PECE. If the external shunt trip power is derived internally, provisions shall be put in place to prevent an external event from causing damage to PECE control circuit. The emergency stop or output disable circuit design shall be fail-safe, causing a trip in the event of cable damage. When remote control is specified (see 6.2), PECE shall have the ability to accept external hard-wired emergency stop or output disable signal. The emergency stop or output disable circuit shall be a hard-wired interface without any software control processing in the loop.

3.6.13 Arc fault detection. When specified (see 6.2), arc fault detection shall be provided.

3.6.14 Crowbar circuits. When specified (see 6.2), a crowbar circuit (see 6.4.4) shall be provided.

3.6.15 Partial discharge. When specified (see 6.2), PECE shall be designed to be partial discharge-free (corona-free) with an acceptance criteria of less than 10 to 15 picocoulombs.

3.6.16 Fault isolation. Fault isolation prevents catastrophic events on individual modules from interfering with the PECE overall operation. Fault isolation shall be provided for input, internal bus link and output voltage interfaces. PECE modules shall provide isolation between each field circuits, resulting in increased noise immunity and limited damage to the system due to an electrical malfunction of the field wiring. PECE shall continue to operate within required power quality parameters in the event of input power quality fluctuations and any load variations inside MIL-STD-1399-300 interface requirements.

3.7 Control interface.

3.7.1 Supervisory control and data acquisition (SCADA). PECE shall provide local supervisory control and data acquisition (SCADA). When specified (see 6.2), remote SCADA shall be provided. The controller shall be capable of, but not limited to, managing the following:

a. Operator interface controls.
b. Operator interface indications.
c. Internal controls.
d. External controls.
e. Internal communications.
f. External communications.
g. Safety interlocks.
h. Safety functions.

3.7.2 Operator interface controls and indicator design criteria. The PECE operator interface controls and indicators shall be designed as specified in MIL-STD-1472. Component selection shall be in accordance with MIL-DTL-917. PECE shall provide internal controls to safely operate, troubleshoot, and maintain PECE as designed. When specified (see 6.2), PECE shall provide external controls to safely operate, troubleshoot, and maintain external equipment.

3.7.3 Human machine interface (HMI). When specified (see 6.2), an HMI shall be capable to operate PECE. The HMI shall be accessible from the front of the enclosure. HMI operator interface design, including manual operation (i.e., pushbuttons), indicating lights, and video screen shall follow standard design practices as detailed in MIL-STD-1472. Emphasis shall be placed on graphic illustration of operating status. Monitored conditions required as specified (see 6.2) for operation (e.g., voltage, current, frequency, temperatures, flow rate, switch positions, or other parameters) shall be displayed in a graphical format which does not require cross-referencing other screens.

3.7.4 Communications. PECE shall be able to communicate all control, status, alarm, and fault information internally and externally as specified (see 6.2).

3.7.4.1 Internal communications. PECE with embedded software (firmware) shall have communication protocols, as specified (see 6.2). Infrared and radio frequency (RF) communications shall not be allowed.

3.7.4.2 External communications. PECE external communications shall be transmitted via a link as specified (see 6.2). During a loss of external communications, PECE shall remain in the last commanded state and autonomously perform self-protection functions. External communication connectivity (health) shall be accessible by the PECE operator interface. When specified (see 6.2), PECE shall provide visual and audible alarms upon loss of communication.

3.7.5 Control mode switch. When remote SCADA is specified (see 3.7.1), a physical switch shall be provided at the PECE operator interface to deselect and select the controlling station. When the switch is in the local position, remote communication and indication shall be maintained, but the remote control shall not be functional. When the switch is in the remote position, operation and indication functions of the HMI shall be maintained, but local control (with the exception of output disable/emergency stop) shall not be functional.

3.7.6 Operating states. Unless otherwise specified (see 6.2), PECE shall have the following operating states as identified below:

a. Off: A state where all source power to PECE is secured.

b. Self-powered: A state where only PECE control and auxiliary power is available.

c. Power available: A state where PECE main input power is available.

d. Standby: A state where PECE internal link voltage is available and output power is off.

e. Online: A state where PECE output power is energized.

f. Faulted: A state where PECE output power is disabled due to a fault.

3.7.7 Event reporting and response. PECE control system shall provide indication and response to internal or external events classified as alarms, faults, and catastrophic faults. These events shall be identified to the sub-component level and, if necessary, isolated autonomously so that power continuity is maximized, equipment damage is avoided, and human safety ensured. Each event, regardless of type, shall be reported and placed in a fault stack in the order in which they occur. Unless otherwise specified (see 6.2), each event shall be date-and-time-stamped and synchronized to local time. A log of all events shall be maintained as specified (see 3.7.13).

3.7.7.1 Alarms. PECE shall report an alarm to indicate an abnormal operating condition internally or externally that may affect the safe and reliable operation of the equipment but does not require immediate shutdown of PECE or its subcomponents. Alarms shall be reported locally and remotely via visual and audible indication, as specified (see 6.2). The operator shall be capable of silencing audible alarms. PECE shall latch the alarm on until a reset command is issued locally or remotely. The alarm shall clear when the operating condition returns to normal and the reset has already been activated for that alarm.

3.7.7.2 Faults. PECE shall report a fault for an abnormal external or internal operating condition that requires immediate shutdown of PECE or one of its subcomponents. PECE shall secure the necessary components or subcomponents to protect the equipment in response to the fault detected. PECE shall maintain subcomponents and systems which can be safely operated during the fault in order to provide availability of non-affected outputs. Faults shall be reported locally and remotely via visual and audible indication, as specified (see 6.2). A fault shall not be cleared until a local or remote reset has been issued to acknowledge the condition and the condition that caused the fault no longer exists. Component failure or fault shall be identified to the LRU's level and indicated locally or remotely, as specified (see 6.2).

3.7.7.3 Catastrophic faults. PECE shall de-energize its output and coordinate input isolation from the system during an abnormal operating condition that requires immediate shutdown to protect equipment and personnel from catastrophic damage; this is a catastrophic fault. In the case of a catastrophic fault, PECE shall shut down safely and inhibit a remote or automatic startup. The catastrophic fault shall be a latched fault reported locally and remotely as applicable via visual and audible indication. The visual indication and inhibit function shall only be reset from the local HMI since the operator will be required to perform a visual inspection or service of the equipment prior to placing back in service.

3.7.7.4 Ground faults. PECE shall be designed to continue to operate with the presence of a single ground fault on any input interface, internal bus link, and output interface. PECE components shall be able to withstand expected system DC voltage offset at the interface due to grounded condition at any location in the power distribution system.

3.7.8 Control power supplies. PECE control power supply shall be self-derived internally or externally supplied (see 6.2). Visual indication that is not dependent on any other portion of the equipment functioning shall be provided to indicate when each individual power supply power source is available. Visual indication of the availability of each power supply output shall be provided. When specified (see 6.2), PECE shall include multiple power supplies for controls.

3.7.8.1 Parallel power supplies for redundancy. When paralleled control power supplies fed from a single power source are provided for redundancy, the interconnection of the power supplies shall be such that a fault in one supply does not reduce the output voltage of the other(s). Each power supply shall be capable of furnishing the power requirements of the load circuit under worst case conditions of both input line voltage and frequency, including voltage and frequency transients, temperature, and complete loss of voltage from one source.

3.7.8.2 Parallel power supplies for increased load capability. Paralleled control power supplies fed from a single power source may be used for increased load capability to utilize a standard power supply design. These combined paralleled power supplies are subject to the same design requirements herein.

3.7.9 Backup power. Unless otherwise specified (see 6.2), upon loss of main input power, PECE controls shall remain powered for a minimum of 30 minutes. The alarm and status messages shall remain in non-volatile memory so that it can be retrieved after a system power loss. Indication of time remaining on stored energy shall be provided and displayed during all modes of operation. Indication shall also be provided for standby, discharging, and disconnected states. Any battery charging (see 6.4.1) system shall provide protective measures as specified in MIL-DTL-24765.

3.7.10 Configuration settings. When specified (see 6.2), PECE configuration settings shall be affixed in an easily accessible location on PECE in accordance with MIL-DTL-15024.

3.7.11 Cybersecurity. PECE cybersecurity (see 6.4.5) design shall follow requirements for a secure industrial control system (ICS) in accordance with NIST Special Publications 800-53 and 800-82. ICS includes SCADA systems, distributed control systems (DCS), and other control system configurations such as Programmable Logic Controllers (PLC) that are often found in the industrial control sectors. PECE shall contain interfaces for external digital communications, whether used or unused. Cybersecurity shall be in accordance with Appendix E.

3.7.11.1 Cybersecurity plan. A PECE cybersecurity plan shall be as specified (see 6.2) and approved by NAVSEA.

3.7.12 Username and password protection. When specified (see 6.2), username and password protection shall be required for changing settings and operational characteristics. Username and password protection shall not be required for standard operation of PECE. Sensitive adjustable parameters shall require a supervisor-level security password. Sensitive factory adjustable parameters shall require a technical representative-level password.

3.7.13 Logging. Changes in operating state, alarm conditions, and faults shall be logged. Fault data shall be stored sequentially and log entries shall be date-and-time-stamped and synchronized to local time. When the logging memory buffer is exceeded, PECE shall overwrite the oldest logs first and provide a memory buffer full alarm. A separate means to clear alarms shall be provided on the HMI. Alarm reset shall not clear alarm history. The minimum number of event logs to maintain shall be as specified (see 6.2).

3.7.14 Fiber optic connectors and assemblies. Fiber optic assemblies used in PECE shall be assembled and installed in accordance with MIL-STD-2042. Fiber optic connectors shall comply with the requirements of MIL-DTL-83522 or MIL-PRF-28876 as applicable.

3.7.15 Controller start-up. Unless otherwise specified (see 6.2), PECE controller start-up (see 6.4.2) time shall be no greater than 2 minutes.

3.7.16 Printed wiring assemblies. PECE printed wiring assemblies shall be as specified in MIL-DTL-917.

3.7.17 Data entry devices. Data entry for alignment configuration shall be accomplished using either built in or portable data entry device. Data entry device hardware and software shall be as specified (see 6.2).

3.8 Acoustic requirements.

3.8.1 Airborne noise. Unless otherwise specified (see 6.2), PECE airborne noise shall not exceed the levels listed in MIL-STD-1474.

3.8.2 Structure-borne noise. Unless otherwise specified (see 6.2), PECE structure-borne noise shall not exceed the levels listed in MIL-STD-740-2.

3.9 Environmental requirements.

3.9.1 Temperature. PECE shall meet the operating and non-operating temperature requirements of MIL-DTL-917.

3.9.1.1 Temperature measurement. Temperature measurement shall be in accordance with MIL-DTL-917, Methods 2 or 3.

3.9.2 Humidity. PECE shall operate satisfactorily during and subsequent to exposures to relative humidity in accordance with MIL-STD-810. PECE enclosure and module shall include measures to prevent condensation accumulation and include preventive measures to minimize damage in the event of water runoff.

3.9.3 Moisture and condensation. When specified (see 6.2), PECE shall be designed with effective means to prevent accumulation of moisture and condensation within the enclosure when de-energized. Space heaters shall be used that automatically energize when equipment is de-energized and vice versa. Leak detection shall be provided in accordance with 3.2.16.3.

3.9.4 Shock. PECE shall meet application-specific grade and class requirements, as specified (see 6.2), in accordance with MIL-S-901. Unless otherwise specified (see 6.2), PECE shall be tested while the unit is energized and providing output power.

3.9.5 Vibration. PECE shall meet the application-specific vibration requirements, as specified (see 6.2), in accordance with MIL-STD-167-1. Unless otherwise specified (see 6.2), PECE shall be tested while the unit is energized and providing output power.

3.9.6 Inclined operation. Unless otherwise specified (see 6.2), PECE shall meet performance specifications during inclined operation in accordance with design limits for surface and submarine naval vessels motion as specified in DOD-STD-1399-301.

3.10 Electrical safety. PECE electrical safety requirements shall be in accordance with MIL-DTL-917 and follow safety guidance of S9086-KC-STM-010/300. Recommended practices for electrical safety shall be used in accordance with IEEE-STD-3007.3.

3.10.1 Voltage protection. Safety requirements with regards to hazardous voltages shall be in accordance with S9086-KC-STM-010/300.

3.10.2 Electrical tag-out. PECE shall be designed to provide tag-out protection in accordance with S0400-AD-URM-010/TUM. When specified (see 6.2), the PECE tag-out shall be demonstrated to support MTTR (see 3.5.5).

3.10.3 Maintenance isolation. PECE shall have isolation means to galvanically isolate all inputs and outputs that provide:

a. Means to discharge internal bus.

b. Visible indication of isolation device status (open or closed).

c. Means to tag-out isolation device.

d. Access and means to install ground cluster.

e. Interlock circuit to prevent device operation while source is applied.

f. Safe and effective means to measure the voltage on the (input and output) bus connection.

3.10.4 Grounding means. PECE shall be grounded in accordance with MIL-STD-1310. PECE shall have means to connect grounding clusters during repair or maintenance period in accordance with S9086-KC-STM-010/300.

3.10.5 Stored energy. When PECE is subject to stored energy such as capacitors, batteries, or stray voltages, S9086-KC-STM-010/300 shall be used to remove the potential energy.

3.10.6 Warning and caution plates. Warning and caution plates shall be formatted in accordance with MIL-STD-1472.

3.10.7 Danger plates. Danger plates shall be supplemented by physical barriers or other positive protection where feasible. Danger plates reading “DANGER – HIGH VOLTAGE” or “DANGER [insert maximum voltage] VOLTS” shall be displayed prominently on safety covers, access doors, and inside equipment where hazardous voltages are exposed. Markings on electrical equipment shall be in accordance with NFPA 70E.

3.10.8 Arc flash. PECE shall be designed for Incidental Energy (IE) and arc flash in accordance with IEEE-STD-1584. PECE shall be designed to meet the level of fault current available from the source and provide source protection by removing the fault, as specified (see 6.2). PECE shall be marked with the ratings and arc flash boundaries for personnel safety in accordance with S9086-KC-STM-010/300 and NFPA 70E.

3.10.9 Arc blast. PECE shall be designed to contain the arc blast energy of any internal power component within the cabinet when all covers are secured. When specified (see 6.2), pressure relief rupture discs shall be used.

3.10.10 Battery source isolation. PECE with internal or external battery source shall include both manual and automatic disconnect means. The manual disconnect shall provide a means for galvanic isolation of the input and output of the energy storage device(s). The energy storage disconnects shall be accessible to the operator for tag-out during routine maintenance. The automatic disconnect function shall provide isolation upon detection of a battery system fault condition.

3.11 Instruction sheets. When specified (see 6.2), instruction sheets shall be provided for PECE operation. The information shall be protected in accordance with MIL-DTL-2036.

3.12 Diagrams for customer interface. PECE shall include wiring and schematic diagrams necessary for inspection and troubleshooting. The information shall be protected in accordance with MIL-DTL-2036, Method 1 and shall be attached to the inside of the enclosure in accordance with MIL-DTL-2036. Wiring diagrams shall include wire numbers, component identification, and fuse size and type, if applicable.

3.13 Embedded software. Embedded software (firmware) used in PECE shall appear on the nameplate by name and part number, the version number or designator. Equipment furnished with embedded software and calibration software shall have software certified by independent Verification and Validation (V&V) testing to IEEE-STD-1012. Embedded software is subject to the same Configuration Management (CM) requirements as the higher level software development. All embedded software and firmware code shall be provided on a separate medium with interface tools and detailed technical instructions necessary to reload the code in the event of failure. When specified (see 6.2), software may be designed in an open architecture approach to allow for future alternative upgrade means.

4. VERIFICATION

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

a. First article inspection (see 4.2).

b. Conformance inspection (see 4.3).

4.2 First article inspection. First article inspection shall be performed on one complete PECE unit assembly of each power rating. First article inspection shall be in accordance with table I. Additional testing requirements shall be as specified (see 6.2) and approved by NAVSEA.

4.3 Conformance inspection. Conformance inspection shall be performed on each PECE offered for delivery to verify that it meets specification requirements prior to acceptance. Conformance inspection shall include the inspections specified in table I.

TABLE I. First article and conformance inspections.

Tests	Requirement paragraph	Test paragraph	First article inspection	Conformance inspection
Defects inspections	table II	4.4	X	
Manufacturing screening	3.2.4	4.5	X	X
	3.2.7.2		X	X
	3.2.9		X	X
	3.2.10		X	X
	3.4.13		X	X
	3.4.24		X	X
	3.4.25		X	X
Enclosure	3.2.5	4.6	X	
	3.3.4			
Explosion-proof	3.2.6	4.7	X	
Accessibility	3.2.8	4.8	X	
Thermal management – leak detection	3.2.16	4.9, 4.9.1	X	X
Thermal management – hydrostatic	3.2.16	4.9, 4.9.2	X	X
Thermal management – loss of cooling	3.2.16	4.9, 4.9.3	X	X
	3.6.7		X	X
	3.6.8		X	X
Module rating	3.3.3	4.10	X	
Modular replacement demonstration test	3.3.4	4.11	X	
Module galvanic isolation	3.3.9	4.12	X	
Input power quality – AC	3.4.1.1	4.13, 4.13.1	X	X
	3.4.1.2.6.1		X	
	3.4.1.2.6.4		X	
	3.4.1.2.8		X	
	3.6.3		X	X
	3.6.6		X	X
	3.6.11		X	
Input power quality – DC	3.4.1.1	4.13, 4.13.3	X	X
	3.6.3		X	X
	3.6.6		X	X
	3.6.11		X	X

TABLE I. First article and conformance inspections – Continued.

Tests	Requirement paragraph	Test paragraph	First article inspection	Conformance inspection
Output power quality – AC	3.4.1.2	4.14, 4.14.1	X	X
	3.4.1.2.1		X	
	3.4.1.2.2		X	
	3.4.1.2.3.1		X	
	3.4.1.2.3.2		X	
	3.4.1.2.3.3		X	
	3.4.1.2.4		X	
	3.4.1.2.5		X	
	3.4.1.2.6.2		X	
	3.4.1.2.6.3		X	
	3.4.1.2.7		X	X
	3.4.1.2.8		X	
	3.4.1.2.9		X	
	3.6.2		X	X
	3.6.4		X	X
	3.6.5		X	X
Output power quality – DC	3.4.1.2	4.14, 4.14.2	X	X
	3.4.1.2.2		X	
	3.4.1.2.3		X	
	3.4.1.2.3.1		X	
	3.4.1.2.3.2		X	
	3.4.1.2.3.3		X	
	3.4.1.2.4		X	
	3.4.1.2.5		X	
	3.4.1.2.6.2		X	
	3.4.1.2.6.3		X	
	3.4.1.2.8		X	
	3.6.2		X	X
	3.6.4		X	X
	3.6.5		X	X
Electromagnetic interference, emissions and susceptibility	3.4.1.2.4	4.15	X	
	3.4.2		X	
Electromagnetic pulse	3.4.3	4.16	X	
DC magnetic field testing	3.4.4	4.17	X	
Regenerated power	3.4.6	4.18	X	
Insulation suitability	3.4.7	4.19	X	
	3.4.9		X	

TABLE I. First article and conformance inspections – Continued.

Tests	Requirement paragraph	Test paragraph	First article inspection	Conformance inspection
Electrical isolation	3.4.8	4.20	X	
	3.6.12		X	
Insulation resistance	3.4.10	4.21	X	X
Surge voltage withstand	3.4.11	4.22	X	
Dielectric withstanding voltage	3.4.12	4.23	X	X
Ungrounded circuit	3.4.16	4.24		
Safety leakage current	3.4.17	4.25	X	X
Ground fault	3.4.19	4.26	X	
	3.4.20			
	3.4.21			
Semiconductor device	3.4.26	4.27	X	
Electrical connectors	3.4.27	4.28	X	
100-hr burn-in	3.4.29	4.29	X	X
Accelerated life	3.4.29	4.29.1	X	
Efficiency	3.4.30	4.30	X	X
Repairability demonstration	3.5.5	4.31	X	
Input overcurrent protection	3.6.3	4.32	X	X
	3.6.11		X	
Output overcurrent and short circuit protection	3.6.4	4.33	X	X
	3.6.5		X	X
Emergency stop or output disable	3.6.12	4.34	X	X
Crowbar circuit	3.6.14	4.35	X	
Partial discharge	3.6.15	4.36	X	
SCADA – Local control operation	3.7.1	4.37, 4.37.1	X	X
	3.7.2		X	X
	3.7.3		X	X
	3.7.5		X	X
	3.7.6		X	X
SCADA – Remote control operation	3.7.1	4.37, 4.37.2	X	X
	3.7.2		X	X
	3.7.3		X	X
	3.7.5		X	X
	3.7.6		X	X

TABLE I. First article and conformance inspections – Continued.

Tests	Requirement paragraph	Test paragraph	First article inspection	Conformance inspection
Controls communications	3.7.2	4.38	X	X
	3.7.3		X	X
	3.7.4		X	X
	3.7.4.1		X	X
	3.7.4.2		X	X
	3.7.7		X	X
	3.7.7.1		X	X
	3.7.7.2		X	X
	3.7.7.3		X	X
	3.7.13		X	X
	3.7.15		X	X
Control power supplies	3.7.8	4.39	X	
	3.7.8.1		X	
	3.7.8.2		X	
Backup power	3.7.9	4.40	X	X
Fiber optic connector and assemblies	3.7.14	4.41	X	X
Airborne noise	3.8.1	4.42	X	
Structureborne noise	3.8.2	4.43	X	
Thermal cycling	3.9.1	4.44	X	
Humidity	3.9.2	4.45	X	
	3.9.3		X	
Shock	3.9.4	4.46	X	
Vibration	3.9.5	4.47	X	
Inclined operation	3.9.6	4.48	X	
Battery source isolation	3.10.10	4.49	X	

4.4 Defects inspection. Defects inspections shall be performed on one complete PECE unit assembly of each power rating. The examination shall be conducted using the classification of defects as specified in table II, as applicable. Critical defects shall include, but are not limited to, personnel and equipment safety. Major defects shall include, but are not limited to, equipment design flaws that may compromise the performance of PECE. Minor defects shall include, but are not limited to, design defects that may not compromise the performance of PECE. Noncompliance with any specified requirements or presence of one or more defects preventing or lessening maximum efficiency shall constitute cause for rejection.

TABLE II. Classification of defects.

Categories	Defects	Requirement paragraph
	Critical	
001	Basic design requirements not in accordance with applicable specification, standard, and specified requirements.	3.2.1
002	Prohibited materials are used.	3.2.3.2
003	Enclosure not in accordance with applicable documents and specified requirements.	3.2.5 1/
004	When specified (see 6.2), explosion-proof design not in accordance with applicable specification and specified requirements.	3.2.6 1/
005	Bus bars design, plating, and installation not in accordance with applicable specification and not as specified.	3.2.14
006	Thermal management not in accordance with applicable specification and specified requirements.	3.2.16 1/
007	Liquid-cooled transformer or inductor not in accordance with applicable standards and not as specified.	3.2.17
008	Modular design not as specified.	3.3.1
009	Module accessibility not as specified.	3.3.2
010	Module rating not as specified.	3.3.3 1/
011	When specified (see 6.2), modules not designed as line-replaceable units as required.	3.3.4 1/
012	Module cooling medium interface not as specified.	3.3.5
013	Module galvanic isolation not provided as required and design does not allow for compliance to tag-out requirements.	3.3.9 1/
014	Insulating materials not as specified.	3.4.7 1/
015	PECE galvanic isolation not provided as required and design does not allow for compliance to tag-out requirements.	3.4.8 1/
016	Grounding, bonding, and shielding not in accordance with applicable standard and not as specified.	3.4.14
017	Chassis grounding not in accordance with applicable standard and not as specified.	3.4.15
018	Fusing not as specified.	3.4.28
019	Design for reliability not as specified.	3.5.1
020	PECE parts not derated in accordance with applicable specification, technical manual, and specified requirements.	3.5.2
021	Use of discrete semiconductor not in accordance with derating and application stresses specified.	3.5.2.1
022	MTBF prediction not provided in accordance with specified standard and does not meet requirement.	3.5.4
023	Personnel safety not as specified.	3.6.1
024	Input protection not provided as required.	3.6.11 1/
025	Emergency stop or output disable not provided and when specified (see 6.2), remote shutdown functionality not as specified.	3.6.12 1/

TABLE II. Classification of defects – Continued.

Categories	Defects	Requirement paragraph
	Critical	
026	When specified (see 6.2), PECE visual and audible alarms not provided.	3.7.4.2
027	Operating states not provided as required.	3.7.6 1/
028	PECE control system event reporting and response not as specified.	3.7.7 1/
029	PECE alarm system design and operation not as specified.	3.7.7.1 1/
030	PECE fault system design and operation not as specified.	3.7.7.2 1/
031	PECE catastrophic fault system design and operation not as specified.	3.7.7.3 1/
032	PECE controls backup power system not designed to applicable specifications and not as specified.	3.7.9 1/
033	Cybersecurity not approved or implemented in accordance with applicable standards.	3.7.11, 3.7.11.1, Appendix E
034	Temperature measurement not as required.	3.9.1.1
035	PECE electrical safety not in accordance with applicable specification and recommended practices.	3.10
036	Voltage protection for hazardous voltages not as required.	3.10.1
037	PECE is not designed to meet electrical safety tag-out requirements.	3.10.2
038	Maintenance galvanic isolation for electrical safety not as specified.	3.10.3
039	PECE grounding means for electrical safety not in accordance with applicable standard and as specified.	3.10.4
040	PECE stored energy design not as required.	3.10.5
041	Warning and caution plates not as specified.	3.10.6
042	PECE danger plates not provided in accordance with applicable standard and not displayed as required.	3.10.7
043	Arc flash calculation not provided as required.	3.10.8
044	PECE marking for arc flash boundary not as required.	3.10.8
045	When specified (see 6.2), arc blast rupture disc not provided as required.	3.10.9
046	Battery source isolation not provided as required.	3.10.10 1/
	Major	
101	Size and weight not as specified.	3.2.2
102	Materials not as specified.	3.2.3
103	Use of recycled, recovered, environmentally preferable, or biobased materials are not considered.	3.2.3.1
104	Processes not in accordance with applicable specification and specified requirements.	3.2.4 1/
105	Painting not in accordance with applicable specifications.	3.2.4.1
106	Cable entrance hardware not in accordance with applicable specification.	3.2.7.1

TABLE II. Classification of defects – Continued.

Categories	Defects	Requirement paragraph
Major		
107	When specified (see 6.2), multi-cable transit not used.	3.2.7.1
108	Cable installation not in accordance with applicable specification and not as specified.	3.2.7.2
109	Accessibility not as specified.	3.2.8 1/
110	Equipment identification not in accordance with applicable specification, standard, and specified requirements.	3.2.9
111	Labeling not in accordance with applicable specification and specified requirements.	3.2.10
112	Parts selection not in accordance with applicable specification and specified requirements.	3.2.11
113	Component not specified in an open architecture approach.	3.2.11
114	Fasteners not in accordance with applicable specification and specified requirements.	3.2.12
115	When specified (see 6.2), grab rails not provided in accordance with applicable standard and as required.	3.2.13
116	Component location not as specified.	3.2.15
117	Human engineering not in accordance with applicable standard.	3.2.18
118	Module communication not as specified.	3.3.6
119	Module control connection not as specified.	3.3.7
120	Module electrical connection not as specified.	3.3.8
121	Input power sharing not adjustable as required.	3.4.1.2.6.1 1/
122	Module sharing not adjustable as required.	3.4.1.2.6.2 1/
123	Output sharing not adjustable as required.	3.4.1.2.6.3 1/
124	Voltage and frequency interaction not as required.	3.4.1.2.6.4
125	System stability not as required.	3.4.1.2.8
126	Magnetic field reduction not as required.	3.4.5
127	Insulation system not selected as required.	3.4.9 1/
128	Creepage and clearance distances not as specified.	3.4.13
129	Line filter capacitance not as required.	3.4.18
130	When specified (see 6.2), PECE common mode current not as required.	3.4.19
131	When specified (see 6.2), ground fault detection not as required.	3.4.20
132	When specified (see 6.2), ground fault location detection capability not as required.	3.4.21
133	Internal wiring not in accordance with applicable specification and not as specified.	3.4.22

TABLE II. Classification of defects – Continued.

Categories	Defects	Requirement paragraph
Major		
134	Cable lug terminals not in accordance with applicable specifications and not as specified.	3.4.23
135	Wire identification not as required.	3.4.24
136	Wire, wiring methods, and marking not in accordance with applicable specification and standard.	3.4.25
137	Semiconductor device selection not in accordance with applicable specification.	3.4.26 [1/]
138	Electrical connectors not in accordance with applicable specifications and not as specified.	3.4.27 [1/]
139	Service life prediction not as required and spare parts support not as specified.	3.5.3
140	Overvoltage protection set point not adjustable by operator at HMI.	3.6.2
141	Input overcurrent protection set point not adjustable by operator at HMI.	3.6.3 [1/]
142	Output overcurrent protection set point not adjustable by operator at HMI.	3.6.4 [1/]
143	Short circuit protection set point not adjustable by operator at HMI.	3.6.5 [1/]
144	When specified (see 6.2), fire-fighting measures not provided as required.	3.6.9
145	ESD devices not handled, packaged, and marked in accordance with applicable standards.	3.6.10
146	When specified (see 6.2), arc fault detection not provided as required.	3.6.13
147	When specified (see 6.2), crow bar circuit not provided as required.	3.6.14
148	When specified (see 6.2), PECE design not partial discharge-free (corona-free).	3.6.15
149	When specified (see 6.2), remote SCADA not provided as required.	3.7.1 [1/]
150	Operator interface controls and indicator design criteria not in accordance with applicable standard and as required.	3.7.2 [1/]
151	When specified (see 6.2), HMI not in accordance with applicable standard and does not provide required information in the format specified.	3.7.3 [1/]
152	PECE communications capability and information not provided as specified.	3.7.4 [1/]
153	Internal communication protocols not as specified.	3.7.4.1
154	External communication link not as specified and functions not provided as required.	3.7.4.2 [1/]
155	Control mode switch not provided as required.	3.7.5 [1/]
156	Control power supplies availability indication not as specified.	3.7.8 [1/]
157	When specified (see 6.2), multiple power supplies not provided as required.	3.7.8 [1/]
158	Paralleling PECE power supplies for increased load capability not provided as specified.	3.7.8.2 [1/]
159	When specified (see 6.2), configuration settings not affixed as specified.	3.7.10
160	When specified (see 6.2), user name and password control not provided as specified.	3.7.12

TABLE II. Classification of defects – Continued.

Categories	Defects	Requirement paragraph
Major		
161	PECE data logging not provided as specified.	3.7.13 [1/]
162	Fiber optic connectors not provided in accordance with applicable specifications.	3.7.14 [1/]
163	Printed wire assemblies not provided in accordance with applicable specification.	3.7.16
164	Data entry device not as specified.	3.7.17
165	Automatic disconnect function for battery system fault not as required.	3.10.10
166	When specified (see 6.2), instruction sheets not provided for PECE and not in accordance with applicable specification.	3.11
167	Wiring and schematic diagrams for customer interface not provide as required and not in accordance with applicable specification.	3.12
168	Software identification not as required.	3.13
169	Backup version of software not provided as required.	3.13

NOTE:
[1/] Will also require verification by testing or during other testing.

4.5 Manufacturing screening test. PECE manufacturing screening tests shall be in accordance with MIL-DTL-917.

4.6 Enclosure test. Acceptability of enclosures shall be determined by performing ingress testing in accordance with MIL-STD-108.

4.6.1 Door interlocks test. While operating under normal condition and output is online, each cover, door, or power module shall be opened with an interlock. It shall be verified that the isolation means are engaged and in compliance with 3.2.5.4.

4.7 Explosion-proof test. Explosion-proof testing shall be conducted in accordance with MIL-STD-810, Method 511, Procedure II. The test report for enclosure explosion-proof approval shall be as specified (see 6.2).

4.8 Accessibility test. All PECE assemblies and subassemblies that require inspection, servicing, maintenance, repair, or replacement during the life of the equipment shall be visually examined and demonstrated to determine compliance with 3.2.8.

4.9 Thermal management test. PECE shall be tested at maximum ambient and cooling medium temperature without reduction of the rated performance criteria to meet the requirements of 3.2.16.

4.9.1 Leak detection test. PECE shall be demonstrated to meet the leak detection requirements of 3.2.16.3. When PECE is equipped with a leak detection system, each leak detector shall be exposed to a wet surface and then submerged in approved liquid to verify the leak detection alarm is activated.

4.9.2 Hydrostatic test. PECE and power modules shall withstand a cooling system hydrostatic test pressure of 225 psig for a minimum of 30 minutes without leakage and with no evidence of permanent deformation in pressure containing components. Testing shall be conducted with the cooling medium that the system is designed for, as specified (see 3.2.16).

4.9.3 Loss-of-cooling test. When cooling is lost while operating under normal condition, PECE shall provide a loss-of-cooling alarm while continuing to provide at least 60 seconds of limited or reduced load before reaching a shutdown condition. The over-temperature system shutdown set point shall be verified to be as specified (see 3.2.16).

4.10 Module rating test. PECE shall be tested to verify power module rating under operating conditions as specified (see 3.3.3). All modules in PECE shall be operated at rated load for a minimum of 4 hours.

4.11 Module replacement demonstration. With PECE fully operational, the following module replacement and access functions shall be performed:

a. Turn off module output power.

b. Remove control power to output module.

c. Remove cooling to output module.

d. Disengage the output power module from power and signal connections and pull it out to the lock position.

e. Verify that there is access for trouble shooting and maintenance while still inserted in the module slide hardware.

f. Remove module from PECE enclosure.

g. Attempt to replace power module with one that has an incompatible rating.

h. Remove incompatible power module from PECE enclosure.

i. Install compatible power module and verify operation.

4.12 Module galvanic isolation demonstration. The following electrical isolation tests shall be conducted:

a. While PECE is in operation and the power module is online, power off the module.

b. Disconnect the power module from the backplane and visually verify that it is disconnected.

c. Measure and verify there are no voltages greater than 30 volts on any input and output interface terminals of the power module in accordance with S9086-KC-STM-010/300.

4.13 Input power quality test. AC input power testing shall be performed in accordance with MIL-STD-1399-300 and MIL-STD-1399-680 for the type of power provided to PECE. PECE shall, as a minimum, be subjected to the AC input power quality tests (see 4.13.1) to verify compliance. DC input power quality testing shall be performed as specified (see 6.2). PECE shall, as a minimum, be subjected to the DC input power quality tests (see 4.13.3) to verify compliance.

4.13.1 AC input power quality tests. AC input power quality tests shall be as follows:

a. Voltage and frequency tolerances tests.

b. Voltage and frequency transient tolerance and recovery tests.

c. Voltage spike test.

d. Emergency condition.

e. Grounding.

f. User equipment power profile test.

g. Current waveform test.

h. Voltage and frequency modulation test.

i. Simulated human body leakage current tests for personnel safety.

j. Equipment insulation resistance test.

4.13.2 AC input power quality limit verification. AC input power quality limits shall be verified as follows:

a. Pulsed load limits for rotating machine power sources.

b. Limit line for currents at frequencies greater than 60 Hz.

c. Limit line for currents at frequencies greater than 400 Hz.

d. Surge current limits.

e. Surge current limits for frequencies greater than 60 Hz.

f. Electrical power system protection.

4.13.3 DC input power quality tests. DC input power quality tests shall be conducted as specified (see 6.2). At a minimum, the following DC input power quality tests shall be conducted:

a. Voltage spike test.

b. Emergency condition test.

c. Grounding test.

d. User equipment power profile test.

e. Current ripple test.

f. Simulated human body leakage current tests for personnel safety.

g. Equipment insulation resistance test.

4.14 Output power quality test. AC output power quality testing shall be performed in accordance with MIL-STD-1399-300 and MIL-STD-1399-680. The power quality shall verify the power quality of the type of power PECE must provide to the PECE output interface as defined in Appendices A and B. PECE shall, at a minimum, be subjected to the AC output power quality tests specified in 4.14.1 to verify compliance. Unless otherwise specified (see 6.2), DC output power quality shall be performed in accordance with MIL-STD-1399-390 to verify the power quality of the DC power PECE must provide to the PECE output interface as defined in Appendix C. PECE shall, at a minimum, be subjected to the DC output power quality tests specified in 4.14.2 to verify compliance.

4.14.1 AC output power quality tests. AC output power quality tests shall be as follows:

a. PECE output power profile testing.

(1) Type of power.

(2) Number of phases.

(3) Voltage (rms).

(4) Frequency (Hz).

(5) Line current magnitudes (rms).

(6) Power factor (leading or lagging).

(7) Power kilowatt (kW) rated and typical operating power profile.

(8) Surge/inrush current: peak magnitude and duration.

(9) Pulsed loading.

(10) Ramp loading.

(11) Load unbalanced.

(12) Spike generation.

(13) Line-to-ground capacitance.

(14) Line-to-ground current.

b. Power quality testing in accordance with tables A-I and B-I during all linear, non-linear, pulsed load conditions (see 3.4.1.2.3), and user equipment conditions (see 4.14.1.a).

c. Output voltage harmonics (see 3.4.1.2.1).

d. Output voltage offset (see 3.4.1.2.2).

e. Output voltage regulation (see 3.4.1.2.3.1). The sudden change of load on PECE from no-load to rated-load; from rated-load to no-load; from no-load to ½-load; from ½-load to rated-load; from rated-load to ½-load; and from ¾-load to ¼-load shall not cause an output deviation greater than that identified in Appendix C. The voltage at PECE output terminals shall recover and stay within steady-state regulation band as listed in Appendix C. Voltage transients developed within PECE shall not reflect back into the input system so that limits are in accordance with MIL-STD-1399-300 or MIL-STD-680, as applicable.

f. Transient output voltage and recovery (see 3.4.1.2.3.2). The sudden change of load on PECE from no-load to rated-load; from rated-load to no-load; from no-load to ½-load; from ½-load to rated-load; from rated-load to ½-load; and from ¾-load to ¼-load shall not cause an output deviation of greater than what is listed in Appendices A and B. The voltage at the PECE output terminals shall recover and stay within steady-state regulation band as listed in Appendices A and B. Voltage transients developed within PECE shall not reflect back into the input system so that limits are in accordance with MIL-STD-1399-300 or MIL-STD-680, as applicable.

g. Output voltage ramp-up (see 3.4.1.2.3.3).

h. Power electronic device switching frequency (see 3.4.1.2.4).

i. Module sharing (see 3.4.1.2.6.2).

j. Load sharing (see 3.4.1.2.6.3).

k. Overload (see 3.4.1.2.7).

l. System stability (see 3.4.1.2.8).

m. Variable frequency AC system loads (see 3.4.1.2.9).

n. Grounding (see 3.4.14).

o. Ground fault detection and location (see 3.4.20 and 3.4.21).

p. Emergency condition.

q. Surge or inrush current.

4.14.2 DC output power quality tests. DC output power quality tests shall be as follows:

a. PECE output power profile testing.

(1) Voltage.

(2) Line current magnitudes.

(3) Power kilowatt (kW) rated and typical operating power profile.

(4) Surge or inrush current: peak magnitude and duration.

(5) Pulsed loading.

(6) Ramp loading.

(7) Spike generation.

(8) System DC ground isolation.

(9) System AC ground isolation.

b. Power quality testing in accordance with table C-I during all linear, non-linear, pulsed load conditions (see 3.4.1.2.3), and user equipment conditions (see 4.14.2.a).

c. Output voltage offset (see 3.4.1.2.2).

d. Output voltage regulation (see 3.4.1.2.3.1). The interface voltages of the PECE output listed in Appendix C shall operate in a stable manner from no-load to rated-load; from rated-load to no-load; from no-load to ½-load; from ½-load to rated-load; from rated-load to ½-load; and from ¾-load to ¼-load. PECE shall not produce resonances in any load combination that result in an overvoltage or overcurrent and shall not interact with sources in a manner that causes input or output voltage to exceed the limits of Appendix C.

e. Transient output voltage and recovery (see 3.4.1.2.3.2). The sudden change of load on PECE from no-load to rated-load; from rated-load to no-load; from no-load to ½-load; from ½-load to rated-load; from rated-load to ½-load; and from ¾-load to ¼-load shall not cause an output deviation of greater than what is listed in Appendix C. The voltage at the PECE output terminals shall recover and stay within steady-state regulation band as listed in Appendix C. Voltage transients developed within PECE shall not reflect back into the input system so that limits are within the DC requirements as specified (see 6.2).

f. Output voltage ramp-up (see 3.4.1.2.3.3).

g. Power electronic device switching frequency (see 3.4.1.2.4).

h. Module sharing (see 3.4.1.2.6.2).

i. Load sharing (see 3.4.1.2.6.3).

j. Overload (see 3.4.1.2.7).

k. System stability (see 3.4.1.2.8).

l. Grounding.

m. Ground detection.

n. Emergency condition.

o. Inrush current.

4.15 Electromagnetic interference (EMI) test. PECE shall be subjected to the EMI tests specified in 3.4.2. Acceptance criteria shall be in accordance with MIL-STD-461. DC resistance shall be verified to be as specified (see 3.4.2) between conduction frame of assemblies receiving primary power and PECE bond point.

4.16 Electromagnetic pulse (EMP) test. PECE shall be subjected to ship specific EMP tests in accordance with MIL-STD-461. Acceptance criteria shall be in accordance with MIL-STD-461.

4.17 DC magnetic field emissions test. PECE shall be tested for radiated susceptibility, DC magnetic field in accordance with DOD-STD-1399-070-1.

4.18 Regenerated power test. PECE, or the load to which it is providing power, shall not be harmed from regenerated power that is stored or controlled. Unidirectional and bidirectional PECE shall be tested as follows:

a. Unidirectional test:

(1) Connect PECE to a regenerative load, such as a motor, that generates back electromotive force needing to be dissipated or blocked.

(2) Operate the load such that it regenerates its maximum amount of energy.

(3) Verify that the PECE output module that is providing power to the load is not harmed.

(4) If the regenerated power is dissipated, verify that the device providing the dissipation is not overheated.

b. Bidirectional test:

(1) Connect PECE to a regenerative load, such as a motor, that generates back electromotive force needing to be converted and stored.

(2) Operate the load such that it regenerates its maximum amount of energy.

(3) Verify that the output module receives the regenerated energy, converts it to a usable form, and either stores it or routes it to power PECE.

(4) Verify that the PECE has overcurrent and overvoltage protection limits that protect power coming from the load and converted power either stored or routed back to PECE.

4.19 Insulation suitability test. The insulation suitability test shall be conducted in accordance with MIL-DTL-917.

4.20 Electrically isolated test. The following electrical isolation tests shall be conducted:

a. While PECE is in operation and power modules are online, turn off output and secure input.

b. Engage input circuit galvanic isolation means and visually verify that the indication status of the input power is disconnected.

c. Engage output circuit galvanic isolation means and visually verify that the indication status of the output power is disconnected.

d. Verify that the isolation means allow for a lockout and tag-out device in the open position in accordance with S0400-AE-URM-010/TUM.

e. Measure and verify that there are no voltages greater than 30 volts on any input and output interface of PECE in accordance with S9086-KC-STM-010/300.

f. Verify the interlock circuit prevents operation while attempting to apply source power.

4.21 Insulation resistance test. Insulation resistance testing shall be conducted in accordance with MIL-DTL-917. For test voltages 500 to 1000 volts, refer to MIL-STD-202, Method 302, Test Condition C, for test voltage, conditions, and guidance. PECE insulation resistance acceptance criteria shall be as defined in MIL-DTL-917 and as specified (see 3.4.10).

4.22 Surge voltage withstand test. Surge voltage testing shall be performed in accordance with IEC 61000-4-5.

4.23 Dielectric withstand voltage. Dielectric withstand voltage testing shall be conducted in accordance with MIL-DTL-917. PECE dielectric withstand voltage acceptance criteria shall be as defined in MIL-DTL-917 and as specified (see 3.4.12).

4.24 Ungrounded circuits. PECE shall be operated in ungrounded ship's power system configuration in accordance with MIL-STD-1399-300.

4.25 Safety leakage current. Safety leakage current shall be conducted in accordance with MIL-STD-1399-300. PECE ground fault leakage current acceptance criteria shall be as defined in MIL-DTL-917 and as specified (see 3.4.17).

4.26 Ground fault test. PECE shall be tested in accordance with MIL-STD-1399-300 grounding tests. The ground fault impedance shall be in accordance with MIL-STD-1399-300. The ground fault test shall be performed on the input interface, internal bus link, and output interface of PECE. PECE shall locate the ground fault as specified (see 3.4.21 and 6.2). The common mode current shall be reported and tested as specified (see 3.4.19 and 6.2).

4.27 Semiconductor device test. Semiconductor devices shall be tested in accordance with MIL-PRF-19500.

4.28 Connector alignment verification. The following test for connector alignment shall be conducted on each different (e.g., having different connectors, or a different connector keying arrangement) part number connectorized assembly (e.g., Printed Wiring Assembly (PWA), module, drawer, or other form of removable assembly that is provided with one or more connectors):

a. PECE shall be de-energized.

b. Each connectorized assembly shall be inserted and removed 10 times from its next higher assembly within the PECE enclosure. Connector alignment verification does not apply to connectors that are not connected or disconnected on a periodic basis (i.e., connectors on a drawer where the plug-in modules are removed while the drawer remains installed in the enclosure), or for non-fixed connectors (i.e., a connector on a cable or wiring harness).

c. For PECE input and output modules or designs with guided strips, remove and install the subassemblies 100 times.

d. At the conclusion of the last insertion cycle, the equipment shall be visually inspected and subsequently subjected to the control operational tests (see 4.37.1 and 4.37.2).

e. PECE shall fail the test if one of these conditions exist during or following the test:

(1) Damage that may cause equipment operating problems during the required life of the equipment (e.g., bent connector contacts, contacts corning loose within a connector, recessed contact, solder or crimp joint failures to conductors, and any other form of damage that may be attributed to inadequate alignment or design).

(2) Failure to pass the short-form operational tests (see 4.37.1 and 4.37.2).

(3) Mechanical difficulties encountered when removing and installing the assembly.

4.29 100-hour burn-in test. The 100-hour burn-in test shall be conducted by energizing the equipment for 100 hours at nominal voltage and frequency (if applicable), ambient temperature, and with all inputs and outputs connected to effect maximum rated loading. If a failure occurs during this testing, the test shall be restarted in order to complete the requirement.

4.29.1 Accelerated life test. PECE shall be subject to the following accelerated life test under the following input, output, and environmental conditions:

a. Place PECE in a chamber at 32 °F (0 °C) and energize under nominal input conditions with output modules operating at rated loads. After 30 minutes, record PECE input current, input voltage, input frequency (if applicable), output current, output voltage, output frequency and output power, PECE enclosure surface temperature, test chamber humidity, test chamber ambient temperature, and outside chamber ambient temperature.

b. Change the temperature of the chamber to 77 °F (25 °C) and relative humidity to 50±5 percent. Energize PECE under nominal input conditions with output modules operating at rated loads. After 30 minutes, record PECE input current, input voltage, input frequency (if applicable), output current, output voltage, output frequency and output power, PECE enclosure surface temperature, test chamber humidity, test chamber ambient temperature, and outside chamber ambient temperature.

c. Change the temperature of the chamber to 122 °F (50 °C). Energize PECE at 122 °F (50 °C) for 7 hours (6 hours at full rated load and 1 hour at no-load). Then reduce the temperature to ambient of 77 °F (25 °C) for 3 hours (2 hours at full rated load and 1 hour at no-load). Shut the power off and reboot the system. Repeat this portion of the 10-hour accelerated life test cycle six times (total of 70 hours). If failure occurs during the test, the cause of the failure and the correction shall be recorded.

d. Record the input current, input voltage, input frequency (if applicable), output current, output voltage, output frequency and output power, test chamber ambient temperature, and outside chamber ambient temperature hourly. Any turn-on problems, faults, and failures shall be recorded during each full rated load and no-load cycle for outputs and PECE.

e. With the chamber at 122 °F (50 °C), change the humidity to not less than 90 percent relative humidity. Energize PECE and operate under these conditions at nominal input with output modules operating at rated load for a period of 2 hours. During the last 0.5 hour, performance test data shall be recorded for comparison with the reference test data recorded in 4.29.1.a. Minor adjustments to operating controls will be permitted during this 2-hour test run to ensure optimum equipment performance.

f. With PECE operating at the same test conditions as 4.29.1.d, conduct the following test cycle:

(1) Increase PECE input voltage to 110 percent of nominal for 1 hour and 15 minutes.

(2) Decrease PECE voltage to 90 percent of nominal for 1 hour.

(3) Return PECE input voltage to nominal for 30 minutes and record the data in 4.29.1.a during these 30 minutes.

(4) De-energize PECE for 15 minutes.

(5) Energize PECE after the 15 minutes and reduce the input voltage to 90 percent of nominal for 1 hour.

(6) Increase PECE input voltage to 110 percent nominal for 1 hour and 15 minutes.

(7) Return PECE input voltage to nominal for 30 minutes and record the data in 4.29.1.a during these 30 minutes.

(8) De-energize PECE for 15 minutes.

(9) Repeat steps (1) through (8) three times (total of 24 hours).

g. With PECE still at 122°F (50 °C) and nominal input voltage with output modules operating at rated load, perform the following temperature cycling at a minimum humidity of 90 percent during each steady state temperature condition:

(1) 8 hours at 122 °F (50 °C) recording a humidity measurement after 2 hours.

(2) 4 hours at 77 °F (25 °C) recording a humidity measurement after 2 hours.

(3) Repeat steps (1) and (2) two times (total test time of 36 hours).

Note: Each temperature transition shall not exceed 1.5 hours if PECE remains in one chamber and 1 hour if a two-chamber method is used.

(4) Return the unit to ambient humidity conditions for a maximum of 12 hours and perform a dielectric withstand voltage test in accordance with 4.23. PECE shall meet the requirements of 3.4.12.

4.30 Efficiency. The efficiency test shall be performed on PECE from input to output with all output power modules operating at no-load, 80 percent rated load, and full rated load. PECE acceptance criteria are defined in 3.4.30. Readings shall be recorded after output stabilization. Efficiency shall be calculated by means of the following formula:

$$\text{Overall percent efficiency} = \frac{\text{Output power} \times 100}{\text{Input power}}$$

4.31 Reparability demonstration test. PECE shall meet the MTTR criteria specified in 3.5.5. PECE shall meet the electrical isolation tag-out criteria specified in 3.10.2. The demonstration test should use guidance provided in MIL-HDBK-470 for test planning and development.

4.32 Input overcurrent protection. Perform the following input overcurrent protection test to verify the acceptance criteria of 3.6.3 and 3.6.11:

a. Operate PECE at nominal input with PECE output modules operating at rated load.

b. Induce 125 percent input current across input phases.

c. Verify the input is shut down by opening the input power breakers between the input power source and PECE.

d. Verify that PECE is not harmed by checking the output capability of each of the output modules and comparing the results to those recorded in 4.32.a.

e. Verify that PECE shuts off when the overcurrent protective set point is reached.

4.33 Output overcurrent and short circuit protection. The following overcurrent protection test shall be verified to the acceptance criteria of 3.6.4 and 3.6.5:

a. Operate PECE at nominal input with PECE output module operating at rated load.

b. Load each output module to a minimum of 115 percent, or as specified (see 6.2).

c. Verify that the module output current is limited so that PECE permissible current is not exceeded. PECE shall continue to operate.

d. Verify that PECE is not harmed by checking the output capability of each output module and comparing the results to those recorded in 4.33.a.

e. Verify that PECE is output current limiting when the output overcurrent protection set point is reached.

f. Load each module to a minimum of 130 percent, or as specified (see 6.2).

g. Verify that PECE limits fault current to the simulated shorted module and avoids PECE shut down for the fault current limit duration.

h. Verify that PECE is not harmed by checking the output capability of each output module and comparing the results to those recorded in 4.33.a.

4.34 Emergency stop or output disable test. The following emergency stop or output disable tests shall be conducted:

a. Operate PECE at rated load and engage the emergency or output disable switch.

b. De-energize PECE output(s).

c. Verify that there is no damage during tripping.

d. Reset the emergency stop or output disable switch and bring PECE back to operation at rated load.

e. Verify the fail-safe function of the emergency stop or output disable switch by breaking the circuit wire and ensure that PECE output(s) de-energize.

f. Reconnect the emergency stop or output disable wire and bring PECE back to operation at rated load.

g. If the external shunt trip power is derived internally, verify provisions to prevent an external event from causing damage to PECE control circuit.

h. Reset the emergency stop or output disable switch and bring PECE back to operation at rated load.

i. When remote emergency stop or output disable remote shutdown functionality is present, verify PECE output is disabled remotely.

j. Reset the emergency stop or output disable switch and bring PECE back to operation at rated load.

4.35 Crowbar circuit test. The circuit or component shall be protected by a crowbar circuit and shall not be harmed by overvoltage or short circuit. The circuit shall react fast enough to avoid harm when overvoltage or overcurrent is 110 to 150 percent of the components maximum voltage or current rating.

4.36 Partial discharge test. Partial discharge testing shall be conducted in accordance with ASTM D1868. Acceptance criteria shall be less than 10 to 15 picocoulombs when measured in a test setup with no more than 2 picocoulombs background noise.

4.37 SCADA. PECE controller start up time shall be no greater than 2 minutes from the application of input power, as specified (see 3.7.15).

4.37.1 Local control operational test. The following SCADA functions shall be managed via PECE controller:

a. Operator interface controls.

b. Operator interface indications.

c. PECE internal communications.

d. Internal controls.

e. External controls.

f. Internal communications.

g. External communications.

h. Safety interlocks.

i. Safety functions.

4.37.2 Remote control operational test. The following authorized SCADA functions shall be managed via external PECE interface:

a. Operator interface controls.

b. Display interface indications.

c. PECE internal communications.

d. System shutdown during catastrophic fault.

e. Reset normal faults.

f. Shut off alarm after normal fault reset.

g. Cannot reset catastrophic faults or shut off alarm from catastrophic fault.

h. Cannot change system parameter (faults, alarm settings, module outputs) from remote location.

i. Visual and audible alarm is available and working.

4.38 Control communication test. With PECE fully operational, the functionality of the control communications shall be verified. The following control communication test shall verify PECE meets control and communication requirements criteria (see table I):

a. Check operation of control mode switch when remote SCADA is specified (see 3.7.1).

(1) Verify that the switch will select or deselect the controlling station.

(2) Verify that when the local position of the switch is selected, remote control does not function but remote communication and display is maintained.

(3) Verify that when the remote position of the switch is selected, the operation and functions of the local HMI are maintained but local control will not function.

(4) Verify that when the remote position of the switch is selected, the local control of the emergency stop or output disable functionality still exists.

b. Verify that the PECE internal and external alarm, fault, and catastrophic fault events are reported, responded to, data stored, and properly displayed on the HMI in the following manner.

(1) Events are identified at subcomponent level and isolated to assure power continuity, equipment damage is avoided, and human safety is assured.

(2) Events are placed in fault stack in order of occurrence and are date-and-time-stamped and stored as required.

(3) Faults (normal and catastrophic) are latched faults.

(4) Alarms and faults (normal and catastrophic) are indicated locally and remotely in visual and audible form.

(5) Alarms are only silenced once reset command is received either locally or remotely manually and conditions have returned to normal.

(6) Faults are isolated and rest PECE operates normally under normal fault conditions (not catastrophic in nature).

(7) PECE de-energizes outputs, coordinated input isolation, shuts down safely, and inhibits remote and automatic start up when catastrophic fault condition exists.

(8) Catastrophic faults require local HMI reset for visual indication and inhibit functions.

4.39 Power supply redundancy test. Paralleled power supplies feeding PECE controls shall meet the criteria in 3.7.8.1. Fault testing should be conducted under the following conditions:

a. Loss of input voltage to one power supply.

b. Input power to paralleled power supplies shall be at worst case voltage and frequency.

c. Input power to paralleled power supplies worst case voltage and frequency transients.

d. Paralleled power supplies operating at temperature extremes under conditions specified in 4.39.a and 4.39.b.

4.40 Backup power. The backup power source shall be fully charged and stabilized at room ambient temperature. The operating time on the backup power source shall be determined by shutting off the input power source of the backup power supply. The operating time shall meet acceptance criteria specified in 3.7.9. The rated load shall include the PECE controls while the unit is in full operation.

4.41 Fiber optic connections and assemblies. PECE fiber optic connections and assemblies shall be tested in accordance with MIL-STD-2042. The following minimum tests shall be performed:

a. Visual examination. Verify that there is no evidence of damage and that the fiber optic cable is terminated to the correct location in the fiber optic connector. Verify that there are no kinks, twists, crushing, or sharp bends. Inspect the terminus with a 400 × (minimum) optical microscope to ensure that the optical surface is smooth and free of scratches, pits, chips, epoxy, dirt, and fractures. Verify that the optical surface has the correct geometry (i.e., domed).

b. Cable assembly link loss test. Perform with the pass or fail criteria in accordance with MIL-STD-2042, Method 6C1.

c. Optical return loss test. Perform with the pass or fail criteria in accordance with MIL-STD-2042, Method 6K1.

4.42 Airborne noise. PECE shall be tested for airborne noise in accordance with MIL-STD-1474 and meet the acceptance criteria specified in 3.8.1.

4.43 Structure-borne noise. PECE shall be tested for structureborne noise in accordance with MIL-STD-740-2 and meet the acceptance criteria specified in 3.8.2.

4.44 Thermal cycling. PECE thermal cycling should follow the guidance defined in MIL-HDBK-2164.

4.45 Humidity. PECE shall be subjected to humidity testing in accordance MIL-STD-810, Method 507. A total of 10 cycles shall be conducted. PECE performance shall be checked as specified during the testing.

4.46 Shock. PECE shall be subjected to shock testing in accordance with MIL-S-901 for Grade A, Class I, Type A equipment with weight classification as required by the weight of the equipment. PECE shall be tested in the same mounting configuration as the one chosen for shipboard installation. Mounting shall be as specified for standard mounting bulkhead or deck mounted equipment in accordance with MIL-S-901. The tests shall be conducted with PECE energized and providing output power. A suitable instrument shall be used to monitor PECE output power. PECE shall be subjected to and pass the dielectric withstanding voltage test (see 4.23) after the shock test. PECE shall fail the test if it cannot perform its intended operating functions during and after such tests, or if one or more of the following occurs during the tests:

a. Contact between live parts and the enclosure.

b. Enclosure door opens.

c. Structural parts are damaged or loosened.

d. Functional parts are damaged or loosened.

e. PECE output power not as specified.

f. Relays and contactors open or chatter during testing.

g. Contact opening for more than 0.02 second per bounce.

4.47 Vibration. PECE shall be subjected to Type I vibration testing in accordance with MIL-STD-167-1. The tests shall be conducted with PECE in each of the three rectilinear orientations axis as installed on shipboard. The tests shall be conducted with PECE energized and providing output power. A suitable instrument shall be used to monitor PECE output power. PECE shall be tested in the same mounting configuration as the one chosen for shipboard installation. If shock or isolation mounts are utilized, these shall not cause resonance. PECE shall be subjected to and pass the dielectric withstanding voltage test (see 4.23) after the vibration test. PECE shall fail the test if it cannot perform its intended operating functions during and after such tests, or if one or more of the following occurs during the tests:

a. Contact between live parts and the enclosure.

b. Enclosure door opens.

c. Structural parts are damaged or loosened.

d. Functional parts are damaged or loosened.

e. PECE output power not as specified.

f. Relays and contactors open or chatter during testing.

4.48 Inclined operation. PECE shall be subjected to an inclined operation test in accordance with DOD-STD-1399-301. The voltage and current shall remain within the specified limits during the testing. The test shall be conducted at 122 °F (50 °C) at a 30-degree angle for each inclined position for a duration of 1 hour.

4.49 Battery source isolation. The following battery source isolation tests shall be conducted on PECE with internal or external battery source(s):

a. While PECE controller and backup battery source is online, shut the battery source off with the manual disconnect means.

b. Verify that there is no power being supplied at the internal or external PECE inputs and that there is galvanic isolation of the inputs and outputs to the energy storage device.

c. Simulate faults (over-temperature, short circuit, or other faults) that are programmed into PECE to protect the energy storage and PECE.

d. Verify that automatic shutdown of PECE occurs and that there is no power being supplied at the internal or external PECE inputs. Also verify that there is galvanic isolation of the inputs and outputs to the energy storage device.

e. Verify that energy storage disconnects are accessible to the operator for tag-out for routine maintenance.

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. This specification covers PECE. PECE addressed herein applies to electrical power distribution system component(s) for surface and submarine naval vessels, regardless of voltage level and output type. PECE utilizes solid-state electronics to convert AC or DC source voltage for use in power distribution systems, motor drives, fast acting transfer switches, or any other application requiring specialized power characteristics to optimize system performance and protection.

6.2 Acquisition requirements. Acquisition documents should specify the following:

a. Title, number, and date of this specification.

b. Whether equipment application is for surface or submarine naval vessel (see 1.1).

c. When first article is required (see 3.1).

d. PECE maximum size and weight and center of gravity (see 3.2.2).

e. Enclosure ingress protection ratings (see 3.2.5.1).

f. When door interlock is required (see 3.2.5.4).

g. When explosion-proof enclosure is required (see 3.2.6).

h. When multi-cable transit enclosure is required to be in accordance with ASTM E814 (see 3.2.7.1).

i. Enclosure accessibility requirement, if other than specified (see 3.2.8).

j. The number and location of removable cover(s) and access door(s) (see 3.2.8.3).

k. Enclosure door width requirement (see 3.2.8.3.2).

l. Equipment identification, if other than specified (see 3.2.9).

m. Material and grade of threaded fasteners, if other than specified (see 3.2.12.1).

n. Use of high strength alloy steel screws or bolts, if other than specified (see 3.2.12.3).

o. When grab rails are required at HMI and local controls (see 3.2.13).

p. Alternative bus bar arrangement and spacing requirements (see 3.2.14).

q. Cooling interface requirement (see 3.2.16).

r. When thermal management loss-of-cooling limited or reduced load operation is required (see 3.2.16.2).

s. Pressure relief device pressure value excess requirement, if other than specified (see 3.2.16.4).

t. Module failure system interface isolation requirement, if other than specified (see 3.3.1).

u. Module rating maximum operating condition (see 3.3.3 and 4.10).

v. Module removal requirement (see 3.3.4).

w. Requirements for the operation of door safety interlocks, with respect to live PECE module replacement (see 3.3.4).

x. PECE module extraction requirement (see 3.3.4.3).

y. Arc flash analysis standoff distances (see 3.3.4.4.1.c).

z. Module cooling interface leakage allowance (see 3.3.5).

aa. Module communication link (see 3.3.6).

bb. Module sensor, alarm, fault, configurable parameter, and diagnostic information requirement, if other than specified (see 3.3.6).

cc. Module control connection disconnect requirement, if other than specified (see 3.3.7).

dd. Module electrical connection greater than 1000 volts (see 3.3.8).

ee. DC input power quality interface requirements and testing (see 3.4.1.1 and 4.13).

ff. Fixed frequency low voltage output power quality requirements, if other than specified (see 3.4.1.2).

gg. Fixed frequency high voltage output power quality requirements, if other than specified (see 3.4.1.2).

hh. DC voltage output power quality requirements and testing, if other than specified (see 3.4.1.2, 4.14, and 4.14.2).

ii. Output voltage harmonics requirement, if other than specified (see 3.4.1.2.1).

jj. When output voltage offset is required (see 3.4.1.2.2).

kk. Load characteristics outside linear load, non-linear load, and pulsed load as defined in MIL-STD-1399-300, MIL-STD-1399-390, and MIL-STD-1399-680 (see 3.4.1.2.3).

ll. Output voltage ramp-up requirement (see 3.4.1.2.3.3).

mm. Power electronic switching frequency selection, if other than specified (see 3.4.1.2.4).

nn. Basis for PECE power rating, if other than specified (see 3.4.1.2.6).

oo. When power source sharing is required (see 3.4.1.2.6.1).

pp. When paralleled module output power load sharing is required (see 3.4.1.2.6.2).

qq. When user adjustable output power load sharing is required (see 3.4.1.2.6.3).

rr. Overload capability requirement (see 3.4.1.2.7).

ss. Input source capacity and configuration (see 3.4.1.2.8).

tt. Output power variable frequency requirement (see 3.4.1.2.9).

uu. When electromagnetic pulse (EMP) is required (see 3.4.3).

vv. When magnetic field reduction is required (see 3.4.5).

ww. When regenerated power is required to be controlled by PECE (see 3.4.6).

xx. Requirement for input power terminal isolation from output terminal isolation (see 3.4.8).

yy. Insulation system requirements for systems using greater than 1000 volts (see 3.4.9).

zz. Insulation resistance requirements for systems using greater than 1000 volts (see 3.4.10).

aaa. Dielectric withstand voltage requirements for systems using greater than 1000 volts (see 3.4.12).

bbb. Circuit grounding filter requirement, if other than specified (see 3.4.16).

ccc. When common mode current monitoring is required (see 3.4.19).

ddd. Common mode current limit alarm and testing requirement (see 3.4.19 and 4.26).

eee. When common mode current input isolation is required (see 3.4.19).

fff. When ground fault detection with adjustable threshold is required (see 3.4.20).

ggg. Ground fault impedance requirement (see 3.4.20).

hhh. When ground fault location and testing are required (see 3.4.21 and 4.26).

iii. When ground fault location is required to be reported remotely (see 3.4.21).

jjj. Endurance requirements, if other than specified (see 3.4.29).

kkk. Efficiency requirements, if other than specified (see 3.4.30).

lll. Partial load efficiency requirement (see 3.4.30).

mmm. Operational availability requirement (see 3.5.1).

nnn. Parts derating requirement, if other than specified (see 3.5.2).

ooo. Equipment service life, if other than specified (see 3.5.3).

ppp. When an obsolescence plan is required (see 3.5.3).

qqq. Adjustable overvoltage set point (see 3.6.2).

rrr. Input overcurrent protection set point (see 3.6.3).

sss. Output overcurrent protection set point (see 3.6.4).

ttt. When short circuit current limiting management is required (see 3.6.5).

uuu. When firefighting suppression interface is required (see 3.6.9).

vvv. Input disconnect method (see 3.6.11).

www. When a remote emergency stop or output disable interface is required (see 3.6.12).

xxx. When remote control is required (see 3.6.12).

yyy. When arc fault detection is required (see 3.6.13).

zzz. When a crowbar circuit is required (see 3.6.14).

aaaa. When PECE is required to be designed to be partial discharge-free (see 3.6.15).

bbbb. When remote SCADA is required (see 3.7.1).

cccc. When external control is required (see 3.7.2).

dddd. When HMI equipment operation is required (see 3.7.3).

eeee. HMI monitored conditions or parameters (see 3.7.3).

ffff. Communication for control, status, or alarm/fault information (see 3.7.4).

gggg. Internal communication protocols (see 3.7.4.1).

hhhh. External communications protocols (see 3.7.4.2).

iiii. Loss of external communication alarms requirement (see 3.7.4.2).

jjjj. Operating states requirement, if other than specified (see 3.7.6).

kkkk. Event reporting and response requirement, if other than specified (see 3.7.7).

llll. Remote alarm indicators requirement (see 3.7.7.1).

mmmm. Remote fault indicators requirement (see 3.7.7.2).

nnnn. Remote LRU fault indicator requirement (see 3.7.7.2).

oooo. PECE control power supply source (see 3.7.8).

pppp. When multiple power supplies for control are required (see 3.7.8).

qqqq. Backup power requirement, if other than specified (see 3.7.9).

rrrr. Configuration settings (see 3.7.10).

ssss. Cybersecurity plan requirements (see 3.7.11.1).

tttt. When username and password protection are required (see 3.7.12).

uuuu. Minimum number of logs maintained (see 3.7.13).

vvvv. Controller start-up time requirements, if other than specified (see 3.7.15).

wwww. Data entry hardware and software requirement (see 3.7.17).

xxxx. Airborne noise requirement, if other than specified (see 3.8.1).

yyyy. Structure-borne noise requirement, if other than specified (see 3.8.2).

zzzz. When moisture and condensation prevention are required (see 3.9.3).

aaaaa. Shock grade and class requirements (see 3.9.4).

bbbbb. Shock output power test requirements, if other than specified (see 3.9.4).

ccccc. Vibration requirements (see 3.9.5).

ddddd. Vibration output power test requirements, if other than specified (see 3.9.5).

eeeee. Inclined operation requirements, if other than specified (see 3.9.6).

fffff. When demonstration of PECE tag-out is required (see 3.10.2).

ggggg. Source fault current and protection requirement (see 3.10.8).

hhhhh. When arc blast pressure relief rupture discs are required (see 3.10.9).

iiiii. When instruction sheets are required to be provided (see 3.11).

jjjjj. When software may be designed in an open architecture approach (see 3.13).

kkkkk. Additional testing requirements (see 4.2).

lllll. When test report on enclosure explosion-proof approval is required to be submitted to NAVSEA (see 4.7).

mmmmm. Requirements for conducting DC power quality tests (see 4.13.3).

nnnnn. Minimum output module load requirement, if other than specified (see 4.33.b and 4.33 f).

ooooo. Packaging requirements (see 5.1).

ppppp. Output power system impedance requirement for greater than 155 to less than 1000 VDC, or 1000 VDC (see table C-I).

qqqqq. Output power system maximum departure from nominal user voltage requirement for greater than 155 to less than 1000 VDC or 1000 VDC (see table C-I).

rrrrr. Output power voltage ripple frequency for 155 VDC, greater than 155 to less than 1000 VDC, or 1000 VDC (see table C-I).

sssss. Security category designation (see E.3.1).

ttttt. When a cybersecurity analysis of threats is required (see E.3.2).

uuuuu. When intrusion detection is required (see E.3.3.b(7)).

6.3 Acronyms.

6.3.1 AC. Alternating Current.

6.3.2 DC. Direct Current.

6.3.3 EMI. Electromagnetic Interference.

6.3.4 EMP. Electromagnetic Pulse.

6.3.5 ESD. Electrostatic Discharge.

6.3.6 HMI. Human Machine Interface.

6.3.7 LRU. Line Replaceable Unit.

6.3.8 MTTR. Mean Time To Repair.

6.3.9 MTBF. Mean Time Between Failure.

6.3.10 PCM. Power Conversion Module.

6.3.11 PECE. Power Electronic Conversion Equipment.

6.3.12 RMS. Root Mean Square.

6.3.13 VFD. Variable Frequency Drive.

6.4 Definitions.

6.4.1 Battery charger. A DC converter supplying a charging voltage to a battery system.

6.4.2 Controller start-up. The controller state in which software is booted, SCADA is operational, alarms are functioning, and output modules are providing full rated load.

6.4.3 Converter. A solid-state power switching device that provides a DC output from a DC source or a 60-Hz source to a higher AC frequency output.

6.4.4 Crowbar circuit. A circuit that senses a failure in a monitored circuit which applies a low-impedance fault to the circuit and may be used to intentionally de-energize the circuit.

6.4.5 Cybersecurity. Prevention of damage to, protection of, and restoration of computers, electronic communication systems, electronic communication services, wire communication, and electronic communication, including information contained therein, to ensure its availability, integrity, authentication, confidentiality, and non-repudiation.

6.4.6 Frequency converter. A device that converts the AC power of one frequency to an AC power of another frequency.

6.4.7 Galvanic isolation. A principle of isolating functional sections of electrical systems to prevent current flow; no direct conduction path is permitted. Energy or information can still be exchanged between the sections by other means.

6.4.8 Grounding. Connecting a point of electrical equipment to the ship's hull or ground point for intentional or other reasons.

6.4.9 High voltage. A voltage that is greater than or equal to 1000 volts.

6.4.10 Interlock. A device or system used to prevent undesired states or combination of states, which may be electrical, electronic, mechanical, or electro-mechanical.

6.4.11 Inverter. A solid-state power switching device that provides an AC output from a DC source.

6.4.12 Low voltage. A voltage that is less than 1000 volts.

6.4.13 Maintenance envelope. The distance required to perform routine maintenance from any side of the unit that does not exceed the depth of the unit as measured from front to back.

6.4.14 Nonlinear load. A single-phase or three-phase full wave rectifying system imposed on the source.

6.4.15 Open architecture. A technical architecture that adopts open standards supporting a modular, loosely coupled, and highly cohesive system structure that includes publishing of key interfaces within the system and full design disclosure. Open architecture yields modular, interoperable systems allowing components to be added, modified, replaced, removed, and supported by different vendors throughout the life cycle in order to drive opportunities for enhanced competition and innovation.

6.4.16 PECE module. An LRU that performs a function within the PECE, including, but not limited to, power supply, power conversion, power control, and power conditioning.

6.4.17 Power electronics. Solid-state electronics for the control and conversion of electric power.

6.4.18 Pulsed load. A load which demands frequent or regular repeated power input. A pulsed load is measured as the average power during the pulse interval minus the average power during the same interval immediately preceding the pulse. A pulsed load can result in modulation in the system voltage amplitude and frequency.

6.4.19 Rectifier. A solid-state power switching device that provides a DC output from an AC source.

6.4.20 Regenerative power. A back electromotive force generator from inductive loads such as motors.

6.4.21 Water hammer effects. A pressure surge or wave caused when a fluid in motion is forced to stop or change direction suddenly. Water hammer effects commonly occur when a valve closes suddenly at an end of a pipeline system, and a pressure wave propagates in the pipe. This pressure wave can cause major problems, from noise and vibration to pipe collapse.

6.5 Subject term (key word) listing.

Cybersecurity

Power converter

Power distribution

Power inverter

Power rectifier

Power switching

PECE CONVERSION AC LOW VOLTAGE OUTPUT POWER CHARACTERISTICS

A.1 SCOPE

This appendix covers PECE conversion AC low voltage output power characteristics.

This appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

A.2 PECE CONVERSION AC LOW VOLTAGE OUTPUT POWER CHARACTERISTICS

PECE conversion AC low voltage output power characteristics are listed in table A-I.

TABLE A-I. PECE conversion AC low voltage output power characteristics.

Frequency	AC low voltage, 60 Hz	AC low voltage, 400 Hz
1. Nominal frequency	60 Hz	400 Hz
2. Frequency tolerance	±3%	±0.50%
3. Frequency modulation	0.50%	0.50%
4. Frequency transient tolerance	±4%	±1%
5. Recovery time from items 3 or 4	2 seconds	0.25 second
Voltage		
6. Nominal user voltage	450 Vrms, 3PH, ungrounded	450 Vrms, 3PH, ungrounded
	120 Vrms, 3PH, ungrounded	120 Vrms, 3PH, ungrounded
	120/208 Vrms, 3PH, 4 wire, grounded	120/208 Vrms, 3PH, 4 wire, grounded
7. Line-to-line voltage unbalance	0.5% for 450 Vrms	2%
	1% for 120 Vrms	
8.a. User voltage tolerance: Average line-to-line voltage from nominal	±2%	±2%
8.b. User voltage tolerance: Line-to-line voltage from nominal, including items 7 and 8.a	±3%	±3%
9. Voltage modulation	1%	1%
10. Voltage transient tolerance	±10%	±5%
11. Recovery time	0.25 second	0.25 second
12. Voltage spike (±peak value)	2.5 kV (450 Vrms sys)	2.5 kV (450 Vrms sys)
	1.0 kV (120 Vrms sys)	1.0 kV (120 Vrms sys)
Waveform (voltage)		
13. Maximum total harmonic distortion	3%	3%
14. Maximum single harmonic	2%	2%
15. Maximum deviation factor	3%	5%
Emergency conditions		
16. Frequency excursion	-100 to +12%	-100 to +12%
17. Duration of frequency excursion	2 minutes	2 minutes
18. Voltage excursion	-100 to +35%	-100 to +35%
19.a. Duration of voltage excursion: upper limit (+35%)	2 minutes	0.17 second
19.b. Duration of voltage excursion: lower limit (-100%)	2 minutes	2 minutes
NOTE: Includes line-to-line voltage unbalance and average line-to-line voltage from nominal.		

PECE CONVERSION AC HIGH VOLTAGE OUTPUT POWER CHARACTERISTICS

B.1 SCOPE

This appendix covers PECE conversion AC high voltage output power characteristics.

This appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

B.2 PECE CONVERSION AC HIGH VOLTAGE OUTPUT POWER CHARACTERISTICS

PECE conversion AC high voltage output power characteristics are listed in table B-I.

TABLE B-I. PECE conversion AC high voltage output power characteristics.

Frequency	**4.16 kVrms, 3PH, 60Hz**	**6.60 kVrms, 3PH, 60Hz**	**13.8 kVrms, 3PH, 60Hz**
1. Nominal frequency	60 Hz	60 Hz	60 Hz
2. Frequency tolerance	±1%	±1%	±1%
3. Frequency modulation	0.50%	0.50%	0.50%
4. Frequency transient tolerance	±4%	±4%	±4%
5. Recovery time from items 3 or 4	2 seconds	2 seconds	2 seconds
Voltage			
6. Nominal user voltage	4.16 kVrms, 3PH	6.60 kVrms, 3PH	13.8 kVrms, 3PH
7. Line-to-line voltage unbalance	2%	2%	2%
8.a. User voltage tolerance: Average line-to-line voltage from nominal	±2%	±2%	±2%
8.b. User voltage tolerance: Line-to-line voltage from nominal, including items 7 and 8.a	±3%	±3%	±3%
9. Voltage modulation	±1%	1%	1%
10. Voltage transient tolerance	±10%	±10%	±10%
11. Recovery time	1 second	1 second	1 second
12. Voltage spike (±peak value)	25 kV peak	40 kV peak	75 kV peak
Waveform (voltage)			
13. Maximum total harmonic distortion	3%	3%	3%
14. Maximum single harmonic	2%	2%	2%
15. Maximum deviation factor	3%	3%	3%
Emergency conditions			
16. Frequency excursion	-100 to +12%	-100 to +12%	-100 to +12%
17. Duration of frequency excursion	2 minutes	2 minutes	2 minutes
18. Voltage excursion	-100 to +35%	-100 to +35%	-100 to +35%
19.a. Duration of voltage excursion: upper limit (+35%)	2 minutes	2 minutes	2 minutes
19.b. Duration of voltage excursion: lower limit (-100%)	2 minutes	2 minutes	2 minutes

PECE CONVERSION DC VOLTAGE OUTPUT POWER CHARACTERISTICS

C.1 SCOPE

This appendix covers PECE conversion DC voltage output power characteristics.

This appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

C.2 PECE CONVERSION DC VOLTAGE OUTPUT POWER CHARACTERISTICS

PECE conversion DC voltage output power characteristics are listed in table C-I.

C.3 APPLICABLE DOCUMENTS

C.3.1 General. The documents listed in this section are specified in Appendix C 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 Appendix C of this specification, whether or not they are listed.

C.3.2 Government documents.

C.3.2.1 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-STD-1399-390 - Interface Standard for Shipboard Systems, Section 390, Electric Power, Direct Current, (other than Ship's Battery) for Submarines (Metric)

(Copies of this document are available online at http://quicksearch.dla.mil/.)

TABLE C-I. PECE conversion DC voltage output power characteristics.

DC power characteristics	DC voltage, 155 VDC [1/]	DC voltages, >155 to <1000 VDC	DC voltage, 1000 VDC
1. Nominal user voltage	155 VDC [1/]	>155 to <1000 VDC	1000 VDC
2. User voltage tolerance	±12%	±5%	±5%
3. System voltage ripple (RMS)	3.5%	1.5%	2.5%
4. Voltage transient tolerance	±16%	±8.5%	±8.5%
5. Voltage transient recovery time	0.25 second	0.25 second	0.50 second
6. Voltage spike (peak value)	750 volts	2 × Nominal voltage	2000 VDC
7. DC ground isolation	>200 kOhms	>10 MOhms	>10 MOhms
8. AC ground isolation	<0.02μF per kW measured at 1kHz	<0.005μF per kW measured at 1kHz	<0.005μF per kW measured at 1kHz
9. Power system impedance	See MIL-STD-1399-390	As specified (see 6.2)	As specified (see 6.2)
10. Maximum departure from nominal user voltage as a result of a combination of parameters (1), (2), and (4)	See MIL-STD-1399-390	As specified (see 6.2)	As specified (see 6.2)
11. Power interruption, limited break (vital loads only)	<3 milliseconds	<3 milliseconds	<3 milliseconds
12. Power interruption, no break (vital loads only)	Uninterruptible	Uninterruptible	Uninterruptible
13. Voltage ripple frequency	As specified (see 6.2)	As specified (see 6.2)	As specified (see 6.2)
14. Current ripple	[2/]	[2/]	[2/]
15. Worst case voltage offset from positive terminal to ground	+155 VDC	+ Nominal voltage	+1000 VDC
16. Worst case voltage offset from negative terminal to ground	-155 VDC	- Nominal voltage	-1000 VDC
17. Worst case excursion (tolerance + transient)	±10%	±10%	±10%

NOTES:

[1/] Values shown are for submarine DC power systems in accordance with MIL-STD-1399-390.

[2/] Shall not exceed MIL-STD-1399-390 user equipment's conducted emission differential mode ripple current limits.

DISCRETE SEMICONDUCTOR DERATING AND APPLICATION STRESS FACTORS

D.1 SCOPE

This appendix covers discrete semiconductor derating and application stress factors.

This appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

D.2 DISCRETE SEMICONDUCTOR DERATING AND APPLICATION STRESS FACTORS

Application stress limits and derating factors are listed in table D-I.

TABLE D-I. Application stress limits and derating factor for rectifiers, SCRs, GTOs, bipolar transistors, IGBTs, and MOSFET. 1/, 2/

Stress factor	Stress factor limit in relation to rating factor		Rating factor
	Lower	Upper	
General			
Equipment design ambient, T_{AE}			
T_{AE}, min.	----	----	0 °C
T_{AE}, max.	----	----	50 °C
Component design ambient, T_{AC}			
T_{AC}, min.	----	1.0	T_{AE}, min.
T_{AC}, max.	1.0	----	T_{AE}, max. + T_{AC} - T_{AE} T_{AC} - T_{AE} is the maximum calculated temperature difference between the component ambient and the equipment ambient at the operating conditions being evaluated.
Rectifiers, SCR, and GTO			
DC reverse blocking voltage	----	0.4 V_{RRM}	Repetitive peak reverse voltage
Nominal working voltage reverse voltage	----	0.5 V_{RRM}	Repetitive peak reverse voltage
Repetitive peak reverse voltage	----	0.7 V_{RRM}	Repetitive peak reverse voltage
Non-repetitive peak reverse voltage	----	1.0 V_{RRM}	Repetitive peak reverse voltage
DC forward blocking voltage	----	0.4 V_{DRM}	Repetitive peak off-state voltage
Nominal working peak forward blocking voltage	----	0.5 V_{DRM}	Repetitive peak off-state voltage
Repetitive peak forward blocking voltage	----	0.7 V_{DRM}	Repetitive peak off-state voltage
Non-repetitive peak forward blocking voltage	----	0.8 V_{DRM}	Repetitive peak off-state voltage
Maximum rate of rise of forward blocking voltage	----	0.5 $dv/dt_{critical}$	Critical rate of rise of forward blocking voltage
Minimum duration of voltage reversal (SCR)	$2.0t_q$	----	Turn-off time at maximum rated junction temperature, $T_{j(max)}$
Reapplied forward blocking voltage	----	0.7 $V_{DRM(reapplied)}$	Reapplied forward voltage at rated t_q and $T_{j(max)}$
Rate of rise of reapplied forward blocking voltage (SCR)	----	0.7 $dv/dt_{reapplied}$	Reapplied rate of rise of forward blocking voltage at rated t_q and $T_{j(max)}$
Minimum duration of gate turn-off signal (GTO)	$2.0t_{gq}$	----	Gate controlled turn-off time at maximum rated junction temperature $T_{j(max)}$
Average forward current			
Nominal value	----	0.7 $I_{T(AV)}$	Average forward current at $T_{j(max)}$ for application waveform, conduction angle, duty cycle, and frequency
Maximum value	----	1.0	

TABLE D-I. Application stress limits and derating factor for rectifiers, SCRs, GTOs, bipolar transistors, IGBTs, and MOSFET [1/, 2/] – Continued.

Stress factor	Stress factor limit in relation to rating factor		Rating factor
	Lower	Upper	
Rectifiers, SCR, and GTO -- Continued			
Repetitive peak forward current			
Nominal value	----	0.7 I_{TRM}	Repetitive peak current at $T_{j(max)}$ for the application waveform, conduction angle, duty cycle, and frequency
Maximum value	----	1.0 I_{TRM}	
Surge current			
Peak, one cycle	----	0.7 I_{TSM}	Peak surge current, peak half cycle ($\frac{1}{120}$ sec) surge, non-repetitive
Peak, multiple cycles	----	1.0 I_{TSM}, multiple	Peak surge current rated for the number of cycle expected in the application
Peak, sub-cycle	----	1.0 I_{TSM}, sub-cycle	Peak surge current rated for the application pulse base width
Maximum rate of rise of current during turn-on			
Repetitive maximum	----	0.8 di/dt_{REP}	Maximum repetitive rate of rise of current during turn-on at $T_{j(max)}$ and at rated repetitive peak current for the application waveform, conduction angle, duty cycle, and frequency
Non-repetitive maximum	----	0.5 $di/dt_{critical}$	
During surge	----	1.0 $di/dt_{critical}$	Critical rate of rise of current, repetitive
Turn-on gate power supply characteristics (SCR and GTO)			
Source impedance	----	1.0 R_{SG}	Gate power supply characteristics at rated critical rate of rise of current and peak current during turn-on, repetitive
Open circuit voltage	1.0 V_{SG}	----	
Open circuit voltage transition time	----	1.0 $t_{f,SG}$	
Turn-on gate power supply characteristics (GTO)			
Source impedance	----	1.0 R_{SG}	Gate power supply characteristics at rated rate of fall of anode current and peak anode current during turn-off
Open circuit voltage	1.0 V_{SG}	----	
Open circuit voltage transition time	----	1.0 $t_{f,SG}$	
Peak reverse gate voltage			
Maximum (SCR and GTO)	-----	0.7 V_{GRM}	Peak reverse gate voltage
Minimum for turn-off (GTO)	2.0 V_{GQM}	-----	Reverse gate voltage, minimum to cause turn-off

TABLE D-I. Application stress limits and derating factor for rectifiers, SCRs, GTOs, bipolar transistors, IGBTs, and MOSFET [1/], [2/] – Continued.

Stress factor	Stress factor limit in relation to rating factor		Rating factor
	Lower	Upper	
Rectifiers, SCR, and GTO -- Continued			
Peak reverse gate current (GTO)			
Maximum	----	0.7 I_{GRM}	Peak reverse gate current
Minimum for turn-off	2.0 I_{GQM}	----	Reverse gate current, minimum to cause turn-off
Peak forward gate current (SCR and GTO)			
Maximum for firing	----	0.7 I_{GM}	Peak forward gate current
Minimum for firing	2.0 I_{GTM}	----	Forward gate voltage, minimum to cause firing (maximum value)
Maximum during forward blocking	----	0.0 I_{GTM}	Peak forward blocking gate current
Peak forward gate voltage (SCR and GTO)			
Maximum for firing	----	0.7 V_{GM}	Peak forward gate current
Minimum for firing	2.0 V_{GTM}	----	Forward gate voltage, minimum to cause firing (maximum value)
Maximum during forward blocking	----	0.0 V_{GTM}	Peak forward blocking gate voltage
Maximum gate power dissipation (SCR and GTO)			
Average	----	0.7 $P_{G(AV)}$	Average gate power dissipation
Peak	----	1.0 P_{GM}	Peak gate power dissipation
Junction temperature (calculated)			
Average	----	-40 °C	$T_{j(max)}$ = -40 °C
Repetitive peak	----	-25 °C	$T_{j(max)}$ = -25 °C
Voltage reference diodes			
Bias current	0.8 I_{zt}	1.2 I_{zt}	Zener test current (value for rated Zener voltage)
Diode reverse current (Zener current)			
Minimum	0.1 I_{zt}	----	Zener test current (values for rated Zener voltage)
Maximum	----	0.5 I_{zt}	Maximum Zener current
Maximum continuous duty	----	0.3 I_{zt}	Maximum Zener current
Junction temperature (calculated)	----	100 °C	Maximum calculated junction temperature
Voltage regulator diodes			
Diode reverse current (Zener current)			
Minimum	0.1 I_{zt}	----	Zener test current (values for rated Zener voltage)
Maximum	----	0.5 I_{zt}	Maximum Zener current
Maximum continuous duty	----	0.3 I_{zt}	Maximum Zener current

TABLE D-I. Application stress limits and derating factor for rectifiers, SCRs, GTOs, bipolar transistors, IGBTs, and MOSFET [1/, 2/] – Continued.

Stress factor	Stress factor limit in relation to rating factor		Rating factor
	Lower	**Upper**	
Voltage regulator diodes – Continued			
Surge	----	0.5 I_{zt}	Surge current
Junction temperature (calculated)			
Average	----	-50 °C	$T_{j(max)}$ = -50 °C
Peak	----	-25 °C	$T_{j(max)}$ = -25 °C
Bipolar transistor			
Collector to emitter voltage, cut-off or inverse mode			
DC	----	0.4 V_{CEO}	Collector to emitter voltage
Nominal working	----	0.5 V_{CEO}	
Repetitive peak	----	0.7 V_{CEO}	
Non-repetitive	----	1.0 V_{CEO}	
Collector to base voltage, cut-off or inverse mode			
DC	----	0.4 V_{CEO}	Collector to base voltage
Nominal working	----	0.5 V_{CEO}	
Repetitive peak	----	0.7 V_{CEO}	
Non-repetitive	----	1.0 V_{CEO}	
Emitter to base voltage, cut-off or inverse mode			
DC	----	0.4 V_{CEO}	Emitter to base voltage
Nominal working	----	0.5 V_{CEO}	
Repetitive peak	----	0.7 V_{CEO}	
Non-repetitive	----	1.0 V_{CEO}	
Peak collector current, cut-off or inverse mode	----	0.7 V_{CEO}	Collector cut-off current
Peak emitter current, cut-off or inverse mode	----	0.7 V_{EBO}	Emitter cut-off current
Average collector current, active or saturation mode			
Nominal working	----	0.6 $I_{C(AV)}$	Average collector current at rated $T_{j(max)}$ for the application waveform, conduction angle or period, duty cycle, and frequency
Maximum value	----	0.8 $I_{C(AV)}$	

TABLE D-I. Application stress limits and derating factor for rectifiers, SCRs, GTOs, bipolar transistors, IGBTs, and MOSFET [1/, 2/] – Continued.

Stress factor	Stress factor limit in relation to rating factor		Rating factor
	Lower	Upper	
Bipolar transistor – Continued.			
Repetitive peak collector current, active or saturation mode			
Nominal working	----	0.6 $I_{C(REP)}$	Repetitive peak collector current at rated $T_{j(max)}$ for the application waveform, conduction angle or period, duty cycle, and frequency
Maximum value	----	0.8 $I_{C(REP)}$	
Non-repetitive peak collector current, active or saturation mode	----	1.0 $I_{C(REP)}$	Non-repetitive peak collector current
Peak base current	----	0.7 I_B	Maximum base current at rated $T_{j(max)}$
Peak emitter current	----	0.7 I_E	Maximum emitter current at rated $T_{j(max)}$
Maximum collector to emitter voltage, active or saturation mode	----	0.7 V_{CE}	Repetitive peak collector to emitter voltage at rated repetitive peak collector current and rated $T_{j(max)}$ for the application waveform, conduction angle, or period, duty cycle, and frequency
Circuit current gain	----	0.5 H_{FE}	Static forward current transfer ratio
Minimum duration of base controlled turn-off signal	2.0 (t_s+t_f)	----	Turn-off or cut-off time (storage time and fall time during turn-off rated $T_{j(max)}$)
Junction temperature (calculated)			
Average	----	-50 °C	$T_{j(max)}$ = -50 °C
Repetitive peak	----	-25 °C	$T_{j(max)}$ = -25 °C
MOSFET			
Drain to source voltage, cut-off mode or off-state			
DC	----	0.5 $V_{DS,\ MAS}$	Maximum rated drain to source voltage
Nominal working	----	0.6 $V_{DS,\ MAS}$	
Repetitive peak	----	0.7 $V_{DS,\ MAS}$	
Non-repetitive	----	0.8 $V_{DS,\ MAS}$	
Drain to gate voltage			
DC	----	0.5 V_{DGR}	Drain to gate voltage with R_{GS} = 1 megohm
Nominal working	----	0.6 V_{DGR}	
Repetitive peak	----	0.7 V_{DGR}	
Non-repetitive	----	0.8 V_{DGR}	

TABLE D-I. Application stress limits and derating factor for rectifiers, SCRs, GTOs, bipolar transistors, IGBTs, and MOSFET [1/, 2/] – Continued.

Stress factor	Stress factor limit in relation to rating factor		Rating factor
	Lower	Upper	
MOSFET – Continued.			
Average drain current, active or on-state mode, I_D			
Nominal value	----	0.6 $I_{D, on}$	Average drain current at rated $T_{j(max)}$ for the application waveform, conduction angle or period, duty cycle, frequency, and drain to source on-state resistance
Maximum value	----	0.8 $I_{D, on}$	
Repetitive peak drain current, active or on-state mode, I_D			
Nominal value	----	0.6 $I_{D, on}$	Repetitive peak drain current at rated $T_{j(max)}$ for the application waveform, conduction angle or period, duty cycle, frequency, and drain to source on-state resistance
Maximum value	----	0.8 $I_{D, on}$	
Non-repetitive peak drain current, active or on-state mode, I_D	----	0.8 $I_{D, on}$	Peak drain current at rated $T_{j(max)}$ for the application waveform, conduction angle or period, duty cycle, frequency, and drain to source on-state resistance
Gate to source voltage, V_{GS}	----	0.7 V_{GS}	Gate to source voltage
Minimum duration of gate controlled turn-off signal	2.0 $(t_{d,off} + t_f)$ or t_{rr}	----	Turn-off or cut-off time (turn-off delay and fall time) or body-drain diode reverse recovery time during turn-off at rated $T_{j(max)}$, whichever is greater
Junction temperature (calculated)			
Average	----	-50 °C	$T_{j(max)}$ = -50 °C
Repetitive peak	----	-25 °C	$T_{j(max)}$ = -25 °C
IGBT			
Collector to emitter voltage, cut-off or inverse mode			
DC	----	0.4 V_{CES}	Collector to emitter voltage
Nominal working	----	0.5 V_{CES}	
Repetitive peak	----	0.7 V_{CES}	
Non-repetitive	----	1.0 V_{CES}	
Peak collector current, cut-off or inverse mode	----	0.7 I_{CES}	Collector to emitter leakage current
Maximum collector to emitter voltage, active or saturation mode	----	0.7 V_{CE}	Repetitive peak collector to emitter voltage at rated repetitive peak collector current and rated $T_{j(max)}$ for the application waveform, conduction angle or period, duty cycle, and frequency

TABLE D-I. Application stress limits and derating factor for rectifiers, SCRs, GTOs, bipolar transistors, IGBTs, and MOSFET [1/], [2/] – Continued.

Stress factor	Stress factor limit in relation to rating factor: Lower	Stress factor limit in relation to rating factor: Upper	Rating factor
IGBT – Continued			
Average collector current, active or saturation mode			
Nominal value	----	0.6 $I_{C(AV)}$	Average collector current at rated $T_{j(max)}$ for the application waveform, conduction angle or period, duty cycle, and frequency
Maximum value	----	0.8 $I_{C(AV)}$	
Repetitive peak collector current, active or saturation mode			
Nominal value	----	0.6 $I_{C(REP)}$	Repetitive peak collector current at rated $T_{j(max)}$ for the application waveform, conduction angle, or period, duty cycle, and frequency
Maximum value	----	0.8 $I_{C(REP)}$	
Non-repetitive peak collector current, active or saturation mode	----	1.0 I_{CM}	Maximum pulsed peak collector current
Average emitter current, active or saturation mode			
Nominal value	----	0.6 $I_{E(AV)}$	Average emitter current at rated $T_{j(max)}$ for the application waveform, conduction angle or period, duty cycle, and frequency
Maximum value	----	0.8 $I_{E(AV)}$	
Repetitive peak emitter current, active or saturation mode			
Nominal value	----	0.6 $I_{E(REP)}$	Repetitive peak emitter current at rated $T_{j(max)}$ for the application waveform, conduction angle, or period, duty cycle, and frequency
Maximum value	----	0.8 $I_{E(REP)}$	
Non-repetitive peak emitter current, active or saturation mode	----	1.0 I_{EM}	Maximum pulsed peak emitter current
Average diode forward current			
Nominal value	----	0.7 I_{FM}	Repetitive peak forward current at rated $T_{j(max)}$ for the application waveform, conduction angle, duty cycle, and frequency
Maximum value	----	1.0 I_{FM}	
Repetitive peak diode forward current			
Nominal value	----	0.7 I_{FM}	Repetitive peak forward current at rated $T_{j(max)}$ for the application waveform, conduction angle, duty cycle, and frequency
Maximum value	----	1.0 I_{FM}	
Gate to emitter voltage			
Nominal value	----	0.8 V_{GES}	Gate to emitter voltage
Maximum value	----	1.0 V_{GES}	
Minimum duration of gate controlled turn-off signal	2.0 ($t_{d,\,off} + t_f$) or T_{rr}	----	Turn-off or cut-off time (turn-off delay and fall time) or diode reverse recovery time during turn-off rated $T_{j(max)}$, whichever is greater

TABLE D-I. Application stress limits and derating factor for rectifiers, SCRs, GTOs, bipolar transistors, IGBTs, and MOSFET [1/, 2/] – Continued.

Stress factor	Stress factor limit in relation to rating factor		Rating factor
	Lower	Upper	
IGBT – Continued			
Junction temperature (calculated)			
Average	----	-50 °C	$T_{j(max)}$ = -50 °C
Repetitive peak	----	-25 °C	$T_{j(max)}$ = -25 °C

NOTES:
1/ Silicon-controlled rectifier (SCR). Gate turn-off (switches) (GTO). Insulated Gate Bipolar Transistor (IGBT). Metal-Oxide Semiconductor Field-Effect Transistor (MOSFET).
2/ Stress limit = Rating multiplier × Rating.

PECE CYBERSECURITY REQUIREMENTS

E.1 SCOPE

This appendix covers PECE cybersecurity requirements.

This appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

E.2 APPLICABLE DOCUMENTS

E.2.1 General. The documents listed in this section are specified in Appendix E 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 Appendix E of this specification, whether or not they are listed.

E.2.2 Government documents.

E.2.2.1 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.

DEPARTMENT OF DEFENSE INSTRUCTIONS

DoD Instruction 8500.1 - Cybersecurity

(Copies of this document are available online at www.dtic mil/whs/directives/.)

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

NIST SP 800-53 - Security and Privacy Controls for Federal Information Systems and Organizations

(Copies of these documents are available online at http://www.nist.gov.)

NAVAL SEA SYSTEMS COMMAND (NAVSEA) MANUALS

NAVSEA 9400.2-M - NAVSEA Afloat Information Assurance (IA) Implementation Manual

(Copies of this document are available online at www.navsea.navy.mil.)

E.3 CYBERSECURITY REQUIREMENTS

E.3.1 Security category. The generalized format for expressing the security category is confidentiality, integrity, availability, and specific impact where the acceptable values for potential impact are low, moderate, or high. PECE shall be designed with the appropriate security category for the application (see 6.2). Tailored security controls from the low baseline of security controls defined in NIST Special Publication 800-53 shall ensure that the minimum assurance requirements are satisfied. The minimum security control requirements for PECE shall be as follows:

a. Access control shall include remote control capability. No wireless access shall be allowed.

b. Security assessment and authorization shall include continuous monitoring of PECE interconnections.

c. Audit and accountability controls shall include time stamps.

d. Configuration management controls shall include access restrictions and configuration settings.

e. Identification and authentication controls shall include password based authentication.

f. Physical and environmental protection shall include monitoring and alarms notification.

g. System and communication protection shall include failure in a known state.

E.3.2 Analysis of threats. When specified (see 6.2), an analysis of threats shall drive the PECE control system implementation details, both physically and with respect to cybersecurity, to mitigate those threats and the impacts of attacks. The analysis of threats shall identify PECE assets (e.g., control consoles, HMIs, backbone networks, control processors, communication interfaces, input/output (I/O), networks, and other such assets.) and PECE threats, both accidental and malicious (e.g., advanced persistent threats (APTs) and threats on system availability, integrity, and authenticity). Analysis shall also identify mitigation considerations.

E.3.3 Security measures. The PECE should consider the following security measures:

a. Physical security should provide the following:
   (1) Proper signage of equipment.
   (2) Locked enclosures for primary control elements.
   (3) Enclosures with intrusion detection.
   (4) Obstructed or removed external ports.

b. Network security should provide the following:
   (1) Disabling unused ports.
   (2) Port-based security.
   (3) Media Access Control (MAC) based security.
   (4) Disabling unused services and protocols.
   (5) Default security parameters.
   (6) Secure network protocols.
   (7) Intrusion detection (see 6.2).

c. Controller security should provide the following:
   (1) Password authentication.
   (2) Login failure lockout.
   (3) Password failure lockout.
   (4) Code protection.
   (5) Control firmware validation.
   (6) Digital signatures (such as a Common Access Card (CAC)).

d. Console and computing security should provide the following:
   (1) User access.

(2) Application white-listing (such as running executable files other than control systems).

(3) Operating system patching.

e. Application security should provide the following:

(1) Virus scanning.

(2) Secure coding practices (use the following link for guidance: https://www.securecoding.cert.org/confluence/display/seccode/CERT+Coding+Standards).

(3) Application authentication.

f. System security should provide the following:

(1) Virus scanning.

(2) Change logs.

(3) User authorization.

(4) Secure password practices.

(5) Vendor default modifications.

(6) Disabling or removal of unused ports.

(7) Protocols.

(8) Software features.

(9) System security training.

g. External interface security should provide firewalls.

E.3.4 Implementation. The PECE design shall be implemented in consideration of the above security measures and in accordance with NAVSEA 9400.2-M and DoD Instruction 8500.1.

E.4 CYBERSECURITY VERIFICATION

E.4.1 Security requirements. The requirements specified in E.3 shall be verified (see table II). Any failure to meet these requirements is cause for rejection of the PECE.

E.4.2 Additional specified cybersecurity requirements. Any additional cybersecurity requirements as specified in 6.2 shall be verified. Any failure to meet these requirements is cause for rejection of the PECE.

Custodians:
Army – CR4
Navy – SH
Air Force – 99

Review activities:
Navy – AS, CG
Air Force – 03, 19
DLA – GS, GS2

Preparing activity:
Navy – SH
(Project 6150-2014-002)

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.dla.mil.