INCH-POUND
MIL-DTL-32483
8 November 2013

DETAIL SPECIFICATION

SWITCHGEAR, POWER, HARD-MOUNTED, MEDIUM VOLTAGE, 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 5925

CONTENTS

LIST OF TABLES

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

1. SCOPE

1.1 Scope. This specification covers electrical power dead-front, deck-mounted, medium voltage switchgear for naval shipboard use. The switchgear is hard-mounted and requires the use of shock-hardened equipment with exceptions as detailed below. These requirements cover switchgear assemblies containing, but not limited to, such devices as medium voltage vacuum circuit breakers (VCBs), other interrupting devices, switches, control, instrumentation and metering, and protective and regulating equipment.

2. APPLICABLE DOCUMENTS

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

2.2 Government documents.

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

COMMERCIAL ITEM DESCRIPTIONS

A-A-208	-	Ink, Marking, Stencil, Opaque (Porous And Non-Porous Surfaces)
A-A-59125	-	Terminal Boards, Molded, Barrier Screw and Stud Types and Associated Accessories
A-A-59125/2	-	Terminal Boards, Molded, Barrier Screw Type, Class 38TB
A-A-59125/9	-	Terminal Boards, Molded, Barrier Stud Type, Class 3TB
A-A-59781	-	Light Emitting Diodes for Use as Indicator Lights

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-I-631	-	Insulation, Electrical, Synthetic-Resin Composition, Nonrigid
MIL-S-901	-	Shock Tests, H.I. (High-Impact) Shipboard Machinery, Equipment, and Systems, Requirements for
MIL-E-917	-	Electric Power Equipment Basic Requirements
MIL-DTL-1222	-	Studs, Bolts, Screws and Nuts for Applications Where a High Degree of Reliability is Required; General Specification for
MIL-I-1361	-	Instrument Auxiliaries, Electrical Measuring: Shunts, Resistors, and Transformers
MIL-I-3158	-	Electrical Glass-Fiber (Resin-Filled): and Cord, Fibrous-Glass
MIL-DTL-3661	-	Lampholders, Indicator Lights, Indicator Light Housing, and Indicator Light Lenses, General Specification for
MIL-L-3661/38	-	Housing, Indicator-Light, Style LH80
MIL-L-3661/62	-	Lampholder, Lights, Indicator (Housing), Style LH95 (for D.C. Applications)

MIL-L-3661/63	-	Lampholder, Lights, Indicator (Housing), Style LH96
MIL-L-3661/64	-	Lampholder, Lights, Indicator (Housing), Style LH97
MIL-L-3661/65	-	Lampholder, Lights, Indicator (Housing), Style LH98
MIL-DTL-5541	-	Chemical Conversion Coatings on Aluminum and Aluminum Alloys
MIL-DTL-15024	-	Plates, Tags, and Bands for Identification of Equipment, General Specification for
MIL-P-15024/5	-	Plates, Identification
MIL-T-15108	-	Transformers, Power, Step-Down, Single-Phase, 60-Hertz, 1-Kilovoltampere Approximate Minimum Rating, Dry Type, Naval Shipboard
MIL-DTL-15109	-	Resistors and Rheostats, Naval Shipboard
MIL-PRF-15160	-	Fuses, Instrument, Power, and Telephone, General Specification for
MIL-T-15377	-	Temperature Monitor Equipment Naval Shipboard
MIL-DTL-16034	-	Meters, Electrical-Indicating (Switchboard and Portable Types), General Specification for
MIL-S-16104	-	Synchroscope
MIL-M-16125	-	Meters, Electrical, Frequency
MIL-T-16315	-	Transformers, Power, Step-Down (Miscellaneous, Naval Shipboard Use)
MIL-DTL-16878	-	Wire, Electrical, Insulated, General Specification for
MIL-DTL-18240	-	Fastener Element, Self-Locking, Threaded Fastener, 250 °F Maximum
MIL-S-18396	-	Switches, Meter and Control, Naval Shipboard
MIL-W-19088	-	Wattmeters, Switchboard Type, 4-1/2 Inch
MIL-PRF-19207	-	Fuseholders, Extractor Post Type, Blown Fuse, Indicating and Nonindicating, General Specification for
MIL-DTL-21604	-	Switches, Rotary, Multipole and Selector; General Specification for
MIL-V-23151	-	Voltmeter, Expanded Scale Switchboard Type (Naval Shipboard Use)
MIL-M-23167	-	Meter, Frequency, Expanded Scale Switchboard Type (Naval Shipboard Use)
MIL-I-24391	-	Insulation Tape, Electrical, Plastic Pressure-Sensitive
MIL-PRF-24712	-	Coatings, Powder (Metric)
MIL-DTL-24765	-	Power Supply, Uninterruptible, Static (Naval Shipboard)
MIL-DTL-28803	-	Display, Optoelectronic, Segmented Readouts, Backlighted, General Specification for
MIL-PRF-32484	-	Protective Relays and Attachments, Medium Voltage Vacuum Circuit Breaker Applications

MIL-DTL-32485	-	Circuit Breakers, Vacuum Type (VCB), Electric Power, Medium Voltage, Alternating Current, Draw-Out Removable Construction, without Internal Overcurrent Protection
MIL-DTL-83522	-	Connectors, Fiber Optic, Single Ferrule, General Specification for
MIL-PRF-85045	-	Cables, Fiber Optics, (Metric), General Specification for

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-108	-	Definitions of and Basic Requirement for Enclosure for Electric and Electronic Equipment
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-740-2	-	Structureborne Vibratory Acceleration Measurements and 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
MIL-STD-1399-300	-	Electric Power, Alternating Current
MIL-STD-1399-680	-	High Voltage Electric Power, Alternating Current
MIL-STD-1472	-	Human Engineering
MIL-STD-1474	-	Noise Limits

DEPARTMENT OF DEFENSE HANDBOOKS

MIL-HDBK-454	-	General Guidelines for Electronic Equipment
MIL-HDBK-470	-	Designing and Developing Maintainable Products and Systems Volume I

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

CODE OF FEDERAL REGULATIONS (CFR)

29 CFR 1910	-	Occupational Safety and Health Standards

(Copies of this document are available from the Superintendent of Documents, U.S. Government Printing Office, Washington DC 20401 or online at www.gpoaccess.gov/index.html.)

NAVAL SEA SYSTEMS COMMAND (NAVSEA) PUBLICATIONS

S9074-AR-GIB-010/278 - Requirements for Fabrication Welding and Inspection, and Casting Inspection and Repair for Machinery, Piping, and Pressure Vessels

(Copies of this document are available online at https://nll.ahf.nmci.navy.mil. This publication 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 Y14.38 - Abbreviations and Acronyms for Use on Drawings and Related Documents

(Copies of this document are available from ASME, 22 Law Drive, P.O. Box 2900, Fairfield, NJ 07007-2900 or online at www.asme.org.)

ASTM INTERNATIONAL

ASTM B98/B98M - Standard Specification for Copper-Silicon Alloy Rod, Bar and Shapes

ASTM B187/B187M - Standard Specification for Copper, Bus Bar, Rod, and Shapes and General Purpose Rod, Bar, and Shapes

ASTM B700 - Standard Specification for Electrodeposited Coatings of Silver for Engineering Use

(Copies of these documents are available from ASTM International, 100 Barr Harbor Dr., P.O. Box C700, West Conshohocken, PA 19428-2959 or online at www.astm.org.)

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

IEEE C37.20.2 - IEEE Standard for Metal-Clad Switchgear

IEEE C37.20.4 - IEEE Standard for Indoor AC Switches (1kV-38kV) for Use in Metal-Enclosed Switchgear

IEEE C37.20.6 - IEEE Standard for 4.76 kV to 38 kV Rated Ground and Test Devices Used in Enclosures

IEEE C37.20.7 - IEEE Guide for Testing Medium-Voltage Metal-Enclosed Switchgear for Internal Arcing Faults

IEEE C37.46 - IEEE Standard Specifications for High-Voltage (>1000 V) Expulsion and Current-Limiting Power Class Fuses and Fuse Disconnecting Switches

IEEE C37.47 - IEEE Standard Specifications for High-Voltage (>1000 V) Distribution Class Current-Limiting Type Fuses and Fuse Disconnecting Switches

IEEE C37.235 - IEEE Guide for the Application of Rogowski Coils Used for Protective Relaying Purposes

IEEE C37.301	-	IEEE Standard for High-Voltage Switchgear (Above 1000 V) Test Techniques - Partial Discharge Measurements
IEEE C57.13	-	IEEE Standard Requirements for Instrument Transformers

(Copies of these documents are available from the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331 or online at www.ieee.org.)

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

IEC 60044-8	-	Instrument transformers - Part 8: Electronic current transformers
IEC 61243-5	-	Live working - Voltage detectors - Part 5: Voltage detecting systems (VDS)
IEC 62271-206	-	High-voltage switchgear and controlgear - Part 206: Voltage presence indicating systems for rated voltages above 1 kV and up to and including 52 kV

(Copies of these documents are available from the IEC Central Office, 3 rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland or online at www.iec.ch.)

IPC

IPC-CC-830	-	Qualification and Performance of Electrical Insulating Compound for Printed Wiring Assemblies

(Copies of this document are available from IPC, 3000 Lakeside Drive, 309 S, Bannockburn, IL 60015 or online at www.ipc.org.)

NATIONAL AEROSPACE STANDARDS COMMITTEE (NA/NAS)

NASM17830	-	Nut, Self-Locking, Hexagon-Regular, 250 Degrees F and 450 Degrees F, Non-Metallic Insert, 300 Series CRES

(Copies of this document are available from Aerospace Industries Association, 1000 Wilson Boulevard, Suite 1700, Arlington, VA 22209-3901 or online at www.aia-aerospace.org.)

SAE INTERNATIONAL

SAE-AS7928	-	Terminals, Lug: Splices, Conductor: Crimp Style, Copper, General Specification For
SAE-AS33671	-	Strap, Tiedown, Electrical Components, Adjustable, Self-Clinching, Plastic, Type I, Class 1

(Copies of these documents are available from SAE World Headquarters, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or online at www.sae.org.)

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 switchboard shall be subjected to first article inspection in accordance with 4.2.

3.2 General requirements. The medium voltage switchgear shall comply with the applicable requirements of IEEE C37.20.2 and MIL-STD-1399-680 except as modified or added to by the requirements of this specification.

3.3 Safety. The switchgear shall provide fail-safe features for safety of personnel during the installation, operation, maintenance, and repair or interchanging of a complete equipment assembly or component parts thereof. Equipment design for personnel safety shall be equal to or better than the appropriate requirements of the Occupational Safety and Health Act (OSHA) as identified in Title 29, Part 1910 of the Code of Federal Regulations (CFR). Except as required herein, safety shall be in accordance with MIL-E-917.

3.3.1 Accidental contact. When energized during normal operations, the switchgear shall provide protection to personnel against accidental contact with voltages in excess of 30 volts root mean square (rms) or direct current (DC) with all removable panels in place and hinged doors closed.

3.3.2 Tag-out requirements. Control circuits operating at greater than 30 volts require tag-out provisions for isolation and safety of connected equipment during maintenance.

3.3.3 Maintenance test points. Accessible points for verification of de-energization shall be provided (see 3.6.10.5.1).

3.4 Construction requirements.

3.4.1 Materials and coatings. Materials and coatings contained in or on the switchboard shall meet the requirements of MIL-E-917 except as modified or added to by the requirements of this specification.

3.4.1.1 Polyvinyl chloride (PVC). PVC material shall not be used unless it is a part of or integral to the leads of a component or as a constituent or integrated element of a component.

3.4.1.2 Non-preferred component materials. The following materials are non-preferred and shall be identified to the Naval Sea Systems Command (NAVSEA) materials Technical Warrant Holder (TWH) or TWH representative prior to the start of first article testing (see 6.2):

a. Insulating materials which contain halogens, e.g., chlorine, fluorine, and bromine, which evolve gases during combustion.

b. Organic materials not inherently fungus-resistant or validated to be fungus-resistant. Refer to MIL-HDBK-454, Guideline 4.

c. Corrosion-susceptible materials not in accordance with MIL-E-917 requirements.

d. Lead free solder used for printed circuit boards.

e. Type 1 compositions containing hexavalent chromium in accordance with MIL-DTL-5541.

3.4.1.3 Coatings.

3.4.1.3.1 Painting.

3.4.1.3.1.1 Enamel. Switchboards shall be prepared and painted in accordance with MIL-E-917, with the exception that only one coat of gray enamel shall be applied. Touching up is permitted for marks or scratches due to assembly, testing, or other factory handling.

3.4.1.3.1.2 Powder coating. Powder coating may be used as an alternative to enamel painting. The powder coating shall be in accordance with MIL-PRF-24712. The type of powder, process of application, curing, and repair procedures and testing shall be approved by NAVSEA 05P23.

3.4.1.3.1.3 Grounding fasteners with paint. Grounding connections shall be free of enamel or powder coat paint. Toothed lockwashers or similar shall not be used to grind enamel or powder coat paint away under screws for grounding.

3.4.1.3.2 Chemical conversion coatings. Chemical conversion coatings may be used as a protective coating for aluminum frame and aluminum components internal to the switchboard. Coatings may also be used as a preparation for the paint process. Electrically-conductive Class 3 coating may be used in grounding. When used, coatings shall meet the requirements of MIL-DTL-5541 for visually discernible color.

3.4.1.3.3 Non-preferred component coatings. Corrosion-susceptible coatings not in accordance with MIL-E-917 requirements are non-preferred and shall be identified (see 6.2).

3.4.1.3.4 Conformal coating. All circuit boards shall be conformal coated in accordance with IPC-CC-830.

3.4.2 Switchboard structure.

3.4.2.1 Structural materials. Switchboard structure may be manufactured of steel or aluminum conforming to applicable ASTM specifications. When aluminum is used, aluminum Grade 5052 is preferred.

3.4.2.2 Compartmentation. Major parts of the primary circuit, that is, the circuit switching or interrupting devices, buses, voltage transformers, and control power transformers, shall be completely enclosed by grounded metal barriers or nonconductive material, or a combination of both, that have no intentional openings between compartments. Bus, cable, and primary circuit transformers may be combined into one or more compartments. Bus and cable shall be accessible for thermal imaging scans (see 3.4.2.15). Potential transformers, control power transformers, and fuses are not required to be of a drawout-design as long as they are accessible for maintenance.

3.4.2.3 Assembly. When the switchboard consists of multiple vertical units, they are bolted together to form a switchboard section. All surfaces shall be finished smooth, welded or bolted together, and reinforced where necessary with structural members for vertical units of the switchboard section.

3.4.2.4 Hinging. Front and rear doors shall have rolled or formed edges as required to provide a rigid frame unit and shall be of the hinged or bolted type. Hinge pins shall provide a bearing surface axially for positive alignment. Doors shall be provided with captive hand operable knobs for fastening in place. Panels shall be hinged to provide access to electrical equipment mounted thereon. Means shall be provided so that these hinged sections may be opened without removing the guard rail. Hinged panels shall be provided with door stops or positioning devices to stop the door in its opening swing and to hold it in the open position. The preferred side for hinging panels is the left-hand side when facing the front of the panel. Hinged panels shall be electrically grounded to the unit framework by a separate conductor. Hinges are not considered to be an acceptable grounding path.

3.4.2.5 Layout. The rear portion of the structure shall contain copper bus bars and supports with space for feeder cables or busway entering as required. The front portion of the structure shall contain circuit breakers and metering as required.

3.4.2.6 Lifting. Provisions for lifting such as lifting channels, angles, and lifting eyes shall be provided on the top of each shipping section of sufficient strength and number for lifting, handling, and installation on the ship. Additionally, replacement bolts, with all necessary washers to maintain drip-proof integrity, shall be provided in order for the lifting components to be replaced when the switchboard is installed on the ship.

3.4.2.7 Removable sheets and panels. Removable sheets and panels on the front and rear shall be provided with lifting handles. Mounting and alignment devices shall be provided to facilitate installation and removal of removable enclosing panels. When needed to prevent incorrect assembly, alignment pins or devices shall be staggered or have a unique arrangement in order to prevent interchangeability of panel fronts or rears between units of the same switchboard section and units of other switchboards sections within the same switchboard group or ship's compartment. When installed, the panels shall be electrically grounded to the unit framework. Electrical ground may be achieved by the panel mounting or fastening devices, as long as positive metal-to-metal conductive surfaces are provided for by the addition of other devices that do not interfere with panel removal.

3.4.2.8 Welding. Requirements for welding and allied processes shall be in accordance with applicable American Welding Society (AWS) standards or NAVSEA S9074-AR-GIB-010/278.

3.4.2.9 Guard rails. Each switchboard unit, except for distribution units, shall be provided with a grab rod. The rod shall have a sufficient number of brackets to provide support for personnel under all operating conditions of the ship. The rod shall be attached in such a manner that all panels can be removed and hinged panels opened without removal of the rod from the member to which it is attached. These rods shall be located so that they will not interfere with operation of the equipment and shall not extend more than 4 inches from the front of the panel. Guard rails shall be made from electrically insulating materials.

3.4.2.9.1 Removable guard rails. When specified (see 6.2), removable guard rail sections shall be provided on the rear framework of the switchboard to prevent personnel from being thrown against live buses caused by the motion of the ship when the rear enclosure is removed. Rails shall be required at proper levels when needed to prevent personnel from being thrown against live buses caused by the motion of the ship. Rails shall be mounted on the inside of the rear vertical members so as not to protrude beyond the rear or ends of the structure. Guard rail sections shall be easily removable for maintenance access, but shall be provided with securing bolts or other locking means to prevent dislodgement caused by shock.

3.4.2.10 Top panel. A sheet cover shall enclose the top of each switchboard section. The top shall prevent dripping water or falling objects from entering the switchboard enclosure or damaging instruments on the front panels. It shall extend approximately 4 inches beyond the face of the front panels and 4 inches beyond the rear of the switchboard structure. Clearance between the upper edge of the front panels and the underside of the top sheet, where it extends over the front, shall be at least 1/4 inch. Front and rear edges of the top sheet shall be turned up to form a 1-inch flange along the entire length of the section or switchboard to prevent water from spilling over the front or rear. To ensure watertight integrity at the corners, the turned-up front and rear flanges shall be extended around the corners and along the end of the top sheet approximately 8 inches. The edge of the top sheet shall be turned down to form a flange and shall overlap the side sheets of the switchboard to allow drainage over the end in a manner that prevents water from seeping down the inside of the side sheet. Means such as a ground clip shall be used to ensure that the panels are effectively grounded.

3.4.2.11 Door interlocks. When specified (see 6.2), door interlocks shall de-energize accessible power circuits in a compartment greater than 30 volts.

3.4.2.12 Accessibility.

3.4.2.12.1 Space. Space shall be provided for the installation, securing, and connection of cables. The space for cable routing shall include that required for the bending radius of the cable and for the installation of cable lugs.

3.4.2.12.2 Servicing. Equipment, bus work, fasteners, and electrical connections that may require servicing, repair, or replacement during the life of the switchboard shall be readily accessible for servicing, inspection, tightening, repair, or replacement. Access shall be maintained after all bus work, switchboard wiring, and ship cabling are installed. The enclosure side sheets, or portions thereof, shall be removable to provide installation and maintenance access.

3.4.2.13 Louvers and other openings. Louvers and other openings shall not pass a rod having a diameter greater than 3/8 inch.

3.4.2.14 Control cabinet/compartment. Each switchboard section shall have a metal-enclosed control cabinet/compartment, as specified (see 6.2).

3.4.2.14.1 Control cabinet/compartment location. The location of the control cabinet/compartment shall not place the operator in front of any medium voltage load switching device.

3.4.2.14.2 Control cabinet/compartment shock isolation. The control cabinet/compartment or individual components may be internally shock isolated to allow the use of commercial off-the-shelf (COTS) components.

3.4.2.15 Thermal imaging windows. Thermal imaging windows shall be provided with access to view selected current carrying joints or expected hot spots. Thermal imaging windows shall meet the following requirements:

a. Shall incorporate a specialty lens which allows the infrared wavelengths to transmit through the optic, ultimately to be captured and interpreted by an infrared imager.

b. Shall maintain safe creepage and clearance distances from electrical conductors.

c. Shall have a removable metal cover.

d. Shall not absorb water.

e. Shall not become adrift during first article testing.

f. Shall have an instruction provided in a label near the infrared window to aid thermographers.

3.4.2.16 Arc-resistant design (pressure relief arc flaps). When specified (see 6.2), pressure relief arc flaps shall be used to de-pressurize selected compartments in the event of an arc fault (see 4.4.3.24). Details for pressure relief shall be as specified (see 6.2).

3.4.3 Insulation.

3.4.3.1 Insulating material. Insulating material for bus supports and spacers, fuse bases, and other similar parts shall be a minimum of Class B (130 °C) in accordance with MIL-E-917. Insulating material shall be sealed to prevent the absorption of water. Primary conductor insulating material not in accordance with MIL-E-917 requirements may be used, but such material shall be subjected to flame testing of 4.4.3.23.

3.4.3.2 Insulation distances (creepage and clearance). Safe insulation distances for medium voltage components shall be validated by successful performance when subjected to power frequency withstand voltage for primary conductors and lightning impulse withstand voltage (BIL) testing in accordance with 4.4.3.7 and 4.4.3.9. Low voltage components not covered by other specifications shall meet creepage and clearance requirements in accordance with MIL-E-917 with Set C and enclosed spacing.

3.4.4 Fastener locking devices. Unless otherwise specified in the individual equipment specifications, locking devices shall be provided in accordance with 3.4.4.1 for electrical connections and mechanical assemblies in all switchboards, switchgear units, and in all equipment. A visual method to check bus bar and cable fastener tightness (such as torque check paint) shall be provided.

3.4.4.1 Acceptable locking devices. Unless specified in 3.4.4.2 or otherwise specified herein, any locking device rated for 250 °F or higher that performs successfully in first article testing shall be suitable for use with the following exceptions/caveats:

a. Self-locking nuts are the preferred method and shall be in accordance with applicable military specifications.

b. Castellated nuts with cotter pinning or safety wiring is not recommended for applications requiring accurate loads such as bus joints.

c. Toothed lockwashers may be used where the weight of the part does not exceed 2 ounces per screw such as a terminal block.

d. Split ring lockwashers may be used where the weight of the part does not exceed 2 ounces per screw such as a terminal block.

e. Non-liquid threadlocking adhesive may be used on any electrical joint.

f. Bolt self-locking elements shall be in accordance with MIL-DTL-18240.

3.4.4.2 Prohibited locking devices. The following locking devices shall not be used:

a. Nut and jam nut

b. Belleville washers (plain)

c. Clip-on types of nuts

d. Single-thread engaging nuts formed by stamping a thread-engaging impression in a flat piece of metal

e. Setscrews

f. Liquid threadlocking adhesive

3.4.5 Wiring of control and instrument circuits.

3.4.5.1 Control and instrument cable types. Cables used for control and instrument circuits, ground detector, indicator lights, and communications devices and other parts shall conform to MIL-DTL-16878 and MIL-DTL-16878/32. Control and instrument wiring shall not be smaller than Type AWG-16 of MIL-DTL-16878/32, but may be larger, if necessary, for current carrying capacity requirements. Communication device wiring shall not be smaller than Type AWG-20 of MIL-DTL-16878/32. Control cable for low-level signals for electronic devices (see 6.3.2) and load sharing shall be shielded type. The flexible wire (higher stranded) versions shall be used for wiring between hinged panels and the stationary structure. Cables within each unit shall be of the same solid color.

3.4.5.2 Wire and terminal marking. Internal wiring of equipment shall be marked on both ends by fiber tags or by synthetic resin tubing Type F, Grade A of MIL-I-631. Markings shall agree with the designation shown on the switchboard drawings to facilitate checking of connections. It shall not be necessary to mark the terminal studs on instruments and control switches, but wiring diagrams shall clearly indicate the studs or contacts to which marked wires are connected. Terminal blocks shall be equipped with marking strips. These marking strips shall be permanently marked at each terminal with a number (for example, 1 to 12) and also to agree with the corresponding number on the wiring diagram. Terminal blocks in each unit shall be numbered TB1, TB2, and so forth.

3.4.5.3 Securing of control wiring. Control wiring shall adhere to the following requirements:

a. Wires shall be neatly formed into groups which shall be bundled or banded and supported or clamped in a manner that will prevent chafing of the insulation caused by vibration.

b. Bundling material shall be tie-wraps in accordance with SAE-AS33671, nonflammable cord, glass fiber tape conforming to Type SR-1 of MIL-I-3158, or pressure sensitive adhesive plastic tape conforming to MIL-I-24391. The last two materials are specifically adapted for serving switchgear control wiring in locations subject to abrasion. Glass fiber tape may be coated with adhesive on one side, but when used with this adhesive coating, it shall be covered with pressure sensitive adhesive plastic tape for permanent adhesion.

c. Wire groups running from hinged panels shall be formed and clamped so that sharp bends do not occur with the panel in either the open or closed position and shall be connected to terminal blocks on the fixed portion of the switchgear structure.

d. There shall be no splices in the wire and connections shall be made at the terminal studs of the devices or terminal boards.

e. Where wires run from one section of a switchboard to an adjacent one, and these sections are separated for shipping or installation purposes, a terminal board shall be provided on one of the units and located in order to facilitate completion of the interconnections during installation of the switchboard on the ship.

3.4.5.4 External control cable connections. External control cable connections to the switchboards shall terminate at terminal boards accessibly located near the top or bottom of the switchboard, corresponding to ship's cable entrance. Where calibrated shunt leads are required, they shall terminate on the instrument studs. An excess length of shunt leads shall be neatly coiled and secured to prevent interference with access to other equipment. Small wiring to circuit breaker trip coils shall run directly to the coils and associated contact circuits and shall not be routed through terminals of other apparatus. Taps from bus bars shall be made by through-bolting terminals to the bus bars.

3.4.5.5 Wire end connectors. Ends of each wire shall be connected to the apparatus studs by means of an SAE-AS7928, Type II solderless terminal or by forming a wire loop around the apparatus stud or terminal screw and retaining the loop in a cup or crimped washer. The wire loop shall be soldered to secure the strands together. Locking devices in accordance with 3.4.4 shall be used to secure the nuts or screws connecting wire loops to the apparatus connection point.

3.4.5.6 Fiber optic connections.

3.4.5.6.1 Fiber optic cables. Fiber optic cables shall comply with the requirements of MIL-PRF-85045.

3.4.5.6.2 Fiber optic connectors. Fiber optic connectors shall comply with the requirements of MIL-DTL-83522.

3.4.6 Power cables. The required shipboard cable, terminations, routing, recommended bracing, and the location of the cable connections shall be as specified (see 6.2).

3.4.6.1 Securing of power cables. Power cable groups shall adhere to the following requirements:

a. Cables shall be neatly formed into groups which shall be bundled or banded and supported or clamped in a manner that will prevent chafing of the insulation caused by vibration. Cables shall not be supported by bus bars. There shall be a minimum clearance of 1/4 inch between cables and bus bars to prevent abrasion under conditions of vibration, except at the bus bar terminating end of the cable.

b. Cable straps or metal clamps may be used to support or secure cables, but where metal is used it shall be covered with a flame-retardant, heat-resistant material which will prevent chafing of the cable insulation. Commercial nylon cable straps shall not be used to support or secure power cables to the framework or structure of the switchboard unit.

c. There shall be no power cable splices within the switchgear enclosure. Power cables shall be bolted directly to the bus bars or terminal studs of the device.

d. Lug types and crimping requirements shall be as specified (see 6.2).

3.4.7 Bus bars and bus bar joint connections.

3.4.7.1 Bus bar material. Rectangular copper bus bars with rounded corners or round edges, hard temper in accordance with ASTM B187/B187M shall be used. Aluminum conductors or terminals shall not be used.

3.4.7.2 Bus bar sizes. Size of the bus bars shall be selected on a basis of the current carrying ratings shown in table I. In no case shall the bus bar sizes be smaller for a given current than the corresponding sizes listed in table I.

TABLE I. Bus bar sizes.

Number of bars parallel	Size of bars (inches)	Cross-sectional area (square inches)	Copper bus, silver surface, AC ampere rating, 60 Hz	Copper bus, silver surface, DC ampere rating
1	1/2 x 1/8	0.063	140	140
	5/8 x 1/8	0.078	175	175
	3/4 x 1/8	0.094	210	210
	1 x 1/8	0.125	285	285
	1-1/2 x 1/8	0.188	425	425
	2 x 1/8	0.250	555	555
	3/4 x 3/16	0.140	265	265
	1 x 3/16	0.188	355	355
	1-1/2 x 3/16	0.278	550	550
	2 x 3/16	0.375	700	710
	3/4 x 1/4	0.188	295	295
	1 x 1/4	0.250	410	410
	1-1/2 x 1/4	0.375	600	600
	2 x 1/4	0.500	780	800
	2-1/2 x 1/4	0.625	1,000	1,050
	3 x 1/4	0.750	1,140	1,185
	4 x 1/4	1.000	1,425	1,490
	5 x 1/4	1.250	1,760	1,850
	6 x 1/4	1.500	2,100	2,190
2 (1/4 inch apart)	1 x 1/4	0.500	650	650
	1-1/2 x 1/4	0.750	950	950
	2 x 1/4	1.000	1,350	1,370
	2-1/2 x 1/4	1.250	1,610	1,610
	3 x 1/4	1.500	1,825	2,000
	4 x 1/4	2.000	2,280	2,530
	5 x 1/4	2.500	2,740	3,100
	6 x 1/4	3.000	3,140	3,630
3 (1/4 inch apart)	3 x 1/4	2.250	2,200	2,620
	4 x 1/4	3.000	2,660	3,110
	5 x 1/4	3.750	3,200	3,830
	6 x 1/4	4.500	3,600	4,560
4 (1/4 inch apart)	3 x 1/4	3.000	2,650	3,130
	4 x 1/4	4.000	3,020	3,870
	5 x 1/4	5.000	3,450	4,750

TABLE I. Bus bar sizes - Continued.

Number of bars parallel	Size of bars (inches)	Cross-sectional area (square inches)	Copper bus, silver surface, AC ampere rating, 60 Hz	Copper bus, silver surface, DC ampere rating
4 (2 pairs/phase; 3/4 inch between pairs)	6 x 1/4	6.000	4,000	----
4 (2 pairs/phase; 2-1/2 inches between pairs)	5 x 1/4	5.000	4,200	----
	6 x 1/4	6.000	5,000	----

3.4.7.2.1 Optional bus bar geometry. Bus bars shall be of sufficient size to carry the rated current without exceeding the temperature rating of the bus bar, but in all circumstances shall be no smaller than and conform with the requirements of table I. Bus bars not conforming to the requirements of table I shall require additional temperature sensors during temperature rise testing to validate the design.

3.4.7.3 Bus bar capacity. Main bus bar rating shall not be less than the largest feeder circuit element rating of the power source supplying the main bus as specified (see 6.2).

3.4.7.4 Bus bar forming. Flat bends for 1/8-inch bus bars shall have an inside radius 1.5 times the thickness of the bus bar, and the ends of the bus bars shall be neatly finished. Flat bends for bus bars greater than 1/8 inch shall have an inside radius of no less than the thickness of the bus bar, and the ends of the bus bars shall be neatly finished. Edgewise bends of copper bus bars up to 2 inches in width may be made on an inside radius of 1 inch. Edgewise bends of copper bus bars over 2 inches in width, but not exceeding 4 inches in width, may be made on an inside radius of 2 inches. Bars shall be free from cracks or flaws at bends.

3.4.7.5 Bus bar insulation. Bus bar insulation shall be rated for 130 °C. Insulating materials which contain halogens, e.g., chlorine, fluorine, and bromine, which evolve gases during combustion, shall not be used.

3.4.7.6 Bus bar joints.

3.4.7.6.1 Welding or brazing. Bus bars may be joined by welding or brazing; however, it shall be restricted to assemblies where disassembly will not be required for maintenance or repair of underlying assemblies. All welders and weld procedures for copper bus bars shall be in accordance with S9074-AQ-GIB-010/248. Brazing procedures shall be in accordance with their applicable AWS specification.

3.4.7.6.2 Bolted bus bar joint insulation. Bolted bus bar joints shall have field replaceable boots that allow maintenance access to bus bolts. Boots shall be rated for 130 °C. Insulating materials which contain halogens, e.g., chlorine, fluorine, and bromine, which evolve gases during combustion, shall not be used.

3.4.7.6.3 Connection hardware. Bolts and nuts used in bus bar joints shall be of the coarse thread series made of a 300 series corrosion resistant steel (CRES), silicon bronze conforming to ASTM B98/B98M, ASTM B411/B411M, or ASTM B371, or zinc-plated steel, Grade 5, conforming to MIL-DTL-1222. Silicon bronze hardware shall be used in bus bar joints 4000 amperes and above. Washers of material similar to the nuts and bolts shall be used under all bolt heads and nuts adjacent to the conductors.

3.4.7.6.3.1 Number of bolts/tightening of bolts for bus bar joints. The number of bolts for bus bar joints shall be as shown in table II. Torque values for bolts in bus bar joints shall be as shown in table III. Bolts for bus bar joints may be lubricated.

3.4.7.6.3.2 Tightening nuts for bus bar joints. Prevailing torque self-locking fasteners shall be torqued to 100 percent of applicable table III values, plus the prevailing torque that is measured when the nut is turned on the bolt in its unloaded state. All full height nuts that are not prevailing torque self-locking fasteners shall be torqued to 100 percent of applicable table III values.

3.4.7.6.4 Holes in bus bars. Holes in bus bars for bolting may be either punched or drilled, but the contact area shall be smoothed and burr free before silver surfacing. Where punching is used, the operation shall not appreciably indent the surface of the bus bar in the vicinity of the hole. Slotted holes shall not be used. Holes in bus bars for standard bolts shall have the following dimensions:

Bolt size (inch)	Hole size (inch)
3/8	7/16
1/2	9/16
5/8	11/16

When 5-inch or larger bus bars are joined together, the bolt hole size may be enlarged to provide 1/8-inch clearance. See table II for the diameter and number of holes required.

3.4.7.6.5 Preparation of bus bar joints. Bus bar joints shall be specially prepared before bolting as follows:

a. A thin film of NO-OX-ID "A-SPECIAL" (NSN 8030-00-598-5915) corrosion-preventive paste, or equal, shall be applied to the mating faces of the joint. Paste may be applied to the hardware. If paste is applied to the hardware, the hardware shall be treated as lubricated for torqueing purposes.

b. Without removing the paste, joints shall be bolted together using applicable torque values from table III.

c. After joints are bolted together, paste shall be removed from all exposed surfaces with a clean, dry cloth.

TABLE II. Bolting of connection – bars/diameter and number of bolts.

Size bus bars (in.)	**Size bus bars (inches)**											
	1/2 (inch)	**5/8 (inch)**	**3/4 (inch)**	**1 (inch)**	**1-1/2 (inch)**	**2 (inch)**	**2-1/2 (inch)**	**3 (inch)**	**4 (inch)**	**5 (inch)**	**6 (inch)**	**8 (inch)**
1/2	One 1/4	-	-	-	-	-	-	-	-	-	-	-
5/8	One 1/4	One 3/8	-	-	-	-	-	-	-	-	-	-
3/4	One 1/4	One 3/8	One 3/8	-	-	-	-	-	-	-	-	-
1	Two 1/4	One 3/8	One 3/8	One 1/2	-	-	-	-	-	-	-	-
1-1/2	Two 1/4	Two 3/8	One 3/8	One 1/2	One 5/8	-	-	-	-	-	-	-
2	Two 1/4	Two 3/8	Two 3/8	Two 3/8	One 5/8	One 5/8	-	-	-	-	-	-
2-1/2	Two 1/4	Two 3/8	Two 3/8	Two 3/8	Two 1/2	Two 1/2	Two 1/2	-	-	-	-	
3	Two 1/4	Two 3/8	Two 3/8	Two 1/2	Two 1/2	Two 1/2	Two 5/8	Two 5/8	-	-	-	-
4	Two 1/4	Two 3/8	Two 3/8	Two 1/2	Two 5/8	Two 5/8	Two 5/8	Two 5/8	Four 5/8	-	-	-
5	Two 1/4	Two 3/8	Two 3/8	Two 1/2	Two 5/8	Two 5/8	Two 5/8	Three 5/8	Five 5/8	Five 5/8	-	-
6	Two 1/4	Two 3/8	Two 3/8	Two 1/2	Two 5/8	Two 5/8	Two 5/8	Three 5/8	Five 5/8	Five 5/8	Five 5/8	-
8	Two 1/4	Two 3/8	Two 3/8	Two 1/2	Two 5/8	Two 5/8	Two 5/8	Three 5/8	Five 5/8	Five 5/8	Five 5/8	Six 5/8

TABLE III. Torque on bus bar joints.

Torque (foot-pounds)				
Bolt diameter (inches)	CRES and zinc plated steel		Silicon bronze/copper	
	Min./max. lubricated	Min./max. non-lubricated	Min./max. lubricated	Min./max. non-lubricated
1/4	2/3	3/4	-	-
5/16	6/7	9/10	-	-
3/8	14/16	21/24	10/11	15/16
1/2	30/33	45/50	21/23	31/34
5/8	50/55	75/80	35/39	52/58

3.4.7.6.6 Silver surfacing of bus bar joints. Silver surfacing of bus bars joints shall be electrodeposited Type 1, Grade A, B, or C silver coatings as specified in ASTM B700 with the exception that the silver plate shall not be less than 0.0002 inch thick. Contact surfaces of bus bars shall be silvered up to 1 inch past the joint area. The entire bus may be silver-surfaced.

3.4.7.7 Bus supports. The construction, number, spacing, and mounting of the bus bar supports shall be based on the magnitudes of forces and stresses encountered on the buses being supported when subjected to maximum rms asymmetrical short circuit currents, as specified (see 6.2). Values of maximum stress in the outside fibers shall be based on the yield strength of the bus bar and not upon the tensile strength of the bus bar. Support shall prevent contact of live parts with each other or ground during short circuit, high-impact shock, or vibration. Any permanent deformation or displacement of the bus bars following a short circuit shall not reduce the specified clearance distances by more than 30 percent of their original values.

3.4.8 Identification plates, information plates, and marking. Identification and information plates on the outside of the switchboard shall conform to Types A, B, C, F, or H of MIL-DTL-15024 and MIL-P-15024/5. Plastic identification and information plates shall be light gray. Beveled edges are not required. Inscriptions or markings for all type plates shall be black, except for danger, warning, and caution plates which shall have words in red for emphasis or be red with white markings. Identification and information plates inside the switchboard shall conform to Type F of MIL-DTL-15024 and MIL-P-15024/5.

3.4.8.1 Location. Identification and information plates shall be placed in close proximity to the equipment to which it refers and, generally, either directly above or directly below it.

3.4.8.2 Size. In general, identification and information plates shall be of the size as listed in MIL-DTL-15024 and MIL-P-15024/5.

3.4.8.2.1 Thickness. Thickness of identification and information plates shall be in accordance with MIL-DTL-15024 and MIL-P-15024/5.

3.4.8.2.2 Shape. Information plates for rheostat handwheels and other rotary devices where required shall be circular or some other shape to suit the equipment.

3.4.8.3 Information. Identification plates with information consistent with the following shall be provided at or near the top of the front enclosure of each switchgear section or for each unit, if required individually:

a. Name or functional designation of item.
b. Manufacturer’s name.
c. Manufacturer’s drawing number (front view).
d. Year manufactured.
e. NAVSEA drawing number (front view), if assigned.

f. Stock number, if assigned.

g. NAVSEA number of manual, if assigned.

h. Serial number.

3.4.8.4 Abbreviations. Unless lack of space prevents spelling out the word, abbreviations of words on identification and information plates shall be avoided except in the case of words which have abbreviations in common use in accordance with ASME Y14.38.

3.4.8.5 Installation. Identification and information plates shall be fastened securely to such parts of the equipment as ordinarily will not be renewed during its service life. Identification and information plates shall be attached in accordance with MIL-DTL-15024 and MIL-P-15024/5. Metal and laminated identification and information plates and mimic bus may be attached with an adhesive.

3.4.8.6 Detail application requirements. Information plates shall be installed immediately above each circuit breaker and shall contain the following information:

a. Circuit name.

b. Circuit designation and number.

c. Circuit breaker element rating.

d. Circuit breaker catalog number/certification data sheet number.

3.4.8.7 Blank plates. Information plates without markings shall be provided for mounted spare circuit breakers.

3.4.8.8 Instrument identification. Instruments shall be marked with the name of circuits; marking may appear on the instrument or on a separately mounted information plate. Switchboard devices and component assemblies shall be provided with identification sufficient to identify each component from the information contained on the applicable switchboard drawings.

3.4.8.9 Fuse marking. Fuses for each switchboard control circuit, instrument, and instrument transformer shall have an information plate showing the name or designation of circuit, phase (if applicable), fuse ampere rating, and type designations.

3.4.8.10 Marking switchboard buses. Buses shall be clearly marked in a visible location with their polarity or phase identification. If marking is accomplished by painting (stencil) application, the ink shall conform to A-A-208, Type III. Information plates for buses may be similar to the warning plates specified in 3.4.8.13.

3.4.8.11 Phase identification. Phase identification of A-C buses shall be indicated by the capital letters A, B, or C, as applicable. Letters A, B, C in that order shall indicate the phase sequence.

3.4.8.12 Bus bars. Bus bars facing and closest to the rear of the unit shall be stenciled “DANGER _____ VOLTS”. Applicable voltage shall be entered. Letters shall be white and not less than 3/4 inch high. As an alternative to stenciling, bus bars may be provided with a warning plate bearing the same legend. Letters shall be not less than 3/4 inch high. The plate shall be pressure-sensitive, adhesive-backed elastomeric film with a carrier or separator sheet applied over the adhesive. Film shall consist of a white printed opaque polyvinyl fluoride film 0.002 inch thick laminated to a 0.001-inch clear polyethylene terephthalate film. Plate adhesive shall consist of an acrylic base vinyl polymer of a pressure sensitive type. A minimum of two warning stencils or plates per unit shall be provided, one in the upper and one in the lower section.

3.4.8.13 Circuit breaker information plate. An information plate containing instructions for positioning the circuit breaker in the connected, test, disconnected, and withdrawn positions, shall be provided, including steps and precautions to discharge the opening and closing springs. Additional information plates shall identify operating devices and positions, give pertinent instructions for operation, call attention to special precautions, and call attention to environmental warnings. If possible, all of the information above should be included on one label plate.

3.4.8.14 Programmable items. Equipment which is software programmable shall indicate the identifying number and revision of the software program which has been loaded into memory. The preferred method is to provide either a local or a remote display which is under the control of the software program. However, when the use of a display is not practical, the equipment enclosure should be marked with the identifying number and revision of the software program. The identifying number shall be preceded by the words "software program."

3.5 Environmental performance requirements.

3.5.1 Temperature. See 4.4.3.15.

3.5.1.1 Ambient temperature. The switchgear shall meet all the specification requirements when operating in an ambient temperature of 50 °C.

3.5.1.2 Temperature rise. Temperature rise in compartments other than the control cabinet/compartment shall not exceed 25 °C. Temperature rise in the control cabinet/compartment shall not exceed 20 °C.

3.5.2 Shock. Unless otherwise specified herein, the complete switchboard section, including all subsidiary components and subassemblies installed, shall be able to withstand Grade A, Type A, high-impact shock testing in accordance with MIL-S-901.

3.5.2.1 Shock test procedures and test results. Test procedures shall be approved by the NAVSEA shock TWH or TWH representative prior to the start of testing. Test results shall be approved by the NAVSEA shock TWH or TWH representative.

3.5.3 Vibration. The complete switchboard shall withstand electrically and mechanically the Type I vibration tests specified in MIL-STD-167-1 (see 4.4.3.19).

3.5.4 Electromagnetic interference (EMI). The complete switchboard with electronic devices (if applicable) shall meet and demonstrate compliance with the applicable emissions and susceptibility requirements and limits of MIL-STD-461 for surface ship, below deck, metallic hull installations (see 4.4.3.13).

3.5.4.1 EMI test procedures and results. EMI test procedures and results shall be in accordance with the Electromagnetic Interference Test Procedures (EMITP) and Electromagnetic Interference Test Report (EMITR) requirements of MIL-STD-461. Test procedures shall be approved by the NAVSEA EMI TWH or TWH representative prior to the start of testing. Test results shall be approved by the NAVSEA EMI TWH or TWH representative.

3.5.5 Water spray. When specified (see 6.2), switchgear shall be designed to meet the water spray test requirements of MIL-STD-108 for drip-proof, 15-degree.

3.5.6 Water mist. When specified (see 6.2), switchgear shall be designed to meet the blowing rain test requirements of MIL-STD-810, Method 506.5, Procedure II (see 4.4.3.21 and 4.4.3.22). The pressure, flow rate, droplet size range, and duration of the test shall be as specified (see 6.2).

3.5.7 Flame resistance. See 3.4.3.1 and 4.4.3.23.

3.5.8 Noise. When fans are installed, switchboard shall meet airborne and structureborne noise requirements of MIL-STD-1474, Equipment Grade E, and MIL-STD-740-2, Type IV (see 4.4.3.20).

3.6 Electrical and other performance requirements.

3.6.1 Momentary and short-time withstand ratings. Momentary and short-time withstand ratings as described in IEEE C37.20.2 shall be as specified (see 6.2). See 4.4.3.16 and 4.4.3.17.

3.6.2 Electrical interface characteristics. The complete switchboard shall meet the requirements for voltage and frequency tolerance and emergency condition in accordance with MIL-STD-1399-680 (see 4.4.3.6, 4.4.3.6.1, and 4.4.3.6.2).

3.6.3 Rated maximum voltage. Rated maximum voltage shall be one of the values shown in table IV as specified (see 6.2).

3.6.4 Nominal operating voltage. Nominal operating voltage shall be the value specified in table IV that corresponds to the applicable rated maximum voltage.

3.6.5 Lightning impulse withstand voltage (BIL). Switchgear shall be constructed to withstand applicable BIL voltage shown in table IV between separate circuits and to ground (see 4.4.3.9).

3.6.6 Power frequency withstand voltage for primary conductors. Switchgear shall be constructed to withstand for a period of 1 minute the applicable power frequency withstand test voltage shown in table IV between separate circuits and to ground (see 4.4.3.7). The primary frequency withstand voltage value shall be reduced to 65 percent as the switchboard is subjected to various first article tests. See table V for details.

TABLE IV. Voltage requirements based on rated maximum voltage.

Rating type	Rating		
1. Rated maximum voltage	4.76 kVrms	8.25 kVrms	15 kVrms
2. Nominal operating voltage	4.16 kV	7.2 kV	11/13.8 kV
3. Power frequency withstand voltage for primary conductors (minimum for 1 minute)	19 kV	36 kV	36 kV
4. BIL minimum	60 kV	95 kV	95 kV

3.6.7 Power frequency withstand voltage for conductors less than 1 kV. Except for circuit breaker charging motor leads, conductors less than 1 kV shall be able to withstand, for a period of 1 minute and without breakdown, a dielectric test voltage of twice the rated voltage of the equipment plus 1,000 volts rms between each electrically isolated circuit and all other circuits connected together to ground (frame, chassis, or enclosure as applicable). All circuit breaker charging motor leads, separately and tied together, shall be able to withstand a dielectric test voltage of 900 volts for a period of 1 minute without breakdown (see 4.4.3.8). The primary frequency withstand voltage value shall be reduced to 65 percent as the switchboard is subjected to various first article tests. See table V for details.

3.6.8 Voltage spike. The complete switchboard with electronic devices (if applicable) shall withstand voltage spikes on control circuits in accordance with MIL-STD-1399-300 (see 4.4.3.14). Voltage spikes shall not cause failure or mal-operation of electronic devices.

3.6.9 Insulation resistance (low voltage control circuits). Low voltage control circuits shall be constructed to withstand 500 VDC between separate circuits and maintain an insulation resistance measurement not less than 10 megohms corrected to 25 °C (see 4.4.3.12).

3.6.10 Grounding.

3.6.10.1 System grounding. Equipment shall operate in a high-resistance grounded system in accordance with MIL-STD-1399-680.

3.6.10.2 Bond strap. A bond strap in accordance with MIL-STD-1310, Class C shall connect the switchboard frame to the hull for grounding purposes.

3.6.10.3 Grounding considerations for powder coat/chemical conversion coating applications. See 3.4.1.3.1.3 and 3.4.1.3.2.

3.6.10.4 Grounding considerations for drawout-type potential transformers. See 3.7.10.2.2.1.

3.6.10.5 Maintenance grounding. One of the following methods shall be used for grounding during maintenance as specified (see 6.2):

a. A mechanically and electrically interlocked grounding/earthing switch. An earthing switch shall be installed on each circuit breaker and on each bus system that is separated by a tie circuit breaker. The earthing switch shall be properly rated to withstand the available fault current. The switch shall provide a direct indication of switch position. The grounding/earthing device shall meet the requirements of IEEE C37.20.4 as well as the ratings of the system it is designed to ground.

b. A ground and test (G&T) device. G&T devices are maintenance tools. G&T devices shall ground a specific bus or electrical system, ensuring that the system is deenergized. To install a G&T device, the circuit breaker is removed, and then the G&T device is inserted. The G&T device shall be in accordance with IEEE C37.20.6. The device type and if the device is to be stored in a switchgear compartment shall be as specified (see 6.2).

c. Manually grounding using “hot sticks” to dedicated accessible grounding studs as the bus bars are fully insulated.

3.6.10.5.1 Maintenance test points/ground studs. Since bus bars are fully insulated, easily accessible test points/ground studs shall be provided to perform initial voltage verification and insulation resistance maintenance checks. If a G&T device is used, this requirement is met. Ground studs shall have field replaceable boots that allow maintenance access. Test points shall be provided for every section to be isolated (incoming lines and the bus).

3.6.11 Ground fault monitoring. Ground fault monitoring systems shall meet the following requirements:

a. High-resistance grounded systems shall have provisions for continuous ground fault monitoring. An alarm shall alert personnel that a ground exists.

b. All ground faults shall be immediately removed with time delays required for coordination.

c. Coordinated ground fault monitoring systems shall be proposed for consideration and approval. Use of auxiliary current sensors shall not be used without approval from NAVSEA.

d. The ground fault monitoring system can be internal or external to the switchboard as specified (see 6.2). Where external ground interface is used, protective fusing and interface connections shall be provided.

e. The amount of current required to accurately detect a phase-to-ground fault shall be determined. The required phase-to-ground fault current level shall be provided for resistor sizing. The amount of phase-to-ground fault current required shall be kept to a minimum and shall be sufficient for any system lineup. The minimum phase-to-ground current required for relay protection shall be greater than system charging current.

f. When specified (see 6.2), the ground fault protection can use zero sequence current sensors or zero sequence current derived from the phase current sensors. If zero sequence current sensors are used, they shall not interfere with cable entry.

3.6.12 Nominal control voltage. Nominal voltages in the control cabinet/compartment shall not exceed 450 VAC or 125 VDC. DC voltage is preferred.

3.6.13 Phase rotation. For alternating current (AC), when facing the front of the switchboard or panel, the phase rotation shall be A, B, and C, respectively, from right to left, top to bottom, or front to back.

3.6.14 Maintainability. The switchgear shall facilitate troubleshooting, fault isolation, and repair down to the lowest non-repairable part or non-repairable assembly as specified (see 4.4.3 and 6.2).

3.7 Components and devices.

3.7.1 Circuit breakers, stationary elements (cradles), and lifting devices.

3.7.1.1 Circuit breaker type. Circuit breakers for primary power shall be vacuum type (VCB) in accordance with MIL-DTL-32485.

3.7.1.2 Circuit breaker trip coil circuits. Trip coil circuits (both AC and DC) for tripping circuit breakers shall be routed through a normally open “a” contact (open when the circuit breaker is open) of the circuit breaker auxiliary switch so that the trip coil cannot remain energized after the circuit breaker is open.

3.7.1.3 Interchangeability. Vacuum circuit breakers shall be interchangeable. That is, a vacuum circuit breaker of the same type and frame size from one switchboard compartment shall be able to be moved and installed in any other switchboard compartment that houses a vacuum circuit breaker.

3.7.1.4 Charge motor protection. When specified (see 6.2), a device that protects the circuit breaker charging motor from excessive current and extended operation shall be provided.

3.7.1.5 Circuit breaker lifting device. Maintenance equipment capable of removing circuit breakers from all applicable compartments shall be required (see 6.2). Details of the required aisle space and storage requirements shall be as specified (see 6.2).

3.7.1.6 Circuit breaker rack-in and rack-out. Circuit breakers shall be racked in and out from and to a non-energized position without the removal of the front cover with the exception of the withdrawn position. An access port and cover shall be provided. An electrical racking device (permanently installed or portable) that can be remotely operated shall be provided, as specified (see 6.2). A manually operated racking device that does not place the operator directly in front of a circuit breaker compartment shall be provided, as specified (see 6.2).

3.7.1.6.1 Circuit breaker positions in or on cradle for rack-in and rack-out and racking position indicator. Circuit breaker/cradle configurations shall be provided with connect, test, disconnect, and withdrawn positions. The disconnected and withdrawn positions may be the same for a particular design. The available positions and any exceptions to the requirements above shall be as specified (see 6.2). A racking position indicator shall be provided to allow for visual verification of the racking position.

3.7.1.6.1.1 Connect position. In the connect position, the circuit breaker shall operate manually and electrically, and the circuit breaker main contacts and control circuitry shall be energized.

3.7.1.6.1.2 Test position. In the test position, the circuit breaker shall operate manually and electrically without energizing the circuit breaker main contacts. Control circuitry shall remain energized.

3.7.1.6.1.3 Disconnect position. In the disconnect position, the circuit breaker main contacts and control circuitry shall not be energized. The circuit breaker shall operate manually.

3.7.1.6.1.4 Withdrawn position. In the withdrawn position, the circuit breaker is fully extended on the cradle rails/tray. The circuit breaker main contacts and control circuitry shall not be energized. The circuit breaker shall operate manually.

3.7.1.6.2 Withdrawal interlocks. Interlocks shall be provided for stored energy release during withdrawal to prevent a closed circuit breaker from being racked-out from the connect position to the test position and to prevent a closed circuit breaker from being racked-in from the test position to the connect position.

3.7.1.6.3 By-pass switch and truck-operated cell (TOC) switch. When specified (see 6.2), a by-pass switch or TOC switch, or both, shall be provided. The by-pass switch is comprised of a normally closed limit switch (TOC switch) mounted on the cradle and connected to the stationary secondary contacts in parallel with an “a” auxiliary switch. The TOC switch shall open when the circuit breaker is in the connect or test position and close when the circuit breaker is in the disconnect or withdrawn position. The cell switch rating shall be the same as the breaker auxiliary switch rating.

3.7.1.6.4 Secondary disconnects. Secondary disconnects shall meet the operating requirements of 3.7.1.6.6.

3.7.1.6.5 Shutters. Shutters shall meet the operating requirements of 3.7.1.6.6.

3.7.1.6.6 Mechanical endurance racking. Circuit breakers and cradles (including withdrawal interlocks, secondary disconnects, shutters, and, if applicable, cell switches) shall be able to withstand mechanical endurance racking tests in accordance with 4.4.3.4.2.

3.7.1.7 Circuit breaker cradle or lifting device strength. In the normal vertical/horizontal orientation, cradles and lifting devices shall be able to hold a weight equal to 150 percent of the circuit breaker for 10 minutes with the circuit breaker in the withdrawn position on the cradle rails/tray or lifting device (see 4.4.3.4.3).

3.7.1.8 Anti-rolling (normal vertical/horizontal orientation). When a 25-pound force is applied to the front of the circuit breaker in the horizontal direction towards the cradle backplane, the circuit breaker shall not roll, move, or fall off cradle rails/tray when racked to the test, disconnect, or withdrawn position (see 4.4.3.4.4.2). Manual or automatic means may be used to prevent the circuit breaker from moving.

3.7.1.9 Inclined operation. Circuit breakers, attachments, and stationary elements (cradles) shall operate as specified in 3.7.1.9.1, 3.7.1.9.2, and 3.7.1.9.3 when inclined forward, backward, and to each side, at an angle of 30 degrees from the normal vertical/horizontal orientation (see 4.4.3.4.4).

3.7.1.9.1 Electrical cycling. In the connect position, the circuit breaker shall be able to be electrically cycled five times (see 4.4.3.4.4.1).

3.7.1.9.2 Opening and closing times. In the connect position, the circuit breaker opening and closing times shall be in accordance with MIL-DTL-32485 (see 4.4.3.4.4.1).

3.7.1.9.3 Anti-rolling. The circuit breaker shall not roll, move, or fall off cradle rails/tray when racked to the test, disconnect, or withdrawn position (see 4.4.3.4.1.1.3.1). Manual or automatic means may be used to prevent the circuit breaker from moving. The circuit breaker may be racked-out in the normal vertical/horizontal orientation then inclined.

3.7.2 Arc fault detectors. When required (see 6.2), arc fault detectors that have been previously approved for Navy use shall be installed per the arc fault detector vendor's instructions.

3.7.3 Uninterruptible power supply (UPS). The size of the UPS shall be determined based upon the loads and operating characteristics of the components the UPS is to supply. The UPS shall be able to output full charging current and rated power for all operations simultaneously. The UPS design shall meet the requirements of MIL-DTL-24765 and shall be housed in the switchboard.

3.7.3.1 UPS hold up time. The UPS shall be capable of maintaining all normal loads in the absence of normal control power while having the capability of tripping all vacuum circuit breakers in the given switchboard for a time period as specified (see 6.2), without input to the UPS. This requires the ability to trip the vacuum circuit breakers at the end of the period. A switch on the front panel shall be provided to remove normal power to the UPS and verify hold up time.

3.7.4 Corona detection maintenance equipment/detection level. When specified (see 6.2), maintenance test equipment capable of detecting corona shall be provided. The test equipment used shall be capable of operation in the field for maintenance. Corona shall not be detectible below the level (Corona Inception Voltage - CIV) as specified (see 6.2).

3.7.5 Partial discharge detection maintenance equipment. When specified (see 6.2), maintenance test equipment capable of detecting partial discharge shall be provided. The test equipment used shall be capable of operation in the field for maintenance. Partial discharge inception voltage (PDIV) shall not be detectible below the level specified (see 6.2). The procedures for detecting partial discharge shall be verified during first article testing in accordance with IEEE C37.301 (see 4.4.3.11).

3.7.6 Capacitive voltage indicating systems. When specified (see 6.2), Voltage Detection System (VDS) in accordance with IEC 61243-5 or Voltage Presence Indicating System (VPIS) in accordance with IEC 62271-206 shall be provided. The capacitive outlets of the voltage detection system shall provide the interface for the maintenance partial discharge system (if applicable). Voltage indicators (LEDS) shall be provided for voltage presence detection.

3.7.7 Synchronizing and load control equipment. When specified (see 6.2), the switchboard shall incorporate synchronizing and load control equipment inside the switchboard to control synchronizing and kW and kVAR load control to maintain system voltage and frequency across the power range. Back-up droop mode of control shall be provided to account for failure of load sharing system.

3.7.8 Generator space heater circuit. The space heater circuit shall be wired through a normally closed contact (closed when circuit breaker is open) of the associated generator circuit breaker auxiliary switch. The space heater circuit shall monitor current flow to the heater element to account for open circuited heater element or loss of heater power supply. An indicator shall show when generator heaters are energized.

3.7.9 Metering and control options. The level of metering and control that is required for each switchboard section in the system shall be as specified (see 6.2). The Human Machine Interface (HMI) is the preferred metering and control interface for the switchboard section to limit the amount of discrete meters.

3.7.9.1 HMI. Note the following:

a. MIL-STD-1472 shall be used as a guideline for the HMI design.

b. The HMI panel shall be mounted in the front of the control cabinet.

c. The top of the HMI panel display screen shall be no higher than 72 inches above the deck (total height includes the switchboard foundation).

d. The HMI will be the local operational interface for all features and functions available in the switchboard or switchboard group in which it is installed.

e. The HMI screen shall normally be blank. The display shall become automatically active upon alarm, warning, or manual initiation. The manual initiation shall not result in the initiation of a command to any devices; the HMI screen shall simply come on.

3.7.9.1.1 Display pages. The HMI screen shall have several display pages including, but not limited to:

a. One-line diagram page. This will be a mimic one-line diagram of the switchboard, showing the status of all circuit breakers, and the current through each breaker, and bus voltage.

b. Circuit breaker page. A page for each circuit breaker showing positions as applicable (open/closed/test/removed), currents for all three phases, controls for operating each circuit breaker.

c. Alerts page. The alarms, warnings, and notifications associated with the class switchboard shall be provided on the alert page. Local alarm silence shall be provided. When an alarm is cleared at the Electric Plant Control Panel (EPCP), it shall also clear the alarm at the HMI. Audio and visual indication shall be provided for alarms; visual indication only shall be required for notices and warnings. This feature shall be selectable. Circuit breaker trip information shall be provided on the alert page as applicable.

d. Generator page. This applies only to the ship service and emergency switchboards. The generator page shall provide indications necessary for operations such as, but not limited to, paralleling, start-up, and securing of generators (electrically).

3.7.9.1.1.1 Color conventions. The HMI screens shall use the following colors to display unit operating conditions. Color conventions for other operating conditions not covered below shall be as specified (see 6.2).

a. Green. To indicate that a component is operating within its normally acceptable conditions.

b. Yellow. To indicate that a component is operating outside its normally acceptable conditions and is in a pre-alarm state.

c. Red. To indicate that a device has entered an alarm condition.

3.7.9.1.2 Touch screen. The HMI control interface shall be touch screen. The HMI display shall be flush mounted to the front of the control cabinet.

3.7.9.1.2.1 Viewing requirements.

a. Minimum screen diagonal shall be 18 inches.

b. Maximum screen diagonal shall be 23 inches.

c. Minimum resolution shall be 1280 x 1024.

d. Minimum luminance shall be 150 candles/square meter.

e. Minimum contrast ratio shall be 100:1.

f. Minimum viewing area shall be ±45 degrees side to side, 30 degrees up, and 10 degrees down.

3.7.9.1.3 Software. A graphical user interface (GUI) with software shall be provided. Instructions shall be provided for software and GUI use. GUI software program(s) shall be provided to communicate with external components. This software shall provide functionality as required by ships specifications.

3.7.9.1.4 Redundancy. Provisions shall be made for a backup system for all control and metering functions to be available to the user in the event of an HMI failure. Control shall be easily available to the user through the use of a back-up to the HMI or through other switches and other lights. A dedicated ruggedized personal computer (PC) or similar suitable for naval shipboard use may be used as a backup system to an HMI through an access port. All displays and functions on the HMI shall be accessible on the backup system.

3.7.9.2 Discrete meters. Electrical measuring instruments shall conform to MIL-I-1361, MIL-T-15377, MIL-DTL-16034, MIL-S-16104, MIL-M-16125, MIL-W-19088, MIL-V-23151, and MIL-M-23167 having a 4-1/2-inch, rectangular case with 250-degree scale. Instrument scales shall be white with black markings and lettering, and shall be marked to indicate the full load and normal voltage calibration points.

3.7.9.3 Digital indicators. Digital readout indicators shall be segment readouts in accordance with MIL-DTL-28803. The height of the indicator characters shall be a minimum of 0.45 inch. Display colors shall be selected in accordance with 3.7.17, except that red shall be used for alpha-numeric displays.

3.7.9.3.1 Digital readout circuitry. The need for digital indicators may require that some circuitry be mounted with the digital indicators to reduce the number of connections necessary between the equipment and the digital indicators.

Indicators shall be constructed according to the following guides with the order of importance being the same as the order of the guides:

a. Minimize the complexity of the indicator component.

b. Minimize susceptibility.

c. Minimize the number of connections between the equipment and the digital indicators

3.7.9.3.2 Digital indicator flicker. The digital indicators that display the parameter measurements in engineering units shall reduce flickering of the readout equipment. The least significant digit will inherently change from one digit to another at the transfer point. Every effort shall be made to reduce objectionable flicker in the least significant digit.

3.7.9.3.3 Isolation. Isolation shall be used among the various instrument outputs so that shorting or opening any digital output circuit will not produce a change in any other output in excess of the specified accuracy requirements.

3.7.9.4 Controls. The following controls shall be provided:

a. Local HMI. Equipment shall be capable of operation directly through the HMI interface (normal operation).

b. Remote. Equipment shall be capable of operation through offsite interfaces (lowest priority) independent of the HMI.

c. Local manual. Equipment shall be capable of operation directly (highest priority).

3.7.9.4.1 Controls operations in each control mode. A detailed list of required controls applicable to Local HMI, Remote, and Local Manual shall be provided, as specified (see 6.2).

3.7.10 Transformers.

3.7.10.1 Low voltage transformers. Low voltage transformers shall meet the requirements of MIL-T-15108 and MIL-T-16315, as applicable.

3.7.10.2 Medium voltage transformers.

3.7.10.2.1 Medium voltage current transformers. Medium voltage current transformers shall meet the requirements of IEEE C57.13. Iron core current transformer coil output current shall be analog signals.

3.7.10.2.1.1 Alternative Rogowski medium voltage current transformers. When specified (see 6.2), alternatives to medium voltage current transformers shall be allowed that meet the applicable performance requirements of IEEE C57.13. Medium voltage Rogowski current transformers shall meet the application characteristics of IEEE C37.235 and testing requirements of IEC 60044-8.

3.7.10.2.1.1.1 Primary converter module. The primary converter module represents signal processing circuitry that may be placed in the immediate vicinity of the Rogowski coil and is used to amplify, convert, or encode low-level signals before transmission to the protective relay. The primary converter module functions may be incorporated in the protective relay.

3.7.10.2.2 Medium voltage potential transformers. Medium voltage potential transformers shall meet the requirements of IEEE C57.13.

3.7.10.2.2.1 Grounding of drawout-type potential transformers. Metal cases for drawout-type potential transformers shall meet the grounding requirements of IEEE C37.20.2 (see 4.4.3.5).

3.7.10.2.2.2 Alternatives to medium voltage potential transformers. When specified (see 6.2), alternatives to medium voltage potential transformers shall be allowed that meet the applicable performance requirements of IEEE C57.13. Voltage sensors may be impedance (resistive or capacitive) voltage dividers.

3.7.11 Resistors and rheostats. Resistors and rheostats shall conform to MIL-DTL-15109. Power dissipation shall not exceed 50 percent of the rated value after ambient temperature and other applicable derating factors are applied in accordance with the part specification.

3.7.12 Low voltage fuses and terminal blocks. Fuses shall be in accordance with MIL-PRF-15160. Fuses, fuseholders, and fuseclips shall be silver plated in accordance with MIL-PRF-15160. Fuseholders shall be dead-front type with blown fuse indicator in accordance with MIL-PRF-19207.

3.7.12.1 Fuse mounting. Fuses mounted on switchboards shall be accessibly located for replacement. External mounting of fuses is preferred. Fuses shall be grouped on subpanels insofar as practicable, but the length of leads between fuses and the power circuit taps shall be kept to a minimum.

3.7.12.1.1 Dead-front fuseholders. Dead-front fuseholders shall be of the following types in accordance with MIL-PRF-19207 and shall not be installed for any distribution circuit fuse on power or lighting distribution switchboards or panels:

FHL10U

FHL11U

FHL12U

FHL14G

FHL32W

FHL33W

FHL34W

FHL35W

3.7.13 Medium voltage fuses and fuse accessories. Medium voltage fuses and accessories shall meet the requirements of applicable IEEE C37.46 and IEEE C37.47 standards. Expulsion fuses shall not be used. When specified (see 6.2), fuses shall be silver plated.

3.7.14 Terminal boards. To minimize the possibility of breakage of the terminal boards caused by distortion of the mounting support under shock, the length of the terminal board shall not exceed 12 terminal points. Terminal boards shall be in accordance with A-A-59125 and A-A-59125/2 or A-A-59125/9, or the equivalent.

3.7.15 Switches, disconnecting devices, and transfer switches. Control and instrument switches shall be in accordance with MIL-S-18396. For applications below 125 volts, style JR switches as specified in MIL-DTL-21604 and MIL-DTL-21604/5 may be used. Control and instrument switches shall have gray or natural light tan escutcheon plates with black lettering. Switches shall be provided with four styles of handles to identify the function for which the switch is provided. The handle styles and corresponding function shall be as follows:

a. Round - governor control (spring return)

b. Oval - synchronizing and voltage regulator, synchronizing monitor, and field flashing

c. Round (knurled) - instruments (voltmeter, ammeter, frequency meter, temperature indicator)
- test (emergency switchboard, spring return)

d. Pistol-grip - circuit breaker and ground lamps (spring control)
- control bus selector

Control switches installed within the enclosure (such as relay defeater switches) shall be sufficiently close to the access opening to minimize personnel exposure to energized components.

3.7.16 Fans. Thermostatic fans may be added to the switchboard. When specified (see 6.2), fans shall meet the following requirements:

a. Fans shall activate only when the internal ambient temperature in a compartment exceeds 60 °C.

b. Easily accessible, washable air filters shall be provided for intake fans.

c. Fans shall be disabled by operation of an appropriate maintenance switch.

d. When fans are installed, airborne and structureborne noise testing in accordance with MIL-STD-1474, Equipment Grade E, and MIL-STD-740-2, Type IV shall be included in the first article test.

e. Fans shall be activated during selected first article tests as specified herein.

3.7.16.1 Fan monitoring system. A fan monitoring system shall be provided. The system shall have features for fan failure detection and alarms and temperature monitoring and over-temperature alarms. Individual fuses shall be used for each fan.

3.7.16.2 Fan shutdown during water mist. When water mist is specified, fans shall automatically shut down during water mist events.

3.7.17 Indicator lights. Whenever possible, indicator lights shall be Light Emitting Diode (LED) type. If an LED type indicator light is not available for a particular application, an incandescent type indicator light may be used. LED indicator lights shall be in accordance with A-A-59781. Incandescent indicator lights shall conform to MIL-DTL-3661, MIL-L-3661/38, MIL-L-3661/62, MIL-L-3661/63, MIL-L-3661/64, and MIL-L-3661/65, as applicable. Indicator lights shall be furnished with lamps. For position indication of circuit breakers, blue indicator lights shall be used to show that the circuit breaker is closed. Other indicator lamps have color caps as specified for the particular application. The color code shall be as follows:

a. Red - danger or emergency condition requiring immediate attention or corrective action.

b. Green - normal condition.

c. White - power available or power on.

d. Blue - closed, advisory.

e. Clear (not etched) - synchronizing or ground detector lights.

f. Yellow - abnormal, but not requiring immediate attention.

3.7.18 Non-contact thermal sensors. When specified (see 6.2), fiber optic temperature sensors or other technologies shall be provided to determine temperatures of selected current carrying joints or expected hot spots (see 4.4.3.15.8). Temperature sensors shall be permanently mounted and be provided with dedicated maintenance test ports. The test equipment used shall be capable of operation in the field for maintenance. Functionality will be verified by temperature rise testing when required.

3.7.19 Protective relays. Protective relays used with circuit breakers shall be Type I or Type II in accordance with MIL-PRF-32484.

3.7.20 Tool storage. When specified (see 6.2), maintenance equipment storage shall be provided for all recommended on-board maintenance tools.

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 samples shall be subjected to the examination and tests in the order specified in table V.

4.3 Conformance inspection. Conformance inspection shall be performed in accordance with table V.

4.4 Examination and test methods.

4.4.1 Test equipment. Test equipment shall be as specified in each individual test herein. Test equipment requiring calibration shall be certified to be acceptable at the time of testing.

4.4.2 Test conditions. Unless otherwise specified herein, the inspection and tests of 4.4 shall be performed under the following conditions:

a. Ambient temperature from 10 to 50 °C.

b. Attitude: Normal operation position.

Unless otherwise specified herein, ambient conditions within the specified range need not be controlled.

TABLE V. First article and conformance inspection and schedule.

Order	Inspection	First article	Conformance	Requirement paragraph(s)	Inspection paragraph(s)
1	General examination	X	X	--	4.4.3.1
2	Verification of protective functions	X	X	3.7.19	4.4.3.2
3	Maintainability (if required)	X	-	3.6.14	4.4.3.3
4	Circuit breaker/stationary element (cradle)/lifting device tests	X	-	3.7.1	4.4.3.4
4A	Circuit breaker positions in or on cradle for rack-in/rack-out and racking position indicator	X	-	3.7.1.6.1	4.4.3.4.1
4B	Mechanical endurance racking	X	-	3.7.1.6.6	4.4.3.4.2
4C	Stationary element or lifting device strength	X	-	3.7.1.7	4.4.3.4.3
4D	Inclined operation	X	-	3.7.1.9	4.4.3.4.4
4D(1)	Electrical cycling	X	-	3.7.1.9.1	4.4.3.4.4.1
4D(2)	Opening and closing times	X	-	3.7.1.9.2	4.4.3.4.4.1
4D(3)	Anti-rolling	X	-	3.7.1.9.3	4.4.3.4.4.2
5	Grounding of instrument transformer case tests	X	X	3.7.10.2.2.1	4.4.3.5
6	Electrical interface characteristics	X	-	3.6.2	4.4.3.6
6A	Voltage and frequency tolerance	X	-	3.6.2	4.4.3.6.1
6B	Emergency condition	X	-	3.6.2	4.4.3.6.2
7	Power frequency withstand voltage for primary conductors	X	X	3.6.6	4.4.3.7
8	Power frequency withstand voltage for conductors less than 1 kV	X	-	3.6.7	4.4.3.8
9	Lightning impulse withstand voltage (BIL)	X	-	3.6.5	4.4.3.9
10	Corona (if required)	X	-	3.7.4	4.4.3.10
11	Partial discharge (if required)	X	-	3.7.5	4.4.3.11
12	Insulation resistance (low voltage control circuits)	X	X	3.6.9	4.4.3.12
13	EMI	X	-	3.5.4	4.4.3.13
14	Voltage spike	X	-	3.6.8	4.4.3.14
15	Ambient temperature and temperature rise	X	-	3.5.1.1 3.5.1.2	4.4.3.15
15A	Thermal imaging window and non-contact thermal sensor data check	X	-	3.4.2.15 3.7.18	4.4.3.15.8

TABLE V. First article and conformance inspection and schedule - Continued.

Order	Inspection	First article	Conformance	Requirement paragraph(s)	Inspection paragraph(s)
16	Momentary withstand	X	-	3.6.1	4.4.3.16
17	Short time withstand	X	-	3.6.1	4.4.3.17
18	Shock	X	-	3.5.2	4.4.3.18
19	Power frequency withstand voltage for primary conductors (65% reduced value)	X	-	3.6.6	4.4.3.7
20	Power frequency withstand voltage for conductors less than 1 kV (65% reduced value)	X	-	3.6.7	4.4.3.8
21	Insulation resistance (low voltage control circuits)	X	-	3.6.9	4.4.3.12
22	Vibration	X	-	3.5.3	4.4.3.19
23	Power frequency withstand voltage for primary conductors (65% reduced value)	X	-	3.6.6	4.4.3.7
24	Power frequency withstand voltage for conductors less than 1 kV (65% reduced value)	X	-	3.6.7	4.4.3.8
25	Insulation resistance (low voltage control circuits)	X	-	3.6.9	4.4.3.12
26	Noise (if required)	X	-	3.5.8	4.4.3.20
27	Water spray (if required)	X	-	3.5.5	4.4.3.21
28	Insulation resistance (low voltage control circuits) (if water spray required)	X	-	3.6.9	4.4.3.12
29	Power frequency withstand voltage for primary conductors (65% reduced value) (if water spray required)	X	-	3.6.6	4.4.3.21.1
30	Water mist (if required)	X	-	3.5.6	4.4.3.22
31	Insulation resistance (low voltage control circuits) (if water mist required)	X	-	3.6.9	4.4.3.12
32	Power frequency withstand voltage for primary conductors (65% reduced value) (if water mist required)	X	-	3.6.6	4.4.3.22.1
33	Flame test	X	-	3.5.7	4.4.3.23
34	Arc resistant testing (if required)	X	-	3.4.2.16	4.4.3.24

4.4.3 Detailed inspection.

4.4.3.1 General exam. Switchgear shall be subjected to a thorough examination to determine that the material, workmanship, safety to operating personnel, design, and construction are in conformance with this specification and applicable drawings. Examination shall include, but need not be limited to, the following:

a. Electrical connections and wiring in conformance with applicable documents. An operational (manual, local, remote) check of all low voltage switchgear components and with a ring out of wired connections.

b. Outline and mounting dimensions in conformance with applicable documents (not needed for conformance testing).

c. Designation and marking, including safety warnings, are as specified.

d. Weights and centers of gravity are in conformance with applicable documents (not needed for conformance testing). Centers of gravity may be determined by actual measurement or through the use of three dimensional models.

e. Check of workmanship, fastener integrity, damage to platings or components.

f. The 100-hour burn-in test shall be conducted by energizing control voltage to the equipment for 100 hours at nominal voltage and frequency, ambient temperature and with all inputs and outputs connected to effect maximum rated loading. 100-hour burn-in test may be accomplished at the end of first article testing.

g. Verification of arc fault equipment functionality (as applicable).

h. Verification of UPS hold up time.

i. Verification of Capacitive Voltage Indicating Systems functionality (as applicable).

j. Verification of circuit breaker interchangeability. All circuit breakers of the same type and frame size shall be moved and installed in a new compartment a minimum of one time.

k. Verification of charge motor protection. If equipped, a device that protects the circuit breaker charging motor from excessive current (locked rotor) and extended time of operation (failed cut off) shall be verified to be operational and protect the circuit breaker charge motor from damage during mal-operation.

l. Ground connections shall be inspected for resistance in accordance with MIL-STD-1310.

4.4.3.2 Verification of protective functions. Verification testing of protective and metering functions and communications (as applicable), including timing tests, shall be conducted. Instruments shall be energized from the low voltage winding of the potential transformers and the low current winding of current transformers (secondary injection). Where practical, each instrument shall be operated through its range of voltage, current, and/or phase angle and frequency to produce deflections over the entire scale. Relays shall be tested by applying rated current and/or voltage as required to determine proper performance characteristics. Each relay shall be tested to determine its proper operation in itself and also in the total overall circuit performance. For conformance testing, the manufacturer may develop a reduced scope of testing that verifies operation but not over a full range.

4.4.3.3 Maintainability. When specified (see 6.2), compliance shall be verified through a maintenance demonstration procedure, maintenance task selection, and maintenance task performance. For guidelines, refer to test method 1 of MIL-HDBK-470.

4.4.3.4 Circuit breaker/stationary element (cradle)/lifting device tests.

4.4.3.4.1 Circuit breaker positions in or on cradle for rack-in/rack-out. Rack-in/rack-out tests of 4.4.3.4.1.1 and 4.4.3.4.1.2 may be conducted during mechanical endurance racking test of 4.4.3.4.2.

4.4.3.4.1.1 Rack-out. The circuit breaker shall be racked-out to the test, disconnected, and withdrawn positions and meet the criteria of 4.4.3.4.1.1.1, 4.4.3.4.1.1.2, and 4.4.3.4.1.1.3. With the circuit breaker initially in the connected position and closed, it shall be verified that a closed circuit breaker cannot be advanced from connect position to the test position. The circuit breaker shall then be opened and rack-out continued to the test position.

4.4.3.4.1.1.1 Test position.

4.4.3.4.1.1.1.1 Main contact de-energization, rack-in/rack-out position indicator operation, and cell switch operation. The main contacts shall be verified by measurement to be de-energized, and the rack-in/rack-out position indicator shall be visually verified to be in the "test" position. If applicable, the cell switch shall be verified by measurement to be in the closed position.

4.4.3.4.1.1.1.2 Electrical cycling and mechanical position indicator operation. The circuit breaker shall be cycled electrically to verify that control power is still available. The mechanical position indicator shall be visually verified to properly show the open/closed state of the main contacts as the circuit is cycled.

4.4.3.4.1.1.1.3 Manual cycling and mechanical position indicator operation. The circuit breaker shall be cycled manually. The mechanical position indicator shall be visually verified to properly show the open/closed state of the main contacts as the circuit breaker is cycled.

4.4.3.4.1.1.1.4 Anti-rolling verification. With a 25-pound force applied to the front of the circuit breaker in the horizontal direction towards the cradle backplane, the following criteria shall be met. The force shall be applied as close to the center of the circuit breaker as possible. An instrument or device shall be used to measure and verify that a 25-pound force is applied.

a. The circuit breaker shall not move in and out on the cradle rails/tray.

b. The circuit breaker shall not fall off the cradle rails/tray.

c. No part of the circuit breaker shall come off the cradle rails/tray in such a manner as to require manual repositioning of the circuit breaker.

4.4.3.4.1.1.2 Disconnect position.

4.4.3.4.1.1.2.1 Rack-in/rack-out position indicator operation and cell switch operation. With the circuit breaker racked out to the disconnect position, it shall be visually verified that the rack-in/rack-out position indicator is in the "disconnected" position. If applicable, the cell switch shall be verified by measurement to be in the closed position.

4.4.3.4.1.1.2.2 Manual cycling and mechanical position indicator operation. The circuit breaker shall be cycled manually. The mechanical position indicator shall be visually verified to properly show the open/closed state of the main contacts as the circuit breaker is cycled.

4.4.3.4.1.1.2.3 Anti-rolling verification. With a 25-pound force applied to the front of the circuit breaker in the horizontal direction towards the cradle backplane, the following criteria shall be met. The force shall be applied as close to the center of the circuit breaker as possible. An instrument or device shall be used to measure and verify that a 25-pound force is applied.

a. The circuit breaker shall not move in and out on the cradle rails/tray.

b. The circuit breaker shall not fall off the cradle rails/tray.

c. No part of the circuit breaker shall come off the cradle rails/tray in such a manner as to require manual repositioning of the circuit breaker.

4.4.3.4.1.1.3 Withdrawn position.

4.4.3.4.1.1.3.1 Anti-rolling verification. With a 25-pound force applied to the front of the circuit breaker in the horizontal direction towards the cradle backplane, the following criteria shall be met. The force shall be applied as close to the center of the circuit breaker as possible. An instrument or device shall be used to measure and verify that a 25-pound force is applied.

a. The circuit breaker shall not move in and out on the cradle rails/tray.

b. The circuit breaker shall not fall off the cradle rails/tray.

c. No part of the circuit breaker shall come off the cradle rails/tray in such a manner as to require manual repositioning of the circuit breaker.

4.4.3.4.1.2 Rack-in. With the circuit breaker in the withdrawn position and open, the circuit breaker shall then be racked-in to the disconnect, test, and connect positions and meet the criteria of 4.4.3.4.1.2.1, 4.4.3.4.1.2.2, and 4.4.3.4.1.2.3.

4.4.3.4.1.2.1 Disconnect position. The criteria of 4.4.3.4.1.1.2 shall be met except that the anti-rolling verification of 4.4.3.4.1.1.3.1 shall not be conducted.

4.4.3.4.1.2.2 Test position. The criteria of 4.4.3.4.1.1.1 shall be met except that the anti-rolling verification of 4.4.3.4.1.1.1.4 shall not be conducted. In addition, the circuit breaker shall be closed and it shall be verified that a closed circuit breaker cannot be advanced from the test position to the connected position.

4.4.3.4.1.2.3 Connect position. In the connected position, the following criteria shall be met:

a. Verify by measurement that the main contacts are energized when the circuit breaker is closed and visually verify that the rack-in/rack-out position indicator is in the “connected” position.

b. If applicable, the cell switch shall be verified by measurement to be in the open position.

4.4.3.4.2 Circuit breaker mechanical endurance racking. To demonstrate proper sequential racking operation and to establish satisfactory function of circuit breakers and cradles (including withdrawal interlocks, secondary disconnects, shutters, and, if applicable, cell switches), circuit breakers and cradles shall be subjected to 500 mechanical endurance racking test cycles between connected and test positions for each frame size and type of circuit breaker with all primary and control power disconnected. One cycle shall consist of rack-out from connected position to test position and rack-in from test position back to connected position. After the 500 cycles are completed, the following additional tests shall be conducted to verify withdrawal interlock operation:

a. With the circuit breaker initially in the connected position and closed, verify that a closed circuit breaker cannot be advanced from connect to the test position. Open the circuit breaker and proceed to the test position.

b. With the circuit breaker in the test position and closed, verify that a closed circuit breaker cannot be advanced from the test position to the connected position.

4.4.3.4.3 Circuit breaker stationary element or lifting device strength. A weight equal to 50 percent of the circuit breaker weight shall be added with the circuit breaker in the withdrawn position on the cradle rails/tray or lifting device. A dummy weight equal to the size and weight of the circuit breaker can be used instead of an actual breaker. One-half the additional weight shall be attached on the left and right sides of the cradle as follows:

a. With weight hanging straight down, attach 25 percent of the additional weight to the right side cradle rail or bottom right side of cradle tray with a rope or cable at no more than 1/4 the depth of the circuit breaker measuring from the front of the circuit breaker.

b. With weight hanging straight down, attach 25 percent of the additional weight to the left side cradle rail or bottom left side of cradle tray with a rope or cable at no more than 1/4 the depth of the circuit breaker measuring from the front of the circuit breaker.

The circuit breaker and additional weight shall remain in the withdrawn position for 10 minutes. During that time period, there shall be no collapse or failure. After the 10-minute period, the weight shall be removed and the circuit breaker shall be fully racked in and racked out to the withdrawn position without any failure.

4.4.3.4.4 Inclined operation. Circuit breakers, attachments, and stationary elements shall be subjected to the tests of 4.4.3.4.4.1 and 4.4.3.4.4.2, with the circuit breaker inclined forward, backward, and to each side, at an angle of 30 degrees from the normal vertical/horizontal orientation. Testing can be performed on a switchboard section or an individual switchboard unit. For anti-rolling verification, the circuit breaker may be racked out in the normal vertical/horizontal orientation and then the switchboard section or unit can be inclined.

4.4.3.4.4.1 Electrical cycling/verification of opening and closing times. While in the connect position, the circuit breakers shall be electrically cycled five times using all applicable attachments using local commands. Circuit breaker opening and closing times shall be verified by measurement to be in accordance with MIL-DTL-32485.

4.4.3.4.4.2 Anti-rolling. When racked to the test, disconnect, or withdrawn position, the circuit breaker shall be visually verified to meet the following criteria:

a. The circuit breaker shall not move in and out on the cradle rails/tray.

b. The circuit breaker shall not fall off the cradle rails/tray.

c. No part of the circuit breaker shall come off the cradle rails/tray in such a manner as to require manual repositioning of the circuit breaker.

4.4.3.5 Grounding of instrument transformer case. Grounding of the instrument transformer case shall be tested in accordance with IEEE C37.20.2.

4.4.3.6 Electrical interface characteristics.

4.4.3.6.1 Voltage and frequency tolerance. The switchboard shall be subjected to the voltage and frequency tolerance test in accordance with MIL-STD-1399-680.

4.4.3.6.2 Emergency condition. The switchboard shall be subjected to the emergency condition test in accordance with MIL-STD-1399-680.

4.4.3.7 Power frequency withstand voltage for primary conductors. Primary conductors shall be subjected to power frequency withstand voltage testing in accordance with IEEE C37.20.2. Where dedicated ground studs are present, testing shall be conducted with the removable boots not present.

4.4.3.8 Power frequency withstand voltage for conductors less than 1 kV. For conductors less than 1 kV, power frequency withstand voltage testing shall be made with an alternating potential from a 1 kilowatt or larger power source having a 60 Hertz sinusoidal wave shape. Semiconductors shall be shunted or disconnected for protection during tests. Equipment shall withstand, for a period of 1 minute, a dielectric test voltage of twice the rated voltage of the equipment plus 1,000 volts rms value between each electrically isolated circuit and all other circuits connected together to ground (frame, chassis, or enclosure as applicable). All charging motor leads shall be tested separately and be tied together with 900 volts applied. No breakdown shall be observed.

4.4.3.9 BIL. BIL testing shall be conducted in accordance with IEEE C37.20.2 at the applicable table IV value. If applicable, boots on dedicated ground studs shall be removed for testing. Cable, cable terminations, and cable restraints required for shipboard use shall be included. Cable ends shall be insulated.

4.4.3.10 Corona test. When specified (see 6.2), corona detection equipment shall be used to measure corona level. Corona level shall not be detectible below the CIV level specified (see 6.2). For guidelines on testing, refer to MIL-HDBK-454, Guideline 45.

4.4.3.11 Partial discharge test. Partial discharge testing is dependent on the system chosen for use and the system being tested. Partial discharge test techniques shall be in accordance with IEEE C37.301 as applicable.

4.4.3.12 Insulation resistance.

4.4.3.12.1 Test setup. Insulation resistance tests shall be conducted in accordance with Method 302 of MIL-STD-202. Test conditions shall be as follows:

a. Test potential: 500 V ±10 percent for operating potentials of 450 VAC or less.

b. Points of measure: Between each electrically isolated circuits and all other circuits connected together to ground (frame, chassis, or enclosure as applicable).

c. Application time of test voltage shall be sufficient to take resistance readings.

d. Temperature at time of test: Temperature of parts to be tested shall be measured and recorded.

4.4.3.12.2 Pass/fail criteria. Insulation resistance shall not be less than 10 megohms corrected to 25 °C for any readings before and after shock testing. Correction shall be made on the basis of insulation resistance doubling for each 15 °C decrease in temperature.

4.4.3.13 EMI test. The EMI tests of MIL-STD-461 for surface ship, below deck, metallic hull installations shall be conducted on switchboards with electronic devices. Testing shall not cause false tripping of circuit breakers or failure of electronic devices. Fans shall be energized during EMI testing.

4.4.3.14 Voltage spike testing. The control circuits shall be tested in accordance with the voltage spike testing requirements of MIL-STD-1399-300.

4.4.3.15 Temperature rise.

4.4.3.15.1 Switchboard sample(s). The test shall be conducted on a complete switchboard section for each sample or samples chosen. All equipment (including spare circuit breakers), cabling, and buswork shall be installed in accordance with the shipboard installation. All circuit breakers (except spares) and all disconnects shall be fully cabled including those that are not used as a load during testing.

4.4.3.15.2 Pass/fail criteria. Temperature rise tests shall be conducted to verify that the temperature within any compartment in the switchboard section except for the control cabinet/compartment does not exceed 75 °C when operating within an ambient temperature of 50 °C. The temperature within the control cabinet/compartment shall not exceed 70 °C when operating within an ambient temperature of 50 °C. Insulation, components, and wiring required to be installed in the units shall operate within rated insulation thermal limits or rated limits. A functional check of operating controls and circuit functions shall be performed at temperature stabilization. In addition, a temperature rise limit of 70 °C is required for circuit breaker terminals. The temperature rise limit of power cables shall be based on the power cable chosen as specified (see 6.2).

4.4.3.15.3 Test chamber. Testing shall be conducted without recirculation of air into the test chamber. Fans may be used to maintain ambient temperature and to prevent air stratification within the test chamber. These fans shall be directed away from the switchboard towards the sides of the test chamber enclosure. Air from these fans shall not blow directly onto or be deflected onto any part of the switchboard section during testing.

4.4.3.15.4 Sensors and sensor locations. Temperature sensors (thermocouples or other approved methods) shall be installed to determine ambient temperature within the test chamber (but outside the switchboard section) and temperature rise in each compartment of the switchboard section.

4.4.3.15.4.1 Ambient temperature sensors. Six sensors shall be installed in one of the following configurations:

a. Three sensors shall be installed 3 feet away from both the left and right sides of the switchboard section at half the depth and at the following locations:

(1) One sensor shall be 6 inches from the bottom of the switchboard section.

(2) One sensor shall be 6 inches from the top of the switchboard section.

(3) One sensor shall be at half the height of the switchboard section.

b. Three sensors shall be installed 3 feet away from both the front and back surfaces of the switchboard section at half the section width and at the following locations:

(1) One sensor shall be 6 inches from the bottom of the switchboard section.

(2) One sensor shall be 6 inches from the top of the switchboard section.

(3) One sensor shall be at half the height of the switchboard section.

4.4.3.15.4.2 Compartment temperature sensors.

4.4.3.15.4.2.1 Compartments other than bus compartments. Each switchboard section compartment other than a bus compartment shall have two temperature sensors at the following locations:

a. One sensor shall be 2 inches from the top at the compartment midway point from front-to-back and as close to the center of the compartment as possible.

b. One sensor shall be 2 inches from the bottom at the compartment midway point from front-to-back and as close to the center of the compartment as possible.

4.4.3.15.4.2.2 Bus compartments. There shall be three temperature sensors per switchboard unit in the bus compartment (i.e., a three-unit section shall require nine separate sensors) at the following locations:

a. One sensor shall be 2 inches from the top at the compartment midway point from front-to-back and as close to the midway point of the unit width as possible.

b. One sensor shall be 2 inches from the bottom at the compartment midway point from front-to-back and as close to the midway point of the unit width as possible.

c. One sensor shall be at the halfway point from the top to bottom of the compartment at the compartment midway point from front-to-back and as close to the center of the unit width as possible.

d. Sensors shall be mounted to the bus (if required) to validate the bus insulations temperature rating for non-standard bus geometry.

e. Sensors shall be mounted to each phase of the circuit breaker stationary element line and load terminals.

f. Sensors shall be mounted to each phase of the primary power cable connections.

4.4.3.15.5 Temperature stabilization and temperature rise determination. All temperature readings for each test shall be recorded during the same time frame and shall be of sufficient duration to allow stabilization of the measured temperatures to a rate of rise within 2 °C per hour. Ambient temperature at each ambient sensor location shall be maintained at 50±2 °C. An average ambient temperature shall be determined by averaging together the ambient sensor readings. The average ambient temperature shall be used to determine the temperature rise of the switchboard compartments.

4.4.3.15.6 Circuit breaker loading and equipment energization. Circuit breakers shall be loaded to their designed full load (element rating, continuous current setting, or rating plug value as applicable) at any convenient voltage to simulate the heat dissipation characteristics the switchboard will have under actual operating conditions. All transformers and equipment that utilizes internal transformers shall be energized. Turbine generator control units shall be tested at 75-percent load.

4.4.3.15.6.1 One-unit switchboard section. All circuit breakers shall be fully loaded. If applicable, any remaining load shall be divided among as many different circuit breaker frame sizes as possible. If applicable, disconnects may be used for any remaining load after circuit breakers are loaded as discussed above. Total loading of the unit shall not exceed the rating of the unit.

4.4.3.15.6.2 Multiple-unit switchboard section. Separate temperature rise tests equaling the number of units in the section shall be conducted (i.e., a three-unit section shall require three separate tests). Each unit shall be loaded in accordance with 4.4.3.15.6.1. If applicable, any remaining load shall be divided among the other units as necessary. Total loading of a particular unit shall not exceed the rating of that unit. If the unit being fully loaded receives power from a circuit breaker in another unit of the same switchboard section, that circuit breaker shall be used to provide power to the fully loaded unit.

4.4.3.15.7 Voltage regulator loads. Dummy-type resistive loads shall be used to simulate voltage regulator components in the spaces allocated to these. These dummy loads shall be equal to the maximum heat dissipation ratings of the regulator components.

4.4.3.15.8 Thermal imaging windows and non-contact thermal sensor data check. During temperature rise testing, thermal imaging shall be conducted through the thermal imaging windows and data shall be gathered from non-contact thermal sensors. To verify accuracy, data shall be compared to readings taken from thermocouples during temperature rise testing. Temperature data will be used to create labels located adjacent to the window to aid thermographers for maintenance.

4.4.3.16 Momentary withstand. Momentary withstand testing shall be conducted in accordance with IEEE C37.20.2.

4.4.3.17 Short-time withstand. Short-time withstand testing shall be conducted in accordance with IEEE C37.20.2.

4.4.3.18 High-impact shock. The complete switchboard shall be subjected to Grade A, Type A, high-impact shock test in accordance with MIL-S-901. This equipment shall be tested as a principal unit. The complete switchboard section, including all subsidiary components and subassemblies installed within the switchboard during the test, shall meet the shock test acceptance criteria.

4.4.3.18.1 Test setup. Test setup shall include the following:

a. All equipment, including spare circuit breakers, shall be installed in the switchboard section in accordance with the shipboard configuration during testing.

b. All lengths of ship's cabling (except for spare and blank circuit breakers) and buswork shall be installed in the switchboard section in accordance with the shipboard configuration during testing.

c. All lengths of ship's cabling (except for spare and blank circuit breakers) that extend outside the foundation of the switchboard section shall be stubbed to 12 to 18 inches with the bitter ends insulated.

d. Cable, cable terminations, and cable restraints required for shipboard shall be included in shock testing.

e. The test shall be conducted with all equipment energized. Primary power to circuit breakers needs only to be energized to the level to determine contact bounce.

f. Switchboard section mounting location, mounting plane, and mounting orientation for the shock test shall simulate the worst case shipboard installation as specified (see 6.2).

g. For each compartment of the switchboard section with circuit breakers installed, a minimum of one circuit breaker of each type shall be monitored for contact bounce during testing. Monitoring shall include all main contacts and at least one normally open and one normally closed auxiliary contact.

h. Fans when required shall be energized during this test.

i. Foundations used in shock testing shall simulate shipboard configuration.

j. The switchboard shall be instrumented with a sufficient number of accelerometers to support future shock analysis of components.

4.4.3.18.2 Principal function pass/fail criteria. The following criteria shall be used to determine switchgear component pass or failure acceptance criteria:

a. Hair line cracks are permitted in the framework, but no separation of parts shall result.

b. Any resulting distortion shall not be of sufficient magnitude to impair the operation of the equipment contained within or prevent the circuit breakers from being withdrawn.

c. The enclosure shall not distort to an extent which might result in contact with any electrically conducting part within the section.

d. The bus work shall not be mechanically damaged nor the bus clearance distances reduced below the minimum requirements.

e. Insulation resistance shall not be reduced below that specified in 10 megohms at 25 °C.

f. The section shall pass the dielectric strength test at 65 percent of the specified voltage.

g. Circuit breakers shall not change position/state from "on" to "off", from "off" to "on", or from "on" to "trip" during the test. An "off" to "trip" position/state change is permitted.

h. Any closing of circuit breaker main and auxiliary contacts from the open position shall not be acceptable.

i. Momentary opening of vacuum circuit breaker main and auxiliary contacts shall not be in excess of 0.020 seconds during a single shock event.

j. Circuit breaker control relays or protective relays shall not cause the circuit breakers to change position/state.

k. Protective relay adjustable settings shall not change position.

l. All circuit breakers shall complete an open/close operation after each shock blow.

m. All circuit breakers with racking capability shall complete a racking cycle after each shock blow. Racking shall be accomplished using the racking mechanism and standard racking tool without removal of circuit breaker front cover.

n. No components or pieces of components shall become adrift. Cracks in thermal imaging windows are permitted.

o. Bus and cable fasteners shall not have loosened.

p. After shock testing, power frequency withstand voltage for primary conductors and insulation resistance (low voltage control circuits) testing as shown in table V shall be successfully conducted.

4.4.3.18.3 Disposal of shock-tested equipment. Equipment which has been subjected to high-impact shock may be accepted as a production unit of the contract or order only if each of the following conditions are met:

a. The vibration test is conducted after the completion of all shock tests.

b. Damaged parts are replaced.

c. Damaged structural members are repaired or replaced.

d. Post shock and vibration electrical tests and inspections show conformance to specified performance.

e. The unit is covered by the same guarantee by the manufacturer as other production units.

f. The shock-tested unit is free from any distortion of the frame members or enclosure that would prevent its being bolted to the deck or to other switchgear units to form a switchboard section. Measurements shall be made to detect any misalignment of bolt holes or bent framework.

4.4.3.18.4 Extension of shock tests. Extension of satisfactory shock test results to other sections shall be in accordance with the requirements of MIL-S-901. Requests for test extension shall include, but shall not be limited to, the following (see 6.2):

a. Change in weight and mass.

b. Change in center-of-gravity.

c. Change in moments-of-inertia.

d. Changes in dimensions (i.e., height and footprint).

e. Changes in circuit breaker frame sizes, locations, and quantities.

f. Change in materials or size and location of structural members.

g. Changes in method of circuit breaker mounting.

h. Changes in bus bar arrangement or method of support.

i. Changes in ship mounting classification (i.e., deck or hull mounting).

j. Changes in mounting orientation (i.e., athwartship or fore/aft).

4.4.3.19 Vibration test. The switchgear shall be subjected to Type I tests of MIL-STD-167-1. Maximum frequency of vibration shall be as specified (see 6.2). Test setup, pass/fail criteria, and extensions shall be the same as for shock testing (see 4.4.3.18.1, 4.4.3.18.2, 4.4.3.18.4) with the following exceptions:

a. No circuit breaker contact bounce shall be acceptable.

b. All circuit breakers shall complete an open/close operation between endurance axis change.

c. All circuit breakers with racking capability shall complete a racking cycle between endurance axis change. Racking shall be accomplished using the racking mechanism and standard racking tool without removal of circuit breaker front cover.

d. Extension of vibration test results to other sections shall meet the requirements as specified (see 6.2).

4.4.3.20 Noise. When fans are installed, airborne and structureborne noise testing in accordance with MIL-STD-1474, Equipment Grade E, and MIL-STD-740-2, Type IV shall be conducted.

4.4.3.21 Water spray. Switchgear shall be subjected to the water spray test requirements of MIL-STD-108 for drip-proof 15-degree protected enclosure except that visual exam shall not be permissible to determine acceptability of drip-proof design. Fans shall be energized during this test.

4.4.3.21.1 Pass/fail criteria. Within 30 minutes of the completion of water mist testing, the insulation resistance (low voltage control circuits) and power frequency withstand voltage tests on primary conductors as shown in table V shall be successfully conducted.

4.4.3.22 Water mist. Switchgear shall be subjected to the blowing rain test requirements of MIL-STD-810, Method 506.5, Procedure II. The pressure, flow rate, droplet size range, and duration of the test shall be as specified (see 6.2). Fans shall be activated before water mist testing begins.

4.4.3.22.1 Pass/fail criteria. The following criteria shall be met:

a. Fans shall automatically shut down when water mist event occurs.

b. Within 30 minutes of the completion of water mist testing, the insulation resistance (low voltage control circuits) and power frequency withstand voltage tests on primary conductors as shown in table V shall be successfully conducted.

4.4.3.23 Flame test. Primary conductor insulating material not in accordance with MIL-E-917 requirements shall be subjected to flame testing in accordance with IEEE C37.20.2.

4.4.3.24 Arc-resistant design (pressure relief flaps). Testing of pressure-relief flaps shall be conducted in accordance with IEEE C37.20.7. The fault levels that will occur at locations in the switchboard and the permissible venting locations and clearances shall be as specified (see 6.2).

5. PACKAGING

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

6. NOTES

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

6.1 Intended use. Switchgears covered by this specification are intended to provide protection, control, and distribution of electrical power on naval ships.

6.2 Acquisition requirements. Acquisition documents should specify the following:

a. Title, number, and date of this specification
b. When first article is required (see 3.1).
c. Non-preferred component materials allowed (see 3.4.1.2).
d. Non-preferred component coatings allowed (see 3.4.1.3.3).
e. Removable guard rail sections required (see 3.4.2.9.1).
f. Door interlocks required (see 3.4.2.11).
g. Control cabinet/compartment and PC access (see 3.4.2.14).
h. Arc resistant design required. Details for pressure relief (see 3.4.2.16 and 4.4.3.24).
i. Location of cable entrance, cable restraints, and type of cable terminations (see 3.4.6).
j. Lug types and crimping requirements (see 3.4.6.1).
k. Bus bar capacity (see 3.4.7.3).
l. Maximum available short circuit current (see 3.4.7.7).
m. Water spray required (see 3.5.5).

n. Water mist required. Fan shut off permissible. Water spray pressure, flow rate, droplet size range, and duration of the test (see 3.5.6 and 4.4.3.22).

o. Momentary and short-time withstand ratings (see 3.6.1).

p. Rated maximum voltage (see 3.6.3).

q. Type of ground devices and if the device is to be stored in a switchgear (see 3.6.10.5).

r. Ground fault protection (see 3.6.11).

s. Whether a maintainability demonstration is required (see 3.6.14 and 4.4.3.3).

t. Charge motor protection required (see 3.7.1.4).

u. Circuit breaker lift device (see 3.7.1.5).

v. Remote racking or manually operated racking device required (see 3.7.1.6).

w. Available positions and exceptions (see 3.7.1.6.1).

x. By-pass switch or cell switches, or both, required (see 3.7.1.6.3).

y. Arc fault protection required (see 3.7.2).

z. Required UPS hold up time (see 3.7.3.1).

aa. Maintenance corona capability required. Corona inception voltage (CIV) (see 3.7.4 and 4.4.3.10).

bb. Maintenance partial discharge capability required. Partial discharge inception voltage (PDIV) (see 3.7.5).

cc. Capacitive voltage indicating systems required (see 3.7.6).

dd. Synchronizing control circuits required (see 3.7.7).

ee. Layout of control switches, metering, and similar devices required (see 3.7.9).

ff. Color conventions(see 3.7.9.1.1.1).

gg. Centralized machinery control system requirements of equipment, controls applicable to local HMI, remote, and local manual (see 3.7.9.4.1).

hh. Alternative Rogowski medium voltage current transformers (see 3.7.10.2.1.1).

ii. Alternatives to medium voltage potential transformers (see 3.7.10.2.2.2).

jj. Silver plated fuses required (see 3.7.13).

kk. Fans allowed (see 3.7.16).

ll. Non-contact thermal sensors required (see 3.7.18).

mm. Tool storage location (see 3.7.20).

nn. Temperature rise limit of power cables (see 4.4.3.15.2).

oo. Switchboard section shipboard mounting location, mounting plane, and mounting orientation, additional shock test requirements (see 4.4.3.18.1).

pp. Extension of shock and vibration tests (see 4.4.3.18.4 and 4.4.3.19).

qq. Maximum frequency of vibration (see 4.4.3.19).

rr. Packaging requirements (see 5.1).

6.3 Definitions. Unless otherwise noted below, refer to IEEE C37.100 for definitions.

6.3.1 Corona. Corona is usually denoted by a visual glow or dielectric breakdown of the insulating air around overstressed conductors or the sharp edges of energized parts. Corona is a form of partial discharge.

6.3.2 Electronic devices. Electronic devices are those that have active electrical components such as transistors, diodes and integrated circuits, and associated passive interconnection technologies that would typically be found on a printed circuit board.

6.3.3 Partial discharge (PD). PD is a localized electrical discharge that only partially bridges the insulation between conductors and which can or cannot occur adjacent to a conductor.

6.4 Subject term (key word) listing.

Bus bars
Compartmentation
Corona
HMI
Lightning impulse withstand voltage (BIL)
Partial discharge
Protective relay
Vacuum circuit breaker

Custodians:
Army – AV
Navy – SH
Air Force – 85

Preparing activity:
Navy – SH
(Project 5925-2012-016)

Review activities:
Army – CR, MI
Navy – AS, CG
Air Force – 03, 19, 99
DLA – CC

Civil agencies:
GSA – FAS
MISC – MDA
NASA – NA

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.