INCH-POUND
MIL-DTL-917F(SH)
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SUPERSEDING
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DETAIL SPECIFICATION

ELECTRIC POWER EQUIPMENT, BASIC REQUIREMENTS FOR

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.

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

1. SCOPE

1.1 Scope. This specification covers the basic requirements applicable to the design, materials, and construction of naval shipboard electric power equipment (exclusive of communication equipment, information technology (IT) equipment, and combat systems [fire control and weapons control equipment]). Unless otherwise specified herein, the electric equipment developed for shipboard use under the requirements of this specification are limited to a maximum 450 volt (V) alternating current (AC) and a maximum 1,000 V direct current (DC). This equipment is intended for use on surface and submarine naval vessels (see 6.2).

2. APPLICABLE DOCUMENTS

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

2.2 Government documents.

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

FEDERAL SPECIFICATIONS

FF-S-86 - Screw, Cap, Socket-Head

FF-S-92 - Screw, Machine: Slotted, Cross-Recessed or Hexagon Head

FF-S-200 - Setscrews: Hexagon Socket and Spline Socket, Headless

FF-S-210 - Setscrews: Square Head (Inch) and Slotted Headless (Inch and Metric)

FF-W-84 - Washer, Lock (Spring)

FF-W-92 - Washer, Flat (Plain)

QQ-B-654 - Brazing Alloys, Silver

TT-C-490 - Chemical Conversion Coatings and Pretreatments for Metallic Substrates (Base for Organic Coatings)

TT-P-645 - Paint, Alkyd Type, Formula Number 84

W-C-596 - Connector, Electrical, Power, General Specification for

W-C-596/12 - Connector, Receptacle, Electrical, General Purpose, Duplex, General Grade and Hospital Grade, Grounding, 2 Pole, 3 Wire, 15 Amperes, 125 Volts, 50/60 Hertz

W-C-596/13 - Connector, Plug, Electrical, General Purpose, Hospital Grade, Grounding, 2 Pole, 3 Wire, 15 Amperes, 125 Volts, 50/60 Hertz

FEDERAL STANDARDS

FED-STD-H28/2 - Screw-Thread Standards for Federal Services Section 2 Unified Inch Screw Threads- UN and UNR Thread Forms

FED-STD-595/11120 - Red, Gloss

FED-STD-595/11140 - Red, Gloss

FED-STD-595/16307 - Gray, Gloss

FED-STD-595/26307 - Gray, Semigloss

COMMERCIAL ITEM DESCRIPTIONS

A-A-52080 - Tape, Lacing and Tying, Nylon

A-A-52081 - Tape, Lacing and Tying, Polyester

A-A-52082 - Tape, Lacing and Tying, TFE-Fluorocarbon

A-A-52083 - Tape, Lacing and Tying, Glass

A-A-52084 - Tape, Lacing and Tying, Aramid

A-A-55507 - Clip, Electrical, Fuse, General Requirements for

A-A-55507/1 - Clip, Electrical, Fuse, 30 and 60 Ampere, for Fuse Diameters 1/4 Inch thru 13/16 Inch

A-A-55507/2 - Clip, Electrical, Fuse, P.C. Board, 15 and 30 Ampere, for Fuse Diameter 1/4 Inch

A-A-55507/3 - Clip, Electrical, Fuse, P.C. Board, Up to 15 Ampere, for Fuse Diameter 5 MM

A-A-59125 - Terminal Boards, Molded, Barrier Screw and Stud Types and Associated Accessories

A-A-59770 - Insulation Tape, Electrical, Pressure Sensitive Adhesive and Pressure Sensitive Thermosetting Adhesive

A-A-59781 - Light Emitting Diodes for use as Indicator Lights

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-PRF-20 - Capacitor, Fixed, Ceramic Dielectric (Temperature Compensating), Established Reliability and Non-Established Reliability, General Specification for

MIL-PRF-22 - Resistors, Variable, Wirewound, Power Type, General Specification for

MIL-PRF-27 - Transformers and Inductors (Audio, Power, and High-Power Pulse), General Specification for

MIL-W-80 - Window, Observation, Acrylic Base, Antielectrostatic, Transparent (for Indicating Instrument)

MIL-PRF-81 - Capacitors, Variable, Ceramic Dielectric, General Specification for

MIL-I-631 - Insulation, Electrical, Synthetic-Resin Composition, Nonrigid

MIL-DTL-713 - Twine, Fibrous: Impregnated, Lacing and Tying

MIL-S-901 - Shock Tests, H.I. (High-Impact) Shipboard Machinery, Equipment, and Systems, Requirements for

MIL-Y-1140 - Yarn, Cord, Sleeving, Cloth, and Tape-Glass

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-DTL-2036	-	Enclosures for Electric and Electronic Equipment, Naval Shipboard
MIL-DTL-2212	-	Contactors and Controllers, Electric Motor AC or DC, and Associated Switching Devices
MIL-DTL-2726	-	Receptacles, Receptacle Plugs, Switch and Receptacles, and Outlets (Electrical), General Specification for
MIL-I-3158	-	Insulation Tape, Electrical Glass-Fiber (Resin-Filled): and Cord, Fibrous-Glass
MIL-I-3190	-	Insulation Sleeving, Electrical, Flexible, Coated, General Specification for
MIL-I-3505	-	Insulation Sheet and Tape; Electrical, Coil and Slot, High Temperature
MIL-DTL-3661	-	Lampholders, Indicator Lights, Indicator Light Housing, and Indicator Light Lenses, General Specification for
MIL-L-3661/55	-	Lampholder, Lenses, Indicator Light, Style LC41
MIL-L-3661/56	-	Lampholder, Lenses, Indicator Light, Style LC42
MIL-L-3661/57	-	Lampholder, Lenses, Indicator Light, Style LC43
MIL-L-3661/59	-	Lampholder, Lenses, Indicator Light, Style LC45
MIL-L-3661/61	-	Lampholder, Lights, Indicator (Housing), Style LH94
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-3661/65	-	Lampholder, Lights, Indicator (Housing), Style LH98
MIL-DTL-3786	-	Switches, Rotary (Circuit Selector, Low-Current Capacity), General Specification for
MIL-DTL-3786/4	-	Switch, Rotary, Closed Construction, 2 Amperes, Low Level, Positive Shaft Grounding, Flux Seal, Style SR04
MIL-DTL-3950	-	Switches, Toggle, Environmentally Sealed, General Specification for
MIL-DTL-3971	-	Meters, Time Totalizing, Non-Hermetically Sealed, Electrical: General Specification for
MIL-DTL-5423	-	Boots, Dust and Moisture Seal (for Toggle and Push-Button Switches, Circuit Breakers, and Rotary-Actuated Parts), General Specification for
MIL-PRF-5425	-	Plastic Sheet, Acrylic, Heat Resistant
MIL-DTL-5541	-	Chemical Conversion Coatings on Aluminum and Aluminum Alloys
MIL-R-5757	-	Relays, Electromagnetic, General Specification for
MIL-PRF-6106	-	Relays, Electromagnetic, General Specification for
MIL-DTL-7788	-	Panels, Information, Integrally Illuminated
MIL-A-8625	-	Anodic Coatings for Aluminum and Aluminum Alloys

MIL-PRF-8805	-	Switches and Switch Assemblies, Sensitive, Snap Action (Basic, Limit, Push Button and Toggle Switches), General Specification for
MIL-PRF-10304	-	Meters, Electrical Indicating, Panel Type, Ruggedized, General Specification for
MIL-DTL-15024	-	Plates, Tags, and Bands for Identification of Equipment, General Specification for
MIL-P-15024/5	-	Plates, Identification
MIL-DTL-15090	-	Enamel, Equipment, Light Gray (Navy Formula No. 111)
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-PRF-15160/60	-	Fuses, Instrument, Power, and Telephone (Nonindicating), Style F60
MIL-PRF-15160/61	-	Fuses, Instrument, Power, and Telephone (Nonindicating), Style F61
MIL-PRF-15160/62	-	Fuses, Instrument, Power, and Telephone (Nonindicating), Style F62
MIL-PRF-15160/63	-	Fuses, Instrument, Power, and Telephone (Nonindicating), Style F63
MIL-PRF-15160/64	-	Fuses, Instrument, Power, and Telephone (Nonindicating), Style F64
MIL-PRF-15160/65	-	Fuses, Instrument, Power, and Telephone (Nonindicating), Style F65
MIL-PRF-15160/66	-	Fuses, Instrument, Power, and Telephone (Nonindicating), Style F66
MIL-I-15265	-	Insulation, Electrical, Plastic (Submarine Bus Bar Covering)
MIL-DTL-15291	-	Switches, Rotary, Snap Action and Detent/Spring Return Action, General Specification for
MIL-PRF-15305	-	Coils, Electrical, Fixed and Variable, Radio Frequency, General Specification for
MIL-C-15730	-	Coolers, Fluid, Naval Shipboard: Lubricating Oil, Hydraulic Oil, and Fresh Water
MIL-DTL-15743	-	Switches, Rotary, Enclosed
MIL-S-16032	-	Switches and Detectors, Shipboard Alarm Systems
MIL-DTL-16034	-	Meters, Electrical-Indicating (Switchboard and Portable Types), General Specification for
MIL-DTL-16036	-	Switchgear, Power, Low Voltage, Naval Shipboard
MIL-M-16125	-	Meters, Electrical, Frequency
MIL-PRF-16173	-	Corrosion Preventive Compound, Solvent Cutback, Cold-Application
MIL-T-16315	-	Transformers, Power, Step-Down (Miscellaneous, Naval Shipboard Use)
MIL-T-16366	-	Terminals, Electrical Lug and Conductor Splices, Crimp Style
MIL-B-16392	-	Brakes, Magnet, Naval Shipboard

MIL-DTL-16878	-	Wire, Electrical, Insulated, General Specification for
MIL-DTL-16878/15	-	Wire, Electrical, Crosslinked, Modified Polyethylene (XLPE) Insulated, 125 °C, 1000 Volts
MIL-DTL-16878/16	-	Wire, Electrical, Crosslinked, Modified Polyethylene (XLPE) Insulated, 125 °C, 3000 Volts
MIL-M-17059	-	Motors, 60-Cycle, Alternating-Current, Fractional H.P. (Shipboard Use)
MIL-DTL-17060	-	Motors, Alternating Current, Integral-Horsepower, Shipboard Use
MIL-T-17221	-	Transformers, Power, Distribution, Single Phase, 400 Hertz, Insulation System Class 220 °C, Dry (Air Cooled) (Naval Shipboard Use)
MIL-DTL-17361	-	Circuit Breakers Types AQB/NQB, Air, Electric, Low Voltage, Insulated Housing (Shipboard Use), General Specification for
MIL-M-17413	-	Motors, Direct Current, Integral H.P. Naval Shipboard (Navy)
MIL-M-17556	-	Motor, Direct-Current, Fractional HP (Shipboard Use)
MIL-DTL-17587	-	Circuit Breakers, ACB, Low Voltage, Electric Power, Air, Removable Construction, General Specification for
MIL-C-17588	-	Circuit Breakers (Automatic – ALB-1) and Switch, Toggle (Circuit Breaker, Non-Automatic – NLB-1) Air, Insulated Housing, 125 Volts and Below, A.C. and D.C., (Naval Shipboard Use)
MIL-PRF-17773	-	Switches, Bus Transfer, Electric Power Automatic and Manual
MIL-DTL-18240	-	Fastener Element, Self-Locking, Threaded Fastener, 250 °F Maximum
MIL-F-18327	-	Filters; High Pass, Low Pass, Band Pass, Band Suppression, and Dual Functioning, General Specification for
MIL-S-18396	-	Switches, Meter and Control, Naval Shipboard
MIL-I-19166	-	Insulation Tape, Electrical, High-Temperature, Glass Fiber, Pressure-Sensitive
MIL-PRF-19207	-	Fuseholders, Extractor Post Type, Blown Fuse, Indicating and Nonindicating, General Specification for
MIL-PRF-19500	-	Semiconductor Devices, General Specification for
MIL-R-19523	-	Relays, Control
MIL-C-19836	-	Coolers, Fluid, Industrial, Air, Motor and Generator, Naval Shipboard
MIL-PRF-21038	-	Transformers, Pulse, Low Power, General Specification for
MIL-DTL-21604	-	Switches, Rotary, Multipole and Selector; General Specification for
MIL-E-22118	-	Enamel, Electrical-Insulating
MIL-I-22129	-	Insulation Tubing, Electrical, Polytetrafluoroethylene Resin, Nonrigid
MIL-S-22432	-	Servomotors, General Specification for
MIL-PRF-22710	-	Switches, Code Indicating Wheel (Printed Circuit), Thumbwheel and Push-button, General Specification for

MIL-I-22834	-	Insulation, Electrical, Dielectric Barrier, Laminated, Plastic Film and Synthetic Fiber Mat
MIL-PRF-22885	-	Switches, Push Button, Illuminated, General Specification for
MIL-D-23140	-	Drawings, Installation Control, for Electronic Equipment
MIL-V-23151	-	Voltmeter, Expanded Scale Switchboard Type (Naval Shipboard Use)
MIL-M-23167	-	Meter, Frequency, Expanded Scale Switchboard Type (Naval Shipboard Use)
MIL-PRF-23648	-	Resistors, Thermal (Thermistor), Insulated, General Specification for
MIL-L-23886	-	Liquid Level Indicating Equipment (Electrical)
MIL-I-24092	-	Insulating Varnishes and Solventless Resins for Application by the Dip Process
MIL-PRF-24139	-	Grease, Multipurpose, Water Resistant
MIL-I-24178	-	Insulation Tape, Electrical, Semi-Cured Thermosetting Resin Treated Glass, Armature Banding, Naval Shipboard
MIL-P-24212	-	Pressure Transducer Equipment (Electrical)
MIL-PRF-24236	-	Switches, Thermostatic, (Metallic and Bimetallic), General Specification for
MIL-D-24304	-	Differential Pressure Transducer Equipment (Electrical) (Naval Shipboard Use)
MIL-M-24350	-	Monitors, Reverse Power and Power-Sensing, Electrical Power (Naval Shipboard Use) (Metric)
MIL-M-24359	-	Meters, Milliammeters, Direct Current Panel Mounting (Edgewise Types)
MIL-T-24387	-	Temperature Measurement Equipment Signal Conditioner and Power Supply (Electrical) (Naval Shipboard Use)
MIL-T-24388	-	Thermocouple and Resistance Temperature Detector Assemblies, General Specification for (Naval Shipboard)
MIL-I-24391	-	Insulation Tape, Electrical, Plastic, Pressure-Sensitive
MIL-DTL-24441	-	Paint, Epoxy-Polyamide, General Specification for
DOD-G-24508	-	Grease, High Performance, Multipurpose (Metric)
MIL-S-24561	-	Sensing and Signaling Device, Current-Time (CTS) (Naval Shipboard Use)
MIL-H-24592	-	Hose Assembly, Tetrafluoroethylene Tube, Noncollapsible, High Temperature
MIL-DTL-24643	-	Cables, Electric, Low Smoke Halogen-Free, for Shipboard Use, General Specification for
MIL-DTL-24643/14	-	Cable, Electrical, -20 °C to +105 °C, 1000 Volts, Type LSSSGU
MIL-DTL-24643/15	-	Cable, Electrical, -20 °C to +105 °C, 1000 Volts, Type LSDSGU
MIL-DTL-24643/16	-	Cable, Electrical, -20 °C to +105 °C, 1000 Volts, Type LSTSGU
MIL-DTL-24643/17	-	Cable, Electrical, -20 °C to +105 °C, 1000 Volts, Type LSFSGU

MIL-DTL-24643/18	-	Cable, Electrical, -20 °C to +105 °C, 1000 Volts, Type LSMSCU (Including Variation LSMSCS)
MIL-DTL-24643/19	-	Cable, Electrical, -20 °C to +105 °C, 1000 Volts, Type LS6SGU
MIL-DTL-24643/20	-	Cable, Electrical, -20 °C to +105 °C, 1000 Volts, Type LS7SGU
MIL-DTL-24643/22	-	Cable, Electrical, -20 °C to +90 °C, 5000 Volts, Type LS5KVTSGU
MIL-DTL-24643/48	-	Cable, Electrical, -20 °C to +90 °C, 1000 Volts, Type LSDNW
MIL-DTL-24643/49	-	Cable, Electrical, -20 °C to +90 °C, 1000 Volts, Type LSTNW
MIL-DTL-24643/50	-	Cable, Electrical, -20 °C to +90 °C, 1000 Volts, Type LSFNW
MIL-DTL-24643/51	-	Cable, Electrical, -20 °C to +90 °C, 1000 Volts, Type LSMNW
MIL-DTL-24643/53	-	Cable, Electrical, -20 °C to +90 °C, 3000 Volts, Types LSSRW, LSDRW, and LSTRW
MIL-DTL-24643/67	-	Cable, Electrical, -20 °C to +105 °C, 1000 Volts, Type LS3OW
MIL-DTL-24643/68	-	Cable, Electrical, -20 °C to +105 °C, 1000 Volts, Type LS4OW
MIL-DTL-24643/72	-	Cable, Electrical, -20 °C to +90 °C, 1000 Volts, Type LSFCF
MIL-DTL-24643/73	-	Cable, Electrical, -20 °C to +90 °C, 1000 Volts, Type LSTCF
MIL-C-24707	-	Castings, Ferrous, General Specification for
MIL-C-24707/5	-	Castings, Ductile Iron and Austenitic Ductile Iron
MIL-PRF-24712	-	Coatings, Powder (Metric)
MIL-I-24768	-	Insulation, Plastics, Laminated, Thermosetting; General Specification for
MIL-I-24768/1	-	Insulation, Plastic, Laminated, Thermosetting, Glass-Cloth, Melamine-Resin (GME)
MIL-I-24768/3	-	Insulation, Plastic, Laminated, Thermosetting, Glass-Cloth, Epoxy-Resin (GEB)
MIL-I-24768/4	-	Insulation, Plastic, Laminated, Thermosetting, Glass-Mat, Polyester-Resin (GPO N-1)
MIL-I-24768/5	-	Insulation, Plastic, Laminated, Thermosetting, Glass-Mat, Polyester-Resin (GPO N-2)
MIL-I-24768/6	-	Insulation, Plastic, Laminated, Thermosetting, Glass-Mat, Polyester-Resin (GPO N-3)
MIL-I-24768/8	-	Insulation, Plastic, Laminated, Thermosetting, Glass-Cloth, Melamine-Resin (GMG)
MIL-I-24768/10	-	Insulation, Plastic, Laminated, Thermosetting, Paper-Base, Phenolic-Resin (PBE)
MIL-I-24768/11	-	Insulation, Plastic, Laminated, Thermosetting, Paper-Base, Phenolic-Resin (PBG)
MIL-I-24768/12	-	Insulation, Plastic, Laminated, Thermosetting, Paper-Base, Phenolic-Resin (PBM)

MIL-I-24768/13	-	Insulation, Plastic, Laminated, Thermosetting, Cotton-Fabric-Base, Phenolic-Resin (FBE)
MIL-I-24768/14	-	Insulation, Plastic, Laminated, Thermosetting, Cotton-Fabric-Base, Phenolic-Resin (FBG)
MIL-I-24768/16	-	Insulation, Plastic, Laminated, Thermosetting, Cotton-Fabric-Base, Phenolic-Resin (FBM)
MIL-I-24768/17	-	Insulation, Plastic, Laminated, Thermosetting, Glass-Cloth, Silicone-Resin (GSG)
MIL-PRF-28750	-	Relays, Solid-State, General Specification for
MIL-DTL-28803	-	Display, Optoelectronic, Segmented Readouts, Backlighted, General Specification for
MIL-DTL-28803/1	-	Display, Optoelectronic, Segmented Readout, Backlighted, Style II (Light Emitting Diode), RFI Shielded, Moisture Sealed, High Impact Shock, Type R01
MIL-PRF-31032	-	Printed Circuit Board/Printed Wiring Board, General Specification for
MIL-PRF-32150	-	Static Automatic Bus Transfer (SABT) Switch on Surface and Submarine Naval Vessels
MIL-PRF-32167	-	Transient Voltage Surge Suppressor (TVSS)
MIL-DTL-32258	-	Nut, Self-Locking (Ring Type Non-Metallic Insert), Heavy Hex, Controlled Root Radius, Nickel-Copper Alloy
MIL-PRF-38535	-	Integrated Circuits (Microcircuits) Manufacturing, General Specification for
MIL-PRF-39003	-	Capacitors, Fixed, Electrolytic (Solid Electrolyte), Tantalum, Established Reliability, General Specification for
MIL-PRF-39006	-	Capacitor, Fixed, Electrolytic (Nonsolid Electrolyte), Tantalum, Established Reliability, General Specification for
MIL-PRF-39006/22	-	Capacitors, Fixed, Electrolytic (Nonsolid Electrolyte), Tantalum, (Polarized, Sintered Slug), 85 °C (Voltage Derated to 125 °C), Established Reliability, Style CLR79
MIL-PRF-39014	-	Capacitor, Fixed, Ceramic Dielectric (General Purpose), Established Reliability and Non-Established Reliability, General Specification for
MIL-DTL-39024	-	Jack, Tip (Test Point, Panel or printed Wiring Type), General Specification for
MIL-DTL-53084	-	Primer, Cathodic Electrodeposition, Chemical Agent Resistant
MIL-PRF-55110	-	Printed Wiring Board, Rigid, General Specification for
MIL-PRF-81322	-	Grease, Aircraft, General Purpose, Wide Temperature Range, NATO Code G-395
MIL-DTL-81381	-	Wire, Electric, Polyimide-Insulated, Copper or Copper Alloy
MIL-W-81381/22	-	Wire, Electric, Fluorocarbon/Polyimide Insulated, Medium Weight, Tin Coated Copper Conductor, 600 Volts, 150 °C Nominal 8.4 or 15.4 Mil Wall

MIL-PRF-83401	-	Resistor Networks, Fixed, Film and Capacitor-Resistor Networks, Ceramic Capacitor and Fixed, Film, Resistors, General Specification for
MIL-PRF-83421	-	Capacitors, Fixed, Metallized, Plastic Film Dielectric, (DC, AC, or DC and AC), Hermetically Sealed in Metal Cases or Ceramic Cases, Established Reliability, General Specification for
MIL-DTL-83488	-	Coating, Aluminum, High Purity
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 Requirements for Enclosures for Electric and Electronic Equipment
MIL-STD-129	-	Military Marking for Shipment and Storage
MIL-STD-130	-	Identification Marking of U.S. Military Property
MIL-STD-167-1	-	Mechanical Vibrations of Shipboard Equipment (Type I – Environmental and Type II – Internally Excited)
MIL-STD-202	-	Electronic and Electrical Component Parts
MIL-STD-438	-	Schedule of Piping, Valves, Fittings, and Associated Piping Components for Submarines Service
MIL-STD-461	-	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
MIL-STD-681	-	Identification Coding and Application of Hookup and Lead Wire
MIL-STD-740-2	-	Structureborne Vibratory Acceleration Measurements and Acceptance Criteria of Shipboard Equipment
MIL-STD-777	-	Schedule of Piping, Valves, Fittings, and Associated Piping Components for Naval Surface Ships
MIL-STD-889	-	Dissimilar Metals
MIL-STD-1310	-	Shipboard Bonding, Grounding, and Other Techniques for Electromagnetic Compatibility, Electromagnetic Pulse (EMP) Mitigation, and Safety
MIL-STD-1353	-	Electrical Connectors, Plug-in Sockets and Associated Hardware, Selection and Use of
DOD-STD-1399-070-1	-	Interface Standard for Shipboard Systems, Section 070 – Part 1, D.C. Magnetic Field Environment (Metric)
MIL-STD-1399-300	-	Electric Power, Alternating Current
DOD-STD-1399-301	-	Interface Standard for Shipboard Systems, Section 301, Ship Motion and Attitude (Metric)
MIL-STD-1399-390	-	Interface Standard for Shipboard Systems, Section 390, Electric Power, Direct Current, (Other Than Ship's Battery) for Submarines (Metric)

DOD-STD-1399-532	-	Interface Standard for Shipboard Systems, Section 532, Cooling Water for Support of Electronic Equipment (Metric)
MIL-STD-1399-680	-	High Voltage Electric Power, Alternating Current
MIL-STD-1472	-	Human Engineering
MIL-STD-1474	-	Noise Limits
MIL-STD-1683	-	Connectors and Jacketed Cable, Electric, Selection Standard for Shipboard Use
MIL-STD-1686	-	Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)
DOD-STD-2143	-	Magnetic Silencing Requirements for the Construction of Nonmagnetic Ships and Craft (Metric)

DEPARTMENT OF DEFENSE HANDBOOKS

MIL-HDBK-198	-	Capacitors, Selection and Use of
MIL-HDBK-199	-	Resistors, Selection and Use of
MIL-HDBK-225	-	Synchros Description and Operation
MIL-HDBK-251	-	Reliability/Design Thermal Applications
MIL-HDBK-263	-	Electrostatic Discharge Control Handbook for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices) (Metric)
MIL-HDBK-267	-	Guide for Selection of Lubricants and Hydraulic Fluids for Use in Shipboard Equipment
MIL-HDBK-299	-	Cable Comparison Handbook Data Pertaining to Electrical Shipboard Cable
MIL-HDBK-338	-	Electronic Reliability Design Handbook
MIL-HDBK-344	-	Environmental Stress Screening (ESS) of Electronic Equipment
MIL-HDBK-454	-	General Guidelines for Electronic Equipment
MIL-HDBK-505	-	Definitions of Item Levels, Item Exchangeability, Models, and Related Terms
MIL-HDBK-802	-	Design of Electrical Equipment With Small Stray Magnetic Fields (Metric)
MIL-HDBK-2164	-	Environmental Stress Screening Process for Electronic Equipment

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

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIS-PRF-53095	-	Welding, Resistance, Electronic Circuit Modules

(Copies of this document are available from United States Army Research, Development, and Engineering Command Aviation and Missile Research, Development, and Engineering Center, 5400 Fowler Road, Redstone Arsenal, AL 35898-5000.)

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.

DEFENSE TECHNICAL INFORMATION CENTER (DTIC)

DTIC AD 297457 - United States Testing Company, Report of Test #83413

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

MILITARY STANDARD DRAWINGS

MS21208 - Insert, Screw Thread, Coarse and Fine, Free Running, Helical Coil, CRES

MS21919 - Clamp, Loop Type, Cushioned, Support

MS35335 - Washer, Lock, Flat-External Tooth

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

NAVAL SEA SYSTEMS COMMAND (NAVSEA) PUBLICATIONS

0948-LP-045-7010 - Material Control Standard (Non-nuclear), Volume 1

S6430-AE-TED-010 - Piping Devices, Flexible Hose Assemblies, Volume 1

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

S9086-CH-STM-010/074 - NSTM Chapter 074, Welding and Allied Processes

S9086-CJ-STM-010/075 - NSTM Chapter 075, Threaded Fasteners, User's Guide

S9086-RK-STM-010/505 - NSTM Chapter 505, Piping Systems

S9505-AM-GYD-010 - Technical Manual Description, Design, and Maintenance, Submarine Fastening Criteria (Non-nuclear)

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

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

AEROSPACE INDUSTRIES ASSOCIATION (AIA)

NASM3926 - Knobs, Control (for use with Electronic, Communications, and Allied Equipment)

NASM8975 - Fastener, Blind, High Strength, Installation Formed, CRES, Heat Resistant Steel and Titanium, General Specification for

NASM17828 - Nut, Self-Locking, Hexagon Regular-Height, (Non-Metallic Insert) 250 °F or 450 °F, Nickel-Copper Alloy

NASM17829 - Nut, Self-Locking, Hexagon, Regular Height, 250 °F, Non-Metallic Insert, Non-CRES Steel

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

NASM20995 - Wire, Safety or Lock

NASM21209 - Insert, Screw Thread, Coarse and Fine, Screw Locking, Helical Coil, CRES

NASM21250 - Bolt, Tension, Steel, External Wrenching, Flanged, 12-Point, 180 Ksi Ftu, 450 °F

NASM33540 - Safety Wiring, Safety Cabling, Cotter Pinning, General Practices for

(Copies of these documents are available online at www.aia-aerospace.org.)

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI) AND NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI/NEMA CC 1 - Electric Power Connectors for Substations

ANSI/NEMA FI 1 - Manufactured Electrical Mica

ANSI/NEMA FI 3 - Calendered Aramid Papers Used for Electrical Insulation

ANSI/NEMA HP 3 - Electrical and Electronic Polytetrafluoroethylene (PTFE) Insulated High-Temperature Hook-Up Wire, Types ET (250 V), E (600 V) and EE (1,000 V)

ANSI/NEMA HP 4 - Electrical and Electronic Fluorinated Ethylene Propylene (FEP) Insulated High-Temperature Hook-Up Wire, Types KT (250 V), K (600 V) and KK (1,000 V)

ANSI/NEMA HP 6 - Electrical and Electronic Silicone and Silicone-Braided Insulated Hook-Up Wire, Types S (600 V), ZHS (600 V), SS (1,000 V), ZHSS (1,000 V) and SSB Braided (1,000 V)

ANSI/NEMA MW 1000 - Magnet Wire

ANSI/NEMA Z535.2 - Environmental and Facility Safety Signs

ANSI/NEMA Z535.4 - Product Safety Signs and Labels

(Copies of these documents are available online at http://webstore.ansi.org/ or www nema.org.)

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI), NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA), AND ICEA

ANSI/NEMA-WC-74/ICEA S-93-639 - 5-46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy

(Copies of this document are available online at http://webstore.ansi.org/, www nema.org, or www.icea net.)

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI) AND SAE INTERNATIONAL

ANSI/SAE Z26.1 - Safety Glazing Materials for Glazing Motor Vehicles and Motor Vehicle Equipment Operating on Land Highways - Safety Standard

(Copies of this document are available online at http://webstore.ansi.org/ or www.sae.org.)

ASME

ASME B1.1 - Unified Inch Screw Threads, (UN and UNR Thread Form)

ASME B46.1 - Surface Texture (Surface Roughness, Waviness, and Lay)

ASME Y14.24 - Types and Applications of Engineering Drawings

ASME Y14.34 - Associated Lists

ASME Y14.100 - Engineering Drawing Practices

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

ASTM INTERNATIONAL

ASTM A153/A153M - Standard Specification for Zinc Coating (Hot Dip) on Iron and Steel Hardware

ASTM B456 - Standard Specification for Electrodeposited Coatings of Copper Plus Nickel Plus Chromium and Nickel Plus Chromium

ASTM B633 - Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel

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

ASTM D635 - Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position

ASTM D2303 - Standard Test Methods for Liquid-Contaminant, Inclined-Plane Tracking and Erosion of Insulating Materials

ASTM D2400 - Standard Specification for Varnished Glass-Polyester Cloth Used for Electrical Insulation

ASTM D2754 - Standard Specification for High-Temperature Glass Cloth Pressure-Sensitive Electrical Insulating Tape

ASTM D3638 - Standard Test Method for Comparative Tracking Index of Electrical Insulating Materials

ASTM D3935 - Standard Specification for Polycarbonate (PC) Unfilled and Reinforced Material

ASTM D5213 - Standard Specification for Polymeric Resin Film for Electrical Insulation and Dielectric Applications

ASTM D5363 - Standard Specification for Anaerobic Single-Component Adhesive

ASTM D5948 - Standard Specification for Molding Compounds, Thermosetting

ASTM D6779 - Standard Classification System for and Basis of Specification for Polyamide Molding and Extrusion Materials (PA)

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

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

IEEE 1 - General Principles for Temperature Limits in the Rating of Electric Equipment and for the Evaluation of Electrical Insulation

IEEE 259 - Standard Test Procedure for Evaluation of Systems of Insulation for Dry-Type Specialty and General-Purpose Transformers

IEEE 1018 - Recommended Practice for Specifying Electric Submersible Pump Cable – Ethylene-Propylene Rubber Insulation

IEEE 1580 - Recommended Practice for Marine Cable for Use on Shipboard and Fixed or Floating Facilities

IEEE 1662	- Guide for the Design and Application of Power Electronics in Electrical Power Systems on Ships
IEEE 1709	- IEEE Recommended Practice for 1 kV to 35 kV Medium-Voltage DC Power Systems on Ships
IEEE C37.04	- Standard Rating Structure for AC High-Voltage Circuit Breakers
IEEE C37.09	- Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
IEEE C37.013	- Standard for AC High-Voltage Generator Circuit Breakers Rated on a Symmetrical Current Basis
IEEE C37.20.4	- Standard for Indoor AC Switches (1 kV to 38 kV) for Use in Metal-Enclosed Switchgear
IEEE C37.40	- Standard Service Conditions and Definitions for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories
IEEE C37.42	- Standard Specifications for High-Voltage (>1000 V) Expulsion-Type Distribution-Class Fuses, Fuse and Disconnecting Cutouts, Fuse Disconnecting Switches, and Fuse Links, and Accessories Used with These Devices
IEEE C37.46	- Standard Specifications for High-Voltage (>1000 V) Expulsion and Current-Limiting Power Class Fuses and Fuse Disconnecting Switches
IEEE C37.47	- Standard Specifications for High-Voltage (>1000 V) Distribution Class Current-Limiting Type Fuses and Fuse Disconnecting Switches
IEEE C37.48	- Guide for the Application, Operation, and Maintenance of High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories
IEEE C37.48.1	- Guide for the Application, Operation, and Coordination of High-Voltage (>1000 V) Current-Limiting Fuses
IEEE C37.90	- Standard for Relays and Relay Systems Associated with Electric Power Apparatus
IEEE C37.90.1	- Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus
IEEE C37.90.2	- Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers
IEEE C37.235	- Guide for the Application of Rogowski Coils Used for Protective Relaying Purposes
IEEE C37.301	- Standard for High-Voltage Switchgear (Above 1000 V) Test Techniques - Partial Discharge Measurements
IEEE C57.13	- Standard Requirements for Instrument Transformers
IEEE C57.19	- Standard General Requirements and Test Procedure for Power Apparatus Bushings

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

INTERNATIONAL ASSOCIATION OF CLASSIFICATION SOCIETIES (IACS)

IACS (UR) E11 - E-11 Unified Requirements for Systems with Voltages Above 1kV up to 15kV, International Association of Classification Societies, Concerning Electrical Installations

(Copies of this document are available online at http://www.iacs.org.uk.)

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 online at www.iec.ch.)

IPC

IPC-2221 - Generic Standard on Printed Board Design

IPC-2223 - Sectional Design Standard for Flexible Printed Boards

IPC-TM-650 - Test Methods Manual

J-STD-001 - Requirements for Soldered Electrical and Electronic Assemblies

J-STD-004 - Requirements for Soldering Fluxes

J-STD-005 - Requirements for Soldering Pastes

J-STD-006 - Requirements for Electronic Grade Solder Alloys and Fluxed and Non-Fluxed Solid Solders for Electronic Soldering Applications

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

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 - National Electrical Code

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

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

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

(Copies of this document are available online at http://www.nist.gov.)

SAE INTERNATIONAL

SAE-AMS-DTL-23053 - Insulation Sleeving, Electrical, Heat Shrinkable, General Specification for

SAE-AMS-H-81829 - Heat Transfer Fluid, Fluorochemical

SAE-AMS-QQ-N-290 - Nickel Plating (Electrodeposited)

SAE-AMS2460 - Plating, Chromium

SAE-AS567 - Safety Cable, Safety Wire, Key Washers, and Cotter Pins for Propulsion Systems, General Practices for Use of

SAE-AS4536 - Safety Cable Kit Procurement Specification and Requirement for Use

SAE-AS7928	-	Terminals, Lug: Splices, Conductor: Crimp Style, Copper, General Specification for
SAE-AS7928/1	-	Terminals, Lug and Splices, Conductor, Crimp Style, Copper Terminal, Lug, Crimp Style, Copper, Insulated, Ring Tongue, for Thin Wall Wire, Type II Class 1 for 105 °C Total Conductor Temperature
SAE-AS7928/2	-	Terminals, Lug and Splices, Conductor, Crimp Style, Copper, Insulated, Rectangular Tongue, for Thin Wall Wire, Type II, Class 1 for 105 °C Total Conductor Temperature
SAE-AS13572	-	Springs, Helical, Compression and Extension
SAE-AS20708	-	Synchros, General Specification for
SAE-AS21608	-	Ferrul, Shield Terminating, Crimp Style
SAE-AS22759/47	-	Wire, Electrical, Fluoropolymer-Insulated, Crosslinked Modified ETFE, Low Fluoride, Lightweight, 80 Microinch Silver-Coated, High-Strength Copper Alloy, 200 °C, 600 Volt
SAE-AS22759/48	-	Wire, Electrical, Fluoropolymer-Insulated, Crosslinked Modified ETFE, Low Fluoride, Lightweight, 80 Microinch Silver-Coated Copper, 200 °C, 600 Volt
SAE-AS22759/49	-	Wire, Electrical, Fluoropolymer-Insulated, Crosslinked Modified ETFE, Low Fluoride, Normal Weight, 80 Microinch Silver-Coated, High-Strength Copper Alloy, 200 °C, 600 Volt
SAE-AS22759/50	-	Wire, Electrical, Fluoropolymer-Insulated, Crosslinked Modified ETFE, Low Fluoride, Normal Weight, 80 Microinch Silver-Coated Copper, 200 °C, 600 Volt
SAE-AS23190	-	Wiring, Positioning, and Support Accessories
SAE-AS50151	-	Connectors, Electrical, Circular Threaded, AN Type, General Specification for
SAE-AS81044	-	Wire, Electrical, Crosslinked Polyalkene, Crosslinked Alkane-Imide Polymer, or Polyarlyene Insulated, Copper or Copper Alloy
SAE-AS81044/8	-	Wire, Electric, Crosslinked Polyalkene Insulated, Silver-Coated Copper, Medium Weight, 600-Volt, 150 °C
SAE-AS81044/9	-	Wire, Electric, Crosslinked Polyalkene Insulated, Tin-Coated Copper, Medium Weight, 600-Volt, 150 °C
SAE-AS81044/10	-	Wire, Electric, Crosslinked Polyalkene Insulated, Silver-Coated High Strength Copper Alloy, Medium Weight, 600-Volt, 150 °C
SAE-AS81044/11	-	Wire, Electric, Crosslinked Polyalkene Insulated, Silver-Coated Copper, Light Weight, 600-Volt, 150 °C
SAE-AS81044/12	-	Wire, Electric, Crosslinked Polyalkene Insulated, Tin-Coated Copper, Light Weight, 600-Volt, 150 °C
SAE-AS81044/13	-	Wire, Electric, Crosslinked Polyalkene Insulated, Silver-Coated High Strength Copper Alloy, Light Weight, 600-Volt, 150 °C

SAE J673 - Automotive Safety Glasses

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

SOCIETY FOR PROTECTIVE COATINGS (SSPC)

SSPC-SP 10 - Near-White Blast Cleaning

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

UNDERWRITERS LABORATORIES, INC. (UL)

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

UL 2556 - Wire and Cable Test Methods

(Copies of these documents are available online at www.ul.com.)

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

3. REQUIREMENTS

3.1 Acquisition requirements. Equipment shall be designed and constructed to comply with the requirements for reliability of the individual equipment specification as specified (see 6.2 to 6.4).

3.2 Design requirements.

3.2.1 Safety. Equipment shall be designed and constructed in a way that will ensure safety to operating and maintenance personnel. When the equipment is properly installed and the enclosure is grounded, there shall be no accessible way for operating personnel to receive an electric shock even though an internal fault may exist between any two circuits, between any circuit and a structural member, or between any circuit and ground. The design shall hold to a practical minimum the possibility of maintenance personnel being exposed to electric shock while servicing, adjusting, or checking out the equipment. For access to such circuits, further positive action shall be required to remove a cover or open a portion of the guard means. A warning plate shall be prominently displayed to remind the maintenance personnel of appropriate precautions to ensure de-energization of the guarded circuit (see 3.17).

External moving parts which are a potential hazard to personnel shall be avoided. When their use is unavoidable, positive protection in the form of a guard shall be provided. Sharp corners and projections which may cause injury or catch on clothing shall be avoided.

3.2.2 Compatibility. Materials and parts used in equipment shall be mutually compatible with the environment for which they are intended.

3.2.3 Accessibility. All parts, assemblies, and other items which may require servicing or replacement during the life of the equipment shall be readily accessible for such actions without major disassembly of the equipment and without removing the equipment from its foundation. Installation information shall be in accordance with MIL-D-23140 (see 6.2). Access to internal parts of equipment, other than rotating machinery, shall be from the front of the enclosure since units are likely to be installed with their backs to bulkheads and their sides adjacent to other equipment. Operating controls and indicators shall be conveniently located on the front of the enclosure or on an operating panel appropriately oriented with respect to the operator's station. Non-operating controls shall be located behind access doors within the enclosure or in other accessible locations within the equipment. Adjustment mechanisms; such as for calibration, compensation, or alignment, shall be located within the equipment and shall be readily accessible when the equipment is open for servicing (see 3.2.1 for protection to personnel).

3.2.3.1 Mounting of replaceable items. Items which are identified as replaceable, including individual parts and non-repairable assemblies, shall be mounted so as to permit easy removal and replacement. Riveting and welding shall not be employed for mounting such items. Plug-in modules shall be easily insertable into the proper receptacles and restricted with proper orientation. No damage shall occur to items being engaged. It shall not be necessary to unsolder wires, harness, or other items which are not to be replaced in order to gain access to terminals, soldered connections, mounting screws, and the like, of items which are to be replaced. Connections to parts inside a removable container shall be arranged so as to permit removal of the container without the need to thread connection leads through the container.

3.2.3.2 Doors and covers. Hinges shall be so attached that they will not extend more than ¼ inch beyond the outer surface of the enclosure whether or not the doors are open. Each access panel, cover, or door not designed for complete removal, whether hinged or sliding, and exceeding 45 inches high or 24 inches wide shall be provided with stops or positioning devices to stop the item in fully or partly opened positions as selected, and to prevent its moving from the selected position due to gravity or ship motion. When the access panel, cover, or door is opened to its widest position, it shall provide unimpeded access to the interior of the enclosure. Access doors or covers larger than 4 square feet in area, or weighing more than 35 pounds designed for complete removal, shall be provided with locating pins or other means for support and alignment during removal or replacement.

3.2.3.3 Mounting fasteners. Enclosure mounting bolts that mount the equipment to the ship shall be accessible and removable without removing any component part other than external equipment panels.

3.2.4 Operation of controls. Operation of controls shall conform to the requirements of MIL-STD-1472.

3.2.5 Maintenance and repair. Equipment shall be designed for ease of maintenance and repair as specified (see 6.2). Except where packaging of parts in non-repairable form is approved (see 3.2.3 and 3.13.27), equipment shall be capable of being repaired either by replacement of defective individual electrical parts (relays, semiconductors, switches, resistors, capacitors, and so forth) or mechanical parts (bearings, bushings, springs, latches, and so forth) or by utilizing bulk materials (magnet wire, varnish, insulation, and so forth) commonly available. The use of special design features that simplify maintenance and repair (for example, test jacks, indicating type fuseholders) is encouraged. Standoff legs or other supports or guards shall be provided to protect subassemblies and parts for maintenance and repair.

3.2.6 Fail-safe design. Unless otherwise specified (see 6.2) and to the maximum practical extent, the design of the equipment shall be such that failure of parts or subassemblies will not result in unsafe operating conditions. In the design of fail-safe features, consideration shall be given to their effect upon plant reliability. Fail-safe features shall not cause undue complexity or excessive increase in size or weight.

3.2.7 Remote controls. In equipment specifications where remote controls for equipment are used, precautions shall be taken to ensure that loss or damage to the remote control unit or its connections to the equipment shall not cause equipment shutdown, misoperation, or loss of local control of equipment.

3.2.8 Standardization. The equipment shall be designed so that parts, subassemblies, and assemblies which perform similar functions will be standardized and interchangeable. In selecting parts for the equipment, preference of parts shall be as specified in 3.13.1.

3.2.9 Input power.

3.2.9.1 Alternating current (AC). Unless otherwise specified (see 6.2), AC powered equipment shall operate satisfactorily and adhere to user equipment interface requirements in accordance with MIL-STD-1399-300.

3.2.9.2 Direct current (DC). Unless otherwise specified (see 6.2), DC powered equipment for submarines shall operate satisfactorily and adhere to user equipment interface requirements in accordance with MIL-STD-1399-390.

3.2.10 Grounding. See 6.5.4.

3.2.10.1 Electrical grounding. Electrical equipment operating from an ungrounded power system shall not malfunction if the power system is accidentally electrically grounded or if the power system is connected to ground (hull) by means of high impedance electromagnetic interference suppressor circuits. The equipment shall not impose a ground upon the ship power system, and any equipment which employs internal grounding shall be isolated from the ship power system by means of transformers or separate generator sets. Equipment chassis, equipment enclosure, or the ship hull shall not be used in lieu of appropriate electrical conductors as the equipment circuitry. Circuit grounds necessary for built-in ground detection circuits are excluded from these requirements.

3.2.10.2 Exposed metal or other conductive parts. Design and construction of the equipment shall be so that all exposed parts or panels of metal or other electrically conductive material are at ground (ship's hull) potential at all times in accordance with MIL-STD-1310. Exposed metal portions of electrical parts (switches, rheostats, and so forth) or other parts located near electrical circuits (including parts inside enclosures where access is required for operation or adjustment) shall be in intimate physical contact with the frame of the equipment or electrically connected to the frame if these parts could touch the electrical circuits as a result of deformation, wear, insulation failure, and so forth.

3.2.11 Surge (indicated as spike) voltage suppression. Unless otherwise specified (see 6.2), equipment shall be designed to operate on input power containing voltage spikes in accordance with MIL-STD-1399-300. Equipment shall be protected against part failure or malfunction due to voltage spikes occurring randomly on the input power source.

3.2.11.1 Parts stress limitation. Equipment which employs circuits and parts in such a way that this degree of protection is not inherently achieved shall provide protection by use of spike voltage suppressors or suppression circuitry in accordance with MIL-PRF-32167. Likewise, where equipment is subject to use with power supply or load systems which may supply or produce surge voltages higher than the values specified in 3.2.11, the equipment shall withstand these higher spike voltage stresses (see 3.2.9). Voltage regulator diodes and controlled-avalanche types of rectifier diodes, complying with the requirements specified in 3.13.18, may be used for spike voltage suppression. Also, spike voltage suppressors specified in 3.13.19 may be used for this purpose. All parts which may be subjected to application stresses due to interaction capabilities of circuits, minimum to maximum adjustments, or other deleterious circuit effects that could result from ill-advised sequencing or combinations of prescribed personnel actions shall be of a type, size, design, and performance capability, as applied, that will not be damaged by these stresses (see 3.13.1.1). All parts shall be a type, size, and design that any combination of circuit elements or adjustments shall not induce stresses which will cause damage to the equipment.

3.2.12 Inclined operation. Unless otherwise specified (see 6.2), equipment shall perform satisfactorily during inclined operation in accordance with design limits for surface ship and submarine motion specified in DOD-STD-1399-301.

3.2.13 Temperature and humidity.

3.2.13.1 Temperature. The equipment shall perform reliably and in accordance with specified performance requirements of the equipment throughout the applicable operating temperature range specified (see 6.2). Equipment shall not be damaged nor shall the operational performance be degraded when the equipment is restored to the operating temperature range after having been exposed for long periods in the non-operating ambient temperature range as specified in table I. If exterior shipboard service is intended, this shall be specified in the contract (see 6.2). If not so specified, equipment shall be designed for interior shipboard services.

TABLE I. Temperature ranges ambient.

Service	Operating	Non-operating
Exterior shipboard	-18.4 °F (-28 °C) to 149 °F (+65 °C)	-40 °F (-40 °C) to 167 °F (+75 °C)
Interior shipboard	32 °F (0 °C) to 122 °F (+50 °C) 1/	-40 °F (-40 °C) to 167 °F (+75 °C)

NOTE:
1/ The interior shipboard operating range for non-militarized equipment which can fit through shipboard hatches and can be removed in 1 man-day can have an allowable temperature range of 32 °F (0 °C) to 107 °F (+40 °C).

3.2.13.2 Humidity. Equipment specified in the individual equipment specification shall conform to the requirements of MIL-STD-202, Test Method 103B, for humidity (see 6.2). Equipment shall operate satisfactorily during and subsequent to exposures to relative humidities ranging up to 95 percent for both continuous and intermittent periods, including conditions wherein condensation occurs on the equipment.

3.2.14 Shock and vibration.

3.2.14.1 Shock. Equipment specified in the individual equipment specification shall conform to the requirements of MIL-S-901 for high-impact (H.I.) shock as specified (see 6.2).

3.2.14.2 Vibration. Equipment specified in the individual equipment specification shall conform to the requirements of MIL-STD-167-1 for vibration as specified (see 6.2).

3.2.15 Equipment mounting. For equipment required to meet the H.I. shock requirements of MIL-S-901, the following mounting requirements shall be as specified (see 6.2):

a. Equipment shall be designed for mounting with Grade 5 or stronger bolts or capscrews in accordance with MIL-DTL-1222.

b. Size of mounting holes shall be as specified in table II.

TABLE II. Size of mounting holes.

Nominal bolt diameter	Max. diameter of hole
¾ inch and smaller	Nominal bolt diameter plus 1/32 inch
Larger than ¾ inch	Nominal bolt diameter plus 1/16 inch

c. Equipment may be designed to use fitted (also known as body-bound) bolts for mounting (see 6.2).

3.2.16 Electromagnetic interference (EMI) general requirements. The equipment shall comply with the EMI requirements specified in MIL-STD-461 for surface ship, below deck and submarine, internal to pressure hull, installations. Detailed design and testing requirements shall be included in the individual equipment specification as specified (see 6.2).

3.2.17 DC magnetic field environment. Shipboard equipment shall comply with the static magnetic field environmental interface constraints in accordance with DOD-STD-1399-070 as specified (see 6.2).

3.2.18 Magnetic field reduction. When the individual equipment specification requires that the magnetic field or magnetic signature of the equipment be minimized, the ferrous, stray, and eddy current fields shall be minimized in accordance with DOD-STD-2143 as specified (see 6.2).

3.2.18.1 Ferrous field source. The equipment shall be designed in accordance with DOD-STD-2143 for a Class 1 magnetic field source.

3.2.18.2 Eddy current field source. The equipment shall be designed in accordance with DOD-STD-2143 for a Class 2 magnetic field source.

3.2.18.3 Stray field source. DC equipment and DC circuits in or associated with the equipment shall be designed in accordance with DOD-STD-2143 for a Class 3 magnetic field source. Additional guidance on proper design of DC equipment and DC circuits in or associated with the equipment is provided in MIL-HDBK-802.

3.2.19 Noise reduction. Control of noise generated by equipment shall be accomplished by proper design of the equipment and of those parts which are inherently a source of airborne and structureborne noise, including dynamic balancing of rotating equipment. The use of exterior soundproof enclosures to meet noise requirements is prohibited, except where specified by the individual equipment specification or the contract (see 6.2).

3.2.19.1 Airborne noise. When specified in the individual equipment specification or in the contract (see 6.2), the equipment shall be tested for airborne noise in accordance with MIL-STD-1474. Acceptable levels shall be as specified in the individual equipment specification or in the contract (see 6.2).

3.2.19.2 Structureborne noise. When specified in the individual equipment specification or in the contract (see 6.2), the equipment shall be tested for structureborne noise in accordance with MIL-STD-740-2. Acceptable levels shall be as specified in the individual equipment specification or in the contract (see 6.2).

3.2.19.3 Dynamic balancing. For rotating equipment to be used on submarines, or when specified in the equipment specification (see 6.2), provision for dynamic balancing shall be included as specified in 3.2.20.

3.2.20 Provisions for dynamic balancing. For rotating equipment to be used on submarines, each rotor shall be provided with at least two accessible balancing rings or discs. On double armature machines whose maximum operating speed exceeds the first critical speed of the lateral flexibility of the shaft, three balancing rings shall be provided. One shall be between the armatures. The design of the rings shall have the following features:

a. It shall be possible to add weights of various sizes to the balancing rings in a plane perpendicular or parallel to the shaft axis, either in a continuous groove or 12 or more evenly spaced positions.

b. Means shall be provided to lock the weights in place against centrifugal force and vibration.

c. It shall be possible to place or remove any weight without disassembly of large covers or disturbing the bearing alignment and with minimum danger of loss of small parts inside the machine.

d. It shall be possible to add in a space of 30 degrees in each plane, a total of 10 W/n ounce-inches of balance weights in increments of W/n or less.

Where:

W = the weight of the rotor in pounds.

n = the maximum operating speed of rotation in revolutions per minute (r/min).

e. Where balance is to be achieved by the use of tapped holes and movable screws, each hole shall be permanently numbered. Where balance is to be achieved by the use of a continuous groove, the angular locations shall be permanently marked at intervals of not more than 10 degrees, and the markings shall be permanently numbered at intervals of not more than 30 degrees. All markings and numbering shall be readily observable through access openings.

f. The balancing planes shall be located as close to the rotating mass as feasible, while allowing accessibility for balance correction.

g. Balance weight locations shall be accurately located both angularly and radially. The bottoms of radially tapped holes shall be accurately located. Angular dimensions shall be held within ±1 degree and all linear dimensions within $\pm\frac{1}{64}$ inch.

h. In order that refinement of balance after installation may be accomplished without overcrowding the balancing rings, factory balancing shall be generally accomplished by removal or addition of weight at points other than the balancing rings.

3.2.21 Leakage current. Leakage current through a human body (see 6.5.5) shall be in accordance with MIL-STD-1399-300. This applies even where EMI suppression devices are permitted and used.

3.2.22 Electrical creepage and clearance distances. Creepage (see 6.5.3) and clearance (see 6.5.2) distances between electrical circuits, between each electrical circuit and ground, and across lines and between circuit elements that operate at differences in potential levels shown in each row of table III shall be not less than those values shown in table III for equipment conforming to this specification unless otherwise approved by NAVSEA (see 6.2). UL 840 should be used for design guidance for creepage and clearance, but the creepage and clearance values in UL 840 tables have been found to be too low for the Navy environment. It is emphasized that the values shown in table III represent the minimum acceptable limits for non-arcing rigid construction based on normal volt-ampere ratings (see 6.5.6) and that they take into consideration only the average degree of enclosure and service exposure. Therefore, the designer shall employ creepage and clearance distances in excess of these minimums where it is probable that structural features, contaminants, lack of maintenance, environment, exposure, or application overstress will create service conditions more severe than normal. When necessary, insulating barriers may be used to interrupt continuous electrical creepage paths. Cemented or butted joints will not be accepted as techniques to obtain the minimum creepage distances in table III. For voltage levels greater than 1,000 V, but less than or equal to 15,000 V, refer to IACS (UR) E11 for electrical creepage and clearance distances.

3.2.22.1 Distance from enclosure. Exposed non-arcing current-carrying parts within enclosures shall have an air space of not less than ¾ inch between them and the uninsulated part of the enclosure. However, the values shown in table III may be applied to the creepage and clearance distances between uninsulated parts of enclosures and exposed non-arcing current-carrying parts of devices whose mounting is sufficiently rigid and so designed to prevent decrease of the clearance distance through a blow on or distortion of the enclosure as specified (see 6.2).

TABLE III. Electrical creepage and clearance distance. 1/

Voltage AC or DC	Set 2/	Clearance (inches)	Creepage 3/	
			Open (inches) 4/	Enclosed (inches) 5/
Up to 64	A	1⁄16	1⁄16	1⁄16
	B	1⁄8	1⁄8	1⁄8
	C	1⁄8	3⁄8	1⁄2
Over 64–150	A	1⁄16	1⁄16	1⁄16
	B	1⁄8	1⁄4	1⁄8
	C	1⁄4	3⁄4	3⁄8
Over 150–300	A	1⁄16	1⁄16	1⁄16
	B	1⁄8	1⁄4	1⁄8
	C	1⁄4	3⁄4	1⁄2
Over 300–600	A	1⁄16	1⁄8	1⁄8
	B	1⁄8	1⁄4	1⁄4
	C	1⁄4	3⁄4	1⁄2
Over 600–1,000	A	1⁄8	1⁄2	3⁄8
	B	1⁄4	1	3⁄4
	C	1⁄2	2	1 1⁄2
Over 1,000–15,000 6/	C	6/	6/	6/

NOTES:

1/ Use of electrical parts or assemblies such as potentiometers, connectors, printed wiring assemblies, and similar devices having lesser creepage and clearance distances is permissible provided these parts and assemblies conform with applicable military specifications, and their energized portions are enclosed to protect against entry of dust and moisture.

2/ Set A – Normal operating volt-ampere rating up to 50.
Set B – Normal operating volt-ampere rating of 50 to 2,000.
Set C – Normal operating volt-ampere rating over 2,000.

3/ For top curved surfaces having a radius greater than 3 inches and for top flat surfaces, surface creepage distance shall be increased 33 percent where these surfaces have irregularities which permit the accumulation of dust and moisture.

4/ Open: Equipment or parts with open enclosures in accordance with MIL-STD-108.

5/ Enclosed: Equipment or parts with enclosures in accordance with MIL-STD-108, except open enclosures.

6/ For voltages above 1,000 V, but less than or equal to 15,000 V, use electrical creepage and clearance values in accordance with IACS (UR) E11.

3.2.23 Piping systems. Piping systems shall have socket welded, butt welded, or flanged fittings. Silver brazing and threaded pipe fittings shall not be used. For additional guidance, see S9086-RK-STM-010/505. Requirements for material identification and control of piping systems shall be in accordance with 0948-LP-045-7010.

3.2.24 Screw thread standards for fastening devices. Screw threads for all threaded fastening devices shall be in accordance with ASME B1.1. The threads shall be the coarse-thread series, unified form, Class 2A/2B unless the component design indicates a necessity for the use of the fine thread series.

3.2.24.1 Fastening of parts. Except for motors, generators, and motor generators, through bolting shall be used wherever practicable as specified (see 6.2). For electrical panels and other applications where frequent disassembly is required, blind nuts and captive fasteners shall be used when practical. The preferred blind nuts are blind rivet nuts, blind threaded inserts, and insert nuts when frequent removal for maintenance and repair is required. Self-clinching fasteners and clinch nuts are not preferred and can only be used in cases where disassembly is never required for maintenance and repair. Similarly, these types of fasteners shall be used when practical to prevent a loose fastener from dropping into electrical equipment.

3.2.24.2 Fitted bolts. The holes for fitted (also known as body-bound) bolts shall be reamed with the coupled parts in position and chamfered. Where practicable, the shank of the bolt shall have definite interference with the metal surrounding the hole. The mating surfaces of the bolt and hole shall have a smoothness of 63 micro-inches roughness height rating (RHR) or smoother in accordance with ASME B46.1. Bolt-to-hole fit is shown in table IV.

TABLE IV. Bolt and hole dimensions.

Nominal size (inches)	**Max. clearance (+) diameter (inches)**	**Max. interference (-) diameter (inches)**
½ to 1¼	0.0005	0.0010
1¼ to 1⅞	0.0006	0.0013
2 to 3	0.0007	0.0016

3.2.24.3 Threads in aluminum. Threads in aluminum or aluminum alloys shall be avoided, where practicable, by use of through bolting. Where through bolting is not practicable, and screws must be removed for routine equipment maintenance or where high stress in the screw is required for alignment of a vital part, metal inserts for the fastenings shall be cast or screwed into the aluminum or aluminum alloy. Inserts shall be given a corrosion-resistant treatment, except where bushing type inserts of corrosion-resistant steel are cast into the aluminum or aluminum alloy. Inserts need not be provided for securing identification plates, terminal boards, or other items that are removed only when the equipment is overhauled or modified.

3.2.24.4 Threads in plastic. Metal inserts shall be used where threads in plastic are required.

3.2.24.5 Inserts. Metal inserts, where required in aluminum alloys or plastics, shall be the bushing type or the helical-coil type conforming to NASM21209. Refer to MS21208 for additional guidance. The bushing type is recommended. The use of helical-coil type inserts shall be limited to applications where the threaded hole permits full engagement of the insert. Bushing type inserts shall be the cast-in, molded-in, or screwed-in types. Screwed-in types shall be pin-, key-, swage-, or ring-locked to prevent backing out (see 3.16.6).

3.2.24.6 Thread projection. Except for threading into blind holes or in thick material, bolts and machine screws shall be of such length that when tightened, at least one thread and preferably not more than four threads shall project beyond the outer face of the nut or bolted part. With plastic insert self-locking nuts, the thread projection shall be measured from the crown of the plastic insert.

3.2.24.7 Bolt and screw thread engagement. Minimum thread engagement for tapped holes and threaded inserts is as follows:

a. Minimum thread engagement for tapped holes is whichever is longer: (1) the fastener major (nominal) diameter plus one thread or (2) as calculated per the Design of Unified Scew Threads Appendix of FED-STD-H28/2 plus one thread.

b. Where threaded inserts are used (see 3.2.24.5 for limitations), the length of the thread engagement shall be not less than 1½ times the fastener major (nominal) diameter.

3.2.24.8 Thread locking of mechanical assemblies. Mechanical assemblies where a holding screw, bolt, nut, or fastened part must maintain a tight connection to work properly and avoid parts falling into the equipment due to specified operational conditions, including shock, vibration, and heating, shall be secured by detailed fastener methods, restrictions, and the order of precedence listed in S9086-CJ-STM-010/075 and S9505-AM-GYD-010. There are four basic techniques used to prevent threaded fasteners from loosening in service: preload, prevailing torque, mechanical, and chemical. The preferred methods for securing mechanical assemblies are as follows:

a. Reusable self-locking fasteners – nut self-locking, bolt self-locking (plastic insert), screw self-locking (plastic insert), and nut spring beam. The bolt (plastic insert) and screw (plastic insert) self-locking methods may be used only where removal for maintenance is very infrequent (see 3.2.24.9.2).

b. Pins – with castellated nut (safety wire can be used), in holes drilled through the body of the end through the bolt, and through the bolt at a point beyond the nut. Pin types include cotter, grooved taper, taper, straight solid, spiral, and roll. Castellated nuts with cotter pinning or safety wiring are not recommended for applications requiring accurate loads such as bus joints.

c. Tab locks.

d. Safety cable and locking wire for use to lock bolts when only bolt heads are available to apply a locking device (see 3.2.24.12).

e. Lockwasher (see 3.2.24.11.1).

f. Blind nuts and captive fasteners.

g. Liquid locking adhesive (see 3.2.24.13).

h. Non-liquid thread locking adhesive may be used on any electrical joint except contact nuts and contact spacer nuts.

i. Deformation of screw or bolt threads projecting from nut or secured part. This method may be used only in cases where disassembly is never required for maintenance or repair.

3.2.24.9 Fastening devices. Fastening devices (nuts, bolts, screws, lockwashers, flat washers, and so forth) shall be made of corrosion-resistant material (see 3.3.2.3) or shall be treated to resist corrosion without paint (see 3.14.1). Spring type locking devices, such as lockwashers and retaining rings, when made of precipitation hardened semi-austenitic corrosion-resistant steel, do not require additional protection against corrosion. Aluminum alloy fasteners are not to be considered corrosion-resistant.

3.2.24.9.1 Nuts, bolts, and screws. Nuts, bolts, and screws shall be in accordance with the following: FF-S-86, FF-S-92, FF-S-200, FF-S-210 (for guidance only), MIL-DTL-1222, NASM17828, NASM17829, NASM17830, 12-point collar screws with head style as shown on NASM21250, or equal. Where lockwashers are used with screws and bolts, the lockwasher may be a separate piece or attached as part of an assembled fastener.

3.2.24.9.2 Self-locking screws and bolts. Self-locking screws and bolts shall be in accordance with MIL-DTL-18240. Screws or bolts threaded into non-metallic inserts shall not be used for electrical connections.

3.2.24.9.3 Flat-head screws. Flat-head screws shall not be used in material of a thickness less than 1½ times the height of the screw head. Wherever flat-head screws are used, the head shall be properly and completely seated in the material.

3.2.24.9.4 Blind fasteners. Blind fasteners, when used, shall be in accordance with NASM8975.

3.2.24.9.5 Plastic ring and spring beam nuts. Self-locking plastic ring and spring beam nuts shall be in accordance with MIL-DTL-32258.

3.2.24.10 Thread-cutting screws. Thread-cutting (self-tapping) screws shall not be used, except for information and identification plates (see 3.17.4).

3.2.24.11 Washers. Washers shall be commercial types if Government specification sizes are not available. Refer to FF-W-84 (spring lock) or FF-W-92 (plain flat) for guidance.

3.2.24.11.1 Lockwashers. The following are the preferred, acceptable, and prohibited types of lockwashers (see 3.2.24.9):

a. Preferred type – Split ring (helical spring) lockwashers.

b. Acceptable type – External-tooth lockwashers, preferred for electrical connections, shall be in accordance with MS35335 tin-brass, copper alloy 425 washers (see 3.12.2.8). Toothed lockwashers may be used where the weight of the part does not exceed 2 ounces per screw such as a terminal block.

c. Acceptable type – Internal-tooth lockwashers.

External-tooth lockwashers shall be used in order to bite through protective coatings of aluminum parts if they are to be grounded or electrically bonded through the fastening device. Internal-tooth lockwashers shall be used instead of external-tooth where warranted for appearance or other special conditions. Where internal-tooth lockwashers are used, the size of the washer and diameter of the bolt hole shall be so that the teeth make satisfactory contact.

d. Prohibited type – Serrated lockwashers.

e. Prohibited type – Star lockwashers.

f. Prohibited type – Belleville lockwashers.

g. Prohibited type – Wave lockwashers.

Use of other lockwashers shall obtain NAVSEA approval.

3.2.24.11.2 Flat washers. Flat washers shall be used for the following applications:

a. Between screw heads and soft materials, unless a washer head screw, or similar type that provides a bearing surface equivalent to the bearing surface of the appropriate flat washer, is being used.

b. Between a nut or lockwasher and a soft material.

c. Where lockwashers are used for securing a soft material, a flat washer shall be provided to prevent marring or chipping of the material and the applied protective coating, except in areas where an electrical ground is required.

d. Except where it conflicts with EMI considerations, a flat washer shall be used between an organically finished material and lockwashers, bolt and screw heads, or nuts. A flat washer shall not be installed between two soft materials that are current carrying conductors.

3.2.24.12 Lockwire and safety cable. Lockwire (also called safety wire) or safety cable may be used on any appropriate fasteners (see 3.2.24.8), but any one joint must use one or the other, but not both, in the same joint.

a. Lockwire shall comply with and be installed in accordance with NASM33540. The wire material must conform to NASM20995, except that aluminum and copper lockwire are not permitted.

b. Safety cable shall comply with and be installed in accordance with SAE-AS567 and SAE-AS4536.

3.2.24.13 Liquid locking adhesives. Liquid locking adhesives should be of the anaerobic single component type in accordance with ASTM D5363.

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

a. Nut and jam nut

b. Clip-on types of nuts

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

d. Setscrews

3.2.25 Utilization of standard tools. Insofar as practicable, equipment shall be designed so that only standard tools, namely, those listed in the Federal Supply Catalog, are required for installation, adjustment, maintenance, and repair. Tools other than standard tools are designated as special tools. Special tools may be used only when approved by the contracting activity. Requests for approval of special tools shall be as specified in 3.13.1.3 in which case "tool" shall be substituted for "part". Special tools shall be furnished by the contractor. Special tools required for organizational level maintenance shall be mounted securely in each equipment in a convenient and accessible place, or in a central accessible location for an equipment array requiring such tools.

3.2.26 Equipment insulation requirements. Unless otherwise specified (see 6.2), equipment shall pass insulation and dielectric withstanding voltage tests required by 3.2.26.1 as follows:

a. The insulation resistance from conductor to conductor and conductor to ground shall be not less than 10 megohms at 77 °F (25 °C). User equipment shall tolerate the test voltage between each power conductor and ground without equipment damage, arc-over, degradation, or abnormal operation.

b. The dielectric withstand voltage for each circuit shall be determined by the voltage rating of the circuit (or, if it has no assigned rating, by the maximum voltage of that circuit considering all conditions of equipment operation at rated voltage).

Equipment using active ground detection shall be tested in accordance with MIL-STD-1399-300. No equipment damage or malfunction shall result from this dielectric test which insures compatibility with active ground detectors which superimpose a DC voltage to ground on the normal supply voltage to measure insulation resistance.

3.2.26.1 Required test. When insulation resistance and dielectric withstanding voltage tests are required, but the tests and testing procedures are not otherwise specified in the individual equipment specification, the tests and procedures shall be in accordance with 4.4.1 and 4.4.2. Regardless of whether or not other tests and procedures are applicable to the internal circuit of equipment, all terminals intended for connection to the ship's power distribution system at any point (generator feeder, bus feeder, feeder, main, sub-main, branch, sub-branch, and so forth) shall withstand the tests specified in 4.4.1 (see 6.2).

3.2.27 Special shipboard environmental conditions. The following environmental conditions are applicable to a limited number of equipment types. These requirements shall be selected for inclusion in those individual specifications which cover equipment which will encounter these shipboard environments in their application as specified (see 6.2).

3.2.27.1 Wind speed. Equipment, or portions thereof, exposed to the weather shall operate normally in winds having a relative velocity of 75 knots (kn) and shall withstand, without damage, winds having a relative velocity as great as 100 kn.

3.2.27.2 Ice. Equipment, or portions thereof, exposed to the elements, shall start and operate normally when covered with an ice load of 4½ pounds per square foot (lb/ft^2).

3.3 Materials. Insofar as practicable, each item of materials used in the construction of the equipment shall be of a type, class, form, and grade which is readily available from normal sources of supply. These are standard materials. Other or special materials may be used only when adequately justified taking into account both the technical and economic aspects and considering maintenance and support requirements, as well as initial supply. Technical justification for the selection and use of special materials shall be held by the contractor for inspection by the Government.

3.3.1 Prohibited materials. Materials of the following types shall not be used:

a. Toxic pyrolytic materials (see 3.3.1.1).

b. Mercury (see 3.3.1.2).

c. Asbestos (see 3.3.1.3).

d. Silicone (see 3.3.1.4).

e. Polychlorinate biphenyls (PCBs) (see 3.3.1.5).

f. Polyvinyl chloride (PVC) (see 3.3.1.6).

g. Cadmium and cadmium plating (see 3.3.1.7).

h. Flammable materials (see 3.3.1.9).

i. Fragile or brittle materials (see 3.3.1.10).

j. Freon solvents.

k. Radioactive materials.

l. Magnesium or magnesium base alloys.

3.3.1.1 Toxic pyrolytic materials. Toxic pyrolytic materials include those materials which emit toxic gases or other harmful products when exposed to high temperatures, including fire, such as encountered in naval shipboard service. When a material is subjected to the pyrolysis test in accordance with DTIC AD 297457, the concentrations of gases emitted shall not exceed the values shown in table V.

3.3.1.1.1 Pyrolysis test. The pyrolysis test specified herein is applicable to laminates, molding compounds, encapsulating materials, and other rigid structural insulating materials. It does not apply to the integral parts of coils or windings, such as magnet wire insulation, ground and layer insulation, varnish, tape, and tying cord or similar materials used in the construction of such windings.

TABLE V. Maximum concentration of toxic gases. 1/

Toxic gas	Max. parts per million
Carbon dioxide	15,000
Carbon monoxide	1,500
Ammonia	2,500
Aldehydes as HCOH	100
Cyanides as HCN	100
Oxides of nitrogen as NO_2	150
Hydrogen chloride	100
Sulphur dioxide	400
Hydrogen fluoride	250

NOTE:
1/ For more information on this subject, refer to: "Noxious Gases", Henderson & Haggard, Reichold Publishers, New York.

3.3.1.2 Mercury. Equipment meeting this specification shall be free of mercury. This includes component parts such as switches, thermometers, manometers, and so forth. Mercury may not be used in the manufacture or testing of materials or components.

3.3.1.3 Asbestos. Asbestos, in any form, shall not be used.

3.3.1.4 Silicone. Silicones of any type, whether in the form of insulation, sealants, lubricants, or antifoam agents, shall not be used in total enclosed type motors and generators employing carbon contact brushes. For open ventilated type motors or generators having carbon contact brushes, use of silicone containing materials is acceptable.

3.3.1.5 PCBs. PCBs used as insulating fluids in transformers and capacitors shall not be used in any Navy equipment.

3.3.1.6 PVC. PVC, in any form, shall not be used.

3.3.1.7 Cadmium and cadmium plating. Cadmium plated parts and fasteners shall not be used.

3.3.1.8 Other prohibited materials. The following materials shall not be used, except as specified in the individual equipment specification:

a. Linen
b. Cellulose acetate
c. Cellulose nitrate
d. Regenerate cellulose
e. Wood
f. Jute
g. Leather
h. Cork
i. Paper and cardboard
j. Organic fiberboard
k. Hair or wool felts
l. Plastic materials using cotton, linen, or wood flour as a filler

3.3.1.9 Flammable materials. Flammable materials include any material in a form which will ignite or explode from an electric spark, flame, or from heating, and which, if so ignited, will independently support combustion in the presence of air. As a guide, materials shall be selected on the basis of maximum resistance to burning when tested in accordance with the methods in the applicable documents listed in table VI.

TABLE VI. Material resistance to burning.

Materials [1/]	Applicable document	Limit
Laminated plastics	DTIC AD 297457	Ignition – 95 sec. min.
Molded plastics	ASTM D5948	Burning – 120 sec. max.
Encapsulating compounds	DTIC AD 297457	Weight loss – 15% max. Ratio B/I – 84% max.
All other flammable materials except those used internally in varnished coil structure, metal enclosed shock resilient pads, and gaskets sealing metal surfaces	ASTM D635 Self-support plastics	Burning time – 10 sec. max. Extent of burning – 25 mm max.

NOTE:
[1/] These are organic materials in the open atmosphere having insulating characteristics and used for mechanical protection and structural support. Insulating materials used in the open atmosphere in switchgear, control, regulating, and power applications are materials falling in the category of table VI. Varnished coil structures are excluded from this category at present, on the basis that flame resistant varnishes are not available and, in general, the heat sink capabilities of equipment using varnished coil structures are such that flame propagation is reduced.

3.3.1.10 Fragile or brittle materials. Fragile materials include any materials which are fragile in the form, size, and manner in which they would be used. Brittle materials, in general, fall within this category from the stand-point of use as structural members. However, certain brittle materials may be used in small quantities, within a part, when the materials is so mounted, constrained, or otherwise disposed within the part that it will not be strained under any processing, environmental, and handling conditions to which the part reasonably may be subjected. (For example, glass and ceramic terminal seals and bushings have been employed successfully in packaging certain semiconductor devices.) Any material in a frail form which is not positively protected against mechanical damage as used in a part or subassembly falls within the prohibited fragile category. Cast iron, semi-steel, porcelain, and similar brittle materials shall not be used for frames, brackets, mounting panels, spacers, or enclosures for equipment, and parts thereof, which are intended for use aboard ship.

3.3.2 Metals. Metals shall be selected or processed and applied in a manner that provides corrosion resistance. Metals that are not inherently corrosion-resistant (see 3.3.2.3) shall be processed (treated, plated, or painted) to provide corrosion resistance (see 3.14.1).

3.3.2.1 Selection of metals in direct contact. Equipment shall meet guidelines for minimizing attack due to electrolytic action between dissimilar metals in contact with each other in accordance with MIL-STD-889. Metal-to-metal contact is not normally considered to exist if one of the contact surfaces is hardcoat sulfuric acid anodized aluminum in accordance with MIL-A-8625, Type III, or equivalent, that has not been previously exposed to a corrosive environment. If a metal is coated or plated, the coating or plating metal rather than the base metal shall be considered.

3.3.2.2 Malleable iron and nodular graphitic iron castings. Malleable iron castings or nodular graphitic iron castings shall not be used unless specifically permitted by the individual equipment specification as specified (see 6.2). When permitted, malleable iron castings and nodular graphitic iron castings shall be in accordance with MIL-C-24707 and MIL-C-24707/5.

3.3.2.3 Corrosion-resistant metals. The following commonly used metals, when properly applied, are considered to be inherently corrosion-resistant without further processing when the service environment precludes immersion, condensation, or periodic wetting of the surface. These metals are suitable except where individual equipment specifications require use of specific corrosion-resistant metals for equipment subjected to severe environmental conditions.

a. Brass. Brasses containing 20 to 40 percent zinc are highly susceptible to stress corrosion cracking in marine environments when highly stressed.

b. Bronze

c. Copper

d. Copper-nickel alloy

e. Copper-beryllium alloy

f. Copper-nickel-zinc alloy

g. Nickel-copper alloy

h. Nickel-copper-silicon alloy

i. Nickel-copper-aluminum alloy

j. Aluminum alloys, Types 3003, 3004, 5052, 5056, 5083, 5085, 5086, 5154, 5456, 6061.

k. Titanium

l. Austenitic steels, corrosion-resistant, Types 202, 301, 302, 303, 304, 304L, 309, 310, 316, 316L, 321, 324A, 347. Austenitic stainless steels are susceptible to stress corrosion cracking in marine environments when service temperatures exceed 150 °F (65 °C).

3.3.3 Plastics. Plastics which serve as electrical insulation shall be in accordance with 3.4.1. Plastics which do not serve as electrical insulation (structural parts and so forth) shall meet all physical and mechanical properties required for plastic insulating materials, including non-flammability and non-toxicity; however, these plastics need not meet the arcing and tracking resistance requirements. Unless otherwise specified (see 6.2), the color of plastics shall be as follows:

a. Plastics used as electrical insulation (see 3.4.1.2.2 and 3.4.1.3.1.1).

b. Exterior plastic materials that are not painted shall match the color of MIL-DTL-15090 enamel, except where transparency is required.

c. Internal plastic materials which do not serve as electrical insulation shall be any color.

3.3.3.1 Dials and other transparent and translucent applications. Plastic for dials and other transparent and translucent applications shall be in accordance with MIL-W-80. Material conforming to MIL-PRF-5425 may be used, provided it is treated with an anti-electrostatic coating. Commercial grade polycarbonate or equivalent may be used where mechanical considerations are of primary importance, and transparency importance is secondary.

3.3.4 Glass. Glass for protection of indicator dials and for viewing windows shall meet requirements and be of the shatterproof type in accordance with Class 1, Type I, of ANSI/SAE Z26.1 and SAE J673 (see 3.3.1.10). Glass, so applied, shall be clear and present no evidence of distortion of the viewed object when viewed at any angle. Design and application shall be so that conditions configurative to condensation of moisture on the glass are avoided. Glass windows for meters which are not internally illuminated shall be glareproof.

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

3.3.6 Non-preferred component materials. The following component materials are non-preferred, but allowed, and shall be identified as specified (see 6.2) prior to the start of first article testing:

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

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 3.3.2.3.

d. Lead free solder used for printed circuit boards.

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

3.4 Electrical insulation. Electrical insulation shall be as specified in 3.4.1 through 3.4.18.

3.4.1 Insulation materials.

3.4.1.1 Arc and tracking resistance. Structural insulators, such as laminates, molding compounds, encapsulating materials, bus bar coverings, and similar materials subject to arcing conditions shall have an arc resistance of not less than 130 seconds and a track resistance of not less than 70 minutes (see 4.4.2.3). This applies to low voltage (under 2,000 V) equipment. For equipment rated at 2,000 V or higher, an arc resistance of 150 seconds and a minimum track resistance of 300 minutes shall be required.

3.4.1.2 Laminated plastics. Laminated plastics in the form of sheets, rods, or tubes shall be used where rigid materials with dielectric properties are needed. Such laminates shall meet the temperature, mechanical, and electrical requirements of each application. Other forms, such as channels and formed shapes, except spacers, shall be used only when approved for the particular application (see 3.3). For spacers, see 3.4.9. Laminates shall meet the minimum requirements for toxicity (see 3.3.1.1), flame resistance (see 3.3.1.9), and arc and tracking resistance (see 3.4.1.1).

3.4.1.2.1 Machined edges. Machined edges on glass based laminates shall be sealed with an appropriate coating to prevent moisture infusion.

3.4.1.2.2 Color of laminates. Laminates shall be furnished in the natural color, except polyester laminates may be furnished in tan or red.

3.4.1.3 Molded plastics.

3.4.1.3.1 Molded thermosetting plastics. Molded thermosetting plastics shall generally be used in electrical equipment where a rigid dielectric is needed and where the form or shape is such that fabrication of the part out of sheet stock is too costly, or the part is too complex in design. For molded parts, the following conditions shall be met:

a. The molding compound shall be of the type shown in table VII or equivalent meeting the specified requirements.

b. The molding compound shall meet the minimum requirements for toxicity (see 3.3.1.1), flame resistance (see 3.3.1.9), and arc resistance (see 3.4.1.1).

c. The molding compound shall meet the mechanical and electrical requirements of each application.

TABLE VII. Molding compounds (glass fiber reinforced).

Compounds	Type	Applicable document	Max. temperature, °F (°C)
Polyester glass	MAI-60	ASTM D5948	266 (130)
Polyester glass	MAI-30	ASTM D5948	266 (130)
Polyester glass	MAT-30 1/	ASTM D5948	266 (130)
Melamine glass	MMI-30	ASTM D5948	266 (130)
Melamine glass	MMI-5	ASTM D5948	266 (130)
Diallyl ortho-phthalate	SDG-F	ASTM D5948	311 (155)
Diallyl ortho-phthalate	GDI-30F	ASTM D5948	311 (155)
Diallyl iso-phthalate	SIG-F	ASTM D5948	356 (180)
Diallyl iso-phthalate	GII-30F	ASTM D5948	356 (180)
Silicone mineral 2/	MSG	ASTM D5948	392 (200)
Silicone glass 2/	MSI-30	ASTM D5948	392 (200)
Epoxy glass	GEI-5, -20, -100	ASTM D5948	266 (130)

NOTES:
1/ Mandatory for high voltage application (2,000 V or higher).
2/ See 3.3.1.4 for restrictions on the use of silicone.

3.4.1.3.1.1 Colors of thermosetting plastics. Thermosetting molding compounds for low voltage application shall be furnished in a gray color, with an approximate match to number 26307 (semigloss) or 16307 (gloss) of FED-STD-595. Thermosetting molding compounds for high voltage application, rated at 2,000 V or higher, shall be furnished in a red color to match number 11120 or 11140 of FED-STD-595.

3.4.1.3.2 Thermoplastics. In general, thermoplastics shall not be used in any molded part unless allowed by the individual equipment specification as specified (see 6.2). When the application is such that only a thermoplastic material can be used, then the molding compounds shall be selected in accordance with table VIII or equivalent meeting the specified requirements.

TABLE VIII. Molding compounds (thermoplastic material).

Compounds	Type	Applicable document	Max. temperature, °F (°C)
Polyamide (nylon)	Type III, Grade E	ASTM D6779	221 (105)
Polycarbonate	----	ASTM D3935	221 (105)

3.4.1.4 Ceramics. Ceramics may be used only where they constitute integral portions of specified parts.

3.4.1.5 Silicone. The use of silicone shall be as specified in 3.3.1.4.

3.4.2 Insulating material. Detailed discussion of electrical insulation and temperature limits is contained in IEEE 1.

3.4.2.1 Classes and definitions of insulating materials. Temperature classes of insulating materials have traditionally been established by definition based on a chemical composition of the materials. Methods of temperature classification based on the results of thermal evaluation tests are coming into use as specified (see 6.2). Since the temperature classification of a material that has been accepted for a long time will have been established by field experience, its life-temperature characteristics determined by test provide a basis for comparison with the thermal life of a new material. The purpose of assigning each material to a definite temperature class, therefore, is to facilitate comparisons between materials and to provide a single number to designate each class for purposes of standardization. The life expectancy under the test conditions may be shorter than, and has no direct relation to, the life expectancy of the material in actual service. Materials or combinations of materials other than those listed in table IX may be included in a given class if, by experience or accepted tests, they can be shown to have comparable thermal life at the associated temperature index.

3.4.2.2 Accepted tests. The words “accepted tests” in paragraph 3.4.2.1 above are intended to refer to recognized industry or military test procedures established for the thermal evaluation of materials by themselves or in simple combinations. Experience or test data used in classifying insulating materials are distinct from the experience or test data derived for the use of materials in complete insulation systems. The thermal endurance of complete systems may be determined by test procedures specified elsewhere in this specification or in related equipment specifications. A material that is classified as suitable for a given temperature may be found suitable for a different temperature, either higher or lower, by insulation system test procedures. For example, it has been found that some materials suitable for operation at one temperature in air may be suitable for a higher temperature when used in a system operated in an inert gas atmosphere. It is important to recognize that other characteristics, in addition to thermal endurance, such as mechanical strength, moisture resistance, and corona endurance, are required in varying degrees in different applications for the successful use of insulating materials.

3.4.3 Insulation systems.

3.4.3.1 Temperature classification of insulation systems. Materials of a given temperature index may be used as parts of complete insulation systems that are assigned widely different temperatures, depending on the results of thermal tests of the insulation system. The insulation system classification specified in table IX shall be used for Navy equipment and shall be specified in the individual equipment specification (see 6.2). The materials used in electrical systems shall be characterized by the specific limiting temperatures at the temperature indices shown in table IX. These temperatures are based on service experience or on accelerated life test data that demonstrates an equivalent life expectancy. New or modified systems shall be evaluated by acceptance test procedures and, when so evaluated, shall have equal or longer thermal endurance than a service-proven system of the class at the test conditions. A new insulation system may also be classified in a higher class by test if it has equal or greater thermal endurance at higher test temperatures when compared to a service proven insulation system under the same test conditions.

TABLE IX. Insulation system classes (limiting temperatures).

Insulating material class	Insulating system class	Temperature index, °F (°C) 1/	Example materials
90	Y	194 (90)	Cotton, silk, and paper without impregnation
105	A	221 (105)	Cotton, silk, and paper when suitably impregnated or coated or when immersed in a dielectric liquid such as oil
130	B	266 (130)	Mica, glass fiber, and so forth, with suitable bonding substances
155	F	311 (155)	Mica, glass fiber, and so forth, with suitable bonding substances
180	H 2/	356 (180)	Silicone elastomer, mica, glass fiber, and so forth, with suitable bonding substances such as appropriate silicone resins
200	N 2/	392 (200)	Mica, glass fiber, and so forth, with suitable bonding substances
220	R	428 (220)	----
240	S	464 (240)	----
260	C	500 (260)	Materials consisting entirely of mica, porcelain, glass, quartz, and similar inorganic materials

NOTES:

1/ Temperature index is related to the temperature at which the material will provide a specified life as determined by test or as estimated from service experience. To provide continuity with past procedures, the shown preferred temperature indices shall be used for insulating materials as specified (see 6.2).

2/ Class N insulation was formerly classified as Class H by the Navy and was suitable for 392 °F (200 °C). Since industry has defined Class H as suitable for only 356 °F (180 °C), the Navy has reclassified the former Class H as Class N and the new Navy Class H is defined to be the same as industry. All insulation systems which have been qualified under the former Navy Class H classification, 392 °F (200 °C), shall be re-designated as Class N.

3.4.3.2 Alternative temperature specification of insulation systems. An alternative method to specify class of insulation systems used shall be specified in the individual equipment specification or contract (see 6.2).

3.4.3.3 Insulation class system. A given insulation system is a system utilizing the associated class of materials in accordance with table IX at such temperature rises above stated ambient temperature as the specification for a given type of equipment requires, based on experience or accepted test. This system may alternatively contain materials of any class, provided that experience or a recognized system test procedure for the equipment has demonstrated equivalent life expectancy.

3.4.3.4 Insulation class suitability. In order to furnish equipment utilizing Class 180 materials or higher, the equipment manufacturer shall conduct insulation suitability tests for that class of insulation in accordance with Appendix A of this specification.

3.4.4 Thermal endurance evaluation. Test procedures in accordance with IEEE 259 are acceptable thermal evaluation methods and shall be used to evaluate new or modified insulation systems for specific equipment.

3.4.5 Ground insulation. Ground insulation, known also as barrier insulation, slot armor, basic insulation, wrapper or coil insulation, shall be as specified in table X or equivalent meeting the specified requirements.

TABLE X. Ground insulation.

Material	Applicable document	Type, class, or grade	Max. temperature, °F (°C)
Reinforced mica splittings	MIL-I-3505	All types	As required 1/
Mica-paper composites	ANSI/NEMA FI 1	All types	As required 1/
Mica-paper (silicone binder) 2/	ANSI/NEMA FI 1	All types	392 (200)
Polyester mat-polyester-film	MIL-I-22834 (for guidance only)	All types	266 (130)
Polyester film 3/	MIL-I-631	Type G	248 (120)
Varnished glass cloth 4/	ASTM D2400 (for guidance only) and ASTM D2754	Grade O	194 (90)
Polymeric resin film	ASTM D5213	Type I, Class E	302 (150)
Polyamide paper	ANSI/NEMA FI 3	All types	428 (220)

NOTES:

1/ The temperature class is determined by the binder used; suitable binders are available for 311 °F (155 °C), 356 °F (180 °C), and 392 °F (200 °C) use.

2/ See 3.3.1.4 for equipment restrictions on the use of silicones.

3/ Polyester film is restricted to static parts of electrical equipment and to rotating equipment of outside frame diameter less than 10 inches. The minimum film thickness shall be 0.0075 inch for rotating equipment and 0.001 inch for static equipment.

4/ Varnished glass cloth for ground insulation applications shall be limited to control circuits up to 50 volt-amperes (VA).

3.4.6 Core tubes and bobbins. Core tubes and bobbins for mechanical support shall be laminated plastic types (see 3.4.1.2) or molded plastic types (see 3.4.1.3).

3.4.7 Toroid core boxes. Core boxes for toroid windings may be aluminum with overwrappings of either pressure sensitive insulating tape (see 3.4.11) using the fluidized bed or spray process and oven cured.

3.4.8 Layer and phase insulation. Glass thread interweaving may be used on layer wound magnet coils. Other types of layer or phase insulation shall be any of the types specified in 3.4.5 except varnished glass cloth.

3.4.9 Spacers. Spacer insulation such as slot spacers, coil separators, duct spacers, end plate insulation, supporting rings, interpole washers, or any other flat or formed pieces used primarily for mechanical separation as part of a coil or winding shall be rated at a minimum of 311 °F (155 °C) and selected as specified in table XI.

TABLE XI. Spacers.

Item	Material	Type or grade	Applicable document	Max. temperature, °F (°C)
Spacer (rigid-flat)	Glass melamine	GME	MIL-I-24768/1	266 (130)
	Glass silicone 1/	GSG	MIL-I-24768/17	392 (200)
	Glass epoxy	GEE	MIL-I-24768/3	266 (130)
	Glass polyester	GPO-N1	MIL-I-24768/4	266-356 (130-180) 2/
Spacer (rigid-tube-rod, or formed shape)	Glass melamine	GMG, TR	MIL-I-24768/8, MIL-I-24768/10, MIL-I-24768/11, MIL-I-24768/12, MIL-I-24768/13, MIL-I-24768/14, and MIL-I-24768/16	266 (130)
	Glass silicone 1/	GSG	MIL-I-24768/17	356 (180)
Spacer (flexible)	Reinforced mica	All	MIL-I-3505	266-392 (130-200) 1/
	Varnished glass	0	ASTM D2400 (for guidance only) and ASTM D2754	194 (90)
	Polymeric resin film	Type I, Class E	ASTM D5213	302 (150)

NOTES:
1/ See 3.3.1.4 for restrictions on the use of silicones.
2/ Limiting temperature will depend on the type of resin or binder used.

3.4.10 Binding tape and strips. Binding tape and strips (porous for later impregnation or filling) for mechanical purposes shall be glass in accordance with MIL-Y-1140. For Class 130 and higher temperature applications, glass tape and cloth shall be heat cleaned to remove sizing. Subsequent chemical treatment may be used if compatible with varnish used for filling or impregnating (see 3.4.17).

3.4.11 Electrical tape. Electrical tape shall be in accordance with MIL-I-631. Electrical pressure-sensitive tape shall be in accordance with MIL-I-24391, MIL-I-19166, or Types AFT, GFT, EG, or MFT of A-A-59770.

3.4.12 Slot-wedges (non-metallic). Slot-wedges shall be selected from table XII.

TABLE XII. Slot-wedges (non-metallic).

Item	Material	Type	Applicable document	Max. temperature, °F (°C)
Slot wedge, flat	Glass melamine	GME	MIL-I-24768/1	311 (155)
	Glass silicone [1/]	GSG	MIL-I-24768/17	392 (200)
	Glass epoxy	GEE	MIL-I-24768/3	266 (130)
	Glass polyester	GPO-N1	MIL-I-24768/4	266-356 (130-180) [2/]
Slot wedge, formed	Polyester film	G	MIL-I-631	248 (120)
	Polyester mat-film	----	MIL-I-22834 (for guidance only)	266 (130)
	Polyamide paper	----	ANSI/NEMA FI 3	392 (200)

NOTES:
1/ See 3.3.1.4 for restrictions on the use of silicones.
2/ Limiting temperature will depend on type of resin used.

3.4.13 Insulating panels. Insulating panels shall be in accordance with Type GME of MIL-I-24768/1, Type GSG of MIL-I-24768/17, or MIL-I-24768, and Type GPO-N2 or GPO-N3 of MIL-I-24768/5 or MIL-I-24768/6, respectively.

3.4.14 Sleeving. Sleeving shall be in accordance with MIL-I-3190, MIL-I-631, or MIL-I-22129. Heat shrinkable sleeving shall be in accordance with SAE-AMS-DTL-23053.

3.4.15 Commutator insulation. Commutator segments shall be inorganic bonded mica or reconstructed mica with polyester or melamine binders.

3.4.16 Band insulation. Insulation under banding wire shall be mica-glass composite in accordance with MIL-I-3505, or laminated plastic material with varnished glass cloth underlayment.

3.4.17 Lacing and tying cords for varnished coils and windings. Lacing and tying cords shall be cotton cable laid armature twine for Class 105 insulation; Form 2, Class C in accordance with MIL-Y-1140 for Classes 130 and 155 insulation; and silicone treated glass cord for Classes 180 and 200 insulation. Silicone or polytetrafluoroethylene treated flat glass sleeving may be used for Classes 180 and 200 only (see 3.3.1.4 for restrictions on use of silicone).

3.4.18 Armature and coil banding using glass. Semi-cured thermosetting resin treated glass insulation tape may be used for armature and coil banding in lieu of steel wire banding. The glass banding materials and methods of application shall be in accordance with MIL-I-24178.

3.5 Dielectric barrier. The insulation used for the major ground insulation wall on electric equipment shall provide suitable dielectric barrier action. Satisfactory materials are listed in table X.

3.6 Coils and windings. Coils and windings shall be designed for maximum protection from environmental hazards, and replacement parts containing coils shall not be adversely affected by normal handling during replacement in cramped locations.

Slotcells shall be folded under the slot wedge if a flat wedge is used or slotcells shall be inserted inside the slot wedge if a formed (curved) wedge is used. The wedge shall extend the full length of the slotcell, and shall be positioned so as to cover the slotcell completely.

3.7 Treating methods. Most classes of electrical insulation require the use of varnish or other impregnating compounds to make them satisfactory for service conditions. Without such treatments, the filler materials have dielectric breakdown values approximately the same as air of the same spacing. In addition, proper treatment seals out moisture, dust, corrosive atmospheres, and oil vapor. Experience has demonstrated that a thorough treatment provides essential insurance for satisfactory operation under adverse circumstances. The application of insulating resin, varnish, or compound to windings and coils may be divided into several different classifications as follows:

a. Built-up – for large coils.

b. Brushing or flowing – initial manufacturing process.

c. Vacuum-pressure impregnation (VPI) – preferred method.

d. Dipping.

e. Brushing or spraying (see 3.7.5).

3.7.1 Built-up. By this method, solventless varnish shall be applied by brush between turns as the coil is wound. This method may be used for deep section coils where other methods cannot ensure complete filling of the voids.

3.7.2 Brushing or flowing. By this method, varnish shall be applied to the slot portion of preformed coils by brushing or flowing in order to bond conductors together. Upon curing, this ensures a rigid straight section of the coil and facilitates the application of the ground insulation. This operation is usually performed only on armature and stator coils.

3.7.3 Vacuum-pressure impregnation (VPI). By this method, solventless resin shall be applied to a completed armature or completed stator coil using a VPI cycle. The purpose of this operation is to fill as completely as possible all voids which exist in the structure and to bond the various parts together. Other types of wound coils may also be treated by this method. The impregnating solventless resin is introduced into the evacuated treating vessel or tank without breaking the vacuum seal. After the vacuum cycle is completed, dry air or nitrogen is applied under pressure to complete the VPI cycle.

3.7.4 Dipping. By this method, varnish shall be applied to the individual winding or coil or to the completed stator or armature by immersion. The primary purpose of this operation is to fill the interstices of the coil and to bond the components of the insulation wall together. In addition, a protective coating shall be applied to the surface of the coil. The hosing or flooding method shall not be used.

3.7.5 Brushing or spraying. Varnish applied to electrical coils by these methods does not ensure complete impregnation of the internal sections of the coil and, therefore, shall not be used.

3.8 Treating materials. Electrical windings shall be thoroughly treated or impregnated with a material and by a method which will ensure the evacuation of all air and water from, and the filling in of all interstices within such windings. The varnish or resin selected shall have such characteristics and be so applied as to ensure thorough drying, solidification, or curing throughout the innermost recesses of the windings.

3.8.1 Varnish. Varnish shall be selected in accordance with table XIII.

TABLE XIII. Varnish.

Application	Type or grade	Applicable document
Stationary windings and low speed rotating windings [1/]	Grade CB, CBH solvent types	MIL-I-24092

NOTE:
[1/] Low speed windings are defined as 1800 r/min or less, and not more than 24 inches in diameter. Windings with either a rotational speed greater than 1800 r/min or a diameter greater than 24 inches are defined as high speed windings.

3.8.2 Encapsulants and compounds used on coils and windings. Encapsulants and winding compounds (paste-like material usually applied by brush or spatula) are characteristic in that they cure to a solid state by catalyst reaction plus heat. Typical materials are the polyester and epoxy resins. These materials shall not, either in original application or as a result of aging, have any deleterious effect on the insulation materials to which they are applied and shall not cause corrosion or deterioration of any adjacent parts. These materials shall not crack or flow at the temperatures encountered during normal operation. The conditions under which these materials are applied and used shall in all respects conform to the manufacturer's recommendations. Neither the material itself nor the process by which it is applied shall have a deleterious effect on the operation of the assembly or the overall equipment.

3.9 Varnish treatment. Fabrication operations, such as welding, machining, drilling, and tapping, shall have been completed prior to varnish treating. The windings and coils shall be clean and dry. The drying shall be accomplished by prebaking the windings to remove all moisture and to cure any uncured winding parts. The windings or coils, prior to core insertion, shall then be allowed to cool to a temperature not below 50 °F (10 °C) above room temperature, then immersed in the varnish until bubbling ceases, allowed to drain, and then baked at the temperature and for the time specified by the varnish manufacturer. A minimum of three dips and bakes shall be used. If the VPI process is used, a minimum of one treatment shall be applied. Pre-impregnated coils receive one or more varnish or resin treatments prior to assembly in the slot or on the pole piece. Post-impregnated coils receive all varnish or resin treatments after insertion in the slot.

3.9.1 Baking ovens. The baking ovens shall be rated at least 347 °F (175 °C) for Classes 90, 105, 130, and 155 windings; and at least 500 °F (260 °C) for Class 180 and higher temperature windings. The capacity of the baking ovens shall be sufficient to maintain the appropriate temperatures at a full exhaust rate of two air changes per minute. In addition, baking ovens used to cure VPI treated windings shall be equipped with a rotisserie for rotating the apparatus during curing.

3.9.2 Baking time specified. Baking time for curing varnished windings shall be as specified by the resin or varnish manufacturer on the basis of time after the winding has reached the specified temperature as determined by attached thermocouples.

3.9.3 Typical treating guidelines. The treating checklist in table XIV may be used as a guide in processing electrical windings. The baking times and temperatures vary depending on the type and grade of varnish or resin used and the size of the winding being processed. The varnish or resin manufacturer's recommended treating schedule should be followed as far as preheat time and temperature, baking time and temperature, and piece temperature are concerned.

TABLE XIV. Treating guidelines, armature coils, armatures, stators, and field coils.

	Dip and bake procedure-solvent varnish	VPI using solventless epoxy resin
Step 1	Ensure that varnish is the correct viscosity and solids content is as recommended by the manufacturer.	Ensure that the viscosity and thixotropy index are correct and that the resin has been deaerated.
Step 2	Prebake the winding to cure the bonding, if used, and to drive off any moisture and volatiles.	Prebake the winding to cure the armature banding, drive off moisture, and to maintain a suitable temperature for reducing the viscosity of the resin. Cool to 122 °F (50 °C).
Step 3	Cool to 122 °F (50 °C). Immerse hot coils or wound apparatus in room temperature varnish until bubbling ceases or as recommended by the various manufacturers.	Place the wound unit in the vacuum tank and evacuate until the desired level of vacuum (5 mm of mercury or lower) is reached. Allow resin to enter tank without breaking vacuum seal. Impregnate for ½ hour. Apply dry air or nitrogen to immersed winding at 90 lb/in^2 or higher for l hour. Reduce pressure, remove winding, and pump resin back to the storage tank.
Step 4	Drain and air dry for 1 hour. Rotate wound apparatus to prevent pocketing the varnish.	Drain and air dry for 1 hour. Rotate wound apparatus while draining (10 minutes) to prevent pocketing the resin.
Step 5	After draining, but before baking, the metal surfaces of the armature, the bore of the stator, and the pole faces of the field structure shall be wiped with a cloth moistened with solvent. Remove drips and icicles from winding.	After draining, but before baking, the metal surfaces of the armature, the bore of the stator, and the pole faces of the field structure shall be wiped with a cloth moistened with solvent. Remove drips and icicles from winding.
Step 6	Bake in circuiting type, forced-exhaust baking oven using a 2-step temperature baking schedule.	Bake in a circulating type, forced-exhaust baking oven. Rotate to prevent excessive runoff.
Step 7	Remove from oven and cool to approximately 122 °F (50 °C).	Remove from oven and cool to approximately 122 °F (50 °C).
Step 8	Repeat for a total of three treatments, alternating positions to prevent excessive build up.	Repeat steps 3, 4, 5, 6, and 7 as required, reversing the direction of dipping each cycle.

3.10 Final condition. The treated windings and coils shall be clean, smooth, and glossy with good bonding, filling, and adhesion. Good bonding and adhesion are considered to be achieved when the coil conductors are secure, firm, and immovable to the touch. More than ½ inch square is considered excessive peeling and the winding shall be rejected. Bubbles, air pockets, and voids shall be kept to a minimum (treated windings and coils that are not clean, smooth, and glossy and do not have good bonding, filling, and adhesion shall be subjected to the insulation suitability test of Appendix A). There shall be no dry (uncoated) spots on the surface. Treated windings soft and sticky to the touch shall be rejected.

3.11 Insulation suitability. Insulation suitability tests shall be required only on those insulation systems as specified (see 6.2). The purpose of the test is to determine the insulation resistance, dissipation factor, and capacitance of an electric winding insulation system under conditions of severe moisture exposure (treated windings and coils that are not clean, smooth, and glossy and do not have good bonding, filling, and adhesion shall be subjected to the insulation suitability test of Appendix A). Insulation suitability for electrical windings shall be of the following types (see Appendix A):

a. Type CW – Complete Winding

b. Type PW – Partial Winding

3.12 Wire, wiring methods, marking, and bus bars.

3.12.1 Wire.

3.12.1.1 Lead wire. Lead wire is the type of insulated conductor forming an integral part of components such as motors, transformers, coils, and windings. Lead wire shall be flexible stranded type and, unless otherwise specified in the equipment specifications, shall be of not less than number 18 American Wire Gauge (AWG). Lead wire shall be selected in accordance with table XV. When selecting proper lead wire size, the ampacity (see 6.5.1) should be considered. Wire size shall be determined using National Electric Code NFPA 70 which considers the temperature the wire will see and number of conductors in the wire bundle.

TABLE XV. Lead wire.

Insulation	Applicable document	Max. temperature, °F (°C)
Crosslinked, modified polyethylene	MIL-DTL-16878, /15, and /16	257 (125)
Crosslinked polyalkene	SAE-AS81044, /8, /9, and /10	302 (150)
Silicone rubber 1/	ANSI/NEMA HP 6	392 (200)
Silicone rubber 1/	ANSI/NEMA HP 6	302 (150)
Ethylene Propylene Diene Monomer (EPDM)	IEEE 1018	400 (204)
Fluorinated ethylene propylene 2/	ANSI/NEMA HP 4	392 (200)
Polytetrafluoroethylene 2/	ANSI/NEMA HP 3	392 (200)
Crosslinked ethylene-tetrafluoroethylene 3/	SAE-AS22759/47, /48, /49, and /50	392 (200)

NOTES:
1/ See 3.3.1.4 for specific prohibition on application.
2/ Halogen containing lead wire must be approved as specified in 3.3.6.
3/ Preferred due to low halogen content. Use of other halogen containing lead wire must be approved as specified in 3.3.6.

3.12.1.2 Hook-up wire. Hook-up wire is the type of insulated conductor free at both ends and used for chassis wiring and interconnecting wiring. Hook-up wire shall be flexible stranded type and shall be selected from table XVI. When selecting proper hook-up wire size, the ampacity (see 6.5.1) should be considered. Wire size shall be determined using National Electric Code NFPA 70 which considers the temperature the wire will see and number of conductors in the wire bundle. The National Electric Code NFPA 70 shall be used for calculations and adjustments of wire ampacity when multiple conductors are employed in a wire bundle.

TABLE XVI. Hook-up wire.

Insulation	Applicable document	Max. temperature, °F (°C)
Crosslinked, modified polyethylene	MIL-DTL-16878, /15, and /16	257 (125)
Polytetrafluoroethylene 1/	ANSI/NEMA HP 3	392 (200)
Silicone rubber 2/	ANSI/NEMA HP 6	392 (200)
Silicone rubber 2/	ANSI/NEMA HP 6	302 (150)
Fluorinated ethylene propylene 1/	ANSI/NEMA HP 4	392 (200)
Crosslinked polyalkene	SAE-AS81044/8, /9, /10, /11, /12, and /13	302 (150)
Fluorocarbon/polyamide 1/	MIL-DTL-81381 (refer to MIL-W-81381/22 for guidance only)	302 (150)
Crosslinked ethylene-tetrafluoroethylene 3/	SAE-AS22759/47, /48, /49, and /50	392 (200)

NOTES:
1/ Halogen containing lead wire must be approved as specified in 3.3.6.
2/ See 3.3.1.4 for specific prohibition on application.
3/ Preferred due to low halogen content. Use of other halogen containing hook-up wire must be approved as specified in 3.3.6.

3.12.1.3 Magnet wire. Magnet wire shall be selected in accordance with ANSI/NEMA MW 1000 and as specified in table XVII.

TABLE XVII. Wire.

Wire	Limits of application
Single film (E, T, L, H, K, M)	In circuits less than 50 VA.
Multiple film (E2, T2, T3, T4, and so forth)	M2 is preferred for all applications.
Combination film and fibrous BDg and so forth	All fibrous coverings shall be furnished with film undercoat.
Fibrous coverings GV versus Dg	Polyester fiber-glass coverings (Dg) are preferred to glass fiber coverings (GV).
High temperature coverings MDgGM, M2DgGM, and so forth	For 356 °F (180 °C) and higher temperature 428 °F (220 °C) applications and where a fibrous covering is required, the polyester fiber content shall not exceed 25% of the total material content.
Square and rectangular	All designs shall allow rewinding by naval repair activities using stock sizes shown in table XVIII. If wire sizes other than those shown in table XVIII are going to be supplied in the equipment, NAVSEA approval shall be obtained.

TABLE XVIII. Square and rectangular insulated magnet wire sizes available to naval repair activities. 1/

Bare thickness (mils) 2/	**Bare width (mils) 2/**									
	63	**80**	**100**	**125**	**160**	**200**	**250**	**315**	**400**	**500**
32	3/	3/	3/	4/	4/					
40	3/	3/	4/	4/	4/	4/	4/			
50	3/	4/	4/	4/	4/	4/	4/	4/		
63	4/	4/	4/	4/	4/	4/	4/	4/		
80		4/	4/	4/	4/	4/	4/	4/	4/	4/
100			4/	4/	4/	4/	4/	4/	4/	4/
125				4/	4/	4/	4/	4/	4/	4/
160					4/	4/	4/	4/	4/	4/
200						4/	4/	4/	4/	4/
250							4/	4/	4/	4/
315								4/	4/	4/
400									4/	4/
500										4/

NOTES:
1/ Types suitable for any application up through 428 °F (220 °C).
2/ Dimensions listed are nominal values; tolerances of ANSI/NEMA MW 1000 shall apply.
3/ Available in Types M2 and M4.
4/ Available in Types M2, M4, and M2DgGM.

3.12.2 Wiring methods.

3.12.2.1 Harnessing. Wiring shall be neatly formed into groups which are locked, sleeved, tied, or clamped in a manner that provides support and prevents chafing of the wire insulation due to vibration and shock. There shall be no splices in the wire and all connections shall be made at the terminals of the devices, at terminal blocks, or at part mounting boards. Wire groups running from hinged panels and doors shall be flexible and as specified in 3.12.2.1.3. Finished harness diameter shall not restrict flexibility requirements where necessary. The use of preformed cables and wiring harnesses is preferred to the point-to-point method of wiring. Conductors combined into a harness shall be securely held together by means of lacing, ties, or clamps, or be permanently mounted in cabling ducts. Individual conductors which are thus combined shall lie essentially parallel to one another and shall not entwine other conductors. This requirement does not preclude the use of twisted pairs or triads where required for electrical reasons. The combined heating of bundled wires or proximity heating by components shall not cause maximum temperatures of harnessed wire insulation to be exceeded. The National Electric Code NFPA 70 shall be used for calculations and adjustments of wire ampacity when multiple conductors are employed.

3.12.2.1.1 Harnessing materials. Cord, tape, or sleeves for wire bundle harnessing, tying, lacing, or sleeving shall be of non-flammable materials. Metal ties or clamps, if used, shall be covered with non-flammable insulating material, and plastic straps, clamps, and mounting hardware shall be in accordance with SAE-AS23190. Refer to MS21919 for additional guidance.

3.12.2.1.2 Lacing cord. Lacing cord shall be Type P unwaxed nylon in accordance with MIL-DTL-713 or Type SR-4.5 glass fiber (resin-filled) cord in accordance with MIL-I-3158 for temperatures up to 221 °F (105 °C), neoprene treated glass cord in accordance with MIL-Y-1140 for temperatures up to 266 °F (130 °C), and silicone treated glass cord or sleeving for temperatures up to 392 °F (200 °C) (see 3.4.17). Polyamide tape, in accordance with Type IV or V of A-A-52080, A-A-52081, A-A-52082, A-A-52083, and A-A-52084, also may be used for temperatures up to 392 °F (200 °C).

3.12.2.1.3 Flexible wiring. Where flexible wiring is required by hinged doors, panels, or sliding subassemblies, abrasion and chafing shall be minimized by the use of flexible plastic sheaths on wiring. Wire groups running from hinged panels or doors shall be formed and clamped so that sharp bends do not occur with the panel or door in either the open or closed position; and, if more than three wires are contained in the group and the panel or door is required to be removable, a terminal block (or the receptacle portion of a multi-pin connector, where permitted) mounted on a stationary part of the structure within the enclosure or on the hinged panel or door shall be used for connections. Flexible harnesses shall be broken down into individual bundles.

3.12.2.2 Slack. Slack shall be provided so as not to impair movement or put undue stresses on the wires or parts in those places where movement of parts may be expected. Slack shall also be provided to prevent undue stresses on terminal connections due to shock or vibration. Where soldering is used to connect hook-up wires to the terminals of replaceable parts, sufficient slack shall be provided for at least two replacements of the part in the event that the wires are damaged or have to be clipped at the terminals during disassembly. Where solderless lug terminals are used, sufficient slack shall be provided for two replacements of the terminals on 14 AWG and smaller wires.

3.12.2.3 Mechanical supports. Electrical connections shall be designed and provided with supports to prevent breakage and minimize changes in performance due to vibration, inclination, or shock.

3.12.2.3.1 Clamped connections. Where electrical connections are constructed of members in firm contact, such as parts held together by bolts, the contacts shall not depend on force transmitted through plastic spacers or other deformable parts. Only metal parts shall be so employed and these electrical connections shall not rely on the clamping screw, bolt, or fastener threads to carry current. However, stud type semiconductor devices may be mounted separated from their heat sinks or other mounting surfaces by insulators when direct metallic contact is incompatible with the circuit requirements, provided the method of mounting conforms to the device manufacturer's recommendations.

3.12.2.4 External cable connections. Provision shall be made for the connection of external cables to terminal boards located within the equipment near the cable entrance, except where individual equipment specifications permit or specify some other methods, such as direct connection to parts, connections using wire nuts, or multi-pin plug connectors (see 6.2). All terminal boards for external connections shall be accessible from the front of the enclosure. Circuitous routing of wire shall be avoided.

3.12.2.5 Protection of insulation. Where equipment internal wiring is run through holes in metal partitions, these holes shall be furnished with grommets for the mechanical protection of insulation which otherwise could be subject to abrasion. Care shall be exercised in the running of wires to ensure they are not carried over or bent around any sharp corner or edge. In radio frequency (RF) circuits, the grommets shall be ceramic or polytetrafluoroethylene.

3.12.2.6 Shielded wire. Wire having metallic shielding unprotected by an outer insulation shall be so secured as to prevent the shielding from making contact with exposed terminals or conductors. The shielding shall be terminated as close to the circuit terminals as possible without risk of grounding the terminals. Where grounding of the shielding is required by the circuit design, the ground connection to the chassis shall be made by means of terminal lugs, screw type terminals, or bolts.

3.12.2.7 Stud terminals. Stud terminals of potted parts shall be fastened to the insulating strip or plate or the enclosure itself to conform to the insulation requirements. The soldering of external leads to the stud terminals shall not cause any degradation in the moisture excluding property of the enclosures.

3.12.2.8 Wire connections and terminals. The ends of each conductor (except for conductors requiring solder connections to a terminal or stud) shall be connected to terminals on the part or to terminal boards by means of solderless lug terminals in accordance with MIL-T-16366 or SAE-AS7928, Type II, or by forming the conductor around a part terminal and retaining the loop in a cup or crimped washer. If a wire loop is used, strands of the conductor shall be secured together by soldering. No more than three connections shall be made to each terminal screw or stud. Terminal boards provided with two terminal screws per electrical terminal should be limited to two connections per screw. Terminal jumpers (see 3.12.2.10) are not included in this limitation. Neither pins nor conductors may be paralleled for the purpose of increasing capacity except where capacity above 220 amperes is required or where specifically allowed by the individual equipment specification. Nuts, bolts, studs, and screws used for electrical connections shall be secured by lockwashers, except lockwashers need not be provided for solderless lug type connectors for 14 AWG (4000 circular mils) conductors and smaller or on terminal board or wire terminal combinations in accordance with A-A-59125. External-tooth flat lockwashers are recommended for electrical connections, where practical.

3.12.2.8.1 Spare terminals. Terminal boards or cable connectors used for external cable connections shall be in accordance with SAE-AS50151. Terminal boards or cable connectors shall have not less than 10 percent unused terminals when used for connections in the equipment and when used for the connection of assemblies with cubicles. There shall be not less than two such terminals, except that no spares are required where a total of six or less active terminals are involved. Spare terminals in connectors shall be in the outermost row of terminals. To avoid selecting larger shell size connectors in order to maintain creepage and clearance distances between isolated signal groups within a single connector, the requirement of placing the spare terminals in the outermost rows is not applicable. Spares are required, but may be placed in locations closest to each isolated signal group. Spare terminals shall be labeled accordingly. Where connectors or terminal boards are used only for primary power connections, no spare terminals need be provided. If more than one terminal board or connector is needed at a common place, only 10 percent of the total number of terminals at this place are required as spare terminals.

3.12.2.8.2 Soldered connections. Soldered wiring connections shall be as specified in 3.14.3 through 3.14.3.2.

3.12.2.8.3 Electrical weld connections. Guidance for welded wiring connections can be found in MIL-HDBK-454.

3.12.2.9 Permanent internal connections of windings. Where permanent type connections are made within windings, either soldering (see 3.14.3.1) or solderless pressure connectors may be used.

3.12.2.10 Terminal jumpers. Where required and possible, jumpers between adjacent terminals on terminal boards shall be made with shaped metal conducting straps designated for that purpose.

3.12.3 Wire identification. Wires grouped in harnesses or single wires more than 12 inches in length (unless they are unique in color or size and can be traced visually from one end to the other) shall be marked for identification. Marking may be accomplished by stamping the identification symbol on the wire insulation, if the insulation is a type suitable for this purpose, by sleeve type wire marker over the wire insulation, by identification coding systems in accordance with MIL-STD-681, or by stamping the wire terminal lug if the wire size exceeds 23,000 circular mils. Marking shall be applied in a permanent manner, resistant to water, oil, and abrasion.

3.12.3.1 Marking of hook-up and lead wire. Wiring in the equipment shall be, insofar as practicable, distinctly coded in color or numbered. Codes, when used, shall be in accordance with MIL-STD-681 or as otherwise agreed upon with the contracting activity. Numbers shall not be used where they would be difficult to read or trace, such as in compact assemblies. Wires shorter than 4 inches need not be physically marked, but the coding shall appear on all diagrams showing the wires. Light colored wires shall be marked by hot stamping with black characters and black or dark colored wires shall be hot stamped with white characters. Wires may be marked by printing the coding on white wire markers as specified in 3.12.3.2. The printing shall remain intact and easily readable after the wires are flexed.

3.12.3.2 Wire markers. Wire markers shall be of the tubular sleeve, coiled sleeve, or heat-shrinkable sleeve types made of polyethylene or other insulating material which is compatible with the wire insulation. Adhesive strip type markers may be used provided they are protected by snug fitted transparent heat-shrinkable sleeves. Heat-shrinkable sleeves and their application shall be in accordance with SAE-AMS-DTL-23053.

3.12.3.3 Standard marking for connections. Identification marking shall be in accordance with MIL-STD-681 for those items of equipment listed therein. Other items, the marking of which is not covered by MIL-STD-681 or by other applicable standards or specifications, shall have identifying terminal marking using numbers or letters or a combination of both. Wiring documentation shall be in accordance with ASME Y14.100, ASME Y14.24, and ASME Y14.34, as specified (see 6.2).

3.12.4 Bus bars. Design of bus bars including materials, sizes, spacing, arrangements, and joints shall be in accordance with MIL-DTL-16036. All connections to bus bars shall be made by throughbolting the bus bar. Link or tap changing connectors are not to be considered bus bars. When specified (see 6.2), bus bars shall be insulated with materials in accordance with MIL-E-22118 for surface ships and MIL-I-15265 for submarine applications. All joints, except those required for final shipboard installation, shall be insulated after assembly. Insulation distances (clearance in air and surface creepage) of bus bars with external cabling and all associated hardware (lugs, bolts, nuts, washers, and so forth) installed shall conform to the requirements of MIL-DTL-16036. Installation instructions shall include a list of joints requiring insulation such that all current carrying parts will be insulated upon completion of final shipboard installation. For laminated bus bars, the above requirements do not apply provided that laminated bus bars shall be encapsulated and all exposed hook-up current carrying copper surfaces shall be silver coated to control corrosion.

3.12.5 Fiber optic connections.

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

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

3.13 Parts. Only parts specified herein shall be incorporated into the design of the equipment.

3.13.1 Parts selection. Parts not specified herein shall be selected from the applicable individual equipment specification.

3.13.1.1 Parts derating. Derating of electronic parts shall be in accordance with the requirements of this specification while observing the additional guidance of MIL-HDBK-338.

3.13.1.1.1 Resistor and rheostat derating. Power dissipation in resistors and rheostats shall not exceed 50 percent of the rated value after applicable derating and ambient temperature factors have been applied in accordance with the part specification.

3.13.1.1.2 Capacitor derating. Capacitors shall be derated at least 50 percent. The expected peak voltage of a capacitor under nominal and steady state tolerance conditions of AC voltage and frequency input and signal levels with the equipment operating in the maximum ambient design temperatures shall not exceed ½ times the capacitor maximum voltage rating. Use of a derating factor for capacitors different than 50 percent shall be approved by NAVSEA.

Under transient or over-voltage conditions, no capacitor maximum voltage rating shall be exceeded. A derating factor lower than 50 percent should not be used due to the space required for larger capacitors. The root mean square (rms) value of any capacitor current due to an AC applied voltage or an AC ripple voltage superimposed on a DC basis shall not exceed 50 percent of rated value for the capacitor.

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

Table XIX. Application stress limits and derating factor for rectifiers, SCRs [1/], GTOs [1/], bipolar transistors, and IGBTs [2/].

Stress factor	**Stress factor limit in relation to rating factor**		**Rating factor**
	Lower	**Upper**	
Rectifiers			
Working peak reverse voltage	---	0.5 V_{RRM}	Repetitive peak reverse voltage
Non-repetitive peak reverse voltage	---	0.7 V_{RSM}	Non-repetitive peak reverse voltage
DC reverse blocking voltage	---	0.4 V_{RRM}	Repetitive peak reverse voltage
Average current	---	0.5 $I_{F(AV)}$	Half-cycle forward current average
Peak surge current	---	0.7 I_{TSM}	Peak surge current
Junction temperature	---	0.8 $T_{j(max)}$	Maximum operating junction temperature
SCRs			
Working peak reverse voltage	---	0.5 V_{RRM}	Repetitive peak reverse voltage
Non-repetitive peak reverse voltage	---	0.7 V_{RSM}	Non-repetitive peak reverse voltage
DC reverse blocking voltage	---	0.4 V_{RRM}	Repetitive peak reverse voltage
Working peak forward voltage	---	0.5 V_{DRM}	Repetitive peak off-state voltage
Non-repetitive peak forward voltage	---	0.7 V_{DRM}	Non-repetitive off-state voltage
Peak surge current	---	0.7 I_{TSM}	Surge on-state current
Average current	---	0.5 $I_{T(AV)}$	Half-cycle forward current average
Pulsed gate current for	2.0	10.0 I_{GT}	Gate trigger firing current
Peak reverse gate voltage	---	0.5 V_{GRM}	Maximum reverse gate voltage
Maximum rate of current rise during turn-on	---	0.5 di/dt	Maximum rate-of-rise on state current
Maximum rate-of-rise forward blocking voltage	---	0.5 dv/dt	Maximum allowable rate-of-rise, forward blocking voltage (static)
Turn-off time	---	0.5 t_q	Circuit commutated turn-off time
Junction temperature	---	0.8 $T_{j(max)}$	Maximum operating junction temperature
GTOs			
DC blocking voltage	---	0.4 V_{DRM}	Repetitive peak voltage
Nominal working peak reverse voltage	---	0.5 V_{RRM}	Repetitive peak reverse voltage
Repetitive peak reverse voltage	---	0.7 V_{RRM}	Repetitive peak reverse voltage
Non-repetitive peak reverse voltage	---	1.0 V_{RRM}	Non-repetitive peak reverse voltage
Non-repetitive peak forward blocking voltage	---	0.8 V_{DRM}	Non-repetitive peak off-state voltage
Maximum rate-of-rise of forward blocking voltage	---	0.5 dv/dt (critical)	Critical rate-of-rise of forward blocking voltage
Rate-of-rise of reapplied forward blocking voltage	---	0.7 dv/dt (reapplied)	Reapplied rate-of-rise of forward blocking voltage
Minimum duration of gate turn-off signal	2.0	---t_{gq}	Gate controlled turn-off time (Gain = 4), $T_j = T_{j(max)}$

Table XIX. Application stress limits and derating factor for rectifiers, SCRs [1/], GTOs [1/], bipolar transistors, and IGBTs [2/] – Continued.

Stress factor	Stress factor limit in relation to rating factor: Lower	Stress factor limit in relation to rating factor: Upper	Rating factor
GTOs (Continued)			
Average forward current			
(a) Nominal value	---	0.7 $I_{T(AV)}$	Average forward current at $T_{j(max)}$ for application waveform, conduction angle, duty cycle, and frequency
(b) Maximum value	---	1.0	
Surge current	---	0.7 I_{TSM}	Peak surge current, half cycle surge, (1/120 second) non-repetitive
Maximum rate-of-rise of current during turn-on			
(a) Repetitive maximum	---	0.5 di/dt (rep)	Maximum repetitive rate-of-rise of current during turn-on
(b) Non-rep. maximum	---	0.5 di/dt (critical)	
(c) During surge	---	1.0	
Pulsed forward gate current	2.0	10.0 I_{GT}	
Junction temperature	---	0.8 T_j	Maximum operating junction temperature
Transistors, bipolar			
Pulsed base current-switching	2.0	---	Required base current for circuit collector current and device gain
Collector to emitter operating voltage emitter (nominal working)	---	0.5 $V_{CEO(SUS)}$	Collector to emitter voltage, base-open
Collector current			
(a) Nominal value	---	0.6 $I_{C(AV)}$	Average collector at rated $T_{j(max)}$ for the application waveform, conduct, angle or period, duty cycle and frequency
(b) Maximum value	---	0.8	
Collector power	---	0.5 P_T	Collector power dissipation derated for temperature
Junction temperature	---	0.8 $T_{C(max)}$	Maximum operating junction temperature
Emitter to base voltage-cut-off mode, nominal working	---	0.5 V_{KHO}	Emitter to base voltage
Peak emitter current	---	0.7 I_g	Maximum emitter current at rated $T_{j(max)}$
Transistors, field effect			
Drain to source voltage, cut off mode or off-state			
(a) DC	---	0.5 V_{DS}	Maximum rated drain to source voltage
(b) Nominal working	---	0.6 V_{DS}	
(c) Repetitive peak	---	0.7 V_{DS}	
(d) Non-repetitive	---	0.8 V_{DS}	

Table XIX. Application stress limits and derating factor for rectifiers, SCRs [1/], GTOs [1/], bipolar transistors, and IGBTs [2/] – Continued.

Stress factor	Stress factor limit in relation to rating factor		Rating factor
	Lower	Upper	
Transistors, field effect (Continued)			
Drain to gate voltage			
(a) DC	---	0.5 V_{DGR}	Drain to gate voltage with R_{GS} = 1 megohm
(b) Nominal working	---	0.6 V_{DGR}	
(c) Repetitive peak	---	0.7 V_{DGR}	
(d) Non-repetitive	---	0.8 V_{DGR}	
Average drain current, active or on-state mode, I_D			
(a) Nominal value	---	0.6 $I_D$on	Average drain current at rated $T_{j(max)}$ for the application waveform, conduction angle or period, duty cycle, frequency, and drain to source on-state resistance.
(b) Maximum value	---	0.8 $I_D$on	
Gate to source voltage, V_{GS}	---	0.7 V_{GS}	Gate to source voltage
Minimum duration of gate controlled turn-off signal	2.0	---($t_{d,off} + t_f$)	Turn-off cutoff time or body-drain diode reverse recovery time during turn-off at rated $T_{j(max)}$ whichever is greater.

NOTES:
[1/] Silicon-controlled rectifier (SCR). Gate-turn-off (switches) (GTO).
[2/] See IEEE 1662 for Insulated Gate Bipolar Transistor (IGBT) derating values.

3.13.1.1.4 Microcircuit derating. Unless otherwise specified in the equipment specifications (see 6.2), microcircuits shall be mounted according to manufacturer's requirements and applied so that the maximum ambient operating temperature will be derated to a value less than the maximum operating ambient temperature given by the manufacturer's data sheet. That temperature difference, or derating value, shall be 27 °F (15 °C). For example, maximum operating ambient temperature on manufacturer's data sheet lists 140 °F (60 °C). The derating value would be 140 – 27 = 113 °F (60 – 15 = 45 °C).

3.13.1.2 Standard parts. All parts selected as specified in 3.13.1 shall be considered standard parts.

3.13.1.3 Non-standard parts. Use of non-standard parts shall require NAVSEA approval.

3.13.1.4 Matched parts selection. If matched parts are required for proper performance of the equipment, the matched parts shall be treated as non-standard parts. Sets of matched parts shall be identified by a unique part number and packaged so that the set can be removed, acquired, and replaced as a subassembly.

3.13.1.5 Replacement and interchangeability. Unless otherwise specified in the individual equipment specification (see 6.2), parts shall be individually replaceable. Parts as delineated and specified herein are interchangeable items as defined by MIL-HDBK-505. They shall possess both mechanical and electrical compatibility to permit their installation and replacement without regard to manufacturer, contractor, or special selections (see 3.2.5).

3.13.1.6 Parts tolerances. In the selection of parts, the widest tolerances permitted by the individual part specification, and as otherwise permitted herein and by the equipment specification, shall be used commensurate with the particular long term stable equipment application requirement. However, in equipment fabrication, parts of closer tolerances may be substituted as long as interchangeability is not affected (see 3.13.1.5).

3.13.2 Fuses and fuseholders.

3.13.2.1 Fuses. Fuses shall be in accordance with MIL-PRF-15160, except where protection of semiconductor devices is involved. For protection of semiconductor devices, fuses shall be selected and applied in accordance with the characteristics of the semiconductor devices and with the manufacturer's recommendations. Fuses for semiconductor devices shall be considered non-standard parts (see 3.13.1.3). Fuses shall be chosen so that their clearing I t (where I is current, and t is time) is lower than the I t of the items which are to be protected. The integrated I t of the fuse shall be at least 10 percent less than the integrated I t of the semiconductor device they protect. The use of two or more fuses in parallel is prohibited.

3.13.2.2 Fuse mounting. Fuses shall be mounted either in fuse clips in accordance with A-A-55507, A-A-55507/1, A-A-55507/2, or A-A-55507/3, or in front indicating type fuseholders in accordance with MIL-PRF-19207.

3.13.2.3 Fuse styles and characteristics. For circuits of 250 to 500 V AC or DC, the following style fuses of blowing characteristics C shall be used:

Style	Specification	
F60	MIL-PRF-15160/60	
F61	MIL-PRF-15160/61	(May be used only on existing design equipment. Use of F60 fuses is preferred.)
F62	MIL-PRF-15160/62	
F63	MIL-PRF-15160/63	
F64	MIL-PRF-15160/64	
F65	MIL-PRF-15160/65	
F66	MIL-PRF-15160/66	

3.13.2.4 Fuse selective blowing. Where fused circuits are connected in cascade, a degree of selective blowing is required at each successive level closer to the power input (power supply source). The energy required for fuse element melting shall be not less than two times the total energy required for circuit interruption at the largest of the next adjacent load size fuses.

3.13.2.5 Fuse current ratings. Fuses shall have current ratings not less than 125 percent of continuous load for transformer or non-inductive circuits and not less than the minimum value required to pass, reliably, the peak currents of transient-producing circuits. The ratings shall be low enough to prevent damage to all equipment conductors on the line side of any fault and to limit damage to the immediate area of the short circuit or ground fault. For low-power systems, consideration shall be given to the minimum available short-circuit current to ensure blowing. Fuses used shall be readily replaceable.

3.13.2.6 Fuse and fuseholder installation characteristics.

a. Fuses mounted in clips shall be placed in a readily accessible location and shall provide adequate clearance to ground, ease of replacement, ease of testing, and safety to maintenance personnel.

b. In convection cooled equipment, the fuses shall be mounted in a vertical position to prevent obstruction of cooling air. Fuses shall be so located as not to be influenced by excessive equipment heat flow or near a high operating temperature part.

c. For fuses that are bolted in place, care shall be taken to minimize the loss of screws, washers, and nuts during the removal or replacement of fuses.

d. Fuses with mechanical pop-up blown indicators shall be located so that the position of the indicators may be readily seen.

e. In connections with knife blade type fuses, to prevent possible dislodging under shock and vibration conditions, a melamine bar, which can be easily and safely removed, may be provided across the fuse barrels.

f. Information plates shall be provided for each set of fuses and shall indicate the fuse type designation, schematic reference designation, the circuit, rated rms interrupting current, and maximum interrupting circuit voltage (for example, F03A250V3A-S, F101, regulator circuit, DWG. XXXXXX, 100 A, 250 V_{rms}).

g. When fuses are required to be mounted in fuse clips, copper clad steel fuse clips in accordance with A-A-55507 and A-A-55507/1 shall be used for fuse ratings up to 60 amperes.

h. When used, the dead front indicating type shall be mounted on the front of the equipment. For equipment with a drawer or hinged front panel, the fuseholders may be mounted on the front panel.

i. Fuseholders shall be installed so that the test probe hole is located at the bottom.

3.13.2.7 Fuses, non-standard types. Use of standard fuses is the preferred practice. Where use of non-standard fuses is approved, one spare fuse for every three fuses of the specific type and rating being used shall be located in the equipment and marked as spares. Neon lamp type of blown fuse indicators shall not be used for voltages below 90 V.

3.13.2.8 Fuseholders.

3.13.2.8.1 For F02, F03, and F60 fuses. Fuseholders for use with Styles F02, F03, and F60 fuses shall be Types FHL10G, FHL11G, FHL12G, FHL32W, FHL33W, or FHL35W indicating type fuseholders in accordance with MIL-PRF-19207 when the circuit voltage is 90 V or greater. When the circuit voltage is less than 90 V, Types FHL18G, FHL29G, or FHL30G fuseholders in accordance with MIL-PRF-19207 (incandescent lamp indicators) shall be used except where they will not indicate properly or circuit functions would be adversely affected by their use. In such cases, Type FHN28WB fuseholder (non-indicating type) shall be used.

3.13.2.8.2 For F62 fuses. Fuseholders for use with Style F62 fuses shall be Type FHL14G in accordance with MIL-PRF-19207.

3.13.2.8.3 For F63 fuses. Fuseholders for use with Style F63 fuses shall be Type FHL15G in accordance with MIL-PRF-19207.

3.13.2.8.4 Indicator type. All indicator type fuseholders shall be installed so that the indicators are visible from outside the equipment at all times.

3.13.2.8.5 Non-indicator type. Non-indicating fuseholders for use with F60 fuses shall be Type FHN41WB in accordance with MIL-PRF-19207.

3.13.3 Circuit breakers. Current time sensing (CTS) and signaling devices, when used for protection against overcurrent, shall be supplied in accordance with MIL-S-24561. Circuit breakers shall conform to the following specifications:

Type	Specification
ACB – Open frame up to 500 V_{rms}, 355 VDC	MIL-DTL-17587
AQB and NQB – Insulated enclosure, up to 500 V_{rms}, 250 VDC	MIL-DTL-17361
ALB and NLB – Insulated enclosure, up to 125 V_{rms}, 125 VDC	MIL-C-17588

3.13.4 Resistors and rheostats. Resistors shall be chosen and applied using the guidance in MIL-HDBK-199 as modified by the additions, limitations, and restrictions specified herein and in the applicable equipment specification. Guidance for resistors and rheostats from ½ to 50 watts can be found in MIL-HDBK-199. Rheostats and variable resistors used for adjustments during equipment operation for ratings up to 50 watts shall be in accordance with Form EW of MIL-DTL-15109 or MIL-PRF-22. Above 50 watts, rheostats, variable resistors, and fixed resistors shall be in accordance with MIL-DTL-15109.

3.13.4.1 Resistor networks. Resistor networks-fixed film shall be in accordance with MIL-PRF-83401.

3.13.5 Capacitors. Capacitors shall be chosen and applied using the guidance in MIL-HDBK-198 as modified by the additions, limitations, and restrictions specified herein and in the applicable equipment specification (see 6.2). For radio interference suppression capacitors, see 3.2.16. Capacitors containing PCBs shall not be used.

3.13.5.1 Fixed tantalum (solid electrolyte). Fixed tantalum (solid electrolyte) capacitors shall be in accordance with MIL-PRF-39003. These capacitors may be used for applications where their voltage ratings are applicable and where the AC voltage component does not exceed 5 percent of the DC voltage rating. All capacitors with pigtail leads shall be supported by means other than their leads.

3.13.5.2 Fixed tantalum (liquid electrolyte). Fixed tantalum (liquid electrolyte) capacitors requiring large capacitance values where close tolerances are not an important factor shall be hermetically sealed in accordance with MIL-PRF-39006. Where physical space restraints require smaller sized capacitors, sintered anode, wet electrolyte tantalum capacitors in accordance with MIL-PRF-39006/22 may be used. Otherwise, sintered anode, wet electrolyte tantalum capacitors shall not be used. All capacitors with pigtail leads shall be supported by means other than their leads.

3.13.5.3 Fixed ceramic-dielectric (temperature compensating). Fixed ceramic-dielectric (temperature compensating) capacitors shall be in accordance with MIL-PRF-20. The widest possible capacitance tolerance and the least stringent temperature coefficient commensurate with the requirements of the circuit application shall be used. These capacitors are intended primarily for use in circuits where compensation is necessary for variations in capacitance due to temperature and in bypass and coupling applications. The use of low capacitance [less than 100 picofarad (pF)] capacitors with temperature coefficient of capacitance tolerance of ±60 parts per million or less, shall require approval of the contracting activity.

3.13.5.4 Fixed ceramic-dielectric (general purpose). Fixed ceramic-dielectric (general purpose) capacitors shall be in accordance with MIL-PRF-39014. These capacitors are intended for use as bypass, filter, and coupling capacitors where changes due to temperature can be tolerated.

3.13.5.5 Variable ceramic-dielectric. Variable ceramic-dielectric capacitors shall be in accordance with MIL-PRF-81. These capacitors are intended for operation in circuits where periodic adjustments are required.

3.13.5.6 Variable air-dielectric (tuning). The nominal spacing between opposing plates of air-dielectric capacitors shall be not less than 0.008 inch, unless specifically approved. In all cases where a nominal spacing of less than 0.012 inch has been approved, the capacitors shall be enclosed in a dustproof case. The capacitors shall be constructed of corrosion-resistant material or shall be protected against corrosion. The plates of all capacitors shall be free from grease, dust, dirt, and metallic burrs. As installed in the equipment, all capacitors shall withstand, without breakdown, at least 500 V_{rms}, 60 Hertz (Hz) applied between opposing plates. For variable capacitors, this breakdown voltage shall hold for all relative positions of rotor and stator plates. The rotors of all variable air-dielectric capacitors shall be adequately supported and shall make a low resistance contact with the connectors.

3.13.5.7 Fixed supermetallized plastic film dielectric. Fixed supermetallized plastic film dielectric capacitors (hermetically sealed in metal cases) shall be in accordance with MIL-PRF-83421.

3.13.6 Switches. Switches shall be selected so that rated currents and voltages (make, break, carry) are not exceeded in the intended application, as well as for their ability to withstand the shipboard environments. Momentary contact switches are preferred for panel controls. Snap action switches are preferred for power circuit interruption. Detent action switches are suitable for meter and circuit selection. The switches selected shall conform to one of the specifications specified in 3.13.6.1 through 3.13.6.11, as applicable.

3.13.6.1 Toggle switches. Toggle switches shall be in accordance with MIL-DTL-3950.

3.13.6.2 Sensitive switches. Sensitive switches shall be in accordance with MIL-PRF-8805 and shall not be used for applications above 125 V or 50 VA.

3.13.6.3 Push (snap action) switches. Push (snap action) switches shall be in accordance with MIL-PRF-8805 or MIL-DTL-2212.

3.13.6.4 Pushbutton switches. Illuminated pushbutton switches shall be in accordance with MIL-PRF-22885. Non-illuminated pushbutton switches shall be in accordance with MIL-DTL-2212.

3.13.6.5 Mercury switches. Mercury switches shall not be used (see 3.3.1.2).

3.13.6.6 Pressure and thermostatic switches. Pressure and thermostatic switches, except metallic and bi-metallic types, shall be in accordance with MIL-DTL-2212 or MIL-S-16032.

3.13.6.7 Metallic and bi-metallic thermostatic switches. Metallic and bi-metallic thermostatic switches shall be in accordance with MIL-PRF-24236.

3.13.6.8 Printed circuit switches. Printed circuit switches shall be in accordance with MIL-PRF-22710.

3.13.6.9 Bus transfer switches. Bus transfer switches shall be in accordance with MIL-PRF-17773 or MIL-PRF-32150.

3.13.6.10 Rotary switches.

3.13.6.10.1 Control and power circuits. Switches for control and power circuit applications shall be in accordance with MIL-DTL-15291. SR types shall be utilized for 1SR and 3SR applications. Where more than four positions are required, switches shall be in accordance with MIL-S-18396 or Style JM or JR of MIL-DTL-21604.

3.13.6.10.2 Instrument, metering, alarm, and test circuits. Switches for all instrumentation equipment and for metering, alarm, and test circuitry in control equipment shall conform to the following:

a. For voltages of 125 V or less, switches shall be in accordance with Style JK, JL, JM, or JR of MIL-DTL-21604 or MIL-DTL-3786 and Style SR04 of MIL-DTL-3786/4 modified to include gold plated contacts. Class SR of MIL-DTL-15291 shall not be used in this service.

b. For voltages above 125 V, switches shall be in accordance with MIL-DTL-15291 or MIL-S-18396.

3.13.6.10.3 Switch stops. Stops shall be provided to limit rotation of rotary switches to the minimum number of positions necessary for their application in a system. However, four-position switches having identical alternate positions shall not be required to have stops when only two positions are needed.

3.13.6.10.4 Enclosed rotary. Enclosed rotary switches shall be in accordance with MIL-DTL-15743.

3.13.6.11 Reed switches. Reed switches shall not be used in new equipment design.

3.13.7 Mounting and fastening.

3.13.7.1 Resistor and capacitor mounting. Resistors shall be securely mounted in such a manner as to allow for expansion with temperature changes. Capacitors shall be securely mounted. Resistors and fixed capacitors shall not be mounted by their wire leads without providing other mechanical support for the body of the component, except that components whose weight is ½ ounce or less may be secured by only their leads if the total length of both leads measured between the points on the component from which the leads egress and the midpoints of the lead attachment terminals does not exceed 1 inch. In no case shall the wire leads be less than ¼ inch for components with axial leads, except for printed circuit applications and in non-repairable items. Requirements herein do not apply to parts to which IPC-2221 mounting requirements apply.

3.13.7.2 Receptacle and connector mounting. When receptacles are mounted on a vertical surface, the largest polarizing or prime key or keyway of the receptacle shall be at the top center of the shell of the receptacle, where practical.

3.13.7.2.1 Similar connectors. The use of similar connectors for interconnecting cables shall be minimized. When used, similar connectors shall utilize differences in insert arrangement or size, or keying, to prevent misconnections, unless the connectors are functionally interchangeable.

3.13.7.3 Toggle switch mounting. Requirements for mounting toggle switches shall be in accordance with MIL-STD-1472.

3.13.7.4 Fastening of brittle materials. Guidance for fastening of brittle materials can be found in MIL-HDBK-454.

3.13.8 Meters and instruments, electrical indicating, and accessories.

3.13.8.1 Electrical indicating meters. Where high impact meters that meet the shock test requirements of MIL-S-901 are required, they shall be selected from the following specifications: MIL-PRF-10304, MIL-DTL-3971, MIL-DTL-16034, MIL-M-16125, MIL-V-23151, MIL-M-23167, or MIL-M-24359.

3.13.8.1.1 Indicating meter accessories. Insofar as practicable, indicating meter accessories such as shunts, resistors, and instrument transformers shall be in accordance with MIL-I-1361.

3.13.8.2 Digital indicators. Digital indicators shall be in accordance with MIL-DTL-28803 or as specified in the equipment specifications.

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

3.13.8.3 Frequency meters. Frequency meters shall be in accordance with MIL-M-23167.

3.13.9 Indicator lights.

3.13.9.1 Preferred indicator lights. The preferred indicator light shall contain light emitting diodes (LEDs) in accordance with A-A-59781 or MIL-DTL-28803 and MIL-DTL-28803/1. Indicator lights that incorporate LEDs shall have a minimum display height of 0.29 inch. Indicator lights that incorporate LEDs shall be maintainable with the capability to be easily removed for replacement without disassembly of the equipment or replacement of circuit boards or LED mounting assemblies.

3.13.9.2 Alternative indicator lights for standard and non-standard voltages and frequencies and DC circuits. Indicator lights for standard AC voltages and frequencies shall be Style LH94 or LH98 in accordance with MIL-DTL-3661 and MIL-L-3661/61 or MIL-L-3661/65. Indicator lights for non-standard voltages and frequencies and for DC circuits shall be Style LH95 or LH96, for use with resistors, in accordance with MIL-L-3661/62 and MIL-L-3661/63.

3.13.9.3 Lamp types. Lamps for use with the Style LH94 or LH98 indicators shall be in accordance with MIL-L-3661/61 and MIL-L-3661/65, respectively. Lamps for use with the Style LH95 or LH96 indicators shall be in accordance with MIL-L-3661/62 and MIL-L-3661/63, respectively. The lamp accommodation number shall be marked on the indicator lamp holder.

3.13.9.4 Indicator lenses, mounting, and color. Indicator lights shall be provided with flush mounting type lenses. Finish paint shall be gray. Indicator light styles shall be applied to indicator lens styles as shown in table XX. Alarm lights shall be in accordance with MIL-DTL-3661. Indicator light lens colors and color use shall be in accordance with MIL-STD-1472. Indicator lenses designed for spray-tight, water-tight, and submersible enclosures shall meet the tightness requirements of MIL-DTL-2036.

TABLE XX. Indicator style and specifications.

Light style	Lens style	Lens specifications
LH94, LH95, LH96, LH98	LC41	MIL-L-3661/55
	LC42	MIL-L-3661/56
	LC43	MIL-L-3661/57
	LC45	MIL-L-3661/59

3.13.10 Jacks, tip (test point jacks). Tip jacks shall be selected from MIL-DTL-39024. Banana plugs shall not be used as test points.

3.13.11 Motors. Motors shall be in accordance with MIL-M-17059 or MIL-DTL-17060, and as specified in the equipment specification. Refer to MIL-M-17413 and MIL-M-17556 for guidance. Terminal markings and rotation shall be in accordance with MIL-STD-681.

3.13.12 Servo-motors. Servo-motors shall be in accordance with MIL-S-22432.

3.13.13 Synchros. Synchros shall be in accordance with SAE-AS20708. Guidance for installation requirements can be found in MIL-HDBK-225. The secondary load impedance for the synchro control transformers shall be specified in the equipment service manual in the descriptive data for the synchro heading receiver. This load impedance shall be not less than 30,000 ohms.

3.13.14 Relays. Relays shall be in accordance with MIL-R-19523 except as stated hereinafter. Where the relay is expected to be operated infrequently, especially at low current levels, and immediate acceptable operation of the circuit is required, gold plated contacts shall be used.

a. Overload and time delay relays shall be in accordance with MIL-DTL-2212 for AC and DC applications.

b. Relays that require extremely high insulation resistance, a minimum of contact resistance, and special coil sensitivity, or any of these, so that they cannot be supplied under MIL-R-19523, refer to Category 1, enclosure design symbol 4, of MIL-R-5757. Their selection shall be in accordance with the general requirements of MIL-PRF-6106 and MIL-PRF-28750. Refer to MIL-R-5757 for additional guidance.

c. Rotary relays shall operate in a 194 °F (90 °C) ambient temperature.

d. Solid state relays shall be in accordance with MIL-PRF-28750.

e. Power monitoring and control relays shall be in accordance with MIL-M-24350.

f. Protective relays used with circuit breakers shall be Navy-approved relays (see 6.2).

3.13.15 Terminal boards. Terminal boards shall be in accordance with A-A-59125, except that lock washers are not required under terminal nuts and screws. Terminal boards of the stud type shall be double row, linked, front connected Classes 8TB, 10TB, 17TB, and 26TB, double screw, front connected Classes 37TB, 38TB, and 39TB, or single row through connected Classes 3TB, 5TB, 7TB, 11TB, and 27TB. No more than three wires shall terminate at any one stud or terminal; except where Classes 8TB and 26TB with stud connector are used, only two wires may terminate at any one stud.

3.13.16 Terminal lugs. Terminal lugs shall be in accordance with SAE-AS7928. Class 1 ring tongue terminals and rectangular tongue lug terminals are the preferred types. Ring tongue design in accordance with SAE-AS7928/1 is preferred. Rectangular tongue terminal lugs in accordance with SAE-AS7928/2 are also acceptable, depending on the type and size of cable or hook-up wire being used and the current level.

3.13.16.1 Insulated types. Insulated types shall conform to Type II, Class 1. Insulated types are not to be used when the conductor temperature exceeds 212 °F (100 °C).

3.13.16.2 Uninsulated types. Uninsulated types shall conform to Type I, Class 1. When required, additional sizes of uninsulated lugs are covered by MIL-T-16366.

3.13.16.3 Lower current applications. On all applications of 5 amperes or less, the terminal lugs shall conform to Type II, Class 1. The terminal lugs shall be selected from the appropriate military standard drawing so that the inside diameter of the terminal lug barrel in which the bare wire is to be inserted is smaller than the outside diameter of the insulation on the wire.

3.13.16.4 Higher current applications. On all applications greater than 5 amperes, but within the current limits of SAE-AS7928, the terminal lugs shall conform to Type I, Class 1 or Type II, Class 1 depending on the temperature of the conductor. When the temperature exceeds 212 °F (100 °C), an uninsulated terminal lug Type I, Class 1 that falls within the current limits of SAE-AS7928 shall be selected from the appropriate military standard drawing and used with the addition of an insulating sleeve suitable for the maximum temperature of the conductor.

3.13.16.5 Plated terminal lugs. On those terminal lug applications not satisfied by SAE-AS7928, Types I and II because of cable size, current rating, and thickness of cable insulation, Types CLC, CLCG, and WTG terminal lugs in accordance with MIL-T-16366 shall be used within their current rating with the addition of an insulating sleeve suitable for the maximum temperature of the conductor. The contact surfaces shall be plated with either tin or silver. Only tin plated terminal lugs shall be used for any electrical connections to aluminum material. Unplated copper or copper alloy terminal lugs shall not be used.

3.13.17 Electron tubes. Unless otherwise specified (see 6.2), electron tubes shall not be used.

3.13.18 Semiconductor devices (other than semiconductor integrated circuits (SIC), see 3.13.20). Rectifiers, voltage reference diodes, voltage regulator diodes, control rectifiers, and transistors shall be chosen in accordance with MIL-PRF-19500, the applicable device detail specification, and as specified in 3.13.18.1 and 3.13.18.2. For choice of non-standard semiconductor devices, see 3.13.1.3.

3.13.18.1 Approval and data on non-standard semiconductor devices. Use of a non-standard semiconductor device shall be approved by NAVSEA.

3.13.18.2 Electrostatic discharge (ESD) susceptible items. Electronic parts and assemblies that are subject to ESD damage shall be handled and packaged in accordance with MIL-STD-1686 and using the guidance provided in MIL-HDBK-263. Electrostatic discharge sensitive (ESDS) parts shall be marked in accordance with MIL-STD-129. ESDS assemblies shall be marked with the sensitive electronic device symbol in accordance with MIL-STD-129. A caution statement in accordance with MIL-STD-1686 shall be placed adjacent to the ESDS symbol. The symbol shall be located in a position readily visible to personnel when the assembly is incorporated in its next higher assembly. When physical size or orientation of the assembly precludes compliance with this requirement, alternative marking procedures shall be developed and implemented upon concurrence by the acquiring activity. Equipment containing ESDS parts shall be marked with the ESDS electronic device symbol and caution statement. The symbol shall be located on the exterior surface of the equipment and readily visible to personnel prior to gaining access to ESDS parts and assemblies with the equipment.

3.13.19 Spike voltage suppressors. Spike voltage suppressors in accordance with MIL-PRF-32167, such as metal oxide varistors (MOVs) or controlled-avalanche rectifier diodes, shall be used to limit excessive voltage excursions.

3.13.20 Microcircuits. Standard microcircuits or integrated circuits shall be in accordance with MIL-PRF-38535. Only microcircuits that are enclosed in hermetically sealed cases shall be used.

3.13.21 Filters. Refer to MIL-F-18327 for guidance on high pass, low pass, band pass, notch band suppression, and conduction of electrical filters.

3.13.22 Contactors, motor starters, and controllers. Contactors, motor starters, and controllers shall be in accordance with MIL-DTL-2212.

3.13.23 Transducers.

3.13.23.1 Differential pressure. Refer to MIL-D-24304 for guidance on differential pressure transducers.

3.13.23.2 Pressure. Refer to MIL-P-24212 for guidance on pressure transducers.

3.13.23.3 Temperature. Temperature transducers shall be in accordance with MIL-T-24387 or MIL-T-24388.

3.13.23.4 Thermistors. Thermistors shall be in accordance with MIL-PRF-23648.

3.13.23.5 Liquid level. Refer to MIL-L-23886 for guidance on liquid level transducers.

3.13.24 Transformers and inductors. Transformers and inductors, including fixed, saturable, and saturating types, shall be in accordance with MIL-PRF-27, MIL-T-15108, MIL-I-1361, MIL-PRF-21038, MIL-PRF-15305, MIL-T-16315, and MIL-T-17221. The use of transformers and inductors not approved under the above specifications shall be approved by NAVSEA.

3.13.25 Connectors, plug and receptacle types. When plug-in connectors are used (see 3.12.2.4 and 3.12.2.8 for conditions and limitation), the following requirements shall apply. The mating parts of all connectors shall be furnished with the equipment. Connector plugs or receptacles which continue to be energized after unmating shall have socket contacts. Externally mounted connectors shall be provided with a protective cap. The protective cap shall be affixed adjacent to the connector receptacle. Connectors shall be as specified in 3.13.25.1 through 3.13.25.3.

3.13.25.1 Electrical connectors. Connectors shall be selected in accordance with MIL-STD-1353. Circular connectors intended to mate with shipboard jacketed cable shall be selected from the insert arrangements identified in MIL-STD-1683.

3.13.25.2 Shield grounding ferrules. Shield grounding ferrules shall be insulated crimp type in accordance with SAE-AS21608.

3.13.25.3 General utility connectors. Connectors used to provide power to protected portable auxiliary equipment shall be of the parallel bladed three-wire grounding type in accordance with W-C-596 and W-C-596/13. Connector receptacles shall be in accordance with W-C-596/12. Plugs and receptacles shall be in accordance with MIL-DTL-2726.

3.13.26 Printed wiring assemblies. Printed wiring assemblies shall conform to the following:

a. Unless otherwise specified herein, the printed wiring assemblies shall be manufactured and inspected to comply with the design requirements of IPC-2221.

b. A conformal coating in accordance with IPC-2221 shall be provided on all boards. Only Type AR conformal coating shall be used for new design PWAs unless otherwise approved by NAVSEA. However, Type AR, SR, UR, or XY conformal coating may be used for assemblies that are considered non-repairable (i.e., throwaway assemblies). The coating shall be easily removable by means of a soldering iron without damage to the printed wiring board and shall be inspected to the acceptance criteria of IPC-2223.

c. Refer to MIL-PRF-55110 for guidance on rigid printed wiring boards. All other printed wiring boards shall be in accordance with MIL-PRF-31032.

d. Printed wiring boards shall be plug-in, and shall include a keying provision so that it is not possible to insert a board into the wrong location. A track shall be provided to guide the wiring board into place to assist installation.

e. All mounting hardware shall be captive. No special tools shall be required to remove or install a printed wiring board.

f. An extender board shall be provided to assist in troubleshooting the printed wiring assembly and shall extend all printed wiring circuits including ground. Test jacks shall be provided for each conductor on the extender board, which will accept test probes with the probe axis perpendicular to the board surface. These test jacks shall be accessible with the assembly being tested installed on the extender board and without removing any other assembly.

g. Unless otherwise specified (see 6.2), printed wiring boards or conductor patterns or both shall not be repaired. This requirement applies to the board laminate, printed conductors, and terminal areas and is not intended to prevent replacement of defective parts mounted on a printed wiring board. Printed circuit boards that are an integral part of a component or an assembly, and are not intended to be readily removed from the component, but are considered repairable shall conform to 3.13.26a through 3.13.26d.

h. Part attachment and mounting shall be in accordance with IPC-2221 except as follows:

(1) Parts for mounting on circuit boards shall be such that the part's operating surface temperature does not exceed 212 °F (100 °C) under the printed wiring assembly worst case uncoated operating conditions.

(2) Axial-leaded parts attached to standoff terminals shall be mounted in accordance with IPC-2221 and the following: Parts having axial pigtail leads and not requiring body clamps shall be secured between solder-type terminals. The distance between terminals (center-to-center) shall be equal to, or greater than, the distance equal to the sum of, (a) the maximum size (including tolerance) of the part, (b) the shank diameter of the terminal, and (c) $^3/_8$ of an inch. Unless otherwise required to achieve component lead stress relief, parts shall be centered between terminals in accordance with good workmanship; where terminal spacing approaches the minimum clearance, parts shall be centered between the terminals to $\pm ^1/_{32}$ inch. Guidance for provisions for stress relief and component lead bends and lead radii can be found in MIL-HDBK-454 and shall be made on all conductors.

(3) Transistors and integrated circuits with pigtail leads having one or more leads terminating at standoff terminals shall be held in place by means of clamps. Clamps shall also be provided if the device surface from which the leads project is not parallel to and toward the board surface.

3.13.27 Non-repairable assemblies. A group of electrical or electronic parts may be packaged as a non-repairable assembly upon compliance with the requirements herein. A non-repairable assembly is intended to be discarded in case of failure. All parts of non-repairable assemblies shall meet the specifications set forth herein.

3.13.27.1 Non-repairable assemblies with printed wiring. When non-repairable assemblies have printed wiring, the requirements of 3.13.26a through 3.13.26d shall apply, except for the marking of circuit part designations, polarities, and connection points.

3.13.28 Springs. Compression and extension type helical springs (including garter springs) shall be manufactured in accordance with SAE-AS13572.

3.13.29 Magnetic brakes. Magnetic brakes shall be in accordance with MIL-B-16392.

3.14 Processes.

3.14.1 Treatment and processing of metals for corrosion resistance. Parts made of ferrous metal (except corrosion-resistant metal listed in 3.3.2.3) or of aluminum shall be treated, coated, plated, and painted, as applicable in accordance with tables XXI and XXII. Treatment and processing shall not adversely affect the parts for the uses intended. All fabricating operations, such as welding, machining, drilling, and tapping shall have been accomplished prior to treating, coating, plating, or painting except that paint may be removed from tapped holes.

TABLE XXI. Processing of metals for corrosion resistance treatments where painting is not required. 1/, 2/

Metal	Treatment	Treatment document
Corrosion-resistant (see 3.3.2.3)	Not required	----
Ferrous metals	Aluminum coating, ion vapor deposited	MIL-DTL-83488, Class 3, Type II 3/
	Zinc coating (hot-dip galvanizing) 4/	ASTM A153/A153M
	Electrodeposited zinc 4/	ASTM B633
	Electrodeposited nickel	SAE-AMS-QQ-N-290, Type I (DS), or ASTM B456
	Nickel undercoat plus electrodeposited chromium	SAE-AMS-QQ-N-290, Type I (DS), or ASTM B456, Type DS, and SAE-AMS2460
	Electrodeposited silver	ASTM B700
Aluminum and aluminum alloys	Anodic treatment 5/	MIL-A-8625

NOTES:
1/ Corrosion-resistant metal or metals processed for corrosion resistance may be painted for appearance and as specified in 3.14.2.1.
2/ Tin plating on copper conductors is at the option of the manufacturer.
3/ These coatings have superior corrosion resistance in marine atmosphere and are preferred.
4/ Unpainted zinc coatings shall not be used on equipment or parts to be packed in unventilated containers made of unseasoned wood, unless desiccant is enclosed.
5/ Anodized treatment is considered electronically non-conductive.

TABLE XXII. Painting of metal for corrosion resistance. [1/]

Metal	Pretreatment	Primer [2/]	Topcoats
	Specification	Specification minimum thickness (millimeters) [3/]	Specification minimum thickness (millimeters) [3/]
Ferrous metal	TT-C-490, Type I, II; TT-P-645 or MIL-DTL-53084	0.025	
Ferrous metals with treatments other than those listed in table XVIII	TT-C-490, Type III; MIL-DTL-24441	0.05; Formula 150	MIL-DTL-15090 [4/], 2 coats Type II or each 0.025 Type III
Ferrous metals and aluminum alloys both used in same assembly [5/]	TT-P-645	0.025	Class 2 second coat may be omitted on inside of enclosure and equipment to be installed in interior of ships [6/]
Aluminum and aluminum alloys	MIL-DTL-53084; TT-C-490, Type I; MIL-DTL-5541, Type II, Class 1A	0.025	For MIL-DTL-5541 pretreated materials, only a single coat should be added to equipment installed interior or exterior of the ships [6/]

NOTES:
1/ For details on painting procedures, see 3.14.2.
2/ The preferred primer is MIL-DTL-53084. TT-P-645 is second preference. If MIL-PRF-24712 is chosen as a topcoat, no primer is required.
3/ Minimum dry film thickness.
4/ Applies to ferrous metals.
5/ For metals in direct contact, see 3.4.2.1.
6/ MIL-PRF-24712 is the preferred topcoat applied in one coat at 0.0049 to 0.0098 in. (0.125 to 0.250 mm). MIL-DTL-15090, Types I, II, or III, Class 1 is second preference.

3.14.1.1 Interior surfaces of motors and generators. In case of salient pole motors and generators, metal surfaces of armatures, rotors, and other rotating members shall be coated with insulating varnish. Non-rotating interior surfaces of motors and generators may either be coated with insulating varnish or treated and painted as required for other parts (see 3.14.1). When insulating varnish is used, no other treatment or processing is required. Insulating varnish may be applied during the normal varnishing process required for windings or applied as a separate process. Unless otherwise specified in the individual equipment specification or the contract or order, a minimum of two coats shall be applied, using any method which will ensure coverage of all surfaces. Insulating varnish shall be in accordance with MIL-I-24092.

3.14.2 Painting. The preferred painting method for prevention of corrosion and for environmental reasons is powder coating. Powder coatings used shall be approved in accordance with MIL-PRF-24712.

3.14.2.1 Parts to be painted. Where necessary to obtain corrosion resistance, metal parts, except those of 3.14.2.2, shall be painted. Surfaces of corrosion-resistant metal (see 3.3.2.3) may be painted for appearance. When a gray painted exterior is specified (see 6.2), exterior parts, except those cited in 3.14.2.2, shall be painted whether or not corrosion-resistant.

3.14.2.2 Parts not to be painted. The following parts shall not be painted. Except for grounding contact surfaces and machined metal-to-metal fits, corrosion resistance shall be required and shall be achieved by the use of inherently corrosion-resistant materials, by processes other than painting, or through the nature of the application (example: parts normally covered with grease or oil-film).

a. Grounding contact surfaces (including equipment mounting pads, feet, and so forth).

b. Machined metal-to-metal fits.

c. Parts which if painted, would not function properly.

d. Sealing surfaces of gaskets and packing.

e. Heat exchanger surfaces of water air-cooled equipment.

f. Identification, operating, safety, and warning label plates.

g. Oil holes, grease cups, and grease pipes of machinery.

h. Surfaces that make contact with oil or grease.

i. Bearings and bearing surfaces.

j. Electric wire coils and windings.

k. Commutators, collector rings, brushes, brush holders, and brush rigging.

l. Peripheries of rotating parts of motors and generators and any areas on these parts from which the paint might be thrown by centrifugal force.

3.14.2.3 Normal painting procedure. Except for large parts temporarily stored outdoors (see 3.14.2.4), the sequence of operations shall be as follows:

a. Complete fabricating operations, such as welding, machining, drilling, and tapping.

b. Remove welding flux.

c. Remove grease, oil, and dirt by solvent wiping, vapor degreasing, or caustic washing and rinsing.

d. Remove rust and other visible corrosion products.

e. Apply chemical pretreatment in accordance with Type I or II of TT-C-490 or TT-P-645.

f. Apply primer and then topcoat.

3.14.2.4 Large ferrous metal parts stored outdoors temporarily. One of the following procedures shall be used when large ferrous metal parts are stored outdoors temporarily, prior to welding and machining operations:

Procedure 1:

a. Prior to storage out-of-doors:

(1) Remove welding flux.

(2) Remove grease, oil, and dirt by solvent wiping, vapor degreasing, or caustic washing and rinsing.

(3) Remove rust and other visible corrosion products by abrasive blasting to near-white metal in accordance with SSPC-SP 10.

(4) Apply chemical pretreatment in accordance with Type I of TT-C-490, one coat of MIL-PRF-24712 or primer coating in accordance with TT-P-645, and two coats enamel topcoat in accordance with Type III, Class 2 of MIL-DTL-15090. MIL-PRF-24712 is the preferred coating system.

b. After storage out-of-doors:

(1) Complete all fabricating operations, such as welding, machining, drilling, and tapping. Remove paint, if necessary, before welding.

(2) Repeat steps a(1), a(2), and a(3).

(3) Remove all damaged paint and touch up with pretreatment and primer (see table XIX).

(4) Apply topcoat.

Procedure 2:

a. Prior to storage out-of-doors:

(1) Apply corrosion protection in accordance with Grade 1 of MIL-PRF-16173.

b. After storage out-of-doors:

(1) Remove corrosion protection with solvent.

(2) Complete fabricating operations and follow normal painting procedures as specified in 3.14.2.3.

3.14.3 Soldering. Only non-corrosive fluxes shall be used unless it can be shown that all corrosive products have been satisfactorily removed or neutralized after soldering. Soldering materials and processes shall be in accordance with J-STD-001. Soldered connections shall be of such character and quality that the bending between the soldered items may be determined by visual examination. Excessive amounts of solder shall not be used. Soldering alone shall not be depended upon for a satisfactory connection. Where wire and terminals are joined to be soldered, the wire shall be hooked, wrapped around, or otherwise secured to the terminals, prior to soldering. Solder for connection of electrical windings and parts shall be as specified in 3.14.3.1 and 3.14.3.2, respectively.

3.14.3.1 Solder for windings. Solder for connection of electrical windings shall be in accordance with one of the compositions shown in table XXIII.

TABLE XXIII. Solder for connection of electrical windings.

Windings	Solder composition 1/
Class 105 or 130 insulation, stationary	Sb5 1/, Sn60 1/, Sn63 1/, tin 2/
Class 105 or 130 insulation, rotating	Sb5 1/, tin 2/
Class 155, 180, and 200	Sn10 1/

NOTES:
1/ Composition in accordance with J-STD-004, J-STD-005, and J-STD-006.
2/ Commercially pure tin. Use of tin solder shall be limited to equipment known to be intended for installation in interior of ship.

3.14.3.2 Solder for parts. Solder for connections of electrical and electronic parts shall be composition Sn60 or Sn63 of J-STD-004, J-STD-005, and J-STD-006.

3.14.4 Brazing. Brazing alloys for electrical connections shall be in accordance with S9086-CH-STM-010/074 or QQ-B-654. Brazed electrical connections shall not be used where disconnection and reconnection for maintenance purposes is required.

3.14.5 Welding.

3.14.5.1 Structural welding. Structural welding and applied processes shall be in accordance with S9074-AR-GIB-010/278 with the following exception. Welding practices in accordance with applicable American Welding Society (AWS) specifications may be used for welding applications not referenced in S9074-AR-GIB-010/278. Structural welding and allied processes of S9074-AR-GIB-010/278 will be supplemented as follows:

a. Spray metalizing of shafts will not be permitted.

b. Efficiency of welded joints for motors and generators shall be as follows:

(1) Rotating parts – 100 percent.

(2) Stationary parts subject to stress – 80 to 100 percent.

(3) Stationary parts not subject to stress – as required to meet applicable impact shock requirements.

3.14.5.2 Welding of electrical connections. Welds and welding processes for electrical connections shall be in accordance with MIS-PRF-53095.

3.15 Thermal design.

3.15.1 Selection of the cooling system. The removal of heat to maintain proper operating temperatures shall be accomplished by one of the following, listed in order of preference:

a. Natural convection, conduction, and radiation.

b. Forced air (self-contained).

c. Forced air (not self-contained).

d. Fresh water air cooler.

e. Salt water air cooler.

f. Other methods such as cooling oil or water in proximity or indirect contact with active electrical components.

The individual equipment specification shall indicate the type of cooling to be used. The method selected shall apply the design principles using the guidance provided in MIL-HDBK-251.

3.15.1.1 Air coolers.

3.15.1.1.1 General design requirements. For forced air plenum designed systems for cooling electronic components, a redundant design system shall be used requiring full performance if any one of the redundant forcing elements is non-operational. An alarm system shall be incorporated to indicate loss of forced air or status of redundant element.

3.15.1.1.2 Specific cooling systems.

3.15.1.1.2.1 Air coolers for motors and generators. Air coolers for motors and generators shall be in accordance with MIL-C-19836 and the applicable air cooler part of MIL-DTL-2036.

3.15.1.1.2.2 Air coolers for assembled hardware. Guidance for air coolers for assembled hardware consisting of transformers, semiconductor devices, resistors, capacitors, and so forth, can be found in MIL-HDBK-454.

In addition, heat dissipaters for semiconductor devices shall be constructed of metallic material (see 3.3.2) which is corrosion-resistant, or which is treated or coated (see 3.14.1) to resist corrosion. Heat conduction surface contacts and electrical surface contacts shall not be painted or anodized, but shall be plated, or otherwise coated, to form surfaces to which the connections or junctions are made. These surface windows shall retain mechanical, thermal, and electrical effectiveness for the life of the equipment.

3.15.1.2 Liquid coolers. Liquid coolers for electronic equipment shall be in accordance with DOD-STD-1399-532. Visual indication for liquid coolant level shall be provided.

3.15.1.2.1 General design requirements. The design of electrical equipment using liquid cooling shall include the following:

a. Provisions for thermal shutdown following alarm with continual operation of cooling devices to avoid continued increase in temperature.

b. The degree of operability as well as the time period of operability for 100 percent loss of cooling fluid clearly marked on the cooler.

c. Provisions for cooling during maintenance.

3.15.1.2.2 Design and placement of parts. The design and placement of all parts of the water cooling circuit shall include the following:

a. Vents and drains, as necessary, to allow complete filling, draining, and venting of the cooling system.

b. Minimum possibility of water striking electronic parts or electrical circuitry should a leak occur.

c. Means to prevent liquid level build up in the event of a leak.

d. Electrical components removable and replaceable without disrupting the cooling circuit, if possible.

3.15.1.2.3 Hoses, fittings, and piping systems. Designs for piping systems using flexible hose assemblies shall consider S6430-AE-TED-010 for such systems.

3.15.1.2.3.1 Teflon hose. Teflon hose and hose assemblies shall be in accordance with MIL-H-24592.

3.15.1.2.3.2 Clamps. Hose clamps shall not be used.

3.15.1.2.3.3 Piping and fittings. Piping, fittings, and valves of the cooling system shall be in accordance with MIL-STD-438 and MIL-STD-777.

3.15.1.2.4 Heat exchangers. Heat exchangers shall be located so that water from leaks and condensation will not fall on electrical circuitry. Drains shall be provided at the bottom of enclosure for removal of this water. Heat exchangers shall be easily removable without removal of or damage to adjacent parts or electrical circuitry and shall be in accordance with MIL-C-15730.

3.15.1.2.5 Direct cooling of electrical components. The preferred water source for direct cooling of electrical components shall be the Electronics and Auxiliary Fresh Water (EAFW) system on submersible vessels and the Electronic Cooling Water (ECW) systems on surface ships whose characteristics (pressure and temperature) shall be in accordance with DOD-STD-1399-532. All other fresh water sources including machinery fresh water (MFW), diesel fresh water (DFW), chilled water (CW), and potable water (PW) on surface ships, and engine room fresh water (ERFW), propulsion plant fresh water (PPFW), and chilled water (CW) on submersible vessels used for direct cooling of electrical components shall require:

a. Deionization systems which are self-contained with purification equipment, purity sensors, and alarm systems.

b. Imposed electric potential differences between metal surfaces in contact with non-deionized cooling water is prohibited.

c. Direct cooling with insulating oil shall require that the insulating oil used for heat exchanges be self-contained with purification equipment. Oil characteristics should be in accordance with SAE-AMS-H-81829.

3.16 Mechanical features.

3.16.1 Castings. Equipment may include cast or fabricated construction. Guidance for castings can be found in MIL-HDBK-454.

3.16.2 Panel-mounted parts. Protection for panel-mounted parts may be accomplished by the use of auxiliary sealing devices in accordance with MIL-DTL-5423.

3.16.3 Fastening devices. Panels, covers, and access doors shall be secured to the equipment by means of fastening devices such as captive bolts or screws, draw bolts, trunk fasteners, dogs, levers, and latches in order to provide quick and easy access to the interior.

3.16.4 Handles and control knobs. Handles and control knobs shall conform to the requirements of the individual equipment specification. When a specification does not include requirements for control knobs, they shall be selected from NASM3926. Handles and control knobs shall be firmly secured to the control shafts by the use of setscrews, for which the setscrew contact to the shaft is a flat surface.

3.16.5 Metallic inserts. Metallic inserts for the securing of screws or studs shall be held in the base material so that they will not rotate when the screws or nuts are tightened or loosened. Staking as a means of securing the inserts shall not be permitted (see 3.2.24.5).

3.16.6 Pins. Pins or slotted tubular spring pins and inserts shall be of austenitic corrosion-resistant steel, nickel-copper alloy, or another corrosion-resistant alloy so that corrosion does not occur and affect disassembly. When a non-magnetic material is required, austenitic corrosion-resistant steel shall be used. If the pin is galvanically incompatible with mating insert (see MIL-STD-889), the pins should be coated with an anti-seize or sealant compound that will reduce corrosion and seizing.

3.16.7 Rounded corners and edges. Projections and overhanging edges which may cause personal injury or catch upon clothing shall be avoided. Unless otherwise specified (see 6.2), edges and corners of external surfaces shall be rounded to a minimum radius of 0.04 inch [1 millimeter (mm)], and exposed corners to a minimum of 0.5 inch (13 mm), if practical.

3.16.8 Countersinking. Drilled and tapped holes shall not be countersunk, except as specified in 3.2.24.9.3 and the individual equipment specification (see 6.2).

3.16.9 Marking for rotation. Rotating parts shall be marked in a permanent manner to show the direction of rotation where applicable to the specific function of the equipment.

3.16.10 Lubrication design and lubricants. Guidance for the design for lubrication of equipment can be found in MIL-HDBK-267. As few lubricants and as few tools and accessories as practicable shall be required. Points requiring periodic lubrication shall be conveniently accessible. In this connection, consideration shall be given to the probable installed location of the equipment. Guidance for lubricants, lubrication charts, and instruction plates can be found in MIL-HDBK-267. Grease-lubricated ball bearings shall be lubricated by means of compression grease cups and grease drain plugs. Unless otherwise specified in the applicable equipment specifications, grease type lubricants for antifriction bearings shall be in accordance with DOD-G-24508. For general purpose and high performance shipboard antifriction bearing applications, MIL-PRF-24139 shall be used for low hoist applications with maximum bearing temperature below 230 °F (110 °C) and MIL-PRF-81322 for maximum bearing temperatures between 230 °F (110 °C) and 347 °F (175 °C).

3.16.11 Electrical bonding. Protective finishes shall be omitted at those points where the presence would prevent proper electrical bonding as required for shielding or connection. Provision shall be made to ensure permanence of electrical contact between the surfaces of all parts in contact over long periods of time or in the presence of humid saline atmospheres (see 3.14.2.2).

3.16.12 Test points. Test points shall be provided where practicable to simplify routine maintenance, troubleshooting, and calibration of the equipment (for example, checking significant voltages, currents, and waveforms and the insertion of test signals). The test points shall be capable of being utilized during normal operation without affecting the equipment performance. When the maintenance or operation of equipment employing potentials in excess of 2,000 V requires that these voltages be measured, the equipment shall be provided with test points that permit all the high voltages to be measured at potential levels of less than 1,000 V relative to ground. This shall be accomplished through the application of voltage dividers or other techniques such as the use of safety type panel meters and multipliers. The voltages specified herein shall be interpreted as applying to DC, AC, and DC plus AC voltages.

3.17 Plates for identification and information. Plates for identification and for information (including plates for warning and caution) shall be designed and installed in accordance with MIL-DTL-15024, MIL-P-15024/5, and the requirements herein.

3.17.1 Type of service. The requirements of MIL-P-15024/5 for plates for normal service shall apply, except that for plates to be used in locations exposed to the weather, the requirements of MIL-P-15024/5 for severe service shall apply.

3.17.2 Mounting of plates. Plates shall be mounted by means of screws in tapped holes, screws held by captive nuts, screws held by nuts on the opposite side of the panel or chassis, or by self-tapping screws. Aluminum screws shall not be used.

3.17.3 Color style of plastic plates. The color style of plastic plates shall be in accordance with Type II of MIL-DTL-15024, except as otherwise specified herein or in the individual equipment specification.

3.17.4 Identification plates. Identification plates shall be in accordance with MIL-DTL-15024 and MIL-STD-130 (see 6.2).

3.17.4.1 Warning and caution plates. Warning and caution plates shall be formatted in accordance with ANSI/NEMA Z535.2 and ANSI/NEMA Z535.4.

3.17.4.2 High voltage. Danger signs shall be supplemented by physical barriers or other positive protection where feasible. Signs reading "DANGER – HIGH VOLTAGE" or "DANGER (insert maximum voltage) VOLTS" shall be displayed prominently on safety covers, access doors, and inside equipment where hazardous voltages are exposed. Markings on electrical equipment shall be in accordance with Article 510 of the NFPA 70.

3.17.4.3 Illuminated plates. Illuminated plates shall be in accordance with MIL-DTL-7788.

3.17.5 Control setting indicators. Dials of controls shall be marked numerically or alphabetically so that an increase in the value of the setting results in an increase in the effect controlled. Reverse relationships, if required, shall be as specified in the individual equipment specification (see 6.2). Where verniers are employed for fine control, the marking and numbering shall provide continuity throughout the dial range.

3.18 Identification of parts.

3.18.1 Identification of part leads. For each polarized part, such as electrolytic capacitors and rectifiers, except for stud mounted diodes, the polarity identification shall be marked on the part mounting surface in order to ensure proper replacement of the part. For multiple lead parts such as transistors, where proper circuit operation is dependent on a specific lead hookup, appropriate lead identification shall be marked on the part mounting board to ensure proper placement and replacement of the part.

3.18.2 Method of marking. Markings shall be permanent and legible. The markings on plastic or metallic materials shall be made by stamping, engraving, stenciling, or rubber stamping with smudge-proof ink covered with a coat of clear lacquer or silk screening. Decalcomanias or paper labels shall not be used.

3.19 Requirements for operating voltages greater than 1,000 V, but less than or equal to 15,000 V.

3.19.1 Medium and high voltage power requirements.

3.19.1.1 Medium voltage DC power systems. Unless otherwise specified (see 6.2), medium voltage DC powered equipment shall operate satisfactorily and adhere to user equipment interface requirements in accordance with IEEE 1709.

3.19.1.2 High voltage input power. Unless otherwise specified (see 6.2), AC powered equipment shall operate satisfactorily and adhere to user equipment interface requirements in accordance with MIL-STD-1399-680.

3.19.2 Wire.

3.19.2.1 1,000 to 5,000-V hook-up wire. 1,000 to 5,000-V hook-up wire shall be in accordance with MIL-DTL-24643 and IEEE 1580. Additional guidance can be found in MIL-HDBK-299. 1,000-V wiring shall be selected from MIL-DTL-24643/14, /15, /16, /17, /18, /19, /20, /48, /49, /50, /51, /67, /68, /72, /73, and MIL-DTL-16878/15. 3,000 to 5,000-V wire shall be selected from MIL-DTL-24643/22 and /53 and MIL-DTL-16878/16.

3.19.2.2 5,000 to 15,000-V hook-up wire. 5,000 to 15,000-V hook-up wire shall be in accordance with ANSI/NEMA-WC-74/ICEA S-93-639 and IEEE 1580.

3.19.2.3 Wire methods.

3.19.2.3.1 Wire practices. The recommended practices for 1,000 to 15,000-V marine cable shall be in accordance with IEEE 1580 and ANSI/NEMA CC 1.

3.19.2.3.2 Wire connections and terminals. 1,000 to 15,000-V connections, connectors, and terminals shall be designed, installed, and tested in accordance with ANSI/NEMA CC 1. Common types of connectors are shown in Annex E of ANSI/NEMA CC 1.

3.19.2.3.3 Bus bars. Bus bars shall be designed and installed in accordance with ANSI/NEMA CC 1.

3.19.2.3.4 Connection marking. Connections shall be marked in accordance with ANSI/NEMA CC 1.

3.19.3 Fuses, expulsion and current limiting fuses, and fuse disconnecting switches.

3.19.3.1 Fuses and fuse disconnecting switches design. 1,000 to 15,000-V fuses and fuse disconnecting switches standard service conditions and definitions are defined in IEEE C37.40. Fuses and fuse disconnecting switches shall be designed and tested in accordance with IEEE C37.42 and IEEE C37.47.

3.19.3.2 Expulsion and current limiting fuses and fuse disconnecting switches design. Expulsion and current limiting fuses and fuse disconnecting switches shall be designed and tested in accordance with IEEE C37.46.

3.19.3.3 Fuses, expulsion and current limiting fuses, and fuse disconnecting switches application, operation, coordination, and maintenance. 1,000 to 15,000-V fuses, expulsion and current limiting fuses, and fuse disconnecting switches shall be applied, operated, coordinated, and maintained in accordance with IEEE C37.48 and IEEE C37.48.1.

3.19.4 Circuit breakers.

3.19.4.1 Circuit breakers. 1,000 to 15,000-V circuit breakers shall be designed, rated, constructed, and tested in accordance with IEEE C37.04 and IEEE C37.09. Preferred circuit breaker for primary power shall be vacuum type (VCB) and shall be Navy-approved (see 6.2).

3.19.4.2 Generator circuit breakers. Generator circuit breakers shall be designed, rated, constructed, and tested in accordance with IEEE C37.013.

3.19.5 Switches. 1,000 to 15,000-V switches shall be designed, rated, and tested in accordance with IEEE C37.20.4.

3.19.6 Relays. 1,000 to 15,000-V relays and relay systems used to protect and control power apparatus standard service conditions, standard ratings, performance requirements, and testing requirements are specified in IEEE C37.90. Surge tests shall be in accordance with IEEE C37.90.1 and standardized waveforms that are representative of surges observed and measured in actual installations should be applied to the terminals of the relay system. The relay or relay system shall be able to withstand the applied surges without damage to components and without operating incorrectly. Susceptibility tests shall be in accordance with IEEE C37.90.2. Tests conducted on the relay or relay system should evaluate the susceptibility of the relays and relay system under frequencies they will be subjected to aboard ship.

3.19.7 Insulators. 1,000 to 15,000-V insulators for oil-filled transformers and oil-filled reactors shall have the requirements of IEEE C57.19 and have these requirements verified by the tests defined in IEEE C57.19.

3.19.8 Current transformers. Current transformers shall meet the requirements of IEEE C57.13. Iron core current transformer coil output current shall be analog signals. When specified (see 6.2), alternatives to current transformers shall be allowed that meet the applicable performance requirements of IEEE C57.13. Rogowski current transformers shall meet the application characteristics of IEEE C37.235 and testing requirements of IEC 60044-8.

3.19.9 Maintenance safety.

3.19.9.1 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 4.6.4).

3.19.9.2 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.

3.20 Information assurance (IA). Electrical equipment that contains interfaces for external digital communications, whether used or unused, shall implement an IA plan approved by NAVSEA. Refer to NIST Special Publication (SP) 800-82 for guidance. See 6.2 for other IA requirements.

4. VERIFICATION

4.1 General. Examination and tests shall be as specified herein and in the individual equipment specification. Sampling for examination and tests shall be as specified in the individual equipment specification (see 6.2).

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

a. Manufacturing screening tests (see 4.3).

b. Conformance inspection (see 4.4).

4.3 Manufacturing screening tests. Manufacturing screening tests are exclusively required for electronic systems and only those portions of electric power equipment that are predominantly electronic, such as printed wiring assemblies and subassemblies containing semiconductors. These tests shall include the temperature cycling and random vibration tests of MIL-HDBK-344 using the process guidance found in MIL-HDBK-2164. The purpose of the tests is to stimulate the early occurrence of failures due to manufacturing defects in both parts and workmanship. A 100-hour burn-in test (see 4.3.3) may be performed in lieu of environmental stress screening.

4.3.1 Level of testing. Screening tests shall be performed on equipment having both first article requirements and qualification requirements as specified in the individual equipment specification (see 6.2).

4.3.2 Environmental stress screening test procedures and sequence. Test procedures shall show the chosen system or subsystem. Tests of complete equipment that are referred to as "solid state" shall be tested in entirety, unless capabilities of available test equipment cause limitations of equipment size that can be tested. Testing should follow the process guidance provided for the environmental test screening constituents as defined in MIL-HDBK-2164. The test sequence shall be random vibration, thermal cycling, and random vibration. Thermal cycling shall be a minimum of 10 cycles for all equipment for temperature ranges defined in the applicable equipment specification. If vibration tests require subcontracting effort, these tests may be accomplished independent of thermal cycling and the test sequence as defined by MIL-HDBK-2164. Test results shall show defect-free operation after the random vibration test of circuit cards and assemblies.

4.3.2.1 Circuit card vibration testing. All circuit cards shall be given a random vibration test hard mounted to the test table according to the random vibration spectrum of figure 1. A supplementary test system must be provided to verify card failures of electrical nature to be used before and after the test. Multiple cards may be tested at one time, in the unenergized card mode, at standard ambient test temperature. The preferred axis of vibration for circuit cards will be in a direction perpendicular to the plane of the card. Dual axis testing (at a 45-degree angle) is acceptable provided that levels of the random vibration spectrum of figure 1 are achieved in the direction perpendicular to the plane of the card. The test sequence shall be a run of 5 minutes of pre-defect-free operation, followed by 5 minutes of defect-free vibration. Failures must be treated using the guidance found in MIL-HDBK-2164, and be defined according to the pre-test supplementary test system results. Circuit card testing shall be preliminary to complete assembly and subassembly testing.

4.3.2.2 Vibration and thermal cycling of assemblies and subassemblies. The preferred method is to evaluate the total system rather than system parts using the guidance for the environmental stress screening test constituent's test sequence in MIL-HDBK-2164. The test sequence shall include preliminary vibration tests, preliminary thermal cycling, failure-free thermal cycling, and final failure-free vibration testing. Testing of subsystems is acceptable if equipment to evaluate a total system is not available or the total system includes other electrical components which do not require environmental stress screening such as generators, motors, and so forth.

4.3.2.3 Vibration axis. Where electronic components of assemblies and subassemblies are oriented in more than one plane, such equipment should be shaken sequentially in predetermined selected axis considered essential and presented in the test plan. Where vibration in more than one axis is required, the duration of random vibration should be at least 5 minutes for each axis during the periods indicated in MIL-HDBK-2164.

4.3.2.4 Equipment energization. Equipment shall not be electrically energized for random vibration testing, although energization should begin immediately thereafter to confirm failure-free operation. Equipment shall be energized for thermal cycling, although for high power systems, equipment shall be operated at minimum load level. The last thermal cycle shall be an increase. The equipment shall be turned off during chamber cool-down of thermal cycling to permit internal parts to become cold. Full power load accommodation (for equipment so characterized) shall be demonstrated immediately after temperature cycling, followed by a random vibration defect-free run of 5 minutes.

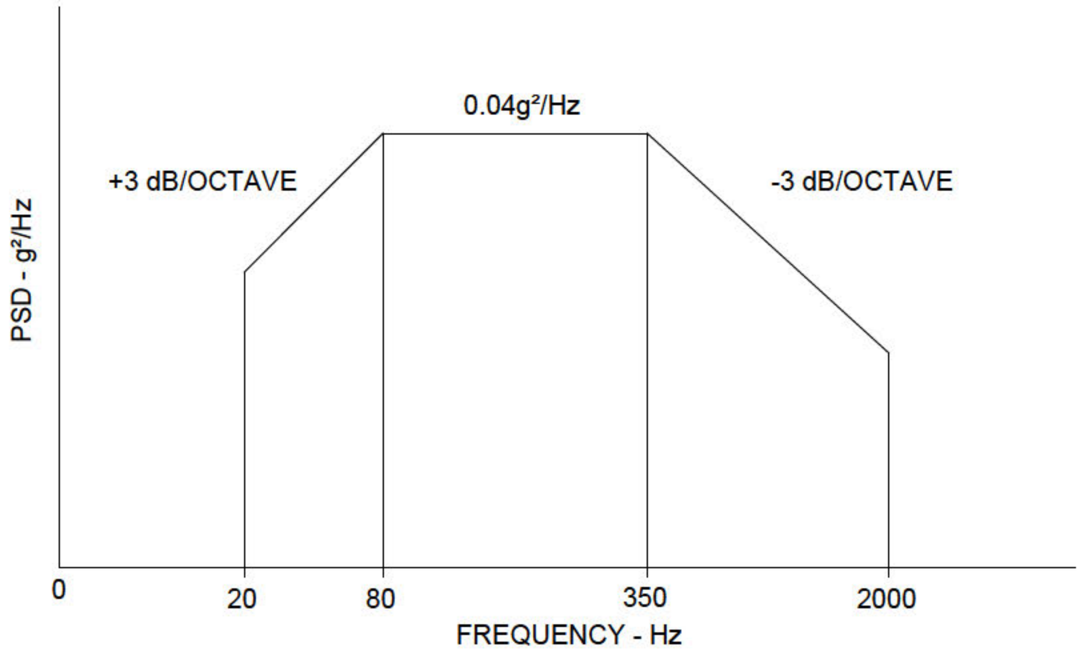

FIGURE 1. Random vibration spectrum.

4.3.3 100-hour burn-in test. This test can be run in lieu of environmental stress screening (see 4.3.2). The 100-hour burn-in test shall be conducted by energizing the equipment for 100 hours at nominal voltage and frequency, ambient temperature, and with all inputs and outputs connected to effect maximum rated loading. If a failure occurs during this testing, the equipment is to be repaired and the test continued from the point where the failure occurred.

4.4 Conformance inspection. Conformance inspection shall include the tests of table XXIV and the examinations of table XXV. These examinations and tests detect deviations from detail design, ability to meet the application environment, and detect hidden defects of materials. Each piece of naval shipboard electric power equipment developed to the detailed requirements of this specification shall be examined for compliance with the requirements specified in table XXIV or in the individual equipment specification developed using this specification. The element of inspection shall encompass all visual examinations and dimensional measurements. The examinations shall be conducted using the classifications of defects as specified in table XXV as applicable or in the individual equipment specification developed using this specification. Non-compliance with any specified requirements or presence of one or more defects preventing or lessening maximum efficiency shall constitute cause for rejection.

TABLE XXIV. Conformance inspections.

Tests	Requirements paragraph	Conformance inspection
Reliability demonstration	3.1	4.4.4.1
Maintainability demonstration	3.1	4.4.4.2
Input power	3.2.9	4.4
Inclined operation	3.2.12	4.4
Temperature	3.2.13.1	4.4
Humidity	3.2.13.2	4.4
Shock	3.2.14.1 and 3.2.15	4.4
Vibration	3.2.14.2	4.4
Electromagnetic interference	3.2.16	4.4
DC magnetic field environment	3.2.17	4.4
Magnetic field reduction	3.2.18, 3.2.18.1, 3.2.18.2, and 3.2.18.3	4.4
Noise control - general	3.2.19	4.4
Airborne noise	3.2.19.1	4.4.6
Structureborne noise	3.2.19.2	4.4.6
Leakage current test	3.2.21	4.4.3
Dielectric withstand voltage	3.2.26 and 3.2.26.1	4.4.1
Insulation resistance	3.2.26 and 3.2.26.1	4.4.2
Wind speed	3.2.27 and 3.2.27.1	4.4
Ice	3.2.27 and 3.2.27.2	4.4
Insulation suitability	3.11	4.4.5
Partial discharge test	3.19.9.1	4.6.4
Manufacturing screening	---	4.3, 4.3.1, 4.3.2, and 4.3.3
Low quantity and non-QPL qualified transformers and inductors	---	4.5 and 6.4
Inspection requirements for low quantity and non-QPL transformers and inductors	---	4.5.1 and 6.4

TABLE XXV. Classification of defects.

Categories	Defects	Requirements paragraph
Critical		
001	Design	3.2
002	Conformance with safety requirements	3.2.1, 3.2.6, and 3.19.9
003	Dynamic balancing	3.2.19.3 and 3.2.20
004	Electrical creepage and clearance distances	3.2.22 and 3.2.22.1
005	Piping systems	3.2.23
006	Screw threads for fastening devices	3.2.24
007	Parts, materials, and finishes	3.3 and 3.13
008	Electrical insulation	3.4
009	Dielectric barrier	3.5
010	Coils and windings	3.6
011	Treating methods	3.7
012	Treating materials	3.8
013	Varnish treatment	3.9
014	Final condition	3.10 and 3.11
015	Wire, wiring methods, wire marking, and bus bars	3.12
016	Parts	3.13
017	Processes	3.14
018	Thermal design	3.15
019	Mechanical features	3.16
020	Requirements for operating voltages greater than 1,000 V, but less than or equal to 15,000 V	3.19
021	IA not as required.	3.20
Major		
101	Utilization of standard tools	3.2.25
102	Plates for identification and marking information	3.17
103	Identification of parts	3.18

4.4.1 Dielectric withstanding voltage tests. Dielectric withstanding voltage tests shall be conducted in accordance with Method 301 of MIL-STD-202 as specified (see 6.2). Test conditions shall be as follows:

a. Magnitude of test voltage.

(1) For circuits rated 60 V or less, the rms test voltage shall be 900 V.

(2) For circuits rated more than 60 V, the rms test voltage shall be twice rated circuit voltage plus 1,000 V.

(3) For circuits containing parts that are applied within their specified ratings and are in accordance with part specifications that specify in (1) or (2) herein, the dielectric test voltage for the circuit shall correspond to that specified for the approved part having the lowest specified dielectric test voltage, but in no case less than:

(a) 900 V for circuits connected to the power supply terminals.

(b) 500 V for circuits electrically isolated from the power supply terminals.

(4) For all testing, voltage shall not be applied or removed at other than zero voltage.

b. Nature of test voltage. The test voltage shall approximate a true sine wave of a frequency of 60 Hz.

c. Points of application. The test voltage shall be applied successively between each electrically isolated circuit and ground with all other circuits grounded (see 4.4.2.1). The test voltage should be applied between stationary and rotating windings of rotating equipment when the equipment is at a standstill.

d. Duration of test. The duration of the test shall be not less than 60 seconds. The test voltage shall be removed by adjustment of its value to zero, not by sudden interruption.

e. Definition of failure. Any evidence of arcing, flashover, odor, or punctured insulation shall be interpreted as a failure. Tripping of the test equipment shall also constitute failure.

Dielectric withstanding voltage tests shall be conducted after all other equipment tests have been completed or as otherwise specified in the equipment specification (see 6.2).

4.4.2 Insulation resistance tests. Insulation resistance tests shall be conducted in accordance with Method 302 of MIL-STD-202 as specified (see 6.2). Test conditions shall be as follows:

a. Test potential. Test condition "B" (500 V ±10 percent). For test voltages 4,160 to 13,800 V, refer to MIL-STD-1399-680 for test voltage, conditions, and guidance.

b. Points of measure. Between each electrically isolated circuit and all other circuits connected together to ground [frame, chassis, or enclosure as applicable (see 4.4.2.1)].

c. Electrification time. Sixty seconds minimum for insulation suitability test and only sufficient time to take resistance readings for all other tests.

d. Temperature at time of test. Temperature of parts to be tested shall be measured and recorded. Insulation resistance measurements shall be corrected to 77 °F (25 °C). Correction shall be made on the basis of insulation resistance doubling for each 18 °F (10 °C) decrease in temperature (good approximation). An alternate method for temperature correction is to perform the test and calculate the change in resistance of the conductor insulation in accordance with UL 2556.

4.4.2.1 Electrically isolated circuits. Electrically isolated circuits shall be determined by application of the following criteria:

a. Circuits whose only connection to each other is by electromagnetic coupling through a magnetic core, which is shared in common by the circuits, shall be considered to be electrically isolated from each other.

b. Circuits whose only connection to each other is through a capacitor shall not be considered to be electrically isolated from each other. When the purpose is to test the insulation resistance of circuits internal to the equipment, and only then, such circuits shall be temporarily interconnected with a jumper wire, or test load.

4.4.2.2 Moisture resistance. When specified (see 6.2), the insulation system to be used shall be tested to determine moisture resistance (insulation suitability) as specified in Appendix A.

4.4.2.3 Arc and tracking resistance. Arc resistance tests shall be conducted in accordance with ASTM D2303 or IPC-TM-650 depending on the materials application. Tracking resistance shall be determined in accordance with ASTM D3638 (see 3.4.1.1).

4.4.3 Leakage current test. Testing for leakage current through a human body simulated impedance shall be in accordance with MIL-STD-1399-300.

4.4.4 Reliability and maintainability assurance.

4.4.4.1 Reliability demonstration tests. Reliability demonstration tests shall consist of performing the reliability tests required by the individual equipment specification or acquisition document as specified (see 3.1 and 6.2).

4.4.4.2 Maintainability demonstration tests. Maintainability demonstration tests shall consist of performing the maintainability demonstration tests required by the individual equipment specification or acquisition document as specified (see 3.1 and 6.2).

4.4.5 Insulation suitability test. Insulation suitability tests on insulated equipment shall be conducted as specified in Appendix A.

4.4.6 Airborne and structureborne noise test. Airborne and structureborne noise tests shall be conducted in accordance with the requirements of MIL-STD-1474 and MIL-STD-740-2 when specified in the individual equipment specification.

4.5 Low quantity and non-Qualified Products List (QPL) qualified transformers and inductors. Where transformers and inductors are not available as approved products under MIL-PRF-27, MIL-T-15108, MIL-I-1361, MIL-PRF-21038, MIL-PRF-15305, MIL-T-16315, and MIL-T-17221, their use shall be approved by NAVSEA as specified in 6.2 and 6.4. Low quantity transformers and inductors are defines as a number less than 100 units.

4.5.1 Inspection requirements for low quantity and non-QPL qualified transformers and inductors. All transformers and inductors that are approved on the procedures of 6.4 shall be subjected to the following inspection from the Group A inspection of MIL-PRF-27, except as modified herein.

a. Visual and mechanical examination (external)

b. Sealing

c. Dielectric strength (except that the dielectric test voltage shall be not less than 500 V_{rms})

d. Induced voltage

e. Insulation resistance

f. Direct-current resistance

g. Turns ratio

h. Polarity

4.6 Temperature measurements.

4.6.1 Methods and procedures. Temperature measuring devices shall be carefully calibrated. The three fundamental methods of temperature measurement and the procedures shall be as specified in 4.6.1.1, 4.6.1.2, and 4.6.1.3.

4.6.1.1 Method 1. The “thermometer” method consists of the determination of the temperature by resistance thermometers, alcohol thermometers, or by surface and contact thermocouples, any of these instruments being applied to the hottest part of the equipment accessible. Mercury thermometers shall not be used. This method is preferred for uninsulated windings, exposed metal parts, gases, and liquids. It is also preferred for surface measurements generally and whenever other methods are not applicable or practical as in the case of some windings with very low resistance. Thermocouples are preferred for measuring rapidly changing surface temperatures, as in the case of resistors, commutators, collector rings, and other parts of rotating equipment.

4.6.1.1.1 Procedure. The number of thermometers or thermocouples used shall be liberal and shall be so disposed as to ascertain the highest temperature. The thermometer bulbs or thermocouple contact points shall be placed in such positions that they make the maximum practicable contact with the part whose temperature is to be measured, and shall be so firmly supported that this degree of contact will not be altered by gravity and vibration. The bulbs of thermometers shall be surrounded by a small amount of oil putty or equivalent to help maintain contact. The probes of contact thermocouples shall be sufficiently sharp to penetrate any oxide film present on the (metal) surface being measured.

4.6.1.2 Method 2. The “resistance” method consists of the determination of temperature by comparison of the resistance of a winding at the temperature to be determined, with the resistance of the winding at a known temperature. This method is preferred for insulated windings, except where measurements cannot be accurately made due to uncontrollable resistance in contacts. Where it is impractical to make connections to obtain resistances less than 1 ohm, a high accuracy instrument, such as a bridge with Kelvin contact terminals, shall be used.

4.6.1.2.1 Procedure. The temperature rise (T_r) of a winding of an inductor or motor for a specific power flow, usually rated power, shall be determined. In the application of Method 2, accuracy is essential in the measurement of all resistance and the temperature of the windings at which the cold and hot resistance is measured. Thermometers and thermocouples shall be used for temperature measurement. To measure the temperature by Method 2, a bench mark of the cold resistance shall be determined by measuring the resistance of the winding at room temperature (R_c). Temporary heating or cooling should be provided to maintain ambient temperature in the room within a band of ±9 °F (5 °C) during the 24-hour stabilization period. To achieve this end, the winding being measured must be stored in the unenergized condition for at least 24 hours at the ambient temperature level. The ambient temperature (T_a) may be measured with a thermometer, and compared to thermocouple measurements at some point on the unenergized windings. The measurements should be equal unless the windings have been given insufficient time to achieve ambient temperature. Operating temperature above ambient is determined by making winding resistance readings as a function of time after the power is removed; ohmmeter or bridge readings are taken with a stopwatch used for timing purposes. Readings are taken periodically for sufficient time to extrapolate back to zero to yield the operating winding resistance (R_h) at zero time after power was removed. From the initial winding resistance (R_c-cold resistance), and the operating resistance at zero time (R_h-hot resistance), winding temperature rise (T_r) is calculated from the following:

T_r (Temperature rise) °C = $(234.5 + T_c)R_h/R_c - (234.5 + T_a)$

Where:

R_c = Cold resistance of winding in ohms.

R_h = Hot resistance of winding in ohms.

T_c = Temperature (°C) of winding when cold resistance was measured.

T_a = Ambient temperature (°C) during the time that the hot resistance reading was taken.

NOTE 1: All readings of resistance should be made with the same equipment during the testing period for identical resistance measurement equipment calibration. Cold resistance of windings from prior measurement periods shall not be used.

NOTE 2: When the final resistance measurements can be performed within 1 minute of power removal, the initial resistance reading can be used as R_h.

NOTE 3: When performing temperature rise tests of equipment with multiple windings, such as transformers, the winding closest to the winding core shall be used as the basis for the test. When the winding physical orientation is not known, the winding with the highest resistance shall be used as the test basis.

4.6.1.3 Method 3. The "embedded detector" method consists of the determination of temperature by thermocouples or resistance temperature detectors built into the equipment either permanently or for test purposes in specified locations inaccessible to thermometers by Method 1 as specified (see 6.2). This method is suitable for interior measurements at designated locations. It is used in those cases where a high degree of accuracy is desired, where other methods are not suitable or practical, and usually for large rotating equipment.

4.6.1.3.1 Procedure. This method shall be used only where specified in the individual equipment specification or contract (see 6.2). A temperature distribution analysis shall be made which will indicate the relationship of normal temperature distribution throughout the areas of interest to the temperature at the measured points.

4.6.2 Inaccessible parts. In the case of inaccessible parts, such as certain rotating parts, the temperature readings shall be taken as soon as possible after shutdown. A curve shall be plotted with temperature readings as the ordinate and time as the abscissa. That portion of the linear curve starting where successive readings show decreasing temperatures shall be extrapolated back to the instant of shutdown. The temperature at the instant of shutdown as determined in this manner shall be considered the shutdown temperature. Where thermometers are used, they shall be preheated to approximate the temperature of the part to be measured.

4.6.3 Measurement of ambient temperature for heat runs.

4.6.3.1 Effective ambient temperature. The effective ambient temperature to be employed in temperature rise calculations shall be the mean value of at least three sets of ambient temperature readings taken at equal time intervals throughout the last quarter of the heat run with stable ambient conditions prevailing. For tests of duration shorter than 2 hours, readings which cover the last half-hour or the entire test, whichever is shorter, shall be employed. The ambient temperature conditions will be considered sufficiently uniform and stable when the maximum difference between similar measurements at different locations does not exceed 9 °F (5 °C) and when the variation between successive readings at the same location does not exceed 1.8 °F (1 °C), the rate of temperature change does not exceed 7.2 °F (4 °C) per hour, and the difference in readings of thermometers in air and in oil-filled cups (in locations where both are required) (see 6.2 and 4.6.3.3.1c) does not exceed 3.6 °F (2 °C). Should these stability criteria not be complied with during the last quarter of the temperature test, continuous duty heat runs shall be continued until three successive sets of readings are obtained that do meet the criteria. Should the stability criteria not be met for heat runs of limited duration (that is, tests at the short-time duty, intermittent duty, and overload ratings), corrective measurements shall be applied and the test shall be repeated until the required conditions are met.

4.6.3.2 Ambient temperature limits. The heat run ambient temperature shall be between 50 and 122 °F (10 and 50 °C). It shall be assumed that the temperature rise is the same for all ambient temperatures between the limits of 50 and 122 °F (10 and 50 °C). No heat runs shall be undertaken on equipment which has recently been brought from a place varying in temperature by 15 °F (8 °C) or more from the room in which the test is to be made. Equipment shall be stored or installed in the test area for at least 24 hours if the originating location varies in temperature by 15 °F (8 °C) or more from the room in which the test is to be made.

4.6.3.3 Method of temperature measurement. Temperature shall be measured as specified in 4.6.1 through 4.6.1.3, as applicable (see 6.2).

4.6.3.3.1 Equipment other than that cooled by water, oil, or forced air from separate sources. Method of temperature measurement for equipment other than that cooled by water, oil, or forced air from separate source shall be as follows:

a. The equipment under test shall be protected from drafts other than those produced by the integral cooling fans in the case of fan-cooled equipment. The equipment under test shall also be protected from heat radiation from outside sources.

b. The ambient temperature shall be measured at four locations around and level with the center of the equipment. For most equipment, the thermometers may be placed at a horizontal distance from the equipment of 3 to 6 feet. In cases where the heat radiation from the equipment under test is negligible, or where an ambient temperature more nearly representative of the conditions of test would be obtained, the thermometers may be placed 12 inches from the equipment.

c. For equipment weighing 500 pounds or more each, the ambient temperature thermometers shall be inserted in heavy oil-filled cups of not less than 1 inch in external diameter and 2 inches in height. Where oil-filled cups are used, each shall be accompanied by an air thermometer to provide an indication as to whether variations in the cooling air temperature are maintained within acceptable limits. Only those temperature readings from thermometers in the oil-filled cups shall be averaged to determine the effective ambient temperature. Likewise, only these readings shall be used to determine the incremental change and the rate of change of temperature when checking compliance with the stability criteria.

4.6.3.3.2 Equipment cooled by forced air from separate source. Ambient temperatures shall be measured by locating the ambient-temperature thermometers at the air intake of the equipment. If this location causes an appreciable radiation error, a compromise location shall be chosen. The number and spacing of thermometers or thermocouples shall ensure the temperature indication is a representative average.

4.6.3.3.3 Equipment cooled by water. Ambient temperature shall be measured as specified in the individual equipment specification (see 6.2).

4.6.3.3.4 Equipment cooled by oil. Ambient temperature shall be measured as specified in the individual equipment specification (see 6.2).

4.6.4 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.

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. It is intended that this specification be invoked in its entirety in individual equipment specifications for electric power equipment and electrical control equipment. This specification covers the basic requirements applicable to equipment intended for naval shipboard use. Specifications for equipments of this type that have need for more restrictive requirements may supplement the individual requirements contained herein, as necessary, to meet that need. In exceptional cases where only portions of this specification are applicable because of peculiar circumstances, the portion should be invoked by reference to this specification by basic specification number and the requirements, by title or descriptive statement or area of coverage, which apply.

6.2 Acquisition requirements. Acquisition documents should specify the following:

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

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

c. Acquisition requirements for the equipment (see 3.1).

d. Reliability and maintainability requirements:

(1) Reliability quantitative requirements (see 3.2).

(2) Applicability of reliability and maintainability requirements and programs (see 3.2 and 3.2.5).

(3) Maintenance concept (see 3.2.5).

(4) Definition of failure (see 4.4.1e).

(5) Reliability testing requirements (see 4.4.4.1).

(6) Reliability test accept-reject criteria (see 4.4.4.1).

(7) Reliability test conditions (see 4.4.4.1).

(8) Maintainability quantitative requirements (see 4.4.4.2).

(9) Maintainability demonstration requirements (see 4.4.4.2).

e. Equipment installation requirements (see 3.2.3).

f. Special performance, if required, in the event of an electrical part failure (see 3.2.6).

g. Input power variations for AC equipment (Type I power of MIL-STD-1399-300 applies unless otherwise specified) (see 3.2.9.1).

h. Input power variations for DC equipment on submarines (MIL-STD-1399-390 applies unless otherwise specified) (see 3.2.9.2).

i. Surge voltage suppression, if other than as specified (see 3.2.11).

j. Inclined operation, if other than as specified (see 3.2.12).

k. Ambient temperature range, if other than that specified (see 3.2.13.1).

l. If exterior shipboard service is intended (see 3.2.13.1).

m. Humidity range and condition, if other than that specified (see 3.2.13.2).

n. H.I. shock and vibration requirements (see 3.2.14, MIL-S-901 ordering data, and 3.2.15).

o. If equipment is to be designed to use fitted (body-bound) bolts for mounting to the ship's structure (see 3.2.15c).

p. EMI design and test criteria (see 3.2.16).

q. DC magnetic field environment, if other than specified in DOD-STD-1399-070 (see 3.2.17).

r. Eddy current magnetism for equipment installed on non-magnetic minesweepers (see 3.2.18).

s. If noise reduction control is other than as specified (see 3.2.19).

t. If airborne noise testing is required and test levels (see 3.2.19.1).

u. If structureborne noise testing is required and test levels (see 3.2.19.2).

v. If dynamic balancing is required for the equipment (see 3.2.19.3 and 3.2.20).

w. The minimum creepage and clearance distances between electric circuits or between any electric circuit and ground are different, if other than as specified in table III (see 3.2.22.1).

x. Whether insulation resistance, leakage current, reliability, and maintainability tests are required (see 3.2.22, 4.4.2, 4.4.3, 4.4.4.1, and 4.4.4.2).

y. If equipment is to be designed to use through bolts for mounting on ship structure (see 3.2.24.1).

z. Insulation resistance and dielectric withstanding voltage test procedures and requirements, if other than as specified (see 3.2.26, 3.2.26.1, 4.4.1, and 4.4.2).

aa. Equipment insulation requirement (see 3.2.26).

bb. Special shipboard environmental conditions (see 3.2.27).

cc. Use of malleable or modular graphitic iron (see 3.3.2.2).

dd. Color of plastics, if other than as specified (see 3.3.3).

ee. Non-preferred component material(s) allowed and identified to the NAVSEA Materials Technical Warrant Holder (TWH) (see 3.3.6).

ff. Thermoplastic insulating materials for molded parts (see 3.4.1.3.2).

gg. Establish a criterion of acceptance for insulation under conditions of use (see 3.4.2.1).

hh. Class of insulation system (see 3.4.3.1).

ii. Alternative method to specify class of insulation systems used (see 3.4.3.2).

jj. When insulation suitability tests are required (see 3.11).

kk. Method of external cable connection, if other than as specified (see 3.12.2.4).

ll. Wiring documentation requirements (see 3.12.3.3).

mm. When bus bars are to be insulated (see 3.12.4).

nn. Alternative microcircuit mounting and derating (see 3.13.1.1.4).

oo. When other than individually replaceable parts can be used (see 3.13.1.5).

pp. Use and application of capacitor using other than guidance in MIL-HDBK-198 (see 3.13.5).

qq. The type of Navy-approved protective relay to be used (see 3.13.14f).

rr. When electron tubes are permitted (see 3.13.17).

ss. Whether repair of printed wiring boards damaged during manufacture will be permitted (see 3.13.26g).

tt. Painting of equipment exterior, if gray appearance is required (see 3.14.2.1).

uu. If the minimum radius of rounded edges and corners is other than 0.04 inch (see 3.16.7).

vv. If drilled and tapped holes are to be countersunk (see 3.16.8).

ww. What identification marking is required (see 3.17.4)

xx. Reverse relationship for control setting indicators required (see 3.17.5).

yy. The user equipment interface requirements for medium voltage DC powered equipment or are to be in accordance with IEEE 1709 (see 3.19.1.1).

zz. High voltage input power variations for AC equipment (Class I, II, and III power of MIL-STD-1399-680 applies unless otherwise specified) (see 3.19.1.2).

aaa. Use of Navy-approved vacuum type circuit breakers (see 3.19.4.1).

bbb. Alternatives to medium voltage potential transformers (see 3.19.8).

ccc. If partial discharge detection maintenance equipment is required and the required minimum detectible partial discharge inception voltage level (see 3.19.9.1).

ddd. Specify if VDS or VPIS is required (see 3.19.9.2).

eee. IA requirements (see 3.20).

fff. Examination, tests, and sampling (see 4.1).

ggg. Level of manufacturing screening testing (see 4.3.1).

hhh. After which tests the dielectric withstand voltage test should be conducted (see 4.4.1).

iii. When insulation system is to be tested for moisture resistance (see 4.4.2.2).

jjj. Non-QPL qualified transformers and inductors requirements (see 4.5).

kkk. If temperature measurement by embedded detectors is to be used and location of embedded detectors (see 4.6.1.3 and 4.6.1.3.1).

lll. Method of temperature measurement (see 4.6.3.3).

mmm. How ambient temperature is to be measured in equipment cooled by water (see 4.6.3.3.3).

nnn. How ambient temperature is to be measured in equipment cooled by oil (see 4.6.3.3.4).

ooo. Packaging requirements (see 5.1).

6.3 Provisioning. Provisioning Technical Documentation (PTD), spare parts, and repair parts should be furnished as specified in the contract. When ordering spare parts or repair parts for the equipment covered by this specification, the contract should state that such spare parts and repair parts should meet the same requirements as the parts used in the manufacture of the equipment.

6.4 Alternate approval method for low quantity and non-QPL qualified transformers and inductors. The procedures below will be accepted as sufficient quality assurance in order to use the non-QPL qualified transformers and inductors.

6.4.1 Similarity process. Establishment of acceptability is based upon similarity to a previously approved and tested design by the same manufacturer under MIL-PRF-27. A given design may be established as similar without testing the units when the purchaser is satisfied that the unit compares as follows with a single unit with tested and approved mechanical design characteristics:

a. Same grade; same class of operation.

b. Same external and internal mounting; similar shape; same case construction; nominal wall thickness within 25 percent when a case is used; linear dimensions not greater than 150 percent nor less than 70 percent of the corresponding dimensions; total volume is not greater than 250 percent.

c. Same terminal construction and material, including insulating and gasketing parts; same or larger size for corresponding terminals; same or greater spacing between terminals and between terminals and the case wall or other grounded surfaces.

d. Same or greater wire size and same coating material for corresponding winding.

e. Same processing and material for case, finish marking, potting, insulating, and impregnating.

6.4.2 Test process. If there is no similar accepted design, a design can be established as acceptable by running the following tests, in the order listed, on two typical units of the same design from each group of similar units from the same manufacturer. The definition of similar is specified in 6.4.1. These tests are as specified in the qualification tests of MIL-PRF-27, except as modified herein.

Test Number	Description
1	Winding continuity
2	Visual and mechanical examination (external)
3	Terminal strength
4	Dielectric strength (except that the dielectric test voltage should be not less than 500 V_{rms})
5	Induced voltage
6	Insulation resistance
7	Temperature rise
8	Vibration (maximum frequency 33 Hz)
9	Shock (Method II of MIL-PRF-27)
10	Immersion
11	Winding continuity
12	Insulation resistance
13	Dielectric strength (90 percent of initial)
14	Induced voltage

Prior to testing, approval of the contracting activity should be obtained for the proposed grouping and the units selected as typical. The test data should be submitted to the contracting activity for approval.

6.4.3 Similarity process based on approved items. When the contracting activity is satisfied that the units compare with a single unit with tested and approved mechanical design characteristics in accordance with 6.4.1, a given design may be established without testing the units.

6.5 Definitions and nomenclature. For names, definitions, and delineation of items used by the Department of Defense, the contractor's attention is invited to Cataloging Handbook H6-1, Section A, Part I of Federal Item Identification Guides for Supply Cataloging, Alphabetical Index of names. Copies of this publication are available for examination at any office of the Government inspector. For names and definitions of electrical terms, the contractor's attention is invited to IEEE 100, Standard Dictionary of Electrical and Electronics Terms. This publication may be obtained from the Institute of Electrical and Electronic Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331 or online at www.ieee.org.

6.5.1 Ampacity. Ampacity is the maximum amount of electrical current a conductor or device can carry before sustaining immediate or progressive deterioration.

6.5.2 Clearance distance. Clearance distance is the shortest point-to-point distance in air between uninsulated energized parts or between an uninsulated energized part and ground.

6.5.3 Creepage distance. Creepage distance along the surface of an insulating material is the shortest distance between uninsulated energized parts or between an uninsulated energized part and ground.

6.5.4 Grounding. Grounding is defined as connecting a point of electrical equipment to the ship hull or ground point for intentional or other reasons.

6.5.5 Leakage current. Leakage current is defined as the current through the parasitic resistances and impedances continuing through a human body, if the safety equipment ground is open.

6.5.6 Volt-ampere ratings. The product of the normal voltage applied to the circuit times the current carried.

6.6 Subject term (key word) listing.

Alternating current equipment

Electrical control equipment

Input power

Shipboard electrical systems

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

PROCEDURE FOR INSULATION SUITABILITY TESTS

A.1 SCOPE

A.1.1 Scope. This Appendix covers the insulation suitability testing procedure for insulation systems classified at temperature of 356 °F (180 °C) or above or other insulation systems as specified by NAVSEA. This Appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

A.1.2 Purposes. The purpose of this test is to determine the insulation resistance (see A.3.5), dissipation factor (see A.3.4), and capacitance (see A.3.1) of an electric winding insulated with silicone or other insulation under conditions of severe moisture exposure.

A.1.3 Classification. Insulation suitability tests for electrical windings are of the following types and shall be so designated in the application for test:

Type CW – Complete Winding (see A.3.2)

Type PW – Partial Winding (see A.3.7)

A.2 APPLICABLE DOCUMENTS

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

A.2.2 Government documents.

A.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.

DEFENSE SPECIFICATIONS

MIL-DTL-2212	-	Contactors and Controllers, Electric Motor AC or DC, and Associated Switching Devices
MIL-G-3111	-	Generators, Electric, Direct-Current (Naval Shipboard Use)
MIL-G-3124	-	Generator, Alternating Current, 60-Hertz (Naval Shipboard Use)
MIL-T-15108	-	Transformers, Power, Step Down, Single-Phase, 60 Hertz, 1 Kilovoltampere Approximate Minimum Rating, Dry Type, Naval Shipboard
MIL-M-17059	-	Motor, 60-Cycle, Alternating-Current, Fractional H.P. (Shipboard Use)
MIL-DTL-17060	-	Motors, Alternating Current, Integral-Horsepower, Shipboard Use
MIL-T-17221	-	Transformers, Power, Distribution; Single Phase, 400 Hertz, Insulation System Class 200 Deg. C, Dry (Air Cooler) (Naval Shipboard Use)
MIL-M-17413	-	Motors, Direct Current, Integral H.P. Naval Shipboard (Navy)
MIL-M-17556	-	Motor, Direct-Current, Fractional H.P. (Shipboard Use)
MIL-G-18473	-	Generators, Motors, and Auxiliary Equipment, Direct Current, Naval Ship Propulsion

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

A.3 DEFINITIONS

A.3.1 Capacitance. The capacitance of an insulating structure is the ratio of the capacitance of the insulator to the capacitance of the equivalent spacing in a vacuum.

A.3.2 Complete winding. A complete winding is an electric winding installed in the electric equipment with which it is used and which requires no further processing. For the purpose of this specification, an AC stator winding, a solenoid coil, a DC armature, a transformer, or a DC field coil assembly may be considered complete windings.

A.3.3 Dielectric constant (K). The dielectric constant of an insulator is the ratio of the capacitance of the insulator to the capacitance of the equivalent spacing in a vacuum.

A.3.4 Dissipation factor (DF or D). The dissipation factor of an insulation structure is the ratio of its parallel reactance to its parallel resistance. It is also the tangent of the loss angle (also called the loss tangent) and the cotangent of the phase angle.

A.3.5 Insulation resistance. The insulation resistance between two electrodes that are in contact with, or embedded in, an insulating structure, is the ratio of the direct voltage applied to the electrodes, to the total current between them. It is dependent upon both the volume and surface resistances of the insulation structure.

A.3.6 Loss angle (δ, delta). The dielectric loss angle is the difference between 90 electrical degrees (90°) and the dielectric phase angle.

A.3.7 Partial winding. A partial winding is an electrical winding which requires further processing when installed in the electrical equipment with which used. For the purpose of this specification, a preformed armature or stator coil or a field coil may be considered partial windings.

A.3.8 Phase angle (θ, theta). The phase angle of an insulating structure is the angle by which the current in a capacitor, in which the material is the dielectric, leads the voltage across it.

A.4 REQUIREMENTS

A.4.1 Reliability. Reliability of operation shall be considered of prime importance in the design and manufacture of the equipment. In those instances where resistance to unusual environmental conditions is a requirement, a criterion of acceptance for the insulation system on the equipment must be established.

A.5 TESTING

A.5.1 Insulation suitability tests.

A.5.1.1 Place of tests. The insulation suitability tests shall be conducted at a laboratory and under conditions acceptable to NAVSEA.

A.5.1.2 Equipment to be tested. As it is not practical to test each design of electric equipment, only representative designs, typical of the line manufactured for each manufacturer's facility, will be tested. Table A-I lists equipment by specification and the form of sample to be tested.

TABLE A-I. Specimens for insulation suitability test.

Equipment specification	Equipment	Form to be tested	Sample quality	Suggested size and type
MIL-DTL-17060	AC integral horsepower (hp) motors	Stator winding	3	10 hp, 215 frame. 3-phase induction type
MIL-M-17059	AC fractional hp motors	Motor	3	¼ hp, single-phase
MIL-G-3124	AC generators	Armature coil	3	Any size over 50 kw
		Field coil	3	
MIL-G-3111 (for guidance only)	DC generators	Armature coil	3	Any size over 50 kw
		Field coil	3	
MIL-M-17413 (for guidance only)	DC integral hp motors	Motor	3	5 hp, shunt
MIL-T-15108	60 Hz transformers	Transformer	3	7.5 kVA single-phase 450/120
MIL-M-17556 (for guidance only)	DC fractional hp motors	Motor	3	¼ hp, shunt
	AC propulsion motors and generators	Armature and field coil	3 each	Any size
MIL-G-18473 (for guidance only)	DC propulsion motors and generators	Armature and field coil	3 each	Any size
MIL-T-17221	400 Hz transformer	Transformers	3	Any size
MIL-DTL-2212	AC controller	Shunt coil	3	Any size
	DC controller	Shunt coil	3	Any size

NOTES:
1. Partial windings submitted for test shall receive all the insulation processing that the final assembly of the equipment would receive so as to represent the complete winding.
2. When testing armature, field, or shunt coils, metal foil electrodes shall be used to simulate ground connections.

A.5.2 Test equipment needed. The following test equipment shall be provided:

a. Humidity chamber
b. High potential test equipment
c. Insulation resistance test bridge
d. Capacitance test bridge
e. Ohmmeter

A.5.3 Type of test equipment.

A.5.3.1 Humidity chamber. This box shall be made of steel, or a transparent plastic film, having a low moisture permeability, and shall be placed over a steel framework. The top of the chamber shall be slanting or peaked (or otherwise arranged) so that the excess condensate does not drip on the equipment. The relative humidity shall be maintained at 100 percent at a temperature of 87.8±3.6 °F (31±2 °C). The humidification shall be sufficient to produce minute droplets of condensate on the insulation surfaces of the equipment under test. However, the amount of condensate shall be controlled so as not to produce puddles or streams of water on the insulation surfaces. Equipment such as a motor, not open for free circulation of air, shall have one end-bracket removed to permit free access of the humidified air to all parts of the winding.

A.5.3.2 High potential test equipment. Any standard high potential test equipment of suitable capacity may be used, provided the frequency of the test voltage is not less than 60 Hz nor greater than 100 Hz, and provided the wave shape approximates a true sine wave. The test voltage shall be measured with a voltmeter deriving its voltage from the high-voltage circuit either directly or through an auxiliary ratio transformer or by means of a voltmeter coil placed in the testing transformer.

A.5.3.3 Insulation resistance test bridge. A megohm bridge shall be used having a DC test voltage of 500 V and with a range of 0.1 to 1,000,000 megohms.

A.5.3.4 Capacitance test bridge. A capacitance test bridge shall be used having a 60 Hz input with a range of 5 μMF to 1100 μF and with a range of dissipation range factor of 0 to 50 percent.

A.5.3.5 Ohmmeter. Any standard laboratory instrument may be used, provided the smallest center scale reading is not over 15 ohms.

A.5.4 Test requirements.

WARNING: Due to the need for exposing copper for the connections to the windings, a leakage path is produced by humidification over the various insulation surfaces between the bare copper and the other parts of the equipment that are otherwise insulated from the copper circuit. Therefore, leads should be kept separated as much as possible and covered with a non-wetting grease. Where insulation measurements are specified, they shall be made with the equipment in the humidity chamber. The length of the leads within the chamber should be as short as possible, not exceeding 24 inches. These leads should be separated. The leads to the windings should not touch any grounded metal parts.

A.5.4.1 Dielectric-high potential. A potential of twice normal rated voltage plus 1000 V shall be applied for a period of 1 minute between isolated circuits to test their insulation, and shall also be applied between each circuit and equipment case to test their insulation.

A.5.4.2 Dielectric-normal potential. A potential of normal rated voltage shall be applied for a period of 1 minute between isolated circuits and between each circuit and equipment case to test their insulation.

A.5.4.3 Insulation resistance. The insulation resistance measurement shall be made using a direct current potential of 500 V applied for a 1-minute period. The insulation resistance between each circuit and ground and between isolated circuits shall be measured and recorded. The temperature of the windings and the relative humidity of the surrounding air shall also be recorded. Insulation resistance values shall be corrected to 77 °F (25 °C) standard temperature.

A.5.4.4 Capacitance and dissipation factor. The capacitance and dissipation factor shall be measured with the capacitance test bridge and the values shall be read directly from the bridge. The capacitance and dissipation factor between each winding and ground and between each winding shall be made.

A.5.4.5 Temperature. The temperatures of the windings shall be measured by Method 2 (see 4.6.1.2). Winding temperature rise is calculated from the procedure as specified in 4.6.1.2.1.

A.5.5 Test procedures. The equipment shall be tested in accordance with the following procedures.

A.5.5.1 Initial tests. Each sample part (complete or partial winding) shall be given a high potential test to determine if the windings meet the requirements of A.5.4.1. The insulation resistance, capacitance, and dissipation factor shall be measured and recorded as well as the ambient temperature and relative humidity. The DC resistance shall also be measured and recorded.

A.5.5.2 Standardizing run. Each sample unit shall next be subjected to a standardizing run to arrive at a dry condition. The equipment under test shall be connected to a suitable power source and the current varied until the average winding temperature reaches a temperature of 266 to 284 °F (130 to 140 °C). This conditioning shall be continued for 48 hours. The temperature shall be measured by Method 2 (see 4.6.1.2). The sample parts may be subjected to oven heat if the method specified herein is not suitable. After the equipment has cooled, but within 8 hours of stopping the run, the insulation resistance, capacitance, and dissipation factor, ambient temperature, relative humidity, and DC resistance of the windings shall be measured and recorded.

A.5.5.3 Humidification run. The equipment shall next be immediately placed in the humidity chamber for a period of 1 week (approximately 168 hours). While under humidification, daily measurements of the insulation resistance, capacitance, and dissipation factor shall be measured. The equipment shall also be given a normal potential test daily. At the end of the humidification period and within 5 minutes after removal from the humidity chamber, the insulation resistance, capacitance, and dissipation factor shall be measured and recorded. A normal dieletric-potential test shall also be applied as specified in A.5.4.2.

A.5.5.4 Assembly of data. Table A-II provides a notional data sheet.

A.5.6 Criterion of failure. Failure is considered to have occurred if any of the test sample windings become open, ground, short circuit, or fail the potential test. In addition, the insulation resistance and dissipation factor values, when plotted graphically, shall conform to the limits shown on figures A-1 and A-2, respectively.

A.5.7 Approval of equipment. The insulation suitability in the equipment will be approved by NAVSEA.

TABLE A-II. Insulation suitability test 100 percent relative humidity plus dew (sample).

<table>
<tr><td>Winding data (rating data as applicable)</td><td colspan="7">Sample No. (1, 2, or 3)
Mfr's name ______
Date of mfr. ______ Address ______
Frame ______ Serial ______
Hp ______ Volts ______ Phase ______ Type ______
R/min ______ Duty ______ F.L. amps ______ Hz ______</td></tr>
<tr><td>Insulation data (or as applicable)</td><td colspan="7">Magnet wire (type ______).
Ground ______ Armature ______ Field ______
Phase ______ Sleeving ______ Varnish ______ No. of dips ______
Wedge ______ Tying cord ______ Leads ______ and bakes ______
Report no. ______ Time and Temp. ______</td></tr>
<tr><td>Date of tests ______
Lab ______</td><td>Insulation resistance (megohms)</td><td>Capacitance (µF)</td><td>Dissipation factor, (percent)</td><td>Normal potential (volts)</td><td>Resistance (ohms)</td><td>Temp. (°C)</td><td>Relative humidity (percent)</td></tr>
<tr><td>Initial tests</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Std. run</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>1 day (24 hrs)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2 (48 hrs)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3 (72 hrs)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4 (96 hrs)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5 (120 hrs)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>6 (144 hrs)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>7 (168 hrs)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Recovery</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="8">NOTE:
1. All winding leads shall be approximately 6 feet in length.</td></tr>
</table>

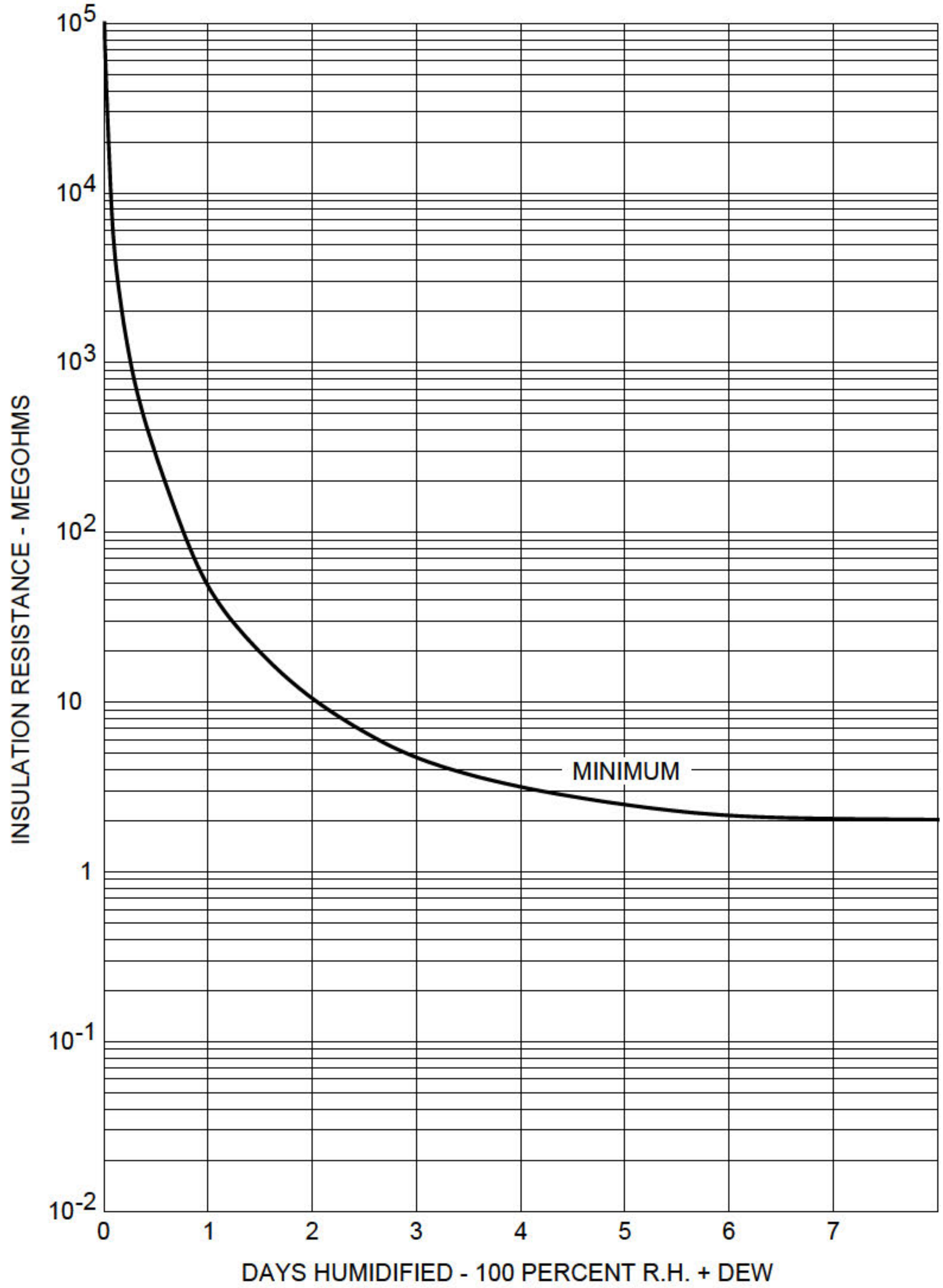

FIGURE A-1. Insulation resistance.

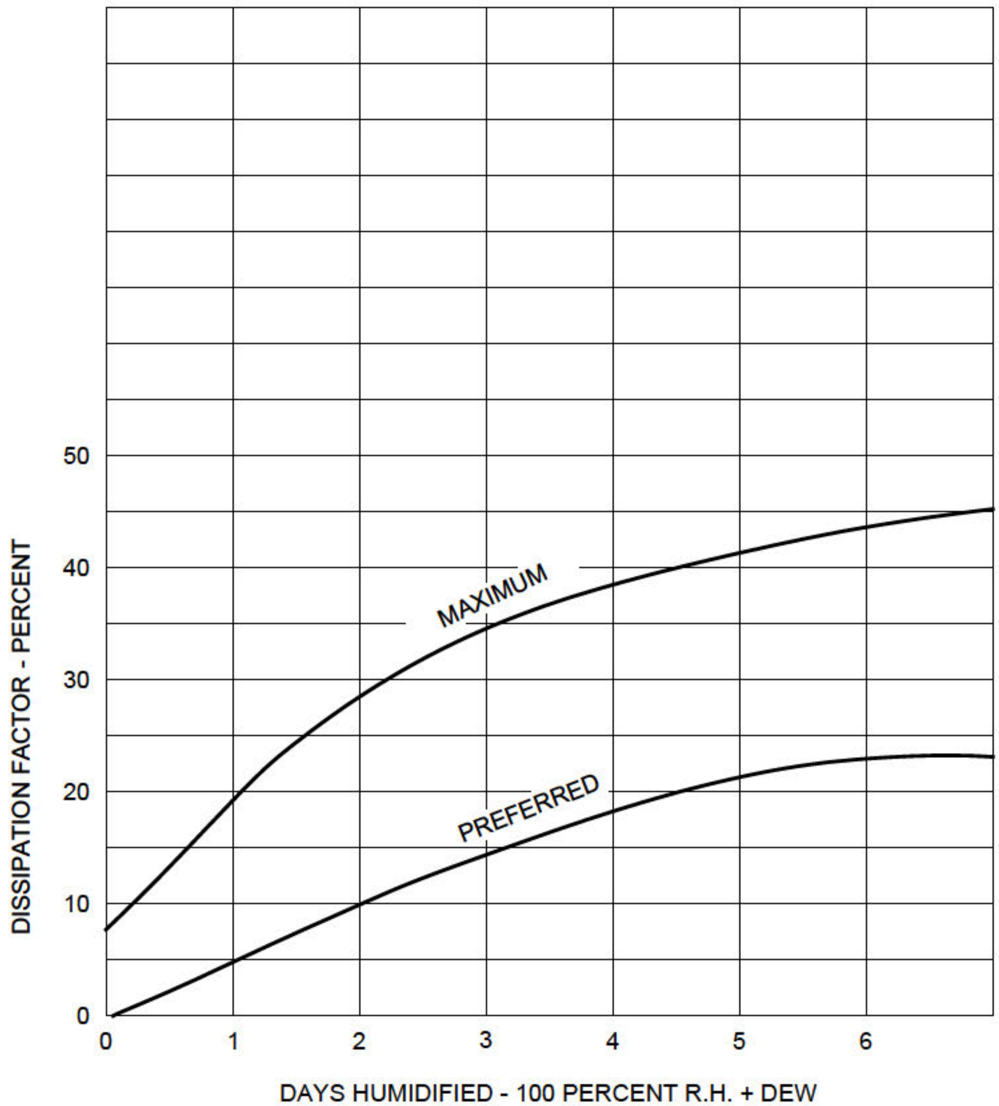

FIGURE A-2. Dissipation factor.

Custodian:
Navy – SH

Preparing activity:
Navy – SH
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Review activity:
DLA – GS

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