INCH-POUND
MIL-E-917E(NAVY)
6 August 1993
SUPERSEDING
MIL-E-917D(NAVY)
28 January 1965
(See 6.10)

MILITARY SPECIFICATION

ELECTRIC POWER EQUIPMENT
BASIC REQUIREMENTS

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

1. SCOPE

1.1 Scope. This specification covers the basic requirements applicable to the design, materials, and construction of Naval shipboard electric power equipment (exclusive of communication equipment, fire control equipment, and electronic equipment, other than that used in electric power applications). Only one classification of equipment is covered by this specification.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 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 listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATIONS

FEDERAL

J-W-1177 - Wire, Magnet, Electrical, General Specification.
W-C-596 - Connector, Electrical, Power, General Specification for.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Sea Systems Command, SEA 03Q42, 2531 Jefferson Davis Hwy, Arlington, VA 22242-5160 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

AMSC N/A FSC 6110

FEDERAL (Continued)

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

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

FF-S-85 - Screw, Cap, Slotted and Hexagon Head.

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 - Washers, Lock (Spring).

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

HH-I-538 - Insulation, Electrical, Pasted-Mica.

QQ-B-650 - Brazing Alloys, Copper, Copper-Zinc, and Copper-Phosphorus.

QQ-B-654 - Brazing Alloys, Silver.

QQ-C-320 - Chromium Plating (Electrodeposited).

QQ-N-290 - Nickel Plating (Electrodeposited).

QQ-S-365 - Silver Plating, Electrodeposited: General Requirements for.

QQ-S-571 - Solder, Tin Alloy: Tin-Lead Alloy; and Lead Alloy.

TT-C-490 - Cleaning Methods for and Ferrous Surfaces and Pretreatments for Organic Coatings.

TT-P-645 - Primer, Paint, Zinc-Molybdate, Alkyd Type.

MILITARY

MIL-M-14 - Molding Compounds, Thermosetting.

MIL-C-20 - Capacitors, Fixed, Ceramic Dielectric (Temperature Compensating), Established and Non-Established Reliability, General Specification for.

MIL-R-22 - Resistors, Variable (Wire-Wound, Power Type), General Specification for.

MIL-T-27 - Transformers and Inductors (Audio, Power, and High-Power Pulse), General Specifications for.

MIL-P-79 - Plastic Rods and Tubes, Thermosetting, Laminated.

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

MIL-C-81 - Capacitors, Variable, Ceramic Dielectric, General Specification for.

MIL-C-92 - Capacitors, Variable, Air Dielectric (Trimmer), General Specification for.

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

MILITARY (Continued)

MIL-T-713 - Twine Fibrous: Impregnated, Lacing and Tying.
MIL-S-901 - Shock Tests, H.I. (High-Impact) Shipboard Machinery, Equipment, and Systems, Requirements for.
MIL-P-997 - Plastic Material, Laminated, Thermosetting, Electrical Insulation: Sheets, Glass Cloth, Silicone Resin.
MIL-Y-1140 - Yarn, Cord, Sleeving, Cloth, and Tape-Glass.
MIL-S-1222 - Studs, Bolts, Hex Cap Screws, Socket Head Cap Screws and Nuts.
MIL-I-1361 - Instrument Auxiliaries, Electrical Measuring: Shunts, Resistors, and Transformers.
MIL-E-2036 - Enclosures for Electric and Electronic Equipment.
MIL-C-2212 - Contactors and Controllers, Electric Motor, AC or DC, and Associated Switching Devices.
MIL-R-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-L-3661 - Lampholders, Indicator Lights, Indicator-Light Housings, and Indicator-Light Lenses, General Specification for.
MIL-L-3661/55 - Lampholder, Lenses, Indicator Light, Style 6C41.
MIL-L-3661/56 - Lampholder, Lenses, Indicator Light, Style 6C42.
MIL-L-3661/57 - Lampholder, Lenses, Indicator Light, Style 6C43.
MIL-L-3661/59 - Lenses, Indicator Light, Style 6C45.
MIL-L-3661/61 - Lampholder, Lights, Indicator (Housing), Style 6H94.
MIL-L-3661/62 - Lampholder, Lights, Indicator (Housing), Style 6H95 (for D.C. Applications).
MIL-L-3661/63 - Lampholder, Lights, Indicator (Housing), Style 6H96.
MIL-L-3661/65 - Lampholder, Lights, Indicator (Housing), Style 6H98.
MIL-S-3786 - Switches, Rotary (Circuit Selector, Low-Current Capacity), General Specification for.
MIL-S-3786/4 - Switch, Rotary, Closed Construction, 2 Amperes, Low Level, Positive Shaft Grounding, Style SR04.
MIL-G-3787 - Glass, Laminated, Flat; (Except Aircraft).
MIL-S-3950 - Switches, Toggle, Environmentally Sealed, General Specification for.
MIL-M-3971 - Meters, Time Totalizing, Non-Hermetically Sealed, Electrical: General Specification for.

MILITARY (Continued)

MIL-B-5423 - Boots, Dust and Water Seal (for Toggle and Pushbutton Switches, Circuit Breakers, and Rotary-Actuated Parts), General Specification for.
MIL-P-5425 - Plastic Sheet, Acrylic, Heat Resistant.
MIL-R-5757 - Relays, Electromagnetic, General Specification for.
MIL-R-6106 - Relays, Electromagnetic (Including Established Reliability (ER) Types), General Specification for.
MIL-P-7788 - Panels, Information, Integrally Illuminated.
MIL-T-7928 - Terminals, Lug: Splices, Conductor: Crimp Style, Copper, General Specification for.
MIL-T-7928/1 - 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.
MIL-T-7928/2 - 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.
MIL-A-8625 - Anodic Coatings, for Aluminum and Aluminum Alloys.
MIL-S-8805 - Switches and Switch Assemblies, Sensitive and Push (Snap Action), General Specification for.
MIL-W-8939 - Welding, Resistance, Electronic Circuit Modules.
MIL-F-8975 - Fasteners, Blind, High Strength, Installation Formed, Corrosion Resistant Steel, Heat Resistant Steel and Titanium, General Specification For.
MIL-M-10304 - Meters, Electrical Indicating, Panel Type, Ruggedized, General Specification for.
MIL-P-13949 - Plastic Sheet, Laminated, Metal-Clad (for Printed Wiring Boards), General Specification for.
MIL-S-13572 - Springs, Helical, Compression and Extension.
MIL-P-15024 - Plates, Tags and Bands for Identification of Equipment.
MIL-P-15024/5 - Plates, Identification.
MIL-P-15037 - Plastic Sheet, Laminated, Thermosetting, Glass-Cloth, Melamine-Resin.
MIL-E-15090 - Enamel, Equipment, Light-Grey (Formula No. 111).
MIL-T-15108 - Transformers, Power, Step-Down, Single-Phase, 60-Hertz, 1-Kilovoltampere Approximate Minimum Rating, Dry Type, Naval Shipboard.
MIL-R-15109 - Resistors and Rheostats, Naval Shipboard.
MIL-I-15126 - Insulation Tape, Electrical, Pressure Sensitive Adhesive and Pressure Sensitive Thermosetting Adhesive.
MIL-F-15160 - Fuses; Instrument, Power, and Telephone.
MIL-F-15160/60 - Fuses; Instrument, Power and Telephone (Nonindicating), Style F60.

MILITARY (Continued)

MIL-F-15160/61 - Fuses; Instrument, Power and Telephone (Nonindicating), Style F61.
MIL-F-15160/62 - Fuses; Instrument, Power and Telephone (Nonindicating), Style F62.
MIL-F-15160/63 - Fuses; Instrument, Power and Telephone (Nonindicating), Style F63.
MIL-F-15160/64 - Fuses; Instrument, Power and Telephone (Nonindicating), Style F64.
MIL-F-15160/65 - Fuses; Instrument, Power and Telephone (Nonindicating), Style F65.
MIL-F-15160/66 - Fuses; Instrument, Power and Telephone (Nonindicating), Style F66.
MIL-I-15265 - Insulation, Electrical, Plastic (Submarine Bus Bar Covering).
MIL-S-15291 - Switches, Rotary, Snap Action and Detent/Spring Return Action General Specification for.
MIL-C-15305 - Coils, Fixed and Variable, Radiofrequency, General Specification for.
MIL-C-15730 - Coolers, Fluid, Naval Shipboard: Lubricating Oil, Hydraulic Oil, and Fresh Water.
MIL-S-15743 - Switches, Rotary, Enclosed.
MIL-S-16032 - Switches and Detectors, Shipboard Alarm Systems.
MIL-M-16034 - Meters, Electrical-Indicating (Switchboard and Portable Types).
MIL-S-16036 - Switchgear, Power, Naval Shipboard.
MIL-M-16125 - Meters, Electrical, Frequency.
MIL-C-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-W-16878 - Wire, Electrical, Insulated, General Specification for.
MIL-W-16878/4 - Wire, Electrical, Polytetrafluoroethylene (PTFE) Insulated, 200°C, 600 Volts, Extruded Insulation.
MIL-W-16878/5 - Wire, Electrical, Polytetrafluoroethylene (PTFE) Insulated, 200°C, 1000 Volts, Extruded Insulation.
MIL-W-16878/7 - Wire, Electrical, Silicone Rubber Insulated, 200°C, 600 Volts.
MIL-W-16878/8 - Wire, Electrical, Silicone Rubber Insulated, 200°C, 1000 Volts.
MIL-W-16878/11 - Wire, Electrical, Fluorinated Ethylene Propylene (FEP) Insulated, 200°C, 600 Volts.
MIL-W-16878/12 - Wire, Electrical, Fluorinated Ethylene Propylene (FEP) Insulated, 200°C, 1000 Volts.

MILITARY (Continued)

MIL-M-17059 - Motors, 60-Cycle, AC, Fractional H.P. (Shipboard Use).

MIL-M-17060 - Motors, 60-Hertz, Alternating Current, Integral-Horsepower Shipboard Use.

MIL-I-17205 - Insulation Cloth and Tape, Electrical, Glass Fiber, Varnished.

MIL-T-17221 - Transformers, Power, Distribution; Single Phase, 400 Hertz, Insulation System Class 200°C, Dry (Air Cooled) (Naval Shipboard Use).

MIL-C-17361 - Circuit Breakers, Air, Electric, Insulated Housing (Shipboard Use), General Specification for.

MIL-M-17413 - Motors, Direct Current, Integral H.P., Naval Shipboard.

MIL-M-17556 - Motor, Direct-Current, Fractional HP (Shipboard Use).

MIL-C-17587 - Circuit Breakers, Low Voltage, Electric Power, Air, Open Frame, Removable Construction.

MIL-C-17588 - Circuit Breakers (Automatic - ALB-1) & Switch, Toggle (Circuit Breaker, Non-automatic - NLB-1) Air, Insulated Housing, 125 Volts & Below, Ac & Dc (Naval Shipboard Use)

DOD-S-17773 - Switches, Bus Transfer, Electric Power, Automatic and Manual. (Metric)
Resistant Steel.

MIL-P-18177 - Plastic Sheet, Laminated, Thermosetting, Glass Fiber Base, Epoxy-Resin.

MIL-F-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-F-19207 - Fuseholders, Extractor Post Type, Blown Fuse Indicating and Nonindicating General Specification for.

MIL-S-19500 - Semiconductor Devices, General Specification for.

MIL-R-19523 - Relays, Control.

MIL-I-19632 - Insulation, Electrical, Dielectric Barrier, Laminated, Plastic Film and Rag Paper.

MIL-C-19836 - Coolers, Fluid, Industrial, Air, Motor and Generator, Naval Shipboard.

MIL-I-19917 - Insulation Sheet, Electrical, Mica Paper, Silicone Bonded.

MIL-S-20708 - Synchros, General Specification for.

MILITARY (Continued)

MIL-T-21038 - Transformers, Pulse, Low Power, General Specification for.
MIL-I-21070 - Insulating Sheet and Tape, Electrical, Reinforced Mica Paper.
MIL-F-21346 - Fuseholders, Block, and Shroud Type, and Associated Fuse Clips; General Specification for.
MIL-F-21346/1 - Fuse Clip, Electrical; Styles FC21, FC22, FC23, and FC25.
MIL-S-21604 - Switches, Rotary, Multipole and Selector, General Specification for.
MIL-F-21608 - Ferrule, Shield Terminating, Crimp Style.

MIL-E-22118 - Enamel, Electrical-Insulating.
MIL-I-22129 - Insulation Tubing, Electrical, Polytetrafluoroethylene Resin, Nonrigid.
MIL-S-22432 - Servo Motors General Specification.
MIL-S-22710 - Switches, Rotary (Printed Circuit), (Thumbwheel, Incline, and Pushbutton), General Specification for.
MIL-I-22834 - Insulation, Electrical, Dielectric Barrier, Laminated, Plastic Film and Synthetic Fiber Mat.
MIL-S-22885 - Switches, Push Button, Illuminated, General Specification for.
MIL-I-23053 - Insulation Sleeving, Electrical, Heat Shrinkable, General Specification for.
MIL-V-23151 - Voltmeter, Expanded Scale Switchboard Type (Naval Shipboard Use).
MIL-M-23167 - Meter, Frequency, Expanded Scale Switchboard Type (Naval Shipboard Use).
MIL-S-23190 - Straps, Clamps, and Mounting Hardware, Plastic and Metal for Cable Harness Tying and Support.
MIL-T-23648 - Thermistor, (Thermally Sensitive Resistor), 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-G-24139 - Grease, Multipurpose, Water Resistant.
MIL-I-24178 - Insulation Tape, Electrical, Semi-Cured Thermosetting Resin Treated Glass, Armature Banding, Naval Shipboard.
MIL-I-24204 - Insulation, Electrical, High Temperature, Bonded, Synthetic Fiber Paper.
MIL-P-24212 - Pressure Transducer Equipment (Electrical).
MIL-S-24236 - Switches, Thermostatic, (Metallic and Bimetallic) General Specification for.
MIL-D-24304 - Differential Pressure Transducer Equipment (Electrical) (Naval Shipboard Use).
MIL-M-24325 - Molding Material, Plastic, Epoxy Compounds Thermosetting.
MIL-M-24350 - Monitors, Reverse Power and Power-Sensing, Electric Power (Naval Shipboard Use). (Metric)

MILITARY (Continued)

MIL-M-24359 - Meters, Millimeters, Direct Current Panel Mounting (Edgewise Types).
MIL-P-24364 - Plastic Sheets, Laminated, Thermosetting, Electrical Insulating Sheet, Glass-Mat.
MIL-P-24364/1 - Plastic Sheets, Laminated, Thermosetting Electrical-Insulating Sheet, Polyester Glass-Mat Grade GPO-N1 (Classes 130, 155, and 180).
MIL-P-24364/2 - Plastic Sheets, Laminated, Thermosetting Electrical-Insulating Sheet, Polyester Glass-Mat Grade GPO-N2 (Class 130).
MIL-P-24364/3 - Plastic Sheets, Laminated, Thermosetting Electrical-Insulating Sheet, Polyester Glass-Mat Grade GPO-N3.
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-P-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, Non-collapsible, High Temperature.
MIL-C-24707 - Castings, Ferrous, General Specification for.
MIL-C-24707/5 - Castings, Ductile Iron and Austenitic Ductile Iron.
MIL-C-24712 - Coatings, Powdered Epoxy. (Metric)
MIL-R-28750 - Relays, Solid State, General Specification for.
MIL-R-28803 - Readouts, Segmented, General Specification for.
MIL-C-28809 - Circuit Card Assemblies, Rigid, Flexible, Rigid-Flex.
MIL-M-38510 - Microcircuits, General Specification for.
MIL-C-39003 - Capacitors, Fixed, Electrolytic (Solid Electrolyte), Tantalum, Established Reliability, General Specification for.
MIL-C-39006 - Capacitors, Fixed, Electrolytic (Nonsolid Electrolyte), Tantalum, Established Reliability, General Specification for.
MIL-C-39006/22 - Capacitors, Fixed, Electrolytic (Nonsolid Electrolyte), Tantalum, (Polarized, Sintered Slug), 85°C (Voltage Derated to 125°C), Established Reliability, Style CLR79.
MIL-C-39014 - Capacitors, Fixed, Ceramic Dielectric (General Purpose) Established Reliability, General Specification for.
MIL-T-43435 - Tape, Lacing and Tying.

MILITARY (Continued)

MIL-I-46058 - Insulating Compound, Electrical (for Coating Printed Circuit Assemblies).
MIL-P-53084 - Primer, Cathodic Electrodeposition, Chemical Agent Resistant.
MIL-P-55110 - Printed-Wiring Boards General Specification for.
MIL-T-55164 - Terminal Boards, Molded, Barrier Screw and Stud Types, and Associated Accessories, General Specification for.
MIL-W-81044 - Wire, Electric, Crosslinked Polyalkene, Crosslinked Alkane-Imide Polymer, or Polyarylene Insulated, Copper or Copper Alloy.
MIL-W-81044/8 - Wire, Electric, Crosslinked Polyalkene Insulated, Silver-Coated Copper, Medium Weight, 600-Volt, 150°C.
MIL-W-81044/9 - Wire, Electric, Crosslinked Polyalkene Insulated, Tin-Coated Copper, Medium Weight, 600-Volt, 150°C.
MIL-W-81044/10 - Wire, Electric, Crosslinked Polyalkene Insulated, Silver-Coated High Strength Copper Alloy, Medium Weight, 600-Volt, 150°C.
MIL-W-81044/11 - Wire, Electric, Crosslinked Polyalkene Insulated, Silver-Coated Copper, Light Weight, 600-Volt, 150°C.
MIL-W-81044/12 - Wire, Electric, Crosslinked Polyalkene Insulated, Tin-Coated Copper, Light Weight, 600-Volt, 150°C.
MIL-W-81044/13 - Wire, Electric, Crosslinked Polyalkene Insulated, Silver-Coated High Strength Copper Alloy, Light Weight, 600-Volt, 150°C.
MIL-G-81322 - Grease, Aircraft, General Purpose, Wide Temperature Range, NATO Code Number G-395.
MIL-W-81381 - Wire, Electric, Polyimide-Insulated, Copper or Copper Alloy.
MIL-W-81381/12 - Wire, Electric, Fluorocarbon/Polyimide Insulated, Medium Weight, Nickel Coated Copper Conductor, 600 Volts, 200°C, Nominal 8.4 or 15.4 Mil Wall.
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-H-81829 - Heat Transfer Fluid, Fluorochemical.
MIL-R-83401 - Resistor Networks, Fixed, Film, and Capacitor-Resistor Networks, Ceramic Capacitor and Fixed Film Resistors, General Specification for.
MIL-C-83421 - Capacitors, Fixed, Supermetallized Plastic Film Dielectric, (DC, AC, or DC and AC), Hermetically Sealed in Metal Cases, Established Reliability, General Specification for.
MIL-C-83488 - Coating, Aluminum, High Purity.

MILITARY (Continued)
STANDARDS

FEDERAL

FED-STD-H28 - Screw-Thread Standards for Federal Services.
FED-STD-595 - Colors Used in Government Procurement.

MILITARY

MIL-STD-108 - Definitions of and Basic Requirements for Enclosures for Electric and Electronic Equipment.
MIL-STD-109 - Quality Assurance Terms and Definitions.
MIL-STD-129 - Marking for Shipment and Storage.
MIL-STD-167-1 - Mechanical Vibrations of Shipboard Equipment (Type I - Environmental and Type II - Internally Excited).
MIL-STD-195 - Marking of Connections for Electric Assemblies.
MIL-STD-198 - Capacitors, Selection and Use of.
MIL-STD-199 - Resistors, Selection and Use of.
MIL-STD-202 - Test Methods for Electronic and Electrical Component Parts.
MIL-STD-242 - Electronic Equipment Parts Selected Standards.
MIL-STD-275 - Printed Wiring for Electronic Equipment.
MIL-STD-280 - Definitions of Item Levels, Item Exchangeability, Models, and Related Terms.
MIL-STD-415 - Test Provisions for Electronic Systems and Associated Equipment, Design Criteria for.
MIL-STD-438 - Schedule of Piping, Valves, Fittings, and Associated Piping Components for Submarines Service.
MIL-STD-454 - Standard General Requirements for Electronic Equipment.
MIL-STD-461 - Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference.
MIL-STD-681 - Identification Coding and Application of Hookup and Lead Wire.
MIL-STD-701 - Lists of Standard Semiconductor Devices.
MIL-STD-740-1 - Airborne Sound Measurements and Acceptance Criteria of Shipboard Equipment.
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-970 - Standards and Specifications, Order of Precedence for the Selection of.
MIL-STD-1310 - Shipboard Bonding, Grounding, and Other Techniques for Electromagnetic Compatibility and Safety.
MIL-STD-1346 - Relays Selection and Application.
MIL-STD-1353 - Electrical Connectors, Plug-In Sockets and Associated Hardware, Selectrion and Use Of.

MILITARY (Continued)

MIL-STD-1364 - General Purpose Electronic Test Equipment.
MIL-STD-1378 - Requirements for Employing Standard Electronic Modules.
DOD-STD-1399, Section 070-Part 1 - Interface Standard for Shipboard Systems Section 070 - Part 1 D.C. Magnetic Field Environment. (Metric)
MIL-STD-1399, Section 300 - Interface Standard for Shipboard Systems Section 300 Electric Power, Alternating Current. (Metric)
DOD-STD-1399, Section 532 - Interface Standard for Shipboard Systems Section 532 Cooling Water for Support of Electronic Equipment. (Metric)
MIL-STD-1562 - Lists of Standard Microcircuits.
MIL-STD-1683 - Connections and Jacketed Cable, Electrical, 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). (Metric)
MIL-STD-2000 - Standard Requirements for Soldered Electrical and Electronic Assemblies.
DOD-STD-2143 - Magnetic Silencing Requirements for the Construction of Nonmagnetic Ship and Craft. (Metric)
MIL-STD-2164 - Environmental Stress Screening Process for Electronic Equipment.
MS17828 - Nut, Self-Locking, Hexagon, Regular-Height, (Non-Metallic Insert) 250°F, Nickel-Copper Alloy.
MS17829 - Nut, Self-Locking, Hexagon, Regular Height, 250°F, (Non-Metallic Insert) Non-Corrosion-Resistant Steel.
MS17830 - Nut, Self-Locking, Hexagon, Regular Height, 250°F, (Non-Metallic Insert) 300 Series Corrosion
MS21208 - Insert, Screw Thread, Coarse and Fine, Free Running, Helical Coil, CRES.
MS21209 - Insert, Screw Thread, Coarse and Fine, Screw Locking, Helical Coil, CRES.
MS21250 - Bolt, Tension, Steel, External Wrenching, Flanged, 12-Point, 180 KSI Ftu, 450°F.
MS21919 - Clamp, Loop-Type, Cushioned, Support.
MS35335 - Washer, Lock, Flat, External-Tooth

HANDBOOKS

MILITARY

MIL-HDBK-225 - Synchros Description and Operation.
MIL-HDBK-251 - Reliability/Design Thermal Applications.
DOD-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 & Hydraulic Fluids for Use in Shipboard Equipment.

MILITARY (Continued)

MIL-HDBK-338 - Electronic Reliability Design Handbook.
DOD-HDBK-344 - Environmental Stress Screening (ESS) of Electronic Equipment.

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Standardization Documents Order Desk, BLDG. 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

2.1.2 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 are those cited in the solicitation.

DEFENSE TECHNICAL INFORMATION CENTER (DTIC)

AD 297457 - United States Testing Company, Report of Test #83413.
Supplementary Technical Requirement (STR) 4P22 - List of Approved Lubricants and Compounds for Shipboard Use In Propulsion Plant Equipment and Piping Systems.

(Application for copies should be addressed to Defense Technical Information Center, Cameron Station, Alexandria, VA 22314.)

PUBLICATIONS

NAVAL SEA SYSTEMS COMMAND (NAVSEA)

0910-LP-057-1900 - Piping Devices, Flexible Hose Assemblies, Volume 1.
0910-LP-076-7000 - Equipment, Electronic, Navy; Parts Application and Reliability Information Manual.
0948-LP-045-7010 - Material Control Standard (Non-Nuclear), Volume 1.
0981-LP-052-8140 - Electrical Equipment - Small Stray Magnetic Field, Manual for Design of.

(Application for copies should be addressed to the Standardization Documents Order Desk, BLDG. 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

2.2 Non-Government publications. The following document(s) form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DOD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2).

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

B1.1 - Unified Inch Screw Threads (UN and UNR Form).
B46.1 - Surface Texture (Surface Roughness, Waviness and Lay). (DOD adopted)

(Application for copies should be addressed to the American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

A 153 - Standard Specification for Zinc Coating (Hot Dip) on Iron and Steel Hardware.
B 456 - Standard Specification for Electrodeposited Coatings of Copper Plus Nickel Plus Chromium and Nickel Plus Chromium.
B 633 - Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel. (DOD adopted)
D 495 - Standard Test Method for High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation. (DOD adopted)
D 568 - Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Flexible Plastics in a Vertical Position. (DOD adopted)
D 635 - Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Flexible Plastics in a Horizontal Position. (DOD adopted)
D 3638 - Standard Test Method for Comparative Tracking Index of Electrical Insulating Materials.
D 3935 - Standard Specification for Polycarbonate (PC) Unfilled and Reinforced Material.
D 4066 - Standard Specification for Nylon Injection and Extrusion Materials (PA). (DOD adopted)
F 1166 - Standard Practice for Human Engineering Design for Marine Systems, Equipment and Facilities.

(Application for copies should be addressed to the American Society for Testing Materials, 1916 Race Street, Philadelphia, PA 19103.)

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

1 - Standard General Principles for Temperature Limits in the Rating of Electric Equipment and for the Evaluation of Electrical Insulation.
117 - Standard Test Procedure for Evaluation of Systems of Insulating Materials for Random-Wound AC Electric Machinery.
200 - Reference Designations for Electrical and Electronics Parts and Equipments. (DoD adopted)
259 - Standard Test Procedure for Evaluation of Systems of Insulation for Specialty Transformers.
266 - Test Procedures for Evaluation of Insulation Systems for Electronic Power Transformers.
275 - Recommended Practice for Thermal Evaluation of Insulation Systems for AC Electric Machinery Employing Form-Wound Preinsulated Stator Coils Machines Rated 6900V and Below.

(Application for copies should be addressed to the Institute of Electrical and Electronic Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.)

STEEL STRUCTURES PAINTING COUNCIL (SSPC)

SP 10 - Near-White Blast Cleaning.

(Application for copies should be addressed to the Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburgh, PA 15213.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of precedence. 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 Essential characteristics. The essential characteristics of the equipment not fully described in the individual equipment specification shall be established as specified in appendix B.

3.2 Reliability. Equipment shall be designed and constructed to comply with the requirements for reliability of the individual equipment specification (see 6.3 and 6.7).

3.2.1 Design improvements. Submission by contractors or interested parties of proposals for design improvements in equipment (simpler, more reliable, more easily maintained, better performance, and so forth) is encouraged. Such proposals may be submitted at any time. Where a contractor is proposing a design improvement that constitutes a departure from specifications, the procedure specified in appendix B, 30.1.1.1 shall be followed.

3.2.2 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 that 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 3.13).

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.

3.2.3 Compatibility. Materials and parts used in equipment shall be mutually compatible with the environment for which they are intended. For example, see limitations on the use of silicone in 3.4.1.4.

3.2.4 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. The clearance dimensions necessary to provide the required accessibility about the equipment shall be given in all

drawings or other guides relating to installation. 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. Nonoperating 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 3.2.2 for protection to personnel).

3.2.4.1 Mounting of replaceable items. Items which are identified as replaceable, including individual parts, and nonrepairable 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.

3.2.4.2 Doors and covers. Hinges shall be so attached that they will not extend more than 1/4 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, and minimum interference to working or passage areas external to the equipment. 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.

3.2.4.3 Mounting fasteners. Enclosure mounting bolts shall be accessible and removable without removing any component part or panel within the enclosure.

3.2.5 Operation of controls. Where operating adjustments are provided which require rotary, lateral, or vertical input motions; such operations, as turning equipment ON, starting a function, advance, or increase in the quantity (for example, voltage, frequency, or speed) shall be accomplished in accordance with the requirements of MIL-STD-1472.

3.2.6 Maintenance and repair. Equipment shall be designed for ease of maintenance and repair (see 6.3 and 6.7). Except where packaging of parts in non-repairable form is approved (see 3.2.4 and 3.9.27), 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.

3.2.7 Fail safe design. 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.

3.2.8 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, mis-operation, or loss of local control of equipment.

3.2.9 Standardization. The contractor shall design the equipment 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 3.9.1.

3.2.9.1 Use of standard electronic modules (SEMs). Plug-in, non-repairable assemblies or subassemblies employed in the control circuits of equipment shall consist of SEMs where suitable and available. SEMs shall be furnished and documented in accordance with MIL-STD-1378 and the applicable SEM specification. For other types of non-repairable assemblies and subassemblies see 3.9.27.

3.3 General requirements. General requirements shall be as specified in 3.3.1 through 3.3.21 (see 6.3).

3.3.1 Input power.

3.3.1.1 Input power variations of alternating current (ac) equipment. Unless otherwise specified (see 6.2), ac powered equipment shall operate satisfactorily when connected to type I power in accordance with section 300 of MIL-STD-1399. Equipment shall meet all requirements of the equipment specifications when operating under specified steady state and transient power system input variations, excluding periods of power interruptions. Equipment shall not be damaged and replacement of any parts shall not be required as a consequence of power interruptions and abnormal voltage conditions in accordance with section 300 of MIL-STD-1399 (see 6.2).

3.3.1.2 Input voltage and frequency. Input voltage and frequency preference, order of preference, and selection shall be in accordance with section 300 of MIL-STD-1399.

3.3.1.3 Equipment-power system interactions. The equipment shall meet the user equipment interface requirements in accordance with section 300 of MIL-STD-1399.

3.3.2 Grounding. The equipment shall conform to 3.3.2.1 and 3.3.2.2 with respect to electrical grounding.

3.3.2.1 Electrical grounding. Grounding is defined as connecting a point of electrical equipment to the ship hull, or groundpoint for intentional or other reasons. Electrical equipment shall operate from the ungrounded ship power system and shall not malfunction if the power system is accidentally 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. Neither equipment chassis, equipment enclosure, nor the ship hull may be used in lieu of appropriate electrical conductors for the equipment circuitry. Circuit grounds necessary for built-in ground detection circuits are excluded from these requirements.

3.3.2.2 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.

3.3.3 Surge 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, section 300. Equipment shall be protected against part failure or malfunction such as intermittent firing of triggering devices due to surge voltage spikes occurring randomly over the instantaneous supply voltage.

3.3.3.1 Parts stress limitation. Equipment which employs circuits and parts in such as way that this degree of protection is not inherently achieved shall provide protection by use of surge voltage suppressors or suppression circuitry. 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 3.3.3, the equipment shall withstand these higher surge voltage stresses (see 3.3.1.3). Voltage regulator diodes and controlled-avalanche types of rectifier diodes, complying with the requirements specified in 3.9.18, may be used for surge voltage suppression. Also, surge and spike voltage suppressors specified in 3.9.19 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 (see 3.9.1.1) damaged by these stresses. All parts shall be of a type, size, and design that any combination of circuit elements or adjustments shall not induce stresses which will cause damage to the equipment.

3.3.4 Inclined operation. Equipment shall perform satisfactorily during inclined operation as follows (see 6.2).

(a) Surface ship equipment. Equipment for surface ships shall operate satisfactorily when permanently inclined in any direction at any angle up to 15 degrees from the normal operating position. Equipment shall function without damage or spilling of lubricant during temporary inclinations such as produced by ship rolling of 45 degrees in any direction from the normal operating position.

(b) Submarine equipment. Equipment for submarines shall operate satisfactorily when permanently inclined in any direction at any angle up to 30 degrees from the normal operating position. Equipment shall function without damage or spilling of lubricant during temporary inclinations such as produced by ship rolling of 60 degrees in any direction from the normal operating position.

3.3.5 Temperature and humidity.

3.3.5.1 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 nonoperating temperature range. If exterior shipboard service is intended, this shall be specified in the individual equipment specification (see 6.7), or in the contract (see 6.2). If not so specified, equipment shall be designed for interior shipboard services.

Temperature ranges ambient.

Service	Operating	Nonoperating
Exterior shipboard	Minus 28 degrees Celsius (°C) to plus 65°C	Minus 40°C to plus 75°C
Interior shipboard	0°C to plus 50°C	Minus 40°C to plus 75°C

3.3.5.2 Humidity. 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.

3.3.6 Shock and vibration.

3.3.6.1 Shock. Equipment specified in the individual equipment specification shall conform to the requirements of MIL-S-901 for high-impact (H.I.) shock (see 6.7).

3.3.6.2 Vibration. Equipment specified in the individual equipment specification shall conform to the requirements of MIL-STD-167-1 for vibration (see 6.7).

3.3.7 Equipment mounting. For equipment required to meet the high-impact shock requirements of MIL-S-901, mounting shall be as follows (see 6.7):

(a) Equipment shall be designed for mounting with grade 2 bolts as a minimum in accordance with MIL-S-1222.
(b) Size of mounting holes shall be as follows:

Nominal bolt diameter	Maximum diameter of hole
3/4 inch and smaller	Nominal bolt diameter plus 1/32 inch
Larger than 3/4 inch	Nominal bolt diameter plus 1/16 inch

(c) Equipment may be designed to use captive (body bound) bolts for mounting.

3.3.8 Electromagnetic interference general requirements. The equipment shall conform to the electromagnetic interference (EMI) requirements of MIL-STD-461. Detailed design and testing requirements shall be included in the individual equipment specification (see 6.2 and 6.7).

3.3.9 Direct current (dc) magnetic field environment. Shipboard equipment shall comply with the static magnetic field environmental interface constraints in accordance with DOD-STD-1399, section 070.

3.3.10 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 (see 6.7).

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

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

3.3.10.3 Stray field source. DC equipment and dc circuits in or associated with the equipment shall be designed in accordance with NAVSEA 0981-LP-052-8140, and meet the requirements of DOD-STD-2143 for a class 3 magnetic field source.

3.3.11 Noise reduction.

3.3.11.1 General requirements. 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 the 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 and 6.7).

3.3.11.2 Airborne and structureborne noise. When specified in the individual equipment specification or in the contract (see 6.7), the equipment shall be tested for airborne or structureborne noise in accordance with MIL-STD-740-1 and MIL-STD-740-2 (see 6.3). Acceptable levels shall be as specified in the individual equipment specification or in the contract (see 6.7).

3.3.11.3 Dynamic balancing. For rotating equipment to be used on submarines, or when specified in the equipment specification, provision for dynamic balancing shall be included as specified in 3.3.12.

3.3.12 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, yet 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 plus or minus 1 degree and all linear dimensions within plus or minus 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.

3.3.13 Leakage current. Leakage current is defined as the peak value of current flowing through the connection when any line of the power source is connected to the frame of the equipment (with equipment case not connected to the ship hull), for test purposes, and with equipment operating.

3.3.13.1 Portable and permanently installed equipment. Leakage current shall not exceed 5 milliamperes (mA). This limit applies even where electromagnetic interference suppression devices are permitted (see appendix A, 10.4.11) and used.

3.3.14 Electrical creepage and clearance distances. Electrical creepage and clearance distances are defined as follows:

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

(b) Creepage distance is the shortest distance between energized parts, or between an uninsulated energized part and ground, along the surface of an insulating material. 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 I.

Creepage and clearance distances between electrical circuits, between each electrical circuit and ground, and across lines and between circuit elements that operate at significantly different potential levels within each circuit shall be not less than those values shown in table I for equipment conforming to this specification. It is emphasized that the values shown in table I represent the minimum acceptable limits for nonarcing rigid construction based on normal volt-ampere1/ ratings 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.

3.3.14.1 Distance from enclosure. Exposed nonarcing current-carrying parts within enclosures shall have an air space between them and the uninsulated part of the enclosure of not less than 0.75 inch. However, the values shown in table I may be applied to the creepage and clearance distances between uninsulated parts of enclosures and exposed nonarcing 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 (see 6.2).

1/ Product of the normal voltage applied to the circuit times the current carried

TABLE I. Electrical creepage and clearance distance. 1/

Voltage ac or dc	Set 2/	Clearance	Creepage 3/	
			Open 4/	Enclosed 5/
		(inches)	(inches)	(inches)
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 600-1000	A	1/8	1/2	3/8
	B	1/4	1	3/4
	C	1/2	2	1-1/2
Over 1000-3000	C	2	4	2
Over 3000-5000	C	3	5	3

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 2000.
Set C - Normal operating volt-ampere rating over 2000.

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.

3.3.15 Piping systems. Piping systems shall have socket welded, butt welded, or flanged fittings. Silver brazing and threaded pipe fittings shall not be used.

3.3.15.1 Material identification and control. Requirements for material identification and control of piping systems shall be in accordance with NAVSEA 0948-LP-045-7010.

3.3.16 Screw thread standards for fastening devices. Screw threads for all threaded fastening devices shall be in accordance with ANSI 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.

3.3.16.1 Fastening of parts. Except for motors, generators, and motor generators, through bolting shall be used wherever practicable (see 6.2). For electrical panels and other applications where frequent disassembly is required, blind nuts and captive fasteners shall be used when practical. Similarly, these types of fasteners shall be used when practical to prevent a loose fastener from dropping into electrical equipment.

3.3.16.2 Fitted bolts. The holes for fitting (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 ANSI B46.1. Bolt to hole fit is shown in table II.

TABLE II. Bolt and hole dimensions.

Nominal size (inches)	Max. clearance (+) diameter (inches)	Max. interference (-) diameter (inches)
1/2 to 1-1/4	0.0005	0.0010
1-1/4 to 1-7/8	0.0006	0.0013
2 to 3	0.0007	0.0016

3.3.16.3 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-resisting 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.

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

3.3.16.5 Inserts. Metal inserts, where required in aluminum alloys or plastics, shall be the bushing type or the helical-coil type conforming to MS21208 or MS21209. 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 3.12.6).

3.3.16.6 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.

3.3.16.7 Bolt and screw thread engagement. For materials having similar mechanical properties, the full thread engagement shall be not less than 1 major diameter (ID). For materials having dissimilar mechanical properties, the minimum thread engagement shall be in accordance with FED-STD-H28, part 1, appendix 5, using the maximum tensile strength of the stud material and minimum specified tensile strength of the body material, plus one thread; but in no instance less than the root diameter. Where helical-coil type threaded inserts are used (see 3.3.16.5 for limitations), the length of the thread engagement shall be not less than 1-1/2 times the major diameter (nominal) of the bolt thread.

3.3.16.8 Thread locking of mechanical assemblies. Bolts, nuts, and screws used for mechanical connections, where the specified operation under all anticipated conditions, including shock, vibration, and heating, depends upon maintaining tight connection of parts, or where a holding screw, bolt, nut, or fastened part may fall into the equipment, shall be secured by one of the following means:

(a) Lockwasher (see 3.3.16.11.1).
(b) Locknut (see 3.3.16.9).
(c) Castellated nut with cotter pin or safety wiring.
(d) Self-locking screws. This method may be used only where removal for maintenance is very infrequent (see 3.3.16.9.2).
(e) 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.
(f) Locking wire for use to lock bolts when only bolt heads are available to apply a locking device.
(g) Self-locking nut
(h) Blind nuts and captive fasteners

3.3.16.9 Fastening devices. Fastening devices (nuts, bolts, screws, lockwashers, flat washers, and so forth) shall be made of corrosion-resisting material (see 3.4.2.3) or shall be treated to resist corrosion without paint (see 3.10.1). Spring type locking devices, such as lockwashers and retaining rings, when made of precipitation hardened semi-austenitic corrosion-resisting steel, do not require additional protection against corrosion. Aluminum alloy fasteners are not to be considered corrosion resistant.

3.3.16.9.1 Nuts, bolts, and screws. Nuts, bolts, and screws shall be in accordance with the following: FF-S-85, FF-S-86, FF-S-92, FF-S-200, FF-S-210, MIL-S-1222, MS17828, MS17829, MS17830, 12 point collar screws with head style as shown on MS21250, 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.

3.3.16.9.2 Self-locking screws. Self-locking screws shall be in accordance with MIL-F-18240. Screws threaded into non-metallic inserts shall not be used for electrical connections.

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

3.3.16.9.4 Blind fasteners. Blind fasteners, when used, shall be in accordance with MIL-F-8975.

3.3.16.10 Thread-cutting screws. Thread-cutting (self-tapping) screws shall not be used, except for information and identification plates (see 3.13.4).

3.3.16.11 Washers. Washers shall be in accordance with FF-W-84 (spring lock) or FF-W-92 (plain flat) or commercial types if Government specification sizes are not available.

3.3.16.11.1 Lockwashers. Lockwashers shall be of the following types (see 3.3.16.9):

(a) Split ring (helical spring). Preferred type.
(b) External tooth lock washers, preferred for electrical connections, to be in accordance with MS 35335 tin-brass, copper alloy 425 washers (see 3.8.2.8).
(c) Internal-tooth.

External-tooth type 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 lockwashers only where necessitated by space limitations, 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 serrations make satisfactory contact.

3.3.16.11.2 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 or the material and the applied protective coating, except in areas where an electrical ground is required.

(d) Except where it conflicts with electromagnetic interference considerations, a flat washer shall be used between an organically finished material and lockwashers, bolt and screw heads, or nuts.

3.3.17 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. (Copies of this catalog may be consulted in the offices of the Defense Contract Management Area Operations (DCMAO)). 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 3.9.1.3 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. For test equipment, see 3.3.19.

3.3.18 Equipment insulation requirements. Unless otherwise specified (see 6.2 and 6.7), equipment shall pass insulation and dielectric withstanding voltage tests required by 3.3.18.1 as follows:

(a) The insulation resistance of each circuit to all other circuits connected together and to ground shall not be less than 10 megohms at 25°C.
(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 intended for submarine application shall withstand a voltage of 500 volts (V)dc applied from any power line to ground while the equipment is energized from its normal source of power. No equipment damage or maloperation 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.

3.3.18.1 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 4.5.2 and 4.5.3. 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, submain, branch, subbranch, and so forth) shall withstand the tests specified in 4.5.2 (see 6.2).

3.3.19 Test equipment requirements. Unless otherwise specified (see 6.2), equipment shall be so designed that the only test equipment required for its maintenance, alignment, calibration, and repair shall be test equipment selected from MIL-STD-1364.

3.3.20 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 (see 6.7).

3.3.20.1 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.

3.3.20.2 Ice. Equipment, or portions thereof, exposed to the elements, shall start and operate normally when covered with an ice load of 4.5 pounds per square foot (lb/ft^2).

3.4 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 if so requested (see appendix B, 30.1.1).

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

(a) Toxic pyrolytic materials (see 3.4.1.1).
(b) Flammable materials (see 3.4.1.9).
(c) Fragile or brittle materials (see 3.4.1.10).
(d) Mercury (see 3.4.1.2).
(e) Asbestos (see 3.4.1.3).
(f) Silicone (see 3.4.1.4).
(g) Polychlorinate biphenyls (PCB) (see 3.4.1.5).
(h) Polyvinyl chloride (PVC) (see 3.4.1.6).
(i) Cadmium and cadmium plating (see 3.4.1.7).
(j) Freon solvents.
(k) Radioactive materials.
(l) Magnesium or magnesium base alloys.

3.4.1.1 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 III.

3.4.1.1.1 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 III. 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

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

3.4.1.2 Mercury. Equipment meeting this specification shall be free of mercury (see 6.3). 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.

3.4.1.3 Asbestos. Materials containing asbestos shall not be used unless there is no acceptable substitute for the application (see appendix B, 30.1.1).

3.4.1.4 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 may be acceptable (see appendix B, 30.1.1).

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

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

3.4.1.7 Cadmium and cadmium plating. Cadmium plated parts and fasteners shall not be used unless there is no substitute for a specific application (see appendix B, 30.1.1).

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

Linen.	Cork.
Cellulose acetate.	Paper and cardboard.
Cellulose nitrate.	Organic fiberboard.
Regenerate cellulose.	Hair or wool felts.
Wood.	Plastic materials using cotton, linen or wood flour as a filler.
Jute.	
Leather.	

3.4.1.9 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 shown in table IV.

TABLE IV. Material resistance to burning.

Materials 1/	Applicable test method	Applicable document	Limit
Laminated plastics	----	DTIC AD 297457	Ignition - 95s min.
Molded plastics	----	MIL-M-14	Burning - 120s max.
Encapsulating compounds	----	DTIC AD 297457	Weight loss - 15 percent max. Ratio B/I - 84 percent max.
All other flammable materials except those used internally in varnished coil structure, metal enclosed shock resilient pads and gaskets sealing metal surfaces	----	ASTM D 568 Flexible Plastics	Burning time - 10s max. Extent of burning - 25 mm max.
		ASTM D 635 Self-support plastics	Burning time - 10s max. Extent of burning - 25 mm max.

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 IV. 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.

3.4.1.10 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 equipments, and parts thereof, which are intended for use aboard ship.

3.4.2 Metals. Metals shall be selected or processed and applied in a manner that provides corrosion-resistance. Metals that are not inherently corrosion-resistant (see 3.4.2.3) shall be processed (treated, plated, or painted) to provide corrosion-resistance (see 3.10.1).

3.4.2.1 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.

3.4.2.2 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 (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.

3.4.2.3 Corrosion-resisting 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-resisting metals for equipment subjected to severe environmental conditions.

(a) Brass. 1/
(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. 2/
(k) Titanium.
(l) Austenitic steels, corrosion-resisting types 202, 301, 302, 303, 304, 304L, 309, 310, 316, 316L, 321, 324A, 347. 3/

1/ Brasses containing 20 to 40 percent zinc are highly susceptible to stress corrosion cracking in marine environments when highly stressed.
2/ Reference: Corrosion of Metals in Marine Environments, Fink, F. W. and Boyd, W. K., Bayer and Company, Inc., Columbus, Ohio, 1970.
3/ Austenitic stainless steels are susceptible to stress corrosion cracking in marine environments when service temperatures exceed 150 degrees Fahrenheit (°F) (65°C).

3.4.3 Plastics. Plastics which serve as electrical insulation shall be in accordance with 3.5.1. 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 nonflammability 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 3.5.1.2.2 and 3.5.1.3.1.1).
(b) Exterior plastic materials that are not painted shall match color of MIL-E-15090 enamel, except where transparency is required.
(c) Internal plastic materials which do not serve as electrical insulation - any color.

3.4.3.1 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-P-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.

3.4.4 Glass. Glass for protection of indicator dials and for viewing windows shall be applied within the constraints of 3.4.1.10 and shall be of the shatterproof type in accordance with class 1, type I, of MIL-G-3787. 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.

3.5 Electrical insulation. Electrical insulation shall be as specified in 3.5.1 through 3.5.18 (see appendix B, 30.1.1).

3.5.1 Insulation materials.

3.5.1.1 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

4.5.3.3). This applies to low voltage (under 2000 V) equipment. For equipment rated at 2000 V or higher, an arc resistance of 150 seconds and a minimum track resistance of 300 minutes shall be required.

3.5.1.2 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 3.4). For spacers, see 3.5.9. Laminates shall meet the minimum requirements for toxicity (see 3.4.1.1), flame resistance (see 3.4.1.9), and arc and tracking resistance (see 3.5.1.1).

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

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

3.5.1.3 Molded plastics.

3.5.1.3.1 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 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 V or equivalent meeting the specified requirements.
(b) The molding compound shall meet the minimum requirements for toxicity (see 3.4.1.1), flame resistance (see 3.4.1.9), and arc resistance (see 3.5.1.1).
(c) The molding compound shall meet the mechanical and electrical requirements of each application.

TABLE V. Molding compounds (glass fiber reinforced).

Compound	Type	Specification	Maximum temperature (°C)
Polyester glass	MAI-60	MIL-M-14	130
Polyester glass	MAI-30	MIL-M-14	130
Polyester glass	MAT-30 1/	MIL-M-14	130
Melamine glass	MMI-30	MIL-M-14	130
Melamine glass	MMI-5	MIL-M-14	130
Diallyl ortho-phthalate	SDG-F	MIL-M-14	155
Diallyl ortho-phthalate	GDI-30F	MIL-M-14	155
Diallyl iso-phthalate	SIG-F	MIL-M-14	180
Diallyl iso-phthalate	GII-30F	MIL-M-14	180

See footnotes at end of table.

TABLE V. Molding compounds (glass fiber reinforced) - Continued.

Compound	Type	Specification	Maximum temperature (°C)
Silicone mineral 2/	MSG	MIL-M-14	200
Silicone glass 2/	MSI-30	MIL-M-14	200
Epoxy glass	GEI-5, -20, -100	MIL-M-24325	130

1/ Mandatory for high voltage application (2000 V or higher).
2/ See 3.4.1.4 for restrictions on the use of silicone.

3.5.1.3.1.1 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 2000 V or higher, shall be furnished in a red color.

3.5.1.3.2 Thermoplastics. In general, thermoplastics shall not be used in any molded part unless allowed by the individual equipment specification (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 VI or equivalent meeting the specified requirements.

TABLE VI. Molding compounds (thermoplastic material).

Compound	Type	Specification	Maximum temperature (°C)
Polyamide (nylon)	Type III, grade E	ASTM D 4066	105
Polycarbonate	-------	ASTM D 3935	105

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

3.5.1.5 Silicone. The use of silicone shall be as specified in 3.4.1.4.

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

3.5.2.1 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 (see 6.7). 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 provides 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. The classes and definitions of insulating materials are grouped according to the following classification:

3.5.2.1.1 Class 90. Materials or combinations of materials such as cotton, silk, and paper without impregnation. Other materials or combinations of materials may be included in this class if by experience or accepted tests they can be shown to have comparable thermal life at 90°C.

3.5.2.1.2 Class 105. Materials or combinations of materials such as cotton, silk, and paper when suitably impregnated or coated or when immersed in a dielectric liquid such as oil. Other materials or combinations of materials may be included in this class if by experience or accepted tests they can be shown to have comparable thermal life at 105°C.

3.5.2.1.3 Class 130. Materials or combinations of materials such as mica, glass fiber, and so forth, with suitable bonding substances. Other materials or combinations of materials may be included in this class if by experience or accepted tests they can be shown to have comparable thermal life at 130°C.

3.5.2.1.4 Class 155. Materials or combinations of materials such as mica, glass fiber, and so forth, with suitable bonding substances. Other materials or combinations of materials may be included in this class if by experience or accepted tests they can be shown to have comparable thermal life at 155°C.

3.5.2.1.5 Class 180. Materials or combinations of materials such as silicone elastomer, mica, glass fiber, and so forth, with suitable bonding substances such as appropriate silicone resins. Other materials or combinations of materials may be included in this class if by experience or accepted tests they can be shown to have comparable thermal life at 180°C.

3.5.2.1.6 Class 200. Materials or combinations of materials such as mica, glass fiber, asbestos, and so forth, with suitable bonding substances. Other materials or combinations of materials may be included in this class if by experience or accepted tests they can be shown to have comparable thermal life at 200°C.

3.5.2.1.7 Class 220. Materials or combinations of materials which by experience or accepted tests can be shown to have the required thermal life at 220°C.

3.5.2.1.8 Class 240. Materials or combinations of materials which by experience or accepted tests can be shown to have the required thermal life at 240°C.

3.5.2.1.9 Class over 240. Materials consisting entirely of mica, porcelain, glass, quartz, and similar inorganic materials. Other materials or combinations of materials may be included in this class if by experience or accepted tests they can be shown to have the required thermal life at temperatures over 240°C.

3.5.2.1.10 Accepted tests. In the above definitions, the words "accepted tests" 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 an 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.

3.5.2.3 Temperature index. 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 following preferred temperature indices shall be used for insulating materials (see 6.7):

Temperature index (°C)
90
105
130
155
180
200
220
240
260

3.5.3 Insulation systems.

3.5.3.1 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 VII shall be used for Navy equipment and shall be specified in the individual equipment specification (see 6.7).

TABLE VII. Insulation system classes (limiting temperatures).

Class	Previous letter class	Limiting temperature (°C)
90	Y	90
105	A	105
130	B	130
155	F	155
180	H	180
200	N	200
220	R	220
240	S	240
260	C	260

The materials used in electrical systems shall be characterized by the specific limiting temperatures shown in table VII. 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.

3.5.3.2 Alternative temperature specification of insulation systems. An alternative method to specify class of insulation systems used shall conform to the following definitions and shall be specified in the individual equipment specification (see 6.3).

3.5.3.2.1 Class A insulation system. A class A insulation system is a system utilizing class 105 materials at such temperature rises above stated ambient temperature as the specification for the specific type of equipment specifies, 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.

3.5.3.2.2 Class B insulation system. Class B insulation system is a system utilizing class 130 materials at such temperature rises above stated ambient temperatures as the specification for the specific type of equipment specifies, based on experience or accepted test data. 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.

3.5.3.2.3 Class F insulation system. A class F insulation system is a system utilizing class 155 materials at such temperature rises above stated ambient temperatures as the specification for the specific type of equipment specifies, based on experience or accepted test data. 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.

3.5.3.2.4 Class H insulation system. A class H insulation system is a system utilizing class 180 materials at such temperature rises above stated ambient temperature as the specification for the specific type of equipment specified, based on experience or accepted test data. 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. (NOTE: Class N insulation was formerly classified as class H by the Navy and was suitable for 200°C. Since industry has defined class H as suitable for only 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 (200°C) shall be redesignated as class N.)

3.5.3.2.4.1 Class H insulation suitability. In order to furnish equipment utilizing class H insulation, the equipment manufacturer shall conduct insulation suitability tests for class H insulation in accordance with the appendix of this specification.

3.5.3.2.5 Class N insulation system. A class N insulation system is a system utilizing class 200 materials at such temperature rises above stated ambient temperatures as the specification for the specific type of equipment specifies, based on experience or accepted test data. 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. (NOTE: Class N insulation was formerly classified as class H by the Navy and was suitable for 200°C. Since industry has defined class H as suitable for only 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 N classification (200°C) shall be redesignated as class N.)

3.5.3.2.5.1 Class N insulation suitability. In order to furnish equipment utilizing class N insulation, the equipment manufacturer shall conduct insulation suitability tests for class N insulation in accordance with the appendix of this specification.

3.5.3.2.6 Class R insulation system. A class R insulation system is a system utilizing class 220 materials at such temperature rises above stated ambient temperatures as the specification for the specific type of equipment specifies, based on experience or accepted test data. 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.

3.5.3.2.6.1 Class R insulation suitability. In order to furnish equipment utilizing class R insulation, the equipment manufacturer shall have qualification approval for class R insulation in accordance with the appendix of this specification.

3.5.3.2.7 Class S insulation system. A class S insulation system is a system utilizing class 240 materials at such temperature rises above stated ambient temperatures as the specification for the specific type of equipment

specifies, based on experience or accepted test data. 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.

3.5.3.2.7.1 Class S insulation suitability. In order to furnish equipment utilizing class S insulation, the equipment manufacturer shall have qualification approval for class S insulation in accordance with the appendix of this specification.

3.5.3.2.8 Class C insulation system. A class C insulation system is a system utilizing class 260 materials at such temperature rises above stated ambient temperatures as the specification for the specific type of equipment specifies, based on experience or accepted test data. 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.

3.5.3.2.8.1 Class C insulation suitability. In order to furnish equipment utilizing class C insulation, the equipment manufacturer shall have qualification approval for class C insulation in accordance with the appendix of this specification.

3.5.4 Thermal endurance evaluation. The following test procedures are acceptable thermal evaluation methods and shall be used to evaluate new or modified insulation systems for specific equipment:

IEEE 117
IEEE 259
IEEE 266
IEEE 275

Test procedures for other items shall be as approved (see appendix B, 30.1.1).

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

TABLE VIII. Ground insulation.

Material	Specification	Type, class, or grade	Maximum temperature (°C)
Pasted mica splitting	HH-I-538	All types	As required 1/
Reinforced mica splittings	MIL-I-3505	All types	As required 1/
Mica-paper composites	MIL-I-21070	All types	As required 1/
Mica-paper composites (for VPI)	----------	Commercial 6/	As required 1/
Pasted mica (silicone binder) 5/	HH-I-538	All types	200

See footnotes at end of table.

TABLE VIII. Ground insulation - Continued.

Material	Specification	Type, class, or grade	Maximum temperature (°C)
Mica-paper (silicone binder) 5/	MIL-I-19917	All types	200
Polyester film-rag-paper	MIL-I-19632	All types	105
Polyester mat-polyester-film	MIL-I-22834	All types	130
Polyester film 2/	MIL-I-631	Type G	120
Varnished glass cloth 3/	MIL-I-17205	Grade O	90
Polyamide paper	MIL-I-24204	All types	220
Polyamide film 4/	----------	Commercial 6/	220

1/ The temperature class is determined by the binder used; suitable binders are available for 155°C, 180°C, and 200°C use.
2/ 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 inches for rotating equipment and 0.001 inches for static equipment.
3/ Varnished glass cloth for ground insulation applications shall be limited to control circuits up to 50 volt amperes (VA).
4/ The minimum film thickness of polyamide film shall be 0.0075 inches for rotating equipment, and 0.001 inches for nonrotating equipment.
5/ See 3.4.1.4 for restrictions on the use of silicones.
6/ For specific material see appendix B, 30.1.1.

3.5.6 Core tubes and bobbins. Core tubes and bobbins for mechanical support shall be laminated plastic types (see 3.5.1.2) or molded plastic types (see 3.5.1.3).

3.5.7 Toroid core boxes. Core boxes for toroid windings may be aluminum with overwrappings of either pressure sensitive insulating tape (see 3.5.11) or coating of epoxy as approved (see appendix B, 30.1.1) using the fluidized bed or spray process and oven cured.

3.5.8 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 3.5.5 except varnished glass cloth.

3.5.9 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 155°C, and selected as specified in table IX.

TABLE IX. Spacers.

Item	Material	Type or grade	Specification	Maximum temperature (°C)
Spacer (rigid-flat)	Glass melamine	GME	MIL-P-15037	130
	Glass silicone 2/	GSG	MIL-P-997	200
	Pasted mica	All	HH-I-538	130-200 1/
	Glass epoxy	GEE	MIL-P-18177	130
	Glass polyester	GPO-N1	MIL-P-24364/1	130-180 1/
Spacer (rigid-tube-rod, or formed shape)	Glass melamine	GMG, TR	MIL-P-79	130
	Glass silicone 2/	GSG	MIL-P-997	180
	Glass epoxy	-------	Commercial 3/	130-155 1/
	Glass polyester	-------	Commercial 3/	130-180 1/
Spacer (flexible)	Reinforced mica	All	MIL-I-3505	130-200 1/
	Varnished glass	0	MIL-I-17205	90

1/ Limiting temperature will depend on the type of resin or binder used.
2/ See 3.4.1.4 for restrictions on the use of silicones.
3/ For specific material see appendix B, 30.1.1.

3.5.10 Binding tape and strips. Binding tape and strip (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 3.5.17).

3.5.11 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 MIL-I-15126.

3.5.12 Slot-wedges (non-metallic). Slot-wedges shall be selected from table X.

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

Item	Material	Type	Specification	Maximum temperature (°C)
Slot wedge, flat	Glass melamine	GME	MIL-P-15037	155
	Glass silicone 2/	GSG	MIL-P-997	200
	Glass epoxy	GEE	MIL-P-18177	130
	Glass polyester	GPO-N1	MIL-P-24364/1	130-180 1/
	Polyamide fabric/ phenolic	------	Commercial 3/	200

See footnotes at end of table.

TABLE X. Slot-wedges (non-metallic) - Continued.

Item	Material	Type	Specification	Maximum temperature (°C)
Slot wedge, formed	Glass polyester	------	Commercial 3/	130
	Glass epoxy	------	Commercial 3/	130
	Polyester film	G	MIL-I-631	120
	Polyester mat-film	------	MIL-I-22834	130
	Polyamide paper	------	MIL-I-24204	220
	Polyamide fabric/ phenolic	------	Commercial 3/	200

1/ Limiting temperature will depend on type of resin used.
2/ See 3.4.1.4 for restrictions on the use of silicones.
3/ For specific material see appendix B, 30.1.1.

3.5.13 Insulating panels. Insulating panels shall be in accordance with type GME of MIL-P-15037, type GSG of MIL-P-997, or MIL-I-24364 and type GPO-N2 or GPO-N3 of MIL-I-24364/2 or MIL-I-24364/3, respectively.

3.5.14 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 MIL-I-23053.

3.5.15 Commutator insulation. Commutator segments shall be pasted mica type PMR, inorganic bonded mica, or reconstructed mica with polyester or melamine binders. Commutator V rings and molded insulation shall be pasted mica type PMM in accordance with HH-I-538.

3.5.16 Band insulation. Insulation under banding wire shall be pasted mica type PMF in accordance with HH-I-538, mica-glass composite in accordance with MIL-I-3505, or laminated plastic material with varnished glass cloth underlayment.

3.5.17 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 class 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 3.4.1.4 for restrictions on use of silicone).

3.5.18 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.

3.6 Insulation procedures. The following general rules shall apply for the processing of electrical insulation for electrical equipment.

3.6.1 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 VIII.

3.6.2 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.

3.6.3 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 3.6.3.5).

3.6.3.1 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 insure complete filling of the voids.

3.6.3.2 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 insures 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.

3.6.3.3 Vacuum-pressure impregnation (VPI). By this method, solventless resin shall be applied to a completed armature or completed stator coil using a vacuum-pressure impregnation 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.

3.6.3.4 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 should be avoided if at all possible since it yields a product of questionable reliability (see appendix B, 30.1.1).

3.6.3.5 Brushing or spraying. Varnish applied to electrical coils by these methods does not ensure complete impregnation of the internal sections of the coil (see appendix C, 30.1.1).

3.6.4 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 insure thorough drying, solidification or curing throughout the innermost recesses of the windings. The Government inspector may require a coil or winding to be cut open to see the extent of the treatment and filling if there is a question as to the effectiveness of the treating method used.

3.6.4.1 Varnish. Varnish shall be selected in accordance with table XI.

TABLE XI. Varnish.

Application	Type or grade	Specification
Stationary windings and low speed rotating windings 1/	Grade CB, CBH solvent types	MIL-I-24092
High speed rotating windings 1/	Solvent types	Commercial 2/
VPI process	Solventless	Commercial 3/

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.
2/ The varnish shall be evaluated for bond strength. Bond strength tests may be made using the helical coil method (see appendix B, 30.1.1).
3/ See appendix B, 30.1.1.

3.6.4.2 Encapsulants and compounds used on coils and windings. Encapsulants, winding compounds (paste-like material usually applied by brush or spatula) and other solventless materials are characteristic in that they cure to a solid state by catalyst reaction plus heat (see appendix B, 30.1.1). 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.

3.6.4.2.1 Application conditions. 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.

3.6.5 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 10°C (50°F) 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.

3.6.5.1 Baking ovens. The baking ovens shall be rated at least 175°C for classes 105, 130, and 155 windings; and at least 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.

3.6.5.2 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.

3.6.5.3 Typical treating guidelines. The treating checklist in table XII 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 XII. Treating guidelines, armature coils, armatures, stators, and field coils.

Dip and bake procedure-solvent varnish		VPI using solventless epoxy resin
Step 1.	Insure that varnish is the correct viscosity and solids content as recommended by the manufacturer.	Insure 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 50°C.
Step 3.	Cool to 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, 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 1/2 hour. Apply dry air or nitrogen to immersed winding at 90 lb/in^2 or higher for 1 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.

TABLE XII. Treating guidelines, armature coils, armatures, stators, and field coils - Continued.

Dip and bake procedure-solvent varnish		VPI using solventless epoxy resin
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 50°C.	Remove from oven and cool to approximately 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.

3.6.6 Final condition. The treated windings and coils shall be clean, smooth, and glossy with good bonding, filling, and adhesion. Good bonding and adhesion is considered to be achieved when the coil conductors are secure, firm, and immovable to the touch. More than 0.50 inch square is considered excessive peeling and the winding shall be rejected. Bubbles, air pockets, and voids shall be kept to a minimum (questionable windings 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.

3.6.7 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, and washer, and so forth) installed shall conform to the requirements of MIL-S-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.

3.7 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 (questionable type windings shall be subjected to the insulation suitability test of appendix A).

3.7.1 Classification. Insulation suitability for electrical windings shall be of the following types (see appendix A):

Type CW - Complete winding.
Type PW - Partial winding.

3.8 Wire, wiring methods, and marking.

3.8.1 Wire.

3.8.1.1 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 XIII.

TABLE XIII. Lead wire.

Insulation	Specification	Maximum temperature (°C)
Chlorosulfonated polyethylene	Commercial 1/	130
Crosslinked ethylene propylene	Commercial 1/	150
Crosslinked polyalkene	MIL-W-81044, /8, /9, and /10	150
Silicone rubber 2/	MIL-W-16878/7 and /8	200
Silicone rubber 2/	MIL-W-16878/29 and 30	150
Fluorinated ethylene propylene	MIL-W-16878/12	200
Polytetrafluoroethylene	MIL-W-16878/4 and /5	200

1/ For specific material see appendix B, 30.1.1.
2/ See 3.4.1.4 for specific prohibition on application.

3.8.1.2 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 XIV.

TABLE XIV. Hook-up wire.

Insulation	Specification	Maximum temperature (°C)
Polytetrafluoroethylene	MIL-W-16878/4 and /5	200
Silicone rubber 1/	MIL-W-16878/7, /8, and /32	200
Silicone rubber 1/	MIL-W-16878/29 and 30	150
Fluorinated ethylene propylene	MIL-W-16878/11 and /12	200
Crosslinked polyalkene	MIL-W-81044/8, /9, /10, /11, /12, and /13	150
Fluorocarbon/polyamide	MIL-W-81381, /12, and /22	150
Crosslinked ethylene propylene	Commercial 2/	150

1/ See 3.4.1.4 for specific prohibition on application.
2/ For specific material see appendix B, 30.1.1.

3.8.1.3 Magnet wire. Magnet wire shall be selected in accordance with J-W-1177, and as follows:

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 180°C and higher temperature (220°C) applications and where a fibrous covering is required, the polyester fiber content shall not exceed 25 percent of the total material content.

Square and rectangular. — All designs shall allow rewinding by Naval repair activities using stock sizes shown in table XV. If wire sizes, other than those shown in table XV are supplied in the equipment, data and instructions shall be furnished for rewinding with stock sizes.

TABLE XV. 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/

1/ Types suitable for any application up through 220°C.
2/ Dimensions listed are nominal values, tolerances of J-W-1177 shall apply.
3/ Available in types M2 and M4.
4/ Available in types M2, M4, and M2DgGM.

3.8.2 Wiring methods.

3.8.2.1 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 3.8.2.1.3. 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.

3.8.2.1.1 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 MIL-S-23190 and MS21919.

3.8.2.1.2 Lacing cord. Lacing cord shall be type P unwaxed nylon in accordance with MIL-T-713 or type SR-4.5 glass fiber (resin filled) cord in accordance with MIL-I-3158 for temperature up to 105°C, neoprene treated glass cord in accordance with MIL-Y-1140 for temperatures up to 130°C, and silicone treated glass cord or sleeving for temperatures up to 200°C (see 3.5.17). Polyamide tape in accordance with type IV or V of MIL-T-43435 also may be used for temperatures up to 200°C.

3.8.2.1.3 Flexible wiring. Where flexible wiring is required by hinged doors, panels or sliding subassemblies, abrasion and chafing shall be minimized by 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.

3.8.2.2 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.

3.8.2.3 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.

3.8.2.3.1 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.

3.8.2.4 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.

3.8.2.5 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 RF circuits, the grommets shall be ceramic or polytetrafluoroethylene.

3.8.2.6 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.

3.8.2.7 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.

3.8.2.8 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-E-16366 or MIL-T-7928, 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. 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 conductors smaller than 14 AWG (4000 circular mils) or on terminal board or wire terminal combinations in accordance with MIL-T-55164. External tooth flat lockwashers are recommended for electrical connections, where practical.

3.8.2.8.1 Spare terminals. Terminal boards or cable connectors used for external cable connections shall be in accordance with MIL-C-5015. 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. 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.

3.8.2.8.2 Soldered connections. Soldered wiring connections shall be as specified in 3.10.3 through 3.10.3.2.

3.8.2.8.3 Electrical weld connections. Welded wiring connections shall be in accordance with requirement 24 of MIL-STD-454.

3.8.2.9 Permanent internal connections of windings. Where permanent type connections are made within windings, either soldering (see 3.10.3.1) or solderless pressure connectors may be used.

3.8.2.10 Printed wiring. Unless otherwise specified (see 6.2), printed wiring may be used for wiring assemblies as specified in 3.9.26 and non-repairable assemblies as specified in 3.9.27.

3.8.3 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.

3.8.3.1 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 3.8.3.2. The printing shall remain intact and easily readable after the wires are flexed.

3.8.3.2 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 MIL-I-23053.

3.8.3.3 Standard marking for connections. Identification marking shall be in accordance with MIL-STD-195 for those items of equipment listed therein. Other items, the marking of which is not covered by MIL-STD-195 or by other applicable standards or specifications, shall have identifying terminal marking using numbers or letters or a combination of both. These identifying markings shall be shown on a schematic diagram on the item or on a separate drawing furnished as part of the documentation used for maintenance and repair.

3.8.4 Bus bars. Design of bus bars including materials, sizes, spacing, arrangements, and joints shall be in accordance with MIL-S-16036. All connections to bus bars shall be made by through-bolting the bus bar. Link or tap changing connectors are not to be considered bus bars.

3.9 Parts. Only parts specified herein (referred to as standard parts) shall be incorporated into the design of the equipment. The use of standard parts does not relieve the supplier of the responsibility of conforming to all performance requirements specified (see appendix B, 30.1.5).

3.9.1 Parts selection. Parts shall be selected from the documents stated below in the same order of precedence:

(a) The applicable individual equipment specification.
(b) This specification, and where applicable, also in accordance with MIL-STD-242.
(c) MIL-STD-970, in the order of precedence therein.

3.9.1.1 Parts derating. The ratings of parts selected shall be sufficiently high to permit derating to the degree appropriate to the requirements of the equipment for performance, life, and reliability under the specified environmental conditions. Derating of electronic parts shall be according to guidelines in accordance with MIL-HDBK-338 and NAVSEA 0910-LP-076-7000, unless specific factors are presented forthwith. All parameters including nominal ratings, tolerances, ambient temperatures, overload conditions, and the like, covered in the parts specifications and in the individual equipment specification shall be taken into account in selecting and applying parts. Probable changes in ratings, tolerances and other part parameters due to prolonged use and to aging shall also be accommodated in the equipment design. Where appropriate, parts shall be protected against excessive stresses.

3.9.1.1.1 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.

3.9.1.1.2 Capacitor derating. Capacitors shall be derated at least 50 percent, that is, the actual peak voltage of the component in the circuit shall be no greater than 0.5 times the specification voltage rating 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.

Under transient or over-voltage conditions, no capacitor maximum voltage rating shall be exceeded. A lower derating factor than 50 percent should not be used due to the space required for larger capacitors (see appendix B, 30.1.1). The 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.

3.9.1.1.3 Discrete semiconductor derating and application stresses. Semiconductor devices rated 5 amperes and less are based on the absolute system (see appendix A of MIL-S-19500). Power diodes and SCR's above 5 amperes shall follow the format as described in table XVI. 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 XVI. Application stress limits and derating factors for rectifiers, SCR's, GTO's, and bipolar transistors. 1/

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 temp.

See footnote at end of table.

TABLE XVI. Application stress limits and derating factors for rectifiers, SCR's, GTO's, and bipolar transistors 1/ - Continued.

Stress factor	Stress factor limit in relation to rating factor		Rating factor
	Lower	Upper	
SCR's			
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

See footnote at end of table.

TABLE XVI. Application stress limits and derating factors for rectifiers, SCR's, GTO's, and bipolar transistors 1/ - Continued.

Stress factor	Stress factor limit in relation to rating factor		Rating factor
	Lower	Upper	
GTO's			
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}	Repetitive peak reverse voltage
Non-repetitive peak fwd. blocking voltage	---	0.8 V_{DRM}	Repetitive peak off-state voltage
Maximum rate-of-rise of forward blocking voltage	---	0.5 dv/dt (critical)	Critical rate-of-rise of forward blocking voltage
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), $T_j = T_j(max)$
Average forward current (a) Nominal value (b) Maximum value	 --- ---	 0.7 $I_{T(AV)}$ 1.0	Average forward current at $T_{j(max)}$ for application waveform, conduction angle, duty cycle, and frequency
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 (b) Non-rep. maximum (c) During surge	 --- --- ---	 0.5 di/dt (rep) 0.5 di/dt (critical) 1.0	Maximum repetitive rate-of-rise of current during turn-on

See footnote at end of table.

TABLE XVI. Application stress limits and derating factors for rectifiers, SCR's, GTO's, and bipolar transistors 1/ - Continued.

Stress factor	Stress factor limit in relation to rating factor		Rating factor
	Lower	Upper	
GTO's (Cont'd)			
Pulsed forward gate current	2.0	10.0 I_{GT}	
Junction temperature	---	0.8 T_J	Maximum operating junction temp.
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 (b) Maximum value	 --- ---	 0.6 $I_{C(AV)}$ 0.8	Average collector at rated $T_{j(max)}$ for the application waveform, conduct, angle or period, duty cycle and frequency
Collector power	---	0.5 P_T	Collector power dissipation derated for temperature
Junction temperature	---	0.8 $T_{C(max)}$	Maximum operating junction temp.
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 $T_{j(max)}$

See footnote at end of table.

TABLE XVI. Application stress limits and derating factors for rectifiers, SCR's, GTO's, and bipolar transistors 1/ - Continued.

Stress factor	Stress factor limit in relation to rating factor		Rating factor
	Lower	Upper	
TRANSISTORS, FIELD EFFECT			
Drain to source voltage, cut off mode or off-state			
(a) DC	---	.5 V_{DS}	Maximum rated drain to source voltage
(b) Nominal working	---	.6 V_{DS}	"
(c) Repetitive peak	---	.7 V_{DS}	"
(d) Non-repetitive	---	.8 V_{DS}	"
Drain to gate voltage			
(a) DC	---	.5 V_{DGR}	Drain to gate voltage with R_{GS}=1, megohm
(b) Nominal working	---	.6 V_{DGR}	"
(c) Repetitive peak	---	.7 V_{DGR}	"
(d) Non-repetitive	---	.8 V_{DGR}	"
Average drain current, active or on-state mode			
(a) Nominal value	---	.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	---	.8 $I_D$on	
Gate to source voltage	---	.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.
		t[rr]	

1/ Silicon-controlled rectifier (SCR).
Gate-turn-off (switches) (GTO).

3.9.1.1.4 Microcircuit derating. Micro-circuits shall be mounted according to manufacturer's requirements and applied so that the maximum ambient operating temperature will be 25°C less than the maximum operating ambient temperature given by the manufacturer's data sheet.

3.9.1.2 Standard parts. All parts selected as specified in 3.9.1 shall be considered standard parts.

3.9.1.3 Non-standard parts. The use of nonstandard parts is permitted only in accordance with the requirements of Appendix B, 30.1.5. Procurement of nonstandard parts prior to receiving NAVSEA approval for its use is at the vendor's risk.

3.9.1.4 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.

3.9.1.5 Replacement and interchangeability. Parts shall be individually replaceable, unless otherwise specified in the individual equipment specification. Parts as delineated and specified herein are interchangeable items as defined by MIL-STD-280. They shall possess both mechanical and electrical compatibility to permit their installation and replacement without regard to manufacturer, contractor, or special selections (see 3.2.6).

3.9.1.6 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 circuit application requirement. However, in equipment fabrication, parts of closer tolerances may be substituted as long as interchangeability is not affected (see 3.9.1.5).

3.9.2 Fuses and fuseholders. Fuses and fuseholders shall be selected and applied as specified in 3.9.2.1 through 3.9.2.8.

3.9.2.1 Fuses. Fuses shall be in accordance with MIL-F-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 3.9.1.3). Fuses shall be chosen so that their clearing I^2t (where I is current, and t is time) is lower than the I^2t of the items which are to be protected. The integrated I^2t of the fuse shall be at least 10 percent less than the integrated I^2t of the semiconductor device they protect. The use of two or more fuses in parallel, is prohibited. Fuses shall be used for short circuit protection only. Fuse ferrules and fuse knife blades shall be silver plated.

3.9.2.2 Fuse mounting. Fuses shall be mounted either in fuse clips in accordance with MIL-F-21346 or in front indicating type fuseholders in accordance with MIL-F-19207.

3.9.2.3 Fuse styles and characteristics. For circuits of 250 to 500 volts (V) ac or dc, the following style fuses of blowing characteristics C shall be used:

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

3.9.2.4 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.

3.9.2.5 Fuse current ratings. Fuses shall have current ratings not less than 125 percent of continuous load for transformer or noninductive 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 insure blowing. Fuses used shall be readily replaceable.

3.9.2.6 Fuse installation practice. Fuse installation practice shall be as follows:

(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 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 root mean square (RMS) interrupting current, and maximum interrupting circuit voltage, (for example, F03A250V3A-S, F101, regulator circuit, DWG. XXXXXX, 100 A, 250 Vac).

(g) When fuses are required to be mounted in fuse clips, copper clad steel fuse clips in accordance with MIL-F-21346/1 shall be used for fuse ratings up to 60 amperes.

3.9.2.7 Fuses, non-standard types. 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.

3.9.2.8 Fuseholder installation practice. Fuseholder installation practice shall be as follows:

(a) 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.

(b) Fuseholders shall be installed so that the test probe hole is located at the bottom.

3.9.2.9 Fuseholders.

3.9.2.9.1 For F02, F03, and F60 fuses. Fuseholders for use with types F02, F03 and F60 fuses shall be types FHL10G, FHL11G, FHL12G, FHL32W, FHL33W, or FHL35W indicating type fuseholders in accordance with MIL-F-19207 when the circuit voltage is 90 volts or greater. When the circuit voltage is less than 90 volts, types FHL18G, FHL29G, or FHL30G fuseholders in accordance with MIL-F-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 (nonindicating type) shall be used.

3.9.2.9.2 For F62 fuses. Fuseholders for use with style F62 fuses shall be type FHL14G in accordance with MIL-F-19207.

3.9.2.9.3 For F63 fuses. Fuseholders for use with style F63 fuses shall be type FHL15G in accordance with MIL-F-19207.

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

3.9.2.9.5 Nonindicator type. Nonindicating fuseholders for use with F60 fuses shall be type FHN41WB in accordance with MIL-F-19207.

3.9.3 Circuit breakers. Circuit breakers shall conform to the following specifications:

Type	Specification
ACB - Open frame up to 500 Vac, 355 Vdc	MIL-C-17587
AQB and NQB - Insulated enclosure, up to 500 Vac; 250 Vdc	MIL-C-17361
ALB and NLB - Insulated enclosure, up to 125 Vac; 125 Vdc	MIL-C-17588

3.9.4 Resistors and rheostats. Resistors shall be chosen and applied in accordance with MIL-STD-199 as modified by the additions, limitations, and restrictions specified herein and in the applicable equipment specification. Resistors and rheostats from 1/2 to 50 watts shall be in accordance with MIL-STD-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-R-15109, or MIL-R-22. Above 50 watts, rheostats, variable resistors, and fixed resistors shall be in accordance with MIL-R-15109.

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.

3.9.4.1 Resistor networks. Resistor networks-fixed film shall be in accordance with MIL-R-83401.

3.9.5 Capacitors. Capacitors shall be chosen and applied in accordance with MIL-STD-198 as modified by the additions, limitations, and restrictions specified herein and in the applicable equipment specification. For radio interference suppression capacitors, see 3.3.8. Capacitors containing PCB's shall not be used.

3.9.5.1 Fixed tantalum (solid electrolyte). Fixed tantalum solid electrolyte capacitors shall be in accordance with MIL-C-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.

3.9.5.2 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-C-39006. Where physical space restraints require smaller sized capacitors, sintered anode, wet electrolyte tantalum capacitors in accordance with MIL-C-39006/22 may be used. Otherwise, sintered anode, wet electrolyte tantalum capacitor shall not be used. All capacitors with pigtail leads shall be supported by means other than their leads.

3.9.5.3 Fixed ceramic-dielectric (temperature compensating). Fixed ceramic-dielectric (temperature compensating) capacitor shall be in accordance with MIL-C-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 plus or minus 60 parts per million or less, shall require approval of the contracting activity.

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

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

3.9.5.6 Variable air-dielectric (trimmer). Variable air-dielectric (trimmer) capacitors shall be in accordance with MIL-C-92. These capacitors are intended for use where relatively few adjustments will be required throughout the life of the equipment.

3.9.5.7 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 (see appendix C, 30.1.1). 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 Vrms, 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.

3.9.5.8 Fixed supermetallized plastic film dielectric. Fixed super-metallized plastic film dielectric capacitors, (hermetically sealed in metal cases) shall be in accordance with MIL-C-83421.

3.9.6 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 3.9.6.1 through 3.9.6.11, as applicable, and MIL-STD-242.

3.9.6.1 Toggle switches. Toggle switches shall be in accordance with MIL-S-3950.

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

3.9.6.3 Push (snap action) switches. Push (snap action) switches shall be in accordance with MIL-S-8805 or MIL-C-2212.

3.9.6.4 Pushbutton. Illuminated pushbutton switches shall be in accordance with MIL-S-22885. Non-illuminated pushbutton switches shall be in accordance with MIL-C-2212.

3.9.6.5 Mercury switches. Mercury switches shall not be used (see 3.4.1.2).

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

3.9.6.7 Metallic and bi-metallic thermostatic switches. Metallic and bi-metallic thermostatic switches shall be in accordance with MIL-S-24236.

3.9.6.8 Printed circuit switches. Printed circuit switches shall be in accordance with MIL-S-22710.

3.9.6.9 Bus transfer switches. Bus transfer switches shall be in accordance with DOD-S-17773.

3.9.6.10 Rotary switches.

3.9.6.10.1 Control and power circuits. Switches for control and power circuit applications shall be in accordance with MIL-S-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-S-21604.

3.9.6.10.2 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-S-21604 or MIL-S-3786 and style SR04 of MIL-S-3786/4 modified to include gold plated contacts. Class SR of MIL-S-15291 shall not be used in this service.
(b) For voltages above 125 V, switches shall be in accordance with MIL-S-15291 or MIL-S-18396.

3.9.6.10.3 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.

3.9.6.10.4 Enclosed rotary. Enclosed rotary switches shall be in accordance with MIL-S-15743.

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

3.9.7 Mounting and fastening.

3.9.7.1 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 1/2 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 1/4 inch for components with axial leads, except for printed circuit applications and in nonrepairable items. Requirements herein do not apply to parts to which MIL-STD-275 mounting requirements apply.

3.9.7.2 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.

3.9.7.2.1 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.

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

3.9.7.4 Fastening of brittle materials. Fastening of brittle materials shall be in accordance with requirement 12 of MIL-STD-454.

3.9.8 Meters and instruments, electrical indicating, and accessories.

3.9.8.1 Electrical indicating meters. Where high impact meters are required, which meet the shock test requirements of MIL-S-901, they shall be selected from the following specifications:

MIL-M-10304
MIL-M-3971
MIL-M-16034
MIL-M-16125
MIL-V-23151
MIL-M-23167
MIL-M-24359

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

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

3.9.8.2.1 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.

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

3.9.9 Indicator lights.

3.9.9.1 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-L-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.

3.9.9.2 Lamp types. Lamps for use with the style LH94 or LH98 indicators shall be industry no. 1769. Lamps for use with the style LH95 or LH96 indicators shall be industry no. 342. The industry lamp number shall be marked on the indicator as shown on figure 1.

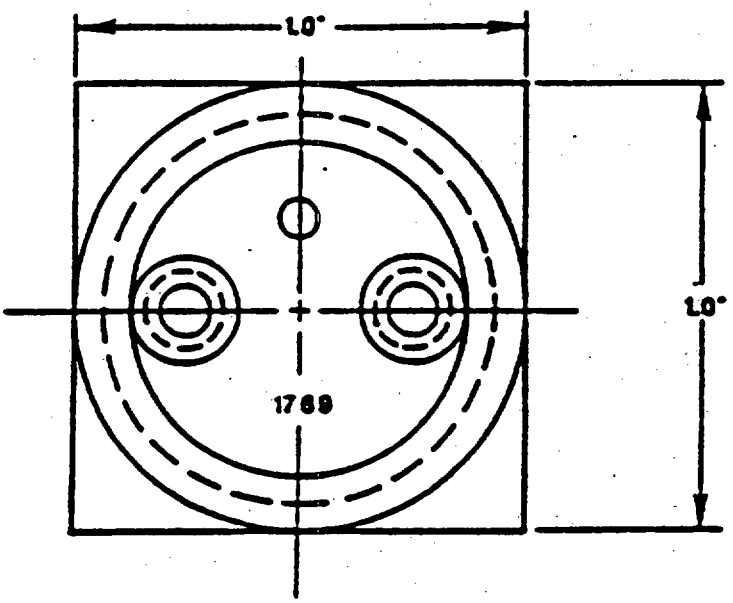
3.9.9.3 Indicator lenses, mounting and color. Indicator lights shall be provided with flush mounting type lenses. Finish paint shall be gray. Indicator light styles shall be applied to indicator lens styles as follows:

TABLE XVII. 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	1/ MIL-L-3661/59

1/ Engraved as shown on figure 2.

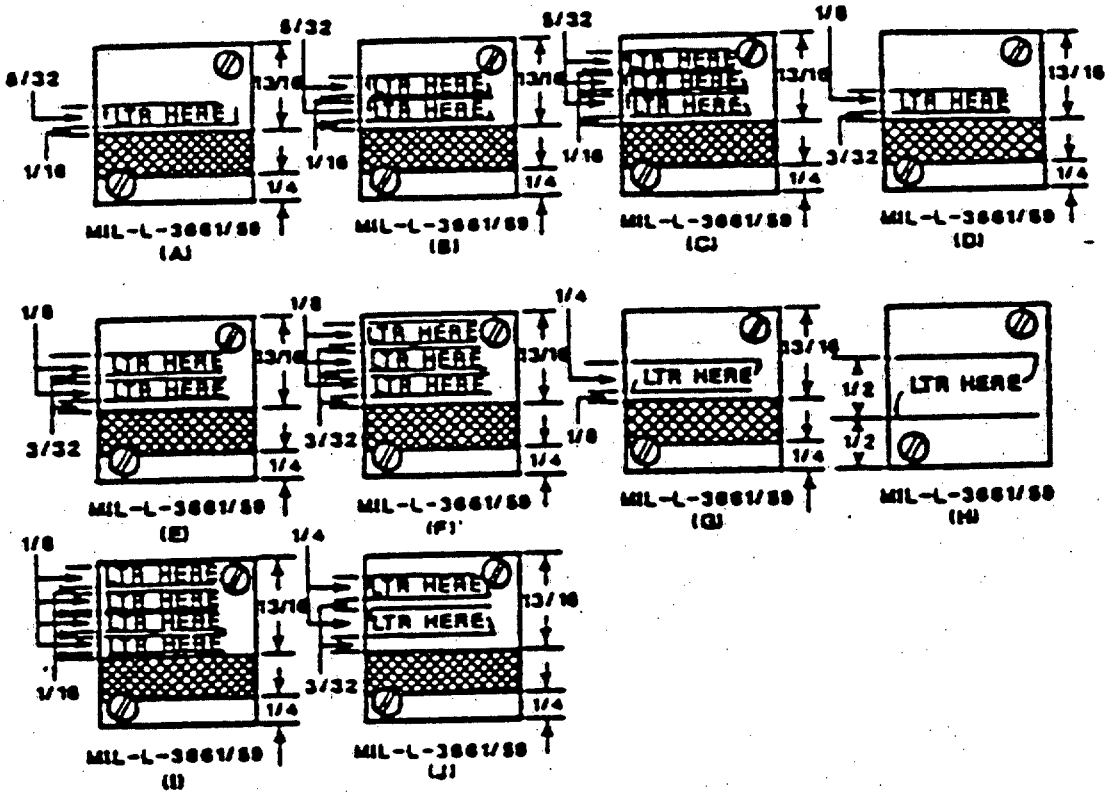
Alarm lights shall use types A, B, and C of figure 2. Indicator light lens colors and color use shall be in accordance with MIL-STD-1472.



NOTES:

1. Styles LH94 or LH98 indicators shall be marked in accordance with no. 1769 (see 3.9.9.2).
2. Styles LH95 or LH96 indicators shall be marked in accordance with no. 342 (see 3.9.9.2).

FIGURE 1. Holder face.



NOTES:

1. Lens face color shall be exposed in cross hatched area. No paint will be permitted in this area (except type H).
2. Types (a) through (g), (i), and (j) shall be engraved where shown. The engraving shall be filled with black paint.
3. Type (h) lens shall have no paint on face except where engraved. Engraving on red, blue, or green lens shall be filled with white paint. Engraving on white, amber (yellow), or colorless lens shall be filled with black paint.

FIGURE 2. Lens engraving details.

3.9.9.4 LED displays. Indicator lights that incorporate light emitting diode (LED) displays shall have a minimum display height of 0.29 inches.

3.9.10 Jacks, tip (test point jacks). Tip jacks shall be selected from MIL-STD-242 and color coded in accordance with MIL-STD-415. Banana plugs shall not be used as test points.

3.9.11 Motors. Motors shall be in accordance with MIL-M-17059, MIL-M-17060, MIL-M-17413, or MIL-M-17556, and as specified in the equipment specification.

3.9.11.1 Motor rotation. Terminal markings and rotation shall be in accordance with MIL-STD-195.

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

3.9.13 Synchros. Synchros shall be in accordance with MIL-S-20708. Installation requirements shall be in accordance with MIL-HDBK-225. The secondary load impedance for the synchro control transformers shall be specified in equipment service manual in the descriptive data for the synchro heading receiver. This load impedance shall be not less than 30,000 ohms.

3.9.14 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-C-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, shall be in accordance with category 1, enclosure design symbol 4, of MIL-R-5757. Their selection shall be in accordance with the general requirements of MIL-R-6106, MIL-R-5757, MIL-R-28750, and MIL-STD-1346.
(c) Rotary relays shall operate in a 90°C ambient temperature.

3.9.14.1 Solid state relays. Solid state relays shall be in accordance with MIL-R-28750.

3.9.15 Terminal boards. Terminal boards shall be in accordance with MIL-T-55164, except that lock washers are not required under terminal nuts. Terminal board shall be double row, linked, front connected classes 8TB, 17TB and 26TB, or single row through connected classes 5TB, 7TB, 11TB, and 27TB. No more than 3 wires shall terminate at any one stud or terminal; except where classes 8TB and 26TB with stud connector are used, only 2 wires may terminate at any one stud. Where space does not permit the use of marking strips, terminal markings may be stamped adjacent to the board. These markings shall be visible when wiring connections are completed.

3.9.15.1 Mounting. Terminal boards shall be secured only by machine screws and shall be capable of ready removal and replacement.

3.9.16 Terminal lugs. Terminal lugs of ring tongue design are preferred and shall be in accordance with MIL-T-7928, MIL-T-7928/1, and MIL-T-7928/2 depending on the type and size of cable being used and the current level. Class 1 terminals are the preferred types and should be listed in the Bill of Material of the appropriate drawing.

3.9.16.1 Insulated types. Insulated types shall conform to type II, class 1. Insulated types are not to be used when the conductor temperature exceeds 100°C.

3.9.16.2 Uninsulated types. Uninsulated types shall conform to type I, class 1. When required, additional sizes of uninsulated lugs are covered by MIL-T-16366.

3.9.16.3 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.

3.9.16.4 Higher current applications. On all applications greater than 5 amperes but within the current limits of MIL-T-7928, 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 100°C, an uninsulated terminal lug type I, class 1 that falls within the current limits of MIL-T-7928 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.

3.9.16.5 Plated terminal lugs. On those terminal lug applications not satisfied by MIL-T-7928, 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 unless specifically approved by NAVSEA (see appendix B, 30.1.1).

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

3.9.18 Semiconductor devices (other than semiconductor integrated circuits (SIC), see 3.9.20). Rectifiers, voltage reference diodes, voltage regulator diodes, control rectifiers, and transistors shall be chosen and applied in accordance with MIL-STD-701 insofar as practical and shall be in accordance with MIL-S-19500, the applicable device detail specification, and as specified in 3.9.18.1, and 3.9.18.2. For choice of non-standard semiconductor devices, see 3.9.1.3.

3.9.18.1 Approval and data on non-standard semiconductor devices. Requests for approval shall be as specified in appendix B, 30.1.5.2 (see 6.3).

3.9.18.2 Electrostatic discharge (ESD) susceptible items. Electronic parts and assemblies which are subject to ESD damage shall be handled and packaged in accordance with DOD-STD-1686 and the procedures in accordance with DOD-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 DOD-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 sensitive 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.

3.9.19 Surge and spike voltage suppressors. Surge and spike voltage suppressors such as metal oxide varistors (MOV's), controlled-avalanche rectifier diodes, or selenium junctions shall be used to limit excessive voltage excursions. Excessive voltage suppressors shall be selected and applied in accordance with the following:

(a) Two products of different manufacturer shall be specified for each application. The product furnished in the original equipment shall be so designated and the other product shall be designated as alternate. The alternate product shall be capable of being used for direct replacement of the installed product without any modification to either the product or the equipment. Mounting detail need not be identical provided the equipment is designed to receive compatible mounting hardware and provided no alteration in connecting electrical leads is required.

(b) Each product certified for the application by the equipment manufacturer shall be of a type which shows suppressor rating, derating, and application criteria suitable for guidance in making a conservative application. A copy of each applicable bulletin shall be forwarded with the equipment drawings when drawing approval action is required (see appendix B, 30.1.2).

(c) The suppressor assembly, shall comply with the material design and construction requirements of this specification and shall be designed for operation in a moist salt-laden atmosphere. Selenium types shall have a protective coating to sustain the above conditions and shall possess a manufacturer's coating designated for military or commercial marine service.

(d) For selenium types, the maximum cell temperature shall not exceed the maximum operating temperature recommended by the suppressor manufacturer minus 20°C, or the operating temperatures corresponding to 40,000 hours life expectancy for 95 percent probability of survival, whichever is smaller.

3.9.20 Microcircuits. Standard microcircuits or integrated circuits, consisting of interconnected circuit elements inseparably associated on or within a continuous semiconductor substrate, shall be in accordance with MIL-M-38510 and

the appropriate detail specifications thereof. Such circuits shall be selected from MIL-STD-1562 and the qualified products list (QPL) of MIL-M-38510. Only microcircuits which are enclosed in hermetically sealed cases shall be used, and the use of circuits not on the given lists requires approval (see appendix B, 30.1.1).

3.9.20.1 Non-standard microcircuits. Devices not included on the QPL of MIL-M-38510 or MIL-STD-1562 shall be acquired to the applicable Defense Electronics Supply Command (DESC) drawing for the device (see appendix B, 30.1.5.3).

3.9.20.1.1 Requests for approval of non-standard microcircuits. The procedures for requesting approval of non-standard microcircuits shall be as specified in 3.9.18.1 (see 6.3).

3.9.21 Filters. High pass, low pass, band pass, notch band suppression and conduction of electrical filters shall be in accordance with MIL-F-18327.

3.9.22 Contactors, motor starters, and controllers. Contactors, motor starters, and controllers shall be in accordance with MIL-C-2212.

3.9.23 Transducers.

3.9.23.1 Differential pressure. Differential pressure transducers shall conform to MIL-D-24304.

3.9.23.2 Pressure. Pressure transducers shall be in accordance with MIL-P-24212.

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

3.9.23.4 Thermistors. Thermistors shall be in accordance with MIL-T-23648.

3.9.23.5 Liquid level. Liquid level transducers shall be in accordance with MIL-L-23886.

3.9.24 Transformers, inductors, and reactors. Transformers, inductors, and reactors, including fixed, saturable and saturating types, shall be in accordance with MIL-T-27, MIL-T-15108, MIL-I-1361, MIL-T-16315, MIL-T-17221, or to requirement 14 of MIL-STD-454, and the requirements of this specification. The applicability of requirement 14 of MIL-STD-454, however, shall be limited to products weighing 15 pounds or less.

3.9.24.1 Instrument and metering transformers. Instrument transformers used for the purpose of metering or measurement shall be in accordance with MIL-I-1361, and shall be applied within the constraints of their ratings.

3.9.24.2 Low power pulse transformers. Low power, pulse transformers shall be in accordance with grade IV or V, class R, S, T, U, or V of MIL-T-21038.

3.9.24.3 Radio frequency coils and transformers. Radio frequency coils and transformers shall be in accordance with grade 1, class A, B, or C of MIL-C-15305.

3.9.24.4 General purpose transformer and inductors less than 100VA. All transformers, reactors, and inductors of less than 100 volt-amperes rating shall be in accordance with grades 4 or 5, class R, S, T, U, or V of MIL-T-27 and the following:

(a) Shall be designed for not less than 40,000 hours life expectancy.
(b) Shall meet the dielectric test as specified, with the exception that the dielectric test voltage must be not less than 500 volts rms.
(c) Shall meet method II shock test of MIL-T-27.
(d) Wire size finer than number 42 AWG shall not be used.
(e) Reactors and inductors used for dc application shall have their volt-ampere rating determined by the following formula:

$$VA = 188 \times L \times (Idc)^2$$

Where: L = Inductance in henries.
Idc = Rated dc current through the inductor in amperes.

(f) Reactors and inductors used for ac application shall have their rating determined by the following formula:

$$VA = (Vrms) \times (Irms)$$

Where: Vrms = The rms voltage developed across inductance in volts at the fundamental ripple frequency.
Irms = The rated rms current through the inductance in amperes.

3.9.24.5 Low quantity and non-QPL qualified transformers. Where transformers, reactors, and inductors are not available on the Qualified Products List of MIL-T-27, and the number of identical units per contract order is less than 100, it will not be necessary to formally qualify these items for inclusion on the Qualified Products List of MIL-T-27 (see 4.3.1).

3.9.24.6 Miscellaneous inductive devices. Miscellaneous inductive devices not falling strictly under the requirements 3.9.24.5 shall be in accordance with type SA of MIL-T-16315, except in the case of linear variable differential transformers where smaller wire sizes can be used subject to approval (see appendix B, 30.1.1). Wire finer than AWG number 32 shall not be used.

3.9.24.7 Substitution. If no products in accordance with the documents cited in 3.9.24 or the requirements of 3.9.24.1, 3.9.24.2, or 3.9.24.3 are appropriate for the application, other products may be used provided they are approved (see appendix B, 30.1.1).

3.9.25 Connectors, plug and receptacle types. When plug-in connectors are used (see 3.8.2.4 and 3.8.2.8 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 protective cap. The protective cap shall be affixed adjacent to the connector receptacle. Connectors shall be as specified in 3.9.25.1 through 3.9.25.4.

3.9.25.1 Electrical connectors. Connectors shall be selected in accordance with MIL-STD-1353. Connectors shall be selected so that the connector crimp or solder cups are of sufficient size to permit termination of the required wire size without cutting or otherwise deforming the wire to fit the cups. Circular connectors intended to mate with shipboard jacketed cable shall be selected from the insert arrangements identified in MIL-STD-1683.

3.9.25.2 Shield grounding ferrules. Shield grounding ferrules shall be insulated crimp type in accordance with MIL-F-21608.

3.9.25.3 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-R-2726.

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

(a) The printed wiring assemblies shall be manufactured, and inspected to comply with the design requirements of MIL-STD-275 unless otherwise specified herein. Reference designations shall be employed to identify each part for its particular circuit application in accordance with IEEE 200.
(b) A conformal coating in accordance with MIL-STD-275 shall be provided on all boards. Such conformal coating shall be in accordance with type UR of MIL-I-46058 and 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 MIL-P-28809.
(c) The component board shall be fabricated from types GF or GH material in accordance with MIL-P-13949 and shall be of a sufficient thickness to prevent damage during insertion or withdrawal.
(d) Printed wiring boards shall be in accordance with MIL-P-55110.
(e) 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.
(f) All mounting hardware shall be captive. No special tools shall be required to remove or install a printed wiring board.
(g) 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.

(h) 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 which 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 (a) through (d).

(i) Part attachment and mounting shall be in accordance with MIL-STD-275 except as follows:

(1) Parts for mounting on circuit boards shall be so that the part's operating surface temperature does not exceed 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 MIL-STD-275 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 plus or minus 1/32 inch. Provisions for stress relief and component lead bends and lead radii in accordance with MIL-STD-454 and MIL-STD-2000 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.

3.9.27 Non-repairable assemblies. A group of electrical or electronic parts may be packaged as a non-repairable assembly upon compliance with the requirements herein (see appendix B, 30.1.1). (For SEM's see 3.2.9.1.) 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.

3.9.27.1 Non-repairable assemblies with printed wiring. When non-repairable assemblies have printed wiring, the requirements of 3.9.26 (a) through (d) shall apply, except for the marking of circuit part designations, polarities and connection points is not required.

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

3.9.29 Current time (CTS) sensing and signaling devices. CTS devices, when used for protection against overcurrent by means of selective tripping in 400-Hz, 3-phase distribution systems supplied by 400-Hz frequency changers shall be supplied in accordance with MIL-S-24561.

3.9.30 Power sensing relays. When ac power monitoring and control relays are required they shall be in accordance with MIL-M-24350.

3.9.31 Springs. Compression and extension type helical springs (including garter springs) shall be manufactured in accordance with MIL-S-13572. Springs should be considered critical in application if they are current carrying, or if they provide pressure to mating current carrying parts.

3.10 Processes.

3.10.1 Treatment and processing of metals for corrosion resistance. Parts made of ferrous metal (except corrosion-resisting metal listed in 3.4.2.3) or of aluminum shall be treated, coated, plated, and painted, as applicable in accordance with tables XVIII and XIX. 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 XVIII. Processing of metals for corrosion-resistance treatments where painting is not required. 1/ 4/

Metal	Treatment	Treatment specification
Corrosion-resisting (see 3.4.2.3)	Not required	---
Ferrous metals	Aluminum coating, ion vapor deposited	2/ MIL-C-83488, class 3, type II
	Zinc coating (hot-dip galvanizing) 3/	ASTM A 153
	Electrodeposited zinc 3/	ASTM B 633

See footnotes at end of table.

TABLE XVIII. Processing of metals for corrosion-resistance treatments where painting is not required 1/ 4/ - Continued.

Metal	Treatment	Treatment specification
	Electrodeposited nickel	QQ-N-290, type I (DS), or ASTM B 456
	Nickel undercoat plus electro-deposited chromium	QQ-N-290, type I (DS), or ASTM B 456, type DS, and QQ-C-320
	Electrodeposited silver	QQ-S-365
Aluminum and aluminum alloys	Anodic treatment 5/	MIL-A-8625

1/ Corrosion-resisting metal or metals processed for corrosion-resistance may be painted for appearance and as specified in 3.10.2.1.
2/ These coatings have superior corrosion-resistance in marine atmosphere, and are preferred.
3/ 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.
4/ Tin plating on copper conductors is at the option of the manufacturer.
5/ Anodized treatment is considered electrically non-conductive.

TABLE XIX. 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-P-53084	0.025	
Ferrous metals with treatments other than those listed in table XVIII	TT-C-490, type III MIL-P-24441	0.05 Formula 150	MIL-E-15090, 6/ 2 coats type II or each 0.025 type III

See footnotes at end of table.

TABLE XIX. Painting of metal for corrosion-resistance 1/ - Continued.

Metal	Pretreatment	Primer 2/	Topcoats
	Specification	Specification minimum thickness (millimeters) 3/	Specification minimum thickness (millimeters) 3/
Ferrous metals and aluminum alloys both used in same assembly 4/	TT-P-645	0.025	5/ Class 2 second coat may be omitted on inside of enclosure and equipment to be installed in interior of ships
Aluminum and aluminum alloys	MIL-P-53084 TT-C-490, type I	0.025	

1/ For details on painting procedures, see 3.10.2.
2/ The preferred primer is MIL-P-53084. TT-P-645 is second preference. If the MIL-C-24712 is chosen as a topcoat, no primer is required.
3/ Minimum dry film thickness.
4/ For metals in direct contact, see 3.4.2.1.
5/ MIL-C-24712 is the preferred topcoat applied in one coat at 0.125 to 0.250 mm. MIL-E-15090, types I, II, or III, class 1 is second preference.
6/ Applies to ferrous metals.

3.10.1.1 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 3.10.1). 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. A minimum of two coats shall be applied, using any method which will insure coverage of all surfaces, unless otherwise specified in the individual equipment specification, or the contract or order. Insulating varnish shall be in accordance with MIL-I-24092.

3.10.2 Painting.

3.10.2.1 Parts to be painted. Where necessary to obtain corrosion-resistance, metal parts except those of 3.10.2.2 shall be painted. Surfaces of corrosion-resistant metal (see 3.4.2.3) may be painted for appearance. When a gray painted exterior is specified (see 6.7), exterior parts except those cited in 3.10.2.2 shall be painted, whether or not corrosion-resistant.

3.10.2.2 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-resisting 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 which 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.

3.10.2.3 Normal painting procedure. Except for large parts temporarily stored outdoors (see 3.10.2.4), 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.

3.10.2.4 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-SP10.

(4) Apply chemical pretreatment in accordance with type I of TT-C-490, one coat of MIL-C-24712 or primer coating in accordance with TT-P-645, and two coats enamel topcoat in accordance with type III, class 2 of MIL-E-15090. MIL-C-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), (2), and (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-C-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 3.10.2.3.

3.10.3 Soldering. Only noncorrosive fluxes shall be used unless it can be shown that all corrosive products have been satisfactorily removed or neutralized after soldering. 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 3.10.3.1 and 3.10.3.2, respectively.

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

TABLE XX. Solder for connection of electrical windings.

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

See footnotes at top of next page.

1/ Composition in accordance with QQ-S-571.
2/ Commercially pure tin. Use of tin solder shall be limited to equipment known to be intended for installation in interior of ship.

3.10.3.2 Soldering for parts. Solder for connections of electrical and electronic parts shall be composition Sn60 or Sn63 of QQ-S-571. Soldering of parts shall be in accordance with MIL-STD-2000.

3.10.4 Brazing. Brazing alloys for electrical connections shall be in accordance with QQ-B-650 or QQ-B-654. Brazed electrical connections shall not be used where disconnection and reconnection for maintenance purposes is required.

3.10.5 Welding.

3.10.5.1 Structural welding. Structural welding and allied processes shall be in accordance with MIL-STD-278, supplemented as follows:

(a) Spray metallizing of shafts will not be permitted.
(b) Unless otherwise specified (see 6.2), details of the fabrication procedure need not be submitted for approval.
(c) 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.

3.10.5.2 Welding of electrical connections. Welds and welding processes for electrical connections shall be in accordance with MIL-W-8939.

3.11 Thermal design.

3.11.1 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 in accordance with MIL-HDBK-251.

3.11.1.1 Air coolers.

3.11.1.1.1 General design requirements. The design of electrical equipment using air cooler shall include the following:

(a) 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.

3.11.1.1.2 Specific cooling systems.

3.11.1.1.2.1 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-E-2036.

3.11.1.1.2.2 Air coolers for assembled hardware. Air coolers for assembled hardware consisting of transformers, semiconductor devices, resistors, capacitors, and so forth, shall be in accordance with MIL-STD-454, requirement 52.

In addition, heat dissipators for semiconductor devices shall be constructed of metallic material (see 3.4.2) which is corrosion resistant, or which is treated or coated (see 3.10.1) 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 and shall be documented.

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

3.11.1.2.1 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.

3.11.1.2.2 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.

3.11.1.2.3 Hoses, fittings, and piping systems. Designs for piping systems using flexible hose assemblies shall consider NAVSEA 0910-LP-057-1900, for such systems.

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

3.11.1.2.3.2 Clamps. Hose clamps shall not be used.

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

3.11.1.2.4 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.

3.11.1.2.5 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, section 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.

For direct cooling with insulating oil it is required that:

(a) Insulating oil used with heat exchanges shall be self-contained with purification equipment, purity sensors, and alarm systems. Oil characteristics should be in accordance with MIL-H-81829.

3.12 Mechanical features.

3.12.1 Castings. Equipment may include cast or fabricated construction. Castings shall be in accordance with requirement 21 of MIL-STD-454.

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

3.12.3 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.

3.12.4 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 MIL-STD-242. 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.

3.12.5 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 3.3.16.5).

3.12.6 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 nonmagnetic 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.

3.12.7 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.

3.12.8 Countersinking. Drilled and tapped holes shall not be countersunk except as specified in 3.3.16.9.3 and the individual equipment specification (see 6.2).

3.12.9 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.

3.12.10 Lubrication design and lubricants. Equipment shall be designed for lubrication in accordance with 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. Lubricants, except as specified in 3.12.10.1 and lubrication charts and instruction plates, shall be in accordance with MIL-HDBK-267. Grease-lubricated ball bearings shall be lubricated by means of compression grease cups and grease drain plugs.

3.12.10.1 Lubricants for antifriction bearings. Unless otherwise specified in the applicable equipment specification, grease type lubricants for antifriction bearings shall be in accordance with DOD-G-24508. For general purpose, high performance, and shipboard nuclear propulsion equipment use; MIL-G-24139 for low hoist applications with maximum bearing temperature below 110°C; and MIL-G-81322 for maximum bearing temperatures between 110 and 175°C.

3.12.10.2 Lubricants for shipboard nuclear propulsion equipment use. Lubricants for shipboard nuclear propulsion equipment shall be restricted to those listed in STR 4P22.

3.12.11 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 3.10.2.2).

3.12.12 Test points. Test points in accordance with MIL-STD-415 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. The test points shall be compatible with Navy standard test equipment in accordance with MIL-STD-1364.

3.12.12.1 High-voltage equipment. When the maintenance or operation of equipment employing potentials in excess of 2000 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 1000 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 (see 6.3). The voltages specified herein shall be interpreted as applying to dc, ac, and dc plus ac voltages.

3.12.13 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 3.2.6.1). Where verniers are employed for fine control, the marking and numbering shall provide continuity throughout the dial range.

3.13 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-P-15024, MIL-P-15024/5, and the requirements herein.

3.13.1 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.

3.13.2 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.

3.13.3 Color style of plastic plates. The color style of plastic plates shall be in accordance with type II of MIL-P-15024 except as otherwise specified herein or in the individual equipment specification (see 3.13.4.2).

3.13.4 Types of plates.

3.13.4.1 Identification plates. Identification plates shall be in accordance with types A, B, C, or H (metallic only) of MIL-P-15024.

3.13.4.1.1 Identification markings. Identification plates shall be marked with the following as a minimum:

(a) Manufacturer's name.
(b) Name of unit, model, and serial number (if applicable).
(c) Rating of unit.
(d) Prime contract number (if marking is specified in contract or order).
(e) National stock number (NSN) (if available).
(f) Technical manual number, or, if not applicable, drawing number.

3.13.4.2 Information plates. Except for illuminated plates for darken-ship operation (see 3.13.4.4), plates for stating the functions of manual control devices and visual indicators, and to show wiring and schematic diagrams, operating instructions, lists of tools, warning and caution, and the like, shall be in accordance with types A, B, C, F, or H of MIL-P-15024. Where the need to change the information from time to time exists, the plates may be held in slide-out frames. Type F plates shall be laminated, using non-flammable, transparent, polyester sheets treated, bonded, and sealed to each side of the printed sheet. Edge sealing alone is not acceptable. Nominal thickness of the polyester sheet shall be at least 0.025 mm (1 mil). The overall thickness of the plate shall be at least 0.075 mm (3 mils).

3.13.4.3 Warning and caution. Where the non-observance of instructions on plates would result in personal injury or material damage, the words WARNING or CAUTION shall immediately proceed the instructions. Warning and caution accident prevention signs shall consist of two panels, the upper one containing the primary warning word signal and symbol, and the lower panel containing the primary warning message. Warning or caution signs shall have the word WARNING or CAUTION in yellow on a black background in the upper panel. The lower panel shall consist of black letters on a yellow background. The warnings shall be in accordance with the following:

(a) WARNING. Where non-observance would result in personal injury or loss of life, whether or not damage to the equipment would occur.
(b) CAUTION. Where non-observance would result in damage or destruction of the equipment or inadvertently shutdown the propulsion plant.

3.13.4.3.1 High voltage. Enclosures containing potentials in excess of 500 Vac rms or 500 Vdc shall be identified by plates marked "DANGER. HIGH VOLTAGE - (Insert maximum voltage applicable) Volts". Danger warning and accident prevention signs shall consist of two panels, the upper one containing the primary warning word, and the lower panel containing the primary warning message. Danger signs shall have the single word "Danger" lettered in white within a red oval, outlined on a black rectangular background in the upper panel. The lower panel shall consist of black letters on a natural metallic or white background.

3.13.4.4 Illuminated plates. Illuminated plates, when required for darken-ship operation, shall be in accordance with type IV or V of MIL-P-7788. The incandescent lamp circuit shall operate from a 2.8-volt power source. Dual lampholders shall be used for visual indicators.

3.14 Identification of parts. Parts shall be identified by reference designations in accordance with IEEE 200 (see 6.3).

3.14.1 Reference designation locations. Reference designations applied in the equipment shall be located adjacent to the parts and shall be marked in accordance with 3.14.4. Designations shall not be marked on parts which will be subject to replacement. The designation for each part shall be marked in such a position as to physically locate the part and still be readily visible for the purposes of maintenance without removal of any other parts. If not visible double marking may be used.

3.14.2 Enclosed parts. Reference designations for parts enclosed in separate and removable shields or compartments shall be marked on the shields or supporting structures for such parts, provided that the replacement of such parts does not require destruction of the original shields or supporting structures and provided that such shields or structures are not interchangeable with other shields or structure within the major unit.

3.14.3 Identification of part leads. For each polarized part, such as electrolytic capacitors and rectifiers, and 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.

3.14.4 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.

3.15 Workmanship. Workmanship shall be in accordance with requirement 9 of MIL-STD-454, except for the following:

(a) Wire splices in all forms are prohibited as specified in 3.8.2.1.
(b) The word "electronic" in all places where used as a modifier of equipment or part is deleted.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements (examinations and tests) as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

4.1.1 Responsibility for compliance. All items shall meet all requirements of sections 3 and 5. The inspection set forth in this specification shall become a part of the contractor's overall inspection system or quality program (see 6.3). The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of the manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept defective material.

4.2 Manufacturing screening tests. Manufacturing screening tests of contract end items are required unless waived (see appendix B, 30.1.1.1). 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. Tests in accordance with DOD-HDBK-344 shall include temperature cycling and random vibration in accordance with MIL-STD-2164. The purpose of the test is to stimulate the early occurrence of failures due to manufacturing defects in both parts and workmanship. A 100-hour burn-in test (see 4.2.3) may be performed in lieu of environmental strees screening.

4.2.1 Level of testing. This specification precludes all requirements of MIL-STD-2164 for 100 percent screening. Screening tests of contract end items are required on a first article basis, unless waived (see appendix B, 30.1.1.1) and on a recurring unit basis as required under contractual qualifications as presented in the original equipment specification.

4.2.1.1 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 3. 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 3 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 in accordance with MIL-STD-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.

4.2.1.2 Vibration and thermal cycling of assemblies and subassemblies. The preferred method is to evaluate the total system rather than system parts in accordance with the environmental stress screening test constituents test sequence of MIL-STD-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 ESS screen such as generators, motors, and so forth.

4.2.1.3 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-STD-2164.

4.2.1.4 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 random vibration defect-free run of 5 minutes.

4.2.2 Test plan outline. A test plan shall show the chosen system or subsystem (see 6.3). Tests of complete equipment which are referred to as "solid state" shall be tested in entirety, unless capabilities of available test equipment cause limitations of equipment size which can be tested. Testing shall follow the environmental test screening constituents as defined in MIL-STD-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-STD-2164. Test results will be required to show defect free operation after the random vibration test of circuit cards and assemblies.

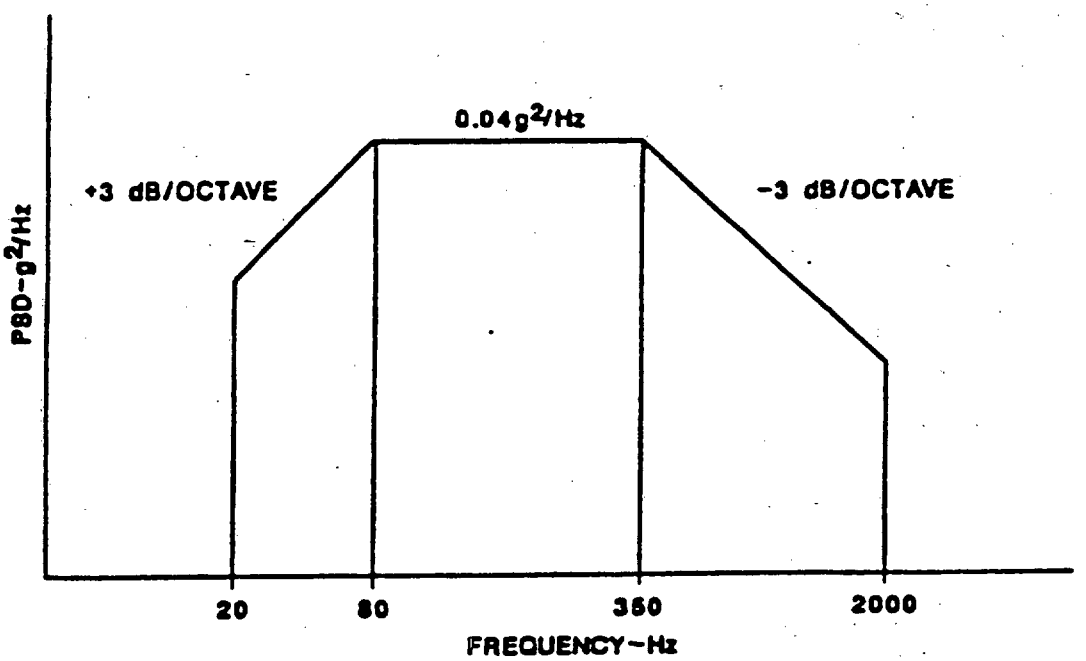


FIGURE 3. Random vibration spectrum.

4.2.3 100-Hour burn-in test. The 100-hour burn-in test shall be conducted by energizing the equipment for 100 hours at nominal voltage and frequency, ambient temperature and with all inputs and outputs connected to effect maximum rated loading. If a failure occurs during his testing, the equipment is to be repaired and the test continued from the point where the failure occurred.

4.3 Examination, tests, and sampling. 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 6.7).

4.3.1 Low quantity and non-QPL qualified transformers. Where transformers, reactors, and inductors are not available on the Qualified Products List of MIL-T-27, and the number of identical units per contract order is less than 100, it will not be necessary to formally qualify these items for inclusion on the Qualified Products List of MIL-T-27. The procedures below will be accepted as sufficient quality assurance in lieu of formal qualification. In obtaining approval of the units, the following data shall be submitted with the request for approval under any of the following procedures:

(a) Core material, core or lamination form and dimensions (include small dimensional sketch if necessary for clarity).
(b) Winding data including the number of turns, taps, wire size and type, terminal identification, dc resistance between terminals at 25°C, and the calculated operating hot spot temperature.
(c) Nominal voltage between terminals, volt-ampere ratings for potential transformers and current ratios for current transformers.
(d) Complete construction and material details including applicable specifications for materials used. Details of core boxes, layer and coil insulation, ground insulation, method of impregnation and treatment, potting methods and materials, terminal boards, grommets, leads, and mechanical construction details.

These data shall be submitted prior to or with the production drawings. For procedure 2, the test schedule shall also be included with these data.

Procedure 1 - Establishment of acceptability based upon similarity to a previously approved and tested design by the same manufacturer under MIL-T-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.

Procedure 2 - 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 as in procedure 1. These tests are as specified in the qualifications tests of MIL-T-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 shall be not less than 500 Vrms).
5	Induced voltage.
6	Insulation resistance.
7	Temperature rise.
8	Vibration (maximum frequency 33 Hz).
9	Shock (method II of MIL-T-27).
10	Immersion.
11	Winding continuity.
12	Insulation resistance test.
13	Dielectric strength (90 percent of initial).
14	Induced voltage.

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

Procedure 3 - Establishment of acceptability based upon similarity to units approved under procedure 2. A given design may be established without testing the units, when the contracting activity is satisfied that the units compare with a single unit with tested and approved mechanical design characteristics in accordance with procedure 1.

4.3.1.1 Inspection requirements for low quantity and non-QPL qualified transformers. All transformers, reactors, and inductors which are approved on the procedures of 4.3.1 shall be subjected to the following inspection from the group A inspection of MIL-T-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 Vrms).
(d) Induced voltage.
(e) Insulation resistance.
(f) Direct-current resistance.
(g) Turns ratio.
(h) Polarity.

4.4 Quality assurance terms and definitions. Quality assurance terms and definitions shall be in accordance with MIL-STD-109.

4.5 Quality conformance inspection. Quality conformance inspection shall consist of such examination and testing as will prove the workmanship and reveal the omissions and errors of the production process, such as functional and performance tests at a limited number of points in the required range. Tests which detect deviations from design, tests of adjustments, and tests which detect hidden defects of materials shall include the following:

Examination or test	Paragraph
General examination	4.5.1
Dielectric withstanding voltage tests	4.5.2
Insulation resistance test	4.5.3

The following tests shall be conducted when specified in the individual equipment specifications (see 6.3).

Examination or test	Requirement	Test method
Insulation suitability test	3.7	4.5.6
Leakage current test	3.3.13.1	4.5.4
Reliability and maintainability	3.2.1	4.5.5
Airborne and structureborne noise tests	3.2.12.2	4.5.7

4.5.1 General examination. The completed equipment shall be given a thorough examination which will include the following:

(a) Workmanship, assembly, and fit (see 3.2 and 3.17).
(b) Parts, materials, and finishes (see 3.4 and 3.9).
(c) Treatment for corrosion prevention (see 3.10.1).
(d) Markings correct for their application and correctly placed (see 3.14 and 3.14.2).
(e) Conformance with safety requirements as specified in 3.2.2.
(f) Proper harness dress as specified in 3.8.2.1.
(g) Ascertaining that all parts including repair parts, are accounted for in the final deliverable package.

4.5.2 Dielectric withstanding voltage tests. Dielectric withstanding tests, shall be conducted in accordance with method 301 of MIL-STD-202 (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 but not greater than 600 V, the rms test voltage shall be twice rated circuit voltage plus 1000 V.
(3) For circuits rated above 600 V, the rms test voltage shall be two times rated circuit voltage plus 1000 V.

(4) For circuits containing parts that are applied within their specified ratings and are in accordance with part specifications that specify in (1), (2), or (3) 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.

(5) 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 4.5.3.1). 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.

4.5.3 Insulation resistance tests. Insulation resistance tests shall be conducted in accordance with method 302 of MIL-STD-202 (see 6.2 and 6.7). Test conditions shall be as follows:

(a) Test potential. Test condition "B" (500 V ± 10 percent).
(b) Points of measure. Between each electrically isolated circuit and all other circuits connected together to ground (frame, chassis, or enclosure as applicable (see 4.5.3.1)).
(c) Electrification time. 60 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 25°C. Correction shall be made on the basis of insulation resistance doubling for each 15°C decrease in temperature.

4.5.3.1 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 circuits internal to the equipment, and only then, such circuits shall be temporarily interconnected with a jumper wire, or test load.
(c) Circuits having only capacitors to ground, as is sometimes the case for EMI suppression in otherwise ungrounded circuits, shall be considered to be electrically isolated from ground.

4.5.3.2 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.

4.5.3.3 Arc and tracking resistance. Arc resistance tests shall be conducted in accordance with ASTM D 495; tracking resistance shall be determined in accordance with ASTM D 3638 (see 3.5.1.1).

4.5.4 Leakage current test. Leakage current tests shall be conducted as specified in 4.5.4.1 and 4.5.4.2 (see 6.7). It is intended that leakage current tests be specified in the individual equipment specification for all hand-held portable equipment and semi-portable equipment to determine conformance with 3.3.13. It is also intended that leakage current tests be specified in the individual equipment specification for the first unit of particular equipment designed for permanent installation. Leakage current tests may be omitted on equipment which fulfills both of the following conditions:

(a) Equipment contains no capacitors connected to ground and its inherent capacitive reactance to ground is found (by actual test) to exceed 200,000 ohms.
(b) Insulation resistance of 1 megohm or more is required by the individual equipment specification and insulation resistance measurement is specified.

Tests shall be conducted with the equipment operating at approximately the normal operating temperature. The frame of the equipment shall be ungrounded. Leakage current shall be measured by a peak-reading meter, suitable for wide frequency range.

4.5.4.1 Portable equipment with cord and plug connector. Prior to the test for leakage current, the resistance from the grounding contact of the plug connector to the frame of the equipment shall be measured and found to be less than 0.1 ohm. For measurement of leakage current, connections shall be made at the contacts of the plug connector. An adaptor may be used with the plug connector to facilitate making connections to the power source and meter. To

operate the equipment, the power source shall be connected to the proper contacts of the plug connector; however, the grounding contact of the plug connector shall be left unconnected except as required for this test. For leakage current measurements, each line shall be connected successively to the grounding contact of the plug connector and the current flowing in the connecting wire measured.

4.5.4.2 Permanently installed equipment. For leakage current measurements, each line shall be connected successively to the frame, while the equipment is operating at rated input voltage, and the current flowing in the connecting wire measured.

4.5.5 Reliability and maintainability assurance.

4.5.5.1 Reliability demonstration tests. Reliability demonstration tests shall consist of the performing of the reliability tests required by the individual equipment specification or acquisition document (see 3.2 and 6.7).

4.5.5.2 Maintainability demonstration tests. Maintainability demonstration tests shall consist of the performing of the maintainability demonstration tests required by the individual equipment specification or acquisition document (see 3.2 and 6.7).

4.5.6 Insulation suitability test. Insulation suitability tests on insulated equipment shall be conducted as specified in appendix A.

4.5.7 Airborne and structureborne noise test. Airborne and structureborne noise tests shall be conducted in accordance with the requirements of MIL-STD-740-1 and MIL-STD-740-2 when specified in the individual equipment specification.

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 a reactor 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 of 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 or the cold resistance shall be determined by measuring the resistance of the winding at room temperature (R_c). 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:

$$T_r \text{ (Temperature rise) } °C = (234.5.5 + T_c)R_h/R_c - (234.5 + T_a)$$

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: 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.

4.6.1.3 Method 3. This is the "embedded detector" method and 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 (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 (see 6.3). 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 of 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 5°C and when the variation between successive readings at the same location does not exceed 1°C, the rate of temperature change does not exceed 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 6.7 and 4.6.3.3.1(c)) does not exceed 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 which 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 10 and 50°C. It shall be assumed that the temperature rise is the same for all ambient temperatures between the limits of 10 and 50°C. No heat runs shall be undertaken on equipment which has recently been brought from a place varying in temperature by 5°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 4.3.3.1 through 4.3.3.4, as applicable (see 6.7).

4.6.3.3.1 Equipment other than that cooled by water, oil, or forced air from separate source. 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 6.7).

4.6.3.3.4 Equipment cooled by oil. Ambient temperature shall be measured as specified in the individual equipment specification (see 6.7).

4.7 Inspection of packaging. Sample packages and packs, and the inspection of the preservation, packing and marking for shipment and storage shall be in accordance with the requirements of section 5 and the documents specified therein.

5. PACKAGING

5.1 Packaging specification. Packaging shall be as specified in the individual equipment specification (see 6.7).

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 (commodity) 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 which 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 must specify the following:

(a) Title, number, and date of this specification.
(b) Issue of DoDISS to be cited in the solicitation, and if required, the specific issue of individual documents referenced (see 2.1.1 and 2.2).
(c) Input power variations for ac equipment (type I power of DOD-STD-1399, Section 300 applies unless otherwise specified (see 3.3.1.1)).
(d) Manual reset of protective devices after interruption of input power, if applicable (see 3.3.1.1).
(e) Surge voltage suppression if other than as specified (see 3.3.3).
(f) Inclined operation if other than as specified (see 3.3.4).
(g) Ambient temperature range if other than that specified (see 3.3.5.1).
(h) If exterior shipboard service is intended (see 3.3.5.1).
(i) If equipment is to be designed to use fitted (body-bound) bolts for mounting to the ship's structure (see 3.3.7(c)).
(j) If electromagnetic interference suppression methods are other than as specified (see 3.3.8).
(k) If noise reduction control is other than as specified (see 3.3.11.1).
(l) 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 I (see 3.3.14.1).
(m) If equipment is to be designed to use captive (body-bound) bolts for mounting on ship structure (see 3.3.16.1).
(n) Insulation resistance and dielectric withstanding voltage test procedures and requirements, if different than specified (see 3.3.18, 3.3.18.1, 4.5.2, and 4.5.3).
(o) Test equipment, if other than as specified (see 3.3.19).
(p) Use of malleable or modular graphitic iron (see 3.4.2.2).
(q) Color of plastics, if other than as specified (see 3.4.3).
(r) Thermoplastic insulating materials for molded parts (see 3.5.1.3.2).

(s) When bus bars are to be insulated (see 3.6.7).
(t) When insulation suitability tests are required (see 3.7).
(u) Method of external cable connection, if other than as specified (see 3.8.2.4).
(v) When printed wiring is not to be used (see 3.8.2.10).
(w) When electron tubes are permitted (see 3.9.17).
(x) Whether repair of printed wiring boards damaged during manufacture will be permitted (see 3.9.26(h)).
(y) If details of the fabrication procedure for welding are to be submitted for approval (see 3.10.5.1(b)).
(z) If the minimum radius of rounded edges and corners is other than 0.04 inch (see 3.12.7).
(aa) If drilled and tapped holes are to be countersunk (see 3.12.8).
(bb) When insulation system is to be tested for moisture resistance (see 4.5.3.2).
(cc) When temperature measurement by embedded detectors is other than as specified (see 4.6.1.3).
(dd) Level of packing required of the vendor (see 5.1).

6.3 Consideration of data requirements. The following data requirements should be considered when this specification is applied on a contract. The applicable Data Item Descriptions (DID's) should be reviewed in conjunction with the specific acquisition to ensure that only essential data are requested/provided and that the DID's are tailored to reflect the requirements of the specific acquisition. To ensure correct contractual application of the data requirements, a Contract Data Requirements List (DD Form 1423) must be prepared to obtain the data, except where DoD FAR Supplement 27.475-1 exempts the requirement for a DD Form 1423.

Reference Paragraph	DID Number	DID Title	Suggested Tailoring
3.2	DI-E-7079	Reliability program plan	----
3.2.6	DI-MNTY-80822	Maintainability program plan	----
3.3, 3.12.12.1, 3.14, 4.6.1.3.1, and appendix C	DI-DRPR-80651	Engineering drawings	Level 3
3.3.12.2	DI-HFAC-80270	Equipment airborne sound measurement plan	----
3.3.12.2	DI-HFAC-80271	Sound test failure notification and recommendations report	----
3.3.12.2	DI-HFAC-80272	Equipment airborne sound measurements test report	----

Reference Paragraph	DID Number	DID Title	Suggested Tailoring
3.3.12.2	DI-HFAC-80273	Equipment structureborne vibratory acceleration measurement plan	----
3.3.12.2	DI-HFAC-80274	Equipment structureborne vibratory acceleration measurements test report	----
3.3.12.2	DI-T-23731	Notification of tests	----
3.4.1.2	DI-E-2121	Certificate of compliance	----
3.9.1.3, 3.9.18.1, 3.9.20.1.1, and appendix B	DI-MISC-80071	Parts approval request	----
3.9.1.3, 3.9.18.1, 3.9.20.1.1, and appendix B	DI-I-7029	Military detail specifications and specification sheets	----
4.1.1	UDI-R-23743	Quality program plan	----
4.2.2	DI-RELI-80250	Reliability test plan	ESS test plan outline
Appendix B, 30.1.1	DI-E-3131	Material specification	----

The above DID's were those cleared as of the date of this specification. The current issue of DoD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL), must be researched to ensure that only current, cleared DID's are cited on the DD Form 1423.

6.4 Technical manuals. The requirement for technical manuals should be considered when this specification is applied on a contract. If technical manuals are required, military specifications and standards that have been cleared and listed in DoD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL) must be listed on a separate Contract Data Requirements List (DD Form 1423), which is included as an exhibit to the contract. The technical manuals must be acquired under separate contract line item in the contract.

6.5 Provisioning. Provisioning Technical Documentation (PTD), spare parts, and repair parts should be furnished as specified in the contract.

6.5.1 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 and quality assurance provisions as the parts used in the manufacture of the equipment. Packaging for such parts should also be specified.

6.5.2 Repair parts. Repair parts are those parts of the equipment, other than bulk materials and standard hardware items, that may be required for maintenance or repair of the equipment. Repair parts to be furnished for the equipment, when required (see 6.5), should be as identified by the ordering documents. Each item of repair parts should be suitable for direct replacement of the originally installed part. Operation of the equipment with repair parts installed should be equal to the original. Where a repair part is not readily replaceable in the assembly as applied, the next higher subassembly or assembly that is readily replaceable should be provided as a repair part. Where matching of parts is necessary, such parts should be incorporated as a replaceable assembly which shall be supportable for repair purposes by replacement of the assembly. The word "set", as applied to any item in the list of repair parts means the total quantity of such part incorporated in a quantity of one of the equipment to which the list applies.

6.6 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.

6.7 Subjects to be covered in equipment specification. Attention of design engineers is directed to the following subjects which should be covered in the individual equipment specification or in the contract or order:

(a) Detail characteristics and performance requirements for the equipment.
(b) Whether equipment is for surface ship or submarine application.
(c) If configured in metric dimensions, whether class M or class H of DOD-M-24680.
(d) Reliability and maintainability requirements:

(1) Applicability of reliability and maintainability requirements and programs (see 3.2 and 3.2.6).
(2) Reliability quantitative requirements (see 3.2).
(3) Definition of failure.
(4) Reliability testing requirements.
(5) Reliability test accept-reject criteria.
(6) Reliability test conditions.
(7) Maintainability quantitative requirements.
(8) Maintenance concept.
(9) Alternate or additional maintainability design requirements or criteria, if required.
(10) Maintainability demonstration requirements.

(e) Special performance, if required, in the event of an electrical part failure (see 3.2.7).
(f) Drawings (see 3.3).

(g) Whether exterior shipboard service is intended (see 3.3.5.1).
(h) High impact shock and vibration requirements (see 3.3.6.1, 3.3.6.2, MIL-S-901 ordering data, and 3.3.7).
(i) Electromagnetic interference requirements of MIL-STD-461 if applicable (see 3.3.8).
(j) Eddy current magnetism for equipment installed on nonmagnetic minesweepers (see 3.3.10).
(k) Noise reduction (see 3.3.11.1 and 3.3.11.2).
(l) Equipment insulation requirement (see 3.3.18).
(m) Special shipboard environmental conditions (see 3.3.20).
(n) Temperature rise (see 3.5.2.3).
(o) Class of insulation system (see 3.5.3.1).
(p) Establish a criterion of acceptance for insulation under conditions of use (see 3.5.2.1).
(q) External cable connections (3.8.2.4).
(r) Painting of equipment exterior, if gray appearance is required (see 3.10.2.1).
(s) Whether autotransformers and open delta connected transformers are permitted.
(t) Quality assurance provisions (see section 4).
(u) Quality inspection system (see 4.1) that shall apply, if other than the contractor's standard inspection system.
(v) Examination, tests, and sampling (see 4.3).
(w) Whether insulation resistance, leakage current, reliability, and maintainability tests are required (see 3.3.14.1, 4.5.3, 4.5.4, 4.5.5.1, and 4.5.5.2).
(x) How ambient temperature is to be measured in equipment cooled by water (see 4.6.3.3).
(y) Packaging (see section 5).
(z) Ordering data to be specified on Form DD 1423.
(aa) Guidance should be included in the individual equipment specification which will assist the contracting activity in the preparation of CDRL (DD Form 1423) and the citing of appropriate DID's (DD Form 1664) as applicable to the particular equipment and type of purchase.
(bb) Manuals (see 6.4).
(cc) When dark adaptation is required, the individual equipment specification or purchase document should so specify.

6.8 Requirements for approval.

3.3.17 - Utilization of special tools - invokes 3.9.1.3.
3.4.1.3 - The use of asbestos with no acceptable substitute.
3.4.1.4 - The use of silicone in ventilated motors and generators.
3.5.1.2 - Use of laminated plastics of special forms.
3.5.4 - Thermal endurance evaluation (of insulation) in other than standard assemblies.
3.5.7 - Coating of epoxy on toroid core boxes.
3.5.12 - Table X, Slotwedges, note 3. - for commercial grades of insulation listed.
3.6.4.2 - Encapsulants and compounds used on coils and windings.
3.9.1.3 - Nonstandard parts.
3.9.2.1 - Fuses for semiconductor protection - invokes 3.9.1.3.

3.9.17 - Electron tubes.
3.9.18.1 - Nonstandard semiconductors.
3.9.20.1 - Nonstandard microcircuits.
3.9.24.7 - Substitution products.
3.9.27 - Packaging of parts into non-repairable assemblies.
3.10.1 - Table XIX - Primer other than specified.
4.1.1 - Inspection system or quality assurance program.
40.5.4 - Insulation suitability test reports, assembly of data. (appendix A)
30.1.1 - Materials and methods requiring advanced approval. (appendix B)

6.9 Subject term (key word) listing.

Alternating current equipment
Electrical control equipment
Input power
Shipboard electrical systems

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

Custodian:
Navy - SH

Preparing activity:
Navy - SH
(Project 6110-N247)

APPENDIX A

PROCEDURE FOR INSULATION SUITABILITY TESTS

10. SCOPE

10.1 Scope. This appendix covers the insulation suitability testing procedure for insulation systems classified at temperature of 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.

10.2 Purposes. The purpose of this test is to determine the insulation resistance, dissipation factor, and capacitance of an electric winding insulated with silicone or other insulation under conditions of severe moisture exposure.

10.3 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.
Type PW - Partial winding.

10.4 Definitions.

10.4.1 Insulation resistance. The insulation resistance between two electrodes which 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.

10.4.2 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.

10.4.3 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.

10.4.4 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.

10.4.5 Power factor (p.f.). The power factor of an insulating structure is the ratio of the watts dissipated in a capacitor in which the material is the dielectric to the product of the sinusoidal voltage and current expressed in effective volt-amperes. It is also the cosine of the phase angle of the material and the sine of the loss angle.

10.4.6 Loss factor (LF). The loss factor of an insulating structure is equal to the product of its dissipation factor and dielectric constant.

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10.4.7 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.

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

10.4.9 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.

10.4.10 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.

10.4.11 Leakage current. Leakage current is defined as the maximum rms value of current flowing through an ammeter connected from each line of the power source to the ungrounded equipment case or enclosure with equipment operating. (Ungrounded means not touching the ships hull or connected to a power safety ground.)

20. APPLICABLE DOCUMENTS

20.1 Government documents.

20.1.1 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 listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATIONS

MILITARY

MIL-G-3111 - Generators, Electric, Direct-Current (Naval Shipboard Use).
MIL-G-3124 - Generators, Alternating Current, 60-Hertz (Naval Shipboard Use).
MIL-G-18473 - Generators, Motors, and Auxiliary Equipment, Direct Current, Naval Ship Propulsion.

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Standardization Documents Order Desk, BLDG. 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

30. REQUIREMENTS

30.1 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.

40. QUALITY ASSURANCE PROVISIONS

40.1 Insulation suitability tests.

40.1.1 Place of tests. The insulation suitability tests shall be conducted at a laboratory and under conditions satisfactory to NAVSEA.

40.1.2 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 manufacturers facility, will be tested. Table XXI lists equipment by specification and the form of sample to be tested.

TABLE XXI. Specimens for insulation suitability test. 1/ 2/

Equipment specification	Equipment	Form to be tested	Sample quality	Suggested size and type
MIL-M-17060	AC integral horsepower (hp) motors	Stator winding	3	10 hp, 215 frame. Three-phase induction type
MIL-M-17059	AC fractional hp motors	Motor	3	1/4 hp, single-phase
MIL-G-3124	AC generators	Armature coil Field coil	3 3	Any size over 50 kw
MIL-G-3111	DC generators	Armature coil Field coil	3 3	Any size over 50 kw
MIL-M-17413	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	DC fractional hp motors	Motor	3	1/4 hp, shunt
	AC propulsion motors and generators	Armature and field coil	3 each	Any size
MIL-G-18473	DC propulsion motors and generators	Armature and field coil	3 each	Any size
MIL-T-17221	400 Hz transformer	Transformers	3	Any size
MIL-C-2212	AC controller DC controller	Shunt coil Shunt coil	3 3	Any size Any size

See footnotes at top of next page.

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.

40.2 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.

40.3 Type of test equipment.

40.3.1 Humidity chamber. This box shall be made of steel, or a transparent plastic film, having a low moisture permeability, 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 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.

40.3.2 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.

40.3.3 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.

40.3.4 Capacitance test bridge. A capacitance test bridge shall be used having a 60 Hz input with a range of 5 or μMF to 1100 μF and with a range of dissipation range factor of 0 to 50 percent.

40.3.5 Ohmmeter. Any standard laboratory instrument may be used, provided the smallest center scale reading is not over 15 ohms.

40.4 Test requirements.

40.4.1 Dielectric-high potential. A potential of twice normal rated voltage plus 1000 volts 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.

40.4.2 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.

40.4.3 Insulation resistance. The insulation resistance measurement shall be made using a direct potential of 500 volts 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 25°C standard temperature.

40.4.4 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.

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 nonwetting 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.

40.4.5 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.

40.5 Test procedures. The equipment shall be tested in accordance with the following procedures:

40.5.1 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 appendix A, 40.4.1. 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.

40.5.2 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 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.

40.5.3 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 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 potential test shall also be applied as specified in appendix A, 40.4.2.

40.5.4 Assembly of data. All data shall be recorded on a form similar to that shown in table XXII.

40.6 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 4 and 5 respectively.

40.7 Approval of equipment. A copy of the insulation suitability test reports shall be prepared by the manufacturer, authenticated by the inspector, and submitted to NAVSEA for approval action. The format of the report may be in any convenient form. The data to be submitted in the report shall be as follows:

(a) Description of all test equipment, including associated limitations of accuracy and resolution.
(b) Description of the equipment with a photograph of the winding taken within 10 minutes after the humidification test.
(c) Data as specified in table XXII sample format.
(d) Curves as specified on figures 4 and 5.

Upon receipt of the report specified herein, approval action will be taken on the basis of test results to allow the use of the equipment for the widest intended purposes.

TABLE XXII. Insulation suitability test 100 percent relative humidity plus dew.

Winding data
(rating data as applicable)

Insulation data
(or as applicable)

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_____

Magnet wire (type_____).
Ground_____ Armature_____ Field_____
Phase_____ Sleeving_____ Varnish_____ No. of dips_____
Wedge_____ Tying cord_____ Leads_____ and bakes_____

Report no._____ Time and Temp._____

Date of tests_____
Lab_____

	Insulation resistance (megohms)	Capacitance (μF)	Dissipation factor, (percent)	Normal potential (volts)	Resistance (ohms)	Temp. (°C)	Relative humidity (percent)
Initial tests							
Std. run							
1 day (24 hrs)							
2 (48 hrs)							
3 (72 hrs)							
4 (96 hrs)							
5 (120 hrs)							
6 (144 hrs)							
7 (168 hrs)							
Recovery							

NOTE: All winding leads shall be approximately 6 feet in length.

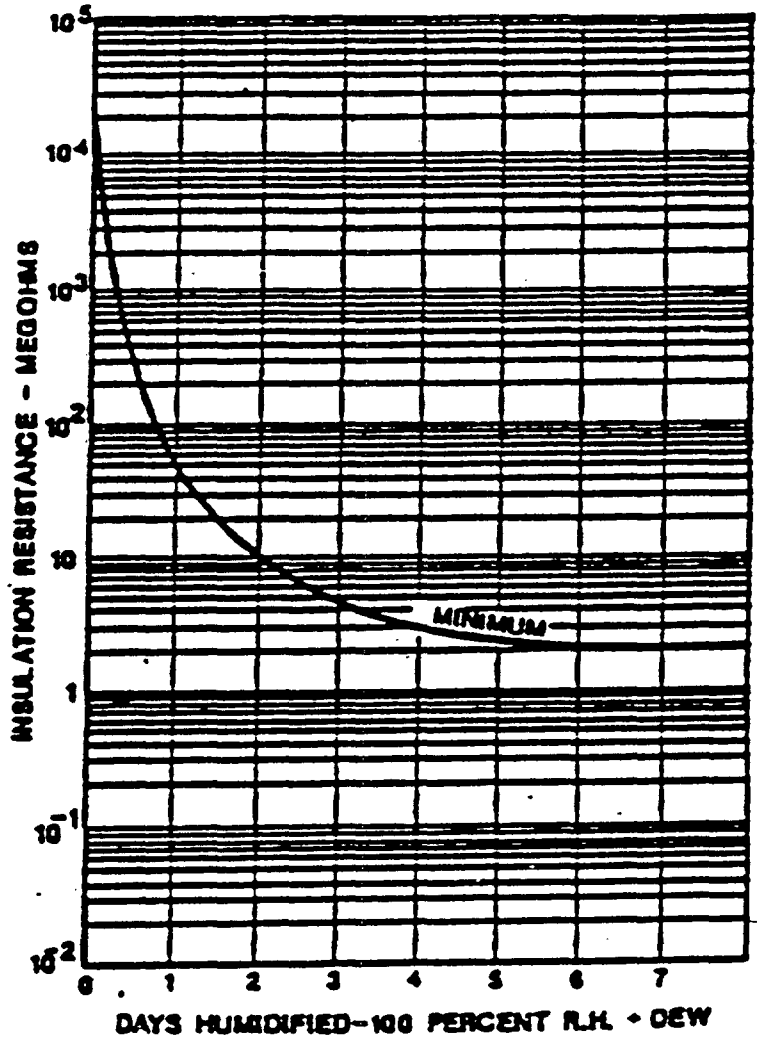

FIGURE 4. Insulation resistance.

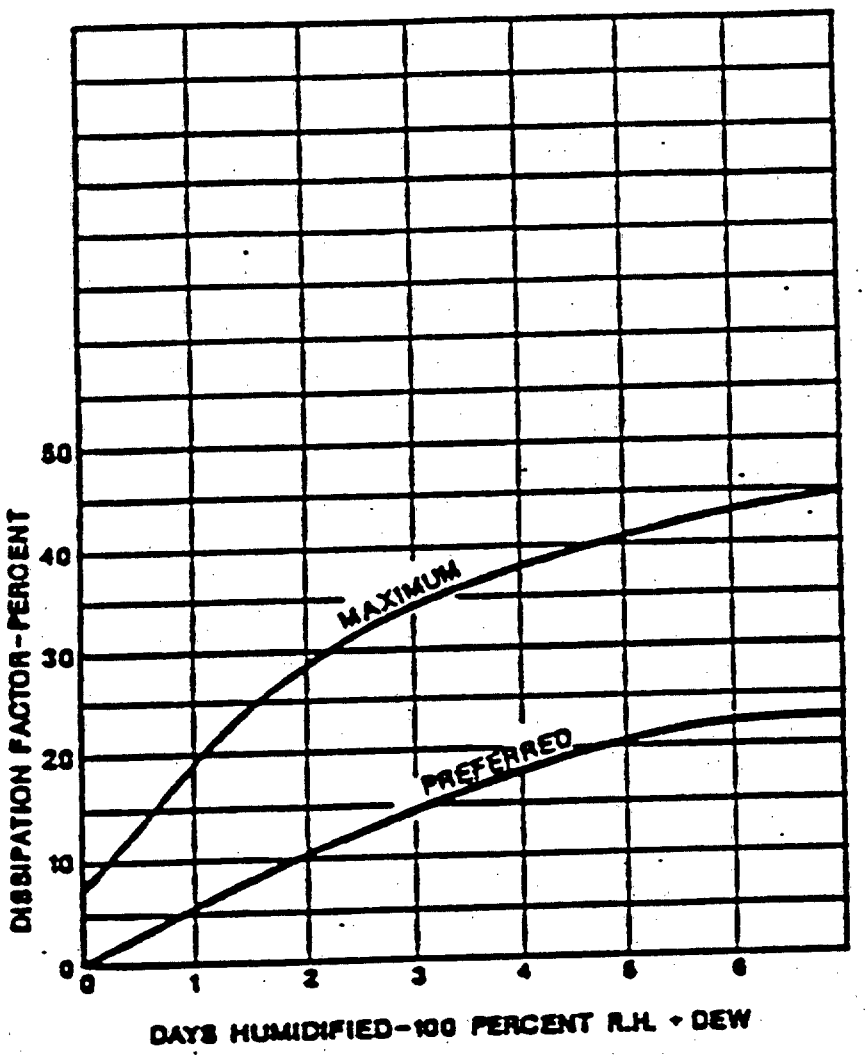

FIGURE 5. Dissipation factor.

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APPENDIX B

ESSENTIAL CHARACTERISTICS

10. SCOPE

10.1 Scope. This appendix provides guidance and procedures for establishing equipment essential characteristics not fully covered in the individual equipment specification. This appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

20. APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

30. PROCEDURES

30.1 Essential characteristics. The contractor shall furnish the Government procuring activity written notification of any function or feature essential to the performance of the specified equipment which is not described in full or which is necessary for the proper performance of the equipment in accordance with the specification requirements.

30.1.1 Materials, methods, parts, and processes requiring specific approval. This specification cannot completely cover all conditions and situations that are suitable for every application, because of continuing progress in the field of material development, technological advances, the lack of specifications for certain materials, methods, parts, and processes, and the limitation that some of these have for particular uses. Where a contractor considers it necessary to substitute a specific material, part, method or process contained in the specification, referenced DOD specifications, or acquisition requirements, permission for such substitutions must be obtained from NAVSEA. Manufacturer shall not commence until confirmation of approval is obtained (see 6.3).

(a) Contract information and applicable equipment identification, including:

(1) Contractor's name.
(2) Contract number and date.
(3) Contracting agency.
(4) Equipment nomenclature, item name, and description.
(5) Applicable equipment specification (indicate issue and date, including amendments).

(b) Complete specification covering material or part proposed or details method of process proposed. Commercial standards if available should be cited. NEMA, IEEE, ASTM, ANSI, and UL standards for a particular material may be sufficient evidence for approval without further testing.

(c) Details of proposed application, including identification of where and how used, normal and worst-case conditions such as temperature, humidity, voltage, current, or tension shear.

(d) Advantages offered by use of proposed material, method or process.
(e) Extent of approval sought (for example, specific contract, specific type of equipment, and so forth). If approval for more than one contract is sought, sufficient details on the proposed material or method (costs, advantages and limitations for general usage, compatibility, and so forth) shall be furnished to enable NAVSEA to consider future coverage by specification change. Requests for approval of materials or method and process of materials in this category shall be submitted, if possible, prior to submission of drawings. If approval is granted, the equipment drawing shall identify the material or method, or process and shall reference NAVSEA letter confirming its approval for use.

30.1.1.1 Departure from specifications. Departures from specifications generally will not be allowed unless some benefit to the Government results. If a contractor finds it necessary or important to change or depart from applicable specifications, he must request permission and receive permission to do so from NAVSEA. The contracting activity may refer the matter to NAVSEA for a decision or consideration as a possible specification change. Requests by contractors for changes shall clearly describe the changes proposed, the reasons for and advantages of the changes, and shall state the contract price increase or decrease that would result. If the proposed change involves the substitution of another material or method for one specifically required, the information listed in 30.1.1 shall also be furnished. The contractor shall proceed with changes which involve a departure from specifications only after written approval has been obtained.

30.1.2 Procedures for drawings. Contracts, orders, or individual equipment specifications normally require that drawings showing equipment design and materials be submitted to NAVSEA or its authorized representative for approval. Approval, in writing, shall be obtained before commencing production of such equipment. If drawings are approved subject to specific modifications and no specific limitations are imposed, the contractor may proceed with manufacture of the equipment incorporating the modifications, with the understanding that revised drawings shall be submitted in due course for file and to record the fact that the specific modifications actually have been made.

30.1.2.1 Significance of drawing approval. By approval of drawings, the Government approval activity agrees to the acceptance of the equipment represented provided all specifications required are met. Such approval does not extend to any exception either explicit or implied by information and data on the drawings except where the exception is specifically identified as such in connection with reference to the applicable specifications. Approval of drawings by the Government does not relieve the contractor of the responsibility for satisfactory performance of the equipment for the purpose intended. If the equipment should fail to perform in accordance with the contract requirements, the contractor is obligated to correct the defects or make any changes necessary to meet the contract requirements without additional cost to the Government.

30.1.3 Clarification of discrepancies. In any case of discrepancy or lack of clarity in this specification or in any individual equipment specification which references this specification, the contractor shall promptly request

clarification from the contracting officer. Neither such request nor the time reasonably necessary to resolve the discrepancy or provide clarification shall relieve the contractor of his responsibility for timely delivery of equipment meeting the performance characteristics of the specifications. Work performed based on such discrepancy or lack of clarity shall be at the contractor's own risk.

30.1.4 Qualified products. When any specification invoked by this specification requires that the product be subjected to and pass qualification tests, unless otherwise approved by NAVSEA, only products which are listed on the applicable Qualified Products List on the date of invitation for bids, or which may be added to the Qualified Products List subsequent to that date, shall be utilized in the construction of equipment specified to be in accordance with this specification. In the event no Qualified Products List has been issued, the supplier shall request instructions as to what testing will be required to determine whether the product meets the requirements of the specification. Inclusion of a part on a Qualified Products List does not relieve the vendor of the responsiblity to ensure the suitability of the part in the vendor's specific design application or configuration. NAVSEA approval shall be obtained to use any part not on the appropriate Qualified Products List. Justification is required for the use of any part not identified on the Qualified Products List.

30.1.5 Non-standard parts. When a supplier has determined that the requirements cannot be met by using a standard part, he shall immediately determine the non-standard part which will be suitable and request approval from NAVSEA to incorporate it into the design. The supplier shall use previously approved non-standard parts prior to requesting approval to use a non-standard part not previously approved. The request shall be accompanied by accurate identifying information on the non-standard part. Each non-standard part data sheet shall be given a number by the supplier which shall not be repeated for any other sheet prepared under the same order. Six copies of this information shall be submitted and shall be accompanied by six copies of all necessary drawings (such as drawings indicating size, shape, material, and method of assembly). Approval will not be granted for the use of parts of special or novel designs where parts specified herein are suitable or available, except in cases where a new or improved part may be submitted which will significantly enhance the overall equipment performance and dependability.

30.1.5.1 Non-standard parts approval. The procedures for requesting approval, and the supporting data to be submitted, shall be as specified in 3.9.1.3. Additional data for semiconductor devices and for microcircuits shall be in accordance with 3.9.18.2 and 3.9.20.1, respectively. A separate document shall be submitted for each non-standard part. In those cases where the use of a non-standard part has been authorized because of delivery schedules, the supplier shall take appropriate action so that a standard part may be easily and quickly installed by semi-skilled Naval field technicians. Mechanical replacement shall be provided for by allowing mounting space and holes for the standard part.

30.1.5.2 Non-standard semiconductor devices. Each request for approval shall include a summary of the technical analysis (see 3.9.18.1). A tabulation showing the application demands or stress levels placed upon it shall be included. These data shall contain no restrictions which would limit their use by the Government or by others in the interest of the Government. A copy of the device manufacturer's published product specification or technical data bulletin which covers each proposed non-standard semiconductor device shall be furnished. Neither of these publications however, is acceptable as the basis for approval unless accompanied by the above data.

30.1.5.3 Non-standard microcircuits. Devices not listed on the QPL and for which a DESC drawing does not exist may be used subject to NAVSEA approval, with the requirement that a source control drawing must be furnished with the request, listing appropriate testing and screening requirements.

APPENDIX C

ENGINEERING DRAWINGS TECHNICAL CONTENT REQUIREMENTS

10. SCOPE

10.1 Scope. This appendix covers information that shall be included on the drawings when specified in the contract or order. This appendix is mandatory only when data item description DI-DRPR-80651 is cited on the DD Form 1423.

20. APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

30. DRAWING CONTENTS

30.1 Drawings and associated lists. Drawings and associated lists shall be in accordance with the data ordering document (see 6.3), and with the levels and types thereof specified in the individual equipment specification and in the contract or order.

30.2 Part drawings. Contractors are required to supply level 3 drawings for all parts of equipment supplied for use in repair part provisioning. Microfilm copies of these drawings shall also be supplied.

30.3 High-voltage equipment. When the maintenance or operation of equipment employing potentials in excess of 2000 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 1000 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. Full details of the method used to obtain each test point voltage, and the multiplier for calculating the voltage represented by each test point voltage shall be shown on the equipment drawings. The voltages specified herein shall be interpreted as applying to dc, ac, and dc plus ac voltages.

30.4 Temperature measurements - method 3. This is the "embedded detector" method and consists the determination of temperature by thermocouples or resistance temperature detectors built into the equipment either permanently or for test purposes (see 4.6.1.3.1). Details of the type, locations and installation of embedded detectors shall be shown on a drawing of the equipment and shall be subject to the design and drawing approval requirements that apply to the basic equipment (see 30.1). 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. Results of this analysis shall be shown on, or provided as a supplement to, the drawing which covers the location and installation of the temperature detectors. Temperature conversion data for the detectors used shall be indicated.

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The index items are categorized under the following major headings:

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INDEX - Continued

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
2. The submitter of this form must complete blocks 4, 5, 6, and 7.
3. The preparing activity must provide a reply within 30 days from receipt of the form.

NOTE: This form may not be used to request copies of documents, nor to request waivers, or clarification of requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or to amend contractual requirements.

I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER	2. DOCUMENT DATE (YYMMDD)
	MIL-E-917E(NAVY)	6 AUGUST 1993

3. DOCUMENT TITLE
ELECTRIC POWER EQUIPMENT BASIC REQUIREMENTS

4. NATURE OF CHANGE *(Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)*

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME (Last, First, Middle Initial)	b. ORGANIZATION	
c. ADDRESS (Include Zip Code)	d. TELEPHONE (Include Area Code) (1) Commercial (2) AUTOVON (If applicable)	7. DATE SUBMITTED (YYMMDD)

8. PREPARING ACTIVITY

a. NAME	b. TELEPHONE (Include Area Code) (1) Commercial	(2) AUTOVON
TECHNICAL ENGINEER: Mr. James Banic, NAVSEA 03E23	(703) 602-5340	332-5340
c. ADDRESS (Include Zip Code) Commander, Naval Sea Systems Command ATTN: SEA 03Q42, 2531 Jefferson Davis Hwy, Arlington, VA 22242-5160	IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT: Defense Quality and Standardization Office 5203 Leesburg Pike, Suite 1403, Falls Church, VA 22041-3466 Telephone (703) 756-2340 AUTOVON 289-2340	