MIL-E-917D(NAVY)
28 January 1965
SUPERSEDING
MIL-E-917C(NAVY)
15 March 1958
(See 6.5)

MILITARY SPECIFICATION

ELECTRIC POWER EQUIPMENT, BASIC REQUIREMENTS

(NAVAL SHIPBOARD USE)

All interested Bureaus of the Department of the Navy
have concurred in the use of this specification

1. SCOPE

1.1 This specification covers the general 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). If a conflict exists between this specification and an individual equipment specification, the latter shall govern.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of the specification to the extent specified herein.

SPECIFICATIONS

FEDERAL

FF-S-85	- Screw, Cap, Slotted- and Hexagon-Head.
FF-S-86	- Screw, Cap, Socket-Head.
FF-S-92	- Screws, Machine, Slotted or Cross-Recessed.
FF-S-200	- Setscrews, Hexagon Socket and Spline Socket, Headless.
FF-S-210	- Setscrews, Square Head and Slotted Headless.
HH-I-538	- Insulation, Electrical, Pasted-Mica.
QQ-B-650	- Brazing Alloy, Copper, Copper-Zinc, and Copper-Phosphorus.
QQ-C-320	- Chromium Plating (Electrodeposited).
QQ-I-666	- Iron Castings, Malleable.
QQ-N-290	- Nickel Plating (Electrodeposited).
QQ-P-416	- Plating, Cadmium (Electrodeposited).
QQ-S-365	- Silver Plating, Electrodeposited, General Requirements for.
QQ-S-571	- Solder, Lead Alloy, Tin Lead Alloy, and Tin Alloy; Flux Cored Ribbon and Wire, and Solid Form.
QQ-Z-325	- Zinc Coating, Electrodeposited, Requirements for.
TT-C-490	- Cleaning Methods and Pretreatment of Ferrous Surfaces for Organic Coatings.
TT-P-645	- Primer, Paint, Zinc-Chromate, Alkyd Type.
TT-P-664	- Primer, Coating, Synthetic, Rust-Inhibiting, Lacquer-Resisting.
TT-P-666	- Primer Coating, Zinc Yellow, For Aluminum and Magnesium Surfaces.

MILITARY

MIL-E-1	- Electron Tubes General Specification for.
MIL-R-11	- Resistors, Fixed, Composition (Insulated), General Specification for.
MIL-M-14	- Molding Plastics and Molded Plastic Parts, Thermosetting.
MIL-R-19	- Resistors, Variable (Wirewound (Low Operating Temperature), General Specification for.
MIL-R-22	- Resistors, Variable (Wirewound, Power Type), General Specification for.
MIL-C-25	- Capacitors, Fixed, Paper-Dielectric, Direct Current (Hermetically Sealed in Metallic Cases), General Specification for.
MIL-R-26	- Resistors, Fixed, Wirewound (Power Type).
MIL-C-62	- Capacitors, Fixed, Electrolytic (DC, Aluminum, Dry Electrolytic, Polarized), General Specification for.

MILITARY (Continued)

MIL-P-79	- Plastic Rods and Tubes, Thermosetting, Laminated.
MIL-R-93	- Resistors, Fixed, Wirewound (Accurate) General Specification For.
MIL-R-94	- Resistors, Variable, Composition, General Specification for.
JAN-I-545	- Insulation, Electrical, Paper, Pressboard.
MIL-W-583	- Wire, Magnet, Electrical.
MIL-I-631	- Insulation, Electrical, Synthetic-Resin Composition, Nonrigid.
MIL-T-638	- Tape, Insulating (Electrical) Linen-Finish, Plain.
MIL-I-695	- Insulation, Electrical, Paper (Slot-Cell).
MIL-B-857	- Bolts, Nuts, and Studs.
MIL-S-901	- Shock Tests, H.I. (High-Impact), Shipboard Machinery, Equipment and Systems, Requirements For.
MIL-D-963	- Drawings, Electrical, Hull and Mechanical Equipment For Naval Shipboard Use.
MIL-P-997	- Plastic-Material, Laminated, Thermosetting, Electrical-Insulating, Sheets, Glass Cloth, Silicone Resin.
MIL-V-1137	- Varnish, Electrical-Insulating (for Electro-Motive Equipment).
MIL-Y-1140	- Yarn, Cord, Sleeving, Cloth, and Tape-Glass.
MIL-I-3042	- Insulation, Electrical, Cotton-Fiber, Untreated.
MIL-I-3053	- Insulation, Electrical, Asbestos-Fiber, Treated and Untreated.
MIL-I-3190	- Insulation Sleeving, Electrical, Flexible, Treated.
MIL-I-3374	- Insulation Cloth and Tape, Electrical, Varnished Cambric.
MIL-I-3505	- Insulation Sheet and Tape, Electrical, Coil and Slot, High Temperature.
MIL-C-3965	- Capacitors, Fixed, Nonsolid Electrolytic, (Tantalum, Foil and Sintered-Slug) General Specification for.
MIL-C-5015	- Connectors, Electric, AN Type.
MIL-C-5541	- Chemical Films and Chemical Film Materials for Aluminum and Aluminum Alloys.
MIL-I-7798	- Insulation Tape, Electrical, Pressure-Sensitive Adhesive, Plastic.
MIL-T-7928	- Terminals; Lug and Splice, Crimp-Style, Copper.
MIL-P-8585	- Primer Coatings, Zinc Chromate, Low-Moisture-Sensitivity.
MIL-A-8625	- Anodic Coatings, for Aluminum and Aluminum Alloys.
MIL-C-11015	- Capacitors, Fixed, Ceramic-Dielectric (General Purpose), General Specification for.
MIL-C-11693	- Capacitors, Feed Through, Radio Interference Reduction, AC and DC (Hermetically Sealed in Metallic Cases), General Specification for.
MIL-C-12889	- Capacitors, By-Pass, Radio-Interference Reduction, Paper Dielectric, AC and DC, (Hermetically Sealed in Metallic Cases) General Specification for.
MIL-P-13949	- Plastic Sheet, Laminated, Copper Clad (for Printed Wiring).
MIL-P-15037	- Plastic Sheet, Laminated, Thermosetting, Glass-Cloth, Melamine-Resin.
MIL-M-15071	- Manuals, Equipment and Systems.
MIL-E-15090	- Enamel, Equipment, Light-Gray (Formula No. 111).
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-P-15328	- Primer, Pretreatment (Formula No. 117 for Metals).
MIL-B-15395	- Brazing Alloys, Silver.
MIL-C-16173	- Corrosion Preventive Compound, Solvent Cutback, Cold-Application.
MIL-E-16366	- Electrical Clamps, Lug Terminals and Conductor Splices—Pressure Grip.
MIL-T-16784	- Terminal Boards.
MIL-W-16878	- Wire, Electrical, Insulated, High Temperature.
MIL-W-16878/1	- Wire, Electrical, Type B, 105°C., 600 Volts, (Insulated, High Temperature).
MIL-W-16878/2	- Wire, Electrical, Type C, 105°C., 1,000 Volts, (Insulated, High Temperature).
MIL-W-16878/3	- Wire, Electrical, Type D, 105°C., 3000 Volts, (Insulated, High Temperature).
MIL-W-16878/4	- Wire, Electrical, Type E, 200°C. and 260°C., 600 Volts, (Insulated, High Temperature).

MILITARY (Continued)

MIL-W-16878/5 - Wire, Electrical, Type EE, 200°C. and 260°C., 1000 Volts, (Insulated, High Temperature).
MIL-W-16878/9 - Wire, Electrical, Type FFW, 200°C., 1000 Volts, (Insulated, High Temperature).
MIL-W-16878/11 - Wire, Electrical, Type K, 200°C., 600 Volts, (Insulated, High Temperature).
MIL-W-16878/12 - Wire, Electrical, Type KK, 200°C., 1000 Volts, (Insulated, High Temperature).
MIL-I-16910 - Interference Measurement, Electromagnetic, Methods and Limits.
MIL-I-17166 - Iron Castings, Nodular Graphitic (Ductile Iron) (For Shipboard Applications).
MIL-I-17205 - Insulation Cloth and Tape, Electrical, Glass Fiber, Varnished.
MIL-I-18057 - Insulation Sleeving, Electrical, Flexible, Glass Fiber, Silicone Rubber Treated.
MIL-P-18177 - Plastic Sheet, Laminated, Thermosetting, Glass Fiber Base, Epoxy-Resin.
MIL-F-18240 - Fastener, Externally Threaded 250 Deg. F., Self-Locking Element for (ASG).
MIL-C-18312 - Capacitors, Fixed, Paper (Or Mylar) Dielectric, Metalized Dielectric Construction, Direct Current, Hermetically Sealed Metallic Case.
MIL-R-18546 - Resistors, Fixed, Wirewound (Power Type, Chassis Mounted) General Specification for.
MIL-I-19166 - Insulation Tape, Electrical, High-Temperature, Glass Fiber, Pressure-Sensitive.
MIL-S-19500 - Semiconductor Devises, General Specification for.
MIL-I-19526 - Insulation Sheets, Electrical, Pasted Mica, Silicone Bonded.
MIL-I-19632 - Insulation, Electrical, Dielectric Barrier, Laminated, Plastic Film and Rag Paper.
MIL-M-19833 - Plastic Molding Material and Plastic Molded Parts, Glass Fiber Filled, Diallyl Phthalate Resin.
MIL-I-19917 - Insulation Sheet, Electrical, Mica Paper, Silicone Bonded.
MIL-C-19978 - Capacitors, Fixed, Plastic (Or Paper-Plastic) Dielectric (Hermetically Sealed in Metallic, Ceramic, or Glass Cases), General Specification for.
MIL-M-20693 - Molding Plastic, Polyamide (Nylon), Rigid.
MIL-I-21070 - Insulation Sheet and Tape, Electrical, Reinforced Mica Paper.
MIL-M-21556 - Molding Plastic and Molded Plastic Parts, Asbestos-Fiber Filled, Arc- and Flame-Resistant Phenolic Resin.
MIL-I-21557 - Insulation Sleeving, Electrical, Flexible, Glass Fiber, Vinyl Treated.
MIL-I-22834 - Insulation, Electrical, Dielectric Barrier, Laminated, Plastic Film and Synthetic Fiber Mat.
MIL-I-24092 - Insulating Varnish, Electrical, Impregnating.
MIL-C-26655 - Capacitors, Fixed, Solid Electrolyte, Tantalum, General Specification for.
MIL-P-55110 - Printed Wiring Boards.
MIL-T-55164 - Terminal Boards, Molded, Barrier, Screw Type, and Associated Terminal Board Lugs, General Specification for.

STANDARDS

FEDERAL

FED-STD-406 - Plastics, Methods of Testing.
FED-STD-595 - Colors.

MILITARY

MIL-STD-10 - Surface Roughness Waviness and Lay.
MIL-STD-108 - Definitions of and Basic Requirements for Enclosures for Electric and Electronic Equipment.
MIL-STD-195 - Marking of Connections for Electric Assemblies.
MIL-STD-200 - Electron Tubes, Selection and Use of.
MIL-STD-242 - Electronic Equipment Parts Selected Standards.
MIL-STD-275 - Printed Wiring for Electronic Equipment.

MILITARY (Continued)

MIL-STD-278 - Welding and Allied Processes for Machinery for Ships of the United States Navy.
MIL-STD-701 - Preferred and Guidance Lists of Semiconductor Devices.
MIL-STD-761 - Electric Power, Alternating Current for Shipboard Use Characteristics and Utilization of.
MS 17828 - Nuts, Self Locking (Nylon Insert), Hexagon, Regular Height, 250 Deg. F, Nickel-Copper Alloy.
MS 17829 - Nuts, Self Locking (Nylon Insert), Hexagon, Regular Height, 250 Deg. F, Grade 8 Carbon Steel.
MS-17830 - Nuts, Self Locking (Plastic Insert) Hexagon, Regular Height, 250 Deg. F, FS303 Corrosion Resisting Steel.
MS 21208 - Insert, Screw Thread, Coarse and Fine, Free Running, Helical Coil, CRES.
MS 21209 - Insert, Screw Thread, Coarse and Fine, Screw Locking, Helical Coil, CRES.

PUBLICATIONS

BUREAU OF SHIPS

NAVSHIPS 344-0042 - Procedure for Electrodeposition of Chromium on Steel Shafting.

BUREAU OF NAVAL WEAPONS

OS 12531 - Procurement of Plastic Compound, Molding and Extruding, Polycarbonate Resin.

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other Publications. - The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

NATIONAL BUREAU OF STANDARDS

Handbook H28 - Screw Thread Standards for Federal Services.

(Application for copies should be addressed to the Superintendent of Documents, Government Printing Office, Washington 25, D.C.)

UNITED STATES TESTING COMPANY

Report of Test #83413.

(Application for copies should be addressed to Bureau of Ships, Code 634C, Washington 25, D.C.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

A153 - Zinc Coating (Hot-Dip) on Iron and Steel Hardware.
A164 - Electrodeposited Coatings of Zinc on Steel.
A166 - Electrodeposited Coatings of Nickel and Chromium on Steel.
B201 - Chromate Finishes on Electrodeposited Zinc, Hot-Dipped Galvanized, and Zinc Die-Cast Surfaces.
D1932 - Thermal Endurance of Flexible Electrical Insulating Varnishes.
D2132 - Dust-and-Fog-Tracking and Erosion Resistance of Electrical Insulating Materials.

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia 3, Pa.)

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 1 - General Principles upon Which Temperature Limits are Based in the Rating of Electric Equipment.
IEEE 57 - Test Procedure for Evaluation of the Thermal Stability of Enameled Wire in Air.
IEEE 117 - Test Procedure for Evaluation of Systems of Insulating Materials for Random-Wound Electric Machinery.

(Application for copies should be addressed to the Institute of Electrical and Electronics Engineers, Box A, Lenox Hill Station, New York, N.Y. 10021.)

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)
LP 1 - Industrial Laminates - Standards.

(Application for copies should be addressed to the National Electrical Manufacturers Association, 155 East 44th Street, New York 17, N.Y.)

(Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

3. REQUIREMENTS

3.1 Approval procedures. -

3.1.1 Procedures for drawings. - Contracts, orders or individual equipment specifications normally require that drawings showing equipment design and materials be submitted to the bureau concerned 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 specified modifications actually have been made.

3.1.1.1 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 to do so from the Government procuring activity at the earliest possible time. The procuring activity, if other than the cognizant bureau (Bureau of Ships or Bureau of Naval Weapons), may refer the matter to the cognizant bureau 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 3.1.1.2 shall also be furnished. The contractor shall proceed with changes which involve a departure from specifications only after written approval has been obtained.

3.1.1.2 Materials and methods requiring specific approval. - Because of continuing progress in the field of material development, the lack of specifications for certain materials and the limitations that some materials have for particular uses, this specification cannot completely cover all materials suitable for every application. Where this specification states that approval of a method or material by the bureau concerned is required, and the contractor considers it necessary or desirable to use such methods or materials, permission to do so must be specifically requested from the cognizant bureau (Bureau of Ships or Bureau of Naval Weapons). Manufacture shall not be commenced until approval has been obtained. Requests for approval shall include:

(a) Complete specification covering material proposed or details of method proposed.
(b) Details on proposed application (maximum temperature, and so forth, as pertinent).
(c) Advantages offered by use of proposed material or method.
(d) Extent of approval sought (i.e., 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 the cognizant bureau to consider future coverage by specification change. Requests for approval of materials in this category should be submitted if possible, prior to submission of drawings. If approval is granted, the equipment drawing shall identify the material and shall reference the bureau letter approving its use.

3.1.1.3 Non-preferred semiconductor devices (see 3.8.4). - Requests for approval of the use of non-preferred semiconductor devices shall be in accordance with the procedures of MIL-STD-701. If possible, such requests should be made and approval obtained prior to the normal drawing submission. Substantiation of the need for use of a circuit design which requires a non-preferred device is an important part of the justification which is to support the request for approval. The supporting data shall include a preliminary drawing or a sketch and circuit diagram which portrays the application of the proposed device and shall convey performance requirements of the device in the particular circuit.

3.1.1.4 Insulation suitability tests for class H, class N, class R and class S insulated equipment. - Bureau approval of the results of insulation suitability tests (see Appendix to this specification) for class H, class N, class R and class S insulation of individual equipment is required. Manufacturers should arrange to have their products tested prior to award of any contract or order for the equipments covered by this specification. Information pertaining to suitability testing may be obtained from the bureau concerned with the particular equipment.

3.1.2 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.

3.1.3 Clarification of discrepancies. - In any case of discrepancy or lack of clarity in this specification or in an 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.

3.2 Fundamental equipment characteristics. - The equipment shall be capable of performing its function with minimum maintenance throughout long periods of time under Naval service conditions. It shall be capable of performing reliably both upon demand following varying intervals of non-use and for long periods without unscheduled shut-down (exclusive of the starting and stopping that is inherent in intermittent and short-time duty cycles).

(a) 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 between any two circuits, between any circuit and a structural member, or between any circuit and ground may exist. 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. External moving parts which are a potential hazard to personnel shall be avoided wherever practicable. When their use is unavoidable, positive protection in the form of a guard shall be provided. Sharp corners and projections which may cause injury in a rough sea on on which clothing may catch shall be avoided. Equipment shall be designed to revert to its least hazardous condition or mode of operation upon failure of a circuit or part. Special performance capabilities (continuation of operation, automatic shut-down or any other specific function) in the event of an electrical part failure shall be as required by the equipment specification (see 6.2). The design shall be such that should failure occur, any resulting damage will be confined to the smallest equipment subdivision (minimum replaceable part or subassembly) within which failure occurred.

(b) Reliability and life. - Equipment shall be designed to operate reliably in accordance with applicable equipment specifications for a design life of 40,000 hours. Specific reliability requirements shall be as specified in the individual equipment specification (see 6.2).

(c) Compatibility. - Materials and parts used in the equipment shall be compatible with each other and with the environment for which they are intended. For example, silicone materials such as lubricants and insulation generally produce excessive brush wear in non-ventilated motors and generators; therefore, such materials shall not be used in combination in such equipment. Compatibility shall be considered from the standpoint of economy as well as from the chemical, physical and electrical aspect. For example, inexpensive short-life parts shall not be combined with expensive long-life parts in a non-repairable subassembly. If it is not practicable to make them individually replaceable, parts having similar reliability and life expectancies for conditions under which they are used shall be grouped together.

(d) Economy. - Equipment shall be designed for maximum overall economy taking into account procurement, operating, and maintenance costs for the specified life.

(e) Accessibility. - All parts which may require servicing, repair or replacement during the life of the equipment shall be readily accessible for repair or replacement. 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 shall be conveniently located on the front of the enclosure or on an operating panel appropriately oriented with respect to the operator's station. Non-operating controls shall be located behind access doors within the enclosure or in other accessible locations within the equipment. Adjustments such as for calibration, compensation, or alignment shall be located within the equipment and shall be readily accessible when the equipment is opened for servicing.

(f) Interchangeability. - All parts, subassemblies and assemblies which are removable shall be interchangeable with corresponding items from a similar equipment, from stock or from production without the necessity for re-forming (for example, drillings, bending, filing) or the use of undue force and without the necessity for individual selection of parts.

(g) Simplicity and ease of operation. - The equipment design shall be made as simple as feasible consistent with the functional and environmental requirements set forth herein and in the individual equipment specification. Where operating adjustments are provided and require rotary, lateral or vertical input motions, such operations as turning equipment "ON", starting a function, or advance or increase in the quantity (voltage, frequency, speed, for example) shall be accomplished by rotary input motions in a clockwise direction, lateral input motions to the right, or vertical motions upward. Examples of devices to which these principles shall be applied are rotary switches, toggle switches, potentiometers, rheostats, levers and thermostats. Pointers or indicators which register the inputs and response of the controlled variable shall respond in a like manner.

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 described in 3.1.1.1 shall be followed.

3.3 Materials. - The materials used in the construction of all parts of the electrical equipment shall be of a type, class, form and grade which is readily available from normal sources of supply without the necessity for additional treatment or processing other than that which is normal to, or readily supplied by, the industry. These are standard materials. Other, or special, materials may be used only when adequately justified taking into account both the technical and economical aspects and considering maintenance and support requirements as well as initial supply. Technical justification for the selection and use of special materials shall be supported by an explanation of why the function is necessary and why the conditions under which it must be performed are such that a special material is required. Copies of the complete specification covering any such special materials shall be furnished to the purchasing activity, the drawing approval activity and to the cognizant technical bureau. The equipment manufacturer shall ascertain compliance of all materials with minimum requirements and suitability of each material for its specific use in the equipment and for the service intended. Material requirements fall into three general catagories as follows:

(a) Specific materials. - Where a specific material and material specification is indicated, the material used shall conform to that specification. Materials purchased in accordance with manufacturers' specifications or specifications other than those indicated are acceptable only if it can be proven that such materials and quality assurance procedures do, in fact, conform with the minimum requirements of the referenced specification. Where a manufacturer's or other specification requirements exceed those of the referenced specification and the referenced specification material can be used for replacement purposes with equal results, the equipment drawing shall list the referenced material specification as being a suitable substitute for the material actually used. If the material in accordance with a manufacturer's or other specification exceeds the referenced specification requirements and the use of the better material is necessary in order to provide the specified performance and life of the equipment, the manufacturer's material specification and principal characteristics of the material indicated on equipment drawings. The bureau concerned should be advised of such instances so that a specification change may be considered.

(b) Materials requiring bureau approval. - Where bureau approval of a material is required, the equipment manufacturer shall submit data on the proposed material and the intended application. The approval procedures are described in 3.1.1.2.

(c) Material not specified. - Where a specific material is not specified or bureau approval is not required, the manufacturer may select any material that will satisfactorily perform the intended function in the equipment and will otherwise comply with specification requirements.

3.3.1 Prohibited materials. - Certain materials, described as follows shall not be used.

(a) Toxic materials.
(b) Flammable materials.
(c) Fragile materials.
(d) Mercury.
(e) Magnesium.

3.3.1.1 Toxic materials. - Materials which are capable of producing dangerous volumes of gases or other harmful effects under high temperature conditions, including fire, encountered in Naval shipboard service shall not be used. As a guide, the maximum concentrations of the toxic gases listed in table I should not be exceeded when the materials are subjected to the pyrolysis test as specified in U. S. Testing Company Report No. 83413.

Table I – Maximum concentration of toxic gases

Toxic gas	Maximum parts per million
Carbon dioxide	15,000
Carbon monoxide	1,500
Ammonia	2,500
Aldehydes as H·CHO	100
Cyanide as HCN	100
Oxides of nitrogen as NO_2	150
Hydrogen chloride	100
Sulphur dioxide	400
Hydrogen fluoride	250

The above pyrolysis test 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 winding such as magnet wire insulation, ground and layer insulation, varnish, tape and tying cord or similar materials used in the construction of such windings.

3.3.1.2 Flammable materials. - This includes 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 listed in table II.

Table II – Material resistance to burning

Material 1/	Test Method	Specification	Limit
Laminated plastics Molded plastics Encapsulating compounds	U.S. Testing Co. Report No. 83413		Ignition - 90 sec. min. Burning - 70 sec. max. Wt. Loss - 15% max. Ratio B/1%-83% max.
All other flammable materials except those used internally in varnished coil structures.	2021.1 or 2022	Fed. Test Method Std. 406	Self extinguishing to 1".

1/ See footnote at the top of the next page.

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

3.3.1.3 Fragile materials. - This includes any material which is fragile in the form, size, and manner in which it would be used. Brittle materials, in general, fall within this category from the standpoint of use as structural members. However, certain brittle materials may be used in small quantities within a part when the material 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, ebony asbestos, 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.

3.3.1.4 Mercury. - Mercury in any form shall not be used in shipboard equipment, including materials and parts thereof. Mercury shall not be used in manufacturing and test processes (including test equipment such as mercury thermometers) applying to the basic equipment but may be used in the manufacturing and test processes for materials and parts provided it is used in such a way that contamination of the materials and parts themselves cannot result.

3.3.1.5 Magnesium. - Magnesium or magnesium base alloys shall not be used in shipboard equipment.

3.3.1.6 Radioactive materials. - Radioactive materials shall not be used.

3.3.2 Metals. - Metals shall be selected or processed and applied in a manner that provides corrosion-resistance. Metals that are not inherently corrosion-resistant (see 3.3.2.3) shall be processed (treated, plated or painted) to provide corrosion-resistance (see 3.9.1).

3.3.2.1 Selection of metals in direct contact. - In order to minimize corrosion attack due to electrolytic action between dissimilar metals, in contact with each other, metal-to-metal contacts shall be limited to those metals which, when coupled, are designated by an open square, an open circle, an open delta, or an open delta with a cross bar in table III under the following conditions:

(a) For combinations of metals subject to immersion, splashing, or spray from seawater, condition S, E, or L, as applicable, in table III shall apply.
(b) For combinations of metals exposed to atmosphere but not subject to immersion, splashing, or spray from seawater, condition E in table III shall apply.

If a metal is coated or plated, the coating or plating metal rather than the base metal shall be considered. Metal-to-metal contact is considered to exist between parts that depend upon painting for corrosion-resistance.

3.3.2.1.1 Corrosion-resistant steel inserts integrally cast in aluminum are considered satisfactory.

Table III

SEA WATER CORROSION OF GALVANIC COUPLES

Legend

- □ The corrosion of the metal under consideration will be reduced considerably in the vicinity of the contact.
- ○ The corrosion of the metal under consideration will be reduced slightly.
- △ The galvanic effect will be slight with the direction uncertain.
- ⌂ The corrosion of the metal under consideration will be increased slightly.
- ▲ The corrosion of the metal under consideration will be increased moderately.
- ● The corrosion of the metal under consideration will be increased considerably.

- *S* Exposed area of the metal under consideration is small compared with the area of the metal with which it is coupled.
- *E* Exposed area of the metal under consideration is approximately equal to that of the metal with which it is coupled.
- *L* Exposed area of the metal under consideration is large compared to that of the metal with which it is coupled.

METAL CONSIDERED ↓ / IN CONTACT WITH →

Metal considered		Magnesium	Magnesium Alloys	Zinc	Galvanized Steel	Aluminum 52S	Aluminum 4S	Aluminum 3S	Aluminum 2S	Alclad	Aluminum 53S-T	Aluminum 61S-T	Cadmium	Aluminum A17S-T	Aluminum 17S-T	Aluminum 24S-T	Mild Steel
Magnesium	S	△	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	△	▲	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	L	△	⌂	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	●
Magnesium Alloys	S	○	△	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	○	△	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	L	○	△	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	●
Zinc	S	□	□	△	△	●	●	●	●	●	●	●	●	●	●	●	●
	E	□	□	△	△	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂
	L	○	○	△	△	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂
Galvanized Steel	S	□	□	△	△	●	●	●	●	●	●	●	●	●	●	●	●
	E	□	□	△	△	⌂	⌂	⌂	⌂	⌂	⌂	⌂	▲	⌂	⌂	⌂	⌂
	L	○	○	△	△	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂
Aluminum 52S	S	△	△	□	□	△	△	△	△	△	△	△	⌂	●	●	●	●
	E	●	●	□	□	△	△	△	△	△	△	△	△	▲	▲	▲	●
	L	⌂	⌂	○	○	△	△	△	△	△	△	△	△	⌂	⌂	⌂	▲
Aluminum 4S	S	△	△	□	□	△	△	△	△	△	△	△	⌂	●	●	●	●
	E	●	●	□	□	△	△	△	△	△	△	△	△	▲	▲	▲	●
	L	⌂	⌂	○	○	△	△	△	△	△	△	△	△	⌂	⌂	⌂	▲
Aluminum 3S	S	△	△	□	□	△	△	△	△	△	△	△	⌂	●	●	●	●
	E	●	●	□	□	△	△	△	△	△	△	△	△	▲	▲	▲	●
	L	⌂	⌂	○	○	△	△	△	△	△	△	△	△	⌂	⌂	⌂	▲
Alclad	S	△	△	□	□	△	△	△	△	△	△	△	⌂	●	●	●	●
	E	●	●	□	□	△	△	△	△	△	△	△	△	▲	▲	▲	●
	L	⌂	⌂	○	○	△	△	△	△	△	△	△	△	⌂	⌂	⌂	▲
Aluminum 2S	S	△	△	□	□	△	△	△	△	△	△	△	⌂	●	●	●	●
	E	●	●	□	□	△	△	△	△	△	△	△	△	▲	▲	▲	●
	L	⌂	⌂	○	○	△	△	△	△	△	△	△	△	⌂	⌂	⌂	▲
Aluminum 53S-T	S	△	△	□	□	△	△	△	△	△	△	△	⌂	●	●	●	●
	E	●	●	□	□	△	△	△	△	△	△	△	△	▲	▲	▲	●
	L	⌂	⌂	○	○	△	△	△	△	△	△	△	△	⌂	⌂	⌂	▲
Aluminum 61S-T	S	△	△	□	□	△	△	△	△	△	△	△	⌂	●	●	●	●
	E	●	●	□	□	△	△	△	△	△	△	△	△	▲	▲	▲	●
	L	⌂	⌂	○	○	△	△	△	△	△	△	△	△	⌂	⌂	⌂	▲
Cadmium	S	□	□	□	□	○	○	○	○	○	○	○	△	●	●	●	●
	E	□	□	□	□	△	△	△	△	△	△	△	△	⌂	⌂	⌂	⌂
	L	○	○	○	○	△	△	△	△	△	△	△	△	⌂	⌂	⌂	⌂
Aluminum A17S-T	S	○	○	□	□	□	□	□	□	□	□	□	□	△	⌂	⌂	●
	E	●	●	□	□	□	□	□	□	□	□	□	□	△	△	△	●
	L	△	△	○	○	○	○	○	○	○	○	○	○	△	△	△	▲
Aluminum 17S-T	S	○	○	□	□	□	□	□	□	□	□	□	□	□	△	⌂	●
	E	●	●	□	□	□	□	□	□	□	□	□	□	□	△	⌂	●
	L	△	△	○	○	○	○	○	○	○	○	○	○	○	△	△	▲
Aluminum 24S-T	S	○	○	□	□	□	□	□	□	□	□	□	□	□	□	△	●
	E	●	●	□	□	□	□	□	□	□	□	□	□	□	○	△	●
	L	△	△	○	○	○	○	○	○	○	○	○	○	○	○	△	▲

Metal considered		Wrought Iron	Low-Alloy Steels	Cast Iron	Low-Alloy Cast Irons	4-6% Chromium Steel	Ni Cast Iron	12-14% Chromium Steel	Lead-Tin Solder	16-18% Chromium Steel	Lead	Tin	Muntz Metal	Manganese Bronze	Naval Brass	Nickel	Yellow Brass
Magnesium	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	L	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Magnesium Alloys	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	L	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Zinc	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	⌂	⌂	⌂	⌂	⌂	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	L	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂
Galvanized Steel	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	⌂	⌂	⌂	⌂	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	L	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂
Aluminum 52S	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	▲	●	▲	●	●	●	●	●	●	●
	L	▲	▲	▲	▲	▲	▲	⌂	▲	⌂	▲	▲	▲	▲	▲	▲	▲
Aluminum 4S	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	▲	●	▲	●	●	●	●	●	●	●
	L	▲	▲	▲	▲	▲	▲	⌂	▲	⌂	▲	▲	▲	▲	▲	▲	▲
Aluminum 3S	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	▲	●	▲	●	●	●	●	●	●	●
	L	▲	▲	▲	▲	▲	▲	⌂	▲	⌂	▲	▲	▲	▲	▲	▲	▲
Alclad	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	▲	●	▲	●	●	●	●	●	●	●
	L	▲	▲	▲	▲	▲	▲	⌂	▲	⌂	▲	▲	▲	▲	▲	▲	▲
Aluminum 2S	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	▲	●	▲	●	●	●	●	●	●	●
	L	▲	▲	▲	▲	▲	▲	⌂	▲	⌂	▲	▲	▲	▲	▲	▲	▲
Aluminum 53S-T	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	▲	●	▲	●	●	●	●	●	●	●
	L	▲	▲	▲	▲	▲	▲	⌂	▲	⌂	▲	▲	▲	▲	▲	▲	▲
Aluminum 61S-T	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	▲	●	▲	●	●	●	●	●	●	●
	L	▲	▲	▲	▲	▲	▲	⌂	▲	⌂	▲	▲	▲	▲	▲	▲	▲
Cadmium	S	●	●	●	●	●	●	●	●	○	●	●	●	●	●	●	●
	E	⌂	⌂	⌂	⌂	⌂	⌂	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	L	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂
Aluminum A17S-T	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	L	▲	▲	▲	▲	▲	▲	⌂	▲	⌂	▲	▲	▲	▲	▲	▲	▲
Aluminum 17S-T	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	L	▲	▲	▲	▲	▲	▲	⌂	▲	⌂	▲	▲	▲	▲	▲	▲	▲
Aluminum 24S-T	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	L	▲	▲	▲	▲	▲	▲	⌂	▲	⌂	▲	▲	▲	▲	▲	▲	▲

Metal considered		Admiralty Brass	Aluminum Bronze	Red Brass	Copper	Silicon Bronze	Nickel Silver	70-30 Copper Nickel	Composition G Bronze	Composition M Bronze	Inconel	Silver Solder	70-30 Nickel Copper	25-30% Chromium Steel	Cr-Ni Stainless Steel	Cr-Ni-Mo Stainless Steel	Graphite
Magnesium	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	L	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Magnesium Alloys	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	L	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Zinc	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	L	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂
Galvanized Steel	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	L	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	▲
Aluminum 52S	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	●	●	●	▲	▲	●	▲	▲	▲	●
	L	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	⌂	⌂	⌂	▲
Aluminum 4S	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	●	●	●	▲	▲	●	▲	▲	▲	●
	L	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	⌂	⌂	⌂	▲
Aluminum 3S	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	●	●	●	▲	▲	●	▲	▲	▲	●
	L	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	⌂	⌂	⌂	▲
Alclad	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	●	●	●	▲	▲	●	▲	▲	▲	●
	L	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	⌂	⌂	⌂	▲
Aluminum 2S	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	●	●	●	▲	▲	●	▲	▲	▲	●
	L	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	⌂	⌂	⌂	▲
Aluminum 53S-T	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	●	●	●	▲	▲	●	▲	▲	▲	●
	L	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	⌂	⌂	⌂	▲
Aluminum 61S-T	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	●	●	●	▲	▲	●	▲	▲	▲	●
	L	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	⌂	⌂	⌂	▲
Cadmium	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	L	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂	⌂
Aluminum A17S-T	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	L	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	⌂	⌂	⌂	▲
Aluminum 17S-T	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	L	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	⌂	⌂	⌂	▲
Aluminum 24S-T	S	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	L	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	⌂	⌂	⌂	▲

Table III - (Cont'd.)

SEA WATER CORROSION OF GALVANIC COUPLES — Continued

Legend

□ The corrosion of the metal under consideration will be reduced considerably in the vicinity of the contact.
○ The corrosion of the metal under consideration will be reduced slightly.
△ The galvanic effect will be slight with the direction uncertain.
◬ The corrosion of the metal under consideration will be increased slightly.
▲ The corrosion of the metal under consideration will be increased moderately.
● The corrosion of the metal under consideration will be increased considerably.

S Exposed area of the metal under consideration is small compared with the area of the metal with which it is coupled.
E Exposed area of the metal under consideration is approximately equal to that of the metal with which it is coupled.
L Exposed area of the metal under consideration is large compared to that of the metal with which it is coupled.

METAL CONSIDERED ↓ / IN CONTACT WITH →		Magnesium	Magnesium Alloys	Zinc	Galvanized Steel	Aluminum 52S	Aluminum 4S	Aluminum 3S	Alclad	Aluminum 2S	Aluminum 53S-T	Aluminum 61S-T	Cadmium	Aluminum A17S-T	Aluminum 17S-T	Aluminum 24S-T	Mild Steel	Wrought Iron	Low-Alloy Steels	Cast Iron	Low-Alloy Cast Irons	4-6% Chromium Steel	Ni Cast Iron	12-14% Chromium Steel	Lead-Tin Solders	16-18% Chromium Steel	Lead	Tin	Muntz Metal	Manganese Bronze	Naval Brass	Nickel	Yellow Brass	Admiralty Brass	Aluminum Bronze	Red Brass	Copper	Silicon Bronze	Nickel Silver	70-30 Copper Nickel	Composition G Bronze	Composition M Bronze	Inconel	Silver Solder	70-30 Nickel Copper	25-30% Chromium Steel	Cr-Ni Stainless Steel	Cr-Ni-Mo Stainless Steel	Graphite
Mild Steel	S	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	△	▲	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	□	□	○	○	□	□	□	□	□	□	□	□	□	□	□	△	△	◬	◬	◬	◬	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	
Wrought Iron	S	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	△	△	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	□	□	○	○	□	□	□	□	□	□	□	□	□	□	□	△	△	◬	◬	◬	◬	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬
Low-Alloy Steels	S	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	△	□	△	▲	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	□	□	○	○	□	□	□	□	□	□	□	□	□	□	□	○	○	△	○	△	◬	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	○	△	△	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬
Cast Iron	S	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	△	△	●	△	●	▲	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	□	□	○	○	□	□	□	□	□	□	□	□	□	□	□	○	○	◬	△	◬	◬	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	◬	△	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬
Low-Alloy Cast Iron	S	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	△	□	△	▲	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	□	□	○	○	□	□	□	□	□	□	□	□	□	□	□	○	○	△	○	△	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	○	△	△	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬
4-6% Cr Steel	S	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	▲	□	▲	△	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	□	□	○	○	□	□	□	□	□	□	□	□	□	□	□	○	○	△	○	△	△	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	○	△	△	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬
Ni Cast Iron	S	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	△	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	□	□	○	○	□	□	□	□	□	□	□	□	□	□	□	○	○	○	○	○	○	△	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬
12-14% Chromium Steel	S	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	△	▲	●	▲	▲	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	○	△	◬	◬	◬	◬	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	●
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	●
Lead-Tin Solders	S	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	△	△	△	△	△	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	▲
16-18% Chromium Steel	S	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	◬	△	◬	△	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	○	○	△	△	△	△	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	●
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	△	△	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	●
25-30% Chromium Steel	S	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	△	□	△	△	□	□	□	□	●	●	●	●	●	●	●	●	●	●	●	●	●	△	□	△	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	△	□	△	△	○	○	○	○	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	△	○	△	●
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	○	△	△	○	○	○	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	●
Austenitic Cr-Ni Stainless Steel	S	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	△	□	△	△	□	□	□	□	●	●	●	●	●	●	●	●	●	●	●	●	●	△	△	●	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	△	□	△	△	○	○	○	○	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	△	◬	●
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	○	△	△	○	○	○	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	●
Austenitic Cr-Ni-Mo Stainless Steel	S	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	△	□	△	△	□	□	□	□	●	●	●	●	●	●	●	●	●	●	●	●	●	△	□	△	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	△	□	△	△	○	○	○	○	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	△	○	△	●
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	○	△	△	○	○	○	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	▲
Lead	S	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	◬	△	◬	△	△	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	[illegible]
	S	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	◬	△	◬	△	△	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	▲

Table III - (Cont'd.)

SEA WATER CORROSION OF GALVANIC COUPLES — *Continued*

Legend

- □ The corrosion of the metal under consideration will be reduced considerably in the vicinity of the contact.
- ○ The corrosion of the metal under consideration will be reduced slightly.
- △ The galvanic effect will be slight with the direction uncertain.
- ◬ The corrosion of the metal under consideration will be increased slightly.
- ▲ The corrosion of the metal under consideration will be increased moderately.
- ● The corrosion of the metal under consideration will be increased considerably.

- *S* Exposed area of the metal under consideration is small compared with the area of the metal with which it is coupled.
- *E* Exposed area of the metal under consideration is approximately equal to that of the metal with which it is coupled.
- *L* Exposed area of the metal under consideration is large compared to that of the metal with which it is coupled.

METAL CONSIDERED ↓ / IN CONTACT WITH →		Magnesium	Magnesium Alloy	Zinc	Galvanized Steel	Aluminum [illegible]	Aluminum [illegible]	Aluminum [illegible]	Alclad	Aluminum [illegible]	Aluminum [illegible]S-T	Aluminum [illegible]S-T	Cadmium	Aluminum A17S-T	Aluminum 17S-T	Aluminum 24S-T	Mild Steel	Wrought Iron	Low-Alloy Steels	Cast Iron	Low-Alloy Cast Irons	4-6% Chromium Steel	Ni Cast Iron	12-14% Chromium Steel	Lead-Tin Solders	16-18% Chromium Steel	Lead	Tin	Muntz Metal	Manganese Bronze	Naval Brass	Nickel	Yellow Brass	Admiralty Brass	Aluminum Bronze	Red Brass	Copper	Silicon Bronze	Nickel Silver	70-30 Copper-Nickel	Composition G Bronze	Composition M Bronze	Inconel	Silver Solder	70-30 Nickel Copper	25-30% Chromium Steel	Cr-Ni Stainless Steel	Cr-Ni-Mo Stainless Steel	Graphite
Muntz Metal	*S*	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	▲	▲	●	▲	▲	△	●	△	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	◬	◬	◬	◬	◬	△	◬	△	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	●
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	◬	△	△	△	△	△	◬	△	△	△	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬
Manganese Bronze	*S*	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	▲	▲	●	▲	▲	□	△	□	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	◬	◬	◬	◬	◬	○	△	○	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	●
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	△	△	△	△	△	△	◬	△	△	◬	◬	◬	◬	◬	◬	◬	◬	△	◬	◬	△	◬	◬	◬
Naval Brass	*S*	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	▲	▲	●	▲	▲	◬	●	△	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	◬	◬	◬	◬	◬	△	◬	△	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	△	◬	◬	◬	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	△	△	△	△	△	△	◬	△	△	△	△	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬
Nickel	*S*	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	◬	△	△	△	□	□	□	△	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	○	△	○	△	△	○	○	○	△	△	◬	△	◬	◬	◬	◬	◬	◬	◬	△	◬	△	◬	◬	◬	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	▲
Inconel (13% Cr, 6.5% Fe, Bal. Ni)	*S*	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	△	□	◬	◬	□	□	□	△	●	●	●	●	●	●	●	●	●	●	△	△	●	●	●	●	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	○	△	○	◬	△	○	○	○	△	△	◬	△	◬	◬	◬	◬	◬	◬	◬	△	△	◬	◬	◬	◬	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	▲
Yellow Brass	*S*	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	▲	▲	●	▲	▲	□	□	□	▲	△	●	●	●	●	●	●	●	●	●	●	◬	●	●	●	●	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	△	◬	◬	◬	◬	○	○	○	△	△	◬	◬	◬	◬	◬	◬	◬	◬	◬	△	△	◬	◬	◬	◬	●
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	△	△	△	○	○	△	△	△	△	△	△	△	△	△	◬	◬	△	△	△	◬	◬	◬	◬	◬
Admiralty Brass	*S*	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	▲	●	▲	▲	□	□	□	□	□	△	□	●	●	●	▲	●	●	●	□	◬	●	●	●	●	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	○	◬	◬	◬	◬	○	○	○	○	○	△	○	◬	◬	△	△	◬	◬	◬	○	△	◬	◬	◬	◬	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	△	△	○	○	○	△	△	△	○	△	△	△	△	△	△	△	△	△	◬	◬	◬	◬	△
Aluminum Bronze	*S*	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	▲	●	▲	▲	□	□	□	△	□	▲	△	●	●	●	▲	●	●	●	△	▲	●	●	●	●	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	○	△	◬	△	△	○	○	○	△	○	◬	△	◬	◬	◬	△	◬	◬	◬	△	△	◬	◬	◬	◬	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	△	△	○	○	○	△	○	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	◬
Red Brass	*S*	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	▲	▲	▲	▲	□	□	□	□	□	□	□	△	▲	▲	▲	●	▲	▲	□	▲	●	●	●	●	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	○	△	△	△	△	○	○	○	○	○	○	○	△	◬	△	△	◬	◬	◬	○	△	◬	◬	◬	◬	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	△	△	○	○	○	○	○	△	○	△	△	△	△	△	△	△	○	△	△	△	△	△	◬
Copper	*S*	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	▲	▲	▲	▲	□	□	□	□	□	□	□	□	△	△	△	●	△	△	□	◬	●	●	●	●	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	○	△	△	△	△	○	○	○	○	○	○	△	○	△	△	△	◬	△	△	○	△	◬	◬	◬	◬	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	△	△	○	○	○	○	○	○	○	○	△	△	△	△	△	△	○	△	△	△	△	△	◬
Silicon Bronze	*S*	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	▲	▲	▲	▲	□	□	□	□	□	△	□	△	△	△	△	●	△	△	□	◬	●	●	●	●	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	○	△	△	△	△	○	○	○	○	○	△	○	△	△	△	△	◬	△	△	○	△	◬	◬	◬	◬	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	△	△	○	○	○	○	○	○	○	○	△	△	△	△	△	△	○	△	△	△	△	△	◬
Nickel Silver	*S*	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	◬	□	◬	◬	□	□	□	□	□	△	△	△	△	△	△	▲	△	△	□	◬	●	●	●	●	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	○	△	○	△	△	○	○	○	○	○	△	△	△	△	△	△	◬	△	△	○	△	◬	◬	◬	◬	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	○	△	△	○	○	○	○	○	△	△	△	△	△	△	△	△	△	○	△	△	△	△	△	◬
70-30 Copper Nickel	*S*	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	◬	□	△	△	□	□	□	□	□	□	□	□	□	□	□	△	△	◬	□	△	□	●	●	●	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	○	△	○	△	△	○	○	○	○	○	○	○	○	○	○	○	△	△	△	○	△	◬	◬	◬	◬	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	○	△	△	○	○	○	○	○	○	○	○	○	○	○	△	△	△	○	△	△	△	△	△	◬
Composition G Bronze (88% Cu, 8% Sn, 10% Zn)	*S*	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	◬	□	△	△	□	□	□	□	□	□	□	□	△	△	△	△	△	△	□	△	●	●	●	●	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	○	△	△	△	△	○	○	○	○	○	○	○	○	△	△	△	△	△	△	○	△	◬	◬	◬	◬	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	△	△	○	○	○	○	○	○	○	○	△	△	△	△	△	△	○	△	△	△	△	△	▲
Composition M Bronze (88% Cu, 8% Sn, 6.5% Zn, 1.5% Pb)	*S*	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	◬	□	△	△	□	□	□	□	□	□	□	□	△	△	△	△	△	△	□	□	●	●	●	●	●
	E	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	○	△	△	△	△	○	○	○	○	○	○	○	○	△	△	△	△	△	△	○	○	◬	◬	◬	◬	▲
	L	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	△	△	○	○	○	○	○	○	○	○	△	△	△	△	△	△	○	○	△	△	△	△	[illegible]

Table III - (Cont'd.)

SEA WATER CORROSION OF GALVANIC COUPLES — *Continued*

Legend

- □ The corrosion of the metal under consideration will be reduced considerably in the vicinity of the contact.
- ○ The corrosion of the metal under consideration will be reduced slightly.
- △ The galvanic effect will be slight with the direction uncertain.
- ◬ The corrosion of the metal under consideration will be increased slightly.
- ▲ The corrosion of the metal under consideration will be increased moderately.
- ● The corrosion of the metal under consideration will be increased considerably.
- *S* Exposed area of the metal under consideration is small compared with the area of the metal with which it is coupled.
- *E* Exposed area of the metal under consideration is approximately equal to that of the metal with which it is coupled.
- *L* Exposed area of the metal under consideration is large compared to that of the metal with which it is coupled.

METAL CONSIDERED ↓ / IN CONTACT WITH →		Magnesium	Magnesium Alloys	Zinc	Galvanized Steel	Aluminum 52S	Aluminum 4S	Aluminum 2S	Alclad	Aluminum 3S	Aluminum 53S-T	Aluminum 61S-T	Cadmium
Silver Solder	S	□	□	□	□	□	□	□	□	□	□	□	□
	E	□	□	□	□	□	□	□	□	□	□	□	□
	L	○	○	○	○	○	○	○	○	○	○	○	○
70-30 Nickel-Copper	S	□	□	□	□	□	□	□	□	□	□	□	□
	E	□	□	□	□	□	□	□	□	□	□	□	□
	L	○	○	○	○	○	○	○	○	○	○	○	○

METAL CONSIDERED ↓ / IN CONTACT WITH →		Aluminum A17S-T	Aluminum 17S-T	Aluminum 24S-T	Mild Steel	Wrought Iron	Low-Alloy Steels	Cast Iron	Low-Alloy Cast Irons	4-6% Chromium Steel	Ni Cast Iron	12-14% Chromium Steel	Lead-Tin Solders
Silver Solder	S	□	□	□	□	□	□	□	□	□	□	□	□
	E	□	□	□	□	□	□	□	□	□	□	○	○
	L	○	○	○	○	○	○	○	○	○	○	△	△
70-30 Nickel-Copper	S	□	□	□	□	□	□	□	□	□	□	□	□
	E	□	□	□	□	□	□	□	□	□	□	○	○
	L	○	○	○	○	○	○	○	○	○	○	○	○

METAL CONSIDERED ↓ / IN CONTACT WITH →		16-18% Chromium Steel	Lead	Tin	Muntz Metal	Manganese Bronze	Naval Brass	Nickel	Yellow Brass	Admiralty Brass	Aluminum Bronze	Red Brass	Copper
Silver Solder	S	○	□	□	□	○	□	□	□	□	□	□	□
	E	○	○	○	○	○	○	△	○	○	○	○	○
	L	△	△	△	△	△	△	△	△	△	△	△	△
70-30 Nickel-Copper	S	□	□	□	□	□	□	□	□	□	□	□	□
	E	○	○	○	○	○	○	○	○	○	○	○	○
	L	○	○	○	○	○	○	○	○	○	○	○	○

METAL CONSIDERED ↓ / IN CONTACT WITH →		Silicon Bronze	Nickel Silver	70-30 Copper Nickel	Composition G Bronze	Composition M Bronze	Inconel	Silver Solder	70-30 Nickel Copper	25-30% Chromium Steel	Cr-Ni Stainless Steel	Cr-Ni-Mo Stainless Steel	Graphite
Silver Solder	S	□	□	△	△	△	△	△	◬	◬	◬	◬	●
	E	○	○	△	△	△	△	△	◬	◬	◬	◬	◬
	L	△	△	△	△	△	△	△	△	△	△	△	◬
70-30 Nickel-Copper	S	□	□	□	□	□	□	□	△	◬	◬	◬	●
	E	○	○	○	○	○	○	○	△	△	△	△	◬
	L	○	○	○	○	○	○	○	△	△	△	△	◬

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3.3.2.2 Malleable and nodular graphitic iron castings. - Malleable iron castings or nodular graphitic iron castings shall not be used unless specifically permitted by the equipment specification. When permitted, malleable iron castings shall be in accordance with QQ-I-666 and nodular graphitic iron castings in accordance with MIL-I-17166.

3.3.2.3 Corrosion-resisting metals. - The following commonly used metals when properly applied are considered to be inherently corrosion-resistant without further processing. These metals are suitable except where equipment specifications require use of specific corrosion-resisting metals for equipment subjected to severe environmental conditions.

(a) Brass
(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) Austenitic steels, AISI types 202, 302, 303, 304, 304L, 309, 310, 316, 316L, 321, 324A, 347

3.3.3 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 non-flammability and non-toxicity; however, these plastics need not meet the arcing and tracking resistance requirements. Unless otherwise specified in equipment specifications, the color of plastics shall be as follows:

(a) Plastics used as electrical insulation - see 3.5.1.2.2 and 3.5.1.3.3.
(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 except red.

3.4 General design requirements. -

3.4.1 Grounding. -

3.4.1.1 Electrical circuits. - Equipment (power consuming, generation, distribution and conversion equipment) shall be designed to operate satisfactorily on an ungrounded ship's power system. In the event of a single accidental ground or if high impedance circuits such as radio interference suppressors are connected to ground, the equipment shall operate satisfactorily. Furthermore, the equipment design shall be such that it does not impose a ground upon the electrical power system from which it is energized.

3.4.1.2 Exposed metal (or other conductive) parts. - Design and construction of the equipment shall be such that all exposed parts or panels of metal or other electrically conductive material are at ground (ship's hull) potential at all times. 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.

3.4.2 Input power variations (alternating current equipment). - Unless other input power variation requirements are included in the individual equipment specifications or contracts, alternating current equipment shall be capable of operating from type I power as defined in MIL-STD-761. The equipment shall be capable of delivering rated performance when operating under allowable power system input variations.

3.4.3 Surge voltage suppression. - Unless otherwise specified in the equipment specification or in the contract or order, it shall be assumed that peak surge voltages of 5 times the rms (root-mean-square) value of the nominal working voltage of the supply circuit to which the equipment will be connected will occur occasionally at the open power supply terminals and between any such terminal and ground. Equipment shall be capable of withstanding without damage to any part those peak surge voltages that result from similar conditions except with the equipment connected and operating. Equipment which employs circuits and parts in such way that this degree of protection is not inherently achieved shall provide protection by judicious 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 5 times nominal rms value specified above, the equipment shall be designed to withstand these higher surge voltage stresses. Voltage regulator diodes and controlled-avalanche types of rectifier diodes, insofar as each is permitted by 3.8.4, may be used in suitable circuit arrangements for surge voltage suppression. Also, either selenium type surge voltage suppressors or voltage-sensitive nonlinear resistors in accordance with commercial specifications may be used for this purpose under the conditions specified in 3.8.5.

3.4.4 Inclined operation. - Unless otherwise specified by equipment specifications, equipment shall be capable of inclined operation as follows:

(a) Surface ships. - Equipment shall operate satisfactorily when permanently inclined in any direction at any angle up to 15° from the normal operating position. Equipment shall be designed to function without damage or spilling of lubricant during temporary inclinations such as produced by ship's rolling of 45° in any direction from the normal operating position.
(b) Submarines. - Equipment shall operate satisfactorily when permanently inclined in any direction at any angle up to 30° from the normal operating position. Equipment shall be designed to function without damage or spilling of lubricant during temporary inclinations such as produced by ship's rolling of 60° in any direction from the normal operating position.

3.4.5 Ambient temperature. - Unless otherwise specified in the equipment specification, equipment shall be designed for operation in ambient temperatures up to 50°C.

3.4.6 Impact shock and vibration. - Impact shock and vibration requirements of individual equipment specifications shall apply (see 6.2).

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

(a) Equipment shall be designed for mounting with grade 2 bolts in accordance with MIL-B-857. Grade 2 bolts shall be used for mounting equipment for shock tests.
(b) Size of mounting bolt 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 shall be designed to use fitted (body-bound) bolts for mounting to the ship's structure only when so specified by the equipment specification.

3.4.8 Radio interference. - Equipment shall be designed to minimize generation of radio interference.

3.4.8.1 Limits and tests. - When specified (see 6.2), conformance with MIL-I-16910 for radiated interference only is required for equipment with any of the following characteristics:

(a) Having commutators, collector rings or vibrating contacts.
(b) Having other than metal enclosure without openings.
(c) Intended for installation in a location where interference with electronic equipment could occur (communications ship, wooden hull ships or above main deck).

3.4.8.1.1 Radio-interference free equipment. - The following types of equipment are considered inherently capable of meeting the radio interference requirements and tests are not required.

(a) Ammeter.
(b) Circuit breaker, manual.
(c) Controller, motor, manual.
(d) Cubicle, power.
(e) Enclosure.
(f) Incandescent lighting fixture.
(g) Meter, electric.
(h) Motor, induction, a.c.

(i) Panel, welding.
(j) Push button.
(k) Reactor, electric.
(l) Resistor, power, wirewound.
(m) Rheostat, manual.
(n) Starter, motor, manual.
(o) Switchboard, power.
(p) Transformer.
(q) Valve, solenoid.
(r) Voltmeter.

3.4.8.2 Radio interference suppression. - Radio interference filters or filter capacitors shall not be used unless permitted by the equipment specification or specifically approved by the bureau concerned. Where used, capacitors shall conform to MIL-C-25, MIL-C-11693 or MIL-C-12889.

3.4.9 Electrical shock hazard. - Equipment shall be designed to preclude shock hazard to the maximum practicable extent. All exposed conductive parts (connection boxes or enclosure doors, for example) shall be in good physical contact with or connected to the equipment frame.

3.4.9.1 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 for test purposes with equipment operating.

3.4.9.1.1 Portable equipment. - Leakage current shall not exceed 5 milliamperes. This limit applies even where radio interference suppression devices are permitted (see 3.4.8.2) and used.

3.4.9.1.2 Permanently installed equipment. - The leakage current of equipment intended for permanent installation (grounded frame) shall be limited to 5 milliamperes or less where practicable. If the leakage current exceeds 5 milliamperes, a warning plate reading: "DANGER - DO NOT ENERGIZE THIS EQUIPMENT UNLESS FRAME IS GROUNDED - OTHERWISE SHOCK HAZARD EXISTS" shall be mounted in a conspicuous location on the equipment. This plate may be omitted on equipment such as large motors and generators that because of their size cannot be removed from their installed (grounded) mounting position for maintenance, repair and test aboard ship.

3.4.9.2 Measurement of leakage current. - When specified by equipment specifications (see 6.2) leakage current tests shall be conducted. Measurement of leakage current shall be in accordance with 4.4.

3.4.10 Electrical creepage and clearance distances. - Creepage and clearance distances are defined as follows:

(a) Clearance distance is the shortest point to point distance in air between energized parts or between an energized part and ground.
(b) Creepage distance is the shortest distance between energized parts, or between an energized part and ground, along the surface of an insulating material. Cemented or butted joints do not add to the creepage path. Insulating barriers shall be used wherever practicable to interrupt continuous creepage paths.

The minimum creepage and clearance distances between electric circuits or between any electric circuit and ground specified in table IV shall be met. It is to be emphasized that the values shown in table IV represent the minimum acceptable limits for non-arcing rigid construction based on normal volt-ampere ratings and that they take into consideration only the average degree of enclosure and service exposure. Therefore, the designer should employ creepage and clearance distances in excess of these minimums where it is known that structural features, contaminants, lack of maintenance, environment, exposure or application overstress create service conditions more severe than normal.

3.4.10.1 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 3/4 inch. However, the values shown in table II 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 distance through a blow on or distortion of the enclosure.

Table IV - Electrical creepage and clearance distances

Voltage a.c. or d.c.	Set 1/	Clearance	Creepage	
			Open 2/	Enclosed 3/
		Inches	Inches	Inches
Up to 64	A	1/16	1/16	1/16
	B	1/16	1/8	1/8
	C	1/16	1/2	3/8
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	1	5	3
Over 3000-5000	C	3	5	4

1/ 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.

2/ Open. - Equipment or parts with open enclosures as defined in MIL-STD-108. 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.

3/ Enclosed. - Equipment or parts with enclosures defined in MIL-STD-108, except open enclosures.

3.4.11 Noise reduction for submarine equipment. -

3.4.11.1 General requirements. - The noise reduction shall be accomplished by proper design of the equipment and those parts which are inherently a source of airborne and structureborne noise. No exterior soundproof enclosures will be permitted. Sound isolating mounts may be used only where permitted by the equipment specification.

3.4.11.2 Rotating equipment. - For rotating equipment, 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 these 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 $\frac{10W}{N}$ ounce-inches of balance weights in increments of $\frac{W}{N}$ or less,

Where:
W = the weight of the rotor in pounds.
N = the maximum operating speed of rotation in revolutions per minute (r.p.m.).

(e) Angular locations shall be marked and numbered permanently at intervals of not more than 10 degrees on the balancing rings so as to 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. All angular dimensions shall be held within ±1 degree and all linear dimensions within ± 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.

3.4.12 Piping systems. - Piping systems shall have socket welded, butt welded, silver brazed or flanged fittings. Threaded pipe fittings shall not be used.

3.4.13 Threaded parts and fastening devices. -

3.4.13.1 Screw thread standards. - Screw threads for all threaded fastening devices shall conform to Handbook H28. The threads shall be the coarse-thread series, unified form, class 2A/2B or the American National form, class 2, except that the fine-thread series may be used where a definite advantage exists.

3.4.13.2 Fastening of parts. - Except for motors and generators, through bolting shall be used wherever practicable.

3.4.13.2.1 Fitted bolts. - The holes for fitted (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 RHR (roughness height rating) or smoother, in accordance with MIL-STD-10. Bolt to hole fit shall be as follows:

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

3.4.13.2.2 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 or bolts must be removed for routine equipment maintenance or where high stress in the screw or bolt is required for alignment of a vital part, metal inserts to take fastenings shall be cast or screwed into the aluminum or aluminum alloy. Inserts shall be cadmium plated 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.

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

3.4.13.2.4 Inserts. - Where metal inserts are required in aluminum alloys or plastics, bushing type inserts are recommended although helical-coil type inserts in accordance with MS 21208 and MS 21209 may be used. Use of the helical-coil type inserts shall be limited to those applications where bolting stress is primarily in shear and tension stress is negligible. 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.

3.4.13.2.5 Bolt and screw-projection. - All 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.

3.4.13.2.6 Bolt and screw thread engagement. - The length of the thread engagement shall be not less than the major diameter (nominal) of the thread. Where helical-coil type threaded inserts are used (see 3.4.13.2.4 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.

3.4.13.2.7 Thread locking. -

3.4.13.2.7.1 Electrical connections. - All nuts, bolts, studs and screws used for electrical connections shall be secured by lockwashers, except that lockwashers need not be provided with lug type terminals used on conductors less than 4000 cm. External-tooth flat lockwashers are recommended for electrical connections.

3.4.13.2.7.2 Mechanical assemblies. - All 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 could fall into the equipment, shall be secured by one of the following means:

(a) Lockwasher (see 3.4.13.3.2).
(b) Locknut (see 3.4.13.3.1).
(c) Castellated nut with cotter pin or safety wiring.
(d) Deforming screw or bolt thread projecting from nut or secured part. This method may be used only in cases where disassembly is never required for maintenance or repair.

3.4.13.3 Fastening devices. - Fastening devices (nuts, bolts, screws, lockwashers, flat washers, and so forth) shall be of corrosion-resisting material (see 3.3.2.3) or treated to resist corrosion without paint (see 3.9.1 table XVI). 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.

3.4.13.3.1 Nuts, bolts and machine screws. - Nuts, bolts and machine screws shall conform to the specifications listed below. Where lockwashers are used with screws and bolts, the lockwasher may be a separate piece or attached as part of an assembled fastener.

FF-S-85 - Slotted and Hexagon Head Cap Screws.
FF-S-86 - Socket Head Cap Screws.
FF-S-92 - Slotted and Cross-Recessed Machine Screws.
FF-S-200 - Hexagon Socket and Spline Socket Headless Setscrews.
FF-S-210 - Square Head and Slotted Headless Setscrews.
MIL-B-857 - Bolts, Nuts and Studs.
MS 17828 - Nuts, Self Locking (Nylon Insert), Hexagon, Regular Height, 250°F, Nickel-Copper Alloy.
MS 17829 - Nuts, Self Locking (Nylon Insert), Hexagon, Regular Height, 250°F, Grade 8 Carbon Steel.
MS 17830 - Nuts, Self Locking (Plastic Insert), Hexagon, Regular Height, 250°F, FS303 Corrosion Resistant Steel.

(MS 17828, MS 17829, MS 17830: Locknuts for use at temperatures not exceeding 180°F.)

Self locking screws in accordance with MIL-F-18240 are considered satisfactory for certain applications where removal for routine maintenance is not required. Use of self locking screws shall be specifically approved by the Bureau for each application.

3.4.13.3.2 Lockwashers. - Lockwashers shall be of the following types:

(a) Split ring (helical spring).
(b) External-tooth.
(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 lock washers shall be used instead of external-tooth lock washers only where necessitated by space limitations, appearance, or other special conditions. Where internal-tooth lock washers are used, the size of the washer and diameter of the bolt hold shall be such that the serrations make satisfactory contact.

3.4.14 Utilization of standard tools. - The design of the equipment shall be such that no special tools are required for adjustment and maintenance. Special tools are defined as those tools not listed in the Federal Supply Catalog, Department of Defense Section. (Copies of this catalog may be consulted in the office of the Government inspector.)

3.5 Electrical insulation. -

3.5.1 Plastics. -

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. This applies to low voltage (under 2000 volts) equipment. For equipment rated at 2000 volts or higher a minimum track resistance of 300 minutes shall be required. Arc resistance tests shall be conducted in accordance with Method 4011.2 of Federal Test Method Standard 406. Tracking resistance shall be determined in accordance with ASTM Method D2132.

3.5.1.2 Laminated plastics. - Laminated thermosetting plastics in the form of sheets, rods, tubes and special shapes (channels and similar items requiring bureau approval, see 3.3) are used in electrical equipment where a rigid material that has dielectric properties is needed. Laminates in the above forms can be readily machined or fabricated to meet most needs. In laminates considered for use in electrical power and lighting applications, the following three conditions must be met:

(a) The laminate shall be an approved type, listed below.
(b) The laminate shall meet the minimum requirements for toxicity (3.3.1.1), arc resistance (3.5.1.1), and flame resistance (3.3.1.2).
(c) The laminate shall meet the mechanical and electrical requirements of each application.

Glass base laminates provide the best all around combination of properties to suit shipboard conditions. Laminates shall be selected in accordance with table V. (These are approved fire and arc resistant types of low toxicity.)

Table V – Laminates

Laminate	Form	Type	Specification	Max.	Temp.	°C.
Glass melamine	sheet	GME	MIL-P-15037		130	
Glass silicone	sheet	GSG	MIL-P-997		200	
Glass melamine	rods, tubes	R, Tr	MIL-P-79		130	
Glass silicone	rolled tubes	G-7	NEMA LP-1		180	
Glass polyester 1/	sheet	GPO-3	NEMA LP-1		130	

1/ Polyester glass mat laminates of this type exhibit arc tracking resistance and are mandatory for use in high voltage electrical equipment rated at 2000 volts or higher.

3.5.1.2.1 Machined edges. - Glass base laminates need not be treated with lacquer as the moisture absorption of the cut edge or surface is usually no greater than the normal moisture absorption of the uncut surface.

3.5.1.2.2 Color. - All laminates shall be furnished in the natural color except laminates used in high voltage electrical equipment rated at 2000 volts or higher, in which case the color shall be red.

3.5.1.3 Molded plastics. -

3.5.1.3.1 Thermosetting plastics. - Molded thermosetting plastics are generally 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. In the molded part considered for use in electrical power and lighting applications the following three conditions must be met:

(a) The molding compound shall be an approved type, listed below.
(b) The molding compound shall meet the minimum requirements for toxicity (3.3.1.1), arc resistance (3.5.1.1), and flame resistance (3.3.1.2).
(c) The molding compound shall meet the mechanical and electrical requirements of each application. Usually, this means a high impact shock test and dielectric test on the assembled item of equipment. Glass fiber reinforced molding compounds provide the best all around combination of properties to suit shipboard conditions. Molding compounds shall be selected in accordance with table VI. These are approved fire and arc resistant types of low toxicity.

Table VI - Molding compounds (glass fiber reinforced)

Compound	Type	Specification	Max. temp. °C.
Alkyd glass	MAI-60	MIL-M-14	130
Alkyd glass	MAI-30	MIL-M-14	130
Melamine glass	MMI-30	MIL-M-14	130
Melamine glass	MMI-5	MIL-M-14	130
Phenolic asbestos 1/	MFA-30	MIL-M-21556	130
Polyester glass 2/	MAT-30	MIL-M-14	130
Diallyl phthalate	SDG-F	MIL-M-14	130
Diallyl phthalate	GDI-30F	MIL-P-19833	130
Silicone glass	MSG	MIL-M-14	200
Silicone glass	MSI-30	MIL-M-14	200

1/ Phenolic asbestos molded parts exhibit less abrasion on sliding contact surfaces than glass filled compounds.
2/ Polyester glass molding compounds of this type exhibit arc tracking resistance and are mandatory for use in high voltage electrical equipment rated at 2000 volts or higher.

3.5.1.3.2 Thermoplastics. - In general, thermoplastics shall not be used in any molded part unless allowed by the equipment specification. When the application is such that only a thermoplastic material can be used, then the molding compounds shall be selected in accordance with table VII.

Table VII - Molding compounds (thermoplastic material)

Compound	Type	Specification	Max. temp. °C.
Polyamide (nylon)	III, grade E	MIL-M-20693	105
Polycarbonate	-	OS-12531	105

3. 3.5.1.3.3 Color. - Thermosetting molding compounds for low voltage application shall be furnished in a gray color and an approximate match to number 26307 (semigloss) or 16307 (gloss) of FED-STD-595. Thermoplastic molding compounds shall be furnished clear or in any color unless a specific color is specified in the procurement document. The coloring matter shall not reduce the electrical properties below the specified values. Thermosetting molding compounds for high voltage application rated at 2000 volts or higher shall be furnished in a red color.

3.5.2 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. 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 and, except where noted, are in accordance with IEEE Standard No. 1:

3.5.2.1 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.

3.5.2.2 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.

3.5.2.3 Class 130. - 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 130°C.

3.5.2.4 Class 155. - 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 155°C.

3.5.2.5 Class 180. - Materials or combinations of materials such as silicone elastomer, mica, glass fiber, asbestos, 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.

3.5.2.6 Class 200 1/. - 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.

3.5.2.7 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.

3.5.2.8 Class 240 1/. - Materials or combinations of materials which by experience or accepted tests can be shown to have the required thermal life at 240°C.

3.5.2.9 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.

3.5.2.10 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.

3.5.3 Classes and definitions of insulation systems. - Experience has shown that the thermal life characteristics of composite insulation systems cannot be reliably inferred solely from information concerning component materials. To assure satisfactory service life, insulation specifications need to be supported by service experience or life tests. Accelerated life tests are being used increasingly to evaluate

1/ Adoption under consideration by IEEE.

the many new synthetic insulating materials that are available thus shortening the period of service experience required before they can be used with confidence. Tests on complete insulation systems, representative of each type of equipment, are necessary to confirm the performance of materials for their specific functions in the equipment. The electrical insulation of equipment is made up of many different components selected to withstand the widely different electrical, mechanical, and thermal stresses occurring in different parts of the structure. How long an insulation system will be serviceable depends on the effectiveness of the physical support for the insulation, and the severity of the forces acting on it, as well as on the materials themselves and the service environment. Therefore, the length of useful life of the insulation system will depend on the way that its individual components are arranged, the interactions upon each other, and the contribution of each component to the electrical and mechanical integrity of the system. An insulation system is an assembly of insulation materials in a particular type, and sometimes size, of equipment. In general, a specific piece of equipment has one insulation system but, for some types of equipment having two or more distinct sub-assemblies, it may be desirable to consider that there are a corresponding number of insulation systems. Most equipment specifications now classify the insulation in one or more insulating material classes and include appropriate limiting temperature rise standards (see 6.2) for equipment using each of these classes. Although the classification has nominally been by material classes, the wide divergence in both observable temperature and hottest-spot temperature between different types of equipment of the same material classes indicates that the real classification was by insulation systems. The class of insulation system used shall conform to the following definitions and shall be as specified in the individual equipment specification (see 6.2). Insulating materials used in one insulation system may be used in any other insulation system having a lower temperature rating:

3.5.3.1 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 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.

3.5.3.3 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.

3.5.3.4 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.)

3.5.3.4.1 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.

3.5.3.5 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 H classification (200°C) shall be redesignated as class N.)

3.5.3.5.1 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.

3.5.3.6 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.

3.5.3.6.1 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.

3.5.3.7 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.

3.5.3.7.1 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.

3.5.3.8 Class C insulation system. - A Class C insulation system is a system utilizing Class over 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.

3.5.4 Insulation system thermal endurance evaluation. - The following insulation system classes are considered to be service proven when constructed in accordance with the materials and methods described in this specification:

Class A insulation system using Class 105 materials.
Class B insulation systems using Class 130 materials.
Class H insulation systems using Class 180 and Class 200 materials.
Class N insulation systems using Class 200 materials.

All other insulation systems, until they are service proven for a reasonable life expectancy (40,000 Hours), shall be evaluated by accepted test procedures such as IEEE No. 117. In the absence of an accepted insulation system test procedure, procedures shall be as agreed upon by the contractor and the Bureau of Ships. New or modified insulation systems when tested by an accepted insulation system test procedure will be classified as to thermal endurance based on a comparison to a service proven insulation system under the same test conditions.

3.5.5 Magnet wire. - Magnet wire shall be selected in accordance with MIL-W-583 and as follows:

Wire	Limits of Application
Single film (E, T, B, L, H, K, M)	In circuits less than 50 volt-amperes
Multiple films (E2, T2, T3, T4, B2, etc)	Preferred for all applications.
Combination film and fibrous (BDg, etc.)	All fibrous coverings shall be furnished with film undercoat.

Wire	Limits of Application
Fibrous coverings GV versus Dg	Polyester fiber-glass fiber coverings (Dg) are preferred to glass fiber coverings (GV)
High temperature coverings (MDgGM, etc)	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 fibrous material content.
Square and rectangular	All designs shall be such as to allow rewinding by Naval activities using stock sizes listed in Table III. If wire sizes other than those listed in Table III are supplied in the equipment, data and instructions shall be furnished for rewinding with stock sizes.

Table VIII - Square and rectangular insulated magnet wire sizes available to Naval repair activities1/

Bare2/ Thickness, Mils	Bare Width Mils2/									
	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 MIL-W-583 apply.

3/ Available in types M2 and M4.

4/ Available in types M2, M4 and MDgGM.

3.5.6 Ground insulation. - Ground insulation, known also as barrier insulation, slot armor, basic insulation, wrapper or coil insulation shall conform to table IX.

Table IX - Ground insulation

Material	Specification	Type, class, grade	Maximum Temperature - °C.
Pasted mica splittings	HH-I-538	All types	as required 1/
Reinforced mica splittings	MIL-I-3505	Class B	130
Mica-paper composites	MIL-I-21070	Class H	200
Pasted mica (silicone binder)	MIL-I-19526	All types	200
Mica-paper (silicone binder)	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
Treated asbestos	MIL-I-3053	All types	130 2/
Polyester film 3/	MIL-I-631	Type G	120
Silicone rubber	–	4/	4/
Varnished glass cloth 5/	MIL-I-17205	Grade O	130
Epoxy-oriented glass filament	–	6/	6/
Polyamide paper	–	7/	7/

1/ The temperature class is determined by the binder used; suitable binders are available for 130°, 155° and 200° C use.

2/ Refined asbestos products with special treatments are available and have been found suitable for 180°C use. (Approval by cognizant bureau required (see 3.1.1.2).)

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

4/ Silicone rubber materials compounded for special coil applications have been found to be suitable for use at temperatures up to 220° C. (Approval by cognizant bureau required (see 3.1.1.2).)

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

6/ Non-woven continuous filament glass oriented and preimpregnated with epoxy resin for applications up to 180° C. (Approval by cognizant bureau required (see 3.1.1.2).)

7/ Polyamide paper suitably impregnated with high temperature varnish has been found suitable for temperatures up to 200° C. (Approval by cognizant bureau required (see 3.1.1.2).)

3.5.7 Core tubes and bobbins. - Core tubes and bobbins for mechanical support may be pressboard in accordance with JAN-I-545 or fishpaper or ragpaper in accordance with MIL-I-695. For dielectric purposes the above materials may be used only if supplemented with a ground insulator in accordance with 3.5.6. Laminated plastic types (3.5.1.2) or molded plastic types (3.5.1.3) may be used.

3.5.8 Toroid core boxes. - Core boxes for toroid windings may be aluminum with overwrappings of either pressure sensitive insulating tape (3.5.12) or coated with epoxy, as approved by the Bureau concerned (see 3.1.1.2), using the fluidized bed or spray process and oven cured.

3.5.9 Layer and phase insulation. - Cotton or glass thread interleaving may be used on layer wound magnet coils. Other types of layer or phase insulation shall be any of the types specified in 3.5.6, varnished cambric in accordance with MIL-I-3374 or varnished glass (grade O) in accordance with MIL-I-17205. Silicone varnished glass shall not be used for layer or phase insulation, if the wire size exceeds 22 AWG.

3.5.10 Spacers. - Spacer insulation such as slot spacers, coil separators, duct spacers, end plate insulation, supporting rings, interpole washers or any other flat or formed piece used primarily for mechanical separation as part of a coil or winding shall be selected in accordance with the table X.

Table X – Spacers

Item	Material	Type	Specification	Maximum Temperature °C.
Spacer (rigid - flat)	Glass melamine	GME	MIL-P-15037	130
	Glass silicone	GSG	MIL-P-997	200
	Pasted mica	All	HH-I-538	130-200 1/
	Asbestos-silicone	–	Commercial 2/	200
	Glass epoxy	GEE	MIL-P-18177	130
	Glass polyester	GPO-1	NEMA LP-1	130
Spacer (rigid - tube or formed shape)	Glass melamine	GMG, TR	MIL-P-79	130
	Glass silicone	G-7	NEMA LP-1	200
	Glass epoxy	–	Commercial 2/	130
	Glass polyester	–	Commercial 2/	130
Spacer (flexible)	Varnished cambric	I	MIL-I-3374	105
	Reinforced mica	All	MIL-I-3505	130-200 1/
	Varnished glass	O	MIL-I-17205	130
	Varnished asbestos	2RT, 4RT	MIL-I-3053	130

1/ Limiting temperature will depend on type of resin binder used.

2/ Bureau approval required for specific material.

3.5.11 Binding tape and cloth. - Binding tapes and strips (porous for later impregnation or filling) for mechanical purposes shall be cotton in accordance with MIL-T-638, MIL-I-3042, asbestos in accordance with MIL-I-3053, or glass in accordance with MIL-Y-1140. For class B 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.

3.5.12 Electrical tape. - Electrical tape shall conform to MIL-I-631. Electrical pressure sensitive tape shall conform to MIL-I-7798 or types AFT, GFT, EF or MFT of MIL-I-15126 or to MIL-I-19166.

3.5.13 Slot wedges (non-metallic). - Slot wedges shall be selected in accordance with table XI.

Table XI – Slot wedges (non-metallic)

Item	Material	Type	Specification	Maximum Temperature °C.
Slot wedge, flat	Glass melamine	GME	MIL-P-15037	130
	Glass silicone	GSG	MIL-P-997	200
	Glass epoxy	GEE	MIL-P-18177	130
	Glass polyester	GPO-1	NEMA LP-1	130

(Cont'd.)

Table XI - Slot wedges (non-metallic) (Continued)

Item	Material	Type	Specification	Maximum Temperature °C.
Slot wedge, formed	Glass polyester	–	Commercial 1/	130
	Glass epoxy	–	Commercial 1/	130
	Glass-asbestos-silicone	–	Commercial 1/	200
	Polyester film (see 3.5.6)	G	MIL-I-631	120
	Polyester mat-film 1/	–	MIL-I-22834	130
	Polyamide paper 1/	–	-------	200

1/ Bureau approval required for specific material.

3.5.14 Insulating panels. - Insulating panels shall be type GME in accordance with MIL-P-15037 or type GSG in accordance with MIL-P-997.

3.5.15 Sleeving. - Sleeving used, where no bending is required, shall be class A-A-1 (cotton) or class B-A-1 (glass) in accordance with MIL-I-3190. Sleeving used where bending is required shall be synthetic resin type A or F in accordance with MIL-I-631 or where total temperature does not exceed 80 C., acrylic glass, vinyl-glass B-A-1 in accordance with MIL-I-21557, or silicone rubber-glass in accordance with MIL-I-18057.

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

3.5.17 Band insulation. - Insulation under banding wire shall be pasted mica type PMF in accordance with HH-I-538 or mica-glass composites in accordance with MIL-I-3505, or laminated plastic material with varnished glass cloth underlayment. Varnished asbestos may be used over the mica for cushion purposes.

3.5.18 Lacing and tying cords for varnished coils and windings. - Lacing and tying cords shall be cotton cable laid armature twine for class A; neoprene treated glass cord, form 2, class C in accordance with MIL-Y-1140 for class B and silicone treated glass cord for class H. Silicone or polytetrafluoroethylene treated flat glass sleeving may be used.

3.5.19 Armature and coil banding using glass. - Fibrous glass strands or roving treated with "B" stage (semi-cured) resins may be used for banding purposes in lieu of steel banding. The materials and method of application shall receive bureau approval before use.

3.6 Insulating 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 3.5.6. Fish paper, rag paper, pressboard and similar materials do not in themselves provide sufficient dielectric barrier action even when varnish treated so their use shall be restricted to mechanical protection only (up to 1/3 total thickness).

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 affected by normal handling during replacement in cramped locations. Ground insulation subject to mechanical puncture or tearing shall be protected by an overwrap.

3.6.3 Special requirements for Class B or higher temperature windings. - Materials such as adhesive tape, glue, friction tape, cotton tying cord and tape, paraffin wax and paper, which are commonly employed by conventional windings, shall not be used. These materials degrade during the high temperature bakes or later during operation. This results in gassing which renders the insulation porous and susceptible to moisture attack.

3.6.4 Treating methods. - Most classes of electrical insulation require the use of varnish or other impregnating compounds to make them satisfactory for service conditions. Withoug 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 for insulating 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) preferred methods.
(d) Dipping)
(e) Brushing or spraying (see 3.6.4.5).
(f) Encapsulating - best moisture protection.

3.6.4.1 Built-up. - By this method varnish or compound shall be applied by brush between turns as the coil is wound. The varnish shall be heavy and viscous for complete filling of all the interstices. This method shall be used for deep section coils where other methods cannot insure complete filling of the voids.

3.6.4.2 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 the conductors together. Upon curing this insures a rigid straight section of the coil and facilitates the application of the ground insulation. Usually this operation is performed only on armature and stator coils.

3.6.4.3 Vacuum-pressure. - By this method varnish shall be applied to a completely or partially "treated" coil by means of a vacuum-pressure impregnation cycle. This is commonly called "impregnation." 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. The use of the word "treated" herein means previous varnish treatment or use of precoated materials such as varnished glass. The pressure may be eliminated if the vacuum is 24 inches of mercury or more.

3.6.4.4 Dipping. - By this method varnish shall be applied to the individual winding or coil or to the completed stator or armature by immersion. The main 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. For large windings where immersion of the complete stator is not practical, the hosing or flooding method may be used. By this method the winding shall be rotated in a shallow pan or tank and the varnish allowed to saturate the winding, or the varnish may be hosed or flooded over the winding and allowed to drain into a tank.

3.6.4.5 Brushing or spraying. - By this method varnish shall be applied to the finished coil or stator winding by brushing or spraying. This method may be used only on compounded mica insulated windings.

3.6.4.6 Encapsulating. - By this method varnish or compound shall be applied to the wound coil or structure by vacuum-pressure, hot-pour, or casting using molds or dikes or by buttering. For maximum environmental protection this method shall be used.

3.6.5 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, compound or encapsulant 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.

3.6.5.1 Varnish. - Varnish shall be selected in accordance with table XII.

Table XII - Varnish

Application	Class	Specification	Maximum Temperature °C.
Stationary windings and Low speed rotating windings 1/	105	MIL-T-24092	105
	130		130
	155		155
	180		180
	200		200
	220		220
High speed rotating windings 1/	---	Commercial 2/	130 3/

1/ Low speed windings are defined as 1800 rpm or less and not more than 24 inches in diameter. Windings with either a rotational speed greater than 1800 rpm or a diameter greater than 24 inches are defined as high speed windings.

2/ The varnish must be evaluated for bond strength and receive Bureau approval before use. Bond strength tests may be made using the helical coil method using aluminum wire coils or by any other method (spin test, and so forth) to demonstrate bond strength at operating temperatures.

3/ For use in class F and higher temperature applications, the varnish must be thermally evaluated and receive Bureau approval before use. Thermal screening tests shall be made in accordance with the procedures of ASTM D1932. Thermal rating tests shall be made in accordance with the procedure of IEEE 57 as modified by thermal stability requirements for preproduction inspection of MIL-W-583. The magnet wire shall be of the same class (temperature) as the varnish being evaluated. The thermal rating shall be based on a 40,000 hour extrapolated life.

3.6.5.2 Encapsulants and compounds. - Encapsulants, winding compounds (paste-like materials 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. Typical of these materials are the polyester and epoxy resins. All encapsulants, winding compounds and similar materials shall be approved by the bureau concerned in regard to the material and procedure of application.

3.6.6 Treatment. - All fabricating operations, such as welding, machining, drilling and tapping, shall be completed prior to varnish treating. The windings and coils shall be clean and dry. The drying shall be accomplished by prebaking the windings so as to remove all moisture and to cure any uncured winding parts. The windings or coils shall then be allowed to cool to a temperature not below 10°C. above room temperature, then immersed in the varnish until bubbling ceases, allowed to drain, and then baked at the temperature and for the time specified by the varnish supplier. A maximum of three dips and bakes shall be used. If the vacuum-pressure treating process is used a minimum of one treatment shall be used and shall be followed by one dip and bake. If compounded mica insulation is used as armature coil insulation, a minimum of four spraying, brushing, immersion or flooding treatments with a grade CA (clear air-drying) varnish in accordance with a clear air-dry varnish as approved by the Bureau. The compounded coils shall receive at least two varnish treatments by immersion before assembly and the assembled winding shall receive at least two treatments by any of the above methods. Encapsulated windings shall be prepared in a manner satisfactory to the bureau concerned.

3.6.6.1 Baking ovens. - The baking ovens shall be rated at 350°F. for class A, B and F windings and 500°F. for higher temperature windings and shall be of sufficient capacity to maintain these temperatures at a full exhaust rate of two air changes per minute.

3.6.6.2 Baking time specified. - Baking time for curing varnished windings shall be specified on the basis of time after the winding has reached the specified temperature; therefore, all baking times specified herein do not include the heat-up for the particular winding being baked.

3.6.6.3 Typical treating schedule. - The following treating schedule may be used as a guide in processing electrical windings. The baking time and temperature may vary depending on the type and grade of varnish used and the size of the winding being processed:

Armature coils, armatures, stators and field coils

	Class A, Class B and Class F systems	Class H and higher temperature systems
Step 1: Prebaking	Put into oven at 110°C. (230°F.). Hold at temperature for 4 hours Cool to approximately 50°C. (122°F.).	Put into oven at 150°C. (302°F.). Raise temperature 50°C. (90°F.) per hour to a maximum of 200°C. (392°F.). Hold at temperature for 4 hours. Cool to approximately 50°C. (122°F.).
Step 2: Dipping	Immerse coils or wound apparatus in 40°C. (104°F.) in varnish until bubbling ceases. Viscosity shall be held between 150 to 250 centipoises. Thin Class A, Class B varnish with mineral spirits to maintain viscosity. Use xylene for Class F varnish.	Immerse coils or wound apparatus in varnish for not over 5 minutes. Varnish types or grades shall not be mixed. Viscosity shall be held between 125 to 225 centipoises. Thin with xylene to maintain viscosity.
Step 3: Draining	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 to prevent pocketing the varnish.
Step 4: Wiping	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.	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.
Step 5: Baking	Bake in a circulating type, forced exhaust, baking oven at temperature of 150°C. (302°F.) for 6 to 8 hours.	Put into a circulating type, forced exhaust, baking oven at temperature of 200°C. (392°F.) for 2 hours.
Step 6: Cooling	Remove from oven and cool to approximately 50°C. (122°F).	Remove from oven and cool to approximately 50°C. (122°F.).
Step 7: Second treatment (dip in opposite direction).	Repeat steps 2 (immerse for 1 minute), 3, 4, 5, and 6.	Repeat steps 2 (immerse for 1 minute), 3, 4, 5 and 6.
Step 8: Third treatment (dip in original direction).	Repeat steps 2 (immerse for 1 minute), 3, 5, and 6.	Repeat steps 2 (immerse for 1 minute), 3, 5 (baking additional 8 hours at 230°C. (446°F.)) and 6.

3.6.7 Final condition. - The treated windings and coils shall be clean, smooth and glossy with good bonding and filling. There should be no bubbles, air pockets, voids or dry spots on the surfaces. Soft and sticky windings shall be rejected.

3.6.8 Warning. - Some materials produce side effects under certain conditions of application which may defeat the original purpose for which the materials were selected. An example of this is the enclosed recirculating-air dc motors and generators where silicone insulation is used. The silicone vapor evolved during operating conditions causes excessive brush wear and premature failure of the machine. Therefore, silicone materials are prohibited in non-ventilated rotating equipment using brushes. Another example of this is in sealed windings or systems where moisture evolved during thermal degradation of organic insulation may cause hydrolysis of the magnet wire insulation of other components and premature failure of the equipment. The necessary precautions should be taken in the selection of insulating materials to see that the materials are compatible in themselves as well as with the proposed application conditions.

3.7 Wire, wiring methods and marking. - (See 3.5.5 for magnet wire).

3.7.1 Wire. -

3.7.1.1 Lead wire. - Lead wire shall be flexible stranded type of not less than number 18 American Wire Gauge (AWG) and selected according to table XIII.

Table XIII – Lead wire

Insulation	Type	Specification	Max. Temp. °C.
Neoprene	–	Commercial	90
Irrad. polyethylene	–	Commercial	105
Tetrafluoroethylene	EE	MIL-W-16878/5	260
Silicone rubber	FFW	MIL-W-16878/9	200
Fluor. ethylene propylene	KK	MIL-W-16878/12	200

3.7.1.2 Hook-up wire. - Hook-up wire shall be selected from the table XIV.

Table XIV - Hook-up wire

Insulation	Type	Specification	Max. Temp. °C.
Polyvinyl chloride	B, C or D	MIL-W-16878/1, /2, and /3	105
Tetrafluoroethylene	E, EE	MIL-W-16878/4 and /5	260
Silicone rubber	FFW	MIL-W-16878/9	200
Fluor. ethylene propylene	K, KK	MIL-W-16878/11 and /12	200

3.7.2 Wiring methods. -

3.7.2.1 Harnessing. - All wiring shall be neatly formed into groups which shall be laced, 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 or at terminal blocks. Wire groups running from hinged panels shall be formed and clamped so that sharp bends do not occur with the panel in either the open or closed position and if more than 3 wires are contained in the group, a terminal block mounted on the hinged panel shall be used for connections.

3.7.2.1.1 Harnessing materials. - Nonflammable cord, tape or sleeving shall be used as lacing and tying materials. Ties or clamps of nonflammable material may be used. Metal ties or clamps, if used, shall be covered with nonflammable insulating material.

3.7.2.2 Slack. - Sufficient slack shall be provided so as not to impair movement or put undue stresses on the wire or components in those places where movement of components may be expected. Slack shall also be provided to prevent undue stress on terminal connections due to shock or vibration. Where wire terminals are used, 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.

3.7.2.3 Mechanical supports. - All electrical connections shall be designed and provided with supports so as to prevent breakage and minimize changes in performance due to vibration, inclination or shock.

3.7.2.4 External cable connections. - Provision shall be made for connection of external cables to terminal boards located within the equipment near the cable entrance except where equipment specifications permit or specify some other method (examples: direct connection to parts, connection using wire nuts or multi-pin plug connectors in accordance with MIL-C-5015) or where some other method is specifically approved by the bureau concerned. All terminal boards for external connections shall be accessible from the front of the enclosure. Circuitous routing of wire shall be avoided.

3.7.2.5 Insulation protection. - Wherever wires are run through holes in metal partitions, the holes shall be equipped with grommets for mechanical protection of insulation. Care shall be exercised in the running of wires to insure that they are not carried over or bent around any sharp corner or edge.

3.7.2.6 Stud terminals. - Stud terminals of potted parts shall be so designed and fastened to the insulating strip or plate (or the enclosure itself if this conforms to insulation requirements) as not to cause any degradation in the moisture excluding property of the enclosure by the normal soldering and resoldering of external leads to the stud terminals.

3.7.2.7 Wire end connectors and terminals. - The ends of each wire (except for wires requiring solder connection 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 wire around a part terminal and retaining the wire loop in a cup or crimped washer. If a wire loop is used, strands of the wire shall be secured together by soldering. No more than 3 connections shall be made to each terminal. Multi-pin plug connectors in accordance with MIL-C-5015 may be used where approved by the bureau concerned.

3.7.2.8 Soldering connections. - All soldering studs, lugs and terminals shall be notched or otherwise provided with means for mechanically securing the wire or lead prior to the application of solder. All solder terminations shall be completely coated with tin or silver. All solder type studs and terminals shall be sturdily designed and shall be constructed of materials which will render them suitable for repeated soldering and unsoldering operations without breaking or loosening. All solder type studs shall be mounted in such manner as to preclude their loosening or rotation due to soldering operations or from strains due to attached wires or leads. No more than three wires, including wires from parts, shall terminate at any one terminal.

3.7.2.9 Printed wiring. - Printed wiring shall not be used unless specifically permitted by the individual equipment specification or approved by the bureau concerned. When permitted, printed wiring boards shall be designed and constructed in accordance with MIL-STD-275 and MIL-P-55110 except that only glass base laminates in accordance with MIL-P-13949 shall be used. The temperature cycling, continuity and bond strength tests of MIL-P-55110 are not required for printed wiring boards for which all connections are of the following types of MIL-STD-275.

Type I - Clinched jumper wire.
Type A - Eyelets with clinched leads.
Type C - Standoff terminals.

Conductor spacings in accordance with Grade A of MIL-STD-275 are acceptable for printed wiring. Printed wiring boards shall be designed to permit replacement of all parts without special tools or techniques.

3.7.3 Wire identification. - Wires grouped together in harnesses or single wires more than 12 inches in length shall be marked for identification. Marking may be accomplished by stamping the identification symbol directly on the wire insulation if the insulation is a type suitable for this purpose, by sleeve type wire markers over the wire insulation 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.

3.7.3.1 Wire markers. - Wire markers shall be of the tubular sleeve, coiled sleeve or heat shrinkable sleeve types made of polyvinyl chloride, polyethylene, or other insulating material and compatible with the wire insulation. Markers shall stay in place, preferably by means of a snug fit. Where markers will not stay in place, even though they fit snugly, cement may be used. Adhesive strip type markers designed for wrapping around wires shall not be used.

3.7.3.2 Standard marking for connections. - Identification marking shall be in accordance with MIL-STD-195.

3.8 Parts. - Parts shall conform with the specifications indicated and insofar as practicable, the standard sizes and ratings listed in MIL-STD-242 shall be used. Parts shall be selected and applied in a manner to meet the requirements specified herein and those of the equipment specification. Where the design requirements for the equipment exceed those of the referenced parts specification (longer life, higher ambient temperature, more severe impact shock, etc.), parts shall be derated or applied so as to satisfy the equipment requirements. Parts shall be individually replaceable unless otherwise permitted by the equipment specifications or approved by the bureau concerned.

3.8.1 Fuses. - Fuses shall be in accordance with MIL-F-15160. Fuse ferrules and blades shall be silver plated.

3.8.2 Resistors and rheostats. - Rheostats, variable resistors and fixed resistors shall conform with MIL-R-15109 if the rating is above 50 watts. For ratings of 50 watts or less, rheostats and variable resistors used for adjustments during equipment operation shall conform to MIL-R-15109, Form EW or MIL-R-22. Other rheostats and resistors with ratings of 1/2 to 50 watts shall conform to MIL-R-11, MIL-R-19, MIL-R-22, MIL-R-26, MIL-R-93, MIL-R-94, MIL-R-15109 or MIL-R-18546. Power dissipation in resistors and rheostats shall not exceed 50 percent of the rated value after ambient temperature derating factors have been applied in accordance with the part specification or MIL-STD-242, as applicable, except that in the case of resistors and rheostats which operate on a short-time or intermittent basis, these power dissipation limitations may be applied to the higher power ratings that would result in equivalent overall life expectancy.

3.8.3 Capacitors. - Capacitors shall be applied in accordance with the guidelines of MIL-STD-242 as modified by those limitations and restrictions listed herein. For radio interference supression capacitors, see 3.4.8.2.

3.8.3.1 Selection of capacitors. Capacitors shall be selected in accordance with table XV. Selection shall be made from the first group listed below in which the characteristics (rating, size and so forth) of that type are consistent with the requirements of intended application. Groups are listed in order of preference. Group I shall be used where practicable; otherwise select from the succeeding groups in order.

Table XV - Capacitors

Group	Specification	Type
Group I	MIL-C-11015 MIL-C-25 1/ MIL-C-18312 1/ MIL-C-19978 1/	Ceramic Paper Metalized dielectric, paper or nylon Plastic dielectric
Group II	MIL-C-3965 MIL-C-26655	Tantalum, nonsolid electrolytic Tantalum, solid electrolytic
Group III	MIL-C-62 1/	Dry, electrolytic, aluminum
Group IV	Other types as listed in MIL-STD-242	

1/ For dc applications, the sum of the highest dc voltage level plus the peak ac amplitude voltage (including normal and recurring transients) shall not exceed 70 percent of the working voltage rating of the capacitor. The working voltage rating of the capacitor shall not be exceeded in case of voltage transient imposed by extreme or abnormal conditions. The 70 percent rerating factor shall be in addition to voltage derating with temperature as required by the capacitor specification. The 70 percent rerating for dc applications shall be reduced to 60 percent for 60 cycle ac applications and to 50 percent for 400 cycle ac applications.

(Footnotes continued on next page)

Footnotes for table XV cont'd.

[2] Use polarized capacitors in dc circuits only. Do not derate in voltage (from ratings available select one as near to but not less than the maximum voltage to be imposed on the capacitor by the conditions of application). Select capacitors of the plug-in type and mount them with a retaining device. Dry aluminum electrolytic capacitors shall be used only under the following circumstances:

(a) Voltage or capacitance requirements exceed the ratings of tantalum types.
(b) Idle storage or shelf life does not exceed four years.
(c) Ambient temperature is above -40°C.

3.8.4 Semiconductor devices. - Semiconductor rectifiers, voltage reference diodes, voltage regulator diodes, controlled rectifiers, and transistors shall be chosen and applied in accordance with MIL-STD-701, MIL-S-19500, the applicable device detail specification, and 3.8.4.2. Devices other than those listed in MIL-STD-701 shall be used only where specifically approved in writing by the bureau concerned on the basis of justification submitted in accordance with requirements of MIL-STD-701. Any such device shall comply with an existing military specification (device detail specification); or, if none exists, the requirements of 3.8.4.1 shall apply.

3.8.4.1 Semiconductor device special specifications. - If approval is sought, in accordance with 3.8.4, for a device for which there is no existing detail specification issued under MIL-S-19500 or MIL-E-1, or in other acceptable form, a special detail specification shall be submitted by the contractor with the request for approval. The special specification shall, insofar as practicable, use the detail specification for the MIL-S-19500 device of comparable construction which is closest in size to the device for which approval is sought. The MIL-S-19500 detail specification so used is referred to herein as the guide specification. Insofar as they are appropriate, requirements of the guide specification shall be invoked by the special specification, and the device manufacturer's latest published commercial specification rating and characteristic values shall be substituted for any inapplicable values in the guide specification to form the new special specification. The changes in, and additions to, the guide specification as set forth in the special specification shall be in sufficient detail and completeness to enable direct Government procurement of completely acceptable devices from any device manufacturer who has the production capability and willingness to comply with the special specification. The special specification shall be assigned a drawing number and when approved, shall form a part of the set of drawings covering the equipment.

3.8.4.2 Device ratings and application stresses. - Semiconductor device ratings are based on the absolute system (see MIL-S-19500 Appendix A) and shall not be exceeded under any service or test condition. Further, no two of the rated values (e.g., voltage and current) shall be imposed at the same time even under extreme or abnormal conditions. Semiconductor devices shall be chosen and applied in such a way that the worst stress of each type imposed on the device under any conditions of operation and test of the equipment with any available setting of adjustable circuit components does not exceed its rated value for that stress factor as specified by the applicable device specification. This shall include stresses under surge or transient conditions that may result from operation of protective devices, clearing of grounds, shorts or other faults on the power system, clearing of failed parts or circuit elements within the equipment, switching transients on the power supply system, in load circuits or within the equipment, and such other occurrences as are reasonable to expect on an electric power system aboard a Navy ship. Included are switching and transfer functions which may occur subsequent to the operation of circuit protective devices (for example, the disconnection of input power to a rectifier type power supply with no output load connected after a fuse has blown disconnecting the output filter capacitor).

3.8.5 Surge voltage suppressors. - Surge voltage suppressors shall be of the selenium type, the voltage-sensitive nonlinear resistance type, or another type specifically authorized and approved in writing for the particular application. (Other kinds of devices such as voltage regulator diodes, controlled-avalanche rectifier diodes and capacitors may be used to fnuction as suppressors but requirements applicable to these are contained eslewhere in this specification.) Surge voltage suppressors of the types identified above may be used when selected and applied in accordance with the following:

(a) Two products of different manufacturer shall be certified as suitable 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 either using the same 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 is covered by a published technical data bulletin, or equivalent, issued by the suppressor manufacturer and 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.

(c) The suppressor stack, or assembly, shall comply with the material design and construction requirements of this specification and shall have a protective coating suitable for operation in moist salt-laden atmosphere (manufacturer's finish coating designated for military or commercial marine service).

(d) 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.

3.8.6 Electron tubes. - The use of electron tubes will be permissible only where specified in the individual equipment specification or where approved by the bureau concerned. Where permitted, electron tubes shall be selected from MIL-STD-200, except that if circuit applications cannot be met with electron tbues listed therein, the use of nonstandard tubes will be permitted under the conditions listed in MIL-STD-200.

3.8.7 Terminal boards. - Terminal boards shall be of the molded type having terminal connections molded integral with the board. Nuts, machine bolts, machine screws or cap-screws shall be used for connecting and disconnecting lug terminals and other connections to the conducting parts of the terminal boards. Where studs are installed integral with the terminal board for making connections on either side, the studs shall be prevented from rotating by a positive locking means, such as pins or square shanks. Terminal boards in accordance with MIL-T-16784 or MIL-T-55164 (when selected to provide proper electrical creepage and clearance, see 3.4.10, are satisfactory types. Terminals shall be plainly marked.

3.9 PROCESSES

3.9.1 Treatment and processing of metals for corrosion-resistance. - Ferrous metal (except corrosion-resisting steels listed in 3.3.2.3) and aluminum parts shall be treated, coated, plated and painted as specified in table XVI. The treatment and processing shall be selected so as not to adversely affect the part for the use intended. All fabricating operations such as welding, machining, drilling and tapping shall be accomplished prior to treating, coating, plating or painting.

3.9.1.1 Use of insulating varnish as corrosion-resistant treatment for interior surfaces of 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 (3.9.1). 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 2 coats shall be applied using any method which will insure coverage of all surfaces. Insulating varnish shall be in accordance with MIL-I-24092 or grade CA of MIL-V-1137.

3.9.2 Painting. -

3.9.2.1 Parts to be painted. - Painting is required where necessary to obtain corrosion resistance of metal parts (see 3.9.1) except those mentioned in 3.9.2.2. Metal surfaces that are considered corrosion resistant without painting may be painted for appearance.

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

Table XVI – Processing of metals for corrosion resistance 1/

TREATMENTS NOT REQUIRING PAINTING

METAL	TREATMENT	PAINTING
Corrosion-resisting metals (See 3.3.2.3)	Not required	Not required– may be painted for appearance
Ferrous metals	Zinc coating (hot-dip galvanizing) 2/ ASTM A153 Electrodeposited zinc 2/ {QQ-Z-325, Type II Class 2 or ASTM A164 and B201} Electrodeposited chromium, QQ-C-320 over nickel undercoat {QQ-N-290, Type I(DS) or ASTM A166, Type DS} Electrodeposited nickel {QQ-N-290, Type I(DS) or ASTM A166, Type DS} Electrodeposited silver QQ-S-365 Electrodeposited cadmium 3/ QQ-P-416, Type II Class 1, except Class 3 for fasteners	
Aluminum and Aluminum alloys	Anodic treatment, MIL-A-8625	

PROCESSES REQUIRING PAINT

METAL	PRETREATMENT	PAINTING 4/ PRIMER 5/	PRIMER THICKNESS	TOPCOAT(S)	No. of COATS AND THICKNESS 9/
Ferrous metals or Ferrous metals with treatments other than those listed above as not requiring paint	MIL-C-15328 coating .0003" to .0005" dry film thickness TT-C-490, Type I phosphate treatment	6/ MIL-P-8585 6/ TT-P-664 7/ TT-P-666 TT-P-645	.0004" - .001" .001" min.	MIL-E-15090 8/ Type II or III, Class 2	2 coats, each .001", 2nd coat may be omitted on inside of enclosures and equipment to be installed in interior of ship
Aluminum and aluminum alloys	MIL-C-5541 chemical film TT-C-490, Type I phosphate treatment				1 coat, - .001"

1/ Select one treatment or painting process from each applicable column.

2/ Unpainted zinc coatings should not be used on equipment or parts to be packed in unventilated containers made of unseasoned wood unless desiccant is enclosed.

3/ Unpainted cadmium coatings shall be avoided in nonventilated electrical equipment where unstable materials, phenolic resinous substances and other materials containing unsaturated carbon-to-carbon linkages are present. Unpainted cadmium coatings shall not be used for parts to be placed in contact with wood or cardboard packing materials. These materials may have a deleterious effect on cadmium coatings, especially in the presence of moisture.

4/ For details on painting procedures, see 3.9.2.

5/ One coat primer. Primer other than those listed may be used if suitable evidence can be provided to show by experience or tests that the primer is the equivalent in performance to those listed. When MIL-C-15328 pretreatment is used and where it is known definitely that the equipment will be used only in shipboard interior spaces and will not be exposed to the weather, either as described in 3.9.2.4 or other storage, the coat of primer may be omitted.

6/ Preferred primers for aluminum and aluminum alloys.

7/ TT-P-645 primer may be lifted when topcoats are applied. If this occurs cleaning and repainting is required. Use other primer or alter process details (amount of solvent, thickness of film, etc.) to eliminate the problem.

8/ MIL-E-15090, Type II or III, class 1 may be used for portable equipment.

9/ Minimum dry film thickness.

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

Machined metal-to-metal fits.

Parts which if painted would not function properly.

Gaskets and packing.

Heat exchanger surfaces of water-air-cooled equipment.

Identification, operating, safety and warning label plates.

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

Surfaces which make contact with oil or grease.

Bearings and bearing surfaces.

Electric wire coils and windings.

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

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

3.9.2.3 Normal painting procedure. - Except for large parts temporarily stored outdoors (see 3.9.2.4) the sequence of operations shall be as follows:

(a) Complete all fabricating operations, such as welding, machining, drilling and tapping.
(b) Remove all welding flux.
(c) Remove all rust and other visible corrosion products.
(d) Remove all grease, oil, and dirt by solvent wiping, vapor degreasing, or caustic washing and rinsing.
(e) Apply primer pretreatment coating or chemical treatment and primer.
(f) Apply enamel topcoat(s).

3.9.2.4 Procedure for painting of large ferrous metal parts stored outdoors temporarily. - One of the following procedures shall be used when large ferrous metal parts are stored outdoors prior to welding and machining operations.

Procedure 1:

(a) Remove all welding flux.
(b) Remove all rust and other visible corrosion products.
(c) Remove all grease, oil and dirt by solvent wiping, vapor degreasing or caustic washing and rinsing.
(d) Apply MIL-C-15328 pretreatment, primer and one coat enamel topcoat.
(e) Storage out of doors.
(f) Complete all fabricating operations, such as welding, machining, drilling and tapping.
(g) Repeat steps (a), (b) and (c).
(h) Remove all damaged paint, and touch up with MIL-C-15328 coating and primer.
(i) Apply enamel topcoat(s).

Procedure 2:

(a) Apply a rust preventive conforming to grade 1 of MIL-C-16173.
(b) Storage out of doors.
(c) Remove rust preventative with solvent.
(d) Complete fabricating operations and follow normal painting procedures of 3.9.2.3.

3.9.3 Soldering. - The soldering process shall be such as to minimize the spattering of solder and flux onto surrounding surfaces. Only noncorrosive fluxes shall be used, unless it can be shown that all corrosive products have been satisfactorily removed or neutralized after soldering. All soldered connections shall be of such character and quality that the bonding between the soldered items may be determined by visual examination. There shall be no evidence of "cold soldering", and the use of excessive amounts of solder will not be permitted. Soldering alone shall not be depended upon for a satisfactory connection, but where wire and terminals are jointed to be soldered, the wires shall be hooked, wrapped around, or otherwise secured to the terminals, prior to soldering.

3.9.3.1 Windings. - Solder for connection of electrical windings shall be in accordance with one of the compositions listed in table XVII.

Table XVII - Solder for connection of electrical windings

Winding	Solder composition 1/
Class A or B insulation, stationary	S65, Sn60, Sn63, tin 2/
Class A or B insulation, Rotating	S65, tin 2/
Class F, H and N	Sn 10

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. (Tin is affected by temperatures below 55°F.)

3.9.3.2 Parts. - Solder for connections of electrical and electronic parts shall be composition Sn60 and Sn63 of QQ-S-571.

3.9.4 Brazing. - Brazing alloys for electrical connections shall conform to QQ-B-650 or MIL-B-15395.

3.9.5 Welding. - 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 in the equipment specification, details of the fabrication procedure need not be submitted to the bureau concerned 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 or 100 percent
    (3) Stationary parts not subject to stress – as required to meet applicable impact shock requirements.

3.9.6 Undersize shaft build-up. - Undersize shafts may be corrected by chromium plating in accordance with NAVSHIPS 344-0042.

3.9.7 Temperature measurement. -

3.9.7.1 Methods and procedures. - All temperature measuring devices shall be carefully calibrated. The three fundamental methods of temperature measurement and the procedures which shall be complied with in using the methods shall be as specified in 3.9.7.1.1, 3.9.7.1.2 and 3.9.7.1.3.

3.9.7.1.1 Method 1. - This is the "thermometer" method and consists in 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.

3.9.7.1.1.1 Procedure. - The number of thermometers or the 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.

3.9.7.1.2 Method 2. - This is the "resistance" method and consists of the determination of temperature by comparison of the resistance of a winding at the temperature to be determined, with the resistance at a known temperature. This method is preferred for insulated windings, except where measurements cannot be accurately made due to uncontrollable resistance in contacts or where it is impractical to make connections to obtain measurements before an undesirable drop in temperature occurs. For resistances less than one ohm a high accuracy instrument, such as a Kelvin bridge shall be used.

3.9.7.1.2.1 Procedure. - 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 resistance is measured. Care shall be taken not to include any unnecessary external resistances. The following formula shall be used in computing temperature rise of co^per conductors by the resistance method:

$$\text{Temperature rise, °C.} = (234.5 + t_c)\frac{R_h}{R_c} - (234.5 + t_a)$$

Where:

R_c = Cold resistance of winding.

R_h = Hot resistance of winding.

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

t_a = Ambient temperature (°C.) during the last quarter of the test.

3.9.7.1.3 Method 3. - This is the "embedded detector" method and consists in 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. 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.

3.9.7.1.3.1 Procedure. - This method shall be used only where specified in the individual equipment specification or when specifically approved by the bureau or agency concerned. 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. A temperature distribution analysis shall be made which will indicate the relationship of the 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.

3.9.7.2 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.

3.9.7.3 Measurement of ambient temperature for heat runs. -

3.9.7.3.1 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 shorter duration 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 3.9.7.3.3.1 (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 measures shall be applied and the test shall be repeated until the required conditions are met.

3.9.7.3.2 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.

3.9.7.3.3 Method of temperature measurement. -

3.9.7.3.3.1 Equipment other than that cooled by water or forced air from separate source. -

(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) The 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. (The purpose of these cups is to avoid errors due to the time lag between the temperature of large machines and unavoidable variations in the cooling air temperature.) Where oil-filled cups are used, each shall be accompanied by an air thermometer so as 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.

3.9.7.3.3.2 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 be such as to assure that the temperature indication is a representative average.

3.9.7.3.3.3 Equipment cooled by water. - Ambient temperature shall be measured as specified in the applicable equipment specification.

3.10 Drawings. - Drawings shall be as required by the individual equipment specification (see 6.2). Normally, for Bureau of Ships equipment, drawings in accordance with MIL-D-963 are required; exceptions being portable test equipment, portable tools and equipment covered by Government standard sheets. Drawings, if required, shall include the following information, in addition to that normally specified:

(a) Primer and paint materials and their method of application.
(b) Stress relief heat treatment when this treatment is required.
(c) Class of welded joints for rotating parts of motors and generators.
(d) Welding details and symbols.
(e) Detail of balancing rings or discs for submarine rotating equipment (see 3.4.11.2) and description of balance adjustments.

3.11 Manuals. - The need for manuals and requirements for their content depends upon the nature and complexity of the equipment; therefore, the requirements for manuals are contained in the individual equipment specification (see 6.2). Normally, for Bureau of Ships equipment, manuals conforming with MIL-M-15071 are required.

3.12 Workmanship. - Workmanship shall be first class in all respects.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. - Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the Government. The Government reserves the right to perform any of the inspections set forth in the specification: where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Sampling, examination and test. - Sampling, examination and tests shall be as specified in the individual equipment specification (see 6.2).

4.3 Insulation suitability tests. - Insulation suitability tests on class H, N, R and S insulated equipment shall be conducted at a laboratory satisfactory to the bureau concerned. These tests shall be as required by the appendix of this specification.

4.4. Leakage current tests. - Leakage current tests, when specified by the equipment specification (see 6.2) shall be conducted in accordance with the procedures of 4.4.1 and 4.4.2. It is intended that leakage current tests be specified for all hand held portable equipment and semi-portable equipment to determine conformance with 3.4.9.1.1. It is also intended that leakage current tests be specified for the first unit of particular equipment designed for permanent installation to determine the need for the warning plate described in 3.4.9.1.2. Leakage current tests may be omitted on equipment which fulfills both of the following conditions:

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

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

4.4.1 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, all 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.

4.4.2 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.

5. PREPARATION FOR DELIVERY

5.1 Preparation for delivery shall be as specified in the individual equipment specification (see 6.2).

6. NOTES

6.1 Intended use. - It is intended that this specification be referenced in individual equipment specifications applicable to electric power equipment which is expected to withstand long periods of use under Naval shipboard conditions. The use of this specification will help achieve the minimum degree of quality and uniformity of practice and workmanship that is acceptable based on experience regarding specialized equipment requirements. It is not intended that this specification be referenced in individual equipment specifications applicable to such items as wire, cable, electric contact brushes, fuses and lamps. Comparable requirements for electronic equipment and interior communication equipment are covered by other specifications.

6.2 Attention of the design engineers is directed to the following subjects which should be covered on the equipment specification:

(a) Detail characteristics and performance requirements for the equipment.
(b) Whether equipment is for surface ship or submarine application.
(c) Special performance, if required, in the event of an electrical part failure (see 3.2. (a)).
(d) Specific reliability requirements (see 3.2. (b)).
(e) Impact shock and vibration requirements (see 3.4.6 and MIL-S-901 ordering data).
(f) Whether radiated interference requirements of MIL-I-16910 apply (see 3.4.8.1).
(g) Whether leakage current tests are required (see 3.4.9.2).
(h) Class of insulation system (see 3.5.3).
(i) Temperature rise (see 3.5.3).
(j) Drawings (see 3.10).
(k) Manuals (see 3.11).
(l) Quality assurance provisions (see 4.2 and 4.4).
(m) Preparation for delivery (see 5.1).

6.3 Attention of design engineers is directed to the following requirements which will apply unless specific exception is taken or other requirement specified in equipment specifications. Requirements in this category were written for most of the equipment covered by this specification, recognizing that for certain equipment or under specific circumstances, changes may be advisable or necessary. Particular consideration should be given to the following subjects when preparing equipment specifications:

(a) Use of malleable or nodular graphitic iron (not permitted by 3.3.2.2).
(b) Input power variations for ac equipment (Type I power applies unless otherwise specified; see 3.4.2).
(c) Inclined operation (Specific requirements of 3.4.4 apply unless otherwise specified).
(d) Ambient temperature (50°C unless otherwise specified; see 3.4.5).
(e) Radio interference suppression (Filters or filter capacitors not permitted by 3.4.8.2).
(f) Noise reduction for submarine equipment (Sound isolating mounts not permitted by 3.4.11).
(g) Thermoplastic insulating materials for molded parts (not permitted by 3.5.1.3.2).
(h) Method of external cable connection (Terminal boards required by 3.7.2.4 unless otherwise specified).
(i) Printed wiring (not permitted by 3.7.2.9).
(j) Electron tubes (not permitted by 3.8.6).
(k) Temperature measurement by embedded detectors (not permitted by 3.9.7.1.3.1).

6.4 Definitions and nomenclature. - For names, definitions and delineation of items used by the Department of Defense, the supplier'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 Inspector of Naval Material. For names and definitions of electrical terms, the supplier's attention is invited to American Standard C42, Definitions of Electrical Terms, This publication may be obtained from the American Standards Association, Inc., 10 East 40 Street, New York, New York, 10016.

6.5 CHANGES FROM PREVIOUS ISSUE. - THE EXTENT OF CHANGES, (DELETIONS, ADDITIONS, ETC.) PRECLUDE THE ANNOTATION OF THE INDIVIDUAL CHANGES FROM THE PREVIOUS ISSUE OF THIS DOCUMENT.

Custodian:
Navy-SH
Review activity:
Navy-WP

Preparing activity:
Navy-SH
(Project MISC-N019(NAVY))

APPENDIX

PROCEDURE FOR INSULATION SUITABILITY TESTS

10. SCOPE

10.1 Scope. - This appendix covers the insulation suitability testing procedure for class H (silicone), class N, class R, and class S insulation.

10.2 Purpose. - 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 shall be 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. - The dissipation factor of an insulating structure is the ratio of its parallel reactance to its parallel resistance. It is also the tangent of the loss angle (also called loss tangent) and the cotangent of the phase angle.

10.4.3 Capacitance. - The capacitance is the ratio of the charge which can be stored in a capacitor to the potential applied to it.

10.4.4 Dielectric constant. - The dielectric constant of an insulator is the ratio of its capacitance to the capacitance of the equivalent spacing in a vacuum.

10.4.5 Power factor. - The power factor of an insulating material is the ratio of the power in 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. - The loss factor of an insulating material is equal to the product of its dissipation factor and dielectric constant.

10.4.7 Phase angle. - The phase angle of an insulating material 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. - The loss angle of an insulating material is the complement of its phase angle.

10.4.9 Complete winding. —A complete winding is an electric winding which requires no further processing when installed in the electric equipment with which used. For the purpose of this specification an a.c. stator winding, a solenoid coil, a d.c. armature, a transformer or a d.c. 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.

20. APPLICABLE DOCUMENTS

20.1 The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of the specification to the extent specified herein.

SPECIFICATIONS

MILITARY

MIL-C-2174 - Controllers, Direct - Current, Naval Shipboard.
MIL-C-2212 - Controllers, Alternating Current, Naval Shipboard.
MIL-G-3111 - Generators, Electric, Direct-Current (Naval Shipboard Use).
MIL-G-3124 - Generators, Alternating Current, 60-Cycle (Naval Shipboard Use).
MIL-T-15108 - Transformers, Power, Step-Down, Single Phase, 60-Cycle, 1-KVA Approximate Minimum Rating; and Reactors (Balance Coils) - Dry, Naval Shipboard.
MIL-M-17059 - Motors, Alternating-Current, Fractional HP (Shipboard Use).
MIL-M-17060 - Motors; Alternating-Current, Integral HP (Shipboard Use).
MIL-T-17221 - Transformers, Power Distribution; Single Phase, 400 Cycle, Class H Insulation, Dry (Air Cooled), Naval Shipboard.
MIL-M-17413 - Motors, Direct Current, Integral HP, Naval Shipboard.
MIL-M-17556 - Motors, Direct-Current, Fractional HP (Shipboard Use).
MIL-G-18473 - Generators and Motors, Direct Current, Naval Ship Propulsion.
MIL-G-18474 - Generators and Motors, Alternating Current Naval Ship Propulsion.

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

30. REQUIREMENTS

30.1 Reliability. - Reliability of operation shall be considered of prime importance in the design and manufacture of the equipment. As class H or other special insulation is usually specified to be used under environmental conditions of heat and moisture beyond the limitations of conventional insulation, a criterion of acceptance for equipment so insulated shall 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 the Bureau of Ships.

40.1.2 Equipment to be tested. - As it is not practical to test each design of electric equipment insulated with class H or other special insulation to determine compliance with the specification requirements, only representative designs, typical of the line manufactured, will be tested. Table XVIII lists equipment by specification and the form of sample to be tested.

Table XVIII - Specimens for insulation suitability test

Equipment specification	Equipment	Form to be tested	Sample quantity	Suggested size and type
MIL-M-17060	A.c. integral hp. motors	Stator winding	3	10 hp., 215 frame, 3 ϕ induct
MIL-M-17059	A.c. fractional hp. motors	Motor	3	1/4 hp., 1 ϕ,
MIL-G-3124	A.c. generators	Armature coil Field coil	3 3	Any size over 50 kw.
MIL-G-3111	D.c. generators	Armature coil Field coil	3 3	Any size over 50 kw.
MIL-M-17413	D.c. integral hp. motors	Motor	3	5 hp., shunt
MIL-T-15108	60 cycle transformers	Transformer	3	7-1/2 KVA, 1 ϕ, 440/120 v.
MIL-M-17556	D.c. fractional hp. motors	Motor	3	1/4 hp., shunt
MIL-G-18474	A.c. propulsion motors and generators	Armature and field coil	3 each	Any size
MIL-G-18473	D.c. propulsion motors and generators	Armature and field coil	3 each	Any size
MIL-T-17221	400 cycle transformers	Transformers	3	Any size
MIL-C-2212	A.c. controller	Shunt coil	3	Any size
MIL-C-2174	D.c. controller	Shunt coil	3	Any size

NOTES:

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

40.1.3 Application for test. - Application for test shall be submitted to the bureau or agency concerned stating the following:

(a) Manufacturer's name and address.
(b) Test specimen rating and kind of equipment, type of winding.
(c) Range of sizes for which approval is desired.
(d) Availability of test facilities including manufacturer's name and designation or style number for each equipment or instrument.

40.2 Test equipment needed. - The following test equipment shall be provided:

(a) Humidity chamber.
(b) 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 by placing a transparent plastic film having a low moisture permeability 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 winding. The relative humidity shall be maintained at 100 percent at a temperature of 88 ± 3°F. 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 the 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 then 60 nor more than 100 cycles per second (c.p.s.) 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 direct current test voltage of 500 volts 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 c.p.s input with a range of 5 micromicrofarads to 1100 microfarads and with a range of dissipation factor of zero 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 rated voltage plus a thousand 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 ground.

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 ground 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 3.9.7.1.2). Thermometers, thermocouples, or ammeters shall be used in adjusting the temperature and keeping it constant. To measure the temperature by method 2, a bench mark or the cold resistance shall be set up by measuring the resistance at room temperature, and recording this value. When the operating temperature is to be checked, a stop watch shall be started the instant the power is shut off, the ohmmeter bridge shall be connected as quickly as possible and then simultaneous readings of resistance and time shall be taken. This is usually a two man job. One man sets the bridge at regular intervals of resistance readings and calls "read" when the galvanometer of the bridge swings through zero. The other man reads and records the elapsed time to each "read" signal. This data shall be plotted and the value of resistance, obtained by extrapolating to zero time, shall be used with the bench mark values to calculate the operating temperature. It is apparent that the sooner the first point is taken the greater will be the precision of measurement. The maximum time between power shut off and the first resistance reading shall be 30 seconds. This method is always desirable and for high temperature it becomes a "must", since the temperature drop is so rapid. In making the calculation, any of several formulae may be used. However, the following form is preferred:

$$\frac{r}{R} = \frac{t + 234.5}{T + 234.5}$$

Where:
- r = low or cold resistance in ohms.
- R = high or hot resistance in ohms.
- t = coil temperature (cold) in °C.
- T = coil temperature (hot) in °C.

NOTE: It is also advisable to check the bench mark or cold resistance values at regular intervals because of the increase in resistance of the copper due to aging.

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 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 d.c. resistance shall also be measured and recorded.

40.5.2 Standardizing run.- Each sample unit shall next be subjected to a standardization 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. The sample parts may be subjected to oven heat if the above method 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 d.c. 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 one 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.

40.6 Assembly of data. - All data shall be recorded on the form shown in table XIX.

Table XIX - Insulation suitability test (100% R.H. plus dew).

Winding data (rating data as applicable)

Sample No. (1, 2 or 3)

Date of mfr.________ Mfr's name________
Frame________ Address________
Hp.______ Volts______ Serial________
R.p.m.______ Duty______ Phase____ Type____
F.L. amps____ Cycle____

Insulation data (or as applicable)

Magnet Wire
Ground______ Armature______ Field______
Phase______ Sleeving______ Varnish____ No. of dips____
Wedge______ Tying cord______ Leads____ and bakes____

Test Data

Report No.______ Time and Temp.______

Date of tests____ Lab____	Insulation resist., 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.

40.7 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 1 and 2 respectively.

40.8 Approval of equipment. - Three copies of the insulation suitability test reports shall be prepared by the manufacturer, authenticated by the Government inspector, and submitted to the bureau concerned 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 the equipment with a photograph of the winding taken within 10 minutes after the humidification test.
- (b) Data in accordance with table VI.
- (c) Curves in accordance with figures 2 and 3.

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

50. PREPARATION FOR DELIVERY

50.1 Not applicable.

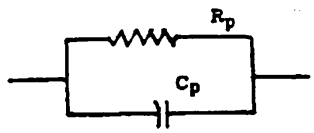
60. NOTES

60.1 Insulation resistance tests.- Insulating materials are used in general to insulate and support parts of an electrical equipment from each other and from ground. For this purpose it is generally desirable to have the insulation resistance as high as possible consistent with acceptable mechanical, chemical and heat resisting properties. Since insulation resistance combines both volume and surface resistance, its measured value is strictly applicable only when the test specimen has the same form as is required in actual use. When adequate correlating data are available, insulation resistance may be used to indicate the suitability of a material in other respects such as moisture content, degree of cure, mechanical continuity and deterioration from whatever cause. While the initial value of resistance may be important initially for any material, it is the change in resistance that is significant when there is a change in the material.

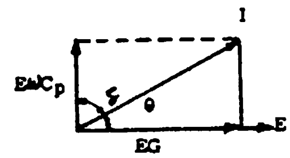
60.1.1 The determination of the resistance of an insulator is not fundamentally different from that of a conductor. In both cases, the resistance is measured by ratio of a voltage to a current. The methods available for measuring insulation resistance can be separated into two groups, the voltmeter-ammeter method and the comparison method. The former indicates current by measuring the voltage drop across a known resistor and the latter method the unknown resistance is compared with a standard resistance.

60.2 Dielectric loss tests.- It is generally desirable to have the capacitance of an insulation structure as small as possible consistent with acceptable mechanical, chemical and heat resisting properties. A low value of dielectric constant is usually desirable. The power loss should also be small both in order to reduce the heating of the material and to minimize its effect on the rest of the system. As most insulating materials will change in dielectric constant and loss factor as the frequency is changed, it is necessary to measure these properties at the frequency the materials are going to be used. The changes in dielectric constant and loss factor with frequency are produced by the dielectric polarizations which exist in the material. The two most important are dipole polarization due to polar molecules, and interfacial polarization caused by inhomogeneities in the material. Any d.c. conductance in the dielectric caused by free ions or electrons, while having no direct effect on dielectric constant will produce a dissipation factor which varies inversely with frequency and which becomes infinite at zero frequency. The effect of temperature and humidity on insulating materials tends to increase the relaxation frequency of its polarization. They increase exponentially with temperature. The effect of humidity on an insulating material is to greatly increase the magnitude of its interfacial polarization, thus increasing both its dielectric constant and loss factor and also its d.c. conductance. These effects of humidity are caused both by absorption of water into the volume of the material and by the formation of an ionized water film on its surface. An insulator or insulation structure may be represented by an equivalent parallel circuit. Dielectric losses such as capacitance and dissipation factor may be measured directly by using a series resistance circuit bridge with a 60 c.p.s. input voltage. The following symbols, circuits and formulae may be found useful in understanding this test:

D	=	dissipation	Z	=	impedance	ω	=	2π times frequency
F	=	power factor	Rp	=	parallel resistance	θ	=	theta, phase angle
K	=	dielectric constant	Rs	=	series resistance	δ	=	delta, loss angle
LF	=	loss factor	X_p	=	parallel reactance	f	=	frequency
C	=	capacitance	X_s	=	series reactance	π	=	3.1416
G	=	conductance	C_p	=	parallel capacitance	E	=	voltage
B	=	susceptance	C_s	=	series capacitance	I	=	current
Q	=	storage factor	C_v	=	capacitance in vacuum			



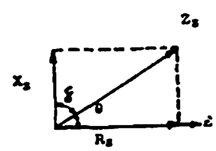
Equivalent parallel circuit



Vector diagram

$$D = \cot\theta = \tan\delta = \frac{G_s}{B_s} = \frac{X_p}{R_p} = \frac{G}{\omega C_p} = \frac{1}{R_p \omega C_p}$$

Equivalent series circuit



Vector diagram

$$D = \cot\theta = \tan = \frac{G_p}{B_p} \quad \frac{R_s}{X_s} = R_s \omega C_s$$

$$X_s = \frac{1}{\omega C_s} \qquad D = \frac{1}{R_p \omega C_p} = R_s \omega C_s$$

$$LF = D \times K \qquad X = \frac{1}{2\pi FC} \qquad F = \frac{D}{\sqrt{1 + D^2}} = \frac{R_s}{Z_s} = \cos\theta$$

$$K = \frac{C_p}{C_v} \qquad C = \frac{Q}{E}$$

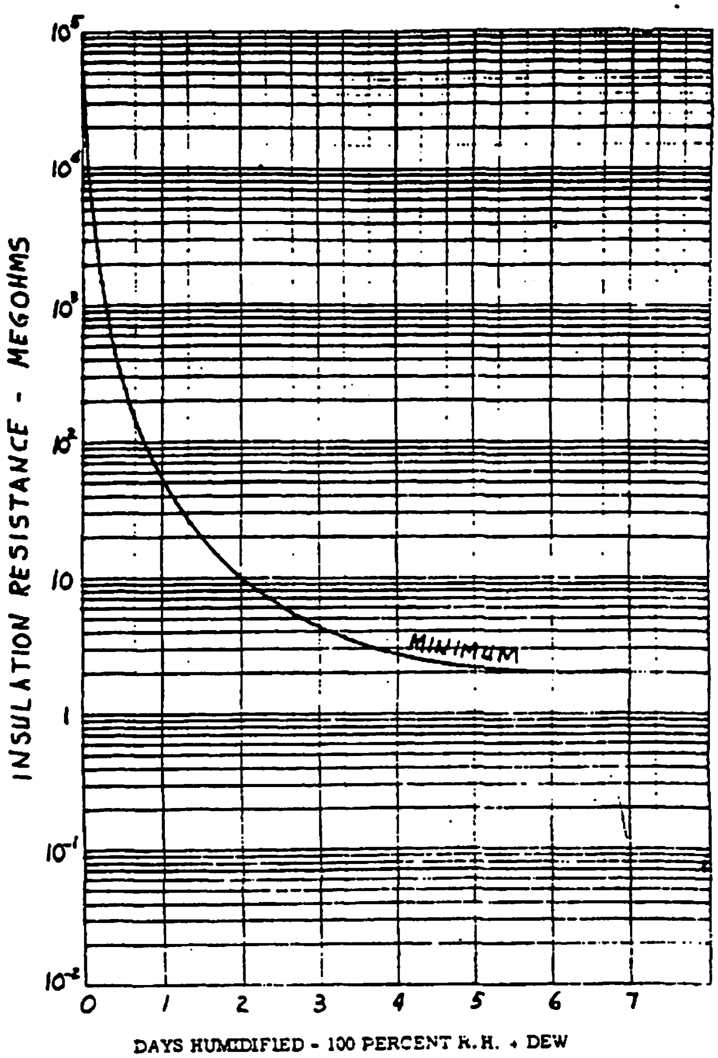


Figure 1 – Insulation resistance.

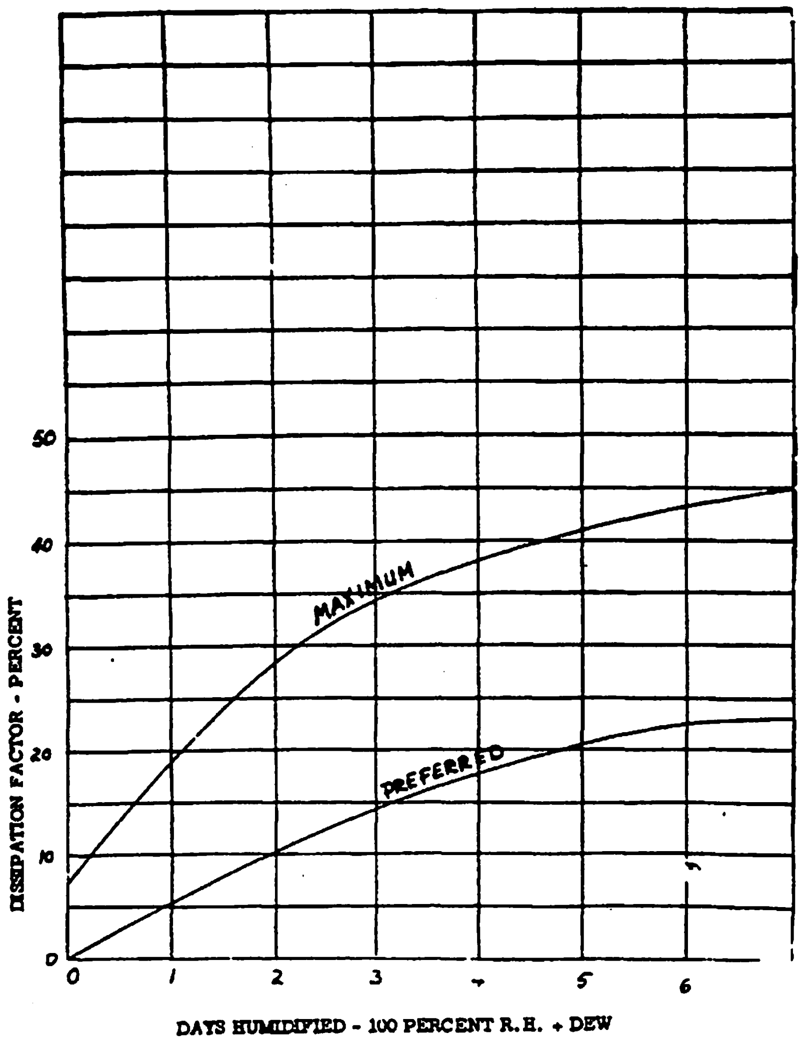


Figure 2 - Dissipation factor.

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