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INCH-POUND
MIL-DTL-3124E(SH)
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SUPERSEDING
MIL-G-3124D(SH)
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DETAIL SPECIFICATION

# GENERATOR, ALTERNATING CURRENT, 60-HERTZ (NAVAL SHIPBOARD USE)

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

## 1. SCOPE

1.1 Scope. This specification covers salient-pole and round rotor (cylindrical), continuous duty, 60-Hertz, constant speed, single- and three-phase generators, up to 8,000 kilowatts (kW).

## 2. APPLICABLE DOCUMENTS

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

2.2 Government documents.

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

DEPARTMENT OF DEFENSE SPECIFICATIONS

| | | |
|---|---|---|
| MIL-S-901 | - | Shock Tests, H.I. (High-Impact) Shipboard Machinery, Equipment, and Systems, Requirements for |
| MIL-E-917 | - | Electric Power Equipment, Basic Requirements |
| MIL-DTL-1222 | - | Studs, Bolts, Screws and Nuts for Applications Where a High Degree of Reliability is Required; General Specification for |
| MIL-DTL-2036 | - | Enclosures for Electric and Electronic Equipment, Naval Shipboard |
| MIL-R-2729 | - | Regulator-Exciter Systems, Voltage, A.C. Generator, Naval Shipboard Use |
| MIL-G-3087 | - | Generator Sets, Steam Turbine (Direct and Alternating Current), Naval Shipboard Use |
| MIL-DTL-15024 | - | Plates, Tags, and Bands for Identification of Equipment, General Specification for |

Comments, suggestions, or questions on this document should be addressed to Commander, Naval Sea Systems Command, ATTN: SEA 05S, 1333 Isaac Hull Avenue, SE, Stop 5160, Washington Navy Yard DC 20376-5160 or emailed to CommandStandards@navy.mil, with the subject line "Document Comment". Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.dla.mil.

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| | | |
|---|---|---|
| MIL-P-15024/5 | - | Plates, Identification |
| MIL-T-15377 | - | Temperature Monitor Equipment, Naval Shipboard |
| MIL-T-16366 | - | Terminals, Electrical Lug and Conductor Splices, Crimp-Style |
| MIL-PRF-17331 | - | Lubricating Oil, Steam Turbine and Gear, Moderate Service |
| MIL-C-19836 | - | Coolers, Fluid, Industrial, Air, Motor and Generator, Naval Shipboard |
| MIL-G-21296 | - | Generator Set, Diesel Engine, Direct and Alternating Current (Naval Shipboard Use) |
| MIL-G-21410 | - | Governing Systems, Speed and Load-Sensing, Naval Shipboard Use |
| MIL-G-22077 | - | Generator Sets, Gas Turbine, Direct and Alternating Current, Naval Shipboard Use |
| MIL-H-22577 | - | Heating Elements, Electrical, Cartridge, Strip and Tubular Type |
| MIL-I-24092 | - | Insulating Varnishes and Solventless Resins for Application by the Dip Process |
| MIL-T-24388 | - | Thermocouple and Resistance Temperature Detector Assemblies, General Specification for (Naval Shipboard) |
| DOD-G-24508 | - | Grease, High Performance, Multipurpose (Metric) |
| MIL-DTL-24643 | - | Cables, Electric, Low Smoke, Halogen-Free, for Shipboard Use, General Specification for |
| MIL-DTL-24643/16 | - | Cable, Electrical, -20 °C to +105 °C, 1000 Volts, Type LSTSGU |
| MIL-C-24707/1 | - | Castings, Ferrous, for Machinery and Structural Applications |
| MIL-C-24707/5 | - | Castings, Ductile Iron and Austenitic Ductile Iron |
| MIL-I-24768 | - | Insulation, Plastics, Laminated, Thermosetting; General Specification for |
| MIL-DTL-32353 | - | Hydraulic & Lubricating Oil, Synthetic Hydrocarbon Base |

DEPARTMENT OF DEFENSE STANDARDS

| | | |
|---|---|---|
| MIL-STD-167-1 | - | Mechanical Vibrations of Shipboard Equipment (Type I – Environmental and Type II – Internally Excited) |
| MIL-STD-461 | - | Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment |
| MIL-STD-705 | - | Generator Sets, Engine Driven Methods of Tests and Instructions |
| MIL-STD-1399-300 | - | Interface Standard for Shipboard Systems, Section 300, Electric Power, Alternating Current |
| MIL-STD-1474 | - | Noise Limits |

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DEPARTMENT OF DEFENSE HANDBOOKS

MIL-HDBK-298 - Selection, Installation and Troubleshooting of Resistance Thermometers and Thermocouple Sensors

MIL-HDBK-454 - General Guidelines for Electronic Equipment

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

2.2.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

NAVAL SEA SYSTEMS COMMAND (NAVSEA) DRAWINGS

810-1385861 - Flanges, Sea Water, 700 PSI Max

(Copies of this document are available from the applicable repositories listed in S0005-AE-PRO-010/EDM, which can be obtained online at https://nll.ahf nmci.navy.mil, requested by phone at 215-697-2626, or requested by email at nllhelpdesk@navy.mil. Copies of this document may also be obtained from the Naval Ships Engineering Drawing Repository (NSEDR) online at https://199.208.213.105/webjedmics/index.jsp. To request an NSEDR account for drawing access, send an email to NNSY_JEDMICS_NSEDR_HELP_DESK@navy mil.)

NAVAL SEA SYSTEMS COMMAND (NAVSEA) PUBLICATIONS

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

S9086-HN-STM-010/244 - NSTM Chapter 244, Propulsion Bearings and Seals

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

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

AEROSPACE INDUSTRIES ASSOCIATION (AIA)

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

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

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

ASTM INTERNATIONAL

ASTM A47/A47M - Standard Specification for Ferritic Malleable Iron Castings

ASTM A395/A395M - Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures

ASTM A439 - Standard Specification for Austenitic Ductile Iron Castings

ASTM A572/A572M - Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel

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| | | |
|---|---|---|
| ASTM A976 | - | Standard Classification of Insulating Coatings for Electrical Steels by Composition, Relative Insulating Ability and Application |
| ASTM B23 | - | Standard Specification for White Metal Bearing Alloys |
| ASTM B26/B26M | - | Standard Specification for Aluminum-Alloy Sand Castings |
| ASTM B209 | - | Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate |
| ASTM B700 | - | Standard Specification for Electrodeposited Coatings of Silver for Engineering Use |
| ASTM D5948 | - | Standard Specification for Molding Compounds, Thermosetting |
| ASTM E208 | - | Standard Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels |

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

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

ANSI/NEMA MW 1000 - Magnet Wire

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

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 115 - Guide for Test Procedures for Synchronous Machines

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

SAE INTERNATIONAL

SAE-AS50151 - Connectors, Electrical, Circular Threaded, AN Type, General Specification for

SAE-J1926/1 - Connections for General Use and Fluid Power – Ports and Stud Ends

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

UNDERWRITERS LABORATORIES INC. (UL)

UL 1446 - Standard for Systems of Insulating Materials – General

(Copies of this document are available online at http://www.ul.com.)

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

## 3. REQUIREMENTS

3.1 First article. When specified (see 6.2), a sample shall be subjected to first article inspection in accordance with 4.3.

3.2 Material. Material shall be as specified in 3.2.1 through 3.2.4.

3.2.1 Material requirements. The requirements for materials to be used in the generator shall be as specified in table I. The requirements for wire sizes shall be as specified in table I below or in accordance with MIL-E-917. Use of other wire sizes shall be approved in accordance with the procedures specified in MIL-E-917. Materials other than those listed below may be used with NAVSEA approval.

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TABLE I. Material requirements.

| Item no. | Item | Limitation | Material | Remarks |
|---|---|---|---|---|
| 1 | Ball bearing cap cartridge | All sizes | Steel<br>Malleable iron | ASTM A47/A47M, Grade 35018 |
| 2 | Bearing shells | Where used | Steel or bronze | |
| 3 | Covers, hand hole or access | All sizes | Steel<br>Malleable iron<br>Aluminum | ASTM A47/A47M, Grade 35018, ASTM B26/B26M, or ASTM B209 |
| 4 | End brackets | | Steel 1/<br>Nodular iron | MIL-C-24707/5, ASTM A395/A395M, and ASTM A439 |
| 5 | Eyebolts, lifting | Where used | Steel | ASTM A572/572M |
| 6 | Fans | All sizes | Steel | |
| 7 | Flanges (stator) | | Steel 1/ | |
| 8 | Frames | | Steel 1/ | |
| 9 | Grease cups and pipes | Where used | Steel | |
| 10 | Oil seals | | | |
| | a. Sleeve bearings | All sizes | Metal (copper, aluminum, aluminum bronze or brass) | |
| | b. Ball bearings | All sizes | Steel or malleable iron | |
| 11 | Punchings, armature and field | All sizes | Steel | Nonaging, low hysteresis |
| 12 | Resistance temperature sensing, elements (RTEs) | (1) Sleeve bearings 300 kW and larger<br>(2) Stator windings and cooling at 500 kW and larger | | MIL-T-24388 |
| 13 | Roller bearings | Where used | | See 3.3.8.2.1 |
| 14 | Shaft 2/ | All sizes | Steel | As approved by NAVSEA. |
| 15 | Sleeve bearings | Where used | Babbitt | ASTM B23 |
| 16 | Spacers and coil separators | All sizes | Plastic | MIL-I-24768, Type GSG, GMG, or GME. ASTM D5948, mineral-filled |

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TABLE I. Material requirements – Continued.

| Item no. | Item | Limitation | Material | Remarks |
|---|---|---|---|---|
| 17 | Spiders | | Steel | Fabricated, cast forged, laminated |
| 18 | Laminated sheet top sticks | All sizes | Plastic | MIL-I-24768, Type GSG, GMG, or GME.<br>ASTM D5948 |
| 19 | Terminal boxes and terminal box covers | All sizes | Steel<br>Malleable iron | ASTM A47/A47M, Grade 35018 |
| 20 | Varnish, insulating | All sizes | | Solventless varnishes MIL-I-24092. Solvent Varnish Class F or greater insulation. |
| 21 | Wedges | All types | Steel 2/<br>Brass<br>Plastic<br>Aluminum 2/ | MIL-I-24768, Type GSG or GMG |
| 22 | Wire, electric | All size and types | Copper and insulation | ANSI/NEMA MW 1000. No half-size wire allowed. |

NOTES:

1/ Unless otherwise specified herein, steel parts shall be cast, fabricated, wrought, or forged. Cast steel shall be in accordance with Class B of MIL-C-24707/1, or equivalent, except that radiographic and magnetic particle inspection shall not be required.

2/ For cylindrical rotor material requirements, see 3.3.27.

3.2.2 Electrical insulation. Insulation systems shall be Class F, or greater, as specified (see 6.2).

3.2.3 Non-structural parts. Non-structural parts, such as covers, terminal boxes, housings, ducts, and similar parts, may be of aluminum or aluminum alloy. Any threaded sections in aluminum or aluminum alloy shall be reinforced with steel bushings, such as helical inserts.

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

3.3 Construction. The construction requirements specified herein (see 6.2) shall be in accordance with MIL-E-917.

3.3.1 Accessibility. Accessibility shall be provided for parts which require routine examination, maintenance, or replacement in service without the need for disconnection or removal of another part or assembly other than an access panel or cover. Each access panel and cover shall open and close or be reusable and replaceable (as applicable), starting from the secured position and returning to the secured position, in not more than 0.5 hour. Time required for examination, maintenance, or replacement of the part shall not be included.

3.3.2 Phases. Generators rated 1,000 kilowatts or larger shall be three-phase machines. Generators rated less than 1,000 kilowatts shall be either single- or three-phase, as specified (see 6.2).

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3.3.3 Parallel operation. Single-phase generators shall not be required to operate in parallel. Three-phase generators shall operate in parallel with real kilowatt and reactive kilovar load division in accordance with MIL-G-21410 and MIL-R-2729.

3.3.4 Enclosures. The requirements for enclosures shall be in accordance with MIL-E-2036. Electrical parts shall be enclosed to provide personnel protection against physical contact with electrically energized or moving parts. The enclosures shall be one of the following, as specified (see 6.2):

a. Open.

b. Dripproof.

c. Dripproof-protected.

d. Totally enclosed.

e. Totally enclosed (fan-cooled).

f. Totally enclosed (water-air-cooled).

g. Spraytight.

3.3.5 Ventilation. The ventilation system air inlets shall prevent hot air, developed by the prime mover, from circulating through the generator. Water-air-cooled generators shall be as specified in 3.3.26.

3.3.6 Assembly. Assembly shall be as specified in 3.3.6.1 and 3.3.6.2.

3.3.6.1 Joints. Adjoining portions of machinery shall be given corresponding marks, where required, to ensure correct assembly. Forcing bolts shall be provided for breaking babbitted, fitted, and stepped joints, and are not required for inside bearing caps. "Where required" means anywhere two parts may be incorrectly assembled.

3.3.6.2 Dowels. Generators, other than flange-mounted, shall be doweled against movement by the use of fitted holding-down bolts. Dowels shall meet the shock conditions specified in 3.4.17. Dowels, ½ inch or more in diameter (diameters refer to the small end of the dowel), shall be provided with threads and nut for withdrawal. Taper dowels shall not be larger than ⅜ inch in diameter. Dowels shall be located so as to be removable using a boxed or open ended wrench without disassembly of adjacent parts.

3.3.7 Armatures (see 6.5.3). Laminations shall be insulated with a C-5 coating in accordance with ASTM A976. Spacers used for ventilation shall be riveted or welded to the laminations to prevent their coming loose due to vibration in service. In the assembly of the cores, burrs or projecting laminations in the slot portion of the core shall be removed to prevent injury to the coils.

3.3.8 Bearings. Bearings shall be sleeve, ball, or roller type as specified (see 6.2). Other bearing types may be proposed, but are subject to NAVSEA review and approval. The lubrication system shall prevent oil, oil-laden vapor, or grease from leaking or migrating from the oil seal bearing housing or split lines under the inclined operation conditions specified in 3.4.19, and maintain positive seal cavity pressure during operation. Bearings shall be insulated where required (see 3.3.24.5).

3.3.8.1 Sleeve bearings. Sleeve bearings mounted in a pedestal shall be self-aligning. Bracket-mounted sleeve bearings need not be self-aligning. Sleeve bearings for generators with a frame size larger than that corresponding to 100 kilowatts at 1200 revolutions per minute (r/min) shall be split to permit removal and replacement without taking the rotor out of the frame, removing the coupling from the driving end, or removing the bearing bracket from the generator. Sleeve bearings for generators with frame sizes corresponding to 100 kilowatts at 1200 r/min and smaller need not be of the split type under the following conditions:

a. The bearing shell and oil seal shall be removable and replaceable without removing the bracket.

b. The bearing shell shall be removable without removing any overhung exciters, armatures, or coupling.

3.3.8.1.1 Lubrication. Sleeve bearings shall be lubricated by the prime mover forced feed lubrication system (see 3.4.11). Lubricating oil shall be in accordance with MIL-PRF-17331, Symbol 2190 TEP, or MIL-DTL-32353, Symbol 2190S, as specified by NAVSEA.

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3.3.8.1.2 Clearances. Bearing clearances shall be as specified in table II.

TABLE II. Bearing clearances.

| Basic diameter of journal (inches) | Maximum design diametrical bearing clearance, including shaft and bearing tolerances (inch) |
|---|---|
| 1.000 | 0.004 |
| 2.000 | 0.005 |
| 3.000 | 0.007 |
| 4.000 | 0.009 |
| 5.000 | 0.010 |
| 6.000 | 0.012 |
| 7.000 | 0.014 |
| 8.000 | 0.016 |
| 9.000 | 0.018 |
| 10.000 | 0.020 |

3.3.8.1.3 Bearing housings. For forced lubricated systems, the housing shall prevent the escape or migration of oil and oil-laden vapor along the shaft and split line by maintaining a positive pressure in the bearing cavity under operating conditions. The use of felt and friction type seals shall be prohibited. Provision shall also be made to ensure against the suction of oil vapor into the interior of the generator or externally mounted components, that is, permanent magnet alternator, slip rings, brushless exciter, and so forth. Where resistance temperature indicators (RTEs) are not provided, a tapped hole shall be provided for insertion of a thermometer into the bearing and bearing shell for bearing temperature observation. These observation openings shall be made oiltight by a cover secured by screws, screw plugs, or equivalent means.

3.3.8.1.4 Oil-filling and level indicators. Where forced lubrication is not used, an opening or standpipe for filling, for preventing overfilling, and for indicating the oil level shall be provided in the reservoir and shall be fitted with an oiltight plug or cap to prevent the escape of oil when the generator is subject to the inclination specified in 3.4.19. The diameter of the filling opening shall be not less than ⅜ inch.

3.3.8.2 Ball and roller bearings. Ball and roller bearings shall be as specified in 3.3.8.2.1 through 3.3.8.2.8.

3.3.8.2.1 General. When used, ball and roller bearings shall be in accordance with an ANSI/ABMA Dimension Series.

3.3.8.2.2 Grease cups. Compression grease cups of steel shall be used on generators where grease is used for lubrication. The grease cups shall be preferentially placed on top of the bearing housing unless another location is required to ensure optimal distribution of grease as determined by the manufacturer. Grease shall be in accordance with DOD-G-24508.

3.3.8.2.3 Drain plugs. Accessible drain plugs shall be provided in locations to afford maximum purging of grease during regreasing.

3.3.8.2.4 Grease pipes. Extension grease pipes shall provide accessibility for grease cups and drain plugs. The use of extension grease pipes is permitted in order to provide accessibility to grease cups and drain plugs.

3.3.8.2.5 Axial end play. A 0.020-inch minimum axial clearance between the opposite shaft extension end bearing outer race and housing shoulder shall be provided for shaft thermal expansion. Axial movement of the shaft shall be not greater than 0.040 inch including bearing end play.

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3.3.8.2.6 Bearing seals. The housing shall provide a close-clearance metallic seal (non-rubbing) on both sides of the bearings (one side only where shaft does not extend through cap) to prevent leakage of oil or grease along the shaft.

3.3.8.2.7 Housing construction. The bearing housing shall permit removal of the end bracket without removing the bearings.

3.3.8.2.8 Addition of grease lubricant. When grease is the lubricant used, the correct amount, in accordance with S9086-HN-STM-010/244, shall be added to the bearing housing before the generator leaves the place of manufacture.

3.3.9 Shafts. When oil lubrication is used, shafts shall be provided with deflecting flanges or slingers to minimize the passage of oil into the bearing seal cavity (see 3.3.8.2.6). Generators shall be provided with a shaft extension for the prime mover as specified (see 6.2).

3.3.10 Rotors. Keys, in conjunction with press fits or shrink fits, shall be provided to prevent movement of the core or spider on the shaft. Axial displacement shall be prevented under operating or test conditions. A pin through the shaft shall not be used to prevent axial displacement. Welding shall not be used to secure the core or spider to the shaft. Spiders constructed of individual flutes welded to the shaft may be used if pre-heat and stress-relieving procedures are employed in accordance with S9074-AR-GIB-010/278, Class M-1.

3.3.11 Connections and terminals. Connections and terminals shall be as specified in 3.3.11.1 through 3.3.11.9.

3.3.11.1 Wiring connections. Main generator power terminals shall be located as specified herein, and shall be installed within a dripproof-protected enclosure as specified (see 3.3.4). The enclosure shall be located on the side of the generator to allow side entry of cables to generator armature output. Except for generator armature output and field input power terminals, electrical items which require connections to ship's wiring shall be wired to terminal boards which shall be enclosed, dripproof-protected, and conveniently located. Separate connection boxes or separate enclosed compartments within a common connection box shall be provided for each of the auxiliary services which require connection to the ship's electrical wiring, such as space heaters and temperature detectors. Connection boxes for space heater wiring shall be provided with a warning plate which indicates that heaters are energized when the generator is de-energized. Wiring between parts, such as field coils and terminal boards, shall be in accordance with MIL-E-917 and shall be arranged for convenience of maintenance and repair accessibility.

3.3.11.2 Securing connections. Connections shall be provided with locking devices in accordance with MIL-E-917. Connectors and leads shall be secured to prevent contact with moving or stationary parts. Excess solder shall be removed from soldered connections.

3.3.11.3 Bus bar leads. Bus bar leads shall be silver plated using 99.9 percent pure silver. The silver thus applied shall be not less than 0.0002 inch thick and shall withstand the adhesion test in accordance with ASTM B700 and shall show no tendency to peel. The contact surfaces of the bus bars shall be silvered, as a minimum, 1 inch past the joint area. The entire bus bar may be silver surfaced at the discretion of the manufacturer or NAVSEA.

3.3.11.4 Generators with frame sizes not greater than 10 kilowatts at 1800 r/min. A lead clamp shall be provided for the terminal leads. The terminal leads shall not be attached to the end brackets but shall be attached to the frame and extend to at least 6 inches beyond the point of support. The methods of fastening shall prevent strain from the outside from being transmitted to the connections within the generator frame. Unclamped rubber bushings shall not be used for securing leads. The ends of each generator lead shall be fitted with a connector in accordance with MIL-T-16366. Terminal lead holes in the generator frames shall have rounded edges to prevent injury to lead insulation.

3.3.11.5 Generators with frame sizes not less than 10 kilowatts and not greater than 25 kilowatts at 1800 r/min. Leads shall be brought to and terminated at a terminal board.

3.3.11.6 Generators with frame sizes not less than 25 kilowatts and not greater than 200 kilowatts at 1800 r/min. Leads shall be brought to and terminated at a terminal board which shall be located on the side of the frame below the horizontal axis. The terminal board shall be located to facilitate connections and shall accommodate the ship leads from below.

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3.3.11.7 Generators with frame sizes not less than 200 kilowatts at 1800 r/min and all generators using bus bar in lieu of cable. Terminal boards need not be provided. The leads shall be clamped into position so that strain from the outside cannot be transmitted to the connections within the generator frame. The leads shall be of sufficient length to facilitate making connections and shall be provided with a means for making connections to the ship cables. Terminal lugs shall not be provided.

3.3.11.7.1 Bus bar leads. Bus bar leads shall be in accordance with 3.3.11.3.

3.3.11.8 Terminal markings. When facing the opposite drive end, terminals shall be marked T1, T2, T3 reading from front (the end opposite the drive) to back, right to left, or top to bottom. Direct current (DC) field leads shall be marked F1 and F2. A labeled schematic vector placard shall be mounted on the generator, showing inverted-wye windings or delta windings, as appropriate.

3.3.11.9 Minimum radius of cable bend. The location of connections and clearances shall be such that specified cable can be installed using the minimum radius of bend in accordance with MIL-DTL-24643. As construction design guidance, Type LSTSGU cable in accordance with MIL-DTL-24643/16 is shown for selected size cables, with recommended current-carrying capacities and minimum radius of bend:

| **Wire size, MCM [1/] or AWG [2/]** | **Current rating (amperes) at 60 Hz and 122 °F (50 °C)** | **Cable overall maximum diameter (inches)** | **Minimum allowable radius for cable bend (inches)** |
|---|---|---|---|
| 16 | 10 | 0.411 | 3.5 |
| 14 | 17 | 0.449 | 3.5 |
| 10 | 36 | 0.575 | 4.5 |
| 9 | 47 | 0.718 | 5.5 |
| 7 | 64 | 0.812 | 6.5 |
| 3 | 101 | 0.969 | 8.0 |
| 1 | 136 | 1.134 | 9.0 |
| 000 | 216 | 1.515 | 12.0 |
| 300 | 320 | 1.957 | 15.5 |
| 400 | 400 | 2.203 | 17.5 |

NOTES:

1/ MCM is the old abbreviation for one thousand circular mils.

2/ AWG is the abbreviation for American wire gauge.

3.3.12 Frame. The frame shall be of rigid construction, either integral with the support structure or detachable.

3.3.12.1 Detachable frames. Detachable frames shall have feet large enough to accommodate holding-down bolts, dowel pins, and jackscrews, where used, to ensure attachment to the common bedplate or to the structural foundations of the vessel, as required. The frame feet shall be machined and drilled for holding-down bolts. Fitted bolt holes shall be left with an allowance for reaming at time of installation of generator with prime mover.

3.3.13 End brackets. Where end brackets are used, a machined shoulder joint shall be provided between the frame and the end brackets. End brackets shall be secured to the frame by not less than four hexagon-head bolts or cap screws of suitable size and strength.

3.3.13.1 Resilient gaskets. Resilient gaskets shall not be placed between any bearing support members and the frame.

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3.3.13.2 Generators with frame sizes larger than 100 kilowatts at 1200 r/min. For generators with frame sizes larger than that corresponding to 100 kilowatts at 1200 r/min, end brackets and air seals shall be split on the horizontal centerline to permit access to the generator windings and internal parts for inspection and cleaning without uncoupling the prime mover.

3.3.14 Lifting means. Eyebolts or other means shall be provided for lifting any generator component weighing 50 pounds or more.

3.3.15 Vertical adjustment. Jackscrews shall be used to facilitate vertical adjustment of generator frames weighing 1,000 pounds or more. Jackscrews shall be used only for installation purposes.

3.3.16 Access holes. For generators over 500 kilowatts, access holes shall be placed in each shield to allow inspection of nearby internal parts.

3.3.17 Excitation and regulation system. The excitation and regulation system shall be as specified in 3.3.17.1 through 3.3.17.2.1.

3.3.17.1 Automatic voltage regulator and exciter system. A combined automatic voltage regulator and exciter system shall be provided as part of the generator equipment. The combined automatic voltage regulator and exciter system shall be in accordance with Type II of MIL-R-2729, as modified by applicable equipment specifications. No brushes or slip rings shall be used.

3.3.17.2 Rotating exciters. The requirements of this specification regarding generators apply to rotating exciters except for exciter mounting (see 3.3.17.2.1).

3.3.17.2.1 Exciter mounting. The exciter shall be mounted so that it does not interfere with the accessibility of the main generator windings for inspection and cleaning. The output of the rotating rectifier assembly shall be directly connected by leads that run through the shaft to the main generator field. The exciter armature and rotating rectifier assembly shall be removable from the shaft.

3.3.18 Field discharge resistors. Field discharge resistors shall be prohibited.

3.3.19 RTEs. Generators rated 300 kilowatts and larger shall be provided with RTEs on generator sleeve bearings and generator stator windings for detecting the temperature of generator cooling air where totally enclosed water-air-cooled generators are specified (see 3.3.26). RTEs shall connect with monitors which are in accordance with MIL-T-15377.

3.3.19.1 Generator air temperature. Two RTEs shall be provided to measure generator air temperature. One of the RTEs shall be located so as to measure the temperature of air inlet to the generator air cooler and the other located so as to measure the temperature of the air outlet from the generator air cooler. Air temperature RTEs shall be removable without the removal of the complete air cooler cover.

3.3.19.2 Generator stator windings. Not less than two embedded RTEs per phase shall be provided in the stator winding, with the first placed at the estimated hot spot of the machine winding, and the remainder spaced at equal intervals around the stator.

3.3.19.3 Generator sleeve bearings (for submarine ship service application only). Sleeve bearings shall be fitted with RTEs at the full power load line. One RTE in each sleeve bearing shall be located in the middle third of the axial length of the bearing. The RTEs shall be in accordance with MIL-T-24388, with element wiring protruding from the bottom or ending at the bottom.

3.3.19.3.1 RTE installation. The RTEs shall be installed in a radial hole in the bearing shell, with the sensing tip $\frac{1}{16}$ inch below the bearing surface and with the bottom of the RTE casing bottoming on the shoulder in hole.

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3.3.19.3.2 RTE lead wire connection. The RTE lead wires that connect to the monitor shall be brought through a radially drilled 0.187-inch maximum diameter hole and channeled into a groove (approximately ⅛ by $^{3}/_{16}$ inch) connecting the radial hole with a connection block recessed in bearing within 30 degrees of the bearing part line. An air hardening epoxy-resin or room temperature hardening (RTV) silicone, following the guidance provided in MIL-HDBK-298, shall be applied in the groove to protect the wiring. The wires shall be soldered or room temperature hardened (RTV), following the guidance provided in MIL-HDBK-298, to the connection block.

3.3.19.3.3 Pivoted shoe bearing. The procedures specified in 3.3.19.3.1, 3.3.19.3.2, and 3.3.19.3.4 for sleeve bearings shall generally apply for installing RTEs in pivoted shoe bearings, except that the RTE shall be installed at the trailing edge of one lower shoe, and the bearing connection block shall be recessed in the edge or end of the shoe on the pivot line.

3.3.19.3.4 Connection block wiring. Wiring between the bearing connection block and the casing (or bearing pedestal) wall shall be required to complete the circuit. The wiring shall be recessed in epoxy-resin-filled grooves, in holes, or in an armored sheath to prevent damage in accordance with MIL-E-917; additional guidance can be found in MIL-HDBK-298. The wiring shall be easily disconnected (mechanically or by melting soft solder) from the bearing connection block and shall penetrate the casing wall through a Type AN connector in accordance with SAE-AS50151. Location of connectors shall minimize damage to the attached connector and cables. Penetration points shall be oiltight if the internal surfaces of these points are subject to being submersed or splashed with oil.

3.3.19.3.5 Caution plate. A caution plate, warning that the RTE wires to bearings shall be disconnected before rolling out the bearing, shall be permanently affixed to the external top of the bearing cap. A similar caution plate shall also be installed on the generator where disassembly of the generator could result in damage to the RTE arrangement installed in the generator stator and cooling air sections. Label plates shall be anodized-hydrated aluminum in accordance with ASTM B209, manufactured in accordance with MIL-DTL-15024, Type H, and shall have black letters on a background color of natural anodized-hydrated aluminum.

3.3.19.3.6 Terminal box. Wiring from RTEs shall be brought out to a dripproof-protected terminal box as specified in 3.3.4. The external wiring from RTEs to the terminal box shall be firmly supported and protected by rigid or flexible conduit.

3.3.20 Bedplate bolting. When generator bolt holes, provided for securing the generator to the bedplate, are used with dowels and non-fitted bolts, such bolts shall be in accordance with Types I, II, or III, Grade 5 of MIL-DTL-1222, and self-locking nuts shall be in accordance with NASM17828 and NASM17829. Bolts of higher grade may be used with NAVSEA approval. Clearance between bolt holes and bolts shall be not greater than the following:

| **Nominal bolt diameter** | **Maximum diameter of holes** |
|---|---|
| ¾-inch or smaller | Nominal bolt diameter plus $^{1}/_{32}$ inch |
| Larger than ¾-inch | Nominal bolt diameter plus $^{1}/_{16}$ inch |

3.3.20.1 Rigidly supported units. Rigidly supported units shall not be attached to two structures which can deflect relative to each other under shock.

3.3.21 Welding and casting. Welding and casting shall be in accordance with S9074-AR-GIB-010/278.

3.3.21.1 Welding review. When S9074-AR-GIB-010/278 requires review of specific aspects of welding and allied processes, the reviewing activity shall be NAVSEA.

3.3.21.2 Stress relief. Welded rotating parts of the generators shall be stress relieved. Stationary parts shall be stress relieved in accordance with S9074-AR-GIB-010/278.

3.3.22 Creepage and clearance distances. Creepage and clearance shall be in accordance with the requirements of MIL-E-917.

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3.3.23 Special noise limitations. When special airborne and structureborne noise limitations are required for the application, details of limitations for airborne and structureborne noise (whether generator and detached units should be resiliently mounted, the type of resilient mount to be used, and the procedure for noise tests) shall be specified (see 6.2). The following factors shall be considered in the construction of the generator, as necessary, to meet the noise limitations:

a. Precision machining of rolling, rubbing, and fitted parts.

b. In the production phase, minimize corrections required during the final balancing phase of the generator.

c. In-place balancing of the rotor and provision for access plates for the in-place balancing.

d. Avoid sharp cutoffs and turbulence in air cooling systems. Ventilation ducts and housing shall be damped to prevent flow excited vibration.

e. Favorable combination of the following generator design features:

(1) Number of slots for each pole pitch.

(2) Number of slots magnetically under one pole.

(3) Slot frequency as a function of the natural frequency of the magnetic frame.

(4) Skewing of stator slots.

(5) Skewing of pole tips and fairing of pole tip edges.

f. Spring mounting of generator stator punchings.

g. Close tolerance of generator air gap.

h. Any other features specified (see 6.2).

3.3.24 Salient-pole generators. For salient-pole generators, the requirements of 3.3.24.1 through 3.3.24.5 shall apply.

3.3.24.1 Armature windings. Armature windings for generators with frame sizes corresponding to 25 kilowatts at 1800 r/min and larger shall be form-wound (wound, formed, and insulated with or without impregnation before assembly in core slots) and interchangeable with duplicate windings. The windings shall be secured in the slots by slot wedges.

3.3.24.2 Field poles and pole shoes. Field poles and pole shoes shall not be secured by dowels or in such manner as to prevent removal, replacement, and adjustment. The method of securing poles to the spider or shaft shall result in a factor of not less than 2 based on the elastic limit of the material, at rated speed of the generator. Integral laminated field poles, pole shoes, and spiders for salient-pole generators shall be optional for generators rated 1,000 kilowatts and less. Two-pole generators shall be integral shaft-field pole machines.

3.3.24.3 Field coils. Field coils shall be form-wound. This shall not preclude the use of a salient-pole piece as the form. Field coils of the same type or one design of machines shall be interchangeable in accordance with MIL-E-917. The coils shall be secured so that they cannot become loosened or damaged by vibration, or produce vibration by a slight shifting in coil position. Like coils of the same polarity shall be series-connected with respect to each other.

3.3.24.4 Damper bars. Damper bars (amortisseur) shall be interconnected between poles.

3.3.24.5 Shaft currents. The induction of voltages in the shaft shall be minimized by selection of a number of slots per pole and a number of lamination segments per circle in relation to the pole. Bearings and bearing housings, or both, for generators rated 500 kilowatts and more, shall be insulated to prevent induced shaft currents from flowing through these components. The insulation shall be of the double or sandwich type so that insulation integrity can be verified with the rotor connected to the prime mover and without disassembly. The insulation shall be designed into the system to isolate the bearing housing from the frame. Insulation shall not be used on the shaft to bearing surfaces.

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3.3.25 Electrical insulation. Class F systems, or greater, in accordance with UL 1446 shall be constructed for 250- to 1,000-volt generators.

3.3.25.1 Electrical insulation varnish. At least one vacuum pressure impregnation (VPI) process shall be used, followed by two times dip-and-bake varnishing. Varnishing procedures for either VPI or dip-and-bake processes shall not be used without prior approval from NAVSEA. When the VPI method is used, the type of coil or winding shall be as specified (see 6.2).

3.3.25.2 Air dry varnish. Air dry insulating varnish shall not be used without prior approval from NAVSEA.

3.3.26 Totally enclosed generators. Totally enclosed generators rated 500 kilowatts and more shall be cooled by one of the following methods as specified (see 6.2):

a. Air-cooled with an air-to-water heat exchanger as specified in 6.2.

b. Liquid-cooled with a liquid-to-water heat exchanger.

RTEs for totally enclosed generators shall be as specified in 3.3.19.1 through 3.3.19.3.

3.3.26.1 Air-cooled generators. Air-cooled generators with air-to-water heat exchangers shall be as specified in 3.3.26.1.1 through 3.3.26.1.3.

3.3.26.1.1 Air cooler. The generator air cooler shall be in accordance with MIL-C-19836. Protective zincs shall not be required when fresh water cooling is specified (see 6.2). Unless otherwise specified (see 6.2), construction shall be based on the following:

a. Coolant inlet temperature range of 34 to 95 °F (1.11 to 35 °C).

b. Coolant pressure drop in accordance with MIL-C-19836.

c. Coolant system design pressure of 150 pounds per square inch ($lb/in^2$) gauge.

d. Operation of the turbine generators and cooler at design coolant flow with no throttling required over the specified range of coolant inlet temperatures.

e. Water coolant flow as specified in applicable equipment specifications.

f. Heat transfer capability as specified in applicable equipment specifications.

3.3.26.1.1.1 Water connections. Water connections to cooler heads or waterboxes subject to design or operating pressure in normal operation shall be integral or welded to the heads in accordance with S9074-AR-GIB-010/278; brazing of pipe connections to cooler heads shall be prohibited. Connecting flanges shall be in accordance with 810-1385861. Flanges shall be edge drilled and tapped for Military standard threaded pressure tap connections. If cooler heads or waterboxes have existing, accessible, Military standard threaded vent or drain connections, flanges need not be drilled and tapped. After completion of pressure drop testing plugs, in accordance with SAE-J1926/1, with O-ring seals, shall be installed.

3.3.26.1.1.2 Vent and drain connections. Vent and drain connections shall be in accordance with SAE-J1926/1, ¾-16 UNF-2B.

3.3.26.1.2 Condensation drain. Condensation liquid shall drain to the outside of the machine without contacting electrical windings.

3.3.26.1.3 Generator air temperature measurement. The generator air temperature RTEs shall be located to measure the temperature of air to and from the generator air cooler. Air temperature RTEs shall be removable without the removal of the complete air cooler cover.

3.3.26.2 Liquid-cooled generators. Liquid-cooled generators shall provide a cooling liquid-to-water heat exchanger with construction as specified in 3.3.26.1.1.

3.3.26.3 Electric heaters. Electric heaters, in accordance with MIL-H-22577, shall be provided. The size and number of heaters shall prevent condensation of moisture on the windings. The heaters shall be readily removable for replacement from the outside of the generator without removing more than the access covers.

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3.3.26.4 Drain plugs. Drain plugs, in accordance with MIL-E-2036, shall be provided to properly drain the generator.

3.3.27 Cylindrical rotor field. The cylindrical rotor field shall be as specified in 3.3.24 through 3.3.26.4 (except for 3.3.24.3, 3.3.24.4, and 3.3.25 through 3.3.25.2). In addition, cylindrical rotors shall be as specified in 3.3.27.1 and 3.3.27.2.

3.3.27.1 Field coils. Field coils of non-salient-pole generators shall be form-wound (see 3.3.24.1) before assembly in the core slots, and shall be interchangeable. Field coils shall be secured by slot wedges. The end turns shall be bound with resin treated glass tape in accordance with MIL-E-917, or one-piece shrink-on steel retaining rings as approved by NAVSEA.

3.3.27.2 Slot wedges. Aluminum or beryllium copper slot wedges may be used when high rotational speed and large mass in the rotating element introduce height stresses due to centrifugal force as determined by the manufacturer. Slot wedges shall form a continuous circuit to function as a damper or amortisseur winding.

3.4 Performance. Performance shall be as specified in 3.4.1 through 3.4.30.

3.4.1 Operating life. The generator shall operate satisfactorily over an operating life of not less than 150,000 hours. The life shall be predicated on 20,000 hours at rated-load; 90,000 hours at 60 percent rated-load; and 40,000 hours at 40 percent rated-load. The generator shall withstand not less than 100,000 start/stops during its operating life.

3.4.2 Reliability prediction. The reliability prediction of the generator shall be based on the failure rate of parts, and shall be as specified (see 3.4.1 and 6.2). The inherent mean-time-between-failure (MTBF) of the generator shall be not less than 25,000 hours and the mean-time-to-repair (MTTR) for the generator shall be not greater than 12 hours, assuming that the repair parts are available aboard the ship (see 6.2).

3.4.3 Airborne and structureborne noise. When special noise reduction limitations are not applicable (see 3.3.23), the generator airborne noise shall not exceed levels in accordance with Steady State Noise Category B of MIL-STD-1474.

3.4.4 Power output ratings. Unless otherwise specified (see 6.2), generators shall have the following power output kilowatt ratings based on 80 percent lagging power factor (p.f.):

| **Kilowatt ratings** | |
|---|---|
| 30 | 1,000 |
| 60 | 1,500 |
| 100 | 2,000 |
| 200 | 2,500 |
| 300 | 3,000 |
| 500 | 4,000 |
| 750 | 8,000 |

The kilowatt rating shall be the net power for continuous use. If the generator has any auxiliary equipment, such as a static excitation system that receives power from the generator and functions as an essential part of the basic generator set, the generator shall have capacity in excess of the net power rating to furnish this power. Such capacity shall be the gross kilowatt rating.

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3.4.5 Short circuit requirements. Generators and associated excitation systems shall withstand, without injury to any part, three-phase and single-phase (line-to-line) short circuits at the generator terminals for a period of time as determined by $I^2t = 180$, where I is the sustained value of line current in per-unit and t is the time in seconds. Unless otherwise specified (see 6.2), the sustained value of current during a three-phase or single-phase short circuit shall be not less than 3.2 times rated current.

3.4.6 Voltage rating. Unless otherwise specified (see 6.2), the generators shall be rated at 450 volts.

3.4.6.1 Duty. Generators shall deliver continuous rated current at rated voltage, frequency, and power factor.

3.4.7 Three-phase generators. Three-phase generators shall be as specified in 3.4.7.1 and 3.4.7.2.

3.4.7.1 Phase unbalance. Under a condition of a single-phase load of 15 percent of rated current at any power factor between rated and unity, and with no other load on the generator, the variation in voltage between phases line-to-line shall not exceed 5 percent of rated voltage. The temperature rises shall be not greater than those specified in table III (see 4.6.26).

TABLE III. Maximum temperature rise. 1/

| Machine part | Method of temperature determination | Temperature rises for class of insulation 2/ °F (°C) | | | | |
|---|---|---|---|---|---|---|
| | | F | H | N | R | S |
| Armature winding | | | | | | |
| a. All kVA 3/ ratings | Resistance | 203 (95) | 239 (115) | 275 (135) | 302 (150) | 338 (170) |
| b. 1563 kVA and less | Embedded detector | 221 (105) | 266 (130) | 302 (150) | 356 (180) | 392 (200) |
| c. Over 1563 kVA | Embedded detector | 212 (100) | 257 (125) | 293 (145) | 329 (165) | 365 (185) |
| Field windings | | | | | | |
| a. Salient-pole | Resistance | 203 (95) | 239 (115) | 275 (135) | 302 (150) | 338 (170) |
| b. Cylindrical rotor | Resistance | 203 (95) | 239 (115) | 275 (135) | 302 (150) | 338 (170) |

NOTES:

1/ The temperatures attained by cores, amortisseur windings, and mechanical parts shall not injure the machine in any respect.

2/ Temperature rises are based on an ambient temperature of 233 °F (50 °C). For 104 °F (40 °C) ambient, the temperature rises may be increased 50 °F (10 °C).

3/ kVA stands for kilovolt-ampere.

3.4.7.2 Negative-sequence impedance. Negative-sequence impedance (see 6.5.10) shall be determined as specified (see 4.6.27). Specific limits shall be required only when specified (see 6.2).

3.4.8 Frequency and revolutions per minute. Generators shall have a frequency rated at 60 Hertz and shall be of the r/min rating specified (see 6.2).

3.4.9 Power factor. The rated power factor shall be 0.80, lagging.

3.4.10 Ambient temperature. Unless otherwise specified (see 6.2), generators shall meet the performance requirements as specified herein at an ambient temperature of 122 °F (50 °C).

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3.4.11 Prime movers. The generator shall operate with the following prime movers as specified (see 6.2):

a. Steam turbine.

b. Diesel engine.

c. Gas turbine.

3.4.12 Overload. Each generator shall deliver 150 percent of rated current for 2 minutes (see 4.6.13.2).

3.4.13 Temperature limits. The temperature rises of the various parts of a generator shall not exceed the maximum permissible temperature rises as specified in table III with rated continuous kilowatt load at rated power factor on the generator.

3.4.14 Efficiency. The generator efficiency shall be as specified (see 6.2).

3.4.15 Exciter rating. The capacity of the exciter shall meet the load and overload requirements specified herein.

3.4.15.1 Voltage buildup. Exciters intended for emergency use shall provide rapid, positive voltage buildup under all initial starting conditions and for all normal shipboard operating conditions. Positive buildup shall be obtained at all times regardless of the manner in which the set is shut down. Excitation and regulation equipment, which requires the exciter residual magnetism to be reduced to and held at the minimum to meet performance requirements, shall not be used without auxiliary field flashing or similar devices for positive buildup. Auxiliary circuit devices shall be completely static (no relays) and fail-safe in operation. Acceptability shall be demonstrated by testing with the associated generator, exciter, and voltage regulator (see 4.6.18).

3.4.15.2 Automatic voltage regulator. The automatic voltage regulator shall meet the requirements specified in MIL-R-2729.

3.4.16 Wave shape. Wave shape shall be as specified in 3.4.16.1 and 3.4.16.2 (see 4.6.15).

3.4.16.1 Deviation factor. The deviation factor of the open-circuit terminal voltage shall be not greater than 5 percent on any phase.

3.4.16.2 Harmonic content. From no load to full load, the harmonic content of the output voltage wave shall meet the requirements of the table for Type I power of MIL-STD-1399-300. Harmonic content shall be measured as specified (see 4.6.15.1).

3.4.17 Resistance to shock. The generator shall be shockproof in accordance with hull-mounted items, Grade A, Class I, Type A of MIL-S-901. The generator shall meet the performance requirements of this specification when subjected to the magnitude of shock specified for static and dynamic analyses, or that encountered during the shock test, as applicable (see 4.6.19).

3.4.17.1 Shock test versus static and dynamic analysis. Equipment tested, by reason of weight and size not exceeding the available facilities, shall be subjected to the shock test specified (see 4.6.19). Shock testing shall be used to the maximum extent possible, and static and dynamic analysis shall be used where shock testing is impracticable as approved by NAVSEA (see 4.6.19.1).

3.4.17.2 Use of static shock factor values. The equipment shall withstand shock loads due to steady acceleration at the static shock factor values applied separately in each direction (plus or minus). Each mass element of the unit shall have an inertia load applied equal to:

$$dm \times G \times g$$

Where:

dm = Distribution mass

G = Static shock factor value tabulated herein

g = Acceleration of gravity

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The resulting stresses and deflections, when added to the maximum normal operating values, shall be not more than the allowable stresses or deflections.

3.4.17.3 Allowable stresses. The combination of shock and operating stresses shall be not more than 0.2 percent offset yield strength at operating temperature. The unit loading for combined shock and operating loads on babbitted bearings shall be limited to 22,000 $lb/in^2$. The criteria for failure when plastic set is permissible shall be the effective yield strengths in tension and shear of the material defined as follows:

$$\sigma = \sigma y + F(\sigma u - \sigma y)$$

$$\gamma = 0.6\sigma$$

Where:

$\sigma$ = Effective yield strength in $lb/in^2$.

$\gamma$ = Effective shear strength in $lb/in^2$.

$\sigma y$ = 0.2 percent offset yield, elastic limit, or other normal definition of material yield strength in $lb/in^2$.

$\sigma u$ = Tensile strength or other normal definition of material failure strength in $lb/in^2$.

F = Factor which takes into account the efficiency with which the material in the member is utilized, the cross-section of the material, and the type of loading. The value of F is equal to the quantity (load required to completely yield the member divided by that load required to initiate yielding) minus 1.

The following are examples of F:

F = 0.0 if element is in pure tension.

F = 0.0 for any brittle material, that is, one which has less than 10 percent elongation before fracture in a tension test.

F = 0.5 if section is rectangular and loading is pure bending.

F = 0.7 if section is solid and circular and loading is pure bending.

F = A / (6 + 2A) if section is I beam.

$$A = \frac{\text{(Web width) x (Depth of section)}}{\text{2 x (Flange width) x (Flange thickness)}}$$

3.4.18 Nil-ductility properties. When carbon steels with less than 1 percent of any one alloy are used in the generator mounting feet or mounting brackets, bearing caps, bearing pedestals, and frames, nil-ductility transition temperatures shall be not greater than 53.6 °F (see 4.6.19.2). This requirement shall not apply to plate thicknesses less than ⅝ inch or greater than 4 inches.

3.4.19 Inclined operation. The generator shall operate in accordance with the performance requirements of this specification, shall maintain satisfactory lubrication, and shall experience no loss of lubricating oil under the following conditions. The momentary inclination cycle shall be as specified (see 6.2).

a. When the generator is permanently inclined from the normal horizontal position as much as 5 degrees rotated on the normal horizontal axis through the center of the machine and 15 degrees rotation clockwise or counterclockwise about the axis of rotation.

b. When the generator is momentarily inclined from the normal horizontal position as much as 10 degrees in lieu of 5 degrees as specified in (a) and 45 degrees in lieu of 15 degrees as specified in (a).

3.4.20 Vibration resistance (environmental vibration). The generator shall withstand environmental vibration conditions in accordance with Type I of MIL-STD-167-1.

3.4.21 Vibration (internally excited). The generator shall be balanced so that the reading of the vibration indicator shall be in accordance with MIL-STD-167-1 (see 4.6.5).

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3.4.22 Dynamic balance. The generator rotor shall be balanced dynamically by one of the following methods so that, at rated speed of the rotor, the remaining unbalanced centrifugal force shall not exceed the limits in accordance with Type II of MIL-STD-167-1 (see 4.6.6):

a. Balance weights attached by securely locked, noncorrodible bolts.

b. Balance weights dovetailed and anchored in balancing grooves.

c. Drilling out material or use of various lengths of threaded studs.

d. Securely welded balance weights.

3.4.23 Dielectric strength. The generators shall withstand a dielectric strength test of twice the normal voltage of the circuit, plus 1,000 volts (see 4.6.11).

3.4.24 Electromagnetic interference (EMI). EMI for the generator and associated control equipment (see 4.6.29) shall be in accordance with the following requirements in accordance with MIL-STD-461:

a. CE01

b. CE03

c. CS01

d. CS02

e. CS06

f. RE01

g. RE02

h. RS03

i. UM05

3.4.25 Overspeed. Generators shall withstand an overspeed of 25 percent (see 4.6.9), and not greater than 5,000 overspeed operations of 15 percent.

3.4.26 Transient-subtransient reactance. The transient reactance shall not exceed 20 percent. The range of subtransient reactance shall be between 13 and 16 percent.

3.4.27 Electrical insulation. A sample coil or winding (see 3.3.25.1) shall be provided (see 6.2), which shall have interstices filled in and be free of air and water (see 4.6.1).

3.4.28 Calculations. The voltage dip shall be determined at the generator switchboard, and at the terminals of an induction motor having the characteristics given below when it is started, with the generator carrying an initial load of the magnitude specified below. The voltage dip at the generator switchboard shall not exceed 14 percent rated voltage, and the voltage dip at the motor terminals shall not exceed 16 percent.

a. Motor characteristics:

(1) Rated voltage: 450 volts

(2) Locked-rotor current: I = 0.67 per-unit

(3) Locked-rotor power factor: 0.25 p f.

(4) Full-load power requirements: 0.20 per-unit at rated power factor

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b. Generator switchboard initial load:

(1) Load at rated power factor: 0.80 per-unit

c. Motor cables for submarine ship service application only:

(1) Type: LSTGA-400 in accordance with MIL-DTL-24643

(2) Length: 114 feet from switchboard to motor

(3) Quantity: 4 cables in parallel

d. For other applications, a cable impedance of 0.022 + 0.018j per-unit

3.4.29 Insulation resistance. The insulation resistance, when corrected to 77 °F (25 °C), shall be not less than the following (see 4.6.10):

| | **Megohms** |
|---|---|
| Armature | |
| Totally enclosed generator, rated 750 kW or less | 50 |
| Totally enclosed generator, rated greater than 750 kW | 25 |
| Fields | 50 |

3.4.30 Lubrication system. The bearing lubrication system shall limit the back pressure within bearing cavity to maintain a positive pressure in the bearing seal cavity during operation.

3.5 System safety program. Safety design features, including fail-safe features, shall be incorporated into the design to prevent damage to equipment and to ensure optimal personnel protection during repair or interchanging of any component or assembly (see 6.3).

3.6 Identification plates. The identification plates shall be attached to the part of the generator which is not ordinarily renewed during its normal service life, and shall be located in an accessible position which can be read at all times without danger to personnel. The plates shall be in accordance with Type C or D of MIL-DTL-15024 and MIL-P-15024/5, and shall be installed on and furnished as a part of the generator for which it is intended. Type A identification plates in accordance with MIL-DTL-15024 and MIL-P-15024/5, and constructed of corrosion-resistant steel, nickel-copper alloy, or sheet brass may be used, except where one plate dimension exceeds 5 inches or where more than one plate dimension exceeds 3 inches.

3.6.1 Identification plate markings. The main identification plates for generators shall include the following:

a. Manufacturer's name, identification symbols, serial number, Government drawing number of assembly, and year of manufacture.

b. Salient design characteristics: type, kilowatt, capacity, voltage, current, kilovolt-ampere, frequency, number of phases, power factor, revolutions per minute, overload rating, and permissible temperature rise (unless classified).

c. Contract number.

d. National stock number (NSN).

e. Section for Defense Contracts Management Agency (DCMA) stamp.

3.6.2 Permanent marking. Permanent marking shall be as specified in 3.6.2.1 and 3.6.2.2.

3.6.2.1 Magnet frame. The contractor's serial number shall be stamped on the housing which supports the stator laminations.

3.6.2.2 Rotors. Markings on rotors shall identify the manufacturer, style, and type of generator. The serial number of the rotor shall be stamped on the shaft at the end opposite to the prime mover.

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3.7 Interchangeability. In no case shall parts be physically interchangeable or reversible unless such parts are also interchangeable or reversible with regard to function, performance, and strength.

3.8 Workmanship. Workmanship should follow the guidance provided in Guideline 9 of MIL-HDBK-454.

4. VERIFICATION

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

a. First article inspection (see 4.3).

b. Conformance inspection (see 4.4).

4.2 Inspection conditions. All measurements shall be made within the following ambient conditions:

a. Temperature: 50 to 95 °F (15 to 35 °C).

b. Atmospheric pressure: 550 to 800 millimeters of mercury.

c. Relative humidity: 20 to 80 percent.

4.3 First article inspection. First article inspection shall be performed on the first generator of a design, type, and size offered for delivery when a first article sample is required (see 3.1). This inspection shall include the examination and the tests specified in table IV (see 6.3).

TABLE IV. First article and conformance inspection.

| Test | Requirement | Test method | First article inspection | Conformance inspection | |
|---|---|---|---|---|---|
| | | | | Group A | Group B |
| Examination | 3.2, 3.3, 3.7, and 3.8 | 4.5 | X | X | X |
| Electrical insulation | 3.4.27 | 4.6.1 | X | X | X |
| Air-gap measurements | 1/ | 4.6.2 | X | X | X |
| Resistance | 1/ | 4.6.3 | X | X | X |
| Airborne and structureborne noise | 3.4.3 | 4.6.4 | X | X | X |
| Vibration | 3.4.21 | 4.6.5 | X | X | X |
| Dynamic balance | 3.4.22 | 4.6.6 | X | X | X |
| No-load, rated voltage saturation data | 1/ | 4.6.7 | X | X | X |
| Lubrication | 3.4.30 | 4.6.8 | X | X | X |
| Overspeed | 3.4.25 | 4.6.9 | X | X | X |
| Insulation resistance | 3.4.29 | 4.6.10 | X | X | X |
| Dielectric | 3.4.23 | 4.6.11 | X | X | X |
| Effectiveness of enclosure | 3.3.4 | 4.6.12 | X | --- | --- |
| Heating and overload tests | 3.4.12 and 3.4.13 | 4.6.13 | X | --- | X |
| Insulation resistance (hot) | 3.4.29 | 4.6.14 | X | --- | X |
| Automatic voltage regulator | 3.4.15.2 | 4.6.18 | X | --- | --- |
| Shock tests | 3.4.17 | 4.6.19 | X | --- | --- |
| For three-phase generators only: | | | | | |
| Voltage and current balance | 3.4.6 | 4.6.20 | X | --- | X |
| Three-phase and single-phase short circuit | 3.4.5 | 4.6.21 | X | --- | --- |

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TABLE IV. First article and conformance inspection – Continued.

| Test | Requirement | Test method | First article inspection | Conformance inspection | |
|---|---|---|---|---|---|
| | | | | Group A | Group B |
| Open-circuit saturation | 2/ | 4.6.22 | X | --- | --- |
| Synchronous impedance | 2/ | 4.6.23 | X | --- | --- |
| Transient and subtransient reactance 3/ | 3.4.26 | 4.6.24 | X | --- | --- |
| Phase unbalance | 3.4.7.1 | 4.6.25 | X | --- | --- |
| Phase unbalance heating test 2/ | 3.4.7.1 | 4.6.26 | X | --- | --- |
| Negative-sequence impedance | 3.4.7.2 | 4.6.27 | X | --- | --- |
| Voltage dip determination | 3.4.28 | 4.6.28 | X | --- | --- |
| EMI | 3.4.24 | 4.6.29 | X | --- | --- |
| Short-circuit characteristic data | 1/ | 4.6.30 | X | --- | --- |
| Maintainability | 3.4.2 | 4.7 | X | --- | --- |
| Wave shape | 3.4.16 | 4.6.15 | X | --- | --- |

NOTES:

1/ Observe – no specified requirement.

2/ Only to be performed on the first generator of a given design.

3/ Data is taken from the three-phase short circuit test.

4.4 Conformance inspection. Conformance inspection shall include the Group A and Group B tests specified in table IV (see 6.3).

4.4.1 Sampling for group A tests. Each generator shall be subjected to the Group A tests specified in table IV.

4.4.2 Sampling for group B tests. Generators shall be selected in accordance with table V and subjected to the Group B tests of table IV.

TABLE V. Sampling for group B tests.

| Quantity of machines on contract or order (of the size design, type, and size) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Size of machine in kW | 2 to 8 | 9 to 15 | 16 to 25 | 26 to 40 | 41 to 65 | 66 to 110 | 111 to 180 | 181 to 300 |
| Up to 5 | 4 | 5 | 6 | 8 | 10 | 13 | 17 | 22 |
| 6 to 25 | 4 | 4 | 5 | 7 | 9 | 12 | 15 | 19 |
| 26 to 110 | 3 | 4 | 5 | 6 | 8 | 10 | 13 | 17 |
| 111 to 460 | 3 | 3 | 4 | 5 | 7 | 9 | 12 | 15 |
| 461 to 8,000 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 13 |

4.4.3 Nonconformance. Failure of Group A or Group B tests shall be cause for rejection.

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4.5 Examination. Each generator shall be thoroughly examined to ascertain that the material, workmanship, and construction conform to this specification. The fit of parts shall be observed with particular reference to the interchangeability of such parts as are likely to require replacement during the normal service life of the generator.

4.6 Test methods. Test methods shall be as specified (see 4.6.1 through 4.6.30). Measurements taken shall be provided as specified in the contract or order. Digital data acquisition and computer analysis methods may be used instead of manual calculations with approval from NAVSEA.

4.6.1 Electrical insulation. A sample coil or winding shall be provided (see 3.4.27). The sample shall be cut open and examined for evacuation of all air and water, and the filling in of all interstices as approved by NAVSEA.

4.6.2 Air-gap measurements. The air-gap between the rotor and stator iron shall be measured for generators, exciters, and permanent magnet alternators. The air-gap shall be measured by steel feelers or gauges. The measurements shall be made at four radii (two horizontal and two vertical) at each end of the generator.

4.6.3 Resistance. The DC resistance of the stator and the rotor windings and the temperature at which they are measured shall be taken.

4.6.4 Airborne and structureborne noise. When special noise limitations are required (see 3.3.23 and 6.2), airborne and structureborne noise tests for generator sets shall be in accordance with MIL-G-3087, MIL-G-21296, and MIL-G-22077, or applicable equipment specifications.

4.6.5 Vibration (internally excited). When a generator with a keyed coupling is tested prior to assembly of the couplings on the shaft, the generator shall be balanced with one-half a standard key in the keyway, which shall consist of a key of full length flush with the top of the keyway. When subjected to vibration tests, the rotor shall be mounted in bearing brackets. The method of testing shall be in accordance with MIL-STD-167-1, Type II. A vibration indicator, whereby vibrations of the amplitude of 0.0005 inch may be readily observed on a suitable scale, may be used as a measuring device. Vibration tests shall be taken at no-load, rated speed, and at speed-load conditions.

4.6.6 Dynamic balance. The actual unbalance shall be measured to ensure that the limits in accordance with MIL-STD-167-1, Type II, are achieved. Calculated values based on vibration amplitudes and frequency shall be optional as specified (see 6.2).

4.6.7 No-load, rated voltage saturation data. This test shall be performed in one of the following ways:

a. The generator shall be driven as a synchronous motor with varying field excitation. At the value of minimum armature current, with rated voltage at rated frequency applied to the terminals, the voltage between phases, watts input, field current, field voltage, and speed shall be measured. The generator shall run to allow stable temperatures before readings are taken.

b. The generator shall be driven by any convenient prime mover and sufficient excitation shall be applied to produce rated voltage. Readings of voltage between phases, field current, field voltage, and speed shall be taken. The generator shall run to allow stable temperatures before readings are taken.

4.6.8 Lubrication. The lubricating system shall be observed when the generator is operating in a normal horizontal position to determine whether lubrication is provided. For generators in the inclined positions, lubrication shall be determined when the generator is operating with the prime mover as a unit. This test shall be observed during the progress of the other tests, or as the circumstances warrant. The test may be made at any convenient ambient temperature.

4.6.9 Overspeed. Each generator shall be subjected to an overspeed test at 25 percent greater than the normal operating speed for a period of 5 minutes. Field excitation shall be applied to the field to produce rated voltage. The speed shall be increased slowly until the generator reaches the maximum test speed. The generator shall be at no-load condition. Checks shall be made for noise, mechanical balance, and smoothness of running during the test and for evidence of distortion, damage, or noticeable change in the condition of any part after shutdown. No attached rotating parts, such as welded fans and spiders, need to be tested for a greater overspeed.

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4.6.10 Insulation resistance. This test shall be made before and after the dielectric tests (see 4.6.11). Prior to application of the test voltage, the winding of the machine shall be thoroughly discharged. Separate measurements shall be made on the stator and rotor windings. Circuits of equal voltage above ground shall be connected together. Circuits or groups of circuits of different voltage above ground shall be separated. Insulation resistance shall be measured with an insulation-resistance-indicating meter. The time of test voltage application shall be not less than 60 seconds. The temperature of the generator windings at the time of the test shall be measured. Insulation resistance measurements shall be corrected to 77 °F (25 °C). Correction shall be made on the basis of insulation resistance doubling for each 18 °F (10 °C) decrease in temperature. The insulation resistance test may be conducted at any convenient ambient temperature. The relative humidity at the time of the test shall be measured.

4.6.11 Dielectric. The dielectric test shall be made after all other tests have been completed. If the insulation resistance of the windings is lower than specified, because of dirt or moisture or damage to windings, the condition shall be remedied before application of the dielectric test voltage. The dielectric test shall be made on the completely assembled generator and not upon individual parts unless: (1) it can be demonstrated that the tests on the individual parts are equivalent to a test on the assembled generator; (2) the generator is not assembled when all other routine tests have been completed and the generator is to be shipped in a disassembled condition. If the generator is to be shipped elsewhere for assembly and combined testing, the dielectric test may be conducted there after assembly. An exception is made in the case of maintenance parts, such as coils and rotating elements with insulated windings, which require dielectric testing.

4.6.11.1 Armature windings. The dielectric test voltage shall be equal to twice the rated value of the rms terminal voltage plus 1,000 volts. The frequency of the testing voltage shall be not less than 60 Hertz. The voltage wave shall approximate a sine wave. The testing voltage shall be applied continuously for not less than 60 seconds. Generators built in large quantities for which the test voltage is 2,500 volts or less may be tested for 1 second, with a test voltage 20 percent higher than the 60-second test voltage.

4.6.11.2 Field coils. The dielectric test voltage for field coils shall be equal to 10 times the exciter voltage, but shall be not less than 1,500 volts, nor more than 3,500 volts. The frequency of the testing voltage shall be not less than 60 Hertz. The voltage wave shall approximate a sine wave applied continuously for not less than 60 seconds.

4.6.11.3 Measurements of test voltage. The voltage used in dielectric tests shall be measured by a voltmeter which derives voltage directly from the high voltage circuit, either by a voltmeter coil placed in the testing transformer, or through an auxiliary potential transformer.

4.6.11.4 Points of application. The test voltage shall be applied between each electric circuit and the frame, with all other electric circuits and metal parts grounded. Interconnected polyphase windings shall be one circuit. The test voltage shall be applied in a manner as to prevent pitting the bearings in case of insulation failure. Voltage need not be applied between stationary and rotating windings.

4.6.12 Enclosure. The enclosure shall be tested in accordance with MIL-E-2036.

4.6.13 Heating and overload. Heating and overload tests shall be as specified in 4.6.13.1 through 4.6.13.4.4.

4.6.13.1 Test conditions. The heating and overload tests shall be conducted with the generator assembled to its prime mover in accordance with MIL-G-3087, MIL-G-21296, or MIL-G-22077, as applicable.

4.6.13.2 Duration. Heat runs on continuous-duty (see 6.5.4) generators shall be continued until the steady final temperatures have been attained in all parts of the generator. Steady final temperatures have been reached when at least four consecutive readings taken at 15-minute intervals show no change in the temperature greater than 3.6 °F (2 °C) of any part of the generator. Immediately following all other loads and overloads, the generator shall be run at 150 percent of rated current for 2 minutes at rated voltage and frequency, and at a power factor of 0.5 lagging or less. Temperature measurements are not required. The exciter which is supplied as part of the complete generator set shall be used to supply excitation during the tests.

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4.6.13.3 Measurement of the ambient temperature. Measurement of ambient temperature shall be as specified in 4.6.13.3.1 through 4.6.13.3.4.

4.6.13.3.1 Ambient temperature. A generator may be tested at any convenient ambient temperature above 50 °F (10 °C); however, the maximum temperature rise specified herein shall not be exceeded. Heat runs shall not be undertaken on generators which have recently been brought from a place varying in temperature by 9 °F (5 °C) or more from that in which the test is to be made, or where the temperature of the room in which the generator under test has stood varied 9 °F (5 °C) or more during the preceding 2-hour period.

4.6.13.3.2 Temperature variance during test. Conditions in the testing room shall be such that the ambient temperature will not vary greatly during test. A variation of 18 °F (10 °C) or more during a period of 6 hours, or a proportional change for runs of shorter durations, shall not be exceeded. If the ambient temperature is irregular during the run or changes rapidly at the end, the test shall be repeated.

4.6.13.3.3 Temperature sensors. The ambient temperature shall be measured by two or more temperature sensors placed at different points around (and on a level with) the generator shaft, and at distances 3 to 6 feet from the generator. The ambient temperature sensors shall be protected from drafts, heat radiation, equipment under tests, or outside sources. The sensors shall be inserted in heavy oil-filled cups of not less than 1 inch in external diameter and 2 inches in height.

4.6.13.3.4 Ambient temperature readings. The value to be adopted for the ambient temperature during the tests shall be the readings of several temperature sensors, placed as specified (see 4.6.13.3.3), and taken at four equal intervals of time during the last quarter of the test. During the first part of the heat run, temperature sensor readings shall be taken at ½-hour intervals.

4.6.13.4 Method of measuring temperature. Temperature rise shall be measured as specified in 4.6.13.4.1 through 4.6.13.4.4.

4.6.13.4.1 Temperature rise. Except as specified herein, the method of measuring temperature rise shall be optional. In determining temperature rise, correction shall not be made for barometric pressure, humidity, or deviations of the recorded ambient temperature from the standard ambient temperature of reference. Only one method of temperature determination shall be required for any particular part. Temperature rise for rotating fields shall be measured in accordance with Method 2 of MIL-E-917, and bearings and mechanical parts shall be measured in accordance with Method 1 of MIL-E-917.

4.6.13.4.2 Temperature sensors. When the temperature sensors are furnished for permanent bearing measurements in the case of ring and disk lubrication, additional temperature sensor measurements shall not be taken. When test temperature sensors are necessary, the temperature of the oil shall be taken by the temperature sensor inserted in the inspection hole at the top of the bearing cap and touching the bearing shell.

4.6.13.4.3 Forced lubrication. For forced lubrication, the maximum temperature rise of the bearing shall be taken as the difference between the temperature of the entering oil adjacent to the bearing pedestal and the oil leaving the bearing pedestal, as determined by temperature sensors in the oil feed and drain lines.

4.6.13.4.4 Shutdown temperature. For shutdown, preheated temperature sensors shall be placed on the rotor core and windings. Precautions shall be taken to reduce to a minimum the period of time elapsing between the stopping of the machine and application of the temperature sensors. A curve shall be plotted with temperature readings as ordinates and time as 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.

4.6.14 Insulation resistance (hot). Immediately following the heat run, measurements of insulation resistance shall be taken as specified in 4.6.10.

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4.6.15 Wave shape. The wave shape shall be taken by photographic means from oscilloscopes or by means of digital data acquisiters. The test shall be made when the generator is operating at rated frequency, rated voltage, and no load, as well as rated full-load unity power factor. The following tests shall be conducted with the generator under control of the excitation-voltage regulation system.

4.6.15.1 Harmonic analysis. A harmonic analysis shall be made with the equipment operating at rated frequency, rated voltage, and no load, as well as full-load unity power factor (purely resistive load). All harmonics up to the $31^{st}$ harmonic shall be measured.

4.6.15.2 Deviation factor. The deviation factor shall be determined with the equipment operating under the conditions specified in 4.6.15.1.

4.6.16 Efficiency. When the efficiency of a generator is stated without specific reference to the load conditions, rated load shall be understood. The efficiency shall correspond or be corrected to conditions of rated voltage, current, frequency, and power factor, as may apply. The efficiency shall be determined for 50, 75, and 100 percent of rated continuous kilowatts at rated voltage, frequency, and power factor.

4.6.16.1 Detailed measurement of losses. For generators rated 30 kilowatts or less, it shall not be necessary to segregate the several losses indicated herein. In such cases it shall be sufficient to measure the sum of those losses which remain substantially constant at each load (bearing friction and windage, brush friction, brush contact, and core losses), and separate these from each other and from those losses which vary with the load (armature and field $I^2R$ losses and stray load losses), only as necessary to the proper computation of efficiency. For generators rated more than 30 kilowatts, the several losses shall be measured in the manner specified herein.

4.6.16.2 $I^2R$ losses. The armature and field $I^2R$ losses shall be separately calculated as the product of the square of the current at the load for which the loss is to be computed and the measured DC resistance of the circuit corrected to 257 °F (125 °C).

4.6.16.3 Friction and windage losses. The generator shall be driven at rated speed by an independent motor or prime mover, the output of which shall be determined when driving the generator not excited. The prime mover output, when driving the generator, represents the friction and windage loss.

4.6.16.4 Core loss. Core loss shall be measured in accordance with IEEE 115.

4.6.16.5 Stray load losses. Stray load losses shall be measured in accordance with IEEE 115.

4.6.16.6 Miscellaneous losses. Miscellaneous losses shall be as specified in 4.6.16.6.1 and 4.6.16.6.2.

4.6.16.6.1 Blower supply losses. When a separately driven blower supplies air to a single generator, the power required shall be charged against the generator. When one or more separately driven blowers supply air through a single duct to two or more generators, the power required to drive the blower or blowers shall be charged in proportion against each single generator.

4.6.16.6.2 Voltage regulator and excitation system losses. Power supplied to the voltage regulator and the brushless excitation system shall be considered a loss in determining efficiency.

4.6.17 Weight. The weight of the generator shall be measured.

4.6.18 Automatic voltage regulator. One completely assembled generator and exciter shall be tested with the intended voltage regulator. This test shall be conducted in accordance with MIL-R-2729.

4.6.19 High-impact shock test. The generator shall be tested with the prime mover and meet the requirements of MIL-G-3087, MIL-G-21296, or MIL-G-22077, as applicable. The high-impact shock tests shall be in accordance with MIL-S-901.

4.6.19.1 Design analysis. The "Procedure for Dynamic Shock, Analyses, Review and Acceptance" shall be followed with regard to review and acceptance of dynamic design analysis. (A copy of this procedure may be obtained from NAVSEA.) Identical procedures shall be followed with regard to static analyses. The reviewing activity is the Supervisor of Shipbuilding, New York.

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4.6.19.1.1 Static analyses. Shock analyses of equipment not tested (see 3.4.17.1) shall be based on the following minimum static shock factor values which apply at the bottom of mounting or feet.

| Static shock factor | | | |
|---|---|---|---|
| **Application** | **Vertical** | **Athwartship** | **Fore and aft** |
| Generator | 75 | 45 | 20 |

4.6.19.1.2 Dynamic analysis. When specified (see 6.2), a concurrent dynamic analysis shall be conducted.

4.6.19.2 Nil-ductility. Nil-ductility tests shall be conducted in accordance with ASTM E208 (see 3.4.18). Subject to the acceptance of NAVSEA, impact tests may be substituted when statistical data show correlation between nil-ductility properties and impact values.

4.6.20 Voltage and current balance. Voltage and current balance measurements shall be taken as specified in 4.6.20.1 and 4.6.20.2.

4.6.20.1 Voltage balance. The voltage balance test shall consist of simultaneous measurements of voltage of each phase at an excitation which produces rated voltage in at least one phase. This may be a part of the no-load, rated-voltage saturation data test. The voltage across each phase and field current and field voltage shall be recorded.

4.6.20.2 Current balance. The current balance test shall consist of simultaneous measurements of current in each phase at an excitation which produces rated current in at least one phase. This may be a part of the no-load saturation data tests, if the generator is run as a synchronous motor, by increasing the field current until rated current is produced, or this data may be obtained by short-circuiting the generator terminals and applying sufficient field current to cause rated current to flow. The current per phase, field voltage, and field current shall be measured.

4.6.21 Three-phase and single-phase short circuits. Each of the following short circuit tests shall be conducted with the generator initially at no-load, rated voltage, rated frequency, and under control of the voltage regulator:

a. An abrupt three-phase short circuit.

b. An abrupt single-phase short circuit between any two line terminals.

The short circuit shall be applied for a time not less than that determined by $I^2T = 180$, where I is the sustained value of line current on a per-unit basis. The generator field shall be at rated full load temperature. The test shall demonstrate that the generator and associated excitation system meet the requirements of 3.4.5 and that normal voltage is restored upon removal of the short circuit.

4.6.22 Open-circuit saturation. When specified, sufficient data to plot a no-load saturation curve shall be obtained. Points for this curve shall be taken as follows: four below 60 percent of rated voltage; one between 60 and 90 percent; one at rated voltage; and three above rated voltage. Readings shall be taken with increasing values of field current and, when it is necessary to reduce the field, it shall be reduced to zero and then increased to the desired value. When taking the saturation curve, readings of the driving motor input at zero-field and at rated voltage shall be measured.

4.6.23 Synchronous impedance. Sufficient data to plot a synchronous impedance curve shall be obtained. Six readings from 150 percent rated current shall be measured.

4.6.24 Transient and subtransient reactance. Direct-axis transient and subtransient reactance tests shall be performed in accordance with MIL-STD-705, and the values calculated.

4.6.25 Phase unbalance. The generator shall be loaded with a single-phase load connected line-to-line of 15 percent of continuous rated current at rated voltage and at a power factor not less than the rated power factor (see 3.4.7.1).

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4.6.26 Phase unbalance heating test. The generator shall be loaded with a single-phase load of 15 percent of continuous rated current simultaneously with a balanced three-phase load. The total load shall be not less than generator rated power factor, and the current in two phases shall be approximately (but not greater than) continuous rated current. The single-phase load shall be a unity power factor load and shall not contain rotating equipment. The test shall be continued until steady final temperatures have been attained in all parts of the generator. The applicable requirements specified in 3.4.7.1 shall be met.

4.6.27 Negative-sequence impedance. A negative-sequence reactance ($X_2$) and resistance ($r_2$) test shall be performed in accordance with MIL-STD-705, and the values calculated.

4.6.28 Voltage dip determination. The generator shall be driven by any convenient prime mover and operated with its own exciter and regulator connected in a normal manner, except that the generator voltage regulator reactive droop compensation shall be inoperative.

4.6.28.1 Load application. With the generator driven at a rated speed, voltage, and no-load, a balanced three-phase impedance load, with an impedance of 2.0 per-unit and a power factor of 0 to 0.4 lagging, shall be suddenly applied. One of the line-to-line voltages shall be measured by an oscilloscope. The voltage trace shall be adjusted to not less than 80-millimeter peak-to-peak displacement for rated voltage and not less than 30 cycles before the instant of load application to not less than 6 seconds of operation after the instant of application of load.

4.6.28.2 Calculation. From oscillograms, five peak-to-peak voltage measurements, not less than 5 cycles apart, immediately preceding the instant of load application, shall be made and recorded. Similar measurements at least every 5 cycles immediately following the load application shall also be made. The measurements shall be made by measuring the peak-to-peak displacement between two lines drawn through the center of the light spots of the peaks of the voltage waves which define the envelope of the voltage trace. With the average of the five measurements before the load was applied taken as the reference reading or as unit voltage, the recorded readings after the load was applied shall be divided by the reference reading to obtain the per-unit voltage during the voltage transient. The per-unit voltages shall be plotted against time to a scale on graph paper. A curve shall be drawn through the plotted points. The maximum voltage dip shall be the maximum deviation of the curve from the initial voltage.

4.6.29 EMI. EMI testing for generator sets shall be in accordance with MIL-G-3087, MIL-G-21296, or MIL-G-22077, as applicable (see 3.4.24).

4.6.30 Short-circuited characteristic data. The following tests shall be made to calculate and plot the following data (current against time) on logarithmic coordinate paper. Curves shall be based on a hot field:

a. Symmetrical rms current shall be obtained from a short-circuit, the generator operating at no-load, rated voltage with automatic voltage regulation.

b. Maximum asymmetrical rms current shall be obtained from a short-circuit, the generator operating at full-load, rated voltage with automatic voltage regulation.

4.7 Maintainability demonstration. When the generator is part of a generator set, a maintainability demonstration test shall be conducted on the assembled generator set in accordance with MIL-G-3087, MIL-G-21296, or MIL-G-22077, as applicable (see 6.3 and 6.6). The MTTR shall be as specified in 3.4.2. Accessibility shall be as specified in 3.3.1.

4.7.1 Maintainability test conditions. The maintainability test shall be performed with the equipment or system installed in a manner which simulates, to the satisfaction of the contracting activity, an actual shipboard installation. The access envelope (see 3.3.1) shall be simulated with panels and screens. Test equipment, tools, repair parts, and maintenance instructions shall be available for the performance of the tests. Test team, facilities, and support material shall represent normal shipboard resources. Test mechanics shall be given no outside assistance.

4.7.2 Skill levels. The skill levels of contractor's shop personnel who perform the maintenance tasks of the demonstration test shall be commensurate with Navy personnel who will maintain the generator.

4.7.3 Fault simulation. Simulation of faults or failures by introducing defective parts shall not be required.

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4.8 Pressure drop flow. Cooler pressure drop versus flow curves shall be determined by test for the first air cooler supplied only under each contract or order. Pressure drop shall be measured in accordance with MIL-C-19836 and recorded at 10, 25, 50, 75, and 100 percent of maximum flow (see 3.3.26.1.1.b).

## 5. PACKAGING

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

## 6. NOTES

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

6.1 Intended use. The 60-Hertz AC generator will be used to provide ship service and emergency power when coupled to the prime mover specified in MIL-G-3087, MIL-G-21296, or MIL-G-22077.

6.2 Acquisition requirements. Acquisition documents should specify the following:

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

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

c. Class of insulation system required (see 3.2.2).

d. Whether single- or three-phase generators are required for ratings less than 1,000 kilowatts (see 3.3.2).

e. Type of enclosures required (see 3.3.4).

f. Type of bearings required (see 3.3.8).

g. Type of shaft extension required (see 3.3.9).

h. When special airborne and structureborne noise limitations are required, and any special details, procedures, or features not covered (see 3.3.23 and 4.6.4).

i. Type of coil or winding specified for electrical insulation (see 3.3.25.1).

j. Methods required to cool totally enclosed generators rated 500 kilowatts and above (see 3.3.26 and 3.3.26.1.1).

k. Construction criteria, if other than specified (see 3.3.26.1.1).

l. Reliability prediction of the generator required (see 3.4.2).

m. Kilowatt rating required, if other than specified (see 3.4.4).

n. Per-unit value of current, if other than specified (see 3.4.5).

o. Voltage ratings required, if other than specified (see 3.4.6).

p. When the negative-sequence impedance rating is required (see 3.4.7.2).

q. Revolutions per minute rating required (see 3.4.8).

r. Ambient temperature, if other than specified (see 3.4.10).

s. Type of prime mover required (see 3.4.11).

t. Efficiency required (see 3.4.14).

u. Momentary inclination cycle of the generator required (see 3.4.19).

v. If sample coil or winding is required (see 3.4.27).

w. When dynamic balance calculated values are required (see 4.6.6).

x. When dynamic analysis is required (see 4.6.19.1.2).

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y. Packaging requirements (see 5.1).

6.3 First article. When first article inspection is required, the contracting officer should provide specific guidance to offerors whether the item(s) should be a preproduction sample, a first article sample, a first production item, a sample selected from the first production items, a standard production item from the contractor's current inventory (see 3.1), and the number of items to be tested as specified in 4.4.2. The contracting officer should also include specific instructions in acquisition documents regarding arrangements for examinations, approval of first article test results, and disposition of first articles. Invitations for bids should provide that the Government reserves the right to waive the requirement for samples for first article inspection to those bidders offering a product which has been previously acquired or tested by the Government, and that bidders offering such products, who wish to rely on such production or test, must furnish evidence with the bid that prior Government approval is presently appropriate for the pending contract. Bidders should not submit alternate bids unless specifically requested to do so in the solicitation.

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

6.4.1 Spare parts. When ordering spare parts or repair parts for the equipment covered by this specification, the contract or order should state that such spare parts and repair parts should meet the same requirements and quality assurance provisions as the parts used in the manufacture of the equipment. Packaging for such parts should also be specified.

6.5 Definitions. The following definitions apply to the various technical terms wherever such terms appear in this specification.

6.5.1 Air-gap line. The air-gap line is the extended straight-line part of the no-load saturation curve.

6.5.2 Amortisseur winding. An amortisseur winding is a winding consisting of a number of conducting bars short-circuited at the ends by conducting rings or plates and distributed on the field poles of a synchronous machine to suppress pulsating changes in magnitude or position of the magnetic field linking the poles.

6.5.3 Armature. The armature is that part of the generator which includes the main current-carrying windings.

6.5.4 Continuous duty. Continuous duty is a requirement of service that demands operation at a substantially constant load for an indefinitely long time.

6.5.5 Conventional efficiency. Conventional efficiency is the ratio of output to input where input is determined by addition of the component losses to the output.

6.5.6 Deviation factor. The deviation factor of a wave is the ratio of the maximum difference between corresponding ordinates of the wave and the equivalent sine wave to the maximum ordinate of the equivalent sine wave when the waves are superimposed to make the maximum difference as small as possible.

6.5.7 Direct axis. The direct axis is the axis of magnetization of the main field winding coinciding with the polar axis.

6.5.8 Direct-axis voltage. A direct-axis voltage is a voltage generated by a flux in the direct axis.

6.5.9 Efficiency. The efficiency of a generator is the ratio of the useful power output to the total power input.

6.5.10 Negative-sequence impedance. The negative-sequence impedance is the rated current value of impedance. The value of impedance is obtained from a single-phase short circuit applied between two terminals of the generator when operating at rated speed, and with an excitation which circulates rated armature current in the short-circuited phase. The negative impedance is defined as:

$$\text{Negative-sequence impedance in per-unit } (Z_2) = \frac{0.577E}{I}$$

Where: E = The voltage, per-unit, between the open terminal and either of the short-circuited phases.

I = The sustained armature current, per-unit, measured in the short-circuited phase.

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6.5.11 Per-unit system. In this system, the rating quantity is regarded as unity. Any other amount of the quantity is expressed as a fraction of the rated amount. The per-unit system is the same as the percentage system, except that unity is used as a base instead of 100.

6.5.12 Short-circuit ratio. The short-circuit ratio is the ratio of the field current for rated open-circuit armature voltage at rated frequency to the field current required to produce rated armature current for a sustained symmetrical short circuit at rated frequency.

6.5.13 Subtransient reactance. The subtransient reactance is the rated voltage direct-axis subtransient reactance. This value of reactance will be that obtained from the sudden application of a three-phase short-circuit at the terminals of the generator at rated speed and rated armature voltage and is defined as:

$$\text{Subtransient reactance per-unit } (X''_d) = \frac{E_t}{I''}$$

Where: $E_t$ = The terminal voltage of the generator, per-unit, at the instant before the short circuit is applied.

$I''$ = The value of the short-circuit current, per-unit, is determined by the extrapolation of the envelope of the AC component of the current wave to the sudden application of short-circuit.

6.5.14 Synchronous reactance. The synchronous reactance is the direct-axis unsaturated synchronous reactance. This value is defined as:

$$\text{Synchronous reactance in per-unit } (X_d) = \frac{I_{fec}}{I_{feg}}$$

Where: $I_{fec}$ = The field current required to produce rated armature current under a sustained symmetrical short-circuit at the terminals of the generator.

$I_{feg}$ = The field current required for rated open-circuit voltage on the air-gap line (see 6.5.1).

6.5.15 Transient open-circuit time constant. The transient open-circuit time constant is the direct-axis transient open-circuit time constant, and is defined as the time in seconds required for the rms AC value of the slowly decreasing component present in the direct-axis component of symmetrical armature voltage on open circuit to decrease to 0.368 of its initial value when the field winding is suddenly short-circuited with the machine running at rated speed.

6.5.16 Transient reactance. The transient reactance is the rated voltage direct-axis transient reactance. This value of reactance will be that obtained from the sudden application of a three-phase short-circuit at the terminals of the generator at rated speed and rated armature voltage, and is defined as:

$$\text{Transient reactance in per-unit } (X'_d) = \frac{E_t}{I'}$$

Where: $E_t$ = The terminal voltage of the generator, per-unit, at the instant before the short-circuit is applied.

$I'$ = The value of the short-circuit current, per-unit, determined by the extrapolation on the envelope of the AC component of the current wave to the instant of the sudden application of short circuit, neglecting the high decrement currents during the first few cycles.

6.6 Maintainability test schedule. The contracting activity and NAVSEA should be notified at least 30 days in advance of scheduled maintainability demonstration tests so that arrangements can be made to witness the demonstration, if desired.

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6.7 Responsibility of prime mover manufacturer.

6.7.1 Capacity. The prime mover manufacturer should provide a prime mover of sufficient capacity to drive the generator and exciter under all conditions of load and overload specified herein. Requirements for complete prime mover-driven generator sets incorporating generators built in accordance with this specification are contained in MIL-G-3087 if steam turbine-driven, MIL-G-21296 if diesel engine-driven, and MIL-G-22077 if gas turbine-driven.

6.7.2 Parallel operation. The prime mover manufacturer should successfully demonstrate that angular variation of the rotor of a diesel engine-driven generator due to torsional vibration will not interfere with successful synchronizing of the generators.

6.8 Sub-contracted material and parts. The packaging requirements of referenced documents listed in section 2 do not apply when material and parts are acquired by the contractor for incorporation into the equipment and lose their separate identity when the equipment is shipped.

6.9 Subject term (key word) listing.

Armature

Constant speed

Continuous duty

Exciter

Prime mover

Resistance temperature sensing element

Rotor

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

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