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MILITARY SPECIFICATION

REGULATOR-EXCITER SYSTEMS, VOLTAGE, A.C. GENERATOR, NAVAL SHIPBOARD USE

This specification is approved for use by the 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 high impact (HI) shockproof alternating current (ac) generator voltage regulator-exciter systems for use on Naval surface ships and submarines.

1.2 Classification. Regulator-exciter systems shall be of the following types, as specified (see 6.2).

Type I - Not used.
Type II - Rotary brushless exciter and voltage regulator system.
Type III - Combined static exciter and voltage regulator system.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Sea Systems Command, SEA 55Z3, Department of the Navy, Washington, DC 20362-5101 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

AMSC N/A
FSC 6110

SPECIFICATIONS

FEDERAL

PPP-F-320 - Fiberboard; Corrugated and Solid Sheet Stock (Container Grade), and Cut Shapes.

MILITARY

MIL-S-901 - Shock Tests, H.I. (High-Impact) Shipboard Machinery, Equipment, and Systems, Requirements for.
MIL-E-917 - Electric Power Equipment, Basic Requirements (Naval Shipboard Use).
MIL-I-1361 - Instrument Auxiliaries, Electrical Measuring: Shunts, Resistors, and Transformers.
MIL-E-2036 - Enclosures for Electric and Electronic Equipment.
MIL-C-2212 - Controllers, Electric Motor, A.C. or D.C., and Associated Switching Devices.
MIL-G-3087 - Generator Sets, Steam Turbine (Direct and Alternating Current) Naval Shipboard Use.
MIL-G-3124 - Generator, Alternating Current, 60-Cycle (Naval Shipboard Use).
MIL-C-5015 - Connectors, Electrical, Circular Threaded, AN Type, General Specification for.
MIL-P-15024 - Plates, Tags and Bands for Identification of Equipment.
MIL-P-15024/5 - Plates, Identification.
MIL-S-15291 - Switches, Rotary, Snap Action and Detent/Spring Return Action General Specification for.
MIL-T-16315 - Transformers, Power, Step-Down (Miscellaneous, Naval Shipboard Use).
MIL-E-17555 - Electronic and Electrical Equipment, Accessories, and Provisioned Items (Repair Parts): Packaging of.
MIL-S-18396 - Switches, Meter and Control, Naval Shipboard.
MIL-M-19097 - Motor-Generators, DC to AC, Shipboard Service.
MIL-L-19140 - Lumber and Plywood, Fire-Retardant Treated.
MIL-S-19500 - Semiconductor Devices, General Specification for.
MIL-G-21296 - Generator Sets, Diesel Engine, 450-Volt, 60 Hertz A.C. Single and Twin Engine Driven, Naval Shipboard.
MIL-G-22077 - Generator Sets, Gas Turbine, Direct and Alternating Current Naval Shipboard Use.
MIL-C-26482 - Connectors, Electrical, (Circular Miniature, Quick Disconnect, Environment Resisting), Receptacles and Plugs, General Specification for.
MIL-C-28748 - Connectors, Electrical, Rectangular, Rack and Panel, Solder Type and Crimp Type Contacts General Specification for.
MIL-C-28809 - Circuit Card Assemblies, Rigid, Flexible, and Rigid-Flex.
MIL-M-38510 - Microcircuits, General Specification for.

MILITARY (Continued)

MIL-I-46058 - Insulating Compound, Electrical (for Coating Printed Circuit Assemblies).
MIL-P-55110 - Printed Wiring Board General Specification for.
MIL-C-55302 - Connectors, Printed Circuit Subassembly and Accessories.
MIL-C-83723 - Connectors, Electrical, Circular, (Environment Resisting), Receptacles and Plugs, General Specification for.

STANDARDS

MILITARY

MIL-STD-108 - Definitions of and Basic Requirements for Enclosures for Electric and Electronic Equipment.
MIL-STD-167-1 - Mechanical Vibrations of Shipboard Equipment (Type I - Environmental and Type II - Internally Excited).
MIL-STD-275 - Printed Wiring for Electronic Equipment.
MIL-STD-471 - Maintainability Verification/Demonstration/ Evaluation.
MIL-STD-701 - Lists of Standard Semiconductor Devices.
MIL-STD-721 - Definitions of Terms for Reliability and Maintainability.
MIL-STD-781 - Reliability Testing for Engineering Development, Qualification, and Production.
MIL-STD-1331 - Parameters to be Controlled for the Specification of Microcircuits.
MIL-STD-1629 - Procedures for Performing a Failure Mode, Effects and Criticality Analysis.

HANDBOOKS

MILITARY

MIL-HDBK-217 - Reliability Prediction of Electronic Equipment.
MIL-HDBK-472 - Maintainability Prediction.

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

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

PUBLICATION

NAVAL SEA SYSTEMS COMMAND (NAVSEA)

0967-LP-312-8010 - Electronic Equipment, Shipboard, Maintainability Design Criteria Handbook for Designers of.

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

2.2 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 First article. When specified (see 6.2), a sample shall be subjected to first article inspection (see 6.5) in accordance with 4.3.

3.2 Materials. Materials shall be in accordance with MIL-E-917.

3.2.1 Recovered materials. Unless otherwise specified herein, all equipment, material, and articles incorporated in the products covered by this specification shall be new and may be fabricated using materials produced from recovered materials to the maximum extent practicable without jeopardizing the intended use. The term "recovered materials" means materials which have been collected or recovered from solid waste and reprocessed to become a source of raw materials, as opposed to virgin raw materials. None of the above shall be interpreted to mean that the use of used or rebuilt products is allowed under this specification unless otherwise specifically specified.

3.2.2 Nonstructural parts. Nonstructural parts such as terminal boxes, housings, ducts, and similar parts shall be fabricated from aluminum alloy, where feasible.

3.2.3 Hazardous materials (see 6.6.11). The material shall have no adverse effect on the health of personnel when used for its intended purpose. Questions pertinent to this effect shall be referred by the contracting activity to the appropriate departmental medical service who will act as an advisor to the contracting agency.

3.2.4 Prohibited materials. Regardless of any other requirements, materials and parts containing radioactive material, mercury, cadmium, asbestos, or other materials giving off toxic fumes under operating or casualty conditions, shall not be used.

3.3 Design.

3.3.1 General. Unless otherwise specified herein, regulators and exciters shall conform to MIL-E-917.

3.3.2 Reliability and maintainability.

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

3.3.2.2 Definitions. Unless otherwise specified herein, definitions of terms for reliability and maintainability shall be in accordance with MIL-STD-721.

3.3.2.3 Reliability. The reliability measure shall be Mean Time Between Failures (MTBF) as specified in MIL-STD-781. The MTBF shall be greater than 25,000 hours.

3.3.2.3.1 Reliability prediction. Reliability prediction analysis shall be in accordance with the parts and stress analysis of MIL-HDBK-217 (see 6.2).

3.3.2.3.2 Equipment failure. Voltage regulator-exciter system failure shall be defined as inability of the system to perform and function within the requirements of this specification.

3.3.2.3.3 Stress levels. Stress levels shall be calculated from design data in accordance with MIL-HDBK-217.

3.3.2.4 Maintainability.

3.3.2.4.1 Maintainability measure. The measure of maintainability shall be Equipment Repair Time (ERT) in accordance with MIL-STD-471. The ERT shall be not more than 3 hours. No repair shall require more than 10 hours.

3.3.2.4.2 Maintainability design. Maintainability design shall be in accordance with NAVSEA 0967-LP-312-8010.

3.3.2.4.3 Maintainability prediction. Maintainability prediction shall be in accordance with MIL-HDBK-472, procedure II (see 6.3).

3.3.2.5 Failure modes and effects analysis. Failure modes and effects analysis shall be in accordance with MIL-STD-1629 (see 6.3). Critical items shall be identified.

3.3.3 Detail requirements.

3.3.3.1 Basic requirement. Voltage regulator-exciter systems shall conform to MIL-E-917 (see 6.3). Insulation shall be class A, B, F, or H as selected by the manufacturer in accordance with MIL-E-917. If a rotary brushless exciter is used, it shall conform to the construction and design requirements of MIL-G-3124. Semiconductors used in the rotating rectifier assembly shall be as specified in 3.3.3.5. All verification testing specified in MIL-G-3124 shall be performed with the rotary brushless exciter supplying excitation to the field of the main generator.

3.3.3.2 Enclosure and mounting.

3.3.3.2.1 Type II. Enclosure and mounting shall be as follows:

(a) Rotary exciter - enclosure and mounting shall be as specified (see 6.2).
(b) Voltage regulator - protected enclosure for vertical mounting in switchgear unit.
(c) Voltage adjusting rheostats - open construction for back of board mounting, front of board operation.
(d) Control switch and flashing switch - open construction for back of board mounting, front of board operation.

3.3.3.2.2 Type III. The enclosure shall be either arrangement A or arrangement B as specified (see 6.2).

3.3.3.2.2.1 Arrangement A. Enclosures and mounting shall be as follows:

(a) Static exciter including field rectifiers - dripproof protected enclosure for deck-mounting.
(b) Voltage regulator - dripproof protected enclosure for deck-mounting.
(c) Voltage adjust rheostats - open construction for back of board mounting, front of board operation.
(d) Control switch and flashing switch - open construction for back of board mounting, front of board operation.

3.3.3.2.2.2 Arrangement B. Enclosure and mounting shall be the same as arrangement A, except that the regulator shall be mounted in the exciter enclosure.

3.3.3.2.3 Ambient. Deck-mounted equipment shall be designed for a 50 degree Celsius (°C) ambient. Switchboard, back of board mounted shall be designed for a 65°C ambient. The equipment shall have a non-operating temperature range of minus 40 to 85°C.

3.3.3.2.4 Enclosures. Enclosures shall be spraytight protected in accordance with MIL-E-2036. Ready accessibility of electrical connections, test points, and adjustments shall be provided for convenience in installation and maintenance. Wherever possible, line voltage connections and control circuit test points shall be separated to permit safe troubleshooting with equipment operating. Enclosures and framework shall be constructed of steel, aluminum, or both. The use of aluminum for weight reduction is considered desirable and shall be used if structurally suitable. Enclosures shall be of the dead-front type.

3.3.3.2.5 Cooling. Unless otherwise specified (see 6.2), all components not mounted in the generator airstream shall be cooled by natural convection. Only those components which require forced air-cooling shall be mounted in the airstream. Equipment mounted in the airstream shall be designed with creepage and clearance distances as defined in table IV of MIL-E-917.

3.3.3.3 Resistors, capacitors and rheostats. Resistors, capacitors and rheostats shall be selected and applied in accordance with MIL-E-917.

3.3.3.4 Transformer application. Separate current, potential, and combination transformers shall be used with each regulator-exciter system and no other burden shall be placed on the transformers. Transformers shall be ungrounded.

3.3.3.4.1 Power transformers. Current, potential, or combination transformers used to provide generator field current shall be in accordance with type SA of MIL-T-16315 and shall conform to the materials and methods of manufacture of MIL-E-917 except that allowable temperature limits shall be as specified in table I.

TABLE I. Maximum permissible temperature (°C) - (continuous rated load).

Name of part 1/	Insulation class A	B	C	H
Coils:				
Measured by thermocouples or thermometers	90	110	135	170
Measured by resistance	100	120	145	190
Cores and mechanical parts adjacent to insulation	90	110	135	170
	All classes			
Capacitors - air within 1/2 inch of case:	85			
Rectifiers:	2/			
Rheostats and resistors:				
Bare resistor material	425			
Resistor embedding material	350			
Bolted connection and terminal studs:				
Not plated	100			
Silver plated	115			
Contact:				
Solid	120			
Solid silver faced	130			

1/ Where no measurement method is indicated, thermometer or thermocouple method shall be used.

2/ Silicon rectifiers, voltage reference elements, voltage regulator elements and transistors-permissible temperature rise on these parts is dependent upon operating conditions. Maximum permissible case temperature shall be shown on the equipment drawing.

3.3.3.4.2 Current transformers. Current transformers shall be in accordance with MIL-I-1361 and shall conform to the materials and methods of manufacture specified in MIL-E-917, except that the allowable temperatures shall be as specified in table I.

3.3.3.4.3 Reactors. Reactors shall be in accordance with the materials and methods of manufacture specified in MIL-E-917 except the allowable temperature limits shall be as specified in table I.

3.3.3.5 Semiconductor devices. Individual diodes and controlled rectifiers shall be selected and applied in accordance with MIL-E-917. They shall be of the silicon type and shall be individually replaceable.

3.3.3.5.1 Microcircuits. All integrated circuits shall be selected from MIL-STD-1331, and shall conform to the requirements of MIL-M-38510, class B.

3.3.3.5.2 Discrete devices. All semiconductor devices other than those specified in 3.3.3.5.1 shall be selected from MIL-STD-701 and shall conform to the requirements of MIL-S-19500. The use of devices not listed in MIL-STD-701 shall require specific approval in accordance with the requirements of MIL-E-917.

3.3.3.6 Prohibited parts. The design of the regulator-exciter shall not employ electron tubes.

3.3.3.7 Operating modes. The regulator-exciter system shall have the following operating modes:

(a) Automatic.
(b) Backup.
(c) Off.

The "Off" function may be on either the control switch (see 3.3.3.8.1) or the field flashing switch (see 3.3.3.8.2) where used. When the operation mode is "Off", the design shall be such that the regulator-exciter output is zero.

3.3.3.8 Operators controls.

3.3.3.8.1 Control switch. Control switches shall be in accordance with MIL-S-15291 for switchboard mounting, and shall be rated in accordance with the table for class designation therein. A single control switch shall be provided having "Automatic", "Backup" and "Off" positions. Switches for ship's service generator sets shall be furnished with a spare set of contacts which shall be rated for 5 amperes (A), 450 volts (V), single phase, ac and arranged to close in the "Off" position. Switches for emergency generator set applications shall be furnished with a spare set of contacts which shall be rated for 5 A, 450 V single phase, ac and arranged to close in the "Automatic" position only. The switch contact arrangement shall be such that input signals to the switch for "Automatic" and "Backup" operation can be electrically isolated. The design of the system and the switching arrangement shall be such that excitation control can be switched from "Automatic" to "Backup" and from "Backup" to "Automatic" under any condition of load on the generator without injury or damage to any system component. If switch design limits the number of contacts, the "Off" function may be contained on the flashing switch (if used) rather than the control switch.

3.3.3.8.2 Field flashing. For ship's service generator applications, field flashing power for initial voltage build-up shall be applied by means of a separate switch or pushbutton to electrically isolate the flashing source when not in use. Switches for applying field flashing power shall be in accordance with MIL-S-15291 or MIL-S-18396, for switchboard mounting. The switch shall be provided with either "Flash" and "Normal" or "Flash", "Normal", and "Off" positions. The "Flash" position shall be of the momentary type with forced spring return to the "Normal" position. Pushbuttons, if used, shall be of the normally-open, double pole type in accordance with MIL-C-2212 and suitable for back of board mounting, front of board operation. For emergency generator set applications, only devices that are completely static (no switches or relays) shall be used in the field flashing circuit to ensure that field flashing will be automatic and completely reliable, the only exception being an "Off" position contact, to remove flashing current in the "Off" position.

3.3.3.8.3 Voltage adjusting means. Separate manual adjustment of the generator voltage maintained by the voltage regulator and backup voltage control shall be furnished. The adjusting means provided shall be suitable for back of panel mounting, front of panel operation.

3.3.3.8.4 Backup voltage control. A voltage control, suitable for back of board mounting and front of board operation, shall be provided for control of the generator voltage without the use of the basic voltage regulator circuit and its associated components. This control may be manual or automatic. If automatic, it shall duplicate the voltage regulator.

3.3.3.8.5 Direction of rotation - rotary control devices. Voltage adjusting devices shall be provided to increase the generator terminal voltage by turning to the right (clockwise) and decrease voltage by turning to the left (counter-clockwise).

3.3.3.9 Heating. The maximum allowable temperatures shall be as specified in table I.

3.3.3.10 Insulation resistance. The insulation resistance, when tested in accordance with 4.6.16, shall be not less than 5 megohms.

3.3.3.11 Dielectric strength. Voltage regulator sets shall withstand the dielectric test voltage specified in 4.6.17.

3.3.3.12 Shock. The voltage regulator-exciter system shall withstand the HI shock test as specified in MIL-S-901 (see 4.6.18).

3.3.3.13 Vibration.

3.3.3.13.1 Type II. The regulator and all switchboard mounted components shall be designed and tested, to withstand externally excited vibration, type I, as specified in MIL-STD-167-1 (see 4.6.19). The rotating exciter shall be designed and tested for the same degree of vibration resistance as specified for the generator to which it is attached.

3.3.3.13.2 Type III. The exciter, the regulator, and all switchboard mounted components shall be designed and tested to withstand externally excited vibration, type I, as specified in MIL-STD-167-1 (see 4.6.19).

3.3.3.14 Life. Wherever the expected life of parts is predictable and can be controlled through design of application, the parts shall be designed or applied so that equipment life of 40,000 hours of operation can be expected.

3.3.3.15 Configuration and excitation source.

3.3.3.15.1 Type II. Unless otherwise specified (see 6.2), generator excitation power shall be obtained by rectifying the output of voltage and current transformers or combination transformers connected to the ac generator terminals. If specified, excitation power for turbine and engine-driven generators may be furnished wholly from a shaft-mounted permanent magnet alternator (PMA). If specified, excitation power for a motor-driven generator may be furnished wholly from the motor power supply.

3.3.3.15.2 Type III. Unless otherwise specified (see 6.2), generator excitation power shall be obtained by rectifying the output of voltage and current transformers or combination transformers connected to the ac generator terminals. If specified, excitation power for a motor-driven generator may be furnished wholly from the motor power supply.

3.3.3.15.3 Flashing source. Unless otherwise specified (see 6.2), the system shall not depend on any voltage source external to the prime mover-generator set for flashing the ac generator field in either the "Automatic" or "Backup" mode of operation. Provision may be made for automatically flashing the ac generator field from the ship's service power supply during the starting of a motor-driven generator (see 6.2).

3.3.3.16 Voltage sensing. The voltage regulator sensing circuit shall sense the average of the three line-to-line voltages of the generator. The overvoltage limiting shall sense individual line-to-line voltages.

3.3.3.17 Isolation. The voltage regulator, voltage adjusting rheostats, exciter (either type II or type III) and generator field shall be electrically isolated by transformers from the generator armature output terminals.

3.3.3.18 Assembly. To facilitate troubleshooting and repair, the equipment shall, insofar as practicable, be packaged into functional assemblies. Such assemblies, except those which are plug-in assemblies, shall be wired to associated assemblies with screw terminal connections for ease of replacement.

3.3.3.19 Printed circuit board assemblies. Printed circuit board assemblies shall be in accordance with MIL-STD-275 unless otherwise specified herein.

(a) Each printed circuit board shall be protected by a conformal coating in accordance with MIL-STD-275. Such conformal coating shall be type UR of MIL-I-46058 and shall be easily removable by means of a soldering iron without damage to the printed circuit board and shall be inspected to the acceptance criteria of MIL-P-28809.

(b) Printed circuit board assemblies shall be plug-in, and each shall include keying provisions such that it shall not be possible to plug in any assembly in an incorrect mounting location.

(c) Guides or tracks shall be provided to direct each printed circuit board assembly into its mounting location. Each printed circuit board assembly shall be restrained in its mounting location by captive hardware. No special tools shall be required to remove or install an assembly.

(d) An extender board shall be provided to assist in troubleshooting the printed circuit board assembly. The extender board shall extend each circuit at the terminals of the printed circuit board assembly. Each circuit shall be readily accessible on the extender board without removing any other assembly.

3.3.3.19.1 Printed circuit boards. Printed circuit boards shall be in accordance with MIL-P-55110.

3.3.3.20 Multipin connectors. Multipin connectors shall conform to MIL-C-5015, MIL-C-26482, MIL-C-28748, MIL-C-55302, or MIL-C-83723 series 3. Connectors shall be selected such that the connector crimp or solder cups are of sufficient size to permit termination or the required wire size without cutting or otherwise deforming the wire to fit the crimp or cups.

3.3.3.21 Test and readout panel. The equipment shall include a test and readout panel to aid in monitoring circuitry for ease of maintenance. The panel shall provide test points for control circuits for making measurements of voltage, current, and resistance as necessary for troubleshooting and adjusting operation of the equipment. Test points shall be provided at terminals arranged on a terminal board located in a readily accessible position on the panel.

3.3.3.22 Under-frequency operation. The regulator-exciter shall withstand without damage sustained operation at any frequency from rated to zero. Protective devices shall not be used to meet this requirement.

3.3.3.23 Over-frequency operation. The regulator-exciter shall withstand without damage sustained operation at frequencies between rated and 125 percent rated. The regulator-exciter need not maintain the required steady-state voltage regulation (see 3.4.1) during overspeed operation above 105 percent of rated speed.

3.3.3.24 Overvoltage limiting. Overvoltage limiting shall be provided to limit the voltage in the event of a failure in the regulator or exciter. The voltage limiting feature shall be functional in both the "Automatic" and "Backup" modes of operation.

3.4 Performance requirements.

3.4.1 Steady-state voltage regulation (see 6.6.5). With all reactive compensation circuits inoperative, the voltage regulator system shall maintain the average voltage on the generator with which it is intended to operate within a steady-state voltage regulation band (see 6.6.5) of 2 percent of rated voltage at any frequency between 95 to 105 percent of rated frequency. The generator shall operate anywhere from no load to rated kilowatt (kW) load at any power factor (p.f.) between 0.5 lagging and 0.8 leading. The average of the three line-to-line voltages at each load point shall be considered as the average voltage of the generator. The above limits apply for extended periods of time (minimum 8 hours) and for any mounting orientation of the regulator-exciter. The average voltage maintained by the voltage regulator-exciter shall be within 3 percent of rated voltage for single-phase loading as specified in 4.6.4. The average voltage maintained by the voltage regulator-exciter after any or all blows of the class HI shock test shall be not more than 1 percent above or below the average voltage held before the shock test, without adjustment.

3.4.2 Transient voltage variation (dip or rise). With the regulator-exciter system in the "Automatic" mode, the maximum dip or rise in generator voltage for a given load change shall be as required by MIL-G-3124.

3.4.3 Recovery time. The time to return to, and remain within, 3 percent of rated voltage following the application or removal of 2.0 per unit impedance load of at zero to 0.4 lagging power factor shall not exceed 1.5 seconds.

3.4.4 Short circuit current. The voltage regulator-exciter system shall be capable of maintaining, 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. The sustained value of current during a three-phase or single-phase short circuit shall be at least 3.2 per unit. The system shall restore normal voltage upon removal of the short circuit.

3.4.5 Generator overload. The voltage regulator-exciter system shall maintain generator voltage within 5 percent of rated voltage with the generator delivering 150 percent of rated line current of 0.5 p.f. lagging and rated frequency for 2 minutes. Where a generator kW overload rating is specified (see 6.2), the voltage regulator-exciter shall maintain rated generator voltage for the overload and duration specified.

3.4.6 Voltage adjustment range and steps. The voltage adjusting means furnished for the "Automatic" and "Backup" modes shall be capable of changing the voltage from 3.0 percent below to 7.0 percent above rated voltage in steps of not more than 1.0 percent of rated voltage at any load from no load to full load at rated p.f. This requirement shall be met with the reactive droop compensation circuit, if provided, inoperative.

3.4.7 Parallel operation of generators. When parallel operation is specified (see 6.2), a reactive compensation circuit shall be provided, as specified (see 6.2).

3.4.7.1 Reactive droop compensation. When specified (see 6.2), an adjustable reactive droop compensation circuit shall be provided. The range of adjustment shall be from zero to at least 10 percent of rated voltage in steps not to exceed 0.2 percent of rated voltage.

3.4.7.2 Reactive differential compensation. When specified (see 6.2), a reactive differential compensation circuit shall be provided.

3.4.7.3 Division of reactive (KVAR) load. The KVAR load of any generator (expressed as a percentage of its KVAR rating) shall not differ from the total KVAR load of all paralleled generators (expressed as a percentage of the total KVAR rating of all paralleled generators) by more than 5 percent as load is varied from 0 to 100 percent of the total KVAR rating of the generators at any power factor from 0.5 lagging to 0.8 leading.

3.4.8 Voltage waveform. The voltage regulator-exciter system shall not contribute more than 0.5 percent to the generator voltage deviation factor, nor more than 0.5 percent of any individual frequency voltage harmonic.

3.4.9 Power factor. The ship's loads are normally of lagging p.f. It is possible, however, that generators may occasionally operate at leading p.f. At rated kW load with 0.8 leading p.f., the regulator-exciter shall be capable of maintaining generator terminal voltage within the steady-state voltage regulation band.

3.4.10 Overvoltage limit. An overvoltage limiting circuit shall be incorporated in the voltage regulator-exciter system. This circuit shall automatically limit generator overvoltage to a value not exceeding the set value between 105 and 130 percent, in steps not exceeding 2.0 percent of rated voltage. The normal setting for overvoltage limiting shall be 110 percent of rated voltage.

3.5 Identification plates. The identification plates shall be attached to the part of the equipment which will not ordinarily be renewed during its normal service life. These plates shall be located in a readily accessible position where they can be read at all times without danger to personnel. Identification plates shall be either type A, B, or C in accordance with MIL-P-15024 and MIL-P-15024/5. All engraved, stamped or direct etched markings shall be filled with black paint, enamel or lacquer. The information marked on the plates shall include the following items:

(a) Manufacturer's name, identification symbols, serial number, contract or order number, and date of manufacture.
(b) Salient design characteristics, for example, type, frequency, voltage, and capacity.
(c) Space for inspector's official stamp.
(d) National stock number, if available.

3.6 Workmanship.

3.6.1 General. Workmanship shall be in accordance with the requirements herein applicable to soldering, marking of parts and assemblies, wiring, welding and brazing, plating, riveting, finishes, machine operations, screw assemblies, and freedom of parts from burrs, sharp edges, or any other damage or defect that could make the part (or equipment) unsatisfactory for the purpose intended.

3.6.2 Threaded parts or devices. Screws, nuts, and bolts shall show no evidence of cross threading, mutilation, or detrimental or hazardous burrs.

3.6.2.1 Tightness. Screw-type fasteners shall be tight. The word tight means the screw shall be firmly secured and that there shall be no relative movement possible between the attached parts.

3.6.3 Wiring. Insulated wire shall be formed into cables or ducted wherever practicable. Wires and cables shall be positioned or protected to avoid contact with rough or irregular surfaces.

4. QUALITY ASSURANCE PROVISIONS

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

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

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

(a) First article inspection (see 4.3).
(b) Quality conformance inspection (see 4.4).

4.3 First article inspection. First article inspection shall be made on the first voltage regulator-exciter of a given design, type, and size as specified in table II. First article inspection shall be required after any change in design or use with a new generator design which affects the performance characteristics. Only those performance characteristics affected by the change in design need be repeated.

4.4 Quality conformance inspection. Quality conformance inspection shall be conducted on every voltage regulator-exciter equipment offered for delivery as specified in table II.

TABLE II. First article inspection and quality conformance inspection.

Examination and tests	Requirement	Test method	First article inspection	Quality conformance inspection
Visual examination	3.2, 3.2.2, 3.3.2.1, 3.3.3.3, through 3.3.3.8.5	4.5	X	X
Creepage and clearance distances	3.3.3.17	4.6.1	X	--
Steady-state voltage regulation	3.4.1	4.6.2	X 1/	X 2/
Frequency effect	3.4.1	4.6.3	X 1/	X 2/
Average of phase voltages	3.4.1	4.6.4	X 1/	--
Voltage waveform	3.4.8	4.6.5	X 1/	--
Voltage adjustment	3.4.6	4.6.6	X 1/	X 2/
Voltage transient and recovery time	3.4.2, 3.4.3	4.6.7	X 1/	--
Generator short circuit	3.4.4	4.6.8	X 1/	--
Leading power factor	3.4.9	4.6.9	X 1/	--
Under-frequency operation	3.3.3.22	4.6.10	X 1/	--
Over-frequency operation	3.3.3.23	4.6.11	X 1/	--
Parallel operation	3.4.7	4.6.12	X 1/	--
Generator overload	3.4.5	4.6.13	X 1/	X 2/
Endurance and heating	3.3.3.9	4.6.14	X 1/	--
Enclosure	3.3.3.2.4	4.6.15	X	--
Insulation resistance	3.3.3.10	4.6.16	X	X
Dielectric strength	3.3.3.11	4.6.17	X	X
Shock	3.3.3.12	4.6.18	X	--
Vibration	3.3.3.13	4.6.19	X	--
Maintainability	3.3.2.4.3	4.6.20	X	--
Overvoltage limiting test	3.3.3.24, 3.4.10	4.6.21	X 1/	X 2/

1/ These tests shall be conducted with the generator, or with the generator and prime mover, for which the regulator-exciter system is intended.
2/ These tests may be conducted with the generator, or with the generator and prime mover for which the regulator-exciter system is intended, or a simulated generator operation may be used (see 4.6.22).

4.5 Visual examination. A careful examination shall be made of the materials and workmanship to ascertain that they are of the quality specified herein. The principal features of the design such as terminal connections, case construction mounting, nonstructural parts, assembly, and identification plate data shall be checked for compliance with this specification.

4.6 Test procedures (see 6.3).

4.6.1 Creepage and clearance distances. Creepage and clearance distances shall be demonstrated by actual measurement to be in accordance with MIL-E-917.

4.6.2 Steady-state voltage regulation. Steady-state voltage regulation tests shall be conducted as follows:

(a) The generator used for the test shall be loaded with a second generator or a balanced impedance load at rated frequency and any convenient p.f.

(b) The test shall be conducted with the rotating and control equipment at room temperature. The reactive droop compensation circuit, if provided, shall be inoperative.

(c) The voltage regulator-exciter system shall be in the "Automatic" mode with no load on the generator. Adjust the average voltage and the frequency to their rated values; no further adjustments shall be made to the voltage regulator system during the remainder of the test. The first set of readings shall be taken within 2 minutes after the equipment energized. The equipment shall then be operated in this no load condition for 30 minutes after which another set of readings shall be taken.

(d) Load shall be applied to the generator from no load to rated full load, rated field current, in five approximately equal steps, and back to no load in the same manner. A set of readings shall be taken at each point after voltage and current levels have stabilized. The average of the three voltages read at each point shall be considered the voltage for that load point.

(e) The minimum readings to be taken during the tests shall be the three generator root mean square (rms) voltages and output line currents, frequency, kW output, and generator field voltage and current, to determine compliance with 3.4.1.

(f) If the "Backup" mode is automatic (duplicate of the voltage regulator), the tests shall be repeated with the voltage regulator-exciter system in the "Backup" mode. This test of the "Backup" mode shall not be performed until after the average of phase voltages test (see 4.6.4) is completed.

4.6.3 Frequency effect. Immediately following the test of the "Automatic" mode specified in 4.6.2, without making any adjustment and with the generator operating at no load, the generator frequency shall be varied from 95 to 105 percent of rated frequency in six steps, approximately equally spaced. This test shall be repeated either at (a) full rated kW load and rated p.f., or (b) with the generator operating at a load corresponding to rated full load rated field current at any convenient p.f. At each point the three line rms voltages shall be read and the average obtained, after voltage levels have stabilized, to determine compliance with 3.4.1. The minimum readings taken during the test shall be the three generator line-to-line rms voltages, the three line currents, frequency, kW output, and the generator field current and field voltage.

4.6.4 Average of phase voltages. Immediately following the test for the frequency effect specified in 4.6.3, without making any adjustments and with the generator operating at rated revolutions per minute (r/min), no load, a single-phase resistance load of 15 percent of the generator rated full load current shall be applied, rated full load current being the current at rated kW and rated p.f. The minimum readings to be taken during this test at each set point shall be three line-to-line rms voltages, three line currents, kW frequency, field current, and field voltage to determine compliance with 3.4.1.

4.6.5 Voltage waveform. The reactive droop compensation circuit, if provided, shall be inoperative. With the generator operating at rated r/min, kW, and p.f., the voltage waveform and spectral analyses of the generator shall be taken. With the generator operating at rated r/min, kW, and p.f. and with the regulator/exciter disconnected and the generator field supplied by a direct current (dc) power supply, the voltage waveform and spectral analysis of the generator shall be recorded. The results of these two tests shall be compared to determine compliance with 3.4.8.

4.6.6 Voltage adjustment range and steps. Voltage adjustment range and steps test shall be conducted as follows:

(a) The reactive droop compensation circuit, if provided, shall be inoperative. With the voltage regulator-exciter system in the "Automatic" mode and the generator at rated r/min at no load:

(1) Operate the voltage adjustment device at the maximum and minimum values.
(2) Operate the voltage adjustment device from 3 percent below to 7 percent above rated voltage in 1 percent steps.

(b) Repeat (1) and (2) above for rated load conditions.

4.6.6.1 The minimum parameter for each set of readings taken during the tests shall be the three generator line voltages, the three line currents, frequency, kW, field voltage and field current, and division numbers on the voltage adjust rheostat, if it is marked.

4.6.6.2 Repeat the tests of 4.6.6 with the voltage regulator-exciter system in the "Backup" mode.

4.6.7 Voltage transient and recovery time.

4.6.7.1 General. The generator shall be operated with its intended voltage regulator-exciter system. The reactive droop compensation circuit, if provided, shall be inoperative.

4.6.7.2 Load application and removal. Load application and removal shall be conducted as follows:

(a) With the generator at rated speed, voltage, and no load, a balanced 3-phase load having an impedance no greater than 2 per unit and a p.f. of zero to 0.4 lagging shall be applied suddenly, to determine compliance with 3.4.2 and 3.4.3.
(b) This test shall be repeated for sudden removal of the same load, without adjustment of the generator r/min or of the voltage.
(c) If reactive droop compensation is provided, transient tests (a) and (b) shall be repeated with reactive droop compensation set at 4 percent.

4.6.7.3 Minimum readings. The minimum readings to be taken during each test are as follows:

(a) Steady state: Before and after each load application or removal; three line-to-line generator rms voltages, three line currents, frequency, kW, field voltage, and current.

(b) Transient: At least one of the line to line voltages, one of the line currents, a timing trace, and field voltage shall be determined by means of a moving galvanometer-type magnetic oscillograph. The voltage trace shall be adjusted so as to have no less than 4 inches peak-to-peak displacement for rated voltage. This film speed shall be such as to give approximately eight cycles per inch, and sufficient film used to record continuous operation from at least 0.5 second before the instant of load application or removal to at least 4 seconds of operation after the instant of application or removal of load.

4.6.7.4 Calculation. From oscillograms, five peak-to-peak measurements of voltage, at least five cycles apart, immediately preceding the instant of load change shall be made. These 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 and current waves which define the envelope of the trace. The average of these five readings will give the reference reading before load change. Make similar measurements immediately following the load change in the following manner: one measurement after one cycle, then five measurements spaced two cycles apart, and additional measurements spaced five cycles apart until steady state conditions exist. These readings divided by the reference reading shall be considered as p.u. values during the transient. These p.u. values versus time shall be plotted to scale on graph paper. A curve shall be drawn through these plotted points. A horizontal straight line shall be drawn through the average of the results plotted for the last recorded second of readings, which should be for a time interval starting at least 3 seconds after the load was applied or removed, in order to obtain the recorded oscillographic voltage or current for the final sustained reference. The limits of 3.4.2 and 3.4.3 shall also be drawn on this graph.

4.6.8 Generator short circuit test. The generator short circuit test shall be conducted as follows:

(a) The generator at rated r/min, rated voltage, and no load shall be suddenly short circuited, 3-phase. The short circuit shall be maintained for a period as determined by the formula in 3.4.4.

(b) Repeat the test in (a) above except that the generator shall be initially operating at rated load, unity p.f.

(c) Repeat the test in (a) above except that the short shall be applied line to line (rather than 3-phase) and maintained for a period of time determined by the formula in 3.4.4.

(d) The minimum readings to be taken during each test shall be as follows:

(1) Steady state readings, before and after the short circuit; three line-to-line voltages, three line currents, frequency, kW, field current and field voltage. During the short, one of the line currents, field current, and field voltage shall be taken.

(2) Transient: During the short, one of the line voltages, one of the shorted line currents, field voltage and field current shall be taken by means of a moving galvanometer-type magnetic recorder. The deflections of the oscillograph elements shall be as large as possible, consistent with obtaining legible oscillograms. The film speed shall be at least 0.5 feet per second. Sufficient film shall be used to record continuous operation from at least 0.5 second before the instant of short-circuit until the voltage has fully recovered and stabilized after the fault removal.

4.6.9 Leading power factor test. Leading power factor test shall be conducted as follows:

(a) With the generator operating at rated speed and voltage, a leading p.f. load shall be applied. The load shall be rated kW and 0.8 p.f. leading.
(b) Minimum readings to be taken are, at no load and at rated load, the three line-to-line voltages, the three line currents, kW, frequency, field voltage, and field current.

4.6.10 Under-frequency operation. The generator, at no load and under the control of its intended voltage regulator-exciter, shall be operated at rated frequency to zero output in 5 hertz (Hz) steps. The unit shall be operated at each point until temperatures stabilize, to determine that allowable temperatures of table I are not exceeded nor any other damage will occur. No other requirements apply to the underfrequency operation.

4.6.11 Over-frequency operation. The voltage regulator-exciter system shall be in the "Automatic" mode. The generator shall be operated at no load in 2 Hz steps from rated frequency to that frequency corresponding to rated overspeed of the prime mover. The unit shall be operated at each point until temperatures stabilize, to determine that allowable temperatures of table I are not exceeded nor any other damage occurs.

4.6.12 Parallel operation. The parallel operation test shall be conducted as specified in MIL-G-3087 for turbine generators, or MIL-G-21296 for diesel generators, or MIL-G-22077 for gas turbine generators, or MIL-M-19097 for motor driven generators to determine compliance with 3.4.7.3 for reactive load division. The test shall be performed with the voltage regulator-exciter system of each generator in the "Automatic" mode, and the reactive compensation circuit of each system operative. The reactive compensation circuits of both generators must either be reactive droop compensation or reactive differential compensation, as specified (see 6.2).

4.6.13 Generator overload. With the generator initially operating at rated voltage, rated frequency, no load and with the voltage regulator-exciter in the "Automatic" mode, a balanced load of 150 percent of rated generator current at 0.5 to zero p.f. lagging shall be applied and maintained for 2 minutes to demonstrate compliance with 3.4.5. Readings of the three output voltages shall be taken prior to applying the load. At the end of the 2 minute test period readings of the output voltages, line currents, field voltage, field current, and output power shall be taken prior to removing the test load.

4.6.14 Endurance and heating.

4.6.14.1 Endurance. The voltage regulator-exciter system shall be required to control its intended generator continuously for 8 hours at rated load without any adjustment. The unit shall be checked for any possible change in regulated voltage or other erratic operation that may occur. A sufficient warm up period may be permitted prior to conducting this test to allow for any changes or drift in voltage regulator characteristics in going from cold to hot running conditions.

4.6.14.2 Heating. Heating tests shall be made on the voltage regulator-exciter when operated at rated voltage and current conditions. At the supplier's option, the heating tests may be performed at the same time as the endurance test specified in 4.6.14.1. In those cases where the loading of certain circuit components may be greater at some low or intermediate load point than its rated load, additional tests shall be required to demonstrate that these components are not overheating at these loads. The equipment shall be operated until the temperature has stabilized in all components. However, in no case shall the duration of the test be less than 4 hours. Temperature measurements shall be taken at 30 minute intervals. It shall be considered that stabilized temperatures have been reached, when at least three consecutive readings taken at 15 minute intervals do not differ by more than 2°C. Maximum temperatures taken, shall be within the limits shown in table I when corrected to a 50°C ambient.

4.6.14.3 Heat and endurance readings. The following minimum reading shall be taken during the heating tests. If the endurance test is run separately, (a) shall apply:

(a) Three generator output voltages and line currents, frequency, kW output, and generator field voltage and current.
(b) Room ambient temperature.
(c) Temperature of air entering and leaving any enclosure whose height exceeds 36 inches. The latter measurement shall be taken not more than 4 inches below the top cover of the cubicle.
(d) Thermometer or thermocouple readings of all parts. Where two or more identical components are used in a circuit (such as three single phase transformers in a 3-phase bank) readings shall be taken on at least 1/3 of the components.

4.6.14.4 Measurement methods. Measurement methods used in the heating tests shall be as specified herein. Detailed procedures of method 1 (thermometer) and method 2 (resistance) shall be as specified in MIL-E-917.

4.6.14.5 Ambient temperature. The ambient temperature shall be measured in accordance with MIL-E-917.

4.6.14.6 Semiconductor devices. The temperature rise of semiconductor devices shall be measured as follows: The case or cell temperature required for semiconductor devices relying upon a cooling fin or other surface, to dissipate heat from the case to the ambient shall be measured by placing a thermocouple in direct contact with the case. Position on the case shall be on the high temperature side of the case. In no instance shall the thermocouple be placed on the cooling fin or other heat dissipating surface.

4.6.15 Enclosure test. The enclosure test shall be as specified in MIL-STD-108 to determine if the enclosure is dripproof.

4.6.16 Insulation resistance. The insulation resistance test shall be conducted before the dielectric test. Prior to the application of the test voltage, all circuits shall be thoroughly discharged. The test voltage shall be applied between all electrically isolated circuits and between each circuit and frame (or chassis). Circuit diagrams shall be carefully studied prior to conducting this test, to ascertain that circuits which may be isolated by transformers are not inadvertently neglected. When testing between the circuits and frame (or chassis), all circuits may be tied together so that only one test voltage need be applied, providing that the insulation resistance when tested in this manner meets the minimum value specified in 3.3.3.11. Insulation resistance shall be measured with an insulation resistance indicating instrument. The time of test voltage application shall be not less than 60 seconds. The temperature of the circuits at the time of the test shall be measured and readings taken. Insulation resistance measurements shall be corrected to 25°C. Corrections shall be made on the basis of insulation resistance doubling for each 15°C decrease in temperature. The relative humidity at the time of the test shall be determined.

4.6.17 Dielectric strength test. The dielectric strength test shall be conducted on the completely assembled unit and not on an individual part. The test voltage shall be applied between electrically isolated circuits and between each circuit and frame (or chassis). The dielectric test voltage shall be twice the rated voltage plus 1,000 V but not less than 1,500 V applied for a period of 1 minute. The frequency of the test voltage and the wave form shall be not less than 60 Hz and shall approximate a true sine wave.

4.6.18 Shock test. The shock test shall be conducted in accordance with grade A, class I of MIL-S-901 and as follows:

(a) General. The voltage regulator-exciter system or components thereof shall be energized during the shock test. The equipment may be tested when operating with its intended generator or under simulated loading. All equipment or parts shall be mounted on the shock machine in a manner simulating the actual installation onboard ship. The weight designation of the shock test shall be as required by the combined weight of the equipment or components thereof being tested. The output readings of the equipment shall be taken before and after the test, to determine compliance with 4.6.18(b).

(b) Criteria for compliance with the shock tests. The voltage regulator-exciter system shall comply with the shock tests unless any of the following failures are experienced. Any of the following failures shall be considered as cause for rejection of the equipment:

(1) Breakage of any parts, including mounting bolts. Cracking or signs of cracking in parts vital to operation shall be considered breakage.

(2) Appreciable distortion or dislocation of any parts such as mounting feet, coils, or conducting terminals.
(3) A value of insulation resistance (corrected to 25°C) less than that permitted by 3.3.3.10.
(4) Failure to withstand a dielectric test voltage equal to 65 percent of that specified in 4.6.17.
(5) Failure to meet the steady-state voltage regulation requirements (see 3.4.1).
(6) Shift in the value of regulated voltage of more than 1 percent.
(7) Failure of the standby voltage control to meet the voltage adjustment requirements of 3.4.6 (see 4.6.6.2). If the standby voltage control duplicates the voltage regulator, it shall also meet the steady-state voltage regulation requirements of 3.4.1 (see 4.6.2).
(8) Failure of any of the protective circuits which may be provided to meet the requirements for overvoltage limiting and underfrequency operation.
(9) Failure of the field flashing circuit, where provided.

(c) Shock tests shall be performed at the contractor's plant, commercial laboratory, or Government laboratory which is equipped to perform these tests. When shock tests are conducted at other than the contractor's plant, copies of all master drawings shall accompany the equipment.
(d) Correction and disposal of shock-tested equipment.

(1) Equipment which has been subjected to the HI shock test and has failed to perform any of the principal functions specified herein shall not be acceptable, either in whole or any of the parts, until it has been modified and successfully passed the HI shock test, or until the design modifications have been approved by the contracting activity.
(2) Equipment which has been subjected to the HI shock test and has successfully performed all the principal functions specified herein will be acceptable, provided the following post-shock tests are satisfactorily met:

a. Dielectric.
b. Insulation resistance.
c. Steady-state voltage regulation. The steady-state voltage regulation test may be conducted with the test generator or by use of simulated loading conditions. When simulated means are used, an input-output form of test shall be conducted on the equipment prior to and again after the shock test, to demonstrate that the electrical operating characteristics of the equipment meet the voltage regulation requirements of 3.4.1. To the extent possible, the equipment shall be energized and loaded to its rated values.

d. Standby voltage control.
e. Overvoltage limiting.
f. Underfrequency protection.
g. Field flashing.

4.6.19 Vibration test. The voltage regulator-exciter equipments shall be tested in accordance with MIL-STD-167-1, to demonstrate that the equipment meets the requirements of 3.3.3.13. The method of energizing and loading during the test and the readings taken before, during, and after the test, shall conform to 4.6.18. Criteria for compliance shall be as specified in 4.6.18(b).

4.6.20 Maintainability demonstration test. Maintainability shall be demonstrated in accordance with MIL-STD-471 (see 6.3).

4.6.21 Overvoltage limiting test. An analysis shall be made of the regulator-exciter system, to determine that no single failure will result in voltages in excess of the overvoltage limits specified in 3.4.10. To determine compliance with 3.4.10, the following tests shall be conducted:

(a) With the generator operating at no load, rated voltage, and rated frequency, a failure in the voltage regulator to cause overvoltage shall be simulated. The overvoltage limit shall be set at the minimum and maximum limits and then approximately three equally spaced points, to determine satisfactory operation.
(b) The following minimum readings shall be taken before, during, and after the simulated failure: the three line-to-line voltages, frequency, field current, and field voltage.

4.6.22 Electric performance tests. Quality conformance tests may be conducted without the use of the generator (open-loop), rather than with a generator, as specified in footnote 2 to table II. These tests shall ensure that the requirements of the regulator-exciter system are met, when operated with the intended generator. The following list is furnished for guidance to illustrate the nature of the tests that are to be conducted (see 6.3). The composite test shall be of such nature to ensure that all polarity connections (primary and secondaries) and polarity of transformers, phase connection, and so forth within the equipment are correct.

(a) Voltage regulator range and gain (input-output characteristic).
(b) Static exciter range and gain (input-output characteristic).
(c) Standby voltage control operation.
(d) Rectifier test.
(e) Field flashing circuit check.
(f) Feedback circuit polarity and time constant.
(g) Reactive load division circuit check.

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

5. PACKAGING

(The packaging requirements specified herein apply only for direct Government acquisition. For the extent of applicability of the packaging requirements of referenced documents listed in section 2, see 6.9.)

5.1 General.

5.1.1 Navy fire-retardant requirements.

(a) Treated lumber and plywood. Unless otherwise specified (see 6.2), all lumber and plywood including laminated veneer material used in shipping container and pallet construction, members, blocking, bracing, and reinforcing shall be fire-retardant treated material conforming to MIL-L-19140 as follows:

Levels A and B - Type II - weather resistant.
Category 1 - general use.

Level C - Type I - nonweather resistant.
Category 1 - general use.

(b) Fiberboard. Unless otherwise specified (see 6.2), fiberboard used in the construction of class-domestic, nonweather resistant fiberboard and cleated fiberboard boxes including interior packing forms shall meet the flamespread index and the specific optic density requirements of PPP-F-320 and amendment thereto.

5.2 Packaging requirements. The packaging (preservation, packing and marking) requirements shall be in accordance with MIL-E-17555 for the level of preservation (A, B, C, or commercial), level of packing (A, B, C, or commercial) and marking including bar coding and other packaging acquisitioning options therein as specified (see 6.2).

6. NOTES

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

6.1 Intended use. Voltage regulator-exciter systems are intended to supply excitation power to, and control the output voltage of, ships service generators on military ships, and to control reactive load division when generators are operated in parallel

6.2 Acquisition requirements. Acquisition documents must specify the following:

(a) Title, number, and date of this specification.
(b) Type required (see 1.2).
(c) Issue of DoDISS to be cited in the solicitation, and if required, the specific issue of individual documents referenced (see 2.1.1 and 2.2).

(d) If first inspection is required (see 3.1).
(e) Type and arrangement of enclosure and mounting required (see 3.3.3.2.1 and 3.3.3.2.2)
(f) If type of cooling is other than specified (see 3.3.3.2.5).
(g) Excitation source (see 3.3.3.15.1 and 3.3.3.15.2).
(h) Source of initial excitation if external to the generator set (see 3.3.3.15.3).
(i) Flashing source (see 3.3.3.15.3).
(j) Generator kW overload rating (see 3.4.5).
(k) Parallel operation required (see 3.4.7); type of reactive compensation required (see 3.4.7, 3.4.7.1, and 3.4.7.2).
(l) Treated lumber and plywood (see 5.1.1).
(m) Fiberboard (see 5.1.1).
(n) When fire-retardant materials are not required (see 5.1.1).
(o) Level of preservation, packing, and marking required (see 5.2).

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

Reference Paragraph	DID Number	DID Title	Suggested Tailoring
3.3.2.3.1	DI-R-7082	Reliability predictions report	----
3.3.2.4.3	DI-R-7106	Maintainability predictions report	----
3.3.2.5	DI-R-7085	Failure mode, effects, and criticality analysis report	----
3.3.3.1	DI-E-7031	Drawings, engineering and associated lists	Level 3
4.6	UDI-T-23473	Report, test/inspection	----
4.6.20	DI-R-7113	Report, maintainability demonstration	----
4.6.22	UDI-T-23732	Procedures, test	----

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

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

6.5 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 4.3. 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.

6.6 Definitions. For the purpose of this specification, the following definitions should apply:

6.6.1 Type II - Rotary brushless exciter and voltage regulator. The rotary exciter is a rotary a.c. exciter, without brushes, and with rotating rectifiers. The regulator is composed of completely static components.

6.6.2 Type III - Combined static exciter and voltage regulator. The type III system is one which supplies the generator excitation and controls the voltage through a completely static arrangement of transformers, reactors, rectifiers, resistors, capacitors, transistors and silicon controlled rectifiers.

6.6.3 Reactive droop compensation. Reactive droop compensation is a system which introduces, through the voltage sensitive element, a drooping voltage characteristic as a function of the lagging reactive load on the generator. Two or more generators, each equipped with reactive droop compensation, can be made to share reactive load while operating in parallel through individual adjustment of this drooping voltage characteristic. This type of compensation does not require interconnections between the voltage regulator systems of each generator.

6.6.4 Reactive differential compensation. Reactive differential compensation is a system that provides for the division of reactive load between paralleled generators by introducing a corrective effect, through the voltage sensitive element in proportion to the difference in the reactive load of each generator. A connection between each of the voltage regulator systems is required to provide the proper division of lagging reactive load without introducing a drooping voltage characteristic.

6.6.5 Steady-state voltage regulation. Steady-state voltage regulation is the change in sustained voltage, expressed in percent of rated voltage, when the output of the generator is varied from no load to rated kW output at rated p.f. and back to zero output with fixed settings for all adjustments of the voltage regulator. Voltage regulation is considered positive when the voltage increases with decrease in power output.

6.6.6 Steady-state voltage regulation band. A steady-state regulation band is a band formed on a steady-state voltage regulation graph (with voltage as the ordinate and load as the abscissa) by two straight lines parallel to the load axis, representing a specified regulation. These two lines are separated by a specified voltage spread, expressed in percent of rated voltage.

6.6.7 Dead band. Dead band is the total magnitude of the sustained change in voltage, expressed in percent of rated voltage, within which there is no resulting measurable change in the position of the regulator-controlled devices. All definitions herein concerning voltage regulation are based upon zero dead band.

6.6.8 Voltage dip or rise. The voltage dip or rise (under transient conditions) is the maximum deviation of the regulated voltage from the initial voltage, following a sudden load change of a specified magnitude and power factor.

6.6.9 Voltage recovery time. The voltage recovery time (under transient conditions) is the time in seconds, measured from the instant of sudden load change of specified magnitude, for the regulated voltage to return to, and stay within a specified band of the final voltage sustained.

6.6.10 Schematic electrical diagram. A schematic electrical diagram shows all major components and all interconnections arranged in simplified form for purposes of clearly presenting electrical circuitry. The diagram need not group components with respect to their physical location except where convenient without complicating the schematic. The diagram should not use more than one sheet to complete a given circuit.

6.6.11 Hazardous material. A hazardous item is any substance, mixture, material, component or equipment which may cause personal injury, property damage, or environmental deterioration through transportation, use, or disposal.

6.7 Cross reference of classification. The following is a cross-reference between the types in MIL-R-2729C(SHIPS), dated 14 October 1955, and the types in this specification (see 1.2):

MIL-R-2729C(SHIPS)	This specification
Type I	Deleted
Type II	Deleted
---	Type II
Type III	Type III

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

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

6.9 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.

6.10 Conditions for use of level B preservation. When level B preservation is specified (see 5.1), this level of protection should be reserved for the acquisition of regulator-exciter systems for resupply worldwide under known favorable handling, transportation, and storage conditions.

6.11 Subject term (key word) listing.

Control system, excitation
Control system, voltage
Excitation, brushless
Excitation, static
Regulator
Regulator, voltage

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

Preparing activity:
Navy - SH
(Project 6110-N329)

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

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I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER MIL-R-2729D(SH)	2. DOCUMENT DATE (YYMMDD)

3. DOCUMENT TITLE
REGULATOR-EXCITER SYSTEMS, VOLTAGE, A.C. GENERATOR, NAVAL SHIPBOARD USE

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

5. REASON FOR RECOMMENDATION

6. SUBMITTER

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

8. PREPARING ACTIVITY

a. NAME Technical Point of Contact (TPOC): Mr. John Murphy (SEA 56Z31) PLEASE ADDRESS ALL CORRESPONDENCE AS FOLLOWS:	b. TELEPHONE (Include Area Code) (1) Commercial (2) AUTOVON TPOC: 703-602-3124
c. ADDRESS (Include Zip Code) Commander, Naval Sea Systems Command Department of the Navy (SEA 55Z3) Washington, DC 20362-5101	IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT: Defense Quality and Standardization Office 5203 Leesburg Pike, Suite 1403, Falls Church, VA 22041-3466 Telephone (703) 756-2340 AUTOVON 289-2340