
USACE / NAVFAC / AFCEA UFGS-16236 (August 2004)

Preparing Activity: NAVFAC Superseding
UFGS-16236N (September 2000)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated 22 December 2004

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DIVISION 16 - ELECTRICAL

SECTION 16236

MOTOR-GENERATOR SETS, 400 HERTZ (HZ)

08/04

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SECTION 16236

MOTOR-GENERATOR SETS, 400 HERTZ (HZ)
08/04

NOTE: This guide specification covers the requirements for the repair and replacement of motor generator sets, 60 to 400 Hz.

Comments and suggestions on this guide specification are welcome and should be directed to the technical proponent of the specification. A listing of technical proponents, including their organization designation and telephone number, is on the Internet.

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR).

Use of electronic communication is encouraged.

Brackets are used in the text to indicate designer choices or locations where text must be supplied by the designer.

NOTE: This specification should not be used for new equipment procurements. Motor generated sets do not comply with Navy energy efficiency standards. Designers should use Section 16268 for new 400 Hz solid state frequency converter systems for all inverters rated higher than 60 KW. If used to procure motor-generator sets with 50 Hz input, the guide specification needs to be tailored for this application by the specifier.

NOTE: The following information shall be shown on the project drawings:

1. Equipment: Show location of all equipment. Provide single-line diagrams, elevations, limiting dimensions, and equipment ratings which are not covered in the specification. Indicate remote indicating or control requirements.

PART 1 GENERAL

1.1 REFERENCES

NOTE: Issue (date) of references included in project specifications need not be more current than provided by the latest guide specification. Use of SpecsIntact automated reference checking is recommended for projects based on older guide specifications.

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN BEARING MANUFACTURERS ASSOCIATION (ABMA)

ABMA 9 (1990; R 2000) Load Ratings and Fatigue Life for Ball Bearings

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C12.11 (1987) Instrument Transformers for Revenue Metering, 10 kV BIL through 350 kV BIL (0.6 kV NSV through 69 kV NSV)

ANSI C2 (1997) National Electrical Safety Code

ANSI C39.1 (1981; R 1992) Requirements for Electrical Analog Indicating Instruments

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE C57.13 (1993) Requirements for Instrument Transformers

IEEE Std 115 (1995; R 2002) Test Procedures for Synchronous Machines: Part I: Acceptance and Performance Testing; Part II: Test Procedures and Parameter Determination for Dynamic Analysis

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA ICS 2 (2000) Industrial Controls and Systems: Controllers, Contactors, and Overload Relays Rated Not More than 2000 Volts AC or 750 Volts DC

NEMA ICS 6 (1993; R 2001) Industrial Control and Systems: Enclosures

NEMA MG 1 (2003) Motors and Generators

NEMA WD 1 (1999) General Color Requirements for

Wiring Devices

NEMA WD 6 (2002) Wiring Devices - Dimensional Requirements

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2005) National Electrical Code

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-STD-1399-300 (Rev A; Notice 1) Interface Standard for Shipboard Systems Section 300A Electric Power, Alternating Current (Metric)

MIL-STD-461 (Rev E) Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment

MIL-STD-462 (Rev D; Am 3; Notice 4) Measurement of Electromagnetic Interference Characteristics

MIL-STD-704 (Rev F) Aircraft Electric Power Characteristics

MIL-STD-810 (Rev F; Notice 3) Environmental Engineering Considerations and Laboratory Tests

UNDERWRITERS LABORATORIES (UL)

UL 467 (1993; Rev thru Feb 2001) Grounding and Bonding Equipment

UL 489 (2002; Rev thru May 2003) Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures

UL 506 (2000; Rev thru Feb 2004) Specialty Transformers

UL 508 (1999; Rev thru Dec 2003) Industrial Control Equipment

1.2 RELATED REQUIREMENTS

Section 16050N BASIC ELECTRICAL MATERIALS AND METHODS, applies to this section, with the additions and modifications specified herein.

1.3 SYSTEM DESCRIPTION

Provide motor-generator set[s] with accessories, auxiliary equipment, and associated work as specified.

1.3.1 Equipment Design and Construction

The motor-generator[s] shall be designed and constructed so that no parts work loose in service and shall be built to withstand strains, jars,

vibrations, and other conditions incident to shipping, storage, installation, and services.

1.3.2 Protective Device Coordination

Protective equipment shall be coordinated to ensure correct overload and fault clearing sequences. Provide recommended settings of adjustable protective devices.

1.3.3 Safety Features

Power transmission apparatus (belts, pulleys, couplings, etc.) shall be enclosed or properly guarded to prevent injury to personnel who might accidentally come in contact with them.

1.3.4 Environmental Conditions

MIL-STD-810. The motor-generator set[s] shall operate satisfactorily at rated single- and three-phase loads under the following conditions:

[1.3.4.1 Indoor Units

- a. Ambient temperatures ranging from zero degrees C to plus 40 degrees C when operating
- b. Ambient storage temperature ranging from minus 25 degrees C to plus 55 degrees C
- c. Relative humidity up to 95 percent.

] [1.3.4.2 Outdoor Units - Nominal Conditions

- a. Ambient temperatures ranging from minus 20 degrees C to plus 50 degrees C when operating
- b. Ambient storage temperature ranging from minus 20 degrees C to plus 55 degrees C
- c. Rainfall as encountered in a locale
- d. Relative humidity up to 100 percent, including conditions where condensation takes place in the form of water or frost
- e. Fungus growth as encountered in tropical climates
- f. Dust as encountered in desert areas.

] [1.3.4.3 Outdoor Units - Extreme Conditions

- a. Ambient temperatures ranging from minus 46 degrees C to plus 55 degrees C when operating
- b. Ambient storage temperature ranging from minus 46 degrees C to plus 55 degrees
- c. Rainfall as encountered in any locale
- d. Relative humidity up to 100 percent, including conditions where condensation takes place in the form of water or frost

- e. Fungus growth as encountered in tropical climates
- f. Dust as encountered in desert areas
- g. Exposure to salt-laden fog.

]1.3.5 Design Data

1.3.5.1 Motor-Generator Sets Calculations

Submit with explanatory data for calculations, listing applicable parameters, the formula symbol for each parameter, and applicable formulas plus the step-by-step calculations, as a minimum:

- a. Overload and fault clearing sequence coordination calculations and time-current characteristic curves of the system's low-voltage protective devices and schemes. Provide recommended settings of adjustable protective devices.

[b. Mean time between failure reliability calculations for:

- (1) Motor generator sets
- (2) Bearings.]

1.3.5.2 Motor-Generator Sets Data Sheets

Submit motor generator set data sheets (each size) in conformance with the requirements for shop drawings. Include applicable values for 75 degrees Celsius (C) and 400 Hz operation, with the exception of the 60 Hz devices for which 60 Hz values shall be noted. List two frequency ratings for equipment operated at 400 Hz and utilizing equipment normally rated at 60 Hz.

- a. Motor-generator set combined component characteristics

- (1) Mean time between failures (MTBF) in hours: [_____]
- (2) Overload capacity, satisfactory operating period:
 - (a) At 1.25 full load in minutes [_____]
 - (b) At 1.20 full load in minutes [_____]
 - (c) At 1.10 full load in minutes [_____]
- (3) Efficiency:
 - (a) At 0.25 full load in percent [_____]
 - (b) At 0.50 full load in percent [_____]
 - (c) At 0.75 full load in percent [_____]
 - (d) At full load in percent [_____]
- (4) Short-circuit capability at three times rated current in seconds or provide short-circuit capability on a per-unit basis

and duration of capability in seconds [_____]

(5) Frequency characteristics:

(a) Steady-state regulation in percent [_____]

(b) Deviation change rate curve [_____]

(c) Transient limits envelope modulation in percent [_____]

(6) Voltage characteristics:

(a) Steady-state regulation in percent [_____]

(b) Stability from no load to full load +[_____] to -[_____]

(c) Sensitivity in percent from no load to full load +[_____] to -[_____]

(d) Drift over a 30-day interval for an ambient temperature range from 10 degrees C to 40 degrees C +[_____] to -[_____]

(e) Step-load change at 20 percent of full load +[_____] to -[_____]

(f) Full-load change +[_____] to -[_____]

(g) Recovery to the regulation band in seconds [_____]

(h) Modulation in percent [_____]

(i) Voltage unbalance, balanced loads in percent [_____]

(j) Voltage unbalance, unbalanced loads in percent [_____]

(7) Waveform characteristics:

(a) Total balanced load root mean square (rms) harmonics line-to-line in percent, line-to-neutral in percent [_____]

(b) Maximum balanced load, single rms harmonic of the fundamental at the steady state voltage in percent [_____]

(c) Deviation factor in percent [_____]

(d) Waveform oscillograph for all above conditions [_____]

b. Motor

(1) Make [_____]

(2) Model [_____]

(3) Type of motor [_____]

(4) Type of field [_____]

(5) Power factor, lagging [_____]

- (6) Input rating in volts [_____]
- (7) Frequency in Hz [_____]
- (8) Full-load motor current in amperes [_____]
- (9) Number of poles [_____]
- (10) Full-load rating in kilowatts horsepower [_____]
- (11) Synchronous speed in revolutions per minute (rpm) [_____]

c. Generator

- (1) Make [_____]
- (2) Model [_____]
- (3) Type of generator [_____]
- (4) Type of field [_____]
- (5) Power factor, lagging [_____]
- (6) Output rating in volts [_____]
- (7) Frequency in Hz [_____]
- (8) Full-load generator current in amperes [_____]
- (9) No-load field current in amperes or field rating in volt-amperes [_____]
- (10) Number of poles [_____]
- (11) Full-load rating in kilovolt-amperes (kVA) [_____]
- (12) Synchronous speed in rpm [_____]

1.3.5.3 Parallel Operation Studies

Submit a parallel operation study before manufacturing the motor-generator set. Indicate that satisfactory operation can be expected. [Analyze existing motor-generator sets, voltage regulators, and electromechanical energy transients to determine compatibility with units supplied.] As a part of the study, confirm that transients do not exceed required values.

1.4 SUBMITTALS

NOTE: Submittals must be limited to those necessary for adequate quality control. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item should be required.

A "G" following a submittal item indicates that the submittal requires Government approval. Some submittals are already marked with a "G". Only

delete an existing "G" if the submittal item is not complex and can be reviewed through the Contractor's Quality Control system. Only add a "G" if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy projects.

Submittal items not designated with a "G" are considered as being for information only for Army projects and for Contractor Quality Control approval for Navy projects.

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are [for Contractor Quality Control approval.] [for information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] The following shall be submitted in accordance with Section 01330 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Motor-generator set fabrication

Indicate as a minimum, the certified outline, general arrangement (setting plan), and anchor bolt details.

SD-03 Product Data

Motor-generator sets

Miscellaneous controls and ancillary control devices

Input/Output device

Protective control devices

Electrical instruments

[Paralleling control equipment]

SD-05 Design Data

Motor-generator sets calculations

Motor-generator sets data sheets

Parallel operation studies

SD-06 Test Reports

Transient

Ground resistance tests

Submit transients test results as required in paragraphs entitled "Transient Test." Indicate on each, acceptable limits for voltage and frequency. For ground resistance test, submit results as required in paragraph entitled "Ground Resistance Tests."

SD-07 Certificates

Manufacturer's Representative's Qualifications

Factory test data

Factory test schedule

Field test schedule

Submit evidence that the manufacturer's representative is qualified to provide specified services, as specified in paragraph entitled "Qualifications," in this section.

SD-08 Manufacturer's Instructions

Motor

Generator

Control unit

Anchor bolt

Submit installation drawings for the above.

SD-09 Manufacturer's Field Reports

NOTE: Require witnessed factory tests only when required by the using agency or the critical nature of the load. Electromagnetic interference tests complying with MIL-STD-461 shall be required for facilities which support airborne weapons systems and computer and communications projects.

Motor-generator sets

NEMA MG 1. Submit [5] [_____] copies of each for motor-generator set. Include design tests, production tests, and conformance tests for approval before delivery of equipment to the project site. Manufacturer's tests shall be performed at the manufacturer's facilities [and shall be witnessed by the Contracting Officer or a representative of the Contracting

Officer]. Tests shall conform to the test method requirements of NEMA MG 1, except for parts relating to electromagnetic interference, and repetition of voltage regulation and required voltage adjustment tests.

SD-10 Operation and Maintenance Data

Motor-generator sets, Data Package 3

Submit in accordance with Section 01781 OPERATION AND MAINTENANCE DATA.

1.5 QUALITY ASSURANCE

1.5.1 Certification

Certify final test plans and procedures, instrumentation used, and test reports. Comply with the requirements of the paragraph entitled, "Factory Test Schedules[,][]" [including requirements for oscillographs, in paragraph entitled, "Transients."]

1.5.2 Manufacturer's Representative's Qualifications

Evidence that the manufacturer's representative is qualified to provide specified services. The manufacturer's representative shall be qualified by knowledge of the design, installation, and testing of 400 Hz, low voltage systems, acquired through professional education and related practical experience.

PART 2 PRODUCTS

2.1 MATERIALS AND EQUIPMENT

Conform to the standards and specifications herein. Electrical ratings shall be as indicated.

2.1.1 Bearings

Ensure reliability in accordance with ABMA 9, Method L-10 calculations.

2.1.2 Molded-Case Circuit Breakers, Low-Voltage Type

UL 489.

2.1.3 Electrical Instruments, Indicating Type

ANSI C39.1; 108 mm 4.25 inch square switchboard type accurate to within one percent of full scale or equivalent accuracy digital-readout type when specifically permitted. Digital meters shall have a minimal numeral height of 19 mm 0.75 inch and shall provide a three-figure readout for values of less than 100.

2.1.4 Electromagnetic Interference Limits

NOTE: Do not include electromagnetic interference requirements unless specifically included in the project requirements or requested by the using agency.

MIL-STD-461 for Class C2 equipment measured in accordance with MIL-STD-462.

2.1.5 Indicator Lights

Self-contained, transformer-type operating at approximately [6 volts or miniature base-type operating at 12 volts and having minimum 14,000-hour life] [24 volts and having a minimum 60,000-hour life].

2.1.6 Insulation

NEMA MG 1, Class F or H for synchronous machines, except that asbestos insulation is prohibited.

2.1.7 Nameplates

Provide laminated plastic nameplates, a minimum size of 25 by 65 mm one inch by 2.5 inches. Install on equipment, controls, instrumentation, indicator lights to identify functions and, where applicable, positions. Lettering shall be a minimum height of 10 mm 0.25 inch, engraved on a black-on-white matte finish.

2.1.8 Identification

A metal nameplate not exceeding 125 by 155 mm 5 by 6 inches shall be permanently attached by the manufacturer of the unit in a convenient location on the outside of the unit. Nameplate information shall include manufacturer's name and code identification number, required input and output voltage, frequency and current at full load, and total weight.

2.1.9 Reliability Calculation Data Base

**NOTE: Designer should refer to MIL-HDBK-217 for
reliability calculation data base.**

Provide failure rate calculation on the motor-generator and the electronic components.

2.1.10 Synchronous Machines

NEMA MG 1.

2.1.11 Instrument Transformers

ANSI C12.11 and IEEE C57.13.

2.2 MOTOR-GENERATOR SETS

**NOTE: Include paralleling requirement when it is
required to parallel two or more machines to serve a
common load or bus. Indicate required data of any
existing motor-generator sets which are to be
paralleled.**

Provide motor-generator set[s], [each] consisting of a motor-generator assembly for [60 to 400 Hz] [50 to 400 Hz] conversion, exciter-voltage regulator system, voltage regulator with standard controls, protective devices, input/output devices, instrumentation, ancillary control devices, [necessary devices for paralleling and control,] and other accessories as specified. Set[s] shall conform to the applicable standards and specifications herein. Electrical ratings shall be as indicated. The complete equipment shall be enclosed in accordance with NEMA ICS 6, Type [1] [3] [_____]. Frames and enclosures shall be vermin-proof.

2.2.1 Rating

Provide set[s] which [has] [have] a calculated mean time between failures (MTBF) exceeding 15,000 hours when provided with yearly servicing and maintenance.

2.2.1.1 Motor

Three-phase, [1,200] [_____] rpm, synchronous, with a [480] [208] [_____] -volt, [60 Hz] [50 Hz] rated input which maintains a minimum 0.9 power factor for loads exceeding 49 percent of rated load and a minimum 0.8 power factor for lesser loads or which maintains a unity power factor at full load and operates on a constant excitation regardless of load. Ensure adequate horsepower to drive the generator at 120 percent rated load with the output characteristics specified.

2.2.1.2 Generator

NOTE: Coordinate with motor speed in above paragraph. The 1200 RPM shown is for 60 Hz. Indicate appropriate RPM if 50 Hz motor is chosen.

Three-phase, [1,200] [_____] rpm, synchronous, with a [_____] -volt, 400 Hz rated output having a minimum full-load capacity of [_____] kVA at 0.8 lagging power factor when providing the output characteristics specified.

2.2.2 Capability and Performance Requirements

2.2.2.1 Overload Capacity

Satisfactory operating time is based on not more than one overload per 24 consecutive hours of operation.

Percent of full load	Satisfactory operating time
125 percent	5 minutes
120 percent	30 minutes
110 percent	60 minutes

2.2.2.2 Efficiency of the Motor Generator

NOTE: Choose the efficiency rating for the proposed unit from this table according to the size of the unit.

Motor Generator Set Rating in kW	Minimum Percent Efficiency			
	25 Percent Load	50 Percent Load	75 Percent Load	100 Percent Load
7.5 - 15	--	63	--	70
20 - 30	--	65	--	72
40 - 75	60	70	74	77
100 - 160	70	80	83	85
200	75	83	87	88
250	76	84	87	88

In addition, the percent efficiencies shall be in accordance with the latest manufacturer's energy efficient equipment for minimum acceptance values.

The efficiency shall be at least [_____] percent at rated load, [_____] percent at 25 percent load, [_____] percent at 50 percent load, [_____] percent at 75 percent load, and [_____] percent at 100 percent (rated) load.

2.2.2.3 Short Circuit

When a three-phase symmetrical short circuit is applied to the unit, the unit shall be capable of sustaining at least 300 percent of rated current for not less than a 10-second duration or not less than the time required for the integral system protective devices to interrupt the fault.

2.2.2.4 Radio Frequency Interference

Provide factory installed devices on synchronous machines to suppress generated radio noise to the limits required by MIL-STD-461.

2.2.2.5 Frequency Characteristics

- a. Input/output: Provide 400 Hz output at [60 Hz] [50 Hz] input.
- b. Steady-state limits:
 - (1) Regulation: Not to exceed plus or minus one percent
 - (2) Deviation change rate: Not to exceed values shown in Figure 5 of MIL-STD-704.
- c. Transient limits: [Not to exceed values shown in Figure 5 of MIL-STD-704 upon sudden application or removal of full load at rated power factor] [As specified in MIL-STD-1399-300].
- d. Modulation: Not to exceed 0.5 percent.

2.2.2.6 Voltage Characteristics

- a. Voltage buildup: Initial voltage buildup shall be completely automatic.
- b. Voltage adjustment: The output voltage shall be capable of being adjusted over a minimum range of plus or minus 10 percent from rated voltage.

c. Steady-state limits

- (1) Regulation: Not to exceed plus or minus one percent [in accordance with paragraph entitled, "Voltage Regulation System," in this section]
- (2) Stability: Not to exceed plus or minus 0.5 percent from no load to full load
- (3) Sensitivity: Not to exceed plus or minus 0.25 percent from no load to full load for a one-hour interval
- (4) Drift: Not to exceed plus or minus 0.5 percent over a 30-day interval for an ambient temperature range of 10 degrees C to 40 degrees C.

d. Transient limits

- (1) Step-load change: Not to exceed plus or minus 3 percent for step-load changes equal to 20 percent of full load
- (2) Full-load change: Not to exceed plus or minus 16 percent [in compliance with MIL-STD-1399-300]
- (3) Recovery time: Not to exceed 0.25 second for a recovery to the regulation band

NOTE: Include this requirement when it is required to parallel two or more machines to serve a common load or bus. Indicate required data of any existing motor-generator sets which are to be paralleled.

[(4) Parallel-load change: Not to exceed the value of the unit-load change transient divided by the number of units paralleled or a no-load change transient of 3 percent.]

e. Modulation: Not to exceed 0.5 percent

f. Line-to-neutral, phase-voltage unbalance

- (1) Balanced load: Not to exceed one percent between individual line voltages
- (2) Unbalanced load: Not to exceed 4 percent for a one-line voltage from the average of the three-line voltages with one-third rated current on one phase and no load on the other two phases.

2.2.2.7 Waveform Characteristics

a. Balanced load

- (1) Total rms harmonics: Not to exceed 2 percent line-to-line and line-to-neutral
- (2) Maximum single rms harmonic: Not to exceed 1.5 percent of the fundamental at the steady-state voltage

- b. Unbalanced load, total rms harmonics: Not to exceed 4 percent, line-to-neutral
- c. Deviation factor: Not to exceed 5 percent.

2.2.3 Motor-Generator Set Fabrication

NOTE: Include paralleling requirement when it is required to parallel two or more machines to serve a common load or bus. Indicate required data of any existing motor-generator sets which are to be paralleled.

For some installations with more stringent noise level standards than OSHA for an 8-hour exposure, the following suggested noise level table can be used for operations of a motor-generator set.

Octave Band Center Frequencies (Hz)	Sound Pressure Levels dB ref. (0.002 dynes/cm squared)
63	78
125	72
250	67
500	64
1,000	62
2,000	60
4,000	58
8,000	57

Provide a vertical, two-bearing single shaft to support the motor and the generator, an exciter-voltage regulator system, [and necessary devices for paralleling and control]. Mount on a common rigid steel base with the rotor assembly statically and dynamically balanced so as not to exceed a 0.002 double-amplitude indicator reading. The noise level shall not exceed 85 decibels adjusted at a distance of 915 mm 3 feet from the set and approximately one-half the set height.

2.2.3.1 Bearing Requirements

Provide vertical shaft configuration. Construct shaft using bearings with a minimum calculated 150,000-hour life when properly lubricated. Provide either a cylindrical roller or ball-type top bearing with an angular contact-type bottom bearing or an angular contact-type top bearing with a cylindrical roller or ball-type bottom bearing. Conform construction to the following requirements:

- a. Cylindrical roller or ball-type bearing: Lock either on the inner

or outer race of the shaft in a manner which permits free movement axially with the other race and eliminates thrust on the bearing.

- b. Angular contact-type bearing: Provide the necessary thrust and radial load capacity.

NOTE: Coordinate with paragraph entitled "Alarm Indication" for requirements of oil temperature and low oil level indications on the type of lubrication system selected.

- c. Lubrication: Provide either a single lubrication reservoir for both bearings or individual lubrication reservoirs for each bearing. Provide a built-in oil spray or grease lubrication system with pump for angular contact-type bearings and an oil bath lubrication system for cylindrical roller or ball-type bearing. Individual reservoir capacity shall be a minimum of 2 liters 2 quarts and of sufficient size to provide adequate lubrication. Use lubricant recommended by the manufacturer. Equip each reservoir with a sight gauge plus specified alarm systems; provide bearing-closure lubricant seals, where necessary, to prevent leaks.

2.2.3.2 Synchronous Machines

Brushless-type, self-ventilated, dripproof construction with windings which are impervious to oil, solvents, moisture, mild acids, and alkalis. [Provide with a stator-shifting drive mechanism able to shift the motor stator with respect to the generator stator.] Limit temperature rise to 110 degrees C above a 40-degree C ambient temperature. Ambient operating temperature range shall be as specified in the paragraph entitled, "Environmental Conditions," in this section.

2.2.3.3 Voltage Regulation System

The voltage regulator shall stabilize the output voltage within one minute after start-up and shall remain within a total regulation band of one percent within the unit rating and over an ambient temperature range in accordance with the paragraph entitled, "Environmental Conditions," in this section. Regulator shall include an adjustable boost circuit, and a means shall be provided to obtain cable drop compensation of up to 5 percent resistive and up to 5 percent inductive in order to maintain voltage regulation as specified in MIL-STD-704 at a point distant from the 400 Hz output terminals.

2.2.3.4 Exciter-Voltage Regulator System

Shall be a totally static system utilizing either one or two shaft-mounted, three-phase, silicon-diode bridge assemblies to supply the motor and generator fields. Control excitation with a solid-state voltage regulator stabilized against long-term drift and ambient temperature variation.

2.2.3.5 Dimensions

NOTE: When available space is a critical factor, specify the maximum dimensions acceptable, otherwise omit this paragraph. Motor-generator excitation

control system and protective devices may be provided in a separate enclosure.

Physical dimensions shall not exceed [____].

2.2.3.6 Control Cabinet

NOTE: The control cabinet requirements, as stipulated, may not be pertinent to certain parallel configurations of motor-generator sets. Parallel configurations may involve provision of a central control scheme which serves all the motor-generator sets operating in parallel; such a scheme may preclude the need for some of the features/capabilities identified in this paragraph.

UL 508. Mount controls, indicating lights, protective devices, and instruments in the control cabinet. Wiring shall have ample service loops and be protected from abrasion. Secure wiring and wiring harnesses at least every 150 mm 6 inches. Identify terminals in accordance with the wiring diagram. All components shall be UL recognized or listed, and the control panel shall have the UL 508 label.

2.2.3.7 Convenience Outlets

Each motor-generator shall have a 5-15R duplex, 120 V, 60 Hz outlet. The 5-15R outlets shall be labeled, weather protected, and supplied by the control transformer through a 15-ampere circuit breaker. Each motor-generator shall have a L5-15 duplex, 120 V, 400 Hz, single-phase outlet. The L5-15 outlets shall be labeled, weather protected, and isolated from power until the motor-generator is supplying stable power. Outlets shall conform to NEMA WD 1 and NEMA WD 6, as required.

2.2.4 Input/Output Device Requirements

Fully-rated, three-pole devices for protection and control of [60 Hz] [50 Hz] input to the motor generator, for protection and control of 400 Hz output of the motor generator, and for disconnecting the 400 Hz motor generator set output from the 400 Hz load.

2.2.4.1 Input Circuit Breaker

Provide an industrial-type input circuit breaker with thermal overload and short circuit protection. Circuit breaker shall conform to UL 489.

2.2.4.2 Input Motor Controller

UL 508, NEMA ICS 2. Start and stop the synchronous motor with a synchronous motor controller. Equip with thermal overload units. Limit full-voltage starting current to 300 percent of running current. Controllers shall incorporate undervoltage and overcurrent protection. Provide protective schemes for protection of the field winding and rectifier assembly during starting or pulling out of step. Provision shall be made to permit remote operation.

2.2.4.3 Output Disconnect

Interrupt the 400 Hz output with a vacuum contactor, utilizing that contactor's 400 Hz input plus integral control devices to provide suitable control voltage. Provide circuit breaker disconnect and fuse protection for the control circuit.

2.2.5 Paralleling Control Equipment and Circuitry

**NOTE: Include this requirement when it is required
to parallel two or more machines to serve a common
load or bus. Indicate required data of any existing
motor-generator sets which are to be paralleled.**

Provide a completely automatic control for normal operation and manual controls for backup operation. Control the stator-shifting drive mechanism to permit shifting of the unit's phase angle, as necessary, to parallel and share loads equally with the other motor generator sets of the installation. Equip the motor generator set with necessary switchgear or switchboards. Allow closing of the output disconnect only when that motor generator set's voltage and phase angle matches bus voltage and phase angle of a common bus supported by motor generator sets having the same electrical characteristics, internal impedances, voltage, and frequency. Install controls, instruments, and indicator lights on the switchgear or switchboard control. Provide each set with two white indicator lights with nameplates inscribed "Unit Synchronism" and "Bus Synchronism," respectively. Alternatively, provide one white indicator light with an indicator nameplate inscribed "Synchronism in Process" and one digital readout indicating that the synchronism did not take place. The paralleling system shall provide the necessary termination for remote and local operation.

2.2.5.1 Automatic Paralleling

- a. Provide for unmanned control to start up, load share, load shed, and shutdown units as necessary to meet load demand. Either automatic or manual means for alternating the units to equalize load machine selection and unit running times between units shall be provided.
 - (1) Provide a master selector switch which selects the unit to be the master unit. The slave units will be started in order after the master unit reaches a predetermined percent of load.
 - (2) Provide by-pass selector switch to provide a means of by-passing the motor generator set in which a fault has occurred or to perform the routine maintenance as necessary on any motor-generator set.
- b. The automatic paralleling operating shall function as follows:
 - (1) When the 400 Hz load reaches 70 percent (adjustable from 50 to 100 percent), of the master's maximum rating, as measured at the main output bus, the first slave will be "ready" to start, but will be prevented by a time delay relay (adjustable from two to five minutes). If the load remains over 70 percent, and the time delay of two to five minutes has been reached, the slave will

start and be automatically paralleled with the main bus. After phase alignment between the main bus and the unit being paralleled has been achieved, the main output breaker of the slave generator will close and the two motor-generators will share the total load.

When the second motor-generator reaches 70 percent rating, the same sequence will bring the next motor-generator on line.

(2) Automatic droop compensation sensing and control circuitry shall be provided, to insure that load sharing with 5 percent will be maintained from no-load to full-load output rating of the combined motor-generators.

(3) Provision shall be made to prevent "Short Cycling." Once a machine is started, it will be controlled to run at least one hour (time to the adjustable from five minutes to one hour), regardless of load.

(4) When the 400 Hz load share by motor-generators decreases to 30 percent (adjustable from 20 to 50 percent), of the combined output of the connected motor-generators as sensed at the main output bus, the slaves will be turned off in sequence.

2.2.5.2 Manual Paralleling

Provide for manual control of functions required for automatic paralleling.

2.2.5.3 Paralleling Circuitry Malfunction

Open an output disconnect automatically upon failure of that set to properly parallel or share load with any other set in a parallel group.

2.2.6 Protective Control Devices

Provide relays, instrument transformers, and circuitry on the generator's 400 Hz output as necessary to provide protective control. Design protection to meet short circuit and overload requirements. Design protective circuits to require operation of a reset button to allow output disconnect closing after a protective device opens the disconnect.

2.2.6.1 Overvoltage

Protect by tripping input/output devices for instantaneous overvoltage of 30 percent or more and for 10 to 30 percent overvoltage lasting more than 0.25 second using a relay having an inverse-time characteristic.

2.2.6.2 Undervoltage

Protect by preventing the closing of the output disconnect until the output voltage is 95 percent of the rated output. If, after closing, the voltage decreases to below 90 percent for longer than 5 seconds, provide relaying to trip input/output devices utilizing a field-adjustable, time-delayed circuit with a range of from 4 to 10 seconds. Alternatively, provide an inverse-time-versus-voltage relay whose characteristics reflect those of Figure 7 of MIL-STD-704.

2.2.6.3 Reverse Power

NOTE: Include this requirement when it is required

to parallel two or more machines to serve a common load or bus. Indicate required data of any existing motor-generator sets which are to be paralleled.

Protect by tripping input/output devices for reverse power in excess of 5 percent of the motor-generator rating.

2.2.6.4 Underfrequency

Protect by tripping input/output devices for underfrequency in excess of 5 percent of the rated output frequency (380 Hz).

2.2.7 Miscellaneous Controls and Ancillary Control Devices

Provide heavy-duty industrial or switchboard-type devices for manual control and alarm and data indication on the control panel.

2.2.7.1 Manual Control

- a. Set control: Provide two "open/close" switches, each with a red position light in the center of the switch. One switch shall operate the input motor controller; the other switch shall operate the output disconnect. Connect lights, and provide nameplates inscribed "Motor Generator On" and "Output Disconnect Closed."

NOTE: Include this requirement when it is required to parallel two or more machines to serve a common load or bus. Indicate required data of any existing motor-generator sets which are to be paralleled.

- [b. Synchronization control: Provide a synchronizing switch for manual control of the paralleling mechanism.]
- c. Alarm reset: Provide an "Alarm Reset" pushbutton to silence audible alarms.
- d. Push-to-reset: Provide a "Push-to-Reset" pushbutton to test indicator lights.

[2.2.7.2 Alarm Indication

Provide nameplates, safety devices, white indicator lights, and audible alarms for the following alarm conditions:

- a. Overload
- b. Overvoltage
- c. Undervoltage (audible alarm on tripping only)
- d. Underfrequency
- [e. Oil overtemperature for pumped lubrication systems]
- [f. Low oil level for pumped lubrication systems]

- g. High winding temperature
- h. High top bearing temperature
- i. High lower bearing temperature
- [j. Reverse power]
- [k. Failure to parallel].

Shutdown of the problem motor-generator set shall automatically bring the next available motor-generator set "on-line."

]2.2.7.3 Data Indication

Provide on the control panel the following for data indication and control. Digital meters are permitted.

- a. An input voltmeter and an output voltmeter, each with a voltmeter transfer switch having three "line-to-line" positions and one "off" position. The voltmeter scale shall provide reading for at least 10 percent overvoltage. (Voltmeter shall be rated 1.0 percent accuracy.)
- b. An output ammeter to read full-load output in the upper third of the scale with an ammeter transfer switch having three "phase" positions and one "off" position.
- c. A digital output frequency meter, 390 Hz to 410 Hz scale, having a 400 Hz center with an on/off switch. Field calibrate so that a 60 Hz input to the motor provides a 400 Hz reading on the meter. Provide a digital meter accurate to plus or minus one Hz.
- d. A running-time meter, 99,999-hour, digital, full-scale.
- e. A motor-start, five-digit operation counter.
- [f. Power factor meter.]
- g. Other instruments normally provided by the manufacturer.

2.2.7.4 Control Circuit Transformer

A transformer with a fused, 120-volt, 60 Hz secondary shall be provided for operation of control and indicating devices. Transformer shall conform to UL 506.

2.2.7.5 Terminal Blocks

Suitable, clearly and permanently labeled terminal blocks which are readily accessible shall be included in each separately mounted unit for the interconnecting wiring and for the power supply and load connections.

2.2.7.6 Lifting Provisions

Provide two forklift openings at each end of the base and two lifting eyes at each end of the entire set meeting NEMA MG 1 requirements.

2.2.7.7 Heating

Provide heaters of a maximum 1,000 watts in the motor generator frame to prevent condensation. Automatically deenergize heaters in the motor and generator when the set is operating, and automatically energize heaters when the unit is not operating.

2.2.8 Remote Indicating Provisions

Provide remote indicating circuitry, and connect to suitable, clearly and permanently labeled terminal blocks located in a terminal compartment adjacent to the input terminal compartment. The circuitry shall be such that indicator light information can be extended from the terminals to a remote location [as shown] [to be designated by the Contracting Officer].

2.2.9 Test Points

A number of test points shall be provided and brought to a common location in the control panel. These test points shall be shown on the schematics and in the maintenance manuals. Each test point shall be clearly and uniquely labeled.

2.2.10 Display

Readily readable copies of schematics for the motor, generator, control unit, and 400 Hz distribution shall be posted inside the control panel doors and covered with 6.35 mm 1/4 inch plexiglass shields. [Manufacturer shall leave ample space for the distribution schematics to be added in the field.]

2.3 FACTORY TESTS

Perform the tests described herein at the manufacturer's plant. Test components by operating at 400 Hz to determine suitability for operation at the full 400 Hz nameplate rating.

2.3.1 Factory Test Data

Separate test plans and procedures from test reports. Submit explanations of the methods to be used in demonstrating the requirements. Define tests required to ensure that the system meets technical, operational, and performance specifications. Note milestones that the test requires, identifying equipment and personnel required. Identify the capabilities and functions to be tested, including the values and situations comprising the test. Provide recordings and readable data demonstrating that equipment tested meets the limits and operation characteristics specified. In addition, submit the following outlined data:

2.3.2 Factory Test Schedule

Submit plans and procedures for factory test at least 60 calendar days prior to scheduled delivery.

2.3.3 Motor Generator Set

**NOTE: If only a motor-generator set is specified,
include the bracketed sentence.**

NEMA MG 1, except for parts relating to electromagnetic interference and repetition of voltage regulation and required voltage adjustment tests. Test one set of each rating size for compliance with the performance requirements of the equipment. [Paralleling tests may be simulated at the factory.]

2.3.3.1 Motor Generator

a. IEEE Std 115, including the following

- (1) Operate every motor generator continuously at least 8 hours. Operate at least one hour at each load point (25, 50, 75, and 100 percent of rated load) and 2 hours at 110 percent of rated load at either 0.8 or 1.0 power factor. Record efficiencies and other relevant data during each load run.
- (2) Insulation: Test from each winding to grounded machine frame with other windings grounded.
- (3) High voltage dielectric tests: Test from each winding to grounded machine frame with other windings grounded.
- (4) Total harmonic content: Test at no load and full load.
- (5) Transients: Test for short-term voltage and frequency transients occurring upon instantaneous removal of 50 percent and 100 percent load. Repeat each test three times.

**NOTE: At the text below, do not include
electromagnetic interference requirements unless
specifically included in the project requirements or
requested by the using agency.**

- b. MIL-STD-461 for Class C2 equipment, except that the radiated interference measurements shall be made at a distance of 2 meters 6 feet. Suppress conducted and radiated electromagnetic interference so that the normal operation of communications and adjacent electrical equipment is not affected.

PART 3 EXECUTION

3.1 INSTALLATION

Conform to NFPA 70 and ANSI C2 and the approved manufacturer's drawings, written recommendations, and directions.

3.1.1 Grounding

**NOTE: Where rock or other soil conditions prevent
obtaining a suitable ground, other methods of ground
should be specified. Where it is impractical to
obtain the indicated ground resistance values, the
designer should make every effort within reason to
obtain ground resistance values as near as possible
to the indicated values.**

Grounds shall have a maximum resistance-to-solid earth ground of 5 ohms for low voltage systems.

3.1.1.1 Grounding Electrodes

Utilize electrically continuous metallic buried water piping for grounding electrodes, supplemented by grounding electrodes of the sectional type driven ground rods. Connect ground conductors to the upper end of the ground rods using exothermic weld method. Provide bolted (clamped) connection at equipment end of ground conductors.

3.1.1.2 Grounding and Bonding Equipment

UL 467.

3.1.2 Manufacturer's Representative

**NOTE: Include paralleling requirements when it is
required to parallel two or more machines.**

Furnish a manufacturer's representative to place the motor generator set(s) in operation and make necessary adjustments to ensure optimum operation [including the paralleling under load].

3.1.3 Foundation for Equipment and Assemblies

**NOTE: Mounting base connections may have to be
given in detail depending on the requirements for
the seismic zone in which the equipment is located.
Include construction requirements for concrete base
only if base is not detailed in the drawings.**

Mount motor-generator set on concrete base. [The top of the concrete base shall be approximately 100 mm 4 inches above the finished floor. Edges above floor shall have 15 mm 1/2 inch chamfer. The base shall be of adequate size to project at least 200 mm 8 inches beyond the equipment on each side.] Concrete work shall be as specified in Section [03300N CAST-IN-PLACE CONCRETE.] ["_____."] Provide anchor bolt.

3.2 FIELD TESTS AND INSPECTIONS

**NOTE: Determine whether test loads can be furnished
by the using agency, but do not state so without
written station approval.**

Perform field tests and trial operations, and conduct field inspections. Provide labor, equipment, and incidentals required for the tests [including load banks], except that the Government will furnish electricity [and test loads]. Provide the Contracting Officer with 7-days notice, in writing, of the dates and times scheduled for tests, trial operations, and inspections.

3.2.1 Field Test Schedule

Submit plans and procedures for field test at least 30 calendar days prior to the field tests.

3.2.2 Test Conditions

The tests shall be made at atmospheric pressure and at room temperature.

3.2.3 Electrical Equipment and Materials Tests

Test procedures, inspections, and sampling shall be conducted as specified in the specifications referenced and as noted in the following paragraphs. Record test data.

3.2.3.1 Instruments

Instruments and instrumentation procedures to be followed shall be appropriate for the tests to be performed. Instruments shall be capable of measuring and recording or displaying test data at a higher resolution and greater accuracy than specified for system and equipment performance. The instruments and apparatus used for the tests shall be calibrated by an approved laboratory within 30 days of these tests. Verify calibration and adjustments of installed instruments furnished under this contract just prior to accomplishing field tests.

3.2.3.2 Insulation Resistance Tests

Perform on equipment as listed herein. Perform tests with motor-driven or rectifier-type insulation resistance testers, having a range of up to 500 volts direct current (dc). Disconnect equipment, including solid-state, which might be damaged by such tests before tests are made. Tests shall measure insulation resistance from line to ground. Test 600-volt class circuits and equipment, including current-transformer and voltage-transformer secondary circuits and equipment. Minimum acceptable values of insulation resistance of circuits and equipment shall be as recommended by the manufacturer.

[3.2.4 Transient Tests

Conduct voltage and frequency transient tests on each set by instantaneously removing 50 percent and 100 percent of rated load at 0.8 power factor. Provide oscilloscope photographs of each transient test, and state the time interval required to return to stable voltage and frequency conditions. Indicate acceptable limits for voltage and frequency on each photograph. Repeat each transient test three times, and record data.

]3.2.5 Preliminary Operation

Place into operation equipment provided and installed. Make adjustments necessary to ensure proper operation, as instructed by manufacturers of the equipment. Lubricate equipment prior to operation in accordance with manufacturer's instructions. Dry out motors before operation as required to develop and maintain proper and constant insulation resistance. Upon approval by the Contracting Officer, operate motor generator sets under the supervision of the manufacturer's representative at varying loads throughout the load range to demonstrate that operation is proper, that temperatures are normal and within the specified limits, and to ensure that the units are ready to carry the test loads specified in the paragraph

entitled, "System Acceptance Tests," in this section, without damage to the components.

3.2.6 System Acceptance Tests

When installation is complete and in operating condition, perform tests to ensure that equipment is functioning properly. Run each unit continuously for a minimum of 2 hours at rated 0.8 power factor load before performing operating tests. Perform three separate operations on each device. Tests shall include, but not be limited to, the following:

NOTE: Include this requirement when it is required
to parallel two or more machines to serve a common
load or bus. Indicate required data of any existing
motor-generator sets which are to be paralleled.

- a. [Parallel operation: With one unit at full load, automatically and manually place a second unit in parallel at no load; divide load equally between the two units, and operate in parallel with each unit at one-half load for 15 minutes. Provide additional load, and increase the load in several increments until both units are fully loaded. Observe and record load-sharing characteristics at the different loads. Adjust load again until each unit is at one-half load. Transfer load from the first unit to the second unit. During the preceding operations, check the steadiness of load sharing and observe and record periodic pulsations, evidence of frequency hunting, and load surges. Repeat the preceding test until units in the plant have been tested for parallel operation with each other and collectively. Demonstrate capability of units to alternate as the starting machine. Record results.]
- b. Control operation checks during field testing: During testing, perform operation checks of which controls are capable to ensure that controls are functioning satisfactorily. Each instrument on the set and engine panel shall be observed at several points during the tests to ensure that instruments are functioning properly. Record results.
- c. Perform operating test on each protective device and protective scheme to ensure that devices and schemes are functioning properly.

3.2.7 Ground Resistance Tests

Measure ground resistance of each ground rod. Upon completion and before final acceptance of the work, submit in writing to the Contracting Officer the measured ground resistance of each ground rod and grounding system, indicating the location of the rod and grounding system, as well as the resistance and soil conditions at the time measurements were made. Make ground resistance measurements in normally dry weather, at least 48 hours after rainfall, and with the ground rod under test isolated from other ground rods. Also, measure ground resistance from each piece of equipment to the ground rod. Record data.

3.3 TRAINING

Furnish a representative of the 400 Hz equipment manufacturer to field train Government personnel. The field training period shall be limited to

[one 8-hour day] [[_____] 8-hour days] and shall be scheduled with the Contracting Officer at least 2 weeks in advance.

-- End of Section --