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USACE / NAVFAC / AFCEC / NASA **UFGS-26 32 15.00 (May 2020)**

Preparing Activity: USACE

Superseding
UFGS-26 32 13.00 20 (August 2018)
UFGS-26 32 14.00 10 (February 2010)
UFGS-26 32 15.00 10 (October 2007)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated April 2021

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SECTION TABLE OF CONTENTS

DIVISION 26 - ELECTRICAL

SECTION 26 32 15.00

ENGINE-GENERATOR SET STATIONARY 15-2500 KW, WITH AUXILIARIES

05/20

-- End of Section Table of Contents --

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SECTION 26 32 15.00

ENGINE-GENERATOR SET STATIONARY 15-2500 KW, WITH AUXILIARIES
05/20

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NOTE: This guide specification covers the requirements for stationary generator sets up to 2500 kilowatt capacity.

Adhere to UFC 1-300-02 **Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.**

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR)**.**
****

PART 1 GENERAL

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NOTE: This guide specification will require modification for applications where automatic transfer switches are not used. When generators are to be operated in parallel with utility or with other generators, and for medium voltage (greater than 600 volt) systems, contact the responsible Facilities Engineering Command (FEC) for determination as to which specification or sample specification is to be used. If Echelon III Reach-back Support from NAVFAC LANT or NAVFAC PAC is required for shop drawing review or field acceptance testing, the FEC technical representative

(electrical engineer) editing this document for a specific project must contact the appropriate Capital Improvements Electrical Engineering Office for consultation during the design stage of the project.

On drawings, show:

1. Engine-generator set foundation design and details.

2. Piping for ventilation of engine crankcase to atmosphere where required.

3. Details of exhaust, cooling water, and fuel piping, including penetrations through walls and roofs showing piping sleeves and exterior flashing where applicable.

4. Fuel day tank capacity where applicable.

5. Location of remote alarm annunciator where applicable.

6. Circuiting for the jacket coolant heating system, electric motor driven radiator fan where applicable, fuel supply system, starting battery charger, remote alarm annunciator storage battery charger where applicable, and generator space heater.

7. Grounding Plan. For applications using transfer switches, the transfer switch must be four pole and the generator must be grounded as a separately derived system.

This specification is for procurement of engine-generator sets which are suitable for serving general purpose and commercial-grade loads (loads which may be served by an electric utility). These are loads which can endure or recover quickly from transient voltage and frequency changes (as much as 30 percent transient voltage drop, and plus or minus 5 percent frequency deviation, with recovery time of 2 seconds). For applications where strict control of voltage, frequency, and transient response is required, provide uninterruptible power supplies.

This specification is for procurement of fossil-fueled engine-generator sets. Transient-load-response performance characteristics of natural gas, digester gas, propane, and liquefied petroleum gas engines differ significantly from those of diesel engines because of the fuel differences. Consult manufacturers for sample specifications.

Select the features and fill in blanks with values appropriate for the design condition. This specification does not apply to 400 Hz applications.

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1.1 REFERENCES

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NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

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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 SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B16.1	(2020) Gray Iron Pipe Flanges and Flanged Fittings Classes 25, 125, and 250
ASME B16.3	(2016) Malleable Iron Threaded Fittings, Classes 150 and 300
ASME B16.5	(2020) Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard
ASME B16.9	(2018) Factory-Made Wrought Buttwelding Fittings
ASME B16.11	(2016) Forged Fittings, Socket-Welding and Threaded
ASME B16.21	(2016) Nonmetallic Flat Gaskets for Pipe Flanges
ASME B31.1	(2020) Power Piping
ASME B31.3	(2016) Process Piping
ASME BPVC SEC IX	(2017; Errata 2018) BPVC Section IX-Welding, Brazing and Fusing Qualifications
ASME BPVC SEC VIII D1	(2019) BPVC Section VIII-Rules for

Construction of Pressure Vessels Division 1

ASSOCIATION OF EDISON ILLUMINATING COMPANIES (AEIC)

AEIC CS8	(2013) Specification for Extruded Dielectric Shielded Power Cables Rated 5 Through 46 kV

ASTM INTERNATIONAL (ASTM)

ASTM A53/A53M	(2020) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A106/A106M	(2019a) Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service
ASTM A126	(2004; R 2019) Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings
ASTM A181/A181M	(2014; R 2020) Standard Specification for Carbon Steel Forgings, for General-Purpose Piping
ASTM A193/A193M	(2020) Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service and Other Special Purpose Applications
ASTM A194/A194M	(2020a) Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High-Pressure or High-Temperature Service, or Both
ASTM A234/A234M	(2019) Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
ASTM B395/B395M	(2018) Standard Specification for U-Bend Seamless Copper and Copper Alloy Heat Exchanger and Condenser Tubes
ASTM D975	(2020) Standard Specification for Diesel Fuel Oils

ELECTRICAL GENERATING SYSTEMS ASSOCIATION (EGSA)

EGSA 101P	(1995) Performance Standard for Engine Driven Generator Sets

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 1	(2000; R 2011) General Principles for Temperature Limits in the Rating of Electric Equipment and for the Evaluation of Electrical Insulation

IEEE 43	(2013) Recommended Practice for Testing Insulation Resistance of Rotating Machinery
IEEE 48	(2020) Test Procedures and Requirements for Alternating-Current Cable Terminations Used on Shielded Cables Having Laminated Insulation Rated 2.5 kV through 765 kV or Extruded Insulation Rated 2.5 kV through 500 kV
IEEE 81	(2012) Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System
IEEE 100	(2000; Archived) The Authoritative Dictionary of IEEE Standards Terms
IEEE 115	(2019) Guide for Test Procedures for Synchronous Machines: Part I Acceptance and Performance Testing; Part II Test Procedures and Parameter Determination for Dynamic Analysis
IEEE 120	(1989; R 2007) Master Test Guide for Electrical Measurements in Power Circuits
IEEE 404	(2012) Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2500 V to 500,000 V
IEEE 484	(2019) Recommended Practice for Installation Design and Implementation of Vented Lead-Acid Batteries for Stationary Applications
IEEE 485	(2020) Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications
IEEE 519	(2014) Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
IEEE C2	(2017; Errata 1-2 2017; INT 1 2017) National Electrical Safety Code
IEEE C50.12	(2005; R 2010) Standard for Salient Pole 50 HZ and 60 Hz Synchronous Generators and Generation/Motors for Hydraulic Turbine Applications Rated 5 MVA and above
IEEE C57.13	(2016) Requirements for Instrument Transformers
IEEE C57.13.1	(2006; R 2012) Guide for Field Testing of Relaying Current Transformers

INTERNATIONAL CODE COUNCIL (ICC)

ICC IBC	(2021) International Building Code

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

NETA ATS	(2021) Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

IEC 60034-2A	(1974; ED 1.0) Rotating Electrical Machines Part 2: Methods for Determining Losses and Efficiency of Rotating Electrical Machinery from Tests (Excluding Machines for Traction Vehicles) Measurement of Losses by the Calorimetric Method

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 3046	(2002, 2006, 2009, 2001) Reciprocating Internal Combustion Engines - Performance--Part 1, 3, 4, 5, 6
ISO 8528	(1993; R 2018) Reciprocating Internal Combustion Engine Driven Alternating Current Generator Sets--Part 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13

MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY (MSS)

MSS SP-58	(2018) Pipe Hangers and Supports - Materials, Design and Manufacture, Selection, Application, and Installation
MSS SP-70	(2011) Gray Iron Gate Valves, Flanged and Threaded Ends
MSS SP-71	(2018) Gray Iron Swing Check Valves, Flanged and Threaded Ends
MSS SP-80	(2019) Bronze Gate, Globe, Angle and Check Valves
MSS SP-85	(2011) Gray Iron Globe & Angle Valves Flanged and Threaded Ends

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA ICS 2	(2000; R 2005; Errata 2008) Industrial Control and Systems Controllers, Contactors, and Overload Relays Rated 600 V
NEMA ICS 6	(1993; R 2016) Industrial Control and Systems: Enclosures

NEMA MG 1	(2018) Motors and Generators
NEMA PB 1	(2011) Panelboards
NEMA PB 2	(2011) Deadfront Distribution Switchboards
NEMA WC 74/ICEA S-93-639	(2012) 5-46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy
NEMA/ANSI C12.11	(2006; R 2019) Instrument Transformers for Revenue Metering, 10 kV BIL through 350 kV BIL (0.6 kV NSV through 69 kV NSV)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 30	(2021; TIA 20-1; TIA 20-2) Flammable and Combustible Liquids Code
NFPA 37	(2021) Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines
NFPA 54	(2021) National Fuel Gas Code
NFPA 58	(2020; TIA 20-1; TIA 20-2; TIA 20-3) Liquefied Petroleum Gas Code
NFPA 70	(2020; ERTA 20-1 2020; ERTA 20-2 2020; TIA 20-1; TIA 20-2; TIA 20-3; TIA 20-4) National Electrical Code
NFPA 99	(2021; TIA 20-1) Health Care Facilities Code
NFPA 110	(2016) Standard for Emergency and Standby Power Systems

SOCIETY OF AUTOMOTIVE ENGINEERS INTERNATIONAL (SAE)

SAE ARP892	(1965; R 1994) DC Starter-Generator, Engine
SAE J537	(2016) Storage Batteries

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-DTL-5624	(2016; Rev W; Notice 1 2020) Turbine Fuel, Aviation, Grades JP-4 and JP-5
MIL-DTL-16884	(2017; Rev P) Fuel, Naval Distillate
MIL-STD-461	(2015; Rev G) Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
UFC 3-301-01	(2019) Structural Engineering

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

40 CFR 60	Standards of Performance for New Stationary Sources

UNDERWRITERS LABORATORIES (UL)

UL 142	(2006; Reprint Jan 2021) UL Standard for Safety Steel Aboveground Tanks for Flammable and Combustible Liquids
UL 429	(2013; Reprint Jan 2020) Electrically Operated Valves
UL 467	(2013; Reprint Jun 2017) UL Standard for Safety Grounding and Bonding Equipment
UL 489	(2016) UL Standard for Safety Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures
UL 891	(2005; Reprint Oct 2012) Switchboards
UL 1236	(2015; Reprint Feb 2021) UL Standard for Safety Battery Chargers for Charging Engine-Starter Batteries
UL 1437	(2006) Electrical Analog Instruments - Panel Board Types

1.2 RELATED MATERIALS

Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM, and Section 26 08 00 APPARATUS INSPECTION AND TESTING apply to this section, except as modified herein.

1.3 SUBMITTALS

****

NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a “G” to an item, if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters 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, Air Force, and NASA projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.
****

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Engine-Generator Set and Auxiliary Equipment; G[, [_____]]

Auxiliary Systems; G[, [_____]]

Detailed Drawings; G[, [_____]]

Acceptance; G[, [_____]]

SD-03 Product Data

Harmonic Requirements; G[, [_____]]

Engine-Generator Set Efficiencies; G[, [_____]]

Emissions; G[, [_____]]

filters; G[, [_____]]

special tools; G[, [_____]]

Remote Alarm Annunciator; G[, [_____]]

Engine-Generator Parameter Schedule

Heat Exchanger

Generator

Manufacturer's Catalog

Site Welding

Spare Parts

Onsite Training

Vibration-Isolation

Posted Data and Instructions; G[, [_____]]

Instructions; G[, [_____]]

Experience

Field Engineer

General Installation

Exciter

SD-05 Design Data

Performance Criteria

Sound Limitations; G[, [_____]]

Integral Main Fuel Storage Tank

Day Tank

Power Factor

Heat Exchanger

Time-Delay on Alarms

Cooling System

Vibration Isolation

Battery Charger

Capacity Calculations for Engine-Generator Set; G[, [_____]]

Brake Mean Effective Pressure (BMEP) Calculations; G[, [_____]]

Torsional Vibration Stress Analysis Computations; G[, [_____]]

Capacity Calculations for Batteries; G[, [_____]]

Turbocharger Load Calculations; G[, [_____]]

SD-06 Test Reports

Performance Tests

Factory Inspection and Tests

Factory Tests

Onsite Inspection and Tests; G[, [_____]]

Acceptance Checks and Tests; G[, [_____]]

Functional Acceptance Tests; G[, [_____]]

Maintenance Procedures; G[, [_____]]

Operation and Maintenance Manuals; G[, [_____]]

Inspections; G[, [_____]]

Functional Acceptance Test Procedure; G[, [_____]]

SD-07 Certificates

Cooling System

Vibration Isolation

Prototype Test

Reliability and Durability

Fuel System Certification; G[, [_____]]

Start-Up Engineer; G[, [_____]]

Instructor's Qualification Resume; G[, [_____]]

Engine Emission Limits; G[, [_____]]

Sound Limitations

Site Visit

Current Balance

Materials and Equipment

Factory Inspection and Tests

SD-09 Manufacturer's Field Reports

Engine Tests; G[, [_____]]

Generator Tests; G[, [_____]]

Assembled Engine-Generator Set Tests; G[, [_____]]

SD-10 Operation and Maintenance Data

Preliminary Assembled Operation and Maintenance Manuals; G[, [_____]]

Submit in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA and the paragraph ASSEMBLED OPERATION AND MAINTENANCE MANUALS.

SD-11 Closeout Submittals

Posted Data and Instructions; G[, [_____]]

Training Plan; G[, [_____]]

1.4 QUALITY ASSURANCE

1.4.1 Conformance to Codes and Standards

Where equipment is specified to conform to requirements of any code or standard such as UL, NEMA, etc., the design, fabrication and installation must also conform to the code.

1.4.2 Site Welding

Weld structural members in accordance with Section 05 05 23.16 STRUCTURAL WELDING. For all other welding, qualify procedures and welders in accordance with ASME BPVC SEC IX.

a. Welding procedures qualified by others, and welders and welding operators qualified by a previously qualified employer may be accepted as permitted by ASME B31.1.

b. Submit a copy of qualifying procedures and a list of names and identification symbols of qualified welders and welding operators.

c. Submit a letter listing the welder qualifying procedures for each welder, complete with supporting data such as test procedures used, what was tested to, and a list of the names of all welders and their identification symbols.

d. Perform welder qualification tests for each welder whose qualifications are not in compliance with the referenced standards. Notify the Contracting Officer 24 hours in advance of qualification tests which must be performed at the work site, if practical.

e. The welder or welding operator must apply the personally assigned symbol near each weld made as a permanent record.

1.4.3 Vibration Limitation

Limit the maximum engine-generator set vibration in the horizontal, vertical, and axial directions to 0.15 mm 6 mils (peak-peak RMS), with an overall velocity limit of 24 mm/second 0.95 inches/second RMS, at rated speed for all loads through 110 percent of rated speed. [Install a vibration isolation system between the floor and the base to limit the maximum vibration transmitted to the floor at all frequencies to a maximum of [_____] (peak force).][The engine-generator set must be provided with vibration isolation in accordance with the manufacturer's standard recommendation.] Where the vibration isolation system does not secure the base to the structure floor or unit foundation, provide seismic restraints in accordance with the seismic parameters specified.

1.4.4 Torsional Analysis

Submit torsional analysis including prototype testing or calculations which certify and demonstrate that no damaging or dangerous torsional vibrations will occur when the prime mover is connected to the generator, at synchronous speeds, plus/minus 10 percent.

1.4.5 Performance Data

Submit vibration isolation system performance data for the range of frequencies generated by the engine-generator set during operation from no load to full load and the maximum vibration transmitted to the floor. Also submit a description of seismic qualification of the engine-generator mounting, base, and vibration isolation.

1.4.6 Seismic Requirements

****

NOTE: Provide seismic requirements, if a Government designer (either Corps office or A/E) is the Engineer of Record, and show on the drawings. Delete the bracketed phrase if seismic details are not provided. Pertinent portions of UFC 3-301-01 and Sections 13 48 73, 23 05 48.19, and 26 05 48.00 10, properly edited, must be included in the contract documents.

****

[Seismic requirements must be in accordance with UFC 3-301-01 and Sections 13 48 73 SEISMIC CONTROL FOR MECHANICAL EQUIPMENT, 23 05 48.19 [SEISMIC] BRACING FOR HVAC and 26 05 48.00 10 SEISMIC PROTECTION FOR ELECTRICAL EQUIPMENT] [as shown on the drawings].

1.4.7 Experience

Each component manufacturer must have a minimum of 3 years' experience in the manufacture, assembly and sale of components used with stationary engine-generator sets for commercial and industrial use. The engine-generator set manufacturer/assembler must have a minimum of 3 years' experience in the manufacture, assembly and sale of stationary engine-generator sets for commercial and industrial use. Submit a statement showing and verifying these requirements.

1.4.8 Field Engineer

The engine-generator set manufacturer or assembler must furnish a qualified field engineer to supervise the complete installation of the engine-generator set, assist in the performance of the onsite tests, and instruct personnel as to the operational and maintenance features of the equipment. The field engineer must have attended the engine generator manufacturer's training courses on installation and operation and maintenance of engine generator sets. Submit a letter listing the qualifications, schools, formal training, and experience of the field engineer.

1.4.9 Detailed Drawings

Submit detailed drawings showing the following:

a. Base-mounted equipment, complete with base and attachments, including anchor bolt template and recommended clearances for maintenance and operation.

b. Starting system.

c. Fuel system.

d. Cooling system.

e. Exhaust system.

f. Electric wiring of relays, breakers, programmable controllers, and switches including single line and wiring diagrams.

g. Lubrication system, including piping, pumps, strainers, filters, [heat exchangers for lube oil and turbocharger cooling,] [electric heater,] controls and wiring.

h. Location, type, and description of vibration isolation devices for all applications.

i. The safety system, including wiring schematics.

j. One-line schematic and wiring diagrams of the generator, exciter, regulator, governor, and instrumentation.

k. Panel layouts.

l. Mounting and support for each panel and major piece of electrical equipment.

m. Engine-generator set rigging points and lifting instructions.

1.4.10 Auxiliary Systems Engine-Generator Set and Auxiliary Equipment Drawing Requirements

Submit drawings pertaining to the engine-generator set and auxiliary equipment, including but not limited to the following:

a. Certified outline, general arrangement (setting plan), and anchor bolt details. Show total weight and center of gravity of assembled equipment on the steel sub-base.

b. Detailed elementary, schematic wiring, and interconnection diagrams of the engine starting system, jacket coolant heating system, engine protective devices, engine alarm devices, engine speed governor system, generator and excitation system, and other integral devices.

c. Detailed elementary, schematic wiring; and interconnection diagrams of the fuel system, starting battery system, engine-generator control panel, generator circuit breaker[, and remote alarm annunciator].

d. Dimensional drawings or catalog cuts of exhaust silencers, radiator, fuel day tanks, fuel oil cooler, valves and pumps, intake filters, vibration isolators, and other auxiliary equipment not integral with the engine-generator set.

1.4.11 Auxiliary Systems Drawing Requirements

****

NOTE: When the engine-generator set installation includes field installed exhaust, air intake, fuel oil cooler, or jacket coolant water systems (i.e., the engine-generator set is installed internal to a building in lieu of in a self-contained outdoor

enclosure), include the following paragraph.
****

Submit drawings showing floor plan arrangement of[exhaust,][air intake,][fuel oil cooler,][and][jacket coolant water] systems including arrangement of piping and pipe sizes.

1.4.12 Vibration Isolation System Certification

Submit certification from the manufacturer that the vibration isolation system will reduce the vibration to the limits specified in the paragraph VIBRATION ISOLATION.

1.4.13 Fuel System Certification

When the fuel system requires a fuel oil cooler as described in the paragraph FUEL OIL COOLER, submit certification from the engine manufacturer that the fuel system design is satisfactory.

1.5 DELIVERY, STORAGE, AND HANDLING

Properly protect materials and equipment, in accordance with the manufacturers recommended storage procedures,before, during, and after installation. Protect stored items from the weather and contamination. During installation, cap piping and similar openings to keep out dirt and other foreign matter.

Deliver equipment on pallets or blocking wrapped in heavy-duty plastic, sealed to protect parts and assemblies from moisture and dirt. Protect and prepare batteries for shipment as recommended by the battery manufacturer. Store auxiliary equipment at the site in covered enclosures, protected from atmospheric moisture, dirt, and ground water.

1.6 EXTRA MATERIALS

Provide [two] [_____] sets of special tools and [two] [_____] sets of filters required for maintenance. Special tools are those that only the manufacturer provides, for special purposes, or to reach otherwise inaccessible parts. One handset must be provided for each electronic governor when required to indicate and/or change governor response settings. Furnish 4 liters one gallon of identical paint used on engine-generator set in manufacturer's sealed container with each engine-generator set.

Wrenches and tools specifically designed and required to work on the new equipment, which are not commercially available as standard mechanic's tools, must be furnished to the Contracting Officer.

Provide proposed operating instructions for the engine-generator set and auxiliary equipment laminated between matte-surface thermoplastic sheets and suitable for placement adjacent to corresponding equipment. After approval, install operating instructions where directed.

1.7 MAINTENANCE SERVICES

Submit the operation and maintenance manuals and have them approved prior to commencing onsite tests.

1.7.1 Operation Manual

Provide [three] [_____] copies of the [manufacturers standard operation manual] [operation manual in 216 by 279 mm8-1/2 by 11 inch three-ring binders]. Sections must be separated by heavy plastic dividers with tabs which identify the material in the section. Fold drawings with the title block visible, and placed in 216 by 279 mm8-1/2 by 11 inch plastic pockets with reinforced holes. The manual must include:

a. Step-by-step procedures for system startup, operation, and shutdown;

b. Drawings, diagrams, and single-line schematics to illustrate and define the electrical, mechanical, and hydraulic systems with their controls, alarms, and safety systems;

c. Procedures for interface and interaction with related systems to include [automatic transfer switches] [fire alarm/suppression systems] [load shedding systems] [uninterruptible power supplies] [_____].

1.7.2 Maintenance Manual

Provide [three] [_____] copies of the [manufacturers standard maintenance manual] [maintenance manual containing the information described below in 216 x 279 mm8-1/2 x 11 inch three-ring binders]. Separate each section by a heavy plastic divider with tabs. Fold drawings with the title block visible, and placed in plastic pockets with reinforced holes. The manual must include:

a. [Procedures for each routine maintenance item.][Procedures for troubleshooting.][Factory-service, take-down overhaul, and repair service manuals, with parts lists.]

b. The manufacturer's recommended maintenance schedule.

c. A component list which includes the manufacturer's name, address, type or style, model or serial number, rating, and catalog number for the major components.

d. A list of spare parts for each piece of equipment and a complete list of materials and supplies needed for operation.

1.7.3 Assembled Operation and Maintenance Manuals

The contents of the assembled operation and maintenance manuals must include the manufacturer's O&M information required by the paragraph SD-10, OPERATION AND MAINTENANCE DATA and the manufacturer's O&M information specified in Section 26 36 23 AUTOMATIC TRANSFER SWITCHES AND BY-PASS/ISOLATION SWITCH.

a. Manuals must be in separate books or volumes, assembled and bound securely in durable, hard covered, water resistant binder, and indexed by major assembly and components in sequential order.

b. A table of contents (index) must be made part of the assembled O&M. The manual must be assembled in the order noted in table of contents.

c. The cover sheet or binder on each volume of the manuals must be identified and marked with the words, "Operation and Maintenance Manual."

1.8 SITE CONDITIONS

Protect the components of the engine-generator set, including cooling system components, pumps, fans, and similar auxiliaries when not operating and provide components capable of the specified outputs in the following environment:

a. Site Location: [_____]

b. Site Elevation: [_____] meters[_____] feet above mean sea level.

c. Ambient Temperatures:

****

NOTE: Ambient temperatures, design wind velocity, and prevailing wind direction must be as defined by UFC 3-400-02, Design Engineering Weather Data.

****

(1) Maximum [_____] degrees C[_____] degrees F dry bulb, [_____] degrees C[_____] degrees F wet bulb.

(2) Minimum [_____] degrees C[_____] degrees F dry bulb.

d. Design Wind Velocity: [_____] km/h[_____] mph.

e. Prevailing Wind Direction: [_____]

f. Seismic Zone: Zone [_____] as defined by ICC IBC.

PART 2 PRODUCTS

2.1 SYSTEM REQUIREMENTS

a. Provide and install each engine-generator set complete and totally functional, with all necessary ancillary equipment to include: air filtration; starting system; generator controls, protection, and isolation; instrumentation; lubrication; fuel system; cooling system; and engine exhaust system. Each engine-generator set must satisfy the requirements specified in the Engine-Generator Parameter Schedule. Submit certification that the engine-generator set and cooling system function properly in the ambient temperatures specified.

b. Provide each engine-generator set consisting of one engine, one generator, and one exciter mounted, assembled, and aligned on one base; and all other necessary ancillary equipment which may be mounted separately. Assemble sets having a capacity of 750 kW or smaller and attach to the base prior to shipping. Sets over 750 kW capacity may be shipped in sections. Provide set components that are environmentally suitable for the locations shown and that are the manufacturer's standard product offered in catalogs for commercial or industrial use. Provide a generator strip heater for moisture control when the generator is not operating. Identify any nonstandard products or components and the reason for their use.

2.1.1 Engine-Generator Parameter Schedule

****

NOTE: Where multiple engine-generator sets of different sizes or applications are to be provided, a Parameter Schedule should be shown on the contract drawings (one for each engine-generator set to be installed). If only one engine-generator set is provided (or multiples of the same type, size, etc.), the schedule may be in the body of the specification. Note that the specifications refer to the Engine Generator Parameter Schedule and the designer must provide one each by that name.

Some load applications require precise generator output frequency, voltage, level waveform characteristics and control of transient response. Most loads do not require stricter control than most off-the-shelf engine generator sets can provide. The criticality of the output and response characteristics can affect: selection of the governor type, whether it is to be isochronous or droop, and its steady state bandwidth; selection of the voltage regulator parameters; transient recovery time for frequency and voltage; maximum voltage and frequency deviation for a transient event; and because of the maximum deviations and transient recovery times, the sizing or oversizing of the engine and generator. The notes below are included to assist the designer in making informed choices when filling in the Engine Generator Parameter Schedule.

Power Ratings and Industry Terminology. The following definitions are from the Electrical Generating Systems Association Standard 101P, Engine Driven Generating Sets. Stationary, diesel-engine-driven, electric generator sets are divided into the following four rating categories: EMERGENCY STANDBY, LIMITED RUNNING TIME, PRIME POWER, and INDUSTRIAL.

"EMERGENCY STANDBY RATING means the power that the generator set will deliver continuously under normal varying load factors for the duration of a power outage." It must be understood that this definition uses the term "normal varying load condition factors". Most manufacturers use this terminology to indicate that their units typically are not rated for continuous operation at the nameplate rating, but rather that the units provided are rated for continuous operation at 70 to 80 percent of their nameplate rating, with periodic loading up to 100 percent of the nameplate rating for short (cyclical) periods during a power outage. Additionally, the designer must analyze the load characteristics and profiles of the load to be served to determine the peak demand, maximum step load increase and decrease, motor starting requirements represented as

starting kVA, and the non-linear loads to be served. This information should be included in the engine-generator set parameter schedule or on the drawings for each different unit provided. For this application service load is the peak estimated loading to be placed on the engine generator set. Peak demand calculation provides a figure from which to determine the service load. When specifying an engine-generator be sure to specify what the peak load is and how much is continuous.

"LIMITED RUNNING TIME RATING means the power that the generator set will deliver when used as a utility type power source, typically in load curtailment type service, for a limited number of hours, where there are non-varying load factors and/or constant dedicated loads."

"PRIME POWER RATING means the power that the generator set will deliver when used as a utility type power plant under normal varying load factors to run continuously. This rating requires a minimum momentary overload capability of 10 percent."

"INDUSTRIAL RATING means the power that the generator set will deliver 24 hours per day when used as a utility type power plant where there are non-varying load factors and/or constant dedicated loads."

Overload Capacity. Overload capacity is only for PRIME rated units. Delete for standby applications.

Gross bhp rating of engine must be the total rated power output before deducting power requirements of electric motor-driven equipment or engine driven radiator fan.

Net brake power rating of engine must include deductions for the total power requirements of electric motor-driven or engine-driven accessories as defined in ISO 3046. Net ratings must include a deduction in power output for cooling media system power requirements including radiator fans and any other power consuming devices required to provide cooling as specified.

Power Factor. Commercial engine-generator power ratings are usually based on 0.8 power factor. Select 0.8 unless the application requires one more stringent.

Loading. When specifying engine-generator sets, the designer will analyze the load characteristics and profiles of the load to be served to determine the peak demand, maximum step load increase and decrease, motor starting requirements represented as starting kVA, continuous and non-continuous (cyclical / periodic), and the non-linear loads to

be served. This information should be included in the engine-generator set parameter schedule or on the drawings for each different unit provided. For this application, service load is the peak estimated loading (continuous plus non-continuous) to be placed on the engine generator set.

Peak demand calculation provides a figure from which to determine the service load. For prime applications the service load should include spare capacity for future load growth and spinning reserve (reserve generation beyond that required to satisfy immediate needs and/or system peak demands). Spare capacity for prime applications should be based on the facility master plan load projections.

Motor Starting Load. Motor starting requirements are important to properly size engine generator sets because the starting current for motors can be as much as six times the running current, and can cause generator output voltage and frequency to drop, even though the gensetengine-generator has been sized to carry the running load. The designer must analyze the motor loads to determine if the starting characteristics of a motor or a group of motors to be started simultaneously will cause objectionable engine-generator performance. Provide a motor starting kVA value for the largest motor or combination of motors to be started simultaneously. An increase in the size rating of the engine-generator may be necessary to compensate for the inrush current. This assists the engine-generator supplier in properly sizing the engine generator set.

Maximum Speed. The maximum allowable speed for emergency standby applications is 1800 RPM. If there is not specific requirement or user requirement for slower speed machines, select 1800 RPM. Selection of the maximum 1800 RPM does not preclude provision of slower speed machines, for example, in the larger sizes (above 2000 kW), where 1800 RPM machines may not be available. However, for prime power or continuous duty plant applications, the lowest total cost of ownership would result by specifying a much lower speed, as recommended in UFC 3-540-04N, Section 5.1, Table 7. Lower speed engines require fewer overhauls, fewer oil changes, have a higher availability factor, and can be more fuel efficient. Even though prime duty power plants are the minority case, improper specification can result in very large increase in cost over the life of the installation. Frequently these plants are installed forward in contingency environments at FOBs or base camps which by nature demand reliable power at the lowest total cost. Furthermore, as prime sources of power these plants are relied upon as "the grid" and must perform as such for reliable power. Additionally, several

manufacturers' medium speed (600-1200 RPM) engines will tolerate the varieties of fuel found in CONUS and OCONUS with minimal or no power or durability degradation.

Heat Exchanger Type. Fin-tube heat exchangers (radiators) are the predominate method of cooling. Specify either a fin-tube or a shell-tube heat exchanger for each engine-generator set. Heat exchangers located remote from the engine-generator set (i.e., not mounted on the engine-generator set base) will be shown on the project plans, including the power source for associated fans and pumps.

Governor. The type of governor to be used on each engine generator set should be identified as isochronous or droop on the engine-generator set parameter schedule. Isochronous governors hold frequency at the setpointset-point frequency (within bandwidth) for all steady state loads from 0 to 100 percent load and are required for applications where severe demands are made on voltage and frequency regulation. Droop governors allow frequency to droop to the specified percentage proportional to steady state loads from 0 to 100 percent load and are generally acceptable for general purpose and commercial applications.

Engine-generator sets in stand alonestand-alone service (isolated bus) may utilize either droop or isochronous governors. The designer should analyze the application and loads to determine if the more expensive isochronous unit is actually required. Droop units provide added stability (less engine cycling) in single unit applications where constant speeds are not critical and are less expensive than isochronous governors.

Engine-generator sets in parallel (on an isolated bus) may also utilize either droop or isochronous governors. Load swings are shared proportionally based on the governor droop settings. The load will be split equally among the units for all units equipped with isochronous governors with load sharing controls, or if all units have droop governors that are set with the same droop. "Lead units" are often designated in multiple unit applications for tighter frequency control by setting one governor at a much lower droop than the others. A "lead unit" can be designated for gensetengine-generators equipped with isochronous governors if all units have governors with load sharing controls. In this case the "lead unit" will accept all load swings and the other units will remain at a constant load. When all units have droop governors, the "lead units" will accept most of the load swings and the other units will equally split a small portion of the load. If isochronous governors are specified for two or more units to be

paralleled on an isolated bus, the governors must be specified with load sharing controls. For applications involving units in parallel operation which are not operator supervised the designer should specify a load-sharing system which can proportionally load two or more sets in parallel, each having isochronous governors. Generators for use with existing generators in parallel applications must have similar characteristics. Droop paralleling is specified for electrical and electro-hydraulic governors where interconnection of all controls is not possible such as when paralleling to a large electrical utility grid network. When paralleling two or more droop units with a utility grid (or with other droop units), to achieve load sharing, the unit governors must be compatible, their speed settings must be matched, and the droop must be set the same on all units. Droop adjustment range of 0 to 7 percent is typical for mechanical-hydraulic governors, and 0 to 10 percent is typical for electro-hydraulic governors. Isochronous units should not be paralleled with an infinite bus (utility grid system) without also specifying synchronizing and governor-load sharing controls. Delete speed droop adjustment for isochronous governors in non-parallel applications.

Frequency Bandwidth. Governor frequency bandwidth defines the allowable steady state variation in frequency and is typically quite small for commercially available governors (typically less than plus or minus 0.4 percent with plus or minus 0.25 percent readily available). The predominant type of device loads which are susceptible to steady state frequency deviations less than plus or minus 0.4 percent are those which employ switching power supplies (computers and variable frequency drives). The designer should select the least restrictive value for bandwidth for the application.

Voltage Regulators. Solid state regulators are readily available which maintain the voltage level (regulation or voltage droop) to plus or minus 0.5 percent. Voltage regulator bandwidth is important relative primarily to transient response. EGSA Standard 100R-1992 defines three performance classes for voltage regulators: standard (2 percent bandwidth); high (1 percent bandwidth); and precision (0.5 percent bandwidth). Select the least restrictive bandwidth necessary to satisfy the application requirement.

Generator frequency and voltage should be shown on the engine-generator set schedule. (For example: 208Y/120 volts, 3-phase, 4-wire).

Sub-transient Reactance. The sub-transient reactance of a generator is the impedance characteristic which determines current during the

first cycle after a system short circuit condition is presented to the generator. Therefore, it is used to determine the necessary interrupting capacity of the engine-generator circuit interrupting device. It also is utilized to predict generator response to non-linear loads. Typical values for generator sub-transient reactance are found in IEEE Standard 141. Sub-transient reactance is specified in per unit of the generator rated kVA. Also, see the following discussion on non-linear loads.

Non-linear Loads: Non-linear loads are addressed in IEEE 519. They are loads that draw a non-sinusoidal current waveform when supplied by a sinusoidal voltage source. Typical non-linear loads include solid state switching power supplies, computer power supplies (including those found in desktop PC's, uninterruptible power supplies, variable frequency drives, radar power supplies, and solid state ballasts in fluorescent light fixtures. They cause distortion of the source voltage and current waveforms that can have harmful effects on many types of electrical equipment and electronics, including generators. Non-linear loads are similar to short circuits in that they provide momentary, sub-cycle-duration, short-circuiting of two phases. Switching power supplies consist of SCR/thyristor-controlled rectifier bridges which act as three single-phase loads, each connected across two phases of the power system. When the SCR/thyristors are switched on and off a notch in the voltage waveform will occur as a result of an instantaneous phase-phase short-circuit during the commutation of current. A low generator sub-transient reactance minimizes the voltage waveform distortion in the presence of such loads. For this reason when the non-linear loads comprise 25 percent or more of the loads served, the generator sub-transient reactance should be limited to no more than 0.12. Delete Sub-transient Reactance from the Engine-Generator Parameter Schedule where the engine-generator manufacturer is responsible for sizing the generator breaker and where the non-linear loads served are less than 25 percent.

Generators are particularly vulnerable to control problems and instability, excessive winding heating, neutral overheating, reduced efficiency, reduced torque, shaft fatigue, accelerated aging, and induced mechanical oscillations when non-linear loads are applied without careful consideration of the generator's capability to supply them. Measures which can be used to mitigate the effects of non-linear loads on generators include: procurement of low impedance generators with special windings to compensate for the additional heating; installation of harmonic filter traps; avoidance of self-excited

generators; use of 2/3 pitch factor (rather than 5/6 pitch) generator windings; and generator derating with oversized neutrals.

For large non-linear loads, filter traps which are tuned to the dominant harmonic frequencies of the non-linear loads should be procured/provided with the load component. This approach is normally less costly than procurement of specially designed or de-rated generators.

For combinations of linear and non-linear loads where the percentage of non-linear loads is small relative to the capacity rating of the generator (25 percent or less), standard generator configurations are normally acceptable.

Provide a list of the non-linear loads in the parameter schedule, either on the drawings (and denoted on the single-line diagram) or in tabular form in the specification section. The list should contain a description of the load including equipment type, whether the rectifier is 6-pulse or 12-pulse, kVA rating, and frequency. Provide a linear load value (kVA at PF) which represents the maximum linear load demand when non-linear loads will also be in use. The generator manufacturer will be required to meet the total harmonic distortion limits established in IEEE 519. Delete the non-linear load paragraph when non-linear loads are not served from the engine-generator set.

Maximum Step Load Increase. Maximum step load increase is used to account for the addition of block loads. These affect engine-generator set frequency and voltage output and usually initiate governor and regulator response. The change in engine-generator set output and the response of the governor and regulator defines the transient loading response. In the size range covered by this specification (and for standby applications) acquisition of full load in one step is typical for major engine-generator manufacturers (voltage deviation of 30 percent or less, frequency deviation of plus 5 percent, recovery time 3 to 5 seconds, typical). If the application requires a more stringent response, specify the actual maximum step load and add the allowable deviations and recovery times to the Engine Generator Set Parameter Schedule. If it is critical enough to add these requirements, also add the Transient Response Test to verify the results in the field. It should be noted that this adds significant cost to the cost of an engine-generator. The designer should provide the actual loads to be applied to the engine-generator set because specification of maximum step load increases of 75 or 100 percent requires significant oversizing of engines and generators and/or addition of mass to fly-wheel, all

of which add cost. Additionally, oversizing of engines causes maintenance problems and increases operating costs. The following percentages may be used when the actual load acquisition rate cannot be determined. A maximum step load increase of 25 percent should be used for prime rated sets, 50 percent for optional standby rated sets with step loading, and 100 percent for legally required standby (emergency) service with no step loading.

Transient Response Criteria (short time duration). Engine-generator-set response and recovery times vary according to the size of the set, the block load, and the controls specified. Normal response to addition of a block load will include dips in either output voltage or frequency or both and possible "overshoot" as the governor and voltage regulator respond to bring the voltage and frequency back within bandwidth. Normal response to loss of a block load will include an upward spike in output voltage or frequency back within bandwidth. The Maximum Voltage and Frequency Deviation apply to under-voltage / under-frequency ("dips") from the addition of block loads and any undershoot resulting from the recovery of an upward spike, as well as overvoltage / over-frequency (upward spikes) from the loss of block loads and any overshoot resulting from the recovery of a dip.

Cost Impact. If stringent transient-response requirements are specified, the manufacturer may select engine and generator models which have nominal rating much larger than the service load; may use an unnecessarily expensive governor; and may use a higher inertia flywheel. The designer should investigate what may actually be provided so that the cost estimate will be reasonably accurate and to confirm the selected transient requirements are not unnecessarily stringent. A maximum size for the engine-generator set may be needed to avoid the problems associated with a small load on a large capacity set.

The designer must determine the cost benefits of providing an uninterruptible power system for transient ride-through versus purchasing a generator with stringent transient response requirements. In determining the allowable voltage and frequency variation and recovery times, analyze the effects on equipment performance and recovery. Consult the NEMA utilization equipment standards to determine the maximum allowable voltage dips/overshoots (excursions).

Maximum Voltage Deviation. Select the 5 percent Maximum Voltage Deviation option only if communication equipment or other sensitive electronic equipment are a critical part of the load, and there is no UPS provided. Fluorescent

lights can tolerate a maximum of 10 percent voltage variation. NEMA induction motors and control relays can tolerate a maximum of 10 percent variation, for 30 cycles and one cycle respectively. Solenoids (brakes, valves, clutches) and ac and dc starter coils can tolerate a maximum of minus 30 percent variation, for 1/2 cycle, 2 cycles (dropout), and 5 - 10 cycles (dropout) respectively. (The times listed in cycles are not given to define the recovery time back to bandwidth, but to assist the designer in defining the maximum allowable voltage deviation.) The designer should realistically asses the need for limiting the transient voltage dip to less than 30 percent.

Maximum Voltage Deviation [5] [10] [30] [_____] with Step Load Increase percent of rated voltage.

Maximum Frequency Deviation. Computers can usually tolerate only plus or minus 0.5 Hz variation, so an UPS is normally required where computer services should not be interrupted, or where system recovery times are critical. Inverters can tolerate plus or minus 2 Hz variation. NEMA induction motors and control relays can tolerate a maximum of 5 percent frequency variation. (The times listed in cycles are not given to define the recovery time back to bandwidth, but to assist the designer in defining the maximum allowable frequency deviation.) The designer must be realistic in assessing the needs of the facility to be served so that unnecessarily stringent requirements are not specified.

Maximum Frequency Deviation [2.5] [5] [_____] with Step Load Increase frequency.

Recovery Time Back to Bandwidth. The designer should determine the required recovery time for the loads served. The recovery time to bandwidth is not critical to operation of most equipment if the voltage and frequency do not deviate from the critical limits, or if momentary interruption is acceptable to the loads being served. The primary importance of this requirement is to ensure that the engine generator set recovers and stabilizes after load changes. Most engine generator sets can respond to 100 percent block loads and return to voltage and frequency bandwidths within 15 - 20 seconds, depending on the size of the machine (RPM, relative mass of the rotating elements, and ambient conditions).

Transient Recover Time [_____] seconds with Step Load Increase (Voltage).

Transient Recovery Time [_____] seconds with Step Load Increase (Frequency).

Maximum Step Load Decrease (without shutdown). An

engine generator set should be capable of being unloaded in a single step without tripping offline. In these situations the voltage and frequency transients are of no concern because there is no load being served.

Nominal Step Load Decrease. Step load decrease is used to account for dropping of block loads. This affects engine-generator set frequency and voltage output and usually initiates governor and regulator response. The change in engine-generator set output and the response of the governor and regulator defines the transient loading response. Where the load served may be sensitive to voltage and frequency variation due to significant load decrease, include the items below in the Parameter Schedule. The Nominal Step Load Decrease provides the engine-generator manufacturer with the information necessary to set the governor response for load decreases such than an over-speed (over-frequency) condition does not occur. The cost of engine-generator sets increase by large percentages for smaller frequency and voltage deviations from bandwidth and improved recover times. Carefully analyze the user's need for restrictions on frequency, voltage, and waveform characteristics. If required, add the following to the Engine Generator Set Parameter Schedule and also add the Transient Response Test to verify the results in the field.

Nominal Step Load [25] [50] [75] Decrease at [_____] PF percent of Service Load.

Transient Recovery Time [_____] seconds with Step Load Decrease (Voltage).

Transient Recovery Time [_____] seconds with Step Load Decrease (Frequency).

Maximum Voltage Deviation [5] [10] [30] with Step Load Decrease [_____] percent of rated voltage.

Maximum Frequency Deviation [2.5] [5] [_____] with Step load Decrease percent of rated frequency.

Maximum Time To Start and Assume Load. Choose 10 seconds for emergency-standby applications (critical for life safety). NFPA 70 requires that standby engine-generator sets used in emergency applications start and assume load in 10 seconds. Most commercially available engine generator sets are capable of starting and assuming load within 10 seconds, however, a default value of 20 seconds is non-restrictive and provides a reasonable maximum value for non-critical applications.

Temperature Management. The designer is responsible for temperature control in the space occupied by the

engine generator set. However, because the engine-generator supplier normally provides the engine cooling system (and block heaters where required), the designer must provide ambient conditions under which the engine generator must operate, so that the supplier can size the equipment. Typically, high temperature provides the most restrictive condition, therefore the designer must design air-flow of adequate temperature and sufficient quantity to maintain the temperature of the generator and engine space within acceptable limits. This requires the designer to consult manufacturers' literature and/or representatives to determine the nominal heat rejection to the surroundings at rated gensetengine-generator capacity (from all heat sources) to determine the required cooling or air flow through the engine generator set room or enclosure. In turn the manufacturer must submit the specific operating data in order for the contracting officer/designer to verify that the proposed equipment meets the design parameters.

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Engine-Generator Set and Auxiliary Equipment Capacity Calculations for Engine-Generator Set

ENGINE-GENERATOR PARAMETER SCHEDULE	
Identification	Make/Model
Electrical Characteristics	
Power Rating	[Prime][Limited Running Time][Emergency Standby] [Industrial] Gross bhp rating / Net brake power rating [_____] kW at 0.8 power factor
Governor Type	Type Make / Model [Isochronous][Droop]
Overload Capacity (Prime applications only)	110 percent of Service Load for 1 hour in 12 consecutive hours
Service Load	[_____] kVA (maximum) [_____] kVA (continuous)
Motor Starting kVA (Max.)	[_____] kVA
Power Factor	[0.8][_____] lagging
Engine-Generator Applications	[stand-alone][parallel with infinite bus][parallel with other generators on an isolated bus][parallel with other generators on an infinite bus]

ENGINE-GENERATOR PARAMETER SCHEDULE	
Voltage Regulation (No Load to Full Load)(Stand-alone applications)	plus or minus 2 percent (maximum)
Voltage Bandwidth (steady state)	plus or minus [0.5][1][2] percent
Frequency	[50][60] Hz
Voltage	[_____] volts
Phases	[3 Phase, Wye][3 Phase, Delta][1 Phase]
Minimum Generator Sub-transient Reactance	[_____] percent Sub-transient
Nonlinear Loads	[_____] kVA
Max Step Load Increase	[25][50][75] [100] percent of Service Load at [_____] PF
Transient Recovery Time with Step Load Increase (Voltage)	[_____] seconds
Transient Recovery	[_____] seconds
Time with Step Load Increase (Frequency)	
Maximum Voltage Deviation with Step Load Increase	[5][10][30][ ] percent of rated voltage
Maximum Frequency Deviation with Step Load Increase	[2.5][5][ ] percent of rated frequency
Max Step Load Decrease (without shutdown)	100 percent of Service Load at [_____] PF
Frequency Bandwidth (steady state)	plus or minus [ ][0.4][0.25] percent
Frequency Regulation (droop) (No Load to Full Load)	[3][_____] percent (maximum)
Frequency Bandwidth (steady state)	plus or minus [_____][0.4][0.25] percent

ENGINE-GENERATOR PARAMETER SCHEDULE					
Reactances	Synchronous reactance, Xd Transient reactance, X'd Sub-transient reactance, X"d Negative sequence reactance, X2 Zero sequence reactance, Xo				
Capacity Calculations					
Calculations must verify that the engine-generator set power rating is adequate for the following load conditions:					
Lighting	[_____] kW				
Computer	[_____] kW				
Uninterruptible Power Supplies (UPS)	[_____] kVA, [3][6][12][24] pulse				
Variable Frequency Drives (VFD)	[_____] kVA, [3][6][12][24] pulse				
Motor Starting Sequence	Starting Order	Size (hp)	Locked Rotor NEMA Code	Starting Method	Maximum Voltage Dip
	[_____]	[_____]	[F] [_____]	[Full Voltage] [_____]	[25] [_____] Percent
	[_____]	[_____]	[F] [_____]	[Full Voltage] [_____]	[25] [_____] Percent
	[_____]	[_____]	[F] [_____]	[Full Voltage] [_____]	[25] [_____] Percent
Other Load	kW at 0.8 power factor				
Capacity Calculations for Batteries					
Calculation must verify that the engine starting battery capacity exceeds dc power requirements.					
Mechanical Characteristics					
Engine Description	Strokes/cycle Number of cylinders Bore and Stroke, mminches				
Engine Speed	[_____][900][1200][1800] rpm				
Piston Speed	[_____] m/sfpm				
Heat Exchanger Type	[fin-tube (radiator)][shell-tube]				
Engine Cooling Type	water/ethylene glycol				

ENGINE-GENERATOR PARAMETER SCHEDULE	
Intercooler Type	Air-to-Air / Jacket Water
Induction Method	Naturally Aspirated / Turbocharged
Turbocharger	Make / Model
Max Time to Start and be Ready to Assume Load	[10][_____] seconds
Max Summer Indoor Temp (Prior to Engine-generator Operation)	[_____] degrees C F
Min Winter Indoor Temp (Prior to Engine-generator Operation)	[_____] degrees C F
Max Allowable Heat Transferred To Engine Generator Space at Rated Output Capacity	[_____] MBTU/hr
Max Summer Outdoor Temp (Ambient)	[_____] degrees C F
Min Winter Outdoor Temp (Ambient)	[_____] degrees C F
Installation Elevation	[_____] above sea level
Engine-Generator Set Efficiencies	
Fuel Consumption	At 0.8 power factor, liters / hour Gallons / hour for: 1 / 2 load 3 / 4 load Full Load
Generator Efficiency	At 0.8 power factor,(per cent) [in accordance with IEC 60034-2A] for: 1 / 2 load 3 / 4 load Full Load
Radiator Capacity	Coolant Type L/s gpm coolant L/s cfm air through radiator kW Btu per hr of heat exchange based on optimum coolant temperature to and from engine
Engine-Generator Set Emissions Data	
Exhaust Temperature	Degrees C F at full load
Weight of Exhaust Gas	Kg per hr lb per hr at full load
Weight of Intake Air	Kg per hr lb per hr at full load

ENGINE-GENERATOR PARAMETER SCHEDULE	
Total Heat Rejected	kW Btu per hr, at full load to: Jacket Coolant System Fuel Oil Cooling System
Emissions	Kg per hr lb per hr, at full load Total Suspended Particulate Particulate Matter with an average aerodynamic diameter of 10 microns Sulfur Dioxides Nitrogen Oxides (as NO2) Carbon Monoxide Volatile Organic Compounds
Visible Emissions	Percent opacity at full load
Brake Mean Effective Pressure (BMEP) Calculations	
Calculation must verify that the engine meets the specified maximum BMEP, as follows: BMEP kPa psi = (120,000 X bkW) X (792,000 X bhp) (rpm X liters cu. in.) Where: bkW bhp = bkW' + bkW" bhp' + bhp" bkW" bhp" is the Brake kW horsepower required by engine driven fan for cooling radiator or motor driven fan for cooling radiator. bkW' bhp' = kW/GEN.EFF. kW/(GEN.EFF. times 0.746) GEN.EFF. = Generator efficiency liters cu. in. = Total engine piston displacement in liters cubic inches rpm = Engine revolutions per minute kW = Minimum power rating	
Torsional Vibration Stress Analysis Computations	

ENGINE-GENERATOR PARAMETER SCHEDULE
Torsional vibrational stresses in the crankshaft and generator shaft of assembled engine and driven generator must not exceed 34,450 kPa 5000 psi when engine is driving generator at rated speed while assembled unit is loaded to rated engine-generator set power. Computations must be based on a mathematical model of the assembled generator set provided or based on calculations using measured values from tests on a unit identical to the one provided. Calculations based on models of, or measured data from, the unassembled engine and generator will not be acceptable. Calculations must include: a. A description of the system relating information pertinent to analysis such as operating speed range and identification plate data. b. A mass elastic assembly drawing, showing the arrangement of the units in the generator set and dimensions of shafting, including minimum diameters (or section moduli) of shafting in the system. c. A labeled line diagram of the mass elastic system indicating values of masses, stiffness, equivalent lengths, and equivalent diameters including basic assumptions and definition of terms. d. Sample computations showing procedures used to obtain resulting stress values. e. Computations indicating assembled engine-generator speed of 1800 rpm with assembly loaded to rated generator power and the resulting computed critical torsional stress values in the assembled engine crankshaft and generator shaft.
Turbocharger Load Calculations
NOTE: When the engine-generator set installation includes field installed exhaust system (i.e., the engine-generator set is installed internal to a building in lieu of in a self-contained outdoor enclosure), include the following paragraph. When the proposed exhaust system layout is different from that shown on the contract drawings, submit calculations showing that the external loads from the exhaust system such as weight and thermal expansion do not exceed the engine manufacturer's maximum allowed forces and moments on the turbocharger.

2.1.2 Rated Output Capacity

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NOTE: The service load for each engine-generator should be shown on the Engine-Generator Parameter Schedule. The designer must determine the service load. The Contractor, through the supplier's manufacturer/assembler, determines the efficiency and associated ancillary equipment loads. The

designer must examine spare capacity requirements for spinning reserve.
****

Provide each engine-generator-set with power equal to the sum of service load plus the machine's efficiency loss and associated ancillary equipment loads. Rated output capacity must also consider engine and/or generator oversizing required to meet requirements in paragraph Engine-Generator Parameter Schedule.

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NOTE: Select the appropriate engine-generator set from three manufacturers that suit the intended application based on power rating (kW) and kind of power (i.e., number of operating hours per year and average power output). Using the specified kW and the total engine piston displacement per the selected engine-generator sets catalog data, calculate the BMEP to be specified in accordance with the paragraph CALCULATIONS FOR BMEP. A value of 0.9 may be used for generator efficiency.
****

The engine must meet the specified maximum BMEP requirements at rated speed as calculated in accordance with the calculations in the engine-generator parameter schedule. The engine capacity must be based on the following:

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NOTE: Contact the activity to find out fuel type to be used.
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a. Engine burning diesel fuel conforming to [MIL-DTL-16884][ASTM D975, Grade 2-D,] or [MIL-DTL-5624, Grade JP-5] at an ambient temperature of 29 degrees C 85 degrees F. For stationary engines operated in the United States, diesel fuel requirements are found in 40 CFR 60 Subpart IIII.

b. Engine cooled by a radiator fan mechanically driven by the engine or remote with a motor driven fan.

c. Engine cooled by coolant mixture of water and ethylene glycol, 50 percent by volume of each.

Maximum BMEP, kPa psi			
	Naturally Aspirated	Turbocharged	Turbocharged and Intercooled
Four-cycle engines	[_____]	[_____]	[_____]
Engine speed, rpm:	[1800][1500]	[_____]	[_____]

2.1.2.1 Engine Emission Limits

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NOTE: Include the following paragraph when an air pollution permit is required by local, state, or

federal law to install and operate the engine generator set. Contact the engine-generator set manufacturer for achievable limits. Contact the activities environmental department representative to determine permit requirements.

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Engine must be certified by the manufacturer to meet applicable EPA emission standards found in 40 CFR 60 Subpart IIII. In addition, engine must meet any applicable state or local emission requirements (ex: California SCAQMD).

2.1.2.2   Performance Class

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NOTE: See the following guidelines and table for selecting the appropriate performance class:

1. Select Class G1 where the connected loads are such that only basic parameters of voltage and frequency are needed, e.g., general purpose lighting and other simple electrical loads.

2. Select Class G2 where the demands on voltage characteristics are very much the same as for the commercial power system, e.g., lighting systems, pumps, fans, hoists.

3. Select Class G3 where the connected equipment may make severe demands on frequency, voltage, and waveform characteristics, e.g., telecommunications as thyristor-controlled loads.

4. Select Class G4 where the demands on the frequency, voltage, and waveform characteristics are exceptionally severe, e.g., data processing equipment or computer systems. Performance values for Class G4 must be determined by the designer and an appropriate table similar to the following table must be inserted into the Specification.

Parameter	Performance Class		
	G1	G2	G3
100 Percent Load Increase Frequency Deviation (Percent)	less than minus 15	less than minus 10	less than minus 7
100 Percent Load Decrease Frequency Deviation (Percent)	less than plus 18	less than plus 12	less than plus 10

100 Percent Load Change Frequency Recovery Time (Seconds)	**less than 10**	**less than 5**	**less than 3**
100 Percent Load Increase Voltage Deviation (Percent)	**less than minus 25**	**less than minus 20**	**less than minus 15**
100 Percent Load Decrease Voltage Deviation (Percent)	**less than plus 35**	**less than plus 25**	**less than plus 20**
100 Percent Load Change Voltage Recovery Time (Seconds)	**less than 10**	**less than 6**	**less than 4**
Frequency Droop (Percent)	**less than minus 8**	**less than minus 5**	**less than minus 3**
Steady-State Frequency Band (Percent) (plus or minus	**less than 2.5**	**less than 1.5**	**less than 0.5**
Steady-State Voltage Regulation (Percent) (plus or minus)	**less than 5**	**less than 2.5**	**less than 1.0**

****

The voltage and frequency behavior of the generator set must be in accordance with ISO 8528 operating limit values for performance Class[G1][G2][G3][G4 as follows].

2.1.3 Power Ratings

Power ratings must be in accordance with EGSA 101P.

2.1.4 Transient Response

The engine-generator set governor and voltage regulator must cause the engine-generator set to respond to the maximum step load changes such that output voltage and frequency recover to and stabilize within the operational bandwidth within the transient recovery time. The engine-generator set must respond to maximum step load changes such that the maximum voltage and frequency deviations from bandwidth are not exceeded.

2.1.5 Reliability and Durability

****

NOTE: Mean time between overhauls describes the average number of operating hours that the engine will operate satisfactorily without overhaul. Overhaul is a natural consequence of the engine in operation due to worn out parts after the indicated operating hours.

****

[Provide prime engine-generator sets that have both an engine and a generator capable of delivering the specified power on a prime basis with an anticipated mean time between overhauls of not less than 10,000 hours operating with a 70 percent load factor. Cite two like engines and two like generators that have performed satisfactorily in a stationary power plant, independent from the physical location of the manufacturer's and assembler's facilities. The engine and generators should have been in operation for a minimum of 8000 actual hours at a minimum load of 70 percent of the rated output capacity. During two consecutive years of service, the units should not have experienced any failure resulting in a downtime in excess of 72 hours. Provide engines that are the same model, speed, bore, stroke, number and configuration of cylinders and rated output capacity. Provide generators that are the same model, speed, pitch, cooling, exciter, voltage regulator and rated output capacity.] [Each standby engine-generator set must have both an engine and a generator capable of delivering the specified power on a standby basis with an anticipated mean time between overhauls of no less than 5,000 hours operating with a load factor of 70 percent. Cite two like engines and two like generators that have performed satisfactorily in a stationary power plant, independent and separate from the physical location of the manufacturer's and assembler's facilities, for standby without any failure to start, including all periodic exercise. Provide like engines and generators that have had no failures resulting in downtime for repairs in excess of 72 hours during two consecutive years of service. Provide engines that are the same model, speed, bore, stroke, number and configuration of cylinders, and rated output capacity. Provide generators that are the same model, speed, pitch, cooling, exciter, voltage regulator and rated output capacity.]

Submit a reliability and durability certification letter from the manufacturer and assembler to prove that existing facilities are and have been successfully utilizing the same components proposed to meet this specification, in similar service. Certification may be based on components, i.e. engines used with different models of generators and generators used with different engines, and does not exclude annual technological improvements made by a manufacturer in the basic standard-model component on which experience was obtained, provided parts interchangeability has not been substantially affected and the current standard model meets the performance requirements specified. Provide a list with the name of the installations, completion dates, and name and telephone number of a point of contact.

2.1.6 Parallel Operation

****

NOTE: Specification of an engine-generator set capable of parallel operation with a utility requires a 2/3 pitch generator winding and special coordination of protective devices with the utility system protection scheme. Do not specify this option without also providing a design for the protective device coordination which has been approved by the utility involved.

****

Configure each engine-generator set specified for parallel operation for [automatic] [manual] parallel operation. Each set must be capable of parallel operation with [a commercial power source on an infinite bus] [one or more sets on an isolated bus] [a commercial power source on an infinite bus and with one or more sets on an isolated bus].

2.1.7 Load Sharing

****
NOTE: Coordinate with paragraph Engine Generator Parameter Schedule.
****

Configure each engine-generator set specified for parallel operation to [manually load share with other sets.] [automatically load share with other sets by proportional loading. Proportional loading must load each set to within 5 percent of its fair share. A set's fair share is its nameplate-rated capacity times the total load, divided by the sum of all nameplate-rated capacities of on-line sets. Incorporate both the real and reactive components of the load.]

2.1.8 Engine-Generator Set Enclosure

****
NOTE: If the engine-generator set is to be installed outdoors include requirements for the weatherproof enclosure in the engine-generator set schedule. Define corrosion resistance and/or material required for the environment. Provide structural loading required for the geographic area (wind loads, snow loads, etc.). A generator set enclosure may also be needed to mitigate excessive noise caused by the engine generator set mechanical components. Delete the reference to mechanical noise limitations if an enclosure is not needed to mitigate sound emissions. If a sound enclosure is not provided, the designer must provide a design to prevent excessive noise (meet OSHA requirements). Delete this paragraph if no engine-generator set enclosure is needed.
****

Provide engine-generator set enclosures that are corrosion resistant and fully weather resistant. The enclosure must contain all set components and provide ventilation to permit operation at Service Load under secured conditions. Provide access doors to controls and equipment requiring periodic maintenance or adjustment. Provide removable panels for access to components requiring periodic replacement. The enclosure must be capable of being removed without disassembly of the engine-generator set or removal of components other than the exhaust system. The enclosure must reduce the noise of the generator set to within the limits specified in the paragraph SOUND LIMITATIONS.

2.1.9 Vibration Isolation

****
NOTE: See UFC 3-450-01, Noise and Vibration Control for Mechanical Equipment for vibration criteria. Vibration isolation systems should be applied where vibration transmitted through the genset support structure produces (either directly or by resonant frequencies of structural members) annoying or damaging vibration in the surrounding environment. Select the manufacturer's standard or provide the

maximum allowable vibration force where necessary to limit the maximum vibration. Delete the vibration isolation requirement for applications where vibration does not affect the floor or foundation.
****

[Install a vibration isolation system between the floor and the base. The vibration isolation system must limit the maximum vibration transmitted to the floor at all frequencies to a maximum of [_____] (peak force).] [Provide an engine-generator set with a vibration isolation system in accordance with the manufacturer's standard recommendation.] Submit vibration isolation system performance data for the range of frequencies generated by the engine-generator set during operation from no load to full load and the maximum vibration transmitted to the floor plus description of seismic qualification of the engine-generator mounting, base, and vibration isolation. Submit torsional analysis including prototype testing or and calculations which certify and demonstrate that no damaging or dangerous torsional vibrations will occur when the prime mover is connected to the generator, at synchronous speeds, plus 10 percent. Design and qualify vibration isolation systems as an integral part of the base and mounting system in accordance with the seismic parameters specified. Where the vibration isolation system does not secure the base to the structure floor or unit foundation, provide seismic restraints in accordance with the seismic parameters specified.

2.1.10 Harmonic Requirements

****
NOTE: Coordinate with paragraph ENGINE-GENERATOR PARAMETER SCHEDULE.
****

Non-linear loads to be served by each engine-generator set are as indicated. The maximum linear load demand (kVA at PF) when non-linear loads will also be in use is as indicated.

2.1.11 Starting Time Requirements

Upon receipt of a signal to start, each engine generator set will start, reach rated frequency and voltage and be ready to assume load within the time specified. For standby sets used in emergency power applications, each engine generator set will start, reach rated frequency and voltage, and power will be supplied to the load terminals of the automatic transfer switch within the starting time specified.

2.2 NAMEPLATES

****
NOTE: Delete any equipment not applicable to the project.
****

Provide the manufacturer's name, type or style, model or serial number and rating on a plate secured to the equipment for each major component of this specification. Provide plates and tags sized so that inscription is readily legible to operating or maintenance personnel and securely mounted to or attached in proximity of their identified controls or equipment. Lettering must be normal block lettering, a minimum of 6.4 mm0.25 inch high. As a minimum, provide nameplates for:

Engines	Relays
Generators	Transformers (CT & PT)
Regulators	Day tanks
Pumps and pump motors	Governors
Generator Breaker	Air Starting System
Economizers	Heat exchangers (other than base mounted)

Where the following equipment is not provided as a standard component by the engine generator set manufacturer, the nameplate information may be provided in the maintenance manual in lieu of nameplates.

Battery charger	Heaters
Switchboards	Exhaust mufflers
Switchgear	Silencers
Battery	Exciters

2.2.1 Materials

Construct ID plates and tags of 16 gage minimum thickness bronze or stainless steel sheet metal engraved or stamped with inscription. Construct plates and tags not exposed to the weather or high operational temperature of the engine of laminated plastic, 3.2 mm0.125 inch thick, matte white finish with black center core, with lettering accurately aligned and engraved into the core.

2.2.2 Control Devices and Operation Indicators

Provide ID plates or tags for control devices and operation indicators, including valves, off-on switches, visual alarm annunciators, gages and thermometers, that are required for operation and maintenance of provided mechanical systems. Plates or tags must be minimum of 13 mm0.5 inch high and 50 mm2 inches long and must indicate component system and component function.

2.2.3 Equipment

Provide ID plates of a minimum size of 75 mm 3 inches high and 130 mm 5 inches long on provided equipment indicating the following information:

a. Manufacturer's name, address, type and model number, serial number, and certificate of compliance with applicable EPA mission standards;

b. Contract number and accepted date;

c. Capacity or size;

d. System in which installed; and

e. System which it controls.

2.3 SAFETY DEVICES

Exposed moving parts, parts that produce high operating temperatures, parts which may be electrically energized, and parts that may be a hazard to operating personnel must be insulated, fully enclosed, guarded, or fitted with other types of safety devices. Install safety devices such that proper operation of the equipment is not impaired.

2.4 MATERIALS AND EQUIPMENT

Submit certification stating that where materials or equipment are specified to comply with requirements of UL, written proof of such compliance has been obtained. The label or listing of the specified agency, or a written certificate from an approved, nationally recognized testing organization equipped to perform such services, stating that the items have been tested and conform to the requirements and testing methods of the specified agency are acceptable as proof.

2.4.1 Circuit Breakers, Low Voltage

UL 489.

2.4.2 Filter Elements

Provide the manufacturer's standard fuel-oil, lubricating-oil, and combustion-air filter elements.

2.4.3 Instrument Transformers

NEMA/ANSI C12.11.

2.4.4 Revenue Metering

IEEE C57.13.

2.4.5 Pipe (Fuel/Lube-Oil, Compressed Air, Coolant, and Exhaust)

ASTM A53/A53M, or ASTM A106/A106M steel pipe. Pipe smaller than 50 mm 2 inches must be Schedule 80. Pipe 50 mm 2 inches and larger must be Schedule 40.

2.4.5.1 Flanges and Flanged Fittings

ASTM A181/A181M, Class 60, or ASME B16.5, Grade 1, Class 150.

2.4.5.2 Pipe Welding Fittings

ASTM A234/A234M, Grade WPB or WPC, Class 150 or ASME B16.11, 1360.7 kg 3000 lb.

2.4.5.3 Threaded Fittings

ASME B16.3, Class 150.

2.4.5.4 Valves

MSS SP-80, Class 150.

2.4.5.5 Gaskets

Manufacturer's standard.

2.4.6 Pipe Hangers

MSS SP-58.

2.4.7 Electrical Enclosures

NEMA ICS 6.

2.4.7.1 Switchboards

NEMA PB 2.

2.4.7.2 Panelboards

NEMA PB 1.

2.4.8 Electric Motors

Provide electric motors that conform to the requirements of NEMA MG 1. Motors must have sealed ball bearings and a maximum speed of 1800 rpm. Motors used indoors must have drip-proof frames; enclose those that are used outside. Alternating current motors larger than 373 W 1/2 Hp must be of the squirrel-cage induction type for operation on 208 volts or higher, [50] [60] Hz, and three-phase power. Alternating current motors 373 W 1/2 Hp or smaller, must be suitable for operation on 120 volts, [50] [60] Hz, and single-phase power. Direct current motors must be suitable for operation on [125] [_____] volts.

2.4.9 Motor Controllers

Provide motor controllers and starters that conform to the requirements of NFPA 70 and NEMA ICS 2.

2.5 ENGINE

****

NOTE: Specify fuel type.

If units are required to operate on more than one fuel the designer must edit the components, performance requirements, and testing requirements of this specification to define the requirements for the fuels specified. If full performance is required for the weakest or poorest burning fuels, then the units will be overrated for other fuels.

****

Each engine must operate on [No. 2-D diesel fuel][_____] conforming to [ASTM D975][_____], must be designed for stationary applications and must be complete with ancillaries. The engine must be a standard production model shown in the manufacturer's catalog describing and depicting each engine-generator set and all ancillary equipment in sufficient detail to demonstrate complete specification compliance. The engine must be naturally aspirated, supercharged, or turbocharged. The engine must be 2- or 4-stroke-cycle and compression-ignition type. The engine must be vertical in-line, V- or opposed-piston type, with a solid cast block or individually cast cylinders. The engine must have a minimum of two cylinders. Opposed-piston type engines must have more than four cylinders. Each block must have a coolant drain port. Equip each engine with an over-speed sensor.

ISO 3046. Diesel engines must be four-cycle naturally aspirated, or turbocharged, or turbocharged and intercooled; vertical in-line or vertical Vee type; designed for stationary service. Engines must be capable of immediate acceleration from rest to normal speed without intermediate idle/warm up period or pre-lubrication to provide essential electrical power. Two-cycle engines are not acceptable.

2.5.1 Sub-base Mounting

Mount each engine-generator set on a structural steel sub-base sized to support the engine, generator, and necessary accessories, auxiliaries and control equipment to produce a complete self-contained unit as standard with the manufacturer. Design the structural sub-base to properly support the equipment and maintain proper alignment of the engine-generator set in the specified seismic zone. In addition, provide sub-base with both lifting rings and jacking pads properly located to facilitate shipping and installation of the unit. Factory align engine and generator on the sub-base and securely bolt into place in accordance with the manufacturer's standard practice. Crankshaft must have rigid coupling for connection to the generator.

2.5.2 Assembly

Completely shop assemble each engine-generator set on its structural steel sub-base. Paint entire unit with manufacturer's standard paints and colors. After factory tests and before shipping, thoroughly clean and retouch painting as necessary to provide complete protection.

2.5.3 Turbocharger

If required by the manufacturer to meet the engine-generator set rating, provide turbine type driven by exhaust gas from engine cylinders, and direct connected to the blower supplying air to the engine intake manifold.

2.5.4 Intercooler

Provide manufacturer's standard intercooler for engine size specified.

2.5.5 Crankcase Protection

****

NOTE: Include details on the drawings for the crankcase ventilation piping and associated penetrations through walls and roofs showing the piping sleeve and exterior flashing when the radiator is remote and the engine-generator set is to be installed inside a building. Provide manufacturer's standard method of preventing crankcase explosions and standard method of

crankcase ventilation.[Provide ventilation of crankcase via piping to the atmosphere as indicated on the drawings.]
****

2.5.6 Miscellaneous Engine Accessories

Provide the following engine accessories where the manufacturer's standard design permits:

a. Piping on engine to inlet and outlet connections, including nonstandard companion flanges.

b. Structural steel sub-base and vibration isolators, foundation bolts, nuts, and pipe sleeves.

c. Level jack screws or shims, as required.

d. Rails, chocks, and shims for installation of sub-base on the foundation.

e. Removable guard, around fan. Support guard, on engine sub-base, to suit manufacturer's standard.

2.5.7 Intercooler

Provide manufacturer's standard intercooler for engine size specified.

2.6 FUEL SYSTEM

Provide fuel system conforming to the requirements of NFPA 30 and NFPA 37 and containing the following elements.

****
NOTE: The selection of a gas-fueled (natural or LP) over diesel-fueled engine-generator has significant impact depending on the load characteristics and application. The following general differences between gas and diesel fuels, and their use in engine-generator applications, should be considered:

Characteristic	**Gas**	**Diesel**
Economy	**Lower initial cost, but higher long-term costs, due to more maintenance and shorter installed life**	**Higher initial cost, but lower long-term costs, due to less maintenance and longer installed life**
Availability	**Non-renewable but available worldwide**	**Non-renewable, less available than gas**

Environmental Emissions	**No significant ground pollution, soot or sulfur dioxide emissions, lower CO_2 emissions than diesel. Lean burn mode lowers emissions from traditional gas.**	**Higher viscosity, spills cause ground pollution, must meet EPA Tier 4 standards, except for emergency standby application.**
Noise	**Quieter**	**Louder, requires muffling and noise insulation**
Step Loading	**Step loading and unloading limited to 25-40 percent of load rating**	**Step loading and unloading not limited**
Running Load	**Less problems with light loading, due to higher burn temperature**	**Optimal loading 50-70 percent rated, light loading causes "wet stacking", increasing buildup in exhaust system**
Startup Time	**Typ. more than 10 seconds, from startup to ready to assume load**	**Typ. 10 seconds or less, from startup to ready to assume load**
Sizing	**Typ. same as diesel, but sometimes oversized to compensate for step loading limitation**	**Sized to match existing load, plus anticipated future load growth**
Safety	**Extremely flammable, any leaks can be catastrophic**	**Less flammable, but water contamination during storage of fuel can cause engine damage**

****

2.6.1 Pumps

****

NOTE: Delete this paragraph when remote fuel transfer pump(s) are provided. Select duplex pumps for facilities complying with UFC 4-510-01, "Design: Medical Military Facilities."

****

Fuel transfer pumps may be mounted on the day tank. Pump[s] must be [duplex,] horizontal, positive displacement. Direct-connect pump to motor through a flexible coupling. Equip each pump with a bypass relief valve, if not provided with an internal relief valve. Provide motor and controller in accordance with the paragraphs ELECTRIC MOTORS and MOTOR CONTROLLERS, respectively.

2.6.1.1 Main Pump

Provide engines with an engine driven pump. The pump must supply fuel at a minimum rate sufficient to provide the amount of fuel required to meet the performance indicated within the parameter schedule. Base the fuel flow rate on meeting the load requirements and all necessary recirculation.

2.6.1.2 Auxiliary Fuel Pump

****

NOTE: The auxiliary fuel pump is required to support the main pump if the length of pipe from the day tank to the main pump is greater than the value recommended by the engine manufacturer. This value may be approximately 12 m 40 feet; however, engine manufacturers should be consulted during design to verify the pumping requirements.

****

Provide auxiliary fuel pumps to maintain the required engine fuel pressure, if either required by the installation or indicated on the drawings. The auxiliary pump must be driven by a dc electric motor powered by the starting/station batteries. Automatically actuate the auxiliary pump by a pressure-detecting device.

2.6.2 Fuel Filter

Provide a minimum of one full-flow fuel filter for each engine. The filter must be readily accessible and capable of being changed without disconnecting the piping or disturbing other components. Mark the inlet and outlet connections of the filter.

****

NOTE: Select the options for duplex filters when changing of the filter will be required while the engine-generator set is operating. Do not provide duplex filters when the engine-generator set is to be installed in an enclosure or provided with an engine-driven radiator.

****

Provide intake filter assemblies for each engine of the oil bath or dry type, as standard with the manufacturer. Filters must be capable of removing a minimum of 92 percent of dirt and abrasive 3 microns and larger from intake air. Size filters to suit engine requirements at 100 percent of rated full load. Design unit for field access for maintenance purposes.

2.6.3 Relief/Bypass Valve

Provide a relief/bypass valve to regulate pressure in the fuel supply line, return excess fuel to a return line and prevent the build-up of excessive pressure in the fuel system.

2.6.4 Integral Main Fuel Storage Tank

****

NOTE: Delete this paragraph if an integral main fuel storage tank is not desired.

An integral main fuel storage tank will be the only fuel source for the engine. These tanks may be useful for applications that require a minimal fuel storage capacity.

Due to the minimal storage capacity, integral main fuel storage tanks are not practical for prime power usage. They are also not practical for standby units that require large fuel quantities. The designer should consider the availability and anticipated frequency of fuel truck deliveries when deciding whether or not to use an integral main fuel storage tank. These tanks should also not be used in locations where a truck fueling hose can not reach the generator set.

See NFPA 99 and NFPA 110 for guidance on fuel tank sizes.

See NFPA 37 restrictions on allowable tank sizes and enclosures. Integral tanks allow for 1 to 8 hours of operation depending on generator size and configuration. Consult generator set manufacturer for the proper hours of operation for the application of integral tanks. Standby applications for use with fire pumps will have tanks sized for 8 hours duration. The tank can be sized by the designer or the Contractor. The size of the tank should be based on a fuel flow rate that is equal to the value of a typical engine manufacturer for the indicated engine generator size. A value of 200 percent of the expected fuel consumption of the engine is not unusual for the flow rate of the main fuel pump. Since the excess fuel will be returned to the tank, the designer should consider the impact of heat buildup when sizing the tank. If a fuel oil cooler is not used, the day tank size may need to be increased to properly dissipate the heat absorbed by the fuel.

****

Provide each engine with an integral main fuel tank. Each tank must be factory installed and provided as an integral part of the generator manufacturer's product. Provide each tank with connections for fuel supply line, fuel return line, local fuel fill port, gauge, vent line, and float switch assembly. Provide a fuel return line cooler as recommended by the manufacturer and assembler. The temperature of the fuel returning to the tank must be below the flash point of the fuel. Mount the tank within the enclosure for each engine-generator set provided with weatherproof enclosures. The fuel fill line must be accessible without opening the enclosure.

****

NOTE: Use the following guidelines for specifying fuel integral base tanks:

1. Select integral base tank in skid where applicable and available. Tank capacity available varies from 100 gallons to 5,000 gallons.

2. See NFPA 37 for allowable tank sizes and restrictions.

3. Provide an overflow or return line between the fuel day tank and storage tank in accordance with NFPA 37 if the generator is equipped with both an external supply tank and a day tank.

4. Tank capacity must be in accordance with the following table for facilities complying with MIL-HDBK-1191, "DOD Medical and Dental Treatment Facilities Design and Construction Guide."

50 KW - 100 KW GEN SET: 25 MIN - 50 MAX GAL
101 KW - 200 KW GEN SET: 50 MIN - 75 MAX GAL
201 KW - 300 KW GEN SET: 75 MIN - 100 MAX GAL
OVER 300 KW GEN SET: 100 MIN - 250 MAX GAL
****

a. All Tanks: UL 142. Provide [integral in skid] [free standing] double wall (110 percent containment) fuel tanks with a [minimum capacity of [_____] hours of engine-generator set operation at full-rated load] [capacity as indicated]. Epoxy coat day tanks inside and prime and paint outside. Construct tanks of not less than 4.76 mm 3/16 inch steel plate with welded joints and necessary stiffeners on exterior of tank. Provide a braced structural steel framework support. Weld tank top tight. Provide 114 mm 4 1/2 inch square inspection port with a 2 inch NPT fill connection and spill box. Provide proper normal and emergency venting for the primary tank and emergency venting only for the secondary tank / containment basin in accordance with UL 142 requirements.[Provide an overflow or return line between the fuel day tank and storage tank in accordance with NFPA 37.]

b. Float Switches for Day Tanks: Provide tank-top mounted or external float cage, single-pole, single-throw type designed for use on fuel oil tanks. Arrange high level float switches to close on rise of liquid level, and low level float switches to close on fall of liquid level. Mount float cage units with isolating and drain valves. Contacts must be suitable for the station battery voltage.

(1) Critical low level float switch which must activate at 5 percent of normal liquid level must shut engine off.

(2) Low-low level float switch which must activate alarm at 30 percent of normal liquid level.

(3) Low level float switch which must open the fuel oil solenoid valve and start the [remote] fuel transfer pump at 75 percent of normal liquid level.

(4) High level float switch which must close the fuel oil solenoid valve and stop the [remote] fuel transfer pump at 90 percent of normal liquid level.

(5) Critical high level float switch which must activate alarm at 95 percent of normal liquid level.

c. Leak Detector Switch for All Tanks: Actuates when fuel is detected in containment basin, stops fuel transfer pump, and closes the fuel oil solenoid valve.

d. Control Panel for All Tanks: Provide NEMA ICS 6, Type [1] [_____], enclosed control panel for each day tank. Control panel must include the following accessories.

(1) Power available LED (green).

(2) Critical low fuel alarm contacts for shut down of engine.

(3) Low-low level fuel alarm LED.

(4) Low-low level fuel alarm contracts for remote annunciator.

(5) Critical high level fuel alarm LED.

(6) Leak detecting alarm LED.

(7) Alarm horn.

e. Tank Gages for All Tanks: Provide buoyant force type gages for fuel tanks with dial indicator not less than 100 mm 4 inches in size and arranged for top mounting. Calibrate each reading dial or scale for its specific tank to read from empty to full, with intermediate points of 1/4, 1/2, and 3/4.

f. Integral Base Tanks Used as Primary Tank: Provide a 2 inch opening at the tank fill port, fitted an overfill prevention valve (OPV). Additionally, the fill opening must be perpendicular to the tank in order to allow operation of the OPV. Integral base tank must be sized and configured such that the filling and venting nozzles are outside the generator cabinet for ease of accessibility, inspection, and maintenance. Level gage must be in the line of sight from the fill port.

g. Integral Base Tanks Located Inside Buildings. The tank vents must discharge outside the building in accordance with NFPA 30 and NFPA 37. The fill pipe must terminate outside the building. The fill pipe connection point must be housed in a sealed spill box. High level alarms or level gauges used as overfill protection mechanisms must annunciate at the fill connection point. Provide an overfill prevention valve (OPV) at the tank with a check valve mounted on the fill line in the spill box. The fill connection point must be labeled with tank contents and capacity.

h. External tanks (all non-integral base tanks) are specified in Section 33 56 10 FACTORY-FABRICATED FUEL STORAGE TANKS.

2.6.4.1 Fuel Transfer Pump[s]

****

NOTE: Delete this paragraph when remote fuel transfer pump(s) are provided. Select duplex pumps for facilities complying with UFC 4-510-01, "Design: Medical Military Facilities."

****

Fuel transfer pumps may be mounted on the day tank. Pump[s] must be [duplex,] horizontal, positive displacement. Direct-connect pump to motor through a flexible coupling. Equip each pump with a bypass relief valve, if not provided with an internal relief valve. Provide motor and controller in accordance with the paragraphs ELECTRIC MOTORS and MOTOR

CONTROLLERS, respectively.

2.6.4.2 Capacity

Each tank must have capacity [as shown] [to supply fuel to the engine for an uninterrupted [4-hour][_____] period] at 100 percent rated load without being refilled.

2.6.4.3 Local Fuel Fill

Each local fuel fill port on the day tank must have a screw-on cap.

2.6.4.4 Fuel Level Controls

Provide tanks with a float-switch assembly to perform the following functions:

a. Activate the "Low Fuel Level" alarm at 70 percent of the rated tank capacity.

b. Activate the "Overfill Fuel Level" alarm at 95 percent of the rated tank capacity.

2.6.4.5 Arrangement

Integral tanks may allow gravity flow into the engine. Gravity flow tanks and any tank that allows a fuel level above the fuel injectors must have an internal or external factory installed valve located as near as possible to the shell of the tank. The valve must close when the engine is not operating. Provide integral day tanks with any necessary pumps to supply fuel to the engine as recommended by the generator set manufacturer. The fuel supply line from the tank to the manufacturer's standard engine connection must be welded pipe.

2.6.5 Day Tank

****

NOTE: Delete this paragraph if an integral main fuel storage tank is used.

See NFPA 99 and NFPA 110 for guidance on fuel tank sizes.

See NFPA 37 restrictions on allowable day tank sizes and enclosures. Select either self-supporting or integral day tank. Select the first option below for applications where fuel is returned to the day tank. Select the second option below for applications where fuel is returned to the main tank. Integral day tanks allow for 1 to 8 hours of operation. Consult generator set manufacturer for the proper hours of operation for the application of integral day tanks. Standby applications for use with fire pumps will have day tanks sized for 8 hours duration. Select day tank capacity for either prime or standby application. The day tank can be sized by the designer or the Contractor. The size of the day tank should be based on a fuel flow rate that is equal to the value of a typical engine

manufacturer for the indicated engine generator size. A value of 200 percent of the expected fuel consumption of the engine is not unusual for the flow rate of the main fuel pump. The excess fuel may be returned to the day tank or main fuel tank. The designer should also consider the impact of heat buildup when sizing the day tank. If a fuel oil cooler is not used or if fuel is returned to the day tank, the day tank size may need to be increased to properly dissipate the heat absorbed by the fuel.
****

Provide engine with [a separate self-supporting] [integral] day tank. Submit calculations for the capacity of each day tank, including allowances for recirculated fuel, usable tank capacity, and duration of fuel supply. Provide connections for fuel supply line, [fuel return line, fuel overflow line, local fuel fill port, gauge, vent line, drain line, and float switch assembly for control for each day tank. Provide a fuel return line cooler as recommended by the manufacturer and assembler. The temperature of the fuel returning to the day tank must be below the flash point of the fuel. Install a temperature sensing device in the fuel supply line], [fuel overflow line, local fuel fill port, gauge, vent line, drain line, and float switch assembly for control]. Mount the day tank within the enclosure for each engine-generator set with weatherproof enclosures. The fuel fill line must be accessible without opening the enclosure.

2.6.5.1 Capacity, Prime

Provide day tank with the capacity [as shown] [to supply fuel to the engine for an uninterrupted [8-hour] [_____] period at 100 percent rated load without being refilled, plus any fuel which may be returned to the main fuel storage tank. Submit calculations for the capacity of each day tank, including allowances for recirculated fuel, usable tank capacity, and duration of fuel supply. The calculation of the capacity of each day tank must incorporate the requirement to stop the supply of fuel into the day tank at a "High" level mark of 90 percent of the ultimate volume of the tank].

2.6.5.2 Capacity, Standby

Provide day tank with the capacity [as shown] [to supply fuel to the engine for an uninterrupted [4-hour] [_____] period at 100 percent rated load without being refilled, plus any fuel which may be returned to the main fuel storage tank. Submit calculations for the capacity of each day tank, including allowances for recirculated fuel, usable tank capacity, and duration of fuel supply. The calculation of the capacity of each day tank must incorporate the requirement to stop the supply of fuel into the day tank at 90 percent of the ultimate volume of the tank].

2.6.5.3 Drain Line

Each day tank drain line must be accessible and equipped with a shutoff valve. Arrange self-supporting day tanks to allow drainage into a 305 mm 12 inch tall bucket.

2.6.5.4 Local Fuel Fill

Each local fuel fill port on the day tank must have a screw-on cap.

2.6.5.5 Fuel Level Controls

Provide day tank with a float-switch assembly to perform the following functions:

a. [When the main storage tank is located higher than the day tank, open the solenoid valve located on the fuel supply line entering the day tank and start the supply of fuel into the day tank] [Start the supply of fuel into the day tank] when the fuel level is at the "Low" level mark, 75 percent of the rated tank capacity.

b. [When the main storage tank is located higher than the day tank, stop the supply of fuel into the day tank and close the solenoid valve located on the fuel supply line entering the day tank] [Stop the supply of fuel into the day tank] when the fuel level is at 90 percent of the rated tank capacity.

c. Activate the "Overfill Fuel Level" alarm at 95 percent of the rated tank capacity.

d. Activate the "Low Fuel Level" alarm at 70 percent of the rated tank capacity.

e. Activate the automatic fuel supply shut-off valve located on the fill line of the day tank and shut down the fuel pump which supplies fuel to the day tank at 95 percent of the rated tank capacity. Stop the flow of fuel before any fuel can be forced into the fuel overflow line.

2.6.5.6 Fuel Oil Solenoid Valve

UL 429. Provide electric solenoid type control valve for each day tank. Solenoid must be rated for starting battery voltage. Valve body must have a minimum working pressure rating of 1033 kPa 150 psig at 93 degrees C 200 degrees F. Valve must be capable of passing 0 to 0.63 L/s 0 to 10 gpm of fuel oil. Valves must be two-way, direct acting, normally closed (open when energized, closed when de-energized), with stainless steel body and resilient seat material. Solenoid enclosures must be NEMA ICS 6, Type 1. Body connections must be same size as connecting piping. Valve must be in line before the fuel pump.

2.6.5.7 Arrangement

****

NOTE: Select between integral and self-supporting day tanks. Also, select between applications where the main fuel storage tank is located above the day tank and applications where the main fuel storage tank is located below the day tank. The location of all tanks, piping, and valves should also be indicated on the drawings.

****

[Integral day tanks may allow gravity flow into the engine. Provide gravity flow tanks with an internal or external valve located as near as possible to the shell of the tank. The valve must close when the engine is not operating. Provide integral day tanks with any necessary pumps to supply fuel to the engine as recommended by the generator set manufacturer. Arrange the overflow connection and the fuel supply line for integral day tanks which do not rely upon gravity flow so that the highest possible fuel level is below the fuel injectors.] [Arrange self-supporting day tanks so that the fuel level in the day tank remains above the suction port of the engine driven fuel pump or be provided with a transfer pump to provide fuel to the engine driven pump. Arrange the overflow connection and fuel supply line so that the highest possible fuel level is below the fuel injectors.] [When the main fuel storage tanks are located below the day tank, provide a check valve in the fuel supply line entering the day tank.] [When the main fuel storage tanks are located above the day tank, install a solenoid valve in the fuel supply line entering the day tank. The solenoid valve must be in addition to the automatic fuel shut off valve.] The fuel supply line from the day tank to the manufacturer's standard engine connection must be welded pipe.

2.6.6 Fuel Supply System

Provide the fuel supply from the main storage of fuel to the day tank as specified in Section 33 56 10 FACTORY-FABRICATED FUEL STORAGE TANKS.

2.6.7 Strainer

****

NOTE: Select the options for duplex filters when changing of the filter will be required while the engine-generator set is operating. Do not provide duplex filters when the engine-generator set is to be installed in an enclosure or provided with an engine-driven radiator.

****

[Simplex][Duplex] strainers must comply with Section 33 52 10 SERVICE PIPING, FUEL SYSTEMS.

2.6.8 Fuel Oil Meters

****

NOTE: Provide fuel oil meters when required by the using activity.

****

Fuel oil meter must comply with Section 33 52 10 SERVICE PIPING, FUEL SYSTEMS.

2.6.9 Fuel Oil Cooler

Provide an air cooled fuel oil cooler if the temperature of the fuel returned to the tank from the engine will cause overheating of the tank fuel above the maximum fuel temperature allowed by the engine manufacturer when operating at maximum rated generator power output and low fuel level in the tank. The fuel oil cooler must be furnished by the engine manufacturer for the application and the installation must be complete including piping and power requirements.

2.7 LUBRICATION

****

NOTE: Delete the adjustable requirement for pressure regulation on sets smaller than 1000 kW. Sets larger than 500 kW will utilize a

pressure-relief valve on the crankcase. Show crankcase vent piping for indoor installations.
****

Provide engine with a separate lube-oil system conforming to NFPA 30 and NFPA 37. Pressurize each system by engine-driven pumps. Regulate system pressure as recommended by the engine manufacturer. Provide a pressure relief valve on the crankcase for closed systems. Vent the crankcase in accordance with the manufacturer's recommendation. Do not vent the crankcase to the engine exhaust system. Crankcase breathers, if provided on engines installed in buildings or enclosures, must be piped to vent to the outside. The system must be readily accessible for service such as draining, refilling, etc. Each system must permit addition of oil and have oil-level indication with the set operating. The system must utilize an oil cooler as recommended by the engine manufacturer.

2.7.1 Lube-Oil Filter

Provide one full-flow filter for each pump. The filter must be readily accessible and capable of being changed without disconnecting the piping or disturbing other components. Mark inlet and outlet connections.

2.7.2 Lube-Oil Sensors

Equip each engine with lube-oil pressure sensors located downstream of the filters and provide signals for required indication and alarms. Submit two complete sets of filters, required for maintenance, supplied in a suitable storage box. Provide these filters in addition to filters replaced after testing.

2.7.3 Precirculation Pump

Provide a motor-driven precirculation pump powered by the station battery, complete with motor starter, if recommended by the engine manufacturer.

2.8 COOLING SYSTEM

****
NOTE: Coordinate with paragraph SYSTEM REQUIREMENTS.
****

Provide each engine with its own cooling system to operate automatically while its engine is running. The cooling system coolant must use a combination of water and ethylene-glycol sufficient for freeze protection at the minimum winter outdoor temperature specified. The maximum temperature rise of the coolant across each engine must not exceed that recommended below. Submit a letter which certifies that the engine-generator set and cooling system function properly in the ambient temperature specified, stating the following values:

a. The maximum allowable inlet temperature of the [coolant fluid][cooling air].

b. The minimum allowable inlet temperature of the [coolant fluid through the engine][cooling air across the engine].

c. The maximum allowable temperature rise in the [coolant fluid through the engine][cooling air across the engine].

d. The minimum allowable inlet fuel temperature.

2.8.1 Coolant Pumps

****

NOTE: Delete raw-water pump for closed-loop systems.

****

Provide centrifugal coolant pumps. Each engine must have an engine-driven primary pump. Provide secondary pumps that are electric motor driven and have automatic controllers. Control raw-water circulating pump by manual-off-automatic controllers and must be [electric motor] [engine] driven.

2.8.2 Heat Exchanger

Provide heat exchanger with the size and capacity to limit the maximum allowable temperature rise in the coolant across the engine to that recommended and submitted for the maximum summer outdoor design temperature and site elevation. Submit manufacturer's data to quantify heat rejected to the space with the engine generator set at rated capacity. Provide heat exchangers that are corrosion resistant, suitable for service in ambient conditions of application.

2.8.2.1 Fin-Tube-Type Heat Exchanger (Radiator)

****

NOTE: Retain this paragraph and remove the next one as required by the project.

****

Heat exchanger may be factory coated with corrosion resistant film, provided that corrective measures are taken to restore the heat rejection capability of the radiator to the initial design requirement via over sizing, or other compensating methods. Provide internal surfaces that are compatible with liquid fluid coolant used. Materials and coolant are subject to approval by the Contracting Officer. Provide heat exchangers that are pressure type incorporating a pressure valve, vacuum valve and a cap. Design caps for pressure relief prior to removal. Provide heat exchanger and cooling system that is capable of withstanding a minimum pressure of 48 kPa 7 psi and protect with a strong grille or screen guard. Provide heat exchanger with at least two tapped holes; equip one tapped hole with a drain cock, and plug the rest.

****

NOTE: Generally utilize the engine sub-base radiator as the less expensive option. In cases where insufficient cooling air or space or additional reliability is necessary (requiring cross-connecting of radiators), provide remote radiators.

****

****

NOTE: At the text below, use the maximum dry-bulb temperature of the site plus 8 degrees C 15 degrees F for the first temperature, but not less than 43 degrees C 110 degrees F. Use minus 18 degrees C 0 degrees F, except where minimum dry-bulb temperature

permits use of a higher temperature.
****

Provide for each engine-generator set, as standard with the manufacturer.

a. Design Conditions: Each radiator unit must have ample capacity to remove not less than the total kW Btu per hour of heat rejected by its respective engine at 100 percent full-rated load to the jacket water, fuel oil, and lubricating oil system, and intercooler. Radiator capacity must be rated at optimum temperature of coolant leaving the engine and intercooler as recommended by the engine manufacturer with an ambient dry bulb air temperature outside the enclosure of [_____] degrees C [_____] degrees F maximum, and [_____] degrees C [_____] degrees F minimum at the site elevation specified in the paragraph SITE CONDITIONS, and with the coolant mixture specified in the paragraph ENGINE CAPACITY. Pressure drop through the radiator must not exceed 41.34 kPa 6 psi when circulating the maximum required coolant flow. Radiator air velocity must be a maximum of 7.6 meters per second 1500 feet per minute.

b. Engine Mounted Radiator Construction: Radiator fan must direct airflow from the engine outward through the radiator. Fan must be V-belt driven directly from the engine crankshaft. Radiator fan must have sufficient capacity to meet design conditions against a static restriction of [_____] Pa [_____] inch of water. Fan static capacity must be adjusted to suit the ductwork furnished. Cooling section must have a tube and fin-type core consisting of copper or copper base alloy tubes with nonferrous fins. Select engine-driven fans for quiet vibration-free operation. Make provision for coolant expansion either by self-contained expansion tanks or separately mounted expansion tanks, as standard with the manufacturer. Provide suitable guards for each fan and drive.

****
NOTE: Radiator fan cycling controls should be considered for engines to be operated above 500 hours per year.
****

c. Remote Radiator Construction: Provide radiators as described above, except radiators must be remotely piped and provided with electric motor driven fan. Drive must be multiple V-belt or reduction gears. Expansion tanks must be separately mounted. Air flow must be vertical or horizontal as indicated. Interlock fan with engine operation such that fan must operate when engine operates when recommended by engine manufacturer.[Provide controls and control devices complete which must cycle fan on and off based upon coolant temperature.] Provide motors and controllers in accordance with the paragraphs ELECTRIC MOTORS and MOTOR CONTROLLERS, respectively. Motors, controllers, contactors, and disconnects must conform to Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

d. Coolant solution must be a mixture of clean water and ethylene glycol, 50 percent by volume each. Provide an anti-freeze solution tester suitable for the mixture.

****
NOTE: Include the following paragraph when providing cooling system with a remote radiator.

****

Field installed jacket coolant water piping must conform to the following:

a. Piping: Provide seamless steel pipe, Schedule 40, conforming to ASTM A53/A53M, Grade A.

b. Fittings and Flanges: Fittings, 40 mm 1 1/2 inches or smaller, must be malleable iron conforming to ASME B16.3 for Class 300 threaded type. Fittings, 50 mm 2 inches and larger, must be steel butt welding conforming to ASME B16.9. Utilize either ASME B16.1 or Class A of ASTM A126 for Class 125 cast-iron flanged fittings. Flanges must be Class 150 slip-on forged steel welding flanges in accordance with ASME B16.5, with material in accordance with ASTM A181/A181M, Grade I. Provide flat face flanges for connecting to Class 125 standard cast-iron valves, fittings, and equipment connections.

c. Valves

    (1) Gate Valves: For valves, 40 mm 1 1/2 inches and smaller, provide double disk, rising stem, inside screw, union bonnet type, Class 125 bronze material conforming to MSS SP-80. For valves, 50 mm 2 inches and larger, provide double-disk, parallel seat type, hydraulic-rated, Class 125, outside screw and yoke type with flanged ends and bronze trim conforming to MSS SP-70. Provide stem packing of material compatible with the system coolant.

    (2) Globe Valves: For valves, 40 mm 1 1/2 inches and smaller, provide rising stem, inside screw, union bonnet type, Class 125 bronze valves conforming to MSS SP-80. For valves, 50 mm 2 inches and larger, provide Class 125 cast iron, flanged ends, bronze trim globe valves conforming to MSS SP-85. Valves must have renewable composition or cast iron discs compatible with the system coolant.

    (3) Check Valves: MSS SP-71 or MSS SP-80, swing check type.

d. Hangers and Supports: MSS SP-58.

****
NOTE: Include on the drawings a detail of the cooling piping penetrations through walls and roofs showing the piping sleeve and exterior flashing.
****

e. Piping Sleeves: Provide where piping passes through masonry or concrete walls, floors, roofs, and partitions. Place sleeves during construction. Unless indicated otherwise, pipe sleeves must comply with following requirements: Sleeves in outside walls below and above grade, in floor, or in roof slabs, must be standard weight zinc coated steel pipe. Sleeves in partitions must be zinc coated sheet steel having a nominal weight of not less than 4.4 kg per square meter 0.90 pound per square foot. Space between piping insulation and the sleeve must be not less than 6 mm 0.25 inch. Sleeves must be held securely in proper position and location during construction. Sleeves must be of sufficient length to pass through entire thickness of walls, partitions, or slabs. Sleeves in floor slabs must extend 50 mm 2 inches above the finished floor. Space between the pipe and the sleeve must be firmly packed with insulation and caulked at both ends of the sleeve with plastic waterproof cement.

2.8.2.2 Shell and U-Tube Type Heat Exchanger

****
NOTE: Retain this paragraph and remove the one above as required by the project.
****

Provide multiple pass shell, U-tube type heat exchanger. Exchanger must operate with low temperature water in the shell and high temperature water in the tubes. Provide exchangers that are constructed in accordance with ASME BPVC SEC VIII D1 and certified with ASME stamp secured to the unit. Provide U-tube bundles that are completely removable for cleaning and tube replacement and free to expand with the shell. Construct shells of seamless steel pipe or welded steel. Tubes must be cupronickel or inhibited admiralty, constructed in accordance with ASTM B395/B395M, suitable for the temperatures and pressures specified. Tubes less than 19 mm 3/4 inch unless otherwise indicated are not acceptable. Design shell side and tube side for 1.03 MPa 150 psig working pressure and factory tested at 2.06 MPa 300 psig. Locate high and low temperature water and pressure relief connections in accordance with the manufacturers standard practice. Water connections larger than 75 mm 3 inches must be ASME Class 150 flanged. Water pressure loss through clean tubes must be as recommended by the engine manufacturer. Minimum water velocity through tubes must be 300 mm/sec 1 fps and assure turbulent flow. Provide one or more pressure relief valves for each heat exchanger in accordance with ASME BPVC SEC VIII D1. The aggregate relieving capacity of the relief valves must be not less than that required by the above code. Install discharge from the valves indicated. Install the relief valves on the heat exchanger shell. Install a drain connection with 19 mm 3/4 inch hose bib at the lowest point in the system near the heat exchanger. Install additional drain connection with threaded cap or plug wherever required for thorough draining of the system.

2.8.3 Expansion Tank

****
NOTE: Delete this paragraph if a shell and U-tube type heat exchanger is not needed.
****

The cooling system must include an air expansion tank which will accommodate the expanded water of the system generated within the normal operating temperature range, limiting the pressure increase at all components in the system to the maximum allowable pressure at those components. The tank must be suitable for operating temperature of 121 degrees C 250 degrees F and a working pressure of 0.86 MPa 125 psi. Provide welded steel tank , tested and stamped in accordance with ASME BPVC SEC VIII D1 for the stated working pressure. Do not use a bladder type tank. Support the tank by steel legs or bases for vertical or steel saddles for horizontal installation.

2.8.4 Thermostatic Control Valve

Provide a modulating type, thermostatic control valve in the coolant system to maintain the coolant temperature range submitted in paragraph SUBMITTALS.

2.8.5 Ductwork

Provide ductwork as specified in Section Section [23 31 13.00 40 METAL DUCTS][23 30 00 HVAC AIR DISTRIBUTION] except use a flexible connection to connect the duct to the engine radiator. Material for the connection must be wire-reinforced glass. Provide airtight connection.

2.8.6 Temperature Sensors

Equip each engine with coolant temperature sensors. Provide temperature sensors with signals for pre-high and high indication and alarms.

2.9 SOUND LIMITATIONS

****

NOTE: The designer must perform an analysis in accordance with UFC 3-450-01 NOISE AND VIBRATION CONTROL. The designer must consider air intake, exhaust, and diesel generator casing noise. The designer must also coordinate with the architect for proper material selections for the sound transmittance characteristics of the mechanical equipment room and adjacent areas. The designer should consider sound within the equipment room, adjacent areas and building exterior. Acceptable sound levels will vary depending on the function of the space. As a minimum the design should comply with the following OSHA safety requirements; however, more stringent sound restrictions may be required to meet the functional requirements of the occupied spaces.

Frequency Band (Hz)	Maximum Acceptable Sound Level (Decibels)	
	Industrial	Residential
20-75	87	81
75-150	77	71
150-300	70	64
300-600	64	58
600-1,200	61	55
1,200-2,400	60	54
2,400-4,800	60	54
4,800-10,000	62	56

Typically, the generator manufacturer can provide information concerning the noise generated by the generator in a free field environment. The manufacturer does not have control over any other

building parameters or additional mechanical equipment noise. Therefore the designer should indicate the required sound limits for each of the indicated octave bands for the sound pressure level of the generator set operating at 100 percent load in a free field. The designer should develop these numbers based on the desired sound levels that should exist at various locations after the generator is installed. This information should be based on the values used in the acoustical analysis and verified by coordination with equipment manufacturers during design. In some cases, a sound attenuated enclosure may be needed to achieve the desired result.

The designer should also indicate the desired sound pressure levels that will be measured in the field. The pressure levels should be based on the acoustical analysis and should consider the specified operating conditions of the generator operating in a free field, other mechanical equipment, the building's sound absorption characteristics, OSHA requirements, and the building's functional requirements. The location of the measurement points for the installed generator should be coordinated with the SAFETY RUN TEST paragraph. Modify the radial distance requirement from the engine,exhaust, and air-intake to account for obstructions, variations in site conditions, building configurations or indicate points on the contract drawings at which measurements are to be made.
****

Submit sound power level data for the packaged unit operating at 100 percent load in a free field environment. The data should demonstrate compliance with the sound limitation requirements of this specification. Submit certification from the manufacturer stating that the sound emissions meet the specification. Do not exceed the following sound pressure levels in any of the indicated frequencies when measured in a free field at a radial distance of 22.9 feet 7 meters at 45 degrees apart in all directions when operating at 100 percent load.

Frequency Band (Hz)	Maximum Acceptable Sound Level (Decibels)
31	[_____]
63	[_____]
125	[_____]
250	[_____]
500	[_____]

Frequency Band (Hz)	Maximum Acceptable Sound Level (Decibels)
1,000	[_____]
2,000	[_____]
4,000	[_____]
8,000	[_____]

2.10 AIR INTAKE EQUIPMENT

Locate filters and silencers in locations that are convenient for servicing. Provide high-frequency filter type silencers and locate in the air intake system as recommended by the engine manufacturer. Provide silencer to reduce the noise level at the air intake so that the indicated pressure levels specified in paragraph SOUND LIMITATIONS will not be exceeded. A combined filter-silencer unit meeting requirements for the separate filter and silencer items may be provided. Provide [copper] [rubber] expansion elements in air-intake lines.

Provide intake filter assemblies for each engine of the oil bath or dry type, as standard with the manufacturer. Filters must be capable of removing a minimum of 92 percent of dirt and abrasive 3 microns and larger from intake air. Size filters to suit engine requirements at 100 percent of rated full load. Design unit for field access for maintenance purposes.

2.11 EXHAUST SYSTEM

****

NOTE: Include on the drawings a detail of the exhaust piping that penetrates construction such as walls or roof.

****

Provide a separate and complete system for each engine. Support piping to minimize vibration. Where a V-type engine is provided, use a V-type connector, with necessary flexible sections and hardware, to connect the engine exhaust outlets.

2.11.1 Flexible Sections and Expansion Joints

Provide a flexible section at each engine and an expansion joint at each muffler. Provide flexible sections and expansion joints that have flanged connections. Provide flexible sections made of convoluted seamless tube without joints or packing. Provide bellows type expansion joints. Provide stainless steel expansion and flexible elements suitable for engine exhaust gas at the maximum exhaust temperature that is specified by the engine manufacturer. Provide expansion and flexible elements that are capable of absorbing vibration from the engine and compensation for thermal expansion and contraction.

2.11.2 Exhaust Muffler

****

NOTE: Muffler locations and mountings should be shown on the drawings.

****

Provide a chamber type exhaust muffler. Provide welded steel muffler designed for [outside] [inside] [vertical] [horizontal] mounting. Provide eyebolts, lugs, flanges, or other items as necessary for support in the location and position indicated. Do not exceed the engine manufacturer's recommended pressure drop. Outside mufflers must be zinc coated or painted with high temperature 204 degrees C 400 degrees F resisting paint. The muffler and exhaust piping together must reduce the noise level to less than the maximum acceptable level listed for sound limitations in paragraph SOUND LIMITATIONS. Provide muffler with a drain valve, nipple, and cap at the low-point of the muffler.

****

NOTE: The normal values given in the table for exhaust sound reduction are for installations in residential applications. If the installation is in a critical environment (such as a hospital), more stringent criteria must be applied, including engine noise dampening, and the attenuation values in the table for critical class should be selected.

****

A[residential class][critical class] silencer must be provided for each engine which will reduce the exhaust sound spectrum by the following listed values at a 23 m 75 foot radius from the outlet, with generator set loaded to rated capacity and clear weather. Inlet and outlet connections must be flanged.

Octave Band Center Frequency (Hertz)								
Minimum Silencer Attenuation Decibels	63	125	250	500	1000	2000	4000	8000
[Residental Class]	[10]	[25]	[32]	[30]	[25]	[25]	[24]	[23]
[Critical Class]	[15]	[32]	[37]	[36]	[30]	[36]	[37]	[37]

2.11.3 Exhaust Piping

****

NOTE: Exhaust piping will be sized at a gas velocity of less than 25.4 meters per second 5000 fpm. Show piping on the drawings.

****

Slope horizontal sections of exhaust piping downward away from the engine to a drip leg for collection of condensate with drain valve and cap. Changes in direction must be long radius. Insulate exhaust piping, mufflers and silencers installed inside any building in accordance with paragraph THERMAL INSULATION and covered to protect personnel. Provide vertical exhaust piping with a hinged, gravity-operated, self-closing, rain cover.

****

NOTE: Include the following paragraph when the engine-generator set is installed internal to a building in lieu of in a self-contained outdoor enclosure. The designer is responsible for ensuring

that:

1. External loads from the exhaust system, such as weight and thermal expansion do not exceed the engine manufacturer's maximum allowed forces and moments on the turbocharger, and;

2. The exhaust piping system pressure loss is coordinated with the visible emission limits of the engine-generator set when air pollution permitting is required.

****

Field installed exhaust piping must conform to the following:

a. Exhaust Piping: Provide flanges for connections to engines, exhaust mufflers, and flexible connections. Provide steel pipe conforming to ASTM A53/A53M for each engine complete with necessary fittings, flanges, gaskets, bolts, and nuts. Exhaust piping must be Schedule 40 pipe for 300 mm 12 inches and smaller, standard weight for sizes 350 mm 14 inches through 600 mm 24 inches, and 6 mm 0.25 inch wall thickness for sizes larger than 600 mm 24 inches. Flanges must be Class 150 slip-on forged steel welding flanges in accordance with ASME B16.5, with material in accordance with ASTM A181/A181M, Grade I. Fittings must be butt welding conforming to ASTM A234/A234M, with wall thickness same as adjoining piping. Fittings must be of same material and wall thickness as pipe. Built-up miter welded fittings may be used. Miter angles of each individual section must not exceed 22.5 degrees total and not more than 11.25 degrees relative to the axis of the pipe at any one cut. Gaskets for exhaust piping must be of high temperature asbestos-free material suitable for the service and must be ASME B16.21, composition ring, 1.6 mm 0.0625 inch thick. Bolting material for exhaust flanges must be alloy-steel bolt-studs conforming to ASTM A193/A193M, Grade B7 bolts and alloy-steel nuts conforming to ASTM A194/A194M, Grade 7. Bolts must be of sufficient length to obtain full bearing on the nuts and must project not more than two full threads beyond the nut. Provide stainless steel counterbalance type rain caps at termination of each exhaust pipe.

****

NOTE: Select option for liners in expansion joints when required to reduce exhaust pressure drop.

****

b. Expansion (Flexible) Joints: Provide sections of multiple corrugated stainless steel expansion joints [with liners] in the engine exhaust piping for each engine to absorb expansion strains and vibration transmitted to the piping. Flexible joints must be suitable for operation at 93 degrees C 200 degrees F above normal exhaust gas temperature at 100 percent load, 10,000 cycles, minimum. Joints must be flanged and located between engine exhaust manifold and exhaust piping, must be the same size as exhaust piping size, and must be designed and constructed for engine exhaust service.

c. Hangers and Supports: MSS SP-58.

****

NOTE: Include on the drawings a detail of the

exhaust piping penetrations through walls and roofs showing the piping sleeve and exterior flashing.
****

d. Piping Sleeves: Provide where piping passes through masonry or concrete walls, floors, roofs, and partitions. Sleeves must be placed during construction. Unless indicated otherwise, pipe sleeves must comply with following requirements: sleeves in outside walls below and above grade, in floor, or in roof slabs, must be standard weight zinc coated steel pipe. Sleeves in partitions must be zinc coated sheet steel having a nominal weight of not less than 4.4 kg per square meter 0.90 pound per square foot. Space between piping insulation and the sleeve must not be less than 6 mm 0.25 inch. Sleeves must be held securely in proper position and location during construction. Sleeves must be sufficient length to pass through entire thickness of walls, partitions, or slabs. Sleeves in floor slabs must extend 50 mm 2 inches above the finished floor. Space between the pipe and the sleeve must be firmly packed with insulation and caulked at both ends of the sleeve with plastic waterproof cement.

e. Piping Insulation: Provide exhaust piping insulation in accordance with Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

2.12 PYROMETER

****
NOTE: For sets smaller than 200 kW delete this paragraph. Pyrometers with individual thermocouples are not normally available and should not be specified for units smaller than 1000 kW.
****

Provide a pyrometer, [multi-point selector switch, and individual thermocouples] [and thermocouple] with calibrated leads to show the temperature [in each engine cylinder and the combined exhaust] [of the combined exhaust]. For a supercharged engine, provide additional points, thermocouples and leads to show the temperature in the turbocharger exhaust gas outlet and combustion air discharge passages. Graduated scale length less than 150 mm 6 inches is not acceptable. Provide double pole selector switch with an "off" position, one set of points for each thermocouple, and suitable indicating dial. Calibrate the pyrometer, thermocouples, leads and compensating devices to show true exhaust temperature within plus or minus 1 percent above the highest temperature encountered at 110 percent load conditions.

2.13 EMISSIONS

****
NOTE: The designer will coordinate emissions requirements with the installation (base/post) environmental office and provide a listing of the requirements. The identification of environmental requirements should be identified at the beginning of the project as a special study effort which requires funding separate from the normal design.
****

The finished installation must comply with Federal, state, and local regulations and restrictions regarding the limits of emissions, as listed here: [_____]. Submit certification from the engine manufacturer stating that the engine exhaust emissions meet the federal, state, and local regulations and restrictions specified. At a minimum this certification must include emission factors for criteria pollutants including nitrogen oxides, carbon monoxide, particulate matter, sulfur dioxide, non-methane hydrocarbon, and for hazardous air pollutants (HAPs).

2.14 STARTING SYSTEM

****

NOTE: Either electrical or pneumatic starting system should be used and the other paragraphs deleted. Electrical starting will be used for most applications. Engines up to 750 kW should be equipped for electric starting. Starting battery system must be 24-volt dc for engine-generator sets greater than 100 kW and 12-volt dc for engine-generator sets rated 100 kW and less. See manufacturers literature to determine availability for sizes above 750 kW. For units used in emergency applications, select the first option and delete all other starting system paragraphs.

****

Provide starting system for [standby engine generator sets used in emergency applications in accordance with NFPA 99 and NFPA 110and as follows.] [engine generator sets used in non-emergency applications as follows.]

2.14.1 Controls

Provide an engine control switch with functions including: run/start (manual), off/reset, and, automatic mode. Provide start-stop logic for adjustable cycle cranking and cool-down operation. Arrange the logic for [manual starting] [and] [fully automatic starting in accordance with paragraph AUTOMATIC ENGINE-GENERATOR-SET SYSTEM OPERATION]. Provide electrical starting systems with an adjustable cranking limit device to limit cranking periods from 1 second up to the maximum duration.

2.14.2 Capacity

Provide starting system with sufficient capacity, at the maximum [outdoor] [indoor] summer temperature specified to crank the engine without damage or overheating. The system must provide a minimum of three cranking periods with 15 second intervals between cranks. Each cranking period must have a maximum duration of 15 seconds. Starting must be accomplished using an adequately sized dc starter system with a positive shift solenoid to engage the starter motor and to crank the engine continuously for 60 seconds without overheating.

2.14.3 Electrical Starting

Manufacturers recommended dc system, utilizing a negative circuit ground. Starting motors must be in accordance with SAE ARP892.

2.14.3.1 Battery

****

NOTE: The ambient temperature selected must be the

lowest temperature at which the engine might be cranked. Battery configuration must be two parallel sets of two 12-volt batteries for engine-generator sets rated 750 kW and above. Select nickel-cadmium only when the battery temperature cannot be maintained above minus 6 degrees C 22 degrees F.
****

Provide a starting battery system including the battery, battery rack, intercell connectors, spacers, automatic battery charger with overcurrent protection, metering and relaying. Provide battery in accordance with SAE J537. Size critical system components (rack, protection, etc.) to withstand the seismic acceleration forces specified. Provide [lead-acid] [nickel-cadmium] battery with sufficient capacity, at the minimum [outdoor] [indoor] and maximum [outdoor] [indoor] temperature specified, to provide the specified cranking periods. Valve-regulated lead-acid batteries are not acceptable.

Provide maintenance free, sealed, lead-acid, SAE Type D engine starting batteries.[Battery configuration must be two parallel sets of two 12-volt batteries.] Batteries must have sufficient capacity to provide 60 seconds of continuous cranking of the engine in an ambient temperature of [_____] degrees C [_____] degrees F.

2.14.3.2 Battery Charger

Provide a current-limiting battery charger, conforming to UL 1236, that automatically recharges the batteries. Submit battery charger sizing calculations. The charger must be capable of an equalize charging rate [for recharging fully depleted batteries within [24] [_____] hours] [which is manually adjustable in a continuous range] and a floating charge rate for maintaining the batteries at fully charged condition. Provide an ammeter to indicate charging rate. Provide a voltmeter to indicate charging voltage. Provide a timer for the equalize charging-rate setting. A battery is considered to be fully depleted when the output voltage falls to a value which will not operate the engine generator set and its components.

Provide [120] [_____] volt ac, enclosed, automatic equalizing, dual-rate, solid-state, constant voltage type battery charger with automatic ac line compensation. DC output must be voltage regulated and current limited. Charger must have two ranges, float and equalize, and must provide continuous taper charging. The charger must have a continuous output rating of not less than 10 amperes and must be sized to recharge the engine starting batteries in a minimum of 8 hours while providing the control power needs of the engine-generator set. Enclosure must be NEMA ICS 6, Type [1] [_____]. The following accessories must be included:

a. DC ammeter

b. DC voltmeter

c. Equalize light

d. AC on light

e. Low voltage light

f. High voltage light

g. Equalize test button/switch

h. AC circuit breaker

i. Low dc voltage alarm relay

j. High dc voltage alarm relay

k. Current failure relay

l. AC power failure relay

2.14.4 Storage Batteries

Provide storage batteries of suitable rating and capacity to supply and maintain power for the remote alarm annunciator for a period of 90 minutes minimum without the voltage applied falling below 87.5 percent of normal. Provide a [120] [_____] volt ac automatic battery charger.

2.14.5 Pneumatic

****

NOTE: Pneumatic starting should be used on sets 750 kW and larger.

The complete compressed air system should be shown on the drawings. Two receivers, redundant piping, and two compressors may be required so that starting capability is not lost when tank maintenance is required. Valve arrangement must permit any receiver to be removed from service, drained, repaired, or replaced without loss of starting air from the system. The designer must analyze the starting scenarios and determine the necessity to provide a gasoline or diesel-engine-driven compressor for a "black-plant" (no electrical sources available) startup.

Size each compressor to restore in 15 minutes the air used in one engine start.

Size each receiver to provide sufficient capacity to crank the largest engine for 60 seconds at an ambient temperature of 21 degrees C 70 degrees F without recharging.

Recommended working pressures are 2068.5 kPa (gauge) 300 psig for cylinder injection or, 1034.2 kPa (gauge) 150 psig for air-motor starting.

Either motors or cylinder injection should be used and the other type deleted.

****

Provide a pneumatic starting system. Provide compressed air system as specified in Section 22 00 00 PLUMBING, GENERAL PURPOSE, for a working pressure of [2.07 MPa 300 psi] [1.03 MPa 150 psi].

2.14.5.1 Air Driven Motors

Provide air driven motors complete with solenoid valve, strainer, and lubricator.

2.14.5.2 Cylinder Injection

Perform starting by admitting compressed air into two or more engine cylinders through a timing valve, or through a distributor into a sufficient number of cylinders to assure successful starting regardless of piston positions.

2.14.6 Starting Aids

****

NOTE: Jacket coolant and/or lube-oil heaters are normally provided for most applications to aid starting. Some manufacturers may require glow plugs for combustion air temperatures significantly below 0 degrees C 32 degrees F. Consult manufacturers for availability in the application size range.

****

Provide one or more of other following methods to assist engine starting.

2.14.6.1 Glow Plugs

Design glow plugs to provide sufficient heat for combustion of fuel within the cylinders to guarantee starting at an ambient temperature of -32 degrees C -25 degrees F.

2.14.6.2 Jacket-Coolant Heaters

Mount a thermostatically controlled electric heater in the engine coolant jacketing to automatically maintain the coolant within plus or minus 1.7 degrees C 3 degrees F of the control temperature. The heater must operate independently of engine operation so that starting times are minimized. Power for the heaters must be [_____] volts ac. Include necessary equipment, piping, controls, wiring, and accessories.

2.14.6.2.1 Prime Rated Sets

The control temperature must be the higher of the manufacturer's recommended temperature or the minimum coolant inlet temperature of the engine recommended in paragraph SUBMITTALS.

2.14.6.2.2 Standby Rated Sets

The control temperature must be the temperature recommended by the engine manufacturer to meet the starting time specified at the minimum winter outdoor temperature.

2.14.6.3 Lubricating-Oil Heaters

Mount a thermostatically controlled electric heater in the engine lubricating-oil system to automatically maintain the oil temperature within plus or minus 1.7 degrees C 3 degrees F of the control temperature. The heater must operate independently of engine operation so that starting times are minimized. Power for the heaters must be [_____]

volts ac.

2.14.7 Exerciser

****

NOTE: Coordinate the need for an exerciser with the user. The plant exerciser is required for stand-by rated sets only, so delete this paragraph for prime applications. Ensure that the exerciser is compatible with the automatic transfer scheme (see reset provisions). It is usually desirable to utilize system loads for genset exercise loads. Coordinate requirement with the user. The designer must ensure that the design provides warning signs in areas where the engine generator can start automatically.

****

Provide exerciser in accordance with Section 26 36 23 AUTOMATIC TRANSFER SWITCH AND BY-PASS/ISOLATION SWITCH.

2.15 GOVERNOR

****

NOTE: Coordinate with paragraph ENGINE GENERATOR PARAMETER SCHEDULE.

****

Provide a forward acting type engine speed governor system. Steady-state frequency band and frequency regulation (droop) must be in accordance with the operating limit values of the performance class specified in the paragraph PERFORMANCE CLASS.

Provide engine with a governor which maintains the frequency within a bandwidth of the rated frequency, over a steady-state load range of zero to 100 percent of rated output capacity. Configure the governor for safe manual adjustment of the speed/frequency during operation of the engine-generator set, without special tools, from 90 to 110 percent of the rated speed/frequency, over a steady state load range of 0 to 100 percent or rated capacity. Submit two complete sets of special tools required for maintenance (except for electronic governor handset). Special tools are those that only the manufacturer provides, for special purposes, or to reach otherwise inaccessible parts. Provide a suitable tool box for tools. Provide one handset for each electronic governor when required to indicate and/or change governor response settings. [Maintain the midpoint of the frequency bandwidth at the same value for steady-state loads over the range of zero to 100 percent of rated output capacity for isochronous governors.] [Maintain the midpoint of the frequency bandwidth linearly for steady-state loads over the range of zero to 100 percent of rated output capacity, [with 3 percent droop] [configured for safe, manual, external adjustment of the droop from zero to [7] [_____] percent] for droop governors.]

2.16 GENERATOR

****

NOTE: Armature and field winding insulation classes are specified based on the allowable temperature rise (the temperature in the windings above the

temperature of the air used to cool the windings). See NEMA MG 1 for a discussion of the classes with respect to size range, elevation, method of measurement, and ambient temperature. Select the class insulation for each application based on operating conditions. Class F is considered industry standard. If a different class is required for different machines, specify the one for each application in the Parameter Schedule for the respective engine-generator.
****

Provide synchronous type, one or two bearing, generator conforming to the performance criteria in NEMA MG 1, equipped with winding terminal housings in accordance with NEMA MG 1, equipped with an amortisseur winding, and directly connected to the engine. Submit calculations of the engine and generator output power capability, including efficiency and parasitic load data. Provide [Class H] [Class F] insulation.

a. Select NEMA MG 1, Part 16, standby duty, and temperature rise of 130 degrees C for engine-generator sets which are expected to operate for less than 300 hours per year. Select NEMA MG 1, Part 22, continuous duty, and temperature rise of 105 degrees C for engine-generator sets expected to operate 300 hours or greater per year or rated 300 kW and above.

b. Select 2/3 pitch design option for engine-generator sets rated 300 kW and above.

c. Select 10-12 lead re-connectable for engine-generator sets rated 300 kW to 800 kW.

d. For applications requiring high SCR loading or in harsh environments laden with salts and chemicals, select vacuum pressure impregnation (VPI) insulated coils. When engine-generator sets are rated 800 kW and larger, also select form wound coils.

e. Provide salient-pole type, ac, brushless-excited, revolving field, air-cooled, self-ventilated, [drip-proof guarded,] coupled type, synchronous generator conforming to NEMA MG 1, Part [16] [22], and IEEE C50.12. Generator must be rated for [standby] [continuous] duty at 100 percent of the power rating of the engine-generator set as specified in paragraph ENGINE-GENERATOR SET RATINGS AND PERFORMANCE. Temperature rise of each of the various parts of the generator must not exceed[130][105] degrees C as measured by resistance, based on a maximum ambient temperature of 40 degrees C. Winding insulation must be Class H.

f. Stator: Stator windings must be [2/3 pitch design] [,] [10-12 lead re-connectable] [with VPI insulated [and form wound] coils].

g. Rotor: The rotor must have connected amortisseur windings.

h. Generator Space Heater: Provide [120] [_____] volt ac heaters. Heater capacity must be as recommended by the generator manufacturer to aid in keeping the generator insulation dry.

i. Grounding: Provide non-corrosive steel grounding pads located at two opposite mounting legs.

j. Filters: Provide manufacturer's standard generator cooling air filter assembly.

k. Design generator to protect against mechanical, electrical and thermal damage due to vibration, 25 percent overspeeds, or voltages and temperatures at a rated output capacity of 110 percent for prime applications and 100 percent for standby applications.

l. Provide generator ancillary equipment meeting the short circuit requirements of NEMA MG 1. Select drip-proof guarded option for generators without weatherproof enclosures.

m. Submit manufacturer's standard data for each generator (prototype data at the specified rating or above is acceptable), listing the following information:

(1) Direct-Axis sub-transient reactance (per unit).

(2) The generator kW rating and short circuit current capacity (both symmetric and asymmetric).

2.16.1 Current Balance

At 100 percent rated output capacity, and load impedance equal for each of the 3 phases, the permissible current difference between any 2 phases must not exceed 2 percent of the largest current on either of the 2 phases. Submit certification stating that the flywheel has been statically and dynamically balanced and is capable of being rotated at 125 percent of rated speed without vibration or damage.

2.16.2 Voltage Balance

At any balanced load between 75 and 100 percent of rated output capacity, the difference in line-to-neutral voltage among the 3 phases must not exceed 1 percent of the average line-to-neutral voltage. For a single phase load condition, consisting of 25 percent load at unity power factor placed between any phase and neutral with no load on the other 2 phases, the maximum simultaneous difference in line-to-neutral voltage between the phases must not exceed 3 percent of rated line to neutral voltage. The single-phase load requirement must be valid utilizing normal exciter and regulator control. The interpretation of the 25 percent load for single phase load conditions means 25 percent of rated current at rated phase voltage and unity power factor.

2.16.3 Waveform

The deviation factor of the line-to-line voltage at zero load and at balanced rated output capacity must not exceed 10 percent. The RMS of all harmonics must be less than 5.0 percent and that of any one harmonic less than 3.0 percent of the fundamental at rated output capacity. Design and configure engine-generator to meet the total harmonic distortion limits of IEEE 519.

2.17 EXCITER

Provide brushless generator exciter. Provide semiconductor rectifiers that have a minimum safety factor of 300 percent for peak inverse voltage and forward current ratings for all operating conditions, including 110 percent generator output at 40 degrees C 104 degrees F ambient. The exciter and regulator in combination must maintain generator-output voltage within the limits specified.

****
NOTE: Select all options for engine-generator sets rated 300 kW and above.
****

Provide a brushless excitation system consisting of an exciter and rotating rectifier assembly [, and permanent magnet generator] integral with the generator and a voltage regulator. Insulation class for parts integral with the generator must be as specified in paragraph GENERATOR. System must provide a minimum short circuit of 300 percent rated engine-generator set current for at least 10 seconds. Steady state voltage regulation must be in accordance with the operating limit values of the performance class specified in the paragraph PERFORMANCE CLASS.

a. Exciter and Rotating Rectifier Assembly: Rectifiers must be provided with surge voltage protection.

b. Permanent Magnet Generator: Provide a voltage spike suppression device for permanent magnet generator (PMG) excitation systems.

c. Voltage Regulator: Voltage regulator must be solid state or digital, automatic, three-phase sensing, volts per hertz type regulator. Regulator must receive its input power from a PMG. Voltage variation for any 40 degree C change over the operating temperature range must be less than plus or minus 1.0 percent. Operating temperature must be minus 40 degree C to plus 70 degree C. Voltage adjust range must be plus to minus 5.0 percent of nominal. Inherent regulator features must include over excitation shutdown.

2.17.1 Electromagnetic Interference (EMI) Suppression

****
NOTE: Include electromagnetic interference (EMI) suppression for engine-generator set installations in the proximity of sensitive electronic equipment.
****

Provide as an integral part of the generator and excitation system, EMI suppression complying with MIL-STD-461.

2.18 VOLTAGE REGULATOR

****
NOTE: Delete reactive droop/differential compensation for non-parallel configuration.
****

Provide a solid-state voltage regulator, separate from the exciter, for each generator. Maintain the voltage within a bandwidth of the rated voltage, over a steady-state load range of zero to 100 percent of rated output capacity. Configure regulator for safe manual adjustment of the engine-generator voltage output without special tools, during operation, from 90 to 110 percent of the rated voltage over the steady state load range of 0 to 100 percent of rated output capacity. Regulation drift exceeding plus or minus 0.5 percent for an ambient temperature change of

20 degrees C 68 degrees F is not acceptable. Reactive droop compensation or reactive differential compensation must load share the reactive load proportionally between sets during parallel operation. Provide voltage regulator with a maximum droop of 2 percent of rated voltage over a load range from 0 to 100 percent of rated output capacity and automatically maintain the generator output voltage within the specified operational bandwidth.

2.19 GENERATOR ISOLATION AND PROTECTION

****

NOTE: Generator protection should be based on the application and size of the generator and should comply with the recommendations of IEEE 242 and IEEE Standard 446 for both generator breaker features and protection schemes. See AFMAN 32-1077 for recommended protection schemes for Air Force projects. The designer must perform a power system coordination study (reference UFC 3-520-01, Coordinated Power System Protection) to specify the breaker ratings, breaker trip unit features and settings, relay protection scheme, and relay settings for coordination for each engine-generator installed. The configuration should always include a disconnecting means for isolation of the generator for maintenance purposes. If the scope of protection is small the designer may elect to incorporate the appropriate Section 26 28 01.00 10 COORDINATED POWER SYSTEM PROTECTION, paragraphs in this section. Show panelboard, switchboard, and switchgear ratings on the contract drawings for each engine-generator. Rating information should include voltage, phase, bus continuous capacity (amperes), and bus withstand capacity (amperes) (see NEMA PB 1 and NEMA PB 2 for necessary rating information). Show breaker frame, trip, and interrupting ratings on the contract drawings.

Surge capacitors and surge arresters should be provided when the sets are to be connected to exposed overhead lines directly or through transformers, even though connection may be only for transfer of load without service interruption. Surge arrester protection is not required for separately derived sets which serve single buildings isolated from overhead lines by automatic or manual transfer switches, where provision has been made to prevent simultaneous connection to both sources. The designer will specify the surge arrester rating.

****

Provide necessary devices for electrical protection and isolation of each engine-generator set and its ancillary equipment. The generator circuit breaker (IEEE Device 52) ratings must be consistent with the generator rated voltage and frequency, with continuous, short circuit withstand, and interrupting current ratings to match the generator capacity. Provide [manually operated] [electrically operated] [operated as indicated] generator circuit breaker. Mount a set of surge capacitors at the generator terminals. Provide monitoring and control devices as specified in paragraph GENERATOR PANEL.

The generator circuit breaker must comply with UL 489 requirements for molded case, adjustable thermal magnetic trip type circuit breaker. The circuit breaker continuous current rating must be adequate for the power rating of the engine-generator set and the circuit breaker must be rated to withstand the short circuit current provided by the generator set. Provide circuit breaker in a NEMA ICS 6, Type [1] [_____] enclosure mounted on the engine-generator set.

2.19.1 Switchboards

Provide free-standing, metal-enclosed, general purpose, 3-phase, 4-wire, [600] [_____] volt rated, with neutral bus and continuous ground bus, switchboards conforming to NEMA PB 2 and UL 891. Neutral bus and ground bus capacity must be [as shown] [full capacity]. Provide panelboards conforming to NEMA PB 1. Provide enclosure designs, construction, materials and coatings [as indicated] [suitable for the application and environment]. Bus continuous current rating must be [at least equal to the generator rating and correspond to the UL listed current ratings specified for panelboards and switchboards] [as indicated]. Current withstand (short circuit rating) must be [equal to the breaker interrupting rating] [as indicated]. Provide copper buses.

2.19.2 Devices

Provide switches, circuit breakers, switchgear, fuses, relays, and other protective devices as specified in Section 26 28 01.00 10 COORDINATED POWER SYSTEM PROTECTION.

Furnish with respective pieces of equipment. Motors, controllers, contactors, and disconnects must conform to Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Provide electrical connections under Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Provide controllers and contactors with maximum of 120-volt control circuits, and auxiliary contacts for use with controls furnished. When motors and equipment furnished are larger than size indicated, the cost of providing additional electrical service and related work must be included under this section.

2.20 SAFETY SYSTEM

Provide and install devices, wiring, remote panels, and local panels, etc., as a complete system to automatically activate the appropriate signals and initiate the appropriate actions. Provide a safety system with a self-test method to verify its operability. Provide alarm signals that have manual acknowledgment and reset devices. The alarm signal systems must reactivate for new signals after acknowledgment is given to any signal. Configure the systems so that loss of any monitoring device will be dealt with as an alarm on that system element.

2.20.1 Audible Signal

****

NOTE: High dB levels are required for alarms located near engine. Specify over 100 dB for engine room application and show alarm location.

****

Provide audible alarm signal sound at a frequency of [70] [_____] Hz at a volume of [_____] [75] dB at 3.1 m 10 feet. The sound must be continuously activated upon alarm and silenced upon acknowledgment. Locate signal devices as shown.

2.20.2 Visual Signal

The visual alarm signal must be a panel light. The light must be normally off, activated to be blinking upon alarm. The light must change to continuously lit upon acknowledgement. If automatic shutdown occurs, the display must maintain activated status to indicate the cause of failure and must not be reset until cause of alarm has been cleared and/or restored to normal condition. Shutdown alarms must be red; all other alarms must be amber.

2.20.3 Alarms and Action Logic

2.20.3.1 Shutdown

Accomplish simultaneous activation of the audible signal, activation of the visual signal, stopping the engine, and opening the generator main circuit breakers.

2.20.3.2 Problem

Accomplish activation of the visual signal.

2.20.4 Safety Indications and Shutdowns

****

NOTE: The designer must provide design features in accordance with the requirements of NFPA 70 and NFPA 99 for medical facilities. The designer must provide design features in accordance with the requirements of NFPA 70 and NFPA 110 for emergency and standby applications. For emergency and standby applications select either Level 1 or Level 2. Level 1 defines the most stringent equipment performance requirements for applications where the failure of the equipment to perform could result in loss of human life or serious injury. Level 2 defines equipment performance where failure of the equipment to operate is less critical to human life. Edit the table to include all required shutdowns and alarms. Delete optional alarms which are not required. Delete all columns except the first column and the appropriate code reference column. Add necessary parameters to define critical limits for alarms or shutdown.

For example, references to day tanks should be removed if integral main fuel storage tanks are used.

Provide a local alarm panel with the following shutdown and alarm functions [as indicated] [in accordance with [NFPA 99] [NFPA 110 level [1] [2]]] mounted either on or adjacent to the engine generator set.

****

NOTE: Depending on the application, a remote alarm panel may also be required. The Remote Alarm Panel

should be shown on the drawings. Delete remote alarm panel where not required. Select the first option if the application is prime power plant. For prime power units provide panel elevations depicting desired configurations, together with a listing of alarms and instruments. Select the second option for engine generator sets utilized on emergency or standby applications. The designer must provide design features in accordance with the requirements of NFPA 70, and NFPA 99 for medical facilities. The designer must provide design features in accordance with the requirements of NFPA 70 and NFPA 110 for emergency and standby applications. A remote panel is required for NFPA 99 and NFPA 110, Level 1 applications. A remote panel is not required for NFPA 110, Level 2 applications. Edit the table to include all required alarms. Delete optional alarms which are not required. Delete all columns except the first column and the appropriate code reference column. Add necessary parameters where required to define critical limits for alarms.

****

A remote alarm panel is [is not] required for audible alarms, e.g., in the control room.

Indicator Function (at battery voltage)	NFPA 99 Level 1 CV S RA	NFPA 110 Level 1 CV S RA	NFPA 110 Level 2 CV S RA
Overcrank	X X X	X X X	X X O
Low water temperature	X NA X	X NA X	X NA O
High engine temperature pre-alarm	X NA X	X NA X	O NA NA
High engine temperature	X X X	X X X	X X O
Low lube oil pressure pre-alarm	X NA X	NA NA NA	NA NA NA
Low lube oil pressure	X X X	X X X	X X O
Overspeed	X X X	X X X	X X O
Low fuel main tank	X NA X	X NA X	O NA O
Low coolant level	X O X	X O X	X O X
EPS supplying load	X NA NA	X NA NA	O NA NA
Control switch not in automatic position	X NA X	X NA X	X NA X

Indicator Function (at battery voltage)	NFPA 99 Level 1 CV S RA	NFPA 110 Level 1 CV S RA	NFPA 110 Level 2 CV S RA
High battery voltage	X NA NA	X NA NA	O NA NA
Low cranking voltage	X NA X	X NA X	O NA NA
Low voltage in battery	X NA NA	X NA NA	O NA NA
Battery charger ac failure	X NA NA	X NA NA	O NA NA
Lamp test	X NA NA	X NA NA	X NA NA
Contacts for local and remote common alarm	X NA X	X NA X	X NA X
Audible alarm silencing switch	NA NA X	NA NA X	NA NA O
Low starting air pressure	X NA NA	X NA NA	O NA NA
Low starting hydraulic pressure	X NA NA	X NA NA	O NA NA
Air shutdown damper when used	X X X	X X X	X X O
Remote emergency stop	NA X NA	NA X NA	NA X NA
Symbology: CV: Control panel-mounted visual. S: Shutdown of EPS indication. RA: Remote audible. Symbology: CV: Control panel-mounted visual. S: Shutdown of EPS indication. RA: Remote audible. X: Required. O: Optional. NA: Not applicable.			

2.20.5 Time-Delay on Alarms

For startup of the engine-generator set, install time-delay devices bypassing the low lubricating oil pressure alarm during cranking, and the coolant-fluid outlet temperature alarm. Submit the magnitude of monitored values which define alarm or action set points, and the tolerance (plus and/or minus) at which the devices activate the alarm or action for items contained within the alarm panels. The lube-oil time-delay device must return its alarm to normal status after the engine starts. The coolant time-delay device must return its alarm to normal status 5 minutes after the engine starts.

2.21 SYNCHRONIZING PANEL

****

NOTE: Delete the Synchronizing Panel if no parallel service is intended. All panels except the remote panel can be combined into a single panel paragraph.

****

Provide panel as specified in paragraph PANELS and provide controls, gauges, meters, and displays to include:

a. Frequency meters, dial type, with a range of 90 to 110 percent of rated frequency. Do not use vibrating-reed type meters . One must monitor generator output frequency ("Generator Frequency Meter") and the other must monitor the frequency of the parallel source ("Bus Frequency Meter").

b. Voltmeters, ac, dial type, 3-phase, with 4-position selector switch for the generator output ("Generator Volt Meter") and for the parallel power source ("Bus volt meter").

c. Automatic synchronizer.

d. Manual synchronizing controls.

e. Indicating lights for supplementary indication of synchronization.

f. Synchroscope.

g. Wattmeter, indicating.

2.22 PANELS

****

NOTE: All panels except the remote panel can be combined into a single panel paragraph.

Provide a panel-mounting location and detail for panels not mounted on the engine-generator base. The designer may elect other locations such as adjacent to engine-generator set, in the generator enclosure, in or on the exciter-regulator cabinet, or in or on the switchgear enclosure. Provide panel nameplate and instrument nameplate unique identifiers or user preferred identifiers. Provide sizes, materials and attachment preferences.

Delete either the "analog" or "electronic instruments" paragraph.

****

Each panel must be of the type and kind necessary to provide specified functions. Mount panels [on the engine-generator set base by vibration/shock absorbing type mountings] [as shown]. Mount instruments flush or semiflush. Provide convenient access to the back of panels to facilitate maintenance. Calibrate instruments using recognized industry calibration standards. Provide a panel identification plate identifying the panel function. Provide a plate identifying the device and its function for each instrument and device on the panel. Provide switch plates identifying the switch-position function.

2.22.1 Enclosures

Design enclosures for the application and environment, conforming to NEMA ICS 6. Locking mechanisms [are optional.] [must be keyed alike.]

Provide for each engine-generator set and fabricate from zinc coated or phosphatized and shop primed 16 gage minimum sheet steel in accordance with the manufacturer's standard design. Provide a complete, weatherproof enclosure for the engine, generator, and auxiliary systems and equipment. Support exhaust piping and silencer so that the turbocharger is not subjected to exhaust system weight or lateral forces generated in connecting piping that exceed the engine manufacturer's maximum allowed forces and moments. The housing must have sufficient louvered openings to allow entrance of outside air for engine and generator cooling at full load. Design louvered openings to exclude driving rain and snow. Provide properly arranged and sized, hinged panels in the enclosure to allow convenient access to the engine, generator, and control equipment for maintenance and operational procedures. Provide hinged panels with spring type latches which must hold the panels closed securely and will not allow them to vibrate. Brace the housing internally to prevent excessive vibration when the set is in operation

2.22.2 Analog

Provide analog electrical indicating instruments in accordance with UL 1437 with semi-flush mounting. Switchboard, switchgear, and control-room panel-mounted instruments must have 250 degree scales with an accuracy of not less than 99 percent. Unit-mounted instruments must [be the manufacturer's standard] [have 100 degree scales] with an accuracy of not less than 98 percent. The instrument's operating temperature range must be minus 20 to plus 65 degrees C minus 4 to plus 158 degrees F. Distorted generator output voltage waveform of a crest factor less than 5 must not affect metering accuracy for phase voltages, hertz and amps.

2.22.3 Electronic

Electronic indicating instruments must be true RMS indicating instruments, 100 percent solid state, state-of-the-art, microprocessor controlled to provide specified functions. Provide control, logic, and function devices that are compatible as a system, sealed, dust and water tight, and that utilize modular components with metal housings and digital instrumentation. Provide an interface module to decode serial link data from the electronic panel and translate alarm, fault and status conditions to set of relay contacts. Instrument accuracy less than 98 percent for unit mounted devices and 99 percent for control room, panel mounted devices, throughout a temperature range of minus 20 to plus 65 degrees C minus 4 to 158 degrees F is not acceptable. Provide LED or back lit LCD data display. Additionally, the display must provide indication of cycle programming and diagnostic codes for troubleshooting. Numeral height must be [13 mm 0.5 inch] [_____].

2.22.4 Parameter Display

Provide indication or readouts of the tachometer, lubricating-oil pressure, ac voltmeter, ac ammeter, frequency meter, and safety system parameters. Specify a momentary switch for other panels.

2.23 SURGE PROTECTION

Electrical and electronic components must be protected from, or designed to withstand the effects of surges from switching and lightning.

2.24 AUTOMATIC ENGINE-GENERATOR-SET SYSTEM OPERATION

****

NOTE: Automatic operation is for standby. For hospital emergency/standby requirements, an emergency power plant of sufficient capacity to handle the essential load must be provided, arranged to operate automatically with the failure or restoration of normal current. Delete automatic paralleling and loading where not required. Adapt to fit application and provide desired actuation sequence.

****

Provide fully automatic operation for the following operations: engine-generator set starting and load transfer upon loss of [normal] [preferred] source; retransfer upon restoration of the [normal] [preferred] source; sequential starting; paralleling, and load-sharing for multiple engine-generator sets; and stopping of each engine-generator set after cool-down. Devices must automatically reset after termination of their function.

2.24.1 Automatic Transfer Switch

Provide automatic transfer switches in accordance with Section 26 36 23 AUTOMATIC TRANSFER SWITCH AND BY-PASS/ISOLATION SWITCH.

2.24.2 Monitoring and Transfer

Provide devices to monitor voltage and frequency for the [normal] [preferred] power source and each engine-generator set, and control transfer from the [normal] [preferred] source and retransfer upon restoration of the [normal] [preferred] source. Describe functions, actuation, and time delays as described in Section 26 36 23 AUTOMATIC TRANSFER SWITCH AND BY-PASS/ISOLATION SWITCH.

2.24.3 Automatic Paralleling and Loading of Engine-Generator Sets

Provide an automatic loading system to load and unload engine-generator sets in the sequence indicated. Monitor the system load and cause additional engine-generator sets to start, synchronize, and be connected in parallel with the system bus with increasing load. Actuation of the additional engine-generator set start logic must occur when the load exceeds a percentage set-point of the operating set's rating for a period of approximately 10 seconds. Provide an adjustable set-point range from 50 to 100 percent. When the system load falls below the percentage set-point of the operating set's rating for a period of approximately [_____], the controller must unload and disconnect engine-generator sets from the system, stopping each engine-generator set after cool-down.

2.25 MANUAL ENGINE-GENERATOR-SET SYSTEM OPERATION

****

NOTE: Delete synchronization for non-parallel operation.

****

Provide complete facilities for manual starting and testing of each set without load, loading and unloading of each set, and synchronization of each set with an energized bus.

2.26 STATION BATTERY SYSTEM

****

NOTE: The station battery system should be shown on the drawings.

Delete this requirement when not needed. A station battery is required only when dc-operated devices other than engine starting motors are provided. The station battery and starting battery may be combined where all dc-operated devices are the same voltage level and are not affected by the voltage drop caused by engine starting. Because lead calcium batteries are more economical and require less maintenance, nickel cadmium batteries should be specified only where very high discharge rate with constant voltage over a short period of time is required, or for applications where the battery temperature cannot be maintained above minus 6 degrees C 22 degrees F. Slush does not begin to form in lead acid batteries until the temperature reaches minus 29 degrees C minus 20 degrees F, but the battery voltage output and current capacity fall below useful values at minus 6 degrees C 22 degrees F. The designer should provide measures to maintain battery temperature between 16 and 32 degrees C 60 and 90 degrees F; 25 degrees C 77 degrees F is the target temperature for optimum service life and performance. The engine starting battery for smaller size sets is sufficient for dc requirements and a station battery is not required.

Define loads which are to be served by the station battery.

Calculations of battery capacity utilize a median temperature of 25 degrees C 77 degrees F. If the predominate battery operating temperature varies by more than plus or minus 2.5 degrees C plus or minus 5 degrees F from 25 degrees C 77 degrees F, specify the median operating temperature.

****

Provide a station battery system including the battery, battery rack, spacers, automatic battery charger and distribution panelboard with overcurrent protection, metering and relaying. Size components to withstand the seismic acceleration forces specified. Provide batteries that have a rated life of 20 years and a manufacturer's 5-year, no cost replacement guarantee.

2.26.1 Battery

Provide [lead-acid] [nickel-cadmium] battery sized in accordance with IEEE 485 and conforming to the requirements of IEEE 484. Valve-regulated lead-acid batteries are not acceptable. Provide battery environment temperature range between [_____] and [_____] degrees. The battery must be rated for at least [_____] ampere hours at the 8-hour rate.

2.26.2 Battery Capacity

****

NOTE: Delete loads which are not to be served from the Station Battery System. Add the following load for engine-generators 1000 kW and larger: precirculating lube-oil pumps for diesels for [_____] minutes.

****

The battery must be rated for at least [_____] ampere hours at the 8-hour rate, and must have sufficient capacity to serve the following loads without recharging for a period of [_____] hours. At the end of the discharge period, the battery must have the capacity to simultaneously close and trip all the circuit breakers provided, based on a 1-minute load to final voltage of [_____] volts per cell.

a. Diesel-generator safety circuits.

b. Switchgear indicating lights, control relays, protective relays, and other switchgear dc components as required for 24 hours.

c. Voltage regulator (dc power supplies).

d. Emergency-lighting and power load at [_____] watts for [_____] hours.

2.26.3 Battery Charger

Furnish a current-limiting, [_____]-volt battery charger to automatically recharge the batteries. Provide a charger that is capable of an equalize charging rate [for recharging fully depleted batteries within [8] [_____] hours] [which is continuously adjustable] and a floating-charge rate for maintaining the batteries in a fully charged condition. Equip the charger with a low-voltage alarm relay, 0- to 24-hour equalizing timer, an ammeter to indicate charging rate, and necessary circuit breakers. The charger must conform to the requirements of UL 1236. A battery is considered to be fully depleted when the voltage falls to a level incapable of operating the equipment loads served by the battery.

2.27 BASE

Provide a steel base. Design the base to rigidly support the engine-generator set, ensure permanent alignment of rotating parts, be arranged to provide easy access to allow changing of lube-oil, and ensure that alignment is maintained during shipping and normal operation. The base must permit skidding in any direction during installation and must withstand and mitigate the affects of synchronous vibration of the engine and generator. Provide base with [suitable holes for anchor bolts] [[_____] diameter holes for anchor bolts] and jacking screws for leveling.

2.28 THERMAL INSULATION

Provide thermal insulation as specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

2.29 PAINTING AND FINISHING

Clean, prime and paintthe engine-generator set in accordance with the manufacturer's standard color and practice.

2.30 FACTORY INSPECTION AND TESTS

Submit [six] [_____] complete reproducible copies of the factory inspection result on the checklist format specified below. Perform the factory tests on each engine-generator set. The component manufacturer's production line test is acceptable as noted. Run each engine-generator set for at least 1 hour at rated output capacity prior to inspections. Complete inspections and make all necessary repairs prior to testing. Use engine generator controls and protective devices that are provided by the generator set manufacturer as part of the standard package for factory tests. When controls and switchgear are not provided as part of the generator set manufacturer's standard package, the actual controls and protective devices provided for the project are not required to be used during the factory test. The Contracting Officer may provide one or more representatives to witness inspections and tests.

2.30.1 Factory Inspection

****
NOTE: Delete inapplicable inspection items.
****

Perform inspections prior to beginning and after completion of testing of the assembled engine-generator set. Look for leaks, looseness, defects in components, proper assembly, etc. and note any item found to be in need of correction as a necessary repair. Use the following checklist for the inspection:

INSPECTION ITEM	GOOD	BAD	NOTES
Drive belts			
Governor and adjustments			
Engine timing mark			
Starting motor			
Starting aids			
Coolant type and concentration			
Radiator drains			

INSPECTION ITEM	GOOD	BAD	NOTES
Block coolant drains			
Coolant fill level			
All coolant line connections			
All coolant hoses			
Combustion air filter			
Combustion air silencer			
Lube oil type			
Lube oil sump drain			
Lube-oil filter			
Lube-oil-level indicator			
Lube-oil-fill level			
All lube-oil line connections			
All lube-oil lines			
Fuel type and amount			
All fuel-line connections			
All fuel lines			
Fuel filter			
Coupling and shaft alignment			
Voltage regulators			
Battery-charger connections			
All wiring connections			
Instrumentation			
Hazards to personnel			
Base			
Nameplates			
Paint			

INSPECTION ITEM	GOOD	BAD	NOTES
Exhaust-heat recovery unit			
Switchboard			
Switchgear			

2.30.2 Factory Tests

****

NOTE: For dual fuel units, choose the fuel type to be used for the factory test. Decision should be based on providing satisfactory operation with the fuel which has the lowest heat value or on the fuel which presents the factors critical to satisfactory operation.

Delete Voltage Waveform tests for general purpose and commercial application categories.

Delete the Frequency and Voltage Stability and Transient Response Test for general-purpose and commercial-type applications. Perform this test either as a factory test or a field test (delete it from either the factory or field testing). This is not a standard manufacturer's test and requires most manufacturers to procure additional equipment (large reactive load banks) to test engine-generators over 1000 kW. Perform as a field test where required to ensure system operability using project loads. Revise the test steps to delete steps where the Maximum Step Increase is larger than final load to be placed on the engine-generator.

Voltage Unbalance with Unbalanced Load Test is not a standard manufacturer's test. Delete the test for applications where only balanced three phase loads are served.

Delete parallel operation where not required.

****

Submit a letter giving notice of the proposed dates of factory inspections and tests at least 14 days prior to beginning tests, including:

a. A detailed description of the manufacturer's procedures for factory tests at least [14] [_____] days prior to beginning tests.

b. [Six] [_____] copies of the Factory Test data described below in 216 by 279 mm 8-1/2 by 11 inch binders having a minimum of 3 rings from which material may readily be removed and replaced, including a separate section for each test. Separate sections by heavy plastic dividers with tabs. Provide full size (216 by 279 mm 8-1/2 by 11 inch minimum) data plots showing grid lines, with full resolution.

    (1) A detailed description of the procedures for factory tests.

(2) A list of equipment used, with calibration certifications.

(3) A copy of measurements taken, with required plots and graphs.

(4) The date of testing.

(5) A list of the parameters verified.

(6) The condition specified for the parameter.

(7) The test results, signed and dated.

(8) A description of adjustments made.

On engine-generator set tests where the engine and generator are required to be connected and operated together, the load power factor must be [the power factor specified in the engine generator set parameter schedule] [[_____] power factor]. For engine-generator set with dual-fuel operating capability, perform the following tests using [the primary fuel type] [[_____] type fuel]. Perform electrical measurements in accordance with IEEE 120. Temperature limits in the rating of electrical equipment and for the evaluation of electrical insulation must be in accordance with IEEE 1. In the following tests where measurements are to be recorded after stabilization of an engine-generator set parameter (voltage, frequency, current, temperature, etc.), stabilization is considered to have occurred when measurements are maintained within the specified bandwidths or tolerances, for a minimum of four consecutive readings. Tests specifically for the generator may be performed utilizing any prime mover.

a. Insulation Resistance for Stator and Exciter Test, IEEE 115 and IEEE 43, to the performance criteria in NEMA MG 1, Part 22. Generator manufacturer's production line test is acceptable.

b. High Potential Test, in accordance with IEEE 115 and NEMA MG 1, test voltage in accordance with NEMA MG 1. Generator manufacturer's production line test is acceptable.

c. Winding Resistance Test, Stator and Exciter, in accordance with IEEE 115. Generator manufacturer's production line test is acceptable.

d. Phase Balance Voltage Test, to the performance criteria specified in paragraph GENERATOR. This test can be performed with any prime mover. Generator manufacturer's production line test results are acceptable.

    (1) Start and operate the generator at no load.

    (2) Adjust a regulated phase voltage (line-to-neutral) to rated voltage.

    (3) Read and record the generator frequency, line-to-neutral voltages, and the line-to-line voltages.

    (4) Apply 75 percent rated load and record the generator frequency, line-to-neutral voltages, and the line-to-line voltages.

    (5) Apply rated load and record the generator frequency, line-to-neutral voltages, and the line-to-line voltages.

(6) Calculate average line-neutral voltage and percent deviation of individual line-neutral voltages from average for each load condition.

e. Current Balance on Stator Winding Test, by measuring the current on each phase of the winding with the generator operating at 100 percent of Rated Output Capacity, with the load impedance equal for each of the three phases: to the performance criteria specified in paragraph GENERATOR.

f. Voltage Waveform Deviation and Distortion Test in accordance with IEEE 115 to the performance criteria specified in paragraph GENERATOR. Use high-speed recording instruments capable of recording voltage waveform deviation and all distortion, including harmonic distortion. Include appropriate scales to provide a means to measure and interpret results.

g. Voltage and Frequency Droop Test. Verify that the output voltage and frequency are within the specified parameters as follows:

(1) With the generator operating at no load, adjust voltage and frequency to rated voltage and frequency. Record the generator output frequency and line-line and line-neutral voltages.

(2) Increase load to Rated Output Capacity. Record the generator output frequency and line-line and line-neutral voltages.

(3) Calculate the percent droop for voltage and frequency with the following equations:

$$\text{Voltage droop percent} = \frac{\text{(No-Load Volts) - (Rated Capacity Volts)}}{\text{(Service-Load Volts)}} \times 100$$

$$\text{Frequency droop percent} = \frac{\text{(No-Load Hertz) - (Rated Capacity Hertz)}}{\text{(Service-Load Hertz)}} \times 100$$

(4) Repeat steps 1 through 3 two additional times without making any adjustments.

h. Frequency and Voltage Stability and Transient Response. Verify that the engine-generator set responds to addition and dropping of blocks of load in accordance with the transient response requirements. Document maximum voltage and frequency variation from bandwidth and verify that voltage and frequency return to and stabilize within the specified bandwidth, within the specified response time period. Document results in tabular form and with high resolution, high speed strip chart recorders or comparable digital recorders, as approved by the Contracting Officer. Include the following tabular data:

(1) Ambient temperature (at 15 minute intervals).

(2) Generator output current (before and after load changes).

(3) Generator output voltage (before and after load changes).

(4) Frequency (before and after load changes).

(5) Generator output power (before and after load changes).

(6) Graphic representations must include the actual instrument trace of voltage and frequency showing: charts marked at start of test; observed steady-state band; mean of observed band; momentary overshoot and undershoot (generator terminal voltage and frequency) and recovery time for each load change together with the voltage and frequency maximum and minimum trace excursions for each steady state load condition prior to and immediately following each load change. Generator terminal voltage and frequency transient recovery time for each step load increase and decrease.

(a) Perform and record engine manufacturer's recommended pre-starting checks and inspections.

(b) Start the engine, make and record engine manufacturer's after-starting checks and inspections during a reasonable warm-up period and no load. Verify stabilization of voltage and frequency within specified bandwidths.

(c) With the unit at no load, apply the Maximum Step Load Increase.

****

NOTE: For applications where the Maximum Step Load Increase is 100 percent, delete steps 4., 5., and 6.

****

(d) Apply load in steps equal to the Maximum Step Load Increase until the addition of one more step increase will exceed the Service Load.

(e) Decrease load to the unit such that addition of the Maximum Step Load Increase will load the unit to 100 percent of Service Load.

(f) Apply the Maximum Step Load Increase.

(g) Decrease load to zero percent in steps equal to the Maximum Step Load Decrease.

(h) Repeat steps (c) through (g).

j. Test Voltage Unbalance with Unbalanced Load (Line-to-Neutral) to the performance criteria specified in paragraph GENERATOR. Prototype test data is acceptable in lieu of the actual test. Submit manufacturer's standard certification that prototype tests were performed for the generator model proposed. This test may be performed using any prime mover.

(1) Start and operate the generator set at rate voltage, no load, rated frequency, and under control of the voltage regulator. Read and record the generator frequency, line-to-neutral voltages, and the line-to-line voltages.

(2) Apply the specified load between terminals L_1-L_2, L_2-L_0, and L_3-L_0

in turn. Record all instrument readings at each line-neutral condition.

(3) Express the greatest difference between any two of the line-to-line voltages and any two of the line-to-neutral voltages as a percent of rated voltage.

(4) Compare the largest differences expressed in percent with the maximum allowable difference specified.

PART 3 EXECUTION

****

NOTE: Provide an equipment layout on the plans, which provides the clear space for operation and maintenance in accordance with NFPA 70 and IEEE C2. Include requirements for a staging/laydown area for disassembly or removal and replacement of major parts of the engine-generator. Additionally, it is advisable to provide access to remove the unit and/or major parts of equipment from the room and building either through doors/passageways or equipment hatches.

****

3.1 EXAMINATION

After becoming familiar with all details of the job, perform a Site Visit to verify the information shown on the drawings, before performing any work. Submit a letter stating the date the site was visited and listing discrepancies found. Notify the Contracting Officer in writing of any discrepancies.

3.2 GENERAL INSTALLATION

Provide clear space for operation and maintenance in accordance with NFPA 70 and IEEE C2. Submit a copy of the manufacturer's installation procedures and a detailed description of the manufacturer's recommended break-in procedure. Install pipe, duct, conduit, and ancillary equipment to facilitate easy removal and replacement of major components and parts of the engine-generator set.

3.3 PIPING INSTALLATION

Weld piping. Provide flanged valve connections. Provide flanged connections at equipment. Provide threaded connections to the engine if the manufacturers standard connection is threaded. Except where otherwise specified, use welded flanged fittings to allow for complete dismantling and removal of each piping system from the facility without disconnecting or removing any portion of any other system's equipment or piping. Make connections to equipment with vibration isolation-type flexible connectors. Support and align piping and tubing to prevent stressing of flexible hoses and connectors. Flash pipes extending through the roof. Install piping clear of windows, doors and openings, to permit thermal expansion and contraction without damage to joints or hangers, and install a 13 mm 1/2 inch drain valve with cap at each low point.

The installation of gas engines must conform to the requirements of NFPA 37 and its references therein, including NFPA 54, NFPA 58, and ASME B31.3.

3.3.1 Support

Provide hangers, inserts, and supports to accommodate any insulation and conforming to MSS SP-58. Space supports no more than 2.1 m 7 feet on center for pipes 50 mm 2 inches in diameter or less, no more than 3.6 m 12 feet on center for pipes larger than 50 mm 2 inches but smaller than 100 mm 4 inches in diameter, and not more than 5.2 m 17 feet on center for pipes larger than 100 mm 4 inches in diameter. Provide supports at pipe bends or change of direction.

3.3.1.1 Ceiling and Roof

Support exhaust piping with appropriately sized Type 41 single pipe roll and threaded rods; support all other piping with appropriately sized Type 1 clevis and threaded rods.

3.3.1.2 Wall

Make wall supports for pipe by suspending the pipe from appropriately sized Type 33 brackets with the appropriate ceiling and roof pipe supports.

3.3.2 Flanged Joints

Provide flanges that are Class 125 type, drilled, and of the proper size and configuration to match the equipment and engine connections. Provide gasketed flanged joints that are square and tight.

3.3.3 Cleaning

After fabrication and before assembly, piping interiors must be manually wiped clean of debris.

3.3.4 Pipe Sleeves

Fit pipes passing through construction such as ceilings, floors, or walls with sleeves. Extend each sleeve through and fasten in its respective structure and cut flush with each surface. Build the structure tightly to the sleeve. The inside diameter of each sleeve must be minimum 13 mm 1/2 inch, and where pipes pass through combustible materials 25 mm 1 inch larger than the outside diameter of the passing pipe or pipe insulation/covering.

3.4 ELECTRICAL INSTALLATION

Perform electrical installation in compliance with NFPA 70, IEEE C2, and Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. For vibration isolation, provide flexible fittings for conduit, cable trays, and raceways attached to engine-generator sets; provide flexible stranded conductor for metallic conductor cables installed on the engine generator set and from the engine generator set to equipment not mounted on the engine generator set; and provide crimp-type terminals or lugs for terminations of conductors on the engine generator set.

3.5 FIELD PAINTING

****

NOTE: For Air Force work, add that the exterior of all equipment must be finished in the base standard

color.
****

Perform field painting as specified in Section 09 90 00 PAINTS AND COATINGS.

3.6 ONSITE INSPECTION AND TESTS

****
NOTE: Include the bracketed option below for projects located outside the continental United States (OCONUS).
****

Perform and report on factory tests and inspections prior to shipment. Provide certified copies of manufacturer's test data and results. Test procedures must conform to ASME, IEEE, [IEC,] and ANSI standards, and to ISO requirements on testing, as appropriate and applicable. The manufacturer performing the tests must provide equipment, labor, and consumables necessary for tests and measuring and indicating devices must be certified to be within calibration. Tests must indicate satisfactory operation and attainment of specified performance. If satisfactory, equipment tested will be given a tentative approval. Equipment must not be shipped before approval of the factory test reports for the following tests.

Submit a letter giving notice of the proposed dates of onsite inspections and tests at least [14] [_____] days prior to beginning tests.

a. Submit a detailed description of the Contractor's procedures for onsite tests including the test plan and a listing of equipment necessary to perform the tests at least [_____] days prior to beginning tests.

b. Submit [six] [_____] copies of the onsite test data described below in 216 by 279 mm 8-1/2 by 11 inch binders having a minimum of 3 rings from which material may readily be removed and replaced, including a separate section for each test. Separate sections by heavy plastic dividers with tabs. Provide full size (216 by 279 mm 8-1/2 by 11 inch minimum) data plots showing grid lines, with full resolution.

   (1) A detailed description of the procedures for onsite tests.

   (2) A list of equipment used, with calibration certifications.

   (3) A copy of measurements taken, with required plots and graphs.

   (4) The date of testing.

   (5) A list of the parameters verified.

   (6) The condition specified for the parameter.

   (7) The test results, signed and dated.

   (8) A description of adjustments made.

3.6.1 Test Conditions

3.6.1.1 Data

Make and record measurements of all parameters necessary to verify that each set meets specified parameters. If the results of any test step are not satisfactory, make adjustments, replacements, or repairs and repeat the step until satisfactory results are obtained. Unless otherwise indicated, record data in 15 minute intervals during engine-generator set operation and include: readings of all engine-generator set meters and gauges for electrical and power parameters; oil pressure; ambient temperature; and engine temperatures available from meters and gauges supplied as permanent equipment on the engine-generator set. Perform electrical measurements in accordance with IEEE 120. Definitions of terms are in accordance with IEEE 100. Provide temperature limits in the rating of electrical equipment and for the evaluation of electrical insulations in accordance with IEEE 1.

3.6.1.2 Power Factor

Submit the generator capability curve showing generator kVA output capability (kW vs. kvar) for both leading and lagging power factors ranging from 0 to 1.0. For all engine-generator set operating tests the load power factor must be [the power factor specified in the engine-generator set parameter schedule] [[_____] power factor].

3.6.1.3 Contractor Supplied Items

Provide equipment and supplies required for inspections and tests including fuel, test instruments, and loadbanks at the specified power factors.

3.6.1.4 Instruments

Verify readings of panel gauges, meters, displays, and instruments provided as permanent equipment during test runs, using test instruments of greater precision and accuracy. Test instrument accuracy must be within the following: current plus or minus 1.5 percent, voltage plus or minus 1.5 percent, real power plus or minus 1.5 percent, reactive power plus or minus 1.5 percent, power factor plus or minus 3 percent, frequency plus or minus 0.5 percent. Calibrate test instruments by a recognized standards laboratory within 30 days prior to testing.

3.6.1.5 Sequence

Provide the sequence of testing as specified in the approved testing plan unless variance is authorized by the Contracting Officer. Perform field testing in the presence of the Contracting Officer. Schedule and sequence tests in order to optimize run-time periods; however, follow the general order of testing: Construction Tests; Inspections; Pre-operational Tests; Safety Run Tests; Performance Tests; and Final Inspection.

3.6.2 Construction Tests

****

NOTE: Coordinate the construction test requirements with the other specification sections to eliminate redundant tests and provide additional reference to necessary tests.

****

Perform individual component and equipment functional tests for fuel piping, coolant piping, and lubricating-oil piping, electrical circuit continuity, insulation resistance, circuit protective devices, and equipment not provided by the engine-generator set manufacturer prior to connection to the engine-generator set.

3.6.2.1 Piping Test

a. Flush lube-oil and fuel-oil piping with the same type of fluid intended to flow through the piping, until the outflowing fluid has no obvious sediment or emulsion.

b. Test fuel piping which is external to the engine-generator set in accordance with NFPA 30. Pressure all remaining piping which is external to the engine-generator set with air pressure at 150 percent of the maximum anticipated working pressure, but not less than 1.03 MPa 150 psi, for a period of 2 hours to prove the piping has no leaks. If piping is to be insulated, perform the test before the insulation is applied.

3.6.2.2 Electrical Equipment Tests

****
NOTE: Delete ground resistance tests where covered by other project specifications, or where no grounds are installed.
****

a. Perform low-voltage cable insulation integrity tests for cables connecting the generator breaker to the [automatic transfer switch] [panelboard] [main disconnect switch] [distribution bus] [_____]. Test low-voltage cable, complete with splices, for insulation resistance after the cables are installed, in their final configuration, ready for connection to the equipment, and prior to energization. Apply a test voltage of 500 volts dc for one minute between each conductor and ground and between all possible combinations conductors in the same trench, duct, or cable, with all other conductors in the same trench, duct, or conduit. Provide the minimum value of insulation as follows:

(1) R in meg-ohms = (rated voltage in kV plus 1) x 304.8/(length of cable in meters)

(2) R in meg-ohms = (rated voltage in kV plus 1) x 1000/(length of cable in feet)

(3) Each cable failing this test must be repaired or replaced. The repair cable must be retested until failures have been eliminated.

b. Perform medium-voltage cable insulation integrity tests for cables connecting the generator breaker to the [generator switchgear] [main disconnect switch] [distribution bus]. After installation and before the operating test or connection to an existing system, perform a high potential test on the medium-voltage cable system. Apply direct-current voltage on each phase conductor of the system by connecting conductors as one terminal and connecting grounds of metallic shields or sheaths of the cable as the other terminal for each test. Prior to making the test, isolate the cables by opening applicable protective devices and disconnecting equipment. Conduct the test with all splices, connectors, and terminations in place. Provide the method, voltage, length of time, and other characteristics of the test for initial installation in accordance with [NEMA WC 74/ICEA S-93-639] [_____] for the particular type of cable installed, except provide 28kV and 35kV insulation test voltages in accordance with either AEIC CS8 or AEIC CS8 as applicable, and do not exceed the recommendations of IEEE 404 for cable joints and IEEE 48 for cable terminations unless the cable and accessory manufacturers indicate higher voltages are acceptable for testing. Should any cable fail due to a weakness of conductor insulation or due to defects or injuries incidental to the installation or because of improper installation of cable, cable joints, terminations, or other connections, make necessary repairs or replace cables as directed. Retest repaired or replaced cables.

c. Ground-Resistance Tests. Measure the resistance of [each grounding electrode] [each grounding electrode system] [the ground mat] [the ground ring] using the fall-of-potential method defined in IEEE 81. On systems consisting of interconnected ground rods, perform tests after interconnections are complete. Take measurements in normally dry weather, not less than 48 hours after rainfall. Provide site diagram indicating location of test probes with associated distances, and provide a plot of resistance vs. distance. The combined resistance of separate systems may be used to meet the requirements resistance, but the specified number of electrodes must still be provided as follows:

(1) Single rod electrode - [25] [_____] ohms.

(2) Multiple rod electrodes - [_____] ohms.

(3) Ground mat - [_____] ohms.

d. Examine and test circuit breakers and switchgear in accordance with the manufacturer's published instructions for functional testing.

3.6.3 Inspections

Perform the following inspections jointly by the Contracting Officer and the Contractor, after complete installation of each engine-generator set and its associated equipment, and prior to startup of the engine-generator set. Submit a letter certifying that all facilities are complete and functional; that each system is fully functional; and that each item of equipment is complete, free from damage, adjusted, and ready for beneficial use. Perform checks applicable to the installation. Document and submit the results of those which are physical inspections (I) in accordance with paragraph SUBMITTALS. Present manufacturer's data for the inspections designated (D) at the time of inspection. Verify that equipment type, features, accessibility, installation and condition are in accordance with the contract specification. Provide manufacturer's statements to certify provision of features which cannot be verified visually.

Drive belts	I

Governor type and features	I
Engine timing mark	I
Starting motor	I
Starting aids	I
Coolant type and concentration	D
Radiator drains	I
Block coolant drains	I
Coolant fill level	I
Coolant line connections	I
Coolant hoses	I
Combustion air filter	I
Intake air silencer	I
Lube oil type	D
Lube oil sump drain	I
Lube-oil filter	I
Lube-oil level indicator	I
Lube-oil fill level	I
Lube-oil line connections	I
Lube-oil lines	I
Fuel type	D
Fuel level	I
Fuel-line connections	I
Fuel lines	I
Fuel filter	I
Access for maintenance	I
Voltage regulator	I
Battery-charger connections	I

Wiring and terminations	I
Instrumentation	I
Hazards to personnel	I
Base	I
Nameplates	I
Paint	I
Exhaust-heat system	I
Exhaust muffler	I
Switchboard	I
Switchgear	I
Access provided to controls	I
Enclosure is weather resistant	I
Engine and generator mounting bolts (application)	I

3.6.4 Engine Tests

Perform customary commercial factory tests in accordance with ISO 3046 on each engine and associated engine protective device, including, but not limited to the following:

a. Perform dynamometer test at rated power. Record horsepower at rated speed and nominal characteristics such as lubricating oil pressure, jacket water temperature, and ambient temperature.

b. Test and record the values that the low oil pressure alarm and protective shutdown devices actuate prior to assembly on the engine.

c. Test and record values that the high jacket water temperature alarm and protective shutdown devices actuate prior to assembly on the engine.

3.6.5 Generator Tests

****
NOTE: Include the bracketed option below for projects located outside the continental United States (OCONUS).
****

Tests must be performed on the complete factory assembled generator prior to shipment. Conduct tests in accordance with IEEE 115[, IEC 60034-2A], and NEMA MG 1.

3.6.5.1 Routine Tests

Perform the following routine tests on the generators and their exciters:

a. Resistance of armature and field windings.

b. Mechanical balance.

c. Phases sequence.

d. Open circuit saturation curve and phase (voltage) balance test.

e. Insulation resistance of armature and field windings.

f. High potential tes.t

3.6.5.2 Design Tests

Submit the following design tests made on prototype machines that are physically and electrically identical to the generators specified.

a. Temperature rise test

b. Short circuit saturation curve and current balance test

3.6.6 Assembled Engine-Generator Set Tests

****
NOTE: Select the first option for engine-generator sets rated up to 250 kW. Select the second option for engine-generator sets rated greater than 250 kW.
****

[Submit the following tests made on prototype machines that are physically and electrically identical to the engine-generator set specified.][Perform the following tests on the assembled engine-generator set.]

3.6.6.1 Initial Stabilization Readings

Operate the engine-generator set and allow the set to stabilize at rated kW at rated power factor, rated voltage, and rated frequency. During this period record instrument readings for output power (kW), terminal voltage, line current, power factor, frequency (rpm) generator (exciter) field voltage and current, lubricating oil pressure, jacket water temperature, and ambient temperature at minimum intervals of 15 minutes. Adjust the load, voltage, and frequency to maintain rated load at rated voltage and frequency. Adjustments to load, voltage, or frequency controls must be recorded on the data sheet at the time of adjustment. Stabilization must be considered to have occurred when four consecutive voltage and current recorded readings of the generator (or exciter) field either remain unchanged or have only minor variations about an equilibrium condition with no evident continued increase or decrease in value after the last adjustment to the load, voltage, or frequency has been made.

3.6.6.2 Regulator Range Test

Remove load and record instrument readings (after transients have subsided). Adjust voltage to the maximum attainable value or to a value just prior to actuation of the overvoltage protection device. Apply rated load and adjust voltage to the minimum attainable value or a value just prior to activation of the under-voltage protection device. The data sheets must indicate the voltage regulation as a percent of rated voltage and the maximum and minimum voltages attainable. Voltage regulation must be defined as follows:

$$\text{Percent Regulation} = \frac{((\text{No-Load Voltage}) - (\text{Rated-Load Voltage})) \times 100}{(\text{Rated-Load Voltage})}$$

3.6.6.3 Frequency Range Test

Adjust the engine-generator set frequency for the maximum attainable frequency at rated load. Record instrument readings. Adjust the engine-generator set frequency for the specified minimum attainable frequency at rated load. Record instrument readings. Reduce the load to zero and adjust the engine-generator set frequency for the maximum attainable frequency. Record instrument readings. Adjust the engine-generator set frequency for the minimum attainable frequency. Record instrument readings. The data sheet must show the maximum and minimum frequencies attained at rated load, and at no load.

3.6.6.4 Transient Response Test

Drop the load to no load and re-apply rated load three times to ensure that the no load and rated load voltage and frequency values are repeatable and that the frequency and voltage regulation is within the limits specified. Record generator terminal voltage and frequency using a high speed strip chart recorder. The data sheet must show the following results:

a. Frequency

(1) Stability bandwidth or deviation in percent of rated frequency.

(2) Recovery time.

(3) Overshoot and undershoot.

b. Voltage

(1) Stability bandwidth or deviation in percent of rated voltage.

(2) Recovery time.

(3) Overshoot and undershoot.

3.6.7 Pre-operational Tests

****

NOTE: Specify the protective devices to be tested. Devices which shut down the engine because of an abnormal electrical or generator condition should be detailed under Safety Run Tests. Delete current transformer tests when none are to be installed.

****

3.6.7.1 Protective Relays

****
NOTE: Delete the protective devices coordination study reference if the project does not require one. See UFC 3-520-01 and Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM, Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION, and Section 26 28 01.00 10 COORDINATED POWER SYSTEM PROTECTION, for guidance.
****

Visually and mechanically inspect, adjust, test, and calibrate protective relays in accordance with the manufacturer's published instructions. Include pick-up, timing, contact action, restraint, and other aspects necessary to ensure proper calibration and operation. Implement relay settings in accordance with the installation coordination study. Manually or electrically operate relay contacts to verify that the proper breakers and alarms initiate. Field test relaying current transformers in accordance with IEEE C57.13.1.

3.6.7.2 Insulation Test

Test generator and exciter circuits insulation resistance in accordance with IEEE 43. Take stator readings including generator leads to [switchgear] [switchboard] at the circuit breaker. Record results of insulation resistance tests. Readings must be within limits specified by the manufacturer. Verify mechanical operation, insulation resistance, protective relay calibration and operation, and wiring continuity of [switchgear] [switchboard] assembly. Do not damage generator components during test.

3.6.7.3 Engine-Generator Connection Coupling Test

When the generator provided is a two-bearing machine, inspect and check the engine-generator connection coupling by dial indicator to prove that no misalignment has occurred. Use the dial indicator to measure variation in radial positioning and axial clearance between the coupling halves. Take readings at four points, spaced 90 degrees apart. Align solid couplings and pin-type flexible couplings within a total indicator reading of 0.012 to 0.025 mm 0.0005 to 0.001 inch for both parallel and angular misalignment. For gear-type or grid-type couplings, 0.05 mm 0.002 inch will be acceptable.

3.6.8 Safety Run Test

****
NOTE: For the sound level tests, modify the radial distance requirement from the engine intake and exhaust to account for obstructions, variations in site conditions, building configurations, or indicate points on the contract drawings at which measurements are to be made. Add item x. to the list below when a test for over/under frequency alarms are provided. Coordinate the requirement with paragraph Alarm Panels. Item x. should be included as follows:

x. Manually adjust the governor to speed up the engine to a level beyond the over frequency alarm

set-point and record the frequency when the audible alarm sounds. Return the speed to the rated value. Shut down the engine-generator set.

****

For the following tests, repeat the associated safety tests if any parts are changed, or adjustments made to the generator set, its controls, or auxiliaries.

a. Perform and record engine manufacturer's recommended prestarting checks and inspections.

b. Start the engine, record the starting time, make and record engine manufacturer's after-starting checks and inspections during a reasonable warm-up period.

c. Activate the manual emergency stop switch and verify that the engine stops.

d. Remove the high and pre-high lubricating oil temperature sensing elements from the engine and temporarily install a temperature gauge in their normal locations on the engine (required for safety, not for recorded data). Where necessary provide temporary wiring harness to connect the sensing elements to their permanent electrical leads.

e. Start the engine, record the starting time, make and record engine manufacturer's after-starting checks and inspections during a reasonable warm-up period. Operate the engine-generator set at no load until the output voltage and frequency stabilize. Monitor the temporarily installed temperature gauges. If either temperature reading exceeds the value required for an alarm condition, activate the manual emergency stop switch.

f. Immerse the elements in a vessel containing controlled-temperature hot oil and record the temperature at which the pre-high alarm activates and the temperature at which the engine shuts down. Remove the temporary temperature gauges and reinstall the temperature sensors on the engine.

g. Remove the high and pre-high coolant temperature sensing elements from the engine and temporarily install a temperature gauge in their normal locations on the engine (required for safety, not for recorded data). Where necessary provide temporary wiring harness to connect the sensing elements to their permanent electrical leads.

h. Start the engine, record the starting time, make and record engine manufacturer's after-starting checks and inspections during a reasonable warm-up period. Operate the engine generator-set at no load until the output voltage and frequency stabilize.

i. Immerse the elements in a vessel containing controlled-temperature hot oil and record the temperature at which the pre-high alarm activates and the temperature at which the engine shuts down. Remove the temporary temperature gauges and reinstall the temperature sensors on the engine.

j. Start the engine, record the starting time, make and record engine manufacturer's after-starting checks and inspections during a reasonable warm-up period.

k. Operate the engine generator-set for at least 2 hours at 75 percent of Service Load.

l. Verify proper operation and set-points of gauges and instruments.

m. Verify proper operation of ancillary equipment.

n. Manually adjust the governor to increase engine speed past the over-speed limit. Record the RPM at which the engine shuts down.

o. Start the engine, record the starting time, make and record engine manufacturer's after-starting checks and inspections and operate the engine generator-set for at least 15 minutes at 75 percent of Service Load.

p. Manually adjust the governor to increase engine speed to within 2 percent of the over-speed trip speed previously determined and operate at that point for 5 minutes. Manually adjust the governor to the rated frequency.

q. Manually fill the day tank to a level above the overfill limit. Record the level at which the overfill alarm sounds. Verify shutdown of the fuel transfer pump. Drain the day tank down below the overfill limit.

r. Shut down the engine. Remove the time-delay low lube oil pressure alarm bypass and try to start the engine.

s. Attach a manifold to the engine oil system (at the oil pressure sensor port) that contains a shutoff valve in series with a connection for the engine's oil pressure sensor followed by an oil pressure gauge ending with a bleed valve. Move the engine's oil pressure sensor from the engine to the manifold. Open the manifold shutoff valve and close the bleed valve.

t. Start the engine, record the starting time, make and record engine manufacturer's after-starting checks and inspections and operate the engine generator-set for at least 15 minutes at 75 percent of Service Load.

u. Close the manifold shutoff valve. Slowly allow the pressure in the manifold to bleed off through the bleed valve while watching the pressure gauge. Record the pressure at which the engine shuts down. Catch oil spillage from the bleed valve in a container. Add the oil from the container back to the engine, remove the manifold, and reinstall the engine's oil pressure sensor on the engine.

v. Start the engine, record the starting time, make and record engine manufacturer's after-starting checks and inspections and operate the engine generator-set for at least 15 minutes at 100 percent of Service Load. Record the maximum sound level in each frequency band at a distance of [22.9] [_____] m [75] [_____] feet from the end of the exhaust and air intake piping directly along the path of intake and discharge for horizontal piping; or at a radius of [22.9] [10.7] [_____] m [75] [35] [_____] feet from the engine at 45 degrees apart in all directions for vertical piping. [If a sound limiting enclosure is provided, modify or replace the enclosure, the muffler, and intake silencer must be modified or replaced as required to meet the sound requirements contained within this specification] [If a sound limiting enclosure is not provided, the muffler and air intake silencer as required to meet the sound limitations of this specification. If the sound limitations can not be obtained by modifying or replacing the muffler and air intake silencer, notify the Contracting Officers Representative and provide a recommendation for meeting the sound limitations.]

w. Manually drain off fuel slowly from the day tank to empty it to below the low fuel level limit and record the level at which the audible alarm sounds. Add fuel back to the day tank to fill it above low level alarm limits.

3.6.9 Performance Tests

****

NOTE: The onsite tests have been developed from MIL-STD 705 methods with input from many sources including industry. Each designer must verify the adequacy of the tests that are needed for each application. Modifications to these specifications may be necessary beyond the removal of brackets.

Delete the Frequency and Voltage, Stability and Transient Response Test and the Voltage Regulator and Governor Range Test for general-purpose and commercial-type applications. Perform this test either as a factory test or a field test (delete it from either the factory or field tests). Perform as a field test where required to ensure system operability using project loads. Revise the test steps to delete steps where the Maximum Step Increase is larger than final load to be placed on the engine-generator.

If possible, specify an ambient temperature for the load run test which is typical for the average maximum temperature. This is most strenuous operating condition. Specify a month which typically provides the most restrictive operating condition.

Delete all 110 percent load references from testing requirements for standby applications.

****

In the following tests, where measurements are to be recorded after stabilization of an engine-generator set parameter (voltage, frequency, current, temperature, etc.), stabilization is considered to have occurred when measurements are maintained within the specified bandwidths or tolerances, for a minimum of four consecutive readings. For the following tests, repeat the associated tests if any parts are changed, or adjustments made to the generator set, its controls, or auxiliaries.

3.6.9.1 Continuous Engine Load Run Test

Test the engine-generator set and ancillary systems at service load to demonstrate durability; verify that heat of extended operation does not adversely affect or cause failure in any part of the system; and check all parts of the system. If the engine load run test is interrupted for any reason, repeat the entire test. Accomplish the engine load run test during daylight hours, with an average ambient temperature of [_____] degrees C F, during the month of [_____]. After each change in load in the following test, measure the vibration at the end bearings (front and back of engine, outboard end of generator) in the horizontal, vertical, and axial directions. Verify that the vibration is within the allowable range. Take data taken at 15 minute intervals and include the following:

Electrical: Output amperes, voltage, real and reactive power, power factor, frequency.

Pressure: Lube-oil.

Temperature: Coolant, Lube-oil, Exhaust, Ambient.

a. Perform and record engine manufacturer's recommended prestarting checks and inspections. Include as a minimum checking of coolant fluid, fuel, and lube-oil levels.

b. Start the engine, make and record engine manufacturer's after-starting checks and inspections during a reasonable warmup period.

c. Operate the engine generator-set for 2 hours at 75 percent of Service Load.

d. Increase load to 100 percent of Service Load and operate the engine generator-set for 4 hours.

e. For prime rated units, increase load to 110 percent of Service Load and operate the engine generator-set for 2 hours.

f. Decrease load to 100 percent of Service Load and operate the engine generator-set for 2 hours or until all temperatures have stabilized.

g. Remove load from the engine-generator set.

3.6.9.2 Voltage and Frequency Droop Test

For the following steps, verify that the output voltage and frequency return to and stabilize within the specified bandwidth values following each load change. Record the generator output frequency and line-line and line-neutral voltages following each load change.

a. With the generator operating at no load, adjust voltage and frequency to rated voltage and frequency.

b. Increase load to 100 percent of Rated Output Capacity. Record the generator output frequency and line-line and line-neutral voltages.

c. Calculate the percent droop for voltage and frequency with the following equations.

$$\text{Voltage droop percent} = \frac{\text{No-load volts - rated output capacity volts}}{\text{Rated output capacity volts}} \times 100$$

Frequency droop percent = No load hertz - rated output capacity hertz

--- x 100
Rated output capacity volts

d. Repeat steps a. through c. two additional times without making any adjustments.

3.6.9.3 Voltage Regulator Range Test

a. While operating at no load, verify that the voltage regulator adjusts from 90 to 110 percent of rated voltage.

b. Increase load to 100 percent of Rated Output Capacity. Verify that the voltage regulator adjusts from 90 to 110 percent of rated voltage.

3.6.9.4 Governor Adjustment Range Test

a. While operating at no load, verify that the governor adjusts from 90 to 110 percent of rated frequency.

b. Increase load to 100 percent of Rated Output Capacity. Verify that the governor adjusts from 90 to 110 percent of rated frequency.

3.6.9.5 Frequency and Voltage Stability and Transient Response

****
NOTE: For applications where the Maximum Step Load Increase is 100 percent, delete steps d, e, and f.
****

Verify that the engine-generator set responds to addition and dropping of blocks of load in accordance with the transient response requirements. Document maximum voltage and frequency variation from bandwidth and verify that voltage and frequency return to and stabilize within the specified bandwidth, within the specified response time period. Document results in tabular form and with high resolution, high speed strip chart recorders or comparable digital recorders, as approved by the Contracting Officer. Include the following tabular data:

(1) Ambient temperature (at 15 minute intervals).

(2) Generator output current (before and after load changes).

(3) Generator output voltage (before and after load changes).

(4) Frequency (before and after load changes).

(5) Generator output power (before and after load changes.

(6) Include the actual instrument trace of voltage and frequency in graphic representations showing:

Charts marked at start of test; observed steady-state band; mean of observed band; momentary overshoot and undershoot (generator terminal voltage and frequency) and recovery time for each load change together with the voltage and frequency maximum and minimum trace excursions for each steady state load condition prior to and immediately following each load change. Generator terminal voltage and frequency transient recovery time for each step load increase and decrease.

a. Perform and record engine manufacturer's recommended prestarting checks and inspections.

b. Start the engine, make and record engine manufacturer's after-starting checks and inspections during a reasonable warm-up period and no load. Verify stabilization of voltage and frequency within specified bandwidths.

c. With the unit at no load, apply the Maximum Step Load Increase.

d. Apply load in steps equal to the Maximum Step Load Increase until the addition of one more step increase will exceed the Service Load.

e. Decrease load to the unit such that addition of the Maximum Step Load Increase will load the unit to 100 percent of Service Load.

f. Apply the Maximum Step Load Increase.

g. Decrease load to zero percent in steps equal to the Maximum Step Load Decrease.

h. Repeat steps c. through g.

3.6.10 Parallel Operation Test

****
NOTE: Delete the generator paralleling/load sharing test if parallel sets are not intended. This test must be performed at a power factor other than unity to verify proportional reactive power sharing.
****

Test the capability of each engine-generator set to parallel and share load with other generator sets, individually and in all combinations. This test must be performed with the voltage regulator and governor adjustment settings used for the Frequency and Voltage Stability and Transient Response test. If settings are changed during the performance of this test, a voltage and frequency stability and transient response test must be performed for each engine generator set using the setting utilized in this test. During operations record load-sharing characteristics of each set in parallel operation. Include the following data:

(1) Ambient temperature (at 15 minute intervals).

(2) Generator output current (before and after load changes).

(3) Generator output voltage (before and after load changes).

(4) Power division and exchange between generator sets.

(5) Real power (watts) and reactive power (vars) on each set.

3.6.10.1 Combinations

Connect each set, while operating at no load, parallel with one other set in the system, operating at service load, until all possible combinations have been achieved. Verify stabilization of voltage and frequency within specified bandwidths and proportional sharing of real and reactive loads.

Document stabilization of voltage and frequency within specified bandwidth, the active power division, active power exchange, reactive power division, and voltage and frequency stability and transient response in the following steps for each combination.

a. Divide the load proportionally between the sets and operate in parallel for 15 minutes.

b. Increase the load, in steps equal to the Maximum Step Increase, until each set is loaded to its service load.

c. Decrease the load, in steps equal to the Maximum Step Decrease, until each set is loaded to approximately 25 percent of its service load.

d. Increase the load, in steps equal to the Maximum Step Increase, until each set is loaded to approximately 50 percent of its service load Verify stabilization of voltage and frequency within specified bandwidths and proportional sharing of real and reactive load.

e. Reduce the sum of the loads on both sets to the output rating of the smaller set.

f. Transfer a load equal to the output rating of the smaller of the 2 sets to and from each set. Verify stabilization of voltage and frequency within specified bandwidths and proportional sharing of real and reactive load.

g. Document the active power division, active power exchange, reactive power division, and voltage and frequency stability and transient response.

3.6.10.2 Multiple Combinations

Connect each set, while operating at no load, parallel with all multiple combinations of all other set in the system, while operating at service load, until all multiple combinations of parallel operations have been achieved.

3.6.11 Parallel Operation Test (Commercial Source)

****

NOTE: Delete the parallel to commercial source test if sets are not to be paralleled with the commercial power source.

****

Connect each set parallel with the commercial power source. Operate in parallel for 15 minutes. Verify stabilization of voltage and frequency within specified bandwidths. Record the output voltage, frequency, and loading to demonstrate ability to synchronize with the commercial power source.

3.6.12 Automatic Operation Tests

****

NOTE: Delete automatic operation test where not required. Adapt this paragraph based on the number of engine-generator sets, the desired starting order, and load sequencing. The designer will

provide the sequence of operation (load sequences for load acquisition and load shedding) in the design documents.
****

Test the automatic operating system to demonstrate [automatic starting,] [loading and unloading,] [the response to loss of operating engine-generator sets,] and paralleling of each engine-generator set. Utilize [load banks at the indicated power factor] [and actual loads to be served] for this test, and the loading sequence is the indicated sequence. Record load-sharing characteristics during all operations. Perform this test for a minimum of two successive, successful tests. Include the following data:

(1) Ambient temperature (at 15 minute intervals).

(2) Generator output current (before and after load changes).

(3) Generator output voltage (before and after load changes).

(4) Generator output frequency (before and after load changes).

(5) Power division and exchange between generator sets.

(6) Real and reactive power on each set.

a. Initiate loss of the preferred power source and verify the specified sequence of operation.

b. Verify resetting of automatic starting and transfer logic.

3.6.13 Automatic Operation Tests for Stand-Alone Operation

****
NOTE: Substitute manual operation and transfer for automatic operation where automatic operation is not required by the project. Delete automatic loading system where not required. The designer will provide the sequence of operation (load sequences for load acquisition and load shedding) in the design documents.
****

Test the automatic loading system to demonstrate [automatic starting,] [and] [loading and unloading] of each engine-generator set. Utilize the actual loads to be served for this test, and the loading sequence is the indicated sequence. Perform this test for a minimum of two successive, successful tests. Include the following data:

(1) Ambient temperature (at 15 minute intervals).

(2) Generator output current (before and after load changes).

(3) Generator output voltage (before and after load changes).

(4) Generator output frequency (before and after load changes).

a. Initiate loss of the primary power source and verify automatic sequence of operation.

b. Restore the primary power source and verify sequence of operation.

c. Verify resetting of controls to normal.

3.7 GROUNDING

****

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

****

NFPA 70 and IEEE C2, except that grounding systems must have a resistance to solid earth ground not exceeding 5 ohms.

3.7.1 Grounding Electrodes

Provide driven ground rods as specified in [Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION] [and] [Section 33 71 01 OVERHEAD TRANSMISSION AND DISTRIBUTION]. Connect ground conductors to the upper end of ground rods by exothermic weld or compression connector. Provide compression connectors at equipment end of ground conductors.

3.7.2 Engine-Generator Set Grounding

Provide separate copper grounding conductors and connect them to the ground system as indicated. When work in addition to that indicated or specified is required to obtain the specified ground resistance, the provision of the contract covering "Changes" must apply.

3.7.3 Connections

Make joints in grounding conductors by exothermic weld or compression connector. Exothermic welds and compression connectors must be installed as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION paragraph regarding GROUNDING.

3.7.4 Grounding and Bonding Equipment

UL 467, except as indicated or specified otherwise.

3.8 START-UP ENGINEER

Provide the services of a qualified factory trained start-up engineer, regularly employed by the engine-generator set manufacturer. The start-up services must include conducting preliminary operations and functional acceptance tests. The start-up engineer must be present at the engine generator set installation-site, full-time, while preliminary operations and functional acceptance tests are being conducted.

3.9 PREREQUISITES FOR FUNCTIONAL ACCEPTANCE TESTING

Completion of the following requirements is mandatory prior to scheduling functional acceptance tests for the engine-generator set and auxiliary equipment.

3.9.1 Piping Tests

Complete as specified in Section 33 52 10 SERVICE PIPING, FUEL SYSTEMS.

3.9.2 Performance of Acceptance Checks and Tests

The acceptance checks and tests must be accomplished by the testing organization as described in Section 26 08 00 APPARATUS INSPECTION AND TESTING.

3.9.3 Generator Sets

Complete as specified in the paragraph ACCEPTANCE CHECKS AND TESTS.

3.9.3.1 Automatic Transfer Switches

Complete acceptance checks and tests as specified in Section 26 36 23 AUTOMATIC TRANSFER SWITCHES AND BY-PASS/ISOLATION SWITCH.

3.9.4 Preliminary Operations

The start-up engineer must conduct manufacturer recommended start-up procedures and tests to verify that the engine-generator set and auxiliary equipment are ready for functional acceptance tests. Give the Contracting Officer 15 days' advance notice that preliminary operations will be conducted. After preliminary operation has been successfully conducted, the start-up engineer will notify the Contracting Officer in writing stating the engine-generator set and auxiliary equipment are ready for functional acceptance tests.

3.9.5 Preliminary Assembled Operation and Maintenance Manuals

Preliminary assembled operation and maintenance manuals must have been submitted to and approved by the Contracting Officer. Manuals must be prepared as specified in the paragraph ASSEMBLED OPERATION AND MAINTENANCE MANUALS.

3.9.6 Functional Acceptance Test Procedure

Test procedure must be prepared by the start-up engineer specifically for the engine-generator set and auxiliary equipment. The test agenda must cover the requirements specified in the paragraph FUNCTIONAL ACCEPTANCE TESTS. The test procedure must indicate in detail how tests are to be conducted. A statement of the tests that are to be performed without indicating how the tests are to be performed is not acceptable. Indicate what work is planned on each workday and identify the calendar dates of the planned workdays. Specify what additional technical support personnel is needed such as factory representatives for major equipment. Specify on which testing workday each technical support personnel is needed. Data recording forms to be used to document test results are to be submitted with the proposed test procedure. A list of test equipment and instruments must also be included in the test procedure.

3.9.7 Test Equipment

Test equipment and instruments must be on hand prior to scheduling field tests or, subject to Contracting Officer approval, evidence must be provided to show that arrangements have been made to have the necessary equipment and instruments on-site prior to field testing.

3.10 FIELD QUALITY CONTROL

****
NOTE: Include the bracketed option below for NAVFAC projects. Coordinate Echelon III Reach-back Support with NAVFAC LANT CI44 Office or NAVFAC PAC CI44 Office during the design stage of the specific project.
****

Give Contracting Officer [NAVFAC [_____], Code [_____]] 30 days' notice of dates and times scheduled for tests which require the presence of the Contracting Officer. The Contracting Officer will coordinate with the using activity and schedule a time that will eliminate or minimize interruptions and interference with the activity operations. The Contractor must be responsible for costs associated with conducting tests outside of normal working hours and with incorporating special arrangements and procedures, including temporary power conditions. The Contractor must provide labor, equipment, fuel, test load, and consumables required for the specified tests. The test load must be a cataloged product. Calibration of measuring devices and indicating devices must be certified. Refer to Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM, for requirements for a cataloged product. Perform the following field tests.

3.10.1 Acceptance Checks and Tests

Perform in accordance with the manufacturer's recommendations, and include the following visual and mechanical inspections and electrical tests, performed in accordance with NETA ATS.

3.10.1.1 Circuit Breakers - Low Voltage Insulated Case/Molded Case

a. Visual and Mechanical Inspection

(1) Compare nameplate data with specifications and approved shop drawings.

(2) Inspect circuit breaker for correct mounting.

(3) Operate circuit breaker to ensure smooth operation.

(4) Inspect case for cracks or other defects.

(5) Verify tightness of accessible bolted connections and cable connections by calibrated torque-wrench method. Thermo-graphic survey is not required.

(6) Inspect mechanism contacts and arc chutes in unsealed units.

b. Electrical Tests

(1) Perform contact-resistance tests.

(2) Perform insulation-resistance tests.

(3) Adjust breaker(s) for final settings in accordance with

engine-generator set manufacturer's requirements.

3.10.1.2 Current Transformers

a. Visual and Mechanical Inspection

(1) Compare equipment nameplate data with specifications and approved shop drawings.

(2) Inspect physical and mechanical condition.

(3) Verify correct connection.

(4) Verify that adequate clearances exist between primary and secondary circuit.

(5) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method. Thermo-graphic survey is not required.

(6) Verify that all required grounding and shorting connections provide good contact.

b. Electrical Tests

(1) Perform insulation-resistance tests.

(2) Perform polarity tests.

(3) Perform ratio-verification tests.

3.10.1.3 Metering and Instrumentation

a. Visual and Mechanical Inspection

(1) Compare equipment nameplate data with specifications and approved shop drawings.

(2) Inspect physical and mechanical condition.

(3) Verify tightness of electrical connections.

b. Electrical Tests

(1) Determine accuracy of meters at 25, 50, 75, and 100 percent of full scale.

(2) Calibrate watt-hour meters according to manufacturer's published data.

(3) Verify all instrument multipliers.

(4) Electrically confirm that current transformer secondary circuits are intact.

3.10.1.4 Battery Systems

a. Visual and Mechanical Inspection

(1) Compare equipment nameplate data with specifications and approved shop drawings.

(2) Inspect physical and mechanical condition.

(3) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method. Thermo-graphic survey is not required.

(4) Measure electrolyte specific gravity and temperature and visually check fill level.

(5) Verify adequacy of battery support racks, mounting, anchorage, and clearances.

b. Electrical Tests

(1) Set charger float and equalizing voltage levels.

(2) Verify all charger functions and alarms.

(3) Measure each cell voltage and total battery voltage with charger energized and in float mode of operation.

(4) Perform a capacity load test.

3.10.1.5 Engine-Generator Set

a. Visual and Mechanical Inspection

(1) Compare equipment nameplate data with specifications and approved shop drawings.

(2) Inspect physical and mechanical condition.

(3) Inspect for correct anchorage and grounding.

b. Electrical and Mechanical Tests

(1) Perform an insulation-resistance test on generator winding with respect to ground. Calculate polarization index.

(2) Perform phase rotation test to determine compatibility with load requirements.

3.10.1.6 Grounding System

a. Visual and Mechanical Inspection

(1) Inspect ground system for compliance with contract plans and specifications.

b. Electrical Tests

(1) Perform ground-impedance measurements utilizing the fall-of-potential method defined in IEEE 81. On systems consisting of interconnected ground rods, perform tests after interconnections are complete. Take measurements in normally dry weather, not less than 48 hours after rainfall. Provide site

diagram indicating location of test probes with associated distances, and provide a plot of resistance vs. distance.

3.10.2 Functional Acceptance Tests

****

NOTE: Include the bracketed option below for NAVFAC projects.

****

The tests must be performed by the start-up engineer. Upon successful test completion, the start-up engineer must provide the Contracting Officer with a written test report within 15 calendar days showing the tests performed and the results of each test. The report must include the completed approved test data forms and certification from the start-up engineer that the test results fall within the manufacturer's recommended limits and meet the specified requirements performance. The report must be dated and signed by the start-up engineer, and submitted for approval by the Contracting Officer. The Contracting Officer [and NAVFAC [_____], Code [_____]] will witness final acceptance tests. Testing must include, but not be limited to, the following:

a. Verify proper functioning of each engine protective shutdown device and pre-shutdown alarm device. Testing of the devices must be accomplished by simulating device actuation and observing proper alarm and engine shutdown operation.

b. Verify proper functioning of the engine over-speed trip device. Testing of the over-speed trip device must be accomplished by raising the speed of the engine-generator set until an over-speed trip is experienced.

c. Verify proper functioning of the crank cycle/terminate relay. Testing of the relay must be accomplished by engaging the starter motor with the engine being prevented from running. Observe the complete crank/rest cycle as described in the paragraph STARTING SYSTEM.

d. Verify proper functioning of the following automatic and manual operations. Testing must include, but not be limited to, the following:

    (1) Loss of Utility: Initiate a normal power failure with connected test load of rated kW at 1.0 power factor. Record time delay on start, cranking time until engine starts and runs, time to come up to operating speed, voltage and frequency overshoot, and time to achieve steady state conditions with all switches transferred to emergency position.

    (2) Return of Utility: Return normal power and record time delay on retransfer for each automatic transfer switch, and time delay on engine cool-down and shutdown.

    (3) Manual starting.

    (4) Emergency stop.

e. Operate the engine-generator set at rated current (amperes) until the jacket water temperature stabilizes. Stabilization will be considered to have occurred when three consecutive temperature readings remain unchanged. Continue to operate the generator set for an additional 2 hours. Record instrument readings for terminal voltage, line current, frequency (Hz), engine speed rpm, lubricating oil pressure, jacket water temperature, and ambient temperature at 5 minute intervals for first 15 minutes and at 15 minute intervals thereafter.

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NOTE: Include the following paragraph when verification of engine emission limits are required by air pollution permit.

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[f. Emissions Tests. Provide on-site testing by a certified testing organization of each engine-generator set. Testing must be in accordance with an EPA approved method, 40 CFR 60, (Appendix, Method 7, 7A, 7B, 7C, 7D or 7E). Emissions at rated full load must be within the limits specified in the paragraph ENGINE EMISSIONS LIMITS.]

3.11 DEMONSTRATION

Upon completion of the work and at a time approved by the Contracting Officer, the Contractor must provide instructions by a qualified instructor to the Government personnel in the proper operation and maintenance of the equipment. [_____]Government personnel must receive training comparable to the equipment manufacturer's factory training. The duration of instruction must be for not less than one 8 hour working day for instruction of operating personnel and not less than one 8 hour working day for instruction of maintenance personnel.

3.11.1 Instructor's Qualification Resume

Instructors must be regular employees of the engine-generator set manufacturer. The instruction personnel provided to satisfy the requirements above must be factory certified by the related equipment manufacturer to provide instruction services. Submit the name and qualification resume of instructor to the Contracting Officer for approval.

3.11.2 Training Plan

Submit training plan 30 calendar days prior to training sessions. Training plan must include scheduling, content, outline, and training material (handouts). Content must include, but not be limited to, the following:

3.11.2.1 Operating Personnel Training

This instruction includes operating the engine-generator set, auxiliary equipment including automatic transfer switches in all modes, and the use of all functions and features specified.

3.11.2.2 Maintenance Personnel Training

Training must include mechanical, hydraulic, electrical, and electronic instructions for the engine-generator set and auxiliary equipment including automatic transfer switches.

a. Mechanical Training: Must include at least the following:

(1) A review of mechanical diagrams and drawings.

(2) Component location and functions.

(3) Troubleshooting procedures and techniques.

(4) Repair procedures.

(5) Assembly/disassembly procedures.

(6) Adjustments (how, when, and where).

(7) Preventive maintenance procedures.

(8) Review of flow diagram.

(9) Valve locations and function.

(10) Valve and hydraulic equipment adjustment and maintenance procedures.

(11) Hydraulic system maintenance and servicing.

(12) Lubrication points, type, and recommended procedures and frequency.

b. Electrical and Electronic Maintenance Training: Must include at least the following:

(1) A review of electrical and electronic systems including wiring diagrams and drawings.

(2) Troubleshooting procedures for the machine and control systems.

(3) Electrical and electronic equipment servicing and care.

(4) Use of diagnostics to locate the causes of malfunction.

(5) Procedures for adjustments (locating components, adjustments to be made, values to be measured, and equipment required for making adjustments).

(6) Maintenance and troubleshooting procedures for microprocessor or minicomputer where applicable.

(7) Circuit board repair procedures where applicable (with schematics provided).

(8) Use of diagnostic tapes.

(9) Recommended maintenance servicing and repair for motors, switches, relays, solenoids, and other auxiliary equipment and devices.

3.12 ONSITE TRAINING

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NOTE: Delete videotaping if not required.
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Conduct a training course for the operating staff as designated by the Contracting Officer. The training period must consist of a total [_____] hours of normal working time and must start after the system is functionally completed but prior to final acceptance.

a. Submit a letter giving the date proposed for conducting the onsite training course, the agenda of instruction, a description of the digital video recording to be provided. The course instructions must cover pertinent points involved in operating, starting, stopping, servicing the equipment, as well as major elements of the operation and maintenance manuals. Additionally, the course instructions must demonstrate routine maintenance procedures as described in the operation and maintenance manuals.

b. Submit a digital video recording of the [entire training session] [manufacturers operating and maintenance training course].

c. One full size reproducible Mylar ach drawing must accompany the booklets. Mylars must be rolled and placed in a heavy cardboard tube with threaded caps on each end. The manual must include step-by-step procedures for system startup, operation, and shutdown; drawings, diagrams, and single-line schematics to illustrate and define the electrical, mechanical, and hydraulic systems together with their controls, alarms, and safety systems; the manufacturer's name, model number, and a description of equipment in the system. The instructions must include procedures for interface and interaction with related systems to include [automatic transfer switches] [fire alarm/suppression systems] [load shedding systems] [uninterruptible power supplies] [_____]. Each booklet must include a CD containing an ASCII file of the procedures.

d. Provide approved operation and maintenance manuals for the training course. Post approved instructions prior to the beginning date of the training course. Coordinate the training course schedule with the using service's work schedule, and submit for approval 14 days prior to beginning date of proposed beginning date of training.

3.13 INSTALLATION

Installation must conform to the applicable requirements of IEEE C2, NFPA 30, NFPA 37, and NFPA 70.

3.14 FINAL TESTING AND INSPECTION

a. Start the engine, record the starting time, make and record all engine manufacturer's after-starting checks and inspections during a reasonable warm-up period.

b. Increase the load in steps no greater than the Maximum Step Load Increase to 100 percent of Service Load, and operate the engine-generator set for at least 30 minutes. Measure the vibration at the end bearings (front and back of engine, outboard end of generator) in the horizontal, vertical, and axial directions. Verify that the vibration is within the same range as previous measurements and is within the required range.

c. Remove load and shut down the engine-generator set after the recommended cool down period.

d. Remove the lube oil filter and have the oil and filter examined by the engine manufacturer for excessive metal, abrasive foreign particles, etc. Verify any corrective action for effectiveness by running the engine for 8 hours at Service Load, then re-examine the oil and filter.

e. Remove the fuel filter and examine the filter for trash, abrasive foreign particles, etc.

f. Visually inspect and check engine and generator mounting bolts for tightness and visible damage.

g. Replace air, oil, and fuel filters with new filters.

3.15 MANUFACTURER'S FIELD SERVICE

The engine generator-set manufacturer must furnish a qualified representative to supervise the installation of the engine generator-set, assist in the performance of the onsite tests, and instruct personnel as to the operational and maintenance features of the equipment.

3.16 POSTED DATA AND INSTRUCTIONS

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NOTE: The designer should check with the customer to determine if framed instructions can be placed in the project area (requires wall space), and where they are to be placed. Select the 216 X 279 mm 8 1/2 X 11 inch notebook option where instructions will have to be placed in the engine-generator enclosure or a switchgear cubicle (or other suitable enclosure).

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Post Data and Instructions prior to field acceptance testing of the engine generator set. [Provide two sets of instructions/data, typed and framed under weatherproof laminated plastic, and post side-by-side where directed. Include a one-line diagram, wiring and control diagrams and a complete layout of the system in the first set. Include the condensed operating instructions describing manufacturer's pre-start checklist and precautions; startup procedures for test-mode, manual-start mode, and automatic-start mode (as applicable); running checks, procedures, and precautions; and shutdown procedures, checks, and precautions in the second set. Submit posted data including wiring and control diagrams showing the key mechanical and electrical control elements, and a complete layout of the entire system.

a. Include procedures for interrelated equipment (such as heat recovery systems, co-generation, load-shedding, and automatic transfer switches).] [Provide two sets of typed instructions/data in 216 X 279 mm 8-1/2 x 11 inch format, laminated in weatherproof plastic, and placed in three-ring vinyl binders. Place the binders as directed by the Contracting Officer. Provide the instructions prior to acceptance of the engine generator set installation.

b. Include a one-line diagram, wiring and control diagrams and a complete layout of the system in the first set. Include the condensed operating instructions describing manufacturer's pre-start checklist and precautions; startup procedures for test-mode, manual-start mode, and automatic-start mode (as applicable); running checks, procedures, and precautions; and shutdown procedures, checks, and precautions in the second set. Include procedures for interrelated equipment (such as heat recovery systems, co-generation, load-shedding, and automatic transfer switches).]

c. Submit instructions including: the manufacturers pre-start checklist and precautions; startup procedures for test-mode, manual-start mode, and automatic-start mode (as applicable); running checks, procedures, and precautions; and shutdown procedures, checks, and precautions. Include procedures for interrelated equipment (such as heat recovery systems, co-generation, load-shedding, and automatic transfer switches). Provide weatherproof instructions, laminated in plastic, and post where directed.

3.17 ACCEPTANCE

Submit drawings which accurately depict the as-built configuration of the installation, upon acceptance of the engine-generator set installation. Revise layout drawings to reflect the as-built conditions and submit them with the as-built drawings. Final acceptance of the engine-generator set will not be given until the Contractor has successfully completed all tests and all defects in installation material or operation have been corrected.

-- End of Section --