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USACE / NAVFAC / AFCEC / NASA **UFGS-26 32 15.00 10 (October 2007)**

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UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated April 2016
****

SECTION TABLE OF CONTENTS

DIVISION 26 - ELECTRICAL

SECTION 26 32 15.00 10

DIESEL-GENERATOR SET STATIONARY 100-2500 KW, WITH AUXILIARIES

10/07

PART 1 GENERAL

1.1 REFERENCES
1.2 SUBMITTALS
1.3 QUALITY ASSURANCE
1.3.1 Conformance to Codes and Standards
1.3.2 Site Welding
1.3.3 Vibration Limitation
1.3.4 Seismic Requirements
1.3.5 Experience
1.3.6 Field Engineer
1.3.7 Detailed Drawings
1.4 DELIVERY, STORAGE, AND HANDLING
1.5 EXTRA MATERIALS

PART 2 PRODUCTS

2.1 SYSTEM REQUIREMENTA
2.1.1 Engine-Generator Parameter Schedule
2.1.2 Rated Output Capacity
2.1.3 Power Ratings
2.1.4 Transient Response
2.1.5 Reliability and Durability
2.1.6 Parallel Operation
2.1.7 Load Sharing
2.1.8 Engine-Generator Set Enclosure
2.1.9 Vibration Isolation
2.1.10 Fuel Consumption
2.1.11 Fuel-Consumption Rebates
2.1.12 Harmonic Requirements
2.1.13 Starting Time Requirements
2.2 NAMEPLATES
2.3 SAFETY DEVICES
2.4 MATERIALS AND EQUIPMENT
2.4.1 Filter Elements
2.4.2 Instrument Transformers

2.4.3 Revenue Metering
2.4.4 Pipe (Fuel/Lube-Oil, Compressed Air, Coolant, and Exhaust)
2.4.4.1 Flanges and Flanged Fittings
2.4.4.2 Pipe Welding Fittings
2.4.4.3 Threaded Fittings
2.4.4.4 Valves
2.4.4.5 Gaskets
2.4.5 Pipe Hangers
2.4.6 Electrical Enclosures
2.4.6.1 Power Switchgear Assemblies
2.4.6.2 Switchboards
2.4.6.3 Panelboards
2.4.7 Electric Motors
2.4.8 Motor Controllers
2.5 ENGINE
2.6 FUEL SYSTEM
2.6.1 Pumps
2.6.1.1 Main Pump
2.6.1.2 Auxiliary Fuel Pump
2.6.2 Fuel Filter
2.6.3 Relief/Bypass Valve
2.6.4 Integral Main Fuel Storage Tank
2.6.4.1 Capacity
2.6.4.2 Local Fuel Fill
2.6.4.3 Fuel Level Controls
2.6.4.4 Arrangement
2.6.5 Day Tank
2.6.5.1 Capacity, Prime
2.6.5.2 Capacity, Standby
2.6.5.3 Drain Line
2.6.5.4 Local Fuel Fill
2.6.5.5 Fuel Level Controls
2.6.5.6 Arrangement
2.6.6 Fuel Supply System
2.7 LUBRICATION
2.7.1 Lube-Oil Filter
2.7.2 Lube-Oil Sensors
2.7.3 Precirculation Pump
2.8 COOLING SYSTEM
2.8.1 Coolant Pumps
2.8.2 Heat Exchanger
2.8.2.1 Fin-Tube-Type Heat Exchanger (Radiator)
2.8.2.2 Shell and U-Tube Type Heat Exchanger
2.8.3 Expansion Tank
2.8.4 Thermostatic Control Valve
2.8.5 Ductwork
2.8.6 Temperature Sensors
2.9 SOUND LIMITATIONS
2.10 AIR INTAKE EQUIPMENT
2.11 EXHAUST SYSTEM
2.11.1 Flexible Sections and Expansion Joints
2.11.2 Exhaust Muffler
2.11.3 Exhaust Piping
2.12 PYROMETER
2.13 EMISSIONS
2.14 STARTING SYSTEM
2.14.1 Controls
2.14.2 Capacity
2.14.3 Electrical Starting

2.14.3.1 Battery
2.14.3.2 Battery Charger
2.14.4 Pneumatic
2.14.4.1 Air Driven Motors
2.14.4.2 Cylinder Injection
2.14.5 Starting Aids
2.14.5.1 Glow Plugs
2.14.5.2 Jacket-Coolant Heaters
2.14.5.2.1 Prime Rated Sets
2.14.5.2.2 Standby Rated Sets
2.14.5.3 Lubricating-Oil Heaters
2.14.6 Exerciser
2.15 GOVERNOR
2.16 GENERATOR
2.16.1 Current Balance
2.16.2 Voltage Balance
2.16.3 Waveform
2.17 EXCITER
2.18 VOLTAGE REGULATOR
2.19 GENERATOR ISOLATION AND PROTECTION
2.19.1 Switchboards
2.19.2 Devices
2.20 SAFETY SYSTEM
2.20.1 Audible Signal
2.20.2 Visual Signal
2.20.3 Alarms and Action Logic
2.20.3.1 Shutdown
2.20.3.2 Problem
2.20.4 Local Alarm Panel
2.20.5 Time-Delay on Alarms
2.20.6 Remote Alarm Panel
2.21 ENGINE GENERATOR SET CONTROLS AND INSTRUMENTATION
2.21.1 Controls
2.21.2 Engine Generator Set Metering and Status Indication
2.22 SYNCHRONIZING PANEL
2.23 PANELS
2.23.1 Enclosures
2.23.2 Analog
2.23.3 Electronic
2.23.4 Parameter Display
2.24 AUTOMATIC ENGINE-GENERATOR-SET SYSTEM OPERATION
2.24.1 Automatic Transfer Switch
2.24.2 Monitoring and Transfer
2.24.3 Automatic Paralleling and Loading of Engine-Generator Sets
2.25 MANUAL ENGINE-GENERATOR-SET SYSTEM OPERATION
2.26 STATION BATTERY SYSTEM
2.26.1 Battery
2.26.2 Battery Capacity
2.26.3 Battery Charger
2.27 BASE
2.28 THERMAL INSULATION
2.29 PAINTING AND FINISHING
2.30 FACTORY INSPECTION AND TESTS
2.30.1 Factory Inspection
2.30.2 Factory Tests

PART 3 EXECUTION

3.1 EXAMINATION

3.2 GENERAL INSTALLATION
3.3 PIPING INSTALLATION
3.3.1 Support
3.3.1.1 Ceiling and Roof
3.3.1.2 Wall
3.3.2 Flanged Joints
3.3.3 Cleaning
3.3.4 Pipe Sleeves
3.4 ELECTRICAL INSTALLATION
3.5 FIELD PAINTING
3.6 ONSITE INSPECTION AND TESTS
3.6.1 Test Conditions
3.6.1.1 Data
3.6.1.2 Power Factor
3.6.1.3 Contractor Supplied Items
3.6.1.4 Instruments
3.6.1.5 Sequence
3.6.2 Construction Tests
3.6.2.1 Piping Test
3.6.2.2 Electrical Equipment Tests
3.6.3 Inspections
3.6.4 Pre-operational Tests
3.6.4.1 Protective Relays
3.6.4.2 Insulation Test
3.6.4.3 Engine-Generator Connection Coupling Test
3.6.5 Safety Run Test
3.6.6 Performance Tests
3.6.6.1 Continuous Engine Load Run Test
3.6.6.2 Voltage and Frequency Droop Test
3.6.6.3 Voltage Regulator Range Test
3.6.6.4 Governor Adjustment Range Test
3.6.6.5 Frequency and Voltage Stability and Transient Response
3.6.7 Parallel Operation Test
3.6.7.1 Combinations
3.6.7.2 Multiple Combinations
3.6.8 Parallel Operation Test (Commercial Source)
3.6.9 Automatic Operation Tests
3.6.10 Automatic Operation Tests for Stand-Alone Operation
3.6.11 Fuel Consumption Tests
3.7 ONSITE TRAINING
3.8 FINAL TESTING AND INSPECTION
3.9 POSTED DATA AND INSTRUCTIONS
3.10 ACCEPTANCE

-- End of Section Table of Contents --

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USACE / NAVFAC / AFCEC / NASA **UFGS-26 32 15.00 10 (October 2007)**

Preparing Activity: USACE **Superseding**
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SECTION 26 32 15.00 10

DIESEL-GENERATOR SET STATIONARY 100-2500 KW, WITH AUXILIARIES
10/07

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NOTE: This guide specification covers the requirements for stationary diesel-driven generator sets in the 100 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 items(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 Specification is not for Procurement of Gas-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 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 NATIONAL STANDARDS INSTITUTE (ANSI)

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

ASME INTERNATIONAL (ASME)

ASME B16.11	(2011) Forged Fittings, Socket-Welding and Threaded
ASME B16.3	(2011) Malleable Iron Threaded Fittings, Classes 150 and 300
ASME B16.5	(2013) Pipe Flanges and Flanged Fittings: NPS 1/2 Through NPS 24 Metric/Inch Standard
ASME B31.1	(2014; INT 1-47) Power Piping
ASME BPVC SEC IX	(2010) BPVC Section IX-Welding and Brazing Qualifications
ASME BPVC SEC VIII D1	(2010) 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 A106/A106M	(2014) Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service
ASTM A181/A181M	(2014) Standard Specification for Carbon Steel Forgings, for General-Purpose Piping
ASTM A234/A234M	(2013; E 2014) Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
ASTM A53/A53M	(2012) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM B395/B395M	(2013) Standard Specification for U-Bend Seamless Copper and Copper Alloy Heat Exchanger and Condenser Tubes
ASTM D975	(2015b) 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 115	(2009) 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 43	(2013) Recommended Practice for Testing Insulation Resistance of Rotating Machinery
IEEE 48	(2009) Standard for 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 484	(2002; R 2008) Recommended Practice for Installation Design and Implementation of Vented Lead-Acid Batteries for Stationary Applications
IEEE 485	(2010) 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 81	(2012) Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System
IEEE C2	(2012; Errata 1 2012; INT 1-4 2012; Errata 2 2013; INT 5-7 2013; INT 8-10 2014; INT 11 2015) National Electrical Safety Code
IEEE C57.13	(2008; INT 2009) Standard Requirements for Instrument Transformers
IEEE C57.13.1	(2006; R 2012) Guide for Field Testing of Relaying Current Transformers
IEEE Stds Dictionary	(2009) IEEE Standards Dictionary: Glossary of Terms & Definitions

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

MSS SP-58	(1993; Reaffirmed 2010) Pipe Hangers and Supports - Materials, Design and Manufacture, Selection, Application, and Installation
MSS SP-80	(2013) Bronze Gate, Globe, Angle and Check Valves

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA ICS 2	(2000; R 2005; Errata 2008) Standard for Controllers, Contactors, and Overload Relays Rated 600 V
NEMA ICS 6	(1993; R 2011) Enclosures
NEMA MG 1	(2014) Motors and Generators
NEMA PB 1	(2011) Panelboards
NEMA PB 2	(2011) Deadfront Distribution Switchboards
NEMA SG 6	(2000) Standard for Power Switching Equipment

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	(2007) 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 110	(2016) Standard for Emergency and Standby Power Systems
NFPA 30	(2015) Flammable and Combustible Liquids Code
NFPA 37	(2015) Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines
NFPA 70	(2014; AMD 1 2013; Errata 1 2013; AMD 2 2013; Errata 2 2013; AMD 3 2014; Errata 3-4 2014; AMD 4-6 2014) National Electrical Code
NFPA 99	(2015) Health Care Facilities Code

SOCIETY OF AUTOMOTIVE ENGINEERS INTERNATIONAL (SAE)

SAE J537	(2011) Storage Batteries

U.S. DEPARTMENT OF DEFENSE (DOD)

UFC 3-310-04	(2013) Seismic Design for Buildings

UNDERWRITERS LABORATORIES (UL)

UL 1236	(2015) Standard for Battery Chargers for Charging Engine-Starter Batteries
UL 891	(2005; Reprint Oct 2012) Switchboards

1.2 SUBMITTALS

****

NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project.

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

An "S" following a submittal item indicates that the submittal is required for the Sustainability Notebook to fulfill federally mandated sustainable requirements in accordance with Section 01 33 29 SUSTAINABILITY REPORTING.

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" designation; submittals not having a "G" designation are for [Contractor Quality Control approval.] [information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] Submittals with an "S" are for inclusion in the Sustainability Notebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Detailed Drawings; G[, [_____]]
Acceptance; G[, [_____]]

SD-03 Product Data

Harmonic Requirements
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

SD-05 Design Data

Performance Criteria
Sound Limitations; G[, [_____]]

Integral Main Fuel Storage Tank
Day Tank
Power Factor
Time-Delay on Alarms
Battery Charger

SD-06 Test Reports

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

SD-07 Certificates

Cooling System
Vibration Isolation
Prototype Test
Reliability and Durability
Emissions
Sound Limitations
Site Visit
Current Balance
Materials and Equipment
Inspections
Cooling System

SD-10 Operation and Maintenance Data

Operation and Maintenance Manuals; G[, [_____]]
Maintenance Procedures; G[, [_____]]
Special Tools
Filters

1.3 QUALITY ASSURANCE

1.3.1 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 shall also conform to the code.

1.3.2 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. 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. Submit a copy of qualifying procedures and a list of names and identification symbols of qualified welders and welding operators. 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. 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 shall be performed at the work site, if practical. The welder or welding operator shall apply the personally assigned symbol near each weld made as a permanent record.

1.3.3 Vibration Limitation

The maximum engine-generator set vibration in the horizontal, vertical, and axial directions shall be limited to 0.15 mm 6 mils (peak-peak RMS), with an overall velocity limit of 24 mm/second 0.95 inches/second RMS, for all speeds through 110 percent of rated speed.

1.3.4 Seismic Requirements

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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 3-310-04 and Sections 13 48 00, 13 48 00.00 10, and 26 05 48.00 10, properly edited, must be included in the contract documents.

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[Seismic requirements shall be in accordance with UFC 3-310-04 and Sections 13 48 00 SEISMIC PROTECTION FOR MISCELLANEOUS EQUIPMENT, 13 48 00.00 10 SEISMIC PROTECTION FOR MECHANICAL EQUIPMENT and 26 05 48.00 10 SEISMIC PROTECTION FOR ELECTRICAL EQUIPMENT] [as shown on the drawings].

1.3.5 Experience

Each component manufacturer shall have experience in the manufacture, assembly and sale of components used with stationary diesel engine-generator sets for commercial and industrial use. The engine-generator set manufacturer/assembler shall have a minimum of 3 years experience in the manufacture, assembly and sale of stationary diesel engine-generator sets. Submit a statement showing that each component manufacturer has a minimum of 3 years experience in the manufacture, assembly and sale of components used with stationary diesel engine-generator sets. The engine-generator set manufacturer/assembler has a minimum of 3 years experience in the manufacture, assembly and sale of stationary diesel engine-generator sets for commercial and industrial use.

1.3.6 Field Engineer

The engine-generator set manufacturer or assembler shall 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. Submit a letter listing the qualifications, schools, formal training, and experience of the field engineer. The field engineer shall have attended the engine generator manufacturer's training courses on installation and operation and maintenance of engine generator sets.

1.3.7 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. Complete starting system.

c. Complete fuel system.

d. Complete cooling system.

e. Complete exhaust system.

f. Layout of relays, breakers, programmable controllers,switchgear, and switches including applicable single line and wiring diagrams with written description of sequence of operation and the instrumentation provided.

g. The complete 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, together with a detailed description of how it is to work. Wiring schematics, safety devices with a listing of their normal ranges, alarm and shutdown values (to include operation parameters such as pressures, temperatures voltages, currents, and speeds) shall be included.

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

k. Layout of each panel.

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

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

1.4 DELIVERY, STORAGE, AND HANDLING

Properly protect material 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, piping and similar openings shall be capped to keep out dirt and other foreign matter.

1.5 EXTRA MATERIALS

Submit a complete list of spare parts for each piece of equipment and a complete list of all material and supplies needed for continued operation. Lists shall include supply source and current prices. Separate each list into two parts, those elements recommended by the manufacturer to be replaced after 3 years of service, and the remaining elements.

PART 2 PRODUCTS

2.1 SYSTEM REQUIREMENTA

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NOTE: Engine Generator Parameter Schedule. 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 conditions". 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. When specifying a genset 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.

Power Factor. Commercial genset 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 genset 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 genset 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 genset may be necessary to compensate for the inrush current. This assists the genset supplier in properly sizing the engine generator set.

Maximum Speed. The maximum allowable speed 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.

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 setpoint 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 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 gensets 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 as is typically quite small for commercially available governors (typically less than ± 0.4 percent with ± 0.25 percent readily available). The predominant type of device loads which are susceptible to steady state frequency deviations less than ± 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 ± 2 percent from no load to full load, while some manufacturers offer regulators which limit the droop to ± 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).

Subtransient Reactance. The subtransient 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 genset circuit interrupting device. It also is utilized to predict generator response to non-linear loads. Typical values for generator subtransient reactance are found in IEEE Std 141. Subtransient 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 subtransient 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 subtransient reactance should be limited to no more than 0.12.

Delete Subtransient Reactance from the Engine-Generator Parameter Schedule where the genset 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 derated 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 @ 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. 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). Genset-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 undervoltage/underfrequency ("dips") from the addition of block loads and any undershoot resulting from the recovery of an upward spike, as well as overvoltage/overfrequency (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 & 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 Frequency Deviation. Computers can usually tolerate only $\pm$ 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 $\pm$ 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.

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).

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 genset manufacturer with the information necessary to set the governor response for load decreases such than an overspeed (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.

Nominal Step Load Decrease	[25] [50] [75] percent of Service Load at [_____] PF
Transient Recovery Time with Step Load Decrease (Voltage)	[_____] seconds
Transient Recovery Time with Step Load Decrease (Frequency)	[_____] seconds
Maximum Voltage Deviation with Step Load Decrease	[5] [10] [30] [_____] percent of rated voltage
Maximum Frequency Deviation with Step Load Decrease	[2.5] [5] [_____] 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 second 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 genset 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 genset 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.

****

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 shall satisfy the requirements specified in the Engine-Generator Parameter Schedule.

b. Each set shall consist of one engine, one generator, and one exciter mounted, assembled, and aligned on one base; and other necessary ancillary equipment which may be mounted separately. Sets having a capacity of 750 kW or smaller shall be assembled and attached to the base prior to shipping. Sets over 750 kW capacity may be shipped in sections. Each set component shall be environmentally suitable for the location shown and shall be the manufacturer's standard product offered in catalogs for commercial or industrial use. Any nonstandard products or components and the reason for their use shall be specifically identified.

2.1.1 Engine-Generator Parameter Schedule

Submit description of the generator features which mitigate the effects of the non-linear loads listed.

ENGINE-GENERATOR PARAMETER SCHEDULE	
Power Rating	[Prime] [Limited Running Time][Emergency Standby] [Industrial]
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]
Maximum Speed	[_____] [900] [1200] [1800] rpm
Heat Exchanger Type	[fin-tube (radiator)] [shell-tube]
Voltage Regulation (No Load to Full Load)(Stand alone applications)	± 2 percent (maximum)
Voltage Bandwidth (steady state)	± [0.5] [1] [2] percent

ENGINE-GENERATOR PARAMETER SCHEDULE	
Frequency	[50] [60] Hz
Voltage	[_____] volts
Phases	[3 Phase, Wye] [3 Phase, Delta]
Minimum Generator Subtransient Reactance	[_____] percent
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 Time with Step Load Increase (Frequency)	[_____] seconds
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
Max Time to Start and be Ready to Assume Load	[10] [_____] seconds
Max Summer Indoor Temp (Prior to Genset Operation)	[_____] degrees C F
Min Winter Indoor Temp (Prior to Genset 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 PARAMETER SCHEDULE - Governor	
Governor Type	Isochronous
Frequency Bandwidth (steady state)	± [_____] [0.4] [0.25] percent

][

ENGINE-GENERATOR PARAMETER SCHEDULE - Governor	
Governor Type	Droop
Frequency Regulation (droop) (No Load to Full Load)	[3] [_____] percent (maximum)
Frequency Bandwidth (steady state)	± [_____] [0.4] [0.25] percent

]

2.1.2 Rated Output Capacity

****

NOTE: The service load for each genset 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.

****

Each engine-generator-set shall provide power equal to the sum of Service Load plus the machine's efficiency loss and associated ancillary equipment loads. Rated output capacity shall also consider engine and/or generator oversizing required to meet requirements in paragraph Engine-Generator Parameter Schedule.

2.1.3 Power Ratings

Power ratings shall be in accordance with EGSA 101P.

2.1.4 Transient Response

The engine-generator set governor and voltage regulator shall 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 shall 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.

****

[Each prime engine-generator set shall 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. Two like engines and two like generators shall be cited 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. Like engines shall be of the same model, speed, bore, stroke, number and configuration of cylinders and rated output capacity. Like generators shall be of the same model, speed, pitch, cooling, exciter, voltage regulator and rated output capacity.] [Each standby engine-generator set shall 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. Two like engines and two like generators shall be cited 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. Each like engine and generator shall have had no failures resulting in downtime for repairs in excess of 72 hours during two consecutive years of service. Like engines shall be of the same model, speed, bore, stroke, number and configuration of cylinders, and rated output capacity. Like generators shall be of 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.

****

Each engine-generator set specified for parallel operation shall be configured for [automatic] [manual] parallel operation. Each set shall 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.

****

Each engine-generator set specified for parallel operation shall be configured to [manually load share with other sets.] [automatically load share with other sets by proportional loading. Proportional loading shall 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. Load sharing shall 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.
****

The engine-generator set enclosure shall be corrosion resistant and fully weather resistant. The enclosure shall contain all set components and provide ventilation to permit operation at Service Load under secured conditions. Doors shall be provided for access to controls and equipment requiring periodic maintenance or adjustment. Removable panels shall be provided for access to components requiring periodic replacement. The enclosure shall be capable of being removed without disassembly of the engine-generator set or removal of components other than the exhaust system. The enclosure shall 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 3-450-02, Power Plant Acoustics, and 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.
****

[A vibration-isolation system shall be installed between the floor and the base. The vibration-isolation system shall limit the maximum vibration transmitted to the floor at all frequencies to a maximum of [_____] (peak force).] [The engine-generator set shall be provided 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, $\pm$ 10 percent. Vibration-isolation systems shall be designed and qualified (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, seismic restraints shall be provided in accordance with the seismic parameters specified.

2.1.10 Fuel Consumption

****
NOTE: Delete this paragraph for standby applications. For prime applications the designer should discuss this requirement with the installation to determine if it is required.
****

Engine fuel consumption shall not exceed the following maximum limits based on the conditions listed below.

Size Range Net kW	Percent of Rated Output Capacity	Fuel Usage kg/kWH lbs/kWH
100 - 299	75 and 100	0.2720.600
	50	0.2920.643
300 - 999	75 and 100	0.2610.575
	50	0.2720.600
1000 - 2500	75 and 100	0.2430.536
	50	0.2600.573

Conditions:

a. Net kW of the Set corrected for engine auxiliaries that are electrically driven, where kW is electrical kilowatt hours.

b. 45 MJ/kg (19,350 Btu/pound) 19,350 Btu/pound high-heat value for fuel used.

c. Sea level operation.

d. Intake-air temperature not over 32 degrees C 90 degrees F.

e. Barometric pressure of intake air not less than 95.7 kPa 28-1/4 inches of mercury.

2.1.11 Fuel-Consumption Rebates

****
NOTE: Delete this paragraph for standby applications. The designer will consult the using

Agency to determine the projected operating hours, including exercise periods.
****

Fuel consumption rebates shall be assessed for failure of engine generator set to meet guaranteed rates. If the guaranteed fuel-consumption rate for 100 percent rated output capacity is verified in the tests but the rates for 75 or 50 percent rated output capacity are not verified, the appropriate 75 or 50 percent rate differences shall be used in assessing the rebates. If more than one fuel consumption guarantee is not met, rebates shall be computed for 100, 75, and 50 percent rated output capacity, and the highest computed figure shall be used in assessing the rebates.

Rebate = H x C x D x N where:	
C	Local fuel costs in dollars per kg pound
D	A - G
A	Measured fuel consumption in kgs per second pounds per hour
G	kW x R = Guaranteed fuel consumption in kgs per second pounds per hour
N	Number of generator sets provided
H	Operating hours over a projected period of 15 years

Adjust fuel costs to the heat value kJ/kg BTU/lb for the fuel used in the test (requires fuel laboratory test) rationed to the 45,000 kJ/kg 19,350 Btu/pound heat value used as the basis of the guarantee.

2.1.12 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 @ PF) when non-linear loads will also be in use is as indicated.

2.1.13 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.

****

Each major component of this specification shall have the manufacturer's name, type or style, model or serial number and rating on a plate secured to the equipment. As a minimum, nameplates shall be provided 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 diesel 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

2.3 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 shall be insulated, fully enclosed, guarded, or fitted with other types of safety devices. The safety devices shall be installed so 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 Filter Elements

Fuel-oil, lubricating-oil, and combustion-air filter elements shall be manufacturer's standard.

2.4.2 Instrument Transformers

NEMA/ANSI C12.11.

2.4.3 Revenue Metering

IEEE C57.13.

2.4.4 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 shall be Schedule 80. Pipe 50 mm 2 inches and larger shall be Schedule 40.

2.4.4.1 Flanges and Flanged Fittings

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

2.4.4.2 Pipe Welding Fittings

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

2.4.4.3 Threaded Fittings

ASME B16.3, Class 150.

2.4.4.4 Valves

MSS SP-80, Class 150.

2.4.4.5 Gaskets

Manufacturer's standard.

2.4.5 Pipe Hangers

MSS SP-58.

2.4.6 Electrical Enclosures

NEMA ICS 6.

2.4.6.1 Power Switchgear Assemblies

NEMA SG 6.

2.4.6.2 Switchboards

NEMA PB 2.

2.4.6.3 Panelboards

NEMA PB 1.

2.4.7 Electric Motors

Electric motors shall conform to the requirements of NEMA MG 1. Motors shall have sealed ball bearings and a maximum speed of 1800 rpm. Motors used indoors shall have drip-proof frames; those used outside shall be totally enclosed. Alternating current motors larger than 373 W 1/2 Hp shall 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, shall be suitable for operation on 120 volts, [50] [60] Hz, and single-phase power. Direct current motors shall be suitable for operation on [125] [_____] volts.

2.4.8 Motor Controllers

Motor controllers and starters shall conform to the requirements of NFPA 70 and NEMA ICS 2.

2.5 ENGINE

****

NOTE: Specify fuel type if different than No. 2 diesel.

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 shall operate on No. 2-D diesel fuel conforming to ASTM D975, shall be designed for stationary applications and shall be complete with ancillaries. The engine shall 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 shall be naturally aspirated, supercharged, or turbocharged. The engine shall be 2- or 4-stroke-cycle and compression-ignition type. The engine shall be vertical in-line, V- or opposed-piston type, with a solid cast block or individually cast cylinders. The engine shall have a minimum of two cylinders. Opposed-piston type engines shall have not less than four cylinders. Each block shall have a coolant drain port. Each engine shall be equipped with an overspeed sensor.

2.6 FUEL SYSTEM

The entire fuel system for each engine-generator set shall conform to the requirements of NFPA 30 and NFPA 37 and contain the following elements.

2.6.1 Pumps

2.6.1.1 Main Pump

Each engine shall be provided with an engine driven pump. The pump shall supply fuel at a minimum rate sufficient to provide the amount of fuel required to meet the performance indicated within the parameter schedule. The fuel flow rate shall be based 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 shall be driven by a dc electric motor powered by the starting/station batteries. The auxiliary pump shall be automatically actuated by a pressure-detecting device.

2.6.2 Fuel Filter

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

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

2.6.4.1 Capacity

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

2.6.4.2 Local Fuel Fill

Each local fuel fill port on the day tank shall be provided with a screw-on cap.

2.6.4.3 Fuel Level Controls

Each tank shall have 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.

2.6.4.4 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 shall be provided with an internal or external factory installed valve located as near as possible to the shell of the tank. The valve shall close when the engine is not operating. Integral day tanks shall be provided 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 shall 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.
****

Each engine shall be provided 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. Each day tank shall be provided with 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. A fuel return line cooler shall be provided as recommended by the manufacturer and assembler. The temperature of the fuel returning to the day tank shall be below the flash point of the fuel. A temperature sensing device shall be installed in the fuel supply line], [fuel overflow line, local fuel fill port, gauge, vent line, drain line, and float switch assembly for control]. Each engine-generator set provided with weatherproof enclosures shall have its day tank mounted within the enclosure. The fuel fill line shall be accessible without opening the enclosure.

2.6.5.1   Capacity, Prime

Each day tank shall have 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. The calculation of the capacity of each day tank shall 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

Each day tank shall have 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. The calculation of the capacity of each day tank shall 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 shall be accessible and equipped with a shutoff valve. Self-supporting day tanks shall be arranged 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 shall be provided with a screw-on cap.

2.6.5.5   Fuel Level Controls

Each day tank shall have 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. The flow of fuel shall be stopped before any fuel can be forced into the fuel overflow line.

2.6.5.6   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. Gravity flow tanks shall be provided with an internal or external valve located as near as possible to the shell of the tank. The valve shall close when the engine is not operating. Integral day tanks shall be provided with any necessary pumps to supply fuel to the engine as recommended by the generator set manufacturer. The overflow connection and the fuel supply line for integral day tanks which do not rely upon gravity flow shall be arranged so that the highest possible fuel level is below the fuel injectors.] [Self-supporting day tanks shall either be arranged 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. The overflow connection and fuel supply line shall be arranged so that the highest possible fuel level is below the fuel injectors.] [When the main fuel storage tanks are located below the day tank, a check valve shall be provided in the fuel supply line entering the day tank.] [When the main fuel storage tanks are located above the day tank, a solenoid valve shall be installed in the fuel supply line entering the day tank. The solenoid valve shall 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 shall be welded pipe.

2.6.6 Fuel Supply System

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

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.
****

Each engine shall have a separate lube-oil system conforming to NFPA 30 and NFPA 37. Each system shall be pressurized by engine-driven pumps. System pressure shall be regulated as recommended by the engine manufacturer. A pressure relief valve shall be provided on the crankcase for closed systems. The crankcase shall be vented in accordance with the manufacturer's recommendation except that it shall not be vented to the engine exhaust system. Crankcase breathers, if provided on engines installed in buildings or enclosures, shall be piped to vent to the outside. The system shall be readily accessible for service such as draining, refilling, etc. Each system shall permit addition of oil and have oil-level indication with the set operating. The system shall 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 shall be readily accessible and capable of being changed without disconnecting the piping or disturbing other components. The filter shall have inlet and outlet connections plainly marked.

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. These filters shall be 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 DESCRIPTION.
****

Provide each engine with its own cooling system to operate automatically while its engine is running. The cooling system coolant shall 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 shall 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.

b. The minimum allowable inlet temperature of the coolant fluid.

c. The maximum allowable temperature rise in the coolant fluid through the engine.

2.8.1 Coolant Pumps

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

Coolant pumps shall be the centrifugal type. Each engine shall have an engine-driven primary pump. Secondary pumps shall be electric motor driven and have automatic controllers. Raw-water circulating pump shall be controlled by manual-off-automatic controllers and shall be [electric motor] [engine] driven.

2.8.2 Heat Exchanger

Each heat exchanger shall be of a 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. Each heat exchanger shall be 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 corrosive resistant film, provided that correction measures are taken to restore the heat rejection capability of the radiator to the initial design requirement via over sizing, or other compensating methods. Internal surfaces shall be compatible with liquid fluid coolant used. Materials and coolant are subject to approval by the Contracting Officer. Heat exchangers shall be pressure type incorporating a pressure valve, vacuum valve and a cap. Caps shall be designed for pressure relief prior to removal. Each heat exchanger and the entire cooling system shall be capable of withstanding a minimum pressure of 48 kPa 7 psi and shall be protected with a strong grille or screen guard. Each heat exchanger shall have at least two tapped holes; one tapped hole shall be equipped with a drain cock, the rest shall be plugged.

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.
****

Heat exchanger shall be multiple pass shell and U-tube type. Exchanger shall operate with low temperature water in the shell and high temperature water in the tubes. Exchangers shall be constructed in accordance with ASME BPVC SEC VIII D1 and certified with ASME stamp secured to the unit. U-tube bundles shall be completely removable for cleaning and tube replacement and shall be free to expand with the shell. Shells shall be constructed of seamless steel pipe or welded steel. Tubes shall be cupronickel or inhibited admiralty, constructed in accordance with ASTM B395/B395M, suitable for the temperatures and pressures specified. Tubes shall not be less than 19 mm 3/4 inch unless otherwise indicated. Shell side and tube side shall be designed for 1.03 MPa 150 psig working pressure and factory tested at 2.06 MPa 300 psig. High and low temperature water and pressure relief connections shall be located in accordance with the manufacturers standard practice. Water connections larger than 75 mm 3 inches shall be ASME Class 150 flanged. Water pressure loss through clean tubes shall be as recommended by the engine manufacturer. Minimum water velocity through tubes shall be 300 mm/sec 1 fps and assure turbulent flow. One or more pressure relief valves shall be provided for each heat exchanger in accordance with ASME BPVC SEC VIII D1. The aggregate relieving capacity of the relief valves shall be not less than that required by the above code. Discharge from the valves shall be installed as indicated. The relief valves shall be installed on the heat exchanger shell. A drain connection with 19 mm 3/4 inch hose bib shall be installed at the lowest point in the system near the heat exchanger. Additional drain connection with threaded cap or plug shall be installed 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 shall 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 shall be suitable for operating temperature of 121 degrees C 250 degrees F and a working pressure of 0.86 MPa 125 psi. The tank shall be constructed of welded steel, tested and stamped in accordance with ASME BPVC SEC VIII D1 for the stated working pressure. A bladder type tank shall not used. The tank shall be supported by steel legs or bases for vertical or steel saddles for horizontal installation.

2.8.4   Thermostatic Control Valve

A modulating type, thermostatic control valve shall be provided in the coolant system to maintain the coolant temperature range submitted in paragraph SUBMITTALS.

2.8.5   Ductwork

Ductwork shall be as specified in Section 23 00 00 AIR SUPPLY, DISTRIBUTION, VENTILATION, AND EXHAUST SYSTEM except that a flexible connection shall be used to connect the duct to the diesel engine radiator. Material for the connection shall be wire-reinforced glass. The connection shall be rendered as airtight as possible.

2.8.6   Temperature Sensors

Each engine shall be equipped with coolant temperature sensors. Temperature sensors shall provide 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 and UFC 3-450-02 POWER PLANT ACOUSTICS. 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 met 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 diesel generator manufacturer can provide information concerning the noise generated by the diesel 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 diesel 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 diesel 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 diesel 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. The noise generated by the diesel generator set operating at 100 percent load shall 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.

Frequency Band (Hz)	Maximum Acceptable Sound Level (Decibels)
31	[_____]
63	[_____]
125	[_____]
250	[_____]
500	[_____]
1,000	[_____]
2,000	[_____]
4,000	[_____]
8,000	[_____]

The noise generated by the installed diesel generator set operating at 100 percent load shall not exceed the following sound pressure levels in any of the indicated frequencies when measured 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.

Frequency Band (Hz)	Maximum Acceptable Sound Level (Decibels)
31	[_____]
63	[_____]
125	[_____]
250	[_____]
500	[_____]
1,000	[_____]

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

2.10 AIR INTAKE EQUIPMENT

Filters and silencers shall be provided in locations that are convenient for servicing. The silencer shall be of the high-frequency filter type, located in the air intake system as recommended by the engine manufacturer. Silencer shall be capable of reducing 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. Expansion elements in air-intake lines shall be [copper] [rubber].

2.11 EXHAUST SYSTEM

****

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

****

The system shall be separate and complete for each engine. Piping shall be supported to minimize vibration. Where a V-type engine is provided, a V-type connector, with necessary flexible sections and hardware, shall connect the engine exhaust outlets.

2.11.1 Flexible Sections and Expansion Joints

A flexible section shall be provided at each engine and an expansion joint at each muffler. Flexible sections and expansion joints shall have flanged connections. Flexible sections shall be made of convoluted seamless tube without joints or packing. Expansion joints shall be the bellows type. Expansion and flexible elements shall be stainless steel suitable for diesel-engine exhaust gas at the maximum exhaust temperature that is specified by the engine manufacturer. Expansion and flexible elements shall be 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.

****

A chamber type exhaust muffler shall be provided. The muffler shall be constructed of welded steel and designed for [outside] [inside] [vertical] [horizontal] mounting. Eyebolts, lugs, flanges, or other items shall be provided as necessary for support in the location and position indicated. Pressure drop through the muffler shall not exceed the recommendations of the engine manufacturer. Outside mufflers shall be zinc coated or painted with high temperature [_____] degrees resisting paint. The muffler and exhaust piping together shall reduce the noise level to less than the maximum acceptable level listed for sound limitations in paragraph SOUND LIMITATIONS. The muffler shall have a drain valve, nipple, and cap at the low-point of the muffler.

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.

****

Horizontal sections of exhaust piping shall be sloped downward away from the engine to a drip leg for collection of condensate with drain valve and cap. Changes in direction shall be long radius. Exhaust piping, mufflers and silencers installed inside any building shall be insulated in accordance with paragraph THERMAL INSULATION and covered to protect personnel. Vertical exhaust piping shall be provided with a hinged, gravity-operated, self-closing, rain cover.

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.

****

A pyrometer, [multi-point selector switch, and individual thermocouples] [and thermocouple] with calibrated leads shall be provided to show the temperature [in each engine cylinder and the combined exhaust] [of the combined exhaust]. For a supercharged engine, additional points, thermocouples and leads shall be provided to show the temperature in the turbocharger exhaust gas outlet and combustion air discharge passages. Graduated scale length shall be not less than 150 mm 6 inches. The selector switch shall be double pole, with an "off" position, one set of points for each thermocouple, and suitable indicating dial. The pyrometer, thermocouples, leads and compensating devices shall be calibrated 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 shall 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 shall include emission factors for criteria pollutants including nitrogen oxides, carbon monoxide, particulate matter, sulfur dioxide, non-methane hydrocarbon, and for hazardous air pollutants (HPAs).

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. 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.

****

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

2.14.1 Controls

An engine control switch shall be provided with functions including: run/start(manual), off/reset, and, automatic mode. Start-stop logic shall be provided for adjustable cycle cranking and cooldown operation. The logic shall be arranged for [manual starting] [and] [fully automatic starting in accordance with paragraph AUTOMATIC ENGINE-GENERATOR-SET SYSTEM OPERATION]. Electrical starting systems shall be provided with an adjustable cranking limit device to limit cranking periods from 1 second up to the maximum duration.

2.14.2 Capacity

The starting system shall be of sufficient capacity, at the maximum [outdoor] [indoor] summer temperature specified to crank the engine without damage or overheating. The system shall be capable of providing a minimum of three cranking periods with 15 second intervals between cranks. Each cranking period shall have a maximum duration of 15 seconds.

2.14.3 Electrical Starting

Manufacturers recommended dc system, utilizing a negative circuit ground.

2.14.3.1 Battery

****

NOTE: Select nickel-cadmium only when the battery temperature cannot be maintained above minus 6 degrees C 22 degrees F.

****

A starting battery system shall be provided and shall include the battery, battery rack, intercell connectors, spacers, automatic battery charger with overcurrent protection, metering and relaying. The battery shall be in accordance with SAE J537. Critical system components (rack, protection, etc.) shall be sized to withstand the seismic acceleration forces specified. The battery shall be [lead-acid] [nickel-cadmium], 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.

2.14.3.2 Battery Charger

A current-limiting battery charger, conforming to UL 1236, shall be provided and shall automatically recharge the batteries. Submit battery charger sizing calculations. The charger shall 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. An ammeter shall be provided to indicate charging rate. A voltmeter shall be provided to indicate charging voltage. A timer shall be provided 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.

2.14.4 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 shall 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.

Each compressor shall be sized to restore in 15 minutes the air used in one engine start.

Each receiver shall be sized 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.

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

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

****

Provide a pneumatic starting system. The compressed air system shall be 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].

2.14.4.1   Air Driven Motors

Air driven motors shall be complete with solenoid valve, strainer, and lubricator.

2.14.4.2   Cylinder Injection

Starting shall be accomplished 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.

2.14.5   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.

****

The manufacturer shall provide one or more of other following methods to assist engine starting.

2.14.5.1   Glow Plugs

Glow plugs shall be designed 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.

2.14.5.2   Jacket-Coolant Heaters

A thermostatically controlled electric heater shall be mounted 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 shall operate independently of engine operation so that starting times are minimized. Power for the heaters shall be [_____] volts ac.

2.14.5.2.1   Prime Rated Sets

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

2.14.5.2.2   Standby Rated Sets

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

2.14.5.3   Lubricating-Oil Heaters

A thermostatically controlled electric heater shall be mounted 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 shall operate independently of engine operation so that starting times are minimized. Power for the heaters shall be [_____] volts ac.

2.14.6 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 shall ensure that the design provides warning signs in areas where the engine generator can start automatically.
****

The exerciser shall be in accordance with Section 26 36 00.00 10 AUTOMATIC TRANSFER SWITCH AND BY-PASS/ISOLATION SWITCH.

2.15 GOVERNOR

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

Each engine shall be provided 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. The governor shall be configured 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. The tools shall be supplied complete with a suitable tool box. One handset shall be provided for each electronic governor when required to indicate and/or change governor response settings. [Isochronous governors shall 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.] [Droop governors shall 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].]

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 genset.
****

Each generator shall be of the synchronous type, one or two bearing, 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. Insulation shall be [Class H] [Class F].

a. Generator design shall 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.

b. Generator ancillary equipment shall meet the short circuit requirements of NEMA MG 1. Frames shall be the drip-proof type.

c. 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 subtransient 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 shall 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 shall 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 shall not exceed 3 percent of rated line to neutral voltage. The single-phase load requirement shall 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 shall not exceed 10 percent. The RMS of all harmonics shall be less than 5.0 percent and that of any one harmonic less than 3.0 percent of the fundamental at rated output capacity. Each engine-generator shall be designed and configured to meet the total harmonic distortion limits of IEEE 519.

2.17 EXCITER

The generator exciter shall be of the brushless type. Semiconductor rectifiers shall 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 4O degrees C 104 degrees F ambient. The exciter and regulator in combination shall maintain generator-output voltage within the limits specified.

2.18 VOLTAGE REGULATOR

****

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

****

Each generator shall be provided with a solid-state voltage regulator, separate from the exciter. The regulator shall 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. Regulator shall be configured 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 shall not exceed plus or minus 0.5 percent for an ambient temperature change of 20 degrees C 68 degrees F. Reactive droop compensation or reactive differential compensation shall load share the reactive load proportionally between sets during parallel operation. The voltage regulator shall have 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 Std 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 genset 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 genset. 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.
****

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

2.19.1 Switchboards

Switchboards shall be free-standing, metal-enclosed, general purpose, 3-phase, 4-wire, [600] [_____] volt rated, with neutral bus and continuous ground bus, conforming to NEMA PB 2 and UL 891. Neutral bus and ground bus capacity shall be [as shown] [full capacity]. Panelboards shall conform to NEMA PB 1. Enclosure designs, construction, materials and coatings shall be [as indicated] [suitable for the application and environment]. Bus continuous current rating shall 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) shall be [equal to the breaker interrupting rating] [as indicated]. Buses shall be copper.

2.19.2 Devices

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

2.20 SAFETY SYSTEM

Devices, wiring, remote panels, local panels, etc. shall be provided and installed as a complete system to automatically activate the appropriate signals and initiate the appropriate actions. The safety system shall be provided with a self-test method to verify its operability. Alarm signals shall have manual acknowledgment and reset devices. The alarm signal systems shall reactivate for new signals after acknowledgment is given to any signal. The systems shall be configured so that loss of any monitoring device shall 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.
****

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

2.20.2 Visual Signal

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

2.20.3 Alarms and Action Logic

2.20.3.1 Shutdown

Simultaneous activation of the audible signal, activation of the visual signal, stopping the engine, and opening the generator main circuit breakers shall be accomplished.

2.20.3.2 Problem

Activation of the visual signal shall be accomplished.

2.20.4 Local Alarm Panel

****
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, the appropriate code reference column,

and the column that shows Corps of Engineers required alarms/controls. Add necessary parameters to define critical limits for alarms or shutdown.

The designer should remove all references to day tanks if integral main fuel storage tanks are used.

The designer should remove all references to integral main fuel storage tanks if day tanks are used.

The following alarms are standard offerings of one or more manufacturers (Kohler, Caterpillar, Cummins - Onan, Detroit diesel). They are not required by NFPA but may be added if there is a specific requirement. Please note that some are not typically offered by three or more manufacturers, and may constitute a sole-source requirement.

Device/Condition/Function	Action/Location/ Function	Number of Manufacturers Offering
Low Coolant Level	SD/CP	3
Overvoltage Protection Shutdown	SD/CP VA O	3
Underfrequency	SD/CP VA	1
Undervoltage	SD/CP VA	1
Magnetic Pickup Failure	SD/CP VA	1
Overcurrent	SD/CP VA	1
Short Circuit	SD/CP VA	1
Auxiliary Fault Alarm	CP VA	1
Audible Alarm	CP VA	1
Overcurrent	CP VA	1
Oil Pressure Sender Fault	CP VA	1
Weak Battery	CP VA	1

****

A local alarm panel shall be provided with the following shutdown and alarm functions [as indicated] [in accordance with [NFPA 99] [NFPA 110 level [1] [2]]] and including the listed Corps of Engineer requirements mounted either on or adjacent to the engine generator set.

Device/ Condition/ Function	What/Where/ Size	NFPA 99	NFPA 110 Level 1	NFPA 110 Level 2	Corps of Engineers Required
Shutdowns w/Alarms					
High engine temperature	Automatic/ jacket/ water/ cylinder	SD/CP VA	SD/CP VA	SD/CP VA	SD VA
Low lube-oil pressure	Automatic/ pressure/ level	SD/CP VA	SD/CP VA	SD/CP VA	SD VA
Overspeed Shutdown & Alarm	(110 percent (+ 2 percent of rated speed)	SD/CP VA	SD/CP VA	SD/CP VA	SD VA
Overcrank, Failure to start	Automatic/Fail to start	SD/CP VA	SD/CP VA	SD/CP VA	
	When used		SD/CP VA	SD/CP VA	
Air shutdown damper (200-600kW)	When used		SD/CP VA	SD/CP VA	
Day tank overfill limit indication & transfer pump shutdown (95 percent volume)	Automatic/Day				SD(Pump)
	Tank/Level				CP VA
Red emergency stop switch	Manual Switch		SD/CP VA	SD/CP VA	SD VA
Alarms					
Day Tank [integral main fuel storage tank] (Low fuel Limit indication) (70 percent volume remaining)	Automatic/ Day Tank Level				CP VA

Device/ Condition/ Function	What/Where/ Size	NFPA 99	NFPA 110 Level 1	NFPA 110 Level 2	Corps of Engineers Required
Low fuel level	Main tank, 3 hrs remaining	VA/AA	CP VA	CP VAO	CP VA
Integral Main Fuel Storage Tank High Fuel Level	95 percent volume				CP VA
Pre-High Temperature	jacket water/ cylinder	CP VA	CP VA	CP VAO	CP VA
Pre-Low Lube-oil Pressure		CP VA			CP VA
High battery Voltage			CP VA	CP VAO	
Low battery Voltage			CP VA	CP VAO	
Battery charger AC Failure	AC supply not available		CP VA	CP VAO	
Control switch not in AUTO			CP VA	CP VAO	
Low starting Air pressure			CP VA	CP VAO	
Low starting hydraulic pressure			CP VA	CP VAO	
SD	Shut Down				
CP	On Control Panel				
VA	Visual Alarm				
AA	Audible Alarm				
O	Optional				

2.20.5 Time-Delay on Alarms

For startup of the engine-generator set, time-delay devices shall be installed 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 shall return its alarm to normal status after the engine starts. The coolant time-delay device shall return its alarm to normal status 5 minutes after the engine starts.

2.20.6 Remote Alarm Panel

****

NOTE: 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.

****

Provide a remote alarm panel [as indicated.] [in accordance with [NFPA 99] [NFPA 110] and as follows.

Device/ Condition/ Function	What/Where/ Size	NFPA 99	NFPA 110 Level 1	NFPA 110 Level 2
Remote annunciator panel	Battery Powered		Alarms	
Loads on genset		VA		
Battery charger malfunction		VA		
Low lube-oil	Pressure/level	VA/AA	AA	AAO
Low temperature	Jacket water	VA/AA	AA	AAO
High temperature	Jacket water/ cylinder	VA/AA	AA	AAO
Low fuel level	Main tank, 3 hrs remaining	VA/AA	AA	AAO
Overcrank	Failure to start	VA/AA	AA	AAO

Device/ Condition/ Function	What/Where/ Size	NFPA 99	NFPA 110 Level 1	NFPA 110 Level 2
Overspeed		VA/AA	AA	AAO
Pre-high temperature	Jacket water/ cylinder		AA	
Control switch not in AUTO			AA	
Common alarm contacts for local & remote common alarm			X	X
Audible alarm silencing switch			X	O
Air shutdown damper	When used		AA	AAO
Common fault alarm			AA	
X	Required			
SD	Shutdown			
CP	On Control Panel			
VA	Visual Alarm			
AA	Audible Alarm			
O	Otional			

]

2.21 ENGINE GENERATOR SET CONTROLS AND INSTRUMENTATION

Devices, wiring, remote panels, local panels, etc. shall be provided and installed as a complete system to automatically activate the appropriate signals and initiate the appropriate actions.

2.21.1 Controls

****

NOTE: Delete the remote control (control room) panel if the application is not a prime power application. Provide plan and elevation drawings of the remote control panels for prime power applications, depicting specific devices, instrument, and meters, including layouts. Generator circuit breaker controls with position indication may be added if required (Not available for standard molded-case breakers. Use only for power circuit breakers or switchgear.)

Edit the table to include all required devices. Delete all columns except the first column and the

appropriate reference columns (always delete the "MFG Offering" column).

A remote stop switch is required by NFPA 37 for 100 hp and above engines, and by NFPA 110 for both Level 1 and Level 2 applications. A remote fuel shutoff switch, and a remote lube-oil shutoff switch are required by NFPA 37 for 100 hp and above engines. Delete the remote fuel shutoff switch, and a remote lube-oil shutoff switch where not required.
****

Provide a local control panel with controls [as indicated] [in accordance with [NFPA 110 level [1] [2]]] [and as follows] mounted [either on or adjacent to the engine generator set] [as indicated]. Provide a remote control panel [with devices as indicated] [fully redundant to the local control panel].

Device/ Condition/ Function	Corps of Engineers Requirements	NFPA 110 Level 1	NFPA 110 Level 2	Manufacturer Offering
Switch: run/start - off/reset - auto	CP			CP/STD
Emergency stop switch & alarm	CP			CP/STD
Lamp test/ indicator test	CP	CP VA	CP VA	CP/STD
Common alarm contacts/ fault relay		X	X	CP/O
Panel lighting	CP			CP/STD
Audible alarm & silencing/ reset switch	CP			
Voltage adjust for voltage regulator	CP			CP/STD
Pyrometer display w/selector switch	CP			
Remote emergency stop switch		CP VA	CP VA	

Device/ Condition/ Function	Corps of Engineers Requirements	NFPA 110 Level 1	NFPA 110 Level 2	Manufacturer Offering
Remote fuel shutoff switch				
Remote lube-oil shutoff switch				
X	Required			
STD	Manufacturers Standard Offering			
CP	On Control Panel			
VA	Visual Alarm			
O	Otional			

2.21.2 Engine Generator Set Metering and Status Indication

****

NOTE: Delete the remote (control room) panel if the application is not a prime power application. Provide plan and elevation drawings of the remote panels for prime power applications, depicting specific devices, instrument, and meters, including layouts. Edit the table to include all required devices. Delete optional devices that are not required for the application. Delete all columns except the first column and the appropriate reference column (always delete the "MFG. Offering" column). Add any necessary parameters to define devices required. A fuel meter display should be added for prime rated applications. A fuel header pressure display should be added for prime rated applications. Delete the pyrometer devices for sets smaller than 200 kW. kWh, kVAR, power factor, meters and reverse power indication may be added as required.

The following instruments may be added as required.

Indicating VAR meter. Power-factor meter, indicating. (Specify one of these. They are normally used only for prime applications, however can be specified for standby units as required.)

Indicating wattmeter. (Normally used only for prime applications, however can be specified for standby units as required.

Totalizing Kilowatt-hour meter with 15 or 30 minute demand register. (Normally used only for prime applications, however can be specified for standby units as required.)

Recording Kilowatt-hour/demand meter. (Normally used only for prime applications, however can be specified for standby units as required.)

The 15-minute demand register is preferred to the 30-minute register in most cases, because it permits more accurate timing of facility peak load occurrence.

Delete Frequency and Volt meters if a Synchronizing Panel is provided.

****

Provide a local panel with devices [as indicated] [in accordance with [NFPA 110 level [1] [2]]] [and as follows] mounted [either on or adjacent to the engine generator set] [as indicated]. A remote control panel shall be provided [with devices as indicated] [fully redundant to the local control panel].

Device/ Condition/ Function	Corps of Engineers Requirements	NFPA 110 Level 1	NFPA 110 Level 2	Manufacturer Offering
Genset Status & Metering				
Genset supplying load		CP VA	CP VAO	CP VAO
System ready				CP/STD
Engine oil pressure	CP			CP/STD
Engine coolant temperature	CP			CP/STD
Engine RPM (tachometer)	CP			CP/STD
Engine run hours	CP			CP/STD
Pyrometer display w/selector switch	CP			
AC volts (generator), 3-phase	CP			CP/STD
AC amps (generator), 3-phase	CP			CP/STD

Device/ Condition/ Function	Corps of Engineers Requirements	NFPA 110 Level 1	NFPA 110 Level 2	Manufacturer Offering
Generator Frequency	CP			CP/STD
Phase selector switches (amps & volts)	CP			CP/STD
Watts/kW				CP/VA-O
Voltage Regulator Adjustment	CP			
X	Required			
STD	Manufacturers Standard Offering			
CP	On Control Panel			
VA	Visual Alarm			
AA	Audible Alarm			
O	Otional			

2.22 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.
****

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

a. Frequency meters, dial type, with a range of 90 to 110 percent of rated frequency. Vibrating-reed type meters shall not be used. One shall monitor generator output frequency ("Generator Frequency Meter") and the other shall 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.

2.23 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 genset 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 shall be of the type and kind necessary to provide specified functions. Panels shall be mounted [on the engine-generator set base by vibration/shock absorbing type mountings] [as shown]. Instruments shall be mounted flush or semiflush. Convenient access to the back of panels shall be provided to facilitate maintenance. Instruments shall be calibrated using recognized industry calibration standards. Each panel shall be provided with a panel identification plate which clearly identifies the panel function. Each instrument and device on the panel shall be provided with a plate which clearly identifies the device and its function as indicated. Switch plates shall clearly identify the switch-position function.

2.23.1 Enclosures

Enclosures shall be designed for the application and environment, conforming to NEMA ICS 6. Locking mechanisms [are optional.] [shall be keyed alike.]

2.23.2 Analog

Analog electrical indicating instruments shall be in accordance with ANSI C39.1 with semiflush mounting. Switchboard, switchgear, and control-room panel-mounted instruments shall have 250 degree scales with an accuracy of not less than 99 percent. Unit-mounted instruments shall [be the manufacturer's standard] [have 100 degree scales] with an accuracy of not less than 98 percent. The instrument's operating temperature range shall 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 shall not affect metering accuracy for phase voltages, hertz and amps.

2.23.3 Electronic

Electronic indicating instruments shall be true RMS indicating instruments, 100 percent solid state, state-of-the-art, microprocessor controlled to provide specified functions. Control, logic, and function devices shall be compatible as a system, sealed, dust and water tight, and shall utilize modular components with metal housings and digital instrumentation. An interface module shall be provided to decode serial link data from the electronic panel and translate alarm, fault and status conditions to set of relay contacts. Instrument accuracy shall be not 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. Data display shall utilize LED or back lit LCD. Additionally, the display shall provide indication of cycle programming and diagnostic codes for troubleshooting. Numeral height shall be [13 mm 0.5 inch] [_____].

2.23.4   Parameter Display

Indication or readouts of the tachometer, lubricating-oil pressure, ac voltmeter, ac ammeter, frequency meter, and safety system parameters shall be provided. A momentary switch shall be specified for other panels.

2.24   AUTOMATIC ENGINE-GENERATOR-SET SYSTEM OPERATION

****

NOTE: Automatic operation is for standby. For hospital emergency/standby requirements, refer to UFC 3-540-02N. Delete automatic paralleling and loading where not required. Adapt to fit application and provide desired actuation sequence.

****

Fully automatic operation shall be provided 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 shall automatically reset after termination of their function.

2.24.1   Automatic Transfer Switch

Automatic transfer switches shall be in accordance with Section 26 36 00.00 10AUTOMATIC TRANSFER SWITCH AND BY-PASS/ISOLATION SWITCH.

2.24.2   Monitoring and Transfer

Devices shall be provided 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. Functions, actuation, and time delays shall be as described in Section 26 36 00.00 10 AUTOMATIC TRANSFER SWITCH AND BY-PASS/ISOLATION SWITCH.

2.24.3   Automatic Paralleling and Loading of Engine-Generator Sets

An automatic loading system shall be provided to load and unload engine-generator sets in the sequence indicated. The loading system shall 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 shall occur when the load exceeds a percentage setpoint of the operating set's rating for a period of approximately 10 seconds. The device shall provide an adjustable setpoint range from 50 to 100 percent. When the system load falls below the percentage setpoint of the operating set's rating for a period of approximately [_____], the controller shall 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.

****

Complete facilities shall be provided 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 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 $\pm$ 2.5 degrees C $\pm$ 5 degrees F from 25 degrees C 77 degrees F, specify the median operating temperature.

****

A station battery system shall be provided to include the battery, battery rack, spacers, automatic battery charger and distribution panelboard with overcurrent protection, metering and relaying. Components shall be sized to withstand the seismic acceleration forces specified. The batteries shall have a rated life of 20 years and a manufacturer's 5-year, no cost replacement guarantee.

2.26.1 Battery

The battery shall be [lead-acid] [nickel-cadmium], sized in accordance with IEEE 485 and conform to the requirements of IEEE 484. Valve-regulated lead-acid batteries are not acceptable.The battery environment temperature shall range between [_____] and [_____] degrees. The battery shall 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 gensets 1000 kW and larger: precirculating lube-oil pumps for diesels for [_____] minutes.

****

The battery shall be rated for at least [_____] ampere hours at the 8-hour rate, and shall have sufficient capacity to serve the following loads without recharging for a period of [_____] hours. At the end of the discharge period, the battery shall 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

A current-limiting, [_____]-volt battery charger shall be furnished to automatically recharge the batteries. The charger shall be 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. The charger shall be equipped with a low-voltage alarm relay, 0- to 24-hour equalizing timer, an ammeter to indicate charging rate, and necessary circuit breakers. The charger shall 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

The base shall be constructed of steel. The base shall be designed 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 shall permit skidding in any direction during installation and shall withstand and mitigate the affects of synchronous vibration of the engine and generator. The base shall be provided with [suitable holes for anchor bolts] [[_____] diameter holes for anchor bolts] and jacking screws for leveling.

2.28 THERMAL INSULATION

Thermal insulation shall be as specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

2.29 PAINTING AND FINISHING

The engine-generator set shall be cleaned, primed and painted 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. Each engine-generator set shall be run not less than 1 hour at rated output capacity prior to inspections. Inspections shall be completed and all necessary repairs made, prior to testing. Engine generator controls and protective devices that are provided by the generator set manufacturer as part of the standard package shall be used 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. Inspectors shall 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. The following checklist shall be used for the inspection:

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

INSPECTION ITEM	GOOD	BAD	NOTES
Radiator drains			
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			

INSPECTION ITEM	GOOD	BAD	NOTES
Paint			
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 gensets 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 genset.

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. Sections shall be separated by heavy plastic dividers with tabs. Data plots shall be full size (216 by 279 mm 8-1/2 by 11 inch minimum), 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 shall be [the power factor specified in the engine generator set parameter schedule] [[_____] power factor]. For engine-generator set with dual-fuel operating capability the following tests shall be performed using [the primary fuel type] [[_____] type fuel]. Electrical measurements shall be performed in accordance with IEEE 120. Definitions of terms are in accordance with IEEE Stds Dictionary. Temperature limits in the rating of electrical equipment and for the evaluation of electrical insulation shall 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. Overspeed Vibration Test, in accordance with IEEE 115 to the performance criteria in NEMA MG 1. The test shall be performed at 110 percent of rated speed for 5 minutes. The vibration shall be measured at the end bearings (front and back of engine, outboard end of generator) in the horizontal, vertical, and axial directions. Vibration amplitude and speed shall be recorded at one minute intervals.

e. 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.

f. 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.

g. Voltage Waveform Deviation and Distortion Test in accordance with IEEE 115 to the performance criteria specified in paragraph GENERATOR. High-speed recording instruments capable of recording voltage waveform deviation and all distortion, including harmonic distortion shall be used. Representation of results shall include appropriate scales to provide a means to measure and interpret results.

h. 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:

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

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

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

i. 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. Tabular data shall include the following:

(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 shall 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 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.

****

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 genset. 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

Installation shall 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. Installation of pipe, duct, conduit, and ancillary equipment shall be configured to facilitate easy removal and replacement of major components and parts of the engine-generator set.

3.3   PIPING INSTALLATION

Piping shall be welded. Connections at valves shall be flanged. Connections at equipment shall be flanged except that connections to the diesel engine may be threaded if the diesel-engine manufacturers standard connection is threaded. Except where otherwise specified, welded flanged fittings shall be utilized 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. Connections to equipment shall be made with vibration-isolation-type flexible connectors. Piping and tubing shall be supported and aligned to prevent stressing of flexible hoses and connectors. Pipes extending through the roof shall be properly flashed. Piping shall be installed clear of windows, doors and openings, to permit thermal expansion and contraction without damage to joints or hangers, and shall be installed with a 13 mm 1/2 inch drain valve with cap at each low point.

3.3.1 Support

Hangers, inserts, and supports shall be of sufficient size to accommodate any insulation and shall conform to MSS SP-58. Supports shall be spaced not more than 2.1 m 7 feet on center for pipes 50 mm 2 inches in diameter or less, not 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. Supports shall be provided at pipe bends or change of direction.

3.3.1.1 Ceiling and Roof

Exhaust piping shall be supported with appropriately sized Type 41 single pipe roll and threaded rods; all other piping shall be supported with appropriately sized Type 1 clevis and threaded rods.

3.3.1.2 Wall

Wall supports for pipe shall be made by suspending the pipe from appropriately sized Type 33 brackets with the appropriate ceiling and roof pipe supports.

3.3.2 Flanged Joints

Flanges shall be Class 125 type, drilled, and of the proper size and configuration to match the equipment and diesel engine connections. Flanged joints shall be gasketed and made up square and tight.

3.3.3 Cleaning

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

3.3.4 Pipe Sleeves

Pipes passing through construction such as ceilings, floors, or walls shall be fitted with sleeves. Each sleeve shall extend through and be securely fastened in its respective structure and shall be cut flush with each surface. The structure shall be built tightly to the sleeve. The inside diameter of each sleeve shall 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

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

3.5 FIELD PAINTING

****

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

****

Field painting shall be as specified in Section 09 90 00 PAINTS AND COATINGS.

3.6 ONSITE INSPECTION AND 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. Submission shall be 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. Sections shall be separated by heavy plastic dividers with tabs. Data plots shall be full size (216 by 279 mm 8-1/2 by 11 inch minimum), 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

Measurements shall be made and recorded of all parameters necessary to verify that each set meets specified parameters. If the results of any test step are not satisfactory, adjustments, replacements, or repairs shall be made and the step repeated until satisfactory results are obtained. Unless otherwise indicated, data shall be recorded in 15 minute intervals during engine-generator set operation and shall 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.Electrical measurements shall be performed in accordance with IEEE 120. Definitions of terms are in accordance with IEEE Stds Dictionary. Temperature limits in the rating of electrical equipment and for the evaluation of electrical insulations shall be 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 shall 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

Readings of panel gauges, meters, displays, and instruments provided as permanent equipment shall be verified during test runs, using test instruments of greater precision and accuracy. Test instrument accuracy shall 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. Test instruments shall be calibrated by a recognized standards laboratory within 30 days prior to testing.

3.6.1.5   Sequence

The sequence of testing shall be as specified in the approved testing plan unless variance is authorized by the Contracting Officer. Field testing shall be performed in the presence of the Contracting Officer. Tests may be scheduled and sequenced in order to optimize run-time periods; however, the following general order of testing shall be followed: 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.
****

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 shall be performed prior to connection to the engine-generator set.

3.6.2.1   Piping Test

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

b. Fuel piping which is external to the engine-generator set shall be tested in accordance with NFPA 30. All remaining piping which is external to the engine-generator set shall be pressure tested 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, the test shall be performed 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. Low-voltage cable insulation integrity tests shall be performed for cables connecting the generator breaker to the [automatic transfer switch] [panelboard] [main disconnect switch] [distribution bus] [_____]. Low-voltage cable, complete with splices, shall be tested for insulation resistance after the cables are installed, in their final configuration, ready for connection to the equipment, and prior to energization. The test voltage shall be 500 volts dc, applied 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. The minimum value of insulation shall be:

   (1) R in megohms = (rated voltage in kV + 1) x 304.8/(length of cable in meters)

   (2) R in megohms = (rated voltage in kV + 1) x 1000/(length of cable in feet)

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

b. Medium-voltage cable insulation integrity tests shall be performed 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, the medium-voltage cable system shall be given a high potential test. Direct-current voltage shall be applied on each phase conductor of the system by connecting conductors as one terminal and connecting grounds of metallic shieldings or sheaths of the cable as the other terminal for each test. Prior to making the test, the cables shall be isolated by opening applicable protective devices and disconnecting equipment. The test shall be conducted with all splices, connectors, and terminations in place. The method, voltage, length of time, and other characteristics of the test for initial installation shall be in accordance with [NEMA WC 74/ICEA S-93-639] [_____] for the particular type of cable installed, except that 28kV and 35kV insulation test voltages shall be in accordance with either AEIC CS8 or AEIC CS8 as applicable, and shall not exceed the recommendations of IEEE 404 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. Repaired or replaced cables shall be retested.

c. Ground-Resistance Tests. The resistance of [each grounding electrode] [each grounding electrode system] [the ground mat] [the ground ring] shall be measured using the fall-of-potential method defined in IEEE 81. Ground resistance measurements shall be made before the electrical distribution system is energized and shall be made in normally dry conditions not less than 48 hours after the last rainfall. Resistance measurements of separate grounding electrode systems shall be made before the systems are bonded together below grade. 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. Circuit breakers and switchgear shall be examined and tested 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. Checks applicable to the installation shall be performed. The results of those which are physical inspections (I) shall be documented and submitted in accordance with paragraph SUBMITTALS. Present manufacturer's data for the inspections designated (D) at the time of inspection. Inspections shall verify that equipment type, features, accessibility, installation and condition are in accordance with the contract specification. Manufacturer's statements shall 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   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.
****

3.6.4.1   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.
****

Protective relays shall be visually and mechanically inspected, adjusted, tested, and calibrated in accordance with the manufacturer's published instructions. Tests shall include pick-up, timing, contact action, restraint, and other aspects necessary to ensure proper calibration and operation. Relay settings shall be implemented in accordance with the installation coordination study. Relay contacts shall be manually or electrically operated to verify that the proper breakers and alarms initiate. Relaying current transformers shall be field tested in accordance with IEEE C57.13.1.

3.6.4.2   Insulation Test

Generator and exciter circuits insulation resistance shall be tested in accordance with IEEE 43. Stator readings shall be taken at the circuit breaker, to include generator leads to [switchgear] [switchboard]. Results of insulation resistance tests shall be recorded. Readings shall be within limits specified by the manufacturer. Mechanical operation, insulation resistance, protective relay calibration and operation, and wiring continuity of [switchgear] [switchboard] assembly shall be verified. Precautions shall be taken to preclude damaging generator components during test.

3.6.4.3 Engine-Generator Connection Coupling Test

When the generator provided is a two-bearing machine, the engine-generator connection coupling shall be inspected and checked by dial indicator to prove that no misalignment has occurred. The dial indicator shall measure variation in radial positioning and axial clearance between the coupling halves. Readings shall be taken at four points, spaced 90 degrees apart. Solid couplings and pin-type flexible couplings shall be aligned 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.

3.6.5 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 setpoint 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, if any parts are changed, or adjustments made to the generator set, its controls, or auxiliaries, the associated safety tests shall be repeated.

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 setpoints of gauges and instruments.

m. Verify proper operation of ancillary equipment.

n. Manually adjust the governor to increase engine speed past the overspeed 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 overspeed 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. The engine's oil pressure sensor shall be moved from the engine to the manifold. The manifold shutoff valve shall be open and bleed valve closed.

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, the enclosure, the muffler, and intake silencer shall 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 shall be modified or replaced 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.

3.6.6   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 genset.

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, if any parts are changed, or adjustments made to the generator set, its controls, or auxiliaries, the associated tests shall be repeated.

3.6.6.1 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, the entire test shall be repeated. The engine load run test shall be accomplished principally 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. Data taken at 15 minute intervals shall 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.

3.6.6.2 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.

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

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

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

3.6.6.3 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.

3.6.6.4 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.

3.6.6.5 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. Tabular data shall include the following:

(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 shall 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 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.

3.6.7 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. Data taken shall include the following:

(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.

3.6.7.1 Combinations

Connect each set, while operating at no load, parallel with one other set in the system, operating at service load, until all possible two-unit-in-parallel 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.

3.6.7.2 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.

3.6.8 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.

3.6.9 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. The loads for this test shall utilize [load banks at the indicated power factor] [and actual loads to be served], and the loading sequence shall be the indicated sequence. During all operations load-sharing characteristics shall be recorded. Perform this test for a minimum of two successive, successful tests. Data taken shall include the following:

(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.

3.6.10 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. The loads for this test shall utilize the actual loads to be served, and the loading sequence shall be the indicated sequence. Perform this test for a minimum of two successive, successful tests. Data taken shall include the following:

(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.

3.6.11 Fuel Consumption Tests

****
NOTE: Fuel consumption tests and rebates are to be used on prime rated applications only. Delete for standby units.
****

Perform fuel consumption tests to confirm the manufacturer's certified rates on engine generator set and tabulate and average the results. Fuel consumption tests shall be conducted under the direct supervision of the engine manufacturer's representative. Fuel consumption readings shall be taken at 15 minute intervals, over a minimum period of 1 hour at 50 percent Service Load, 1 hour at 75 percent Service Load, and 4 hours at 100 percent Service Load. Fuel consumption data may be taken during the 75 percent load test and 100 percent load tests. Fuel consumption readings at site conditions shall be correlated to the guarantee-baseline conditions. Test report shall contain: readings of the output frequency, voltage, current, power factor, and power; barometric pressure; ambient temperature; intake-air temperature; fuel temperature; the site fuel consumption readings, adjustment calculations, factors, and source references for correlation of actual consumption rate of the guaranteed rate.

a. Start and operate the generator set and allow it to stabilize at rated load, rated voltage and rated frequency. During this period, readings of all instruments including thermal instrumentation shall be recorded at minimum intervals of 10 minutes. If necessary, adjustments to the load, voltage and frequency may be made to maintain rated load at rated voltage and rated frequency. However, adjustments to the voltage and frequency shall be limited to those adjustments available to the operator, specifically adjustments to the voltage or frequency adjust devices. On generator sets utilizing a droop-type speed control system as the prime speed control, the speed and droop portions of the control may be adjusted. No other adjustments to the voltage and frequency control systems shall be made unless permitted by the procurement document. Adjustments to the load, voltage or frequency controls shall be recorded on the data sheet. Unless otherwise specified in the procurement document, stabilization will be consideration 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.

b. Perform one of the following procedures:

BALANCE SCALE PROCEDURE.

(1) Supply fuel from auxiliary container mounted on a balance scale.

(2) After stabilization has occurred, set the balance weights at any convenient value slightly less than the total weight of the fuel and container.

(3) Start the stopwatch when the balance weights fall and record the total weight.

(4) Reduce the balance weight a convenient amount and record the amount of the weights removed.

(5) Stop the stopwatch when the balance weights fall and record the total weight and the elapsed time.

(6) Repeat steps (1) thru (2) above until the timed portion of the test exceeds the 2 hours.

(7) From the total elapsed time and total of the weights removed calculate the fuel consumption in terms of pounds per hour.

(8) Using the value obtained in step (7) above, compute the rate of fuel consumption per kilowatt hour, as follows:

$$\text{Pounds per kWH} = \frac{\text{Fuel Consumption in Pounds per Hour}}{\text{kW Load}}$$

(9) Repeat the test for each load condition specified.

(10) Determine the capacity of the generator set fuel tank in pounds of fuel.

(11) For each specified load, compute the number of continuous hours

the generator set will operate on a full tank of fuel. The following formula shall be used.

$$\text{Operating hours} = \frac{\text{Fuel Tank Capacity (Pounds)}}{\text{Fuel Consumption (Pounds per hour)}}$$

ALTERNATE PROCEDURE FOR WEIGHING FUEL

(1) Supply fuel from the auxiliary fuel container, mounted on a platform balance, or other weighing device.

(2) After stabilization has occurred, record weight readings every one-half hour for a period of 2 hours.

(3) Calculate the average hourly fuel consumption rate in pounds per hour.

(4) Using the average hourly fuel consumption rate obtained above, compute the rate of fuel consumption per kilowatt hour, as follows:

$$\text{Pounds per kWH} = \frac{\text{Fuel Consumption}}{\text{kW Load}}$$

(5) Repeat test for each load condition specified.

(6) Determine the capacity of the generator set fuel tank in pounds of fuel.

(7) for each specified load test, compute the number of continuous ours the generator set will operate on a full tank of fuel. The following formula shall be used:

$$\text{Operating Hours} = \frac{\text{Fuel Tank Capacity (Pounds)}}{\text{Fuel Consumption (Pounds per Hour)}}$$

ALTERNATE PROCEDURE USING FLOWMETER.

Flowmeters may be used to determine the fuel rate. They usually are calibrated in either gallons per hour, or pounds per hour, for a fuel of a definite specific gravity and temperature.

(1) After stabilization has occurred record the fuel consumption rate, and continue to record the fuel consumption rate at one-half hour intervals for 2 hours.

(2) Determine the average of the readings (correct for fuel specific gravity and temperature). This is the fuel consumption rate and should be converted, if necessary, to pounds per hour.

(3) Using the average value obtained above, calculate the rate of fuel consumption per kilowatt hour.

(4) Repeat the test for each load condition specified.

(5) Determine the capacity of the generator set fuel tank in pounds of fuel.

(6) For each specified load test, compute the number of continuous hours the generator set will operate on a full tank of fuel. The

following formula shall be used:

$$\text{Operating Hours} = \frac{\text{Fuel Tank Capacity (Pounds)}}{\text{Fuel Consumption (Pounds per Hour)}}$$

c. Results. Compare the operating hours or the fuel consumption rate per kWH.

3.7 ONSITE TRAINING

****
NOTE: Delete video taping if not required.
****

Conduct training course for operating staff as designated by the Contracting Officer. The training period shall consist of a total [_____] hours of normal working time and shall 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 video taping service to be provided, and the kind and quality of the tape to be left with the Contracting Officer at the end of the instructional period.

b. The course instructions shall 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 shall demonstrate routine maintenance procedures as described in the operation and maintenance manuals. Two copies of a video tape of the [entire training session] [manufacturers operating and maintenance training course] shall be submitted.

c. Submit [six] [_____] copies of the operation manual (approved prior to commencing onsite tests) 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 system or subsystem. Sections shall be separated by heavy plastic dividers with tabs which identify the material in the section. Drawings shall be folded blue lines, with the title block visible, and placed in 216 by 279 mm 8-1/2 by 11 inch plastic pockets with reinforced holes.

d. One full size reproducible mylar of each drawing shall accompany the booklets. Mylars shall be rolled and placed in a heavy cardboard tube with threaded caps on each end. The manual shall 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 shall 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 shall include a CD containing an ASCII file of the procedures.

e. All operation and maintenance manuals shall be approved and made available for the training course. All posted instructions shall be approved and posted prior to the beginning date of the training course. The training course schedule shall be coordinated with the Using Service's work schedule, and submitted for approval 14 days prior to beginning date of proposed beginning date of training.

f. Submit [six] [_____] copies of the maintenance manual containing the information described below in 216 by 279 mm 8-1/2 by 11 inch binders having a minimum of three rings from which material may readily be removed and replaced, including a separate section for each item listed. Each section shall be separated by a heavy plastic divider with tabs. Drawings shall be folded, with the title block visible, and placed in plastic pockets with reinforced holes.

[(1) Procedures for each routine maintenance item.

][(2) Procedures for troubleshooting.

][(3) Factory-service, take-down overhaul, and repair service manuals, with parts lists.

] (4) A copy of the posted instructions.

(5) 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 specified for nameplates.

(6) Submit [six] [_____] complete reproducible copies of the final relay and protective device settings. The settings shall be recorded with the name of the company and individual responsible for their accuracy.

3.8 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. Any corrective action shall be verified for effectiveness by running the engine for 8 hours at Service Load, then re-examining 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.

3.9 POSTED DATA AND INSTRUCTIONS

****

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 genset enclosure or a switchgear cubicle (or other suitable enclosure).

****

Posted Data and Instructions shall be posted prior to field acceptance testing of the engine generator set. [Two sets of instructions/data shall be typed and framed under weatherproof laminated plastic, and posted side-by-side where directed. First set shall include a one-line diagram, wiring and control diagrams and a complete layout of the system. Second set of shall 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. 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. Instructions shall include procedures for interrelated equipment (such as heat recovery systems, co-generation, load-shedding, and automatic transfer switches).] [Two sets of instructions/data shall be typed in 216 X 279 mm 8-1/2 x 11 inch format, laminated in weatherproof plastic, and placed in three-ring vinyl binders. The binders shall be placed as directed by the Contracting Officer. The instructions shall be in place prior to acceptance of the engine generator set installation.

b. First set shall include a one-line diagram, wiring and control diagrams and a complete layout of the system. Second set shall 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. Instructions shall 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. Instructions shall include procedures for interrelated equipment (such as heat recovery systems, co-generation, load-shedding, and automatic transfer switches). Instructions shall be weatherproof, laminated in plastic, and posted where directed.

3.10 ACCEPTANCE

Submit drawings which accurately depict the as-built configuration of the installation, upon acceptance of the diesel-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 --