RECLAMATION
Managing Water in the West

Design Standards No. 6

Hydraulic and Mechanical Equipment

Chapter 18: Engine-Generator Sets
Phase 4 Final

U.S. Department of the Interior
Bureau of Reclamation

August 2017

Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Design Standards Signature Sheet

Design Standards No. 6

Hydraulic and Mechanical Equipment

DS-6(18) Phase 4 Final
August 2017

Chapter 18: Engine-Generator Sets

Foreword

Purpose

The Bureau of Reclamation (Reclamation) design standards present technical requirements and processes to enable design professionals to prepare design documents and reports necessary to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public. Compliance with these design standards assists in the development and improvement of Reclamation facilities in a way that protects the public's health, safety, and welfare; recognizes needs of all stakeholders; and achieves lasting value and functionality necessary for Reclamation facilities. Responsible designers accomplish this goal through compliance with these design standards and all other applicable technical codes, as well as incorporation of the stakeholders' vision and values, that are then reflected in the constructed facilities.

Application of Design Standards

Reclamation design activities, whether performed by Reclamation or by a non-Reclamation entity, must be performed in accordance with established Reclamation design criteria and standards, and approved national design standards, if applicable. Exceptions to this requirement shall be in accordance with provisions of *Reclamation Manual Policy*, Performing Design and Construction Activities, FAC P03.

In addition to these design standards, designers shall integrate sound engineering judgment, applicable national codes and design standards, site-specific technical considerations, and project-specific considerations to ensure suitable designs are produced that protect the public's investment and safety. Designers shall use the most current edition of national codes and design standards consistent with Reclamation design standards. Reclamation design standards may include exceptions to requirements of national codes and design standards.

Proposed Revisions

Reclamation designers should inform the Technical Service Center (TSC), via Reclamation's Design Standards Website notification procedure, of any recommended updates or changes to Reclamation design standards to meet current and/or improved design practices.

Chapter Signature Sheet
Bureau of Reclamation
Technical Service Center

Design Standards No. 6

Hydraulic and Mechanical Equipment

Chapter 18: Engine-Generator Sets

DS-6(18) Phase 4 Final
August 2017

Chapter 18 – Engine-Generator Sets is a new chapter within Design Standards No. 6 and includes:

- Design criteria that should be considered when sizing, derating, and installing engine-generator sets.
- Power types and ratings.
- Different fuel types and fuel system sizing criteria.
- Indoor and outdoor installations.
- Environmental considerations.
- Associated components.
- Testing requirements

Prepared by:

8/23/17

Rick Christensen
Mechanical Engineer, Mechanical Equipment Group, 86-68410

Date

Technical Approval:

8/23/17

Shaun Reed, P.E.
Mechanical Engineer, Mechanical Equipment Group, 86-68410

Date

Peer Review:

8/23/17

William D. McStraw, P.E.
Manager, Mechanical Equipment Group, 86-68410

Date

Security Review:

Ryan Stephen P.E.

5/16/2018

Ryan Stephen, P.E.
Mechanical Engineer, Mechanical Equipment Group, 86-68410

Date

Submitted:

5/16/18

William D. McStraw, P.E.
Chief, Electrical and Mechanical Engineering Division, 86-68400

Date

Approved:

T. A. Luebke

8/23/18

Tom Luebke, P.E.
Director, Technical Service Center

Date

Contents

Contents (continued)

Page

Chapter 18

Engine-Generator Sets

18.1 Scope of Chapter

This chapter identifies the design criteria that should be considered when sizing and designing an engine-generator (EG) set. An EG set should meet applicable National Fire Protection Association (NFPA), National Electrical Manufacturer's Association (NEMA), Underwriters Laboratory (UL), Federal, State, and local codes and regulations. An EG set consists of an EG system, a fuel system, and associated components. This chapter concentrates on stationary EG sets, which are the typical EG sets provided at Bureau of Reclamation (Reclamation) sites.

The EG system consists of at least an engine, an electric generator, an alternator, a governor, a starting system, an exhaust system, a heating/cooling system, and a control panel with indicators and alarms. The EG system should be sized to appropriately meet the design load requirements and environmental considerations. Environmental considerations, such as elevation and ambient temperature, can have a drastic impact on the derating of an engine, thus affecting the size of the system needed at the site. Other environmental considerations, such as weather conditions (snow depth, dusty winds, etc.), seismic factors, noise regulation, fire protection, emission regulation, and vandalism may also affect the type of equipment components selected, the location of the equipment at the site, and whether the EG set should be installed indoors or be an outdoor system with or without some type of weather-protective housing.

The fuel system should be sized to meet the requirements of the EG system running at full load over a predetermined minimum time duration. The fuel system consists of at least one fuel tank and the fuel piping system (natural gas systems do not require a fuel tank). Depending on the type of fuel, additional components and/or considerations will be required. For instance, a diesel fuel system may require both a main fuel tank and a day tank, or a sub-base fuel tank may suit the design needs. A Liquefied Petroleum Gas (LPG) system will require regulation of the fuel vapor pressure, may require a vaporizer system in cold climates, and can have the fuel piping buried or installed above ground.

18.2 General Considerations

18.2.1 Codes and Standards

EG sets should comply with the latest editions of the American Society of Mechanical Engineers (ASME), NEMA, NFPA, and UL; and all applicable

regulations and requirements of Federal, State, and local agencies having jurisdiction.

The latest editions of publications and standards listed here are intended as guidelines for design. They are mandatory only when specified in the text of this chapter or in applicable codes. The list is not meant to restrict the use of additional guides and standards. When discrepancies between requirements are encountered, Reclamation will determine the requirement. Codes and standards applicable to this chapter are listed below:

- American Society of Civil Engineers:[1]
  - ASCE 7-10: Minimum Design Loads for Buildings and Other Structures

- American Society of Mechanical Engineers:
  - ASME BPVC, VIII: ASME Boiler and Pressure Vessel Code, Section VIII – Rules for Construction of Pressure Vessels, Division I

- National Electrical Manufacturer's Association:
  - NEMA 250: Enclosures for Electrical Equipment (1000 Volts Maximum)
  - NEMA MG1: Motors and Generators

- National Fire Protection Association:
  - NFPA 20: Installation of Stationary Fire Pumps for Fire Protection
  - NFPA 30: Flammable and Combustible Liquids Code
  - NFPA 31: Installation of Oil-Burning Equipment
  - NFPA 37: Installation and Use of Stationary Combustion Engines and Gas Turbines
  - NFPA 54: National Fuel Gas Code
  - NFPA 58: Liquefied Petroleum Gas Code
  - NFPA 70: National Electric Code
  - NFPA 90A: Installation of Air Conditioning and Ventilating Systems
  - NFPA 110: Emergency and Standby Power Systems

[1] ASCE refers to the American Society of Civil Engineers.

- Underwriters Laboratories:
  - UL 142: Steel Aboveground Tanks for Flammable and Combustible Liquids
  - UL 2085: Insulated Aboveground Tanks for Flammable and Combustible Liquid

18.3 Design

18.3.1 General

The need for an EG set, the site-specific conditions (i.e., site location, site weather conditions including the ambient temperature range, site elevation(s), other environmental considerations, preferred fuels and their availability at the site, etc.), the reliability of the main power source (if EG set is not the primary power source), and the required power voltage(s) and phase(s) shall be identified as part of Reclamation's Design Data Request.

Discussions with designers responsible for the site layout and structures, the site's equipment, the site's distribution of the electrical power and controls, and the operational control requirements need to occur early in the design process and continue through the final design.

18.3.2 Equipment Sizing and Selection

To allow preliminary sizing of the EG set or sets, the site's equipment loadings will first need to be gathered and identified (both motor horsepower [hp] loads and resistive loads). The individual loadings will then need to be identified as to whether they are critical loads that the backup EG set may need to provide power for in the event of a normal power outage.

Final sizing and the derating of the EG set equipment should be made based on actual project conditions and requirements. Equipment from at least two different manufacturers of EG systems should be evaluated to determine that necessary requirements and availability are satisfied. The type of EG set primarily depends on the fuel source; however, the available size of the EG set for a specific fuel type may be limited.

After the equipment type and fuel size have been selected, final layout of the EG set should be determined. The layout and space allocation should ensure that the location of the equipment will meet NFPA requirements and that servicing the EG set will be practicable. The EG set servicing includes general maintenance, exercising, and fuel delivery.

18.3.3 Power Types and Ratings

EG sets may be rated as prime or backup. A prime EG set is used as the main power source when utility power is not typically available. A backup EG set can be rated for emergency loads, legally required standby loads, or optional standby loads as a backup to the main power source.

18.3.3.1 Emergency Loads

If a backup EG set will power a load that is classified as an emergency load, code requirements will give specifications for various EG set requirements, such as the speed at which the loads must receive emergency power. An emergency load is a critical load that is intended to provide public safety, such as to permit safe evacuation from buildings or to provide backup power to a fire pump for fire protection.

18.3.3.2 Legally Required Standby Loads

Similar to emergency loads, legally required standby loads are generally mandated by legal requirements for public safety, but they do not have all the stringent requirements that apply to emergency loads.

18.3.3.3 Standby Loads

Standby loads are not a direct life safety concern. If the EG set does not provide power to any emergency loads, it may be classified with a standby rating. This is the most common type of EG set used in Reclamation facilities, such as hydroelectric powerplants, pumping plants, intake structures, or dams. Common loads may be lighting, pump motors, gate operators, etc.

18.3.4 Fuel Type

18.3.4.1 Diesel

Diesel fuel is typically the preferred fuel type for EG sets at Reclamation sites. This is due to good performance, a simplified system, available fuel source, sites with higher elevations (altitudes) because the derating factor is smaller than for a liquefied petroleum gas (LPG) unit, and where special conditions may require an EG set to be located or fuel piping to run, which could be hazardous if a leak occurred. An EG set that is greater than 100 kilowatts (kW) will normally be a diesel EG set. Diesel EG sets are also available in sizes less than 100 kW.

No. 2-D grade diesel fuel is usually the recommended and standard fuel grade available for most sites. In cold climates, when ambient temperatures dip below freezing, grade 1-D fuel may be required. Heating the fuel or fuel tank may also be required with either fuel grade. A diesel-fueled EG set that will be installed in cold climates should typically be specified to run on both No. 1-D grade diesel fuel and No. 2-D grade diesel fuel, depending on the ambient temperature range and the fuel availability at the site.

Diesel fuel storage generally consists of a day tank, located adjacent to the engine, and a main fuel tank, located nearby. A sub-base fuel tank may be an option if the required quantity of fuel is low, such as an emergency-rated EG set, or if it is located at a facility with a reliable fuel source in close proximity. Due to the remoteness and accessibility of Reclamation facilities, this is often not the case.

Diesel fuel lasts approximately 2 years. If the main tank is larger than the amount of fuel that is used during regular exercising of the EG set, it may be necessary to add a microbicide to the fuel.

Unless the diesel-fueled EG set is relatively small (less than 30 kW), a resistive load bank should be provided to allow proper exercising of the unit. The resistive load bank will typically be sized to provide at least one-half the rated capacity of the EG set supplied.

Galvanized fuel lines, galvanized fittings and valves, or a galvanized fuel tank should never be used with diesel fuel systems.

18.3.4.2 Liquefied Petroleum Gas

Liquefied petroleum gas (LPG) fuel may be preferred if it is readily available to the site and the EG set is not too large. Commercially available, LPG-fueled EG sets are typically not larger than 100 kW; however, somewhat larger sizes may be obtained. A major benefit to LPG fuel is that it can be stored indefinitely. Also, an LPG-fueled EG set may not require a load bank for exercising (consult with EG set manufacturers to determine if a load bank is required for exercising). LPG-fueled EG sets will typically have higher derating factors than diesel EG sets, due to high ambient temperatures and high elevations which reduce the rated capacity of the EG set.

In colder climates, a vaporizer is usually required to ensure that the liquid in the fuel supply line is adequately heated, so only vaporized gas is delivered to the EG. Reclamation typically specifies a direct-fired type vaporizer.

Pressure regulators are required to reduce the pressure in the fuel line before it reaches the EG set; or for indoor units, before the fuel line is piped into the building. Relief valves are required on the fuel tank and in the fuel lines between any valves.

LPG-fueled EG systems need to meet NFPA Standard 58, Liquefied Petroleum Gas Code, requirements concerning the minimum distances required between the EG set, the fuel tank, the direct-fired vaporizer, the building, and the property lines.

18.3.4.3 Natural Gas

Natural gas may be used if it is readily available onsite, which is rare at Reclamation facilities. Commercially available, natural gas fueled EG sets are

typically not larger than 100 kW; however, somewhat larger sizes may be obtained. Natural gas fueled EG sets will typically have higher derating factors, due to high ambient temperatures and high elevations which reduce the rated capacity of the EG set.

18.3.4.4 Gasoline

Gasoline is typically not a suitable fuel for stationary standby EG sets, due to volatility and shelf life of the gasoline fuel; however, small EG sets operating on gasoline fuel are commercially available and can be used as part of a small, portable unit.

18.3.5 Location

18.3.5.1 Indoor

To locate an EG set indoors, it typically should have a separate dedicated room. The room should not be an interior room. The EG set room must have a fire resistance rating as specified by code requirements, which is typically a 1- or 2-hour minimum fire resistance rating. Coordination with the site and building designers, as well as the heating, ventilating, and air-conditioning (HVAC) designers, will be required to properly locate and size the room(s), doors, and the intake and exhaust louvers, and to determine whether site conditions may also require that dampers be provided with the louvers.

The room design should draw intake air directly from the outdoors and discharge the air directly outdoors. The EG set and the louvered intake (inlet) and outlet vent openings should be located within the room, so the air intake flows over the EG set and discharges out the opposite wall on the radiator end of the EG set. This process will allow heat removal from the room and adequate airflow for combustion and cooling of the unit (i.e., locate equipment and vents to prevent short-circuiting airflow). Most EG sets provided at Reclamation sites will be provided with a radiator mounted, fan cooling system; therefore, the ventilation involves large volumes of air (check EG set manufacturers' data sheets for ventilation/cooling requirements). The vent openings must be large enough to allow the required volume of air to flow at a given time. Reclamation typically uses the following air velocities for preliminary sizing of the gross area of stationary louvers: 375 feet per minute (ft/min) for the air intake and 550 ft/min for the air outlet. The airflow restriction for the room where the EG set is located should not exceed the maximum static restriction value listed in the technical information for the EG set (usually not to exceed 0.50 static pressure in inches of water). It will be necessary to check the needs and requirements of the ventilating/cooling system throughout the entire construction phase because there have been cases where a larger engine was provided, which required more airflow, so the louver sizes were not large enough.

For a LPG-fueled EG set installed indoors, NFPA Standard 58 requires that additional vent openings be located in each exterior wall, close to the floor. The bottom of these vents shall be not more than 6 inches above the floor, and the total of all these floor vent openings shall provide at least 1 square inch per square foot (in^2/ft^2) of floor area (see latest code requirements for any changes since this writing). Pressure regulators are required in the LPG fuel line to reduce the gas pressure before it enters the building.

The hot air duct between the EG mounted radiator (or load bank, if mounted to the radiator) and the air outlet (exhaust louver) should be self-supporting and provided with a flexible exhaust duct section to prevent transmission of vibrations from the EG set.

The engine exhaust outlet should be located as high as practical. The engine exhaust should be piped through an approved exhaust pipe thimble mounted through the room outer wall or roof and be directed away from the building intake vents and openings. A heat shield should be provided around the hot exhaust piping and muffler to prevent accidental burns in areas where personnel could contact the piping.

Provide adequate clearance (at least 3 feet) around the EG set (which may also include the load bank) for servicing and ventilation. When designing access into and out of the room, take into account the need for required installation, maintenance, and eventual removal of the equipment. The access door(s) may need to open inward, or they may be provided with louvers so they can still be opened when the EG set is running, which could create a negative pressure in the room.

Indoor fuel storage must be accessible and properly vented; in addition, it may have limitations as specified by code requirements. For instance, LPG fuel, as a liquid, is typically not permissible indoors; therefore, at Reclamation sites, the main LPG fuel tank is installed outdoors. Indoor storage of the diesel main fuel tank typically requires a separate dedicated room, as well as a type of secondary containment system, due to the potential for spills or leakage. The main fuel storage tank must be accessible for fuel delivery. The diesel fuel day tank will be installed next to the EG set and is provided with a type of secondary containment system. A secondary containment type system should also be provided for the diesel fuel piping.

18.3.5.2 Outdoor

An outdoor EG set is typically preferred for simplicity and economical installation. A weather protective, weatherproof, drop over, or a walk-in type housing or enclosure is typically required. The housing may also be designed to regulate noise, provide insulation, and supply heat. Colder climates typically require auxiliary heating devices (thermostatically controlled) for the fuel, battery, engine block, coolant, and, possibly, ambient air in the housing.

Main fuel tanks have typically been installed outdoors at Reclamation sites. The fuel delivery truck must have access to the fuel storage area. The fuel may be affected by colder climates. There may be requirements for certain types or additives for diesel fuel, and/or it may be necessary to switch from fuel grade 2-D to fuel grade 1-D as seasons change. Immersion heaters in the diesel main and day fuel tanks, or a heating blanket/pad with insulation, can also be provided around the main fuel tank. The main diesel fuel tank, diesel day tank, and the fuel piping must all be provided with a type of secondary containment system to prevent spills and leakage.

LPG systems may require that a vaporizer (Reclamation typically provides a direct-fired type vaporizer) be provided for sites with cold climates to prevent restriction of LPG gas flow to the EG set, which would affect its operation. Protective housings or enclosures are typically provided around the vaporizer and around the pressure regulators.

18.3.5.3 General Locations and Spacing of LPG Equipment

Whether indoors, outdoors, or a combination of both, spacing of the LPG equipment must meet the applicable rules and regulations of NFPA Standard 58. This standard provides the minimum spacing required between each of the following: fuel tank (varies with tank capacity and the number of tanks), fuel tank shutoff valve, relief valve, fuel transfer point, vaporizer, building (includes the building intakes and external sources of ignition, such as compressors, AC window units, and open flame units), EG set or other ignition source, and the property lines.

18.3.6 EG Sizing

When sizing the EG, consider all relevant loads, both resistive loads (such as lights, heaters, controls, etc.) and equipment motor loads (hp). The individual loads should be identified with their associated voltage and phase. It will be necessary to coordinate with the electrical design engineers and the designers who specify the equipment for the job to obtain these loads and to determine how the equipment will be operated, whether any loads are critical for fire protection or life safety, whether any of the motors have reduced voltage motor starting capability (soft-start, etc.) and/or delayed start capability, and whether the equipment will be operated by a standby EG set, by an emergency EG set, or by multiple EG sets. Note: At Reclamation sites, when standby power is provided, it is typical that not all loads will need to be operated by the EG set (i.e., the site may have eight radial gates, but the equipment operational requirements may require the EG set supply power to operate only two gates at a time).

In addition, for EG sizing, the timing sequence for starting and operating the motors must be considered. The starting sequence may range from stepped loadings to starting all loads at once. The progressive totals of the accumulated load and the incoming motor's running load will show the continuous kW and

kilovolt-amperes (kVA) demand after each motor is running. In addition, the progressive totals of the accumulated load and the motor's starting load will show the maximum kVA demand during the time each motor is starting. The operational case where the timing sequence starts all loads at once will result in the largest startup loading and thus the largest EG set required. Note: Multiple EG manufacturers have programs that can assist the designers in sizing the EG set based on the provided loads, starting and operating sequences, the fuel type, the site elevation, and the ambient temperature range. The generator set selected must have the capacity of supplying the maximum load during starting for each motor and continuous load when the motors are running.

To determine the minimum, required, commercially available EG size, the derated load values from the EG set manufacturers' data sheets must be larger than the required calculated continuous state running loads and the maximum starting peak loads. Site-specific conditions, such as high ambient temperature and high elevation, can each derate the engine power and generator capacity of the EG set. The derated values for diesel EG sets, LPG EG sets, and natural gas EG sets are usually not the same. In view of this, exercise caution when the design designates switching to an EG set with a different fuel type, or when one type of EG set is compared to another type. The derating values can usually be found on the EG manufacturers' data sheets and are specific for their commercially available EG set. Note: Different manufacturers may have different derated values, even though the same fuel type is used, because they may be using different engines for their commercially available EG set.

18.3.6.1 Voltage

The voltage rating of the EG set is typically determined by the application for which the EG set is to be used and where in the electrical system it is connected. The most common voltage for standby EG sets at Reclamation facilities is 277/480 volts alternating current (VAC) (three-phase, 60 hertz), although other voltages are sometimes required.

18.3.6.2 Phase

Single-phase and three-phase EG sets are generally available from manufacturers. Reclamation's EG sets are typically three-phase, due to the present or future need to power three-phase motors. In general, single-phase EG sets are rated with a 100-percent power factor, and three-phase EG sets are rated with an 80-percent power factor.

18.3.7 Fuel Tank Sizing

The sizing of the main diesel or LPG fuel storage tank is based on the size of the EG set and the minimum amount of run time required to operate the EG set at full load before it is necessary to refill the tank. After the size of the EG set has been determined, the fuel consumption at full load can be obtained from

manufacturers' data sheets. The minimum amount of run time required for sizing the fuel tank is typically 36 to 48 hours, depending on the availability of fuel, the proximity of the site from the fuel supply source, and the accessibility of the site. For special situations, usually requested by the client, a 24-hour run time may be used for sizing the main fuel tank. For a diesel day tank, the capacity should typically provide at least 2 hours of run time. LPG fuel tank sizing may also depend on the minimum ambient temperature. A low minimum ambient temperature will typically require a separate vaporizer (usually direct-fired type vaporizer) to maintain the required fuel vapor and pressure at full load. An alternative can be to provide a much larger LPG tank; however, at cold temperatures, the tank size can be impractically large.

18.3.8 Environmental Considerations

18.3.8.1 Noise Regulation

Select and specify the type of exhaust muffler/silencer (industrial, residential, or critical type of muffler) that will meet site location requirements (present and future). For outdoor installations, the weather protective housing can have variable levels of sound attenuation. Additional sound attenuation is typically included when the EG set will be in close proximity to the public. Sound attenuation can add significant cost and increase the physical area required to install the EG set.

18.3.8.2 Emission Regulation

Federal, State, and local regulations concerning emission control and permitting requirements should be identified in the Design Data Request for the specific job. There are different regulations depending on the classification of the EG set. Emergency EG sets are typically exempt, whereas prime EG sets can have more regulations than standby units. Some States may require that an ultra-low sulfur diesel No. 2 fuel be used for diesel EG set installations and/or may prefer that LPG systems be provided if the EG set size allows the use of this fuel.

An electronic governor can be provided with the electronic fueling system to accommodate the demand and regulation requirements that will increase fuel efficiency, result in lower exhaust emissions, and allow the EG set to recover more quickly from transient load steps than would be possible with a mechanical governor.

18.3.8.3 Fuel Storage

Fuel storage must comply with applicable rules and regulations of NFPA 30, NFPA 37, NFPA 54, and NFPA 58, as well as meet all prevailing Federal, State, and local codes governing the specific type of installation. Regardless of code requirements, Reclamation's present policy is to not bury fuel tanks for EG sets of any fuel type. Note: In the past, some LPG tanks have been buried due to site constraints.

Diesel fuel storage tanks are to be aboveground, double walled, steel fuel tanks; or they can be aboveground, single steel walled, with outer secondary containment system. The diesel fuel tank should be provided with lifting lugs, a leak detection/monitoring system, vent piping (normal, emergency, and interstitial vent piping), overfill/spill protection and containment system(s), fuel supply (withdrawal) and return lines, drain line, a fuel level indicator, manual shutoff valve, and all other components to make a complete fuel system.

LPG fuel storage tanks are aboveground, steel tanks that are designed, fabricated, tested, and stamped (with the official ASME code symbol) in accordance with the requirements of ASME BPVC, VIII. The tank will typically be provided with (but not limited to) the following features: lifting lugs, hinged dome cover with padlock, pressure relief valves, service valve, float gauge, fill valve, vapor withdrawal/return tank connections, liquid withdrawal tank connection, excess flow valves, manual shutoff valves to isolate fuel lines, a pressure gauge, and drain plug. Note: These may all be provided separately, or some may be combined in a multi-valve system. The primary (1^{st} stage) pressure regulator may also be provided at the tank in the vapor withdrawal line (if the vaporizer is not required). The discharge of the pressure relief valves should be vented to the outside air. The maximum allowable working pressure (MAWP) for the LPG tank shall be in accordance with the requirements of the latest NFPA 58 (the code presently requires the MAWP to be 312 pounds per square inch or higher). The LPG tank should not be completely filled with liquid (see requirements of tank manufacturer concerning maximum fuel limit, as well as NFPA 58 code requirements).

Provide fuel tanks with saddle supports or support feet, and with earthquake restraints.

It is Reclamation's policy to not bury diesel fuel piping. Diesel fuel piping should be provided with a secondary containment system (including a leak detection system) between the main fuel tank and the day tank located next to the EG set.

Presently, LPG piping can be installed aboveground and/or buried; however, the latest Federal, State, and local regulations should be checked and followed. If LPG fuel piping is buried, it should be below the frost line, designed for vehicular loads at the site, provided with a continuous length of zinc ribbon anode installed parallel to and approximately 3 inches from each buried fuel line, and buried with a warning tape located approximately 12 inches above the fuel piping.

18.3.8.4 EG Set for Fire Protection

Code requirements typically require a backup power source for fire protection loads. An emergency or legally required standby EG set may be chosen or required to meet these code requirements. Battery backup power may meet some code requirements, such as alarms. Other loads, however, such as a fire pump

motor, will typically require an emergency rated EG set. Due to stringent code requirements for an emergency rated EG set, it may be cost effective to have a dedicated EG set for emergency loads and a standby rated EG set for all other loads.

The maximum voltage drop during starting and operating a fire pump controller line cannot be greater than required by NFPA 20, Standard for the Installation of Stationary Pumps for Fire Protection.

18.3.8.5 Vandalism

Reclamation facilities can often be located in remote areas; as a result, vandalism can occur to varying degrees. To mitigate issues with vandalism, the following items should be considered during design: bullet-resistant and/or fire rated diesel fuel tanks (steel or concrete encased), tamperproof nuts and bolts to secure both the EG set and fuel tank down, walls built around the EG set, walls built around the LPG fuel tank, or a dedicated EG set room or building.

18.3.9 Associated Components

18.3.9.1 Circuit Breaker

EG systems should be provided with main line circuit breakers or other forms of overload protection and means of disconnection.

18.3.9.2 Transfer Switch

A manual or automatic type of transfer switch will be provided with the EG set. Automatic transfer switches are typically used for emergency and standby EG sets. The automatic transfer switch monitors the main service power and, when power is interrupted, will send a signal to start the EG after a preset start time delay. This start time delay prevents startup during momentary utility disturbances. After startup, the EG set is allowed to reach a stable running speed (using a preset transfer delay) before transferring the load to the EG set. The automatic transfer switch monitors for the return of proper voltage of the main service power and provides a retransfer delay that allows the utility to stabilize before the load is retransferred back. The automatic transfer switch provides a stop delay that maintains the generator set for immediate reconnection if the main service power source fails shortly after retransfer, and to also allow gradual generator set cool-down by running with no load before shutdown. The automatic transfer switch may also be used to control and run the exercise cycle for the EG set. If the main service power is interrupted during exercising, the automatic transfer switch would terminate the exercise cycle before switching to the automatic controls that start and transfer the load to the EG set.

A manual transfer switch may be provided where the EG set is the only power source or where local, manual control of the equipment at the site is the normal operating procedure.

18.3.9.3 Control Panel

The EG set will be provided with an electronic control panel with solid-state circuitry, and vibration isolators between the control cabinet and the EG set. The control panel should provide at least the following: a mode selector (typically labeled OFF-MANUAL-AUTO), emergency stop pushbutton or switch, fault reset switch, indicators, alarms (alarm lamps and contacts), cranking controls, shutdown controls, and frequency and voltage regulation. Reference NFPA 110 for minimum annunciation required for critical life safety and emergency/standby requirements.

18.3.9.4 Starting System

Batteries and the battery charging system need to be provided for starting the EG set and for the EG set controls. The battery system consists of a battery or batteries, battery cables, battery storage rack, and battery charger. The required battery system capacity (usually a 12-volt or 24-volt system) depends on the size of the EG set and is typically shown on the manufacturers' data sheet for the specific EG set. The batteries should be located as close as possible to the EG set to minimize the starting circuit resistance. The battery charger should be powered by the normal electric power source. The EG set alternator should recharge the batteries and provide DC power for the control system when the EG set is running.

Lead-acid type batteries are typically selected for EG sets at Reclamation sites because they are more common and are relatively economical. Nickel-Cadmium (NiCad) batteries can be selected where extreme high or low ambient temperatures are expected. NiCad batteries are more expensive, may have a longer service life, but disposal can be difficult because the battery materials are considered hazardous.

18.4 Installation

18.4.1 Foundation

Typically, the EG set is secured to a customized concrete slab or existing concrete deck capable of supporting the equipment. The foundation should be flat and level, especially for EG sets with sub-base fuel tanks; however, it is possible to add steel supports to achieve proper support. Grout is typically used for final leveling of the EG set. Three to five feet of clearance all around the EG and fuel system is typical for maintenance.

18.4.2 Anchoring

Reclamation practice is to secure the EG and fuel tank to the foundation with expansion anchor bolts. Epoxy anchor bolts are not preferred because they may vibrate loose over time.

18.4.3 Seismic Criteria

Use the site class, assigned seismic user group, building category, component importance factor, component response modification factor, component amplification factor, short period response acceleration factor, and one second period response acceleration factor all in the required calculations to determine the extent of seismic restraint that is required by the project. These values will typically be obtained from the structural engineer for the site work, or they may be obtained from ASCE 7-10.

18.4.4. Vibration Isolation

Provide vibration isolators that reduce vibrations transmitted from the EG set base frame to the foundation to help maintain the integrity of the EG set and the foundation. For EG sets with sub-base fuel tanks, the vibration isolators are typically between the sub-base tank and the EG set base frame.

Other vibration isolation features include flexible fuel lines for connecting to the EG set, flexible air duct between the radiator (or from the resistive load bank) and the hot air exhaust duct (if indoors) or the weather protective housing (if outdoors), flexible exhaust connector between the EG set and the engine exhaust pipe, and vibrational isolators between the control panel and the EG set.

18.5 Testing

18.5.1 Factory Testing

Tests should include a full load test and cycle crank test, conducted and documented per NFPA 110. Additionally, vibration tests should be conducted at 50, 75, and 100 percent of the EG nameplate rating, documenting the vibration at each load on the main frame, engine, generator, and associated components. If vibration exceeds the specified tolerance, the component must be balanced or provided with vibration isolators to reduce vibrations to an acceptable level prior to shipping in order to ensure the longevity of the system.

18.5.2 Field Testing

Perform mechanical, electrical, and operational tests to confirm that equipment meets specification requirements and applicable codes, standards, and regulations. Conduct onsite test and document per NFPA 110.