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OPERATING INSTRUCTIONS

GENERATING STES

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1. Safety Precautions

Before operating any generator system, read carefully this manual to become familiar with your equipment. Safe and efficient operation can only happen if the equipment is properly operated and maintained.

No generator manufacturer or installation contractor can anticipate every potential hazard involved with the installation and use of these type of systems. The warnings, decal and labels attached to the equipment and used in this manual can not cover all hazards. Use of methods or procedures other than those recommended by the equipment manufacturer must satisfy you that it is safe for you or others to follow.

The following symbols are highlighted to alert you of conditions that are potentially dangerous to the operator, installation / service / repair personnel, or the equipment.

1.1. General Safety Precautions

DANGER — *This symbol warns of hazards which will result in severe or lethal personal injury.*

WARNING — *This symbol refers to a hazardous or unsafe practice which has the potential to result in personal injury or product / property damage.*

CAUTION — *This symbol warns of immediate hazards which will result in severe or lethal personal injury.*

- Keep equipment clean and properly maintained. Normal maintenance and servicing of equipment is a prerequisite to a functional, safely operated machine.
- Use common sense, read the instructions and information in this manual carefully, and check for other local safety rules that require compliance.

1.2. Installation Precautions

- Be safety conscious. Read all operational, safety and installation information before attempting to install or operate any generator equipment.
- This equipment should be installed, operated, serviced, and repaired by qualified personnel only. The installation and interconnection of this equipment to facility wiring and other equipment must be done by a competent, qualified craftsperson who is familiar with applicable standards and codes governing the installation.

- Installation methods, practices, or procedures that are unauthorized or done improperly are dangerous and could result in serious personal injury or damage to property and equipment.
- Installation, operation, servicing and repair of electrical power generators and their related equipment must be done in accordance to applicable codes, standards, regulations and laws.

- Before start up perform all the verifications described in section 7 of this manual. They prevend accidents or equipment damage.
- Get familiar with the motor and alternator control devices as well as with the emergency stop procedure of the gen-set. Do not allow access to this equipment to people not familiar with it.
- Do not allow access of children or animals near the running equipment.
- Inadequate operation exposes you to electric shocks; do not touch the gen-set with wet hands.
- Connection to a mains network will be performed only by a qualified electrician and needs the approval of the electric energy supplier. Protections against residual current shall be ensured by separating the two circuits with an independent circuit breaker. An incorrect connection to the mains can lead to current leaks into the network. This in turn can lead to electric shocks to the service personnel working on the network. There is also danger of explosion or fire in the alternator or the cables connected to it when the current returns to the mains.
- Any modifications to the gen-set need the **written** agreement of the manufacturer and will be performed only by a qualified electrician.

WARNING ***FUEL AND FUMES ARE FLAMMABLE.*** *A fire or explosion could result from violation of recommended practices or procedures*

- An open flame, smoking, or welding near a generator is a potential fire hazard. Internal combustion engine fuels are flammable.
- Ensure all fuel fittings are properly connected and not leaking. Periodic inspection is required to ensure no leaks develop over time.
- Fuel connection at the engine should be made with an approved flexible fuel line. Use of copper piping for flexible lines is not recommended as copper work hardens and becomes brittle.
- Never fill fuel tanks while the engine is running, unless tanks are outside the engine room. When fuel comes in contact with a hot engine or exhaust system, there is possibility of a fire or explosion.
- Under certain conditions storage batteries will expel explosive hydrogen gas. Do not allow smoking, welding or sparks in the vicinity of any storage battery. Adequate ventilation must be provided around batteries. Battery racks must also be grounded to minimize static charges.

DANGER ***EXHAUST GASES ARE LETHAL***

- Ensure the exhaust system is installed properly and adequate ventilation is provided. Exhaust gases must be safely piped away from the unit to an area not used by people. The engine consumes oxygen and the exhaust given off by the engine contains carbon monoxide gas. Carbon Monoxide is a deadly, lethal gas.
- The installation must have adequate ventilation.

DANGER ***MOVING PARTS CAN KILL***

- While equipment is running, stand clear of moving parts.
- When in service certain automatic start units are capable of starting at anytime. Disable control and power switches before maintaining, servicing or repairing these units.

- Before starting work on a self-starting generator, disconnect the starting battery. Disconnect the negative (-) battery cable first to prevent accidental shorting.
- Ensure all fasteners are secure. Tighten hardware and keep all guards in position over fans, impellers, or other moving parts.
- If adjustments must be made while the unit is running, use extreme care around moving and hot parts. Hot parts include engine and exhaust system, muffler, pipes, flexible exhaust pipe section, etc.

⚠ **WARNING** ***ELECTRICAL SHOCK CAN CAUSE SEVERE INJURY OR DEATH***

- Wire gauge sizes of electrical wiring, cables, and facility circuits must be of sufficient size to handle the maximum electrical current (ampacity) of circuits. Refer to generator system's User Manual to determine appropriate cable/wire size.
- Remove electrical power before removing any generator's protective panels or touching any electrical components.

2. Gen-sets installation

The location for a generator is dependent on applicable codes and associated support systems for the generator such as ventilation, wiring, fuel, and exhaust.
The following factors should be considered:

- The ideal location for any generator is away from extreme ambient temperatures and where the generator is protected from adverse weather conditions. It is recommended that generator be as close to the load it is supporting as possible.
- Place the working gen-set at least 1 m away from buildings or other equipment.
- Place the gen-set on perfectly even ground. Running of the motor in a slanting position determines its faulty greasing, seize up and loss of warranty.
- The structure the Gen-Set (Generator Set) will be set upon must be strong enough to support the weight of the Gen-Set, it’s auxiliary equipment, and other equipment mounted on the structure.
- The structure must meet a 1 hour non-combustion fire rating.
- The installation site must be clean, dry and not subject to flooding.
- Do not use the gen-set if exposed to bad weather conditions. Always keep it in a dry place.
- Because of excessive ambient temperatures associated with the use of stand-alone metal sheds from exposure to sunlight, a concrete pad with a supported roof and an outside security enclosure (fence) to protect the unit from vandalism, birds, rodents, and other small animals is recommended.
- The Gen-Set generates heat while running. Installing the Gen-Set in a tightly enclosed building or shed is not recommended. The site must provide for adequate cooling and ventilation with a minimum of duct work. Adequate ventilation for a generator is specified in cubic feet per minute.

- The site must permit engine exhaust gases to be piped away to an area that is uninhabited by people or animals. Care must be given to ensure that exhaust gases do not re-enter an occupied area.
- The site must provide adequate acoustical noise and vibration isolation.

- The outside site must provide access to the generator to allow for maintenance, service, and repair. A 1 meter service clearance around the unit is recommended.
- Fuel supply and ease of refueling must be taken into consideration.
- Adequate normal and emergency lighting must be provided in any installation.
- When mounting a generator outside on a roof or next to a building the generator must be at least 1 m from any combustible wall and 1,5 m from any opening (i.e. doors, windows, vents, & ducts).
- The foundation for the generator must support the total weight of the generator. This includes fuel, oil, and the weight of any associated support systems.
- When calculating the floor loading, ensure the fuel weight, cooling system fluids (where applicable), piping, pumps, power cables / runways and supporting structures are included in the calculations. Most user's manuals do not include the weight of the fuel tanks since most are sold less tank.
- Optional vibration isolators beyond those already built in the generator also help reduce transmitted noise, however, it is recommended that one verify that the generator manufacturer recommends the use of an isolator.
- Insulation must be a non-combustible material, typically a Fiberglas mat.
- Air cooled unit draws cooling air from different ends of the unit to cool the system, dependent upon the units cooling system design. Check with the generator's manufacturer to determine the optimal cooling method for the system. Factors such as climate and direction of prevailing winds must be considered in an outdoor installation.
- If your generator is expected to be in temperatures lower than -20^{o}F(-29^{o}C) consult the generator sets factory, a cold weather package may be required.
- Where strong prevailing winds are anticipated, face the engine end away from the wind.
- Plan the installation carefully to prevent the cooling air vents on the generator from becoming clogged by leaves, grass, snow, etc.

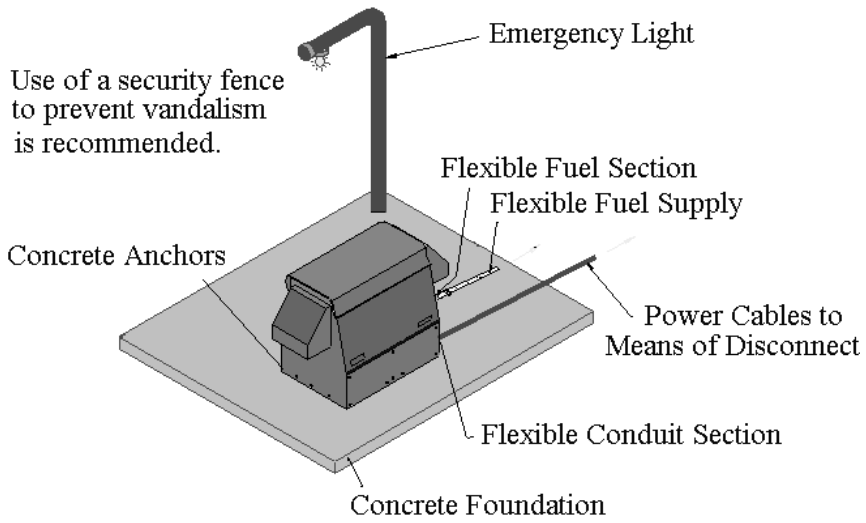

Figure 1 . Typical Outside Small Generator Installation

When a generator is installed and operated in an indoor environment, adequate ventilation for heat dissipation and combustion is required. Ventilation is typically

done through the use of an air inlet, air outlet / exhaust fan, and / or other ventilation openings.
The following rules apply:

- When ever possible, face the generator air inlet openings away from the wind. The wind can prevent the air intake louver from opening on start up.
- The air inlet must be capable of moving enough air through the room to provide the correct minimum CFM (cubic feet per minute) cooling for generator as specified by the generator's manufacturer. (This means the generator's air inlet opening size will be greater than the generator's room exhaust fan outlet.)
- Locate air inlet, ventilation and air outlet openings in a structure so that already exhausted air will not be drawn back into the building.
- Louvers, screening, expanded metal and other materials used to cover air openings are a restriction to air flow. This restriction must be compensated for by making the air opening size proportionally larger.
- When possible, position the engine end of air cooled generators in line with the air inlet per the manufacturer's recommendation.
- When possible, position liquid cooled engines with the engine end in line with the exhaust outlet per the manufacturer's recommendation. The reason or this recommendation is that the air moving through a liquid cooled system is typically pulled past the engine and through the generator's radiator. The generator's radiator is placed so that the air is ducted out of the generator's room.

Some indoor installations may require the use of one or more exhaust fans, to provide adequate ventilation during generator operation.

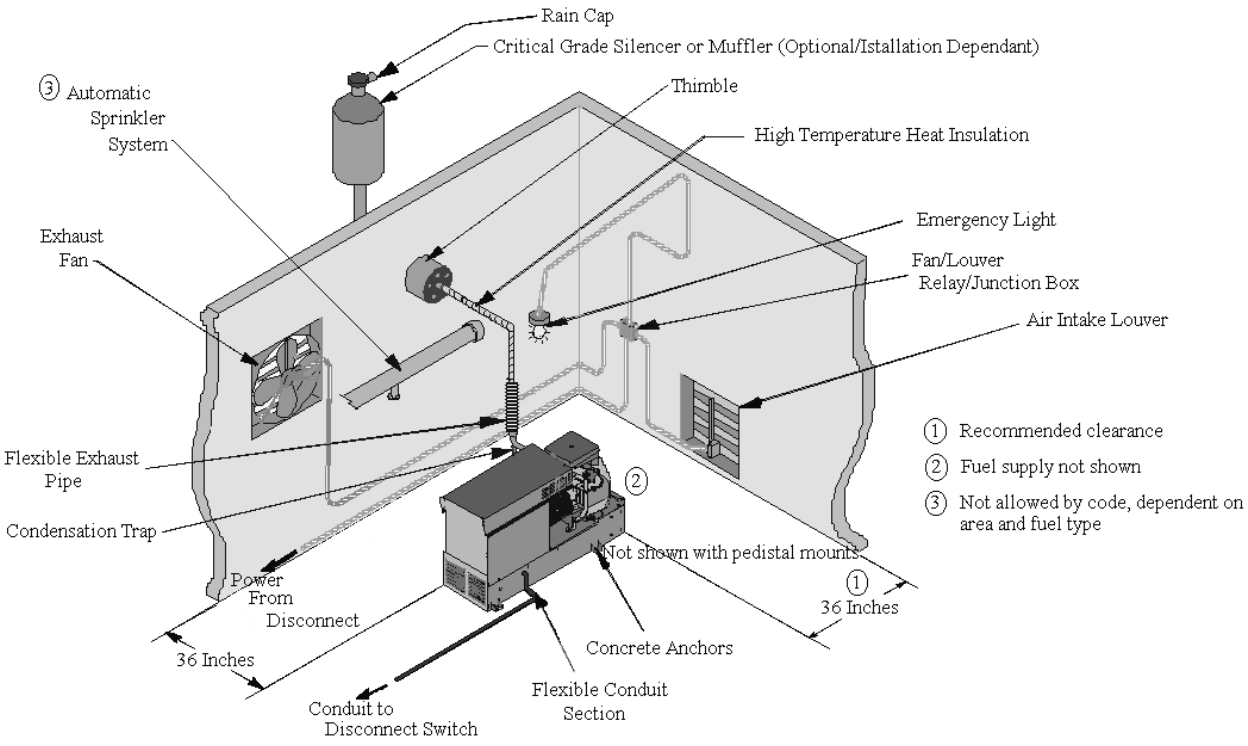

Figure 2. Typical Small Generator Indoor Installation

The following rules apply:

- Exhaust fans must have the proper capacity for the specific application. In addition, the fans must be located so that engine exhaust gases will not re-enter the building.

- Power is required to operate the exhaust fan. Typically, AC is provided from an DC/AC inverter or UPS to operate the exhaust fan and open air inlet louvers.

The engine cooling fan moves a large volume of air during operation. This heated air must be expelled to the outside of any structure housing a generator.

The following rules apply to the ducting of heated engine air out of a building:

- Whenever possible, use no ductwork at all. Simply position the inlet air duct so that air will be drawn directly over the generator and expelled horizontally to the building exterior (outdoors).
- If duct work must be used between the generator installation location and the building air outlet opening, keep such ductwork as short as possible with a minimum number of bends.
- Construct air outlet duct work of self-supported sheet metal.
- Never locate the air outlet opening of a structure close to adjacent buildings or walls as noise is amplified when air is expelled in large volumes.

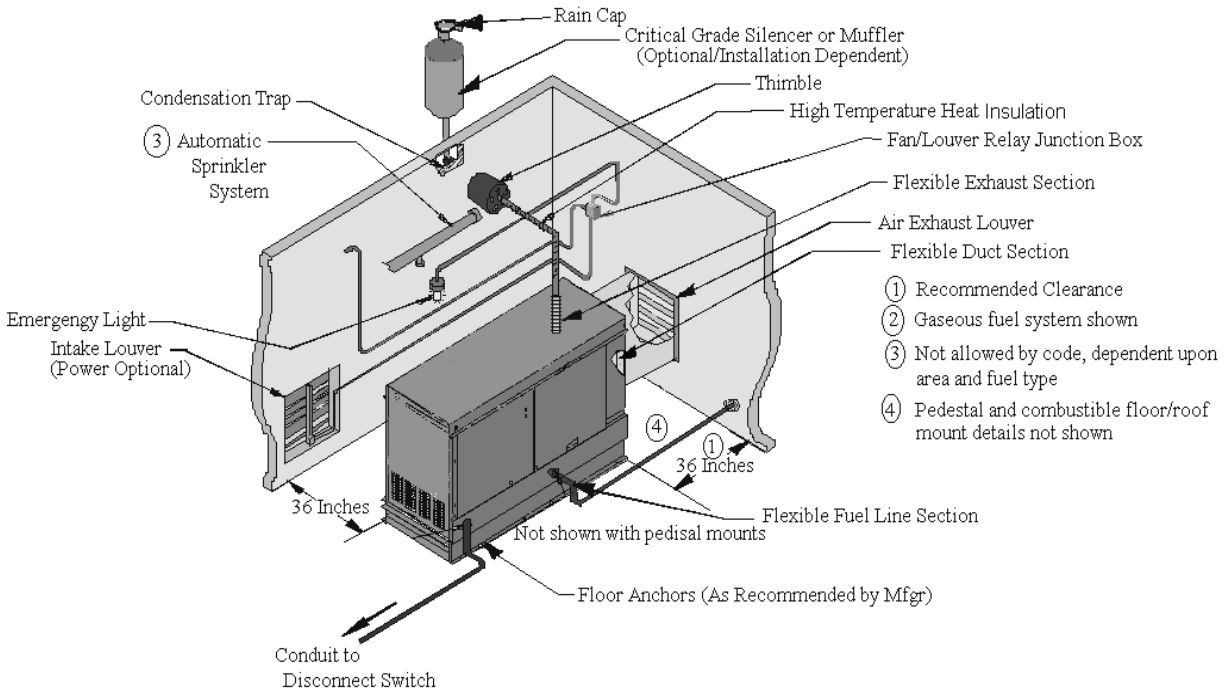

Figure 3. Typical Indoor Larger Generator Installation

Roof mount radiators on liquid cooled units is sometimes done where the installation location of the unit can not dissipate the heat generated by the unit during operation. Roof mount radiators is beyond the scope of this publication.

When louvers, screening or expanded metal are used to cover air openings in buildings housing generators, consideration must be given that these materials do not restrict the free flow of cooling air. Any restriction must be compensated for by making the actual opening size proportionately larger.

Louvers: Either fixed or movable louvers may be installed on the air openings in a structure that houses a generator. The installer must make sure that the total square inches of free air inlet opening is sufficient to limit the heat rise in the room to prevent the room temperature from exceeding the generator 's operating temperature.

Find the actual free air opening as follows:

- Multiply the height of a single louvered opening by its width, to find the opening area of one louvered opening.

- Multiply the opening area of the single louvered opening by the total number of louvered openings to find total free air inlet area.

Screening and expanded metal may be used to cover air inlet and outlet openings in a structure that houses the generator. These materials also offer a restriction to the free flow of cooling air, which must be compensated for by making the actual air opening in the structure proportionally larger. Screening and expanded metal are usually assigned a "free air inlet area" value by the manufacturer, which is given as a percentage.

To find the actual size of the air inlet opening needed, proceed as follows:

- Find the area of the generator's inlet air duct, by multiplying the air duct height by its width.
- Divide the inlet air duct area by the percentage of free air inlet area for the particular screening or expanded metal to be used. The result is the required size of the air inlet opening in the building.

Example 1: If the required inlet air opening area on a particular generator is 400 square inches and the building air opening is to be covered with screening having a 70% "free air inlet area":

Divide 400 square inches by 0.70, to obtain 576 square inches. Actual air inlet opening size in the building should be equal to or greater than 576 square inches. (An opening that measures 24 X 24 inches (576 square inches) would be adequate in this case to achieve the required 1125 Cu. ft/minute (31.86 Cubic Meters/Min.).

Example 2: The required inlet air opening area on a particular generator is 500 square inches and the building air opening is to be covered with screening having a 70% "free air inlet area":

Divide 500 square inches by 0.70, to obtain 714 square inches. Actual air inlet opening size in the building should be greater than 714 square inches. (An opening that measures 27 X 27 inches (729 square inches) would be adequate in this case to achieve the required 2000 Cu. ft/Minute (39 Cubic Meters/Min.).

3. Fuel

3.1. Gasoline

For gasoline egine generators, Unleaded or Regular gasoline with a lower octane rating than 85 may cause pre-detonation (knocking) which can damage the engine. Regular gasoline can be used, however, unleaded gasoline is preferred because it reduces pollution and combustion chamber deposits. See the generator's engine owner's manual for fuel information or contact the generator set's manufacturer.

WARNING ***ENGINE FUEL*** *can cause fire or explosion.*

- Do not operate the engine without the cranking battery connected.
- Do not disconnect the cranking battery while the engine is running.
- Stop engine by turning the Key Switch to OFF before checking oil or adding fuel.
- If fuel is spilled, clean up immediately and dispose of contaminated materials properly.
- Do not refuel if engine is hot or running.
- Do not refuel near sparks or open flame.
- Do not smoke while refueling.

- Do not fill fuel tank to the top; allow room for expansion.

- Fuel consumption varies from one engine to another. Different brands of fuel, operating conditions, condition of engine, etc., also affect the fuel consumption.

 CAUTION ***POOR QUALITY, LOW OCTANE FUEL*** *can damage the engine.*

IMPORTANT:

- Use clean, fresh, unleaded gasoline with at least 85 octane rating.
- Do not mix oil with the gasoline.
- Do not use gasohal or gasoline alcohol fuel blends.

3.2. Gaseous Fuels

Typically on LP Gaseous or Natural Gas powered unit the unit will run on either vaporous fuel source. Most gaseous fuel units are set up for a specific number of ounces of line pressure (a.k.a. as a corresponding number Inch Water Column) with some type of threaded pipe hook up. Note: Use of gaseous fuels decrease the amount of total power the generator is capable of producing by as much as 20 percent, dependent upon thermal content of fuel in your specific area. Refer to Section 8 for Gaseous Fuel Systems.

3.3. Diesel Fuel Piping and Filtration

The basic requirements of a diesel engine fuel system are adequate piping, proper selection of filters for the application and completely air-tight joints, with a minimum number of fittings to prevent air from entering the fuel lines, especially in installations where the fuel tank is lower than the pump.

3.3. A. Piping to the Tank
Vacuum at the transfer pump inlet must be avoided. If an auxiliary pump is used, pressure at the transfer pump must not be less than 0 p.s.i. nor greater than 5 p.s.i.(typical). Pressure after the return line connector assembly must not exceed 5 p.s.i. unless called for in the pump or system specification.
NOTE: The return line must never be piped back to the transfer pump inlet side. Both supply and return line should be connected to standpipes in the tank with the opening for each 2 inches minimum from the bottom of the tank to allow space for water and sediments to settle and to eliminate siphoning problems.
3.3.B. Filter Requirements

1. A pleated paper type filter with large area and minimum pressure drop capable of filtering out 75 - 80% of five micron particles should be used. A Master Filter is recommended since it provides sufficient area for long life and two stage filtration for maximum protection.
2. Where water in the fuel is known to be a problem, a Master Separator is recommended. Contact the generator manufacturer for a recommended filter.

3.3.C. Maximum Pressure Drop
Pressure drop across clean filters should not be more than 2.5 inches of mercury (1.2 p.s.i.) at full load. Pressure drop in the supply system exceeding 10 inches of mercury (4.9 p.s.i.) because of dirty filters or other restriction usually will affect pump and engine performance, (erratic operation, low power, engine stall).

3.4. Fuel Consumption

Fuel consumption is typically specified in the generator's user manual and is specified in a quantity of fuel consumed per hour based on a specified load. Refer to the generator's user manual for expected fuel consumption, which is based upon a specific load. While the generator's manufacturer may not be able to predict the consumption for your site because of the differences in the typical load, by site, an estimate a full load is typically given.
A simple fuel consumption model that is a "ball park" predictor of fuel consumption is as follows:
Based on experience, a generator at no load typically uses about half of the fuel of a generator at full load. The ratio of output power from a generator to the amount of fuel consumed is almost linear. Consumption on diesel fueled generators is somewhat less than gasoline.
Fuel Consumption = (Estimated Load/Maximum Generator Power Output) X .5 X Maximum Fuel Consumption + 50% of Maximum Fuel Consumption
Assuming Maximum fuel consumption = 1 Gallon/Hour
Minimum fuel consumption = .5 Gallon/Hour
At a 50% load, Fuel Consumption = (((50 Amps/100 Amps) X .5 Gallon) + .5 Gallon) = (((.5) X .5) + .5) = .75 Gal./Hr.
Other factors that need to be taken into account are the temperatures of the areas where the fuels are stored are as follows:

- Diesel gels at lower temperatures. It is advisable to use the lowest temperature rated fuel all year around. The reason for this is that the generator will typically run only at scheduled maintenance test times. If higher temperature rated fuel is used, by time the lower temperature fuel is put into the tank, the fuel blend will be less than desired at the time you need the lowest temperature rating.
- Use of LP is a problem at lower temperatures. At 20^{o}F the amount of fuel in an LP tank that is available to vaporize decreases dramatically. Rule of thumb for LP is that the amount of fuel available is about 50 percent of the amount of fuel in the tank. In short, at cold temperatures, only 50 percent of the fuel in the tank is available for the generator.
- At -36^{o}F, LP does not vaporize. This means no fuel will be available for use.

4. Electrical System

There are a number of different generator systems and typical loads in the context of electrical systems. Most systems, unless they contain automated swtich gear, have a means of disconnect between the generator and the load. This is typically a transfer switch or disconnect. Ensure the contacts on the switch are rated for the size of your system. System schematics are beyond the context of this tutorial at this time.

4.1. General (Electrical System)

Generators are rated for a maximum current in Amps and power output in Kilowatts. Typically power outputs can vary between different models. The output is dependent upon fuel type, ambient temperature and altitude of the installation.
Of same model types using different fuels, Gasoline units will have the highest output followed by gaseous fuels (Natural Gas and Liquid Petroleum(Vapor withdrawal). LP is about 95% of that of gasoline and natural gas at about 85% of gasoline.

These units typically derate at about 3% per 1,000 ft (334 meters) starting at about 3,000 feet (1,000 meters) and an additional 1% for every 10 degrees over 78 degrees F. This is fairly common for all asperating engines.
Diesel units derate more for temperature and altitude. Diesels typically derate at about 4% per 1,000 ft (334 meters) starting at sea level and an additional 1% for every 10 degrees over 78 degrees F. At higher elevations, this power loss can be significant.
Circuits to carry power from the generator needs to be sized accordingly. Distance of the generator to the load (Typically a UPS) will also effect wire size. The conduit entryway for the generator is typically specified for a nominal size and may need to be increased in size if you are required to go to the maximum wire size. Flexible liquid tight metallic conduit should be used.
Direct Current (D.C.) Generators typically require a significantly larger cable size from the generator to the load (typically UPS batteries) in order to compensate for voltage drop. Voltage drop is a function of the resistance of the wire over the distance from the source to the load. The typical recommedation for D.C. generators is to keep the generator as close to the load as possible. Refer to the generators manufacturer's recommendations. Refer to N.F.P.A. 70, also known as the National Electric Code (NEC) for cable sizing tables.
When mounting electrical panels, a 3 foot clearance is required and the use of an emergency light to illuminate the unit during operation is typically required. Power for the emergency light should be from both the primary utility and the generator. This is highly recommend so that in the event of a malfunction there is a light source to see to work on the unit. Refer to your local building and electrical codes to ensure compliance.
Use of powered exhaust fans and powered louvers for ventilation is typical for indoor installations. Emergency power will be needed operate the auxillary devices. Make sure the generator is sized large enough to cover the load and the auxillary equipment.

4.2. Conductor Sizing Connection

This information is dependent upon your generator output and intended load. When connecting cables to the generator, unless instructed differently by the equipment manufacture, make connections at the generator first. Make the connections at the load last. Failure to do so may constitute a fire or safety hazard.
All ampacities are typically calculated at 75 º C (Celsius)(167 º F(Fahrenheit) in the conductor size charts. Building wire conductors should be rated at 90ºC(194ºF) to allow for different ambient temperatures that these conductors may pass through.
All conductors are typically required by electrical code to be copper. The recommended conductor sizes are based on maximum current..
Direct Current (D.C.) generators require larger output power cables than comparable A.C. generators due to voltage drops in the cable caused by increased resistance.
Most A.C. Generators require the use of transfer switches. Refer to manufacturer's installation instructions and recommendations.

5. Exhaust System

5.1. General (Exhaust System)

Generator engines give off deadly carbon monoxide gas through their exhaust systems.

Carbon monoxide gas, if breathed in sufficient concentrations, can cause unconsciousness or death. Exhaust gases must be piped safely away from any room or enclosure that houses a generator and to a well ventilated area where people will not be endangered.
Besides the possibility of carbon monoxide poisoning, exhaust piping becomes extremely hot during operation and remains hot for a long time after shutdown. For that reason, the following precautions are necessary:

- Avoid contact with hot engines, exhaust manifolds, exhaust piping and mufflers. Any of these can cause severe burns.
- Where piping must pass through combustible walls or ceilings, special precautions must be taken to prevent fire or heat damage such as using heat thimbles through walls and ceilings.

5.2. General Rules for Exhaust Systems

When installing an exhaust system for a generator, the following rules should be considered:

- Exhaust piping should be of wrought iron or steel having adequate strength and durability.
- Exhaust fittings may be of cast iron. A 9 inch spacing (10 inches (250mm) recommended) from the exhaust pipe and walls is also required by most local codes.
- Low points in horizontal runs of piping should be provided with condensation traps, as well as condensation drains.
- Piping and mufflers must be properly supported and connected.
- A flexible length of exhaust pipe is required between the engine exhaust manifold and rigid exhaust piping.
- Exhaust piping must be terminated safely outside a structure that houses a generator, in such a way that hot gases and sparks will be discharged harmlessly and will not blow against any combustible surface or material.
- Exhaust piping must not terminate under loading platforms, structures, or near any opening in a building.
- Where necessary, exhaust piping must be guarded and/or insulated to prevent burns.
- Provide a clearance of at least 9 inches (229mm)(10 inches (250mm) recommended) between exhaust piping and any combustible material.
- Keep exhaust piping well clear of fuel tanks, fuel lines, etc.
- Exhaust piping that passes through any combustible wall or partition must be guarded at the point of passage by:
- A ventilated metal thimble that is at least 12 inches in diameter larger than the piping, or
- Metal or burned fire clay thimbles built in brickwork that provides not less than 8 inches of insulation between the clay thimble and any combustible material.
- Thermal insulation or protective guards are typically required for exhaust pipes/system by national and local codes to protect users from burns.

Exhaust piping that passes through any combustible roof must be separated from the roof by a ventilated metal thimble that is at least 6 inches in diameter larger than the piping. The thimble must extend at least 9 inches (229mm)(10 inches (250mm) recommended) above and below roof construction.

A rain cap is recommended on the end of the exhaust pipe. The rain cap is attached to the end of the pipe and opens due to the pressure from the exhaust discharge

force. The rain cap protects the exhaust system from the environment when the system is not running.
Use of a spark arrestor is recommended in areas where combustible materials may ignite such as dry grass, leaves, or other combustible materials.
The exhaust back pressure of the generator when measured at full load must not exceed the manufacturer's recommendations. The size of exhaust pipe, number and type of ends and fittings together with the selection and location of muffler determine exhaust back pressure.
A typical 90 degree bend in an exhaust system is equal to adding 8 feet (2.67 meters) of pipe.

6. Gaseous Fuel Systems

6.1. General (Gaseous Fuel Systems)

Some generators are equipped with fuel systems that utilize Liquefied Petroleum (LP) or Natural Gas as a fuel.
Local fuel gas codes may vary widely. For that reason, it is recommended that a local gas distributor or installer be consulted when installing a gaseous fuel supply system.
The installer must ensure that the correct fuel delivery system is installed, and that applicable standards and codes are strictly complied with.

6.2. Advantages of Gaseous Fuels

Use of Natural and LP gas as a fuel may result in a slight power loss. However, that disadvantage is usually compensated for by the many advantages of gaseous fuels. Some of the advantages of gaseous fuels are:

- Reduced sludge build-up in engine oil.
- Low residue content, resulting in minimum carbon formation.
- Reduced valve burning, as compared to gasoline.
- No "wash down" of engine cylinder walls during start up.
- No tetra-ethyl lead to foul spark plugs and other engine parts.
- Excellent anti-knock qualities.
- Reduced amounts of contaminated residues.
- A nearly homogeneous mixture in engine cylinders.
- Fuel can be stored for long periods without breakdown.

6.3. Gaseous Fuel System Variations

Any one of four different types of gaseous fuel systems may typically be installed by the factory on your generator system, dependent upon the model. These are:

- Liquefied Petroleum (LP) gas vapor withdrawal.
- Liquefied Petroleum (LP) gas liquid withdrawal.
- Natural Gas.
- Dual Natural and LP gas (Additional regulator and hardware are not standard on most generators.
- Combination Gas-Gasoline systems (Additional regulator and hardware are not standard on the generator systems. (Contact the manufacturer if you need this option).

6.4. Properties of Gaseous Fuels

Natural Gas: Is lighter than air and tends to settle in high places. Natural gas is found in the gaseous state only at normal ambient conditions. Natural gas is highly explosive and accumulations of the gas can be ignited at the slightest spark. For that reason, adequate ventilation is absolutely essential and fuel lines must be free of leaks. Local fuel/gas codes usually dictate the maximum pressure at which natural gas can enter a structure. A primary regulator is required, to reduce the pressure of the delivered gas to the reduced pressure required by code.
LP Gas: Is heavier than air, tends to settle in low places. The gas is highly explosive and the slightest spark can cause an explosion. LP gas is usually supplied in pressure tanks as a liquid, but is found in gaseous form at normal atmospheric temperature and pressure. It may consist of (1) butane, or (2) propane, or (3) a mixture of these two gases. Fuel suppliers may fill the supply tank with a mixture made up primarily of butane in warm weather. Butane may not provide sufficient vapor pressure in colder weather and more propane may have to be added to the mixture. The ratio of butane to propane is especially important when a large outdoor supply tank is used. LP gas must be converted to its vapor state before it enters the engine carburetor.

6.5. Natural Gas Fuel System

The maximum pressure at which natural gas can enter the building is established by code and may vary from area to area. The gas distribution company will usually provide piping from the main distribution line to the standby generator site. A primary regulator is needed to reduce gas supply pressures to the required safe level before the gas enters a building. Such a regulator may or may not be provided by the gas supplier. It is the responsibility of the gas supplier to ensure that sufficient gas pressure is available to operate the primary regulator.
Gas outlet pressure from the primary regulator to the standby generator's shutoff valve should typically not exceed approximately 0.50 pounds per square inch (psi), or 14 inches of water column. Optimum supply pressure to most small generator's shutoff valve is 11 inches of water column. Depending on the characteristics of the specific shutoff valve in use, the valve may or may not open at supply pressures greater than 0.50 psi (14 inches water column).
Install a flexible length of fuel line between rigid piping and the Generator engine's natural gas connection point.
Natural gas is delivered to the primary regulator. From the primary regulator, in most installations, the gas flows through a solenoid operated fuel shutoff valve, a pressure reducing valve and the engine's natural gas carburetor. The shutoff valve is electrically energized open during startup and running, is de-energized closed on shutdown. The carburetor measures engine air flow and meters gas to the engine based on throttle setting and load. The carburetor also provides a positive gas shutoff.

6.6. LP Gas Vapor Withdrawal System

This type of system utilizes the vapors formed above the liquid fuel in the supply tank. Approximately 10-20 percent of the tank capacity is needed for fuel expansion from the liquid to the vapor state.

Ambient temperatures around the supply tank must be high enough to sustain adequate vaporization or the system will not function properly. In addition to the cooling effects of ambient air, the vaporization process itself provides an additional cooling effect. Vapor withdrawal systems are generally more suited for smaller engines that need less fuel.
When ambient temperatures are low and fuel consumption is high, the vapor withdrawal system may not function efficiently. This is particularly true with larger engine machines.
Many LP gas and Natural Gas vaporous fuel systems are identical as a demand regulator is used to provide fuel to the engine.

6.7. LP Liquid Withdrawal System

This type of system delivers gas in liquid form to a generator. The liquid fuel must then be vaporized before it is delivered to the engine carburetor.
Liquid withdrawal (LP) gas systems usually employ a "vaporizer-regulator" to convert the liquid to its vapor state. A "vaporizer-regulator" is mounted in the air flow of the engine to provide heat to the regulator for fuel vaporization.
LP liquid withdrawal is typically used for equipment used in remote locations where size and availability of refilling the tank is limited. Liquid withdrawal is also used for trailered and construction site equipment.

6.8. Dual Natural/LP Gas Fuel System

In some areas, the cost of Natural gas may be reduced considerably by procuring the gas on "interrupted service" rates. Such "interrupted service" can be obtained by using LP gas as an emergency fuel whenever Natural gas is not available.. Automatic changeover is accomplished by using two regulators - a line pressure regulator for natural gas and a vacuum operated regulator for LP gas. The differences in pressures compensates for the greater BTU value of LP gas.
During operation on Natural gas, a 5 inch (water column) (typical) pressure exists in the common line to the carburetor. This pressure closes the LP gas regulator. Loss of Natural gas pressure causes loss of pressure in the line; the LP gas regulator then opens to admit LP gas into the system. A separate power mixture adjustment in the LP gas line provides precise setting of air/fuel ratios for each of the two fuels. Changeover is automatic with the engine operating.

6.9. Gaseous Fuel System Piping

The following general rules apply to piping used in gaseous fuel systems:

- Piping should be of black iron.
- Piping should be rigidly mounted and protected against vibration.
- **Install an approved length of flexible hose between the generator fuel line connection point and rigid piping.**
- Piping must be of the correct size to maintain required supply pressure under varying conditions, especially when fuel in gaseous form is being supplied (Natural gas and LP gas vapor withdrawal).
- Installed piping must be properly purged and leak tested, in accordance with applicable standards.

7. Pre- operation Verifications

Attention: Check the motor only when it is turned off and the gen-set is in a perfectly horizontal position.
Motor oil is a major factor in the operation and life of any motor. Running of the motor on a low oil level can lead to severe damage.
Note: Check the oil level before each motor start-up.
Check, clean or replace the air filter at time intervals depending on the environment in which the gen-set operates, but no longer than 50 hours of operation.
Check, clean or replace the fuel filter at time intervals depending on fuel quality.
When the fuel level in the tank is low, fill up. Do not fill the tank completely; leave enough space for fuel expansion. Tighten carefully the plug after refilling.
Do not spill fuel on the gen-set or the area surrounding it. Fuel and fuel vapours are highly flammable. If you spilled fuel, immediately clean and ventilate the area before starting the gen-set.
Note: The gen-set is delivered without fuel in its tank.
Do not use any electric equipment with damaged cables or devices. Inspect visually all cables, extensions and plugs before starting the gen-set.
Check the fuel circuit and tank for leaks, including all clips and the filler plug.
Earthing is mandatory in order to avoid electric shocks. The earthing wire must be connected to the frame in the appropriate position.

8. Gen-set Operation

8.1. Motor Start up

The gen-set needs several minutes to reach its nominal speed and stabilize it. Do not connect any load until the motor speed is stable. Ensure all loads connected to the group are stopped. For more information regarding motor start up refer to the motor manual.

8.2. Load Connection

During long term operation do not exceed the alternsator's nominal capacity. The max. capacity or peak can be reached only for a short period of time (max. 2 min). Its purpose is to compensate for the increased motor consumption during start up. In both cases calculate the power of the loads which will operate simultaneously.
Most electrical equipment needs an increased power at start up, after which they operate on their nominal power. The start up power for a given equipment cannot be accurately calculated. Therefore, in order to avoid such an overload, check the max. power of the equipment to establish if it can be powered by the generator.
Attention: **DO NOT** use the single phase and three phase outlets simultaneously.

8.3. Overload Protection

In the gen-sets equipped with overload protection the alternator is protected by means of ciruit breakers. When an overload occurrs the breaker automatically disconnects all alternator phases.
Before reconnecting the load verify and remove the situation that caused the disconnection. Allow the circuit breaker to cool off before reconnecting then re-start the gen-set.

8.4. Low Oil Level Warning System

The gen-sets with the low oil level warning system symbol are equipped with motors which give a warning at low oil levels (Diesel motors) or stop automatically (gasoline engines). The gen-set is protected this way against damage due to insufficient oil in the motor. If this system stops the gen-set when the oil level in not under the prescribed limit, it means the equipment is slanting. Place the equipment in a perfectly horizontal positon in order to allow an even oil level in the crank case.

8.5. Protection of Connected Loads

The gen-sets are wired to power individual equipment with IT system earthing. The neutral wire is not connected to the earthing wire or to the alternator casing. The equipment shall be connected only through the outlets installed on the alternator control panel. When using extension cables, the impedance (combined rezistance) must not exceed 0,75 Ω. The max. acceptable lenghts are:

POWER	SECTION	
	1 ~ (230V)	3 ~ (400V)
< 2 kVA	2.5 mm^2	-
< 5 kVA	4 mm^2	1.5 mm^2
< 8 kVA	6 mm^2	2.5 mm^2
< 12 kVA	10 mm^2	4 mm^2

If several loads are connected to one extension, its length must be reduced by 50%. If the gen-set is to be connected to other networks, ensure the correlation of the protection standards. This operation as well as any intervention into the generator control panel shall be performed by a qualified electrician. He will be directly responsible for the efficiency of the protection measures taken.

9. Maintenance

Periodical maintenance ensures an optimal operation of your equipment and extends its life duration. The intervals for the basic maintenance (i.e. air filter cleaning, oil change) are indicated in the motor manual. Read and observe the recommendations regarding maintenance in the motor manual.
Note: DO NOT modify the motor speed (rpm).