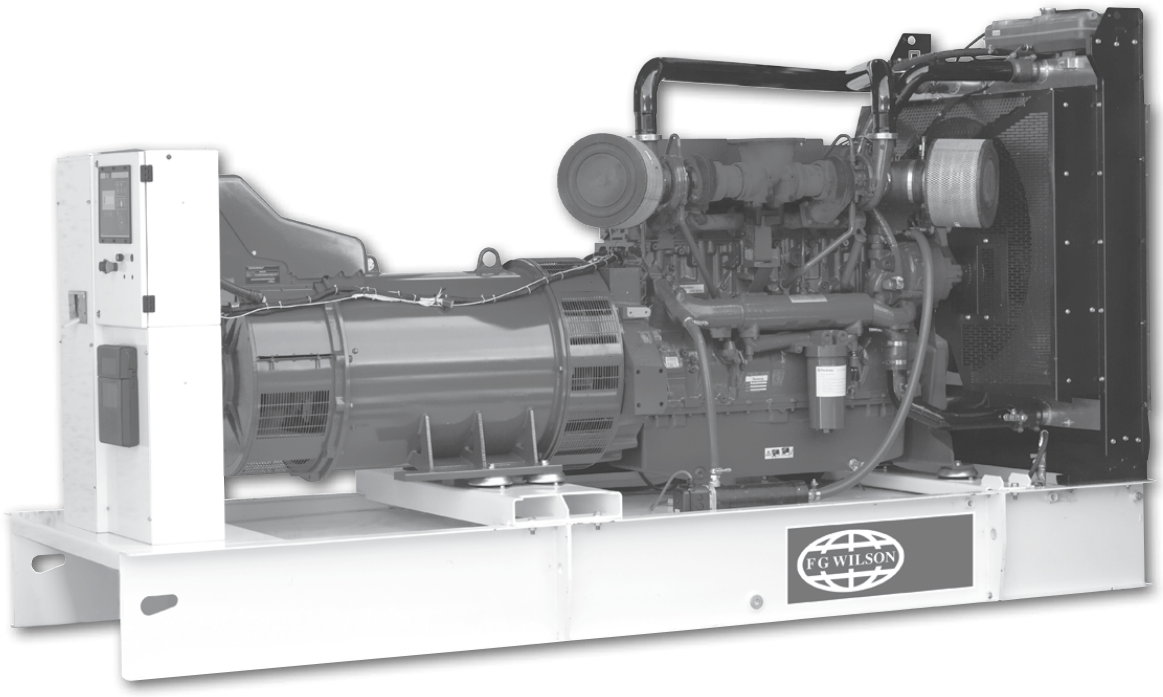
GENERATOR SET
TECHNICAL INSTRUCTION MANUAL



ORIGINAL INSTRUCTIONS

356-7259 (GB) V5 01/13

CONTENTS

1. INTRODUCTION

Thank you for choosing us to supply your electrical power needs. In line with our policy of continuous product improvement, we reserve the right to change the information contained within this manual without notice.

This generator set is one of a family of heavy duty industrial generator sets designed to be ready to run when it arrives, requiring only the addition of coolant, fuel and battery acid. Years of diesel generator set experience has gone into the design to produce a quality source of electrical power that is efficient and reliable.

This Technical Instruction Manual has been prepared to assist in maintenance and operation of the generator set. Using this manual in conjunction with the Engine Manual, Alternator Manual and the Generator set Operator's Manual, will help to ensure that the generator set keeps operating at maximum performance and efficiency for a long life. Please note that in dirty or dusty environments more attention must be paid to frequent servicing to keep the set running properly.

Always ensure that adjustments and repairs are done by personnel who are authorised to do the work and have been properly trained. Maintenance and repairs should also be carried out at regular intervals using genuine parts. We are not liable for any defects or claims due to the user's improper installation, maintenance or use, or for any products which have been modified in any way from the state in which they were sold. All generator sets should only be operated by those required to do so and therefore be safely kept away from non authorised use.

Total liability for any claim of any kind shall in no case exceed the price allocable to the product or part thereof which gives rise to the claim. We shall under no circumstances be held liable for any special, direct, indirect, incidental or consequential damages arising from the use of the product, save that nothing herein shall have the effect of excluding or limiting our liability for death or personal injury resulting from our negligence.

Every generator set is uniquely defined by a model number and serial number indicated on a rating plate generally affixed to the alternator housing. This information is required when ordering spare parts or when service or warranty work is required.
See Section 3.1 for further information.

2. SAFETY

2.1 General

The generator set is designed to be safe when used in the correct manner. Responsibility for safety, however, rests with the personnel who use the set. Before performing any procedure or operating technique, it is the user's responsibility to ensure that it is safe to do so.

Warning:

⚠ **Read and understand all safety precautions and warnings before operating the generator set.**

⚠ **Failure to follow the instructions, procedures and safety precautions in this manual may increase the possibility of accidents and injuries.**

⚠ **Never start the generator set unless it is safe to do so.**

⚠ **Do not attempt to operate the generator set with a known unsafe condition.**

⚠ **If the generator set is unsafe, fit danger notices and disconnect the battery negative (–) lead so that it cannot be started until the condition is corrected.**

⚠ **Ensure the generator set is protected from any unauthorised use, use signs were appropriate.**

⚠ **Disconnect the battery negative (–) lead prior to attempting installation, repairs or cleaning on the generator set.**

⚠ **Install and operate this generator set only in full compliance with relevant National, Local, or Federal Codes, Standards or other requirements.**

2.1.1 Emergency Stop Button

The emergency stop button is in the OUT position for normal engine operation. Push the emergency stop button. The engine will not start when the button is locked. Turn the button clockwise in order to reset.

Warning

⚠ **Familiarise yourself with the location of the Emergency Stop Button. Emergency shutoff controls are for EMERGENCY use ONLY.**

⚠ **DO NOT use emergency shutoff devices or controls for normal stopping procedure.**

⚠ **Do not start the engine until the problem necessitating the emergency stop has been located and corrected.**

2.2 Personal Protective Equipment

Figure 2a – Typical PPE to be worn by an Operator

- Appropriate PPE should always be worn whilst working in and around the generator set. Wear a hard hat, protective glasses, gloves and other protective equipment, as required by generator set location.
- When work is performed around an engine that is operating, wear protective devices for ears in order to help prevent damage to hearing.
- Do not wear loose clothing or jewellery that can snag on controls or on other parts of the engine.

- Ensure that all protective guards and all covers are secured in place on the engine.
- Never put maintenance fluids into glass containers. Glass containers can break.
- Use all cleaning solutions with care.
- Report all necessary repairs.

Unless other instructions are provided, perform the maintenance under the following conditions:

- The engine is stopped. Ensure that the engine cannot be started.
- Disconnect the batteries when maintenance is performed or when the electrical system is serviced. Disconnect the battery ground leads. Tape the leads in order to help prevent sparks.
- Do not attempt any repairs that are not understood. Use the proper tools. Replace any equipment that is damaged or repair the equipment.

2.3 General Hazard Information

2.3.1 Pressurized Air and Water

Pressurized air and/or water (not recommended) can cause debris and/or hot water to be blown out which could result in personal injury.

When pressurized air is used, wear protective clothing, protective shoes and eye protection. Eye protection includes goggles or a protective face shield.

The maximum air pressure for cleaning purposes must be reduced to 205 kPa (30 psi) when the air nozzle is deadheaded and used with effective chip guarding (if applicable) and personal protective equipment. The maximum water pressure for cleaning purposes must be below 275 kPa (40 psi). Always wear eye protection for cleaning the cooling system.

Do not touch any part of an operating engine. Allow the engine to cool before any maintenance is performed on the engine. Relieve all pressure in the air system, in the hydraulic system, in the lubrication system, in the fuel system, or in the cooling system before any lines, fittings or related items are disconnected.

2.3.2 Containing Fluid Spillage

Care must be taken to ensure that fluids are contained during inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Note:

- Dispose of all fluids according to local regulations and mandates.

2.3.3 Lines, Tubes and Hoses

Do not bend or strike lines. Do not install lines, tubes, or hoses that are damaged.

Inspect all lines, tubes, and hoses carefully. Do not use bare hands to check for leaks. Organise with your local Dealer repair of any fuel lines, oil lines, tubes, or hoses that are loose or damaged

Check for the following conditions:

- End fittings that are damaged or leaking
- Outer covering that is chafed or cut
- Wire that is exposed in reinforced hose
- Outer covering that is ballooning
- Flexible part of the hose that is kinked or crushed
- Armoring that is embedded in the outer covering

Ensure that all of the clamps, the guards and the heat shields are installed correctly. Correct installation of these components will help to prevent these effects: vibration, rubbing against other parts and excessive heat during operation.

2.3.4 Disposal of Waste

Improper disposal of waste can threaten the environment. Potentially harmful fluids should be disposed of according to local regulations. Always use leakproof containers when you drain fluids. Do not pour waste onto the ground, down a drain, or into any source of water.

2.4 Fire and Explosion

All fuels, most lubricants, and some coolant mixtures are flammable. Flammable fluids that are leaking or spilled onto hot surfaces or onto electrical components can cause a fire. Fire may cause personal injury and property damage.

Determine whether the engine will be operated in an environment that allows combustible gases to be drawn into the air inlet system. These gases could cause the engine to overspeed. Personal injury, property damage, or engine damage could result. If the application involves the presence of combustible gases, consult your local Dealer for additional information about suitable protection devices.

Do not allow any flammable materials to accumulate on the engine. Store fuels and lubricants in properly marked containers away from unauthorized persons. Store oily rags and any flammable materials in protective containers. Do not smoke in areas that are used for storing flammable materials.

Wiring must be kept in good condition, all electrical wires must be properly routed and securely attached. Check all electrical wires daily, seek appropraite maintenance from your local Dealer for any wires that are loose or frayed, before you operate the engine.

Arcing or sparking could cause a fire. Secure connections, recommended wiring and properly maintained battery cables will help to prevent arcing or sparking.

Never check the battery charge by placing a metal object across the terminal posts. Use a voltmeter or a hydrometer.

The batteries must be kept clean, the covers (if equipped) must be kept on the cells. Use the recommended cables, connections, and battery box covers (where fitted) when the generator set is operated.

Warning

⚠ **Do not charge a frozen battery, this may cause an explosion.**

⚠ **Ensure the generator set room is properly ventilated.**

⚠ **Keep the room, the floor and the generator set clean. When spills of fuel, oil, battery electrolyte or coolant occur, they should be cleaned up immediately.**

⚠ **Never store flammable liquids near the engine.**

⚠ **Store oily rags in covered metal containers.**

⚠ **Do not smoke or allow sparks, flames or other sources of ignition around fuel or batteries. Fuel vapours are explosive. Hydrogen gas generated by charging batteries is also explosive.**

⚠ **Avoid refilling the fuel tank while the engine is running.**

⚠ **Do not attempt to operate the generator set with any known leaks in the fuel system.**

⚠ **Do not use aerosol types of starting aids such as ether. Using these types of items could result in an explosion and personal injury.**

2.4.1 Fire Extinguisher

Fuels and fumes associated with generator sets can be flammable and potentially explosive. Proper care in handling these materials can dramatically limit the risk of fire or explosion. However, safety dictates that fully charged BC and ABC fire extinguishers are kept on hand. Personnel must be familiar with the operation of the fire extinguisher. Inspect the fire extinguisher and service the fire extinguisher regularly. Obey the recommendations on the instruction plate.

2.5 Exhaust Gases

Always start and operate the engine in a well-ventilated area. If the engine is in an enclosed area, vent the engine exhaust to the outside.

Warning

⚠ **Engine exhaust contains products of combustion which may be harmful to your health.**

2.6 Mechanical

The generator set is designed with guards for protection from moving parts. Care must still be taken to protect personnel and equipment from other mechanical hazards when working around the generator set.

Warning:

⚠ **Do not attempt to operate the generator set with safety guards removed. While the generator set is running do not attempt to reach under or around the guards for any reason.**

⚠ **Keep hands, arms, long hair, loose clothing and jewellery away from pulleys, belts and other moving parts.**

⚠ **Some moving parts can not be seen clearly when the set is running.**

⚠ **Keep access doors on enclosures, if equipped, closed and locked when not required to be open.**

⚠ **Avoid contact with hot oil, hot coolant, hot exhaust gases, hot surfaces, sharp edges and corners.**

⚠ **Wear protective clothing including gloves and hat when working around the generator set.**

2.7 Chemical

Fuels, oils, coolants, lubricants and battery electrolyte used in this generator set are typical of the industry. However, they can be hazardous to personnel if not treated properly. The disposal of fuels, oils, coolants, lubricants, battery electrolyte and batteries should be carried out in accordance with local government laws and regulations.

2.7.1 Coolant

When the engine is at operating temperature, the engine coolant is hot. The coolant is also under pressure. The radiator and all hoses to the heaters or to the engine contain hot coolant. Any contact with hot coolant or with steam can cause severe burns. Allow cooling system components to cool before the cooling system is drained. Cooling system conditioner contains alkali. Alkali can cause personal injury. Do not allow alkali to contact the skin, the eyes, or the mouth.

2.7.2 Oils

Hot oil and hot lubricating components can cause personal injury. Do not allow hot oil to contact the skin. Also, do not allow hot components to contact the skin.

2.7.3 Batteries

Electrolyte is an acid. Electrolyte can cause personal injury. Do not allow electrolyte to contact the skin or the eyes. Always wear protective glasses for servicing batteries. Wash hands after touching the batteries and connectors. Use of gloves is recommended.

Warning:

⚠ **Do not swallow or have skin contact with fuel, oil, coolant, lubricants or battery electrolyte. If swallowed, seek medical treatment immediately. Do not induce vomiting if fuel is swallowed. For skin contact, wash with soap and water.**

⚠ **Do not wear clothing that has been contaminated by fuel or lube oil.**

2.8 Noise

Sound levels will vary depending on the configuration of the generator set and the final installation of the generator set.

Refer to the following for factors that influence the level of exposure:

- The characteristics of the area around the generator set
- Other sources of noise
- The number of machines and other adjacent processes
- The length of time of exposure to the noise

This information will enable the user of the machine to evaluate the hazard and the risk.

Warning:

⚠ **Prolonged exposure to noise levels above 80 dBA is hazardous to hearing.**

⚠ **Ear protection must be worn when operating or working around an operating generator set.**

2.9 Electrical

Warning

⚠ **Before the generator set is operated please consult your local dealer to establish whether an NEL has been fitted. As more than one NEL per site may be unsafe, it is important to establish whether one has already been installed on site.**

2.9.1 Neutral-Earth Link (NEL):

Depending on the specific product installation, a Neutral-Earth Link may be required on your generator set. Your local dealer or qualified electrical personnel should be consulted to confirm specific earthing requirements for the generator set installation, and to ensure that local wiring regulations are met.

Safe and efficient operation of electrical equipment can be achieved only if the equipment is correctly operated and maintained.

Warning:

⚠ **Ensure the generator set, including a mobile set, is effectively grounded/earthed prior to operation.**

⚠ **Do not touch electrically energised parts of the generator set and/or interconnecting cables or conductors with any part of the body or with any non insulated conductive object.**

⚠ **Use only Class BC or Class ABC extinguishers on electrical fires.**

⚠ **For generator sets with external socket outlets only – Residual Current Device (RCD) protection on socket outlets, where fitted, is designed to operate within a TN earthing system. Ensure local wiring regulations are met prior to generator set operation and that all equipment connected via the generator set sockets, including plugs and electrical cables, are of the correct specification and are known to be in a safe and undamaged condition.**

2.10 First Aid For Electric Shock

Warning:

⚠ **Do not touch the victim's skin with bare hands until the source of electricity has been turned off.**

⚠ **Switch off the power, if possible.**

⚠ **Otherwise pull the plug or pull the cable away from the victim.**

⚠ **If this is not possible, stand on dry insulating material and pull the victim clear of the conductor, preferably using insulated material such as dry wood.**

⚠ **If victim is breathing, turn the victim into the recovery position.**

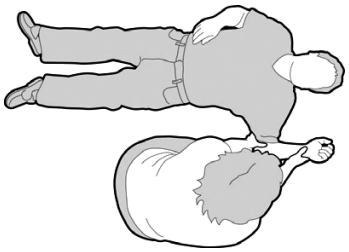
⚠ **If victim is unconscious, perform resuscitation as required:**

OPEN THE AIRWAY:

1. Tilt the victim's head back and lift the chin upwards.
2. Remove objects from the mouth or throat (including false teeth, tobacco or chewing gum).

BREATHING:

1. Check that the victim is breathing by looking, listening and feeling for the breath.



CIRCULATION:

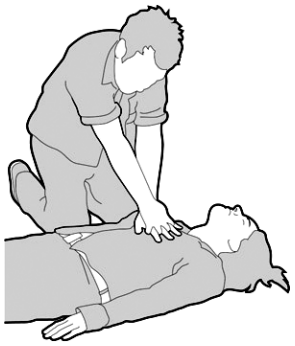
1. Check for pulse in the victim's neck or wrist.

IF NO BREATHING BUT PULSE IS PRESENT:

1. Pinch the victim's nose firmly.
2. Take a deep breath and seal your lips around the victim's lips.
3. Blow slowly into the mouth watching for the chest to rise. Let the chest fall completely. Give breaths at a rate of 10 per minute.
4. If the victim must be left to get help, give 10 breaths first and then return quickly and continue.
5. Check for pulse after every 10 breaths.
6. When breathing restarts, place the victim into the recovery position described later in this section.

IF NO BREATHING AND NO PULSE:

1. Call or telephone for medical help.
2. Give two breaths and start chest compression as follows:
3. Place heel of hand 2 fingers breadth above ribcage/breastbone junction.
4. Place other hand on top and interlock fingers.
5. Keeping arms straight, press down 4–5 cm (1.5–2 inch) 30 times at a rate of 100 per minute. There should be equal timing between chest compression and release.
6. Repeat cycle (2 breaths, 30 compressions) until medical help takes over.
7. If condition improves, confirm pulse and continue with breaths. Check for pulse after every 10 breaths.
8. When breathing restarts, place the victim into the recovery position.

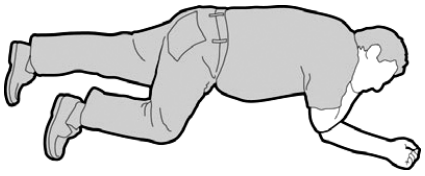


<u>Warning</u>

⚠ **Do not apply pressure over the ribs, lower tip of the victim's breastbone or the abdomen.**

RECOVERY POSITION:

1. Turn the victim onto the side.
2. Keep the head tilted with the jaw forward to maintain the open airway.
3. Make sure the victim cannot roll forwards or backwards.
4. Check for breathing and pulse regularly. If either stops, proceed as above.



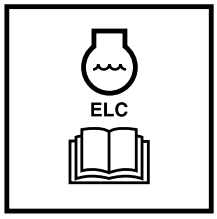
<u>Warning</u>:

⚠ **Do not give liquids until victim is conscious.**

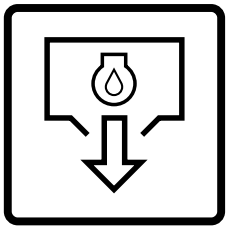
2.11 HAZARD LABEL LEGEND - (6.8 – 275 kVA range)

Ensure that all of the safety messages are legible. Clean the safety messages or replace the safety messages if the words cannot be read or if the illustrations are not visible. Use a cloth, water, and soap to clean the safety messages. Do not use solvents, gasoline, or other harsh chemicals these could loosen the adhesive that secures the safety messages. Safety messages that are loosened could drop off the engine.

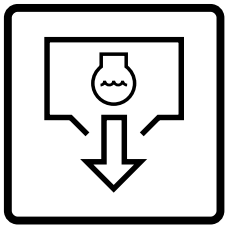
Replace any safety message that is damaged or missing. If a safety message is attached to a part of the engine that is replaced, install a new safety message on the replacement part. Your local Dealer can provide new safety messages.



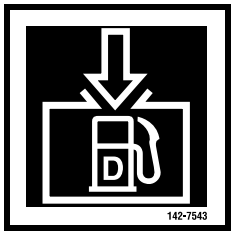
Extended Life Coolant



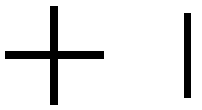
Oil Drain



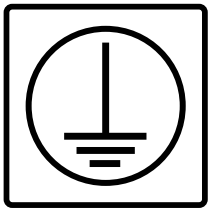
Coolant Drain



Diesel Fuel Fill

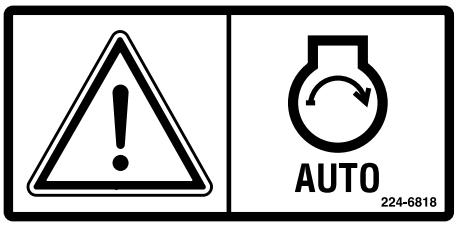


Positive & Neutral Electric Terminals

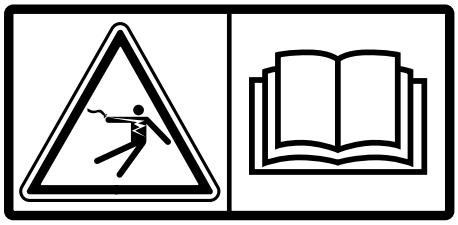


Earth

Hot Fluid Under Pressure



Warning Auto Start



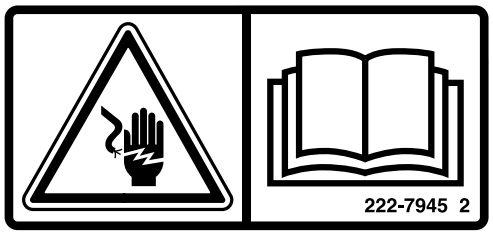
Electric Shock

Warning - Read the manual

Lift Symbol

Do Not Touch Hot Surface

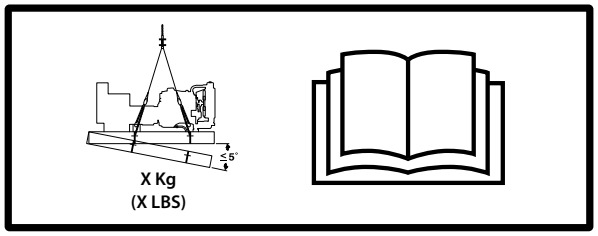
Warning Crush Falling Object



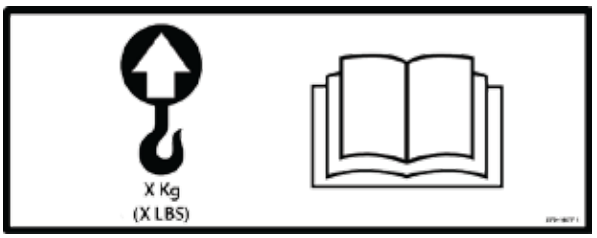
Shock Warning

Centre of Gravity

Do NOT Powerwash

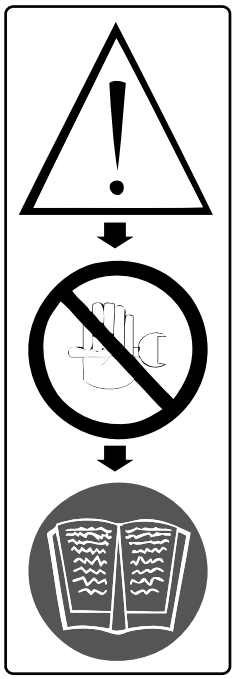


Lifting X Ton 4 Point

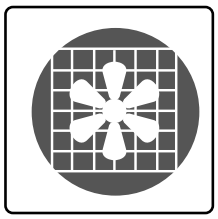


Lifting X Ton 1 Point

HAZARD LABEL LEGEND - (350 – 2500 kVA range)



DO NOT TAMPER WITH UNLESS YOU HAVE READ THE INSTRUCTION MANUAL

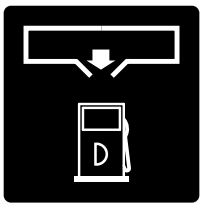


USE FAN GUARDS

ELECTRIC SHOCK HAZARD

HOT EXHAUST GAS

LOW OVERHEAD OBJECTS



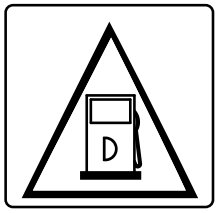
DIESEL FUEL LINE SUPPLY

RATED SPEED

NO NAKED FLAMES

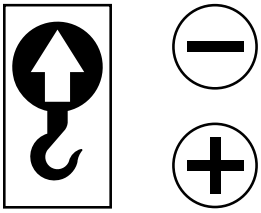
WEAR EAR PROTECTION

EMERGENCY / PANIC EXIT

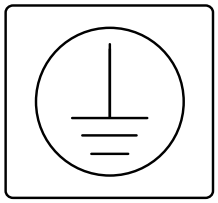


DIESEL FUEL WARNING

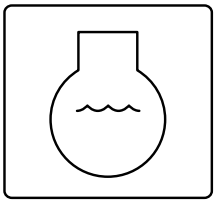
HOT SURFACES



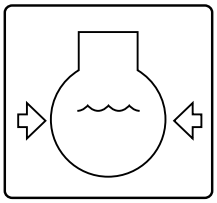
LIFT ELECTRIC TERMINALS



PROTECTIVE EARTH (GROUND)



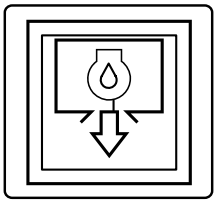
ENGINE COOLANT



ENGINE COOLANT PRESSURE

NO LIFTING FROM THIS POINT

DO NOT POWERWASH



OIL DRAIN

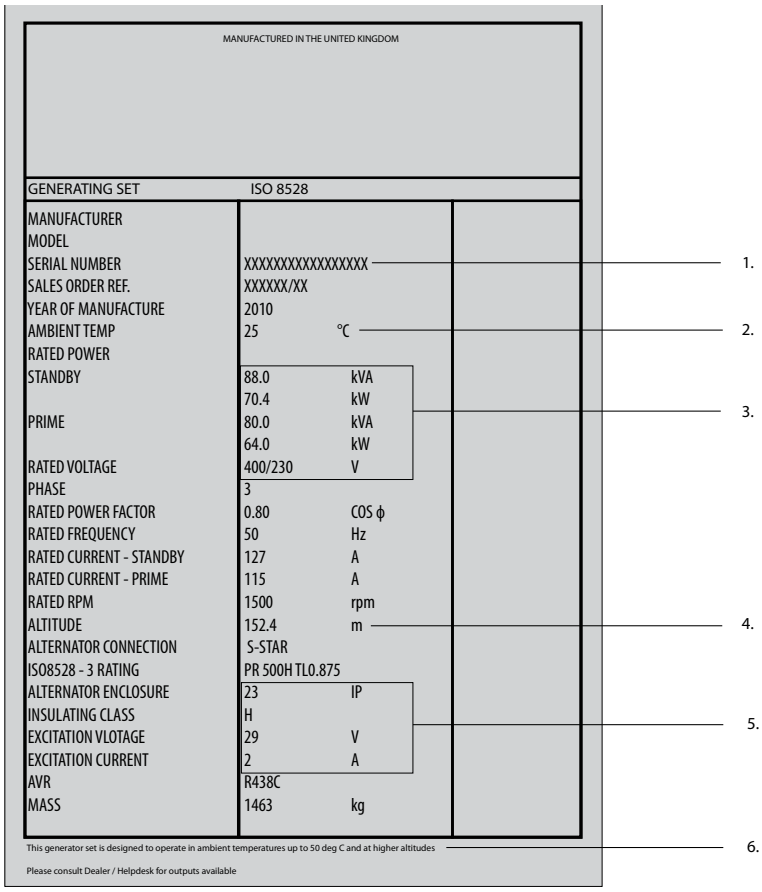
3. GENERAL DESCRIPTION

3.1 Generator set Description and Identification

This generator set has been designed as a complete package to provide superior performance and reliability. Figure 3b identifies the major components. This figure is of a typical generator set. However, every set will be slightly different due to the size and configuration of the major components. This section briefly describes the parts of the generator set. Further information is provided in later sections of this manual.

Each generator set is provided with a Rating Label (item 1) generally affixed to the alternator housing. This label contains the information needed to identify the generator set and its operating characteristics. This information includes, but is not limited to, the model number, serial number, output characteristics such as voltage, phase and frequency, output rating in kVA and kW and rating type (basis of the rating). For reference, this information is repeated on the Technical Data Sheet provided with this manual. The model and serial numbers uniquely identify the generator set and are needed when ordering spare parts or obtaining service or warranty work for the set.

3.2 Rating Plate



1 - Unique Generating Set Number
2 - Rated Ambient Temperature
3 - Voltage Output of Generating Set
4 - Rated Altitude above Sea Level
5 - Relates to AC Alternator
6 - Ambient Temperature Information

Figure 3a – Description of Typical Rating Plate

3.3 Diesel Engine

The diesel engine powering the generator set has been chosen for its reliability and the fact that it has been specifically designed for powering generator sets. The engine is of the heavy duty industrial type with 4 stroke compression ignition and is fitted with all accessories to provide a reliable power supply. These accessories include, among others, a cartridge type dry air filter, a turbocharger fitted on some engines and a mechanical or electronic controled engine speed governor.

3.4 Engine Electrical System

The engine electrical system is negative ground/earth and either 12 or 24 volts DC depending on the size of the set. This system includes an electric engine starter (item 6), battery and battery rack which may also be located on the floor next to the set for some of the larger generator sets and a battery charging alternator. Most sets are provided with lead-acid batteries which are discussed more fully in Section 10, however other types of batteries may be fitted if they had been specified.

3.5 Cooling System

The engine cooling system comprises of a radiator, a high capacity pusher fan (air is 'blown' through the radiator) and a thermostat. The alternator has its own internal fan to cool the alternator components. Note that the air is "pushed" through the radiator so that the cooling air is drawn past the alternator, then past the engine and finally through the radiator.

3.6 Alternator

The output electrical power is normally produced by a screen protected and drip-proof, self-exciting, self-regulating, brushless alternator fine tuned to the output of this generator set. Mounted on top of the alternator is a sheet steel terminal box. Excluding 3 Cylinder generator sets, the alternator terminal box is fitted on the back of the control panel.

3.7 Fuel Tank and Baseframe

The engine and alternator are coupled together and mounted on a heavy duty steel baseframe. Except for the largest sets, this base frame includes a fuel tank with a capacity of approximately 8 hours operation at full load. An extended capacity fuel tank of approximately 24 hours operation may be fitted. Where a fuel tank is not provided with the baseframe, a separate fuel tank must be provided.

3.8 Vibration Isolation

The generator set is fitted with vibration isolators which are designed to reduce engine vibration being transmitted to the foundation on which the generator set is mounted. These isolators are fitted between the engine/alternator feet and the base frame. Alternately, on larger models the engine/alternator is rigidly mounted on the base frame and the vibration isolators are supplied loose to be fitted between the baseframe and the foundation.

3.9 Silencer and Exhaust System

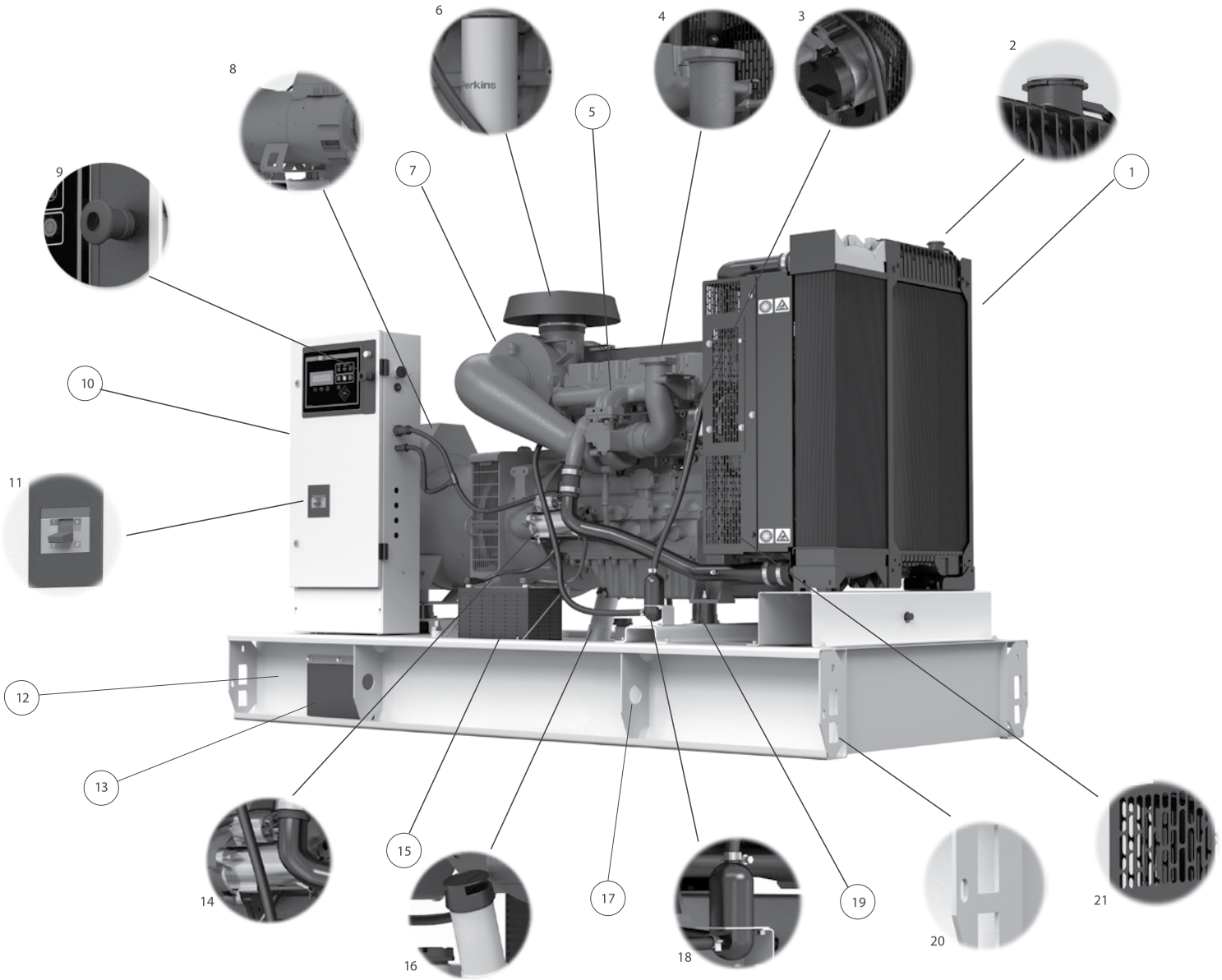
An exhaust silencer is provided loose for installation with the generator set. The silencer and exhaust systems reduce the noise emission from the engine and can direct exhaust gases to safe outlets.

3.10 Control System (Identification)

One of several types of control systems and panels (item 9) may be fitted to control the operation and output of the generator set and to protect the generator set from possible malfunctions. Section 9 of this manual provides detailed information on these systems and will aid in identification of the control system fitted on the generator set.

3.11 Output Circuit Breaker

To protect the alternator, a suitably rated circuit breaker (item 10) selected for the generator set model and output rating is supplied mounted in a steel enclosure. In some cases the output circuit breaker may be incorporated in the automatic transfer system or control panel.



1 - Radiator
2 - Radiator Fill
3 - Battery Charging Alternator
4 - Exhaust
5 - Turbo
6 - Oil Filter*
7 - Air Filter
8 - Alternator
9 - Emergency Stop Pushbutton
10 - Control Panel
11 - Circuit Breaker
12 - Base Frame
13 - Cable Entry
14 - Starter Motor
15 -Battery
16 - Fuel Fill*
17 - Lifting Points
18 - Jacket Water Heater
19 - Anti Vibration Mounts*
20 - Drag Points
21 - Fan Guards
* = Opposite side

⚠ **Generator sets contain moving parts and hot surfaces. Wear the appropraite PPE as required.**

Figure 3b – Typical Generator set Description (this may differ from the Generator set you have received)

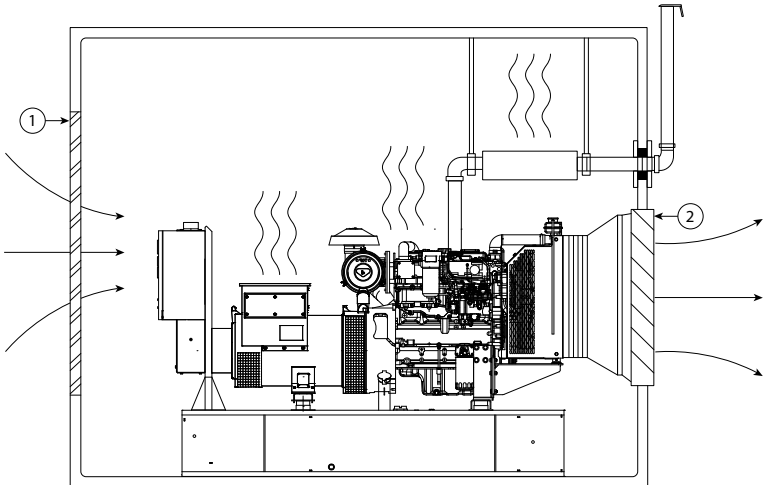
4. INSTALLATION, HANDLING AND STORAGE

4.1 General

This section discusses factors important in the effective and safe installation of the generator set.

Selecting a location for the generator set can be the most important part of any installation procedure. The following factors are important in determining the location:

- Adequate ventilation.



1. Air Inlet Opening
2. Air Exit Opening

Figure 4a – Typical Installation showing Generator set Ventilation

- Protection from the elements such as rain, snow, sleet, wind driven precipitation, flood water, direct sunlight, freezing temperatures or excessive heat.
- Protection from exposure to airborne contaminants such as abrasive or conductive dust, lint, smoke, oil mist, vapours, engine exhaust fumes or other contaminants.
- Protection from impact from falling objects such as trees or poles, or from motor vehicles or lift trucks.
- Clearance around the generator set for cooling and access for service: at least 1 metre (3.3 feet) around the set and at least 2 metres (6.6 feet) headroom above the set. (See Figure 4b)
- Access to move the entire generator set into the room. Air inlet and outlet vents can often be made removable to provide an access point.
- Limited access to unauthorised personnel.

If it is necessary to locate the generator set outside of the building, the generator set should be enclosed in a weatherproof canopy or container-type housing which is available for all generator sets.

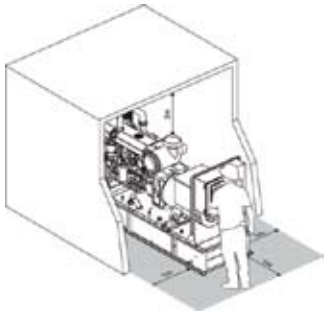


Figure 4b – Typical Installation showing Generator set Access & Operator Workstation

4.2 Foundations

The generator set is shipped assembled on a rigid baseframe that precisely aligns the alternator and engine and needs only to be bolted down on to a suitably prepared surface (see Figure 4c).

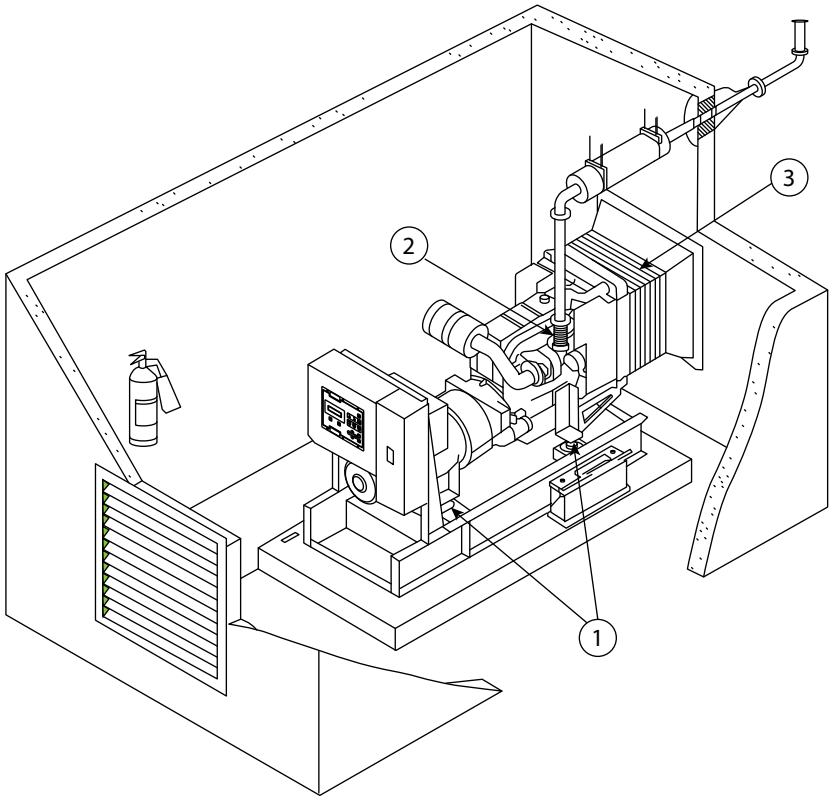


Figure 4c – Typical Installation Highlighting Vibration Reduction Techniques

4.2.1 Foundation

A reinforced concrete pad makes the best foundation for the generator set. It provides a rigid support to prevent deflection and vibration. Typically the foundation should be 150 mm to 200 mm (6 to 8 inches) deep and at least as wide and long as the generator set. The ground or floor below the foundation should be properly prepared and should be structurally suited to carry the weight of the foundation pad and the generator set. (If the generator set is to be installed above the ground floor the building structure must be able to support the weight of the generator set, fuel storage and accessories.) Relevant building codes should be consulted and complied with. If the floor may be wet from time to time, such as in a boiler room, the pad should be raised above the floor. This will provide a dry footing for the generator set and for those who connect, service or operate it. It will also minimise corrosive action on the baseframe.

4.2.2 Floor Loading

Floor loading depends on the total generator set weight (including fuel and water) and the number and size of isolator pads. With the baseframe mounted directly on the floor, the floor loading is:

$$\text{Floor Loading} = \frac{\text{Total Generator set Weight}}{\text{Area of Skids}}$$

With vibration isolation between the baseframe and the floor, if the load is equally distributed over all isolators, the floor loading is:

$$\text{Floor Loading} = \frac{\text{Total Generator set Weight}}{\text{Pad Area x Number of Pads}}$$

Thus, floor loading can be reduced by increasing the number of isolation pads.

If load is not equally distributed, the maximum floor pressure occurs under the pad supporting the greatest proportion of load (assuming all pads are the same size):

$$\text{Max Floor Pressure} = \frac{\text{Load on Heaviest Loaded Pad}}{\text{Pad Area}}$$

4.2.3 Concrete Plinth

Setting the container on a concrete plinth is the preferred method for permanent installation for both ISO and Design to Order (DTO) containers. The concrete plinth should have been designed to withstand the weight of the container. Please consult the installer for further details.

At the installation site, a concrete plinth must be prepared that will have no more than a 10 mm (0.4") drop over the length of the container to be set on it.

For ISO containers, this plinth must also have four depressions to accommodate the four corner blocks of the container. These four corner blocks must extend approximately 12 mm (0.5") minimum below the bottom of the container's channel rail. Each depression must be 250 mm (10") long, 250 mm (10") wide and 25 mm (1") deep (see Figure 4d).

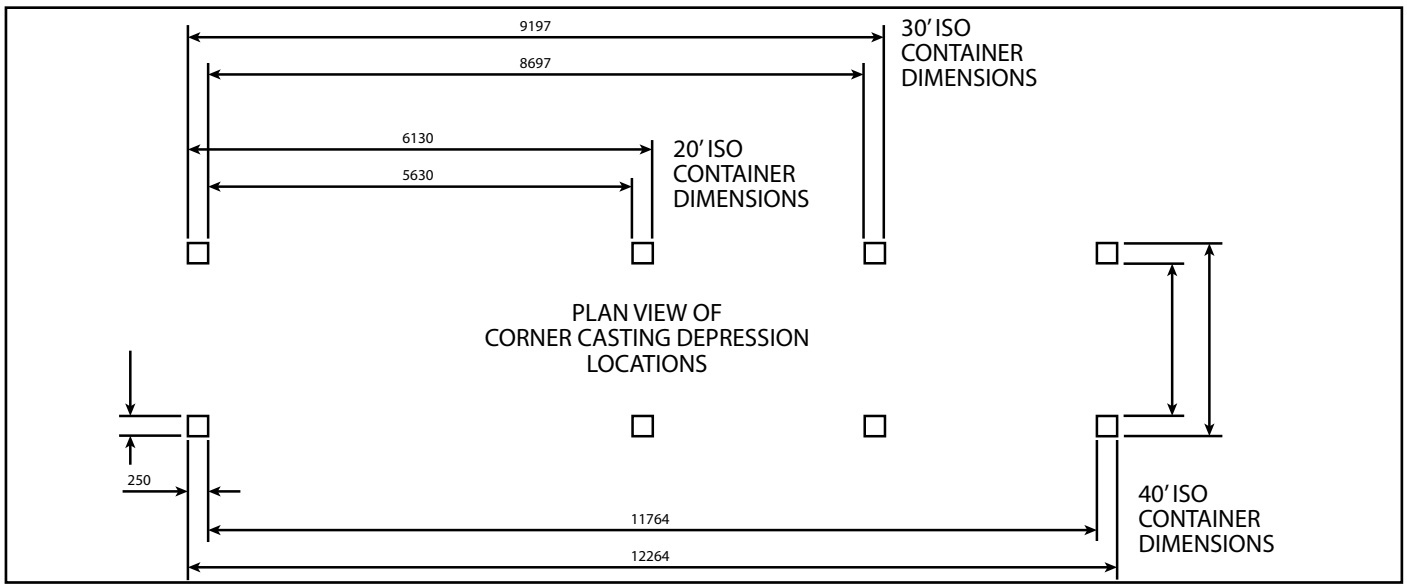


Figure 4d

These depressions will allow the channel rails to rest on the concrete plinth, evenly distributing the weight on the rails. Without the depressions, the corner blocks would support the container weight and the rails would sag in the centre (see Figure 4e). This subjects the container and generator set to unnecessary stress.

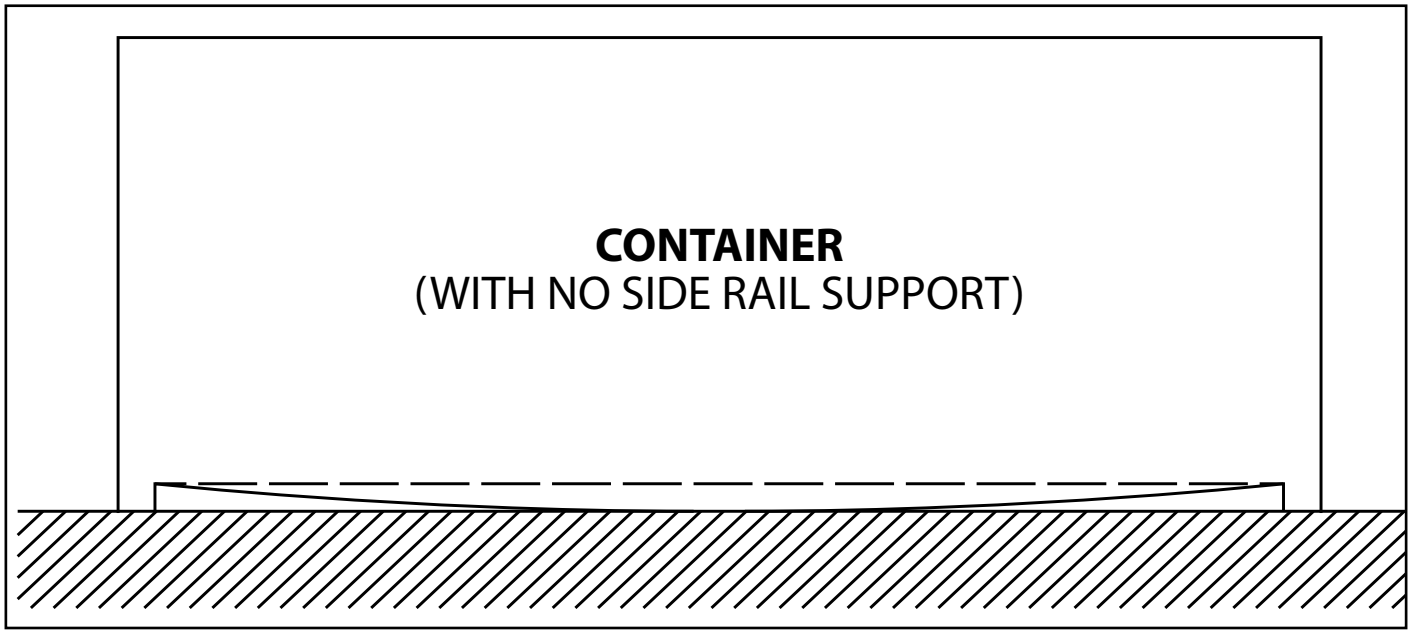


Figure 4e

Another means to support the container, without the depressions in the concrete plinth, is to use an arrangement of flat, steel bars, 100 mm (4") long x 100 mm (4") wide x 12 mm (1/2") thick that will support the container rails. The flat bars can be placed every 600 mm (2 feet) along the length of the channel rail thereby preventing the container from sagging in the middle (see Figure 4f).

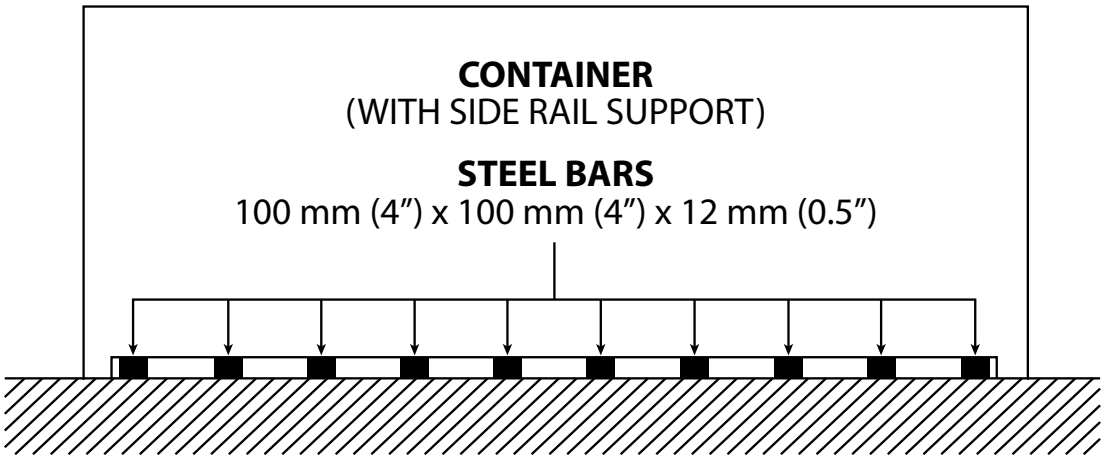


Figure 4f

For all containers, irrespective of the method used to support the side rails, hardwood planks or suitable machine mounting/anti-vibration pads, 100 mm (4") wide by 20 mm (0.75") thick, must be located centrally along the length of the container to support the container floor stringers in that area (see Figure 4g).

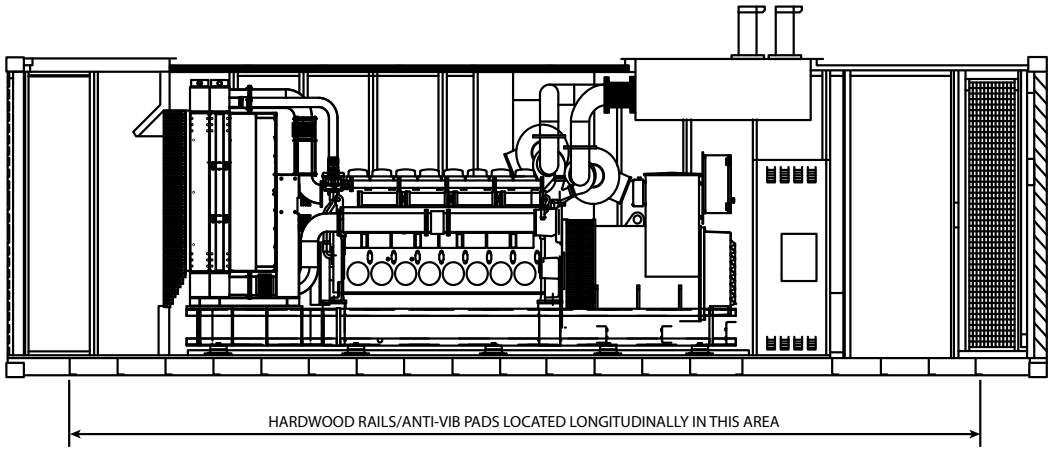


Figure 4g

4.3 Vibration Isolation

To minimise engine vibrations being transmitted to the building, the generator set is fitted with vibration isolators. On small and medium sized sets these isolators are fitted between the engine/alternator feet and the baseframe. This allows the frame to be rigidly bolted to the foundation. On larger sets the coupled engine/alternator is rigidly attached to the baseframe and the vibration isolators are supplied loose for fitting between the baseframe and the foundation. In all cases the generator sets should be securely bolted to the ground (either through the baseframe or through the vibration isolators) to prevent movement.

Vibration isolation is also required between the generator set and its external connections. This is achieved by the use of flexible connections in the fuel lines, exhaust system, radiator air discharge duct, electrical conduit for control and power cables and other externally connected support systems.

4.4 Enclosures

Installation and handling is greatly simplified when the generator set has been equipped with an enclosure. Two basic types may be fitted. The first type is a close fitting canopy enclosure. This may be a weatherproof version designed for sound attenuation. The other is a walk-in type container, similar to a shipping container. It may also be weatherproof and sound attenuated.

These enclosures provide a self contained generator set system that is easily transportable and requires minimal installation. They also automatically give protection from the elements and protection from unauthorised access.

Warning:

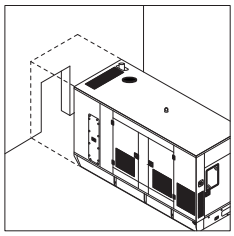
⚠ **Make sure all personnel are out of the canopy or container, if equipped, before closing and latching the enclosure doors.**

⚠ **Before closing canopy or enclosure doors, ensure all obstructions (especially hands and fingers) are clear to prevent damage or injury.**

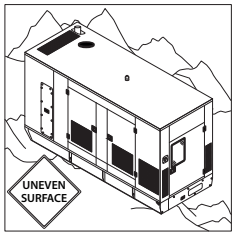
⚠ **For transport purposes, some silencer outlets on generator sets housed in walk-in type enclosures will be fitted with cover plates. These are to be replaced with the supplied stub pipes complete with fitted rain hood.**

⚠ **Ensure there is no debris on the baseframe prior to starting, as loose items will cause radiator damage.**

Because enclosed generator sets are easily transportable and may be installed and operated in a temporary location, many of the fixed installation details given in this chapter may not apply. The following considerations must be still given when temporarily installing the generator set:

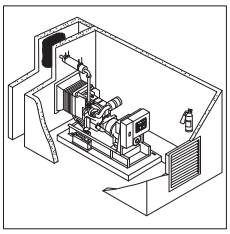


- Locate the generator set where it will be protected from damage and away from the exhaust fumes of other engines or other airborne contaminants such as dust, lint, smoke, oil mist or vapours.



- Ensure the generator set is not positioned in such a way that it will obstruct the entrance or exit to the area where it is situated.

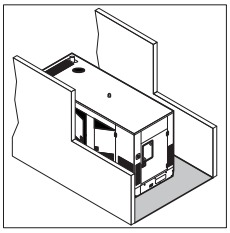
- Locating the generator set on firm, level ground which will not subside or be otherwise affected by the vibration caused by the operation of the generator set.



- Ensuring that fumes from the exhaust outlet will not be a hazard, especially when wind is taken into account.

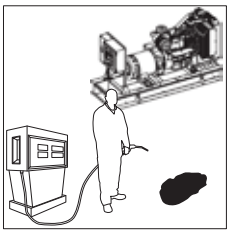
- Ensure there is enough area around the generator set for access and serviceability.

- Ensure electrical grounding of the generator set at all times, in accordance with local regulations.



- Ensure adequate access to refill the fuel tank when required.

- If Protecting electrical cables are laid on the ground ensure they are boxed in or covered to prevent damage or injury to personnel.



Warning

⚠ **Enclosed generator sets should be installed outside. In the event that the enclosed generator set is installed inside, adequate fresh cooling air must be provided and that both engine and hot coolant air exhausts must be ducted outside the building. The ducting and exhaust pipework must be designed to minimise back pressure which would have a detrimental effect on generator set performance.**

4.4.1 Mounting of Walk-in Containers

Proper installation of the container is required if successful generation of power is to be achieved. The following information must be considered in the selection of the operating site for the container:

- The containerised generator set must be placed on a flat surface in order to maintain proper alignment.
- Containers can be successfully installed on a concrete plinth or level, natural surface. The foundation must bear the static weight of the module plus any dynamic forces from engine operation.

Warning

⚠ **For generator sets housed in walk-in type containers, crankcase breather outlets terminated at the external face of the enclosure will be plugged. These are to be removed prior to operation.**

4.5 Moving the Generator set

The generator set base frame is specifically designed for ease of moving the set. Improper handling can seriously damage components.

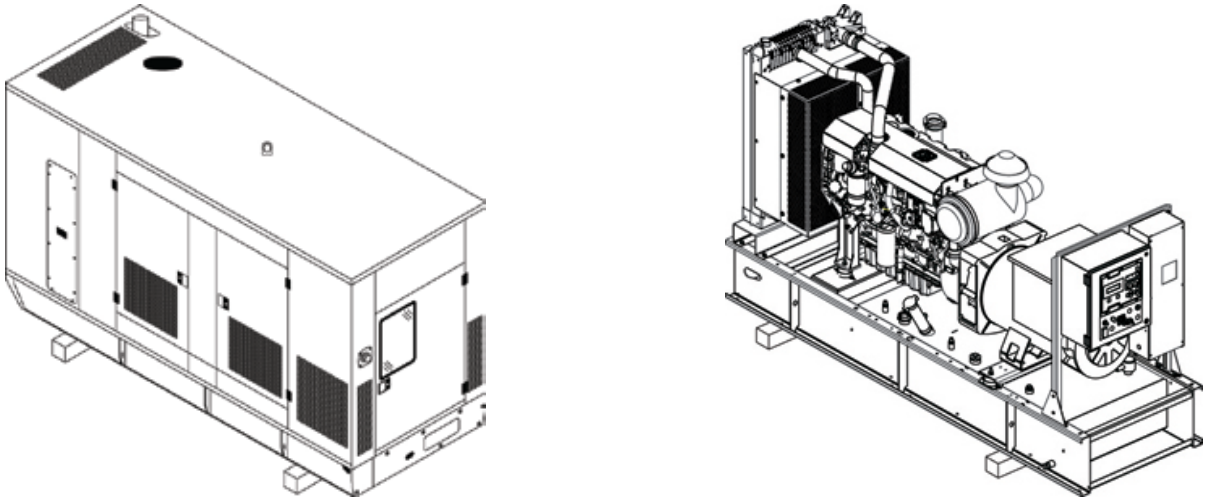


Figure 4c – Open and Closed generator sets on wooden skids

Using a forklift, the generator set can be lifted or carefully pushed/pulled by the base frame. If pushing, do not push the base frame directly with fork.

Warning:

⚠ **Always use wood between forks and the base frame to spread the load and also between the forklift carriage and the side of the canopy to prevent damage.**

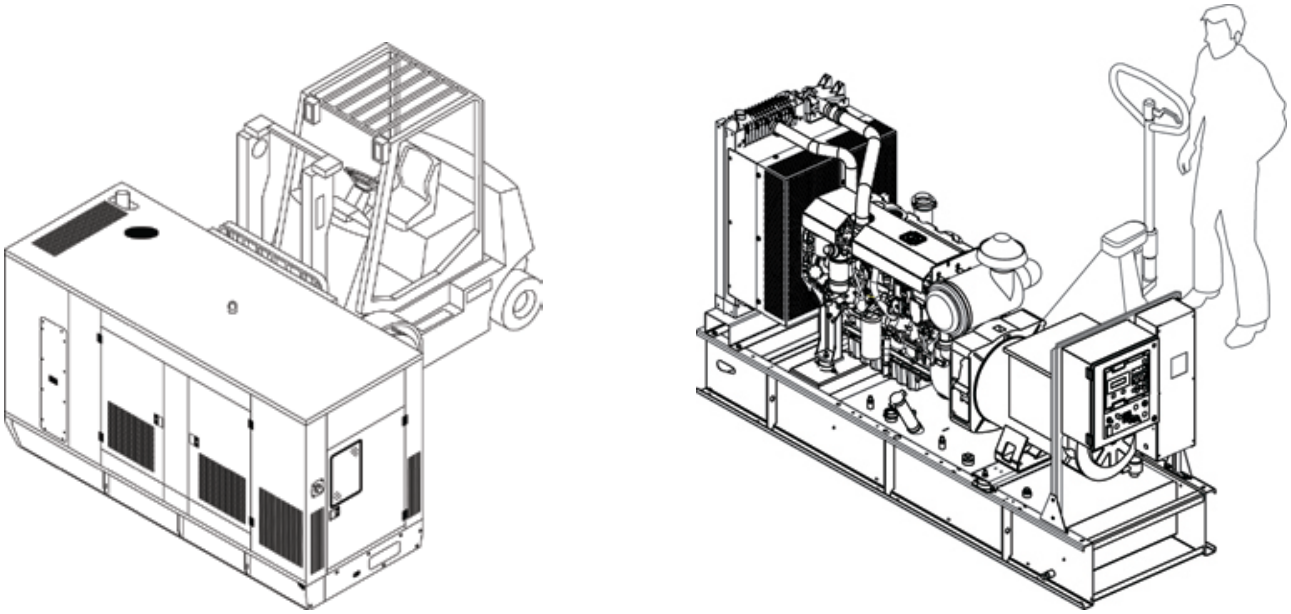
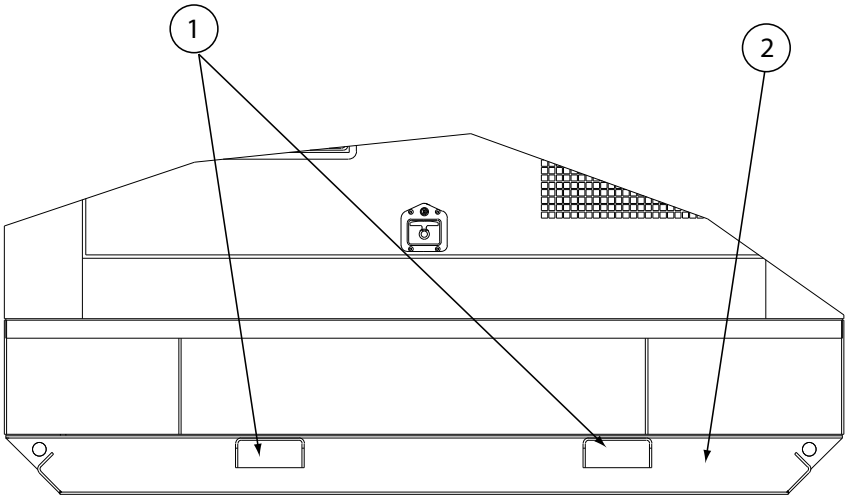


Figure 4d – Transporting a generator set using a forklift truck and forklift trolley



1 - Forklift Pockets
2 - Oil FIeld Skid

Figure 4e – Typical generator set with Oil Field Skid base option

If the generator set will be regularly moved, it should be fitted with the optional Oil Field Skid which provides forklift pockets in the base frame along with eyes for pulling. The smaller sets have forklift pockets in the base frame as standard.

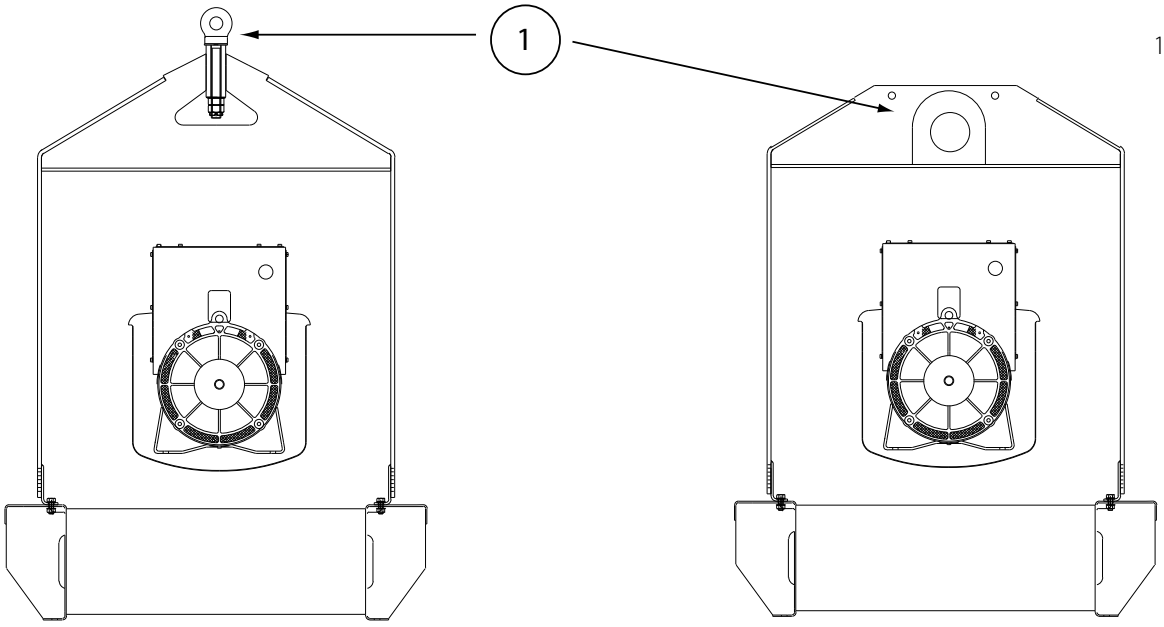
Warning:

⚠ **Never lift the generator set by attaching to the engine or alternator lifting lugs.**

⚠ **Ensure the lifting rigging and supporting structure is in good condition and is suitably rated.**

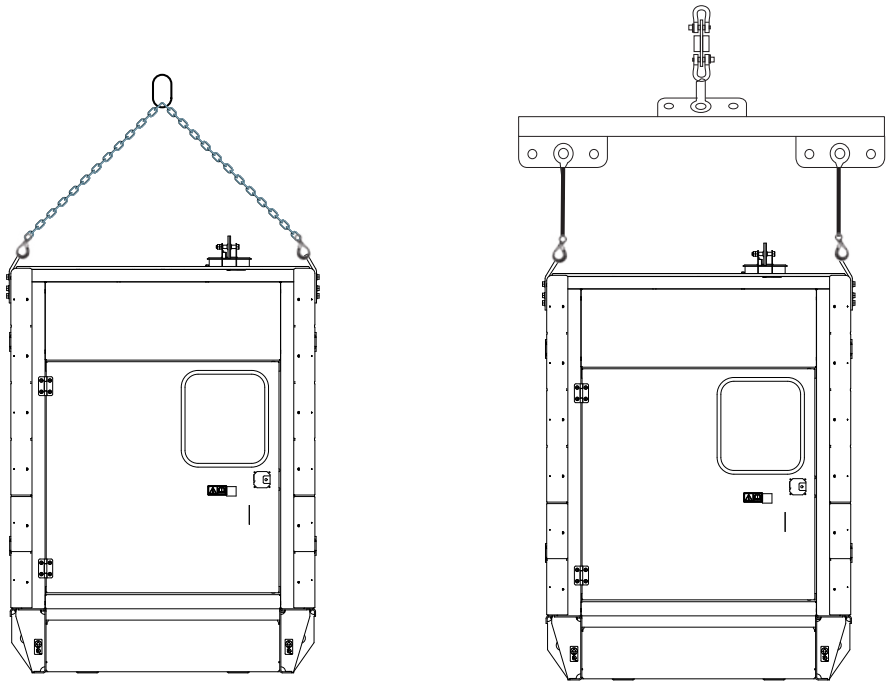
⚠ **Keep all personnel away from the generator set when it is suspended.**

To lift and install the generator set you can use the single / two point lifting points or the lifting points provided on the baseframe. Points of attachment should be checked for cracked welds or loose nuts and bolts before lifting. A spreader bar is required to prevent damage to the generator set whilst lifting from the baseframe (see Figure 4h). It should be positioned over the centre of gravity, to allow a vertical lift. Guide ropes should be used to prevent twisting or swinging of the generator set once it has been lifted clear of the ground. Place the generator set down on a level surface capable of supporting its weight.



1 - Single Point Lift

Figure 4f – Single Point lift



1 - Two Point Lift

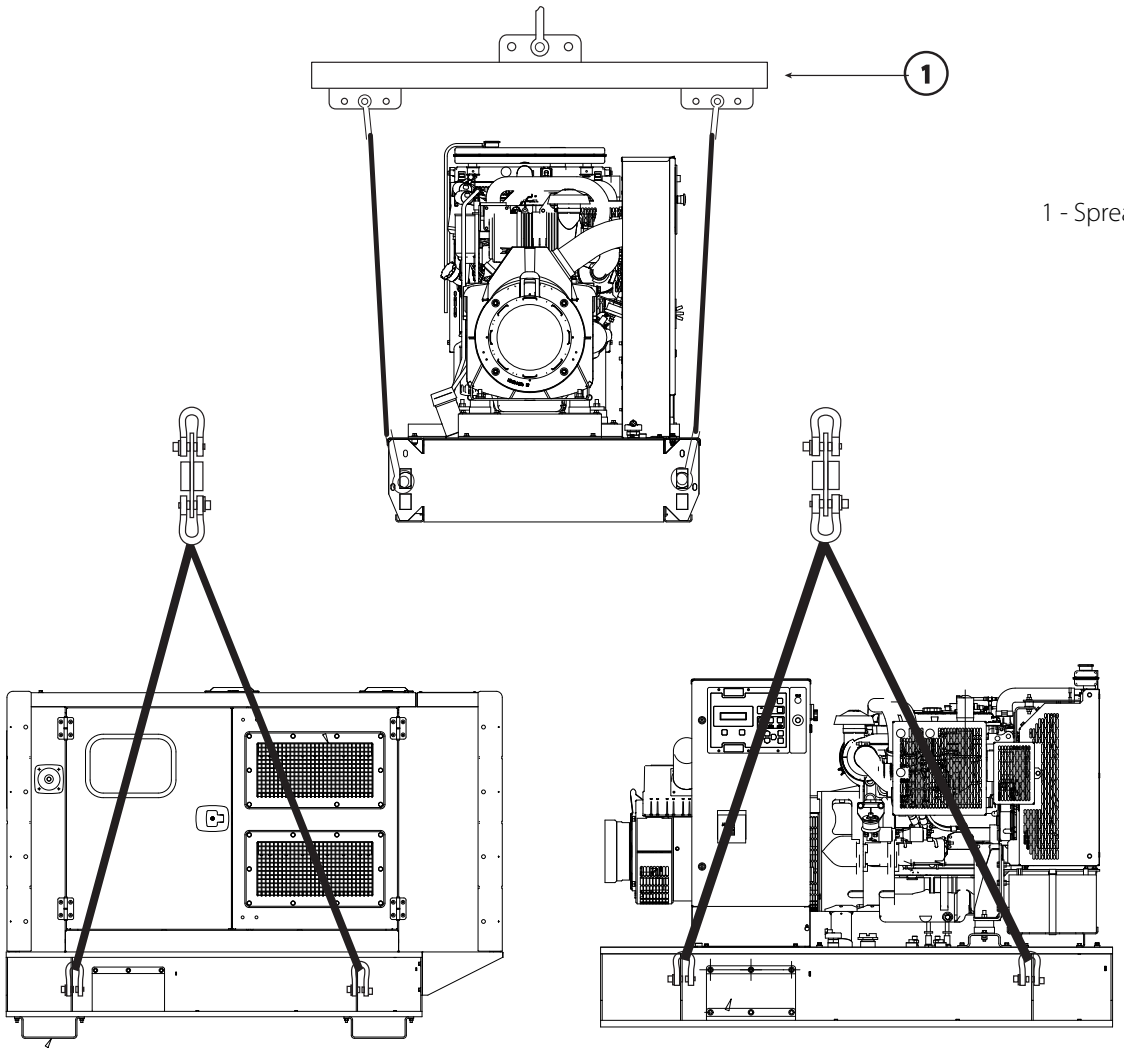
Figure 4g – Two Point lift

Warning

⚠ **Centre of gravity decal is located on the base / canopy of the generator set.**

⚠ **The centre of gravity may not always be located at the centre of the generator set.**

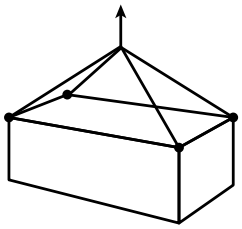
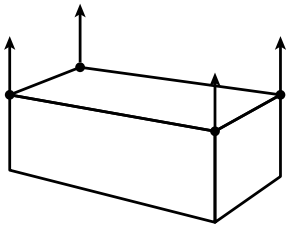
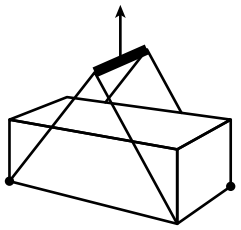
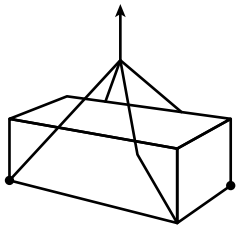
⚠ **Do not attempt to lift in high winds.**



1 - Spreader Bar

Figure 4h – Proper lifting arrangement for installing the generator set (open & enclosed)

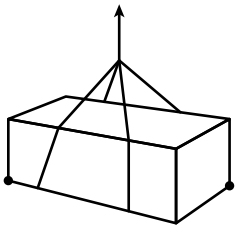
4.5.1 Approved Lifting Methods for ISO Walk-in Containers

ISO Series 1 Freight Containers			
Lift Description	**Loaded / Unloaded**	**Method**	**Diagram**
Top Lift	Unloaded Only	A single pint lift with rated shackles	
Top Lift	Loaded	A vertical lift by means of a spreader bar and rated CAMLOK-CLB type lugs	
Bottom Lift	Loaded	Lifting from bottom four corner casting using CAMLOK-CLB type lugs and rated spreader beam	
Bottom Lift	Loaded and Unloaded	Lifting from bottom four corner castings using CAMLOK-CLB type lugs and nylon straps	

Containers are manufactured to ISO dimensions, ISO 1496-4:1994(E) and ISO 668:1995(E). To ensure the safety of all personnel involved with the handling of containers, it is important that the correct lifting and handling procedures are employed. The procedures detailed below are derived from ISO 3874:1997(E) and must be followed at all times.

4.5.2 Approved Lifting Methods for Non-ISO Walk-in Containers

Containers are manufactured to non-ISO dimensions. To ensure the safety of all personnel involved with the handling of containers, it is important that the correct lifting and handling procedures are employed. The procedures for handling non-ISO containers are detailed below and must be followed at all times.

ISO Series 1 Freight Containers			
Lift Description	**Loaded / Unloaded**	**Method**	**Diagram**
Bottom Lift	Loaded and Unloaded	Lifting from bottom four lifting lugs using rated shackles	

4.6 Cooling and Ventilation

4.6.1 Ventilation

The engine, alternator and exhaust piping radiate heat which can result in a temperature high enough to adversely effect the performance of the generator set. It is therefore important that adequate ventilation is provided to keep the engine and alternator cool. Proper air flow, as shown in Figure 4a, requires that the air comes in at the alternator end of the generator set, passes over the engine, through the radiator and out of the room via a flexible duct. Which should fully seal the full area of the radiator core. Without the ducting of the hot air outside the room, the fan will tend to draw that hot air around and back through the radiator, reducing the cooling effectiveness.

The air inlet and exit openings should be large enough to ensure free flow of air into and out of the room. As a rough guide the openings should each be at least 1.5 times the area of the radiator core.

Both the inlet and exit openings should have louvres for weather protection. These may be fixed but preferably should be movable in cold climates so that while the generator set is not operating the louvres can be closed. This will allow the room to be kept warm which will assist starting and load acceptance. For automatic starting generator sets, if the louvres are movable they must be automatically operated. They should be programmed to open immediately upon starting the engine. The force of radiator air should not be depended upon to open the louvre vanes unless the system has been specifically designed for this.

When a remote radiator or heat exchanger cooling system is used, the radiated heat from the generator set must still be removed from the room.

4.6.2 Inlet / Exit Ventilator Size

Before calculating the inlet ventilator size, it is necessary to take into account the radiator cooling air flow requirements and the fan static pressure available when the generator set is operating at its rated load. In standard room installations, the radiated heat is already taken into account in the radiator air flow.

For generator room installation with remote radiators, the room cooling airflow is calculated using the total heat radiation to the ambient air of the engine and alternator and any part of the exhaust system.

Engine and alternator cooling air requirements for our generator sets when operating at rated power are shown on specification sheets. Exhaust system radiation depends on the length of pipe within the room, the type of insulation used and whether the silencer is located within the room or outside. It is usual to insulate the exhaust piping and silencer so that heat radiation from this source may be neglected in calculating air flow required for room cooling. After determining the required air flow into the room, calculate the size of inlet ventilator opening to be installed in the outside wall. The inlet ventilator must be large enough so that the negative flow restriction will not exceed a maximum of 12 mm (0.5 in) H2O. Restriction values of air filters, screens and louvres should be obtained from manufacturers of these items.

Where the engine and room are cooled by a set mounted radiator, the exit ventilator must be large enough to exhaust all of the air flowing through the room, except the relatively small amount that enters the engine intake.

4.6.3 Engine Cooling

Cooling devices are commonly coolant-to-air (radiator) or coolant-to-raw water (heat exchanger) types.

In the most common generator set installation, the engine coolant is cooled in a generator set-mounted radiator with air blown through the radiator core by an engine driven fan. Some installations use a remotely mounted radiator, cooled by an electric motor driven fan. Where there is a continuously available supply of clean, cool raw water, a heat exchanger may be used instead of a radiator; the engine coolant circulates through the heat exchanger and is cooled by the raw water supply. An important advantage of a radiator cooling system is that it is self-contained. If a storm or accident disrupted the utility power source, it might also disrupt the water supply and disable any generator set whose supply of raw water depended upon a utility. Whether the radiator is mounted on the generator set or mounted remotely, accessibility for servicing the cooling system is important. For proper maintenance, the radiator fill cap, the cooling system drain valves, the fan belt tension adjustment must all be accessible to the operator.

4.6.4 Generator set Mounted Radiator

A generator set mounted radiator is mounted on the base in front of the engine. (see figure 4o). An engine-driven fan blows air through the radiator core, cooling the liquid engine coolant flowing through the radiator.

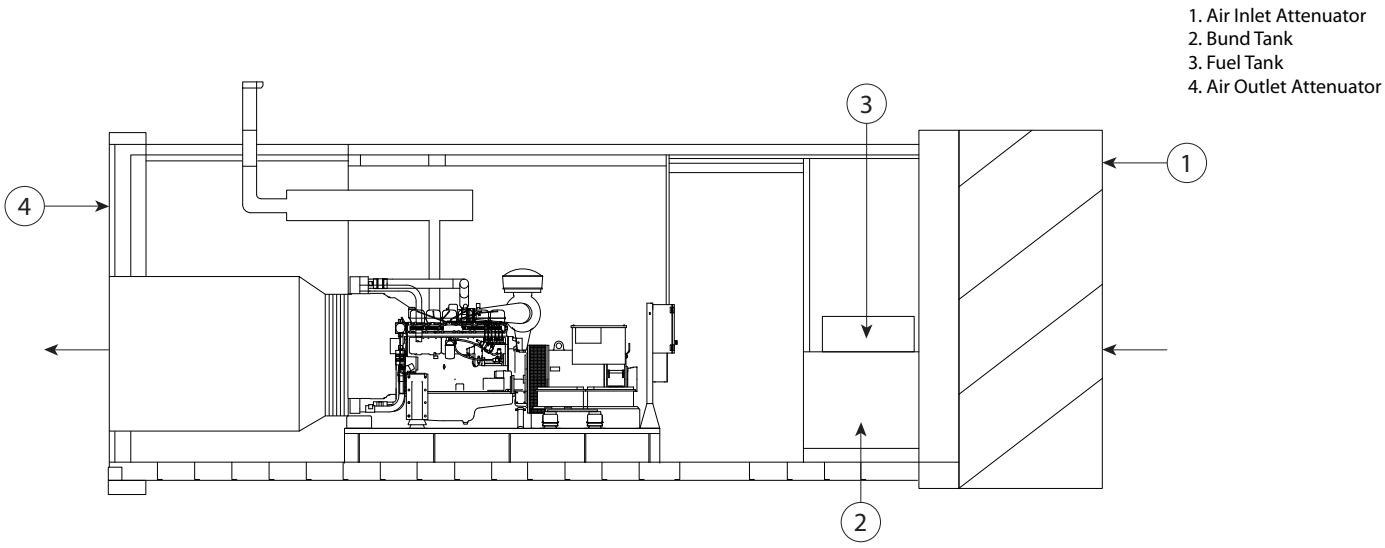


Figure 4n – Typical Sound Attenuated Installation

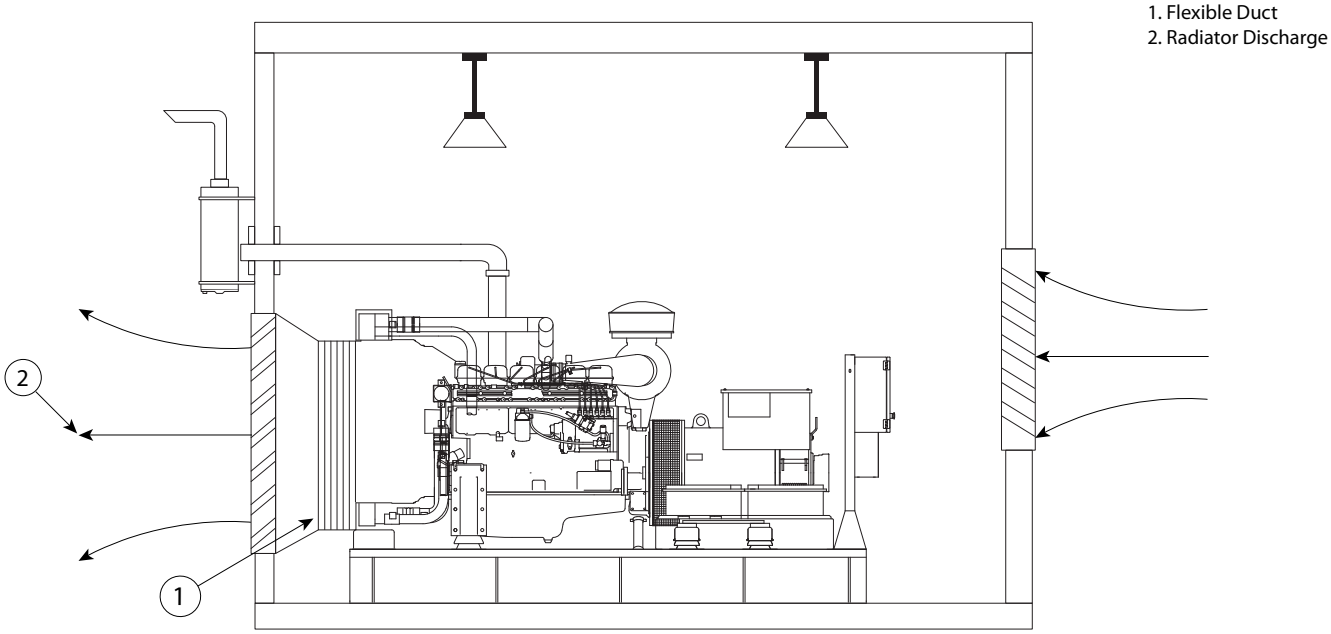


Figure 4o – Generator set Mounted Radiator Discharging Through An Outside Wall

Generator set mounted radiators are of two types. One type is used with the cooling fan mounted on the engine. The fan is belt-driven by the crankshaft pulley in a two-point drive. The fan support bracket, fan spindle and drive pulley are adjustable with respect to the crankshaft pulley in order to maintain proper belt tension. The fan blades project into the radiator shroud, which has sufficient tip clearance for belt tension adjustment.

The other type of generator set mounted radiator consists of an assembly of radiator, fan, drive pulley and adjustable idler pulley to maintain belt tension. The fan is mounted with its centre fixed in a venturi shroud with very close tip clearance for high efficiency performance. The fan drive pulley, idler pulley and engine crankshaft pulley are precisely aligned and connected in a three-point drive by the belts. This second type of set-mounted radiator usually uses an airfoil-bladed fan with the close fitting shroud.

The proper radiator and fan combinations will be provided and furnished with the generator set. Air requirements for cooling a particular generator set are given in the specification sheet. The radiator cooling air must be relatively clean to avoid clogging the radiator core. Adequate filtration of air flowing into the room should assure relatively clean air.
However, if the air at the site normally contains a high concentration of dirt, lint, sawdust or other matter, the use of a remote radiator, located in a cleaner environment, may alleviate a core clogging problem.

It is recommended that a generator set mounted radiator's discharged air should flow directly outdoors through a duct that connects the radiator to an opening in an outside wall. The engine should be located as close to the outside wall as possible to keep the ducting short. If the ducting is too long, it may be more economical to use a remote radiator. The air flow restriction of the discharge and the inlets duct should not exceed the allowable fan static pressure.

When the generator set mounted radiator is to be connected to a discharge duct, a duct adapter should be specified for the radiator. A length of flexible duct material (rubber or other suitable fabric) between the radiator and the fixed discharge duct is required to isolate vibration and provide freedom of motion between the generator set and the fixed duct.

4.6.5 Remote Radiator

A remote radiator with electric driven motor can be installed in any convenient location away from the generator set (see Figure 4p). A well-designed remote radiator has many useful features and advantages that provide greater flexibility of generator set installations in buildings.

More efficient venturi shroud and fan provide a substantial reduction in horsepower required for engine cooling. The fan may be driven by a thermostatically controlled motor, which will only draw power from the generator set when required to cool the engine. A remote radiator can be located outdoors where there is less air flow restriction and air is usually cooler than engine room air, resulting in higher efficiency and smaller size radiator; and fan noise is removed from the building.

Remote radiators must be connected to the engine cooling system by coolant piping, including flexible sections between engine and piping.

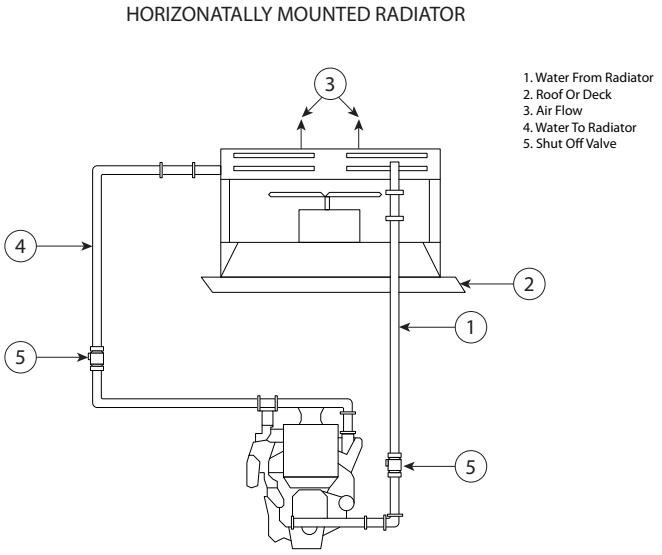


Figure 4p - Remote Radiator Connected directly to Engine Cooling System

4.6.6 Remote Radiator / Heat Exchanger System

Another type of remote radiator system employs a heat exchanger at the engine . See figure 4q. In this application, the heat exchanger functions as an intermediate heat exchanger to isolate the engine coolant system from the high static head of the remote radiator coolant.

The engine pump circulates engine coolant through the engine and the element of the heat exchanger. A separate pump circulates radiator coolant between the remote radiator and the heat exchanger tank.

Heat exchangers also are used for cooling the engine without a radiator, as described in the following section.

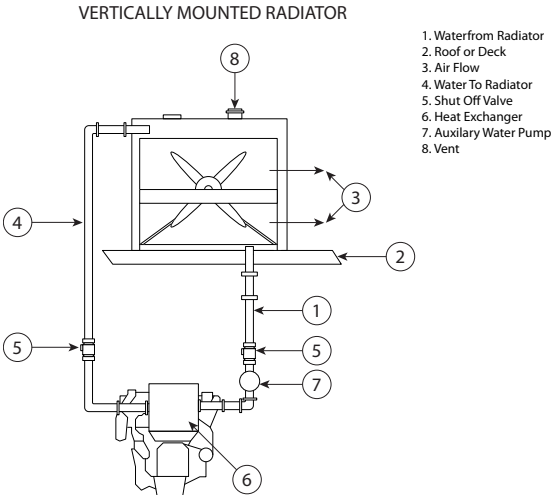


Figure 4q - Remote Radiator Isolated From Engine Cooling System By Heat Exchanger

4.6.7 Heat Exchanger Cooling

A heat exchanger may be used where there is a continuously available supply of clean, cool raw water. Areas where excessive foreign material in the air might cause constant radiator clogging – such as in saw mill installations – may be logical sites for heat exchanger cooling. A heat exchanger cools the engine by transferring engine coolant heat through passages in the elements to cool raw water. Engine coolant and raw cooling water flows are separated completely in closed systems, each with its own pump and never intermix.

A heat exchanger totally replaces the radiator and fan. It usually is furnished as part of the generator set assembly, mounted on the engine, although it can be located remotely. Since the engine does not have to drive a radiator fan, there is more reserve power available.

The raw water side of the heat exchanger requires a dependable and economical supply of cool water. Soft water is desired to keep the heat exchanger in good operating condition. For standby service, a well, lake or cooling tower is preferred over city water since the latter may fail at the same time that normal electric power fails, making the generator set useless.

4.6.8 Antifreeze / Corrosion Protection

If the engine is to be exposed to low temperatures, the cooling water in the engine must be protected from freezing. In radiator-cooled installations, antifreeze may be added to the water to prevent freezing. Ethylene glycol permanent antifreeze is recommended for diesel engines. It includes its own corrosion inhibitor, which eventually may have to be replenished. Only a non-chromate inhibitor should be used with ethylene glycol.

The proportion of ethylene glycol required is dictated primarily by the need for protection against freezing in the lowest ambient air temperature that will be encountered. The concentration of ethylene glycol must be at least 30% to afford adequate corrosion protection. The concentration must not exceed 50% to maintain adequate heat transfer capability.

All sets leaving the factory are pre-filled with extended life coolant (ELC).

For heat exchanger cooling, antifreeze does only half the job since it can only be used in the engine water side of the heat exchanger. There must be assurance that the raw water source will not freeze.

4.6.9 Water Conditioning

Soft water should always be used in the engine whether cooling is by radiator or by heat exchanger. Adding a commercial softener is the easiest and most economical method of water softening. Your Distributor can recommend suitable softeners. Manufacturers instructions should be carefully followed.

Note: The pH level should be regularly checked.

The pH value of the coolant must not be less than pH7 or more than pH9.5. The pH value can be found by the use of a pH meter or test papers, which are available from pharmaceutical manufacturers. If these limits are exceeded the pH value may be adjusted by the addition of a corrosion inhibitor to the same specification as that already in use. If this is not possible, the system may be drained, flushed and filled with a new coolant

4.7 Exhaust

The purpose of the engine exhaust system is to direct the exhaust outside to a location and height where the fumes and odours will not become an annoyance or hazard and also to reduce noise.

Engine exhaust must be directed to the outside through a properly designed exhaust system that does not create excessive back pressure on the engine. A suitable exhaust silencer should be connected into the exhaust piping. Exhaust system components located within the engine room should be insulated to reduce heat radiation. The outer end of the pipe should be equipped with a rain cap or cut at 60° to the horizontal to prevent rain or snow from entering the exhaust system. If the building is equipped with a smoke detection system, the exhaust outlet should be positioned so it cannot set off the smoke detection alarm.

Open generator sets will generally be supplied with a loose industrial class silencer, a stub pipe and a bellows (if required). An optional "Overhead Mounting Kit" includes a bend, silencer support brackets and a bellows (if not standard). An optional "Silencer Installation Kit" includes the wall sleeve, bend and rain cap for directing the exhaust outside (see Figure 4s). In all cases, the straight sections of pipe and screw rods for the support brackets are supplied by the customer.

Warning:

⚠ **Engine exhaust emissions are hazardous to personnel.**

⚠ **The engine exhaust for all indoor generator sets must be piped outdoors via leak-free piping in compliance with relevant Codes, Standards and other requirements.**

⚠ **Ensure hot exhaust silencers, piping and turbochargers, if fitted, are clear of combustible material and are guarded for personnel protection per safety requirements.**

⚠ **Ensure that fumes from the exhaust outlet will not be a hazard.**

In designing an exhaust system, the primary consideration is to not exceed the allowable back pressure permitted by the engine manufacturer. Excessive back pressure seriously affects engine output, durability and fuel consumption. To limit the back pressure the exhaust piping should be as short and straight as possible. Any required bends should have a curve radius of at least 1.5 times the inside diameter of the pipe. Any designed exhaust extensions over 3 metres should be approved by the factory.

Other exhaust design criteria are as follows:

- Exhaust components including turbochargers can be very hot and must be guarded where they could be accidentally touched.
- A flexible connection between the exhaust manifold and the piping system should be used to prevent transmission of engine vibration to the piping and the building and to allow for thermal expansion and any slight misalignment of the piping (see Figure 4v).

- Ensure that the silencer and all pipes are well supported to limit strain on the connectors which could result in cracks or leaks.
- Exhaust system components located within the generator room should be insulated to reduce heat radiation and noise levels. Pipes and the silencer, whether located inside or outside the building, should be located well clear of any combustible material.
- Any long horizontal or vertical piping should slope away from the engine and include drain traps at their lowest points to prevent water from reaching the engine or silencer.
- On generator sets above 150 kVA the silencer installation must include a purge plug for venting of the exhaust system in the event of difficult starting. The plug should be located adjacent to the exhaust flange and positioned to allow access.
- Where the pipe goes through a wall there should be a sleeve in the opening to absorb vibration and isolate combustible material from the hot pipes (see Figure 4t). There may also be an expansion joint in the pipe to compensate for lengthwise thermal expansion or contraction.
- The outer end of the exhaust pipe, if horizontal, should be cut at 60° to the horizontal or should be fitted with a rain hood or cap, if vertical, to prevent rain or snow from entering the exhaust system.
- The exhaust pipe must not be connected to exhausts from other generator sets or other equipment, such as a furnace or boiler.

4.7.1 Exhaust Piping

For both installation economy and operating efficiency, engine location should make the exhaust piping as short as possible with minimum bends and restrictions. Usually the exhaust pipe extends through an outside wall of the building and continues up the outside of the wall to the roof.

There should be a sleeve in the wall opening to absorb vibration and an expansion joint in the pipe to compensate for lengthways thermal expansion or contraction (see Figure 4s).

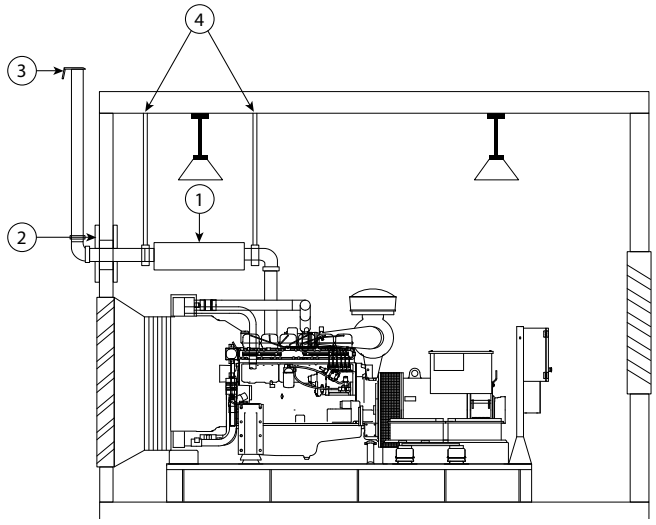
It is not normally recommended that the engine exhaust share a flue with a furnace or other equipment since there is danger that back pressure caused by one will adversely affect operation of the others. Such multiple use of a flue should be attempted only if it is not detrimental to performance of the engine or any other equipment sharing the common flue.

The exhaust can be directed into a special stack that also serves as the outlet for radiator discharge air and may be sound-insulated. The radiator discharge air enters below the exhaust gas inlet so that the rising radiator air mixes with the exhaust gas (see Figures 4t and 4u). The silencer may be located within the stack or in the room with its tail pipe extending through the stack and then outward.

Air guide vanes should be installed in the stack to turn radiator discharge air flow upward and to reduce radiator fan air flow restriction, or the sound insulation lining may have a curved contour to direct air flow upward. For a generator set enclosed on the roof or in a separate outdoor enclosure or trailer, the exhaust and radiator discharges can flow together above the enclosure without a stack. Sometimes for this purpose the radiator is mounted horizontally and air vertically.

Warning

⚠ **Do not use a common exhaust with multiple sets.**



1. Exhaust Silencer
2. Wall Sleeve and Expansion Joint
3. Rain Cap
4. Silencer/Pipework Supports

Figure 4s – Typical Exhaust System Installation

Note:

- The stub pipe is not designed to support the weight of the exhaust. Excessive weight on the stub pipe may lead to cracking / damage to the turbocharger

4.8 Exhaust Pipe Flexible Section

A flexible connection between the manifold and the exhaust piping system should be used to prevent transmitting engine vibration to the piping and the building and to isolate the engine and piping from forces due to thermal expansion, motion or weight of piping. A well designed flex section will permit operation with ± 13 mm (0.5 in) permanent displacement in any direction of either end of the section without damage. Not only must the section have the flexibility to compensate for a nominal amount of permanent mismatch between piping and manifold, but it must also yield readily to intermittent motion of the generator set on its vibration isolators in response to load changes. The flexible connector should be specified with the generator set.

4.8.1 Exhaust Pipe Insulation

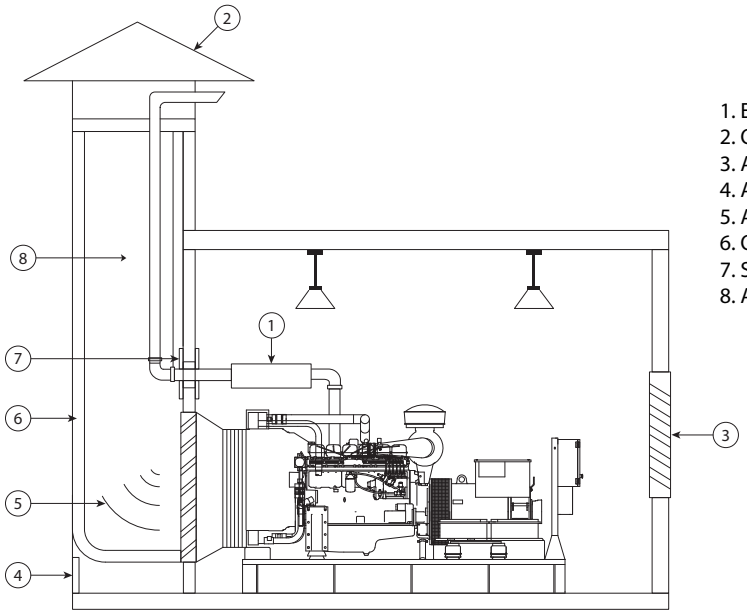
No exposed parts of the exhaust system should be near wood or other inflammable material. Exhaust piping inside the building (and the silencer if mounted inside) should be covered with suitable insulation materials to protect personnel and to reduce room temperature. A sufficient layer of suitable insulating material surrounding the piping and silencer and retained by a stainless steel or aluminium sheath may substantially reduce heat radiation to the room from the exhaust system.

An additional benefit of the insulation is that it provides sound attenuation to reduce noise in the room.

4.8.2 Minimising Exhaust Flow Restriction

Free flow of exhaust gases through the pipe is essential to minimise exhaust back pressure. Excessive exhaust back pressure seriously affects engine horsepower output, durability and fuel consumption. Restricting the discharge of gases from the cylinder causes poor combustion and higher operating temperatures. The major design factors that may cause high back pressure are:

- Exhaust pipe diameter too small
- Exhaust pipe too long
- Too many sharp bends in exhaust system
- Exhaust silencer restriction too high
- At certain critical lengths, standing pressure waves may cause high back pressure



1. Exhaust Silencer
2. Optional Cover
3. Air Inlet Lourves
4. Access Door
5. Air Guide Vanes
6. Optional Sound Reducing Material
7. Sleeve & Expansion Point
8. Air Chimney

Figure 4t – Horizontally Mounted Exhaust Silencer

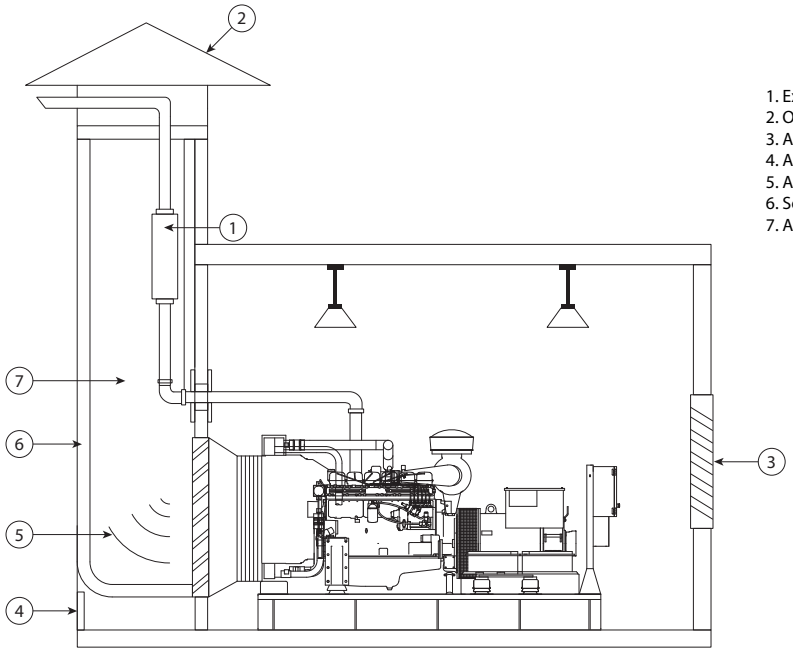


Figure 4u – Radiator Air Discharging into with Exhaust Pipe and Radiator Air Sound-Insulated Stack Containing Utilising Common Stack Exhaust Silencer

Excessive restriction in the exhaust system can be avoided by proper design and construction. To make sure you will avoid problems related to excessive restriction, ask the distributor to review your design.

The effect of pipe diameter, length and the restriction of any bends in the system can be calculated to make sure your exhaust system is adequate without excessive back pressure. The longer the pipe and the more bends it contains, the larger the diameter required to avoid excessive flow restriction and back pressure. The back pressure should be calculated during the installation stage to make certain it will be within the recommended limits for the engine.

Measure the exhaust pipe length from your installation layout (see Figure 4v). Take exhaust flow data and back pressure limits from the generator set engine specification sheet. Allowing for restrictions of the exhaust silencer and any elbows in the pipe, calculate the minimum pipe diameter so that the total system restriction will not exceed the recommended exhaust back pressure limit. Allowance should be made for deterioration and scale accumulation that may increase restriction over a period of time.

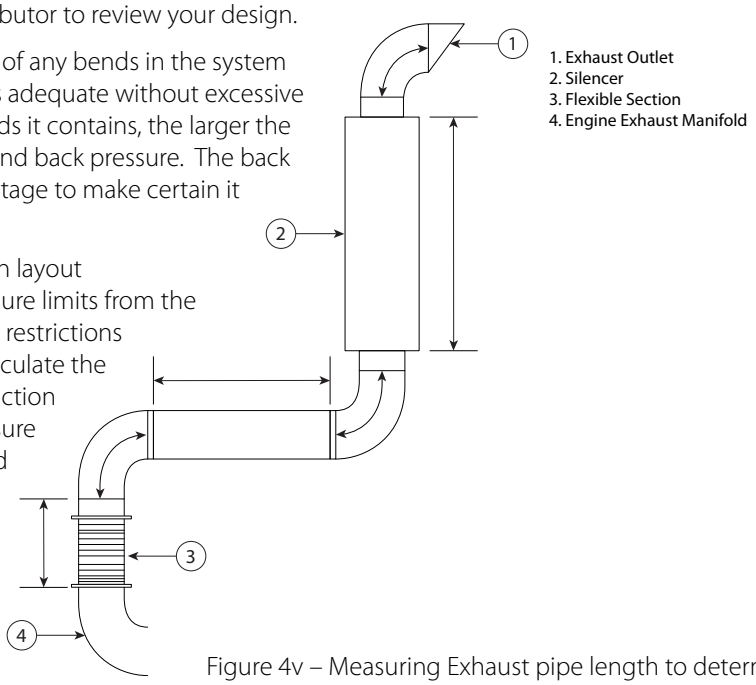


Figure 4v – Measuring Exhaust pipe length to determine exhaust back pressue

Elbow restriction is most conveniently handled by calculating an equivalent length of straight pipe for each elbow and adding it to the total length of pipe. For elbows and flexible sections, the equivalent length of a straight pipe is calculated as follows:

45° Elbow:
Length (ft) = 0.75 x Diameter (inches)

90° Elbow:
Length (ft) = 1.33 x Diameter (inches)

Flexible Sections:
Length (ft): 0.167 x Diameter (inches)

The following formula is used to calculate the back pressure of an exhaust system:

$$P = \frac{CLRQ^2}{D^5}$$

where:

P = back pressure in inches of mercury
C = .00059 for engine combustion airflow of 100 to 400 cfm
= .00056 for engine combustion airflow of 400 to 700 cfm
= .00049 for engine combustion airflow of 700 to 2000 cfm
= .00044 for engine combustion airflow of 2000 to 5400 cfm

L = length of exhaust pipe in feet

R = exhaust density in pounds per cubic foot

$$R = \frac{41.1}{\text{Exhaust temperature } ^oF^* + 460^o\ F}$$

Q = exhaust gas flow in cubic feet per minute*

D = inside diameter of exhaust pipe in inches

* Available from engine specification sheet These formulae assume that the exhaust pipe is clean commercial steel or wrought iron. The back pressure is dependent on the surface finish of the piping and an increase in the pipe roughness will increase the back pressure. The constant 41.1 is based on the weight of combustion air and fuel burned at rated load and SAE conditions. See engine specification sheet for exhaust gas temperature and air flow. Conversion tables to other units are provided in the appendix at the back of this manual.

4.8.3 Exhaust Silencing

Excessive noise is objectionable in most locations. Since a large part of the generator set noise is produced in the engine's pulsating exhaust, this noise can be reduced to an acceptable level by using an exhaust silencer. The required degree of silencing depends on the location and may be regulated by law. For example, the noise of an engine is objectionable in a hospital area but generally is not as objectionable in an isolated pumping station.

4.8.4 Exhaust Silencer Selection

The silencer reduces noise in the exhaust system by dissipating energy in chambers and baffle tubes and by eliminating wave reflection that causes resonance. The silencer is selected according to the degree of attenuation required by the site conditions and regulations. The size of silencer and exhaust piping should hold exhaust back pressure within limits recommended by the engine manufacturer.

Silencers are rated according to their degree of silencing by such terms as "low degree" or "industrial", "moderate" or "residential" and "high degree" or "critical".

Low-Degree or Industrial Silencing – Suitable for industrial areas where background noise level is relatively high or for remote areas where partly muffled noise is permissible.

Moderate-Degree or Residential Silencing – Reduces exhaust noise to an acceptable level in localities where moderately effective silencing is required – such as semiresidential areas where a moderate background noise is always present.

High-Degree or Critical Silencing – Provides maximum silencing for residential, hospital, school, hotel, store, apartment building and other areas where background noise level is low and generator set noise must be kept to a minimum.

The silencer may be located close to the engine, with exhaust piping leading from the silencer to the outside; or it may be located outdoors on the wall or roof. Locating the silencer close to the engine affords best overall noise attenuation because of minimum piping to the silencer. Servicing and draining of the silencer is likely to be more convenient with the silencer indoors.

However, mounting the silencer outside has the advantage that the silencer need not be insulated (though it should be surrounded by a protective screen). The job of insulating piping within the room is simpler when the silencer is outside and the insulation can then aid noise attenuation. Since silencers are large and heavy, consider their dimensions and weight when you are planning the exhaust system. The silencer must be adequately supported so that its weight is not applied to the engine's exhaust manifold or turbocharger. The silencer must fit into the space available without requiring extra bends in the exhaust piping, which would cause high exhaust back pressure. A side inlet silencer may be installed horizontally above the engine without requiring a great amount of headroom.

Silencers or exhaust piping within reach of personnel should be protected by guards or insulation. Indoors, it is preferable to insulate the silencer and piping because the insulation not only protects personnel, but it reduces heat radiation to the room and further reduces exhaust system noise.

Silencers mounted horizontally should be set at a slight angle away from the engine outlet with a drain fitting at the lowest point to allow the disposal of any accumulated moisture.

4.9 Sound Attenuation

If noise level must be limited, it should be specified in terms of a sound pressure level at a given distance from the generator enclosure. Then the enclosure must be designed to attenuate the noise generated inside the enclosure to produce the required level outside. Don't attempt to make this noise level unnecessarily low, because the means of achieving it may be costly.

Use of resilient mounts for the generator set plus normal techniques for controlling exhaust, intake and radiator fan noise should reduce generator set noise to an acceptable level for many installations. If the remaining noise level is still too high, acoustic treatment of either the room or the generator set is necessary. Sound barriers can be erected around the generator set, or the walls of the generator room can be sound insulated, but must not be placed in any way to impede airflow or the generator set can be enclosed in a specially developed sound insulated enclosure.

In most cases it is necessary that the air intake and air discharge openings will have to be fitted with sound attenuators. If it is desired to protect operating personnel from direct exposure to generator set noise, the instruments and control station may be located in a separate sound insulated control room.

4.10 Fuel System

A dependable fuel supply system must assure instant availability of fuel to facilitate starting and to keep the engine operating. This requires, at a minimum, a small day tank (usually incorporated into the generator set baseframe – called a basetank) located close to the generator set. With generally a capacity of 8 hours operation, this day tank can be backed up by an auxiliary remote fuel system including a bulk storage tank and the associated pumps and plumbing (If required).

Warning:

⚠ **For stationary generator sets with remote fuel storage systems, make sure such systems are installed in compliance with relevant Codes, Standards or other requirements.**

⚠ **Do not smoke or allow sparks, flames or other sources of ignition around fuel. Fuel vapours and oil vapours are explosive.**

4.10.1 Day Tank

Day tanks provide a readily available supply of fuel directly to the generator set and should therefore be located within the generator room. The steel baseframe of all but the largest generator sets are designed with a steel or polyethylene day tank built in with the engine fuel lines connected. These "basetanks" provide for at least 8 hours operation at full load or approximately 24 hours if an extended capacity basetank has been fitted.

Warning:

⚠ **Never connect a remote fuel system to polyethylene fuel tanks incorporated in the baseframe on smaller generator sets.**

In addition, the size of the day tank should be large enough to keep fuel temperatures down, since some engines return hot fuel used to cool the injectors

Model	Extra Capacity	
	With Fuel Coolers	Without Fuel Coolers
910-1100 kVA	1500 Litres	3000 Litres
1250-1650 kVA	2250 Litres	4500 Litres
1700-2500 kVA	3000 Litres	6000 Litres

4.10.2 Bulk Storage Tanks

For extended operation, a separate bulk fuel storage tank is required. Especially for standby generator sets it is not advisable to depend on regular delivery of fuel. The emergency that requires use of the standby set may also interrupt the delivery of fuel.

The bulk tank should generally be located outside the building where it will be convenient for refilling, cleaning and inspection. It should not, however, be exposed to freezing weather because fuel flow will be restricted as viscosity increases with cold temperatures. The tank may be located either above or below ground.

A vent must be installed on the bulk tank to relieve the air pressure created by filling the tank or created by evaporation and expansion. It will also prevent a vacuum as the fuel is consumed. The tank should be placed on a 2° tilt to assure a concentrated settling of water and sediment. A sludge drain valve should be installed at the low point to allow removal of water and sediment on a regular basis. Underground tanks should have this water and sediment pumped out regularly. All bulk tanks should be fitted with an external filter and be part of the maintenance programme of the generator set.

Warning:

⚠ **For standby generator sets not used, fuel may become stagnant and contaminated with water and algae. Any fuel over 12 months old should be analysed before use.**

4.10.3 Fuel Lines

The fuel lines can be of any fuel compatible material such as steel pipe or flexible hoses that will tolerate environmental conditions.

Warning:

⚠ **Do not use galvanised pipe or fittings for the fuel system.**

Fuel delivery and return lines should be at least as large as the fitting sizes on the engine and overflow piping should be one size larger. For longer runs of piping or low ambient temperatures the size of these lines should be increased to ensure adequate flow. Flexible piping should be used to connect to the engine to avoid damage or leaks caused by engine vibration.

The fuel delivery line should pick up fuel from a point no lower than 50 mm (2") from the bottom at the high end of the tank (away from the drain plug).

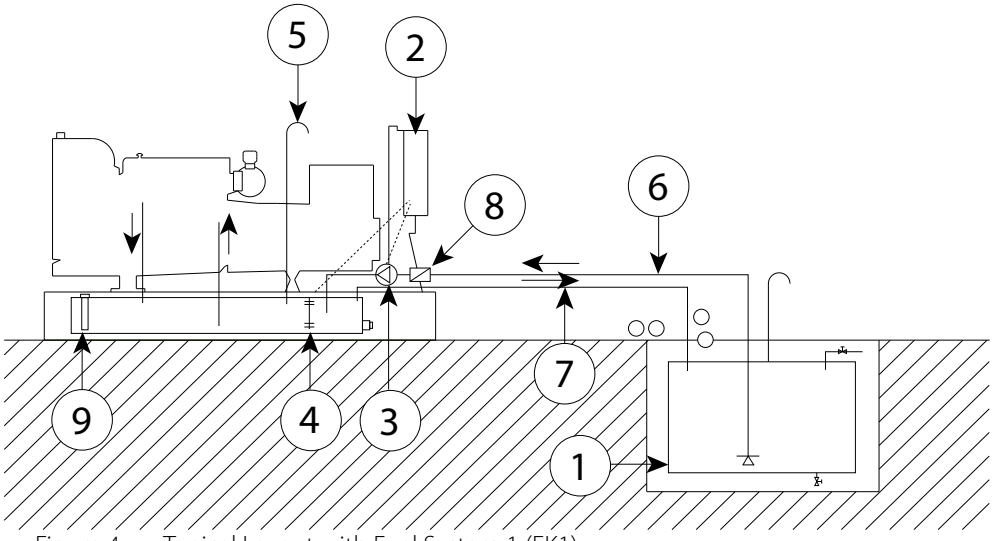
4.10.4 Remote Fuel Systems

Most sets are supplied equipped with a diesel fuel tank in the baseframe. Certain installations, however, require the addition of remote fuel supplies. The manufacturer recommends the 5 types of systems detailed below. It must be noted that as polyethylene fuel tanks are not compatible with remote fuel systems, a metal fuel tank must be fitted.

Fuel System 1 **(FK1)**: For installations where the bulk tank is located below floor level a pumped fuel supply from the bulk tank to the basetank is required (see Figure 4w).

The basetank must include an overflow, extended vent, sealed gauges and no manual fill. All other connections on top of the tank must be sealed to prevent leakage.

The position of the fuel tank should take into account that the maximum suction lift of the fuel transfer pump is 3 metres and that the maximum restriction caused by the friction losses in the return fuel line should not exceed 2 psi. A 1.4m extended vent pipe will be required on the basetank to prevent overflow.



1. Below Floor Level Bulk Tank
2. Control Panel
3. AC Fuel Pump
4. Fuel Level Switches
5. Extended Vent
6. Supply Line
7. Return Line
8. Strainer
9. Level Gauge

Figure 4w – Typical Layout with Fuel System 1 (FK1)

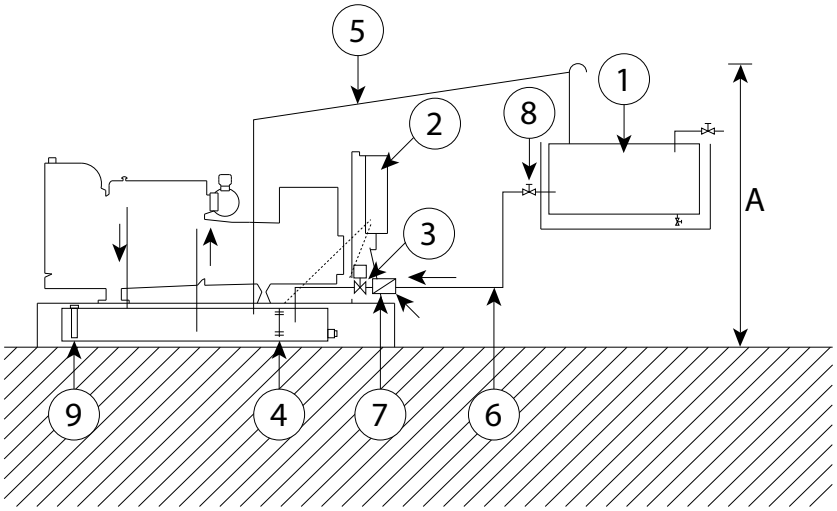
The manufacturer's kit for Fuel System 1 includes an AC fuel pump with mounting bracket, fuel strainer, 4 position float switch and controls for the fuel pump mounted in the generator set control panel. In addition, with this kit the basetank is modified by the removal of the manual fill facility. All other items including fuel lines, bulk tank, extended vent, etc. are supplied by the installer.

Fuel System 2 **(FK2)**: Where the location of the bulk tank is higher than the generator set, a gravity fuel supply from the bulk tank to the basetank is required (see Figure 4x).

The basetank must include an overflow, extended vent, sealed gauges and no manual fill. All other connections on top of the tank must be sealed to prevent leakage.

"Distance "A" in Figure 4x is limited to 1400mm for all metal basetanks except for models 350 – 900 kVA where this distance can be increased to 3700mm.

The manufacturer's kit for Fuel System 2 includes a DC motorised valve with mounting bracket, fuel strainer, 4 position float switch and controls for the motorised valve mounted in the generator set control panel. In addition, with this kit the basetank is modified by the removal of the manual fill facility. All other items including fuel lines, bulk tank, etc. are supplied by the installer.



1. High Level Bulk Tank
2. Control Panel
3. DC Motorised Valve
4. Fuel Level Switch
5. Return Line (Continuous Rise)
6. Supply Line
7. Strainer
8. Isolating Valve
9. Level Gauge

Figure 4x – Typical Layout with Fuel System 2 (FK2)

Note: 4000 series generator sets only: the fuel level in the day tank must not exceed 1500 mm above the level of the fuel injectors.

Fuel System 2b **(FK2b)**: This option provides manual backup for the fuel transfer system where the bulk fuel tank is located higher than the basetank.

Upon failure of the automatic transfer system, the manual backup can be used to transfer fuel from the main bulk tank to the generator set basetank. The manual backup system consists of a bypass with a manually operated shutoff valve. When the fuel level in the generator set basetank is low (as observed by using the mechanical fuel gauge) the manual shut-off valve in the bypass circuit should be opened until the required fuel level is reached. The maximum allowable head pressure of the oil at the Engine Fuel Pump is given below.

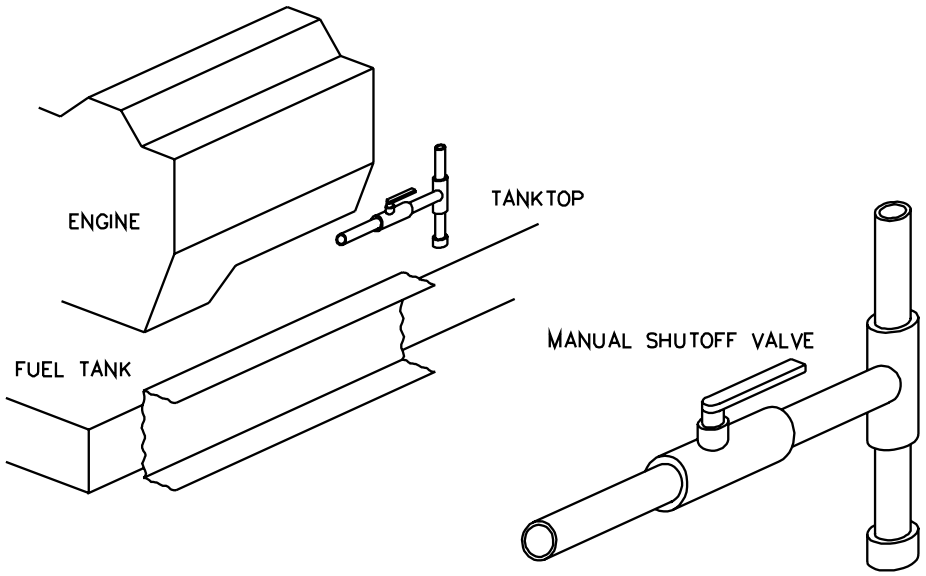


Figure 4y

Fuel System 4 **(FK4)**: Some installations may require a system where fuel is pumped from a free standing bulk tank (see Figure 4z). This pumped system would only be used if gravity feed is not possible from the bulk tank to the basetank.

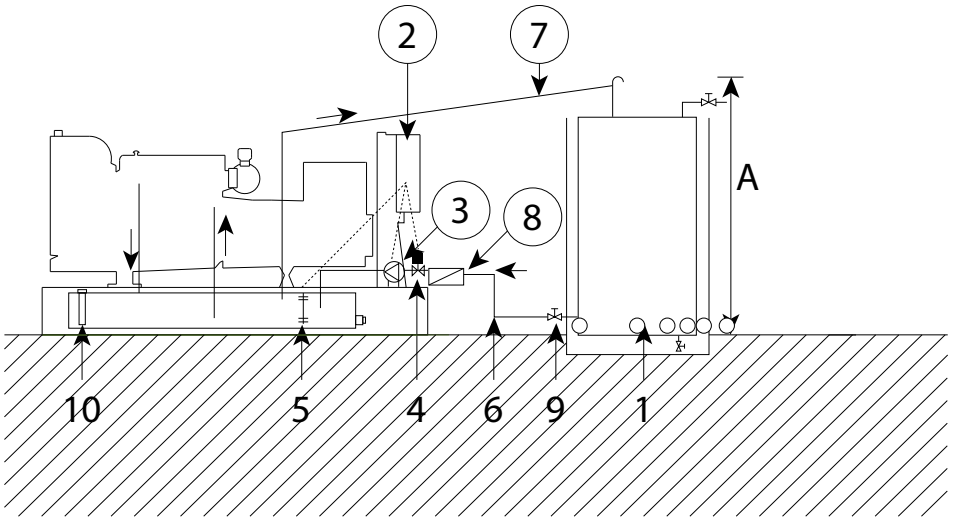
The basetank must include an overflow, extended vent, sealed gauges and no manual fill. All other connections on top of the tank must be sealed to prevent leakage.

"Distance "A" in Figure 4z is limited to 1400 mm for all metal basetanks except models 350 kVA – 900 kVA where this distance is extended to 3700 mm. Note that the maximum restriction caused by friction losses and height of the return line should not exceed 2 psi.

Note:

- 4000 series generator sets only: the fuel level in the day tank must not exceed 1500 mm above the level of the fuel injectors.

The manufacturer's kit for installing this system includes an AC fuel pump with mounting bracket, a DC motorised valve with mounting bracket, fuel strainer, 4 position float switch and controls for the fuel pump and motorised valve mounted in the generator set control panel. In addition, with this kit the basetank is modified by the removal of the manual fill facility. All other items including fuel lines, bulk tank, etc. are supplied by the installer.



1. Above Ground Bulk Tank
2. Control Panel
3. AC Fuel Pump
4. Motorised Valve
5. Fuel Level Switch
6. Supply Line
7. Return Line (Continuous Rise)
8. Strainer
9. Isolating Valve
10. Level Gauge

Figure 4z – Typical Layout with Fuel System 4 (FK4)

4.11 Fire Precautions

When designing the generator set installation the following points should be considered:

- The room should be designed so that there is an easy escape route for operating personnel in the event of fire within the room.
- Supply a Class BC or Class ABC fire extinguisher and/or fire extinguishing system.
- Gravity operated fire valves released by temperature operated fusible links mounted above the engine can be installed in the fuel lines.

4.12 Starting Batteries

Warning:

⚠ **Do not smoke or allow sparks, flames or other sources of ignition around batteries. Hydrogen gas generated by charging batteries is explosive.**

The starting batteries should be located as close as possible to the generator set while still being accessible for servicing. This will prevent electrical losses from long cables that could impact on the engine starting capability of the batteries. See Section 10.

4.13 Electrical Connection

On-site electrical installation will generally consist only of connecting up the site load to the generator set output terminals. Only fully qualified and experienced electrical technicians should carry out electrical installation, service and repair work.

Warning:

⚠ **Make electrical connections in compliance with relevant Electrical Codes, Standards or other requirements. This includes requirements about grounding and ground/earth faults.**

4.13.1 Cabling

Due to movement of generator sets on their vibration mounts, the electrical connection to the set should be made with flexible cable. This will prevent transmission of vibrations and possible damage to the alternator or circuit breaker terminals. If flexible cabling can not be used throughout the installation then a link box should be installed close to the set with a flexible connection to the generator set.

The cable should be protected by laying it in a duct or cable tray. However, the duct or tray should never be rigidly connected to the generator set. When bending cable, reference must be made to the recommended minimum bending radius.

The cable must be suitable for the output voltage and the rated current of the generator set. In determining the size, allowances should be made for ambient temperature, method of installation, proximity of other cables, etc. When single core cables are used the gland plates must be of non-ferrous material such as aluminium, brass or a non-metallic material such as tufnol. Alternatively slots can be cut between gland holes of cables to prevent circulating (eddy) currents in magnetic gland plates.

All connections should be carefully checked for integrity. Phase rotation must be checked for compatibility with the installation. This is vitally important when connection is made to an automatic transfer switch, or if the machine is to be paralleled.

4.13.2 Protection

The cables connecting the generator set with the distribution system are protected by means of a circuit breaker to automatically disconnect the generator set in case of overload or short circuit.

4.13.3 Loading

When planning the electrical distribution system it is important to ensure that a balanced load is presented to the generator set. If loading on one phase is substantially higher than the other phases it will cause overheating in the alternator windings, imbalance in the phase to phase output voltage and possible damage to sensitive 3 phase equipment connected to the system. Ensure that no individual phase current exceeds the current rating of the generator set. For connection to an existing distribution system, it may be necessary to reorganise the distribution system to ensure these loading factors are met.

4.13.4 Power Factor

The power factor (cos Φ) of the connected load should be determined. Power factors below 0.8 lagging (inductive) can overload the generator. The set will provide its kilowatt rating and operate satisfactorily from 0.8 lagging to unity power factor (1.0).

Particular attention must be given to installations with automatic or manual power factor correction equipment such as capacitors to ensure that a leading power factor is never present. This will lead to voltage instability and may result in damaging overvoltages. Generally, whenever the generator set is supplying the load any power factor correction equipment should be switched off.

4.13.5 Grounding Requirements

Regulations vary for different locations. The frame of the generator set must be connected to an earth ground. Since the generator set is mounted on vibration isolators, the ground connection must be flexible to avoid possible breakage due to vibration. On the majority of self contained generator sets the ground connection is located inside the circuit breaker box.

Ground connection cables or straps should have at least full load current carrying capacity and meet applicable regulations.

Warning:

⚠ **Do not remove the earth bonding strap between the engine/alternator and the baseframe.**

4.13.6 Alternator Reconnection

Most alternators can be reconnected (Restrapped) to suit different output voltages. The reconnection procedures are given in the Alternator Manual. Ensure that all other components such as circuit breakers, current transformers, cables and ammeters are suitable before operating at a different voltage.

Warning:

⚠ **If restrapping to a lower voltage the breaker, power cables and CT's will be underrated and require appropriate rated items to be fitted.**

4.13.7 Parallel Running

Extra equipment must be fitted for the standard generator sets to be operated in parallel with other generator sets or with mains power.

4.13.8 Insulation Test

Before starting the generator set after installation, test the insulation resistance of the windings. The Automatic Voltage Regulator (AVR) should be disconnected and the rotating diodes either shorted out with temporary links or disconnected. Any control wiring must also be disconnected.

A 500V Megger or similar instrument should be used. Disconnect any earthing conductor connected between neutral and earth and megger an output terminal to earth. The insulation resistance should be in excess of 5MΩ to earth. Should the insulation resistance be less than 5MΩ the winding must be dried out. See the Alternator Manual for procedures.

4.14 Acoustic Silencing

Control of generator set noise is becoming very important in most installations. There is a range of options available to control the noise level.

Warning:

⚠ **Ear protection must be worn when operating or working around an operating generator set.**

4.14.1 Exhaust Silencers

As discussed in Section 4.8 the exhaust silencer will decrease sound levels from the engine. Varying degrees of sound attenuation are available from different types of silencers. These levels are often described by terms such as industrial, residential, critical or supercritical.

4.14.2 Enclosures

Section 4.2 discusses enclosures that are available in either weatherproof or sound attenuating versions. These enclosures can be designed to meet a specific sound level requirement.

4.14.3 Other Sound Attenuation

For installations in buildings there are other types of equipment such as acoustic louvres, splitter vents and fan silencers, as well as sound absorbing wall coverings, that can be used to reduce the noise levels of generator sets.

4.15 Storage

Long term storage can have detrimental effects on both the engine and alternator. These effects can be minimised by properly preparing and storing the generator set.

4.15.1 Engine Storage

The engine should be put through an engine "preservation" procedure that includes cleaning the engine and replacing all the fluids with new or preserving fluids. See the Engine Manual for the proper procedure.

4.15.2 Alternator Storage

When an alternator is in storage, moisture tends to condense in the windings. To minimise condensation, store the generator set in a dry storage area. If possible use space heaters to keep the windings dry.

After removing the generator set from storage, perform an insulation check as discussed in Section 4.12.8. If the readings are lower than prior to storage, it may be necessary to dry out the windings. See the Alternator Manual for procedures.

If the megger reading is below 1MΩ after drying, the insulation has deteriorated and should be reconditioned.

4.15.3 Battery Storage

While the battery is stored, it should receive a refreshing charge every 12 weeks (8 weeks in a tropical climate) up to a fully charged condition.

5. CONTROL SYSTEM DESCRIPTION AND TROUBLE SHOOTING

5.1 Control System Description

An electronic control system has been designed and installed to control and monitor the generator set. Depending on the requirements of the generator set, one of several different standard control systems may be fitted. Other more specialised systems may be fitted for specific installations in which case separate documentation is provided.

These control systems consist of three major components working together:

Control Panel – provides a means of starting and stopping the generator set, monitoring its operation and output and automatically shutting down the generator set in the event of a critical condition arising such as low oil pressure or high engine coolant temperature to prevent major damage to the engine / alternator.

Engine Interface Module (where fitted) - provides switching relays for the Starter Motor Solenoid, Glow Plug and Fuel Solenoid. Each of these circuits is protected with individual fuses mounted in the module. Individual LED's illuminate when each circuit is energised.

Power Output Circuit Breaker - serves to protect the alternator by automatically disconnecting the load in the event of overload or short circuit. It also provides a means of switching the generator set output.

Note:

- Products within the 6.8 – 200 kVA range are not equipped with an EIM but are provided with the switching relays for Starter Motor Solenoid, glow plug and fuel solenoid in the control panel/Relay box. Each of these products is now protected with individual Miniature Circuit Breakers (MCBs) or fuses mounted inside the control panel/relay box.

5.2 1002T

The 1002T Series Control System provides for manual starting and stopping of the generator set and provides protection for the engine against both high engine coolant temperature and low oil pressure.

Before starting or running the generator set, the operator should become fully acquainted with the instruments and controls. The instruments should be observed from time to time while the generator set is running so that any abnormal readings can be detected before problems arise.

5.2.1 Control Panel Instrumentation

Figure 5a shows typical diagrams of each of the control panels. The addition of optional equipment will add items to the panel so the panel fitted on the generator set may be slightly different from the typical ones shown. The following descriptions explain the function of each item on the panels:

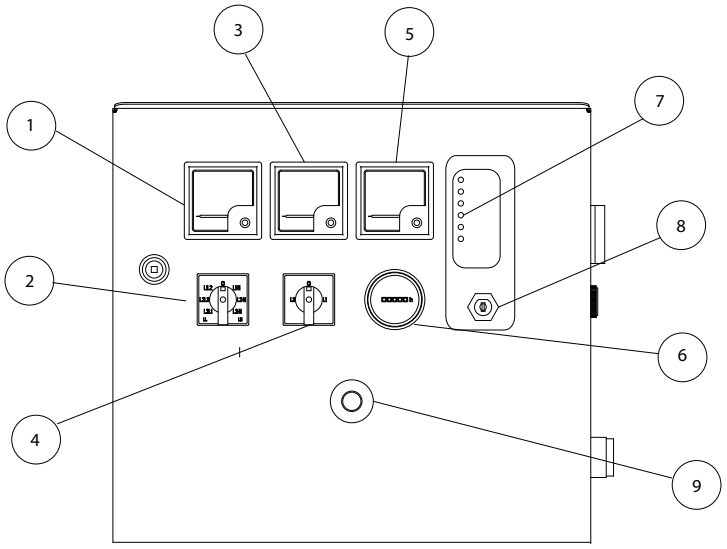
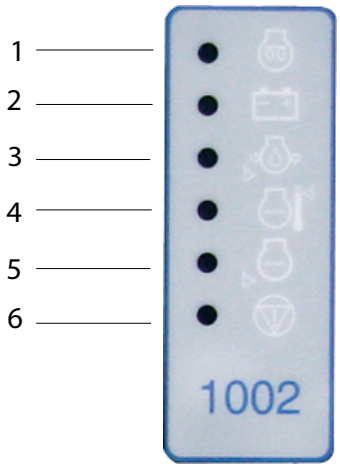


Figure 5a – Layout of 1002T Series Control Panel

1. AC VOLTMETER – indicates the AC voltage generated at the alternator output terminals. The reading indicated on the voltmeter will vary depending on the position of the voltmeter selector switch (item 2). It should not, however, vary while the generator set is operating. If the meter gives no reading while the generator set is running, ensure that the AC voltmeter selector switch is not in the OFF position.
2. AC VOLTMETER SELECTOR SWITCH – allows the operator to select voltage reading between phases or between a phase and neutral. The OFF position allows the voltmeter "zero" position to be checked while the generator set is running.
3. AC AMMETER – indicates the AC electrical current being delivered which is dependant on the connected load. A separate reading from each of the phases is possible using the ammeter selection switch (item 4). If the meter gives no reading while the generator set is running, ensure that the AC ammeter selector switch is not in the OFF position.
4. AC AMMETER SELECTOR SWITCH – allows the operator to select a current reading from each of the phases. The OFF position allows the ammeter "zero" position to be checked while the generator set is running.
5. FREQUENCY METER – Indicates the output frequency of the generator set. At partial load the frequency will be slightly higher than normal, depending on the droop of the governor. In practice, no load frequencies of approximately 52 and 62 Hz for 50 Hz and 60 Hz respectively, are considered normal. The frequencies will fall, as the generator set is loaded, to 50 Hz and 60 Hz at full load.
6. HOURS RUN METER – indicates the total number of hours of generator set operation. This meter assists with maintenance.
7. DC BATTERY VOLTMETER (where fitted) – indicates the state of charge of the battery. When the engine is at standstill the normal battery voltage will be 12 to 14 volts on a 12 volt system and 24 to 28 volts on a 24 volt system. During starting, the needle will drop to about 70% of normal and oscillate as the engine cranks. Once the engine has started, the needle should return to its normal value. If the battery charging alternator is charging correctly, the voltage reading will always be higher with the generator set running than when it is stopped.
8. FAULT INDICATOR LAMPS (where fitted) – illuminate to indicate that the protective circuitry has sensed the indicated condition. The lamp should be red on conditions for which the system will initiate a shutdown of the generator set. For alarms, the lamp can be red or amber.



1 - Pre-Heat Glow Plugs
2 - Charge Alt Fail
3 - Low Oil Pressure
4 - High Engine Temp
5 - Low Coolant Level (Option
6 - Emergency Stop)

Figure 5b – 1002T Fault Lamps

9. KEY SWITCH – A four position switch that provides a means of starting and operating the generator set.

   Position "0" – Off / Reset
   Power is turned off and protection circuitry is reset in this position.

   Position "1" – On
   DC power is supplied to the control system and the fault protection timer relay is initiated.

   Position "" – Thermostart
   DC power is supplied to the thermostart circuit, if fitted.

   Position "" – Start
   DC power is supplied to the starter motor to crank the engine. The thermostart circuit is also powered, if fitted.
10. EMERGENCY STOP Push button – A red lock–down push button that immediately shuts down the generator set and will inhibit start until the push button has been released by turning it clockwise. Prior to restarting the generator set, this fault lamp must be reset by turning the key switch to position "O" (off) (1002T Panel Only).
11. FUSES – A fuse interrupts excessive current so that the circuit(s) it supplies are protected.
12. OUTPUT CIRCUIT BREAKERS – To protect the alternator, a suitably rated circuit breaker selected for the generator set model output rating, is supplied.

5.2.2 General Information 1002T Control Systems

Figure 5c – 1002T Control System

The 1002T control system allows for manual starting and stopping of the generator set and provide protection for the engine against critical failures.

5.2.3 Pre-Start Checks

The following checks should be performed prior to starting the generator set:

1. Ensure the Control Switch / Key Switch is Off on the 1002T.

A visual inspection should take only a few minutes and can prevent costly repairs and accidents – For maximum generator set life, visually inspect the generator set before starting. Look for items such as:

- Loose fastenings / fixings, worn belts or loose connections. Repair as necessary.
- The fan and exhaust guards must be at the correct positions and securely fixed. Repair damaged / loose guards or renew missing guards.
- Wipe clean all filler caps before the engine is serviced or fluids are topped up to reduce the chance of any system contamination.
- For any type of leak (coolant, lubricating oil or fuel), clean away the fluid. If a leak is observed, find the source and correct the leak. If a leak is suspected, check the fluid levels frequently until the leak is found and repaired.
- Accumulated grease and/or oil on an engine is a fire hazard. Remove it by steam cleaning or by the use of a high pressure water jet. Avoid high–pressure water on the electronic / electrical components, provide suitable protection were possible.
- Ensure that the coolant pipes are fitted correctly and that they are secure. Check for leaks. Check the condition of all pipes for splits or signs of rubbing.

Fluid levels

2. Check the engine oil and coolant levels – replenish as necessary (see engine handbook for locations).

   Ensure fluids used are as recommended within the engine handbook.

Warning:

⚠ **Do not remove the radiator cap or any component of the cooling system while the engine is running and while the coolant is under pressure, because dangerous hot coolant can be discharged, posing a risk of personal injury. Do not add large amounts of cold coolant to a hot system as serious engine damage could result.**

Note:

- Diesel engines normally consume lube oil at a rate of 0.25% to 1% of the fuel consumption at full load.
- When adding coolant to the radiator system, always pour slowly to help prevent air from becoming trapped in the engine. Always top up when engine is cold.

Warning:

⚠ **When filling the fuel tank, do not smoke or use an open flame in the vicinity.**

3. Check the fuel level – fill as necessary.

Warning:

⚠ **Before tightening the fan belts, disconnect the battery negative (–) lead to ensure the engine cannot be accidentally started.**

4. Check the condition and tension of the fan and engine alternator belts – tighten as necessary.
5. Check all hoses for loose connections or deterioration – tighten or replace as necessary.
6. Check the battery terminals for corrosion – clean as necessary.

Warning:

⚠ **When working with the batteries, do not smoke or use an open flame in the vicinity. Hydrogen gas from batteries is explosive.**

⚠ **Do not short the positive and negative terminals together.**

7. Check the battery electrolyte level – fill with distilled water as necessary.
8. Check the control panel and the generator set for heavy accumulation of dust and dirt – clean as necessary. These can pose an electrical hazard or give rise to cooling problems.
9. Check the air filter restriction indicator, if fitted – replace the filter as necessary.
10. Clear the area around the generator set of any insecure items that could inhibit operation or cause injury. Ensure cooling air ventilation screens are clear.
11. Visually check the entire generator set for signs of leaks from the fuel system, cooling system or lubrication seals.
12. Periodically drain exhaust system condensate traps, if equipped.
13. Ensure the alternator output circuit breaker is in the "OFF" (handle down) position.

5.2.4 Normal Startup / Shutdown – Key Start Panel

The following procedure should be used for normal starts on a generator set equipped with a 1002T Series Key Start Control System:

Note:

- The generator set may be stopped at any time by turning the Key Switch to Position "0" (Off).

1. Complete Pre-Start checks as per Section 5.2.
2. Check the battery voltage by turning the Key Switch from Position "0" (Off) to Position "1" (On) and reading the battery voltmeter. A fully charged battery will indicate 12 to 14 volts on a 12 volt system or 24 to 28 volts on a 24 volt system. Return the Key Switch to Position "0" (Off).

Note:

- In the event of low battery voltage the LED will indicate on the 1002T PCB (see Figure 5a – 8). There is no battery voltmeter on 1002T panel.
- The engine will not start if any fault indicators are illuminated. Reset the control system by turning the Key Switch to Position "0" (Off). Ensure the faults have been corrected prior to attempting to start the generator set.

WHEN ENGINE HAS STARTED

3. Check for any abnormal noise or vibration.
4. Carry out visual checks for system leaks.
5. Check the control panel for indications of engine temperature and oil pressure
6. Switch the alternator output circuit breaker to "ON" (handle up).

Warning:

⚠ **The Key Switch must not be turned to position "ooo" or position "↷", while the engine is running.**

7. Start: Turn the Key Switch from Position "0" (Off) through Position "1" (On) to Position "ooo" (Thermo) to activate the thermostart, if fitted. Hold for 7 seconds to preheat the induction air. After this time, the Key Switch should be further turned to Position "↷" (Start) to crank the engine. When the engine starts, release the Key Switch immediately allowing it to return to Position "1" (On).

   Do not crank the engine for more than 5 to 7 seconds should the engine fail to start. Allow an interval of 10 seconds and always turn the Key Switch to Position "0" (Off) between cranking attempts. If, after 4 cranking attempts, the engine still has not started, refer to a qualified generator set technician to determine the cause of failure to start.

Note:

- Load can now be applied to the generator set. However, the maximum step load that can be accepted in any one step is dependent on the operating temperature of the generator set.

SHUTDOWN:

8. To shut the generator set down, turn off the load by switching the Alternator Output Circuit Breaker to "OFF" (handle down). Allow the generator set to run without load for a few minutes to cool. Then turn the Key Switch to Position "0" (Off). The generator set will shutdown.

   In case of an emergency where immediate shutdown is necessary, the Key Switch should be turned to Position "0" (Off) immediately without disconnecting the load.

Note:

- Turning the Key Switch to Position "0" (Off) will also reset the protective circuits after a fault has been detected. Ensure that the fault has been rectified prior to restarting the generator set.

When high engine temperature is sensed, the red coloured fault lamp labelled "HIGH ENGINE TEMPERATURE" illuminates (see Figure 5b) and the generator set is automatically shut down. The fault lamp will remain illuminated and the engine locked out until the fault has been acknowledged and reset by turning the Key Switch to Position "0" (Off). On some larger models a low coolant level sensor will also cause the generator set to shutdown and will also illuminate the "HIGH ENGINE TEMPERATURE" fault lamp even though the temperature may be in the normal range.

When low lube oil pressure is sensed the "LOW OIL PRESSURE" fault lamp illuminates and the generator set is automatically shut down. Reset is effected by turning the Key Switch to Position "0" (Off).

Warning

⚠ **If at any time the generator set stops because of a fault, the fault should be rectified before trying to restart the generator set**

5.2.5 Control System Fault Finding / Trouble Shooting Guide 1002T

Fault	Symptom	Remedy
Engine Fails To Start	Engine Does Not Crank When Key Switch Turned To Position " ↷ " (Start)	1. Check Operation Of Key Switch. 2. Check No Fault Lamps Illuminated. Reset, If Required, After Remedying Indicated Fault. 3. Refer To Your Local Dealer.
Engine Stops Due To Low Oil Pressure (All Control Systems)	"LOW OIL PRESSURE" Fault Lamp Illuminates	1. Check Oil Level 2. Refer To Your Local Dealer.
Engine Stops Due To High Coolant Temp	"HIGH COOLANT TEMP" Fault Lamp Illuminates	1. Check Coolant Level. (Be Sure To Allow The generator set To Cool First As Hot Water/Steam Can Be Present When You Remove The Radiator Cap). 2. Refer To Your Local Dealer.
Other Faults	–	Refer To Your Local Dealer.

5.3 PowerWizard (PW1.0 & 2.0)

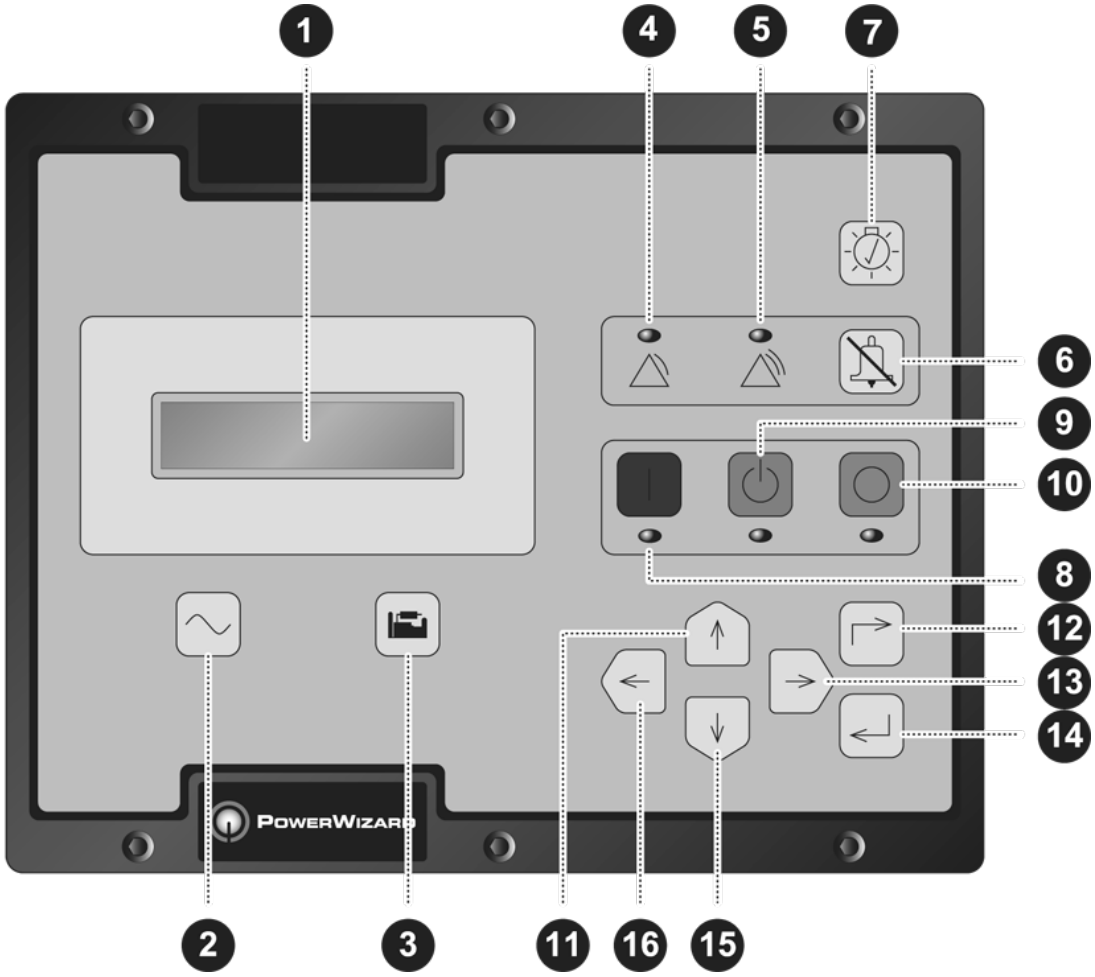
5.3.1 General Information

Figure 5d – PowerWizard Control System Panel

The controller is available in two versions, PowerWizard 1.0 and PowerWizard 2.0. These two versions are based on different features.

This guide is intended to cover the PowerWizard generator set control and its application in generator set systems.

5.3.2 PowerWizard Control Module Description



1 - display screen
2 - AC overview hot key
3 - DC overview hot-key
4 - warning lamp
5 - shutdown lamp
6 - alarm acknowledge
7 - lamp test
8 - run
9 - auto
10 - stop
11 - up cursor
12 - escape
13 - right cursor
14 - escape
15 - down cursor
16 - left cursor

Figure 5e – PowerWizard Control Module Description

5.3.3 Pre-Start Checks (applicable to all control systems)

The following checks should be performed prior to starting the generator set:

1. A visual inspection should take only a few minutes and can prevent costly repairs and accidents – for maximum generator set life, visually inspect the generator set before starting. Look for items such as:
   - Loose fastenings / fixings, worn belts or loose connections. Repair as necessary.
   - The fan and exhaust guards must be at the correct positions and securely fixed. Repair damaged / loose guards or renew missing guards.
   - Wipe clean all filler caps before the engine is serviced or fluids are topped up to reduce the chance of any system contamination.
   - For any type of leak (coolant, lubricating oil or fuel), clean away the fluid. If a leak is observed, find the source and correct the leak. If a leak is suspected, check the fluid levels frequently until the leak is found and repaired.
   - Accumulated grease and / or oil on an engine is a fire hazard. Remove it by steam cleaning or by the use of a high pressure water jet. Avoid high-pressure water on the electronic / electrical components provide suitable protection were possible.
   - Ensure that the coolant pipes are fitted correctly and that they are secure. Check for leaks. Check the condition of all pipes for splits or signs of rubbing.

Fluid levels

2. Check the engine oil and coolant levels – replenish as necessary (see engine handbook for locations). Ensure fluids used are as recommended within the engine handbook.

Warning:

⚠ **Do not remove the radiator cap or any component of the cooling system while the engine is running and while the coolant is under pressure, because dangerous hot coolant can be discharged, posing a risk of personal injury. Do not add large amounts of cold coolant to a hot system as serious engine damage could result.**

3. Check the engine oil and coolant levels – replenish as necessary.

Note:

- Diesel engines normally consume lube oil at a rate of 0.25% to 1% of the fuel consumption.
- When adding coolant to the radiator system, always pour slowly to help prevent air from becoming trapped in the engine. Always top up when engine is cold.

Warning:

⚠ **When filling the fuel tank, do not smoke or use an open flame in the vicinity.**

4. Check the fuel level – fill as necessary.

Warning:

⚠ **Before tightening the fan belts, disconnect the battery negative (–) lead to ensure the engine cannot be accidentally started.**

5. Check the condition and tension of the fan and engine alternator belts – tighten as necessary.
6. Check all hoses for loose connections or deterioration – tighten or replace as necessary.
7. Check the battery terminals for corrosion – clean as necessary.

Warning:

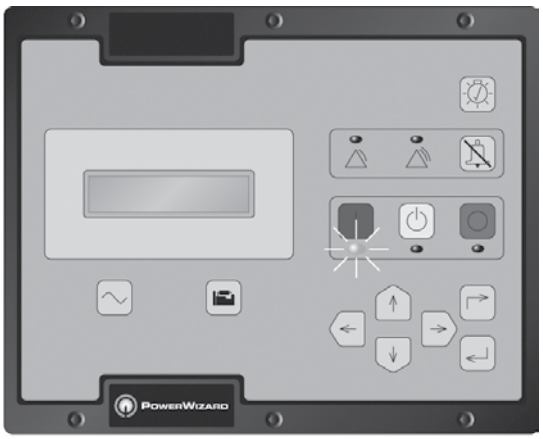
⚠ **When working with the batteries, do not smoke or use an open flame in the vicinity. Hydrogen gas from batteries is explosive.**

⚠ **Do not short the positive and negative terminals together.**

8. Check the battery electrolyte level – fill with distilled water as necessary.
9. Check the control panel and the generator set for heavy accumulation of dust and dirt – clean as necessary. These can pose an electrical hazard or give rise to cooling problems.
10. Check the air filter restriction indicator, if fitted – replace the filter as necessary.
11. Clear the area around the generator set of any insecure items that could inhibit operation or cause injury. Ensure cooling air ventilation screens are clear.
12. Visually check the entire generator set for signs of leaks from the fuel system, cooling system or lubrication seals.
13. Periodically drain exhaust system condensate traps, if equipped.
14. Ensure the Alternator Output Circuit Breaker is in the "OFF" (handle down) position.

5.3.4 Basic Operation

START Mode



 Press Start key

Figure 5f – Basic Operation Start Key

STOP Mode

 Press Stop key

Figure 5g – Basic Operation Stop Key

AUTO Mode

 Press Auto key

Figure 5h – Basic Operation Auto Key

Note:

- When not using PowerWizard in AUTO mode, a "Not in Auto Mode" activate alarm will sound (where enabled).

5.3.5 Fault / Alarm Reset Process

1. Fault / Alarm Reset Process

If either of these indication lamps are flashing or solid there is a warning or shurdown

2. Fault / Alarm Reset

Press **STOP** Key

3. Fault / Alarm Reset

Press and hold **"Alarm Acknowledge"** key for 3 seconds

4. Fault / Alarm Reset Process. The display will show:

Press **ENTER** Key to clear all Warnings and / or Shutdowns

Press **ESCAPE Key to cancel**

Figure 5i – Basic Operation Fault Alarm Reset Process

5.3.6 User Interface Overview

Before starting or running the generator set, the operator should become fully acquainted with the control module's display and push buttons. The display should be observed from time to time while the generator set is running so that any abnormal readings can be detected before problems arise. Figure 5c shows a typical layout of the PowerWizard control panel. Addition of optional equipment may add items to the panel so that the panel fitted on the generator set may be slightly different from the typical one shown. The following descriptions explain the function of each standard item on the panels:

Function Keys:

AC Overview key – The AC Overview key will navigate the display to the first screen of AC information. The AC Overview information contains various AC parameters that summarise the electrical operation of the generator set. (Use the up/down keys to navigate within the AC parameters).

Engine Overview-key – The Engine Overview key will navigate the display to the first screen of engine information. The Engine Overview information contains various engine parameters that summarise the operation of the generator set. (Use the up/down keys to navigate within the Engine parameters).

Lamp Test – Pressing and holding the Lamp Test key will cause all of the LED's and the display screen pixels to turn on.

RUN – Pressing the Run key will cause the engine to enter the run mode.

AUTO – Pressing the Auto key will cause the engine to enter the auto mode.

STOP – Pressing the Stop key will cause the engine to enter stop mode.

Menu Navigators:

Scroll Up – The Scroll Up key is used to navigate up through the various menus or monitoring screens. The Scroll Up key is also used during setpoint entry. During numeric data entry the Scroll Up key is used to increment the digits (0–9). If the setpoint requires selection from a list, the Scroll Up key is used to navigate through the list.

Escape – The Escape key is used during menu navigation in order to navigate up through the menu/sub-menu structure. Each key press causes the user to move backwards/upwards through the navigation menus. The Escape key is also used to exit/ cancel out of data entry screens during setpoint programming. If the Escape key is pressed during setpoint programming, none of the changes made on screen will be saved to memory.

Scroll Right – The Scroll Right key is used during setpoint adjustment. During numeric data entry, the Scroll Right key is used to choose which digit is being edited. The Scroll Right key is also used during certain setpoint adjustments to select or deselect a check box. If a box has a check mark inside, pressing the Scroll Right key will cause the check mark to disappear, disabling the function. If the box does not have a check mark inside, pressing the Scroll Right key will cause a check mark to appear, enabling the function.

Enter – The Enter key is used during menu navigation to select menu items in order to navigate forward/downward in the menu/sub–menu structure. The Enter key is also used during setpoint programming in order to save setpoint changes. Pressing the Enter key during setpoint programming causes setpoint changes to be saved to memory.

Scroll Down – The Scroll Down key is used to navigate down through the various menus or monitoring screens. The Scroll Down key is also used during setpoint entry. During numeric data entry the Scroll Down key is used in order to decrement the digits (0–9). If the setpoint requires selection from a list, the Scroll Down key is used to navigate down through the list.

Scroll Left – The Scroll Left key is used during setpoint adjustment. During numeric data entry, the Scroll Left key is used to choose which digit is being edited. The Scroll Left key is also used during certain setpoint adjustments to select or deselect a check box. If a box has a check mark inside, pressing the Scroll Left key will cause the check mark to disappear, disabling the function. If the box does not have a check mark inside, pressing the Scroll Left key will cause a check mark to appear, enabling the function.

Alarm Indicators:

Yellow Warning Light – A flashing yellow light indicates that there are unacknowledged active Warnings. A solid yellow light indicates that there are acknowledged Warnings active. If there are any active Warnings, the yellow light will change from flashing yellow to solid yellow after the Alarm Acknowledge key is pressed. If there are no longer any active Warnings, the yellow light will turn off after the Alarm Acknowledge key is pressed.

Red Shutdown Light – A flashing red light indicates that there are unacknowledged active shutdown events. A solid red light indicates that there are acknowledged shutdown events active. If there are any active shutdown events the red light will change from flashing red to solid red after the Alarm Acknowledge key is pressed. Any condition that has caused a shutdown event must be manually reset. If there are no longer any active shutdown events, the red light will turn off.

Alarm Acknowledge – Pressing the Alarm Acknowledge will cause the horn relay output to turn off and silence the horn (if installed). Pressing the key will also cause any yellow or red flashing lights to turn off or to become solid depending on the active status of the alarms. The Alarm Acknowledge may also be configured to send out a global alarm silence on the J1939 Data Link, which will silence horns on annunciators. Pressing and holding the Alarm Acknowledge key can be used to reset all active Warnings or shutdowns.

EMERGENCY STOP Push button – A red lock-down push button that immediately shuts down the generator set and will inhibit start until the push button has been released by turning it clockwise. Prior to restarting the set, this fault must be reset by pressing the "stop" button on the module and resetting the fault in the "event log menu".

Display Preferences for PowerWizard Panels:

To change the display preferences, from the main menu scroll down to the "Preferences" item (last in the menu). Press the "Enter" Key. Scroll down through the preferences menu until the desired display preference is highlighted. Press "Enter" to adjust this preference.

CONTRAST: The display contrast may require adjustment from the factory default depending on viewing angle and ambient temperature. The contrast is adjusted between 0% and 100% by pressing the "Left" and "Right" keys. Pressing "Enter" accepts the changes and "Escape" aborts the changes.

BACKLIGHT: The backlight is usually left at 100%, however on occasions the user may wish to reduce the backlight intensity. The backlight can be adjusted between 0 to 100% by pressing the "Left" and "Right" keys. Pressing "Enter" accepts the changes and "Escape" aborts the changes.

PRESSURE UNITS: The pressure units can be adjusted between kPa/psi/bar. Use the "Left" and "Right" keys to select the preferred pressure units. Pressing "Enter" accepts the new pressure units; pressing "Escape" aborts the change in pressure units.

TEMPERATURE UNITS: The temperature units can be adjusted between ºC and °F. Use the "Left" and "Right" keys to select the preferred temperature units. Pressing "Enter" accepts the change; pressing escape aborts the change.

5.3.7 Alarm Log and Resetting

Note:

- To reset the menu back to the start, press the "Escape" key three times.

Alarm Log

1. From the main menu, highlight "EVENT LOGS" and press the "Enter" key.
2. In order to scroll through the events use the "Up" and "Down" keys. Events are ordered with present events first, active events next and inactive events last. Within these classifications they are ordered by engine run hours (or real time clock on PowerWizard 2.0).
3. Press "Enter" after highlighting an event to see additional information such as SPN, FMI, time and date of first occurrence, time and date of last occurrence (PowerWizard 2.0 only), engine hours at first occurrence, and engine hours at last occurrence.

Shutdown Resetting

A flashing red shutdown light indicates there is an unacknowledged shutdown event. The red shutdown light will change from flashing red to solid red when the "Alarm Acknowledged" key is pressed. Once a fault has been checked and the cause rectified, use the following procedure in order to reset the event:

1. Press the "Stop" key.
2. Enter the "EVENT LOGS" option from the main menu.
3. Select an ECM from the list.
4. Scroll through the events in order to highlight the event to be reset.
5. Make sure the event status is active (not present).
6. Press the "Enter" key.
7. "RESET" will be highlighted if the condition is no longer present and the control is in stop.
8. Press the "Enter" key again. The fault will clear.
9. Press the "Escape" key 3 times in order to get back to the main menu.

Quick Alarm Resetting (see section 5.3.5)

In addition to the above procedure there is also a simplified process for resetting all events. To reset all events:

1. Press the "Stop" key.
2. Press and hold the "Alarm Acknowledge" key for three seconds.
3. Press Enter to reset all events, press Escape to cancel.

Note.

- The PowerWizard must be in stop mode to reset events.
- Active faults cannot be reset.

5.3.8 Security

There are three levels of password protection on the PowerWizard control panel. All of the adjustable setpoints are associated with a specific level of security required to make an adjustment to the parameter. The passwords only affect changing setpoints within the control panel.

The level of password protection that is required for each setpoint is identified on the parameter setpoint entry screen. A security level identification number "1", "2" or "3" next to a padlock symbol is displayed on the parameter setpoint entry screen.
A Level 3 security is used for the most secure setpoints and Level 1 security is used for the least secure setpoints. If the PowerWizard is currently at the required level of protection when viewing a parameter, the padlock will not appear.

If a parameter is displayed with a padlock but no security level identification number next to it, the parameter cannot be changed from the PowerWizard display and the Dealer must be contacted. Level 1 and 2 passwords are disabled when installed. Level 1 and 2 passwords are user level passwords and can be used if desired.

The PowerWizard 2.0 also has a SCADA password, which can be used to secure remote communications.

To view the security menu:

MAIN MENU > CONFIGURE > SECURITY

At the top of the security menu the current security level is displayed. Within the security menu are the following options:

DROP TO MINIMUM LEVEL – used to return the current security level to the lowest level set-up. Highlight and press Enter to drop to minimum security level. If no Level 1 or 2 passwords are set-up the minimum level will be 2. If a Level 2 password is set-up, the minimum level will be 1 and if a Level 1 password is set-up the minimum level will be 0.

ENTER LEVEL 1 OR 2 – used to enter Level 1 or 2 passwords. Highlight and press Enter to proceed to the password entry screen. Passwords can be entered using the cursor keys. In PowerWizard, Level 1 and 2 passwords must be different. An entered password is compared against the stored Level 1 and 2 passwords, if the password is correct the PowerWizard will go to the corresponding security level.

ENTER LEVEL 3 – used to obtain Level 3 access. The Level 3 security password is reserved for critical setpoints that should only be changed by a skilled operative. As such you must contact your Dealer if you require a change associated with a Level 3 password.

CHANGING LEVEL 1 PASSWORD – used to set-up, change or disable a Level 1 password. In order to use this feature the control must be at current security Level 1 or higher. Highlight and press Enter to proceed to the password entry screen. To set-up or change the password, enter the new password using the cursor keys. Passwords may be 16 digits long. To disable the Level 1 security password, set the password to '0'. Press the Enter key to save.

CHANGING LEVEL 2 PASSWORD – used to set-up, change or disable a Level 2 password. In order to use this feature the control must be at current security Level 2 or higher. Highlight and press Enter to proceed to the password entry screen. To set-up or change the password, enter the new password using the cursor keys. Passwords may be 16 digits long. To disable the Level 2 security password, set the password to '0'. Press the Enter key to save.

CHANGING SCADA PASSWORD (PowerWizard 2.0 only) – used to set-up, change or disable a SCADA password. Highlight and press enter to proceed to the password entry screen. To set-up or change the password, enter the new password using the cursor keys. Passwords may be 16 digits long. To disable the SCADA security password, set the password to '0'. Press the Enter key to save.

5.3.9 Real Time Clock Programming (PowerWizard 2.0)

The real time clock provides information for the time and date of an automatic time based start/stop control. It also provides a mechanism for time stamps in the event log. The real time clock is not calibrated and is for information only. The date and time are set by the user.

1. In order to set the time or date format:
   MAIN MENU > CONFIGURE > TIME/DATE.
2. To set the time, highlight the time then press the "Enter" key twice.
3. Use the cursor keys to set the time and press the "Enter" key to save. Press the "Escape" key to return.
4. To set the date, highlight the date then press the "Enter" key twice.
5. Use the cursor keys to set the date and press the "Enter" key to save. Press the "Escape" key to return.
6. To set the date format, highlight either the FORMAT DD/MM/YY or FORMAT MM/DD/YY and press the "Enter" key.
7. Use the cursor keys to select the required date format and press the "Enter" key to save.

5.3.10 Fuel Priming – Engines with Electric Fuel Lift Pump

Certain engines fitted with an electric fuel pump do not have a manual priming feature on the engine. In these circumstances the PowerWizard can be used to energise the fuel lift pump in order to prime the engine.

1. In order to prime the generator set:
   MAIN MENU > CONTROL > ENGINE FUEL PRIMING.
2. To prime the generator set press the right cursor key, this will initiate a 2 minute priming cycle.
3. To exit the priming cycle press the left cursor key.

Note.

- The generator set may only be primed when the generator set is stopped and there are no active or present shutdown conditions.

5.3.11 Additional Features Available

Reduced Power Mode

In reduced power mode the screen will go blank and LED's will flash intermitently. Pressing any key will bring the panel out of reduced power mode. Reduced power mode can be disabled (Refer to your local Dealer).

Remote Annunciation of Faults

The PowerWizard Annunciator is used in remote applications, mounted separately from the generator set to provide remote indication of system operating and alarm conditions.

For further information on these features, please contact your Dealer.

5.3.12 Trouble Shooting Guide for PowerWizard

Fault	Symptom	Remedy
Engine Fails To Start	Engine Does Not Crank When Start Signal Is Given, Either Manually Via Run Key Or Automatically Via A Remote Signal	1. Check All Emergency Stop Push Buttons Are Released 2. Check The Stop Button Light Is Not On 3. Check There Are No Shutdown Events Active. Reset, If Required, After Remedying The Indicated Fault 4. Refer To Your Local Dealer
Engine Stops Due To Low Oil Pressure	"LOW OIL PRESSURE" In Event Log. Red Shutdown Led Illuminates	1. Check Oil Level 2. Refer To Your LocaL Dealer
Engine Stops Due To High Coolant Temp	"HIGH COOLANT TEMP" In Event Log. Red Shutdown Led Illuminates	1. Check Coolant Level In The Radiator. Refer To Safety Section Before Removing The Radiator Cap 2. Refer To Your Local Dealer
Engine Stops Due To Overspeed	"OVERSPEED" In Event Log. Red Shutdown Led Illuminates	1. Verify The Actual Engine Speed 2. Refer To Your Local Dealer
Engine Stops Due To Under-Voltage (Powerwizard 2.0 Only)	"UNDER-VOLTAGE" In Event Log, Red Shutdown Led Illuminates	1. Refer To Your Local Dealer
Engine Stops Due To Over-Voltage (Standard On Powerwizard 2.0, Optional On Powerwizard 1.0)	"Over-Voltage" In Event Log, Red Shutdown Led Illuminates	1. Refer To Your Local Dealer
Generator set Does Not Go On Load	Generator set Is Running But The Load Is Not Being Powered	1. Refer To Your Local Dealer
Generator set Does Not Stop Manually	Generator set Keeps Running After Being Switched Off	1. Check That The Generator set Stops When The Emergency Stop Push button Is Depressed 2. Refer To Your Local Dealer
Generator set Does Not Stop When In Auto Mode	Generator set Does Not Stop After Remote Start Signal Is Removed	1. Check That The Generator set Stops When The Emergency Stop Push button Is Depressed Or The Stop Key Is Held Down For 5 Seconds And The Cooldown Time Is Skipped
Alarm For Not In Auto Mode (Standby Sets Only)	"Not In Auto Mode" Alarm In Event Log, Amber Led Illuminates	1. Check The Module Is In "Auto" Mode 2. Check Emergency Stop Push buttons Are Not Pressed 3. Refer To Your Local Dealer

5.4 PowerWizard (PW 1.1, 1.1+ and 2.1)

5.4.1 General Information

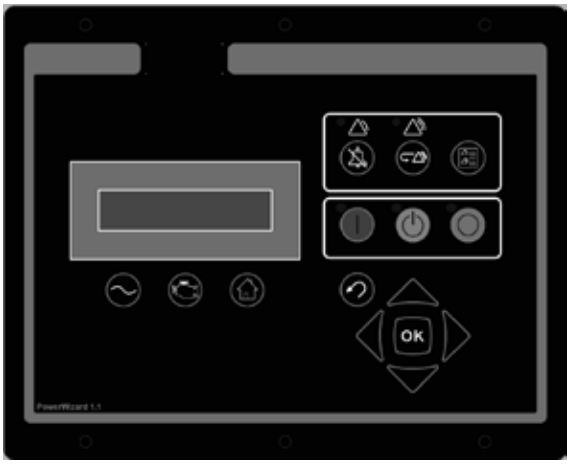
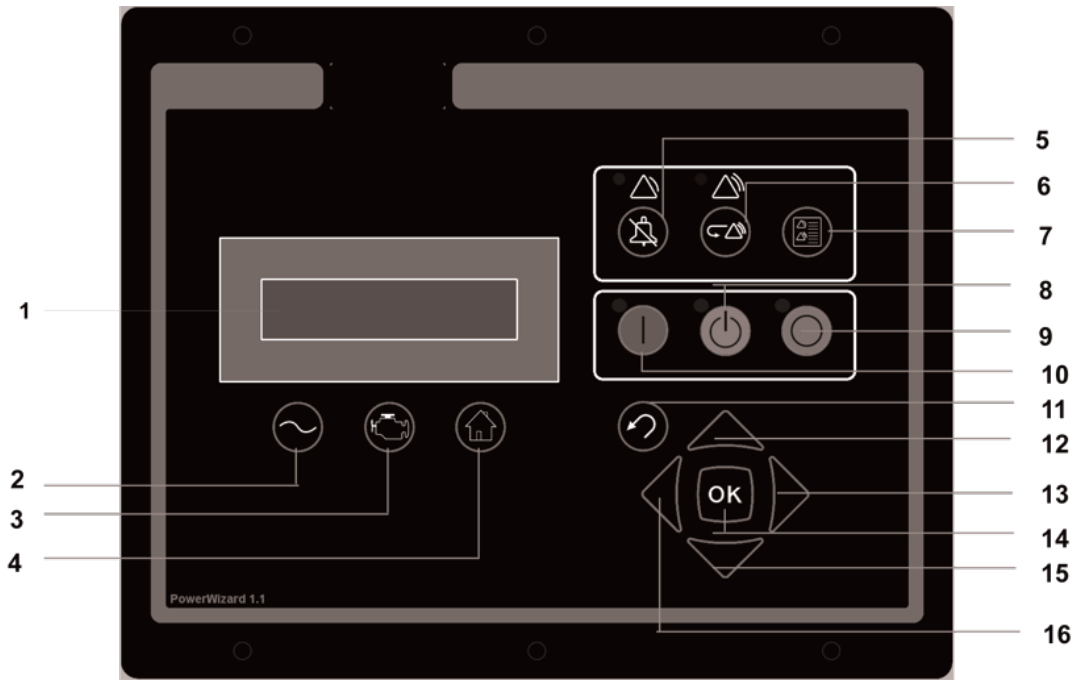


Figure 5j – PowerWizard Control System Panel

The controller is available in three versions, PowerWizard 1.1, 1.1+ and 2.1. These three versions are based on different features. This guide is intended to cover the PowerWizard generator set Control and its application in generator set systems.

5.4.2 PowerWizard Control Module Description



1. Display screen
2. AC overview key
3. Engine overview key
4. Main menu or home key
5. Alarm acknowledge key
6. Event reset key
7. Event log key
8. Auto key
9. Stop key
10. Run key
11. Escape key
12. Up key
13. Right key
14. OK or Enter key
15. Down key
16. Left key

Figure 5k – PowerWizard Control Module Description

5.4.3 Pre-Start Checks (applicable to all control systems)

The following checks should be performed prior to starting the generator set:

1. A visual inspection should take only a few minutes and can prevent costly repairs and accidents – For maximum generator set life, visually inspect the generator set before starting. Look for items such as:
   - Loose fastenings / fixings, worn belts or loose connections. Repair as necessary.
   - The fan and exhaust guards must be at the correct positions and securely fixed. Repair damaged / loose guards or renew missing guards.
   - Wipe clean all filler caps before the engine is serviced or fluids are topped up to reduce the chance of any system contamination.
   - For any type of leak (coolant, lubricating oil or fuel), clean away the fluid. If a leak is observed, find the source and correct the leak. If a leak is suspected, check the fluid levels frequently until the leak is found and repaired.
   - Accumulated grease and / or oil on an engine is a fire hazard. Remove it by steam cleaning or by the use of a high pressure water jet. Avoid high-pressure water on the electronic/electrical components provide suitable protection were possible.
   - Ensure that the coolant pipes are fitted correctly and that they are secure. Check for leaks. Check the condition of all pipes for splits or signs of rubbing.

Fluid levels

2. Check the engine oil and coolant levels – replenish as necessary (see engine handbook for locations). Ensure fluids used are as recommended within the engine handbook.

Warning:

⚠ **Do not remove the radiator cap or any component of the cooling system while the engine is running and while the coolant is under pressure, because dangerous hot coolant can be discharged, posing a risk of personal injury. Do not add large amounts of cold coolant to a hot system as serious engine damage could result.**

3. Check the engine oil and coolant levels – replenish as necessary.

Note:

- Diesel engines normally consume lube oil at a rate of 0.25% to 1% of the fuel consumption.
- When adding coolant to the radiator system, always pour slowly to help prevent air from becoming trapped in the engine. Always top up when engine is cold.

Warning:

⚠ **When filling the fuel tank, do not smoke or use an open flame in the vicinity.**

4. Check the fuel level – fill as necessary.

Warning:

⚠ **Before tightening the fan belts, disconnect the battery negative (–) lead to ensure the engine cannot be accidentally started.**

5. Check the condition and tension of the fan and engine alternator belts – tighten as necessary.
6. Check all hoses for loose connections or deterioration – tighten or replace as necessary.
7. Check the battery terminals for corrosion – clean as necessary.

Warning:

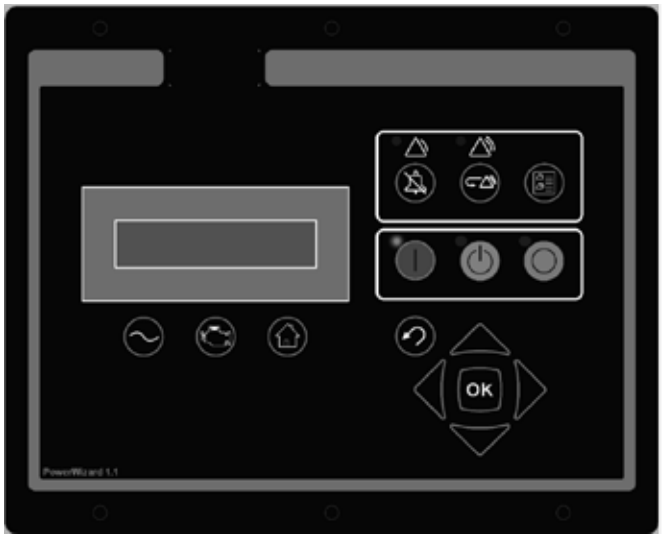
⚠ **When working with the batteries, do not smoke or use an open flame in the vicinity. Hydrogen gas from batteries is explosive.**

⚠ **Do not short the positive and negative terminals together.**

8. Check the battery electrolyte level – fill with distilled water as necessary.
9. Check the control panel and the generator set for heavy accumulation of dust and dirt – clean as necessary. These can pose an electrical hazard or give rise to cooling problems.
10. Check the air filter restriction indicator, if fitted – replace the filter as necessary.
11. Clear the area around the generator set of any insecure items that could inhibit operation or cause injury. Ensure cooling air ventilation screens are clear.
12. Visually check the entire generator set for signs of leaks from the fuel system, cooling system or lubrication seals.
13. Periodically drain exhaust system condensate traps, if equipped.
14. Ensure the Alternator Output Circuit Breaker is in the "OFF" (handle down) position.

5.4.4 Basic Operation

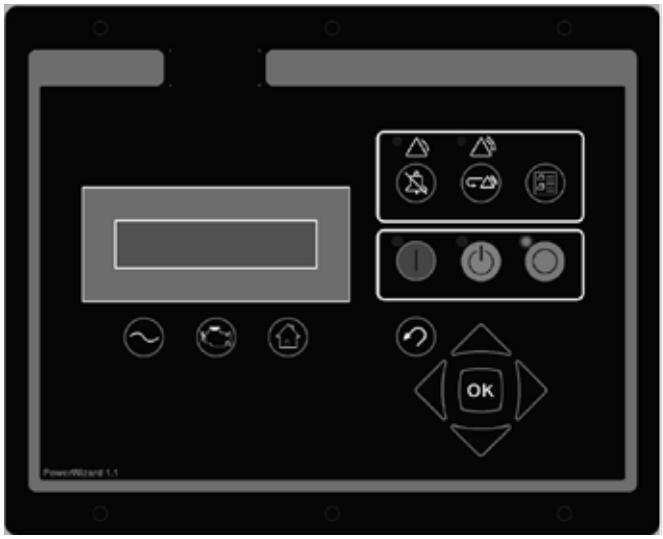
START Mode



Press **START** Key

Figure 5l – Basic Operation Start Key

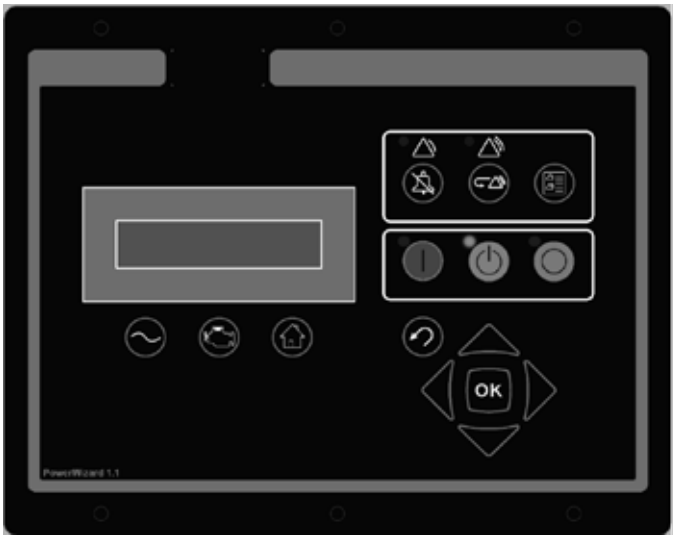
STOP Mode



Press **STOP** Key

Figure 5m – Basic Operation Stop Key

AUTO Mode



Press **AUTO** Key

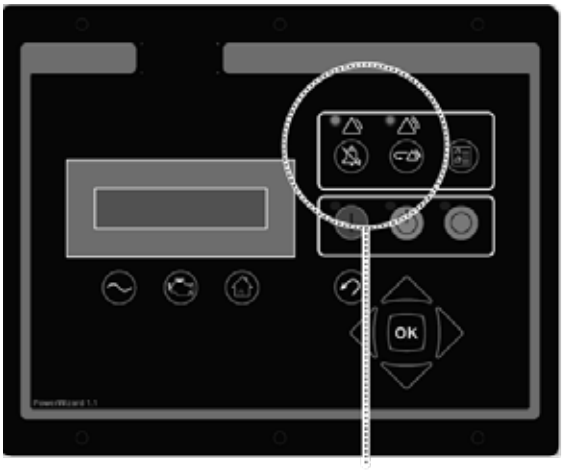
Figure 5n – Basic Operation Auto Key

Note:

- When not using PowerWizard in AUTO mode a "Not in Auto Mode" activate alarm will sound (where enabled).

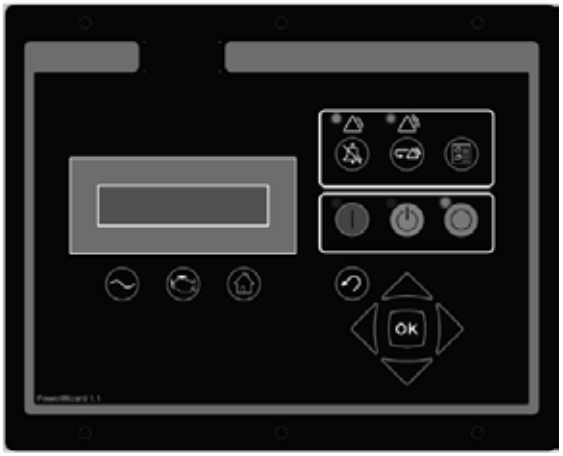
5.4.5 Fault / Alarm Reset Process

1. Fault / Alarm Reset Process



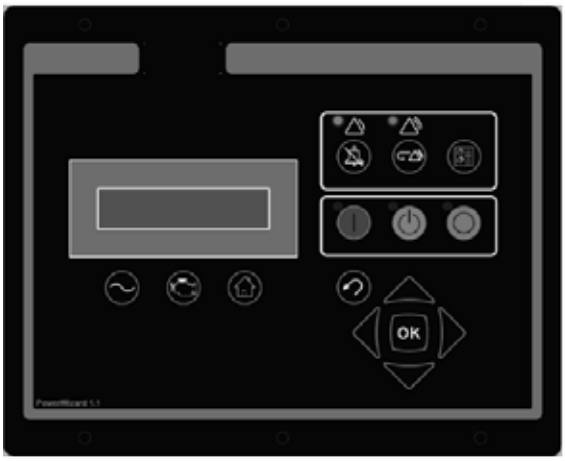
If either of these indication lamps are flashing or solid there is a warning or shurdown

2. Fault / Alarm Reset



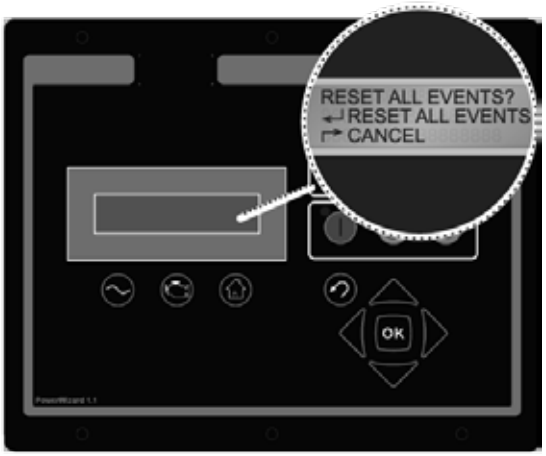
Press **STOP** Key

3. Fault / Alarm Reset



Press and hold **"Alarm Acknowledge"** key for 3 seconds

4. Fault / Alarm Reset Process. The display will show:



OK Press **ENTER** Key to clear all Warnings and / or Shutdowns

Press **ESCAPE Key to cancel**

Figure 5o – Basic Operation Fault Alarm Reset Process

5.4.6 User Interface Overview

Before starting or running the generator set, the operator should become fully acquainted with the control module's display and push buttons. The display should be observed from time to time while the generator set is running so that any abnormal readings can be detected before problems arise. Figure 5c shows a typical layout of the PowerWizard control panel. Addition of optional equipment may add items to the panel so that the panel fitted on the generator set may be slightly different from the typical one shown. The following descriptions explain the function of each standard item on the panels:

Function Keys:

AC Overview key – The AC Overview key will navigate the display to the first screen of AC information. The AC Overview information contains various AC parameters that summarise the electrical operation of the generator set. (Use the up/down keys to navigate within the AC parameters).

Engine Overview key – The Engine Overview key will navigate the display to the first screen of engine information. The Engine Overview information contains various engine parameters that summarise the operation of the generator set. (Use the up / down keys to navigate within the Engine parameters).

Main Menu key – The Main Menu key will navigate the display to the main menu screen. Pressing the navigation keys will allow access to menus at all levels.

Control Keys:

RUN – Pressing the Run key will cause the engine to enter the run mode.

AUTO – Pressing the Auto key will cause the engine to enter the auto mode.

STOP – Pressing the Stop key will cause the engine to enter stop mode.

Navigation Keys:

Scroll Up – The Scroll Up key is used to navigate up through the various menus or monitoring screens. The Scroll Up key is also used during setpoint entry. During numeric data entry the Scroll Up key is used to increment the digits (0–9). If the setpoint requires selection from a list, the Scroll Up key is used to navigate through the list.

Escape – The Escape key is used during menu navigation in order to navigate up through the menu/sub-menu structure. Each key press causes the user to move backwards/upwards through the navigation menus. The Escape key is also used to exit/cancel out of data entry screens during setpoint programming. If the Escape key is pressed during setpoint programming, none of the changes made on screen will be saved to memory.

Scroll Right – The Scroll Right key is used during setpoint adjustment. During numeric data entry, the Scroll Right key is used to choose which digit is being edited. The Scroll Right key is also used during certain setpoint adjustments to select or deselect a check box. If a box has a check mark inside, pressing the Scroll Right key will cause the check mark to disappear, disabling the function. If the box does not have a check mark inside, pressing the Scroll Right key will cause a check mark to appear, enabling the function.

Enter / OK – The Enter key is used during menu navigation to select menu items in order to navigate forward/downward in the menu/sub–menu structure. The Enter key is also used during setpoint programming in order to save setpoint changes. Pressing the Enter key during setpoint programming causes setpoint changes to be saved to memory.

Scroll Down – The Scroll Down key is used to navigate down through the various menus or monitoring screens. The Scroll Down key is also used during setpoint entry. During numeric data entry the Scroll Down key is used in order to decrement the digits (0–9). If the setpoint requires selection from a list, the Scroll Down key is used to navigate down through the list.

Scroll Left – The Scroll Left key is used during setpoint adjustment. During numeric data entry, the Scroll Left key is used to choose which digit is being edited. The Scroll Left key is also used during certain setpoint adjustments to select or deselect a check box. If a box has a check mark inside, pressing the Scroll Left key will cause the check mark to disappear, disabling the function. If the box does not have a check mark inside, pressing the Scroll Left key will cause a check mark to appear, enabling the function.

Event Keys and Indicators:

Yellow Warning Light – A flashing yellow light indicates that there are unacknowledged active warnings. A solid yellow light indicates that there are acknowledged warnings active. If there are any active warnings, the yellow light will change from flashing yellow to solid yellow after the Alarm Acknowledge key is pressed. If there are no longer any active warnings, the yellow light will turn off after the Alarm Acknowledge key is pressed.

Red Shutdown Light – A flashing red light indicates that there are unacknowledged active shutdown events. A solid red light indicates that there are acknowledged shutdown events active. If there are any active shutdown events the red light will change from flashing red to solid red after the Alarm Acknowledge key is pressed. Any condition that has caused a shutdown event must be manually reset. If there are no longer any active shutdown events, the red light will turn off.

Alarm Acknowledge – Pressing the Alarm Acknowledge will cause the horn relay output to turn off and silence the horn. Pressing the key will also cause any yellow or red flashing lights to turn off or to become solid depending on the active status of the alarms.

Event Reset Key – Pressing the Event Reset key will reset all events when the control is in the stopped position. However, "Reset All Events" will not reset "Present" events.

Event Log Key – Pressing the Event Log key will navigate to the "Active Events" menu. In order to scroll through the events, use the up and down keys. After highlighting an event, press the "OK" key to see information about the event such as the SPN and the FMI.

EMERGENCY STOP Push button – A red lock-down push button that immediately shuts down the generator set and will inhibit start until the push button has been released by turning it clockwise. Prior to restarting the set, this fault must be reset by pressing the "stop" button on the module and resetting the fault in the "event log menu".

Display Preferences for PowerWizard Panels:

To change the display preferences, from the main menu scroll down to the "Preferences" item (last in the menu). Press the "Enter" Key. Scroll down through the preferences menu until the desired display preference is highlighted. Press "Enter" to adjust this preference.

CONTRAST: The display contrast may require adjustment from the factory default depending on viewing angle and ambient temperature. The contrast is adjusted between 0% and 100% by pressing the "Left" and "Right" keys. Pressing "Enter" accepts the changes and "Escape" aborts the changes.

BACKLIGHT: The backlight is usually left at 100%, however on occasions the user may wish to reduce the backlight intensity. The backlight can be adjusted between 0 to 100% by pressing the "Left" and "Right" keys. Pressing "Enter" accepts the changes and "Escape" aborts the changes.

PRESSURE UNITS: The pressure units can be adjusted between kPa/psi/bar. Use the "Left" and "Right" keys to select the preferred pressure units. Pressing "Enter" accepts the new pressure units; pressing "Escape" aborts the change in pressure units.

TEMPERATURE UNITS: The temperature units can be adjusted between ºC and °F. Use the "Left" and "Right" keys to select the preferred temperature units. Pressing "Enter" accepts the change; pressing escape aborts the change.

VOLUME: Volume is used on some optional parameters (such as fuel consumption rate). It can be selected between Litres, US Gallons and Imperial Gallons using the "Left" and "Right" keys. Pressing "Enter" accepts the new volume units; pressing "Escape" aborts the change to the volume units.

LAMP TEST: This is used to test the LEDs and display. When LAMP TEST is highlighted, pressing OK will turn on all LEDs and display screen.

5.4.7 Alarm Log and Resetting

Note:

- To reset the menu back to the start, please press the "Escape" key three times.

Event Viewing

There are two ways to view events. Pressing the "EVENT LOG" key navigates directly to the "ACTIVE EVENTS" menu. The other way is to use the Main Menu:

1. From the MAIN MENU/VIEW, highlight "EVENT LOGS" and press the "Enter" key. The "ACTIVE EVENTS" menu will be displayed in this menu.
2. In order to scroll through the events use the up and down keys. Events are ordered with present events first, active events next and inactive events last. Within these classifications they are ordered by engine run hours (or real time clock on PowerWizard 2.1).
3. Press "Enter" after highlighting an event to see additional information such as SPN, FMI, time and date of first occurrence, time and date of last occurrence (PowerWizard 2.1 only), engine hours at first occurrence and engine hours at last occurrence.

Quick Shut Down Resetting

In addition to the above procedure there is also a simplified process for resetting all events. To reset all events:

1. Ensure that the control is in the stopped position.
2. Press the "Reset Event" key from any screen.
3. A confirmation prompt will appear.
4. Press the "OK" key to reset all events on all modules. Press the 'ESCAPE" key to cancel the reset operation.

Note:

- The PowerWizard must be in stop mode to reset events.

Present events cannot be reset.

Shut Down Resetting

A flashing red shutdown light indicates there is an unacknowledged shutdown event. The red shutdown light will change from flashing red to solid red when the Alarm Acknowledged key is pressed. Once a fault has been checked and the cause rectified, use the following procedure in order to reset the event:

1. Press the "Stop" key.
2. Enter the "EVENT LOGS" option from the main menu.
3. Select a "Module" from the list.
4. Scroll through the events in order to highlight the event to be reset.
5. Make sure the event status is active (not present).
6. Press the "Enter" key.
7. "RESET" will be highlighted if the condition is no longer present and the control is in stop.
8. Press the "Enter" key again. The fault will clear.
9. Press the "Escape" or "Main Menu" key in order to get back to the main menu.

5.4.8 Security

There are 3 levels of password protection on the PowerWizard control panel. All of the adjustable setpoints are associated with a specific level of security required to make an adjustment to the parameter. The passwords only affect changing setpoints within the control panel.

The level of password protection that is required for each setpoint is identified on the parameter setpoint entry screen. A security level identification number "1", "2" or "3" next to a padlock symbol is displayed on the parameter setpoint entry screen. A Level 3 security is used for the most secure setpoints and Level 1 security is used for the least secure setpoints. If the PowerWizard is currently at the required level of protection when viewing a parameter, the padlock will not appear.

If a parameter is displayed with a padlock but no security level identification number next to it, the parameter cannot be changed from the PowerWizard display and the Dealer must be contacted. Level 1 and 2 passwords are disabled when installed. Level 1 and 2 passwords are user level passwords and can be used if desired.

The PowerWizard 2.1 also has a SCADA password, which can be used to secure remote communications.

To view the security menu:

MAIN MENU > CONFIGURE > SECURITY.

At the top of the security menu the current security level is displayed. Within the security menu are the following options:

DROP TO MINIMUM LEVEL – used to return the current security level to the lowest level set-up. Highlight and press Enter to drop to minimum security level. If no Level 1 or 2 passwords are set-up the minimum level will be 2. If a Level 2 password is set-up, the minimum level will be 1 and if a Level 1 password is set-up the minimum level will be 0.

ENTER LEVEL 1 OR 2 – used to enter Level 1 or 2 passwords. Highlight and press Enter to proceed to the password entry screen. Passwords can be entered using the cursor keys. In PowerWizard, Level 1 and 2 passwords must be different. An entered password is compared against the stored Level 1 and 2 passwords, if the password is correct the PowerWizard will go to the corresponding security level.

ENTER LEVEL 3 – used to obtain Level 3 access. The Level 3 security password is reserved for critical setpoints that should only be changed by a skilled operative. As such you must contact your Dealer if you require a change associated with a Level 3 password.

CHANGING LEVEL 1 PASSWORD – used to set-up, change or disable a Level 1 password. In order to use this feature the control must be at current security Level 1 or higher. Highlight and press Enter to proceed to the password entry screen. To set-up or change the password, enter the new password using the cursor keys. Passwords may be 16 digits long. To disable the Level 1 security password, set the password to '0'. Press the Enter key to save.

CHANGING LEVEL 2 PASSWORD – used to set-up, change or disable a Level 2 password. In order to use this feature the control must be at current security Level 2 or higher. Highlight and press Enter to proceed to the password entry screen. To set-up or change the password, enter the new password using the cursor keys. Passwords may be 16 digits long. To disable the Level 2 security password, set the password to '0'. Press the Enter key to save.

CHANGING SCADA PASSWORD (PowerWizard 2.1 only) – used to set-up, change or disable a SCADA password. Highlight and press enter to proceed to the password entry screen. To set-up or change the password, enter the new password using the cursor keys. Passwords may be 16 digits long. To disable the SCADA security password, set the password to '0'. Press the Enter key to save.

5.4.9 Real Time Clock Programming (PowerWizard 2.1)

The real time clock provides information for the time and date of an automatic time based start/stop control. It also provides a mechanism for time stamps in the event log. The real time clock is not calibrated and is for information only. The date and time are set by the user.

1. In order to set the time or date format:
   MAIN MENU > CONFIGURE > TIME/DATE.
2. To set the time, highlight the time then press the "Enter" key twice.
3. Use the cursor keys to set the time and press the "Enter" key to save. Press the "Escape" key to return.
4. To set the date, highlight the date then press the "Enter" key twice.
5. Use the cursor keys to set the date and press the "Enter" key to save. Press the "Escape" key to return.
6. To set the date format, highlight either the FORMAT DD/MM/YY or FORMAT MM/DD/YY and press the "Enter" key.
7. Use the cursor keys to select the required date format and press the "Enter" key to save.

5.4.10 Fuel Transfer (PowerWizard 2.1)

Fuel pump in connection with fuel level measurement can be controlled to transfer diesel to the fuel tank.

1. In order to set the Fuel Transfer operation:

   MAIN MENU > CONTROL > FUEL TRANSFER
2. To start or stop the fuel pump, highlight the PUMP CONTROL then press the "OK" key.
3. Use the cursor key to select START FUEL PUMP or STOP FUEL PUMP and press the "OK" key.
4. Auto Fuel Load Pump On and Off thresholds are set at 25% and 75% respectively.

5.4.11 Additional Features Available

Reduced Power Mode

In reduced power mode the screen will go blank and LED's will flash intermitently. Pressing any key will bring the panel out of reduced power mode. Reduced power mode can be disabled (Refer to your local Dealer).

Remote Annunciation of Faults

The PowerWizard Annunciator is used in remote applications, mounted separately from the generator set to provide remote indication of system operating and alarm conditions.

For further information on these features, please contact your Dealer.

5.4.12 Trouble Shooting Guide for PowerWizard

Fault	Symptom	Remedy
Engine Fails To Start	Engine Does Not Crank When Start Signal Is Given, Either Manually Via Run Key Or Automatically Via A Remote Signal	1. Check All Emergency Stop Push Buttons Are Released 2. Check The Stop Button Light Is Not On 3. Check There Are No Shutdown Events Active. Reset, If Required, After Remedying The Indicated Fault 4. Refer To Your Local Dealer
Engine Stops Due To Low Oil Pressure	"LOW OIL PRESSURE" In Event Log. Red Shutdown Led Illuminates	1. Check Oil Level 2. Refer To Your LocaL Dealer
Engine Stops Due To High Coolant Temp	"HIGH COOLANT TEMP" In Event Log. Red Shutdown Led Illuminates	1. Check Coolant Level In The Radiator. Refer To Safety Section Before Removing The Radiator Cap 2. Refer To Your Local Dealer
Engine Stops Due To Overspeed	"OVERSPEED" In Event Log. Red Shutdown Led Illuminates	1. Verify The Actual Engine Speed 2. Refer To Your Local Dealer
Engine Stops Due To Under-Voltage (Powerwizard 2.1 Only)	"UNDER-VOLTAGE" In Event Log, Red Shutdown Led Illuminates	1. Refer To Your Local Dealer

Fault	Symptom	Remedy
Engine Stops Due To Over-Voltage (Standard On Powerwizard 2.1, Optional On Powerwizard 1.1+)	"Over-Voltage" In Event Log, Red Shutdown Led Illuminates	1. Refer To Your Local Dealer
Generator set Does Not Go On Load	Generator set Is Running But The Load Is Not Being Powered	1. Refer To Your Local Dealer
Generator set Does Not Stop Manually	Generator set Keeps Running After Being Switched Off	1. Check That The Generator set Stops When The Emergency Stop Push button Is DepRessed 2. Refer To Your Local Dealer
Generator set Does Not Stop When In Auto Mode	Generator set Does Not Stop After Remote Start Signal Is Removed	1. Check That The Generator set Stops When The Emergency Stop Push button Is Depressed Or The Stop Key Is Held Down For 5 Seconds And The Cooldown Time Is Skipped
Alarm For Not In Auto Mode (Standby Sets Only)	"Not In Auto Mode" Alarm In Event Log, Amber Led Illuminates	1. Check The Module Is In "Auto" Mode 2. Check Emergency Stop Push buttons Are Not PreSsed 3. Refer To Your Local Dealer

5.4.13 Programmable Cycle Timer (PCT) (PowerWizard 2.1)

The Programmable Cycle Timer (PCT) feature allows the operator to program times when two independent tasks, called PCT outputs, will be activated or deactivated automatically during the week.

This is useful for cases where two or more generator sets are required to automatically share the duty of supplying a load throughout the week. Using programmable cycle timer, each generator set can be programmed to start and stop at pre-set times. The cooperation of a transfer switch is required to ensure that the generator sets are not stopped on load.

Programmable Cycle Timer can also be used in cases where a standby set does not have access to a utility supply to power a trickle charger. Programmable Cycle Timer can be used to run the set for an hour a week to keep the battery well charged.

The PCT feature consists of seven independent timers. Each timer has the following setpoints (setpoints shown are for PCT #1):

- Day of the Week - This permits independent selection of each day (0 = Sun, 6 = Sat) that the timer will activate
- Start Time - The time of day (in hours and minutes) that the timer will activate
- Run For - The duration (in hours and minutes) for which the timer will be active (up to 24 hours)
- Output #1 Active (or Inactive) - Determines the first output will be activated (or not) when this timer is active
- Output #2 Active (or Inactive) - Determines the second output will be activated (or not) when this timer is active.

Output #1 is used to run the generator set. Output #2 can be used to drive relay output 8. Please see the Relay Outputs section for more information.

PCT Example:

- PCT #1 is enabled - Output 1 is not selected. Output 2 is selected but is currently inactive.
- PCT #7 is enabled – Output 1 is selected but currently is inactive. Output 2 is not selected.
- PCT #2, to PCT#6 are disabled. They will not activate Output 1 or Output 2.

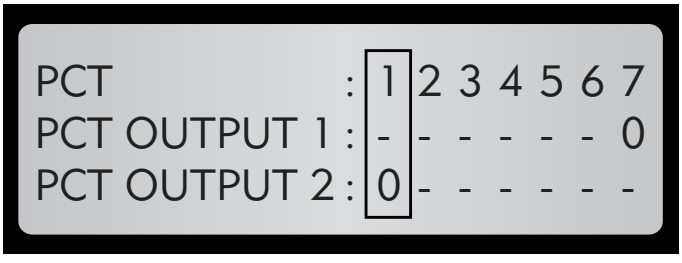


Figure 9i - PCT

5.5 DCP-10 & DCP-20

5.5.1 General Information

Figure 5p – DCP-10 and DCP-20 Control Panels

Illustrated above are the Automatic Start Control Modules (DCP10 & DCP20) designed to automatically start and stop the generator set.

The modules also monitor and protect the engine, indicating operational status, fault conditions and metering on the front panel LCD and LED's.

5.5.2 DCP Control Module Description

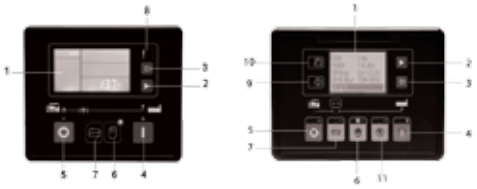


Figure 5q – DCP-10 and DCP-20 Control Module Description

1. Display Screen
2. Scroll Button – Scroll menu, Enter into or exit configuration menu
3. Mute\Lamp Test – For Lamp test press and hold for 2 secs
4. Start Button
5. Stop Button
6. Manual Mode
7. Auto Mode
8. Common Failure LED (DCP-10 Only) – Flashes when Warning occurs, Illuminates permanently when shutdown occurs.
9. Warning LED (DCP-20 Only) – Illuminates permanently until the warning is rectified then automatically turns off.
10. Shutdown LED (DCP-20 Only) – Illuminates permanently shutting engine down
11. Test Mode

5.5.3 Pre-Start Checks (applicable to all control systems)

Warning

⚠ **The following checks detailed below are the only tasks that an operator should undertake.**

The following checks should be performed prior to starting the generator set:

1. A visual inspection should take only a few minutes and can prevent costly repairs and accidents – for maximum generator set life, visually inspect the generator set before starting. Look for items such as:
   - Loose fastenings / fixings, worn belts or loose connections. Repair as necessary.
   - The fan and exhaust guards must be at the correct positions and securely fixed. Repair damaged / loose guards or renew missing guards.
   - Wipe clean all filler caps before the engine is serviced or fluids are topped up to reduce the chance of any system contamination.
   - For any type of leak (coolant, lubricating oil or fuel), clean away the fluid. If a leak is observed, find the source and correct the leak. If a leak is suspected, check the fluid levels frequently until the leak is found and repaired.
   - Accumulated grease and / or oil on an engine is a fire hazard. Remove it by steam cleaning or by the use of a high pressure water jet. Avoid high-pressure water on the electronic / electrical components provide suitable protection were possible.
   - Ensure that the coolant pipes are fitted correctly and that they are secure. Check for leaks. Check the condition of all pipes for splits or signs of rubbing.

Fluid levels

2. Check the engine oil and coolant levels – replenish as necessary (see engine handbook for locations). Ensure fluids used are as recommended within the engine handbook.

Warning:

⚠ **Do not remove the radiator cap or any component of the cooling system while the engine is running and while the coolant is under pressure, because dangerous hot coolant can be discharged, posing a risk of personal injury. Do not add large amounts of cold coolant to a hot system as serious engine damage could result.**

3. Check the engine oil and coolant levels – replenish as necessary.

Note:

- Diesel engines normally consume lube oil at a rate of 0.25% to 1% of the fuel consumption.
- When adding coolant to the radiator system, always pour slowly to help prevent air from becoming trapped in the engine. Always top up when engine is cold.

Warning:

⚠ **When filling the fuel tank, do not smoke or use an open flame in the vicinity.**

4. Check the fuel level – fill as necessary.

Warning:

⚠ **Before tightening the fan belts, disconnect the battery negative (–) lead to ensure the engine cannot be accidentally started.**

5. Check the condition and tension of the fan and engine alternator belts – tighten as necessary.
6. Check all hoses for loose connections or deterioration – tighten or replace as necessary.
7. Check the battery terminals for corrosion – clean as necessary.

Warning:

⚠ **When working with the batteries, do not smoke or use an open flame in the vicinity. Hydrogen gas from batteries is explosive.**

⚠ **Do not short the positive and negative terminals together.**

8. Check the battery electrolyte level – fill with distilled water as necessary.
9. Check the control panel and the generator set for heavy accumulation of dust and dirt – clean as necessary. These can pose an electrical hazard or give rise to cooling problems.
10. Check the air filter restriction indicator, if fitted – replace the filter as necessary.
11. Clear the area around the generator set of any insecure items that could inhibit operation or cause injury. Ensure cooling air ventilation screens are clear.

12. Visually check the entire generator set for signs of leaks from the fuel system, cooling system or lubrication seals.
13. Periodically drain exhaust system condensate traps, if equipped.
14. Ensure the Alternator Output Circuit Breaker is in the "OFF" (handle down) position.

5.5.4 Basic Operation

START Mode

Press **START** Key

STOP Mode

Press **STOP** Key

AUTO Mode

Press **AUTO** Key
(An LED will illuminate to show Auto Mode)

MANUAL Mode

Press **MANUAL** Key
(An LED will illuminate to show Manual Mode)

5.5.5 Fault / Alarm Reset Process - DCP-10

Alarm / Shutdown

Whenever a warning occurs the LED indicator will flash, but the generator set will not shut down.

Once the issue is resolvedthe Warning LED will automatically turn off.

Whenever a shutdown occurs the LED indicator illuminates.. The system is immediately locked out and the generator set stops.

This fault can be reset by pressing the STOP Key. This clears the fault, the LED indicator extinguishes and the generator set is no longer locked out and can be started.

5.5.6 Fault / Alarm Reset Process - DCP-20

Alarm

Whenever a warning occurs the LED indicator illuminates permanently, but the unit will not shut down.

Once the warning is removed or rectified the Warning LED will automatically turn off.

Shutdown

Illuminates permanently when shutdown alarm occurs.

Whenever a shutdown occurs the LED indicator illuminates permanently. The system is immediately locked out and the generator set stops.

This Fault can be reset by pressing the STOP Key. This clears the fault, the LED extinguishes and the generator set is no longer locked out and can be started.

5.5.7 User Interface Overview

Before starting or running the generator set, the operator should become fully acquainted with the control module's display and push buttons. The display should be observed from time to time while the generator set is running so that any abnormal readings can be detected before problems arise. Figure 5q shows a typical layout of the DCP-10 and DCP-20 control panel. Addition of optional equipment may add items, so that the panel fitted on the generator set may be slightly different from the typical one shown. The following descriptions explain the function of each standard item on the panels:

Function Keys:

Scroll Button – The scroll button will allow the user to navigate through the various screens and parameters available to them.

Control Keys:

RUN – pressing the Run key will cause the engine to enter the run mode.

AUTO – pressing the Auto key will cause the engine to enter the auto mode.

MANUAL – pressing the Manual key will cause the engine to enter manual mode.

Navigation Keys – DCP-10

When in parameter setting mode this button is used to increase values.

When in parameter setting mode this button is used to decrease values.

When in parameter setting mode this button will confirm any changes and also exit the configuration menu.

Navigation Keys – DCP-20

When in parameter setting mode this button is used to increase value/scroll down menu.

When in parameter setting mode this button is used to decrease value/scroll up menu.

When in parameter setting mode this button is used to enter into submenu/confirm modification.

When in parameter setting mode this button is used to return to the upper menu.

When in parameter setting mode this button is used to modify the next value.

Used to enter or exit parameter settings, by pressing and holding for 2 seconds.

Event Keys and Indicators:

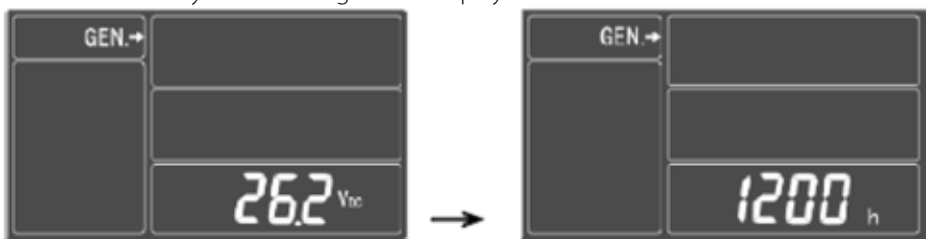
Mute Button – When a failure occurs the alarm buzzer sounds. Pressing the Mute Button will mute the buzzer and the LCD will display the Mute Icon.

Stop Button – Whenever the generator set is at rest pressing the stop button will reset any alarms that have occurred. It will not reset any active events. If a warning or shutdown occurs either text or a symbol will appear on the display indicating what the event is. Please refer to the relevant technical manual for the controller for an accurate description of these events.

Display Preferences for DCP-10 Panel

Pressing any push button will illuminate the backlight and will automatically turn off after a preset time. In normal operating status, you can set the page scroll time to scroll through each screen automatically. Press the scroll button to manually scroll through each screen. When a failure occurs, the LCD displays the corresponding failure icon.

Whenever the controller is in standby the following data is displayed:



When the controller is running normally it cycles through the following data:

Display Preferences for DCP-20 Panel

Each page can display multi-row information simultaneously. Pressing will allow the user to scroll to the next page. The display can also be configured to scroll automatically. When an alarm occurs, the alarm is displayed on the LCD immediately.

When the Generator set is running the LCD scrolls through the screens showing the following data –

Operation	Description	
The voltage/current value displayed on this screen is the average value of 3 phases. Press "▶" to scroll to the next page.	U=380V	I=0A
	P=0kW	F=50.0Hz
	SP=1500rpm	Bat=25.4V
	OP=4.6Bar	TEMP=70°C
	RUN	
This page displays electrical parameters for L1. Press "▶" to scroll to the next page.	V1=220V	U12=380V
	I1=0A	A1=0kVA
	P1=0kW	PF1=1.00
	Q1=0kVAr	
	RUN	
This page displays electrical parameters for L2. Press "▶" to scroll to the next page.	V2=220V	U23=380V
	I2=0A	A2=0kVA
	P2=0kW	PF2=1.00
	Q2=0kVAr	
	RUN	
This page displays electrical parameters for L3. Press "▶" to scroll to the next page.	V3=220V	U31=380V
	I3=0A	A3=0kVA
	P3=0kW	PF3=1.00
	Q3=0kVAr	
	RUN	
This page displays Gen power and average power factor. Press "▶" to scroll to the next page.	G. P=0kW	
	G. A=0kVA	
	G. Q=0kVAr	
	G. PF=1.00	
	RUN	
This page displays running hours, crank attempt and auxiliary sensor level. Press "▶" to scroll to the next page.	Run Hours = 0.0	
	Counters = 0	
	Fuels = 46%	Heat = 40°C
	RUN	
This page displays total active and reactive energy. Press "▶" to scroll to the next page.	G. kWHr = 0	
	G. kVArHr = 0	
	RUN	
Relay Outputs refer to the status of configurable relay output. Digital Inputs refer to the status of configurable inputs. "0" indicates an active Ouput or Input. Press "▶" to scroll to the next page.	Relay Outputs:	
	- - - 0 - - - -	
	Digital Inputs:	
	- - - - - - 0 -	
	RUN	

5.6 Control System Options and Upgrades

A large variety of options may be fitted to customise the control system to a specific installation. The following sections cover the use and operation of some of these options.

5.6.1 Battery Trickle / Switch-Mode Chargers

Both battery chargers are designed to ensure that the starter batteries maintain their charge even if the generator set is not operated for long periods.

Control switches for the chargers are not normally fitted to prevent inadvertent switching off of the charger. However, as additional options, an "ON"/"OFF" switch and a Battery Charger Boost Control may be fitted. The Boost Control overrides the automatic control mechanism of the charger that would normally reduce charging level as the battery becomes charged. This can allow faster charging of the battery. However, care must be taken to only use the boost control for a short time to avoid overcharging the battery and/or boiling the battery dry.

The control system will automatically disconnect the charger on startup of the generator set. While the engine is running the batteries are charged by the engine driven battery charging alternator.

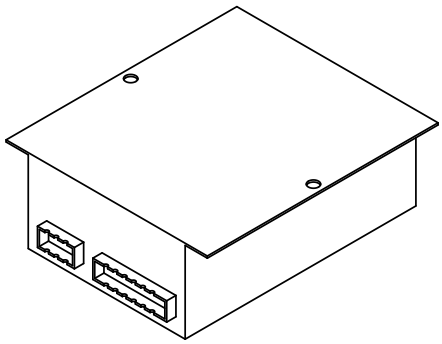


Figure 5r – Battery Charger

The switch-mode charger is an automatic battery charger, when the voltage drops below a preset voltage level it will automatically enter an increased charging voltage state (Boost). Once the batteries have reached this level, the charger will switch back to its normal 'float' voltage. This prevents the battery from over charging, which in turn prevents over gassing and subsequently maximises battery life.

5.6.2 Heaters

Immersion type heaters (engine heaters) may be fitted in the engine coolant system to ensure that the engine is easy to start and able to take load more quickly.

Alternator anti-condensation heaters (alternator heaters) may be fitted to the alternator stator winding to keep them dry in humid conditions.

Panel anti-condensation heaters (panel heaters) may be fitted in the control panel to keep moisture levels down.

Control switches are not normally fitted but may be fitted as an additional option. With or without control switches, the heaters are automatically disconnected on engine start up.

5.6.3 Electric Fuel Transfer Pumps

Fuel transfer pumps are required when fuel must be transferred from a bulk storage tank to the generator set day tank.

The controls consist of two illuminated push buttons on the control panel door or separate box under the panel. The red button is a combined trip lamp and stop button. The green button is a run lamp and manual start push button.

To operate the pump manually, ensure the red push button is in the "ON" position (pulled out). Press and hold the green push button to manually run the pump. The pump will only run in the manual mode while the green button is held in.

To operate the pump in automatic mode, ensure that the red push button is in the "ON" position (pulled out). The pump will start running automatically when the fuel level is low and will illuminate the green run lamp. When the tank is full, the pump is turned off and the green lamp is extinguished.

The red lamp will illuminate if there has been an electrical overload.

Care must be taken to ensure that the pump is primed with fuel prior to operation to lubricate the seals. Also, the pump should never be run when the bulk tanks are empty or when valves on the fuel fill lines are closed.

5.6.4 Meters / Gauges

The following additional meters or gauges may be fitted to the control panel:

- Three ammeters mounted on the panel instead of one ammeter and a selector switch. This allows a continuous indication of the current flowing in each phase, not applicable for PowerWizard as this module will display all phase currents. (Not applicable to 26 – 220 kVA product).
- Kilowatt (kW) Meter to provide accurate readings of the load being supplied by the generator set, not applicable for PowerWizard as the PowerWizard 2.1 can display kilowatts.
- Lube Oil Temperature Gauge to monitor the lubricating oil temperature when the engine is operating. The normal operating temperature should be approximately 90° – 110°C (195° – 230°F), not applicable for PowerWizard 1.1 and 2.1+ as the modules will display this.
- Ammeter for Battery Trickle Charger to monitor the current flow to the battery. It is used to observe the charging current being supplied by the battery trickle charger. When the batteries are fully charged this current will be small (less than 5 Amps) but with a partially discharged battery this current may be as high as 40 Amps.

5.6.5 Speed / Voltage Control

Three controls may be fitted to adjust the speed or voltage of the generator set: Speed Adjust Potentiometer, a Raise/Lower Switch and a Voltage Adjust Potentiometer. These should only be adjusted by a qualified generator set technician according to instructions in the Technical Manual. For some electronic engines, speed can be adjusted on the PowerWizard 2.1+ module.

5.6.6 Alarm Signalling

Three options may be fitted to the control panel to supplement the standard alarm indications of the alarm lamps:

- A panel mounted alarm siren will sound when an alarm condition is indicated. An Alarm Mute push button is fitted on the panel to silence the siren.
- An audible alarm siren supplied loose will sound when an alarm condition is indicated. It can be fitted at a convenient location. An Alarm Mute push button is fitted on the panel to silence the siren.
- A set of volt free contacts for common alarm change over in the event of an alarm condition. These are for connection to an existing alarm system. These contacts remain in the "alarm" state until the control system is reset.

5.6.7 Automatic Preheat Control

If fitted glow plugs operate automatically prior to and during engine cranking. The automatic cranking sequence will be delayed by the preheating period.

5.6.8 Remote Annunciator Panels

Available on PowerWizard.

Remote Annunciator may be fitted to PowerWizard Panels (16 channel) .

6. OPERATION

6.1 Priming Procedure for 1100 Series

Warning:

⚠ **Please wear appropriate Personal Protective Equipment (Section 2.2) before carrying out any of the following procedures as the operator will be in direct contact with diesel fuel. There will also be a risk of spillage.**

Note:

- Please see engine manual to ascertain engine model. If unsure please consult your local Dealer.
- Please see section 3.2 / 3.3 on where the fuel fill can be found on generator set

Following fuel filter servicing or draining (B) of the low pressure fuel system for any reason, re-prime the fuel system as follows

6.1.1 Products fitted with the small Perkins pre-filter / water separator

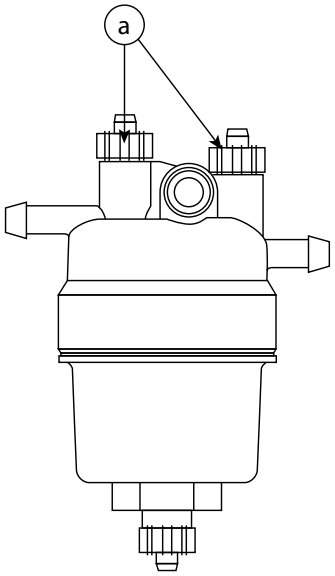


Figure 6a – Example of Pre-Filter / Water Seperator

Note:

- Ensure that the air is removed from the primary filter vent screws (a), before you prime the fuel filters.
- Do not open the vent screws (a) when the fuel system is being primed, as diesel fuel will be discharged.

With Fuel Supply from the Base Tank

- Operate the priming switch for the standard pre-set 2 minute priming cycle (See section 5.3.10).
- Start engine.
- In the event of a failure to start the engine within 3 crank cycles, see the "Troubleshooting" section of this procedure for the repeat prime procedure.

With Fuel Supply from a Remote Tank

- Ensure fuel lines from the remote tank are full of fuel, the pump should never be run when bulk tanks are empty or when valves on the fuel fill lines are closed.
- With the fuel supply switched to remote tank, carry out the priming procedure.

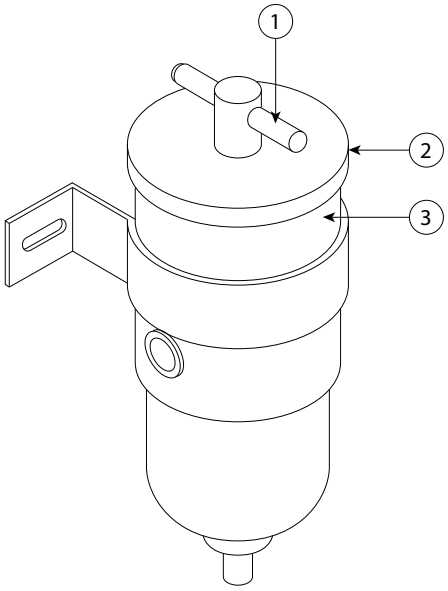
The PowerWizard control panel can be used to energise the fuel lift pump in order to prime the engine as follows:

1. In order to prime the generator set:
   MAIN MENU > CONTROL > ENGINE FUEL PRIMING.
2. To prime the set press the right cursor key, this will initiate a 2 minute priming cycle.
3. To exit the priming cycle press the left cursor key.

Note:

- The generator set may only be primed when the generator set is stopped and there are no active or present shutdown conditions.

6.1.2 Products fitted with the Racor Pre-Filter / Water Separator (Option)



1 - T Handle
2 - Racor Lid
3 - Racor Filter

Figure 6b – Example of a Racor

With Fuel Supply from the Base Tank

Following Racor element change or if the Racor unit is drained for any reason, then repriming of the unit, as specified by Racor, will be required:

- Remove T-handle (1) and lid from the top of the unit.
- Screw T-handle into centre tube finger tight.
- Fill the assembly with clean fuel to just above the top of the element. This ensures the "dirty" side of the unit is completely filled with fuel.
- Lubricate the lid gasket (2) and T-handle (1) o-ring with clean fuel.
- Replace the lid (2) taking care to seat the gasket correctly and tighten the T-handle (1) – do not use tools.
- Operate the priming switch (if fitted) to give the system a 2 minute prime.
- Start engine.
- In the event of a failure to start the engine within 3 crank cycles, see the "troubleshooting" section of this procedure for the repeat prime procedure.

With Fuel Supply from a Remote Tank

If the fuel lines from the remote tank are empty:

- Carry out the manual filling procedure of the Racor unit as detailed above.
- Operate the priming switch for 2 minutes.
- Re-fill the Racor unit as detailed above.
- Re-prime for a further 2 minutes.
- Start engine.
- In the event of a failure to start the engine after 3 crank cycles, see the 'troubleshooting ' section of this procedure for the repeat prime procedure.

If the fuel lines from the remote tank are full:

- Carry out the priming procedure as detailed in fuel supply from base tank.

6.1.3 Troubleshooting

Having completed the designated priming procedure, if the engine does not start, there may be air in the Pressure Regulator Valve (PRV) return loop hose.

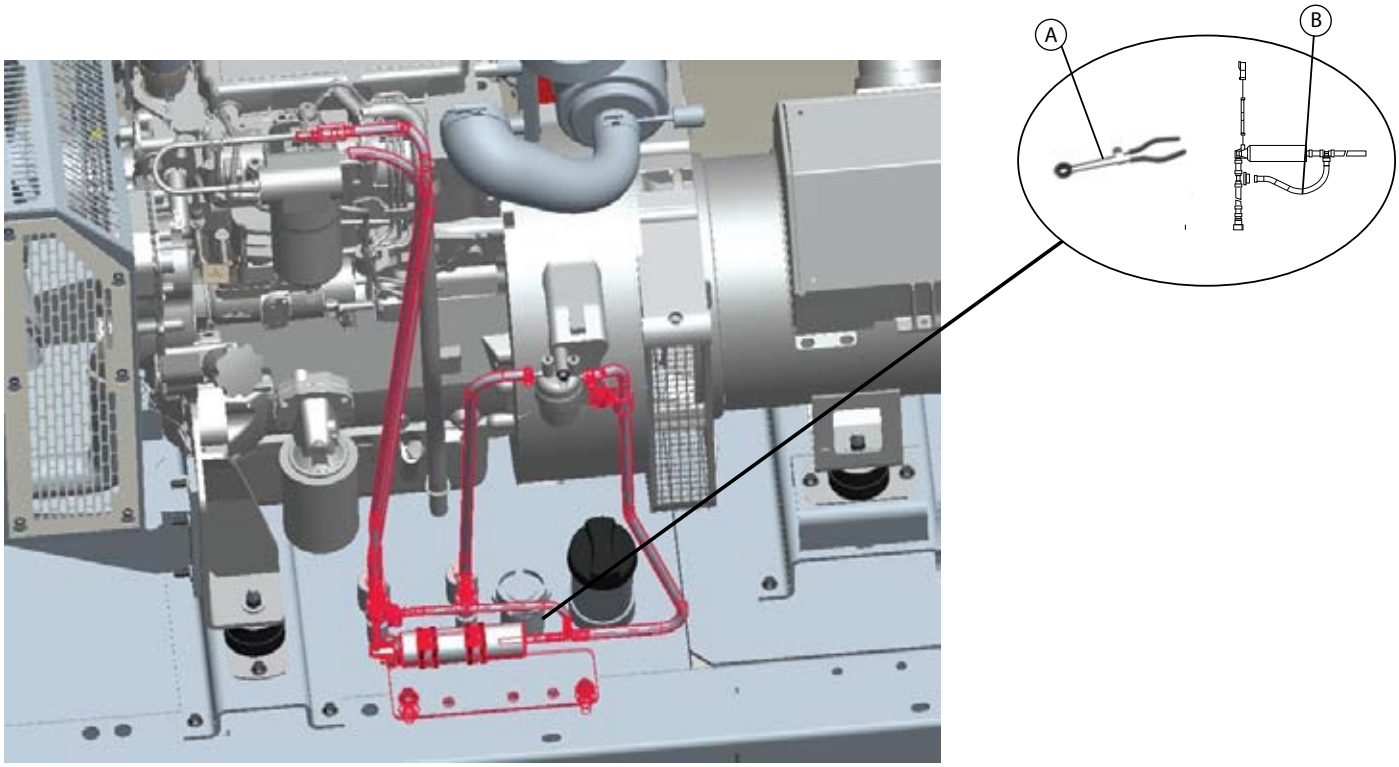


Figure 6c – Tooling (Not supplied) & Pressure Regulator Valve (PRV) return loop hose

1. Close the PRV return loop hose (B). Use Tooling (A) in order to close the PRV return loop hose (B). A typical example of Tooling (A) is shown in the illustration.
2. Repeat the priming procedure that is applicable to the configuration of the fuel system.
3. Release Tooling (A).
4. Start engine. Allow engine to run until smooth operation has been ensured and the pump is free from air.

7. GENERATOR SET MAINTENANCE

7.1 General

A good maintenance programme is the key to long generator set life. Maintenance and service should only be carried out by qualified technicians. Records of this work should be kept to aid in developing an efficient maintenance programme.

In general, the generator set should be kept clean. Do not permit liquids such as fuel or oil film to accumulate on any internal or external surfaces or on, under or around any acoustic material, if fitted. Wipe down surfaces using an aqueous industrial cleaner. Do not use flammable solvents for cleaning purposes.

Any acoustic material with a protective covering that has been torn or punctured should be replaced immediately to prevent accumulation of liquids or oil film within the material.

7.2 Preventative Maintenance

Depending on the application of the generator set, requirement for preventative maintenance will vary. The preventative maintenance requirements associated with the engine are detailed in the Engine Manual which should be reviewed in conjunction with this section. Maintenance intervals for the engine may be more frequent than those shown in this section.

7.2.1 Daily or at Each Startup

(For standby generator sets these procedures may be performed weekly.) A walk around inspection should be performed on a daily basis prior to starting the engine. The pre-start checks contained in Section 5.2 should be performed during this walk around. Procedures for performing the checks on the engine can be found in the Engine Manual which may contain additional requirements to those in Section 5.2.

7.2.2 Every Two Weeks

(For standby generator sets that have not been run.) Perform an operational check on the generator set by starting and running the engine for only 5 minutes.

Warning:

⚠ **Do not run diesel engines at low loads for long periods.**

7.2.3 Every Month

(For standby generator sets that have not been run on load.) Perform an operational and load check on the generator set by starting and running the engine at least 50% load for 1 to 2 hours.

7.2.4 Every Twelve Months or 500 Hours

Repeat the daily procedures plus the following:

1. Check all control system safety devices by electrically simulating faults.
2. Clean all battery cap vents.
3. Tighten all exhaust connections.
4. Tighten all electrical connections.
5. Perform other engine maintenance as specified in the Engine Manual.
6. Start the engine and observe the instrument panel to ensure that all gauges and meters are operating properly.
7. If a spark arrestor has been fitted, this should be removed and thoroughly cleaned to remove any carbon build-up.

7.2.5 Alternator Preventative Maintenance

There is no routine maintenance required on the alternator, however periodic inspection of the alternator winding condition and periodic cleaning is recommended. See Section 8.2, Alternator Maintenance and the Alternator Manual.

7.2.6 Engine Preventative Maintenance

See the Engine Manual provided with this manual for information on regular maintenance required to keep the engine operating efficiently.

7.3 Removal of Engine and/or Alternator

The following procedures should be used for removal of the engine and/or alternator.

1. Isolate and disconnect electrical power supply to auxiliary equipment such as a water heater.
2. Isolate the battery charger supply. Disconnect the battery (negative lead first) and remove if necessary.
3. If the generator set is equipped with a canopy, remove the fixing bolts on each side, disconnect the exhaust system and then remove the canopy.
4. Isolate and disconnect the control panel and remove together with stand from the generator set, ensuring that all cables have been adequately identified to facilitate reconnection.
5. If the engine and alternator are both to be removed, they may be lifted out as one unit using the lifting eyes provided on both the engine and alternator. First the bolts holding the engine/alternator to the baseframe have to be removed.

7.3.1 Engine Removal Only

1. If only the engine is to be removed, the wiring loom should first be removed from the engine.
2. If the alternator is fitted with only one set of feet then the front end of the alternator will have to be firmly supported before removing the engine.
3. Remove the bolts holding the engine to the base. It may also be advantageous to loosen the alternator mounting bolts.
4. Remove the alternator fan guards.
5. Support the rotor assembly using a sling or wooden supports taking care not to damage the fan.
6. Remove the bolts between the flexible coupling and the engine flywheel.
7. Support the rear of the engine using an overhead crane or similar device.
8. Remove the coupling housing bolts.
9. The engine is now moved forward until it is clear of the alternator and may be lifted away from the base.

7.3.2 Alternator Removal Only

1. If the alternator only is to be removed, the rear of the engine must be firmly supported.
2. Remove the AC wiring loom.
3. Remove the bolts holding the alternator to the baseframe. Loosen the engine bolts as well.
4. Remove the alternator fan covers and support the rotor and the front of the alternator. Ensure that the rotor is positioned with a pole at the bottom centre line. This is to avoid any damage to the bearing or exciter by limiting the rotor movement to that of the air gap.
5. Uncouple the alternator from the engine as per Section 6.3.1.
6. Support the alternator using a sling or similar device and slide the complete alternator back on the base before lifting.

8. ENGINE DESCRIPTION AND MAINTENANCE

8.1 Engine Description

8.1.1 General

The engine that powers the generator set is an industrial, heavy duty diesel engine that has been selected for its reliability and efficiency in operation. It is specifically designed and optimised to power generator sets. The engine is a 4 stroke compression ignition type with all the accessories necessary to provide a reliable power supply. Full details of the engine and associated equipment is provided in the Engine Manual. This section gives a brief discussion of the major systems and how they are integrated into the generator set.

If regular preventative maintenance is performed as per the Engine Manual, the diesel engine will continue to provide reliable power for many years.

8.1.2 Cooling System

The engine cooling system is comprised of a radiator, high capacity pusher fan, a mechanically driven water pump and a thermostat. The fan is a pusher type that pushes the air through the radiator. This system provides for cooling of the surface heat of the engine and alternator and internal cooling of the engine by the water circulating in the radiator. The alternator also has an integral fan that circulates cool air inside the housing. The thermostat maintains coolant temperature at a level for efficient operation of the engine.

It is important to pay careful attention to air flow around the generator set to ensure proper cooling. Following the installation instructions in Section 4.7 should ensure satisfactory performance.

8.1.3 Engine Governing

The engine governor is either a mechanical or electronic device designed to maintain a constant engine speed in relation to load requirements. The engine speed is directly related to the frequency of the alternator output, so any variation in engine speed will effect the frequency of the power output.

The governor senses engine speed and controls the fuel rate. As load increases on the alternator the governor will increase fuel flow to the engine. As load is reduced the governor reduces fuel flow.

8.1.4 Fuel System

On most generator sets, the engine fuel system is connected directly to a fuel tank that is built into the baseframe. This tank is designed to provide sufficient fuel for approximately 8 hours operation at full load unless an extended capacity tank has been fitted. In this case approximately 24 hours operation is possible.

The basetank is provided with fittings to facilitate either manual or automatic filling from a larger bulk storage tank. See Section 4.9 for a discussion of the entire fuel system.

On larger sets, the baseframe does not include a fuel tank so the engine fuel system must be connected to a separate tank located next to the generator set.

8.1.5 Exhaust System

Exhaust systems are provided to reduce the noise level of the engine and to direct the exhaust gases to where they will not be a hazard.

On smaller generator sets the exhaust silencer and piping are mounted directly on the engine. On larger engines the exhaust system is supplied loose for installation on-site.

8.1.6 Air Flap Valve

An air flap valve, if fitted, prevents overspeeds due to ingestion of gas or fumes by cutting off the air supply. Functional testing of these combustion air intake valves should not be performed on engines on load. A functional test should only be carried out when the engine is not running. If it is necessary to demonstrate air valves closing when the engine is running this should be done at no load. The engine should absolutely not be restarted immediately afterwards.

Warning:

⚠ **The closing of the air flap valve while the engine is running can cause oil carry over into the exhaust system which is highly volatile. The engine should be left for a period of time to allow these gases to dissipate.**

⚠ **In cases of multiple air flap valves, ensure they have all been reset to the open position before restarting.**

8.1.7 Starting Aids

Ethyl Ether starting aids are not recommended. They will reduce the efficient working life of the engine.

8.2 Engine Maintenance

Please refer to the Engine User's handbook which is included in the Operators manual.

8.3 Radiator Maintenance

8.3.1 General Notes

Corrosion in the radiator can be a prime cause of failure. This is prompted by air in the water. Always ensure pipe connections are free of leaks.

Radiators should not be left standing in a partially filled condition. Radiators left partly filled with water will suffer much more rapidly from the effects of corrosion. For an inoperative generator set, either drain the radiator completely or ensure that it is maintained full. Wherever possible, radiators should be filled with distilled or naturally soft water, dosed with suitable corrosion inhibitors. Please refer to section 4.6.9 for pH levels.

Warning:

⚠ **Radiator coolant is normally very hot and under pressure. Do not work on the radiator or disconnect pipework until it has cooled. Do not work on the radiator or remove any guarding while the fan is in motion.**

8.3.2 Safe removal of Fan Guards

Introduction of access plates means that bolts can easily be made captive and therefore are not completely removeable from the main guarding. (see Figure 7a)

Warning:

⚠ Please ensure the generator set has been switched off, ensuring the generator set has been safely isolated from starting

By adding key slots in the 6 positions as shown, the access plate can be placed over the top of the flanged bolt heads (which are already held captive in the main radiator guard), dropped into place and tightened as normal. Access plates can then easily be removed by loosening the 6 bolts 4 full turns and lifting off the plate

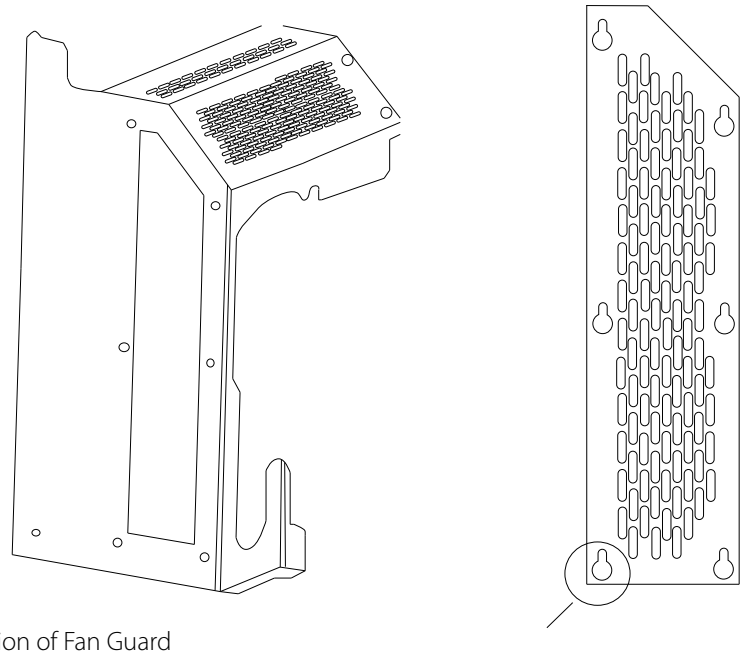


Figure 8a - Illustration of Fan Guard

8.3.3 External Cleaning

In dusty or dirty conditions the radiator fins can become blocked with loose debris, insects, etc. and this fouling will have an effect on the performance of the radiator.

For regular removal of light deposits use a low pressure steam jet. More difficult deposits may need a detergent with a low pressure hot water hose. Spray steam jet or water from the front of the radiator towards the fan. Spraying in the opposite direction will force debris further into the core. Covering the engine/alternator during this process will keep them clean.

Stubborn deposits, which cannot be removed by the above methods may require removal of the radiator and immersion in a heated alkali degreasing solution for about 20 minutes and then washing off with a hot water hose.

8.3.4 Internal Cleaning

If, due to leaky joints for instance, indiscriminate topping-up with hard water has been carried out for some time, or if the generator set has been run without inhibitors the system may become fouled by scale.

To descale the radiator, use the following procedure:

1. Drain the water system and disconnect and blank off the pipe connections to the engine.
2. Prepare a 4% solution of inhibited acid solvent and fresh water. Add the acid to the water, never vice versa.
3. Allow several minutes for mixing, then heat the solution to 49°C (120°F) maximum.
4. Run the solution slowly into the radiator via the filler cap or a branch in the manifold. Effervescence will occur. When it ceases, fill the radiator completely with the heated solvent.
5. Allow to stand for several minutes; then drain the solvent back into the original container through the bottom manifold or drain plug.
6. Examine the interior of the headers. If scale remains repeat the process outlined above with the solvent strength increased to 8%.
7. After descaling the acid solution has to be neutralised as follows:
    - Fill the mixing container with fresh water, heat to boiling point then add common washing soda crystals at the following strength: 0.5 kg of soda to 20 litres water (1 lb. soda to 4 gallons water). Fill the radiator with this solution, then drain it back into the container.
8. Flush the radiator in this manner several times, finally leaving the radiator full for at least an hour. Drain until empty and wash out the radiator with hot fresh water.
9. Before putting the radiator into service again, fill with water and apply a test pressure equal to twice that of the working pressure. Examine carefully for any leaks which may have been revealed by descaling.
10. Prior to recommissioning, the coolant must be dosed with any necessary corrosion inhibitors and/or the correct proportion of antifreeze.

9. ALTERNATOR DESCRIPTION AND MAINTENANCE

9.1 Alternator Description

9.1.1 General

The alternator fitted on the generator set is of the brushless self-excitation type which eliminates the maintenance associated with slip rings and brushes. The control system consists of an automatic voltage regulator, protective circuits and the necessary instruments to allow monitoring of the output of the generator set.

9.1.2 Construction/Major Components

The alternator unit is completely self-contained and is designed and constructed to provide trouble free operation, ease of maintenance and long service life.

The stator core is produced from insulated low loss electrical grade sheet steel laminations. These are built and welded under a fixed pressure to give an extremely rigid core to withstand vibrations and load impulses. The complete wound stator is, after impregnation, pressed into the frame and pinned into position.

A high grade precision machined shaft carries the rotor assembly which comprises the alternator rotating field systems, the exciter rotator/rotating diode system and the cooling fan. The rotor is mechanically wedged and supported on the winding end to allow an overspeed of up to 2250 RPM. The complete rotor assembly is dynamically balanced to ensure vibration-free running.

At the drive end of the rotor assembly a cast-aluminium centrifugal fan draws cooling air through screened/louvered covers at the non drive end and discharges it through similar side mounted covers at the drive end.

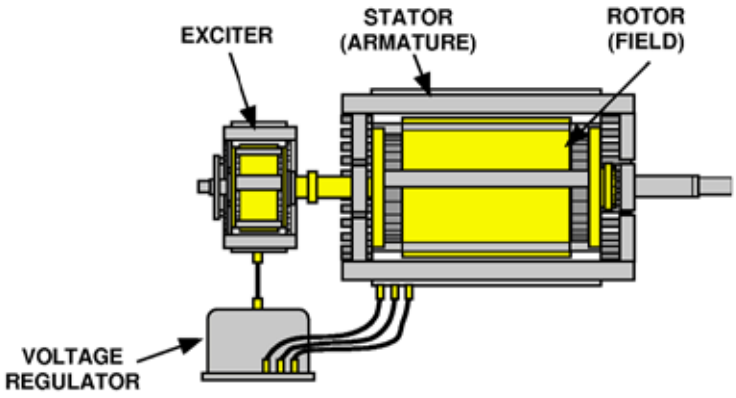


Figure 9a – Simple Alternator Layout

9.1.3 Alternator Method of Operation

The electrical power produced by the generator set is derived from a closed loop system consisting principally of the exciter rotor, the main revolving field and the automatic voltage regulator (see Figure 8a).

The process begins when the engine starts to rotate the main rotor of the alternator. The residual magnetism in the exciter stator produces a small alternating voltage in the exciter rotor as it is rotated by the engine.

This alternating voltage is then rectified through the rotating diodes as a DC voltage into the main rotor, which then creates a magnetic field in the main rotor. This induces an AC voltage in the main stator windings which gives the AC output.

The AVR senses this voltage output and depending on the setting of the voltage adjust potentiometer the AVR will adjust the voltage going to the exciter stator to maintain the voltage output of the generator set as load levels vary.

This process takes place in a few seconds from the time the engine starts turning.

9.1.4 Automatic Voltage Regulator

The Automatic Voltage Regulator (AVR) maintains a no load to full load steady state voltage to tight tolerances. The AVR has a volts/hertz characteristic which proportionally reduces the regulated voltage at reduced speeds. This feature aids the engine during sudden large additions of load.

9.2 Alternator Maintenance

Periodic inspection and cleaning is recommended.

Perform a winding insulation test according to procedures provided in the Alternator Manual, after the generator set has been stored for a period of time, (more often in higher humidity). In high humidity areas, installing space heaters to operate when the generator set is not running will help keep the windings dry.

The alternator air filters, if fitted, should be inspected regularly depending on site conditions. If cleaning is necessary, remove the filter elements from the filter frames and clean accordingly.

Additionally the alternator unit should be cleaned on a regular basis. The frequency of such cleanings depends on the environmental conditions of the operating site. The following procedure should be followed when cleaning is necessary: Disconnect all power. Wipe dust, dirt, oil, water and any other liquids from the external surfaces of the alternator unit and from the ventilation screens. These materials can work their way into the windings and may cause overheating or insulation breakdown. Dust and dirt is best removed using a vacuum cleaner. Do not use compressed air, steam or high pressure water!

The separate Alternator Manual provided with this manual contains more detailed information on alternator maintenance. It also includes a trouble shooting guide for alternator faults.

Note:

- Regular checking of alternator terminal connection lugs should be checked and inspected regularly (each service). Any connections that are found to be loose should be replaced accordingly.

9.2.1 Function (1001 Series)

Section 5 of this manual provides detailed guidance and checklists for the operation of the generator set. This section provides a more detailed description of the functions of the control system during operation.

During starting, turning the Key Switch from Position "O" (Off) to Position "I" (On) powers up the PCB's internal processor (Lamp test will illuminate for 3 seconds) which then energises the panel Fuel Control Relay (FCR) which provides power to the engine Fuel Control Solenoid.

Warning:

The Key Switch must not be turned to position "" (Thermo) or "" (Start) while the engine is running.

During start, turning the Key Switch through Position "I" (On) to Position "" (Thermo) the processor will energize the panel Start Aid Relay (SAR) which then activates the engine thermostart("PRE-HEAT/GLOW PLUGS" LED will illuminate). This preheats the induction air and should be held for 7 seconds.

Turning the Key Switch further to Position "" (Start) the processor will energize the panel Engine Crank Relay (ECR) which provides power to the starter motor which cranks the engine. The starter motor will be disengaged when the Key Switch is released so it must be held in this position until the engine starts and then immediately released and allowed to return to Position "I" (On). To prevent overheating of the starter motor the engine should not be cranked for more than 5 to 7 seconds. An interval of 10 seconds should be allowed between start attempts. If the engine has not started after 4 attempts, refer to the trouble shooting guide or Engine Manual to determine the cause of failure to start.

Turning the Key Switch past Position "I" (On) initiates the processor Fault Protection Timer (FPT). This timer is set at 30 seconds. Until the FPT times out the high engine coolant temperature and low oil pressure protective circuits are inhibited. This will keep the low oil pressure of a starting engine from causing the protection circuits to initiate a shutdown during start. Should the oil pressure not have reached the proper specified operating point by the time FPT times out or, when running, should the pressure drop below this level, the protective circuitry will initiate a shutdown. The "LOW OIL PRESSURE" LED will illuminate. Start up will be inhibited and no attempt should be made to start the generator set until the cause of the fault has been traced and remedied. High engine coolant temperature (and/or low coolant level on some larger models) will also shut down the generator set in the same way and will illuminate the "HIGH ENGINE TEMP" LED.

Warning:

If at any time the generator set stops because of a fault, the fault should be rectified before trying to restart the generator set.

These protective circuits will prevent start of the generator set until they are reset. Turning the Key Switch to Position "O" (Off) resets the protective circuits of the control system. Once the generator set is running properly, the electrical load is applied by switching the alternator output circuit breaker to "ON" (handle in the up position).

When shutting down the generator set, the load should be turned off by switching the alternator output circuit breaker to "OFF" (handle down). The engine should be allowed to cool prior to stopping it. After a few minutes the Key Switch is turned to Position "O" (Off) which shuts the generator set down.

In case of emergency where immediate shutdown is necessary, the Key Switch should be turned to Position "O" (Off) immediately without first disconnecting the load (Alternatively the panel/canopy Emergency-Stop button can be pressed for immediate shutdown).

9.2.2 Protective Circuits (1002 Series):

Engine coolant measured from the resistive temperature sender located on the engine. The PCB processor will monitor this resistance and is preset to shutdown at 107°C (approximatey 20Ω). On reaching the preset shutdown the LED labelled "HIGH ENGINE TEMPERATURE" will illuminate. The internal processor will de-energize the panel Fuel Control Relay (FCR) which in-turn switches off the supply to the Engine Fuel Control Solenoid, shutting down the engine. The LED will remain illuminated and the engine will not start until the fault has been acknowledged and reset by turning the Key Switch to Position "O" (Off).

Engine lubricating oil pressure is also monitored to check for an excessively low pressure condition. This is monitored by an active sender located on the engine which sends a voltage signal to the PCB processor. Should the oil pressure fall to or below about 22 p.s.i. (1.6 bar) the processor will recognize a fault and the internal processor will de-energize the panel Fuel Control Relay (FCR) which in-turn switches off the supply to the Engine Fuel Control Solenoid, shutting down the engine. On reaching the preset shutdown the "LOW OIL PRESSURE" fault lamp will be illuminated and the engine will not start until the fault has been acknowledged and reset by turning the Key Switch to Position "O" (Off).

Should battery voltage drop below 13.1 Volts "CHARGE ALT FAIL" LED will illuminate and remain so until voltage reaches 13.3 Volts. This will indicate a possible fault with Charging Alternator or Battery.

10. 1300 (HEUI) ELECTRONIC ENGINE FAULT DETECTION FLASH CODES

Perkins 1306-E87 electronic engines automatically record engine faults in the Electronic Control Module (ECM) to assist the operator or engineer in troubleshooting. The fault codes can be read using the red and amber lamps situated on the top of the relay box. The relay box can be found mounted on the alternator box below the AVR. The relevant codes can be identified using the fault-finding table below.

Two types of codes may be observed: "active" and "inactive" codes. Active codes are new faults identified which must be rectified before the generator set is operated again. Inactive codes are all codes which have been previously logged.

- To operate the fault finding diagnostic codes, press and hold the red pushbutton. The lamps will flash in the following sequence: amber-red-amber-amber. Once this sequence has finished, while still holding the red button, press and release the green button. Observe the sequence of the flashing lamps.
- If there are no active codes retained in the memory of the ECM, the red lamp will flash once, then the amber lamp will flash three times.
- ECM, the red lamp will flash once. The active codes will then flash on the amber lamp. If there is more than one code there will be a short delay between codes.
- When all of the active codes have been shown, the red lamp will flash twice. Then, if there are any inactive codes retained, the amber lamp will flash a code. If there is more then one code there will be a short delay between codes.
- When the test is complete, the red lamp will flash three times.
- Make a note of any codes that are shown. Active codes will become inactive if the test is done for a second time.

The fault codes can be read using the red and amber lamps situated on the top of the relay box, as shown in the picture below.

1. Relay Box – This interfaces between the Electronic Control Module (ECM) and the control panel.
2. Amber Light – If lit indicates an active fault. Please contact your local Dealership for assistance. The generator set may continue to run but may be on reduced power.
3. Red Light – Used for flash code reading, this will not light in normal operation.
4. Push Buttons – Push buttons 1 & O are used for fault code reading only.
5. Diagnostic Plug – This is used for communication with a laptop / PC. This should only be used by an authorised technician, who has had the appropriate training.

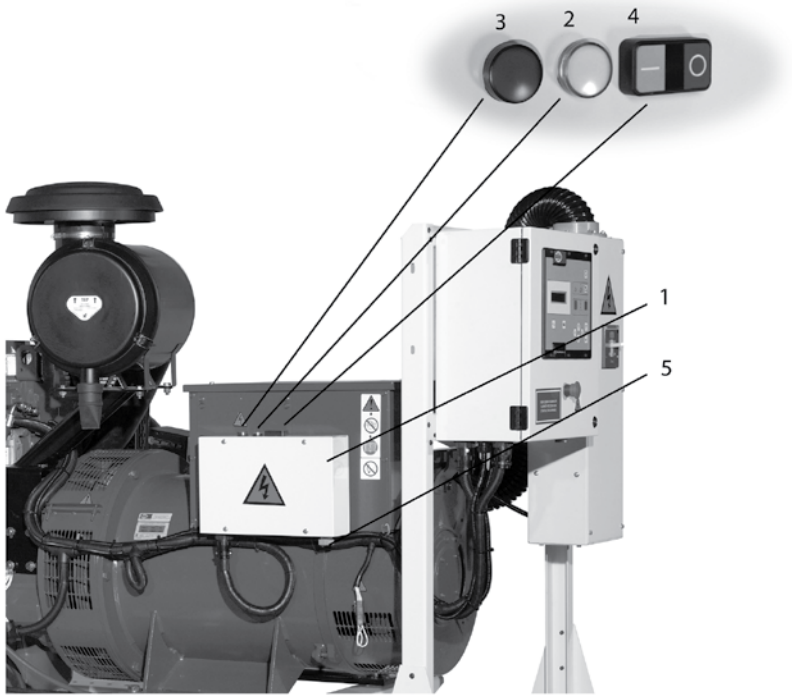


Figure 10a – 1306-E87 Electronic Engines Relay Box

10.1 1300 Series Flash Codes

Flash code	Condition description	Comments	Probable causes
111	No errors found	–	–
112	Electrical system voltage B+ out of range: high	ECM voltage is continuously more than 18V	Charging system fault
113	Electrical system voltage B+ out of range: low	ECM voltage is continuously less than 6.5V. Cause of no start / misfire	Low battery voltage. Loose connections. High resistance in circuit
114	Engine coolant temperature signal out of range: low	Defaults to 180°F (82°C). Signal voltage less than 0.127V	Short circuit to earth
115	Engine coolant temperature signal out of range: high	Defaults to 180°F (82°C). Signal voltage greater than 4.6V	Open circuit. Sensor failure
121	Manifold air pressure signal out of range: high	Defaults to ECM setting. Low power. Slow acceleration. Signal voltage greater than 4.6V	Sensor failure
122	Manifold air pressure signal out of range: low	Defaults to ECM setting. Low power. Slow acceleration. Signal voltage greater than 4.6v	Short circuit to earth. Sensor failure
123	Manifold air pressure fault: in range	Defaults to ECM setting. Low power. Slow acceleration	Hose or sensor for manifold air pressure blocked
124	Injection control pressure signal out of range: low	Defaults to open-loop control. Underrun at low idle. Signal voltage less than 0.039V	Short circuit to low. Open circuit. Sensor failure
125	Injection control pressure signal out of range: high	Defaults to open loop control Underrun at low idle. Signal voltage greater than 4.897V	Short circuit to high. Sensor failure
131	Speed control signal out of range: low	Signal voltage less than 0.152V. Engine at low idle only	Short circuit to earth. Open circuit. Sensor failure.
132	Speed control signal out of range: high	Signal voltage greater than 4.55V. Engine idle only	Short circuit to reference voltage or 12 volts. Sensor failure
133	Speed control signal fault: in range	Speed control position does not match the idle validation switch. Kept to 0% of speed control position	Speed control failure.
134*	Speed control position does not match the idle validation switch.	Kept to 0% of speed control position	Speed control and idle validation switch failure
135*	ECM low idle validation switch faulty.	Speed control position does not match the idle validation switch. Kept to 50% of speed control position. Engine speed limited	Idle validation switch failure
141*	Vehicle speed signal out of range: low	Speed sensor signal is less than 0.48V (0 Kmh/mph). Cruise control nor PTO not engaged. Engine speed limited	Sensor open circuit or short circuit to earth
142*	Vehicle speed signal out of range: high	Speed sensor signal is greater than 4.492V (0 Kmh/mph). Cruise control nor PTO not engaged	Short circuit to reference voltage or 12 volts
143	Wrong number of pulses per revolution from the camshaft position sensor	Intermittent signal	Poor connection or camshaft position sensor failure
144	Interference found at the camshaft position sensor	ECM found excessive external inputs	Interference. Injector unit voltage short circuit to earth

Flash code	Condition description	Comments	Probable causes
145	No signal from the camshaft position sensor but the injection control pressure has increased	Found by the ECM	Short circuit to earth. Open circuit. Sensor failure
151*	Barometric pressure signal out of range: high	Signal voltage greater than 4.9V for more than 1 second. Defaults to 101 kPa (14.7 lbf/in2) (1,0 kgf/cm2)	Short circuit high or open circuit. Sensor failure
152*	Barometric pressure signal out of range: low	Signal voltage less than 1.0V for more than 1 second. Defaults to 101 kPa (14.7 lb/in^2) 1,0 kgf/cm^2	Short circuit to earth low
154	Intake air temperature signal out of range: low	Signal voltage less than 0.127V. Defaults to 170°F (77°C)	Short circuit to earth
155	Intake air temperature signal out of range: high	Signal voltage greater than 4.6V. Defaults to 170°F (77°C)	Open circuit
211	Engine oil pressure signal out of range: low	Signal voltage less than 0.039V	Short circuit to earth low
212	Engine oil pressure signal out of range: high	Signal voltage greater than 4.9V	Short circuit to earth high or open circuit
213*	Remote speed control out of range: low	Remote speed control signal less than 0.249V	Open circuit
214*	Remote speed control out of range: high	Remote speed control signal greater than 4.5V	Short circuit to earth
221*	Cruise / PTO (or remote PTO) switch fault	Signal voltage incorrect, does not match the switch position	Short circuit or high resistance in the speed control circuit
222*	Brake switch circuit fault	Voltage to pins 43 and 44 on the ECM are not the same	Switch or relay faulty or incorrectly adjusted
225	Sensor for engine oil pressure faulty: in range	Signal greater than 276 kPa (40 lbf/in^2) 2,8 kgf/cm^2 with the engine start key in the "ON" position. Engine protection disabled	Faulty circuit connection. Sensor failure
231	ATA data link fault	ATA link open or short circuit. VPM fault	ATA device earthed or overloaded
236*	Engine coolant level switch fault	–	Sort circuit to earth or open circuit
241	Regulator for injection control pressure failed the output circuit test	Output circuit test in engine-off test only	Open circuit or short circuit to earth
244	Engine data link failed open circuit test	Output circuit test in engine-off test only	Open circuit or short circuit to earth
254	Open circuit test out of range: high	–	High voltage during open circuit test
255	Open circuit test out of range: low	–	Low voltage during open circuit test
311	Engine oil temperature signal out of range: low	Signal voltage less greater 4.8V Defaults to 212°F (100°C) No fast idle	Short circuit to earth
312	Engine oil temperature signal out of range: high	Signal voltage less than 0.2V Defaults to 212°F (100°C) No fast idle	Open circuit

Flash code	Condition description	Comments	Probable causes
313	Engine oil pressure below Warning level	Oil Warning light on	No oil or low oil level. Faulty regulator. Suction pipe blocked or damaged. Worn main bearings. Worn oil pump.
314	Engine oil pressure below critical level	Engine will stop, if this option is fitted	No oil or low oil level. Fault in regulator. Suction pipe blocked or damaged. Worn main bearings. Worn oil pump.
315*	Engine speed exceeded Warning limit	ECM recorded an engine speed greater than 3000 rev/min	Incorrect use of gears in automotive application
321	Engine coolant temperature above Warning level	Coolant temperature greater than 224.6°F (107°C)	Cooling system fault
322	Engine coolant temperature too high	Coolant temperature greater than 233.6°F (112.5°C)	Cooling system fault
323*	Engine coolant level below Warning level	ECM finds low coolant level	Coolant level low. Leakage of coolant
325	Power reduced to match cooling system performance	Engine power reduced	High altitude or high ambient temperature
326	Generator set speed control faults	Engine goes to idle on start up or no longer responds to a load/speed control	Wiring loom fault or out of range speed control signal
331	Injection control pressure too high	Injection control pressure above 25 Mpa (3675 lbf/in^2) 2250 kgf/cm^2	Short circuit to earth. Regulator valve stuck
332	Injection control pressure above specification with the engine off	Sensor signal voltage higher than expected with the engine off	Short circuit to voltage. Sensor fault
333	Injection control pressure below best value	Pressure does not match the output signal for a long period of time	Incorrect specification lubricating oil. Air in the lubricating oil. Leakage at the 'O' ring for the injector unit. Regulator fault.
334	Injection control pressure does not reach the correct pressure in the time allowed	Pressure does not match the output signal for a short period of time	Incorrect specification lubricating oil. Air in the lubricating oil. Leakage at the 'O' ring for the injector unit. Regulator fault.
335	Injection control pressure does not increase during engine cranking	Less than 5,1 Mpa (725 lbf/in^2) 51 kgf/cm^2 after 10 seconds of cranking	Air in the lubricating oil. Fault in the high pressure lubricating oil system
336	Injection control pressure does not reach the correct pressure	–	A leakage of lubricating oil or fault in the high pressure lubricating oil system
421	Number 1 injector unit open circuit: high or low	Found by the ECM	Injector unit electrical wiring loom open circuit
422	Number 2 injector unit open circuit: high or low	Found by the ECM	Injector unit electrical wiring loom open circuit
423	Number 3 injector unit open circuit: high or low	Found by the ECM	Injector unit electrical wiring loom open circuit
424	Number 4 injector unit open circuit: high or low	Found by the ECM	Injector unit electrical wiring loom open circuit
425	Number 5 injector unit open circuit: high or low	Found by the ECM	Injector unit electrical wiring loom open circuit

Flash code	Condition description	Comments	Probable causes
426	Number 6 injector unit open circuit: high or low	Found by the ECM	Injector unit wiring loom open circuit
431	Number 1 injector unit short circuit: high or low	Found by the ECM	Injector unit electrical wiring loom shorted high to low
432	Number 2 injector unit short circuit: high or low	Found by the ECM	Injector unit electrical wiring loom shorted high to low
433	Number 3 injector unit short circuit: high or low	Found by the ECM	Injector unit electrical wiring loom shorted high to low
434	Number 4 injector unit short circuit: high or low	Found by the ECM	Injector unit electrical wiring loom shorted high to low
435	Number 5 injector unit short circuit: high or low	Found by the ECM	Injector unit electrical wiring loom shorted high to low
436	Number 6 injector unit short circuit: high or low	Found by the ECM	Injector unit electrical wiring loom shorted high to low
451	Number 1 injector unit short circuit to B+ or earth: high	Found by the ECM	Injector unit electrical wiring loom shorted to earth: low
452	Number 2 injector unit short circuit to B+ or earth: high	Found by the ECM	Injector unit electrical wiring loom shorted to earth: low
453	Number 3 injector unit short circuit to B+ or earth: high	Found by the ECM	Injector unit electrical wiring loom shorted to earth: low
454	Number 4 injector unit short circuit to B+ or earth: high	Found by the ECM	Injector unit electrical wiring loom shorted to earth: low
455	Number 5 injector unit short circuit to B+ or earth: high	Found by the ECM	Injector unit electrical wiring loom shorted to earth: low
456	Number 6 injector unit short circuit to B+ or earth: high	Found by the ECM	Injector unit electrical wiring loom shorted to earth: low
451	Number 1 injector unit short circuit to earth	Found by the ECM	-
452	Number 2 injector unit short circuit to earth	Found by the ECM	-
453	Number 3 injector unit short circuit to earth	Found by the ECM	-
454	Number 4 injector unit short circuit to earth	Found by the ECM	-
455	Number 5 injector unit short circuit to earth	Found by the ECM	-
456	Number 6 injector unit short circuit to earth	Found by the ECM	-
461	Number 1 injector unit failed the contribution test	Found by the ECM	-
462	Number 2 injector unit failed the contribution test	Found by the ECM	-
463	Number 3 injector unit failed the contribution test	Found by the ECM	-
464	Number 4 injector unit failed the contribution test	Found by the ECM	-
465	Number 5 injector unit failed the contribution test	Found by the ECM	–

Flash code	Condition description	Comments	Probable causes
466	Number 6 injector unit failed the contribution test	Found by the ECM	–
513	Bank 1 open circuit: low	Injector units for cylinders 1, 2 and 3 have an open circuit in the high voltage supply	Open circuit
514	Bank 2 open circuit: low	Injector units for cylinders 4, 5 and 6 have an open circuit in the high voltage supply	Open circuit
515	Bank 1 short circuit to earth or B+: low	Injector units for cylinders 1, 2 and 3 have short circuit to earth or B+	Short circuit in wiring loom
521	Bank 2 short circuit to earth or B+: low	Injector units for cylinders 4, 5 and 6 have short circuit to earth or B+	Short circuit in wiring loom
524	Short circuit between bank 1 and bank 2	Short circuit between bank 1 and bank 2	Short circuit in wiring loom
525	Injector unit driver circuit fault ECM unable to supply sufficient voltage to injector units	Engine wiring loom fault	Injector unit wiring loom fault. ECM fault
612	Incorrect ECM installed for the camshaft timing plate	No match between the ECM and the camshaft position sensor	Incorrect ECM fitted
614	Engine family rating code and ECM do not match	ECM programming fault	Components not compatible
621	Engine using default rating	Engine operates AL25 HP, default	ECM installed but not programmed
622	Engine using field default rating	Engine limited to 160 HP. Options not available	ECM installed but not programmed
623	Invalid engine rating code	–	ECM not programmed correctly
624	Field default active	Programming problem	ECM fault
625	ECM fault	ECM software fault	Replace ECM
626	Unexpected ECM reset fault	Temporary ECM power failure	Battery connection fault
631	ROM self test fault	ECM failure	Internal ECM fault
632	RAM self test fault	ECM failure	Internal ECM fault
655	Programmable parameter list level incompatible	Programming problem. ECM memory problem	Programming fault
661	RAM programmable parameter list corrupt	Programming problem ECM memory problem	Programming fault
664	Calibration level incompatible	Programming problem	Programming problem
665	Programmable parameter memory content corrupt	ECM failure	Internal ECM fault

* These codes will not affect the operation of the engine in a generator set application:

Note:

- The engine protection systems e.g. low oil pressure, high coolant temperature, are within the control of the generator set control panel. These sensors will shut the engine down before the ECM sensors.

11. BATTERY DESCRIPTION AND MAINTENANCE

11.1 Battery Theory

11.1.1 General

The battery is an assembly of "cells" containing a number of plates, immersed in an electrically conductive fluid. The electrical energy from the battery comes from chemical reactions taking place within the cells. These reactions are reversible which means that the battery can be repeatedly charged and discharged.

11.1.2 Electrolyte

The electrically conductive fluid, called electrolyte, in a lead-acid battery is a diluted sulphuric acid solution. It aids the chemical reactions occurring at the plates and it acts as the carrier for the electrical current.

11.1.3 Specific Gravity

Specific gravity is a unit of measurement for determining the sulphuric acid content of the electrolyte which compares the weight of the electrolyte compared to the weight of pure water. At 25° C (77° F) a fully charged battery should have a specific gravity of 1.270. The lower the concentration of sulphuric acid, the lower the specific gravity.

As the battery is discharged, the chemical reactions lower the specific gravity of the electrolyte. Therefore, this measurement can be used as a guide to the state of charge of the battery.

11.1.4 Hydrometer

Specific gravity can be measured directly using a hydrometer. This device is a bulb-type syringe which will extract electrolyte from a cell in the battery. A glass float in the hydrometer barrel is calibrated to indicate the specific gravity.

Hydrometer readings should not be taken immediately after water is added to the cell. The water must be thoroughly mixed with the underlying electrolyte, by charging, before hydrometer readings are reliable. Also, if the reading is being taken immediately after the battery has been subjected to prolonged cranking, the reading will be higher than the true value. The water formed in the plates during the rapid discharge will not have had time to mix with the electrolyte above the plates.

11.1.5 High or Low Temperatures

In tropical climates (frequently above 32°C (90°F)) a fully charged battery with a lower specific gravity of 1.240 is used. This milder strength electrolyte increases the service life of the battery. If subjected to low temperatures the battery will not have the same cranking power due to the lower concentration of sulphuric acid, but this situation should not occur in tropical climates.

Batteries prepared for service in extremely cold weather use stronger electrolyte. In some instances specific gravity's of 1.290 to 1.300 are used. The cold cranking performance increases as the specific gravity increases.

11.1.6 Temperature Correction

The hydrometer is calibrated to indicate properly for a specified electrolyte temperature, often 25° C (77° F). For temperatures higher or lower than the reference temperature, a correction must be made. For each 5.5° C (10° F) above the reference add 0.004 to the reading. For each 5.5°C (10°F) below the reference, subtract 0.004 from the reading.

11.2 Battery Maintenance

Warning:

⚠ **Follow all safety instructions when handling batteries. Wear an acid resistant apron and face shield or goggles when servicing the battery.**

⚠ **Batteries contain corrosive sulphuric acid that can destroy clothing and burn the skin. Neutralise acid spills with a paste made of baking soda and water or large quantities of water.**

⚠ **All batteries generate explosive hydrogen gas. Keep sparks, flames and cigarettes away from batteries at all times. Do not connect or disconnect "live" circuits. To avoid creating sparks, always turn charging and testing equipment off before attaching or removing clamps.**

⚠ **ALWAYS DISCONNECT GROUNDED CABLE FIRST AND CONNECT IT LAST TO PREVENT DANGEROUS SPARKS.**

⚠ **Perform all work in a well-ventilated area. Never lean directly over a battery while boosting, testing or charging it.**

11.2.1 Dry Charge Activation

Fill each cell to proper level with battery-grade sulphuric acid of 1.265 specific gravity. Battery and acid must be at a temperature of 16°C to 38°C (60°F to 100°F) at time of filling.

Boost charge 12V batteries at 15 amps until specific gravity is 1.250 or higher and the electrolyte temperature is at least 15.5°C (60°F). BOTH CONDITIONS MUST BE MET. (Boost charge 6V and 12V heavy-duty batteries at 30 amps.) If violent gassing or spewing occurs, reduce charge rate.

After charging, check electrolyte levels. If required, add additional electrolyte to bring all levels to the bottom of the vent wells. DO NOT OVERFILL. If the battery requires top off while in service, add distilled water. DO NOT ADD ACID.

11.2.2 Safe Installation

Before removing old battery, mark the positive (+) and negative (–) cables for proper connection to the new battery.

Always disconnect the ground cable first [usually negative (–)] to avoid any sparking around battery. Then disconnect the positive (+) cable and carefully remove the old battery.

Clean and inspect. If necessary, repaint or replace the tray, hold-down and/or battery cables. Cable ends must be clean and corrosion free. Cable must not be frayed or bare.

Put corrosion protection washers on battery terminals. Install new battery in same position as old one and tighten hold-down. Be sure terminals will clear enclosure doors, air inlets, etc. to avoid damage and/or explosion.

Connect positive (+) cable first. Connect ground cable last. Never over tighten or hammer cables onto terminals.

Coat terminals and cable connection with a corrosion protection spray.

11.2.3 In Machine Service

Follow safety precautions:

- WEAR PROPER EYE PROTECTION!

Prior to any testing, visually inspect the battery. Look for:

- Cracked or broken case or cover
- Loose cable connections
- Leaking case-to-cover seal
- Corrosion
- Damaged or leaking terminals

Neutralise any corrosion with a baking soda/water paste or battery cleaner spray. Scrape or brush off the residue and wash the area with clean water. Following your visual inspection, check the battery's state of charge with a voltmeter. You must boost charge a weak battery before load testing.

11.3 Battery Charging

Warning:

⚠ **Always ensure battery charging is carried out in a well-ventilated area away from sparks and naked flames. If possible, remove the battery filler caps or vent cover during charging.**

⚠ **To avoid a battery explosion, never attempt to charge a frozen battery. Allow it to warm up to room temperature before placing on charge.**

⚠ **Never operate a battery charger where unprotected from rain or snow. The charger should never be used near water.**

⚠ **Always switch the charger off prior to disconnecting the battery.**

⚠ **Important: Never overcharge batteries. Excessive charging will shorten battery life.**

The engine driven alternator and or a static battery charger, if fitted, should maintain the batteries in a charged state. However, if the battery has recently been filled or recharging is required the battery may be disconnected from the generator set and connected to an external battery charger.

Warning:

⚠ **If the electrolyte is accessible, verify that plates are covered before beginning to charge. At the end of charge, add distilled water as needed to bring levels to the proper height. If water is added, charge for an additional 30 minutes to mix. If electrolyte levels are low, but battery is not accessible, remove battery from service.**

The maximum charge rate in amperes should be no more than 1/3 of the battery's reserve capacity minute rating. If the terminal voltage exceeds 16.0 volts while charging, reduce the charge rate.

Continue charging and reduce the rate as needed until a two-hour period results in no increase in voltage or decrease in current.

If violent gassing or spewing of electrolyte occurs, or the battery case feels hot to the touch, temporarily reduce or halt charging.

Battery Voltage	State of Charge	Approximate battery charging time* to full charge at 27°C / 80°F Maximum Rate at:			
12		50 AMPS	30 AMPS	20 AMPS	10 AMPS
12.6	100%	Full Charge			
12.4	75%	20	135	148	190
12.2	50%	45	175	195	180
12	25%	65	115	145	290
11.8	0%	85	150	195	370

*Charging time depends upon battery capacity, condition, age, temperature and efficiency of charger.

11.4 Battery Storage

Batteries should be stored in a cool, dry area in an upright position. Never stack batteries directly on top of each other unless they're in cartons. Do not stack more than 3 high (2 high if battery type is heavy commercial).

Test wet batteries every 4 – 6 months and recharge if necessary. Always test and charge if necessary before installation.

11.5 Battery Charging System Fault Finding/Trouble Shooting Chart

Warning:

⚠ **Removal of the battery charger cover will expose dangerously high voltage terminals.**

Symptom	Possible Fault	Remedy
No charging current	Incorrect or bad battery connections	Check connections and clean terminals.
	Old or sulphated battery with very low terminal voltage	Remove battery and charge on specialist equipment.
	No mains supply	Check mains supply to charger.
	Blown mains fuse	Replace fuse.
	Faulty diode rectifier unit	Remove output connections from each rectifier unit and test for output current into a known load.
No charging current shown on indicator	Faulty indicator	Check charging current with standard ammeter.
Charging rate too low	Low mains voltage	Check mains voltage supply.
	Incorrect mains supply tapping	Check the mains supply tapping with the supply voltage.
	Loose heavy current connections	Check and tighten connections if necessary.
Charging clamps get hot	Faulty connections to the battery	Clean terminals and reconnect.
	Loose screws in clamps	Clean and tighten screws in charging clamps.
Mains supply fuse blows repeatedly	Incorrect fuse rating	Replace with correct fuse.
	Wiring short	Check and remake all connections.
Charging rate does not taper	Old or damaged battery	Charger is not faulty – battery will not rise to full charge voltage. Test battery and replace as necessary.

11.6 Jump Starting Procedures

Warning:

⚠ **Do not attempt to jump start a battery if the electrolyte is frozen or slushy. Bring the batteries up to at least 5°C (41°F) before attempting a jumpstart.**

⚠ **Shield eyes and face at all times. Never lean directly over battery when testing, jump starting or performing other maintenance.**

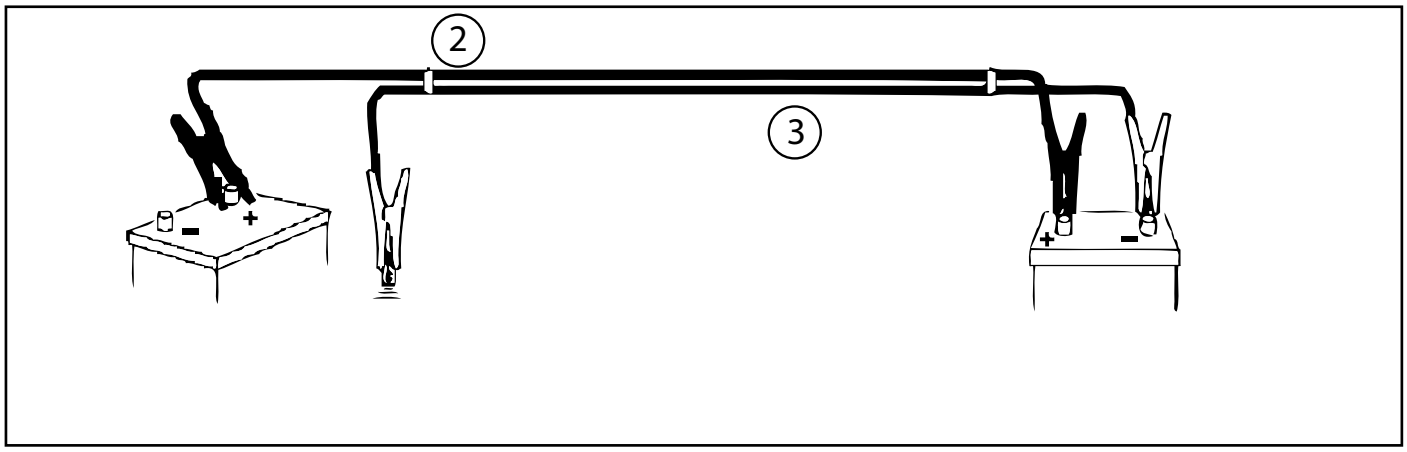
⚠ **Please ensure the generator set is in the off position before completing the instructions below.**

If the generator set battery has insufficient charge to start the generator set, a "jump start" from another battery is possible.

Ensure vent caps are tight and level. Place a damp rag over the vent caps of both batteries. Ensure starting vehicle and generator set do not touch each other.

1. Connect one end of positive (+) booster cable to positive (+) terminal of discharged battery, wired to starter or solenoid.
2. Connect other end of positive (+) booster cable to positive (+) terminal of assisting battery.
3. Connect one end of negative (–) booster cable to negative (–) terminal of assisting battery, wired to ground.
4. Complete hook-up by connecting other end of negative (–) booster cable to engine block of stalled vehicle – as far away from battery as possible...AWAY FROM MOVING FAN AND FUEL LINES.
5. With the engine of the starting vehicle running, start the generator set in accordance with the normal procedures. Avoid prolonged cranking.
6. Remove cables in reverse order of connection. Discard the rag.

See diagram below for proper hookup.



IMPORTANT NOTICE:

⚠ **The Following Notice is Intended only for Units Shipped Into The United States Of America, Canada or U.S. Possessions (Puerto Rico, Virgin Islands, Guam, American Somoa and the Commonwealth of the Northern Mariana Islands)**

For units marked as being intended for stationary use only, which are used in the United States of America, U.S. Possessions or Canada, the following restrictions apply.

This generator set may only be used in stationary applications, as defined by the Environmental Protection Agency (EPA) Regulation in Title 40 of the Code of Federal Regulations (40 CFR Part 89.2(2)).

The definition of stationary, per the regulations, is that: (a) the unit will remain at a single site at a building, structure, facility or installation for more than 12 consecutive months; or (b) will remain at a seasonal source during its full annual operating period, as defined in 40 CFR 89.2(2)(iii).

The following U.S. possessions must comply with U.S. EPA requirements: Puerto Rico, Virgin Islands, Guam, American Somoa and the Commonwealth of the Northern Mariana Islands.

12. APPENDICES

Appendix 1 – Voltages of the world table

Country	Three-phase voltage	Frequency	Number of wires (not including the ground wire)
afghanistan	380 V	50 Hz	4
Albania	400 V	50 Hz	4
Algeria	400 V	50 Hz	4
American Samoa	208 V	60 Hz	3, 4
Andorra	400 V	50 Hz	3, 4
Angola	380 V	50 Hz	4
Antigua	400 V	60 Hz	3, 4
Argentina	380 V	50 Hz	3, 4
Armenia	380 V	50 Hz	4
Aruba	220 V	60 Hz	3, 4
Australia	415 V	50 Hz	3, 4
Austria	400 V	50 Hz	3, 4
Azerbaijan	380 V	50 Hz	4
Azores	400 V	50 Hz	3, 4
Bahamas	208 V	60 Hz	3, 4
Bahrain	400 V	50 Hz	3, 4
Balearic Islands	400 V	50 Hz	3, 4
Bangladesh	380 V	50 Hz	3, 4
Barbados	200 V	50 Hz	3, 4
Belarus	380 V	50 Hz	4
Belgium	400 V	50 Hz	3, 4
Belize	190 V / 380 V	60 Hz	3, 4
Benin	380 V	50 Hz	4
Bermuda	208 V	60 Hz	3, 4
Bhutan	400 V	50 Hz	4
Bolivia	400 V	50 Hz	4
Bosnia & Herzegovina	400 V	50 Hz	4
Botswana	400 V	50 Hz	4
Brazil	220 V / 380 V / 440 V*	60 Hz	3, 4
Brunei	415 V	50 Hz	4
Bulgaria	400 V	50 Hz	4
Burkina Faso	380 V	50 Hz	4
Burundi	380 V	50 Hz	4
Cambodia	400 V	50 Hz	4
Cameroon	380 V	50 Hz	4
Canada	208 V / 240 V / 600 V	60 Hz	3, 4
Canary Islands	400 V	50 Hz	3, 4
Cape Verde	400 V	50 Hz	3, 4
Cayman Islands	208 V	60 Hz	3
Central African Republic	380 V	50 Hz	4
Chad	380 V	50 Hz	4
Channel Islands (Guernsey & Jersey)	400 V	50 Hz	4
Chile	380 V	50 Hz	3, 4
China, People's Republic of	380 V	50 Hz	3, 4

Country	Three-phase voltage	Frequency	Number of wires (not including the ground wire)
Colombia	440 V	60 Hz	3, 4
Comoros	380 V	50 Hz	4
People's Rep. of Congo	400 V	50 Hz	3, 4
Dem. Rep. of Congo (formerly Zaire)	380 V	50 Hz	3, 4
Cook Islands	415 V	50 Hz	3, 4
Costa Rica	240 V	60 Hz	3, 4
Côte d'Ivoire (Ivory Coast)	380 V	50 Hz	3, 4
Croatia	400 V	50 Hz	4
Cuba	190 V	60 Hz	3
Cyprus	400 V	50 Hz	4
Czech Republic	400 V	50 Hz	3, 4
Denmark	400 V	50 Hz	3, 4
Djibouti	380 V	50 Hz	4
Dominica	400 V	50 Hz	4
Dominican Republic	120/208 V / 277/480 V	60 Hz	3, 4
Ecuador	190 V	60 Hz	3, 4
Egypt	380 V	50 Hz	3, 4
El Salvador	200 V	60 Hz	3
Equatorial Guinea	[unavailable]	[unavailable]	[unavailable]
Eritrea	400 V	50 Hz	4
Estonia	400 V	50 Hz	4
Ethiopia	380 V	50 Hz	4
Faeroe Islands	400 V	50 Hz	3, 4
Falkland Islands	415 V	50 Hz	4
Fiji	415 V	50 Hz	3, 4
Finland	400 V	50 Hz	3, 4
France	400 V	50 Hz	4
French Guyana	380 V	50 Hz	3, 4
Gabon	380 V	50 Hz	4
Gambia	400 V	50 Hz	4
Gaza	400 V	50 Hz	4
Georgia	380 V	50 Hz	4
Germany	400 V	50 Hz	4
Ghana	400 V	50 Hz	3, 4
Gibraltar	400 V	50 Hz	4
Greece	400 V	50 Hz	4
Greenland	400 V	50 Hz	3, 4
Grenada (Windward Islands)	400 V	50 Hz	4
Guadeloupe	400 V	50 Hz	3, 4
Guam	190 V	60 Hz	3, 4
Guatemala	208 V	60 Hz	3, 4
Guinea	380 V	50 Hz	3, 4
Guinea-Bissau	380 V	50 Hz	3, 4
Guyana	190 V	60 Hz	3, 4
Haiti	190 V	60 Hz	3, 4
Honduras	190 V	60 Hz	3

Country	Three-phase voltage	Frequency	Number of wires (not including the ground wire)
Hong Kong	380 V	50 Hz	3, 4
Hungary	400 V	50 Hz	3, 4
Iceland	400 V	50 Hz	3, 4
India	400 V	50 Hz	4
Indonesia	400 V	50 Hz	4
Iran	400 V	50 Hz	3, 4
Iraq	400 V	50 Hz	4
Ireland (Eire)	400 V	50 Hz	4
Isle of Man	400 V	50 Hz	4
Israel	400 V	50 Hz	4
Italy	400 V	50 Hz	4
Jamaica	190 V	50 Hz	3, 4
Japan	200 V	50 Hz / 60 Hz**	3
Jordan	400 V	50 Hz	3, 4
Kenya	415 V	50 Hz	4
Kazakhstan	380 V	50 Hz	3, 4
Kiribati	[unavailable]	[unavailable]	[unavailable]
Korea, South	380 V	60 Hz	4
Kuwait	415 V	50 Hz	4
Kyrgyzstan	380 V	50 Hz	3, 4
Laos	400 V	50 Hz	4
Latvia	400 V	50 Hz	4
Lebanon	400 V	50 Hz	4
Lesotho	380 V	50 Hz	4
Liberia	208 V	60 Hz	3, 4
Libya	220 V / 400 V	50 Hz	4
Liechtenstein	400 V	50 Hz	4
Lithuania	400 V	50 Hz	4
Luxembourg	400 V	50 Hz	4
Macau	380 V	50 Hz	3
Macedonia	400 V	50 Hz	4
Madagascar	220 V / 380 V	50 Hz	3, 4
Madeira	400 V	50 Hz	3, 4
Malawi	400 V	50 Hz	3, 4
Malaysia	415 V	50 Hz	4
Maldives	400 V	50 Hz	4
Mali	380 V	50 Hz	3, 4
Malta	400 V	50 Hz	4
Martinique	380 V	50 Hz	3, 4
Mauritania	220 V	50 Hz	3
Mauritius	400 V	50 Hz	4
Mexico	220 V / 480 V	60 Hz	3, 4
Moldova	380 V	50 Hz	4
Monaco	400 V	50 Hz	4
Mongolia	400 V	50 Hz	4
Montenegro	400 V	50 Hz	3, 4
Montserrat (Leeward Islands)	400 V	60 Hz	4
Morocco	380 V	50 Hz	4

Country	Three-phase voltage	Frequency	Number of wires (not including the ground wire)
Mozambique	380 V	50 Hz	4
Myanmar (formerly Burma)	400 V	50 Hz	4
Namibia	380 V	50 Hz	4
Nauru	415 V	50 Hz	4
Nepal	400 V	50 Hz	4
Netherlands	400 V	50 Hz	3
Netherlands Antilles	220 V / 380 V	50 Hz	3, 4
New Caledonia	380 V	50 Hz	3, 4
New Zealand	415 V	50 Hz	3, 4
Nicaragua	208 V	60 Hz	3, 4
Niger	380 V	50 Hz	4
Nigeria	400 V	50 Hz	4
Norway	400 V	50 Hz	3
Oman	415 V	50 Hz	4
Pakistan	400 V	50 Hz	3
Palau	208 V	60 Hz	3
Panama	190 V	60 Hz	3
Papua New Guinea	415 V	50 Hz	4
Paraguay	380 V	50 Hz	4
Peru	220 V	60 Hz	3
Philippines	380 V	60 Hz	3
Poland	400 V	50 Hz	4
Portugal	400 V	50 Hz	3, 4
Puerto Rico	208 V	60 Hz	3, 4
Qatar	415 V	50 Hz	3, 4
Réunion Island	400 V	50 Hz	4
Romania	400 V	50 Hz	3, 4
Russian Federation	400 V	50 Hz	4
Rwanda	400 V	50 Hz	4
St. Kitts and Nevis (Leeward Islands)	400 V	60 Hz	4
St. Lucia (Windward Islands)	400 V	50 Hz	4
St. Vincent (Windward Islands)	400 V	50 Hz	4
San Marino	400 V	50 Hz	4
Saudi Arabia	190 V / 380 V***	60 Hz***	4
Senegal	400 V	50 Hz	3, 4
Serbia	400 V	50 Hz	3, 4
Seychelles	240 V	50 Hz	3
Sierra Leone	400 V	50 Hz	4
Singapore	400 V	50 Hz	4
Slovakia	400 V	50 Hz	4
Slovenia	400 V	50 Hz	3, 4
Somalia	380 V	50 Hz	3, 4
South Africa	400 V	50 Hz	3, 4
Spain	400 V	50 Hz	3, 4
Sri Lanka	400 V	50 Hz	4
Sudan	400 V	50 Hz	4
Suriname	220 V	60 Hz	3, 4
Swaziland	400 V	50 Hz	4

Country	Three-phase voltage	Frequency	Number of wires (not including the ground wire)
Sweden	400 V	50 Hz	3, 4
Switzerland	400 V	50 Hz	3, 4
Syria	380 V	50 Hz	3
Tahiti	380 V	50 Hz / 60 Hz ****	3, 4
Tajikistan	380 V	50 Hz	3
Taiwan	190 V	60 Hz	3, 4
Tanzania	400 V	50 Hz	3, 4
Thailand	380 V	50 Hz	3, 4
Togo	380 V	50 Hz	4
Tonga	415 V	50 Hz	3, 4
Trinidad & Tobago	200 V	60 Hz	3, 4
Tunisia	400 V	50 Hz	4
Turkey	400 V	50 Hz	3, 4
Turkmenistan	380 V	50 Hz	3
Uganda	415 V	50 Hz	4
Ukraine	380 V	50 Hz	4
United Arab Emirates	415 V	50 Hz	3, 4
United Kingdom	400 V	50 Hz	4
United States of America	120/208 V / 277/480 V	60 Hz	3, 4
Uruguay	220 V	50 Hz	3
Uzbekistan	380 V	50 Hz	4
Venezuela	240 V	60 Hz	3, 4
Vietnam	380 V	50 Hz	4
Virgin Islands	190 V	60 Hz	3, 4
Western Samoa	400 V	50 Hz	3
Yemen, Rep. of	400 V	50 Hz	4
Zambia	400 V	50 Hz	4
Zimbabwe	415 V	50 Hz	3, 4

* – In Brazil there is no standard voltage. Most states use 127 V electricity (single-phase) and 220 V (three-phase) (Acre, Amapá, Amazonas, Espírito Santo, Mato Grosso do Sul, Maranhão, Pará, Paraná, Rondônia, Roraima, Sergipe and Minas Gerais). Other – mainly northeastern – states are on 220 V (single-phase) and 380 V (three-phase) (Alagoas, Brasília, Ceará, Mato Grosso, Goiás, Paraíba, Rio Grande do Norte, Santa Catarina and Tocantins). Although in most parts of the states of Bahia, São Paulo, Rio de Janeiro and Rio Grande do Sul 127 V (single-phase) and 220 V (three-phase) is used, the cities of Santos, Jequié, Jundiaí, São Bernardo do Campo, Novo Friburgo, Bagé, Caxias do Sul and Pelotas run on 220 V (single-phase) and 380 V (three-phase). The states of Pernambuco and Piauí use 220 V (single-phase) and 380 V (three-phase), except for the cities of Paulista and Teresina (127 V single-phase and 220 V three-phase).

** – Although the mains voltage in Japan is the same everywhere, the frequency differs from region to region. Eastern Japan uses predominantly 50 Hz (Tokyo, Kawasaki, Sapporo, Yokohama, Sendai), whereas Western Japan prefers 60 Hz (Osaka, Kyoto, Nagoya, Hiroshima).

*** – In most parts of Saudi Arabia - such as the Dammam and al-Khobar area - 190 V three-phase electricity is used (110 V single-phase). 220 V (single-phase) and 380 V (three-phase) can be found as well.

**** – In Tahiti the frequency is 60 Hz, except for the Marquesas archipelago where it is 50 Hz.

Appendix 2 - Tables And Formulas For Engineering Standby Generator sets

Table 1. Length Equivalents

Unit	Microns	Metres	Kilometres	Inches	Feet	Yards	Miles
1 Micron	1	0.000001	--	0.00003937	--	--	--
1 Metre	1,000,000	1	--	39.37	3.281	1.0936	--
1 Kilometre	--	1,000	1	39,370	3281	1093.6	0.621
1 Inch	25,400	0.0254	--	1	0.0833	0.0278	--
1 Foot	--	0.3048	--	12	1	0.3333	--
1 Yard	--	0.9144	--	36	3	1	--
1 Mile	--	1609	1.609	63,360	5280	1760	1

One unit in the left-hand column equals the value of units under the top heading.

Table 2. Area Equivalents

Unit	In^2	Ft^2	Acre	$Mile^2$	M^2	Hectare	Km^2
1 In^2	1	0.006944	--	--	0.00064516	--	--
1 Ft^2	144	1	--	--	0.0929	--	--
1 Acre	--	43,560	1	0.0015625	4,047	0.4047	0.004047
1 $Mile^2$	--	27,878,400	640	1	2,589,998	258.99	2.5899
1 M^2	1550	10.764	--	--	1	--	--
1 Hectare	--	107,639	2.471	0.003861	10,000	1	0.01
1 Km^2	--	10,763,867	247.1	0.3861	1,000,000	100	1

One unit in the left-hand column equals the value of units under the top heading.

Table 3. Mass Equivalents

Unit	Ounces	Pounds	Kilograms	Tons		
				Short	Long	Metric
1 Ounce	1	0.0625	0.02835	--	--	--
1 Pound	16	1	0.4536	--	--	--
1 Kilogram	35.27	2.205	1	--	--	--
1 Short Ton	32000	2000	907.2	1	0.8929	0.9072
1 Long Ton	35840	2240	1016	1.12	1	1.016
1 Metric Ton	35274	2205	1000	1.102	0.9842	1

One unit in the left-hand column equals the value of units under the top heading.

Table 4. Volume and Capacity Equivalents

Unit	$Inches^3$	$Feet^3$	$Yards^3$	$Meters^3$	US Liquid Gallons	Imperial Gallons	Litres
1 $Inch^3$	1	0.000579	0.0000214	0.0000164	0.004329	0.00359	0.0164
1 $Ft.^3$	1728	1	0.03704	0.0283	7.481	6.23	28.32
1 $Yd.^3$	46656	27	1	0.765	202	168.35	764.6
1 M^3	61023	35.31	1.308	1	264.2	220.2	1000
1 US Liq Gal	231	0.1337	0.00495	0.003785	1	0.833	3.785
1 Imp. Gal.	277.42	0.16	0.00594	0.004546	1.2	1	4.546
1 Litre	61.02	0.03531	0.001308	0.001	0.2642	0.22	1

One unit in the left-hand column equals the value of units under the top heading.

Table 5. Conversions for Units of Speed

Unit	Feet/Second	Feet/Min	Miles/Hr	Meters/Sec	Meters/Min	Km/Hr
1 Foot/Sec	1	60.0	0.6818	0.3048	18.288	--
1 Foot/Min	0.0167	1	0.1136	0.00508	--	--
1 Mile/Hr	1.467	88	1		26.822	1.6093
1 Meter/Sec	3.281	196.848	--	1	--	--
1 Meter/Min	0.05468	--	0.03728	--	1	--
1 Km/Hr	--	--	0.6214	0.2778	--	1

One unit in the left-hand column equals the value of units under the top heading.

Table 6. Conversions for Units of Power

Unit	Horsepower	Foot-lb/ Minute	Kilowatts	Metric Horsepower	Btu/Minute
1 Horsepower	1	33,000	0.746	1.014	42.4
1 Foot-lb/Minute	--	1	--	--	0.001285
1 Kilowatt	1.341	44,260	1	1.360	56.88
1 Metric Horsepower	0.986	32,544	0.736	1	41.8
1 Btu. /Minute	0.0236	777.6	0.0176	0.0239	1

One unit in the left-hand column equals the value of units under the top heading. Mechanical power and ratings of motors and engines are expressed in horsepower. Electrical power is expressed in watts or kilowatts.

Table 7. Conversions for Measurements of Water

Unit	$Feet^3$	Pounds	Gal (US)	Gal (IMP)	Litres	Head (Ft)	lb/in^2	Ton/Ft^2	Head (Meters)	Ft^3/ Min	Gal.(US)/ Hr
$Feet^3$	1	62.42	--	--	--	--	--	--	--	--	--
Pounds	0.01602	1	0.12	0.10	0.4536	--	--	--	--	--	--
Gal (US)	--	8.34	1	--	--	--	--		--	--	
Gal (IMP)	--	10.0	--	1	--	--	--		--	--	
Litres	--	2.2046	--	--	1	--	--		--		
Head (Ft)	--	--	--	--	--	1	4.335		--		
lb/in^2	--	--	--	--	--	2.3070	1	0.02784	0.7039		
Ton/Ft^2	--	--	--	--	--	35.92	--	1	--		
Head (Meters)	--	--	--	--	--	--	1.4221	--	1		
Ft^3/Min	--	--	--	--	--	--	--	--	--	1	448.92
Gal. (US)/Hr	--	--	--	--	--	--	--	--	--	0.002227	1

One unit in the left-hand column equals the value of units under the top heading.

Table 8. Barometric Pressures and Boiling Points of Water at Various Altitudes

	Barometric Pressure			Water Boiling Point	
(Ft)	Inches of Mercury	lb/in^2	Feet Water	°F	°C
Sea Level	29.92	14.69	33.95	212.0	100
1000	28.86	14.16	32.60	210.1	99
2000	27.82	13.66	31.42	208.3	98
3000	26.81	13.16	30.28	206.5	97
4000	25.84	12.68	29.20	204.6	95.9
5000	24.89	12.22	28.10	202.8	94.9
6000	23.98	11.77	27.08	201.0	94.1
7000	23.09	11.33	26.08	199.3	93
8000	22.22	10.91	25.10	197.4	91.9
9000	21.38	10.50	24.15	195.7	91
10,000	20.58	10.10	23.25	194.0	90
11,000	19.75	9.71	22.30	192.0	88.9
12,000	19.03	9.34	21.48	190.5	88
13,000	18.29	8.97	20.65	188.8	87.1
14,000	17.57	8.62	19.84	187.1	86.2
15,000	16.88	8.28	18.07	185.4	85.2

One unit in the left-hand column equals the value of units under the top heading.

Table 9. Conversions of Units of Flow

Unit	US Gallons/ Minute	Million US Gallons/Day	Feet^3/Second	Meters^3/Hour	Litres/Second
1 US Gallon/Minute	1	0.001440	0.00223	0.2271	0.0630
1 Million US Gallons/Day	694.4	1	1.547	157.73	43.8
1 Foot^3/Second	448.86	0.646	1	101.9	28.32
1 Meter^3/Hour	4.403	0.00634	0.00981	1	0.2778
1 Litre/Second	15.85	0.0228	0.0353	3.60	1

One unit in the left-hand column equals the value of units under the top heading.

Table 10. Conversions of Units of Pressure and Head

Unit	mm Hg	in. Hg	in H_2O	ft H_2O	lb/in^2	kg/cm^2	Atmos	kPa
1mm Hg	1	0.0394	0.5352	0.0447	0.01934	0.00136	0.0013	--
1 in. Hg	25.4	1	13.5951	1.1330	0.49115	0.03453	0.0334	3.386
1 in H_2O	1.86827	0.0736	1	0.0833	0.03613	0.00254	0.0025	0.249
1 ft H_2O	22.4192	0.8827	12	1	0.43352	0.030479	0.0295	2.989
1 lb/ in^2	51.7149	2.0360	27.6807	2.3067	1	0.07031	0.0681	6.895
1 kg/cm^2	735.559	28.959	393.7117	32.8093	14.2233	1	0.9678	98.07
Atmos.	760.456	29.92	406.5	33.898	14.70	1.033	1	101.3
kPa	7.50064	0.2953	4.0146	0.3346	0.14504	0.0102	0.0099	1

One unit in the left-hand column equals the value of units under the top heading.

Table 11. Approximate Weights of Various Liquids

	Pounds per US Gallon	Specific Gravity
Diesel Fuel	6.88 - 7.46	0.825 - 0.895
Ethylene Glycol	9.3 - 9.6	1.12 - 1.15
Furnace Oil	6.7 - 7.9	0.80 - 0.95
Gasoline	5.6 - 6.3	0.67 - 0.75
Kerosene	6.25 - 7.1	0.75 - 85
Lube. Oil (Medium)	7.5 - 7.7	0.90 - 0.92
Water	8.34	1.00

Table 12. Electrical formulae

Desired Data	Single Phase	Three-Phase	Direct Current
Kilowatts (kW)	$\frac{I \times V \times PF}{1000}$	$\frac{\sqrt{3} \times I \times V \times PF}{1000}$	$\frac{I \times V}{1000}$
Kilovolt-Amperes kVA	$\frac{I \times V}{1000}$	$\frac{\sqrt{3} \times V \times E}{1000}$	
Electric Motor Horsepower Output (HP)	$\frac{I \times V \times Eff \times PF}{746}$	$\frac{\sqrt{3} \times I \times V \times Eff \times PF}{746}$	$\frac{I \times V \times Eff}{746}$
Amperes (I) When Horsepower is known	$\frac{HP \times 746}{V \times Eff \times PF}$	$\frac{HP \times 746}{\sqrt{3} \times V \times Eff \times PF}$	$\frac{HP \times 746}{V \times Eff}$
Amperes (I) When Kilowatts are known	$\frac{kW \times 1000}{V \times PF}$	$\frac{kW \times 1000}{\sqrt{3} \times V \times PF}$	$\frac{kW \times 1000}{V}$
Amperes (I) When kVA is known	$\frac{kVA \times 1000}{V}$		

Where:

V = Volts

I = Amperes

Eff = Percentage Efficiency

PF = Power Factor

Table 13. kVA/kW Amperage At Various Voltages (0.8 Power Factor)

kVA	kW	208V	220V	240V	380V	400V	440V	460V	480V	600V	2400V	33000V	4160V
6.3	5	17.5	16.5	15.2	9.6	9.1	8.3	8.1	7.6	6.1			
9.4	7.5	26.1	24.7	22.6	14.3	13.6	12.3	12	11.3	9.1			
12.5	10	34.7	33	30.1	19.2	18.2	16.6	16.2	15.1	12			
18.7	15	52	49.5	45	28.8	27.3	24.9	24.4	22.5	18			
25	20	69.5	66	60.2	38.4	36.4	33.2	32.4	30.1	24	6	4.4	3.5
31.3	25	87	82.5	75.5	48	45.5	41.5	40.5	37.8	30	7.5	5.5	4.4
37.5	30	104	99	90.3	57.6	54.6	49.8	48.7	45.2	36	9.1	6.6	5.2
50	40	139	132	120	77	73	66.5	65	60	48	12.1	8.8	7
62.5	50	173	165	152	96	91	83	81	76	61	15.1	10.9	8.7
75	60	208	198	181	115	109	99.6	97.5	91	72	18.1	13.1	10.5
93.8	75	261	247	226	143	136	123	120	113	90	22.6	16.4	13
100	80	278	264	240	154	146	133	130	120	96	24.1	17.6	13.9
125	100	347	330	301	192	182	166	162	150	120	30	21.8	17.5
156	125	433	413	375	240	228	208	204	188	150	38	27.3	22
187	150	520	495	450	288	273	249	244	225	180	45	33	26
219	175	608	577	527	335	318	289	283	264	211	53	38	31
250	200	694	660	601	384	364	332	324	301	241	60	44	35
312	250	866	825	751	480	455	415	405	376	300	75	55	43
375	300	1040	990	903	576	546	498	487	451	361	90	66	52
438	350	1220	1155	1053	672	637	581	568	527	422	105	77	61
500	400	1390	1320	1203	770	730	665	650	602	481	120	88	69
625	500	1735	1650	1504	960	910	830	810	752	602	150	109	87
750	600	2080	1980	1803	1150	1090	996	975	902	721	180	131	104
875	700	2430	2310	2104	1344	1274	1162	1136	1052	842	210	153	121
1000	800	2780	2640	2405	1540	1460	1330	1300	1203	962	241	176	139
1125	900	3120	2970	2709	1730	1640	1495	1460	1354	1082	271	197	156
1250	1000	3470	3300	3009	1920	1820	1660	1620	1504	1202	301	218	174
1563	1250	4350	4130	3765	2400	2280	2080	2040	1885	1503	376	273	218
1875	1500	5205	4950	4520	2880	2730	2490	2440	2260	1805	452	327	261
2188	1750			5280	3350	3180	2890	2830	2640	2106	528	380	304
2500	2000			6020	3840	3640	3320	3240	3015	2405	602	436	348
2812	2250			6780	4320	4095	3735	3645	3400	2710	678	491	392
3125	2500			7520	4800	4560	4160	4080	3765	3005	752	546	435
3750	3000			9040	5760	5460	4980	4880	4525	3610	904	654	522
4375	3500			10550	6700	6360	5780	5660	5285	4220	1055	760	610
5000	4000			12040	7680	7280	6640	6480	6035	4810	1204	872	695

Appendix 3 - Conversions

Conversions of Centigrade and Fahrenheit

- Water freezes at 0°C (32°F)
- Water boils at 100°C (212°F)
- °F= (1.8 x °C) + 32
- °C = 0.5555 (°F - 32)

Fuel Consumption Formulas

Fuel Consumption (lb / hr) = Specific FuelCons. (lb / BHP / hr) x BHP

Fuel Consumption (US gal / hr) = $\frac{\text{Spec. Fuel Cons. (lb / BHP / hr) x BHP}}{\text{FuelSpecific Weight (lb / US gal)}}$

FuelSpec.Weight (lb / US gal) = FuelSpecific Gravity x 8.34 lb

Specific Fuel Consumption (lb / BHP / hr) = $\frac{\text{FuelCons. (US gal / hr) x FuelSpec.Wt (lb / US gal)}}{\text{BHP}}$

Specific Fuel Consumption (kg / BHP / hr) = $\frac{\text{Spec.Fuel Cons. (lb / BHP / hr)}}{\text{BHP}}$

Electrical Motor Horsepower

Electrical Motor Horsepower = $\frac{\text{kW Input x Motor Efficiency}}{\text{0.746 x Generator Efficiency}}$

Engine Horsepower Required = $\frac{\text{kW Output Required}}{\text{0.746 x Generator Efficiency}}$

Piston Travel

Feet Per Minute (FPM) = 2 x L x N

Where

- L = Length of Stroke in Feet
- N = Rotational Speed of Crankshaft in RPM

Break Mean Effective Pressure (BMEP) (4 Cycle)

BMEP = $\frac{\text{792 , 000 x BHP}}{\text{Total Displacement x RPM}}$

13. GLOSSARY OF TERMS

ALTERNATING CURRENT (AC) – A current which periodically reverses in direction and changes its magnitude as it flows through a conductor or electrical circuit. The magnitude of an alternating current rises from zero to maximum value in one direction, returns to zero and then follows the same variation in the opposite direction. One complete alternation is one cycle or 360 electrical degrees. In the case of 50 cycle alternating current the cycle is completed 50 times per second.

AMBIENT TEMPERATURE – The air temperature of the surroundings in which the generator set system operates. This may be expressed in degrees Celsius or Fahrenheit.

AMPERE (A) – The unit of measurement of electric flow. One ampere of current will flow when one volt is applied across a resistance of one ohm.

APPARENT POWER (kVA, VA) – A term used when the current and voltage are not in phase i.e. voltage and current do not reach corresponding values at the same instant. The resultant product of current and voltage is the apparent power and is expressed in kVA.

AUTOMATIC SYNCHRONIZER – This device in its simplest form is a magnetic type control relay which will automatically close the generator switch when the conditions for paralleling are satisfied.

BREAK MEAN EFFECTIVE PRESSURE (BMEP) – This is the theoretical average pressure on the piston of an engine during the power stroke when the engine is producing a given number of horsepower. It is usually expressed in pounds/inch^2. The value is strictly a calculation as it cannot be measured, since the actual cylinder pressure is constantly changing. The mean or average pressure is used to compare engines on assumption that the lower the BMEP, the greater the expected engine life and reliability. In practice, it is not a reliable indicator of engine performance for the following reasons:

- The formula favours older design engines with relatively low power output per cubic inch of displacement in comparison with more modern designs. Modern engines do operate with higher average cylinder pressures, but bearings and other engine parts are designed to withstand these higher pressures and to still provide equal or greater life and reliability than the older designs. The formula also implies greater reliability when the same engine produces the same power at a higher speed. Other things being equal, it is unlikely that a 60 Hz generator set operating at 1800 RPM is more reliable than a comparable 50 Hz generator set operating at 1500 RPM. Also it is doubtful that a generator operating at 3000 RPM will be more reliable than one operating at 1500 RPM even if the latter engine has a significantly higher BMEP. The BMEP for any given generator set will vary with the rating which changes depending on fuel, altitude and temperature. The BMEP is also affected by generator set efficiency which varies with voltage and load.

CAPACITANCE (C) – If a voltage is applied to two conductors separated by an insulator, the insulator will take an electrical charge. Expressed in micro-farads (µf).

CIRCUIT BREAKER – A protective switching device capable of interrupting current flow at a pre-determined value.

CONTINUOUS LOAD - Any load up to and including full rated load that the generator set is capable of delivering for an indefinitely long period, except for shut down for normal preventive maintenance.

CONTINUOUS RATING – The load rating of an electric generating system which is capable of supplying without exceeding its specified maximum temperature rise limits.

CURRENT (I) – The rate of flow of electricity. DC flows from negative to positive. AC alternates in direction. The current flow theory is used conventionally in power and the current direction is positive to negative.

CYCLE – One complete reversal of an alternating current or voltage from zero to a positive maximum to zero to a negative maximum back to zero. The number of cycles per second is the frequency, expressed in Hertz (Hz).

DECIBEL (dB) – Unit used to define noise level.

DELTA CONNECTION – A three phase connection in which the start of each phase is connected to the end of the next phase, forming the Greek letter Delta (D). The load lines are connected to the corners of the delta. In some cases a centre tap is provided on each phase, but more often only on one leg, thus supplying a four wire output.

DIRECT CURRENT – An electric current which flows in one direction only for a given voltage and electrical resistance. A direct current is usually constant in magnitude for a given load.

EFFICIENCY – The efficiency of a generator set shall be defined as the ratio of its useful power output to its total power input expressed as a percentage.

FREQUENCY – The number of complete cycles of an alternating voltage or current per unit of time, usually per second. The unit for measurement is the Hertz (Hz) equivalent to 1 cycle per second (CPS).

FREQUENCY BAND – The permissible variation from a mean value under steady state conditions.

FREQUENCY DRIFT – Frequency drift is a gradual deviation of the mean governed frequency above or below the desired frequency under constant load.

FREQUENCY DROOP – The change in frequency between steady state no load and steady state full load which is a function of the engine and governing systems.

FULL LOAD CURRENT – The full load current of a machine or apparatus is the value of current in RMS or DC amperes which it carries when delivering its rate output under its rated conditions. Normally, the full load current is the "rated" current.

GENERATOR – A general name for a device for converting mechanical energy into electrical energy. The electrical energy may be direct current (DC) or alternating current (AC). An AC generator may be called an alternator.

HERTZ (Hz) – SEE FREQUENCY.

INDUCTANCE (L) – Any device with iron in the magnetic structure has what amounts to magnetic inertia. This inertia opposes any change in current. The characteristic of a circuit which causes this magnetic inertia is know as self inductance; it is measured in Henries and the symbol is "L".

INTERRUPTABLE SERVICE – A plan where by an electric utility, elects to interrupt service to a specific customer at any time. Special rates are often available to customers under such agreements.

kVA – 1,000 Volt amperes (Apparent power). Equal to kW divided by the power factor.

kW – 1,000 Watts (Real power). Equal to KVA multiplied by the power factor.

POWER – Rate of performing work, or energy per unit of time. Mechanical power is often measured in horsepower, electrical power in kilowatts.

POWER FACTOR – In AC circuits, the inductances and capacitances may cause the point at which the voltage wave passes through zero to differ from the point at which the current wave passes through zero. When the current wave precedes the voltage wave, a leading power factor results, as in the case of a capacitive load or over excited synchronous motors. When the voltage wave precedes the current wave, a lagging power factor results. This is generally the case. The power factor expresses the extent to which voltage zero differs from the current zero. Considering one full cycle to be 360 degrees, the difference between the zero point can then be expressed as an angle q. Power factor is calculated as the cosine of the q between zero points and is expressed as a decimal fraction (0.8) or as a percentage (80%). It can also be shown to be the ratio of kW, divided by kVA. In other words, kW= kVA x P.F.

PRIME POWER – That source of supply of electrical energy utilised by the user which is normally available continuously day and night, usually supplied by an electric utility company but sometimes by owner generation.

RATED CURRENT – The rated continuous current of a machine or apparatus is the value of current in RMS or DC amperes which it can carry continuously in normal service without exceeding the allowable temperature rises.

RATED POWER – The stated or guaranteed net electric output which is obtainable continuously from a generator set when it is functioning at rated conditions. If the set is equipped with additional power producing devices, then the stated or guaranteed net electric power must take into consideration that the auxiliaries are delivering their respective stated or guaranteed net output simultaneously, unless otherwise agreed to.

RATED SPEED – Revolutions per minute at which the set is designed to operate.

RATED VOLTAGE – The rated voltage of an engine generator set is the voltage at which it is designed to operate.

REACTANCE – The out of phase component of impedance that occurs in circuits containing inductance and/or capacitance.

REAL POWER – A term used to describe the product of current, voltage and power factor, expressed in kW.

RECTIFIER – A device that converts AC to DC.

ROOT MEAN SQUARE (RMS) – The conventional measurement of alternating current and voltage and represents a proportional value of the true sine wave.

SINGLE PHASE – An AC load or source of power normally having only two input terminals if a load, or two output terminals if a source.

STANDBY POWER – An independent reserve source of electrical energy which upon failure or outage of the normal source, provides electric power of acceptable quality and quantity so that the user's facilities may continue in satisfactory operation.

STAR CONNECTION – A method of interconnecting the phases of a three phase system to form a configuration resembling a star (or the letter Y). A fourth or neutral wire can be connected to the centre point.

TELEPHONE INFLUENCE FACTOR (TIF) – The telephone influence factor of a synchronous generator is a measure of the possible effect of harmonics in the generator voltage wave on telephone circuits. TIF is measured at the generator terminals on open circuit at rated voltage and frequency.

THREE PHASE – Three complete voltage/current sine waves, each of 360 electrical degrees in length, occurring 120 degrees apart. A three phase system may be either 3 wire or 4 wire (3 wires and a neutral).

UNINTERRUPTABLE POWER SUPPLY (UPS) – A system designed to provide power.

without delay or transients, during any period when the normal power supply is incapable of performing acceptably.

UNITY POWER FACTOR – A load whose power factor is 1.0 has no reactance's causing the voltage wave to lag or lead the current wave.

WATT – Unit of electrical power. In DC, it equals the volts times amperes. In AC, it equals the effective volts times the effective amps times power factor times a constant dependent on the number of phases.

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