



# **GENERATING SET INSTALLATION MANUAL**

## FOREWORD

This installation manual will guide you to the factors to be considered in the installation of your diesel generator system. It discusses location and mounting of the generating set; size of room; ventilation and air flow; engine cooling water supply or radiator location; exhaust outlet; fuel tank and fuel transfer system.

By following the suggestions in this installation manual, you will be able to plan an economical, efficient generating set installation with operating characteristics suitable to each particular application.

You can make your work easier by enlisting the aid of an FG Wilson Distributor when planning your generating set installation. Getting his advice early may save cost and avoid problems. He knows engines, electrical equipment, local laws and insurance regulations. With his help, you can be sure your generating set installation will fulfil your needs without unnecessary cost.

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## 1. INSTALLATION FACTORS

Once the size of the generating set and the required associated control panel and switchgear have been established, plans for installation can be prepared. Proper attention to mechanical and electrical engineering details will assure a satisfactory power system installation.

Factors to be considered in the installation of a generator are:

- Access and maintenance location.
- Floor loading.
- Vibration transmitted to building and equipment.
- Ventilation of room.
- Engine exhaust piping and insulation.
- Noise reduction.
- Method of engine cooling.
- Size and location of fuel tank.
- Local, national or insurance regulations.
- Smoke and emissions requirements.

## 2. MOVING THE GENERATING SET

The generating set baseframe is specifically designed for ease of moving the set. Improper handling can seriously damage the generator and components.

Using a forklift, the generating set can be lifted or pushed/pulled by the baseframe. An optional "Oil Field Skid" provides fork lift pockets if the set will be regularly moved.

**Never lift the generating set by attaching to the engine or alternator lifting lugs!**

For lifting the generating set, lift points are provided on the baseframe. Shackles and chains of suitable length and lifting capacity must be used and a spreader bar is required to prevent damaging the set. See figure 2.1. An optional "single point lifting bale" is available if the generating set will be regularly moved by lifting.

## 3. GENERATING SET LOCATION

The set may be located in the basement or on another floor of the building, on a balcony, in a penthouse on the roof or even in a separate building. Usually it is located in the basement for economics and for convenience of operating personnel. The generator room should be large enough to provide adequate air circulation and plenty of working space around the engine and alternator.

If it is necessary to locate the generating set outside the building, it can be furnished enclosed in a housing and mounted on a skid or trailer. This type of assembly is also useful, whether located inside or outside the building, if the installation is temporary. For outside installation the housing is normally "weatherproof". This is necessary to prevent water from entering the alternator compartment if the generating set is to be exposed to rain accompanied by high winds.

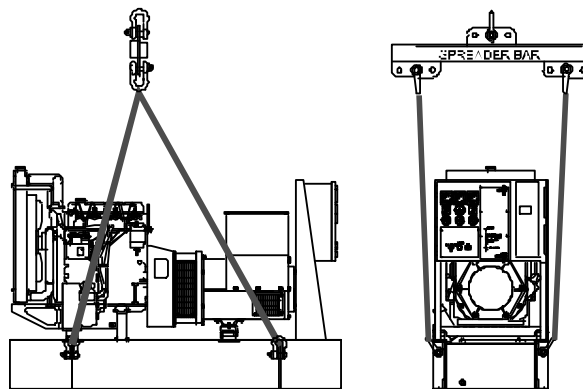


FIG 2.1. PROPER LIFTING ARRANGEMENT

## 4. GENERATING SET MOUNTING

The generating set will be shipped assembled on a rigid base that precisely aligns the alternator and engine and needs merely to be set in place (on vibration isolation pads for larger sets) and levelled. See figure 4.1

### 4.1 Vibration Isolation

It is recommended that the generating set be mounted on vibration isolation pads to prevent the set from receiving or transmitting injurious or objectionable vibrations. Rubber isolation pads are used when small amounts of vibration transmission is acceptable. Steel springs in combination with rubber pads are used to combat both light and heavy vibrations. On smaller generating sets, these isolation pads should be located between the coupled engine/alternator feet and the baseframe. The baseframe is then securely attached to the floor. On larger sets the coupled engine/alternator should be rigidly connected to the baseframe with vibration isolation between the baseframe and floor. Other effects of engine vibration can be minimised by providing flexible connections between the engine and fuel lines, exhaust system, radiator air

discharge duct, conduit for control and power cables and other externally connected support systems.

### 4.2 Floor Loading

Floor loading depends on the total generating 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:

$$\text{Floor Loading} = \frac{\text{Total Generating Set Weight}}{\text{Area of Skids}}$$

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

$$\text{Floor Loading} = \frac{\text{Total Generating Set Weight}}{\text{Pad Area} \times \text{Number of Pads}}$$

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):

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

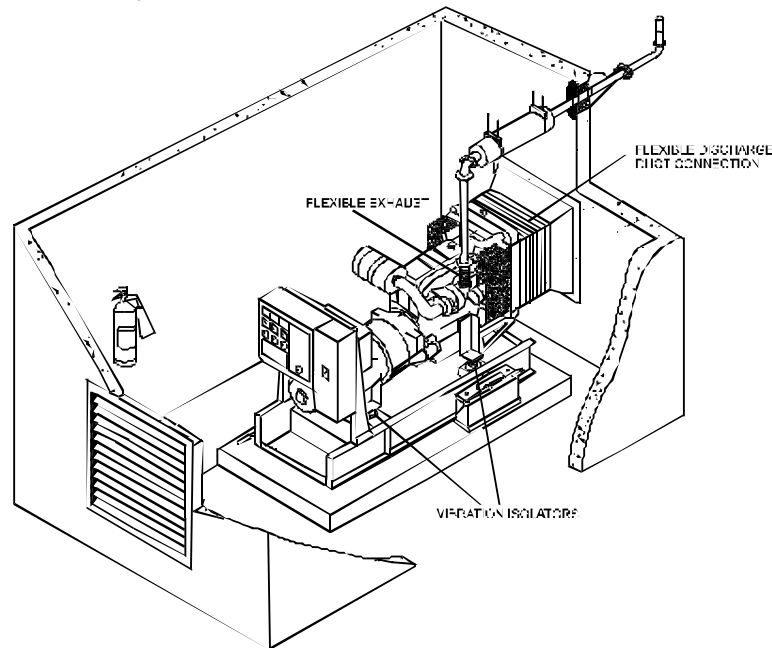


FIG 4.1 REDUCING VIBRATION TRANSMISSION

## 5. VENTILATION

Any internal combustion engine requires a liberal supply of cool, clean air for combustion. If the air entering the engine intake is too warm or too thin, the engine may not produce its rated power. Operation of the engine and alternator radiates heat into the room and raises the temperature of the room air. Therefore, ventilation of the generator room is necessary to limit room temperature rise and to make clean, cool intake air available to the engine.

When the engine is cooled by a set mounted radiator, the radiator fan must move large quantities of air through the radiator core. There must be enough temperature difference between the air and the water in the radiator to cool the water sufficiently before it re-circulates through the engine. The air temperature at the radiator inlet depends on the temperature rise of air flowing through the room from the room inlet ventilator. By drawing air into the room and expelling it outdoors through a discharge duct, the radiator fan helps to maintain room temperature in the desirable range.

In providing ventilation, the objective is to maintain the room air at a comfortable temperature that is cool enough for efficient operation and full available power, but it should not be so cold in winter that the room is uncomfortable or engine starting is difficult. Though providing adequate ventilation seldom poses serious problems, each installation should be analysed by both the distributor and the customer to make sure the ventilation provisions are satisfactory.

### 5.1 Circulation

Good ventilation requires adequate flow into and out of the room and free circulation within the room. Thus, the room should be of sufficient size to allow free circulation of air, so that temperatures are equalised and there are no pockets of stagnant air. See figure 5.1. The generating set should be located so that the engine intake draws air from the cooler part of the room. If there are two or more generating sets, avoid locating them so that air heated by the radiator of one set flows toward the engine intake or radiator fan of an adjacent set. See figure 5.2.

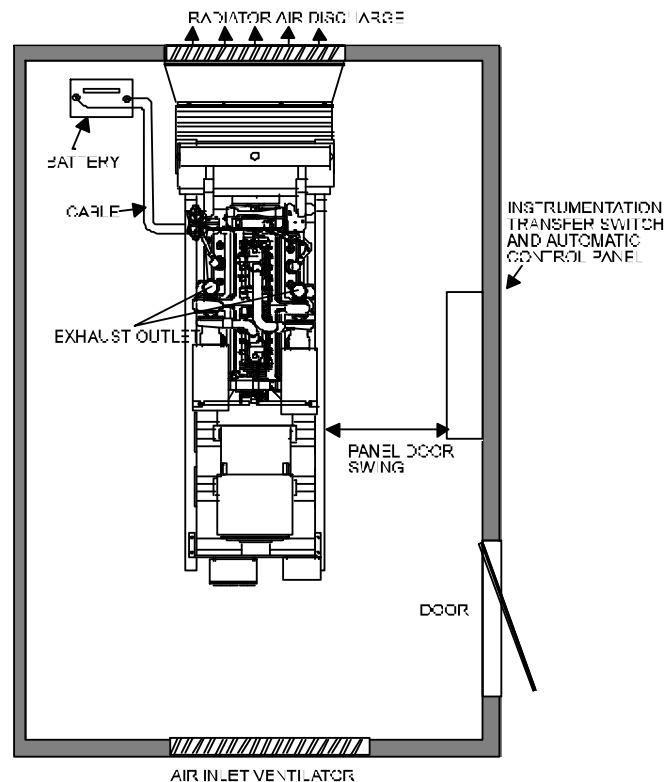


FIG 5.1 TYPICAL ARRANGEMENT FOR ADEQUATE AIR CIRCULATION AND VENTILATION

## 5.2 Ventilators

To bring in fresh air, there should be an inlet ventilator opening to the outside or at least an opening to another part of the building through which the required amount of air can enter. In smaller rooms, ducting may be used to bring air to the room or directly to the engine's air intake. In addition, an exit ventilator opening should be located on the opposite outside wall to exhaust warm air. See Figure 5.3.

Both the inlet and exit ventilators should have louvres for weather protection. These may be fixed but preferably should be movable in cold climates. For automatic starting generating sets, if the louvres are movable, they should be automatically operated and should be programmed to open immediately upon starting the engine.

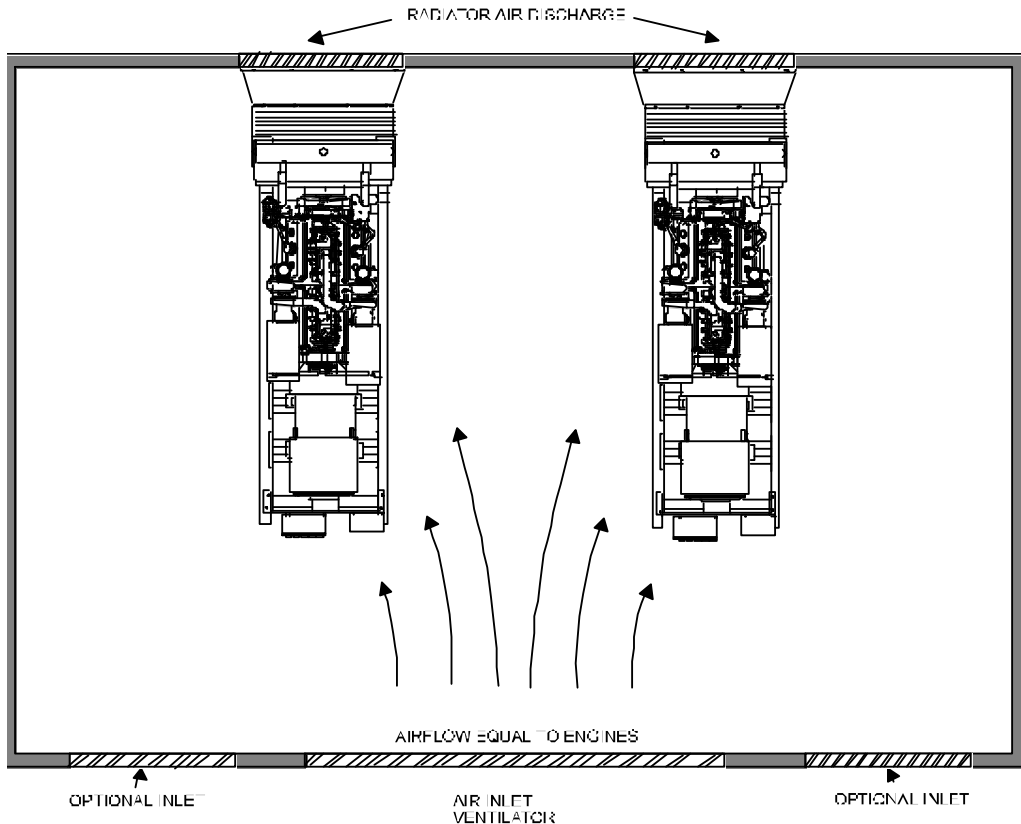


FIG 5.2 TYPICAL ARRANGEMENT FOR PROPER VENTILATION WITH MULTIPLE GENERATING SETS

### 5.3 Inlet 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 generating 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 FG Wilson generating 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 10 mm (0.4 in)  $H_2O$ . Restriction values of air filters, screens and louvres should be obtained from manufacturers of these items.

### 5.4 Exit Ventilator Size

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.

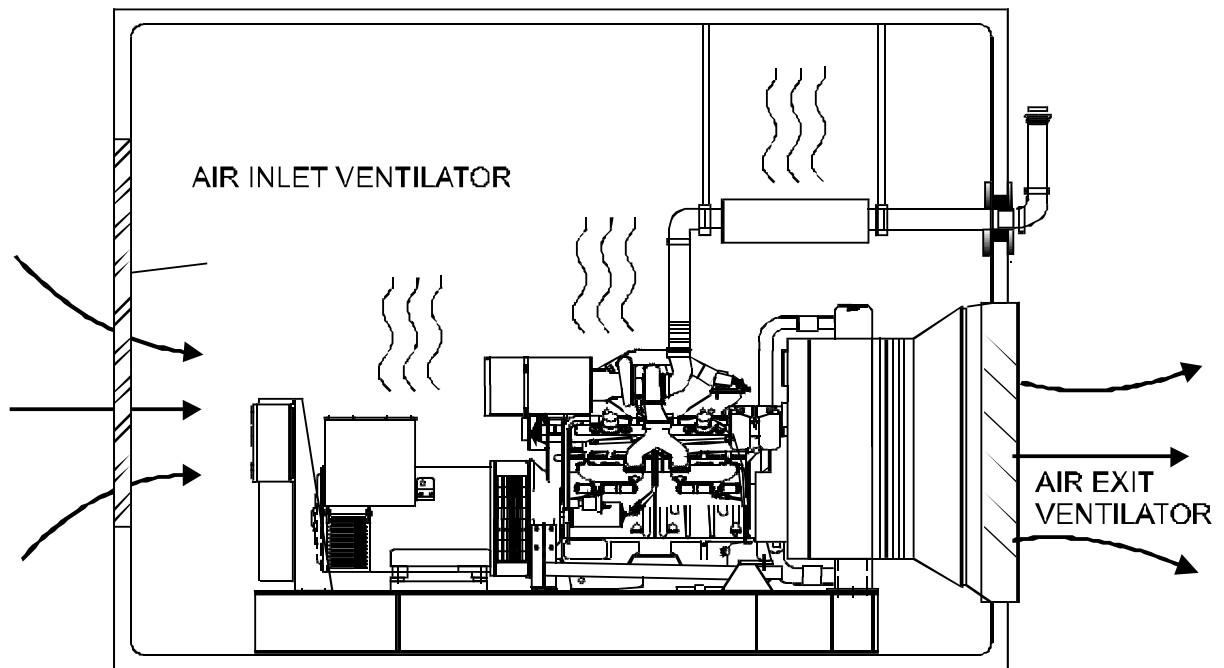


FIG 5.3 INLET AND EXIT VENTILATORS



## 6. ENGINE EXHAUST

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.

### 6.1 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 6.1.

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 6.2 and 6.3. 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 generating set enclosed in a penthouse 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 the fan is driven by an electric motor to discharge air vertically.

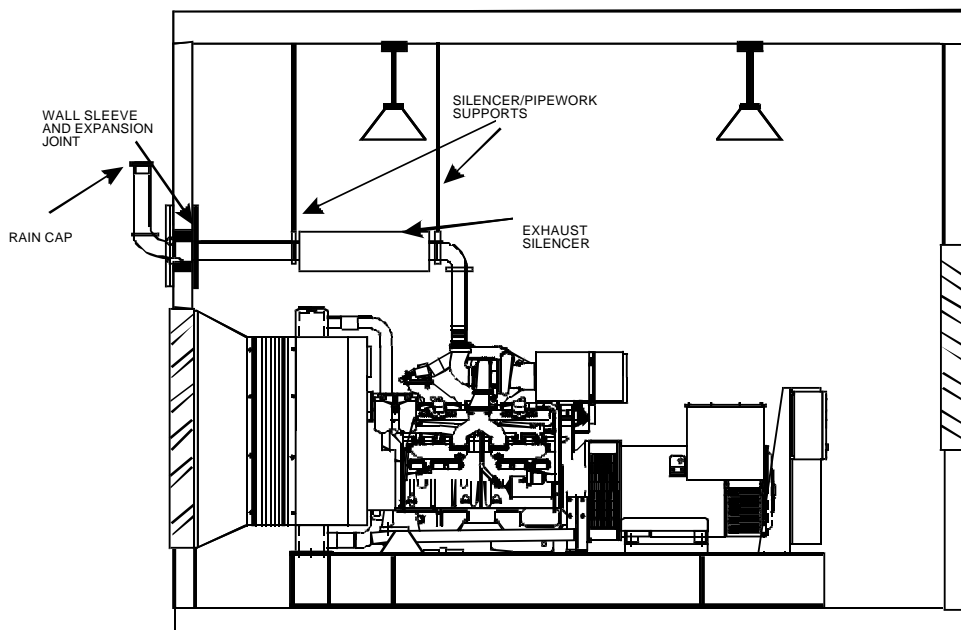


FIG 6.1 TYPICAL EXHAUST SYSTEM INSTALLATION

## 6.2 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  $\pm 13$  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 Generating Set on its vibration isolators in response to load changes. The flexible connector should be specified with the Generating Set.

## 6.3 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.

## 6.4 Minimising Exhaust Flow Restriction

Free flow of exhaust gases through the pipe is essential to minimise 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

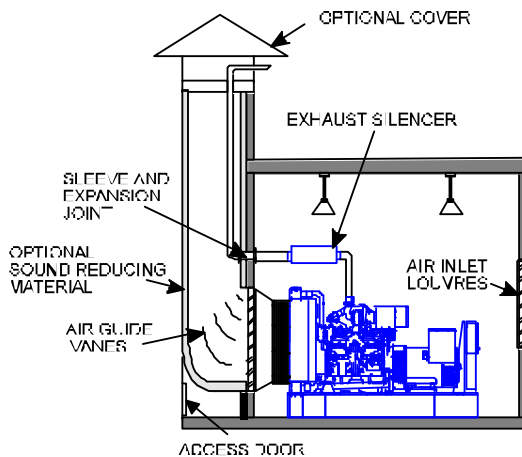


FIG 6.2 HORIZONTALLY MOUNTED EXHAUST SILENCER WITH EXHAUST PIPE AND RADIATOR AIR UTILISING COMMON STACK

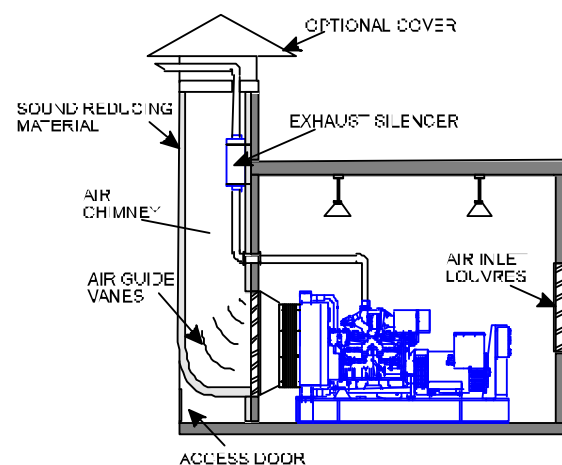


FIG 6.3 RADIATOR AIR DISCHARGING INTO SOUND-INSULATED STACK CONTAINING EXHAUST SILENCER

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 FG Wilson 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 6.4. Take exhaust flow data and back pressure limits from the generating 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.

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 straight pipe is calculated as follows:

45° Elbow:

$$\text{Length (ft)} = 0.75 \times \text{Diameter (inches)}$$

90° Elbow:

$$\text{Length (ft)} = 1.33 \times \text{Diameter (inches)}$$

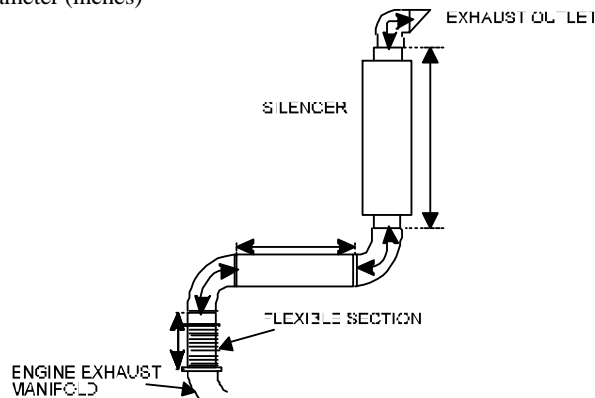


FIG 6.4 MEASURING EXHAUST PIPE LENGTH TO DETERMINE EXHAUST BACK PRESSURE

Flexible Sections:

$$\text{Length (ft)} = 0.167 \times \text{Diameter (inches)}$$

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

$$R = \frac{41.1}{\text{Exhaust temperature } ^\circ\text{F} + 460^\circ\text{F}}$$

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 Section 12.

## 7. EXHAUST SILENCING

Excessive noise is objectionable in most locations. Since a large part of the generating 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.

### 7.1 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 semi-residential 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 generating set noise must be kept to a minimum.

Silencers normally are available in two configurations - (a) end inlet, end outlet, or (b) side inlet, end outlet. Having the choice of these two configurations provides flexibility of installation, such as horizontal or vertical, above engine, on outside wall, etc. The side-inlet type permits 90° change of direction without using an elbow. Both silencer configurations should contain drain fittings in locations that assure draining the silencer in whatever attitude it is installed.

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 then can 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 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.

## 8. 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 generating set plus normal techniques for controlling exhaust, intake and radiator fan noise should reduce generating 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 generating set is necessary. Sound barriers can be erected around the generating set, or the walls of the generator room can be sound insulated, or the generating set can be enclosed in a specially developed sound insulated enclosure. See figure 8.1.

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 generating set noise, the instruments and control station may be located in a separate sound-insulated control room.

## 9. ENGINE COOLING

Some diesel engines are air cooled but the majority are cooled by circulating a liquid coolant through the oil cooler if one is fitted and through passages in the engine block and head. Hot coolant emerging from the engine is cooled and recirculated through

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

In the most common generating set installation, the engine coolant is cooled in a 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 generating set whose supply of raw water depended upon a utility.

Whether the radiator is mounted on the generating set or mounted remotely, accessibility for servicing the cooling system is important. For proper maintenance, the radiator fill cap, the cooling system drain cocks, the fan belt tension adjustment must all be accessible to the operator.

### 9.1 Set Mounted Radiator

A set-mounted radiator is mounted on the generating set base in front of the engine. See figure 9.1. An engine-driven fan blows air through the radiator core, cooling the liquid engine coolant flowing through the radiator.

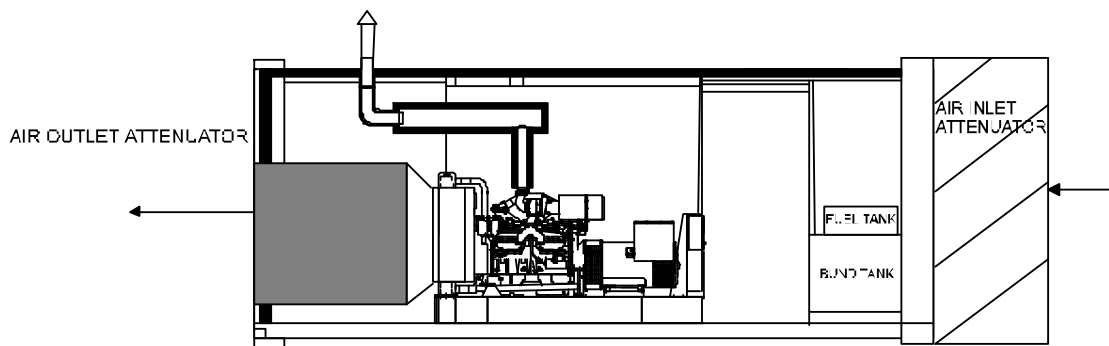


FIG 8.1 TYPICAL SOUND ATTENUATED INSTALLATION

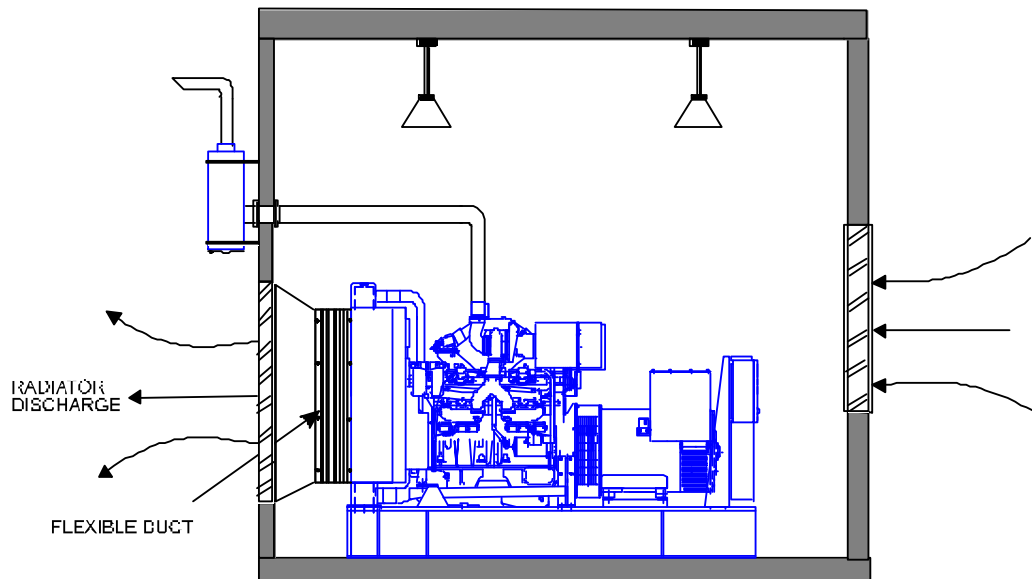


FIG 9.1 SET MOUNTED RADIATOR DISCHARGING THROUGH OUTSIDE WALL

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 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 by FG Wilson and furnished with the generating set. Air requirements for cooling a particular FG Wilson generator 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 set-mounted radiator's discharge 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 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 suitable fabric) between the radiator and the fixed discharge duct is required to isolate vibration and provide freedom of motion between the generating set and the fixed duct.

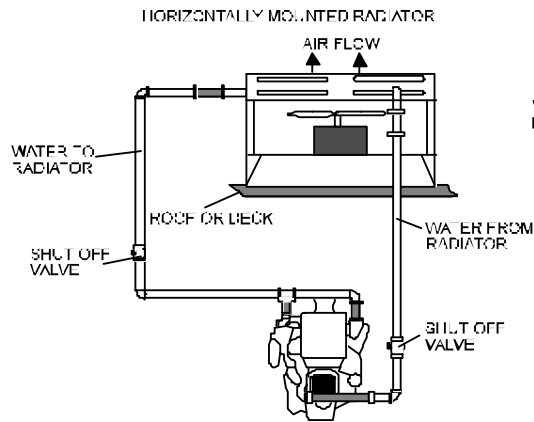


FIG 9.2 REMOTE RADIATOR CONNECTED DIRECTLY TO ENGINE COOLING SYSTEM

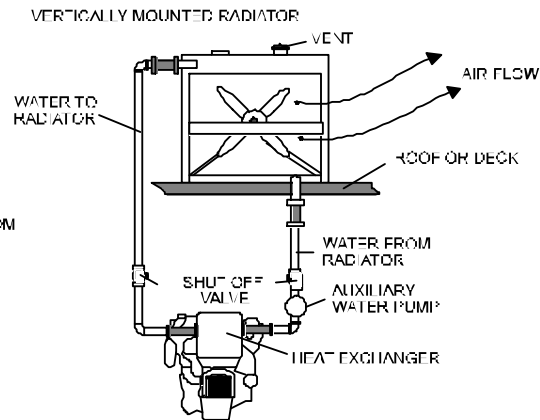


FIG 9.3 REMOTE RADIATOR ISOLATED FROM ENGINE COOLING SYSTEM BY HEAT EXCHANGER

## 9.2 Remote Radiator

A remote radiator with electric motor-driven fan can be installed in any convenient location away from the generating set. See figure 9.2. A well-designed remote radiator has many useful features and advantages that provide greater flexibility of generating 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 generating 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.

## 9.3 Remote Radiator/Heat Exchanger System

Another type of remote radiator system employs a heat exchanger at the engine. See figure 9.3 and 9.4. 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.

## 9.4 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. See figure 9.5. It usually is furnished as part of the generating 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 useless.



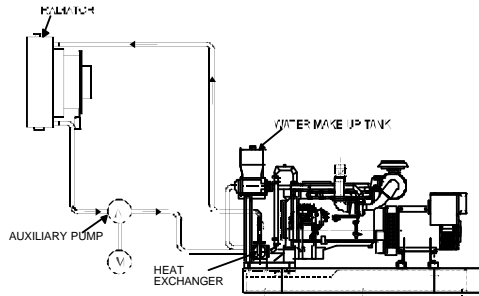


FIG 9.4 TYPICAL HEAT EXCHANGER INSTALLATION

## 9.5 Antifreeze 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 67% to maintain adequate heat transfer capability.

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.

## 9.6 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 FG Wilson Distributor can recommend suitable softeners. Manufacturers instructions should be carefully followed.

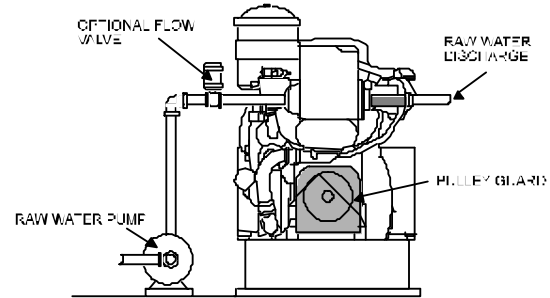


FIG 9.5 HEAT EXCHANGER COOLING SYSTEM

## 10. FUEL SUPPLY

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 generating set baseframe - called a basetank) located close to the set. With generally only a capacity of 8 hours operation, this day tank is often backed up by an auxiliary remote fuel system including a bulk storage tank and the associated pumps and plumbing. Extended capacity basetanks are also generally available for longer operation prior to refuelling. Especially for standby generating sets it 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.

### 10.1 Fuel Tank Location

The day tank should be located as close to the generating set as possible. Normally it is safe to store diesel fuel in the same room with the generating set because there is less danger of fire or fumes with diesel than with petrol (gasoline). Thus, if building codes and fire regulations permit, the day tank should be located in the base of the generating set, along side the set, or in an adjacent room.

Where an remote fuel system is to be installed with a bulk storage tank, the bulk tank may 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 temperature. The tank may be located either above or below ground level.



## 10.2 Remote Fuel Systems

Three types of remote fuel systems are recommended by the manufacturer:

**Fuel System 1:** Installations where the bulk fuel tank is lower than the day tank.

**Fuel System 2:** Installations where the bulk fuel tank is higher than the day tank.

**Fuel System 4:** Installations where fuel must be pumped from a free standing bulk fuel tank to the day tank.

**Fuel System 1:** The bulk fuel tank is lower than the day tank. With this system the fuel must be pumped up from the bulk tank to the day tank which is integrated into the baseframe. See figure 10.1.

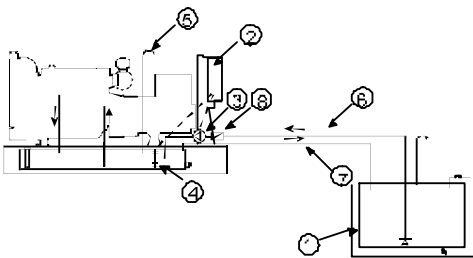


Figure 10.1: Typical Layout with Fuel System 1

The key components are the bulk fuel tank (item 1), which is lower than the basetank, remote fuel system controls (item 2) located in the generator set control panel, a DC motorised fuel valve (item 3), fuel level switches in the basetank (item 4), an AC powered electric fuel pump (item 3), fuel level switches in the basetank (item 4), an extended vent on the basetank (item 5), the fuel supply line (item 6), the fuel return line (item 7), and a fuel strainer (item 8) on the inlet side of the pump.

When set to automatic, the system operates as follows: low fuel level in the basetank is sensed by the fuel level sensor. The pump begins to pump fuel from the bulk tank to the basetank through the fuel supply line. To help ensure that clean fuel reaches the engine, fuel from the bulk tank is strained just prior to the electric fuel pump. When the basetank is full, as sensed by the fuel level sensor, the pump stops. If there should be any overflow of fuel in the basetank, the excess will drain back into the bulk tank via the return line.

With this system, the basetank must include the overflow (via the return line), a 1.4 metre extended vent to prevent overflow through the vent, sealed

fuel level gauges on the basetank and no manual fill facility. All other connections on top of the tank must be sealed to prevent leakage. Fuel System 1 is not compatible with the polyethylene fuel tanks standard on smaller generator sets. The optional metal tank is required. A 2001 Series control system (or above) is required.

The position of the bulk fuel tank should take into account that the maximum suction lift of the fuel transfer pump is approximately 3 metres and that the maximum restriction caused by the friction losses in the return fuel line should not exceed 2 psi.

**Fuel System 2:** The bulk tank is located higher than the basetank. With this system the fuel is gravity fed from the bulk tank to the basetank. See figure 10.2.

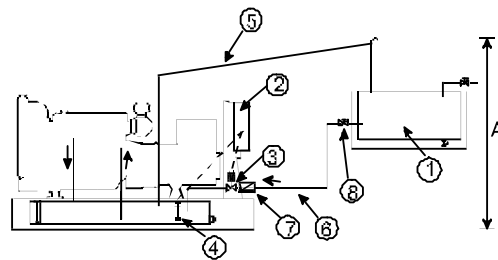


Figure 10.2: Typical Layout with Fuel System 2

The key components are the bulk fuel tank (item 1), which is higher than the basetank, remote fuel system controls (item 2) located in the generator set control panel, a DC motorised fuel valve (item 3), fuel level switches in the basetank (item 4), an extended vent/return line (continuous rise) on the basetank (item 5), the fuel supply line (item 6), a fuel strainer (item 7) and an isolating valve at the bulk tank (item 8).

When set to automatic, the system operates as follows: low fuel level in the basetank is sensed by the fuel level sensor. The DC motorised valve is opened and fuel is allowed to flow from the high level bulk tank to the basetank by the force of gravity. To help ensure that clean fuel reaches the engine, fuel from the bulk tank is strained just prior to the motorised valve. When the basetank is full, as sensed by the fuel level sensor, the motorised valve is closed.

Any overflow into the basetank or overpressure in the basetank will flow back to the bulk tank via the extended vent.

With this system, the basetank must include an overflow via the return line, sealed fuel level gauges and no manual fill facility. All other connections on top of the tank must be sealed to prevent leakage. Fuel System 2 is not compatible with the polyethylene fuel tanks standard on smaller generator sets. The optional metal tank is required. A 2001 Series control system (or above) is required.

Distance 'A' in Figure 10.2 is limited to 1400mm for all generator sets with metal basetanks.

**Fuel System 4:** Some installations may require a system where fuel is pumped from a free standing bulk tank (see Figure 10.4). This pumped system would only be used if gravity feed is not possible from the bulk tank to the basetank.

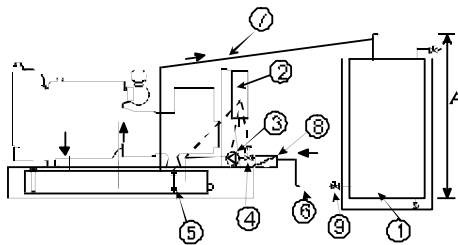


Figure 10.4: Typical Layout with Fuel System 4

The key components are the above ground bulk fuel tank (item 1), remote fuel system controls (item 2) located in the generator set control panel, an AC Fuel Pump (item 3), a DC motorised fuel valve (item 4), fuel level switches in the basetank (item 5), the fuel supply line (item 6), an extended vent/return line (continuous rise) on the basetank (item 7), a fuel strainer (item 8) and an isolating valve at the bulk tank (item 9).

When set to automatic, the system operates as follows: low fuel level in the basetank is sensed by the fuel level sensor. The DC motorised valve is opened and the pump begins to pump fuel from the bulk tank to the basetank through the supply line. To help ensure that clean fuel reaches the engine, fuel from the bulk tank is strained just prior to the motorised valve. When the basetank is full, as sensed by the fuel level sensor, the pump stops and the motorised valve is closed. Any overflow into the basetank or overpressure in the basetank will flow back to the bulk tank via the extended vent.

With this system, the basetank must include an overflow via the return line, sealed fuel level gauges and no manual fill facility. All other connections on

top of the tank must be sealed to prevent leakage. Fuel System 4 is not compatible with the polyethylene fuel tanks standard on smaller generator sets. The optional metal tank is required. A 2001 Series control system (or above) is required.

Distance 'A' on Figure 10.4 is limited to 1400mm for all generator sets with metal basetanks. Note that the maximum restriction caused by friction losses and height of the return line should not exceed 2 psi.

### 10.3 Tank Construction

Fuel tanks are usually made of welded sheet steel or reinforced plastic. If an old fuel tank is used, be sure it is made of a proper material. It should be cleaned thoroughly to remove all rust, scale and foreign deposits.

Connections for fuel suction and return lines must be separated as much as possible to prevent re-circulation of hot fuel and to allow separation of any gases entrained in the fuel. Fuel suction lines should extend below the minimum fuel level in the tank. Where practical, a low point in the tank should be equipped with a drain valve or plug, in an accessible location, to allow periodic removal of water condensation and sediment. Or a hose may be inserted through the tank's filter neck when necessary to suck out water and sediment.

The filler neck of the bulk fuel tank should be located in a clean accessible location. A removable wire screen of approximately 1.6 mm (1/16 inch) mesh should be placed in the filler neck to prevent foreign material from

entering the tank. The filler neck cap or the highest point in the tank should be vented to maintain atmospheric pressure on the fuel and to provide pressure relief in case a temperature rise causes the fuel to expand. It will also prevent a vacuum as fuel is consumed. The tank may be equipped with a fuel level gauge - either a sight gauge or a remote electrical gauge.

### 10.4 Fuel Lines

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

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 of tank at the high end, away from the drain plug.

### **10.5 Day Tank Capacity**

The capacity of the day tank is based on the fuel consumption and the expected number of hours of operation that is requested between refills.

Particularly with standby generators, the availability of fuel delivery service will determine the number of operating hours that must be provided for. Don't depend on quick service the very day your set starts to operate. A power outage may hamper your supplier's operation also.

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
P910-P1100E	1500 litres	3000 litres
P1250-P1650E	2250 litres	4500 litres
P1700-P2200E	3000 litres	6000 litres

## 11. SELECTING FUELS FOR STANDBY DEPENDABILITY

The types of fuels available for diesel engines, vary from highly volatile jet fuels and kerosene to the heavier fuel oils. Most diesel engines are capable of burning a wide range of fuels within these extremes. The following information will assist you in selecting the type of fuel that will afford the best overall performance and reliability of your Generating Set.

### 11.1 Types Of Fuel Oil

The quality of fuel oil can be a dominant factor in satisfactory engine life and performance. A large variety of fuel oils are marketed for diesel engine use. Their properties depend upon the refining practices employed and the nature of the crude oils from which they are produced. For example, fuel oils may be produced within the boiling range of 148 to 371°C (300 to 700°F), having many possible combinations of other properties.

The additional contaminants present in low grade fuels may result in darker exhaust and more pronounced odour. This may be objectionable in hospitals, offices commercial and urban locations. Thus, location, application and environmental conditions should be considered when selecting fuel.

The Generating Set owner may elect to use a low grade fuel because high-grade fuels are not readily available in his area or because he can realise a net saving with low grade fuels despite higher engine maintenance costs. In that case, frequent examination of lubrication oil should be made to determine sludge formation and the extent of lube oil contamination.

Aside from the various grades of fuel oil commonly used in diesel engines, aircraft jet fuels also are sometimes used, especially in circumstances where the jet fuels are more readily available than conventional fuels. Jet fuels are lower in B.T.U. content and lubrication quality than conventional fuels. As a result, some diesel fuel systems must undergo major modifications to accommodate this type of fuel. For use of jet fuel please consult FG Wilson.

Reliable operation of diesel engines may vary from one fuel to another, depending on many factors, including fuel characteristics and engine operating conditions.

The fuels commonly known as high-grade fuels seldom contribute to the formation of harmful engine deposits and corrosion. On the other hand, while refining improves the fuel, it also lowers the B.T.U. or heat value of the fuel. As a result, the higher grade fuels develop slightly less power than the same quantity of low grade fuel. This is usually more than offset by the advantages of high grade fuels such as quicker starts and less frequent overhauls. Before using low-grade fuels, therefore, some understanding of the problems and extra costs that may be encountered is necessary.

Fuels with high sulphur content cause corrosion, wear and deposits in the engine. Fuels that are not volatile enough or don't ignite rapidly may leave harmful deposits in the engine and may cause poor starting or running under adverse operating conditions. The use of low grade fuels may require the use of high priced, higher detergent lubricating oils and more frequent oil changes.

### 11.2 Fuel Selection Guide

Specify fuel properties according to the following chart.

	Final Boiling Point	Cetane Number (Min)	Sulphur Number (Max)
Winter	290°C (550°F)	45	0.5 %
Summer	315°C (600°F)	40	0.5 %

Selecting a fuel that keeps within these specifications will tend to reduce the possibility of harmful deposits and corrosion in the engine, both of which could result in more frequent overhauls and greater maintenance expense. Specify exact fuel properties to your local fuel supplier.

### 11.3 Maintaining Fresh Fuel

Most fuels deteriorate if they stand unused for a period of many months. With standby generators it is preferable to store only enough fuel to support a few days or even only eight hours of continuous running of the Generating Set so that normal engine testing will turn over a tank full within a year and a half.

Other solutions are to add inhibitors to the fuel or to obtain greater turnover by using the fuel for other purposes. A gum inhibitor added to diesel fuel will keep it in good condition up to two years.

If the building furnace has an oil burner, it is possible to burn diesel fuel in the furnace, connecting both the engine and the furnace to the same tank. In this way, a large supply of diesel fuel is available for emergency use by the Generating Set, and the fuel supply is continuously turned over since it is being burned in the furnace. Thus, there is no long term storage problem.

#### **11.4 Self Contained Dependability**

In some areas, where natural gas is cheap, natural gas spark ignition engines are used in Generating Sets that are intended for continuous service. For standby service, however, this is not recommended. The natural gas supply and regulation system adds substantially to the complexity of the installation, and there is little to be gained in terms of fuel cost over a period of time. More important, it makes the emergency power less dependable. Not only is such an engine less dependable than a diesel, but often the same storm or accident that disrupts the normal electric power also cuts off gas service. Thus, a natural gas engine would be disabled at the very time it is needed. By contrast, a diesel engine, with its fuel in a nearby tank, is a self contained system that does not depend on outside services. It is more dependable and affords greater standby protection than systems which depend on a public utility for fuel.

## 12. TABLES AND FORMULAS FOR ENGINEERING STANDBY GENERATING SETS

**Table 1. Length Equivalents**

Unit	Microns	Meters	Kilometres	Inches	Feet	Yards	Miles
1 Micron	1	0.000001	--	0.00003937	--	--	--
1 Meter	1,000,000	1	--	39.37	3.281	1.0936	--
1 Kilometre	--	1000	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 <sup>2</sup>	Ft <sup>2</sup>	Acre	Mile <sup>2</sup>	M <sup>2</sup>	Hectare	Km <sup>2</sup>
1 In <sup>2</sup>	1	0.006944	--	--	0.00064516	--	--
1 Ft <sup>2</sup>	144	1	--	--	0.0929	--	--
1 Acre	--	43,560	1	0.0015625	4,047	0.4047	0.004047
1 Mile <sup>2</sup>	--	27,878,400	640	1	2,589,998	258.99	2.5899
1 M <sup>2</sup>	1550	10.764	--	--	1	--	--
1 Hectare	--	107,639	2.471	0.003861	10,000	1	0.01
1 Km <sup>2</sup>	--	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 <sup>3</sup>	Feet <sup>3</sup>	Yards <sup>3</sup>	Meters <sup>3</sup>	US Liquid Gallons	Imperial Gallons	Litres
1 Inch <sup>3</sup>	1	0.000579	0.0000214	0.0000164	0.004329	0.00359	0.0164
1 Ft. <sup>3</sup>	1728	1	0.03704	0.0283	7.481	6.23	28.32
1 Yd. <sup>3</sup>	46656	27	1	0.765	202	168.35	764.6
1 M <sup>3</sup>	61023	35.31	1.308	1	264.2	220.2	1000
1 U.S.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 <sup>3</sup>	Pounds	Gal (U.S)	Gal (IMP)	Litres	Head (Ft)	lb/in <sup>2</sup>	Ton/Ft <sup>2</sup>	Head (Meters)	Ft <sup>3</sup> /Min	Gal.(U.S) /Hr
Feet <sup>3</sup>	1	62.42	--	--	--	--	--	--	--	--	--
Pounds	0.01602	1	0.12	0.10	0.4536	--	--	--	--	--	--
Gal (U.S)	--	8.34	1	--	--	--	--	--	--	--	--
Gal (IMP)	--	10.0	--	1	--	--	--	--	--	--	--
Litres	--	2.2046	--	--	1	--	--	--	--	--	--
Head (Ft)	--	--	--	--	--	1	4.335	--	--	--	--
lb/in <sup>2</sup>	--	--	--	--	--	2.3070	1	0.02784	0.7039	--	--
Ton/Ft <sup>2</sup>	--	--	--	--	--	35.92	--	1	--	--	--
Head (Meters)	--	--	--	--	--	--	1.4221	--	1	--	--
Ft <sup>3</sup> /Min	--	--	--	--	--	--	--	--	--	1	448.92
Gal. (U.S)/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**

(Ft)	Barometric Pressure			Water Boiling Point	
	Inches of Mercury	lb/in <sup>2</sup>	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	U.S Gallons/Minute	Million U.S Gallons/Day	Feet <sup>3</sup> /Second	Meters <sup>3</sup> /Hour	Litres/Second
1 U.S Gallon/Minute	1	0.001440	0.00223	0.2271	0.0630
1 Million U.S Gallons/Day	694.4	1	1.547	157.73	43.8
1 Foot <sup>3</sup> /Second	448.86	0.646	1	101.9	28.32
1 Meter <sup>3</sup> /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 <sub>2</sub> O	ft H <sub>2</sub> O	lb/in <sup>2</sup>	kg/cm <sup>2</sup>	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 <sub>2</sub> O	1.86827	0.0736	1	0.0833	0.03613	0.00254	0.0025	0.249
1 ft H <sub>2</sub> O	22.4192	0.8827	12	1	0.43352	0.030479	0.0295	2.989
1 lb/ in <sup>2</sup>	51.7149	2.0360	27.6807	2.3067	1	0.07031	0.0681	6.895
1 kg/cm <sup>2</sup>	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 U.S 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**

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

Where:

V = Volts

I = Amperes

Eff = Percentage Efficiency

PF = Power Factor =  $\frac{\text{Watts}}{I \times V}$

**TABLE 13. kVA/kW AMPERAGE AT VARIOUS VOLTAGES  
(0.8 Power Factor)**

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

## Conversions of Centigrade and Fahrenheit

Water freezes at 0 °C (32°F)      Water boils at 100 °C (212°F)

$$^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32$$

$$^{\circ}\text{C} = 0.5555 (^{\circ}\text{F} - 32)$$

## Fuel Consumption Formulas

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

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

$$\text{Fuel Spec. Weight (lb / US gal)} = \text{Fuel Specific Gravity} \times 8.34 \text{ lb}$$

$$\text{Specific Fuel Consumption (lb / BHP / hr)} = \frac{\text{Fuel Cons. (US gal / hr)} \times \text{Fuel Spec. Wt (lb / US gal)}}{\text{BHP}}$$

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

## Electrical Motor Horsepower

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

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

## Piston Travel

$$\text{Feet Per Minute (FPM)} = 2 \times L \times N$$

Where L = Length of Stroke in Feet

N = Rotational Speed of Crankshaft in RPM

## BREAK MEAN EFFECTIVE PRESSURE (BMEP) (4 Cycle)

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

## 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 generating 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<sup>2</sup>. 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 generating set operating at 1800 RPM is more reliable than a comparable 50 Hz generating 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 generating set will vary with the rating which changes depending on fuel, altitude and temperature. The BMEP is also affected by generator 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 ( $\mu$ f).

**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 generating 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 generating 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 rated 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 known 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,  $kW = kVA \times P.F.$

**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 generating 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 generating 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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