



# **Electric Power Application and Installation Guide**

## **Engine Room Design Considerations**

LEBX0034



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# Design Considerations

The engine room should be designed and sized according to the requirements of the application. The most common types of engine rooms consist of single or multiple generator set installations. Engine room design is important for ventilation, cooling and the filtering of dirt and sand from the air. Space in these rooms must also be planned for auxiliary equipment. In addition, heat and noise levels should be adequate for worker's comfort and comply with local or state codes. Considerations must be given to how the generator set is delivered to the site, i.e. by crane or other methods.

## Operational Modes

As mentioned, engine room designs vary by application. In the case of prime power use, the engine room should not be located close to the actual operation room because working conditions would be inconvenient for the operator. Due to minimal usage, a standby set could remain close to the operation's area.

## Single Use Facility

This room is primarily dedicated to generators.

## Multiple Use Facility

The multi use facility would not only have generator sets, but also auxiliary equipment such as boiler units, compressors, etc. For this reason, it is important for the room to have ample space for maintenance and repair of the equipment.

## Serviceability

Adherence to proper generator set maintenance practices is critical to generator set reliability. Caterpillar publishes guidelines and service intervals for every engine and generator model. Reference should be made to these guidelines for specific maintenance practices. However, the installation must be designed for ease of servicing to ensure adequate maintenance.

## Lifting Capabilities

The room enclosures should have adequate clearance to allow lifting of the generator sets for maintenance work, etc.

## Clearances

There are different types of clearances, overhead, side and front/rear.

### Overhead Clearances

Overhead clearance is the clearance above the engine and generator. Special consideration should be made for clearances above the mufflers, exhaust stacks and cylinder heads to allow space for maintenance work.

### Side Clearances

In a single or multiple generator set application, there should be sufficient space between engines for drain carts, tool carriages and other equipment. As a rule, the space between engines should be equal to at least the width of the largest engine installation in the room.

### Front/Rear Clearances

The room should be designed to provide sufficient room in front for removing the radiator and camshaft from the block in case of major overhauls. In a similar manner, there should be sufficient space at the rear of the generator set for removal of the rotor.

## Access

Accessibility is an important feature in any engine room design. Special note should be made as to whether there is a service elevator and service entrance for ease of loading and unloading service vehicles.

There will be periodic preventive maintenance on the engine, so easy access should especially be provided to:

- lube oil filters and drain plug
- fuel and air filters
- jacket water pump
- turbocharger
- heat exchanger

## Routine Maintenance

Access should be available through the service entrance in the case of regular routine maintenance. The entrance should be designed to handle the removal of generator sets, parts, fluids and tools. Maintenance personnel should be able to pass through freely.

## Major Repair

Rooms should be able to handle major repairs, which may involve weight and size constraints. Therefore, the design of the service elevator should be capable of shipping engine installations.

## Service Convenience

### Air

Air should be in sufficient supply for use with air tools as well as ventilation purposes.

### Water

Water is an important resource for cooling purposes as well as for cleaning the room, engine and hands.

## Cable Routing

### Load Testing

There should be provisions in the building for routing cables in cases where the generator set is put on a load test with the load bank. The cable routing would provide for a quick and easy set up. For roof top installations it may be necessary to install permanent cabling to ground level.

## Emergency/Rental Engine

### Room Conditions

The room should be designed to provide adequate space for emergency rental back up power, as well as space for switch gear installation.

## Air Pressure

### Doors

Air restrictions in the room can create a pressure differential between the room and the surrounding areas. A 7 kPa (1.02 psi) pressure differential can create a 1400 kg (3086 lb) force exerted on a  $1 \times 2 \text{ m}^2$  ( $3.28 \times 6.56 \text{ ft}^2$ ) door (as pressure is equal to weight divided by area). The door design and proper ventilation should be taken into consideration when designing the room.

## Louvers

Louvers come in two forms:

### Natural

These are manually opened and closed depending on engine operations. Natural louvers are opened by the engine fan's airflow, and may add to restriction levels.

### Mechanically Operated

In this case, the motorized louvers are hooked up to the control panel of the generator set. When the unit is in operation, the louvers are opened electronically and are closed when the generator set is shut off.

## Air Velocity

While air temperatures must be controlled, air velocities affect worker comfort. The typical air motion conditions include:

Air Velocity		Conditions
m/min	(fpm)	
15.2	50	Offices, seated worker
30.5	100	Factory, standing worker
45.7	150	Capture velocity, light dust
61.0	200	Maximum continuous exposure
396.0	1300	Capture velocity, rain
306.0 – 610.0	1 – 2000	Maximum intermittent exposure

Table 1. Conditions from air velocity

## Temperatures

### Pre-Start

The generator set should be equipped with starting capabilities especially in cold conditions. Provisions such as jacket water heaters, battery heaters, oil heaters, ether start aids and antifreeze concentration are made to ensure proper starting. These measures are taken in cold ambient conditions.

### Operational

In order to maintain temperature and prevent derating of the engine during operation, adequate air and coolant flow are necessary. The radiators provide cooling air for the room, as well as the engine. Heat exchangers and cooling towers for the cooling system remove much of the heat from the room, but ventilation will still be necessary for radiant heat.

## **Future Expansion**

### **Spacing**

The rooms are built for a specific capacity. The generator sets should be planned according to the needs of the application. There should be space available to provide cable lines, fuel storage, exhaust and other supplementary accessories that are needed along with additional installations.

### **Controls**

Along with the space requirements, there should be adequate provisions for the control panels.

## **Installation Considerations**

### **Handling**

#### **Lift Points**

Lift points on the generator set are important as they provide support to the equipment when it is moved.

#### **Standard**

On open packages, the lift points are available on the bottom skid base for ease of lifting. Similarly, in the power module packages, lift points are provided on the edges. This makes it easier to set them up on a trailer base or on the ground.

Use a hoist in order to remove heavy components and an adjustable lifting beam in order to lift the engine. All supporting members (chains and cables) should be parallel to each other and as perpendicular as possible to the top of the object being lifted.

When it is necessary to remove a component on an angle, remember that the capacity of an eyebolt is less than the angle between the supporting members, when the object becomes less than 90 degrees. Eyebolts and brackets should never be bent and should only be loaded under tension.

To remove only the engine, use the lifting eyes on the engine itself.

### **Special Cases**

The lifting eyes are designed for the engine arrangement as sold. If you modify the lifting eyes and/or engine arrangement weight, you are responsible for providing adequate lifting devices. Contact your Caterpillar dealer for information regarding fixtures for proper engine package lifting.

Lifting the engine and generator together requires special equipment and procedures. Contact your Caterpillar dealer for information regarding fixtures for proper lifting of your engine package.

To remove the generator only, use the lifting eyes that are on the generator.

### **Material**

Before installation, the air at the chosen location must be analyzed to see if it contains a large amount of salt or is corrosive due to surrounding industry. These observations will have an impact on the chosen material for handles, louvers, paint etc.

### **Total Package Weight**

#### **Dry vs. Wet**

When a generator set is shipped, it is advisable to ship it dry. It would be shipped without the lube oil and jacket water coolant. A wet package has both oil and coolant.

### **Component Weight**

When installing a complete unit or undertaking a major overhaul, it is necessary to know the weight of the component. This will aid in designing tools such as overhead cranes and service elevators that will help in the transportation of these components.

### **Center of Gravity (CG) Calculations**

This information is important, especially when they are hoisted by overhead cranes. Components with a lower center of gravity have less tendency to tip over when lifted.

## Long Term Storage

### Engine Storage

When an engine is not started for several weeks, the lubricating oil drains from the cylinder walls and piston rings. Rust can then form on the cylinder liner surface, increasing engine wear and decreasing engine life.

To prevent excessive engine wear:

- Be sure all lubrication recommendations mentioned in the Maintenance Schedule intervals chart are completed.
- If freezing temperatures are expected, check the cooling system for adequate protection against freezing. A 50/50 solution of Caterpillar (permanent-type) Antifreeze and approved water will give protection to  $-29^{\circ}\text{C}$  ( $-20^{\circ}\text{F}$ ).

If an engine is out of operation and if use of the engine is not planned, special precautions should be made. If the engine will be stored for more than one month, a complete protection procedure is recommended. Refer to SEHS9031, Storage Procedures for Caterpillar Products, for more detailed information on engine storage.

Your Caterpillar dealer will have instructions for preparing your engine for extended storage periods.

### Generator Storage

When a generator is stored, moisture may condense in the windings. Use a dry storage space and space heaters to minimize condensation.

### Removing Moisture

Drying does not always produce desired results. It may be necessary for the generator to be dipped and baked by a qualified rebuild shop.

- Energize the space heaters in the generator (if equipped).

- Space heaters can be installed on generators (see the Parts Manual). They warm the windings to remove moisture. The heaters should be connected at all times in high humidity conditions, whenever the generator is not running.

Refer to SEHS9124, Special Instructions, Clean and Dry Gen Set, or contact your Caterpillar dealer.

### Air Storage

Test the main stator windings with a megohmmeter:

- before the initial start-up of the generator set
- every three months\* if the generator is operating in a humid environment
- if the generator has not been run under load for three months\* or more

\* This is a guideline only. If the environment is extremely humid or salty, it may be necessary to perform the Megger Test more frequently. Refer to one of the following publications for Megger Test information:

- SEBU6918, SR4B Generators and Control Panels Operation and Maintenance Manual
- SENR5359, SR4B Generator Service Manual

## Ventilation Air

### Air Flow

Ideally, clean, cool, dry air circulates around the switchgear, flows through the rear of the generator, across the engine and discharges through the radiator. Cool air should always be available for the engine air cleaner.

- Locate room air intakes to provide maximum cooling air to the generator set.
- Multiple generator sets require additional openings and fans.
- Units not using radiators require a forced air draft.
- Openings for intake air should be low, near the rear of the engine; position outlets high, on the opposite wall.

## Air Requirements

Depending on the individual diesel engine model and the rating, the engine requires approximately 0.07 m<sup>3</sup>/min (1.84 cfm) of air per brake kW (bhp). Consult TMI for exact data on the specific engine.

Example: A Caterpillar engine, 3412C, high rating, 648 EkW with direct injection, turbo aftercooler and jacket water cooling. The data found in TMI will be:

Engine power: 707.7 BkW (949 BHp)  
Intake air flow: 48.8 m<sup>3</sup>/min (1723 cfm)

$$\text{Air per BkW (BHp)} = \frac{48.8 (979)}{707.7 (1723)}$$

$$= 0.0689 \text{ m}^3/\text{min} (1.81 \text{ cfm})$$

Heavy fuel engines require about 40 percent greater inlet air flow than those burning distillate fuels.

Gaseous fueled engines demand twice that of diesel.

## Intake Location

Although normally obtained from air surrounding the engine, some circumstances require ducting combustion air from outside the engine room. This is particularly true in high altitude operations where light air densities are further affected by engine room temperatures.

- High intake air temperatures can adversely affect engine performance and raise exhaust temperatures, which may damage pistons, exhaust valves and heads.
- Combustion air entering the engine air cleaners should ideally be less than 38°C (100°F).
- On some engine configurations, prolonged operation with extremely cold inlet air to the engine may require a boost control valve to limit intake air manifold pressure and resultant peak cylinder pressure.
- Cold air and altitudes above 2440 m (8000 ft) may cause overfueling when starting automatically, as some governors remain fully open during acceleration to rated speed.

## Flooring Considerations

### Ground Loading

Initial considerations include generator set weight and material supporting this weight.

The wet weight of the total package must be calculated. This includes accessory equipment and weight of all liquids (coolant, oil and fuel) supported by the foundation. Engine and attachments dry weights can be found in the price list. Liquid densities are given in Table 2.

Liquid	Density of Liquids [at 16°C (60°F)]		
	kg/m <sup>3</sup>	lb/U.S. gal	Specific Gravity
Water, Glycol	1024.4	8.55	1.03
Water, Sea	1018.3	8.5	1.02
Water, Fresh	994.6	8.3	1.00
Lube Oil	909.7	7.6	0.916
Diesel Fuel	850.7	7.1	0.855
Kerosene	802.7	6.7	0.807

Table 2. Liquid densities.

Material supporting the foundation must carry the total weight. Table 3 shows bearing load capabilities of common materials.

Material	Safe Bearing Load	
	kPa	psi
Rock, Hardpan	482	70
Hard Clay, Gravel and Coarse Sand	386	56
Loose Medium Sand and Medium Clay	193	28
Loose Fine Sand	96.5	14
Soft Clay	0-96.5	0-14

Table 3. Bearing load capability.

Firm, level soil, gravel or rock provides satisfactory support for single-bearing generator sets used in stationary or portable service. This support can be used where the weight-bearing capacity of the supporting material exceeds pressure exerted by the equipment package, and where alignment with external machinery is unimportant.

Soil, such as fine clay, loose sand or sand near the ground water level, is particularly unstable under dynamic loads and requires substantially larger foundations. Information concerning bearing capacity of soils at the site may be available from local sources and must comply with local building codes.

$$P = \frac{W}{A}$$

Where: P = pressure (kPa), (psi)  
W = weight (kg), (lb)  
A = area (m<sup>2</sup>), (in.<sup>2</sup>)

Pressure imposed by the generator set weight must be less than the load-carrying capacity of supporting material.

Seasonal and weather changes adversely affect mounting surfaces. Soil changes considerably while freezing and thawing. To avoid movement from seasonal change, extend foundations below the frost line.

### Concrete Base

Several basic foundations are applicable for generator sets. The foundation chosen will depend on factors previously outlined as well as limitations imposed by the specific location and application.

Massive concrete foundations are unnecessary for modern multicylinder medium speed generator sets. Avoid excessively thick, heavy bases to minimize subfloor or soil loading. Bases should be only thick enough to prevent deflection and torque reaction, while retaining sufficient surface area for support. Non-parallel units require no foundation anchoring.

If a concrete foundation is required, minimum design guidelines include:

- Strength must support wet weight of units plus dynamic loads.
- Depth sufficient to attain a minimum weight equal to generator set wet weight (only if large mass, i.e. inertia block, is specified for vibration control).
- Outside dimensions exceed that of the generator set, a minimum of 304.8 mm (12 in.) on all sides.

Calculate foundation depth to equal generator set weight by:

$$FD = \frac{W}{D \times B \times L}$$

FD = Foundation depth (m), (ft)

W = Total wet weight of generator set (kg), (lb)

D = Density of concrete (kg/m<sup>3</sup>), (lb/ft<sup>3</sup>)

B = Foundation width (m), (ft)

L = Foundation length (m), (ft)

## Considerations for Roof Top Installation

On sites where there is no ground space or basement available for installation of the generator set, the top of the roof might be considered.

Roof top installations have both advantages and disadvantages. Some of the advantages include the following: noise will no longer be a problem, there will be few space limitations, the generator set will not need long exhaust piping and the overall cost of ductwork will be lowered.

Some disadvantages are that the roof (and possibly the building) may have to be reinforced, there will be limited allowable fuel storage on the roof and a large crane will be needed for installation.

### Flooring and Structure

The roof top must be carefully examined in order to decide if it is strong enough to carry the weight of the generator set. If it is not, a platform may be used, supported by the main columns of the building. These main columns must also be examined for their load capacity.

In a basement installation, the vibration from the generator set must be considered, and appropriate vibration dampers can be installed.

### Fuel Storage

The allowable amount of fuel on the roof top is very limited due to fire and weight considerations. In most cases, a day tank will be installed on the roof. The size of this tank must be approved by the local fire authorities.

To supply the day tank, a bulk tank must be installed at ground level. This installation must comply with the rules of the local fire authorities.

Careful pump calculations must be made in order to size the pump properly so it can lift fuel to the roof. Additional fuel filters must also be considered.

### **Installation**

A large crane will be needed for the installation. It might not be possible to lift the generator set in one piece due to weight restrictions. Therefore, it must be lifted in smaller units and reassembled. When using a crane and large vehicles, the street may have to be closed. Police must be informed in advance of the installation.

### **Exhaust**

Exhaust normally does not provide problems on the roof, but the height of the roof must be considered (in comparison to surrounding buildings). The design and location of the stack should make up for any prevailing winds, neighboring buildings with open windows or fresh air intake of the building it is mounted on.

### **Noise**

Due to weather and noise, the generator set should be installed in a sound proof enclosure. Please consult the local authorities for the allowable noise level.



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