

# **ENGINE ROOM VENTILATION**

**CATERPILLAR®**



# Contents

<b>Engine Room Ventilation .....</b>	<b>1</b>
Sizing Considerations .....	2
Cooling Air .....	2
Combustion Air.....	2
Ventilation Airflow .....	3
Calculating Required Ventilation Airflow .....	3
Engine Room Enclosure Temperature.....	4
Atmospheric Heat Rejection Correction Factor.....	5
Ventilation Fans .....	7
Fan Types .....	7
Fan Location.....	7
Fan Sizing .....	7
Exhaust Fans .....	7
Two Speed Fan Motors.....	8
Routing Considerations .....	9
General Routing Principles .....	9
Single & Dual Engine Applications.....	10
Multiple Engine Applications .....	14
Special Application Routing .....	17
Marine Exhaust Ejector – Automatic Ventilation System .....	24
Additional Considerations.....	24
Radiator Sizing.....	24
Radiator Fan Sizing.....	24

Moveable Louvers .....	25
Refrigeration Equipment .....	25
Exhaust Pipe Insulation .....	25
Test With Doors and Windows Closed.....	25
Ducting Considerations .....	26
Cold Weather Considerations.....	26
Air Cleaner Icing .....	26
Extreme Cold .....	27
Boost Control .....	27

## Foreword

This section of the Application and Installation Guide generally describes Engine Room Ventilation for Caterpillar® engines listed on the cover of this section. Additional engine systems, components and dynamics are addressed in other sections of this Application and Installation Guide.

Engine-specific information and data is available from a variety of sources. Refer to the Introduction section of this guide for additional references.

Systems and components described in this guide may not be available or applicable for every engine.

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# Engine Room Ventilation

This guide addresses engine room ventilation considerations that apply to the successful installation, operation and maintenance of Caterpillar engines, generator sets, compressor units, and other packaged units.

The primary aspects of a properly designed engine room ventilation system are cooling air and combustion air. Cooling air refers to the flow of air that removes radiant heat from the engine, generator, other driven equipment and other engine room components. Combustion air describes the air the engine requires to burn fuel.

Cooling and combustion air directly impact engine and package unit performance and dependable service life; these must be considered in the design of an engine room ventilation system. It is also important to consider all engine room equipment in the design of a ventilation system and provide a comfortable environment for service personnel to perform maintenance.

Some driven equipment, such as a generator in a large engine installation, may require a dedicated ventilation source.

## SECTION CONTENTS

<p><b>Sizing Considerations ..... 2</b></p> <ul style="list-style-type: none"> <li>• Cooling Air</li> <li>• Combustion Air</li> <li>• Ventilation Airflow</li> </ul> <p><b>Ventilation Fans..... 7</b></p> <ul style="list-style-type: none"> <li>• Fan Types</li> <li>• Fan Location</li> <li>• Fan Sizing</li> </ul> <p><b>Routing Considerations ..... 9</b></p> <ul style="list-style-type: none"> <li>• General Routing Principles</li> </ul>	<p><b>Additional Considerations ..... 24</b></p> <ul style="list-style-type: none"> <li>• Radiator Sizing</li> <li>• Louvers</li> <li>• Refrigeration Equipment</li> <li>• Exhaust Pipe Insulation</li> <li>• Ducting</li> </ul> <p><b>Cold Weather Considerations ..... 26</b></p> <ul style="list-style-type: none"> <li>• Air Cleaner Icing</li> <li>• Extreme Cold</li> <li>• Boost Control</li> </ul>
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## Sizing Considerations

### Cooling Air

A portion of fuel consumed by an engine is lost to the environment in the form of heat radiated to the surrounding air. In addition, heat from generator inefficiencies and exhaust piping can easily equal engine-radiated heat. Any resulting elevated temperatures in the engine room may adversely affect maintenance, personnel, switchgear, and engine or generator set performance.

Engine room ventilation air (cooling air) has two basic purposes.

- To provide an environment that permits the machinery and equipment to function properly with dependable service life.
- To provide an environment in which personnel can work comfortably and effectively.

It is important to note that cooling air is needed for more than just the engine; the generator intake also requires cool clean air. The most effective way to do this is to provide a ventilation air source low to the ground at the rear of the package.

The use of insulation on exhaust pipes, silencers, and jacket water pipes will reduce the amount of heat radiated by auxiliary sources.

Radiated heat from the engines and other machinery in the engine room is absorbed by engine room surfaces. Some of the heat is transferred to atmosphere or, on marine installations, to the sea

through the ship's hull. The remaining radiated heat must be carried away by the ventilation system.

A system for exhausting ventilation air from the engine room must be included in the ventilation system design.

### Combustion Air

Combustion air is discussed in detail in the Air Intake Systems section of the Application and Installation Guide. Some aspects of the intake air system are discussed in this guide because they significantly impact the engine room ventilation system design.

In many installations, combustion air is drawn from outside the engine room via ductwork that is designed to move a large amount of air with very little restriction. These installations have very little impact on engine room ventilation design. Other installations, however, require that combustion air be drawn directly from the engine room. In these installations, combustion air requirements become a significant ventilation system design parameter. Approximate consumption of combustion air for a diesel engine is 0.1 m<sup>3</sup> of air/min/brake kW (2.5 ft<sup>3</sup> of air/min/bhp) produced. Engine-specific combustion air requirements can be found using the resources mentioned in the foreword of this guide.

### Ventilation Airflow

Required ventilation airflow depends on the desired engine room air temperature as well as the cooling air and combustion air requirements outlined above. While it is understood that total engine room ventilation airflow must take all equipment and machinery into account, the following sections provide a means for estimating the airflow required for the successful operation of Caterpillar engines and packages.

#### Calculating Required Ventilation Airflow

Engine room ventilation air required for Caterpillar engines and packages can be estimated by the following formula.

$$V = \left[ \frac{H}{D \times C_P \times \Delta T} + \text{Combustion Air} \right] \times F$$

Where:

V = Ventilating Air (m<sup>3</sup>/min), (cfm)

H = Heat Radiation i.e. engine, generator, aux (kW), (Btu/min)

D = Density of Air at air temperature 38°C (100°F).  
The density is equal to 1.099 kg/m<sup>3</sup> (0.071 lb/ft<sup>3</sup>)

C<sub>P</sub> = Specific Heat of Air (0.017 kW x min/kg x °C), (0.24 Btu/LBS/°F)

ΔT = Permissible temperature rise in engine room (°C), (°F)

(**Note:** Max engine room temperature is 120°F)

F = Routing factor based on the ventilation type discussed in the Routing Considerations section of this guide.

**Note:** If combustion air is supplied to the engine through dedicated duct work, "Combustion Air" should be omitted from the formula.

#### Example:

The engine room for a 3412 DITA genset has a Type 1 ventilation routing configuration and a dedicated duct for combustion air. It has a heat rejection value of 659 kW (37,478 Btu/min) and a permissible rise in engine room temperature of 11°C (20°F).

#### Solution:

The estimated engine room ventilation required for this arrangement:

$$V = \left[ \frac{659}{1.099 \times 0.017 \times 11} + 0 \right] \times 1$$

$$V = 3206.61 \text{ m}^3/\text{min}$$

$$V = \left[ \frac{37478}{0.071 \times 0.24 \times 20} + 0 \right] \times 1$$

$$V = 109970.7 \text{ cfm}$$

Proper ventilation is heavily dependent on the path of the ventilation air. Applications involving high load factors and continuous full power operation require a rigorous approach based on classical heat transfer calculations accounting for radiant heat and allowable room temperature rise and adjusting with a ventilation routing factor.

### Engine Room Enclosure Temperature

The primary reason for maintaining engine room temperature at an appropriate level is to protect various components from excessive temperatures. Items that require cool air are:

- Electrical and electronic components.
- Cool air to the air cleaner inlet.
- Cool air to the torsional vibration damper.
- Habitable temperatures for the engine operator or service personnel.
- Cooling air for the generator or other driven equipment.

For electrical and electronic components, the surface temperature should not exceed 90° C (194° F) unless otherwise specified in the component EDS sheet. This is especially important, since many electronic components are placed in high temperature areas of the engine and can be shielded from the direct airflow provided by the engine room ventilation system.

A properly designed engine room ventilation system will maintain engine room air temperatures within 8.5 to 12.5°C (15 to 22.5°F) above the ambient air temperature. For example, if the engine room temperature is 24°C (75°F) without the engine running, the ventilation system should maintain the room temperature between 32.5°C (90°F) and 36.5°C (97.5°F) while the engine is in operation.

Caterpillar recommends a ventilation design that ensures engine room temperature should not exceed 50°C (122°F). If the engine room temperature cannot be maintained below 50°C (122°F), outside air should be ducted directly to the engine air cleaners.

Temperature limits of the driven equipment must also be considered. If the engine room temperature exceeds 40°C (104°F), the generator must be derated per the generator derate schedule and cool outside air must be ducted directly to the generator air intake. Alternatively, custom generators can be sized to handle specific ambient conditions.

In larger multiple engine sites, the normal 8.5 to 12.5°C (15 to 22.5°F) temperature rise guidelines for engine rooms may require unobtainable or uncomfortable air velocities. For these larger sites, a ventilation system needs to give priority to the five items listed above and provides a bottom to top airflow similar to that shown in **Figure 8** and **Figure 9**. In all cases, engine room/enclosure design must ensure that air temperature around the engine will not exceed 50° C (122° F). Critical locations include the engine torsional damper and generator coupling. Air temperature reading should be taken no more than 6 inches away from these components. Note that in these extreme situations, it may be necessary to duct cool air directly to these critical components.

### Atmospheric Heat Rejection Correction Factor

Atmospheric heat rejection values published in TMI are based on ambient cell conditions between 25°C and 29°C. Engine rooms can be designed at much higher ambient conditions; therefore a correction factor can be utilized to define the atmospheric heat rejection at the higher ambient condition.

The correction factors defined below have been developed using fundamentals of heat transfer and can be applied to any object under the same conditions.

There are two distinct correction factors, one is used with wet exhaust and turbo manifolds, the other is used with dry exhaust and turbo manifolds. The skin temperature utilized in the dry manifold calculation is 200°C, approx value of the wrapped, or insulated manifold.

Wet exhaust and turbo manifold correction factor.

$$WCF = -.0156 * T_{ER} + 1.4505$$

Where:

WCF = Wet Correction Factor

$T_{ER}$  = Ambient Engine Room  
Ambient (°C)

Dry exhaust and turbo manifold correction factor.

$$DCF = -.011 * T_{ER} + 1.3187$$

Where:

DCF = Dry Correction Factor

$T_{ER}$  = Ambient Engine Room  
Temperature (°C)

To obtain the corrected atmospheric heat rejection value, multiply the TMI value by the WCF or DCF.

### Radiant Heat

Radiant heat values for the engine and driven equipment is needed to calculate the required ventilation airflow.

**Note:** For the packaged generator sets, ensure that there is adequate airflow near the engine torsional damper. Excessive piping and cooling system structures may prohibit proper airflow near the torsional damper. Monitor damper temperatures per the recommendations found in the Operation and Maintenance Service Manual.

This data is available in the TMI for Caterpillar products. It is located in the Performance Data section.

### Engine

Engine generated radiant heat (heat rejection to atmosphere) is routinely provided with published engine technical data. Values are typically nominal with their tolerance noted. Tolerance should always be added before using published data in calculations.

**Generator**

For generator set installations, the heat radiated by the generator can be estimated by the following formulas.

$$\text{HRG (kW)} = P \times \frac{1}{\text{EFF}-1}$$

$$\text{HRG (Btu/min)} = P \times \frac{1}{\text{EFF}-1} \times 56.9$$

Where:

HRG = Heat Radiated by the Generator (kW), (Btu/min)

P = Generator Output at Maximum Engine Rating (ekW)

Eff = Generator Efficiency % / 100%

**Example:**

A 3512B, 975 ekW standby generator set has a generator efficiency of 92%. The generator radiant heat for this genset can be calculated as follows.

Solution:

$$P = 975 \text{ ekW}$$

$$\text{Efficiency} = 92\% / 100\% = 0.92$$

$$\text{HRG} = 975 \times (0.92 - 1)$$

$$\text{HRG} = 84.78 \text{ kW}$$

$$\text{HRG} = 975 \times (0.92 - 1) \times 56.9$$

$$\text{HRG} = 4824 \text{ Btu/min}$$

**Note:** This data is available in the TMI for Caterpillar generators. It is located in the Performance Data section.

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## Ventilation Fans

Except for special applications, natural draft ventilation is too bulky for practical consideration. Adequate quantities of fresh air are best supplied by powered (fan-assisted) ventilation systems.

### Fan Types

The following types of ventilation fans are typically used.

- Vane-axial
- Tube-axial
- Propeller
- Centrifugal  
(squirrel cage blowers)

The selection of fan type is usually determined by ventilation air volume, pressure requirements and space limitations within the engine room. The fans have various qualities that make them better suited to certain applications.

### Fan Location

Fans are most effective when they withdraw ventilation air from the engine room and exhaust the hot air to the atmosphere. However, ideal engine room ventilation systems will utilize both supply and exhaust fans. This will allow the system designer the maximum amount of control over ventilation air distribution.

The fan motors should be mounted outside the direct flow of hot ventilating air for longest motor life. The design of centrifugal fans (squirrel cage blowers) is ideal in this regard, but their size, relative to the vane-

axial or tube-axial fans, sometimes puts them at a disadvantage.

### Fan Sizing

Fan sizing involves much more than just selecting a fan that will deliver the airflow volume needed to meet the cooling air and combustion air requirements. It requires a basic understanding of fan performance characteristics and ventilation system design parameters.

Similar to a centrifugal pump, a fan operates along a specific fan curve that relates a fan's volume flow rate ( $\text{m}^3/\text{min}$  or cfm) to pressure rise (mm H<sub>2</sub>O or in. H<sub>2</sub>O) at a constant fan speed. Therefore, fan selection not only requires that the volume flow rate be known, but also that the ventilation distribution system be known in order to estimate the system pressure rise. This information allows the optimum fan to be selected from a set of manufacturers' fan curves or tables.

### Exhaust Fans

Ventilation air exhaust systems should be designed to maintain a slight positive or negative pressure in the engine room, depending on the specific application.

Positive pressure should normally not exceed .050 kPa or (0.2 in. H<sub>2</sub>O). This positive pressure provides the following advantages.

- It prevents the ingress of dust and dirt, which is especially beneficial for those applications involving engines that draw their combustion air from the engine room.
- It creates an out draft to expel heat and odor from the engine room.

Some applications, such as a marine application where the engine room is adjacent to living quarters, require that a slight negative pressure be maintained in the engine room. This negative pressure should not normally exceed 0.1275 kPa (0.5 in. H<sub>2</sub>O).

The excess exhaust ventilation provides the following advantages.

- It compensates for the thermal expansion of incoming air.
- It creates an in draft to confine heat and odor to the engine room.

### **Two Speed Fan Motors**

Operation in extreme cold weather may require reducing ventilation airflow to avoid uncomfortably cold working conditions in the engine room. This can be easily done by providing ventilation fans with two speed (100% and 50% or 67% speeds) motors.

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## Routing Considerations

### General Routing Principles

Correct ventilation air routing is vital for proper operation of Caterpillar engines and packaged units.

Maintaining recommended air temperatures in the engine room is impossible without proper routing of the ventilation air. The following principles should be considered when designing an engine room ventilation system.

- Fresh air inlets should be located as far from the sources of heat as practical and as low as possible.
  - Ventilation air should be exhausted from the engine room at the highest point possible, preferably directly over the engine.
  - Ventilation air inlets and outlets should be positioned to prevent exhaust air from being drawn into the ventilation inlets (recirculation).
  - Ventilation air inlets and outlets should be positioned to prevent pockets of stagnant or recirculating air, especially in the vicinity of the generator air inlet.
  - Where possible, individual exhaust suction points should be located directly above the primary heat sources. This will remove heat before it has a chance to mix with engine room air and raise the average temperature. It must be noted that this practice will also require that ventilation supply air be properly distributed around the primary heat sources.
- Avoid ventilation air supply ducts that blow cool air directly toward hot engine components. This mixes the hottest air in the engine room with incoming cool air, raising the average engine room temperature. This also leaves areas of the engine room with no appreciable ventilation.
  - For installations where engines draw combustion air from inside the engine room, the routing should provide the coolest possible combustion air to the turbocharger inlets.
  - For marine and offshore applications, the potential exists for seawater to be drawn into the ventilation air supply; systems for these applications must be designed to prevent seawater from being drawn into the air intake filters and ingested by the turbocharger. Generator cooling air must also be filtered to minimize the ingestion of salt.

These general routing principles, while driven by the same basic principles of heat transfer, will vary with the specific application. This section discusses the general considerations relating to single and dual engine applications, multiple engine (3+) applications, and several special applications.

### Single & Dual Engine Applications

Single and dual engine applications are arguably the most common applications encountered, regardless of engine market.

These applications will generally require smaller engine rooms, which are especially challenging in regard to the use of good routing practices.

Recommended ventilation systems for these applications, presented in order of preference, are Type 1, Type 2, Type 3 and Type 4.

#### ***Ventilation Type 1 (Preferred Design)***

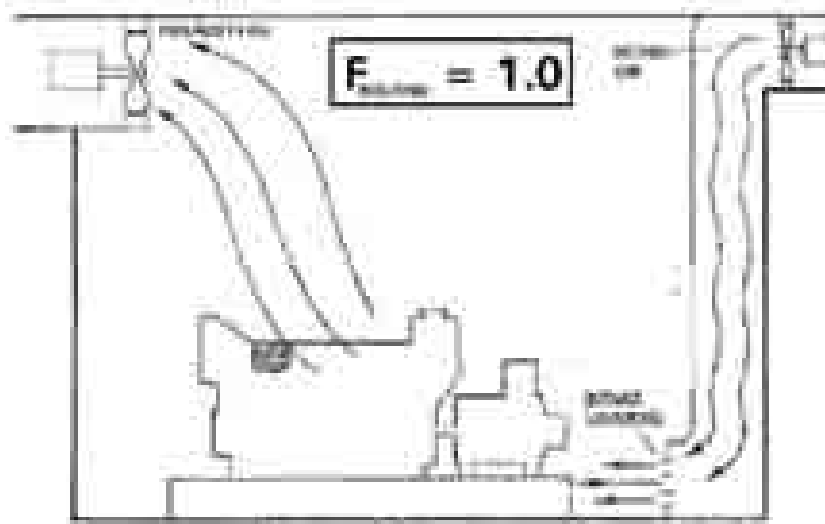
**Note:** In ventilation airflow calculations, Type 1 systems have a Routing Factor of 1.

Outside air is brought into the engine room through a system of ducts. These ducts should be routed between engines, at floor level, and discharge air near the bottom of the engine and generator as shown in **Figure 1**.

Ventilation air exhaust fans should be mounted or ducted at the highest point in the engine room. They should be directly over heat sources.

This system provides the best ventilation with the least amount of air required. In addition, the upward flow of air around the engine serves as a shield which minimizes the amount of heat released into the engine room. Air temperature in the exhaust air duct will be higher than engine room air temperature.

**Ventilation Type 1**



**Figure 1**

**Ventilation Type 2 (Skid Design)**

**Note:** In ventilation airflow calculations, Type 2 systems have a Routing Factor of 1.

A skid design may be preferred in petroleum applications. Similar to the Type 1 system, Type 2 brings outside air into the engine room through a system of ducts and routes it between engines. Type 2, however, directs airflow under the engine and generator so the air is discharged upward at the engines and generators as shown in **Figure 2**.

The most economical method to achieve this design is to use a service platform. The platform is built up around the engines and serves as the top of the duct. This requires the service platform to be constructed of solid, nonskid plate rather than perforated or expanded grating. The duct outlet will be the clearance between the decking and

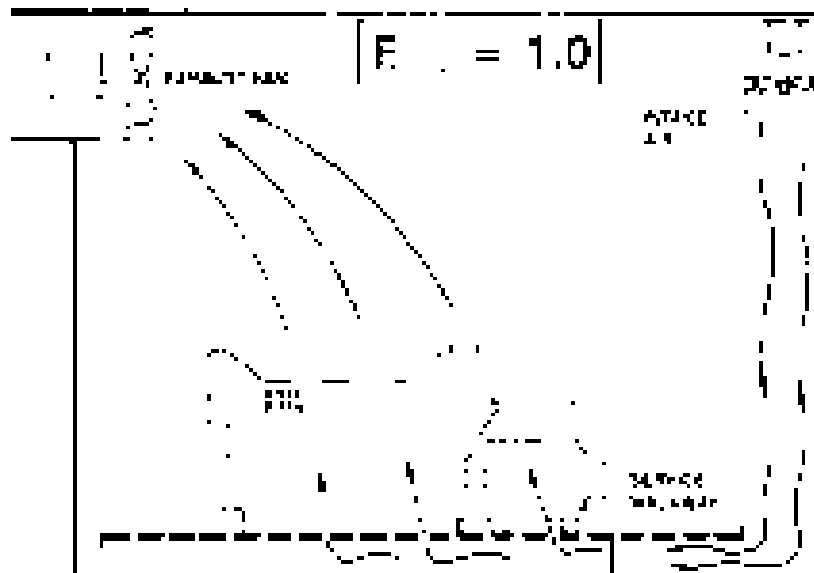
oilfield base. Regular care must be used to ensure grating remains clean and the airflow unrestricted.

Ventilation air exhaust fans should be mounted or ducted at the highest point in the engine room. They should be directly over heat sources.

This system provides the best ventilation with the least amount of air required. In addition, the upward flow of air around the engine serves as a shield which minimizes the amount of heat released into the engine room. Air temperature in the exhaust air duct will be higher than engine room air temperature.

Although the Type 1 system provides effective ventilation for the engine, it does not consider the special ventilation needs of the driven equipment. Large generators, configured with an air inlet positioned high on the generator, will require an additional source of ventilation air.

**Ventilation Type 2**



**Figure 2**

**Ventilation Type 3 (Alternate Design)**

If Ventilation Type 1 or Type 2 is not feasible, an alternative is Type 3; however, this routing configuration will require approximately 50% more airflow than Type 1.

**Note:** In ventilation airflow calculations, Type 3 systems have a Routing Factor of 1.5.

As shown in **Figure 3**, outside air is brought into the engine room utilizing fans or large intake ducts. The inlet is placed as far away as practical from heat sources and discharged into the engine room as low as possible. The air then flows across the engine room from the cool air entry point(s) toward the sources of engine and equipment heat; these include the engine, exposed exhaust components,

generators, or other large sources of heat.

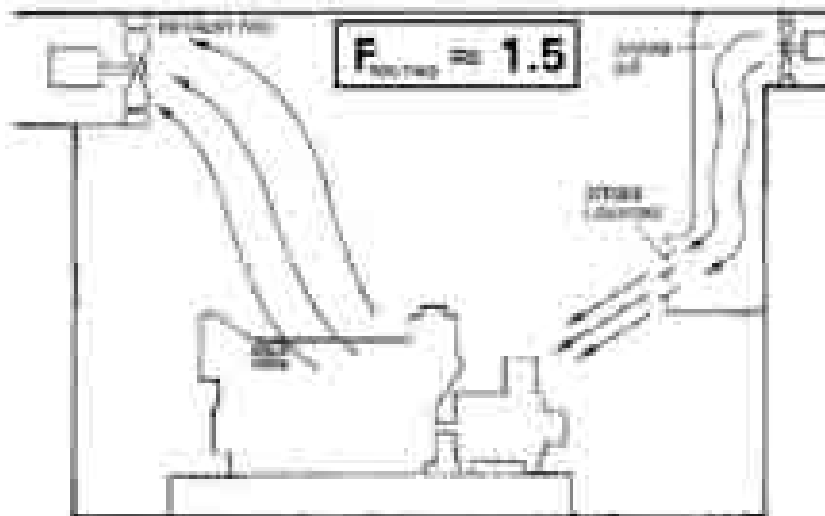
Ventilation air exhaust fans should be mounted or ducted at the highest point in the engine room. Preferably, they should be directly over heat sources.

Engine heat will be dissipated with this system, but a certain amount of heat will still radiate and heat up all adjacent engine room surfaces.

If the air is not properly routed, it will rise to the ceiling before it gets to the engines.

This system will work only where the air inlets circulate the air between the engines, for dual engine applications. Air inlets located at the end of the engine room will provide adequate ventilation to only the engine closest to the inlet.

**Ventilation Type 3**



**Figure 3**

**Ventilation Type 4  
(Less Effective Design)**

If Ventilation Type 1, Type 2 and Type 3 are not feasible, the following method can be used; however, it provides the least efficient ventilation and requires approximately two and a half times the airflow of Ventilation Type 1.

**Note:** In ventilation airflow calculations, Type 4 systems have a Routing Factor of 2.5.

As shown in **Figure 4**, outside air is brought into the engine room using supply fans, and discharged toward the turbocharger air inlets on the engines.

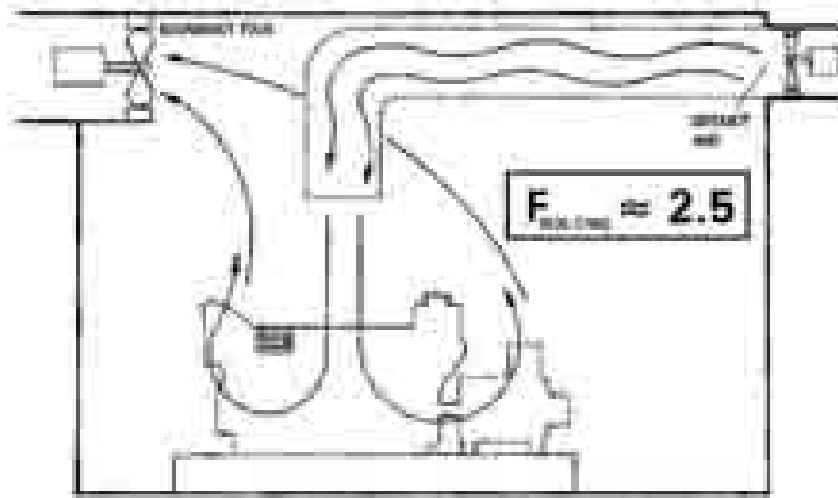
Ventilation exhaust fans should be mounted or ducted from the corners of the engine room.

This system mixes the hottest air in the engine room with the incoming cool air, raising the temperature of all air in the engine room. It also interferes with the natural convection flow of hot air rising to exhaust fans. Engine rooms can be ventilated this way, but it requires extra large capacity ventilating fans.

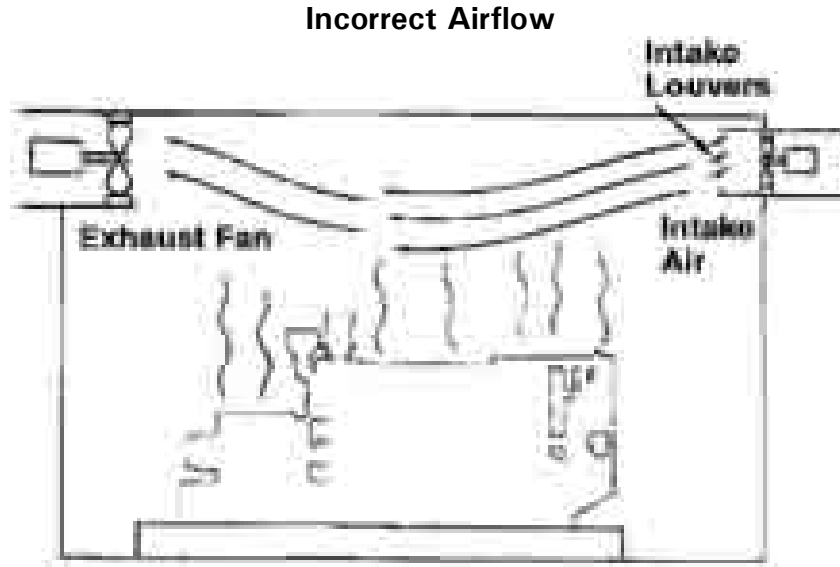
**Incorrect Airflow**

**Figure 5** illustrates an incorrect method to vent engine room heat. Although the inlet duct has louvers to direct airflow toward the engine, rising heat will warm the cool air before it can reach the engine.

**Ventilation Type 4**



**Figure 4**

**Figure 5**

### Multiple Engine Applications

The ventilation systems recommended for single and dual engine applications also apply to multiple engine applications. However, there are additional considerations that are specific to multiple engines.

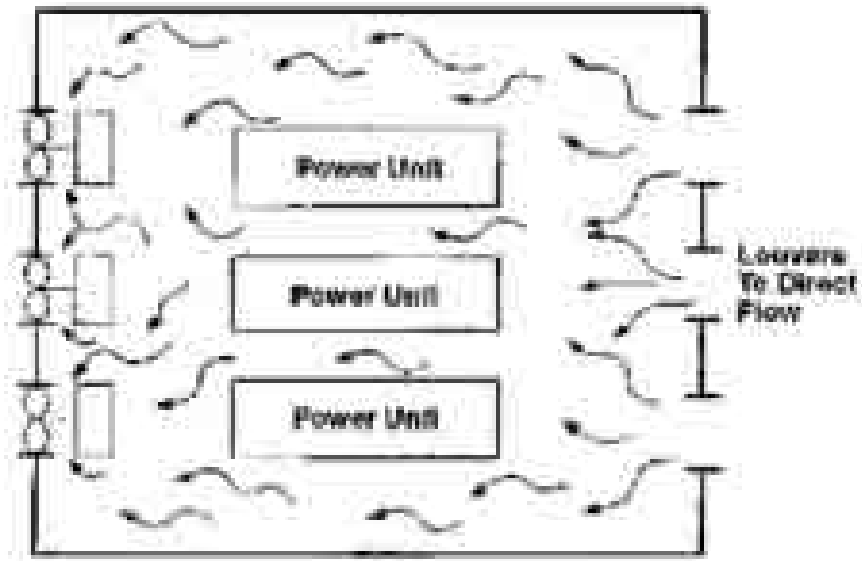
As previously mentioned, using normal temperature rise guidelines will likely result in the requirement for extremely large volumes of air on multiple engine installations. Although the guidelines for these sites may be more generous in regard to temperature rise allowance, the ventilation system must be designed to provide sufficiently cool air in the immediate vicinity of the engine and driven equipment to meet their ventilation requirements.

Large multiple engine sites will generally utilize multiple ventilation fans. These sites often use one or two fans for each engine and an additional fan to direct air to the inlet of the generator or other driven equipment. This practice allows for a very simple arrangement requiring minimal ductwork.

The use of multiple ventilation fans, for either supply or exhaust, will require that airflow between the engines be arranged, either by fan placement or by distribution ductwork.

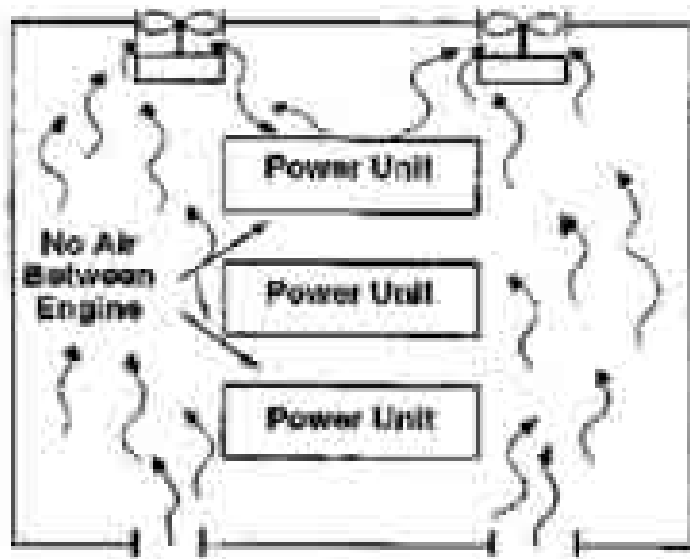
**Figure 6** and **Figure 7** show examples of correct and incorrect airflow patterns for multiple engine sites. (**Note:** generator ends would be on right side of diagrams)

**Correct Airflow**



**Figure 6**

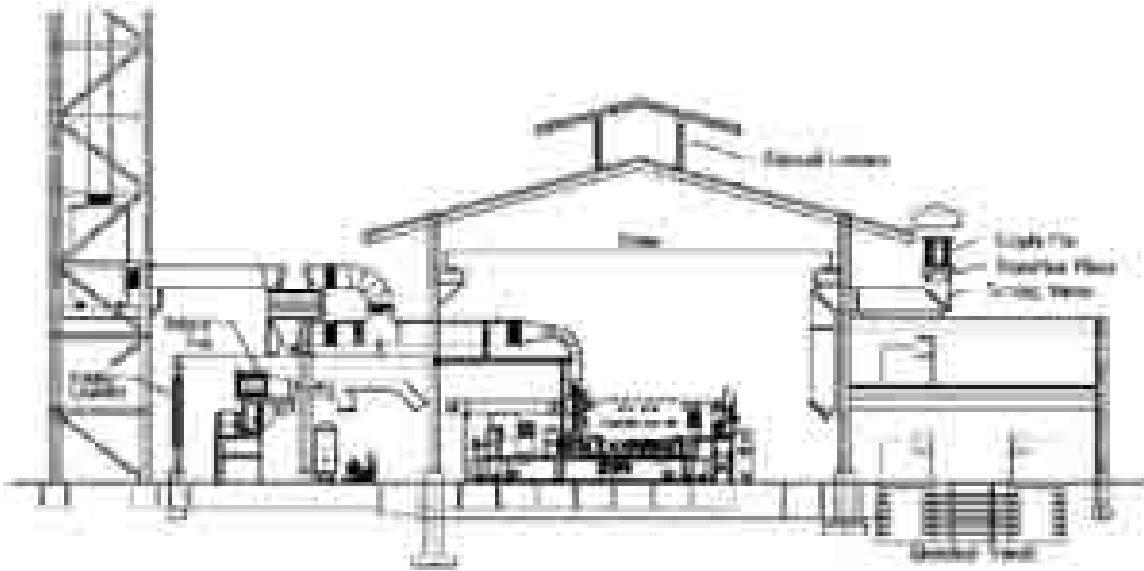
**Incorrect Airflow**



**Figure 7**

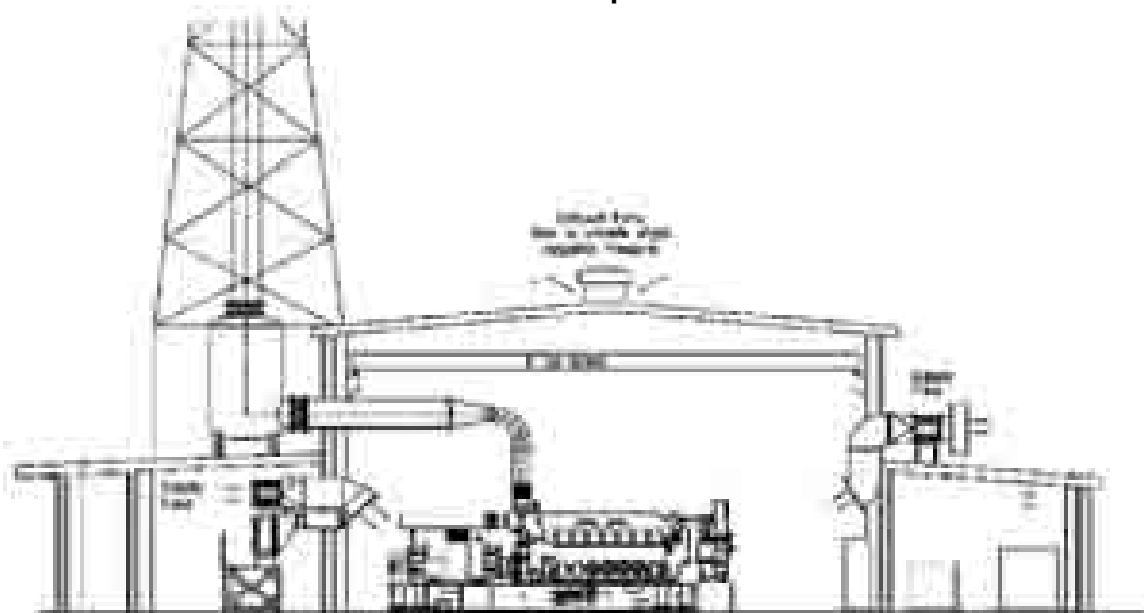
**Figure 8** and **Figure 9** show examples of the bottom-to-top airflow pattern generally used in large power plant applications.

### Bottom-to-Top Airflow



**Figure 8**

### Bottom-to-Top Airflow



**Figure 9**

## Special Application Routing

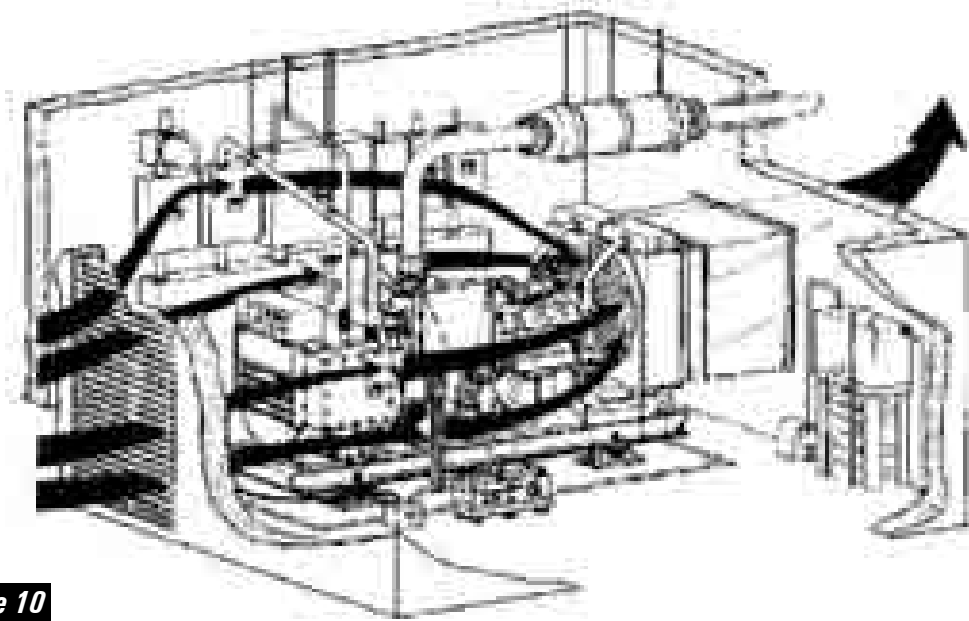
### *Engine Mounted Radiators*

Applications with engine-mounted radiators using engine room air for cooling generally provide more airflow than is necessary for adequate ventilation; refer to **Figure 10**. The high airflow combined with low ambient temperatures, below 21°C (70°F), can cause water to condense inside exposed engine components, such as valve covers. This can result in oil and maintenance problems. Therefore, special installation considerations must be made in cold climates.

Two methods can be used to overcome this problem.

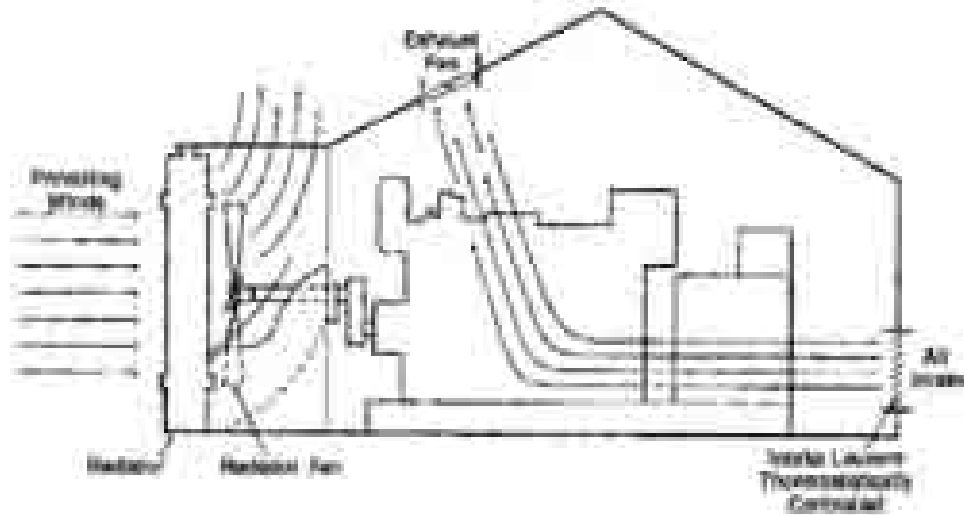
- Remote mounted and specially ducted engine-mounted radiators do not require engine room air for cooling; refer to **Figure 11**. One advantage of such a system is that the air used to cool the radiator is not pre-heated by the engine, thus increasing the ambient capability (or reducing the size) of the unit. The disadvantage is that motor-driven fans must be installed to provide ventilation for the engine which increase the overall cost of the system.

### Engine-Driven Fan Arrangement



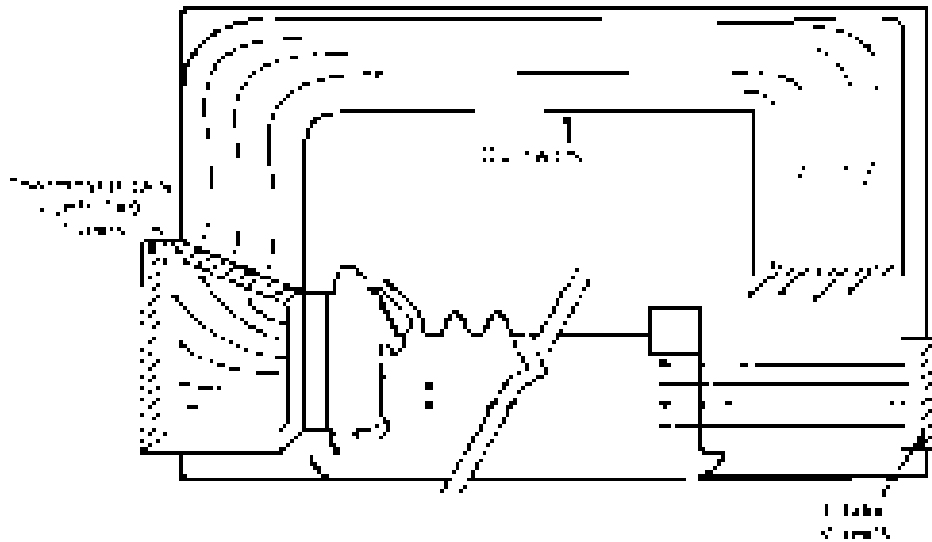
**Figure 10**

### Engine-Driven Fan Arrangement



**Figure 11**

### Radiator with Thermostatically Controlled Louvers



**Figure 12**

- Thermostatically controlled louvers can be installed to recirculate some of the radiator exhaust in order to maintain a warm airflow across the engine. Refer to **Figure 12**. This also maintains a comfortable working environment for

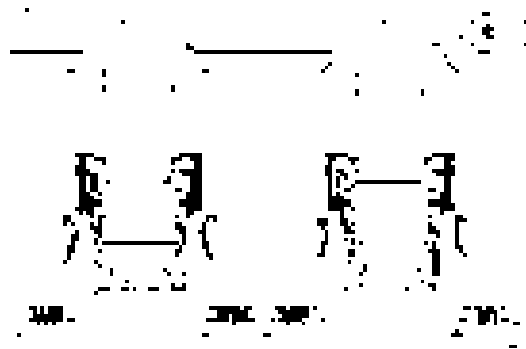
maintenance personnel. Caution must be exercised so that the recirculated air is reintroduced upstream of the engine and is well mixed by the time it reaches the radiator.

For any arrangement where a radiator fan is used to ventilate an engine room, the vacuum created in the engine room must not exceed 0.1275 kPa (0.5 in. H<sub>2</sub>O). Any restriction above this limit could reduce airflow through the radiator and overheat the engine.

### ***Air Curtains***

Air curtains, totally enveloping the generator set, provide ventilation without exposing the equipment room to high air velocities. Refer to **Figure 13**. Radiated heat is removed with approximately half the airflow of a horizontal flow system.

### **Air Curtains**



**Figure 13**

It is important to stretch the air curtain inlet the full length of generator set. Special care must be used to ensure adequate cool airflow at the generator air intake and at the generator coupling.

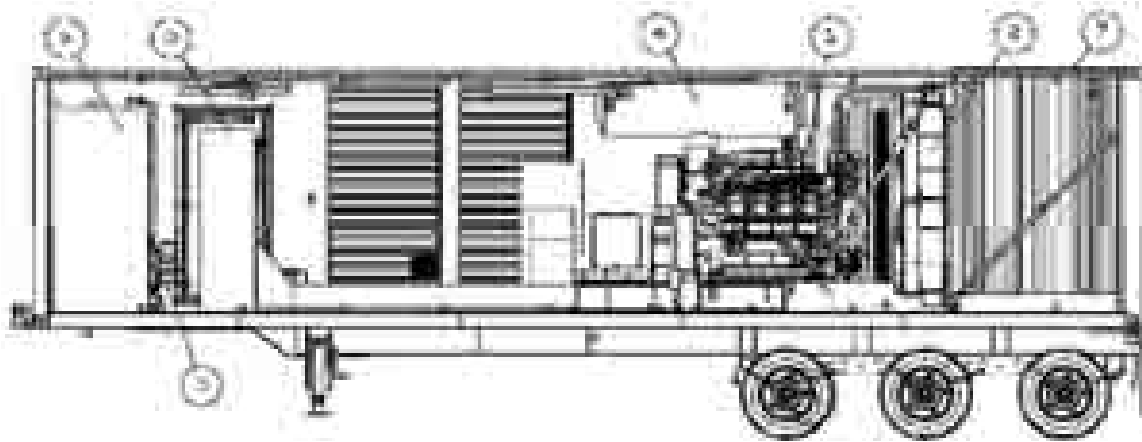
Air curtains present ducting challenges when local fan radiators are used.

**Power Modules**

Power modules generally utilize radiator cooled diesel generator sets. The power module enclosures trap the radiated heat from the engine and generator, and direct it through the radiator, decreasing cooling capabilities 8 to 10°C (14 to 18°F). Even with doors open, radiators can

derate 5 to 7°C (9 to 13°F) when enclosed. Refer to the Enclosure Installation section of the Application & Installation Guide for spacing recommendations for power modules. **Figure 14** and **Figure 15** show examples of typical Caterpillar containerized power modules.

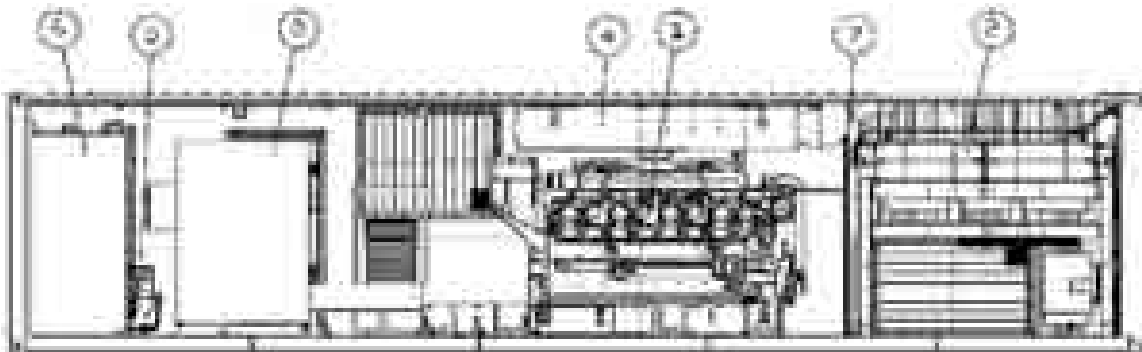
**40' Containerized Power Module**



**Figure 14**

- |                        |                             |
|------------------------|-----------------------------|
| 1. Caterpillar D/G Set | 5. Fuel/Water Separator     |
| 2. Radiator            | 6. Fuel Tank                |
| 3. Switchgear          | 7. Vertical Discharge Chute |
| 4. Silencer            |                             |

**40' Containerized Power Module**



**Figure 15**

- |                        |                         |
|------------------------|-------------------------|
| 1. Caterpillar D/G Set | 5. Fuel/Water Separator |
| 2. Radiator            | 6. Fuel Tank            |
| 3. Switchgear          | 7. Partition Wall       |
| 4. Silencer            |                         |

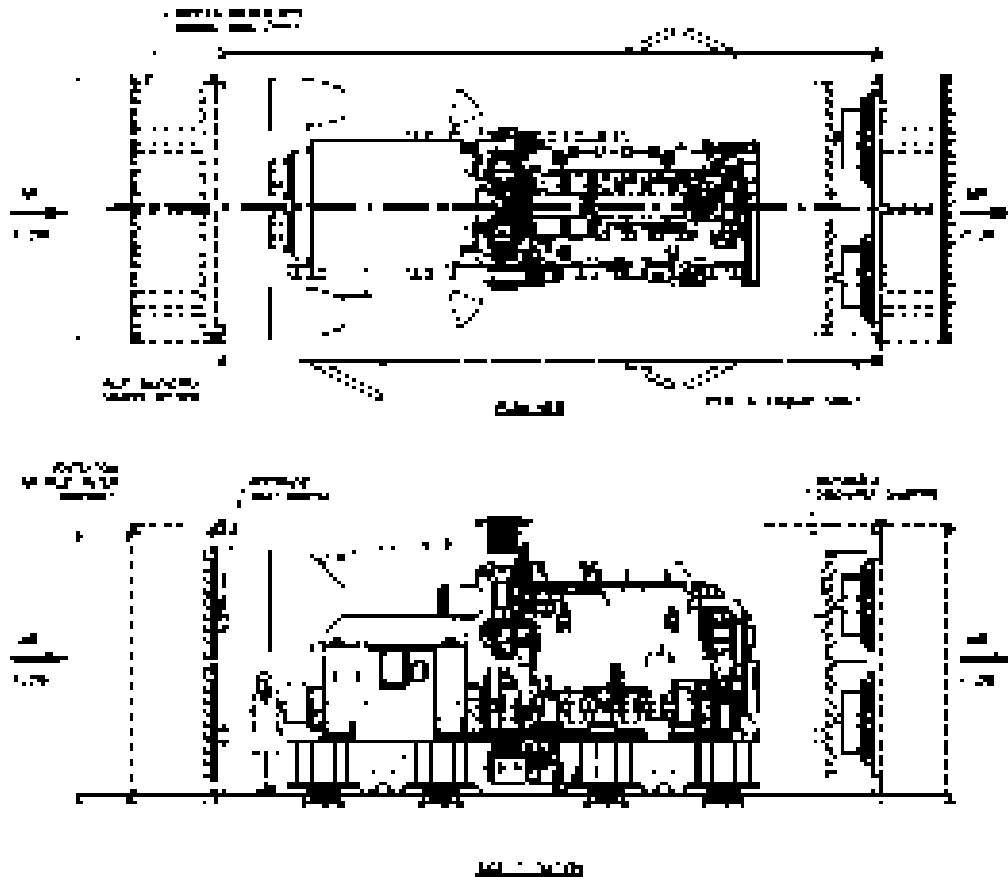
**Drop-Over Enclosures**

Drop-over enclosures are utilized for applications requiring some degree of weather protection or noise attenuation, when a standard building is not available for housing. If the enclosed package is cooled by an engine-mounted radiator, then the power module requirements outlined above apply. If the enclosed package is cooled by a remote radiator or other means, then the enclosure must be provided with a fixed ventilation

system that is subject to the same requirements as previously outlined for single and dual engine applications.

**Figure 16** illustrates a typical diesel generator set with a drop-over enclosure. While this example uses exhaust fans for ventilation, the use of supply or exhaust fans on a particular application will be determined by the need to maintain either a slight positive or negative pressure inside the enclosure.

**Drop-Over Enclosure Example**



**Figure 16**

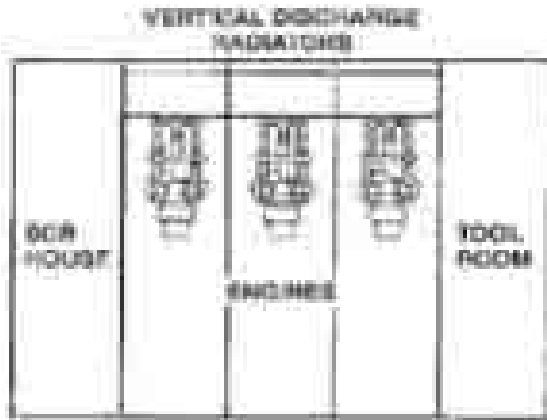
**Land SCR Rig Ventilation Systems**

Land SCR rig engines equipped with suction or blower fan radiators have airflow in excess of that required for recommended engine ventilation. As long as radiator airflow is not obstructed, no further ventilation requirements are needed.

Land rig engine installations with remote radiators or vertical discharge radiators should be inspected to determine if sufficient engine ventilation is provided.

**Figure 17** illustrates a land rig installation where ventilation should be considered. Natural draft ventilation is almost completely blocked by roofs, SCR house, tool room, and vertical discharge radiators. Warm weather operation may result in unacceptable engine and generator temperatures.

**Land Rig Engines Requiring Ventilation**



**Figure 17**

**Figure 18** shows an engine room designed to provide a combination of ventilation and engine/generator air inlet ducting.

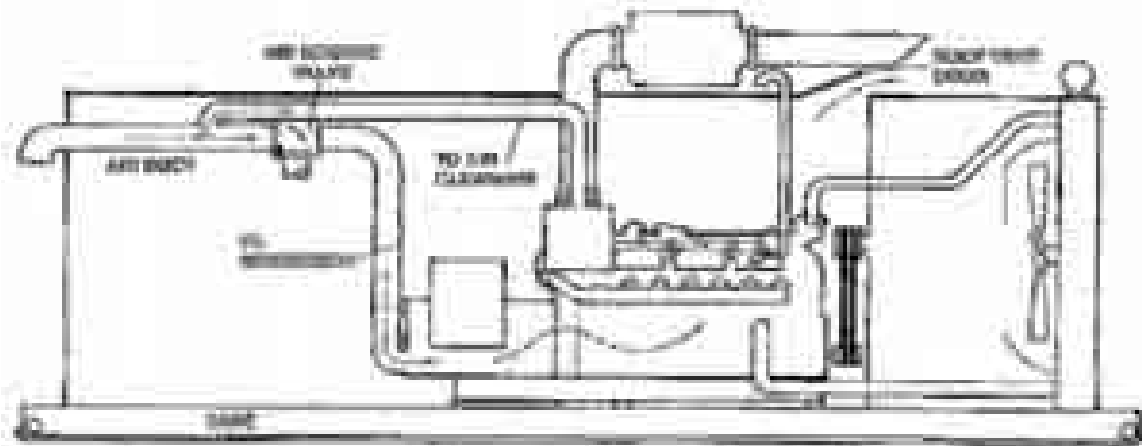
Ventilation is provided by the air discharged from the generator. In warm weather, the air source valve is positioned to provide outside air to the generator ventilation air inlet. Air discharged from the generator exits through the roof vent door and open rear of base, providing engine ventilation as a secondary result.

In cold weather, the air source valve will be positioned to provide partial or total generator ventilation air from within engine room.

If doors are added to rear of base, make sure that total enclosure is not airtight. This prevents pressurizing engine room (reducing generator ventilation airflow) when doors are closed and air source valve is positioned to provide outside air to generator.

An air duct size of 2.0 sq. ft. (0.19 m<sup>2</sup>) is adequate for 3508, 3512, and 3516's on up to 40 ft. (12.2 m) bases. The ducting to the air cleaners from air source valve can match the sizes of the optional air cleaner inlet rectangular adapters.

**Typical SCR Land Rig Ventilation**



**Figure 18**

**Marine Through-Hull Opening Design**

There must be openings for air to enter the engine room and openings for air to leave the engine room.

There should be an inlet for cool air to enter, and a discharge for hot air to leave, on each side of the hull. If it is impractical to have two separate openings per side, then avoid having hot discharged air mix with cool air entering the engine room.

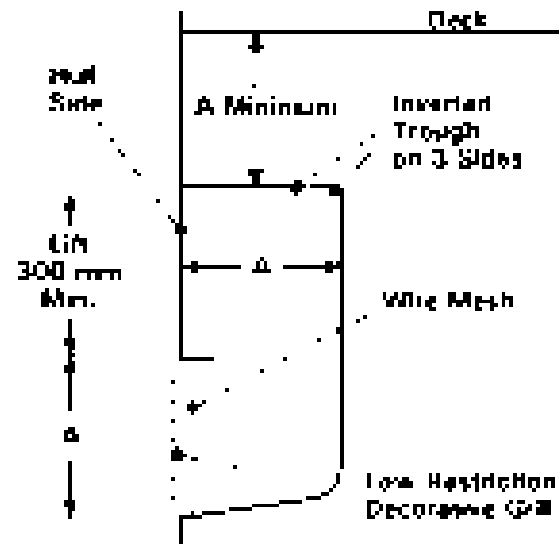
Features of the Marine Through-Hull Opening are shown in **Figure 19**. Opening 'A' should be sized to maintain air velocity through the openings below 610 m/min (2000 ft/min).

**Air Entering the Engine Room**

The engine room must have openings for air to enter. The intake air opening should be located forward of, and, if convenient, at a lower elevation, than the discharge. The air may also enter from the accommodation spaces, such as the galley and staterooms, or directly through the hull or deck. Engine room air inlets

through accommodation spaces can be troublesome.

**Features of Through-Hull Ventilation Openings**



**Figure 19**

If air is to enter the engine room from the accommodation spaces, good design practice will include sound deadening treatments for the opening(s) that conduct air from the accommodation spaces to the engine room. Heating and/or air

conditioning of accommodation spaces will be made much more complicated if the engines must rely on that heated/cooled air for combustion. Engine room air inlets through accommodation spaces simplify the task of ensuring the engine room inlet air is kept clean and free from rain or spray.

### ***Air Leaving the Engine Room***

The through-hull or through-deck openings for discharge of heated ventilation air should be located aft of and higher than all intake openings to minimize recirculation.

The ventilation air opening, discharging heated ventilation air, should be located aft of, and at a higher elevation than the intake air opening in order to minimize recirculation. Cross- and following-winds make total elimination of ventilation air recirculation nearly impossible.

### **Marine Exhaust Ejector – Automatic Ventilation System**

A relatively simple system utilizing an engine's exhaust for ventilating an engine room can be arranged with most dry exhaust systems.

Ductwork can be installed around the engine exhaust piping in such a way that the exhaust flow creates a vacuum that is utilized to draw the hot air out of the upper part of the engine room.

An exhaust ejector system may draw out a quantity of ventilating air approximately equal to the flow of exhaust gas. This method has been used successfully in marine applications with small engine

rooms and minimal ventilation requirements, and is discussed in more detail in the Exhaust Systems section of the Application and Installation Guide.

## **Additional Considerations**

### **Radiator Sizing**

The frontal area of a radiator core should be as large as possible to minimize restriction of airflow. Low radiator core restriction allows the use of a larger slower turning fan.

Radiators that are nearly square can provide the most effective fan performance. They can be installed with a minimum of unswept core area. As a rule, keep core thickness to a minimum, with a maximum of 11 fins per 2.54 cm (1.0 in.). Increasing the number of fins per cm (in.) does increase the radiator heat rejection for a given air velocity through the core, but also increases the resistance to airflow.

While the most economical initial cost will be maximum core thickness and fins per cm (in.), this involves higher fan horsepower with consequent operating cost and noise penalties throughout the life of the installation. In addition, a radiator with more fins per cm (in.) is much more susceptible to plugging from insects and debris.

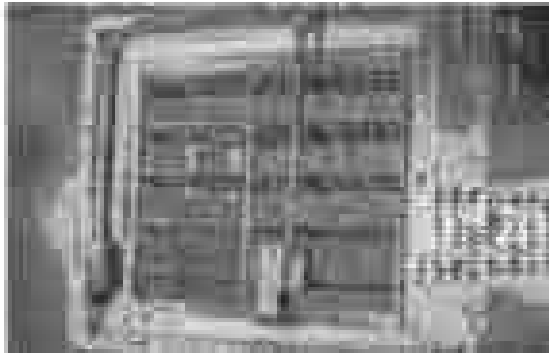
### **Radiator Fan Sizing**

As a rule, the most desirable fan is one having the largest diameter and turning at the lowest speed to deliver the required airflow. This also results in lower fan noise and lowest fan horsepower draw from the engine.

Blade tip speed, while being only one of the elements of cooling fan design, is an item easily changed by choosing an appropriate fan drive ratio. An optimum fan tip velocity of 6096 cm/s (12,000 fpm) is a good choice for meeting noise legislation requirements and cooling system performance requirements. The maximum acceptable fan blade tip speed is 7620 cm/s (15,000 fpm) for Caterpillar fans.

### Moveable Louvers

If moveable louvers are used, specify those which open in a positive manner. Pneumatic and electric-actuated louvers are satisfactory. Refer to **Figure 20**.



**Figure 20**

### Louver Operation

- Louvers which open from the discharge pressure of the radiator fan are discouraged. Rain, ice and snow can render them inoperative within a short time and result in engine overheating and shutdown.
- Do not wait to activate the louvers until the engine warms up. In an emergency, the engine will be loaded immediately and require full airflow. Open the louvers as soon as the engine

starts and install them to open fully in case of an emergency.

- Heat sensors needlessly complicate the system and their malfunction can reduce airflow to the engine which can cause shutdown.

### Refrigeration Equipment

When refrigeration equipment is installed within the engine room space, ensure its location is such that any refrigerant leakage will not be drawn into the engine's combustion airflow. Refrigerant chemicals, such as Freon® and ammonia, become highly corrosive acids in engine combustion chambers. This corrosion will cause severe damage. Locating refrigerant compressors near an engine room air exhaust area is appropriate.

### Exhaust Pipe Insulation

Long runs of hot, uninsulated exhaust piping can dissipate more heat into the engine room than all other machinery surfaces combined.

Completely insulate all exhaust piping within the engine room area. All hot surfaces within the engine room should be insulated if high air temperatures are to be avoided. Do not insulate engine turbochargers.

### Test With Doors and Windows Closed

Ventilating systems must be designed to provide safe working temperatures and adequate airflow when windows, doors, and other normally closed ports are secured for bad weather conditions. Test the ventilation system fully secured for bad weather. This condition will reflect the most

severe test of the ventilation system. Remember that a small room suction can exert a large pressure on an entrance door or window.

**Ducting Considerations**

Design all ducting to withstand extremes of vacuum or pressure and still maintain tight joints.

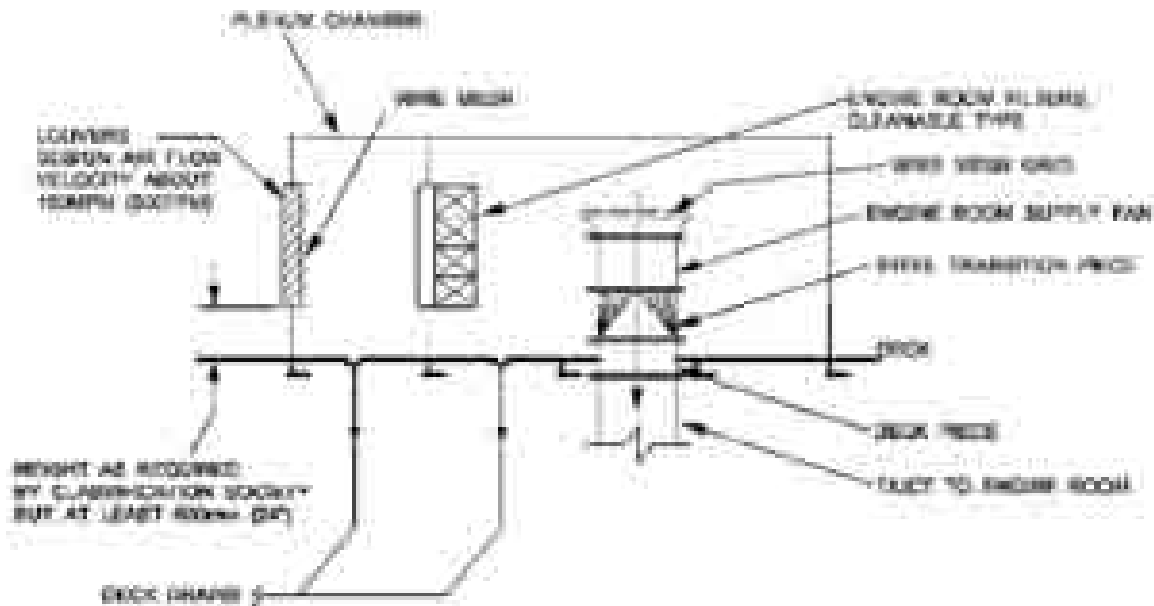
Provide inspection ports (or areas that are easily disassembled) to allow removal of foreign objects. Inspection ports are especially important for standby applications.

**Cold Weather Considerations**

**Air Cleaner Icing**

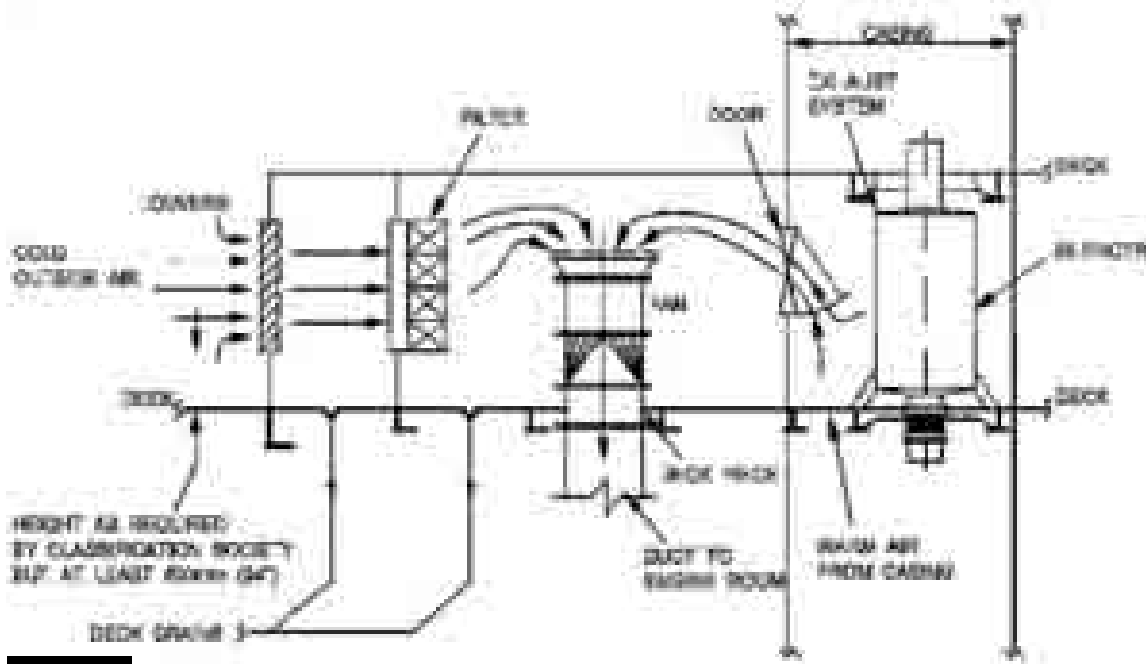
Air cleaner icing can occur in saturated air environments when the dew point of the ambient air is near freezing. Small disturbances to the air such as velocity and pressure changes at the air cleaner inlet reduce the moisture-holding capacity of the air. This results in moisture condensation and ice crystal formation. The ice buildup reduces the airflow area and increases the pressure differential across the air cleaner. Eventually, a plateau is reached where the pressure differential remains constant even though ice buildup may continue. Power loss and increased fuel consumption will result during these periods.

**Typical Air Plenum Arrangement**



**Figure 21**

### Typical Warm Air Arrangement



**Figure 22**

Several techniques may be used to overcome air cleaner icing. One solution is to heat the intake air slightly. It is not necessary to heat the air above freezing. The air requires only enough heat to be above the dew point. Heat can be supplied to the air cleaner housing by recirculating warm engine room air; **Figure 12** shows how this can be accomplished for a radiator cooled application. **Figure 21** shows a typical air plenum arrangement for a marine application and **Figure 22** illustrates the how a warm air arrangement may be configured.

#### Extreme Cold

Heated engine room air may be required (for starting purposes only) in applications at very cold ambient temperatures,  $-25^{\circ}\text{C}$  ( $-13^{\circ}\text{F}$ ). This assumes combustion air is being

drawn from outside the engine building, and the engine is preconditioned with pre-heaters for metal, water and oil temperatures of  $0^{\circ}\text{C}$  ( $32^{\circ}\text{F}$ ). Admitting engine room air must be done without the possibility of allowing dirt or debris into the air inlet system of the engine. **Figure 12** and **Figure 22**, as indicated above, will also apply here.

#### Boost Control

A boost control valve is available for the 3600 diesel engine family for use in extremely cold ambient conditions,  $0^{\circ}\text{C}$  ( $32^{\circ}\text{F}$ ). The valve is used to limit the air inlet manifold pressure during low air temperature conditions to maintain acceptable cylinder pressure.





