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Electric Power Application and Installation Guide

Ventilation

LEBX0033-01

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Ventilation

Ventilation Purpose

Six to ten percent of fuel consumed by an engine is lost as 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 generator set performance.

Ventilation Flow

Correct routing of ventilation air is vital. Without it, airflow will not adequately maintain comfortable engine room temperatures. Ideally, clean, cool, dry air circulates around switchgear, flows through the rear of the generator, across the engine and discharges through the radiator (see Figure 1). Cool air should always be available for the engine air cleaner.

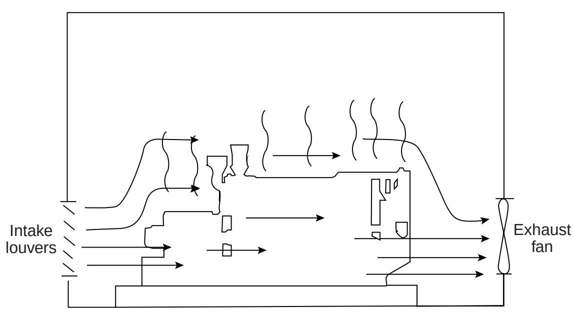

Figure 1. Ideal ventilation.

Locate room air intakes to provide maximum cooling air to the generator set, yet avoid hot, stagnant air in other areas. Multiple generator sets necessitate 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 generator set. Outlets should be positioned high on the opposite wall.

Another way of ventilating the engine room is the use of air curtains, although this is not so commonly utilized. The advantage of an air curtain system is that the engine room is exposed to lower air velocity than a system with radiators.

Ventilation Terms

Ventilation Air:
The flow of air required to carry away the radiated heat of the engine(s) and other engine room machinery.

Combustion Air:
The flow of air required to burn the fuel in the engine.

Crankcase Fumes Disposal:
Elimination of oil laden combustion fumes that collect in the engine crankcase (see “Crankcase Ventilation”).

Radiator Cooling Air:
Air flow passing through the radiator — normally to cool the engine. Certain installations utilize radiator cooling air flow for ventilation purposes.

Ventilation Considerations

Routing

Comfortable air temperatures in the engine room are impossible without proper routing of the ventilation air.

Fresh air should enter the engine room as far from the sources of heat as practical and *as low as possible*. Since heat causes air to rise, it should be discharged from the highest point in the engine room, preferably directly over the engine. Avoid incoming ventilation air ducts which blow cool air toward hot engine components. This mixes the hottest air in the engine room with incoming cool air, raising the temperature of all the air in the engine room, and leaves areas of the room with no appreciable ventilation.

Relative Efficiency Routing

The sketches below (see Figure 2) illustrate the relative efficiency of various ventilation routing. $F_{routing}$ is a factor which relates the relative efficiency of various ventilation air routing.

Example:

If the routing in Figure A (upper left) is used as a base to which the others are compared:

- 1.4 times more air is required (duct cross-sectional area and fan capacity) to adequately ventilate the machinery space illustrated in Figure B (upper right).
- It takes twice as much air (duct cross-sectional area and fan capacity) to adequately ventilate the machinery space illustrated in Figure C (lower left).
- 3.3 times more air is required (duct cross-sectional area and fan capacity) to adequately ventilate the machinery space illustrated in Figure D (lower right).

Horizontal Air Flow

Cool, dry, clean air should enter the engine room as close to the floor as possible using fans/ducts. Allow this air to flow horizontally across the engine room from the entry point across heat sources such as the engine, exposed exhaust, generator, etc. (see Figure 3).

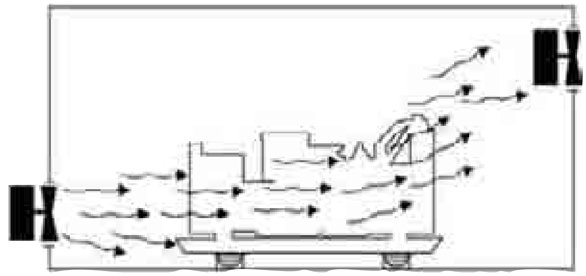

Figure 3. Horizontal air flow.

- For best results, air should flow first across the generator then to both sides of the engine.
- If engine mounted radiators are not used, air discharge fans should be mounted or ducted at the highest point directly over the heat sources.
- Inlet air must circulate between the engines in a multiple engine installation.
- Inlets located at the end of a room with multiple engines will provide adequate ventilation only to the engine nearest the inlet.

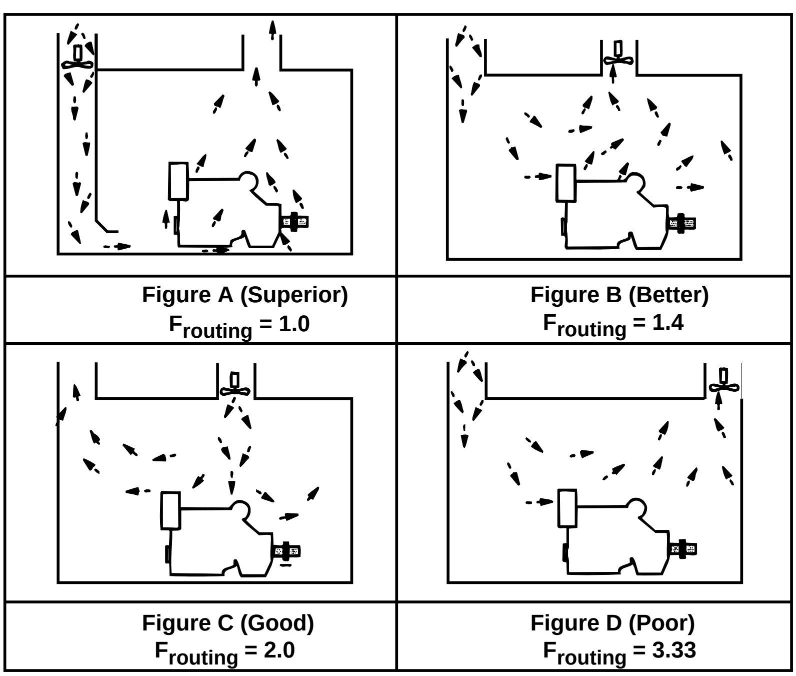

Figure 2. Efficiency of various routings.

Providing horizontal air flow will dissipate engine heat but a certain amount of heat will still radiate and heat the engine room.

Air Curtains
Air curtains, totally enveloping the generator set, provide ventilation without exposing the equipment room to high air velocities (see Figure 4). Radiated heat is removed with approximately half the air flow of a horizontal flow system.

It is important to stretch the air curtain inlet the full length of generator set.

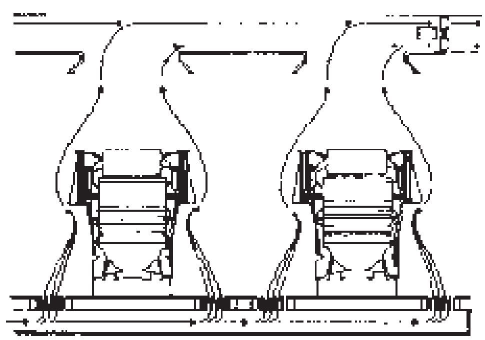

Figure 4. Air curtains.

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

Vertical Air Flow
The least desirable ventilation system discharges outside air directly down on the engines with inlet fans (see Figure 5). Exhaust fans should be mounted in the corners of the room.

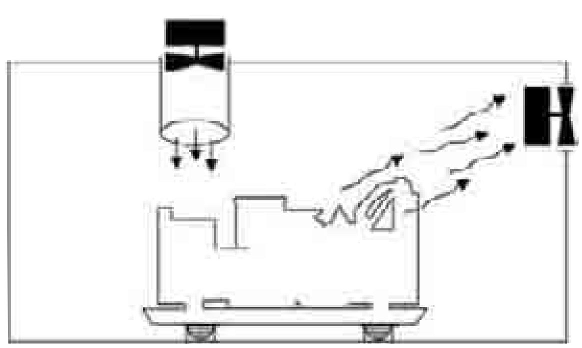

Figure 5. Vertical air flow.

Because this system interferes with the natural rising of hot air, ducting should be used to prevent air from taking the shortest path out of the engine room and bypassing the engine.

Radiator Air
Installations utilizing local free standing or engine-mounted radiators may provide sufficient air flow for cooling. Total ventilation air flow requirements must be compared to radiator fan capabilities.

Intake and exhaust ventilators may have movable or fixed louvers for weather protection. If movable louvers are used, they should be actuated by pneumatic, electric, or hydraulic motors. Do not depend on air pressure developed by the radiator fan to open the vanes. In cold climates, movable louvers can be arranged to provide circulation inside the room until jacket water temperatures reach 88°C (190°F) (see Figure 6).

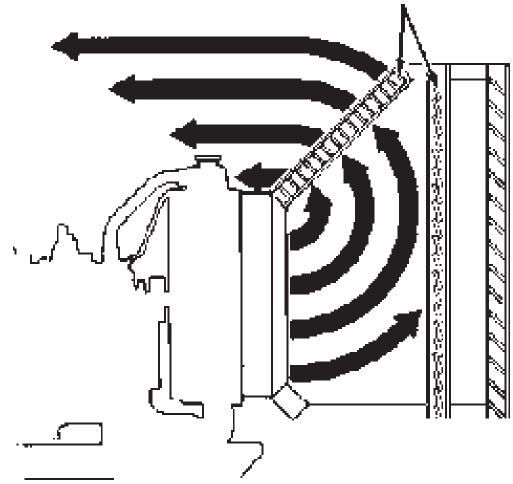

Figure 6. Moveable louvers for recirculation.

Once jacket water temperatures reach 88°C (190°F), the radiator must be furnished with sufficient cooling air. Use a number of small ventilating fans rather than a single large unit. Selective fan operation compensates for varying ambient temperatures while maintaining engine room temperatures.

Increase air flow 10 percent for every 763 m (2500 ft) above sea level to maintain original cooling capability. Final ventilation calculations must use precise heat radiation of selected engine, generator, and power output.

Engine Driven Fans

For most local radiator generator sets, a blower fan (air discharges from engine through radiator) is recommended. The blower fan will move the incoming ventilation air from the generator, past the engine block and manifolds and use that air to cool the radiator.

If a suction fan is used, special considerations must be considered to avoid recirculation of the generator cooling air. It is also much more efficient to use the engine driven blower fan as a room evacuation device than to try to force heated air from a room by pressurizing the room with preheated air from the radiator.

Air Quantity Required

In general, changing the air in the engine room every one or two minutes will be adequate, if flow routing is proper.

Combustion air would be required solely for burning the fuel in the combustion process. Hence the total air intake into the engine room would be the sum of both the combustion air and the cooling air. The quantity of air required for combustion is explained below.

Provisions should be made by the installer to provide incoming ventilation air of 0.1 – 0.2 m^3/min (4-8 cfm) per installed horsepower. This does not include combustion air for the engines.

Engine room exhaust ventilation air should be 110 to 120% of the incoming ventilation air. The excess exhaust ventilation air accomplishes two things:

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

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

Ventilating Fans

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

Fan Location

Fans are most effective when they withdraw ventilation air from the engine room and discharge the hot air to the atmosphere.

Fan Type

Ventilating air fans may be of the axial flow type (propeller fans) or the centrifugal type (squirrel cage blowers). When mounting fans in ventilating air discharge ducts (most effective location), the fan motors should be outside the direct flow of hot ventilating air for longest motor life. The design of centrifugal fans (squirrel cage blowers) is ideal.

Fan Sizing

The *name plate* ratings of fans do not necessarily reflect their *as-installed* conditions. Just because a fan's name plate says it will move 1000 cfm of air does not mean it will move 1000 cfm through an engine room which has severely restricted inlet and/or outlet openings. Fans are often rated under conditions which do not reflect as-installed flow restrictions. In general, the as-installed conditions will be more severe than the fans name plate rating conditions.

Combustion

Required Air Flow

Engine room ventilation can be estimated by the following formula. assuming 38°C (100°F) ambient air temperature:

$$V = \frac{H}{D \times C_p \times \Delta T} + \text{engine combustion air}$$

Where:

V = Ventilating Air (m^3/min), (cfm)

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

D = Density of Air at 38°C (100°F) (1.099 kg/m^3), (0.071 lb/ft^3)

C_p = Specific Heat of Air (0.017 kW × min/kg × K), (0.24 Btu/°F)

ΔT = permissible temperature rise in engine room (°C), (°K)

Note: If duct work is used to bring in air for the engine's combustion air, the last term in the equation can be dropped.

Example:

A 3412 DITA genset has the following data:

Heat rejection: 659 kW (37 478 Btu/min)

Temperature rise: 11°C (20°F)

Solution:

The estimated engine room ventilation required for this arrangement:

$$V = \frac{659}{1.099 \times 0.017 \times 11} = 3206.61\ m^3/min$$

$$V = \frac{37478}{0.071 \times 0.24 \times 20} = 109970.7\ cfm$$

Combustion Air Ducts

Design combustion air ducts to have a minimum flow restriction. Note that very large amounts of air flow through the combustion air ducts.

Air Cleaners

Engines must be protected from ingesting foreign material. The engine-mounted air filter elements must never be remote-mounted, without factory approval.

If large amounts of sea spray, dust, or insects are expected, external, remote-mounted, precleaners may be installed at the inlet to a duct system to extend the life of the engine-mounted filter elements.

Location

The combustion air ducts should be located close to the engine. Usually, flexible connections are used to reduce noise from the ducting system. In addition, all duct work must be supported on the engine to avoid unnecessary loading on the turbochargers.

Duct Restriction

Total duct air flow restriction, including air cleaners, should not exceed 2.49 kPa (10 in. H_2O) measured while the engine is producing full rated power. It is good design practice to design combustion air ducts to give the lowest practical restriction to air flow, since this will result in longer times between filter element service or replacement.

Air Velocity in Combustion Air Ducts

Combustion air duct velocity should not exceed 610 m/min (2000 ft/min). Higher velocities will cause unacceptable noise levels and excessive flow restriction.

Water Traps

Traps should be included to eliminate any rain or spray from the combustion air. Rain and spray can cause very rapid plugging of the paper air filter elements on some engines. This will reduce the flow of air through the engine, raising the exhaust temperature with potentially damaging effects.

Crankcase Ventilation

Normal combustion pressures of an internal combustion engine cause a certain amount of blowby past the piston rings into the crankcase. To prevent pressure buildup within the crankcase, vent tubes are provided to allow the gas to escape. Each engine's fumes disposal should have separate discharge pipes.

Crankcase fumes must not be discharged into air ventilating ducts or exhaust pipes. They will become coated with oil deposits. Crankcase fumes must be either ingested by the engine or piped out of the engine room.

The crankcase vent pipe may be directed into the exhaust gas flow at the termination of the exhaust pipe.

Preferably, the crankcase vent pipe will vent directly to the atmosphere. The vent pipe termination should be directed to prevent rain/spray entering the engine.

Design Considerations

Heat Rejection

Engine Radiant

The heat input into the engine is the sum of the work output and the heat generated. Besides the work output, heat is rejected to the atmosphere, into the oil cooler, aftercooler, through the exhaust stack and also through the jacket water. Hence, while designing the ventilation system in a room, the engine generated heat should be taken into consideration. This information can be found in TMI.

Generator Radiant

The heat radiated by the generator can be calculated by the following formulas:

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

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

Where:

HRG = Heat Radiated by the Generator (kW), (Btu/min)
P = Generator Output at Maximum Engine Rating (ekW)
Eff = Generator Efficiency %/100%
(Example: Eff = 94%/100% = 0.94)

Example:
A 3512B, 975 ekW standby generator set has a generator efficiency of 92%. What is the generator radiant heat for this genset?

Solution:

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

$$\text{Eff} = \frac{92\%}{100\%} = 0.92$$

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

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

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

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

Engine Room Auxiliaries

The consultant should take all auxiliary equipment besides the generator set into consideration while designing the ventilation system. Auxiliary equipment such as switchgear, compressors, pumps, lighting, piping etc. are sources of heat. Thus the design should cover all main and auxiliary equipment so that the room temperature is maintained.

Engine Room Temperature

A 8.5°C (15°F) temperature rise above the ambient temperature is a reasonable target for engine rooms. (Ambient air temperature refers to the air temperature surrounding the engine room.) However, in cold climates this may cause discomfort from the flow of cold air. Restrict flow only if engine combustion air is available and engine jacket water is adequately cooled. In general, engine room temperature should not exceed 49°C (120°F). The primary reason for cooling an engine room is to protect various components from excessive temperatures. Items that require cooling are:

- Electrical components such as magnetos, interface box and timing control.
- Cool air to the air cleaner inlet.
- Cool air to cool the torsional damper.
- Habitable temperatures for the engine operator or service personnel.
- Cooling air for the generator or other driven equipment.

In larger multiple engine sites the normal 8.5° C (15° F) temperature rise guidelines for engine rooms require unobtainable or uncomfortable air velocities.

For larger sites, a ventilation system that gives priority to the five items listed above and provides a bottom to top air flow similar to that shown in Figure 4 can be designed for a temperature rise of 17° C (30° F).

Air Velocity for Personnel Comfort
Maintain air velocity of at least 1.5 m/s (5 ft/s) in working areas adjacent to sources of heat, or where air temperatures exceed 100°F (35°C). This does *not* mean that all the air in the engine room should be agitated so violently. High air velocity around engines and other heat sources is not good ventilation practice. High velocity air aimed at engines will hasten transfer of heat to the air, raising average engine room air temperature.

Table 1 lists typical air motions:

Air Velocity		
m/min	(fpm)	Conditions
15.2	50	Offices, seated worker
30.5	100	Factory, standing worker
45.7	150	Capture velocity, light dust
61	200	Maximum continuous worker exposure
396	1300	Capture velocity, rain
306 – 610	1000-2000	Maximum intermittent exposure

Table 1. Air velocity.

Radiators

Installations with engine-mounted radiators using engine room air for cooling (Figure 7), generally provide more air flow than is needed for adequate ventilation. The high air flow combined with low ambient temperatures, below 21°C (70°F), may cause water to condense inside exposed engine components, like valve covers. This can result in oil and maintenance problems. Therefore, special installation considerations must be made in cold climates.

There are two methods that can be used to overcome this problem.

- Remote mounted and specially ducted engine-mounted radiators do not require engine room air for cooling (see Figure 8). 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, generator and other equipment which increases the overall cost of the system. This system is suitable for continuous duty applications.

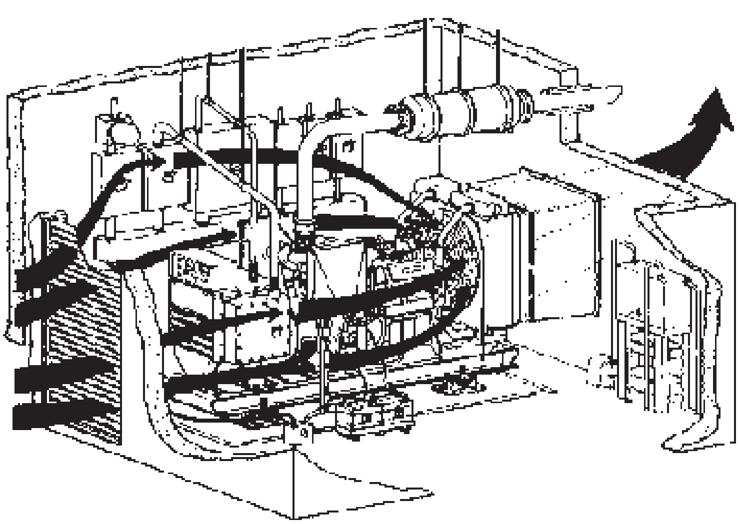

Figure 7. Engine driven fan arrangement.

- Thermostatically controlled louvers can be installed to recirculate some of the radiator exhaust in order to maintain a warm air flow across the engine (see Figure 9). 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 0.12 kPa (0.5 in. H_2O). Any restriction above this limit could reduce air flow through the radiator and overheat the engine.

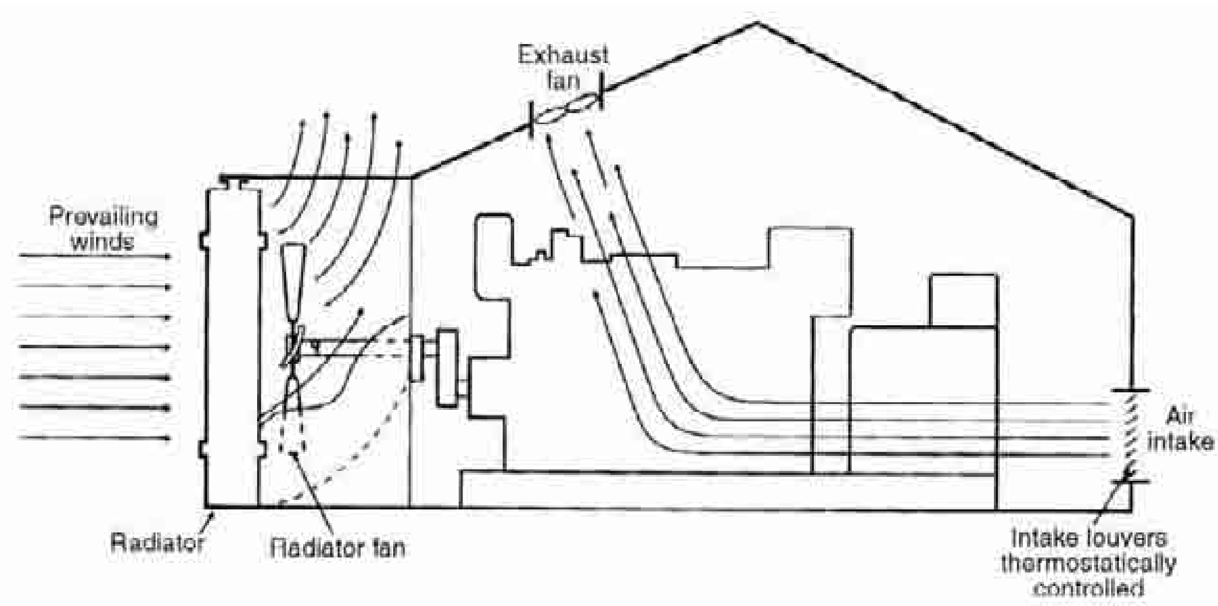

Figure 8. Engine driven fan arrangement.

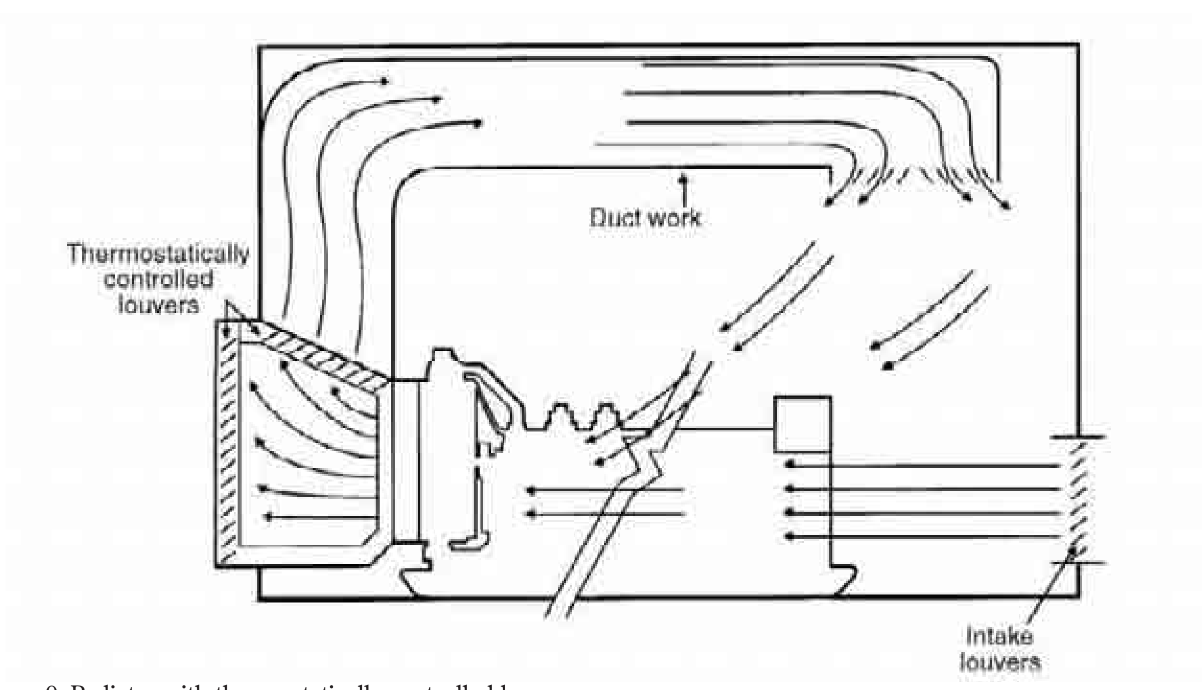

Figure 9. Radiator with thermostatically controlled louvers.

Radiator Sizing

Radiator core frontal area should be as large as possible to minimize restriction to airflow. Low radiator core restriction usually results in being able to provide a larger slower turning fan.

Radiators which are nearly square can provide the most effective fan performance. They can be installed with a minimum of unswept core area. As a general 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 air flow.

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.

Fan Sizing

As a general 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 compromise for meeting noise legislation requirements and cooling system performance requirements. Maximum acceptable 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 (see Figure 10).

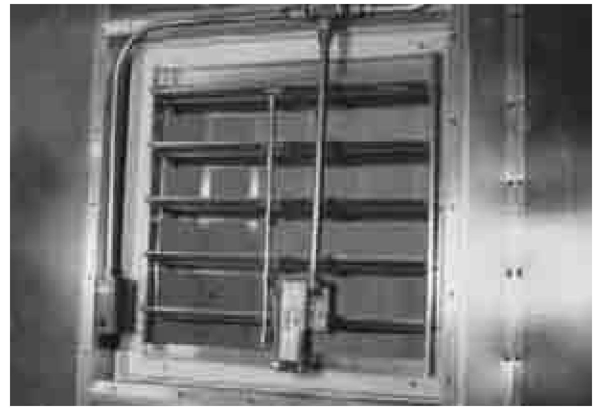

Figure 10. Moveable louvers.

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 air flow. 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 air flow to the engine which can cause shutdown.

Enclosures

Enclosures trap radiated heat 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.

Special Considerations

Refrigeration Equipment

Prevent refrigerant leakage into the engine's air intake system. Freon or ammonia will cause severe engine damage if drawn into the engine's combustion chambers. The chemicals in refrigerants become highly corrosive acids in the engine's combustion chambers.

If refrigeration equipment is installed within the same compartment as a diesel engine, the diesel engine must take its combustion air from a specially supplied ductwork system which carries air to the engine from an area free of refrigerant fumes.

Exhaust Pipe Insulation Recommended

Long runs of hot, uninsulated exhaust piping will dissipate more heat into the engine room than all the 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 air flow 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 — especially for standby applications.

Notes

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