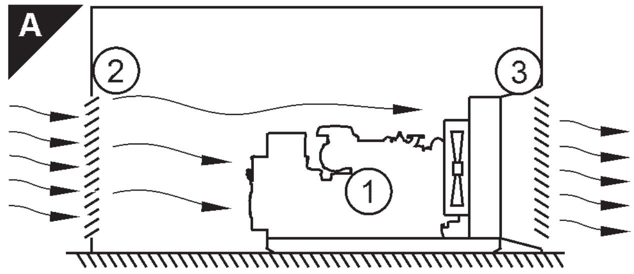
Radiator Cooling

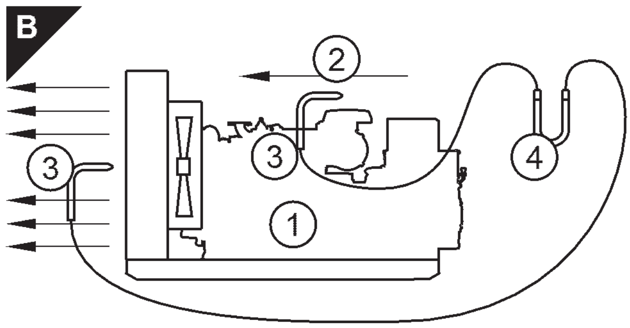
The radiator cooling pack option uses air to cool the engine, rather than sea water. As such a good supply of air is vital to achieving the correct cooling performance. Not only is the supply of air important but so is the exhaust of air from the radiator. The complete air circuit must be given great consideration to achieve the correct cooling performance.

Illustration (A) shows the cooling air circuit. Although the exact details of the layout will need to vary from installation to installation, the basic air circuit will remain the same. The marine genset utilises a pusher fan, which draws cooling air from the inlet (A2) over the generator and engine (A1), and then pushes through the radiator and charge air cooler. Typically the exhaust from the radiator and charge air cooler then exit the engine room via a vent to outside (A3). Cool air enters the engine room from outside through another set of vents.

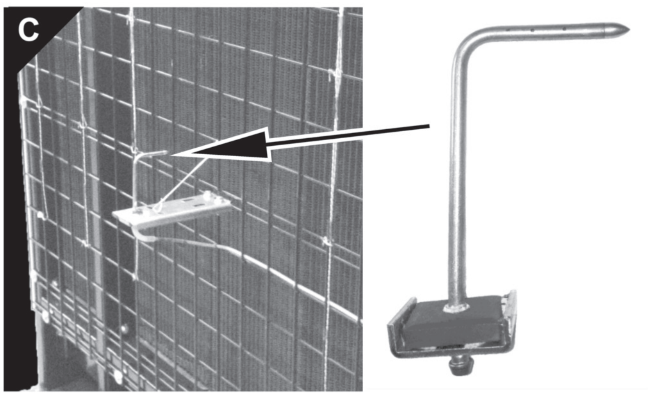


The radiator cooling system is designed for a maximum air temperature behind the genset of 50^{O}C. The design accounts for the radiated heat from the engine and generator which will lead to air temperatures greater than 50^{O}C at the inlet to of the radiator fan. The design does not account for any other heat sources in the engine bay. If other sources of heat are present then additional ventilation will need to be considered. This is especially important for gensets likely to operate in hotter climates.

The radiator cooling system is designed to operate with a maximum duct restriction pressure of 127Pa (0.5 in H20). The pressure is measured from a location in-front of the fan (typically along the length of the engine) to a location directly in-front of the radiator outlet, illustrations (B3) and (C). In this way the total pressure over the cooling pack (B2) is measured, including both the restrictions encountered in drawing the air into the engine and the restriction encountered in air exiting the engine room. When designing the engine room ventilation a pressure restriction target of 63.5Pa should be aimed for, although lower is better.



In order to measure the duct restriction of an installation, static pressure tubes will be required. Use of any other means is likely to give inaccurate results. A water manometer (B4) is normally sufficient for measuring the pressure. The static tube should be aligned parallel with the air flow. A fine thread on a stick is a useful tool in identifying the direction of air flow over the engine. (Care should be taken to keep it away from rotating parts, including the fan) Illustrations (B) and (C) shows typical locations of the static tubes used for taking pressure readings.



Air Flow Measurements

An alternative to taking pressure measurements is to measure the air flow through the radiator. This can be done using an anemometer to measure the air velocity through an opening of known area, from which the volumetric flow can be calculated. As air density decreases with temperature, to get an accurate reading air flow measurements should be taken with the generator running, but at no load, such that there is minimum heating of the air flow.

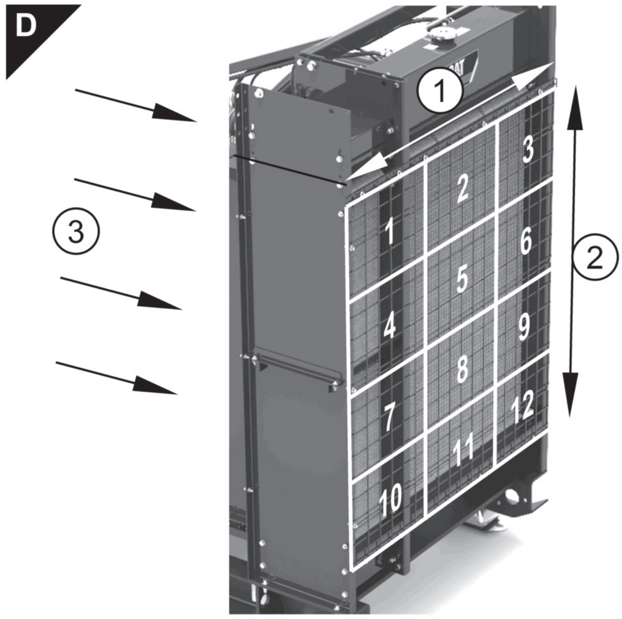
Anemometers are specifically available for ventilation and duct work, an instrument of this type should be used where possible. Measurements should be made where air flow is uniform, ideally just after the radiator outlet, but not after any louvers, bends or obstructions which could lead to non-uniform air velocities. An accurate measurement of volumetric flow is best made by taking at least twelve air velocity readings across the opening. It is best to draw up a grid with each cell being of equal area. Air velocity readings are then averaged, to give a total average air velocity through the opening. This is then multiplied by the opening area to give the volumetric air flow.

Illustration (D) shows the layout of the grid for calculating the volumetric flow

1 Width.

2 Height.

3 Air flow.



TMI contains air flow data for the fans fitted to CAT generator sets along with the restriction curves for radiator cores. Overlaying the two curves will give the operating volumetric air flow at the curve intersection point. If the air flow is measured then the total pressure across the fan can be measured of the fan curve. Given the air flow reading, the pressure drop can also be read off the radiator restriction curve. The difference in the two pressures is the total duct restriction present within the air system.

Volumetric Flow is given by:

- $Q = h \times w \times v_m$
- $v_m = (v_1 + v_2 + v_3 + v_4 + \ldots + v_{12}) / 12$

Where:

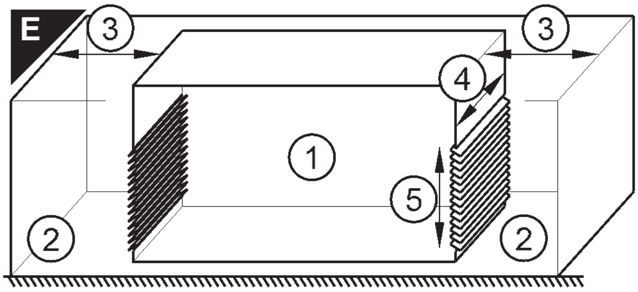
- $V_{1\text{-}12}$: Air velocity readings 1->12 (m/s or ft/min)
- v_m : Average air velocity (m/s or ft/min)
- h : Opening height (m or ft)
- w : Opening width (m or ft)
- Q : Air volumetric flow (m^3/s or cfm)

Whilst taking pressure and air flow measurements can be useful verification methods, good design practice should be used to correctly size and locate inlet and exhaust vents. The biggest restriction around the air circuit is likely to be due to the inlet and exhaust vents themselves. As such the supplier of the vents should be consulted for correct sizing. Other good practices include:

- Exhaust pipes should be lagged, right from the turbine outlet. The lagging should be sufficient to ensure that the external surface temperature does not exceed 220°C at full load. This helps to ensure that no extra heat is carried into the radiator air.
- Exhaust routing should, where possible, be away from the radiator so that the air flow into the radiator is not impeded.
- Ensure there is sufficient space in front and behind of any exhaust or inlet vent (see illustration E), this includes:
    - Fire / heavy weather hatches should be able to fully open away from the vent.
    - Placing the vent such that a bulkhead is not immediately in front or behind the opening.
    - A suggested clearance between the vent and any bulkhead or otherwise is at least the longest of the height or width of the vent itself.

- Inlet air vents should be placed such that they pick up cool ambient air, not air which has picked up any additional heat, such as air exhausted from another engine room.
- The exhaust vent should have a frontal area equivalent to the total radiator exit area and ideally the same dimensions. If this cannot be achieved then tapered ductwork should be used to adapt the two together. A minimum length of 1m (3' 3") is recommended for any adapting ductwork, where a significant dimension change needs to take place.

Illustration (E) shows the basic considerartions for allowing the genset to cool and breath.



1 Engine room.

2 Vents.

3 *D_M: minimum distance.

4 V_W: vent width.

5 V_H: vent height.

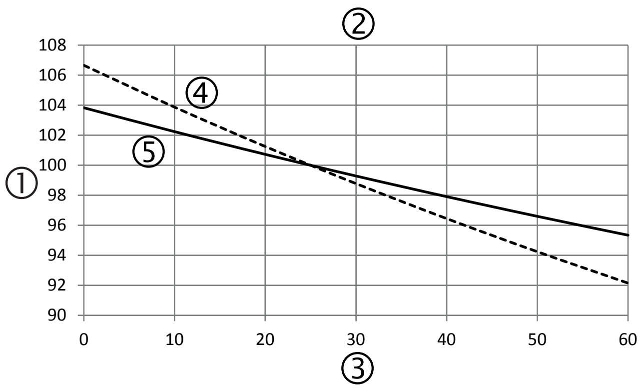
*Dm should meet the following conditions:
Dm ≥ Vw
and
Dm ≥ VH

Power Variability

All engines are subject to variability of power output dependant on various external factors. Two of these factors with high significance are inlet air and fuel. Inlet air is largely affected by temperature, with atmospheric pressure variation being minor for marine sea-level installations. Diesel engines inject fuel by volume, and as such density changes vary the mass of fuel being injected.

The graphs below show the variation on engine power output based on changes to air inlet temperature and fuel density. The power output change with fuel is the same across all engines regardless of cooling system. The power output change with inlet air temperature does however depend on the charge air cooling method. Engines using an air to water cooler, Heat Exchanged and Keel Cooled, have less variation. This is due to the water being a more stable heat-sink, with resulting inlet manifold air temperatures being stable also. Air to air cooling methods, Radiators, are less stable with the ambient air being used to cool the charge air, leading to high output variability.

CAT engines have their rated power defined at standardised conditions; typically these are 25^{O}C air and 850 kg/m^3 fuel. As such operating in conditions away from these will likely cause engine power output to drop. This should be born in mind when designing engine room ventilation, so that ambient air temperatures are kept to a minimum.



1 Power adjustment - %.

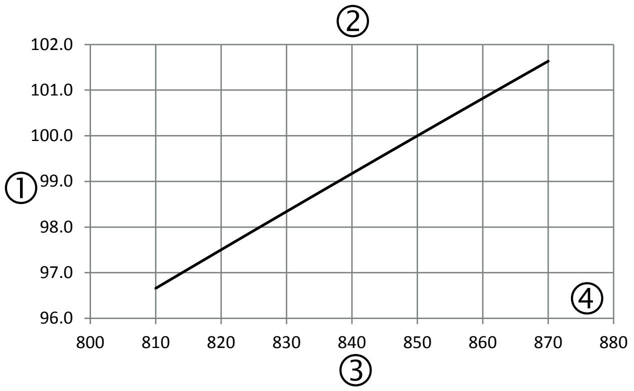
2 Engine power adjustment by ambient temperature. SAE J1995 rating standard.

3 Ambient temperature.

4 Radiator.

5 Heat exchanger & keel cooled.

P_{Baro} = 100 kPa
P_{vap} = 1 kPa
F_m = 0.614 (engine factor).
Turbocharged engines only.



1 Power adjustment - %.
2 Engine power adjustment by fuel density. SAE J1995 rating standard.
3 Fuel density - kg/m^3.
4 All cooling options.