Basic A&I

Application & Installation of Generators

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GPSD
GLOBAL POWER SOLUTIONS DIVISION

CATERPILLAR®

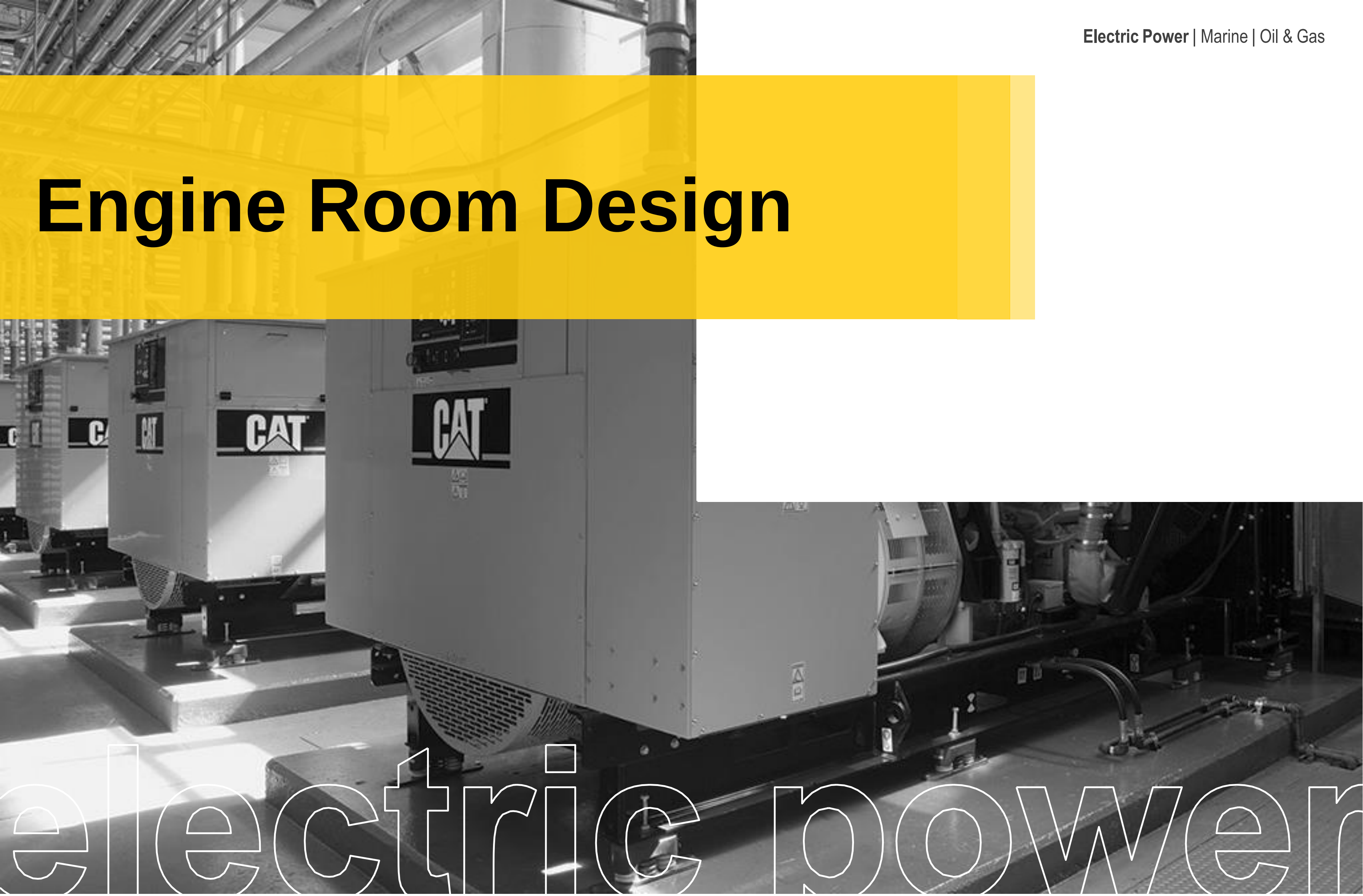
What is A&I?

"A&I" is <u>Application</u> and <u>Installation</u> engineering technical support…

Agenda

- Engine Room Design
- Air Intake Systems
- Cooling Systems
- Exhaust Systems
- Fuel Systems
- Engine Room Ventilation
- Foundations & Isolation

Engine Room Design



Engine Room Design Considerations

- Single or Multiple Use Facility
- Single or Multiple Generators
- Prime Power or Standby
- Ventilation Requirements
- Cooling Requirements
- Serviceability
- Clearances
- Access

Single or Multiple Use Facility

Single Use Facility

This room is primarily dedicated to generators.

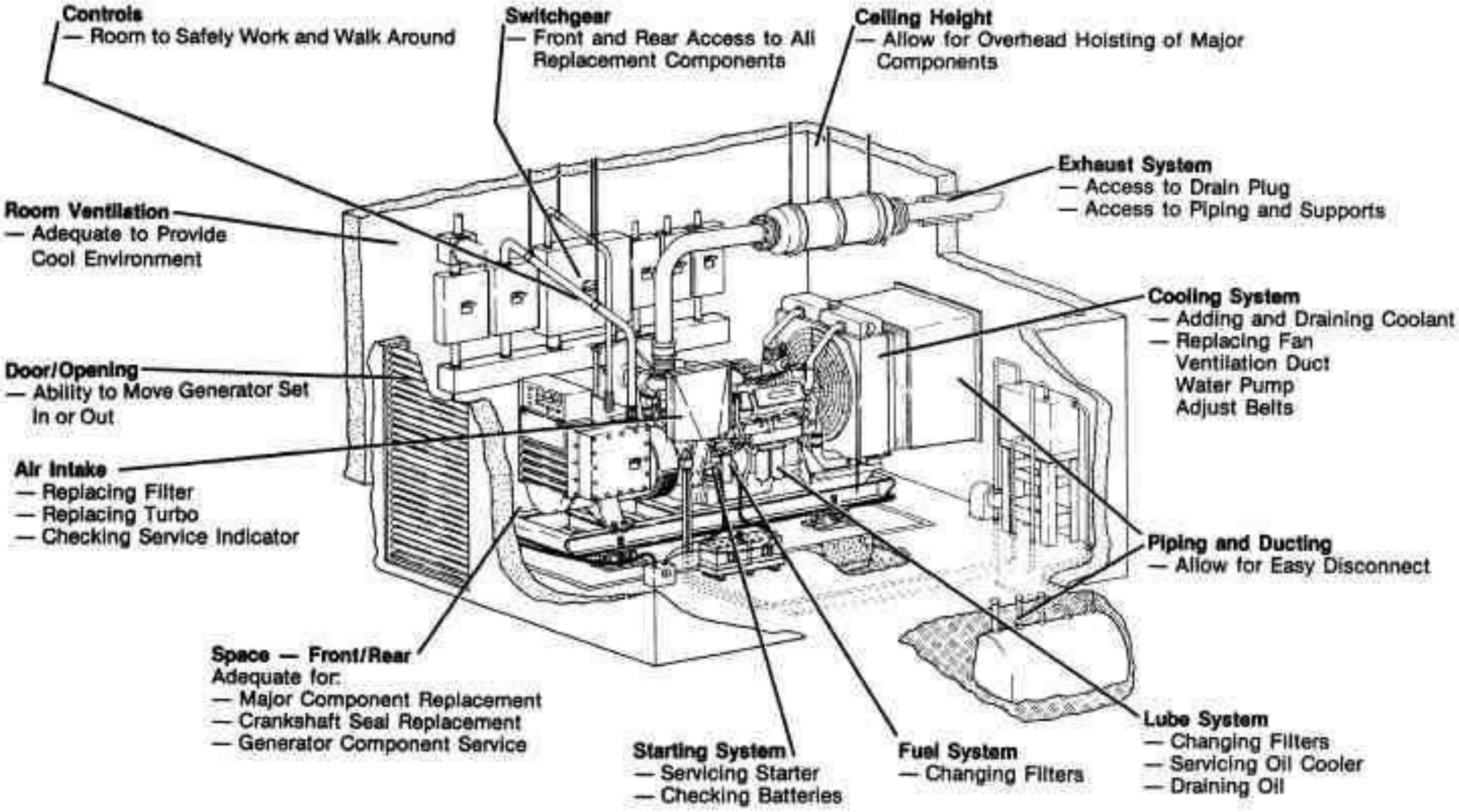
Multiple Use Facility

The multi use facility would not only have generator sets, but also auxiliary equipment such as boiler units, compressors, etc.

Prime or Standby

- Location

Serviceability



Service Convenience

- Compressed Air
- Ventilation Air
- Water
- Emergency Wash Station
- Fire Suppression System
- Cable Routing
- Load Testing

Clearances

- Lifting Capabilities
- Overhead Clearances
- Side Clearances
- Front and Rear Clearances
- Underneath Clearance
- Electrical Connections

Access

- Door Width
- Access for Routine Maintenance
- Major Repair
- Service Elevator

Several Other Considerations

- Emergency/Rental Generator
- Expansion (future genset)
- Installation Considerations - Lift Points
- Total Package Weight
- Engine Storage
- Removing Moisture in Generators
- Flooring Considerations
- Rooftop Installations
- Fire & Explosion Prevention
- Lines, Tubes & Hoses

Air Intake Systems

Air Cleanliness

- Dirt and debris ingested into the engine are a major source of wear on moving engine parts.
- The air intake is a significant path for dirt and debris to enter the engine.
- Sources of dirt and debris in the air intake include:
  - Materials left from initial fabrication and assembly of ducts
  - Filter changes
  - Air intake duct leaks
  - Environment

Particles in Intake Air

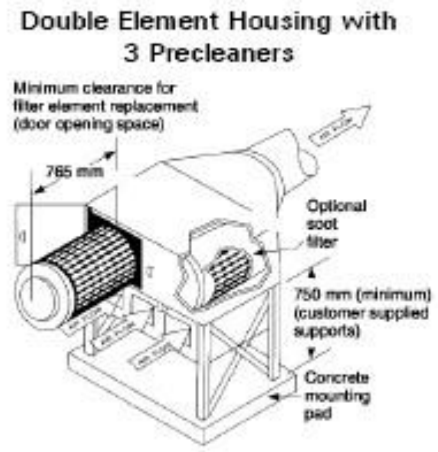
- Particles under 0.001mm (1 micron) diameter have little effect and will pass out through the exhaust

- Particles from 0.001 – 0.01mm (1-10 microns) diameter have a measurable effect on the engine
  - *The average human hair is 0.08mm (80 microns) in diameter*

- One teaspoon of 0.125mm (125 microns) diameter dust per hour will create catastrophic failure of an engine in 24 hours

Air Cleaner Configurations

- Engine mounted
- Remote mounted
- Multiple element
- Multi-stage (Precleaners)



Air Intake Ducts

- May be a requirement of the site configuration
- Best practice to leave engine-mounted air cleaners on the engine and route ducts from them
- For remote-mounted air cleaners, ducts must be completely sealed to ensure all intake air is drawn through the filter elements

Combustion Air Flow Requirements

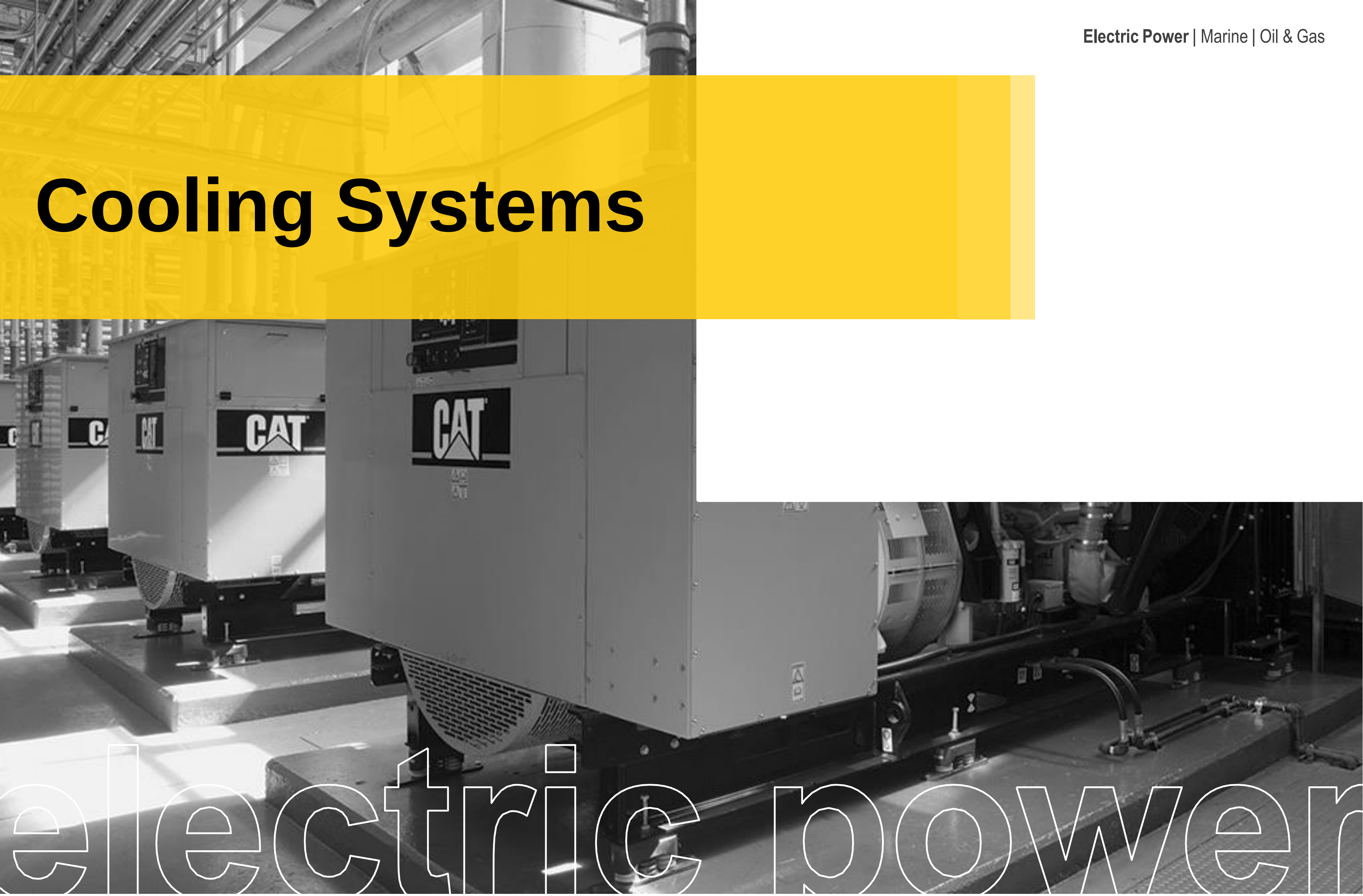
- Varies according to engine model, rating and fuel
- Provided on technical data sheet in both volumetric and mass flow terms
- Establishes total flow requirement for use in design of the site air intake system
- Used in restriction calculations

Gen Power ekW	Percent Load	Engine Power with fan kW	Engine BMEP kPa	BSFC g/kW-hr	Fuel Rate L/hr
900	100	1012.0	2102	200.6	242.0
810	90	914.9	1900	199.6	217.6
720	80	819.1	1701	198.8	194.1
675	75	771.6	1603	198.6	182.6
630	70	724.1	1504	198.7	171.5
540	60	629.9	1308	199.6	149.9
450	50	536.3	1114	201.8	129.0
360	40	445.2	925	205.5	109.0
270	30	352.1	731	212.0	89.0
225	25	30[illegible].7	633	217.2	78.9
180	20	256.8	533	224.8	68.8
90	10	159.4	331	255.0	48.4

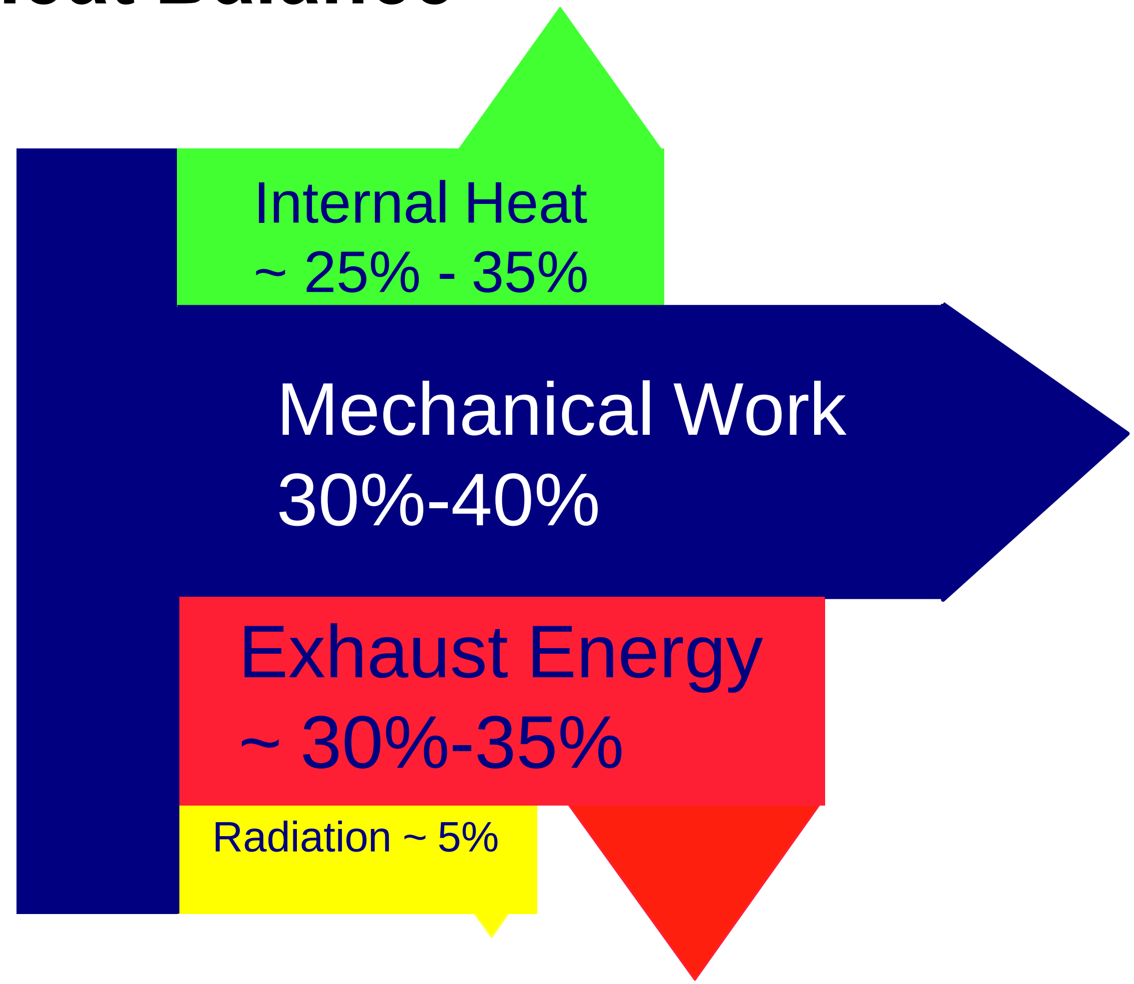
Gen Power ekW	Intake Manifold Temp °C	Intake Manifold Pressure kPa	Intake Air Flow m³/min	Exh Manifold Temp °C	Exh Stk Temp °C	Exh Gas Flow m³/min
900	49.3	194.1	74.80	[illegible]40.7	482.0	199.40
810	45.1	169.3	69.30	[illegible]11.5	461.9	179.60
720	40.3	144.2	63.30	[illegible]84.7	450.3	161.40
675	37.8	131.7	60.40	[illegible]71.4	444.6	152.70
630	35.6	119.7	57.50	[illegible]58.0	438.2	144.10
540	31.5	97.4	52.00	530.0	423.0	127.40
450	28.2	76.7	46.90	500.4	404.5	111.60
360	25.8	58.2	42.10	465.7	382.8	96.90
270	24.1	41.3	37.70	421.2	353.9	82.70
225	23.5	33.7	35.60	395.5	336.4	75.90
180	23.0	26.6	33.70	367.3	316.8	69.30
90	22.2	[illegible]5.7	30.90	300.5	264.2	57.60

Heat Rejection Data

Cooling Systems



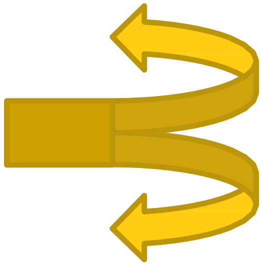
Engine Heat Balance



Review of the Basics

Internal heat is removed by:

- Jacket water
- Oil cooler
- Aftercooler



Oil cooler heat load is included in the jacket water heat load on diesel engines and in the aftercooler heat load on most gas engines.

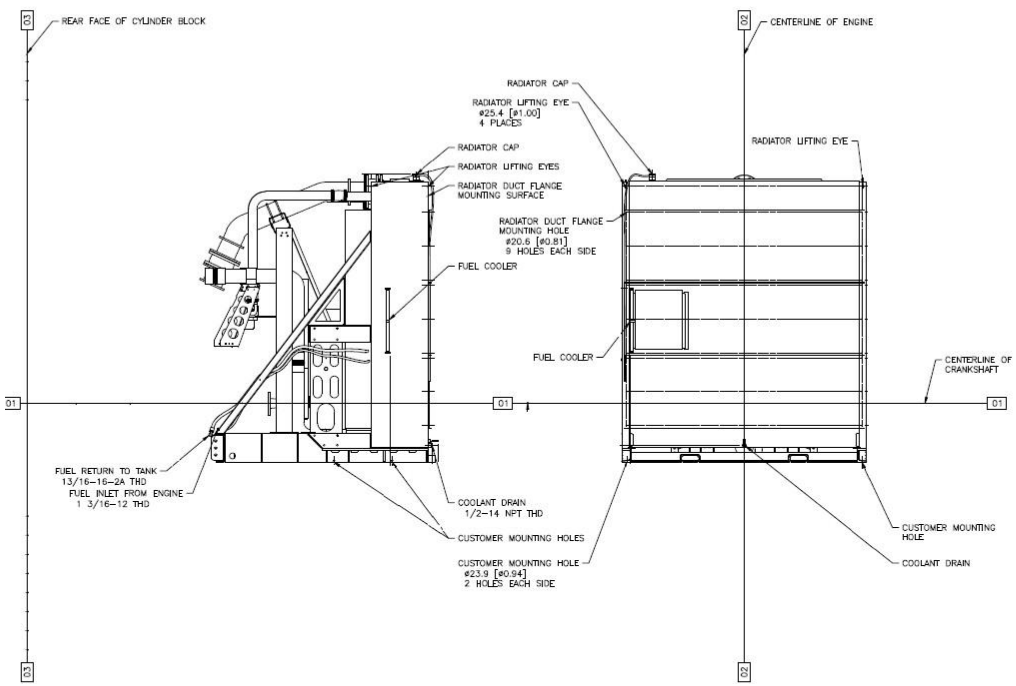
Review of the Basics

Cooling system is defined by how the aftercooler heat is handled:

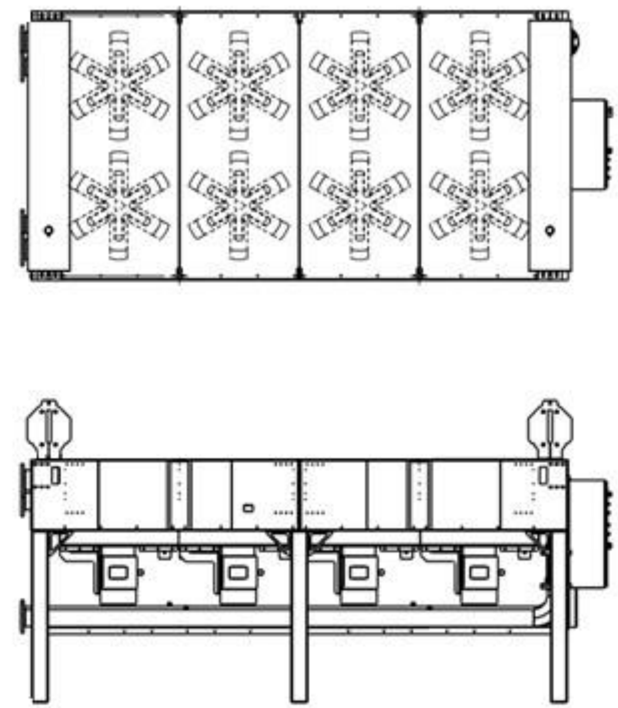
- JWAC jacket water aftercooled
- SCAC separate circuit aftercooled
- ATAAC air to air aftercooled
- Two stage aftercooler (JWAC+SCAC)

Radiators

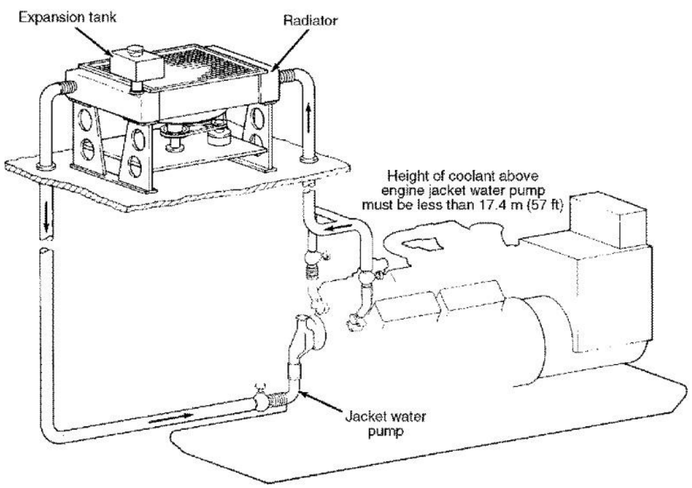
Installed

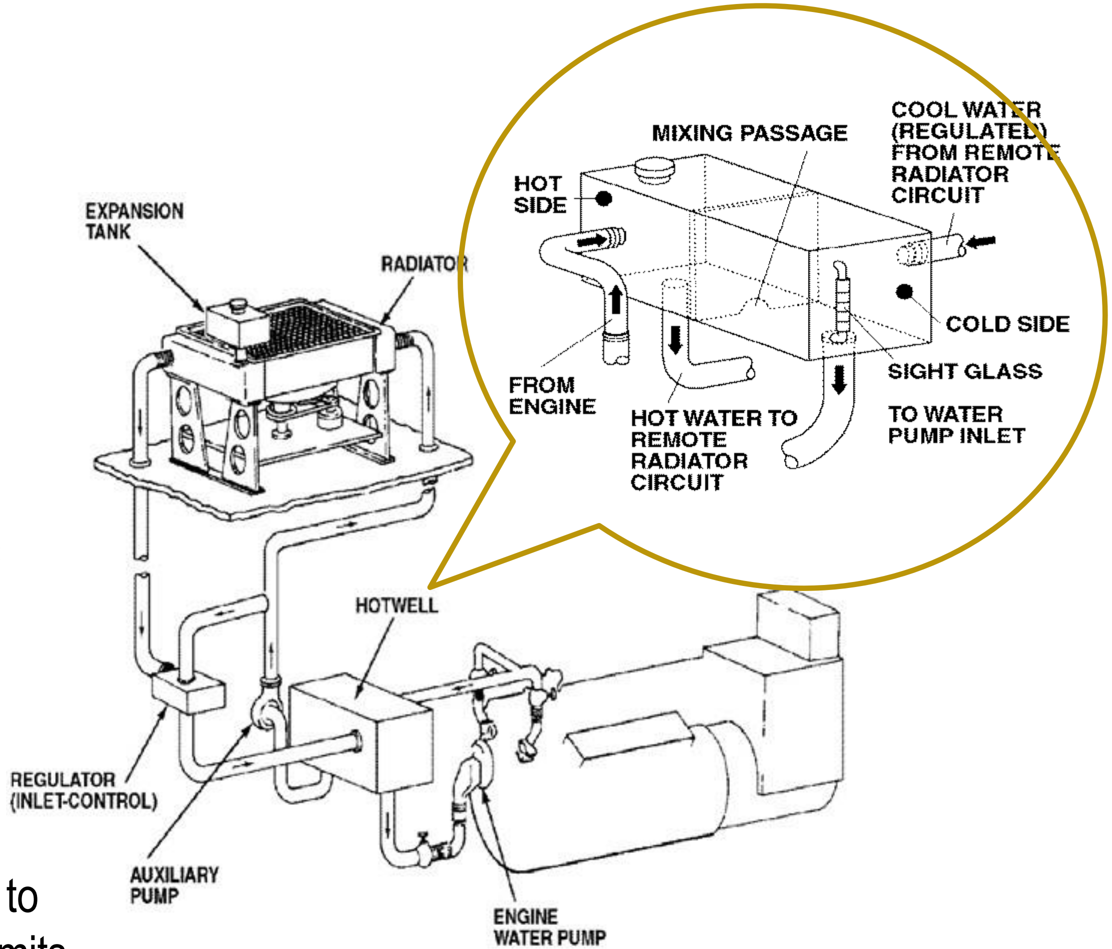


Remote



Radiator Height Limits





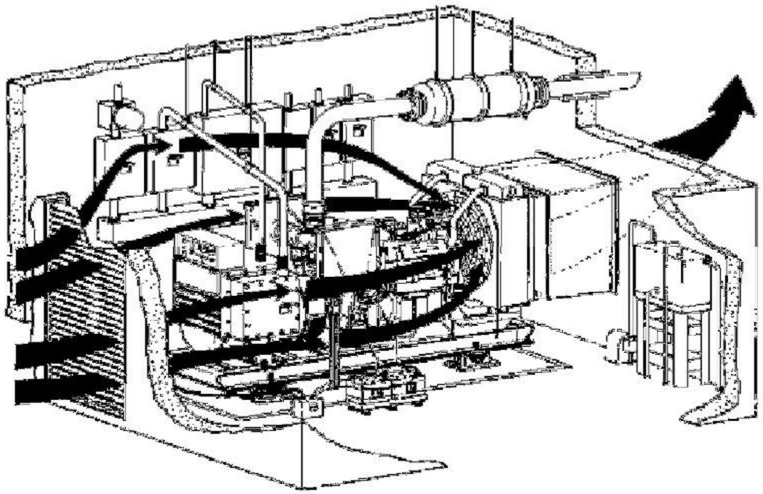
If more than 57ft vertical distance from JW pump to highest point in cooling circuit, a hot well or heat exchanger is needed to keep static head pressure below seal limits.

Radiator Air Flow

- Try to design room to ½” H_2O restriction
- Plan cooling at ¾” H_2O restriction

- Louvers typically require an additional 25-95% opening, heavy duty bird screen material, 20-40%

- Walls at the air exit should be 2 fan diameters or more away from the radiator



Radiator Sizing

Need to Know:

- Heat rejection to JW and AC
- Radiant heat added to room
- Room air restriction (if installed radiator)
- Line loss and pump flow rate (if remote radiator)
- Site altitude
- Max ambient temperature

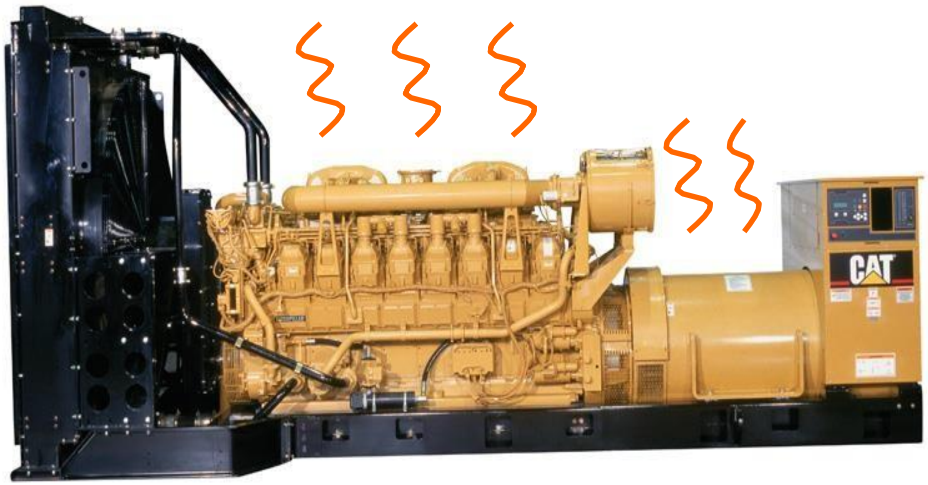
Heat Rise

- Heat Rise - Potential temp rise as intake air moves across gen-set

  Example for Caterpillar Diesel Engines:

  – Tier 2 engine in a power room: 4^{o}C heat rise
  – Tier 4 engine with CEM in a power room: 6^{o}C heat rise
  – Tier 2 engine in an enclosure: 7^{o}C heat rise
  - **THESE ARE MINIMUM VALUES**

- When specifying, make sure to clarify location of ambient temp or specify cooling system capability including heat rise.

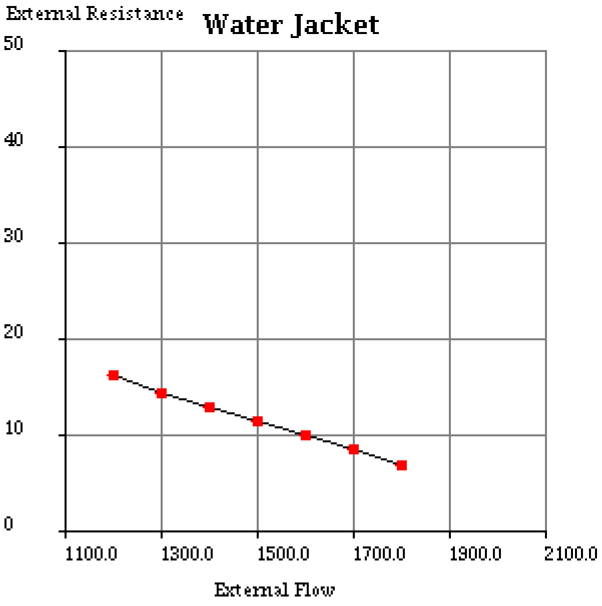


Line Restriction

- **Always keep external restriction between the limits shown for the pump in technical information**
- Too much restriction
  - Too little flow to cool the engine
  - Cavitation that ruins the pump
- Too little restriction
  - Too much velocity erodes the cooling system

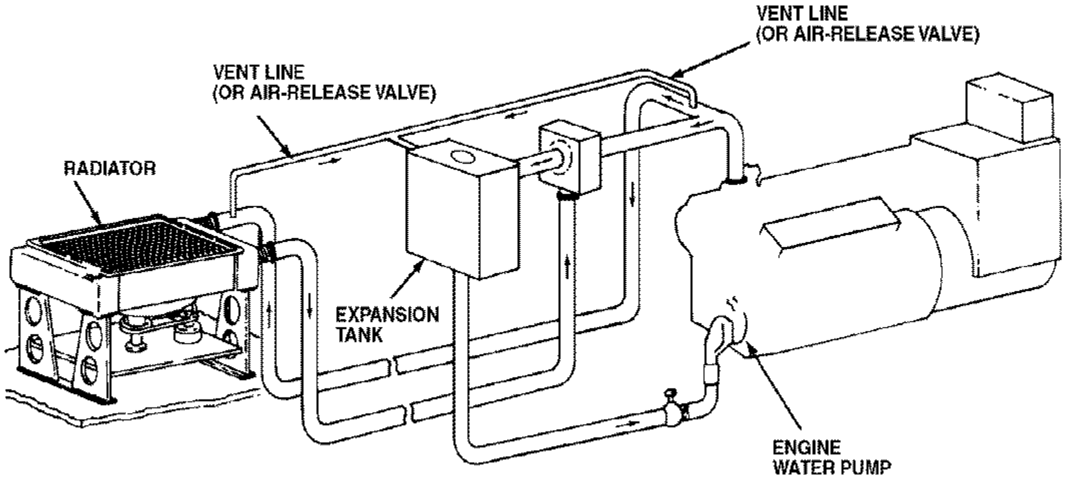
Engine Speed RPM: 1800
Pump Speed RPM: 2400

EXT RESIST M H2O	EXT FLOW L/MIN
6.8	1,802.0
8.4	1,700.0
9.8	1,600.0
11.4	1,500.0
12.9	1,400.0
14.3	1,300.0
16.1	1,200.0

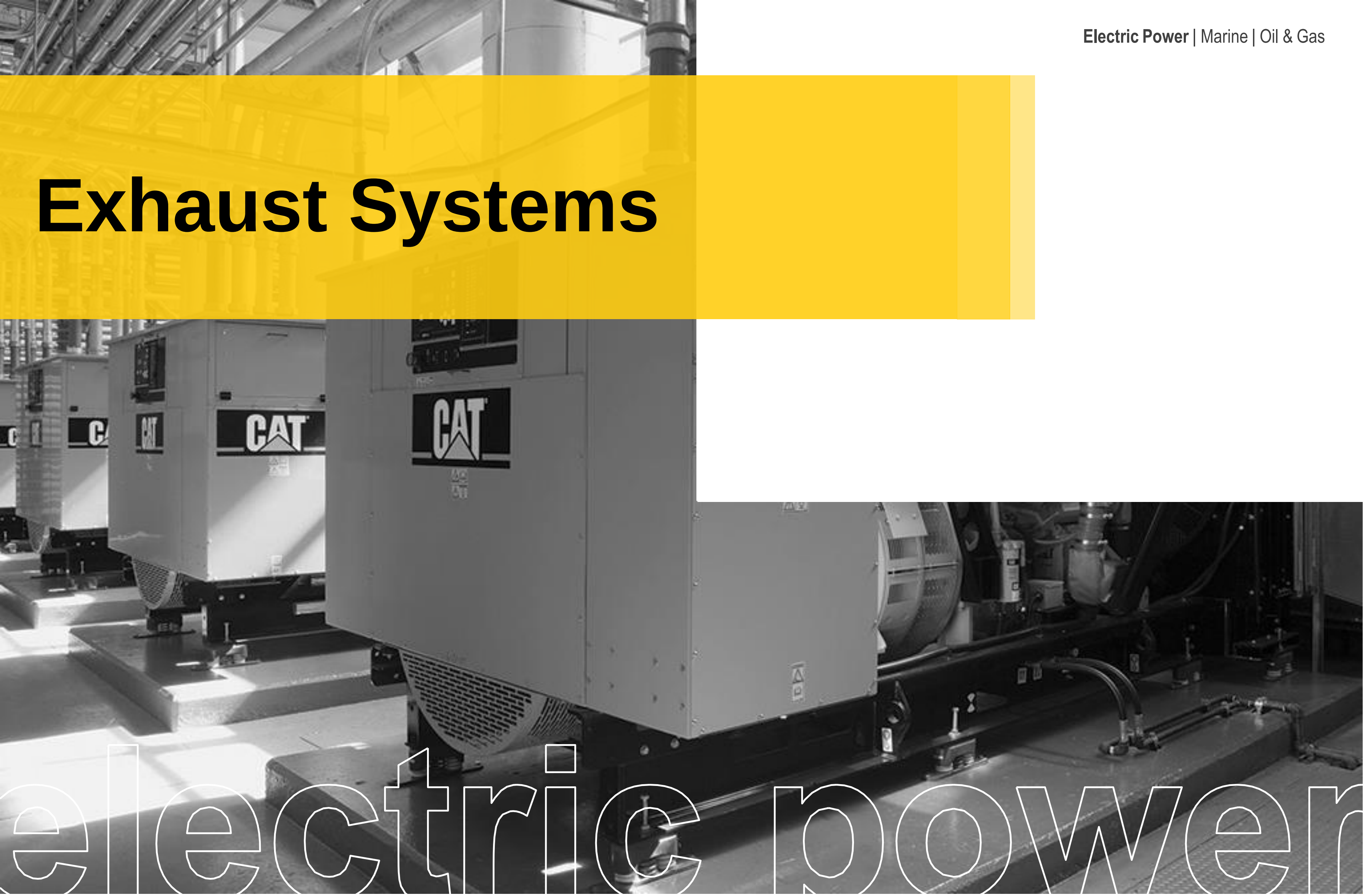


Venting

- Vent lines or air release valves are needed at every air trap point.
- Vent lines need to be constantly rising until they reach the highest point in the system.
- Air release valves use a float and spring to keep the system closed until steam builds up in a cavity.



Exhaust Systems



Exhaust System Considerations

- Minimize back pressure
- Reduce noise
- Provide adequate clearance
- Ensure proper mounting

Back Pressure

- Target – Half the maximum allowable system back pressure
- Common Culprits
  - Exhaust pipe diameter
  - Sharp bends
  - Exhaust pipe length
  - Silencer resistance
- Calculate and Measure

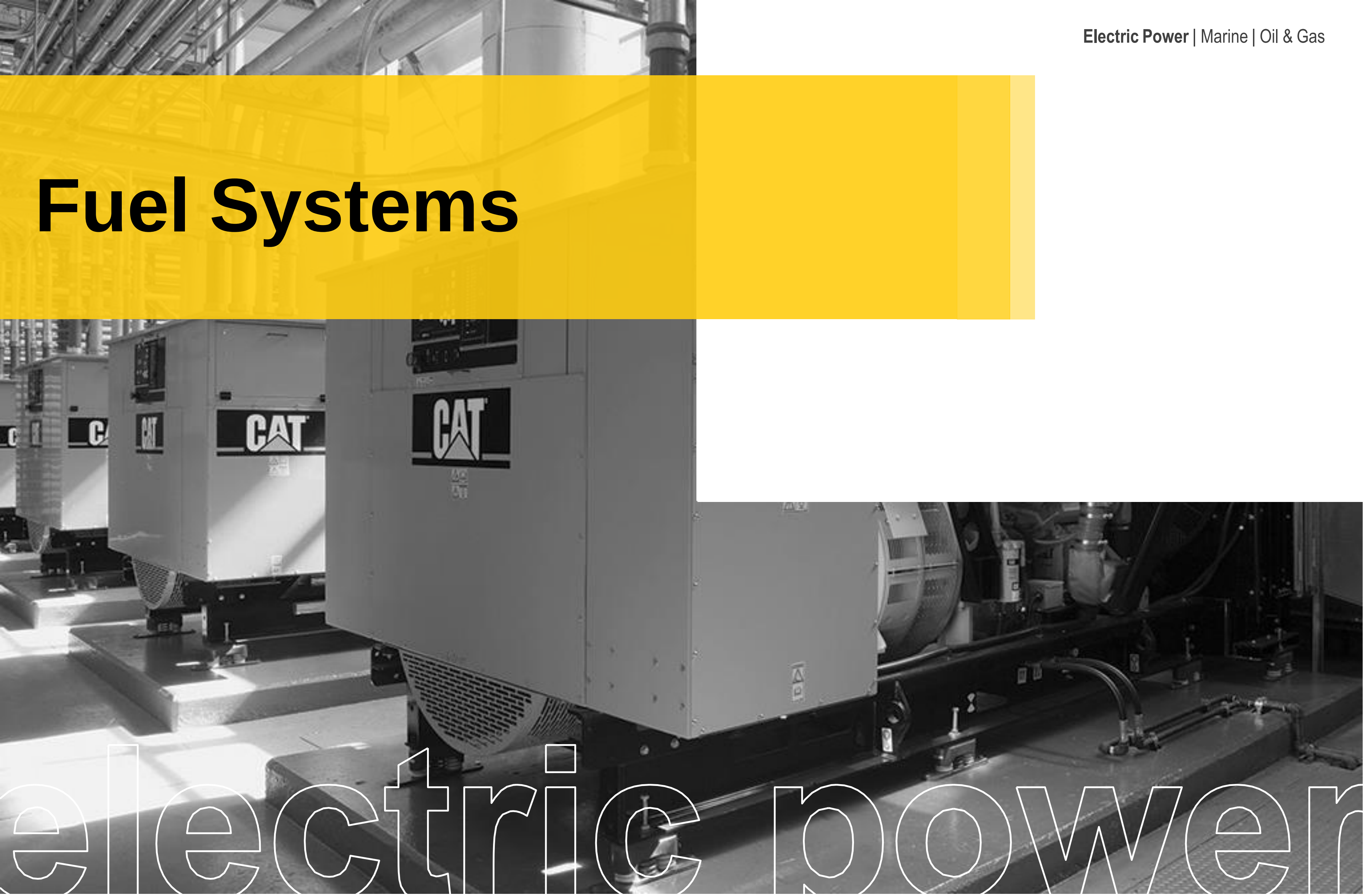
Noise Reduction

- Determine Attenuation Level
  - Residential
  - Critical
  - Supercritical
- Selecting a Silencer
  - Balance sound attenuation with back pressure
  - Space, Cost, Appearance

Clearance and Mounting

- Clearance
  - Overhead cranes
  - Minimum 9 inches from combustible materials
  - Air intake
- Mounting
  - Flexible connections
  - Weight support

Fuel Systems



Diesel Fuel Supply System

- Fuel Storage System
- Fuel Transfer System
- Fuel Filtration System

Fuel Storage System

- Main Tank
  - Sizing Rule of Thumb:

    Fuel Consumption Rate x Hours Between Refills

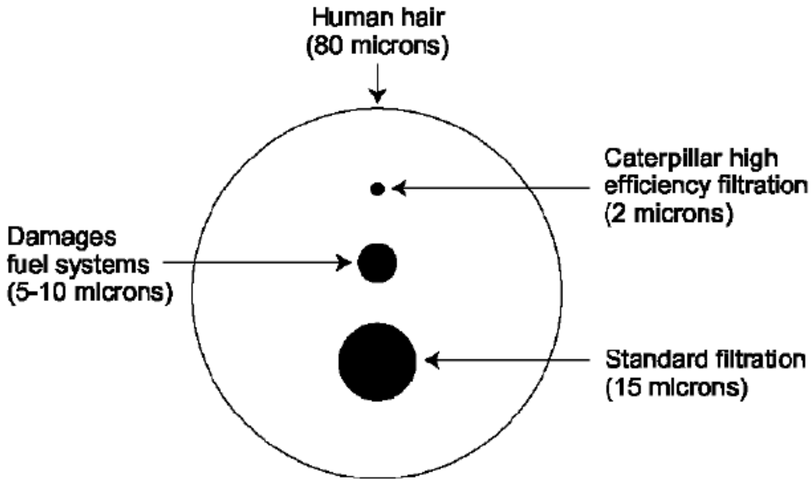
    » (at 100% load factor depending on application)
  - 660 Rule
- Day Tank
  - Required when main fuel tank is:
    - Same level, > 50 ft away
    - > 12 ft below engine
    - Above engine fuel injectors

Fuel Transfer System

- Fuel Pump Capability and Design Considerations
  - Vertical distance from tank to pump
  - Internal piping system losses
  - Elevation
- Routing
  - Avoid hot surfaces
  - Avoid formation of traps
  - Low to the ground

Fuel Filtration System

- Engine fuel filters must never be removed or bypassed
- Removal of water and sediment
  - Water separator
  - Coalescing filter
  - Centrifuge



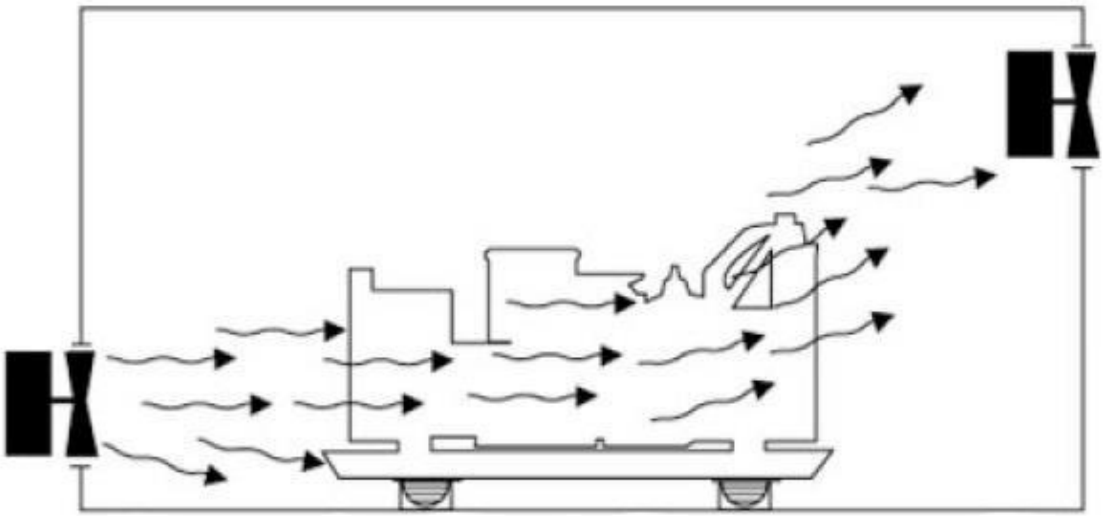
Engine Room Ventilation

Ventilation

- Remove Radiant and Convection Heat
  - Genset and Switchgear performance
  - Adequate conditions for personnel
- Engine Room Temperature Rise
  - $8.5^{o}C$ to $12.5^{o}C$
  - Never exceed $49^{o}C$
- Air Velocity
  - 1.5 m/s in working areas

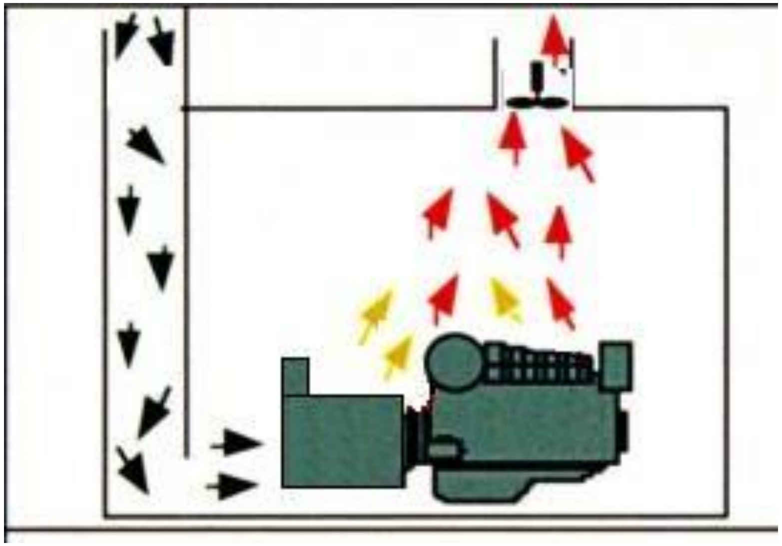
Ventilation Considerations

- **Direction**
  - Cool, dry, clean air
  - Low entry
  - Horizontal air flow
  - Generator first

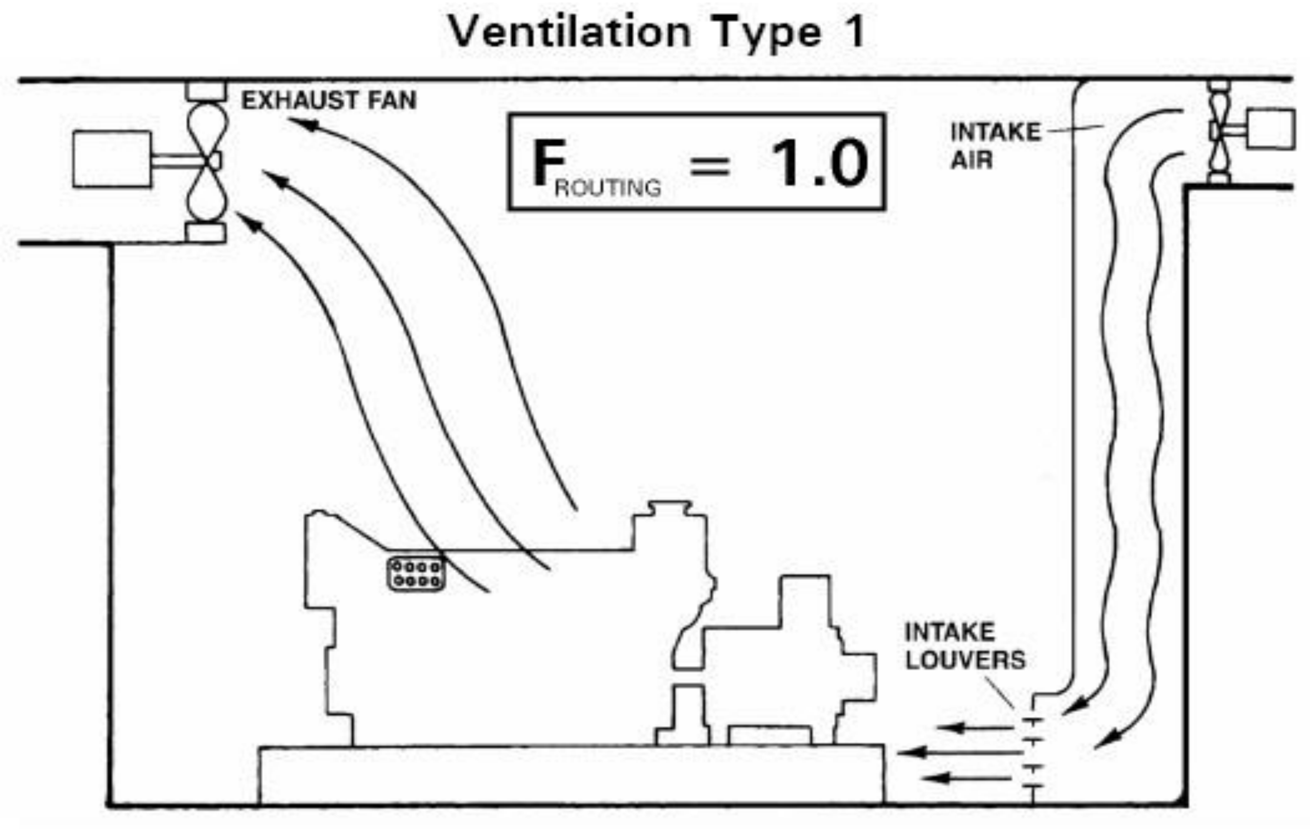


Ventilation Considerations

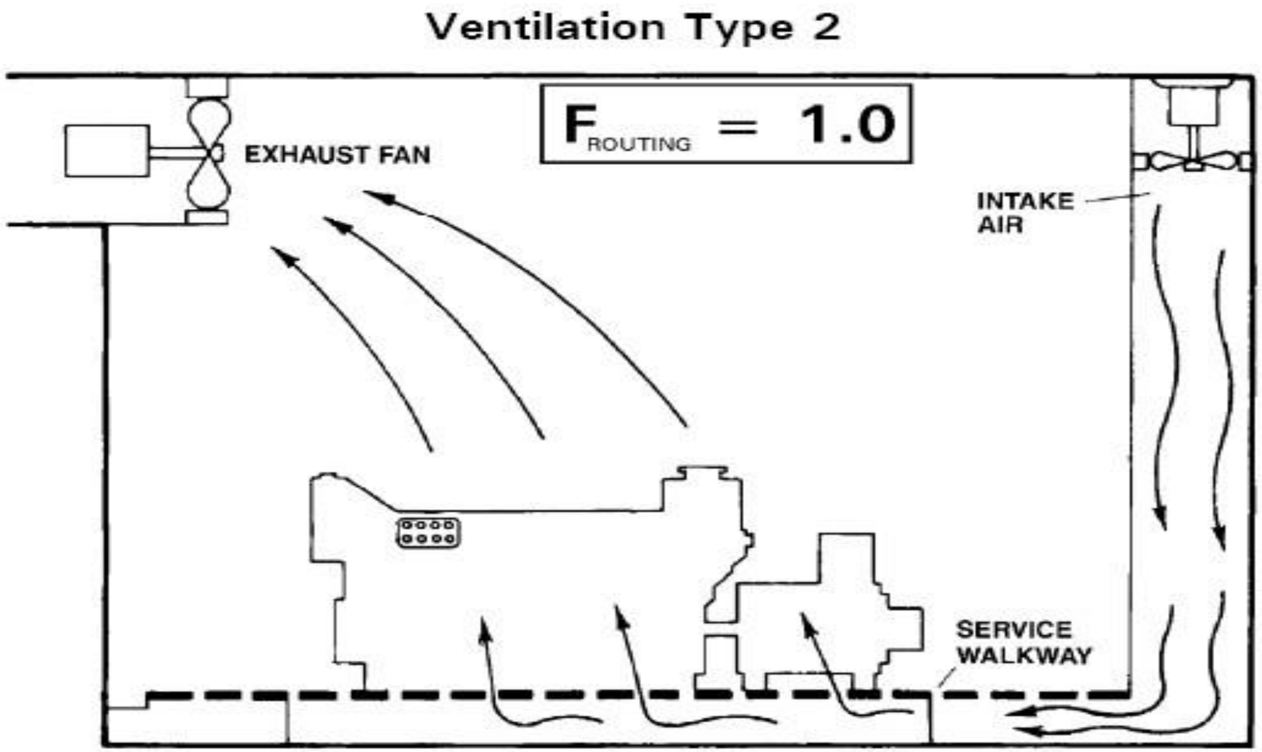
- **Routing**
  - Entry as far and low as possible
  - Discharge as high as possible
  - Do not blow cool air toward hot engine components



Type 1 Ventilation

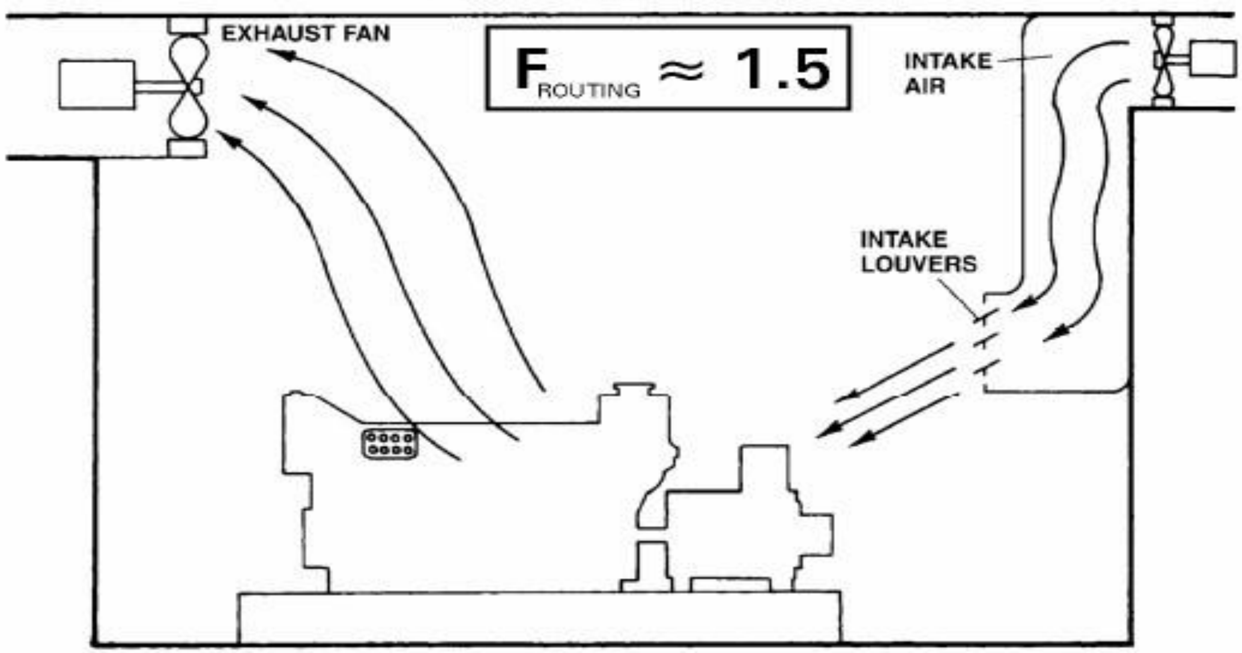


Type 2 Ventilation

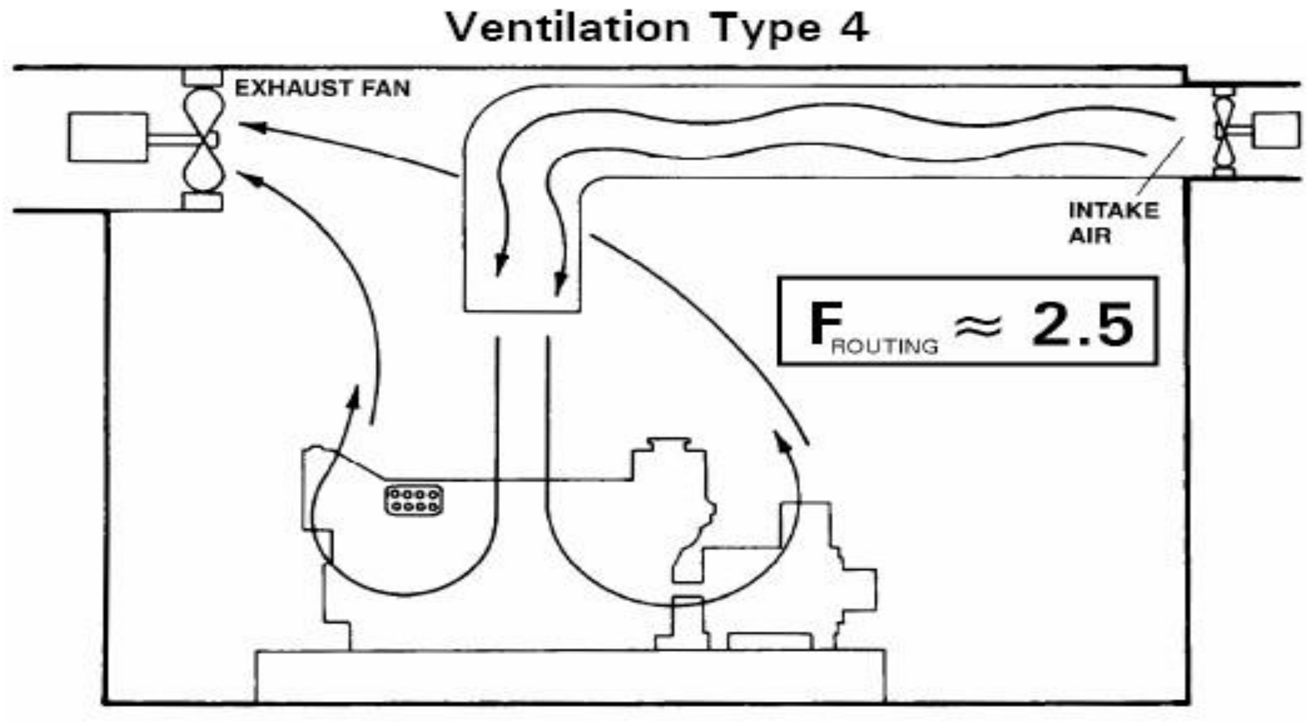


Type 3 Ventilation

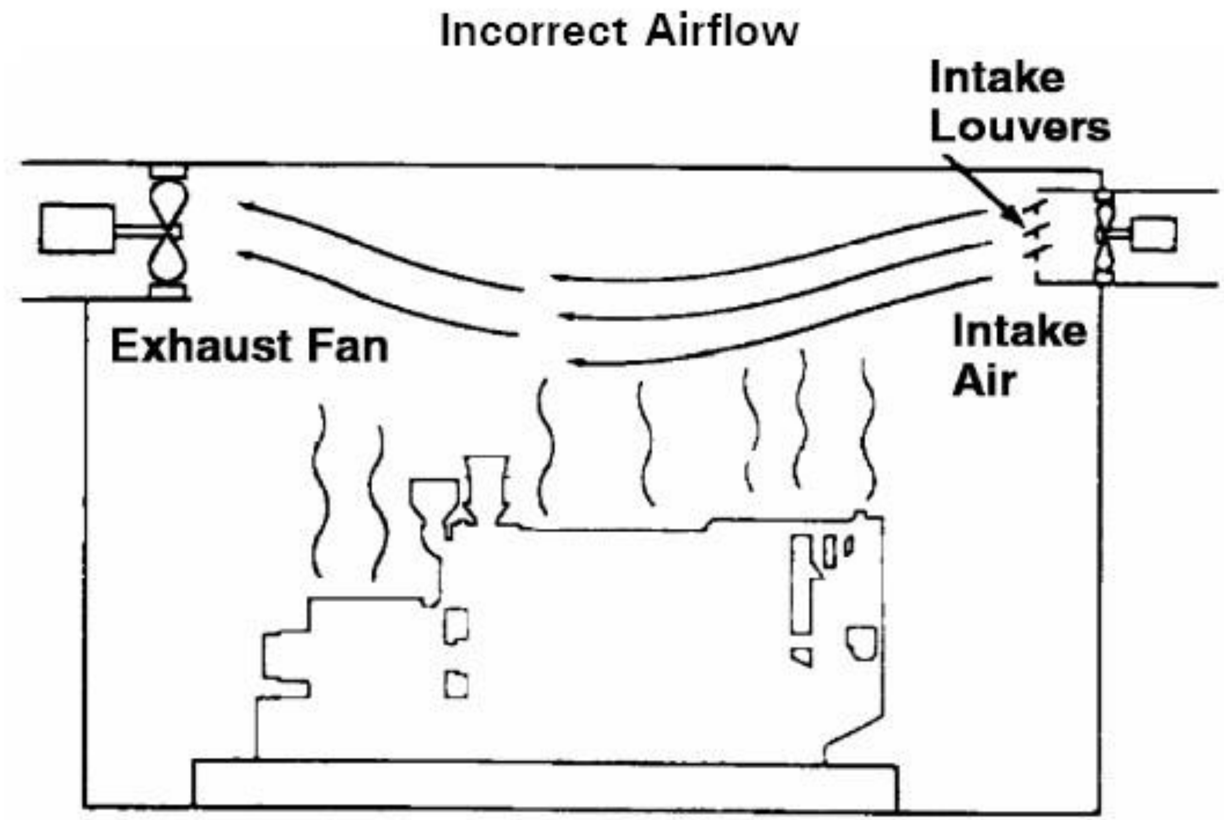
Ventilation Type 3



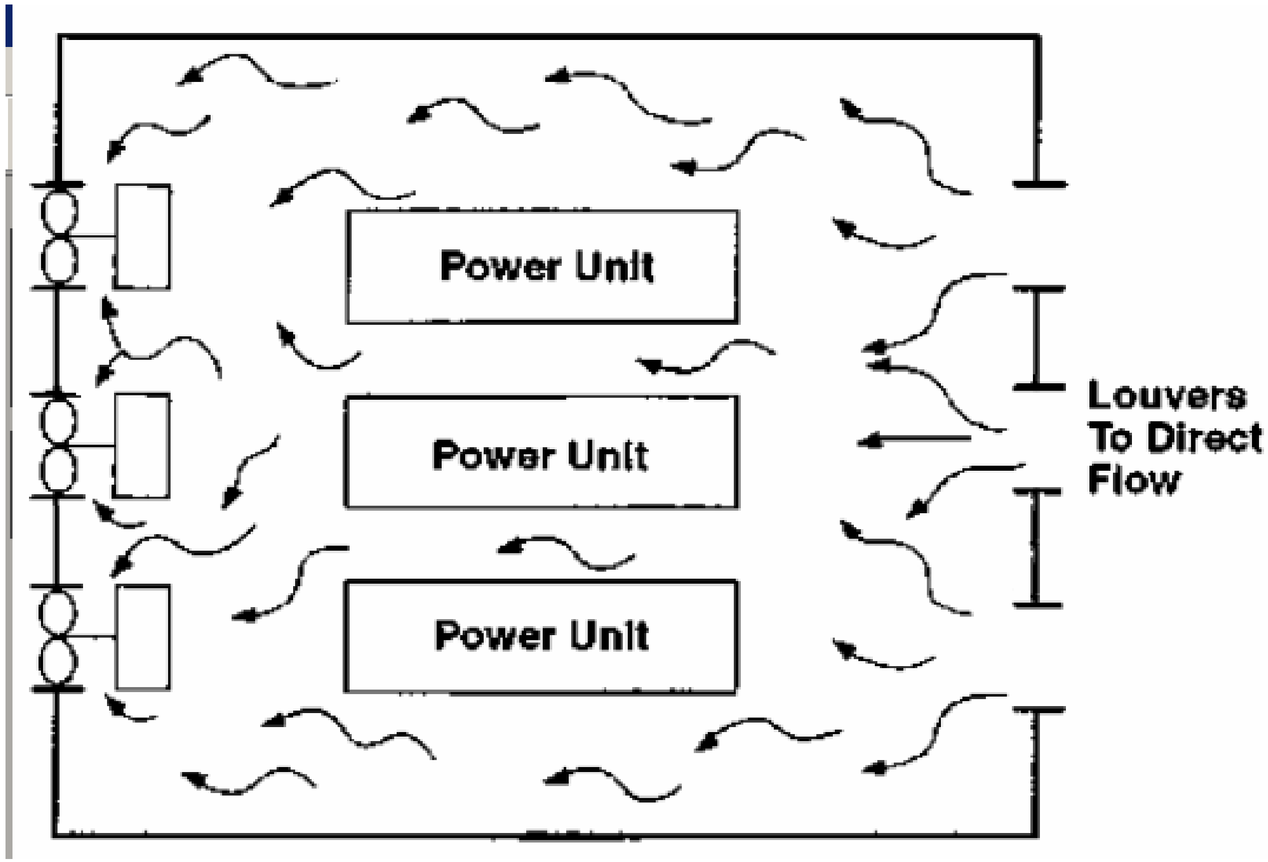
Type 4 Ventilation



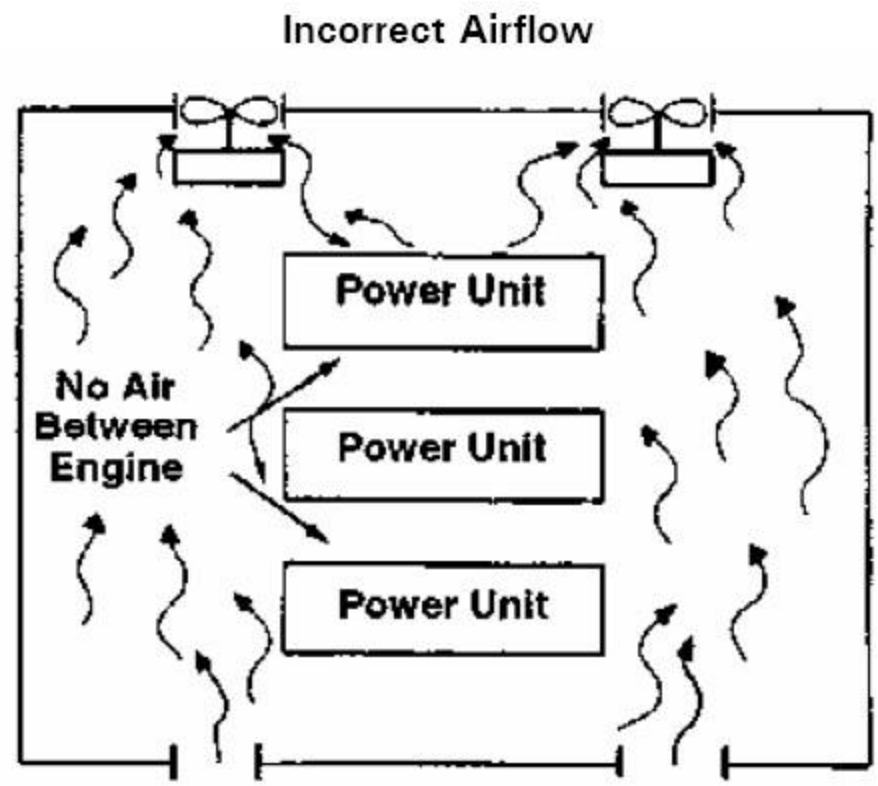
Incorrect Flow Single Engine



Multiple Engine Arrangement



Incorrect Ventilation



Required Air Flow

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

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

Where:

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

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

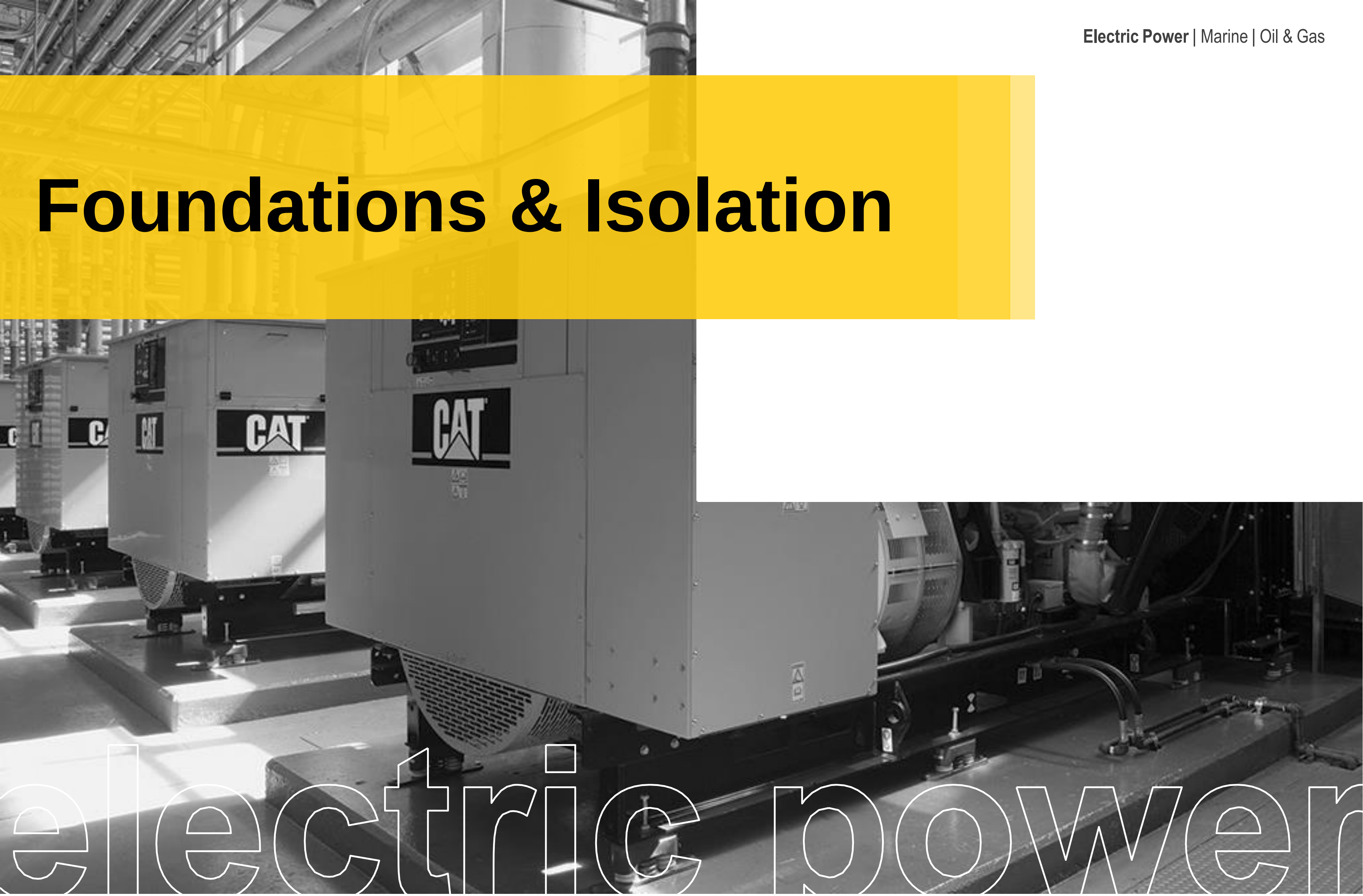
D = Density of Air at air temperature 38°C (100°F). The density is equal to 1.099 kg/m^3 (0.071 lb/ft^3)

C_P = Specific Heat of Air (0.017 kW x min/kg x °C), (0.24 Btu/°F)

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

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

Foundations & Isolation



Functional Requirements for Foundations

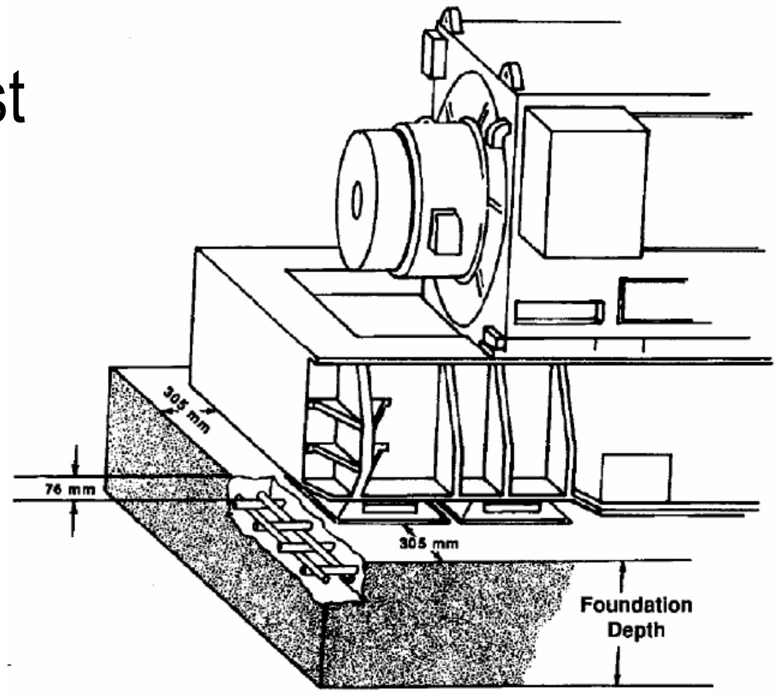
- **Support total weight (mass) & dynamic loading of equipment, accessory equipment and fluids (coolant, oil and fuel)**
- Maintain alignment between engine, driven equipment, and accessory equipment
- Isolate equipment vibration from surrounding structures

Base Material

- Material supporting the foundation must carry the total weight
  - Firm level soil, gravel, or rock
  - Fine clay, loose sand, or sand near ground water level
- Seasonal changes
  - Extend foundations below the frost line

Concrete Foundations

- Avoid excessively thick bases
- For paralleled units foundation must withstand twice the weight
- Minimum 12 inch edge clearance
- Mass no less than mass of equipment
- Depth to attain minimum weight



$$FD = W \div (D \times B \times L)$$

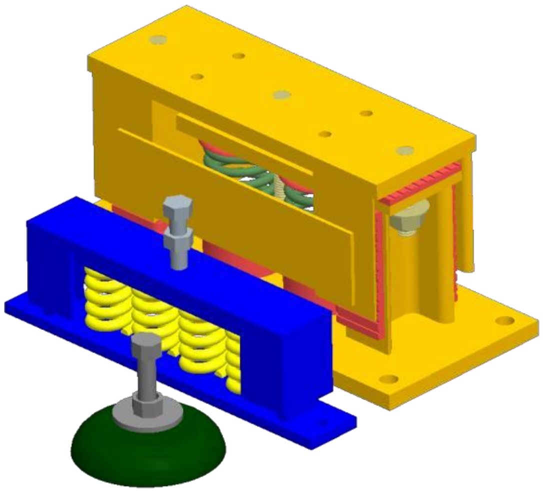
FD = Foundation Depth
W = Total Weight of Equipment
D = Density of Concrete
B = Foundation Width
L = Foundation Length

Functional Requirements for Package Isolators

- Limit vibrations transmitted from genset to foundation
- Ensure that package rigid body vibration modes stay clear of engine excitation frequencies
- Correct for <u>small</u> variations in foundation surface flatness
  - Generally, isolators used on electric power gensets can not correct for foundation flexure under dynamic loads!

Isolators

- Many types
  - Rubber
  - Gravel or Sand (Bulk Isolation)
  - Spring



Summary

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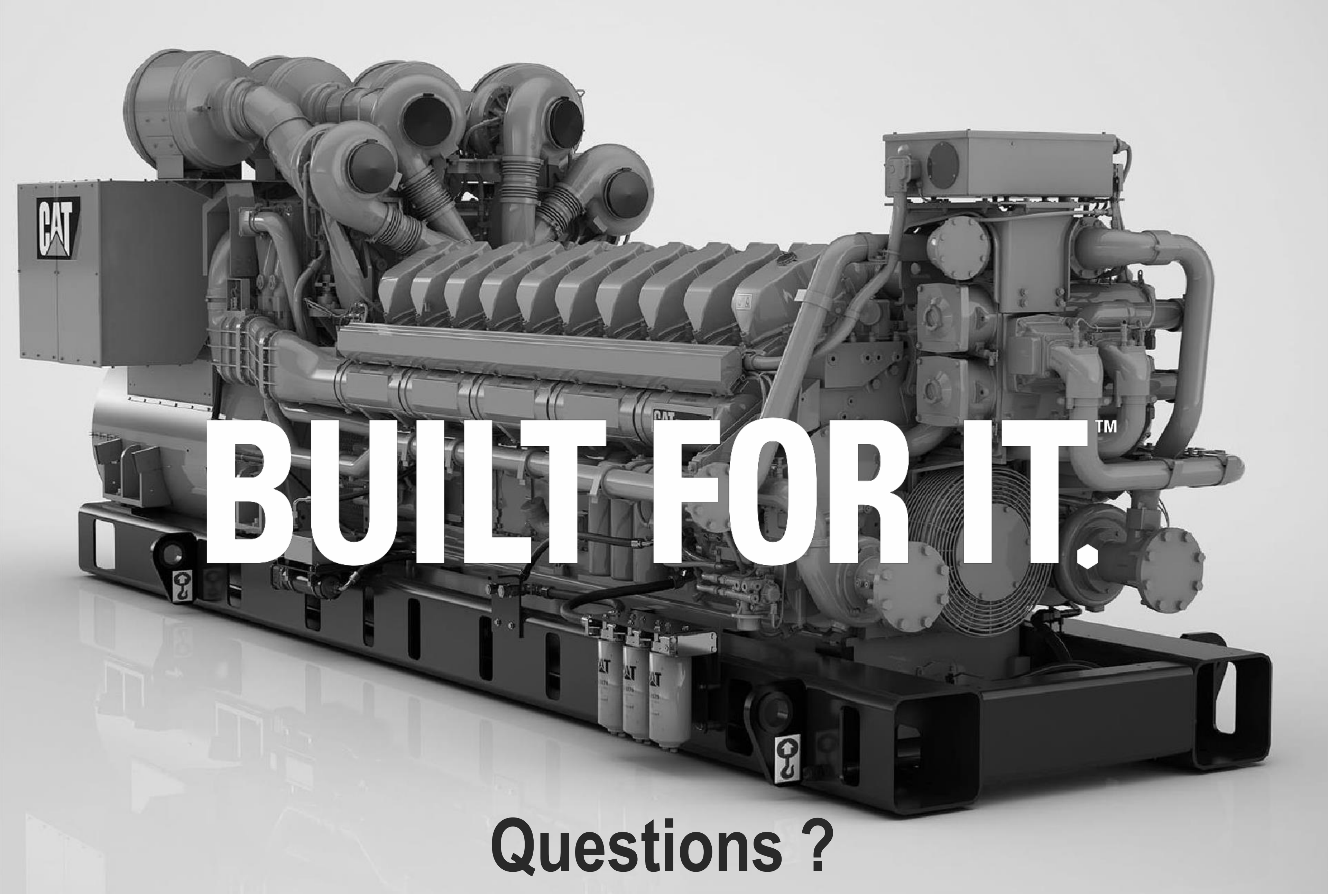
- Engine Room Ventilation
- Foundations & Isolation



Questions ?