

Installation

Commercial Marine Generator Set



Models:

350/500EOZCS

300/450EFOZCS

350/500EOZCS IMO Tier III

300/450EFOZCS IMO Tier III

Controller:

Decision Maker® 3500



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KOHLER®

TP-7127 5/21b

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Safety Precautions and Instructions

IMPORTANT SAFETY INSTRUCTIONS. Electromechanical equipment, including generator sets, transfer switches, switchgear, and accessories, can cause bodily harm and pose life-threatening danger when improperly installed, operated, or maintained. To prevent accidents be aware of potential dangers and act safely. Read and follow all safety precautions and instructions. **SAVE THESE INSTRUCTIONS.**

This manual has several types of safety precautions and instructions: Danger, Warning, Caution, and Notice.



DANGER indicates a hazardous situation which, if not avoided, will result in death or serious injury.



WARNING indicates a hazardous situation which, if not avoided, could result in death or serious injury.



CAUTION indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.

NOTICE

NOTICE is used to address practices not related to physical injury.

Safety decals affixed to the equipment in prominent places alert the operator or service technician to potential hazards and explain how to act safely. The decals are shown throughout this publication to improve operator recognition. Replace missing or damaged decals.

Accidental Starting

 WARNING	Accidental starting. Can cause severe injury or death.
  	Disconnect the battery cables before working on the generator set. Remove the negative (–) lead first when disconnecting the battery. Reconnect the negative (–) lead last when reconnecting the battery.

Disabling the generator set. Accidental starting can cause severe injury or death. Before working on the generator set or equipment connected to the set, disable the generator set as follows: (1) Move the generator set master switch to the OFF position. (2) Disconnect the power to the battery charger. (3) Remove the battery cables, negative (–) lead first. Reconnect the negative (–) lead last when reconnecting the battery. Follow these precautions to prevent starting of the generator set by an automatic transfer switch, remote start/stop switch, or engine start command from a remote computer.

Engine Backfire/Flash Fire

 WARNING	Risk of fire. Can cause severe injury or death.
	Do not smoke or permit flames or sparks near fuels or the fuel system.

Servicing the fuel system. A flash fire can cause severe injury or death. Do not smoke or permit flames or sparks near the fuel injection system, fuel line, fuel filter, fuel pump, or other potential sources of spilled fuels or fuel vapors. Catch fuels in an approved container when removing the fuel line or fuel system.

Servicing the air cleaner. A sudden backfire can cause severe injury or death. Do not operate the generator set with the air cleaner removed.

Combustible materials. A sudden flash fire can cause severe injury or death. Do not smoke or permit flames or sparks near the generator set. Keep the compartment and the generator set clean and free of debris to minimize the risk of fire. Catch fuels in an approved container. Wipe up spilled fuels and engine oil.

Combustible materials. A fire can cause severe injury or death. Generator set engine fuels and fuel vapors are flammable and explosive. Handle these materials carefully to minimize the risk of fire or explosion. Equip the compartment or nearby area with a fully charged fire extinguisher. Select a fire extinguisher rated ABC or BC for electrical fires or as recommended by the local fire code or an authorized agency. Train all personnel on fire extinguisher operation and fire prevention procedures.

Exhaust System

 WARNING 	Carbon monoxide. Can cause severe nausea, fainting, or death. The exhaust system must be leakproof and routinely inspected.
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Carbon monoxide symptoms. Carbon monoxide can cause severe nausea, fainting, or death. Carbon monoxide is a poisonous gas present in exhaust gases. Carbon monoxide is an odorless, colorless, tasteless, nonirritating gas that can cause death if inhaled for even a short time. Carbon monoxide poisoning symptoms include but are not limited to the following:

- Light-headedness, dizziness
- Physical fatigue, weakness in joints and muscles
- Sleepiness, mental fatigue, inability to concentrate or speak clearly, blurred vision
- Stomachache, vomiting, nausea

If experiencing any of these symptoms and carbon monoxide poisoning is possible, seek fresh air immediately and remain active. Do not sit, lie down, or fall asleep. Alert others to the possibility of carbon monoxide poisoning. Seek medical attention if the condition of affected persons does not improve within minutes of breathing fresh air.

Inspecting the exhaust system. Carbon monoxide can cause severe nausea, fainting, or death. For the safety of the craft's occupants, install a carbon monoxide detector. Never operate the generator set without a functioning carbon monoxide detector. Inspect the detector before each generator set use.

Operating the generator set. Carbon monoxide can cause severe nausea, fainting, or death. Be especially careful if operating the generator set when moored or anchored under calm conditions because gases may accumulate. If operating the generator set dockside, moor the craft so that the exhaust discharges on the lee side (the side sheltered from the wind). Always be aware of others, making sure your exhaust is directed away from other boats and buildings.

Fuel System

 WARNING 	Explosive fuel vapors. Can cause severe injury or death. Use extreme care when handling, storing, and using fuels.
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The fuel system. Explosive fuel vapors can cause severe injury or death. Vaporized fuels are highly explosive. Use extreme care when handling and storing fuels. Store fuels in a well-ventilated area away from spark-producing equipment and out of the reach of children. Never add fuel to the tank while the engine is running because spilled fuel may ignite on contact with hot parts or from sparks. Do not smoke or permit flames or sparks to occur near sources of spilled fuel or fuel vapors. Keep the fuel lines and connections tight and in good condition. Do not replace flexible fuel lines with rigid lines. Use flexible sections to avoid fuel line breakage caused by vibration. Do not operate the generator set in the presence of fuel leaks, fuel accumulation, or sparks. Repair fuel systems before resuming generator set operation.

Draining the fuel system. Explosive fuel vapors can cause severe injury or death. Spilled fuel can cause an explosion. Use a container to catch fuel when draining the fuel system. Wipe up spilled fuel after draining the system.

Hazardous Noise

 CAUTION	Hazardous noise. Can cause hearing loss. Never operate the generator set without a muffler or with a faulty exhaust system.
	

Hazardous Voltage/Moving Parts

 DANGER	Hazardous voltage. Moving parts. Will cause severe injury or death. Operate the generator set only when all guards and electrical enclosures are in place.
 	

Servicing the generator set when it is operating. Exposed moving parts will cause severe injury or death. Keep hands, feet, hair, clothing, and test leads away from the belts and pulleys when the generator set is running. Replace guards, screens, and covers before operating the generator set.

Grounding electrical equipment. Hazardous voltage will cause severe injury or death. Electrocutation is possible whenever electricity is present. Ensure you comply with all applicable codes and standards. Electrically ground the generator set and related equipment and electrical circuits. Turn off the main circuit breakers of all power sources before servicing the equipment. Never contact electrical leads or appliances when standing in water or on wet ground because these conditions increase the risk of electrocution.

Disconnecting the electrical load. Hazardous voltage will cause severe injury or death. Disconnect the generator set from the load by turning off the line circuit breaker or by disconnecting the generator set output leads from the transfer switch and heavily taping the ends of the leads. High voltage transferred to the load during testing may cause personal injury and equipment damage. Do not use the safeguard circuit breaker in place of the line circuit breaker. The safeguard circuit breaker does not disconnect the generator set from the load.

Short circuits. Hazardous voltage/current will cause severe injury or death. Short circuits can cause bodily injury and/or equipment damage. Do not contact electrical connections with tools or jewelry while making adjustments or repairs. Remove all jewelry before servicing the equipment.

Electrical backfeed to the utility. Hazardous backfeed voltage can cause severe injury or death. Connect the generator set to the building/marina electrical system only through an approved device and after the building/marina main switch is turned off. Backfeed connections can cause severe injury or death to utility personnel working on power lines and/or personnel near the work area. Some states and localities prohibit unauthorized connection to the utility electrical system. Install a ship-to-shore transfer switch to prevent interconnection of the generator set power and shore power.

Testing live electrical circuits. Hazardous voltage or current will cause severe injury or death. Have trained and qualified personnel take diagnostic measurements of live circuits. Use adequately rated test equipment with electrically insulated probes and follow the instructions of the test equipment manufacturer when performing voltage tests. Observe the following precautions when performing voltage tests: (1) Remove all jewelry. (2) Stand on a dry, approved electrically insulated mat. (3) Do not touch the enclosure or components inside the enclosure. (4) Be prepared for the system to operate automatically. (600 volts and under)

Hot Parts

 WARNING	Hot coolant and steam. Can cause severe injury or death. Before removing the pressure cap, stop the generator set and allow it to cool. Then loosen the pressure cap to relieve pressure. Fill system before starting unit.
	
 WARNING	Hot engine and exhaust system. Can cause severe injury or death. Do not work on the generator set until it cools.
	

Servicing the alternator. Hot parts can cause severe injury or death. Avoid touching the alternator field or exciter armature. When shorted, the alternator field and exciter armature become hot enough to cause severe burns.

Servicing the exhaust system. Hot parts can cause severe injury or death. Do not touch hot engine parts. The engine and exhaust system components become extremely hot during operation.

Notice

NOTICE
This generator set has been rewired from its nameplate voltage to:
246242

NOTICE

Voltage reconnection. Affix a notice to the generator set after reconnecting the set to a voltage different from the voltage on the nameplate. Order voltage reconnection decal 246242 from an authorized service distributor/dealer.

NOTICE

Fuse replacement. Replace fuses with fuses of the same ampere rating and type (for example: 3AB or 314, ceramic). Do not substitute clear glass-type fuses for ceramic fuses. Refer to the wiring diagram when the ampere rating is unknown or questionable.

NOTICE

Saltwater damage. Saltwater quickly deteriorates metals. Wipe up saltwater on and around the generator set and remove salt deposits from metal surfaces.

Information in this publication represents data available at the time of print. Kohler Co. reserves the right to change this publication and the products represented without notice and without any obligation or liability whatsoever.

The safe and successful operation of a marine power system depends primarily on the installation. Use this manual as a guide to install the marine generator set. For operating instructions, refer to the operation manual.

Note:

Only qualified persons should install the generator set.

Marine generator set installations must comply with all applicable regulations and standards.

Use the specification sheets as a guide in planning your installation. Use current dimension drawings and wiring diagrams.

1.1 Decision-Maker® 3500 Controller Information

The following data must be resident for the controller to function.

- **Application program** contains the software that controls system operation. The application file was preprogrammed in the *original* controller at the factory.
- **Personality profile** is specific to the engine and alternator and was preprogrammed in the *original* controller at the factory.

Typically, the Kohler authorized distributor/dealer creates a backup of the personality profile and passes this information onto the owner. Inform the owner to store this information for possible future use such as controller replacement or other circumstances requiring a backup.

Note:

If the personality profile is NOT available, request a replacement from Kohler Aftermarket Parts Department.

Enter an aftermarket parts order for part number *PROFILE*. Include in the order notes the generator set model, specification number, serial number, generator set modifications, and email of recipient.

- **User parameters** unique to an installation include timer values, setpoints, generator set data such as voltage and input/output selections. These parameters are typically set up for or by the installer at the time of installation. User parameters are typically recorded on the personality profile disk, a separate backup disk/drive, or written on a paper form.

Note:

If the user parameters are included on the personality disk, the disk label should indicate Site Program—Yes.

Note:

After the unit is set up on the vessel, Kohler authorized distributor/dealer saves any user parameter changes to an external medium. The installer or a Kohler authorized distributor/dealer passes this information onto the owner. Inform the owner to store this information for possible future use such as controller replacement or other circumstances requiring a backup.

Note:

Controller service replacement kits do not include the three files. The service technician *must* install the three files into the replacement controller.

2.1 Generator Set Lifting

2.1.1 General Precautions

Follow these general precautions when lifting all generator sets.

- Do not lift the generator set using the lifting eyes attached to the engine and/or alternator. These eyes cannot support the generator set's weight. Instead, use the four holes in the mounting skid of each generator set that are intended for attaching lifting hooks. The placement of the holes prevents the lifting cables from damaging the generator set components and maintains balance during lifting.
- If the lifting cables contact air cleaners, shrouds, or other protruding components, use spreader bars on the cables as outlined in subsequent sections. If the cables still do not clear the protruding component(s), remove the component(s).

2.1.2 Determining Weights

Refer to the respective specification sheet and/or the submittal drawing for the weight of the generator set and accessories. Contact your distributor/dealer if weights are not shown.

2.1.3 Lifting Methods

The distributor/lifting contractor should choose one of the following methods to lift the generator set depending upon the location circumstances and the generator set's weight and size. The hook and cable apparatus method may not be appropriate for heavier or bulkier generator sets; therefore, choose the lifting fixture method if there is any doubt regarding the ability of the hook and cable apparatus method to support the generator set's weight or to accommodate its size.

Hook and Cable Apparatus Method

- Lift the generator set by inserting lifting hooks in the skid's lifting holes. Use an apparatus of hooks and cables joined at a single rigging point. See **Figure 1**. If the cables contact any component of the generator set, use spreader bars slightly wider than the generator set skid to avoid damage to the generator set. Apply only vertical force to the skid while lifting.

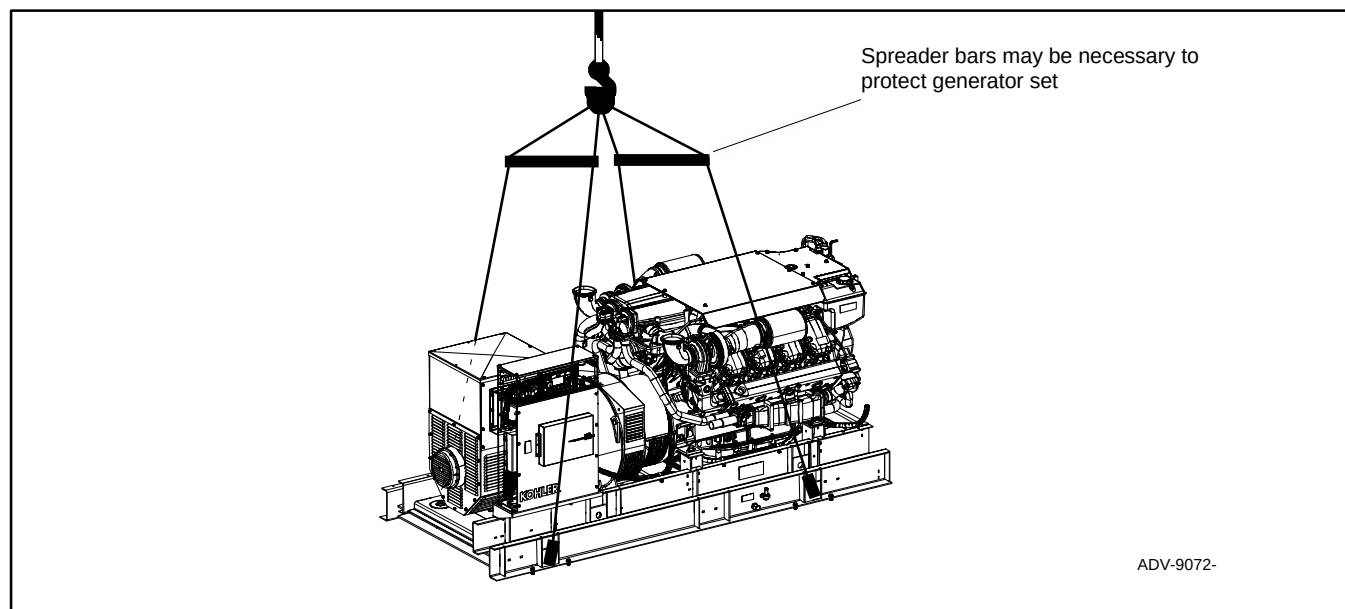


Figure 1 Generator Set with Lifting Hooks in Skid

Lifting Fixture Method

Use a lifting fixture with adjustable cables to adapt to different size generator sets and to compensate for unit imbalance. See **Figure 2**. Select equipment (cables, chains, and bars) capable of handling the weight of the generator set.

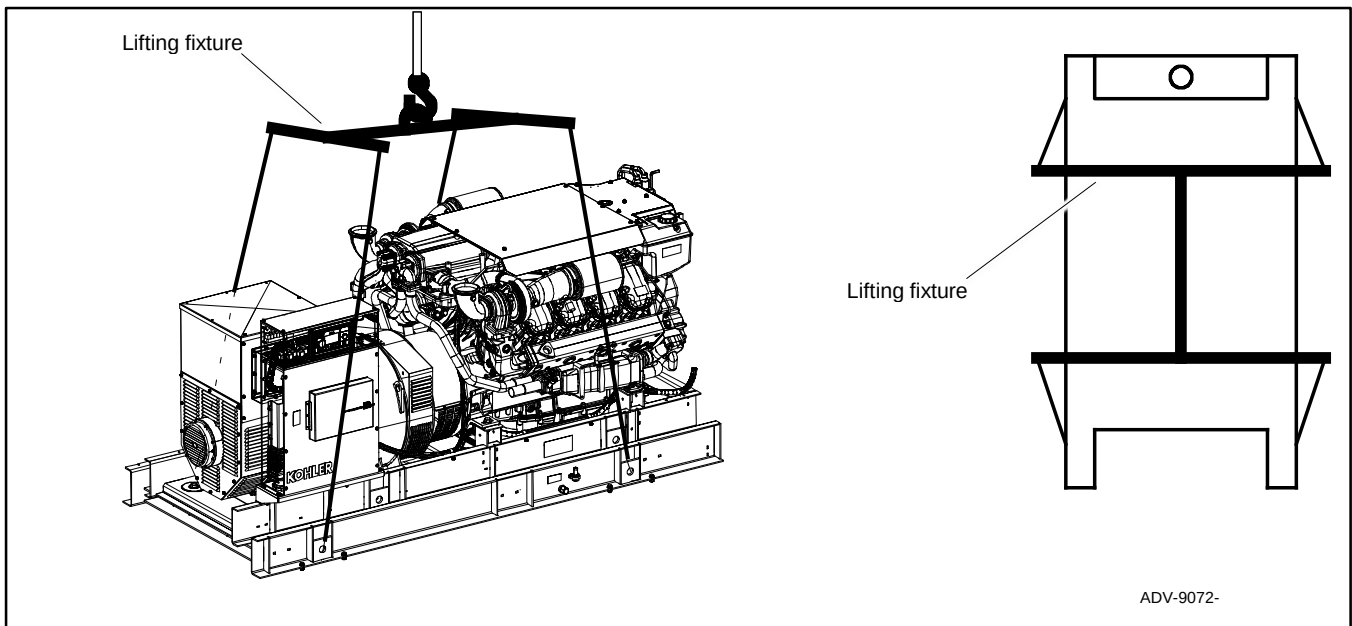


Figure 2 Generator Set with Lifting Fixture

2.2 Generating Set Transporting

Follow these guidelines when transporting the generator set:

- Select the transporting vehicle/trailer based on the dimensions and weight of the generator set as specified in the generator set dimension drawing or specification sheet. Ensure that the gross weight and overall height of the generator set and vehicle/trailer in transport does not exceed applicable transportation codes.
- Securely fasten the generator set to the vehicle/trailer and cover. Even the heaviest of generator sets can move during shipment unless they are secured. Fasten the generator set to the vehicle/trailer bed with a correctly sized chain routed through the mounting holes of the generator set skid. Use chain tighteners to remove slack from the mounting chain. Cover the entire unit with a heavy-duty canvas or tarpaulin secured to the generator set or trailer.

3.1 General Considerations

The key to installation is location. Before making final plans for locating a generator set, consider the following.

Installation Location Considerations

1. Choose a location that allows adequate space for cooling and exhaust system installation, fuel system installation, ventilation, and service access to the generator set (engine and generator).
2. Use craft stringers or other available structural members capable of supporting the generator set's weight.
3. Seal the generator set's engine room from the cabin to prevent exhaust gases and fuel vapors from entering the cabin.

See the current generator set specification sheet or the section titled: **Installation Drawings** of this manual for generator set dimensions and weights.

3.2 Location

Locate the generator set to allow easy service access to the generator set's engine, controller, cooling, and fuel system components. The engine compartment is often the ideal location for the generator set if the propulsion engine(s) does not obstruct access to the generator set and controller.

Marine Generator Set Installations in European Union Member Countries

This generator set is specifically intended and approved for installation below the deck in the engine compartment. Installation above the deck and/or outdoors would constitute a violation of European Union Directive 2000/14/EC noise emission standard.

Allow clearance for vibration and cooling during operation. Allow a minimum of 400 mm (15.75 in.) clearance on all sides (top, front, rear, and sides) of the generator set.

3.3 Mounting

Mount the generator set as high as possible to avoid contact with bilge splash and lower-lying vapors and to allow for downward pitch of the exhaust line toward the exhaust outlet. Use the preexisting mounting holes on the lower skid or locate the mounting holes where desired to mount to the stringers.

Kohler Co. recommends mounting the generator set on a flat, solid, rigid platform attached to the craft stringers. Craft stringers generally provide the best generator set support. Ensure that the structural members can support the generator set's weight and withstand its vibration.

The generator set includes vibration mounts and a skid. If desired, install additional vibration isolating pads underneath the generator set's base. Use the eight mounting holes or drill new mounting holes based on stringer location to mount the generator set securely to the craft. See the ADVs in the section titled: **Installation Drawings** for mounting hole locations.

For angular operating limits, consult the operation manual.

3.4 Dual-Bearing Alternator Alignment

Generator sets equipped with dual-bearing alternators require alignment after mounting the generator set skid to a mounting pad. Refer to Service Bulletin SB-566 for details.

4.1 General

The intake air temperature upstream of the turbocharger should be below 30°C (86°F). If it exceeds 30°C (86°F) continuously, engine output will drop. If the generator is enclosed, or if it is located in a room designed for the purpose, it is important to ensure adequate supply of intake air.

The direct dependence of the engine output on intake air temperature is shown in **Figure 3**. 100% output is shown under actual test conditions at the factory.

If the intake line is located close to exhaust pipes or other hot parts, use radiation protection to avoid unnecessary heating of the intake air.

Contact your Kohler authorized dealer/distributor for advice.

The engine air consumption in kg/min. at full power and at different engine speeds is indicated in the section titled: **Technical Data**.

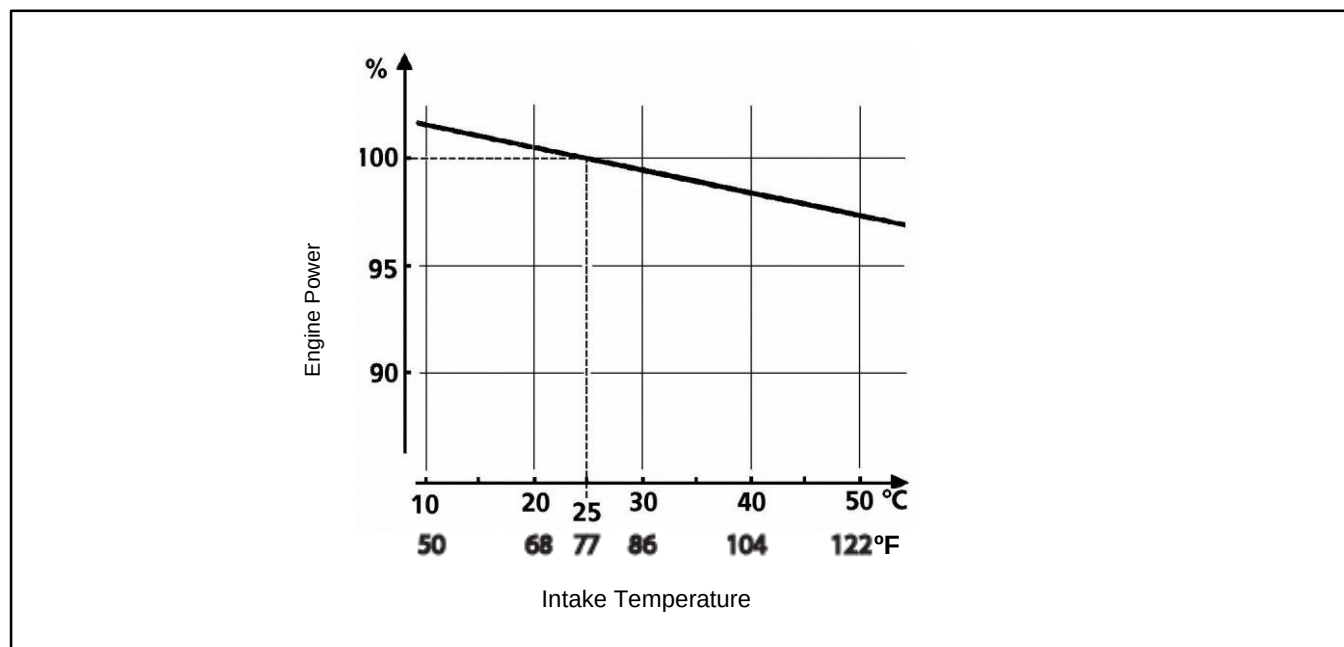


Figure 3 Engine output is dependent on intake air temperature. 100% at 25°C (77°F), 100 kPa, output setting not corrected.

Note:

If the generator set is deck mounted, install a hood over the air cleaner's intake to protect against water intrusion.

4.2 Engine Room Ventilation with Fresh Air Line to the Generator

When the intake air to the engine is taken from outside the engine room, it is important to check that the temperature in the engine room does not exceed 60°C (140°F). If the temperature exceeds this value, there is a risk of malfunction in the engine's electrical components (alternator, charge regulator, engine control unit, etc.).

It may be necessary to arrange for ventilation of the engine room with a fan if there is a risk of the temperature exceeding 60°C (140°F).

In engine systems where the engine intake air comes from outside the engine room via a fresh air line to the engine, measure the vacuum in the intake system. Locate the air intake so that the intake air is as clean as possible and so that neither the engine exhaust gas nor heated air from the engine room can mix with the intake air. The air intake should be designed to exclude water, snow, and contamination. The intake air must not contain any chemical pollutants.

Note:

The maximum permissible vacuum in the intake system is 30 mbar. This value includes the vacuum in the new air filter, connected coarse filter, and in the fresh air line.

The following applies to the fresh air line:

- The fresh air line must not be routed with any sharp bends.
- The inside of the fresh air line must be flat and even.
- If a hose is used as a fresh air line, it must be reinforced so that it does not collapse onto itself.

It is not necessary to check the vacuum if the fresh air line is a max. length of 5 m (16.4 ft.) and has an inner diameter of a min. 210 mm (8.3 in.).

If the planned fresh air line is longer than 5 m (16.4 ft.), calculate the required diameter as shown in **Figure 4**.

Note:

The total vacuum in the intake system with a block air filter must not exceed 65 mbar.

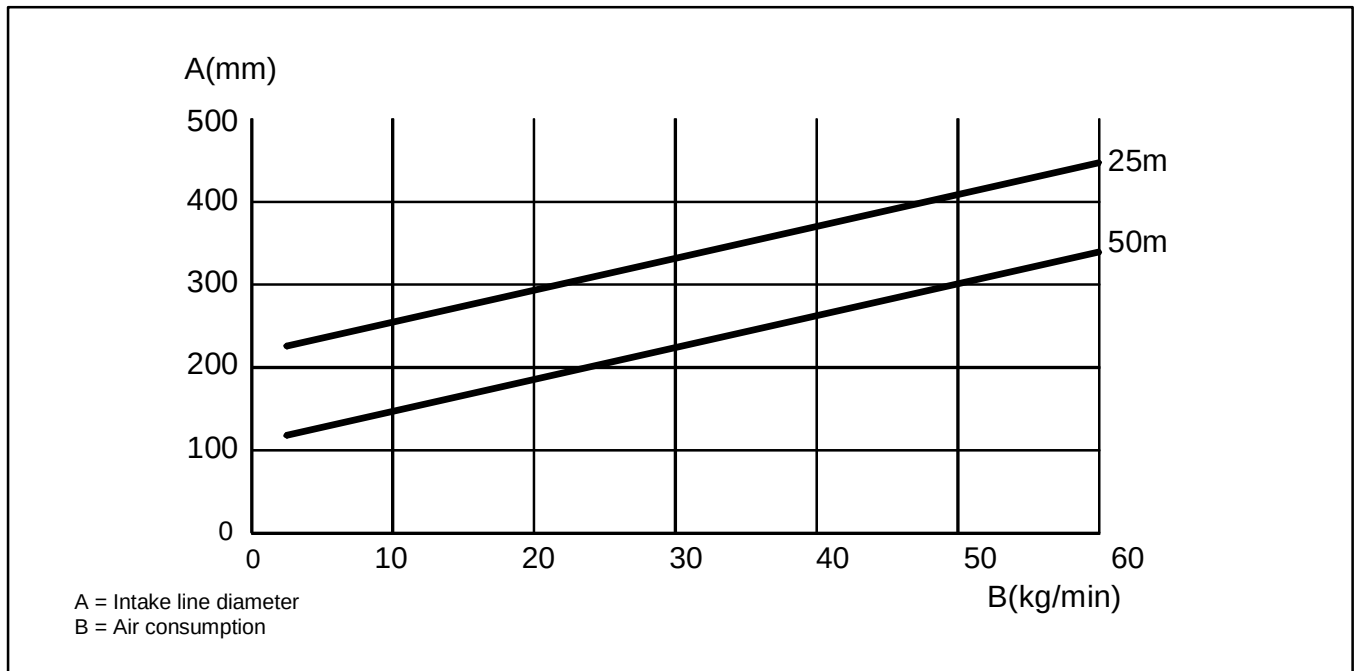


Figure 4 Calculation of min. Diameter of the Intake Line

When dimensioning the engine room ventilation, consider other air consumers in the engine room.

The amount of heat emitted by the generator engine in the form of radiation is indicated in the section titled: **Technical Data**.

The exhaust pipes should be insulated to reduce the radiated heat in the engine room. See the section titled: **Exhaust System**.

4.3 Intake Air From Engine Room

When the generator engine intake air is taken from the engine room, the air intake must be located in the engine room. The open area should be large enough to ensure that no vacuum arises in the engine room. The air intake should also be designed so that it cannot be closed or accidentally blocked by water, snow, or contaminants.

The air intake should be located so that the intake air is as clean as possible and so that neither the generator engine exhaust nor heated air from the engine room can mix with the intake air to the engine.

Based on engine air consumption, the minimum recommended area of the air intake is shown in **Figure 5**.

If several engines or other air consumers are located in the same engine room, the diameter should be increased correspondingly.

Note:

The vacuum in the engine compartment must not exceed 2 mbar.

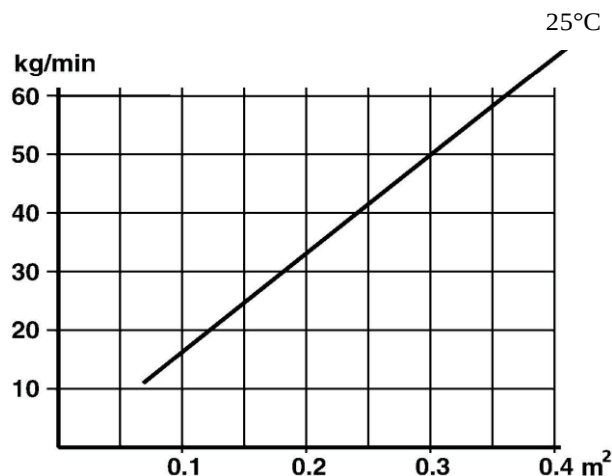


Figure 5 Graph for Calculating Min. Air Intake Cross Section

For installations where the generator engine draws the intake air directly from the engine room, the engine room must be equipped with a ventilation system which extracts the air heated by radiation etc. in order for the low intake air temperature requirement to be met.

If there is a refrigerator compressor in the engine room, it is important that any leakage of refrigerant does not contaminate the intake air.

The radiated heat from the engine exhaust line after the generator engine must also be taken into account. The heat radiated depends on how much of the line is in the engine room and how much is insulated.

There is also additional heat due to efficiency losses in driven units in the engine room.

The amount of heat emitted by the generator engine in the form of radiation is indicated in the section titled: **Technical Data**.

4.4 Air Cleaners

The generator set can be supplied with a turbo-mounted air filter or with an air filter mounted separately. The air cleaner may be available with or without an integrated self-cleaning precleaner.

Keep in the mind the following when installing the air cleaner:

- The air cleaner must be fitted so that it is easily accessible for cleaning and filter renewal.
- If equipped, the vacuum indicator must be positioned so that it can be read easily.
- In order to be able to remove the filter element, clearance in the air cleaner extension is required.
- The intake line between the air cleaner and the turbocharger must be sealed so that no unfiltered air can be drawn into the engine. The intake line must be designed in such a way that it cannot collapse onto itself as a result of a large pressure drop. The intake line should be able to withstand a vacuum of 200 mbar.
- The material and composition of the intake line between the air filter and turbocharger must be such that it cannot release rust or objects that could damage the engine.

It is also important to ensure that any insulation in the engine room and around the exhaust pipes cannot come loose and be drawn into the intake line.

If a non-Kohler air filter is used, engine air consumption and filter element pore size must be considered.

4.5 Air Pressure

On delivery, the generator engine control unit is normally set so that the maximum fuel injection quantity provides 100% engine power when the intake air is at a pressure of 1000 mbar.

If the generator engine will be used at high altitudes, contact your Kohler dealer/distributor to check engine output. Incorrectly set engine output will cause abnormal smoke levels and result in high thermal stress.

The turbocharger may also be damaged by the raised exhaust temperature due to engine over speed.

In cases of continuous operation at air pressures below 1000 mbar, it may be necessary to reduce engine power. Available output is then reduced as shown in **Figure 6**.

The lowest air pressure which can be permitted for short periods without adjusting the output setting is 750 mbar, which corresponds to 2500 m (8202 ft.) above sea level.

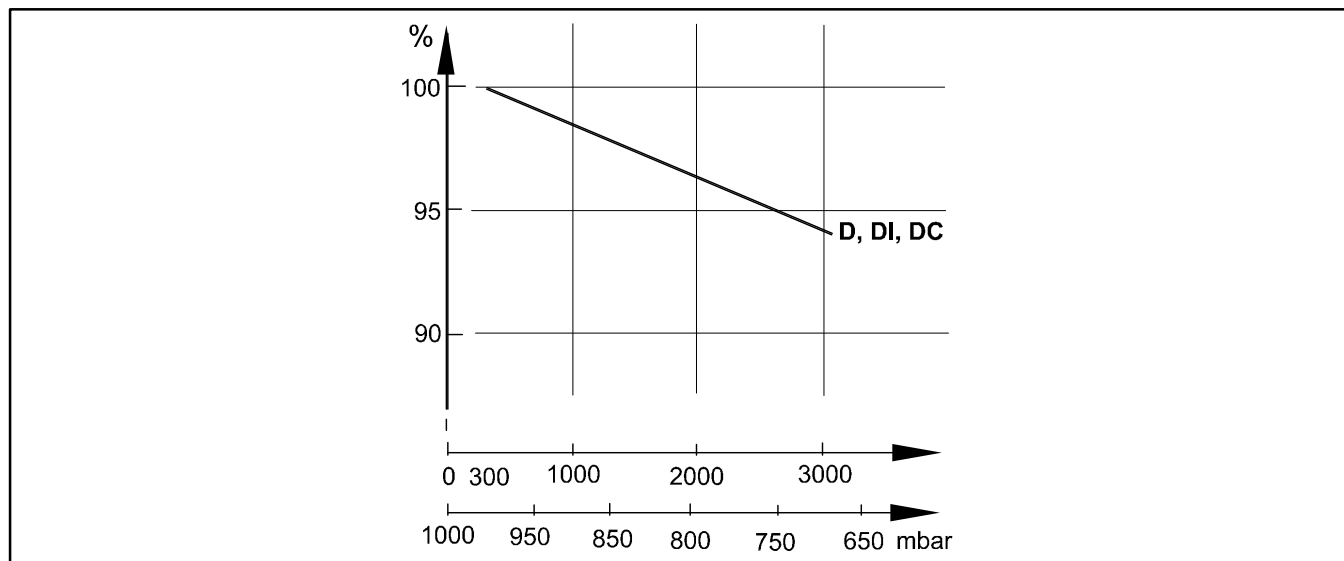


Figure 6 Engine Output Depending on Air Pressure

4.6 Important Data

Max. recommended temperature for engine intake air	30°C (86°F)
Engine output is dependent on intake air temperature	See the figure titled: Engine Output is Dependent on Intake Air Temperature. 100% at 25°C (77°F), 100 kPa, Output Setting Not Corrected
Requirement which must be met for the fresh air line so that the vacuum does not need to be checked	Length: max. 5 m (16.4 ft.) Inner Diameter: at least 210 mm (8.3 in.)
Max. permissible vacuum in the intake system with cleaned or new filter	30 mbar
Max. permissible vacuum in the intake system with blocked filter	65 mbar
Max. temperature in engine room, intake air to engine taken from outside engine room	60°C (140°F)
Calculation of air intake cross-section	See the figure titled: Graph for Calculating Min. Air Intake Cross Section
Max. permissible vacuum in engine room (pressure difference)	2 mbar

 WARNING	Risk of fire. Can cause severe injury or death.
	Do not smoke or permit flames or sparks near fuels or the fuel system.

Servicing the fuel system. A flash fire can cause severe injury or death. Do not smoke or permit flames or sparks near the fuel injection system, fuel line, fuel filter, fuel pump, or other potential sources of spilled fuels or fuel vapors. Catch fuels in an approved container when removing the fuel line or fuel system.

Servicing the air cleaner. A sudden backfire can cause severe injury or death. Do not operate the generator set with the air cleaner/silencer removed.

Combustible materials. A sudden flash fire can cause severe injury or death. Do not smoke or permit flames or sparks near the generator set. Keep the compartment and the generator set clean and free of debris to minimize the risk of fire. Catch fuels in an approved container. Wipe up spilled fuels and engine oil.

Combustible materials. A fire can cause severe injury or death. Generator set engine fuels and fuel vapors are flammable and explosive. Handle these materials carefully to minimize the risk of fire or explosion. Equip the compartment or nearby area with a fully charged fire extinguisher. Select a fire extinguisher rated ABC or BC for electrical fires or as recommended by the local fire code or an authorized agency. Train all personnel on fire extinguisher operation and fire prevention procedures.

 WARNING	Explosive fuel vapors. Can cause severe injury or death.
 	Use extreme care when handling, storing, and using fuels.

The fuel system. Explosive fuel vapors can cause severe injury or death. Vaporized fuels are highly explosive. Use extreme care when handling and storing fuels. Store fuels in a well-ventilated area away from spark-producing equipment and out of the reach of children. Never add fuel to the tank while the engine is running because spilled fuel may ignite on contact with hot parts or from sparks. Do not smoke or permit flames or sparks to occur near sources of spilled fuel or fuel vapors. Keep the fuel lines and connections tight and in good condition. Do not replace flexible fuel lines with rigid lines. Use flexible sections to avoid fuel line breakage caused by vibration. Do not operate the generator set in the presence of fuel leaks, fuel accumulation, or sparks. Repair fuel systems before resuming generator set operation.

Draining the fuel system. Explosive fuel vapors can cause severe injury or death. Spilled fuel can cause an explosion. Use a container to catch fuel when draining the fuel system. Wipe up spilled fuel after draining the system.

5.1 General

Do not modify the tank or the marine auxiliary engine fuel system.

Note:

Fuel system installations must conform to USCG regulations.

In multi-engine installations, the fuel system should be divided into independent systems so that a fault in one fuel line does not cause all engines to stop. Each generator (also known as marine auxiliary engine) must not be combined with any other engines, including propulsion.

Properly ventilate the engine room to evacuate fuel vapors.

Figure 7 shows an example of a marine fuel tank installation. Do not use a shutoff valve on the return pipe. Excessive restriction on the fuel return pipe can lead to or cause a runaway engine condition when added to the return line or closed by the operator.

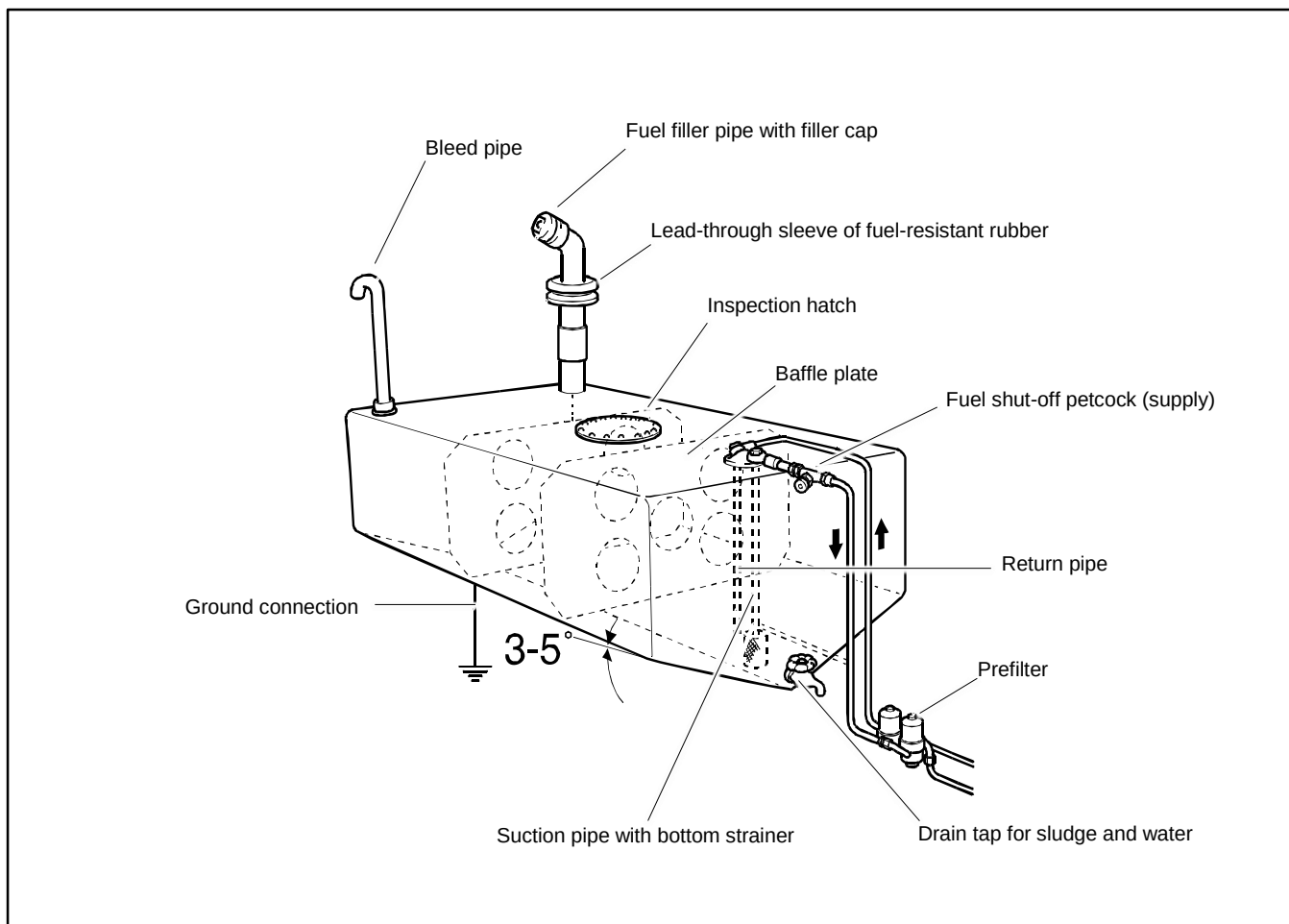


Figure 7 Marine Fuel Tank Installation Example

5.2 Fuel Tank

5.2.1 Position

The fuel tank must not be positioned so low that the vacuum in the feed pump suction pipe exceeds 0.3 bar (4.4 psi). The risk of air leaks in the suction pipe increases with increase vacuum.

If the fuel tank is mounted lower than the maximum suction lift, or if a large tank is required and cannot be mounted close to the engine, a day/buffer tank should be installed at a suitable distance and height.

If a reliable and quick starting response is required, the day/buffer tank should be positioned adjacent to the engine with the lowest fuel level at the same level as the feed pump.

If the fuel tank is placed higher than the engine feed pump, a shut-off petcock should be installed in the fuel line to the feed pump. This is to prevent unfiltered fuel entering the engine during maintenance. However, the fuel return line should never have a shut-off petcock as failure to open, prior to running the generator set, can cause a runaway engine condition (not covered under warranty).

Unless other provisions are provided, maximum fuel level in relation to feed pump must not exceed 3.5 m (11.5 ft.). If an installation exceeds 3.6 m (11.8 ft.) of diesel head, a day/buffer tank is required. See the section titled: **Storage Tank and Day/Buffer Tank**.

Position the fuel tank in as cool a location as possible. If the tank(s) are built in, the space should be well ventilated.

Most marine generator sets draw fuel from the same fuel tank as the craft's propulsion engine(s). If the tank's fuel pickup opening allows a multiple dip tube, use a multiple dip tube arrangement. See **Figure 8**. The multiple dip tube arrangement incorporates a shorter dip tube for the generator set and a longer dip tube for the propulsion engine. With this arrangement, the generator set runs out of fuel before the propulsion engine during a low fuel supply situation. Equip the fuel system with a fuel/water separator to remove any accumulated dirt and water.

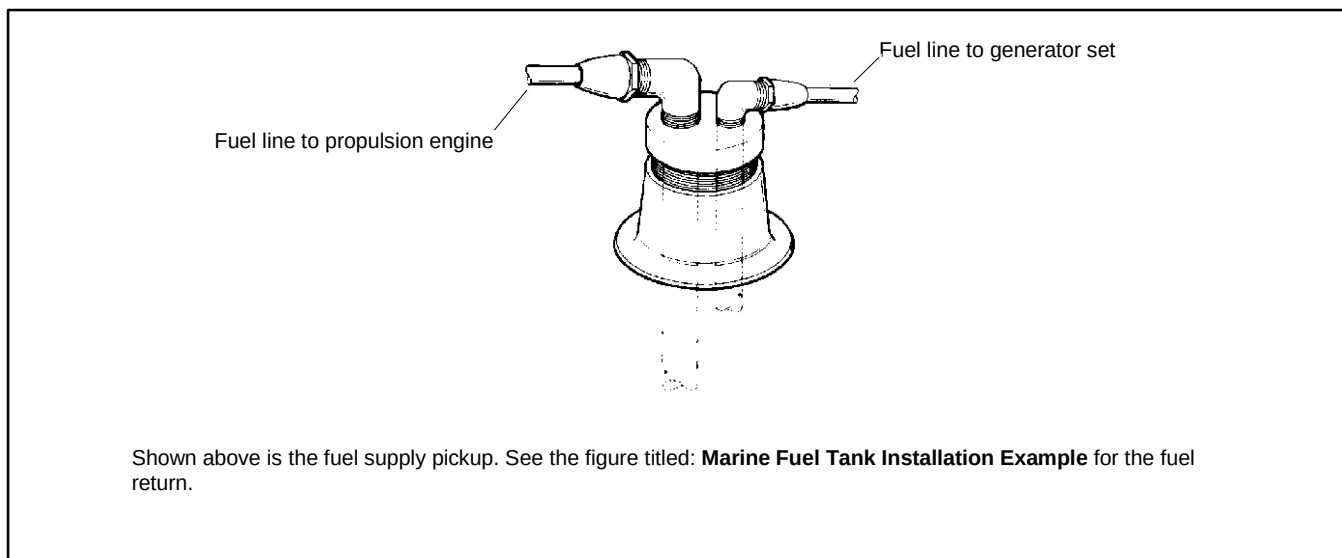


Figure 8 Multiple Dip Tube Arrangement

5.2.2 Tank Design

Design the fuel tank as follows:

- The material for the fuel tank should be corrosion-resistant, such as stainless steel or aluminum.

Note:

Some other materials, such as copper or hot-dip galvanized sheet steel, are unsuitable for use with diesel fuel.

Fuel tanks manufactured from materials which are not resistant to corrosion must be treated externally with anti-corrosion paint.

- The fuel tank must not be painted internally nor be zinc coated or galvanized.
- The fuel tanks must be fully welded.
- The fuel tanks must be equipped with internal baffle plates to prevent the fuel being thrown about in heavy seas.
- Both fuel filling components and the fuel tank must be grounded to prevent sparking from static electricity.

New fuel tanks must be thoroughly cleaned and rinsed internally using clean fuel. They must also be pressure tested to 0.3 bar.

The fuel tank should normally be drained once a year, but this may vary depending on the quality of the fuel.

The fuel tank must have the following devices:

- A drain tap for emptying sludge and water that has sunk to the bottom.
The reason for this is that the water separated out with the prefilter follows the return fuel back into the fuel tank.
- A ventilation or bleed pipe from the upper part of the fuel tank to the outside of the hull. It should be designed so that water cannot enter and so that fuel cannot run out when the ship is leaning heavily.
- Protection or filter to prevent contaminants entering during filling.
- Storage tanks must be fitted with inspection hatches so that they can be inspected and cleaned inside.

5.2.3 Storage Tank and Day/Buffer Tank

If the installation has a day/buffer tank and a storage tank, these should be designed as follows:

- The storage tank should have a sloped bottom or be on a slight incline (about 3-5°) and have a tap at the lowest part for draining condensation.
- The day/buffer tank must also be fitted with a drain tap for condensation.
- The pipes to the day/buffer tank should be as short as possible and should be mounted in such a way that they cannot be exposed to mechanical damage.
- An electric feed pump must be fitted directly downstream of the storage tank. It must be connected so that it only pumps when the engine is running, to avoid the risk of major leaks when the engine is at a standstill.

The flow for the electric feed pump must be 30-40% higher than the flows specified in the section titled: **Important Data**. This is to ensure that the quantity of return fuel is sufficient for lubrication and cooling.

- There must be a return pipe from the day/buffer tank to the storage tank so that any surplus fuel runs back into the storage tank.

Note:

The return pipe should enter below the lowest fuel level in the storage tank. See **Figure 9**.

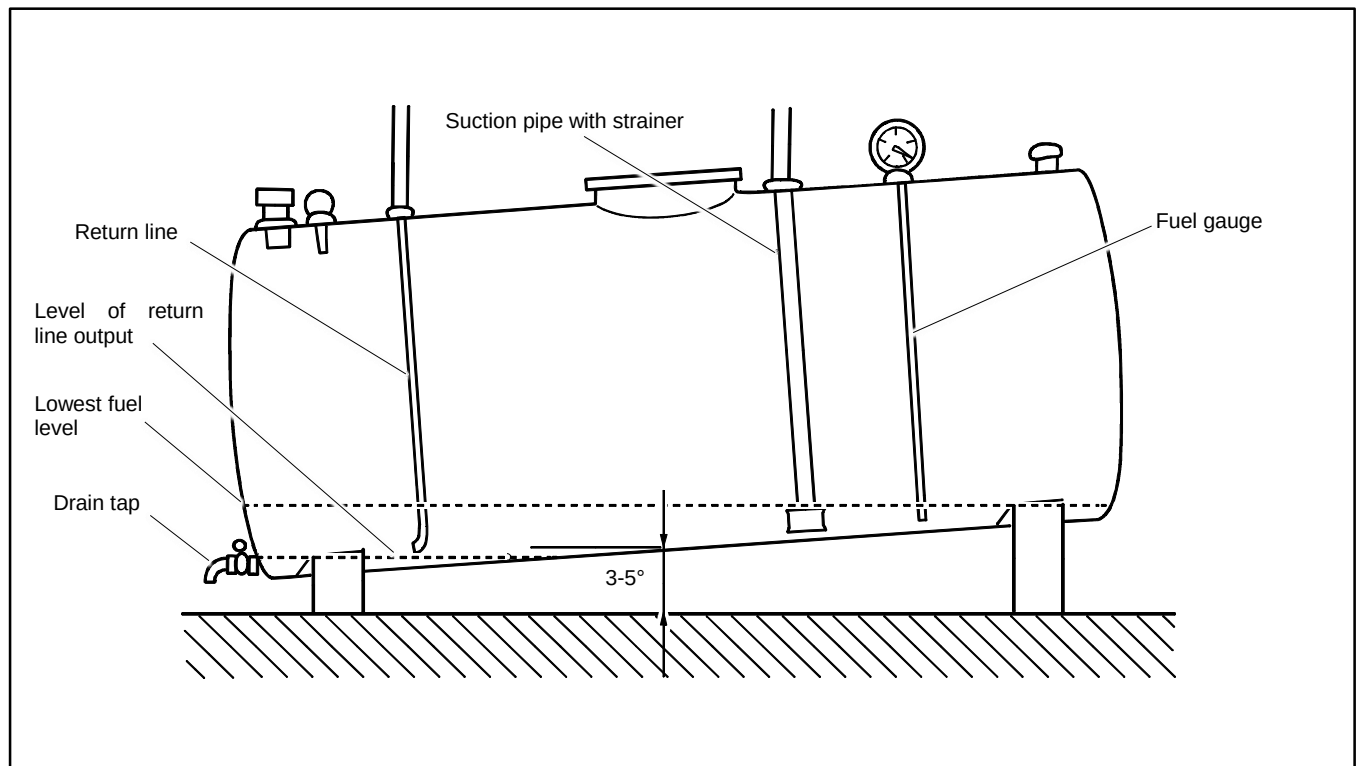


Figure 9 Storage Tank

5.3 Fuel Grade and Output

Different fuel factors such as temperature, density and viscosity influence the output available from the engine: see the graphs.

The listed engine outputs assume fuel with a density of 0.84 kg/dm^3 and specific calorific value of $42,700 \text{ kJ/kg}$ at a fuel temperature of 15°C (59°F).

Since specific calorific value is difficult to measure for the fuel in question, viscosity, density and temperature can be used instead to obtain a fuel correction factor in % for each of the characteristics.

The % correction outputs from **Figure 10**, **Figure 11**, and **Figure 12** should first be added together to obtain the final correction output.

This is then multiplied by the engine output to obtain a correction factor in kW, which is then added to or subtracted from the output specified to obtain the corrected output within given tolerances.

If you have instead measured current output for a particular engine and wish to convert it to normal output, change the sign before the output correction values in the figures.

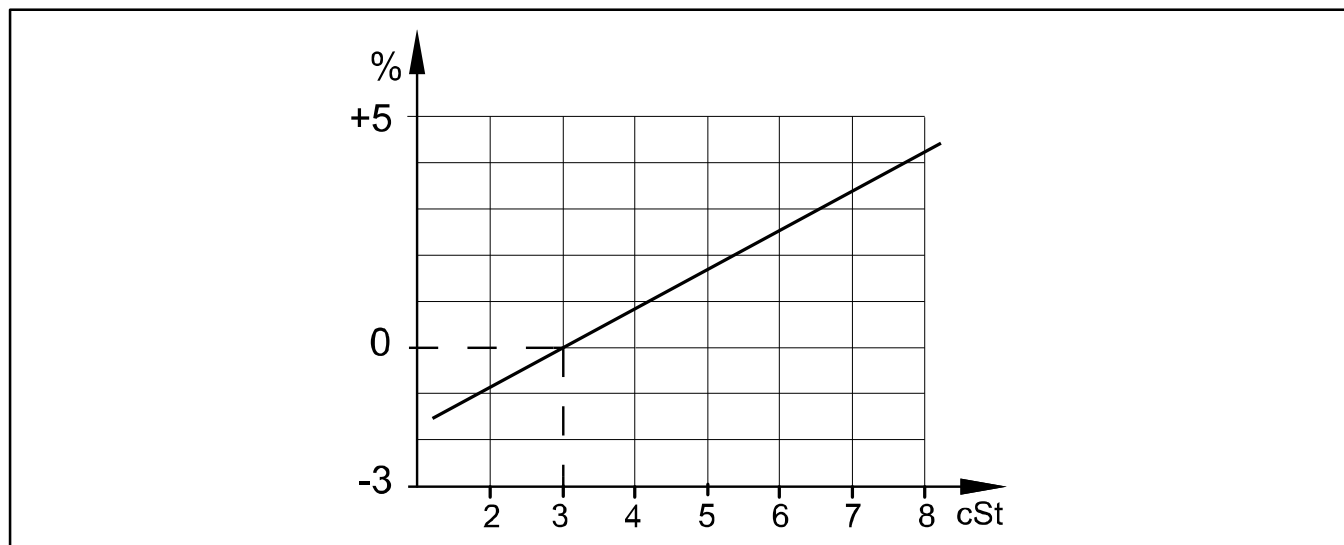


Figure 10 Engine Output Depending on Fuel Viscosity. Normal Value is 3 cSt at 40°C (104°F)

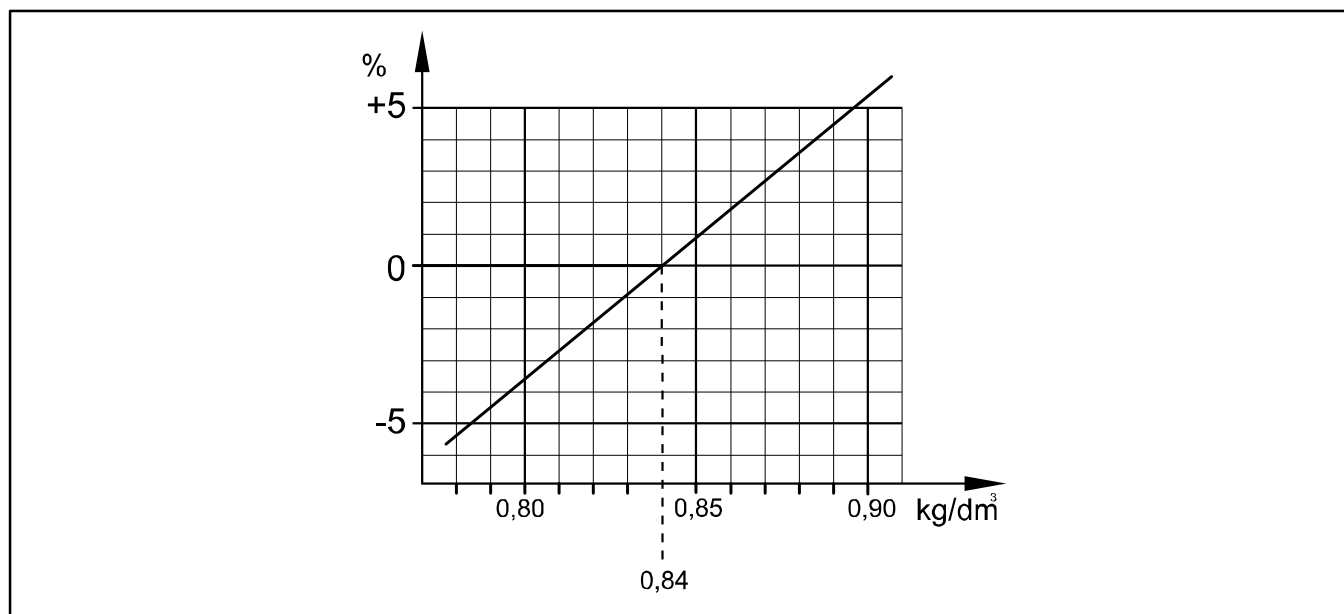


Figure 11 Engine Output Depending on Fuel Density. Normal Value is 0.84 kg/dm^3 at 15°C (59°F)

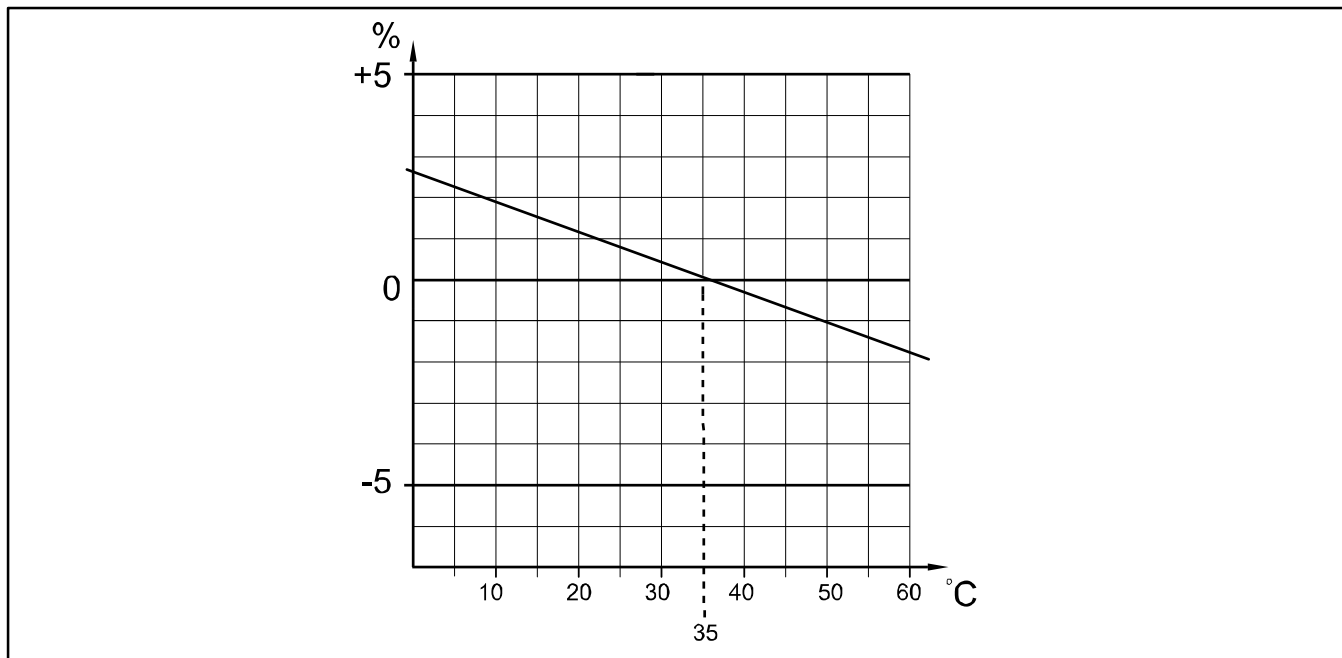


Figure 12 Engine Output Depending on Fuel Temperature. Reference Temperature is 35°C (95°F)

5.4 Fuel Lines

Route the fuel lines so that the fuel cannot be heated by radiated heat from the engine.

Engine output dependence on fuel temperature is shown in the figure titled: **Engine Output Depending on Fuel Temperature**. Maximum permitted fuel temperature in the inlet line is 60°C (140°F).

The minimum inside diameter of the fuel inlet line is shown in **Figure 13**.

The return line from the overflow valve should be routed to the fuel tank. Note that it must not be connected to the inlet line.

Locate the fuel return line as far as practical from the fuel pickup to allow the tank fuel to cool the return fuel before delivery back to the fuel injectors. Incoming fuel cools the injectors to achieve maximum engine efficiency.

Note:

Do not tee into the main propulsion engine's fuel line.

Under no circumstances should the propulsion engine and generator set share pickup or return lines (through a tee arrangement) that would allow the larger engine to starve fuel from the smaller engine. It is possible that the operation of either engine could completely drain the fuel line of the other engine and make starting difficult or cause high restriction leading to or causing a runaway engine condition.

Use a flexible hose section to connect the metallic line from the fuel tank to the engine's fuel pump inlet connection point. Also, use a flexible hose section to connect the metallic line from the fuel tank to the fuel return connection point. The flexible section allows vibrational motion of the generator set during operation.

The return line should have the same diameter as the inlet line.

Route the fuel lines from the fuel tank in a gradual incline to the engine. Do not exceed the height of the generator set and do not route fuel lines above the generator set. Comply with USCG regulation 46CFR182.20 regarding fuel lines and supports.

Both the inlet and return lines are normally connected to the top side of the tank. The return line should enter below the lowest fuel level in the fuel tank. See the figure titled: **Marine Fuel Tank Installation Example**.

The inlet line in the tank should be placed at least 50 mm (2 in.) from the bottom of the tank. This distance also applies to the inlet strainer.

See the section titled: **Installation Drawings** for fuel inlet and return connections.

In multi-engine installations, each engine should have separate fuel lines.

The material for the fuel lines should not be copper as there is a risk of oxidation due to condensation. The sulphur content in the fuel can also have a negative effect on the copper.

Fuel Line Length	Minimum Inside Diameter, mm (in.)	
	350EOZCS/ 300EFOZCS	500EOZCS/ 450EFOZCS
Shorter than 3 m (9.8 ft.)		
Inlet	10 (3/8)	
Return	10 (3/8)	
Longer than 3 m (9.8 ft.)		
Inlet	12 (1/2)	
Return	12 (1/2)	

Figure 13 Inside Diameters of Fuel Lines

5.5 Fuel Filter

Note:

Conform to USCG regulations regarding inline fuel filters or strainers.

5.5.1 General

The generator engine is equipped with an engine-mounted fuel filter. This filter is already fitted to the engine and may be a single filter or double filter which can be replaced during operation.

Engines must also be equipped with a water separating prefilter.

The prefilter should not be placed directly on the engine and a shut-off valve should be fitted before the filter.

Note that all types of fuel filter with water drain should, if possible, be placed before the feed pump and at a low level in relation to the tank so that the fuel is forced into the filter. This prevents air being sucked into the filter during draining.

The prefilter should not be installed higher than the feed pump because that results in an unnecessary high suction height, making the engine more difficult to start.

All connections on the inlet side of the feed pump must be thoroughly sealed so that no air is drawn in during operation.

If a prefilter from an external supplier is installed, a filter with a cleaning efficiency of a maximum of 30 micrometers is recommended.

The water separating prefilter should be changed at the same intervals as the main filter.

In multi-engine installations, there should be extra fuel filters between each engine and the tank.

The fuel vacuum should always be checked after installation.

5.6 Switchable Filters

It is also possible to install prefilters that are switchable, (possible to replace the fuel filter while the engine is running by switching off one filter at a time). These filters have water separators and indicators showing when it is time to replace the filters.

Note:

When replacing filters, both filters must always be replaced.

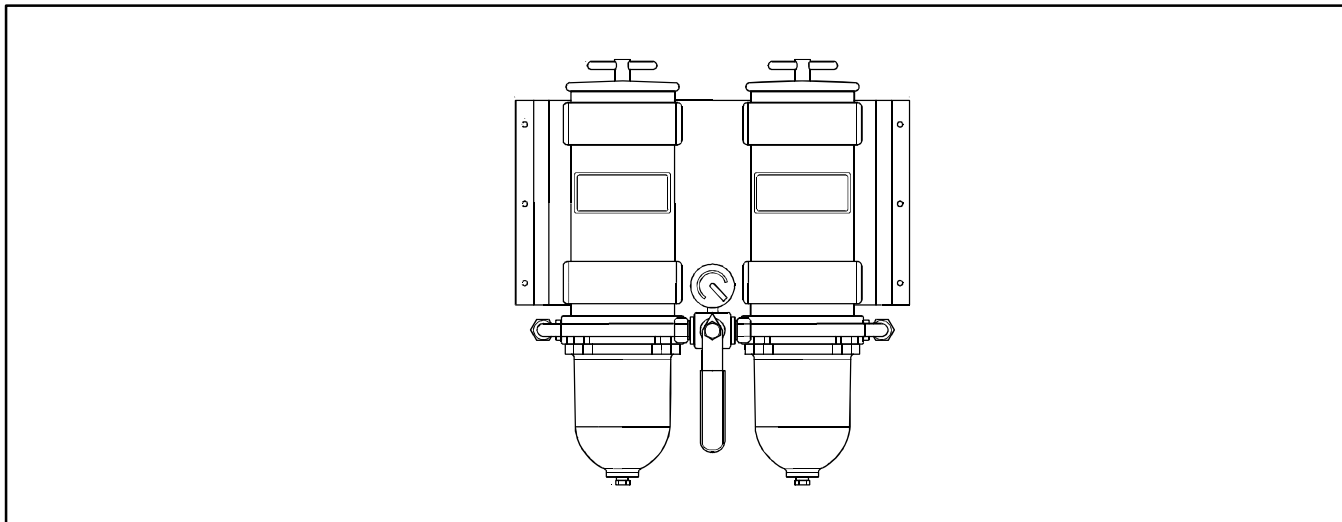


Figure 14 Switchable Prefilters with Water Separators

5.7 Bleeding the Duplex Fuel Filters (Option)

If the fuel tank has been run dry or if the generator set has not been used for a long time, bleed the fuel system.

Note:

Dispose of all waste materials in an environmentally safe manner and in accordance with all applicable laws.

During operation, the rotary control should point 90° towards the filter being used.

1. Turn the rotary control 90° to the right so that it points towards Filter B. The fuel then flows through the filter. See **Figure 15**.

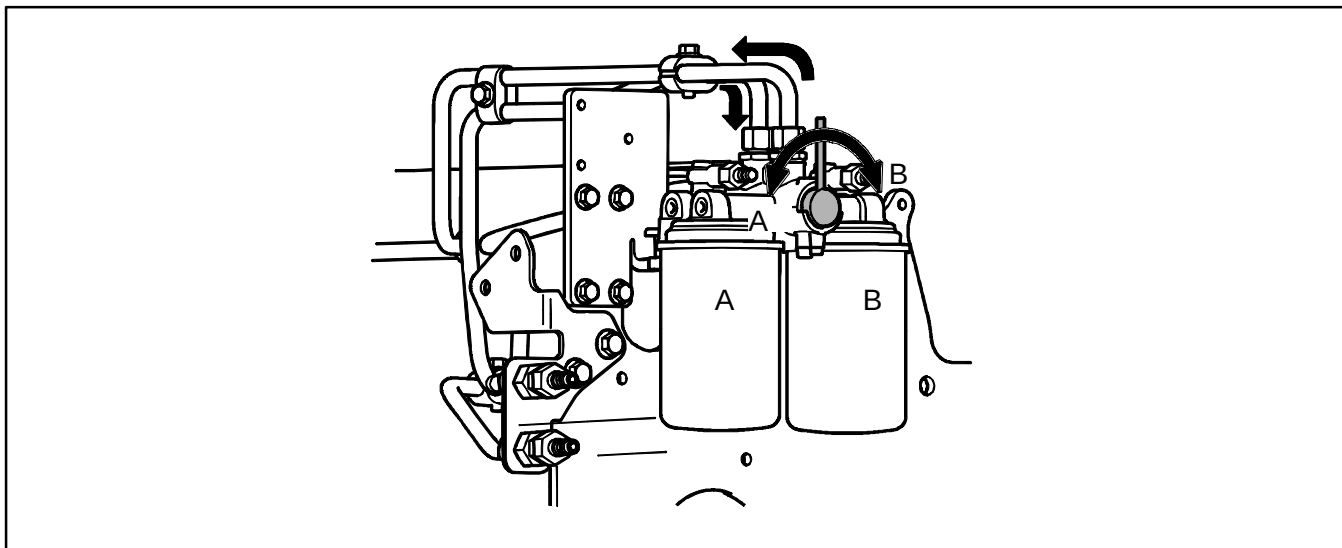


Figure 15 Bleeding Duplex Fuel Filters (Option)

2. Connect a clear plastic hose to the bleed nipple positioned above Filter A. Start by wiping off the bleed nipple. Place the other end of the hose in a container with a capacity of at least 3 liters (1 US gallon).
3. Open the bleed nipple on Side A. The remaining pressure is released.
4. Clean the exterior of the filter with a cloth.

5. Unscrew the filter.
6. Apply oil to the gasket on the new filter.
7. Screw the fuel filter into place by hand until it makes contact. Turn screw a further half turn by hand.
8. Turn the rotary control 90° to the left so that the rotary control points straight up. Both filters now run simultaneously.
9. When the fuel, without air bubbles, comes out, close the bleed nipple. Since the engine is running, a lot of fuel will come through the hose.
10. Turn the rotary control 90° to the left so that the rotary control points towards Filter A. Filter B can now be changed in the same way as Filter A.

5.8 Bleeding the Fuel System Using a Hand Pump

If the fuel tank has been run dry or if the generator set has not been used for a long time, bleed the fuel system.

Note:

Dispose of all waste materials in an environmentally safe manner and in accordance with all applicable laws.

1. Attach a clear plastic hose to the bleed nipple on the fuel manifold. See **Figure 16** or **Figure 17**. Start by wiping off the bleed nipple. Place the end of the plastic hose in a container that holds at least 3 liters (1 gallon).
2. For 500EOZCS/450EFOZCS models, remove the belt guard cover to access the fuel priming pump.

Note:

There is an optional knockout provided. See **Figure 18** for location.

3. Open the bleed nipple and pump with the hand pump until fuel comes out of the hose. If the fuel system is empty, it is necessary to pump approximately 200 strokes in order to draw up the fuel. Depending on the installation, a significantly greater number of pump strokes may be required before fuel comes out.
4. Pump until fuel, without air bubbles, comes out, approximately 20 strokes.
5. Close the bleed nipple and remove the plastic hose.
6. Pump approximately 20 strokes with the hand pump until the overflow valve opens. A hissing sound should be heard.
7. Start the generator set. The generator set should be easy to start.
8. If the fuel filter has been renewed, check that no fuel is leaking from the filter. If there is leakage, tighten the filter.
9. For 500EOZCS/450EFOZCS models, reinstall the belt guard cover.

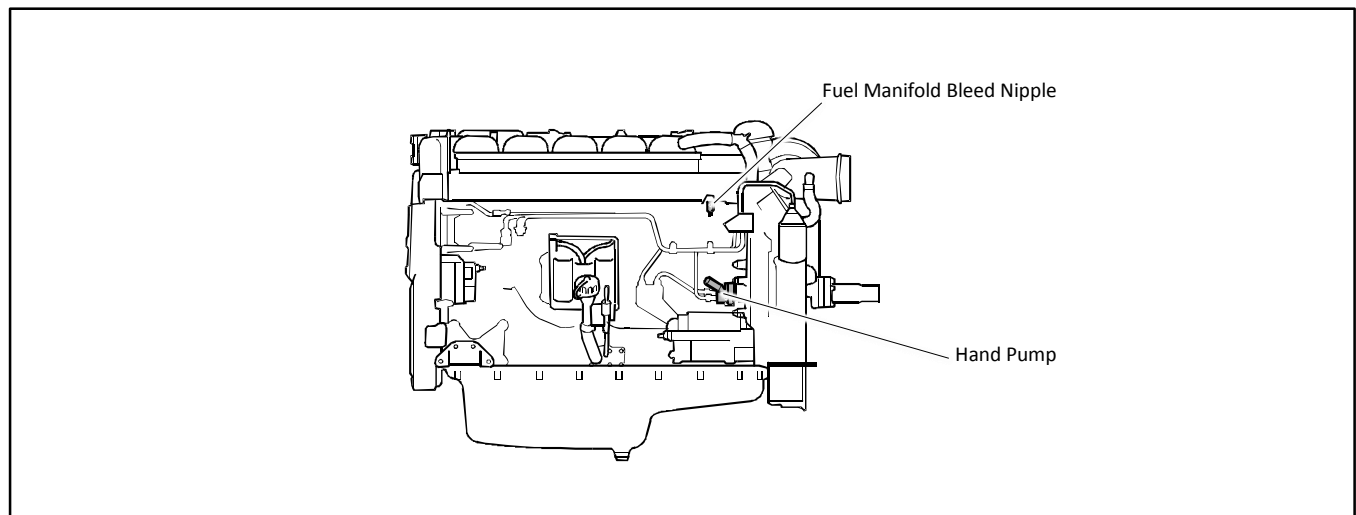


Figure 16 350EOZCS/300EFOZCS Bleed Nipple/ Hand Pump Location

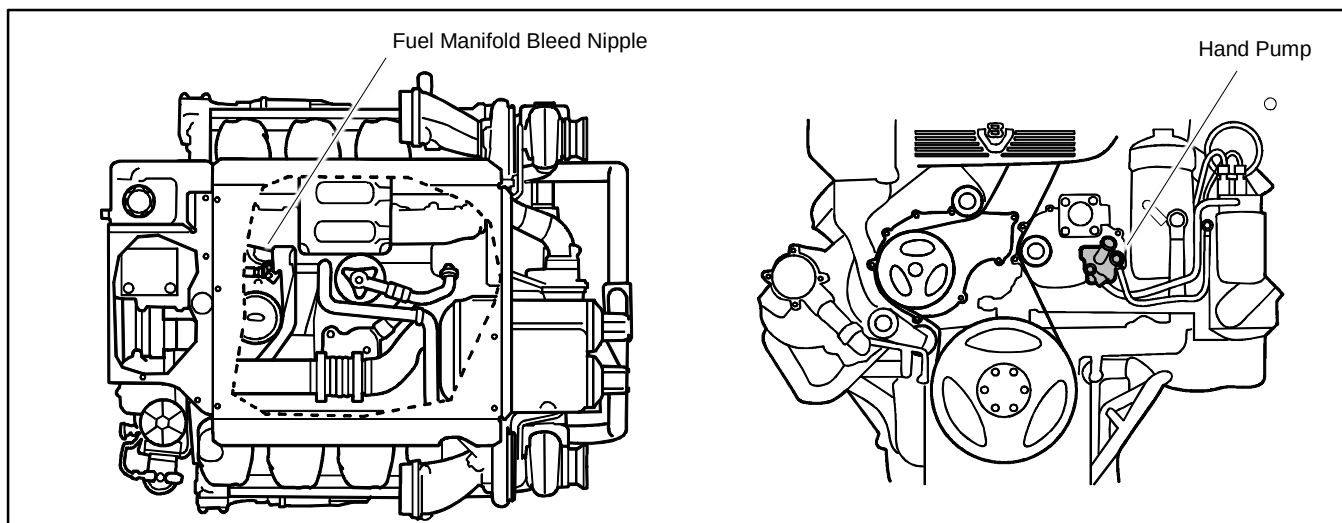


Figure 17 500EOZCS/450EFOZCS Bleed Nipple/ Hand Pump Location

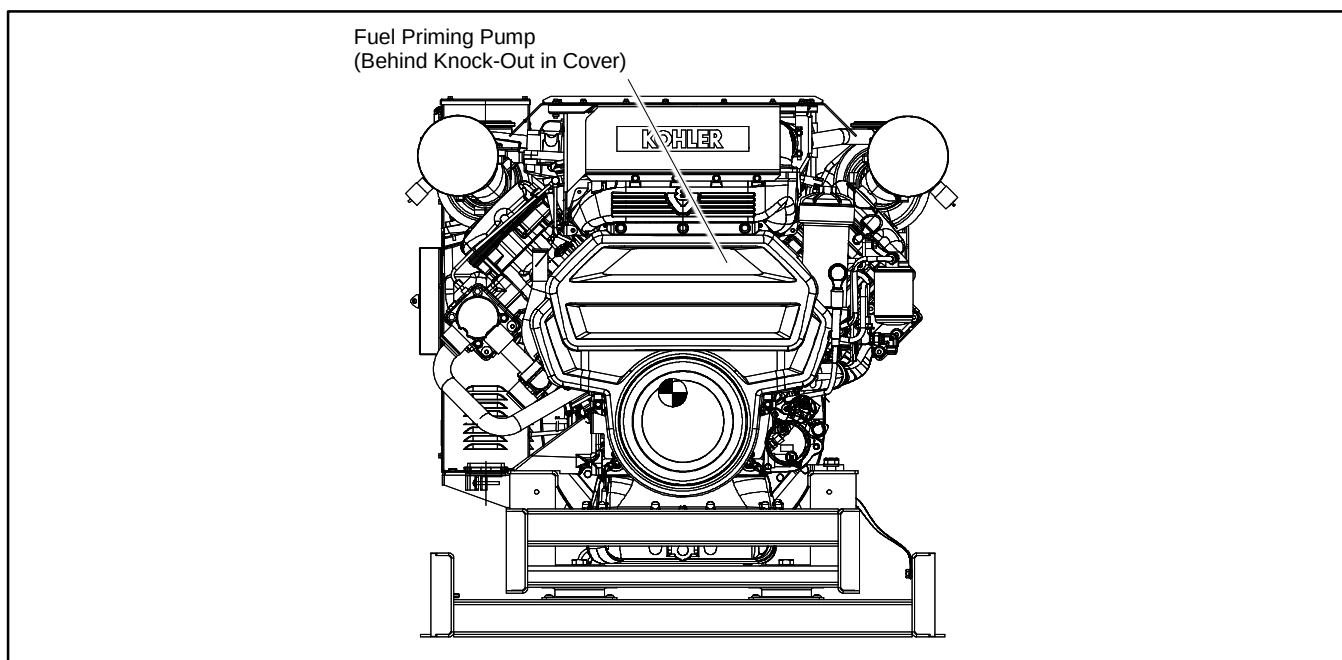


Figure 18 Optional Knockout Location (500EOZCS/450EFOZCS)

5.9 Important Data

Note:

The entire supply system (lines, valves, filters) must be taken into consideration during sizing of the fuel system to ensure the max. vacuum on inlet and max. return is below the limits.

Max. vacuum in feed pump suction line using a cleaned or new filter	0.3 bar (4.4 psi)
Max. fuel level above feed pump	3.5 m (11.4 ft.)
Max. fuel temp. before feed pump	60°C (140°F)
Normal fuel pressure	4- 6 bar (58- 87 psi)
Max. permitted back pressure in the return pipe	0.35 bar (5 psi)
Max. recommended fuel lift	3 m (10 ft.)
Max. feed pump flow to the high pressure pump 350EOZCS/300EFOZCS 500EOZCS/450EFOZCS	5 L/min. 6.75 L/min.
Max. return flow to the fuel tank 350EOZCS/300EFOZCS 500EOZCS/450EFOZCS	4.95 L/min. 6.70 L/min.
Max. flow restriction in fuel pipes	0.3 bar (4.4 psi)
Engine output depending on fuel viscosity	See the figure titled: Engine Output Depending on Fuel Viscosity
Engine output depending on fuel density	See the figure titled: Engine Output Depending on Fuel Density
Engine output depending on fuel temperature	See the figure titled: Engine Output Depending on Fuel Temperature
Inside diameter of fuel lines	See the figure titled: Inside Diameters of Fuel Lines
Fuel consumption	See generator set Spec Sheet

 WARNING	Carbon monoxide. Can cause severe nausea, fainting, or death.
	The exhaust system must be leakproof and routinely inspected.

Carbon monoxide symptoms. Carbon monoxide can cause severe nausea, fainting, or death. Carbon monoxide is a poisonous gas present in exhaust gases. Carbon monoxide is an odorless, colorless, tasteless, nonirritating gas that can cause death if inhaled for even a short time. Carbon monoxide poisoning symptoms include but are not limited to the following:

- Light-headedness, dizziness
- Physical fatigue, weakness in joints and muscles
- Sleepiness, mental fatigue, inability to concentrate or speak clearly, blurred vision
- Stomachache, vomiting, nausea

If experiencing any of these symptoms and carbon monoxide poisoning is possible, seek fresh air immediately and remain active. Do not sit, lie down, or fall asleep. Alert others to the possibility of carbon monoxide poisoning. Seek medical attention if the condition of affected persons does not improve within minutes of breathing fresh air.

Inspecting the exhaust system. Carbon monoxide can cause severe nausea, fainting, or death. For the safety of the craft's occupants, install a carbon monoxide detector. Never operate the generator set without a functioning carbon monoxide detector. Inspect the detector before each generator set use.

Operating the generator set. Carbon monoxide can cause severe nausea, fainting, or death. Be especially careful if operating the generator set when moored or anchored under calm conditions because gases may accumulate. If operating the generator set dockside, moor the craft so that the exhaust discharges on the lee side (the side sheltered from the wind). Always be aware of others, making sure your exhaust is directed away from other boats and buildings.

6.1 Exhaust System Types

6.1.1 General

Both dry and wet exhaust systems are found in marine installations. Kohler® generator sets covered in this manual use either dry or wet exhaust systems. Dry exhaust systems are common in commercial applications. See the engine manual for specifications.

Dry exhaust systems are preferable in the case of stack exhausts. In order to reduce the temperature and the noise level in the engine room, as well as the risk of fire, dry exhaust pipes must be insulated.

For installations with exhaust outlets in the stern or at the sides more or less level with the engine exhaust connection, wet exhaust systems are recommended.

In this case, seawater is brought in and mixed with the exhaust fumes, which results in dampening of the noise level and a lower exhaust temperature. After the connection point for the seawater, the exhaust system components do not necessarily need to be insulated.

A very short exhaust system can be fully encased in water to eliminate the necessity for silencers.

Note:

For 500EOZCS/450EFOZCS models, there are two exhaust banks.

Note:

For IMO Tier III models, the SCR system and bypass pipe must be connected with a branch pipe if a wet exhaust system is to be used. The exhaust gases may only be mixed with seawater downstream of the branch pipe. See **Figure 19**. Otherwise, the SCR system is filled with water when the engine is run in bypass mode. Pay attention to the exhaust back pressure limit provided in the section titled: **Important Data**. The requirements included in the section titled: **Wet Exhaust System** are applicable to the wet exhaust system downstream of the branch pipe. See **Figure 20**.

However, the SCR system may be water-jacketed downstream of the pipe section, where the NO_x sensor and exhaust gas temperature sensor are located. See **Figure 20**.

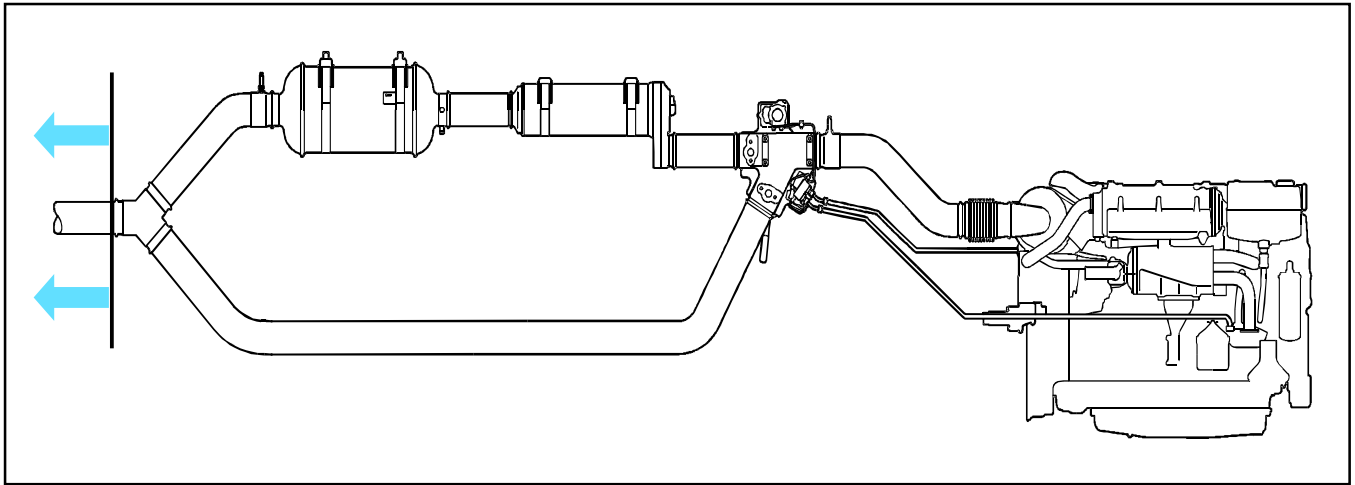


Figure 19 Limit for Wet Exhaust System, Engines with SCR System

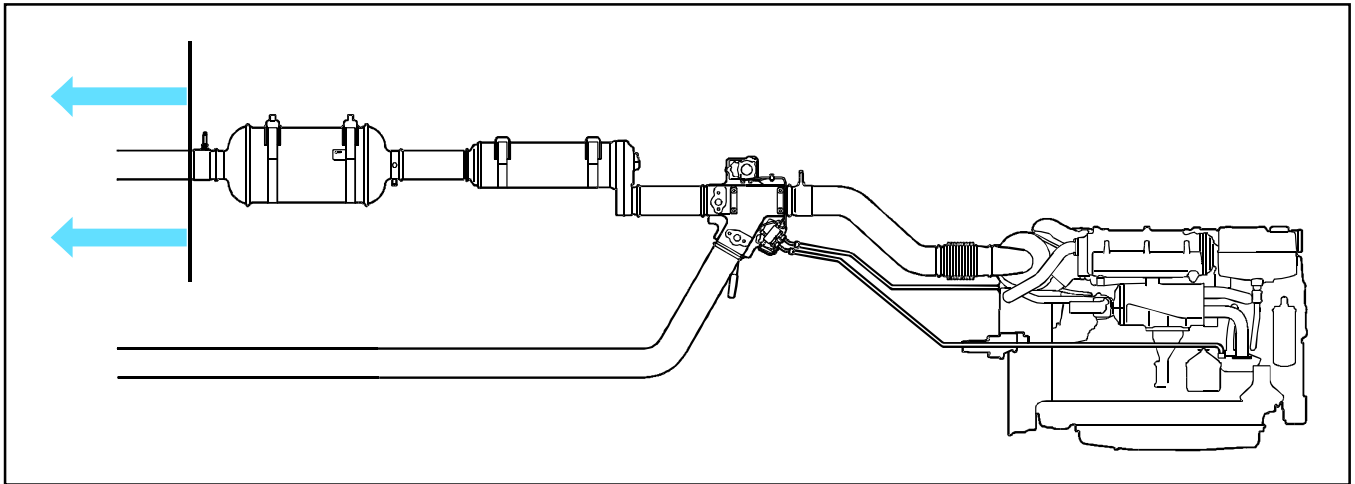


Figure 20 Limit for Water-Jacked Exhaust System, Engines with SCR System

6.2 Dry Exhaust System

6.2.1 Silencing

Some form of exhaust system with silencers is required in most installations.

However, the need for such systems in new installations should be assessed from case to case, based on actual conditions for noise level norms, length and type of exhaust system, location of the exhaust outlet and other factors.

Thermal insulation of the exhaust system has an effect on noise level and an insulated system can be noisier than one which is not insulated.

The customer-provided silencer should be positioned as close to the end of the exhaust system as possible. In order to obtain the best noise suppression, there should only be a short tailpipe after the silencer as shown in **Figure 21**.

If the silencer cannot be positioned close to the exhaust system outlet because of a lack of space, it should be placed as close to the engine as possible. This location is, however, unfavorable in silencing terms if the pipes beyond it are long.

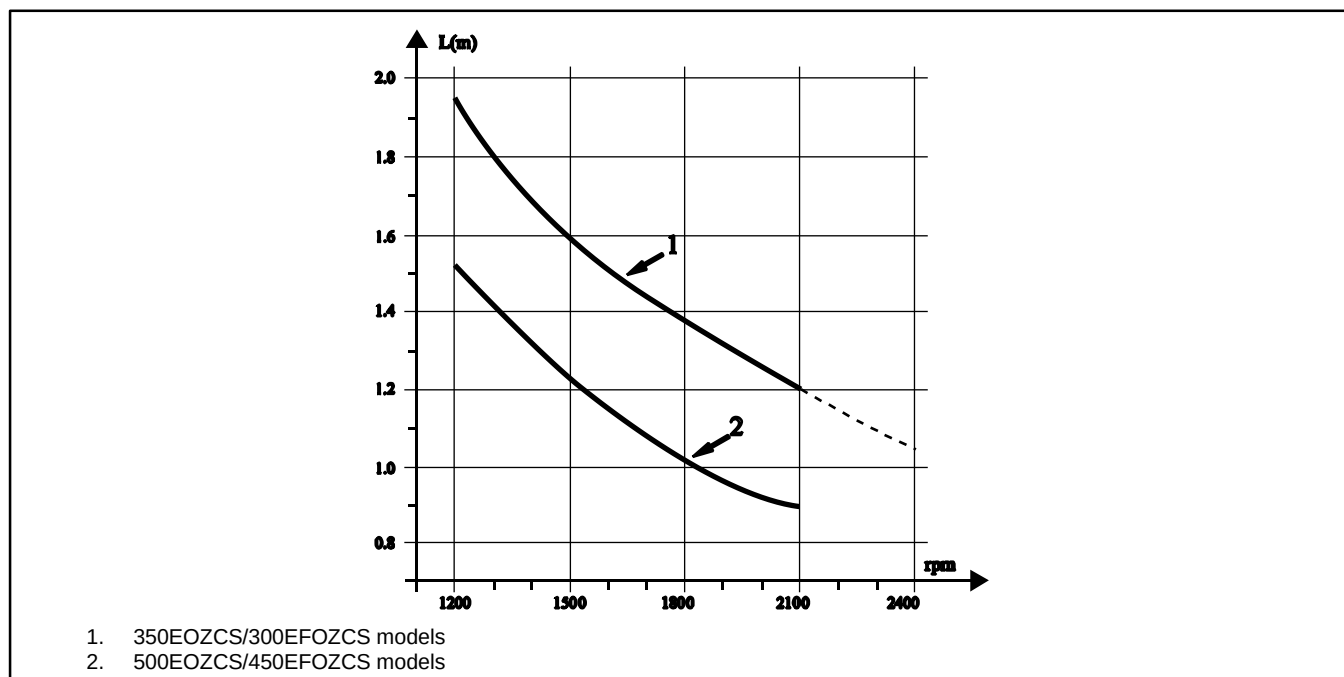


Figure 21 Graph for Determining Tail Pipe Length

It is therefore advisable to install an additional silencer close to the outlet or to end the exhaust system with two 90° bends with a suitable length between them. See **Figure 22** and **Figure 23**.

If 2 silencers are used in the system, they should be placed in series at a distance of $\frac{1}{3}$ of the length of the tail pipe and with the silencer used to dampen high-frequency noise furthest away from the engine.

The end of the exhaust system should be located to avoid reflection of the noise from vertical walls as this can raise the noise level.

In addition, the outlet should be positioned so that no exhaust fumes can be drawn into the intake. As the exhaust fumes always contain soot particles, there is a risk of the air filter becoming blocked while the temperature of the intake air will also dramatically increase.

In addition, the outlet should be positioned so that no exhaust fumes can be drawn into areas occupied by people (such as ship staterooms and crew's quarters).

Since the pipes which form part of an exhaust system also operate as silencers, it is important that they are dimensioned correctly. A number of design examples of short exhaust systems with favorable silencing properties are shown in **Figure 23**.

Figure 22 shows examples of long exhaust systems (> 5 m (16.4 ft.)) with good silencing.

Note:

Back pressure increases with the number of pipe bends and increased pipe length. This leads to higher fuel consumption and loss of power.

Note:

The installer is responsible for ensuring that the exhaust system does not leak when it is installed and that the suspension of pipes and silencers is done in a way which prevents the system leaking during operation.

Note:

Do not use V-clamps to force together joints, but only to fix the flanges.

Note:

For IMO Tier III models (engines with an SCR system), in most cases the exhaust system needs to be supplemented by a silencer. See **Figure 24**. For more information on SCR (Selective Catalytic Reduction), see the section titled: **SCR and Reductant**.

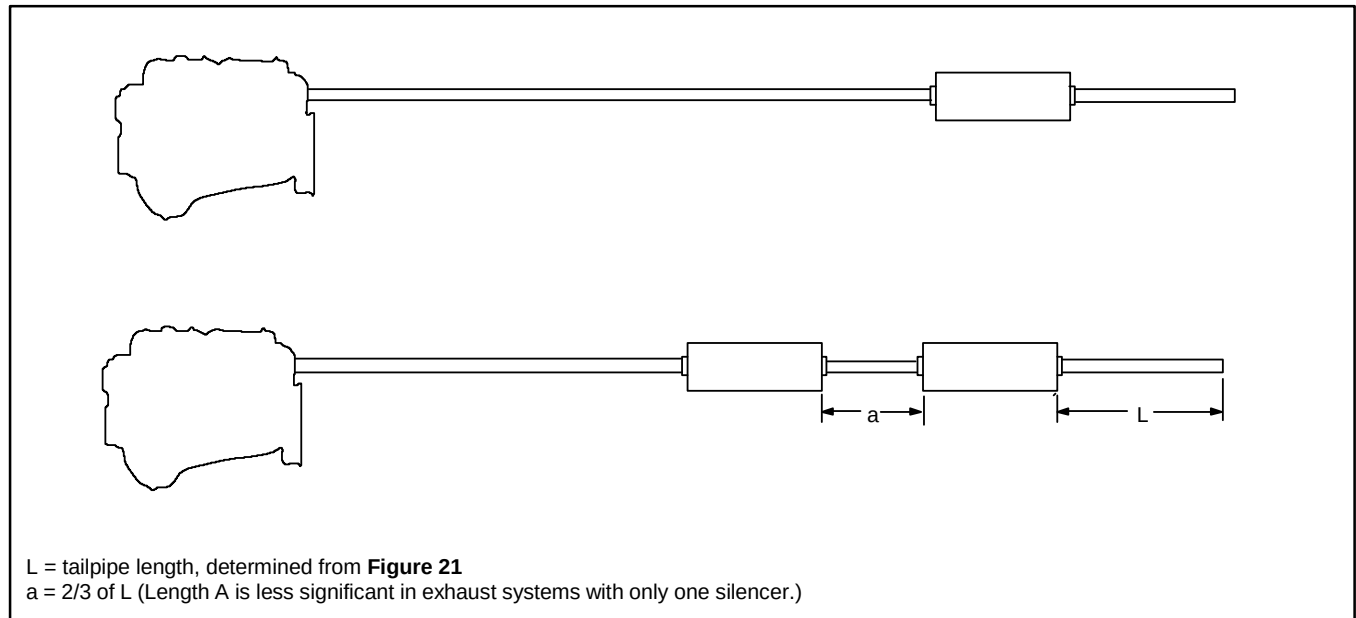


Figure 22 Examples of Long Exhaust Systems with Designs that Aid Sound Reduction

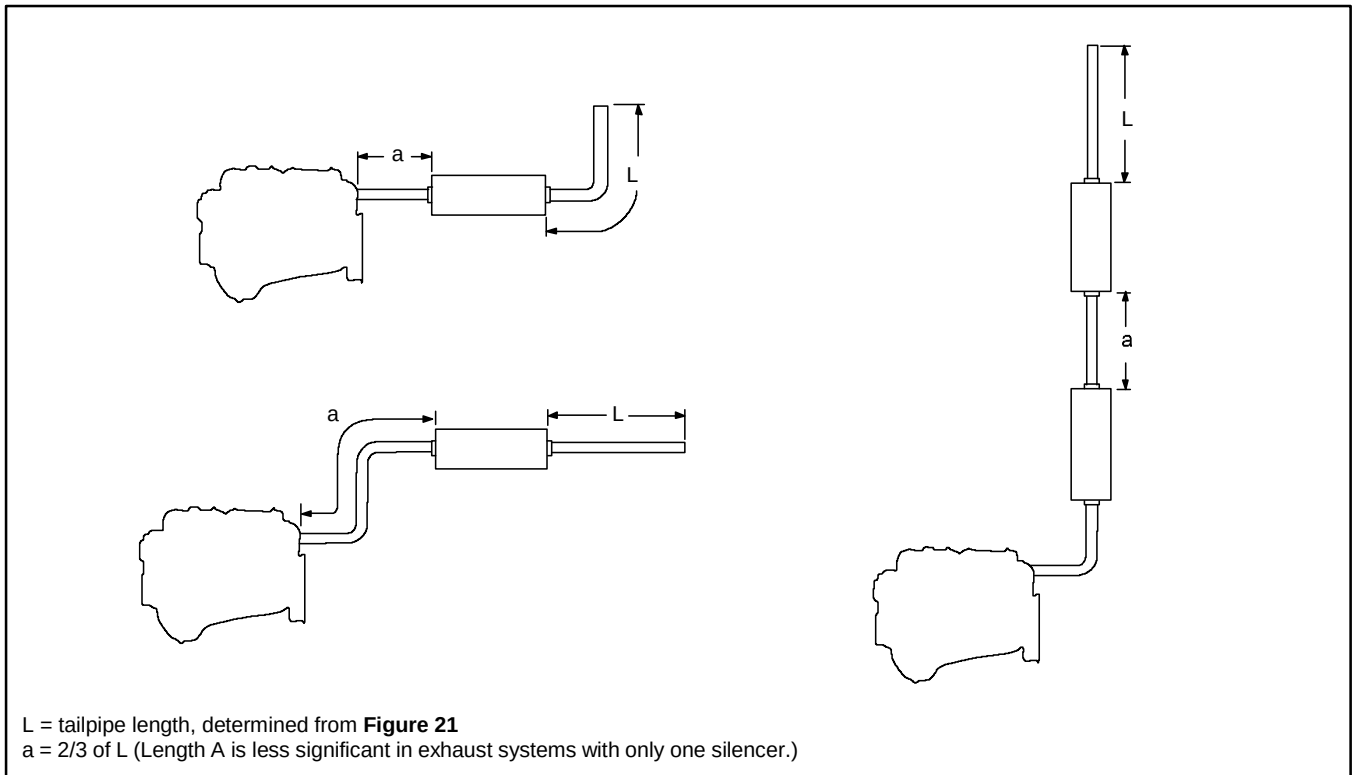


Figure 23 Examples of Short Exhaust Systems with Designs that Aid Sound Reduction

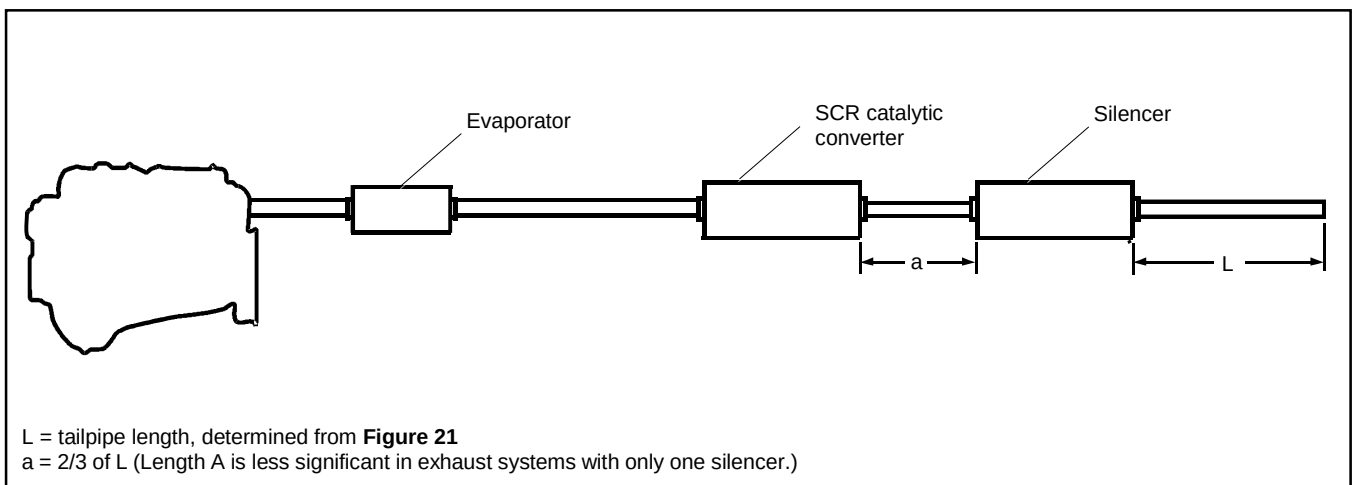


Figure 24 Example of SCR System

6.2.2 Exhaust System Connection to Generator

General

There should always be a flexible connection between the exhaust system and the generator engine to absorb the movement of the generator engine, especially when it has rubber suspension, and changes in length in the exhaust system due to temperature changes.

The need for a flexible connection is particularly great for turbocharged engines since the turbocharger may otherwise be damaged by vibration and thermal stresses. Such a flexible connection may consist of a flexible exhaust. Position the flexible connection as close to the turbocharger connection as possible.

The weight of the exhaust system should not load the flexible exhaust or the turbocharger. Therefore, there must be a suspension point for the exhaust system placed immediately after the flexible connection.

If the exhaust pipes are very long or on exhaust systems that have a relatively long horizontal part between two vertical parts, it may be necessary to have several flexible exhaust connections in the system. There must then be a fixed anchorage point on one side of the vertical flexible exhaust and a suspension which allows axial movement on the other side.

The outlet of the exhaust system should be located to avoid recirculation through the air intakes for combustion or ventilation air.

Flexible Exhaust

The engines are equipped with a 90° bend on the turbocharger exhaust outlet. The exhaust bend can be fitted at different angles, from a rear-facing to an upward-facing outlet flange. See the section titled: **Installation Drawings**, Detail A in the figure titled: **Dimension Drawing, 350EOZCS and 300EFOZCS (Sheet 2 of 3)** and the figure titled: **Dimension Drawing, 500EOZCS and 450EFOZCS (Sheet 2 of 3)**.

The exhaust pipe bend outlet has a flange that is connected with a V-clamp (**Figure 25**). It is usually connected directly to the engine exhaust bellows.

Note:

Do not use V-clamps to force together joints, but only to fix the flanges.

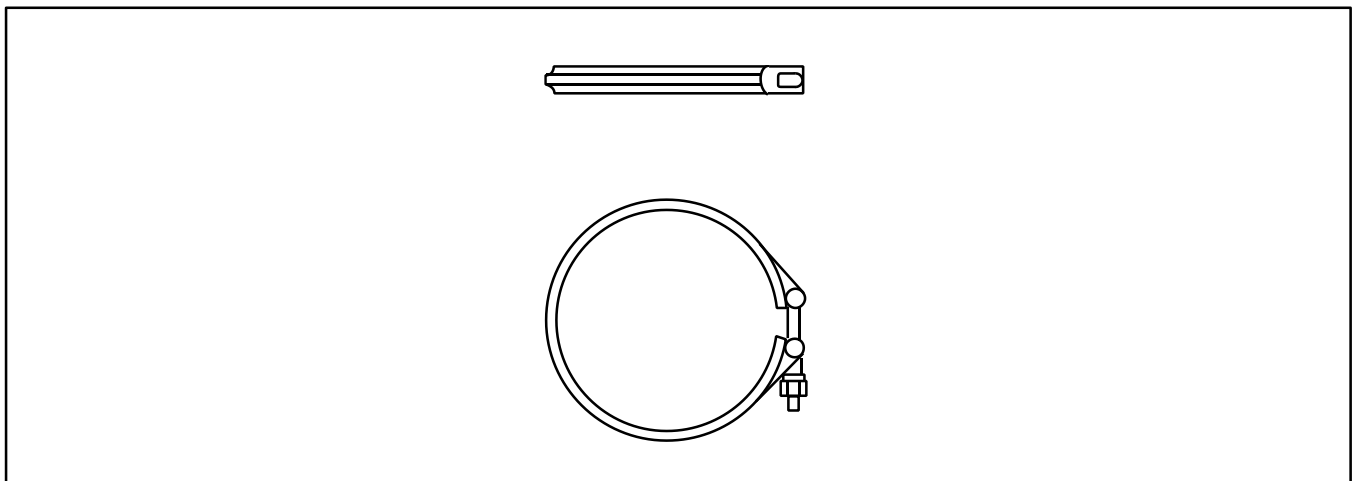


Figure 25 V-clamps

6.2.3 Exhaust System Insulation

The need for insulating exhaust systems should be assessed from case to case.

If the generator engine intake air is taken from the engine room, exhaust pipes should be insulated especially well to keep down the temperature in the engine room.

Other reasons for insulating are to prevent burn injury to personnel, reduce fire hazard from leaking fluids (hydraulic fluid and the like), in passages through or close to combustible materials or to reduce costs for ventilation etc. The exhaust system may also require insulation if there are lead throughs made of or near flammable material.

Insulation should withstand a temperature of at least 700°C (1292°F) and should always be protected from splashes closest to the engine.

Note:

The part of the exhaust system that connects to the outlet flange from the turbocharger must always be insulated.

The outer shell of the insulation must be so well sealed that fibers from the insulation material cannot vibrate loose and block the air filter.

The insulation of long pipes affects the exhaust back pressure. The diameter of the exhaust system should therefore be increased if it is insulated. In addition, an insulated system may have a higher noise level, which should also be taken into account during dimensioning.

It is important that the insulation is carried out so that the flexible part of the exhaust system is not restricted in its movement. It must also be possible to inspect the exhaust system without damaging the insulation during disassembly

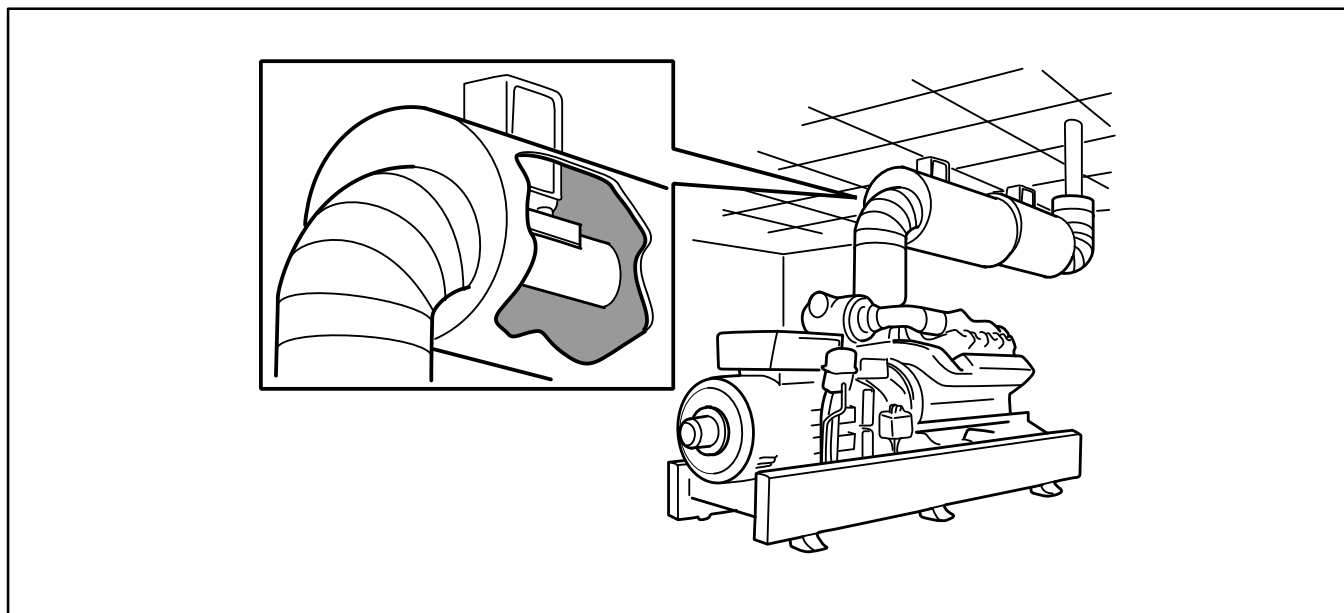


Figure 26 Exhaust System Insulation

6.2.4 Water Protection

Rain or condensation which enters the generator engine will cause corrosion damage and in the worst cases may cause liquid slugging which may result in bent connecting rods and the total destruction of the engine. The exhaust system must therefore be designed to prevent water ingress.

Long exhaust systems should be equipped with a condensation separator. It should be located as close to the engine as possible but after the flexible connection.

Note:

IMO Tier III Models. It is particularly important to protect engines with SCR systems against water ingress as the NO_x sensors can be damaged by moisture.

The occurrence of condensation is greater with a vertical exhaust system since the exhaust gases in a horizontal system carry away much of the condensation.

Even with short exhaust pipes, it may be a good idea to fit a condensation separator if there is any risk of rain water entering. Stack or vertical exhaust outlets should be equipped with a device to prevent water ingress.

The design of a short vertical exhaust system with a condensation separator is shown in **Figure 27**. A drainable water seal should also be connected to the water separator.

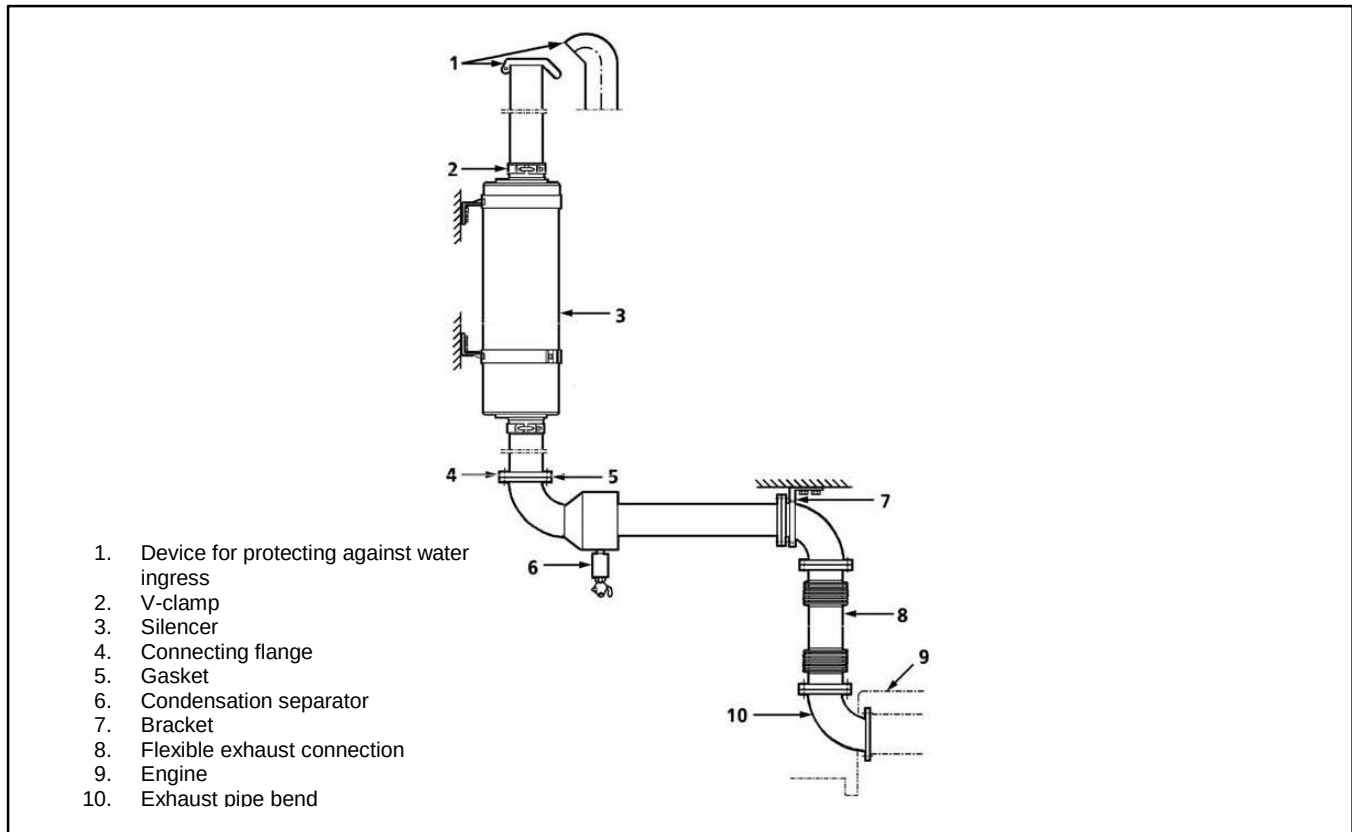


Figure 27 Exhaust Pipe with Flexible Exhaust Condensation Separator and Water Protection Device (Customer Supplied)

6.3 Wet Exhaust System

The exhaust system outlet should always be placed above the water line, even when the boat is heavily loaded. The system must slope downwards towards the outlet, which must therefore be lower than the water inlet in the system to prevent water forcing its way into the engine.

If the exhaust system outlet is higher than the engine exhaust connection, the exhaust system must be designed with a water lock that prevents water from entering the engine when stationary.

If a mixing wet exhaust muffler is used in the wet exhaust system as a water lock and to suppress noise, the lifting height for the gas/water mixture must not be so great that the exhaust back pressure is above 100 mbar.

The mixing vessel must hold at least the amount of water that is drained from the system when the engine is stopped.

The most common type of water lock (when the exhaust connection on the engine is lower than the water line) is an upward-facing, jacketed exhaust bend (exhaust riser) with a height of at least 350 mm (13.7 in.) above the exhaust system outlet. See **Figure 28**

If the engine is installed in such a way that its exhaust connection is located at least 350 mm (13.7 in.) above the water line, it is possible to connect a jacketed exhaust pipe with water inlet after the flexible pipe on the exhaust outlet from the engine. See **Figure 29**.

The jacketed exhaust pipe is then connected to the board lead-through with a rubber exhaust hose. Only corrosion-resistant hose clamps should be used for the rubber hoses and all of these clamped joints must be double clamped.

The jacketed exhaust system can be connected directly to the seawater line outlet. The connection diameter must be at least 50 mm (2 in.).

The material in the jacketed section must be corrosion resistant, although not copper or copper alloy.

The exhaust system must always be supplied with mounting or support so that its weight does not load the flexible exhaust and turbocharger.

Note:

Generator engines that have seawater-cooled exhaust systems comprising rubber hoses must have a warning system that issues an alarm in the event of low seawater pressure. Otherwise there is a risk of these lines overheating in the event of a fault in the seawater pump or if the seawater intake should become blocked. The water intake to the rubber hose must also be designed so that the spread of water over the surface of the hose is assured.

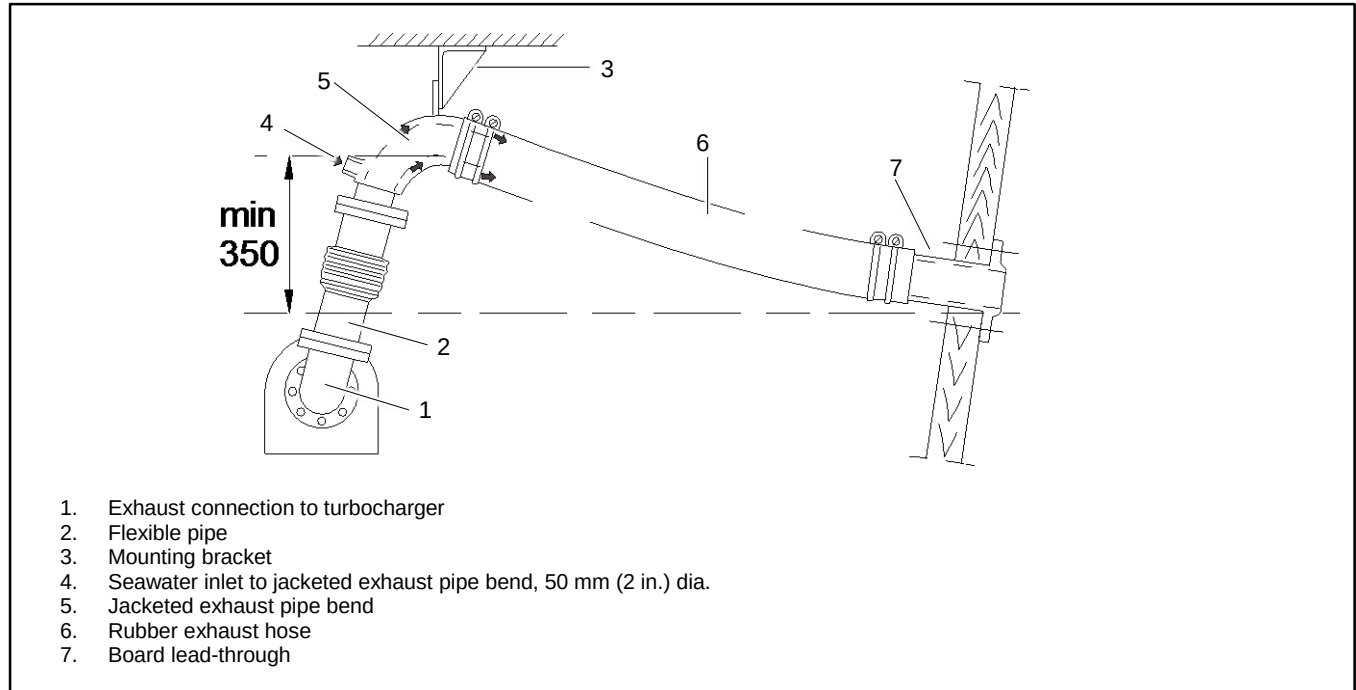


Figure 28 Wet Exhaust System with the Engine Exhaust Connection Below the Waterline (For Custom Heat Exchanger Cooled with Dry Exhaust Elbow Accessory Only)

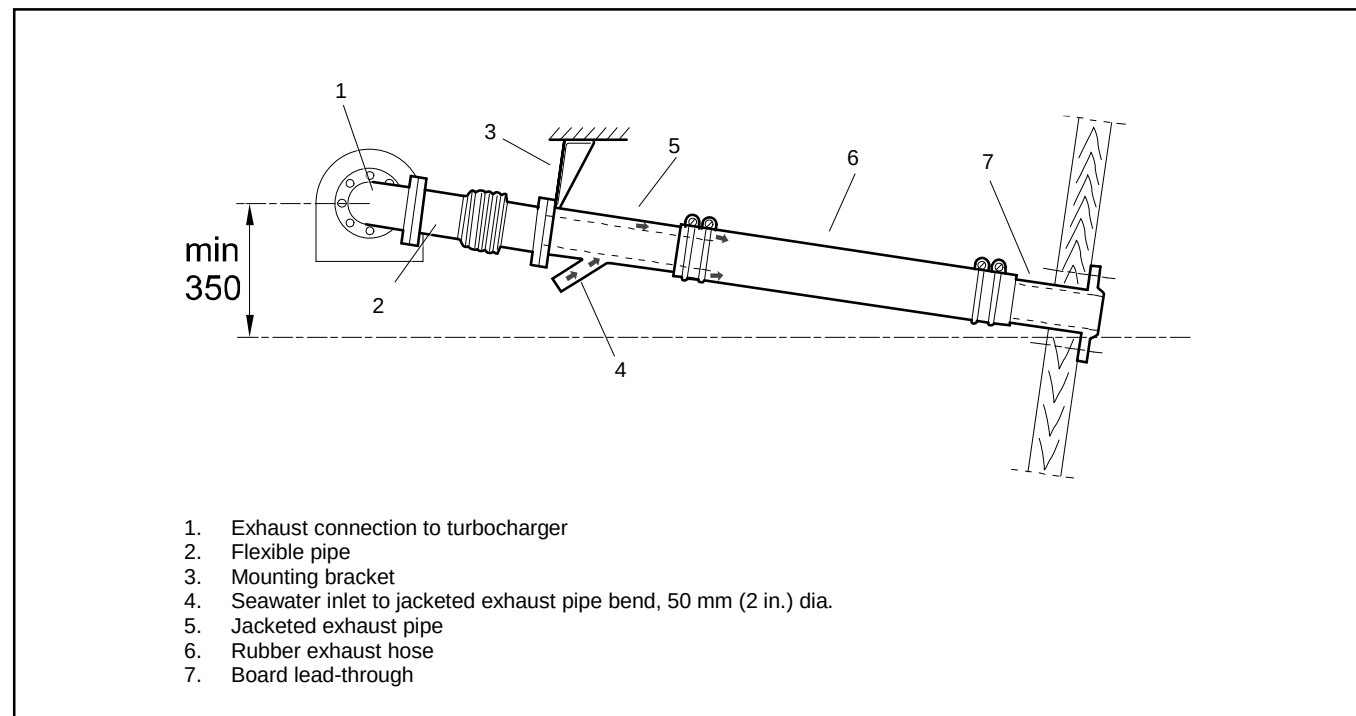


Figure 29 Wet Exhaust System with the Engine Exhaust Connection Above the Waterline (For Custom Heat Exchanger Cooled with Dry Exhaust Elbow Accessory Only)

6.3.1 Exhaust Lines

Use water-cooled exhaust lines in all marine wet exhaust installations. Keep the lines as short and straight as possible. NFPA 302 Fire Protection Standard for Pleasure and Commercial Motor Craft, Clause 4-3, recommends using two corrosion-resistant hose clamps with a minimum width of 13 mm (1/2 in.) on each end of the flexible exhaust hose connections. Kohler Co. requires a downward pitch of at least 13 mm per 30.5 cm (1/2 in. per running foot). Use a flexible exhaust hose that conforms to UL Standard 1129 for the engine's wet exhaust components between the mixer elbow and the exhaust outlet.

6.3.2 Exhaust System Location, Mounting, and Installation

Note:

Should any information regarding installation conflict with USCG regulations, follow USCG regulations.

Mount the silencer independently to eliminate stress on the exhaust system and the exhaust elbow. See the section titled: **Installation Drawings** for the exhaust outlet size. See **Figure 30** for the exhaust connection to the elbow. Provide an adequate hose length from the exhaust connection to the silencer to allow for generator set movement.

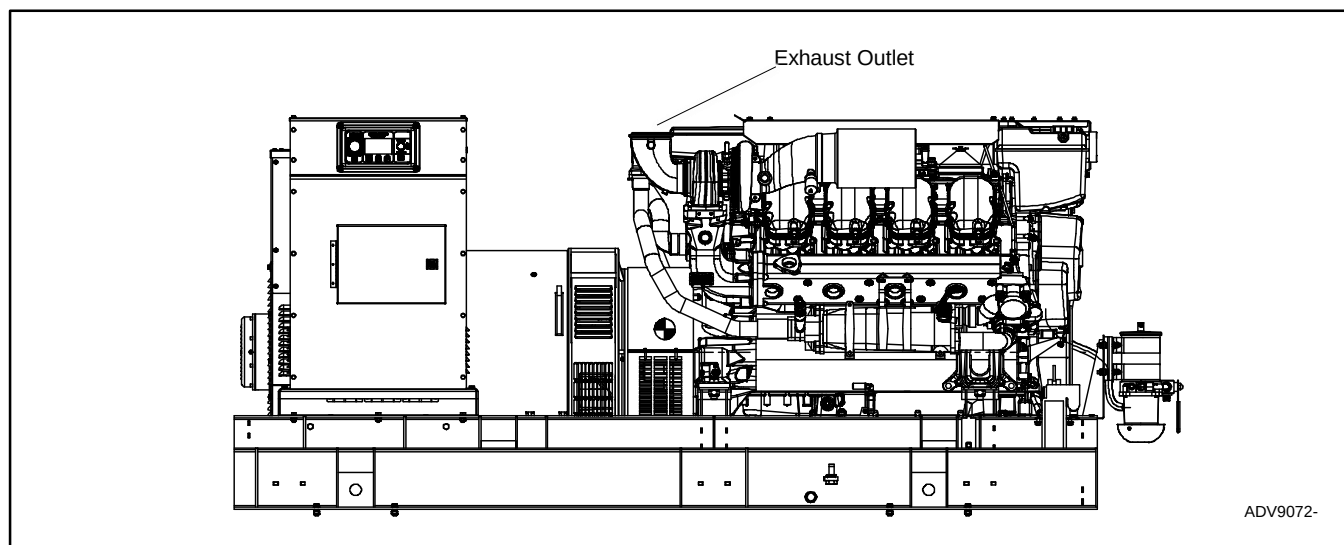


Figure 30 Elbow/Exhaust Connection, Typical

Locate the exhaust outlet at least 10 cm (4 in.) above the waterline when the craft is loaded to maximum capacity. Install an exhaust port with the flap at the exhaust (transom) outlet to prevent water backup in following seas or when moving astern (backward). A lift in the exhaust piping before the piping exits the craft prevents backwash. Support the exhaust lines to prevent the formation of water pockets.

Exhaust system installation guidelines for various generator set locations follow. Information and illustrations of stern- (rear) exhaust installations also apply to side-exhaust installations. Where exhaust lines require passage through bulkheads, use port (left)- or starboard (right)- side exhaust outlets, also in applications in which long exhaust lines to the transom (rear) could cause excessive back pressure. See the section titled: **Back Pressure in Exhaust Systems** for allowable back pressures.

6.3.3 Above-Waterline Installation

Install a customer-supplied silencer with the silencer's outlet at a maximum of 3 m (10 horizontal ft.) from the center of the engine's exhaust outlet. See **Figure 31**. Mount a typical silencer with the inlet and outlet horizontal and with the drain plug down. Use an exhaust hose pitch of at least 13 mm per 30.5 cm (0.5 in. per running foot). Some silencers require two support brackets or hanger straps for installation to stringers or other suitable structure. Follow the instructions provided with the silencer. Install any lift (see **Figure 31**, item 2) in the exhaust line below the engine exhaust manifold outlet.

Note:

Data applies to both rear- and side-exhaust installations.

Note:

Numbers in illustration refer to callouts below and not to dimensions.

Note:

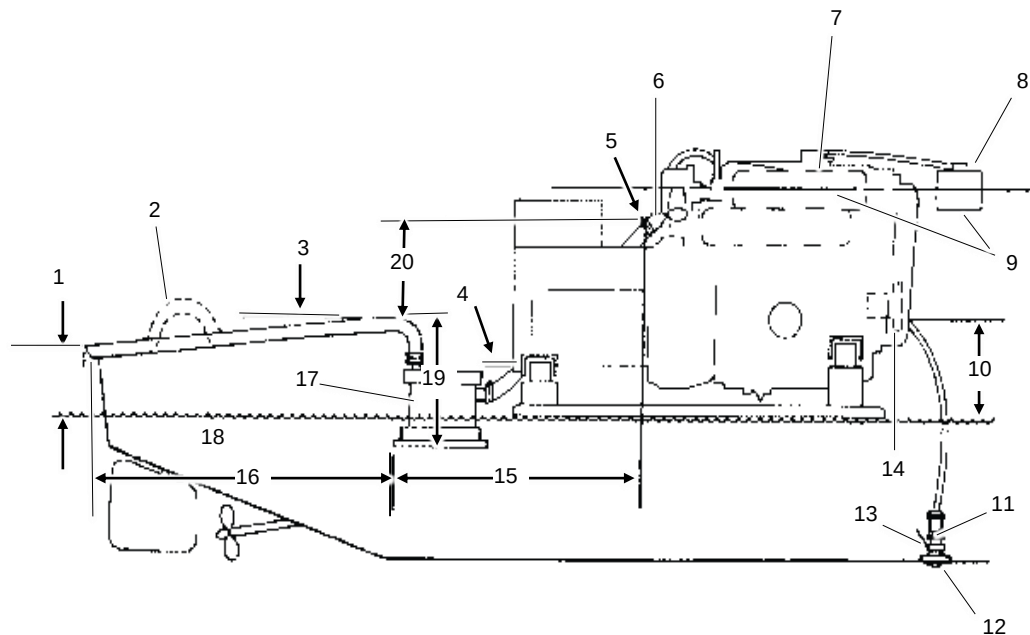
Read the text for complete explanation of dimensions and other installation considerations.

Note:

Use two hose clamps on each end of all flexible exhaust hose connections.

Note:

Damage caused by water ingestion will not be covered by the generator warranty.



1. Minimum exhaust outlet distance above waterline of 10 cm (4 in.). Note: Vessel fully loaded
2. Slight lift improves silencing and prevents water backwash into the silencer (keep below the level of the exhaust manifold outlet)
3. Minimum exhaust hose pitch of 1.3 cm per 30.5 cm (0.5 in. per ft.)
4. Minimum exhaust hose pitch of 1.3 cm per 30.5 cm (0.5 in. per ft.)
5. Exhaust manifold outlet
6. Exhaust mixer elbow
7. Heat exchanger (locations vary by model)
8. Coolant recovery tank (located on the unit on some models)
9. Locate the coolant recovery tank at the same height as the heat exchanger
10. Maximum seawater pump lift of 3 m (10 ft.)
11. Seawater strainer
12. Intake strainer
13. Seacock
14. Engine-driven seawater pump
15. Maximum distance between silencer and exhaust mixer elbow of 3 m (10 ft.)
16. Maximum distance between silencer and exhaust outlet of 1.5 m (5 ft.)
17. Silencer (customer-supplied)
18. Waterline
19. Maximum silencer vertical lift of 1.2 m (4 ft.)
20. Kohler recommends locating the generator set at elevation that exhaust mixer is above the highest point of the exhaust outlet hose.

Figure 31 Typical Above-Waterline Installation

6.3.4 Mid/Below-Waterline Installation

Follow USCG regulations for installing an antisiphon provision to prevent raw water entry into the engine. Use the siphon break if the exhaust manifold outlet is located less than 23 cm (9 in.) above the waterline when the craft is loaded to maximum capacity. Install the siphon break at least 31 cm (1 ft.) above the waterline using the instructions provided with the siphon break kit.

Note:

An improperly installed siphon break will cause engine damage and may void the warranty.

Install the siphon break above the highest point in the exhaust line between the heat exchanger and the exhaust mixer. Support the siphon break and hoses to maintain their position and function. Allow a slight offset to clear the stringers or other permanent structures. Protect the siphon break air inlet from dirt and debris.

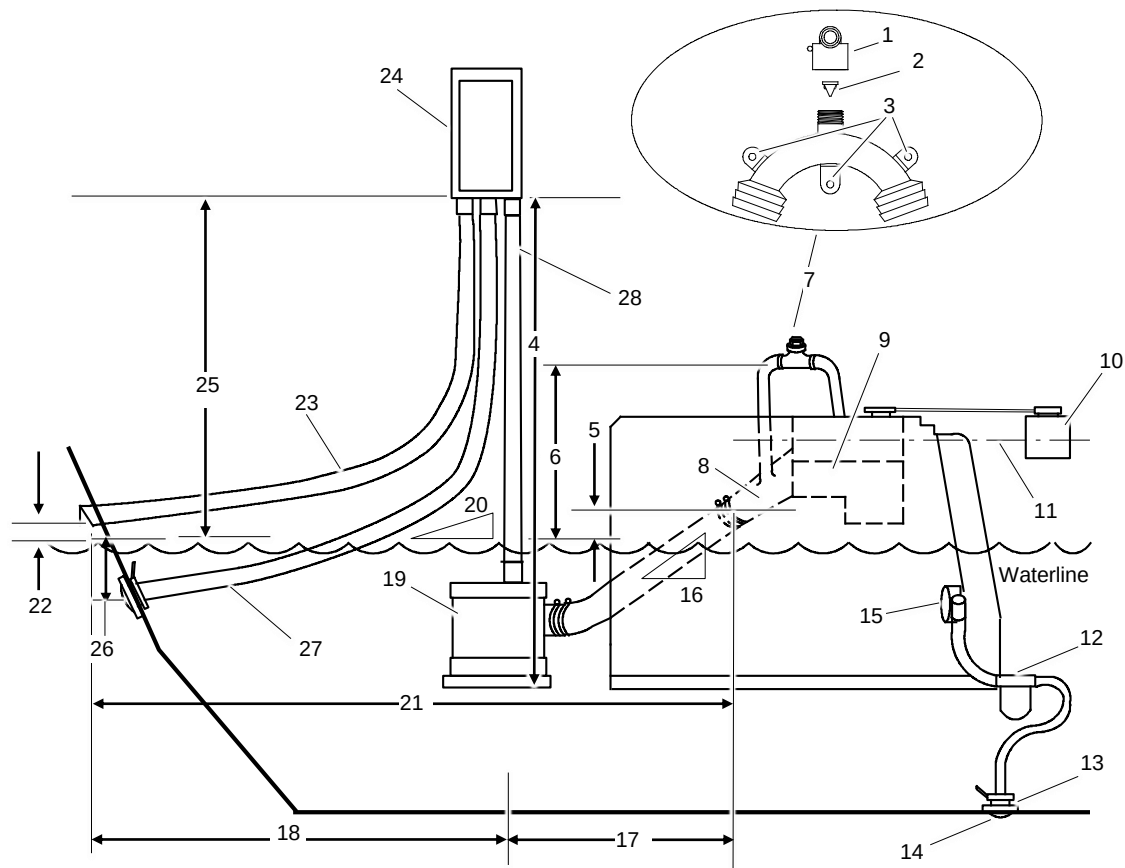
Note:

To prevent water leakage on the generator set, do not mount the siphon break directly over the generator set.

Note:

Ensure that the siphon break's cap is tight before operating the generator set.

Mount a typical silencer's base no more than 1.2 m (4 ft.) below the highest point in the exhaust line. Attach a separate wood mounting base to the hull stringers or other suitable structures. Use the silencer manufacturer's recommendation for securing the silencer to the hull. Mount the silencer with the outlet not more than 3 m (10 horizontal ft.) from the engine's exhaust manifold outlet. Use a USCG-type certified marine exhaust hose.



1. Cap
2. Reed valve
3. Mounting base
4. Maximum silencer vertical lift of 1.2 m (4 ft.)
5. Exhaust mixer elbow distance above waterline; if less than 23 cm (9 in.), a siphon break is required
6. Minimum siphon break distance above waterline of 30.5 cm (1 ft.)
7. Siphon break
8. Exhaust mixer elbow
9. Heat exchanger (locations vary by model)
10. Coolant recovery tank (located on the unit on some models)
11. Indicates the coolant recovery tank is at the same height as the heat exchanger
12. Seawater strainer
13. Seacock
14. Intake strainer
15. Engine-driven seawater pump
16. Minimum exhaust hose pitch of 1.3 cm per 30.5 cm (0.5 in. per ft.)
17. Maximum distance between silencer and exhaust mixer elbow of 3 m (10 ft.)
18. Maximum distance between silencer and exhaust outlet of 1.5 m (5 ft.)
19. Silencer (customer-supplied)
20. Minimum exhaust hose pitch of 1.3 cm per 30.5 cm (0.5 in. per ft.)
21. Maximum distance between exhaust outlet and generator of 4.6 m (15 ft.)
22. Minimum exhaust outlet distance above waterline of 10 cm (4 in.)
23. Exhaust hose, exhaust gas outlet hose after separator.
24. Gas/water separator (optional). Install directly above the canister muffler.
25. Distance above waterline for drain outlet from silencer must be equal to or greater than water drain (item 26) to be greater than 30.5 cm (1 ft.)
26. Water drain distance below waterline
27. Water drain (separated water from item 24)
28. System installer is responsible for designing enough capacity into the lift muffler and plumbing to prevent engine water ingestion upon shutdown. Otherwise, water will drain back into item 19 on generator set shutdown.

Note: Read the text for complete explanation of dimensions and other installation considerations.

Note: Numbers in illustration refer to callouts below and not to dimensions.

Note: Use two hose clamps on each end of all flexible exhaust hose connections.

Note: Data applies to both rear- and side-exhaust installations.

Note: Damage caused by water ingestion will not be covered by the generator warranty.

Figure 32 Typical Mid- and Below-Waterline Installation with Optional Gas/Water Separator

Note:

Data applies to both rear- and side-exhaust installations.

Note:

Numbers in illustration refer to callouts below and not to dimensions.

Note:

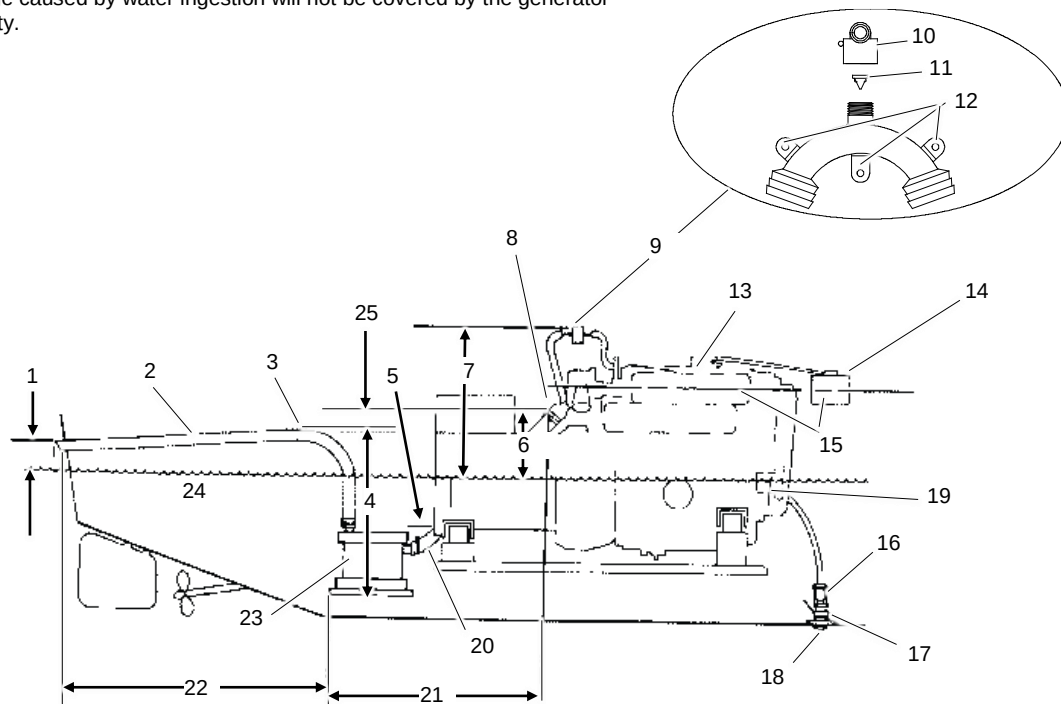
Read the text for complete explanation of dimensions and other installation considerations.

Note:

Use two hose clamps on each end of all flexible exhaust hose connections.

Note:

Damage caused by water ingestion will not be covered by the generator warranty.



1. Minimum exhaust outlet distance above waterline of 10 cm (4 in.)
2. Exhaust hose
3. Minimum exhaust hose pitch of 1.3 cm per 30.5 cm (0.5 in. per ft.)
4. Maximum silencer vertical lift of 1.2 m (4 ft.)
5. Minimum exhaust hose pitch of 1.3 cm per 30.5 cm (0.5 in. per ft.)
6. Exhaust mixer elbow distance above waterline; if less than 23 cm (9 in.), a siphon break is required
7. Minimum siphon break distance above waterline of 30.5 cm (1 ft.)
8. Exhaust mixer elbow
9. Siphon break
10. Cap
11. Reed valve
12. Mounting base
13. Heat exchanger (locations vary by model)
14. Coolant recovery tank (located on the unit on some models)
15. Indicates the coolant recovery tank is at the same height as the heat exchanger
16. Seawater strainer
17. Seacock
18. Intake strainer
19. Engine-driven seawater pump
20. Install optional water lock here
21. Maximum distance between silencer and exhaust mixer elbow of 3 m (10 ft.)
22. Maximum distance between silencer and exhaust outlet of 1.5 m (5 ft.)
23. Silencer (customer-supplied)
24. Waterline
25. Kohler recommends locating the generator set at elevation that exhaust mixer is above the highest point of the exhaust outlet hose.

Figure 33 Typical Mid- and Below-Waterline Installation

Note:

Data applies to both rear- and side-exhaust installations.

Note:

Numbers in illustration refer to callouts below and not to dimensions.

Note:

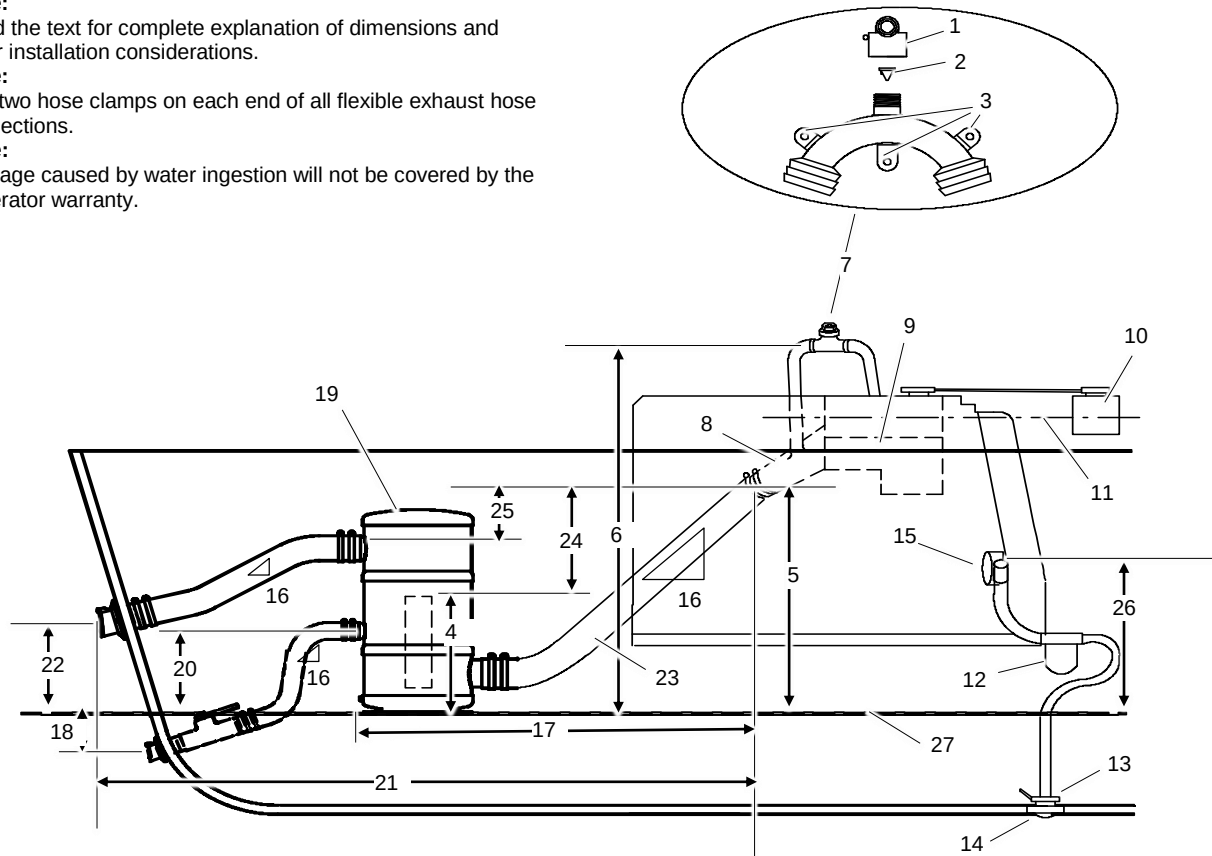
Read the text for complete explanation of dimensions and other installation considerations.

Note:

Use two hose clamps on each end of all flexible exhaust hose connections.

Note:

Damage caused by water ingestion will not be covered by the generator warranty.



1. Cap
2. Reed valve
3. Mounting base
4. Maximum silencer internal vertical lift of 1.2 m (4 ft.)
5. Exhaust mixer elbow distance above waterline; if less than 23 cm (9 in.), a siphon break is required
6. Minimum siphon break distance above waterline of 30.5 cm (1 ft.)
7. Siphon break
8. Exhaust mixer
9. Heat exchanger
10. Coolant recovery bottle
11. Indicates the coolant recovery tank is at the same height as the heat exchanger
12. Seawater strainer
13. Seacock
14. Intake strainer
15. Engine-driven seawater pump
16. Minimum exhaust hose pitch of 1.3 cm per 30.5 cm (0.5 in. per ft.)
17. Maximum distance between silencer and exhaust mixer elbow of 3 m (10 ft.)
18. Water drain distance below waterline
19. Combination silencer that contains lift muffler and gas water separating sections in single component (customer-supplied)
20. Distance above waterline for drain outlet from silencer must be equal to or greater than water drain (item 18) to be greater than 30.5 cm (1 ft.)
21. Exhaust outlet to be diameter appropriate so exhaust back pressure does not exceed limit at engine exhaust manifold
22. Minimum exhaust outlet distance above waterline of 10 cm (4 in.)
23. Exhaust hose
24. Height of internal lift tube to be below generator exhaust manifold
25. Kohler recommends generator be located at elevation that exhaust mixer elbow is above silencer exhaust outlet
26. Seawater pump lift
27. Waterline

Figure 34 Exhaust System

6.3.5 Warning System for Low Seawater Flow

For non-Kohler wet exhaust elbows. Some generator sets with seawater cooled exhaust lines downstream of the engine can have hose connections. In case of a fault in the seawater circuit or blockage of the seawater intake, the hose connections could overheat and melt or catch fire. A warning system should therefore be installed to provide a warning if the seawater flow stops.

An example of a suitable warning system is a temperature monitor that detects the water temperature and the exhaust gas temperature if the seawater flow stops. See **Figure 35**. Another option is a flow monitor installed in the seawater line to the exhaust hose.

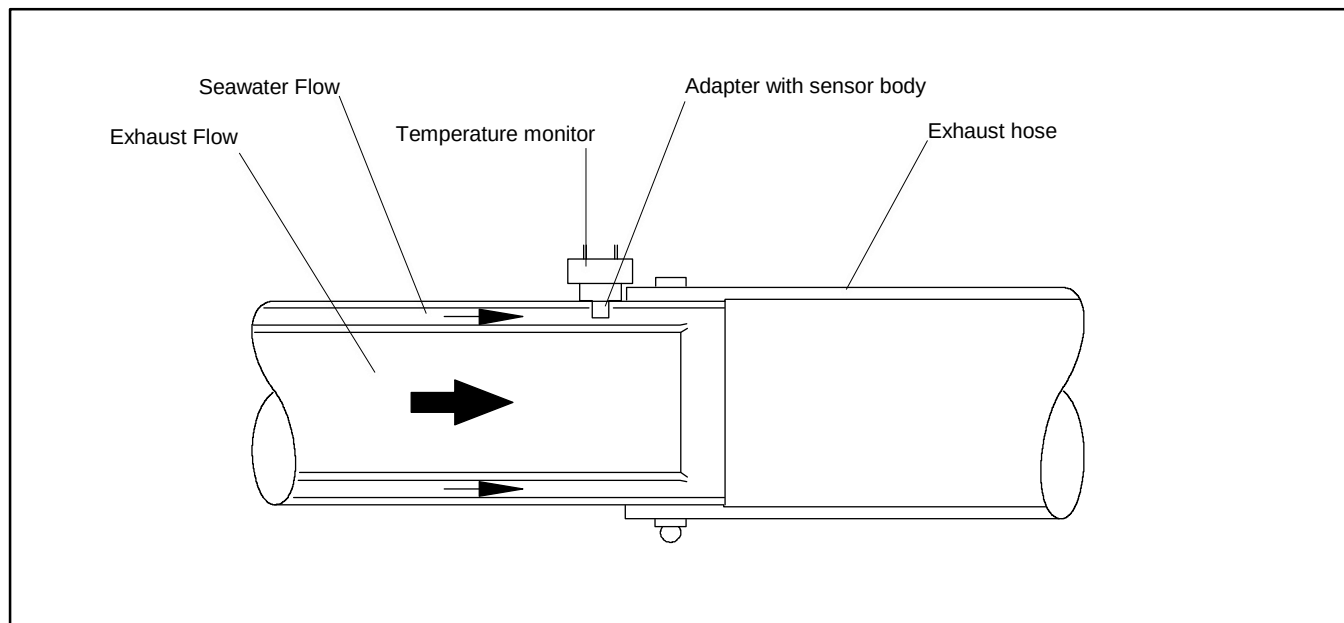


Figure 35 Connecting a Temperature Monitor in the Seawater Outlet

6.4 Back Pressure in Exhaust Systems

Back pressure in the exhaust system should not exceed 1019 mm (40.14 in.) water column including the silencer. A higher back pressure leads to increased fuel consumption, a loss of power, turbocharger failures, smoke, and excess carbon (not covered under warranty).

Back pressure should always be checked when the installation is complete.

Measurement is performed on a straight section of the system, as close to the engine as possible, but at least 1 m (3.2 ft.) downstream of the turbocharger.

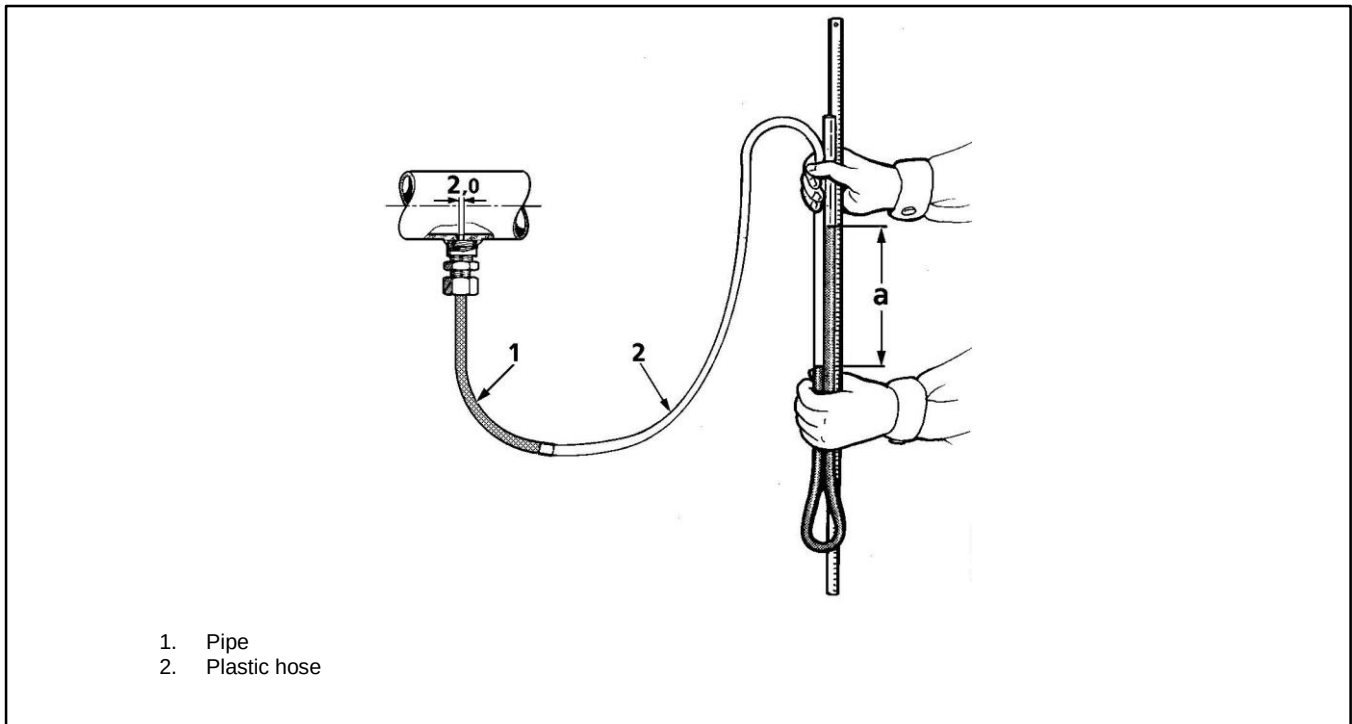


Figure 36 Exhaust Back Pressure Measurement

A simple device for measuring the back pressure is a clear plastic hose which is connected to a test connection on the system as shown in **Figure 36**. The hose is bent and partly filled with water.

It is important for the hole (dia. 2.0 mm (0.078 in.)) which is drilled in the exhaust pipe to have a clean, sharp edge on the inside of the pipe. Residual burrs and unevenness can result in significant measurement errors.

After the generator engine has been warmed up it should be driven with maximum load while the difference in water level in the hose is measured, “a” in **Figure 36**. This is a direct measurement of back pressure in mm (in.) water column.

6.5 Multi-Engine Installation

Multi-Engine Installation

For multi-engine installations, there should be a separate exhaust system for each engine, if possible.

If the exhaust pipes for several engines are linked to a common exhaust system, the exhaust systems for each engine should first be calculated individually using the description below.

Then calculate the necessary area, “A tot”, for the common exhaust system by adding together the areas of the exhaust systems for the individual engines.

- If the engines are of the same type, the diameter of the common system is shown in **Figure 37**.

Number of Engines	Diameter
1	d
2	1.41xd
3	1.73xd
4	2.00xd
5	2.22xd
6	2.45xd

Figure 37 Diameter for Common Exhaust System in Multi-Engine Installations

- If the engines are of different types, the diameter of the common pipe (d gem) is calculated using the formula:

$$d_{gem} = \sqrt{\frac{4 \times A_{tot}}{3.14}}$$

When several engines are connected to a common exhaust system, there must be an easily operated and effective shut-off device in each branch system.

The shut-off device should always be closed for a stationary engine since exhaust gases from an operating engine could otherwise enter the engine which is not in operation and cause corrosion damage. There is also a risk that the exhaust gases could enter the engine room.

6.6 Dimensioning Exhaust System

6.6.1 General

Dimensioning is based on the back pressure in the exhaust system.

The diameter of the exhaust pipes is calculated as follows:

1. Calculate the length of the planned exhaust system (L_u).
2. Decide on the preliminary inside diameter of the exhaust pipes (D_p) from the tables in the figure titled: **Table for Determining the Preliminary and Final Inside Diameter of the Exhaust Pipe (D_p)**.
3. Decide on the total number of 90° pipe bends which will be included in the exhaust system. Two 45° pipe bends equals one 90° pipe bend.
4. Read the additional length (L_t) shown in the figure titled: **Graph for Calculating Additional Length in Exhaust System**. In the figure titled: **Graph for Calculating Additional Length in Exhaust System**, the back pressure is converted from the number of pipe bends used and the discharge resistance to a straight pipe with the length (L_t).

The additional length (L_t) is used only to calculate the new diameter required. Note that even for a system without pipe bends the additional length must be read because of the discharge resistance. See line 0 in the figure titled: **Graph for Calculating Additional Length in Exhaust System**.

5. Add the additional length obtained (L_t) to the planned length (L_u). The total length obtained (L_{tot}) is then used to read the final diameter in the section titled: **Technical Data**. Select the next higher standard diameter.
6. If corrugated hose is used for a large part of the system, the dimension must be increased by at least 10%.

6.6.2 Calculation Example

1. Planned length $L_u = 13$ m (42.6 ft.)
2. Preliminary inside diameter $D_p = 125$ mm (5 in.)
3. Calculated number of 90° bends for the entire system:

90° pipe bends	4
Four 45° pipe bends	2
Total number of 90° pipe bends	6

4. Additional length $L_t = 12$ m (39.3 ft.), see the figure titled: **Graph for Calculating Additional Length in Exhaust System**.
5. L_{tot} (for calculating final diameter) = $L_u + L_t = 25$ m (82 ft.), rounded to 30 m (98.4 ft.)
6. **Figure 38** gives the final inside diameter = 150 mm (5.9 in.).

In the case of short exhaust systems for certain engine types, the calculation may suggest a relatively small pipe diameter (90- 100 mm (3.5- 3.9 in.)).

It would then be a good idea to choose the smallest diameter which can be connected directly to standard components, i.e. 130 mm (5 in.).

The pipe bends on the exhaust system should be designed with a large bend radius (1.5- 2.0 x diameter).

The calculated inside diameter applies to an insulated system, which means that it is not necessary to increase the diameter for insulating.

A wet exhaust system must have a larger inside diameter (approximately 10%) than a dry system due to the increase in the gas flow generated by the evaporated cooling water, while a water-jacketed exhaust system can normally be made with a slightly smaller inside diameter.

Engine Speed rpm	Exhaust Flow * kg/min.	Exhaust Gas Temp. • °C (°F)	Exhaust Pipe Length, m (ft.)					
			5 (16.4)	10 (32.8)	20 (65.6)	30 (98.4)	40 (131.2)	50 (164)
			Exhaust Pipe Inside Diameter, mm (in.)					
1500	26	430 (806)	105 (4.1)	115 (4.5)	130 (5.1)	140 (5.5)	145 (5.7)	150 (5.9)
1800	32	400 (752)	115 (4.5)	125 (4.9)	140 (5.5)	150 (5.9)	155 (6.1)	160 (6.3)

Figure 38 Sample Calculation Example (from the section titled: Calculation Example)

Model	Exhaust Flow * kg/min.	Exhaust Gas Temp.● °C (°F)	Exhaust Pipe Length, m (ft.)					
			5 (16.4)	10 (32.8)	20 (65.6)	30 (98.4)	40 (131.2)	50 (164)
			Exhaust Pipe Inside Diameter, mm (in.)					
Heat Exchanger Cooled Models:								
350EOZCS	34	445 (833)	120 (4.7)	130 (5.1)	145 (5.7)	155 (6.1)	160 (6.3)	170 (6.7)
300EFOZCS	27	463 (865)	110 (4.3)	120 (4.7)	130 (5.1)	140 (5.5)	150 (5.9)	155 (6.1)
500EOZCS	47	430 (806)	140 (5.5)	150 (5.9)	165 (6.5)	175 (6.9)	185 (7.3)	190 (7.5)
450EFOZCS	36	465 (869)	125 (4.9)	135 (5.3)	150 (5.9)	160 (6.3)	165 (6.5)	170 (6.7)
Keeled Cooled Models:								
350EOZCS	34	474 (885)	120 (4.7)	130 (5.1)	145 (5.7)	155 (6.1)	165 (6.5)	170 (6.7)
300EFOZCS	26	512 (954)	110 (4.3)	120 (4.7)	130 (5.1)	140 (5.5)	150 (5.9)	155 (6.1)
500EOZCS	47	443 (829)	140 (5.5)	150 (5.9)	165 (6.5)	175 (6.9)	185 (7.3)	190 (7.5)
450EFOZCS	36	464 (867)	125 (4.9)	135 (5.3)	150 (5.9)	160 (6.3)	165 (6.5)	170 (6.7)
IMO Tier III Models (Heat Exchanger and Keeled Cooled):								
350EOZCS	30	468 (874)	115 (4.5)	125 (4.9)	140 (5.5)	145 (5.7)	155 (6.1)	160 (6.3)
300EFOZCS	23	494 (921)	105 (4.1)	115 (4.5)	125 (4.9)	135 (5.3)	140 (5.5)	145 (5.7)
500EOZCS	42	517 (963)	135 (5.3)	145 (5.7)	160 (6.3)	170 (6.7)	180 (7.1)	185 (7.3)
450EFOZCS	33	531 (988)	120 (4.7)	130 (5.1)	145 (5.7)	155 (6.1)	165 (6.5)	170 (6.7)

Figure 39 Table for Determining the Preliminary and Final Inside Diameter of the Exhaust Pipe (Dp) in mm (in.).

Applies to Models at Full Power According to Power Level Map (Marine Auxiliary Power).

Ambient Conditions 25°C, 1,013, bar.

* ±10% depending on design of intake and exhaust systems.

• Conversion of exhaust gas flow to m³/min. according to:

$$Q2 = \frac{(t+273) \times Q1}{347.72}$$

Q2 = exhaust flow in m³/min.

t = exhaust gas temperature in °C.

Q1 = exhaust flow in kg/min.

Note:

The exhaust gas temperature must be measured approx. 1 m downstream of the turbocharger. A higher value is obtained if the measurement is taken closer to the turbocharger. If the exhaust system is equipped with a water-cooled exhaust pipe bend near the turbocharger, take the measurement in the test connection in the bend. You then obtain a value that is higher by approx. + 30° C.

6.6.3 Calculating the Additional Length

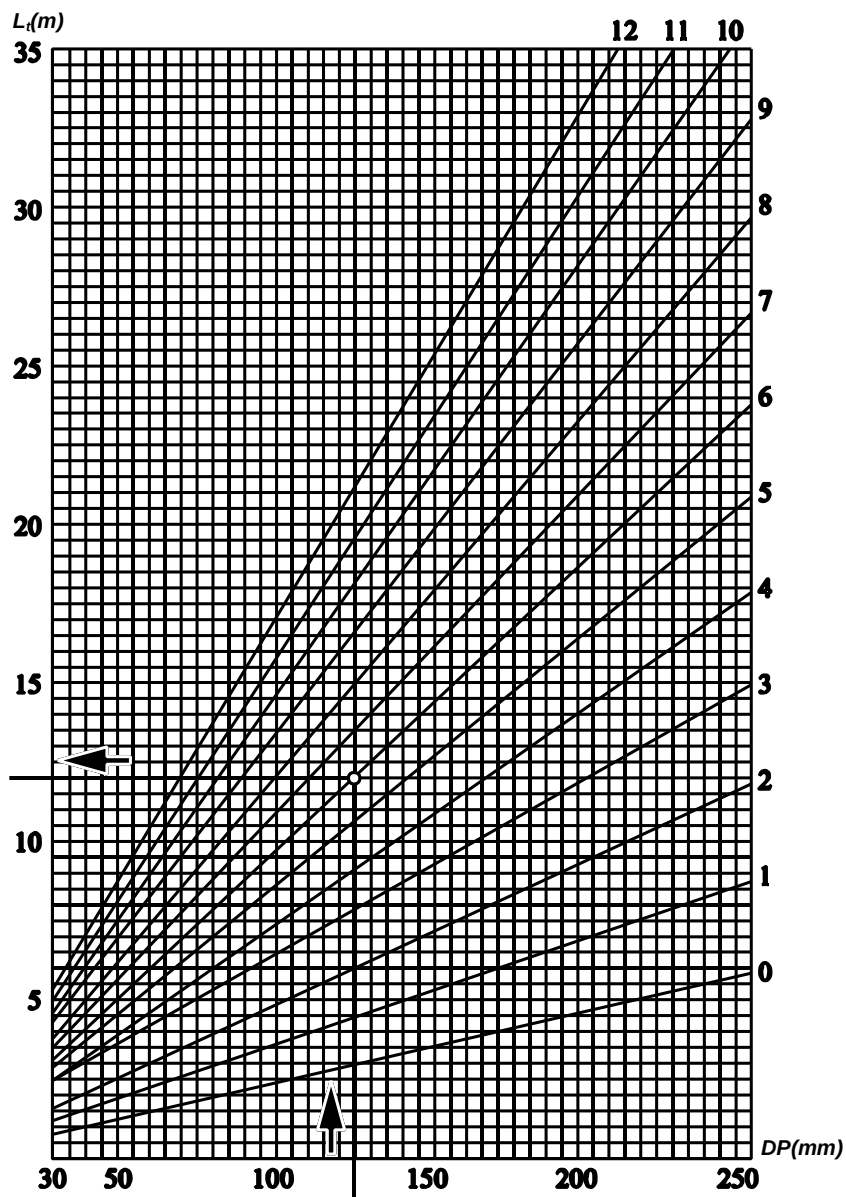


Figure 40 Graph for Calculating Additional Length in Exhaust System

From the Calculation Example:

- * Preliminary inside diameter $D_p = 125$ mm (5 in.)
- * Number of pipe bends = 6
- * Additional length $L_t = 12$ m (40 ft.)

6.7 Important Data

Max. permissible exhaust back pressure with high power silencer All models except IMO Tier III models (see below)	10 kPa (40.1 in. H ₂ O)
Max. allowable total exhaust back pressure (measured at the turbo) 350EOZCS IMO Tier III (Heat Exchanger and Keel Cooled) 300EFOZCS IMO Tier III (Heat Exchanger and Keel Cooled) 500EOZCS IMO Tier III (Heat Exchanger and Keel Cooled) 450EFOZCS IMO Tier III (Heat Exchanger and Keel Cooled)	12.7 kPa (51.0 in. H ₂ O) 11.8 kPa (47.4 in. H ₂ O) 13.3 kPa (53.4 in. H ₂ O) 12.6 kPa (50.6 in. H ₂ O)
Max. allowable back pressure for customer additional piping, post aftertreatment 350EOZCS IMO Tier III (Heat Exchanger and Keel Cooled) 300EFOZCS IMO Tier III (Heat Exchanger and Keel Cooled) 500EOZCS IMO Tier III (Heat Exchanger and Keel Cooled) 450EFOZCS IMO Tier III (Heat Exchanger and Keel Cooled)	5 kPa (20 in. H ₂ O) 5 kPa (20 in. H ₂ O) 5 kPa (20 in. H ₂ O) 5 kPa (20 in. H ₂ O)
Exhaust flow 350EOZCS (Heat Exchanger Cooled) 350EOZCS (Keel Cooled) 350EOZCS IMO Tier III (Heat Exchanger and Keel Cooled) 300EFOZCS (Heat Exchanger Cooled) 300EFOZCS (Keel Cooled) 300EFOZCS IMO Tier III (Heat Exchanger and Keel Cooled) 500EOZCS (Heat Exchanger Cooled) 500EOZCS (Keel Cooled) 500EOZCS IMO Tier III (Heat Exchanger and Keel Cooled) 450EFOZCS (Heat Exchanger Cooled) 450EFOZCS (Keel Cooled) 450EFOZCS IMO Tier III (Heat Exchanger and Keel Cooled)	34 kg/min. 34 kg/min. 30 kg/min. 27 kg/min. 26 kg/min. 23 kg/min. 47 kg/min. 47 kg/min. 42 kg/min. 36 kg/min. 36 kg/min. 33 kg/min.
Exhaust temperature 350EOZCS (Heat Exchanger Cooled) 350EOZCS (Keel Cooled) 350EOZCS IMO Tier III (Heat Exchanger and Keel Cooled) 300EFOZCS (Heat Exchanger Cooled) 300EFOZCS (Keel Cooled) 300EFOZCS IMO Tier III (Heat Exchanger and Keel Cooled) 500EOZCS (Heat Exchanger Cooled) 500EOZCS (Keel Cooled) 500EOZCS IMO Tier III (Heat Exchanger and Keel Cooled) 450EFOZCS (Heat Exchanger Cooled) 450EFOZCS (Keel Cooled) 450EFOZCS IMO Tier III (Heat Exchanger and Keel Cooled)	445° C (833° F) 474° C (885° F) 468° C (874° F) 463° C (865° F) 512° C (953° F) 494° C (921° F) 430° C (806° F) 443° C (829° F) 517° C (963° F) 465° C (869° F) 464° C (867° F) 531° C (988° F)
Min. temperature resistance for insulation material	700° C (1292° F)
Inside diameter for exhaust system at different lengths	See the figure titled: Table for Determining the Preliminary and Final Inside Diameter of the Exhaust Pipe
Graph for calculating additional length	See the figure titled: Graph for Calculating Additional Length in Exhaust System

Section 7. Exhaust Gas Aftertreatment (IMO Tier III Models Only)

 WARNING	Carbon monoxide. Can cause severe nausea, fainting, or death.
	The exhaust system must be leakproof and routinely inspected.

Carbon monoxide symptoms. Carbon monoxide can cause severe nausea, fainting, or death. Carbon monoxide is a poisonous gas present in exhaust gases. Carbon monoxide is an odorless, colorless, tasteless, nonirritating gas that can cause death if inhaled for even a short time. Carbon monoxide poisoning symptoms include but are not limited to the following:

- Light-headedness, dizziness
- Physical fatigue, weakness in joints and muscles
- Sleepiness, mental fatigue, inability to concentrate or speak clearly, blurred vision
- Stomachache, vomiting, nausea

If experiencing any of these symptoms and carbon monoxide poisoning is possible, seek fresh air immediately and remain active. Do not sit, lie down, or fall asleep. Alert others to the possibility of carbon monoxide poisoning. Seek medical attention if the condition of affected persons does not improve within minutes of breathing fresh air.

Inspecting the exhaust system. Carbon monoxide can cause severe nausea, fainting, or death. For the safety of the craft's occupants, install a carbon monoxide detector. Never operate the generator set without a functioning carbon monoxide detector. Inspect the detector before each generator set use.

Operating the generator set. Carbon monoxide can cause severe nausea, fainting, or death. Be especially careful if operating the generator set when moored or anchored under calm conditions because gases may accumulate. If operating the generator set dockside, moor the craft so that the exhaust discharges on the lee side (the side sheltered from the wind). Always be aware of others, making sure your exhaust is directed away from other boats and buildings.

7.1 SCR and Reductant

7.1.1 General

SCR (Selective Catalytic Reduction) is a system in which reductant is added to the exhaust gases before the catalytic converter in order to reduce the nitrogen oxide (NO_x) content. This section describes SCR system components and how they should be connected.

Reductant is a solution consisting of urea and water, and is usually referred to as DEF. If the engine is equipped with an SCR system, the reductant is added to the exhaust gases upstream of the catalytic converter. This reduces nitrogen oxide emissions. The SCR system can be used with either 32.5% or 40% by weight of urea.

Reductant with 32.5% by weight of urea freezes at approx. - 11°C (12°F). With 40% by weight of urea freezes at 0°C (32°F). When the solution freezes, ice and urea always maintain the same concentration. Always store the reductant at a temperature of between 0- 30°C (32-86°F).

Note:

Cleanliness is very important when working on the reductant circuit. Clean thoroughly around all parts to prevent dirt from entering the system.

Note:

When working on the SCR system, the reductant connections may only be lubricated with soapy water or with distilled water with a 3% urea mixture. Any other types of lubricants may block and damage the SCR system components.

Note:

Reductant is highly corrosive. For this reason, only pipes and couplings resistant to urea may be used in the SCR system. The reductant prefilter and the reductant pump between the storage tank and the buffer tank must also be urea resistant. Always rinse away reductant spillage on connections and other parts with lukewarm water to prevent corrosion. If reductant seeps into electrical connections or electrical cables, these must be replaced.

32.5% by Weight of Urea

If 32.5% by weight of urea is used, the reductant should be specified in accordance with ISO 22241 in order to comply with the emission requirements set by the public authorities.

Rec. % by weight of urea	Limit values according to ISO 22241
32.5%	31.8-33.2%

40% by Weight of Urea

If 40% by weight of urea is used, the reductant should be specified in accordance with ISO 18611 in order to comply with the emission requirements set by the public authorities.

Rec. % by weight of urea	Limit values according to ISO 22241
40%	39-41%

7.1.2 System Overview

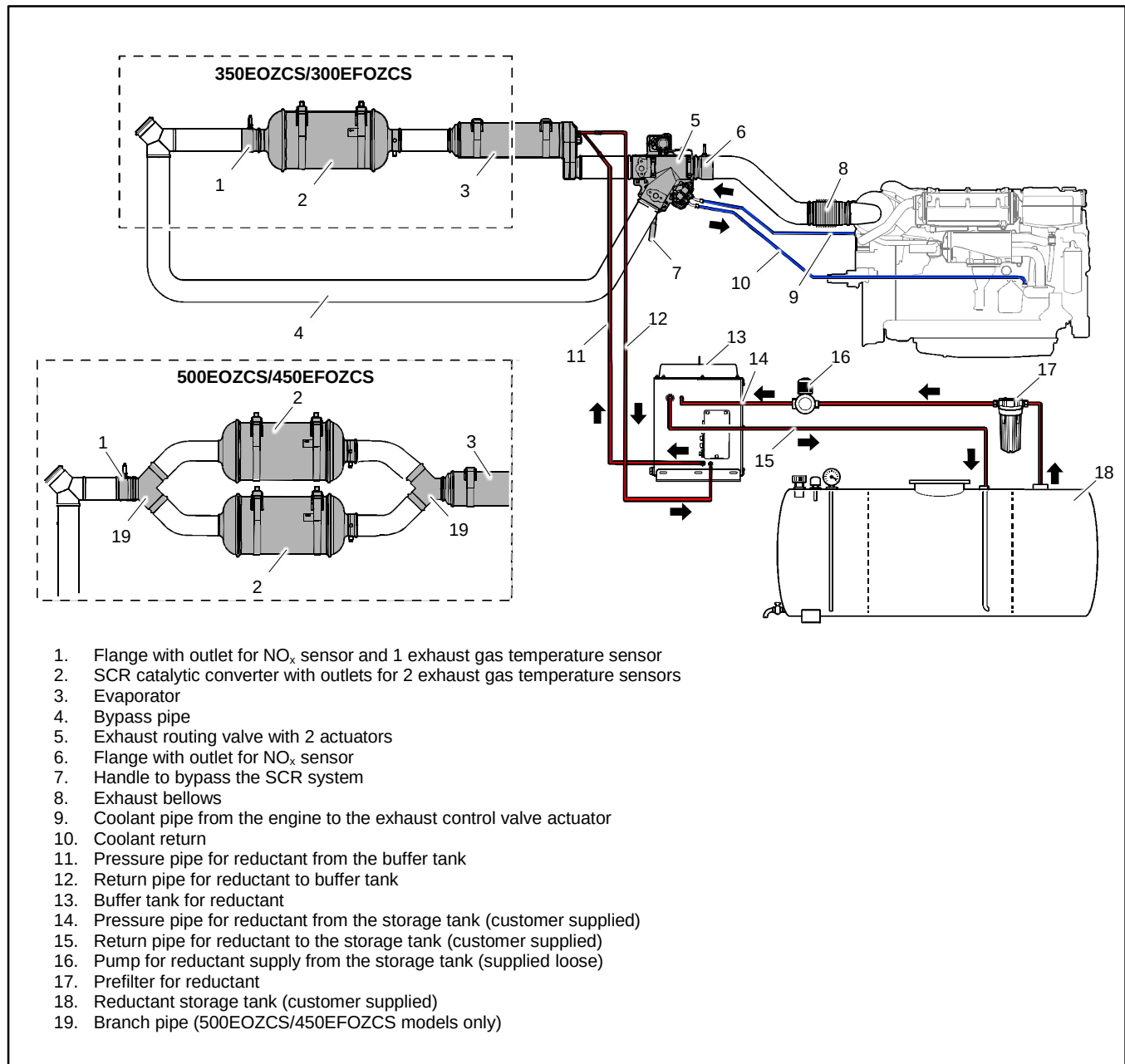


Figure 41 System Overview, Typical

7.1.3 System Overview of Electrics

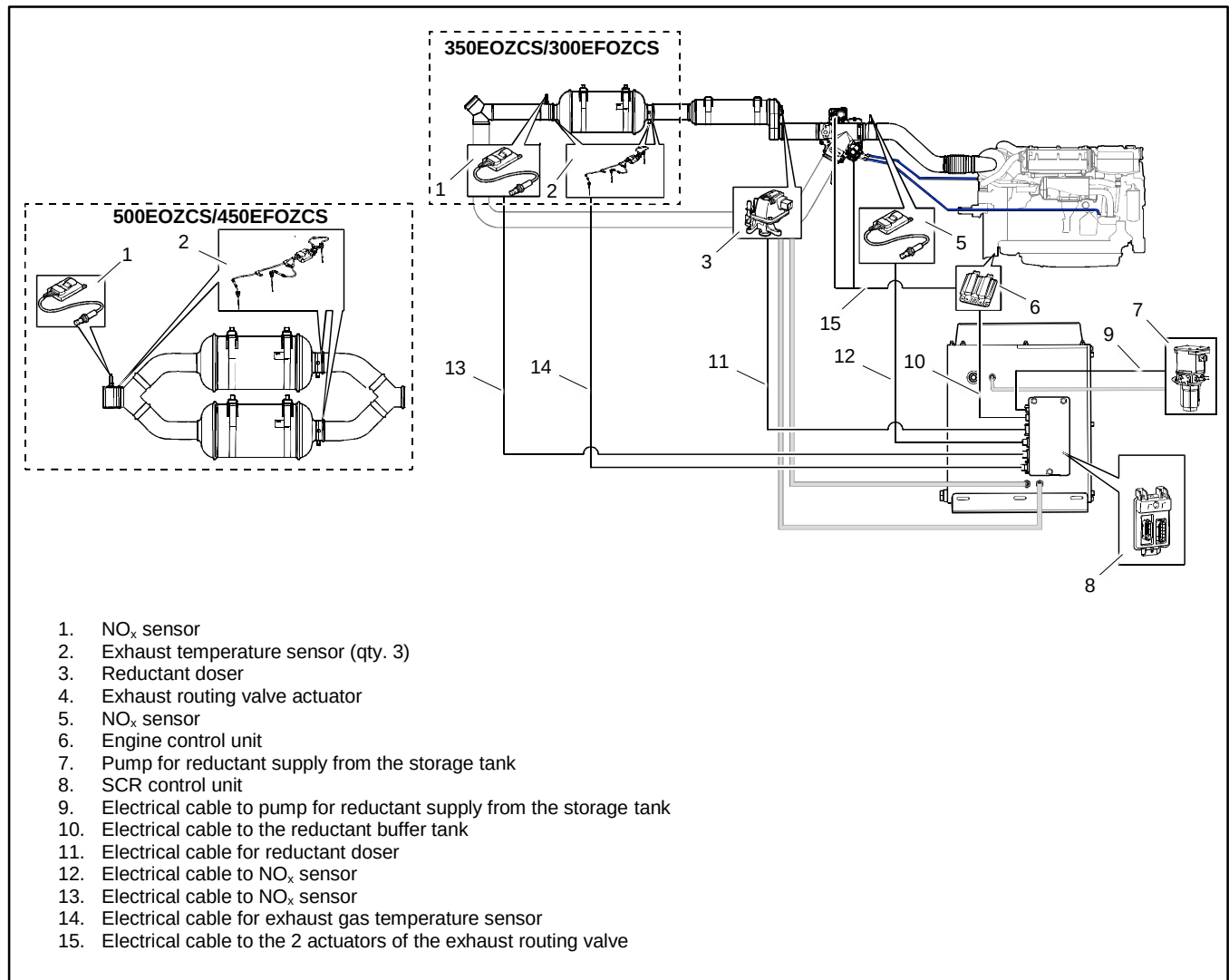
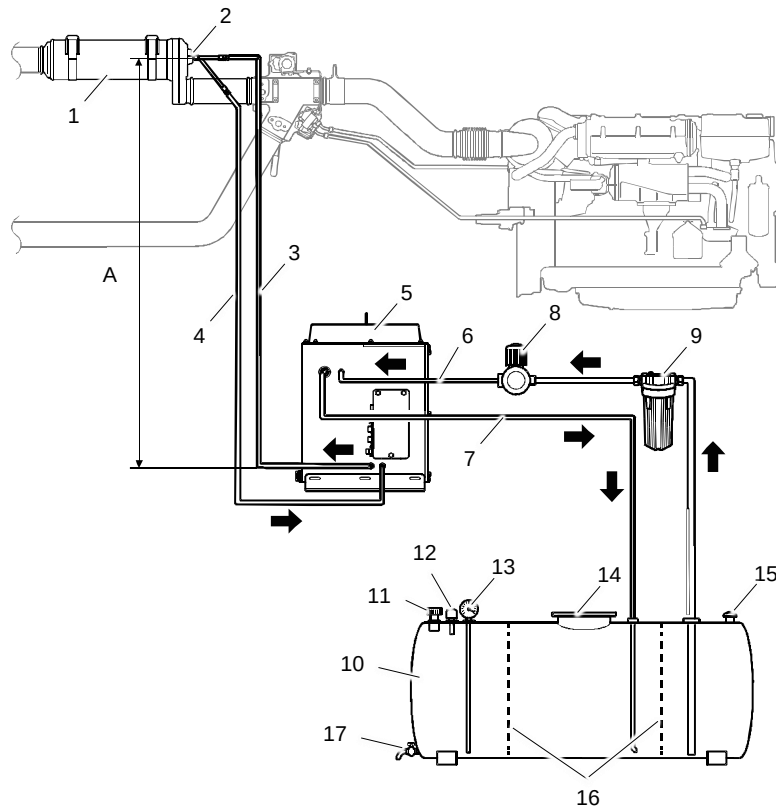


Figure 42 System Overview of Electrics, Typical

7.1.4 Reductant Storage Tank and Reductant Pipes



A= Max. height 2 meters (6.5 ft.) from the pressure pipe connection on the buffer tank to the reductant doser, max. length 16 meters (52.5 ft.).

1. Evaporator
2. Reductant doser
3. Pressure pipe for reductant from the buffer tank
4. Return pipe for reductant to buffer tank
5. Buffer tank
6. Pressure pipe for reductant from the storage tank (customer supplied)
7. Return pipe for reductant to the storage tank (customer supplied)
8. Pump for reductant supply from the storage tank (supplied loose)
9. Prefilter for reductant (prefilter is integrated with the pump (item 8). If the feed pump is not used, a separate filter with a rating of 30-50 microns must be customer supplied)
10. Reductant storage tank (customer supplied)
11. Filling (customer supplied)
12. Overfill protection (customer supplied)
13. Level gauge (customer supplied)
14. Inspection hatch (customer supplied)
15. Ventilating valve (customer supplied)
16. Baffle plate (customer supplied)
17. Draining tap (customer supplied)

Figure 43 Installation Example of the Main Tank for Reductant and Reductant Pipes

7.1.5 Material Pipe and Storage Tank

The reductant storage tank, the reductant pipes, and all couplings must be made of urea-resistant material, such as stainless steel X5CrNi 18-10 in accordance with SS-EN 10088-2 or similar. Follow classification society requirements. If the material is welded, its anti-corrosive qualities must be retained.

Dimension the reductant pipes according to the dimensions of the connections on the buffer tank, as indicated in the section titled: **Connecting the Reductant Tank**.

7.1.6 Storage Tank

- Dimension the storage tank so that there is sufficient reductant for the specific use and geofence zone. Reductant consumption is approx. 9% of fuel consumption.
- The tank must be fitted with internal baffle plate to prevent the reductant from being thrown about at sea.
- The tank must have a drain tap.
- There must be an air duct from the upper part of the tank to the outside of the hull. It should be designed so that water cannot enter and so that reductant cannot run out when the ship is leaning heavily.
- The tank must be fitted with inspection hatches so that it can be inspected and cleaned inside.
- The pipe fitting should be at a sufficient distance from the bottom of the tank, so as not to suck up deposits gathered at the bottom.

7.1.7 Storage Tank for Buffer Tank

It is possible to select other hardware than the manufacturer's to move urea from the storage tank to the buffer tank. The following criteria must be met in order to connect a system with a pump or valve to the engine's control unit.

- The pipes to the buffer tank should be as short as possible and should be mounted in such a way that they cannot be exposed to mechanical damage.
- There must be a return pipe from the buffer tank to the storage tank so that any surplus fluid runs back into the storage tank.

However, if the reductant pump between the main tank and the buffer tank is controlled by the manufacturer's software, no return pipe is required. The reductant tank is then switched off when the level sensor identifies that the buffer tank is full.

In these cases, an air duct with a filter must be connected to the return line connection. The air duct must be routed out on deck, alternatively to a well-ventilated area. Position the filter as high as possible, but at least 500 mm (20 in.) above the buffer tank, so that the reductant cannot come into contact with the filter. Position the filter so that it is protected against moisture.

The air duct can also be routed to the top of the storage tank.

- There must be a prefilter for reductant with a filtration rating of 30- 50 micro meters.
- No separate filter is required if the manufacturer's pump is installed.
- The flow to the buffer tank must be within the interval 0.4 to 5 Lpm (0.1 to 1.3 gpm).
- The pump must be fitted as close to the buffer tank as possible.
- The pump must be fitted as low as possible, max. 1.5 meters (5 ft.) above the lowest level in the storage tank.
- Power outlet EEC3: min. 0.1 A-max. 1.5 A.

7.1.8 Reductant Buffer Tank

An empty reductant tank weighs approx. 25 kg (55 lbs.).

- Total volume: 30 liters (32 qts.)
- Filling volume: 16 liters (17 qts.)

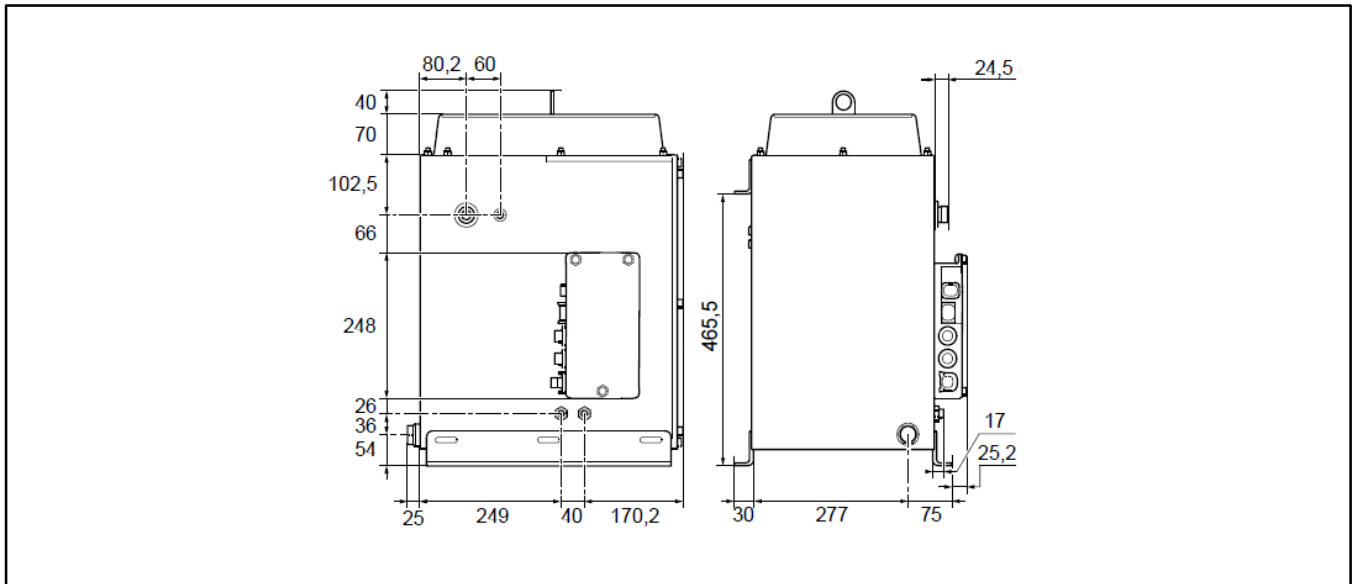


Figure 44 Reductant Buffer Tank

The reductant tank is installed on the unit. See **Figure 45** for location.

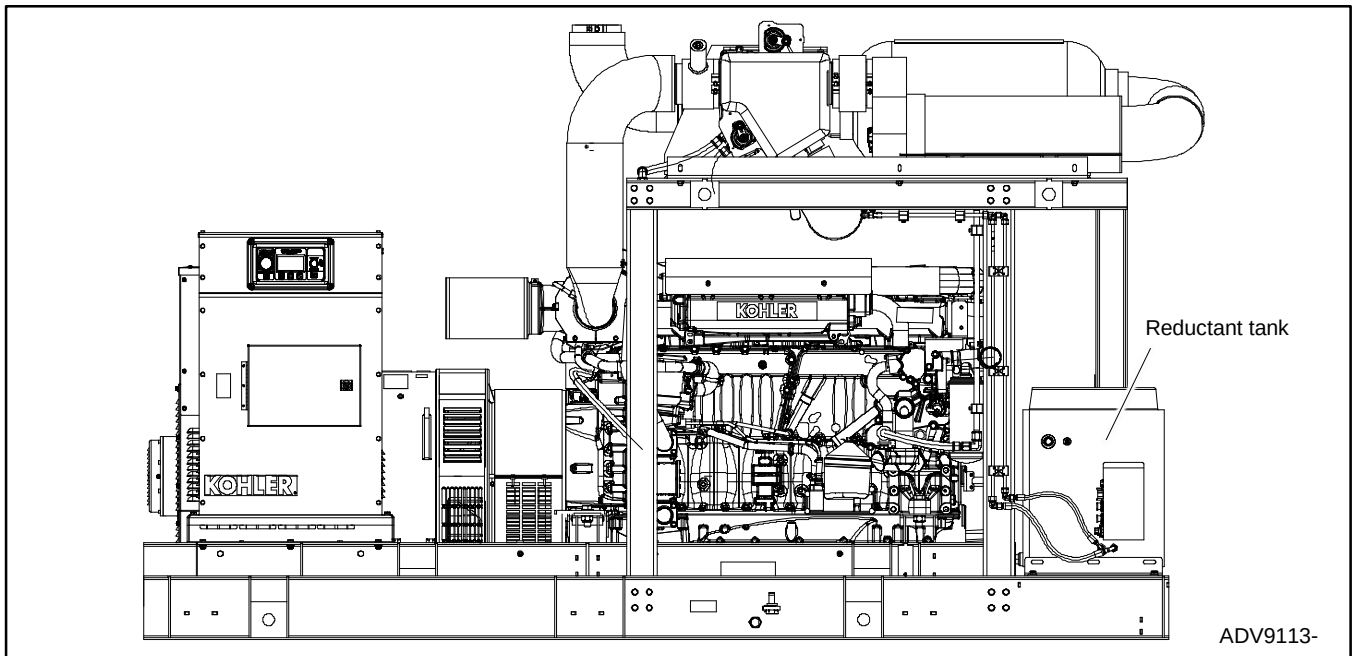
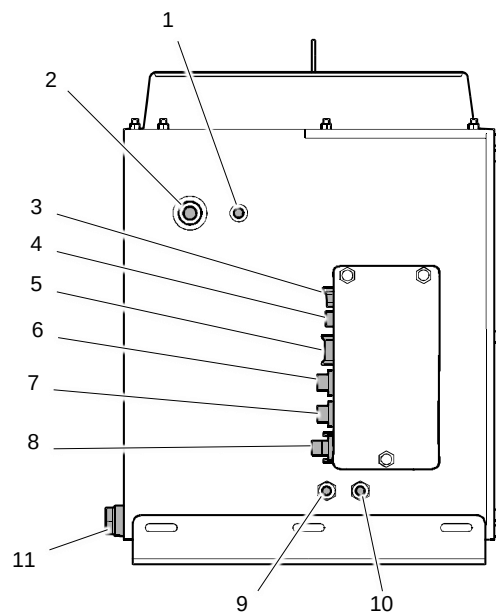


Figure 45 Reductant Tank Location, Typical

7.1.9 Connecting the Reductant Tank



1. Pressure pipe for reductant from the storage tank.
Connection: Nipple, Ø 8 mm, 24° internal conical thread in accordance with DIN 3861.
2. Return pipe for reductant to the storage tank.
Connection: Union, Ø 22 mm, 24° internal conical thread in accordance with DIN 3861.
3. Reductant pump for storage tank.
Connection: C4109 see wiring diagram.
4. Voltage supply from engine. CAN connection.
Connection: C7 see wiring diagram.
5. Reductant doser.
Connection: C316 see wiring diagram.
6. NO_x sensor upstream of the exhaust routing valve.
Connection: C4051 see wiring diagram.
7. NO_x sensor downstream of the SCR catalytic converter.
Connection: C4011 see wiring diagram.
8. Exhaust gas temperature sensor.
Connection: C4092 see wiring diagram.
9. Pressure pipe for reductant from the buffer tank.
Connection: Pipe with ferrule, Ø 8 mm.
10. Return pipe for reductant to buffer tank.
Connection: Pipe with ferrule, Ø 10 mm.
11. Drain plug.
Connection: ¾ in. BSP

Figure 46 Reductant Buffer Tank

7.1.10 Reset Button on the Reductant Tank

The first time you fill the reductant tank, you must keep the reset button (see **Figure 47**) pressed in for at least 5 seconds. A short press of the button will result in the level sensor not registering any level increase in the tank, and a fault code is generated after a few minutes.

When the engine control unit checks the filling, the following applies:

- If you hold the button depressed for 5 seconds, the reductant pump operates for 30 minutes. This function can be used, for example, when the tank is filled for the first time or after cleaning.
- If the reductant pump is operating and you press the button for a short time, the pump stops and a fault code is generated.

The reductant pump can be restarted by pressing the button, causing the fault code to become passive.

- If the level does not increase although the reductant pump is running, the pump is switched off and fault code is generated. If you press the button briefly, the pump restarts.

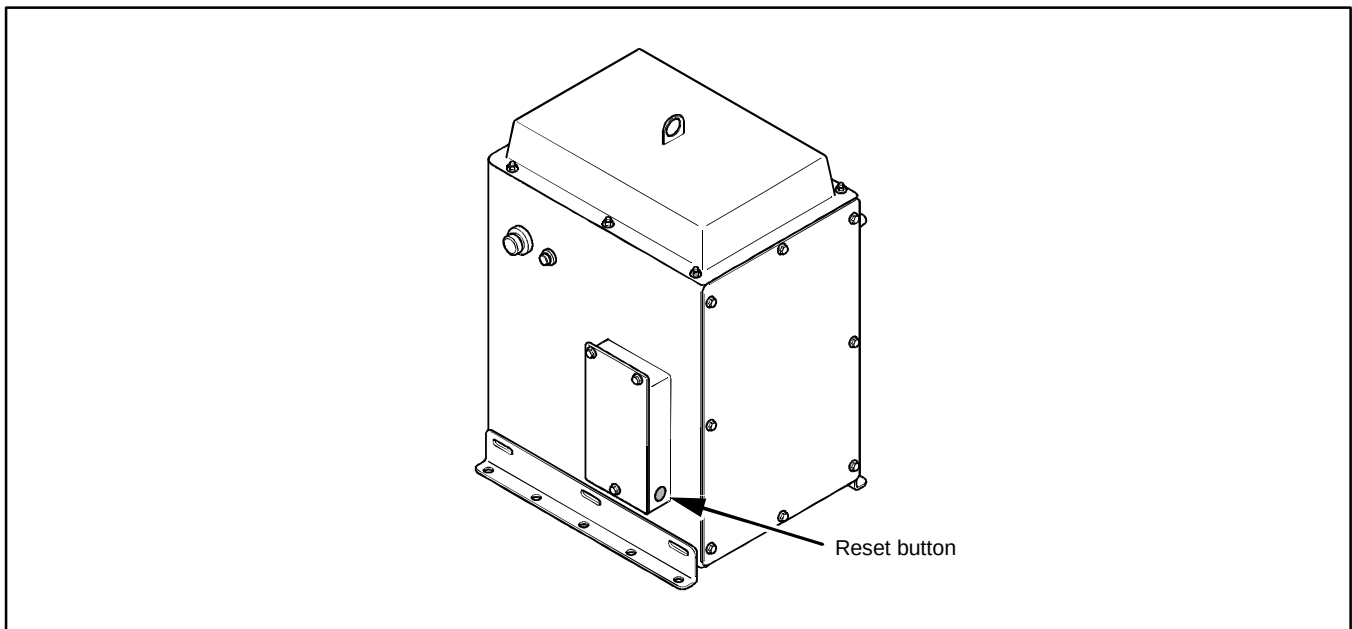


Figure 47 Reset Button on Reductant Tank

7.1.11 Connection of DEF Feed Pump

Mount the DEF feed pump between the main tank and the unit mounted tank. See the installation drawings (ADVs) in the section titled: **Installation Drawings** for DEF feed pump dimensions.

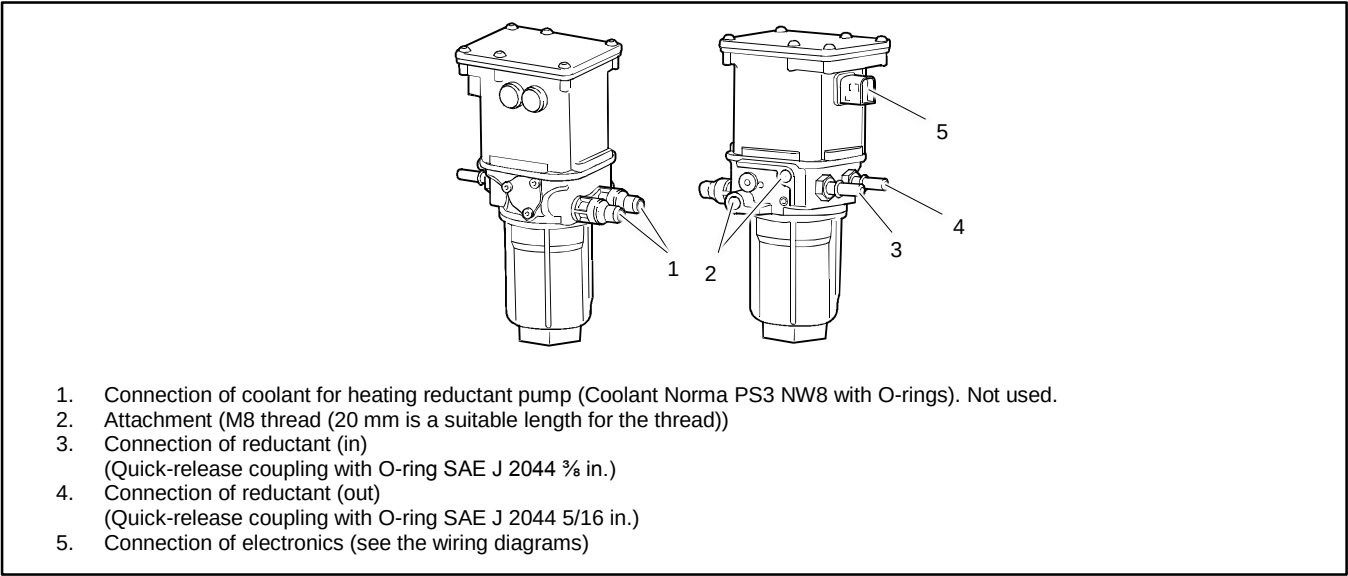


Figure 48 DEF Feed Pump

Replaceable Quick-Release Couplings on DEF Feed Pump

The DEF feed pump’s quick-release couplings in **Figure 48** (items 3 and 4) are replaceable. See **Figure 49**.

Item in Figure 48	Description	Remark	Torque
3	Connection of reductant (in)	M12 x 1.5 with O-ring (ISO6149)	25 Nm
4	Connection of reductant (out)	M14 x 1.5 with O-ring (ISO6149)	35 Nm

Figure 49 DEF Feed Pump Coupling Requirements

The connections must be made from a urea-resistant material, such as stainless steel X5CrNi 18-10 in accordance with SS-EN 10088-2 or similar. Standard classification requirements must be observed. If the material has been welded, its anti-corrosive qualities must be maintained.

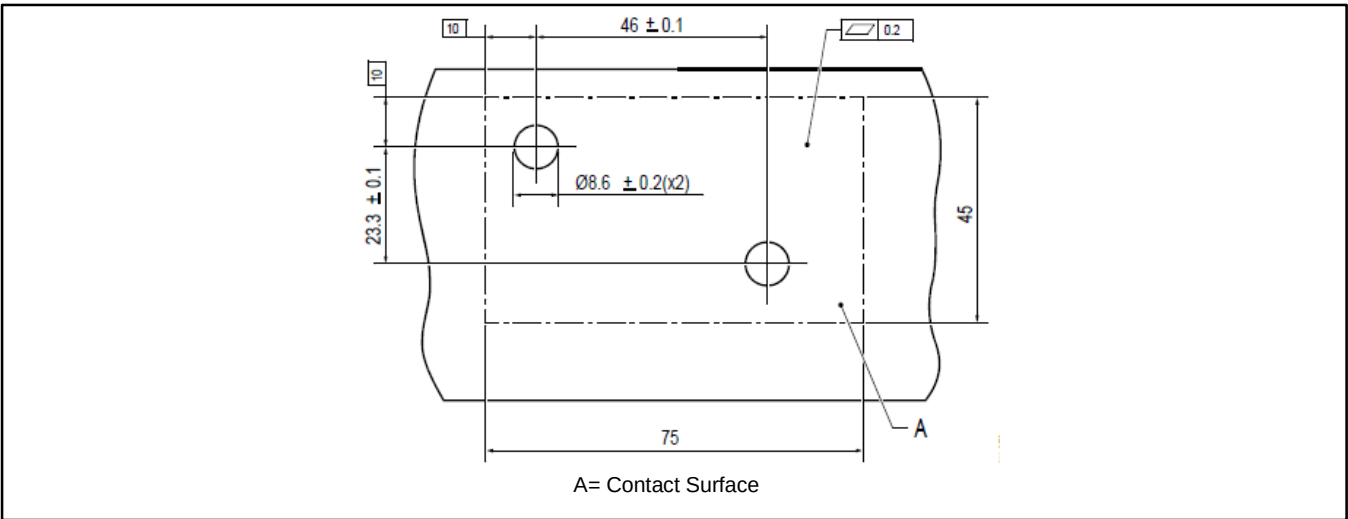


Figure 50 DEF Feed Pump Attachment Details

7.1.12 Exhaust Routing Valve

The maximum permitted temperature at the exhaust routing valve actuator is 90°C (194°F). Measure the temperature when the installation is complete.

The exhaust routing valve weighs approximately 24 kg (53 lbs.).

It must be possible to access the handle of the exhaust routing valve and the lock pin of the handle without removing insulation or other components. See **Figure 51**.

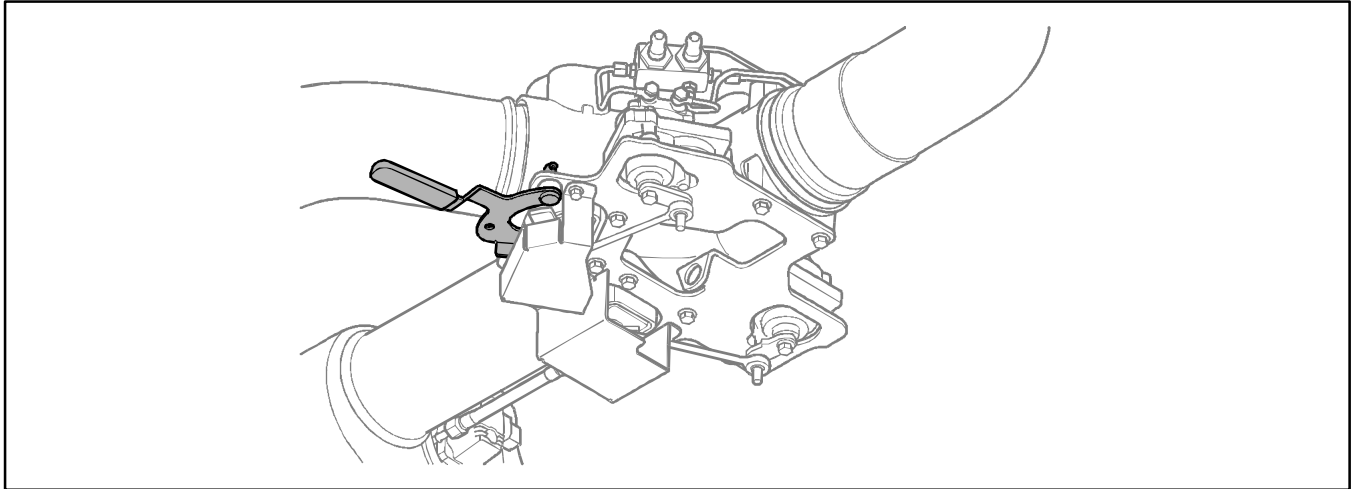


Figure 51 Exhaust Routing Valve Location

Surge Voltage Protection (Installed for Classed Units): The additional surge voltage protection is a requirement for classified installations. The surge voltage protection protects the SCR control unit and the exhaust routing valve against power surges in the event of lightning, for example.

7.1.13 NO_x Sensors

The SCR system comes with two NO_x sensors which have their own control unit. The sensor control units are connected to the SCR control unit in the reductant tank. See the section titled: **Connecting the Reductant Tank**. The control unit should be shielded from radiated heat and knocks. The electrical cables between the sensors and the control units must not be spliced. The NO_x sensors and control units must not be painted.

If the temperature at the NO_x sensor control units is too high, the control units may be damaged. The maximum permitted temperature at the NO_x sensor control units is 90°C (194°F). Measure the temperature when the installation is complete.

7.1.14 Exhaust Gas Temperature Sensors

The SCR system comes with three exhaust gas temperature sensors (Blue, yellow, and white in color), which share a control unit. The sensor control unit is connected to the SCR control unit in the reductant tank. See the section titled: **Connecting the Reductant Tank**. The control units should be shielded from radiated heat and knocks. The electrical cables between the sensors and the control unit must not be spliced. The connection between the sensor and the electrical cables must not be insulated as it may be damaged if it is exposed to temperatures above 200°C (392°F).

The two shorter exhaust temperature sensors (blue and white in color) are installed at the sensor ports on the inlet side of the SCR catalytic converter. See **Figure 52**. On 500EOZCS/450EFOZCS models, one temperature sensor is installed on each SCR catalytic converter and the other outlet plugged.

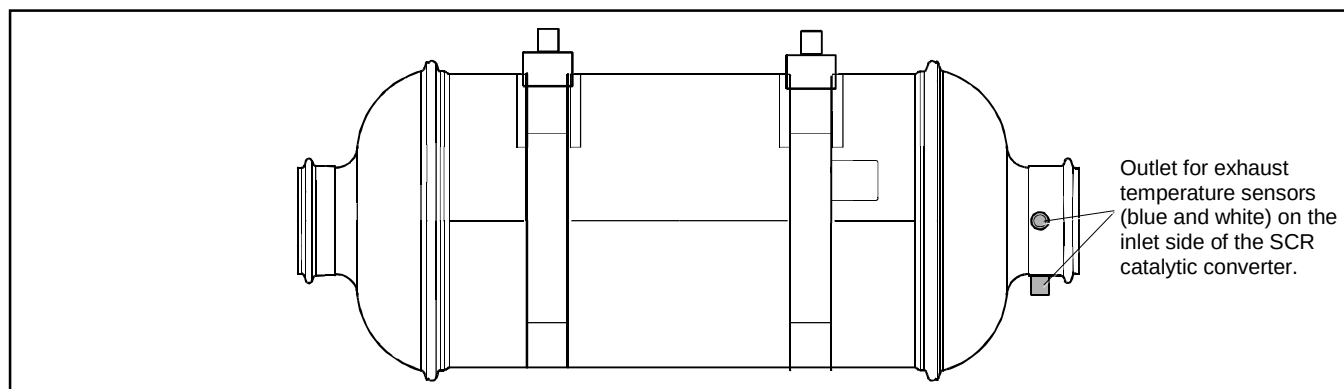


Figure 52 Exhaust Gas Temperature Sensors (Blue and White in color) Location

The longer exhaust temperature sensor (yellow in color) is installed at the flange on the outlet side of the SCR catalytic converter. See **Figure 53**.

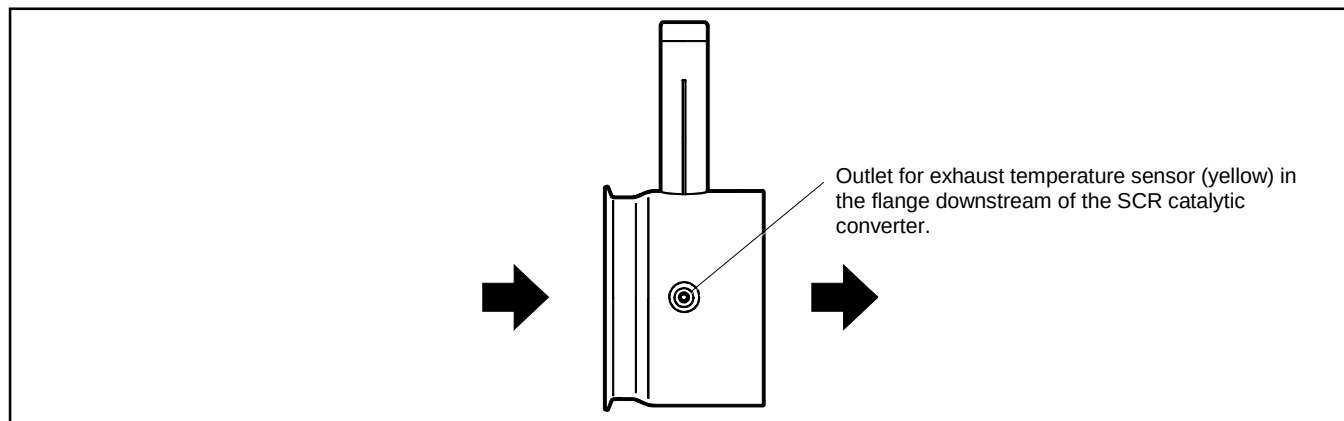


Figure 53 Exhaust Gas Temperature Sensor (Yellow in color) Location

Warnings of Faults in Exhaust Gas Aftertreatment Management: The system warns via CAN messages in the following cases:

- Emission-related faults.
- Faults in the exhaust gas aftertreatment management system.

7.2 Important Data

Highest permitted reductant temperature	55°C (131°F)
Highest permitted temperature at evaporator	115°C (239°F)
Highest permitted temperature at the exhaust routing valve actuator	90°C (194°F)
Maximum permitted temperature at the NO _x sensor control units	90°C (194°F)

8.1 Ventilation

Engine combustion, generator cooling, and expulsion of flammable and lethal fumes require ventilation. Provide ventilation compliant with USCG regulations governing the sizing of vents and other considerations.

As a rule, size each inlet- and outlet-vent area to a minimum of 13 sq. cm/30.5 cm (2 sq. in. per ft.) of the craft's beam. Should this rule conflict with USCG regulations, follow USCG regulations. For applications with screened inlets, double the size (4 sq. in. per ft.) of the hull/deck openings. Extend the vent ducts to bilges to expel heavier-than-air fumes.

For generator sets mounted in the engine compartment, increase the air flow to allow for the generator set's requirements. Install optional detection devices to cause alarm, warning, or engine shutdown should dangerous fumes accumulate in the compartment.

See the generator set specification sheet that shipped with the generator set for air requirements. The air intake silencer/cleaner provides combustion air to the engine. Follow the recommended mounting clearances identified in the section titled: **Location and Mounting**. The engine/generator performance will decline if you compromise these guidelines. See **Figure 54** for allowable intake restriction.

Note:
ISO 3046 derates apply.

Model	Allowable Air Intake Restriction (Max.)	
350/500EOZCS 300/450EFOZCS	26.1 in. H ₂ O (6.5 kPa) or less (with blocked filter)	12 in. H ₂ O (3 kPa) or less (with new filter)

Figure 54 Combustion Air Intake Restrictions

8.2 Cooling System Components (Heat Exchanger Models)

Design the marine generator set's cooling system to include the following features.

8.2.1 Intake Through-Hull Strainer (Seacock Cover)

Install a screened-intake, through-hull strainer to prevent entry of foreign objects. Use perforated, slotted-hole, or unrestricted-hole design strainers. See **Figure 55** for examples of typical strainers. The inner diameter of the strainer opening must be equal to or greater than the inner diameter of the water line hose to the seawater pump.

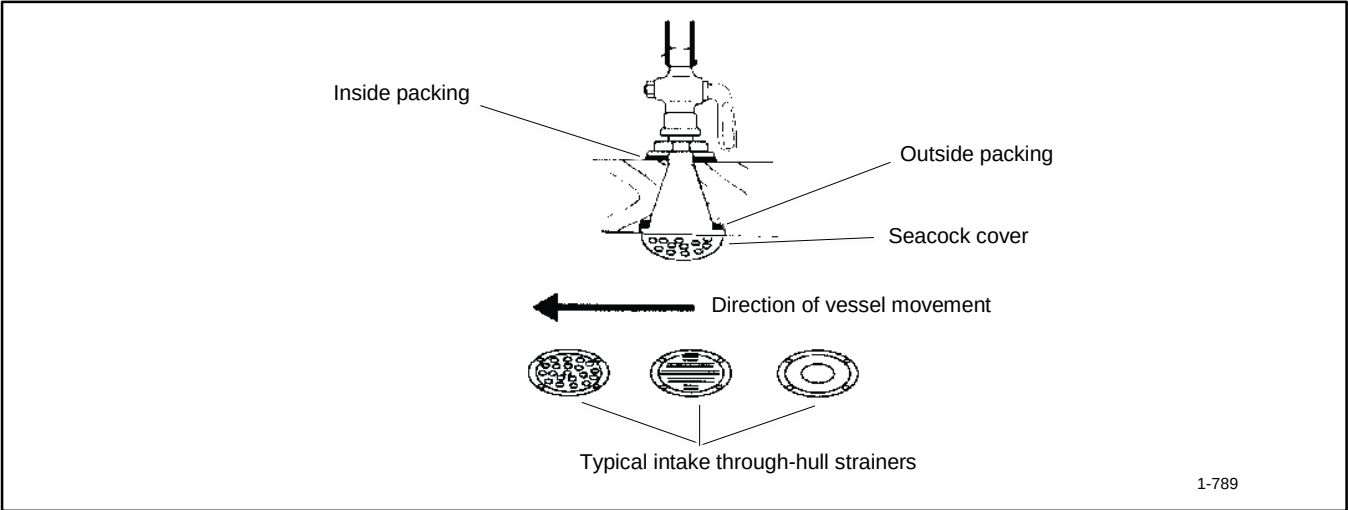


Figure 55 Seacock Installation

Do not align the strainer (in relation to the direction of travel) with any other through-hull intakes. See **Figure 56**. Flush mount the recommended through-hull strainer. Install slotted-hole-design strainers with the slots parallel to the direction of the vessel's movement.

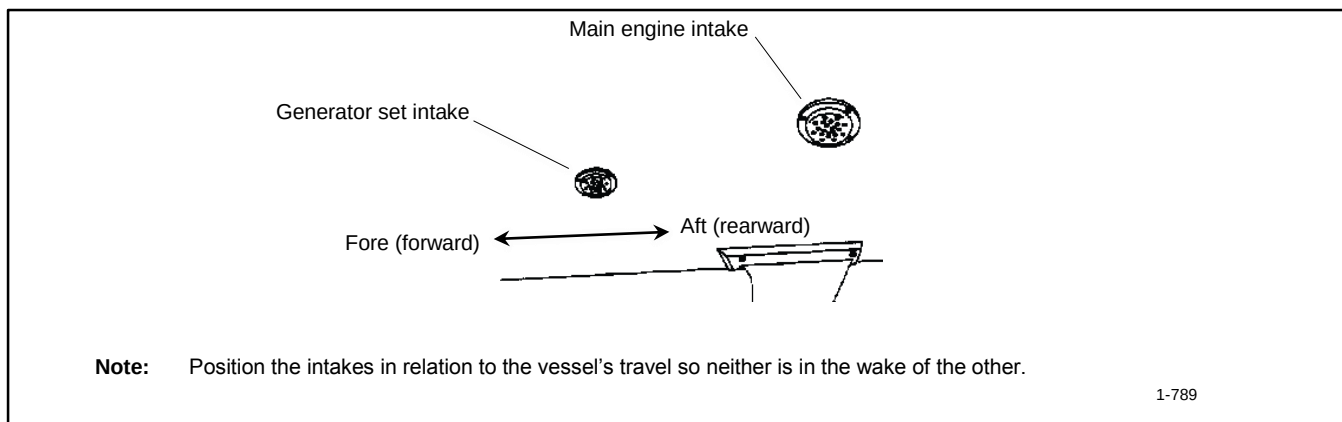


Figure 56 Intake Strainer

Do not use a speed scoop or cup design intake through-hull strainer because it can cause a ramming effect and force water upward, past the seawater pump, and into the engine cylinders when the vessel is moving and the generator set is shut down.

Do not use hull designs incorporating sea chests or other designs that provide a positive pressure to the raw water pump for the intake through-hull strainers. Positive pressure forces water past the raw water pump and into the engine. A sea chest is a concave molded-in-the-hull chamber that aligns to the direction of travel. A sea chest configuration applies a positive pressure similar to a scoop-type through-hull strainer.

The seawater intake should be positioned deep enough in the boat to remain below the water surface when the boat rolls, and to be protected by the keel.

If, due to the distance between seawater intake and engine, the intake pipe must be routed with a relatively long horizontal section, it should be positioned so that it is below the surface of the water. This ensures that it is always water-filled, even when the generator engine is not running.

The suction height for the seawater pump must never exceed 3 m (10 ft.), calculated without compensating for the pressure drop in the suction line.

The intake line must always be fitted with a seacock, with an opening diameter at least as large as the inner diameter of the intake line, to avoid large pressure drops.

It is important that the seacock be easily accessible.

8.2.2 Seacock

Mount the seacock to the hull, assemble it to the intake, and ensure that it is accessible for operation. The figure titled: **Seacock Installation** shows a typical installation.

Avoid overcaulking the seacock. Excess caulk reduces water flow and, in some cases, develops barrier that can force water upward, past the seawater pump, and into the engine cylinders when the vessel is moving, and the generator set is shut down.

8.2.3 Seawater Strainer

Contamination, sludge or sand which is sucked into the seawater line will block the line, thus reducing pump and engine cooling capacity. In addition, sand and contamination will reduce the service life of the impeller and the pump.

To reduce the risk of pump damage and blockages, a filter to separate dirt should be installed in the suction line. The holes in the filter (if fitted) should not be larger than maximum 2 mm (0.08 in.).

The filter should be positioned to facilitate disassembly and cleaning.

Mount the seawater strainer to the seacock or permanent structure at a point not higher than the seawater pump. Ensure that the strainer is accessible for service. See **Figure 57** for a typical installation.

Some seawater strainers include a seacock and an intake through-hull strainer.

Maximum seawater inlet pressure at the seawater pump is 34.5 kPa (5 psi). Excessive pressure will cause water ingestion.

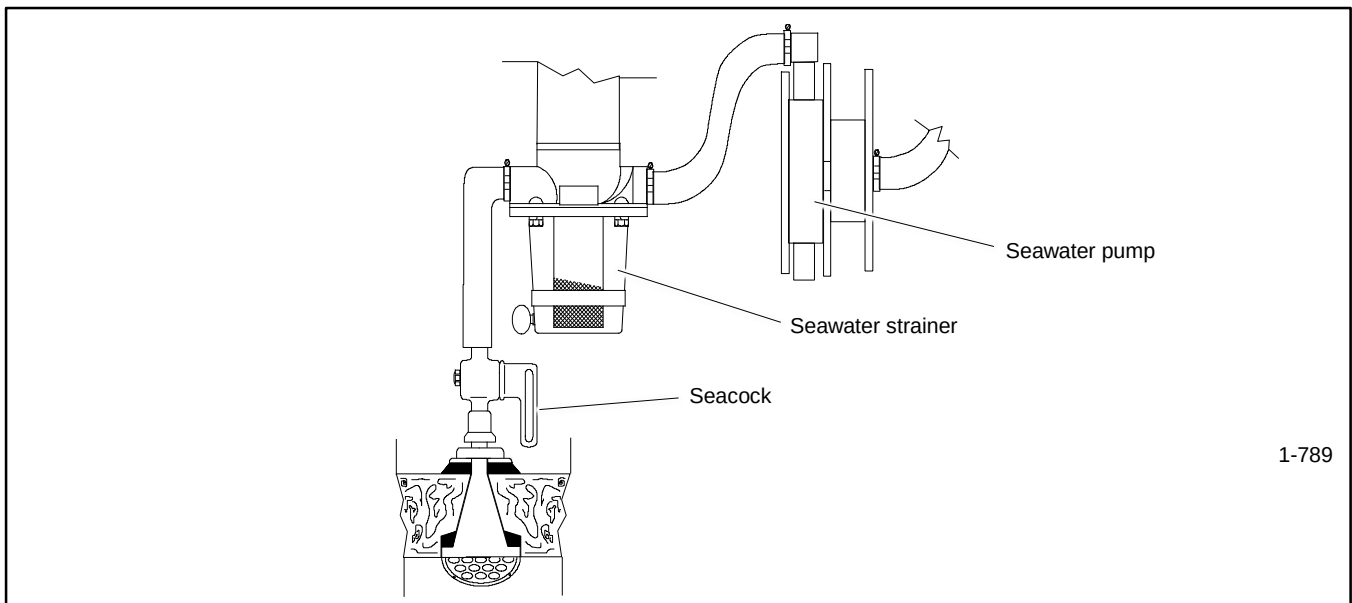


Figure 57 Seawater Strainer

8.2.4 Water Lines

Water lines from the seacock to the engine-driven seawater pump are usually constructed of flexible hose. Connect a flexible section of hose to the seawater pump to allow for vibrational motion of the generator set during operation. Support a nonflexible water line within 102 mm (4 in.) of its connection to the flexible section.

Keep the seawater hose as straight and short as possible. If the hose is too long, usually over 4.6 m (15 ft.), water suction problems may occur. See the section titled: **Installation Drawings** for the inlet water line hose size and the seawater connection to the seawater pump inlet. Avoid running the inlet pipe above the generator. See **Figure 58** for the seawater inlet connection.

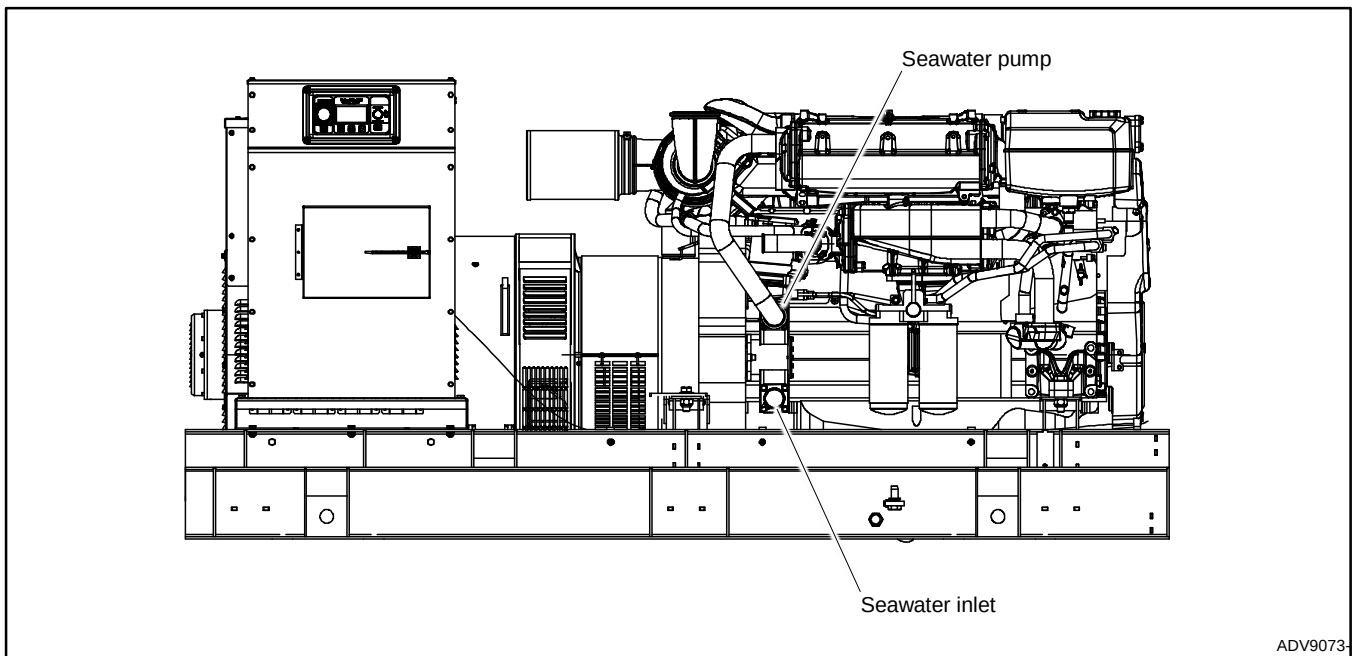


Figure 58 Seawater Inlet Connection, Typical (350EOZCS/300EFOZCS Model Shown)

8.2.5 Closed Heat Exchanger

A closed heat exchanger is the best cooling method for most applications. Provide space to access the water-cooled exhaust manifold pressure cap.

8.3 General

On 350EOZCS/300EFOZCS keel-cooled models, the charge air cooler is connected to the coolant circuit. 500EOZCS/450EFOZCS keel-cooled models, have a separate coolant circuit for the charge air cooler.

Marine generator engines normally have a closed cooling system, with coolant pumped through the engine and a heat exchanger in a closed circuit.

The exhaust manifold is connected to the coolant circuit.

The coolant is cooled by seawater in the heat exchanger.

Note:

The engine may sustain freezing damage in winter if the seawater circuit is not drained, if the engine is not kept warm or if the boat is out of service. To avoid damage caused by freezing during transport or storage the seawater system should be drained even when the engine has been test run on land.

8.4 Seawater Circuit

The seawater is circulated through the seawater circuit by a rubber impeller pump, mounted on the rear of the timing gear casing and driven directly by the timing system via a gear.

Note:

Damage to the seawater pump impeller can result if the pump is run dry for more than approximately ½ minute (or less if the impeller is worn or aged).

From the seawater pump, the water is first led through the charge air cooler where it cools the air from the turbocharger. The water is then led through the heat exchanger, where it cools the internal coolant circuit of the engine. After the heat exchanger, the water is led to the outlet. It is possible to connect a water-cooled exhaust pipe bend to the seawater outlet.

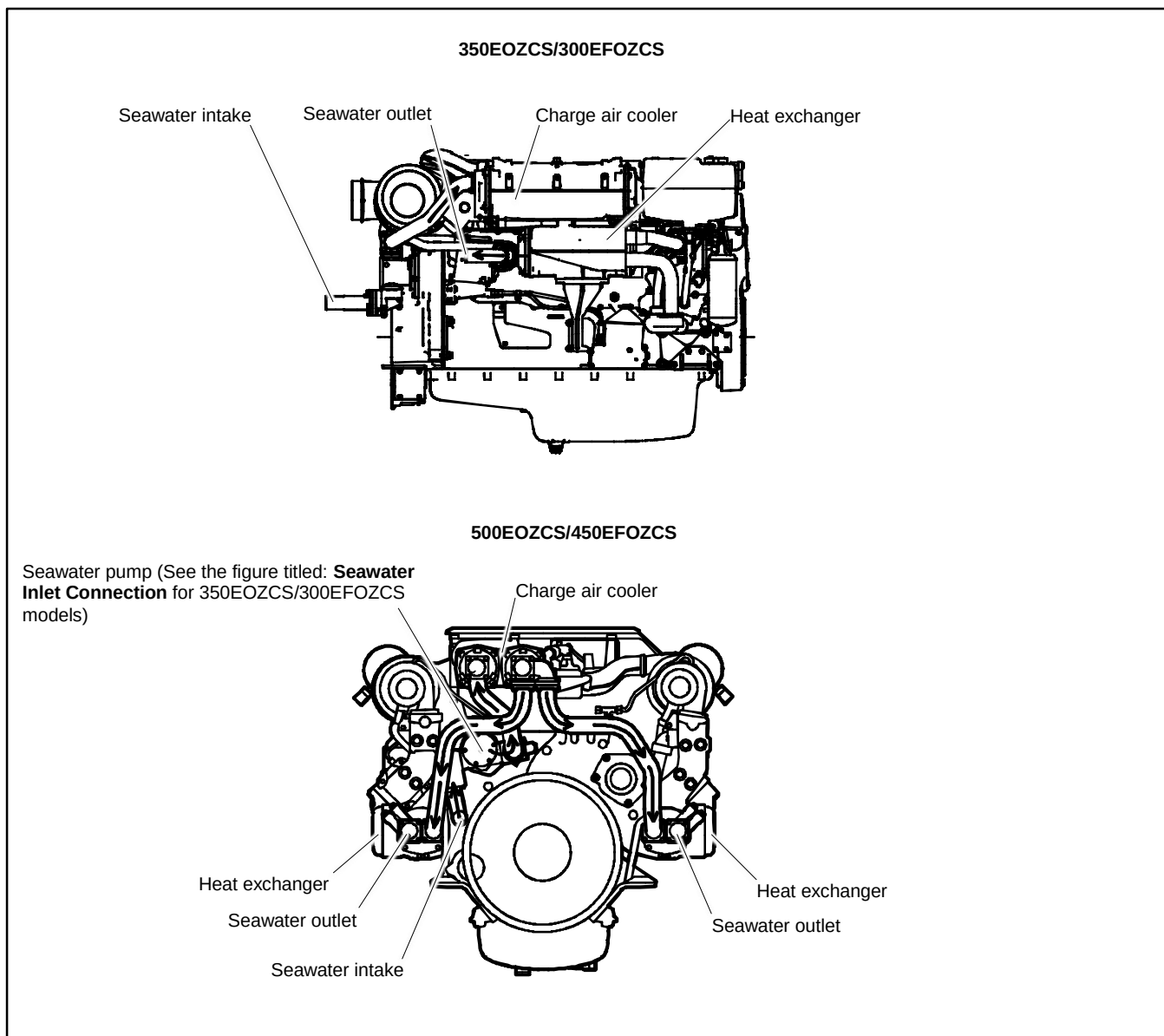


Figure 59 Seawater Circuit

8.5 Draining the Seawater Circuit

When draining the circuit, first close the seacock of the vessel, then remove the connection pipe from the heat exchanger outlet.

Also remove the cover from the seawater pump to completely drain the pump.

The installer is responsible for installing extra drain points in the vessel's piping, if the connection lines are installed in such a way that they are not self-draining. The installer must also ensure that the vessel has a seacock and that the seawater circuit can be drained.

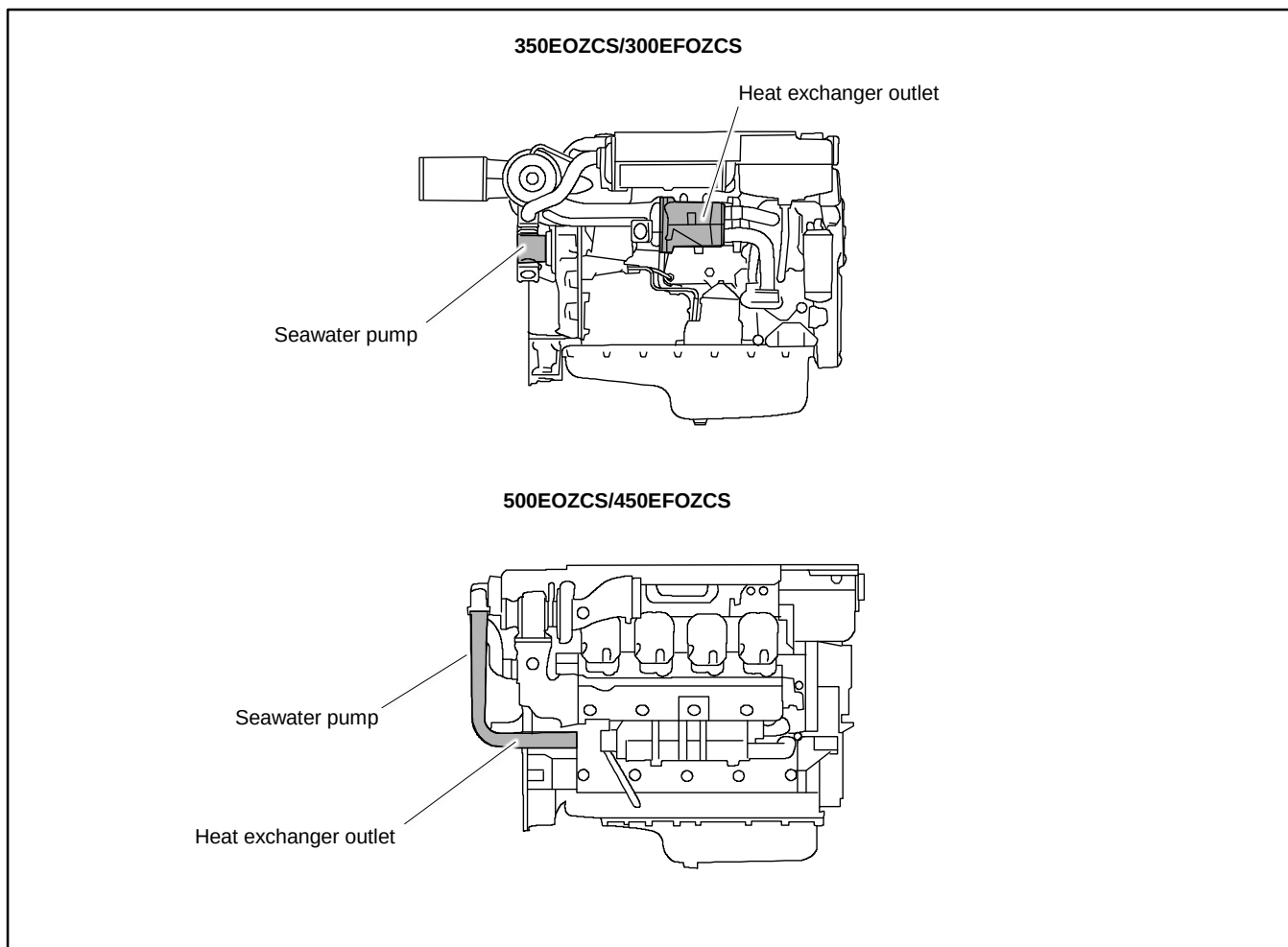


Figure 60 Draining the Seawater Circuit

8.6 External Seawater Circuit

8.6.1 Lines

The seawater pump suction line and the outlet line should have as few bends and valves as possible, and be as short as possible, to keep down the back pressure. Lines made of copper or acid-resistant stainless steel are most suitable.

The suction and outlet connections on the engine are rigid pipe with an outer diameter as shown in **Figure 61**.

Dimensions for Connection of the Seawater Pipe (Ø mm)		
Model	Suction Pipe	Outlet Line
350EOZCS 300EFOZCS	50	50
500EOZCS 450EFOZCS	50	51

Figure 61 Dimensions for Connection of the Seawater Pipe

There should always be a flexible connection between the engine and external pipe system, to ensure that vibrations are not transmitted to the boat.

If there is one common seawater circuit for several engines, then there must be a shut-off mechanism (for example an automatically operated solenoid valve) so that the seawater is not pumped through the engine if it is not running.

It must be possible to drain suction and outlet lines when necessary. The suction and outlet lines must be dimensioned for the prevailing seawater flow and pressure drop conditions.

An excessive pressure rise and/or too much vacuum for the seawater pump reduces the service life of the impeller and reduces cooling capacity.

The following pressure ratios apply:

- The pressure difference between the intake side of the pump (standard-type impeller pump) and the pressure side must not exceed 2 bar (29 psi).
- The vacuum on the intake side must not exceed 0.3 bar (4.4 psi). An increased vacuum means a higher risk of cavitation damage to the pump.
- If the generator engine is located at a level where the pump's maximum suction height is exceeded, a special feed pump must be installed. The feed pump must not produce a pressure so high that the internal pressure in the engine becomes greater than 2 bar (29 psi). Alternately, a seawater day tank can be considered to reduce the height.

The seawater flow values are indicated in **Figure 62**.

The pressure drop across the engine at various seawater flow values is indicated in **Figure 63**. Other pressure drops, caused by the seacock, seawater filter, pipes, level differences, reverse gear oil cooler (if fitted), etc., must also be taken into account.

Seawater Pump Flow Lpm (gpm)		
Engine Speed RPM	350EOZCS 300EFOZCS	500EOZCS 450EFOZCS
1500	215 (57)	215 (57)
1800	250 (66)	250 (66)

Figure 62 Seawater Pump Flow (Heat Exchanger Models)

Pressure Drop Across Engine, bar		
Seawater Flow l/min.	Model	
	350EOZCS 300EFOZCS	500EOZCS 450EFOZCS
190	0.40	0.30
250	0.45	0.35
300	0.50	0.40

Figure 63 Pressure Drop Across the Engine at Different Seawater Flows

8.6.2 Fresh Water Coolant Circuit

Coolant is circulated through the engine and the heat exchanger by a belt-driven centrifugal pump. Coolant flows backwards from the coolant pump through the engine to the thermostat housing.

When the thermostat is closed, the coolant flows directly from the thermostat housing to the suction side of the coolant pump. When the thermostat opens, the coolant flows first through the heat exchanger for cooling and then on to the suction side of the coolant pump.

Engines with a heat exchanger have a separate expansion tank located at the very front of the engine. The expansion tank is connected to the suction side of the coolant pump via a static line pipe. There are bleed pipes from the exhaust manifold and cylinder heads up to the expansion tank. On 500EOZCS/450EFOZCS models, there are also bleed pipes from the coolant pump and oil cooler cover. The expansion tank has a pressure cap with an opening pressure of 0.75 bar (10.9 psi).

If the volume of the cooling system must be increased, (for example, when connecting external cooling or heating systems) it may be necessary to increase the expansion volume. See the section titled: **Connecting the Auxiliary Expansion Tank**.

Note:

These units should always have corrosion protection in the coolant circuit. This must be antifreeze.

The coolant should always contain 35- 55 percent by volume of antifreeze and corrosion protection so that the coolant properties ensure that the coolant works correctly.

Hot Climates. In order to retain the corrosion protection and the higher boiling point, it is essential to use coolant consisting of water mixed with antifreeze (ethylene glycol) and corrosion inhibitor. Even in countries where the temperature never drops below 0°C (32°F).

Freezing Point °C	-21	-24	-30	-38	-45	Cooling System Volume
Ethylene Glycol (vol. %)	35	40	45	50	55	Liters
Ethylene Glycol (Liters)	11	12	14	15	17	30
	12	14	16	18	19	35
	14	16	18	20	22	40
	16	18	20	23	25	45
	18	20	23	25	28	50
	19	22	25	28	30	55
	21	24	27	30	33	60
	23	26	29	33	36	65
	25	28	32	35	39	70
	26	30	34	38	41	75
	28	32	36	40	44	80
	30	34	38	43	47	85
	32	36	41	45	50	90
	33	38	43	48	52	95
	35	40	45	50	55	100
	37	42	47	53	58	105
	39	44	50	55	61	110
	40	46	52	58	63	115
	42	48	54	60	66	120
	44	50	56	63	69	125

Figure 64 Antifreeze and Corrosion Protection Concentration Table

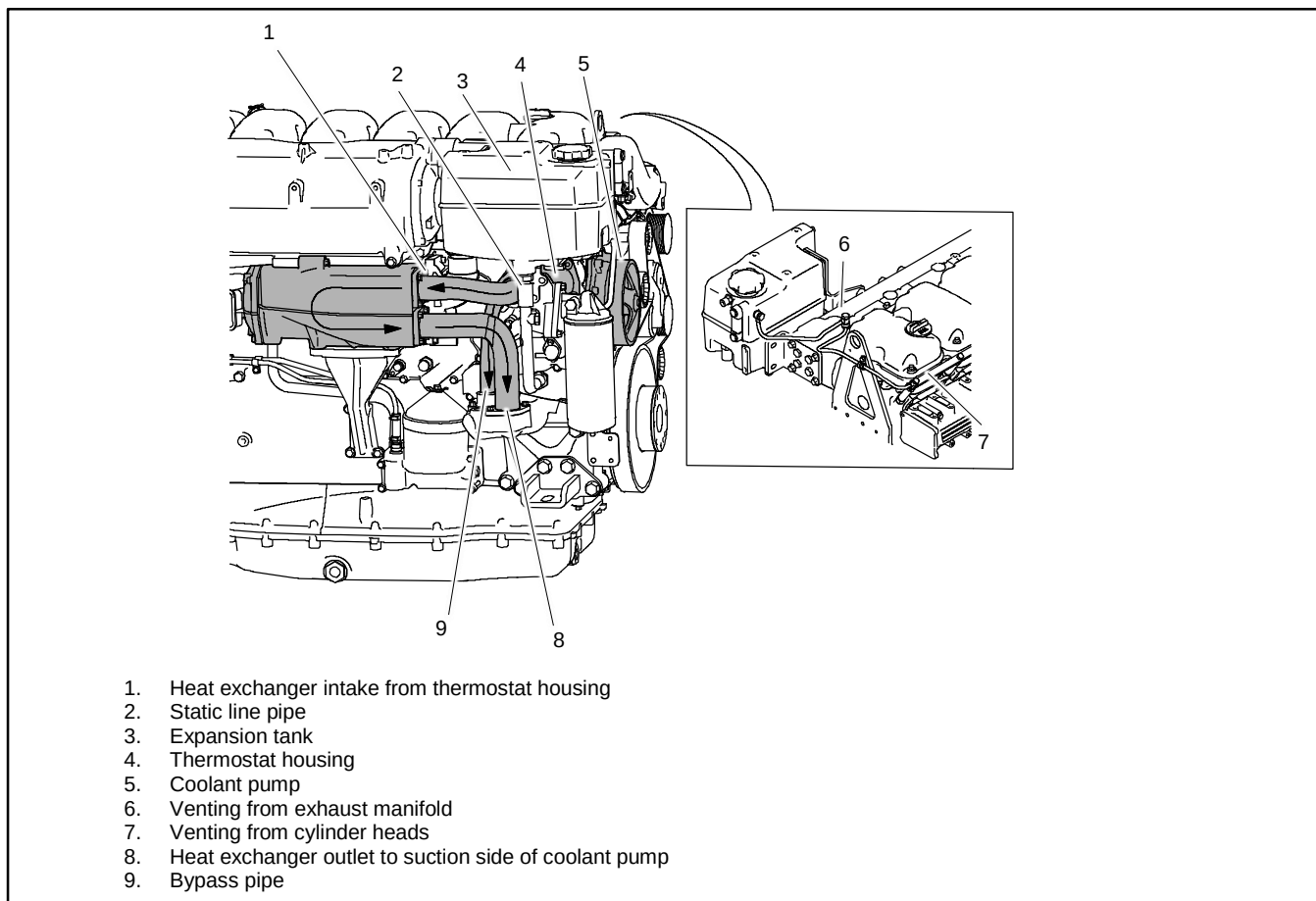
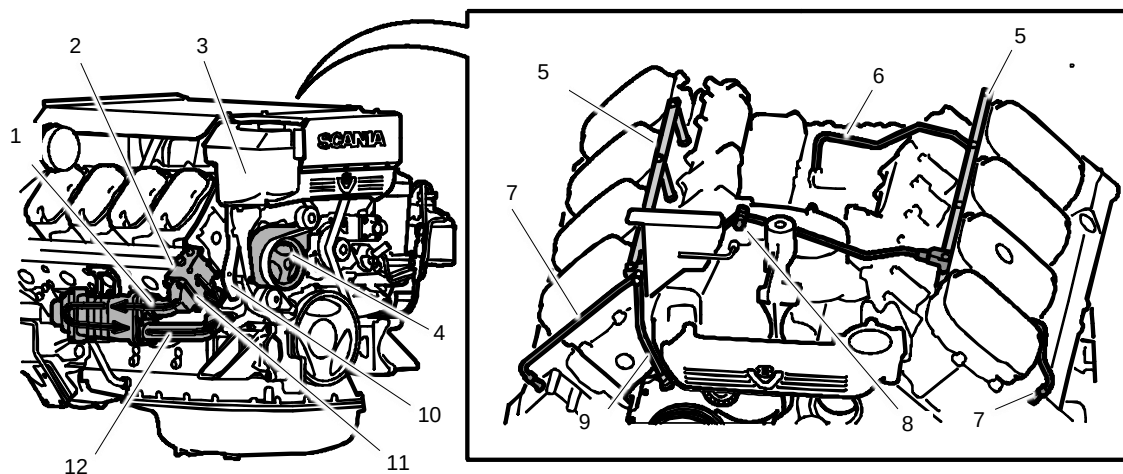


Figure 65 Coolant Circuit (350EOZCS/300EFOZCS)



1. Heat exchanger intake from thermostat housing
2. Thermostat housing
3. Expansion tank
4. Coolant pump
5. Venting from cylinder heads
6. Venting from the oil cooler cover
7. Venting from exhaust manifold
8. Connection to expansion tank
9. Venting from the coolant pump
10. Static line pipe
11. Bypass pipe
12. Heat exchanger outlet to suction side of coolant pump

Figure 66 Coolant Circuit (500EOZCS/450EFOZCS)

8.6.3 Draining Coolant, Fresh Water Circuit

Note:

Obtain adapter tool (Kohler part number GM109265).

The installer must ensure that coolant can be drained.

1. Connect a coolant pump to the lowest drain valve in the cooling system.
2. Place the other hose from the pump into an empty plastic container.

Note:

Dispose of used coolant in an environmentally safe manner and in accordance with all applicable laws.

3. Connect the pump's two cable terminals to the battery's negative and positive terminal. Check that draining starts. If it doesn't, swap the position of the cable terminals.

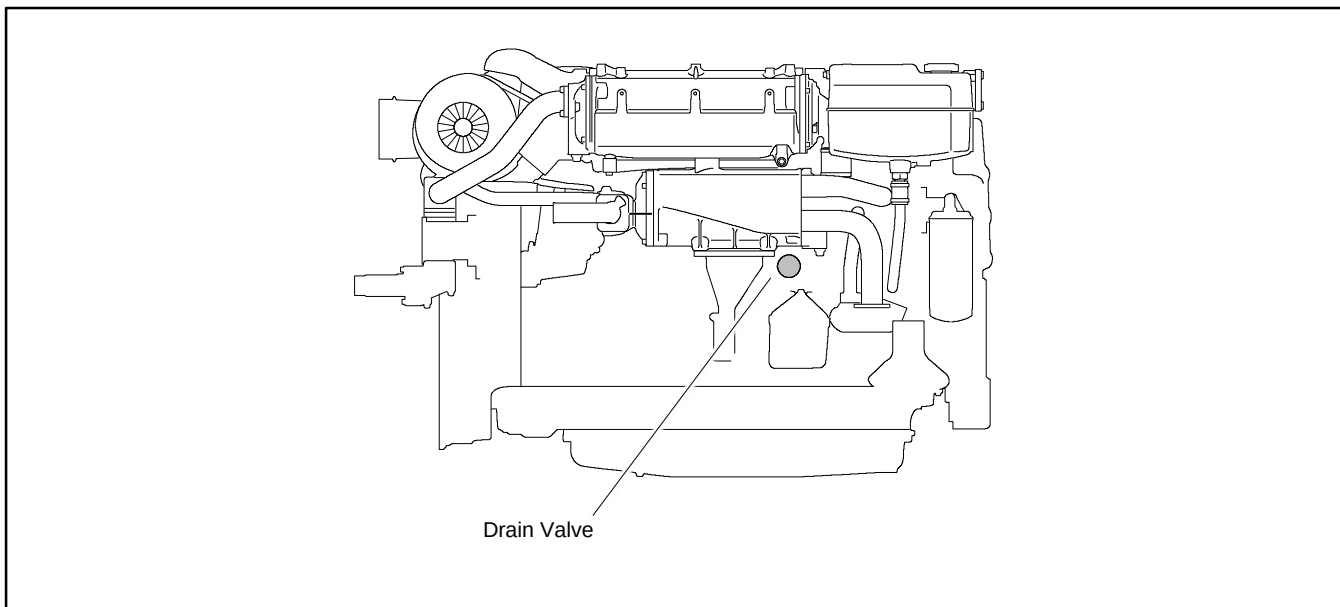


Figure 67 Example of Drain Valve (350EOZCS/300EFOZCS)

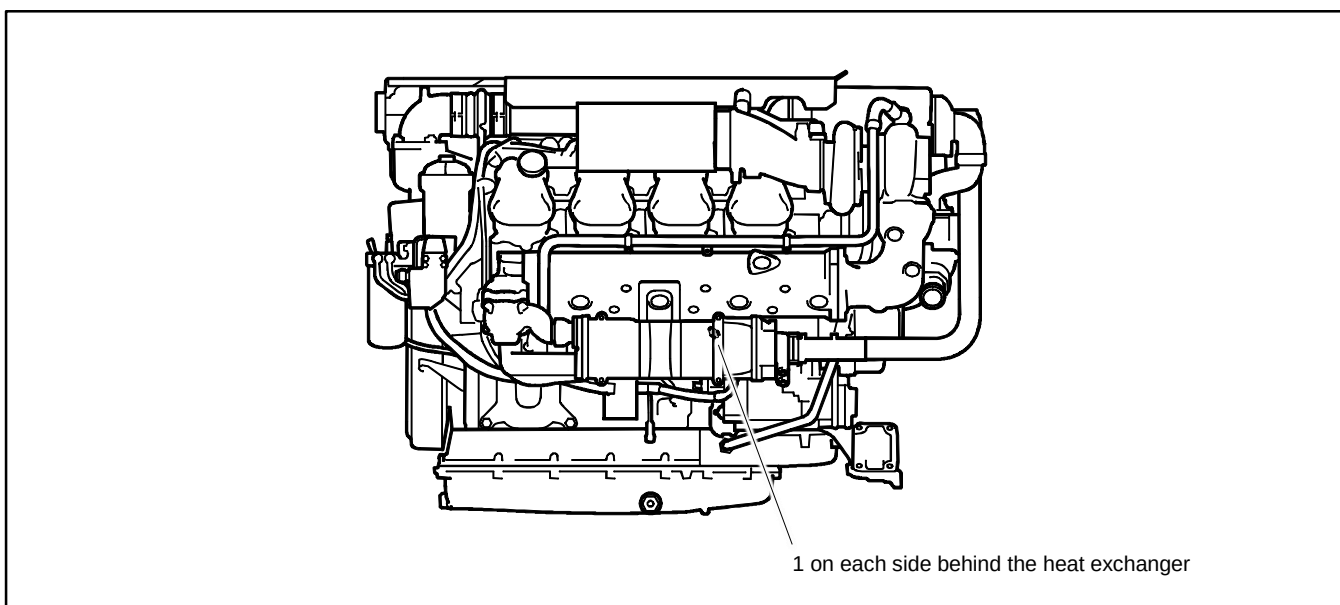


Figure 68 Example of Drain Valve (500EOZCS/450EFOZCS)

8.6.4 Filling Coolant, Fresh Water Circuit

Note:

Obtain adapter tool (Kohler part number GM109265).

The installer must ensure that coolant can be filled.

Note:

It is not permissible to fill large amounts of coolant via the expansion tank. Filling via the expansion tank leads to air pockets in the cooling system, which can damage the coolant pump shaft seal, among other things.

Note:

Never fill a large amount of cold coolant in a hot engine. There is a risk of cracks forming in the cylinder block and cylinder heads.

1. Connect a coolant pump to the lowest drain valve in the cooling system.
2. Connect the pump's two cable terminals to the battery's negative and positive terminal. Check that filling starts. If it doesn't, swap the position of the cable terminals.
3. Start the generator engine when the cooling system has been filled. Let the engine idle for some time. Check that there are no leaks. Then check the coolant level and top up as necessary.

There may still be pockets of air in the cooling system. This air will disappear after the engine has been run for some time. The system usually has to be topped up several times.

The correct level is level with the lower part of the filler pipe.

8.7 Connecting the Auxiliary Expansion Tank

If the volume of the fresh water system is increased (for example, by connecting an external cooling or heating system) it may be necessary to increase expansion capacity by connecting an auxiliary expansion tank.

Note:

If an external expansion tank is to be connected, the existing expansion tank must be removed. Use bleed pipes for keel-cooled engines.

Expansion capacity should be at least 3% of total coolant volume.

This limit on static pressure also limits the height at which the expansion tank may be located. With 0.75 bar (10.9 psi) pressure caps (standard) the maximum height of the expansion tank is 3.5 m (11.4 ft.) above the pump.

If the expansion tank has to be positioned higher, this is permissible up to a maximum height of 8.5 m (27.8 ft.), provided that non-pressure caps are used.

The expansion tank must be connected via a pressure line (static line) to the suction side of the pump, to reduce the risk of vapor forming with the ensuing cavitation in the pump. This connection must have as even a rise as possible to avoid pockets of air and steam.

The outer diameter of the static line must be at least 25 mm for the 350EOZCS/300EFOZCS models and 38 mm for the 500EOZCS/450EFOZCS models.

The inside diameter of the static line should be at least 20 mm for the 350EOZCS/300EFOZCS models and 35 mm for the 500EOZCS/450EFOZCS models.

500EOZCS/450EFOZCS models must have bleed pipes from the exhaust manifolds, the cylinder heads, oil cooler cover, and coolant pump up to the expansion tank.

If the expansion tank and filler system is to be moved, onto the deck for example, the bleed line and static line must always be routed as two separate lines, connected some distance from each other in the expansion tank in order to achieve automatic venting of the system. The maximum inside diameter of the bleed lines is 8 mm (0.3 in.).

See **Figure 69** for coolant volumes.

Model	Coolant Volume L (qts.)
350EOZCS/300EFOZCS:	
With heat exchanger	40 (42)
With keel cooling, 1 coolant circuit	24 (25)
500EOZCS/450EFOZCS:	
With heat exchanger	63 (67)
With keel cooling, 2 coolant circuits	50 (53)

Figure 69 Coolant Volumes (Engine Only)

8.8 Keel Cooling

8.8.1 General

Where the seawater is of such poor quality that it is unsuitable for circulation through a seawater system, (for example, due to a high content of sludge and sand or the seawater contains contamination or ice which might block the seawater intake) a keel cooling system can be installed.

The engine coolant is cooled by circulation through pipe coils or cooling elements mounted at the bottom of the vessel inside or outside the hull.

8.8.2 350EOZCS/300EFOZCS Models with 1 Coolant Circuit

The engine inlet from the external cooling coil is routed to the suction side of the pump. The coolant is then pumped through the engine to the thermostat housing.

When the thermostat opens, the coolant flows from the thermostat housing to the keel cooling system. See **Figure 70**.

The pipe for connection to the engine coolant circuit has an outside diameter of 50 mm.

The highest permitted temperature of the coolant entering the jacket water is 70°C (158°F).

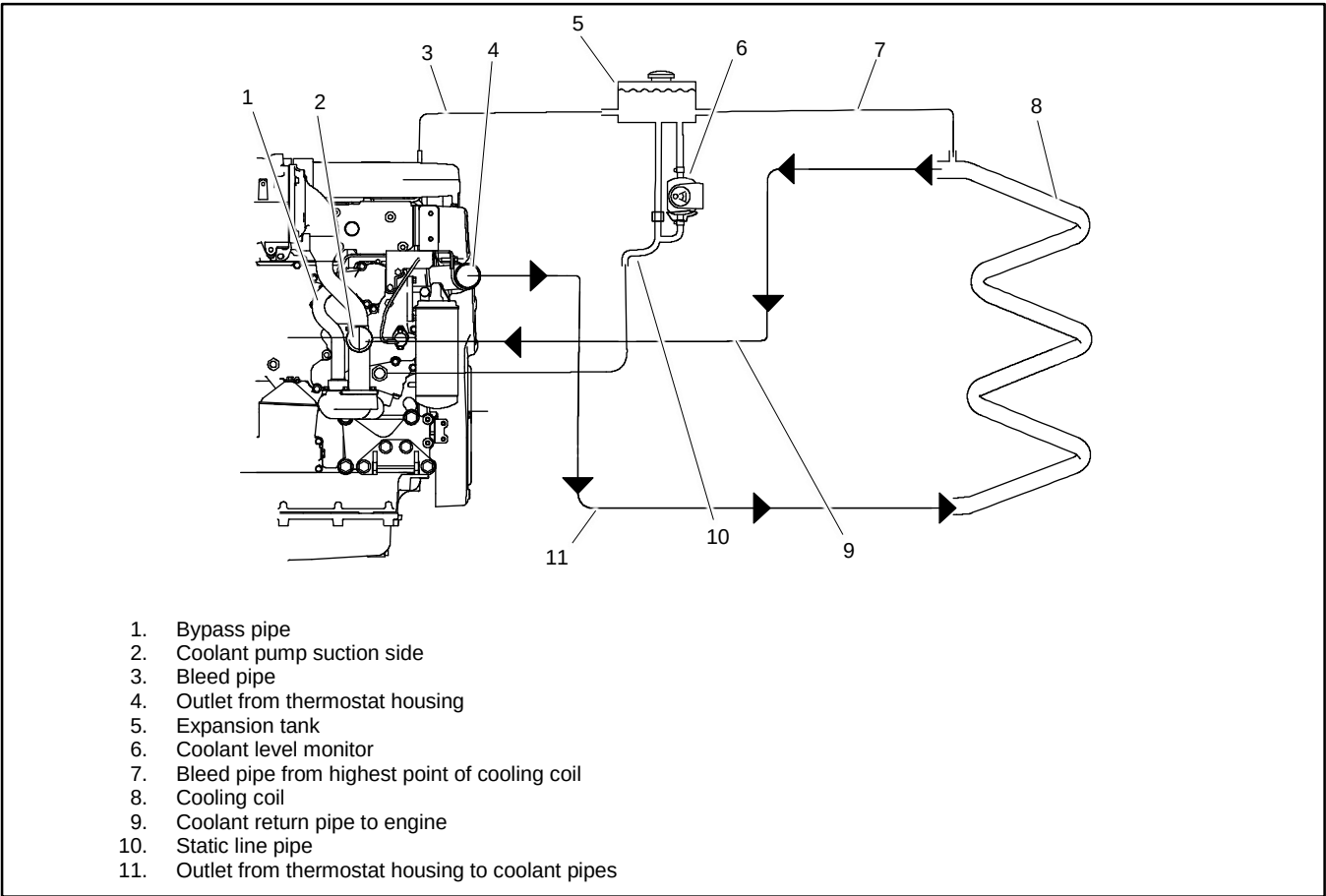


Figure 70 Keel Cooling Circuit and Auxiliary Oil Cooler Connections (350EOZCS/300EFOZCS Model with 1 Coolant Circuit)

8.8.3 500EOZCS/450EFOZCS Models with 2 Coolant Circuits

The coolant flows from the main circuit cooling coil to the suction side of the coolant pump. From there the coolant flows through the engine and to the thermostat housing (See **Figure 71**, item 4). When the thermostat opens the coolant flows from the thermostat housing straight back to the main circuit cooling coil.

Charge air is cooled in a separate coolant circuit with an extra coolant pump. The extra coolant pump is mounted on the engine as shown in **Figure 71**. The charge air circuit has no thermostat, which means that coolant circulates continuously through the charge air cooler.

This coolant circuit must be equipped with a separate expansion tank as shown in **Figure 71**.

The pipe for connection to the engine main circuit has an outside diameter of 63 mm.

The pipes for connection to the charge air circuit have an outside diameter of 51 mm for the outlet and 54 mm for the inlet.

The highest permitted temperature of the coolant entering the charge air circuit is 40°C (104°F).

Note:

If the coolant entering the charge air circuit is hotter than 40°C (104°F), the emission requirements are not met.

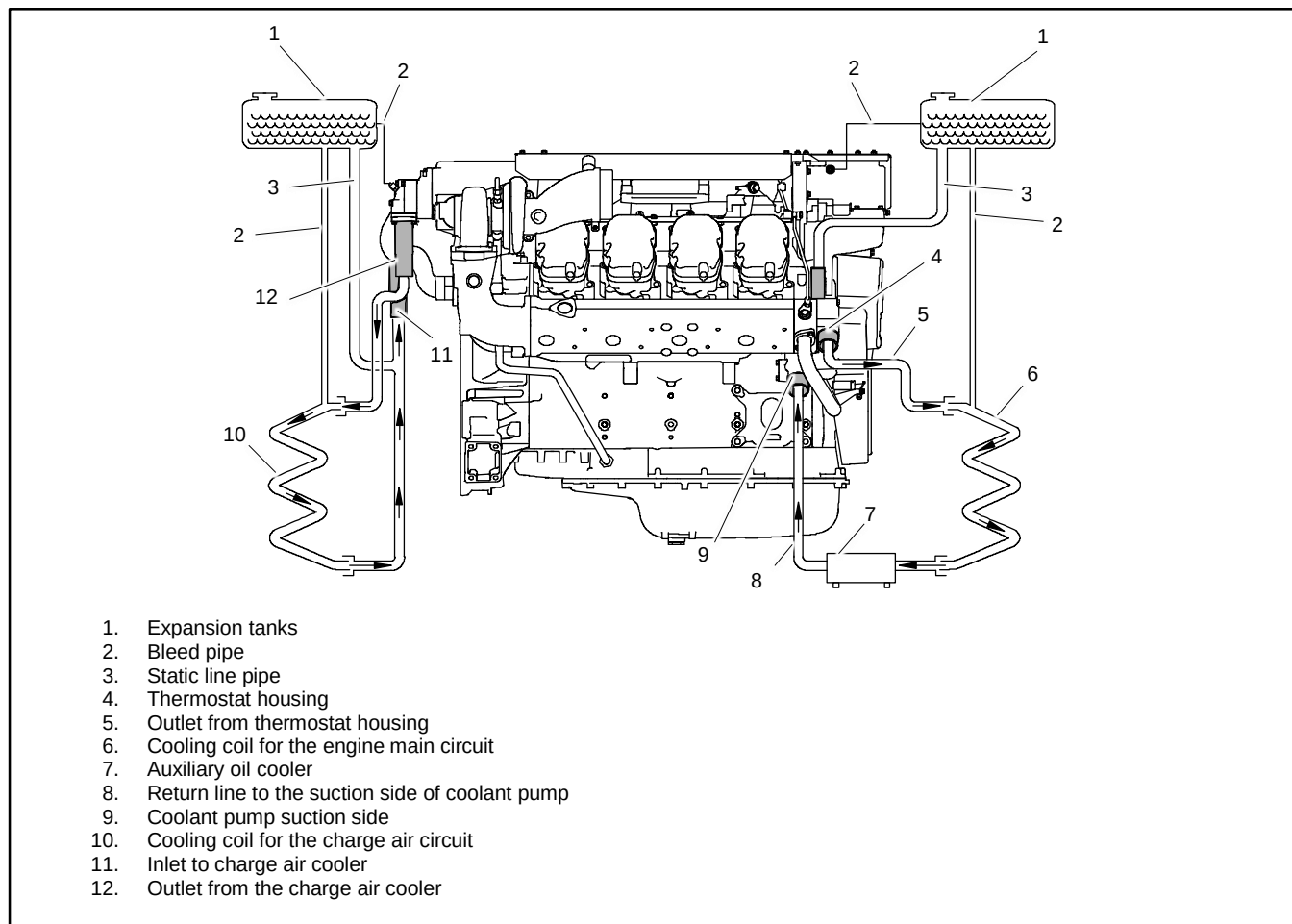


Figure 71 Keel Cooling Circuit and Auxiliary Oil Cooler Connections (500EOZCS/450EFOZCS Models with 2 Coolant Circuits)

8.8.4 Pressure Loss and Required Coolant Flow

Sizing of the coolant pipes and hose connections between engine and cooling coil must be done in a dedicated manner to avoid reduction of the cooling capacity. An adequate quantity of coolant must be able to pass through the pipes, hoses, and keel cooler.

Note:

The amount of coolant passing through the cooler is reduced when components or restrictor valves are connected in the system. This leads to a reduction in cooling capacity. At the same time, this increases the pressure in the thermostat housing, hoses, and cooler.

The coolant lines should be made of pipe, bent and jointed with short, straight hoses. Corrugated or ribbed hoses cause unnecessary resistance to flow.

The maximum permitted pressure drop (D_p) over the external cooling system and the minimum coolant flow in liters/minute at different engine speeds are shown in **Figure 72** and **Figure 73**.

If in doubt, check that the pressure drop across the external system does not exceed permissible values. The pressure drop is determined by measuring the difference in pressure between the thermostat housing and the inlet to the coolant pump with the thermostats blocked in the open position and with no pressure cap.

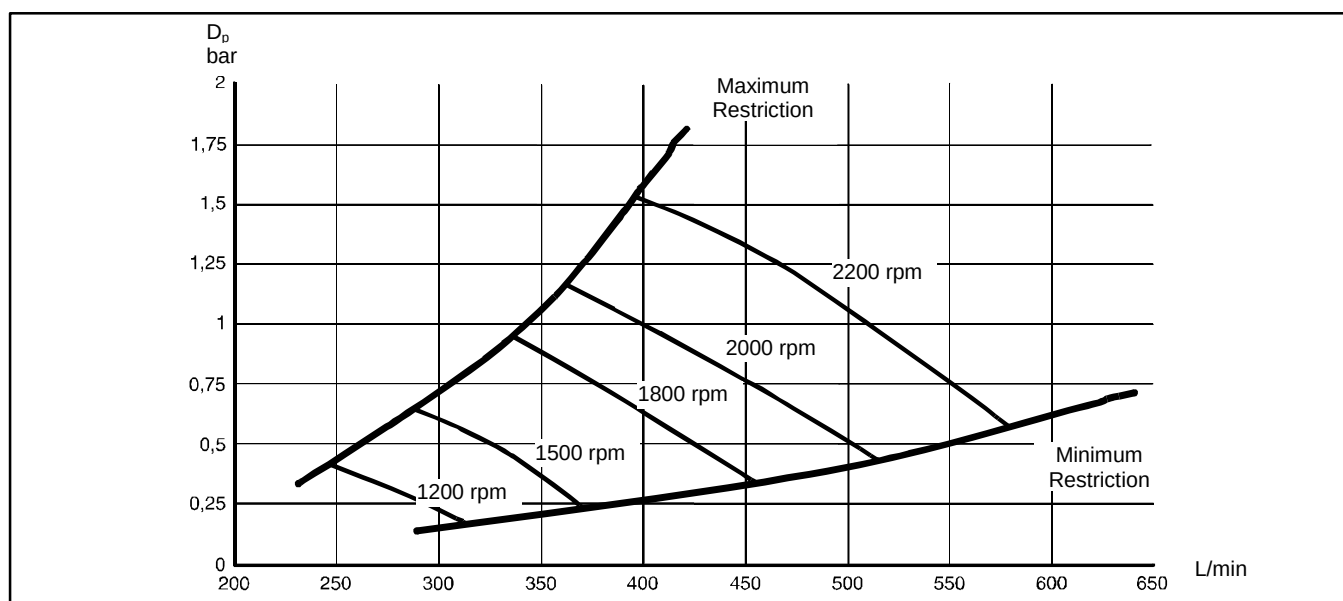


Figure 72 350EOZCS/300EFOZCS Models with 1 Coolant Circuit
Max. Permissible Pressure Drop (D_p) Across External Cooling System and Min. Coolant Flow at Different Engine Speeds

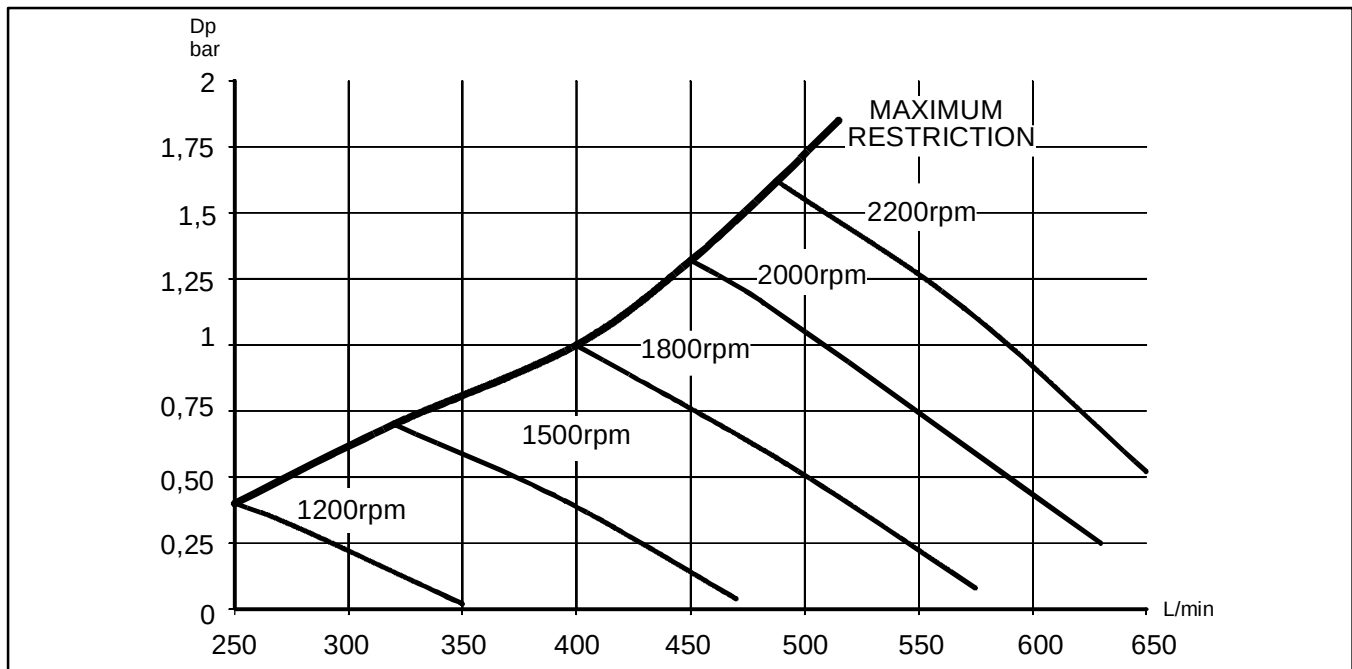


Figure 73 500EOZCS/450EFOZCS Models with 2 Coolant Circuits
Max. Permissible Pressure Drop (Dp) Across External Cooling System and Min. Coolant Flow at Different Engine Speeds

Charge Air Cooler (CAC) Pump (500EOZCS/450EFOZCS Keel-Cooled Models)

The table below indicates the seawater and coolant flow at different engine speeds for the self-priming pump. Max. external pressure drop applies for the separate charge air circuit for keel-cooled models with two coolant circuits.

Engine Speed (rpm)	Flow (L/min.)	Max. External Pressure Drop
1500	190	0.70
1800	260	0.85

Figure 74 Charge Air Cooler (CAC) Pump

8.8.5 Keel Cooling Design and Installation

Kohler generators are prepared for connection to a keel cooling system, but does not supply complete keel cooling systems.

The keel cooling system supplier is responsible for the detailed dimensioning and design of the system.

What follows are a few general notes on the calculation and design of a keel cooling system:

- The keel cooler pipes and the connecting lines to the engine should be copper or acid-resistant stainless steel, with sufficient diameter for the pipes to be a reasonable length.

Kohler recommends an inside diameter of at least 50 mm (2 in.).

- The system pipes should have no sharp bends and the pipes should all have the same dimension to avoid undesired pressure drops.

For the maximum permissible pressure drop and minimum required coolant flow see the figure titled: **350EOZCS/300EFOZCS Models with 1 Coolant Circuit**, the figure titled: **500EOZCS/450EFOZCS Models with 2 Coolant Circuits**, and the figure titled: **Charge Air Cooler (CAC) Pump**.

- If guard plates are used to protect the cooling pipes, these must be positioned so as not to interrupt the flow around the pipes.
- If an auxiliary oil cooler (for example, a reverse gear oil cooler) is incorporated into the system, the added heat from this cooler must be taken into account when calculating the length of the cooling pipes.
- When calculating the length of the coolant pipes, paint and dirt on the pipes must also be considered. Painted or dirty pipes reduce the cooling capacity. In addition, certain bottom paints can have a corrosive effect on copper pipes.

- The keel cooling system must be fitted with an expansion tank, positioned higher than the internal cooling circuit of the engine. The expansion tank must be dimensioned for an expansion capacity of 3% and a reserve volume of 5% (8% in total) of the total keel cooling system volume, i.e. keel cooling circuit + the engine's internal volume.
- However, the reserve volume should always be at least 10 liters (2.6 gallons).

Example:

- Total volume = 150 L (39.6 gal.)
- Expansion volume (3%) = 4.5 L (1.2 gal.)
- Reserve volume (5%) = 7.5 L (2 gal.). However, the reserve volume should be at least 10 L (2.6 gal.).

Expansion tank volume should be $4.5 + 10 = 14.5$ L ($1.2 + 2.6 = 3.8$ gal.).

- The expansion tank must be connected via a pressure line (static-line) to the suction side of the pump, to reduce the risk of vapor and cavitation in the pump. This connection must have as even a rise as possible to avoid pockets of air.

The outer diameter of the static line pipe must be at least 25 mm for the 350EOZCS/300EFOZCS models and at least 38 mm for the 500EOZCS/450EFOZCS models.

Kohler recommends an inner diameter of at least 20 mm for the 350EOZCS/300EFOZCS models and at least 35 mm for the 500EOZCS/450EFOZCS models.

- There must be ventilation line(s) from the regular outlet on the engine to the expansion tank and from the highest point of the keel-cooling circuit, if there are level differences in the keel-cooling pipe system. The max. bleed line inner diameter is 8 mm (0.3 in.).
- Because water temperature will exceed 50°C (122°F), the lines must not be hot dip galvanized due to the risk of galvanic corrosion of iron components of the engine.
- The bleed line and static line must be routed separately to maintain the automatic venting of the system.

8.9 Connecting External Heat Sources

8.9.1 General

External heat sources (for example, cabin heaters) can be connected to the internal coolant circuit of the engine as follows:

Note:

If external circuits are connected, there must always be venting on this circuit.

Line must be dimensioned to match the connection dimensions. For sufficient circulation the minimum inner diameter should be 18 mm (0.7 in.).

Cabin heaters must be equipped with a drain petcock at the lowest point and venting at the highest point. The cooling system expansion tank must always be positioned higher than any external heat source.

8.9.2 350EOZCS/300EFOZCS Models

The heater intake line is routed to the connection above the coolant pump on the cylinder block. Cut a hole in the protective casing perforation to access the connection. The return line is connected to either the static line pipe or the flange pipe. See Figure 75 and Figure 76.

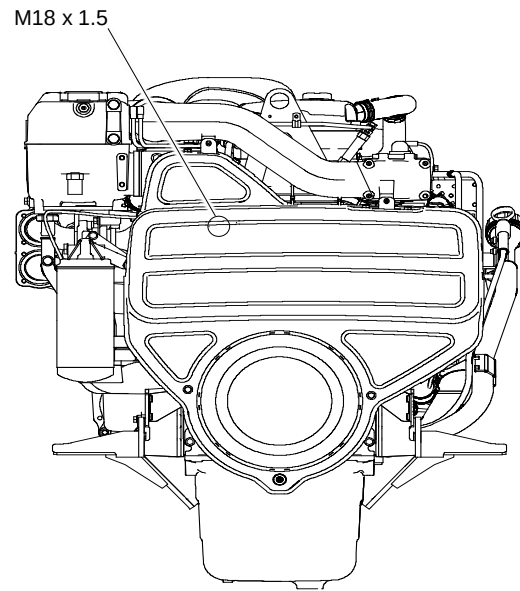


Figure 75 Connection of the Intake Line to the Cab Heater (350EOZCS/300EFOZCS Models)

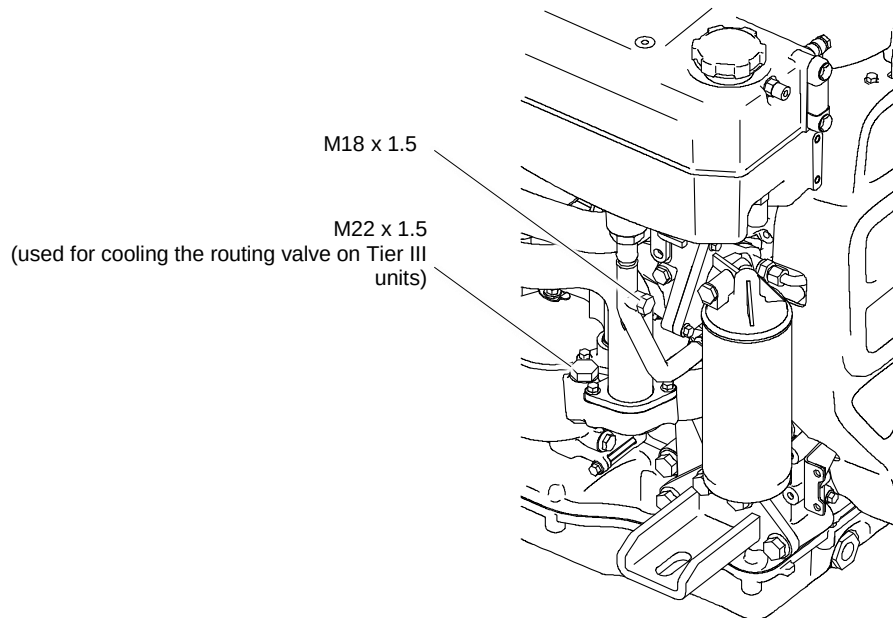


Figure 76 Connection of the Return Line from the Cab Heater (350EOZCS/300EFOZCS Models)

8.9.3 500EOZCS/450EFOZCS Models

The heater intake line is connected to the thermostat housing. The return line is connected to the flange pipe. See **Figure 77**.

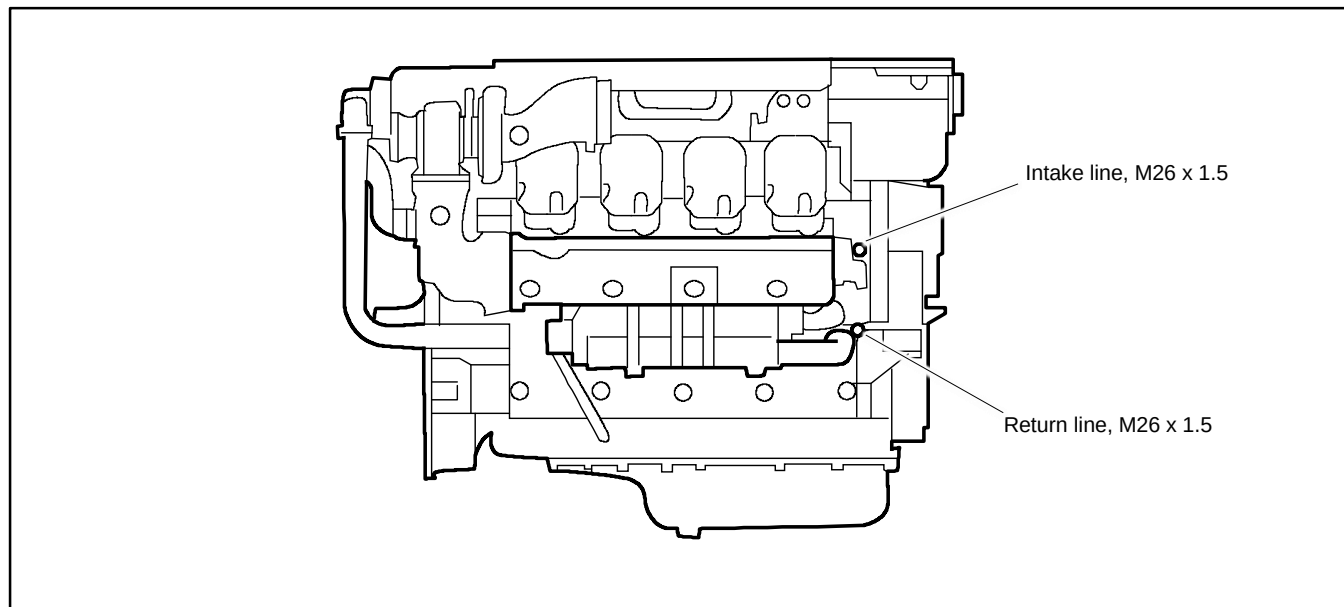


Figure 77 Connection Points of Cab Heater (500EOZCS/450EFOZCS Models)

8.10 Engine Heater

If required, the engines can be supplied with an electric immersion heater (optional accessory, not equipped on all engines). For engines which need to be constantly ready to start and which are stationed in unheated spaces, an external heater is used which can be connected continuously. This is connected to the cooling system on the various engine types as shown in **Figure 78** and **Figure 79**.

The heater has an integral thermostat which is set to a carefully tested temperature to allow sufficient circulation by convection to prevent the temperature from becoming so high that the oil film on parts such as pistons and cylinder liners evaporates or dries out.

The heater is available with one power rating, 500 W. The immersion heater is available for 230 V power supply systems.

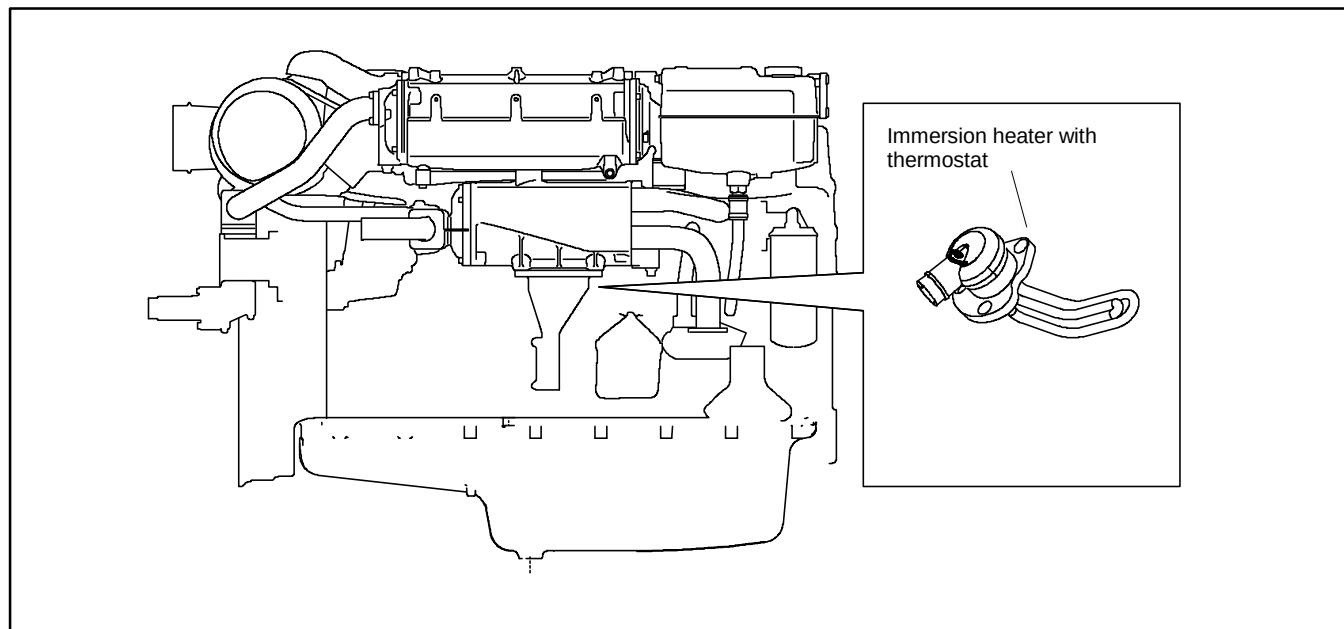


Figure 78 Engine Heater (350EOZCS/300EFOZCS Models)

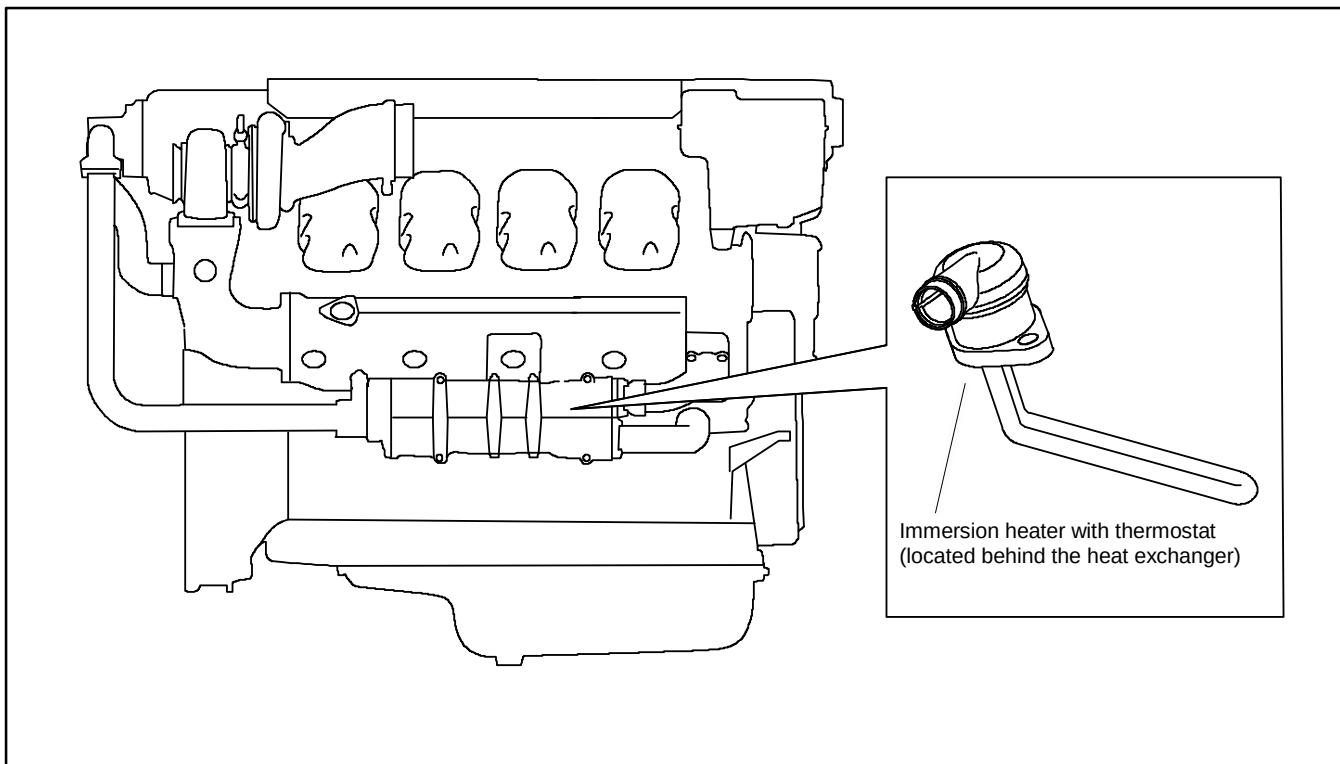


Figure 79 Engine Heater (500EOZCS/450EFOZCS Models)

8.11 Electrolytic Corrosion

Corrosion may occur on seawater system components due to the electrochemical reaction between different metals.

The seawater acts as an electrolyte in which ions migrate from the metal with lower potential (anode), such as iron/steel, to metals with higher potential (cathode), such as copper. Material from the anode thus disappears into the seawater.

To avoid the loss of material from seawater system components, there are a number of zinc anodes in the system.

Material will only be corroded away from the sacrificial zinc anodes. These sacrificial zinc anodes should therefore be checked and replaced regularly.

Note:

Do not block the space around the anodes.

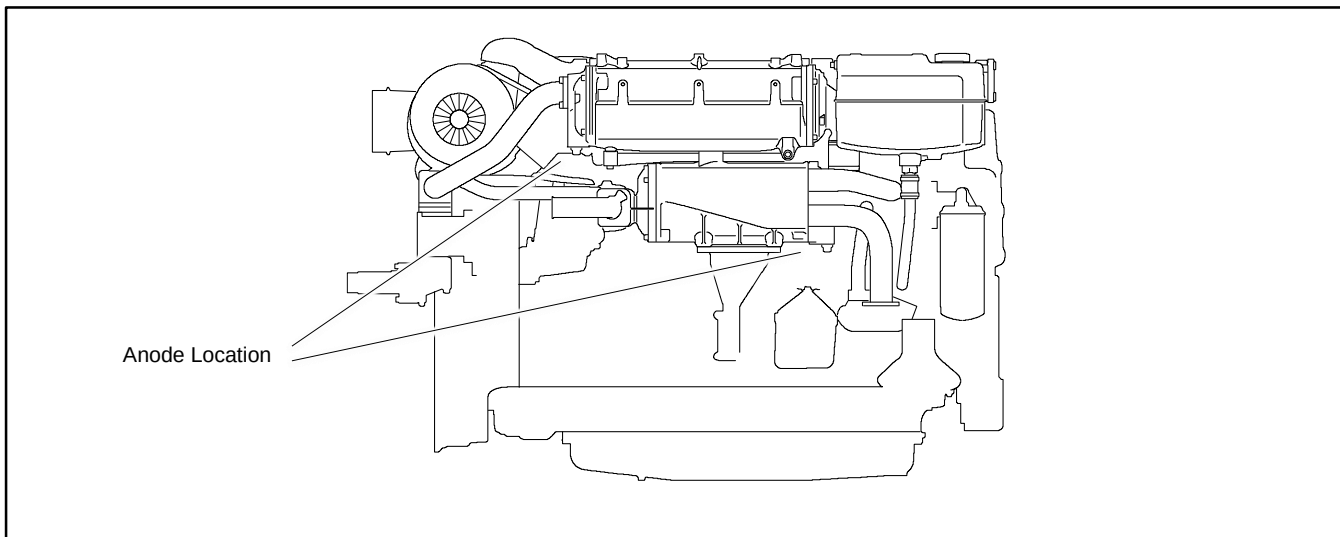


Figure 80 Anode Location (Qty. 2) (350EOZCS/300EFOZCS Models)

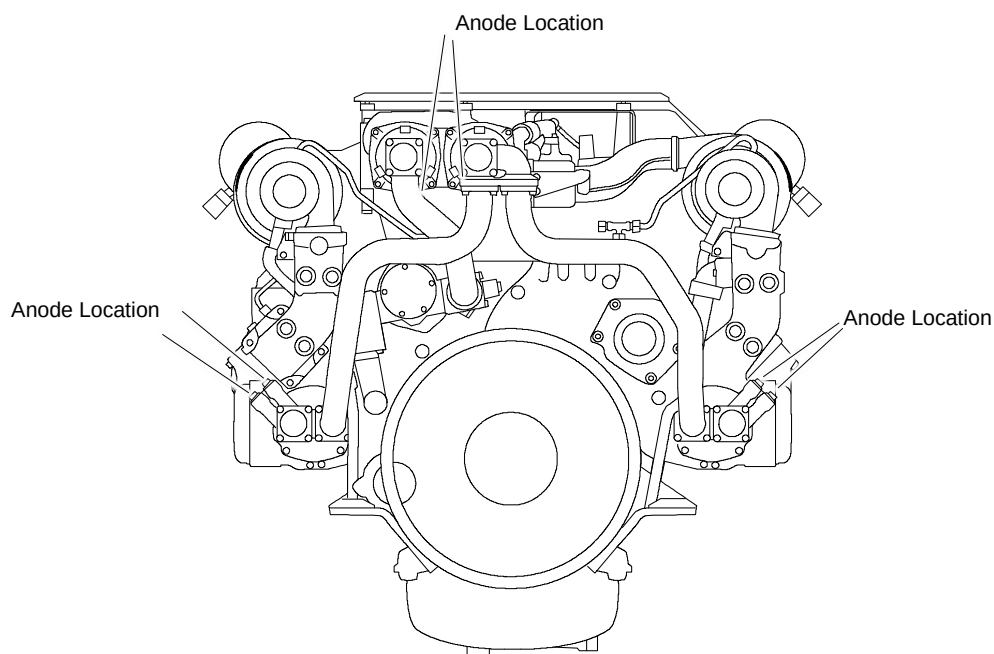


Figure 81 Anode Location (Qty. 6) (500EOZCS/450EFOZCS Models)

8.12 Important Data

Max. suction height of seawater pump	3 m (9.8 ft.)
Max. internal cooling system pressure	2 bar (29 psi)
Max. vacuum on suction side	0.3 bar (4.4 psi)
Max. expansion tank height above the coolant pump intake with 0.75 bar pressure cap	3.5 m (11.5 ft.)
Max. expansion tank height above the pump intake without pressure cap	8.5 m (27.9 ft.)
Min. outer diameter for static line pipe 350EOZCS/300EFOZCS 500EOZCS/450EFOZCS	25 mm (1 in.) 38 mm (1.5 in.)
Min. inner diameter for static line pipe 350EOZCS/300EFOZCS 500EOZCS/450EFOZCS	20 mm (0.75 in.) 35 mm (1.4 in.)
Max. inner diameter bleed pipes	8 mm (0.3 in.)
Seawater flow	See the figure titled: Seawater Pump Flow
Pressure drop across engine	See the figure titled: Pressure Drop Across the Engine at Different Seawater Flows
Coolant volumes	See the figure titled: Coolant Volumes
Max. pressure drop and min. coolant flow	See the figure titled: 350EOZCS/300EFOZCS Models with 1 Coolant Circuit and See the figure titled: 500EOZCS/450EFOZCS Models with 2 Coolant Circuits

9.1 Heat Rejection

Model	Heat Rejection (kW)		
	Type	1500	1800
350EOZCS/300EFOZCS	Heat Exchanger	224	273
350EOZCS/300EFOZCS	Keel Cooled (Single Circuit)	228	269
350EOZCS IMO Tier III/ 300EFOZCS IMO Tier III	Heat Exchanger	210	242
350EOZCS IMO Tier III/ 300EFOZCS IMO Tier III	Keel Cooled (Double Circuit)	177	194
500EOZCS/450EFOZCS	Heat Exchanger	351	416
500EOZCS/450EFOZCS	Keel Cooled (Double Circuit)	294	335
500EOZCS IMO Tier III/ 450EFOZCS IMO Tier III	Heat Exchanger	359	418
500EOZCS IMO Tier III/ 450EFOZCS IMO Tier III	Keel Cooled (Double Circuit)	302	338

Figure 82 Heat Rejection in kW Through a Heat Exchanger or Keel Cooler at Full Power, (at Prime Rating). Ambient Conditions: 25°C (77°F), 1013 bar

Model	Heat Rejection (kW) In the Charge Air Cooling Circuits (kW)		
	Type	1500	1800
350EOZCS IMO Tier III/ 300EFOZCS IMO Tier III	Keel Cooled (Double Circuit)	32	48
500EOZCS/450EFOZCS	Keel Cooled (Double Circuit)	67	94
500EOZCS IMO Tier III/ 450EFOZCS IMO Tier III	Keel Cooled (Double Circuit)	57	80

Figure 83 Heat Rejection in kW in Separate Charge Air Cooling Circuit Ambient Conditions: 25°C (77°F), 1013 bar.

9.2 Air Consumption

Model	Type	Air Consumption (kg/min.*) Engine Speed (rpm)	
		1500	1800
350EOZCS/300EFOZCS	Heat Exchanger	26	33
350EOZCS/300EFOZCS	Keel Cooled (Single Circuit)	25	33
350EOZCS IMO Tier III/ 300EFOZCS IMO Tier III	Heat Exchanger/ Keel Cooled (Double Circuit)	22	29
500EOZCS/450EFOZCS	Heat Exchanger	35	45
500EOZCS/450EFOZCS	Keel Cooled (Double Circuit)	35	45
500EOZCS IMO Tier III/ 450EFOZCS IMO Tier III	Heat Exchanger/ Keel Cooled (Double Circuit)	32	40

* Air consumption is specified in kg/min. Conversion to m³/min. in the specified test conditions: 0.858 x kg/min. 25°C

Figure 84 Air Consumption at Full Power in kg/min (at Prime Rating). Ambient Conditions: 25°C (77°F), 1013 bar.

9.3 Radiated Heat

Model	Type	Rejected Heat (kW)	
		1500	1800
350EOZCS/300EFOZCS	Heat Exchanger	15	18
350EOZCS/300EFOZCS	Keel Cooled (Single Circuit)	16	19
350EOZCS IMO Tier III/ 300EFOZCS IMO Tier III	Heat Exchanger/ Keel Cooled (Double Circuit)	15	17
500EOZCS/450EFOZCS	Heat Exchanger	23	27
500EOZCS/450EFOZCS	Keel Cooled (Double Circuit)	23	27
500EOZCS IMO Tier III/ 450EFOZCS IMO Tier III	Heat Exchanger/ Keel Cooled (Double Circuit)	23	27

Figure 85 Radiant Heat with a Water-Cooled Exhaust Manifold at Full Power (at Prime Rating). Ambient Conditions: 25°C (77°F), 1013 bar.

9.4 Maximum Intake Air Temperature

Model	Max Intake Air Temperature, °C (°F)		
	Type	1500	1800
350EOZCS/300EFOZCS	Keel Cooled (Single Circuit)	80 (176)	87 (189)
350EOZCS IMO Tier III/ 300EFOZCS IMO Tier III	Heat Exchanger/ Keel Cooled (Double Circuit)	45 (113)	48 (118)
500EOZCS/450EFOZCS	Keel Cooled (Double Circuit)	56 (133)	64 (147)
500EOZCS IMO Tier III/ 450EFOZCS IMO Tier III	Heat Exchanger/ Keel Cooled (Double Circuit)	47 (117)	50 (122)

Figure 86 Max Intake Air Temperature Downstream of Charge Air Cooler in °C with Keel Cooling at Full Power (at Prime Rating). Ambient Conditions: 25°C (77°F), 1013 bar.

 DANGER	Hazardous voltage. Moving parts. Will cause severe injury or death. Operate the generator set only when all guards and electrical enclosures are in place.
 	

Electrical backfeed to the utility. Hazardous backfeed voltage can cause severe injury or death. Connect the generator set to the building/marina electrical system only through an approved device and after the building/marina main switch is turned off. Backfeed connections can cause severe injury or death to utility personnel working on power lines and/or personnel near the work area. Some states and localities prohibit unauthorized connection to the utility electrical system. Install a ship-to-shore transfer switch to prevent interconnection of the generator set power and shore power.

 WARNING	Accidental starting. Can cause severe injury or death. Disconnect the battery cables before working on the generator set. Remove the negative (–) lead first when disconnecting the battery. Reconnect the negative (–) lead last when reconnecting the battery.
  	

Disabling the generator set. Accidental starting can cause severe injury or death. Before working on the generator set or equipment connected to the set, disable the generator set as follows: (1) Place the generator set start/stop switch in the STOP position. (2) Disconnect the power to the battery charger, if equipped. (3) Remove the battery cables, negative (–) lead first. Reconnect the negative (–) lead last when reconnecting the battery. Follow these precautions to prevent the starting of the generator set by the remote start/stop switch.

 DANGER	Hazardous voltage. Moving parts. Will cause severe injury or death. Operate the generator set only when all guards and electrical enclosures are in place.
 	

Grounding electrical equipment. Hazardous voltage will cause severe injury or death. Electrocution is possible whenever electricity is present. Ensure you comply with all applicable codes and standards. Electrically ground the generator set, transfer switch, and related equipment and electrical circuits. Turn off the main circuit breakers of all power sources before servicing the equipment. Never contact electrical leads or appliances when standing in water or on wet ground because these conditions increase the risk of electrocution.

Short circuits. Hazardous voltage/current will cause severe injury or death. Short circuits can cause bodily injury and/or equipment damage. Do not contact electrical connections with tools or jewelry while making adjustments or repairs. Remove all jewelry before servicing the equipment.

10.1 AC Voltage Connections

Make AC connections to the generator set inside the junction box. Typically, the generator set connects to a ship-to-shore transfer switch that allows the use of shore/utility power when docked or generator set power when docked or at sea. The wiring then connects to a main circuit breaker box (panel board) that distributes branch circuits throughout the craft.

10.2 Circuit Protection

The AC circuit breakers protect the wiring from the AC circuit breakers to the vessel's distribution panel. AC circuit breakers trip when they detect a fault in the output circuit.

After correcting the fault, reset the AC circuit breaker(s) by placing them in the ON position. Restart the unit. Do not start the unit under load. The unit's voltage configuration determines the circuit breaker selection.

Note:

Circuit breaker ampere rating and availability are subject to change.

10.3 Installation In Steel or Aluminium Vessels

Installation of a generator set in a vessel constructed of a material capable of conducting current (e.g., steel or aluminum) is subject to considerations not normally encountered in fiberglass or wood vessels. These differences include equipment grounding, grounding of neutral conductors, ground-fault protection, and isolation of galvanic currents.

Note:

Isolated ground kits are available as options for steel- or aluminum-hulled vessels. Consult your local dealer/distributor for more information.

The scope of these topics is too extensive to be fully discussed here. Consult your local marine authority for more information.

Before installing the generator set, check the available wiring diagrams in the operation manual to become familiar with the electrical system.

10.4 Installation Regulation

The U.S. Coast Guard governs generator set installation in U.S. pleasurecraft and commercial vessels. Refer to the applicable regulations below:

U.S. Pleasurecraft Installation Regulations

Title 33CFR, Chapter I, U.S. Coast Guard, Part 183

1. Subpart I—Electrical Equipment
2. Subpart J—Fuel Systems

U.S. Commercial Vessel Installation Regulations

Title 46CFR, Chapter I, U.S. Coast Guard

1. Part 111—Electrical Systems
2. Part 182—Machinery Installation

10.5 Batteries

Batteries and their installation must conform to USCG Regulations 183.420 (a) through (g). Provide generator sets with batteries separate from the propulsion engine's whenever possible. The starting/charging systems of both the generator set and the engine must have a common negative (-) ground.

USCG Regulation 183.415, Grounding, requires connection of a common conductor to each grounded cranking-motor circuit. Size the conductor to match the larger of the engine's two battery cables. **Figure 87** show a diagram for sizing the battery cables at various generator set-to-battery distances. Connecting a common conductor to each grounded cranking motor circuit prevents the starting motor current from using alternative electrical paths should the cranking motor ground circuit be restricted or open because of oxidation or loose hardware. Alternative electrical paths include metallic fuel lines that can pose a hazard. See the section titled: **Installation Drawings** for locations of the battery connections to the generator set.

When manufacturing battery cables, dimension the cables between the battery and starter motor as depicted in **Figure 87**. This indicates the minimum cable area at different lengths.

The cable length in the diagram relates to the total length of both positive and negative cables.

The minimum permitted cable area is 70 mm². At an ambient temperature which constantly exceeds 10°C (50°F), the minimum permitted cable area is 50 mm².

Route the cables so that they are not subject to abrasion or can be otherwise damaged.

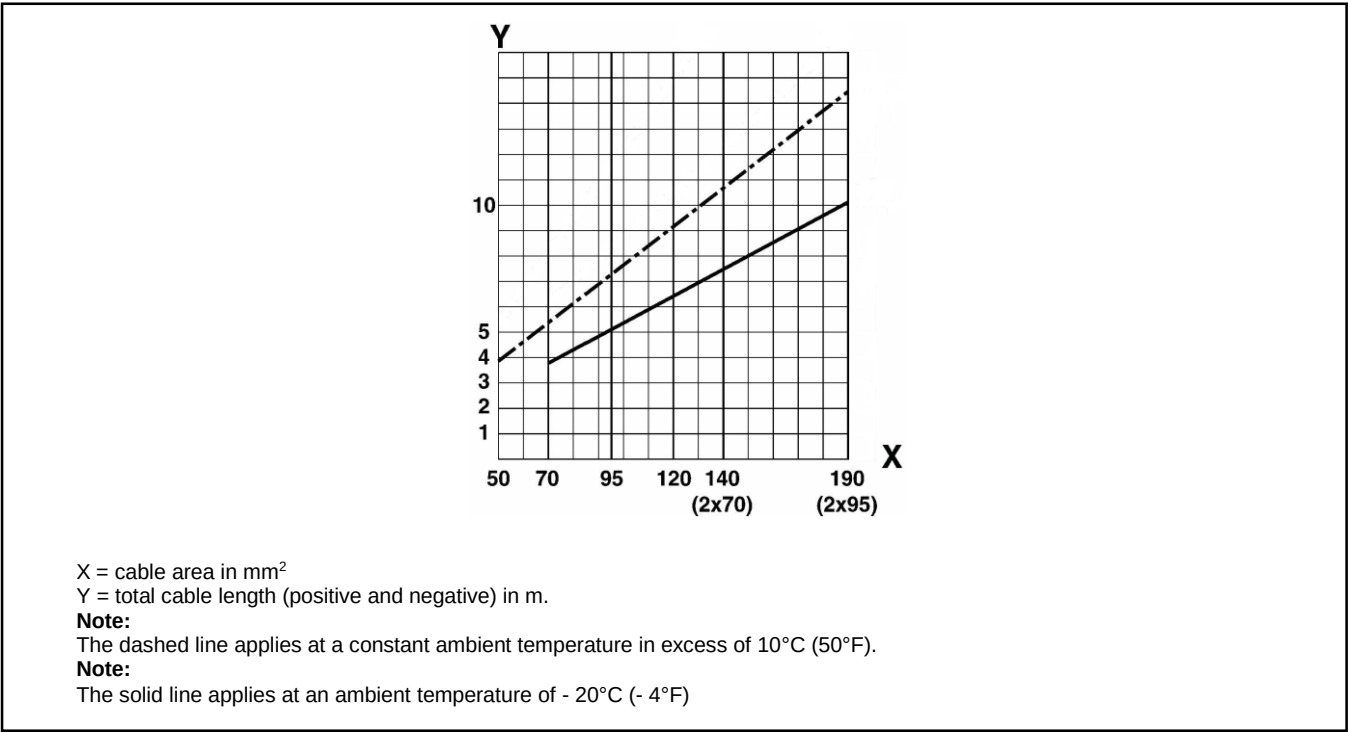


Figure 87 Dimensioning of the Battery Cables.

Kohler Co. recommends connecting two 12-volt battery in series for 24-volt systems to start the generator. See **Figure 88** for minimum cold cranking amps (CCA) recommendations.

24-Volt Starting Battery Size 160 Amp Hour	
Models	CCA
350EOZCS and 300EFOZCS	800
500EOZCS and 450EFOZCS	800

Figure 88 Battery Recommendation.

In warm climates in which the temperature only briefly falls below 0°C (32°F), batteries with a capacity of minimum 118 Ah and a cold crank amp of 490 A at 0°C (32°F) may be used.

The battery capacity (20-hour capacity) indicates the highest current level that can be used to discharge the battery over 20 hours at room temperature, i.e. a 100-Ah battery can be discharged at maximum 5 A over 20 hours.

At low temperatures, the battery capacity is reduced considerably as shown in the following table.

Capacity at 20°C (68°F)	Capacity at - 18°C (0°F)
100%	50%
70%	35%
40%	25%

The cold crank amp above indicates the highest current with which a 12-volt battery can be discharged at - 18°C so that the terminal voltage after 30 seconds is minimum 8.4 volts and the discharge time to 6 volts is no less than 120 seconds.

10.6 Wiring

Use only stranded copper wire. Conform to USCG Regulations 183.425 through 183.460 for wire gauges and insulation, conductor temperature ratings, sheath stripping, conductor support and protection, conductor terminals and splices, and over-current protection (circuit breakers, fuses). Use rubber grommets and cable ties as necessary to protect and secure the wire from sharp objects, the exhaust system, and moving parts.

10.7 Remote Connection

Kohler Co. offers remote panels for connection to the generator set. Contact your local Kohler® distributor/dealer for detailed descriptions. Kohler Co. also offers wiring harnesses in various lengths with a connector keyed to the controller box connector. A “pigtail” harness is also offered which includes the appropriate connector on one end and has pigtails that the installer can use to connect to a customer-supplied start/stop switch or separate lights and hourmeter. Consult wiring diagrams, ADVs, and instruction sheets for connection information/details.

Section 11. Installation Drawings

Use the drawings in this section for installation purposes. Consult the supplier and verify that the drawings are the most current for your specifications. Installation drawings show exhaust outlet locations, fuel inlet and return connections, siphon break locations, and battery connections. See Figure 89 for installation drawing identification.

Model No	Drawing	Page
350EOZCS and 300EFOZCS	ADV-9073-B	94
		95
		96
500EOZCS and 450EFOZCS	ADV-9072-C	97
		98
		99
350EOZCS and 300EFOZCS IMO Tier III Models	ADV-9113-A	100
		101
		102
500EOZCS and 450EFOZCS IMO Tier III Models	ADV-9111-A	103
		104
		105
350EOZCS and 300EFOZCS Accessories	ADV-9114-A	106
		107
500EOZCS and 450EFOZCS Accessories	ADV-9112-A	108
		109

Figure 89 Installation Drawings

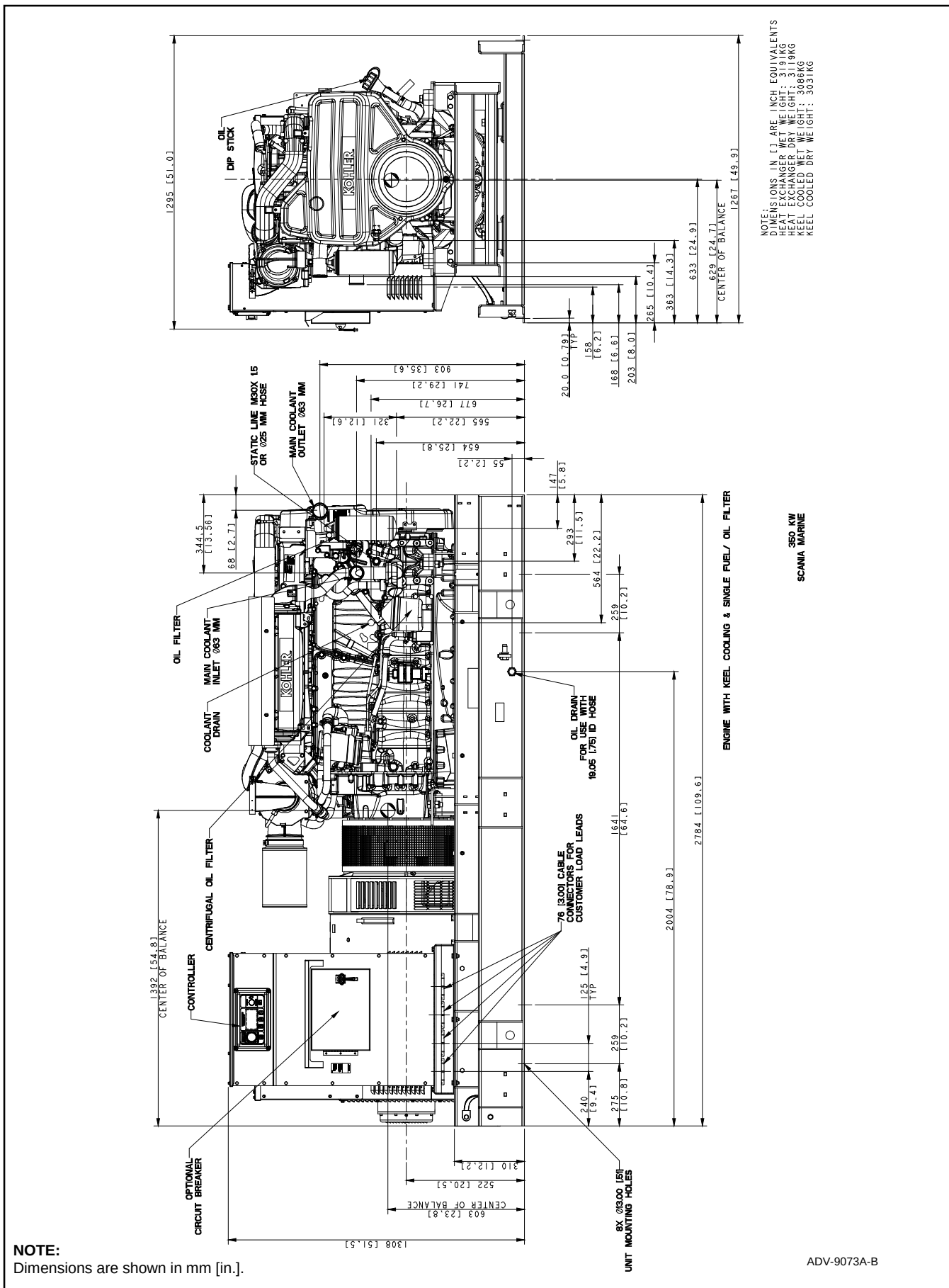


Figure 90 Dimension Drawing, 350EOZCS and 300EFOZCS (Sheet 1 of 3)

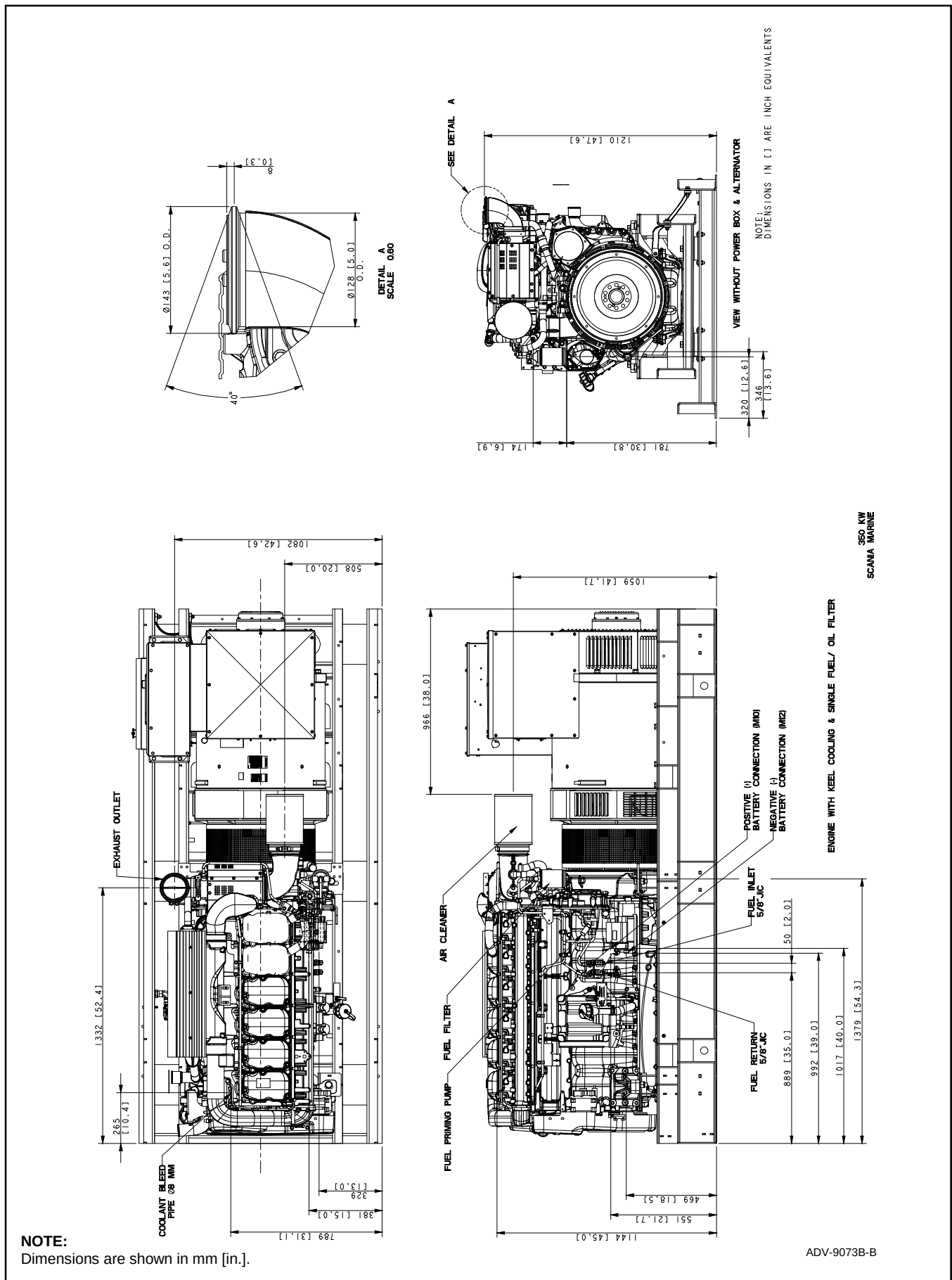


Figure 91 Dimension Drawing, 350EOZCS and 300EFOZCS (Sheet 2 of 3)

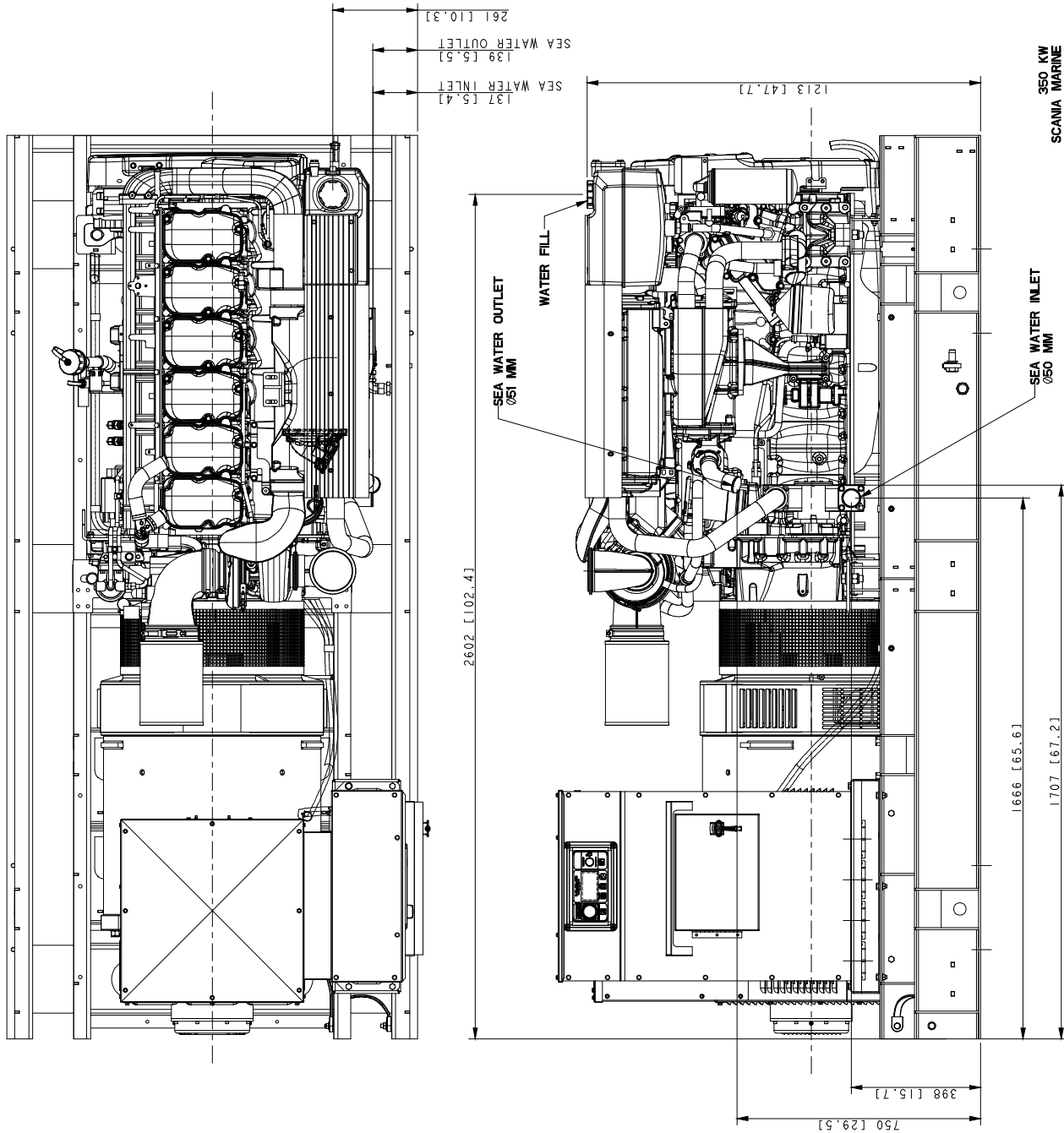


Figure 92 Dimension Drawing, 350EOZCS and 300EFOZCS (Sheet 3 of 3)

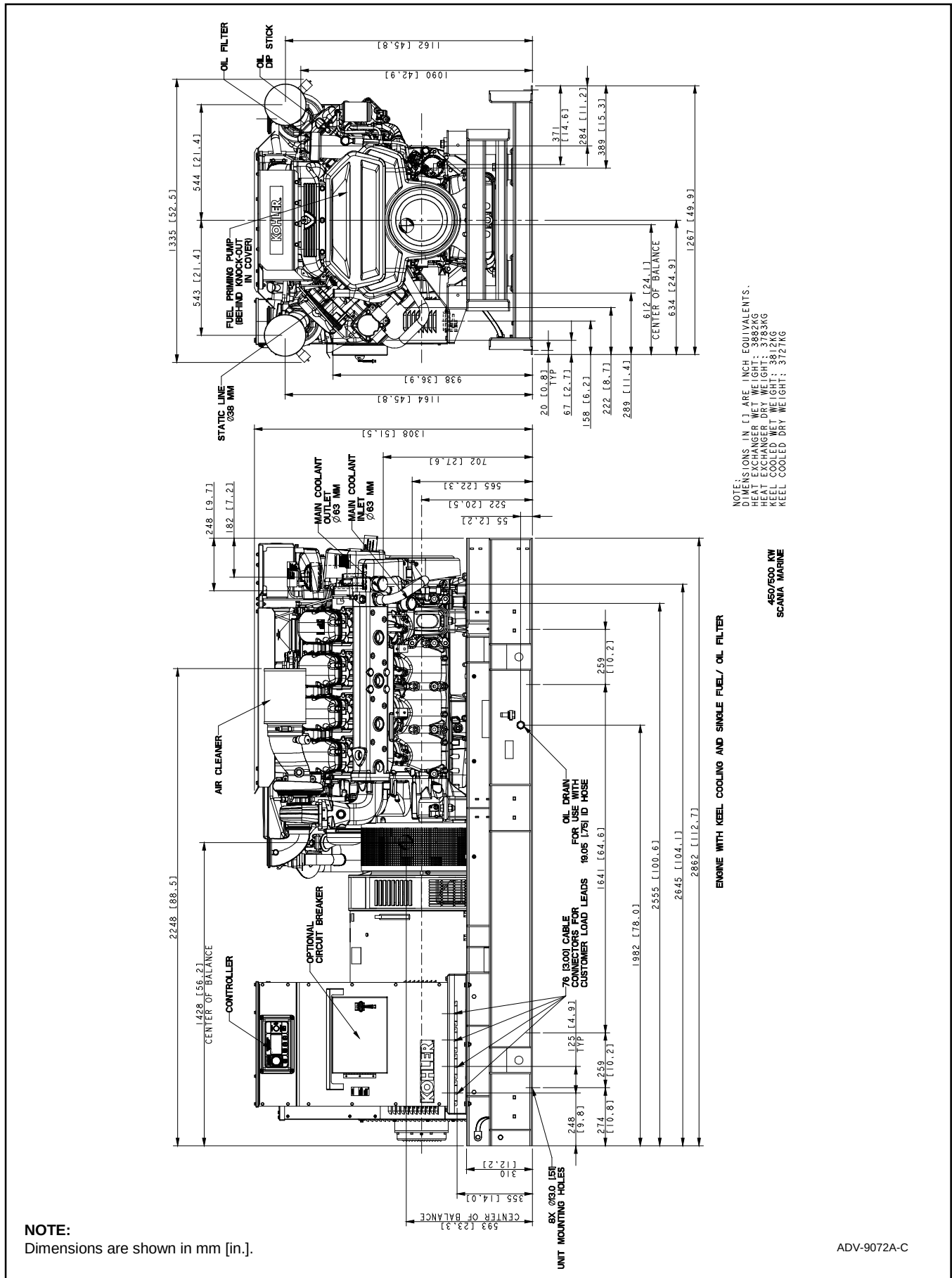


Figure 93 Dimension Drawing, 500EOZCS and 450EFOZCS (Sheet 1 of 3)

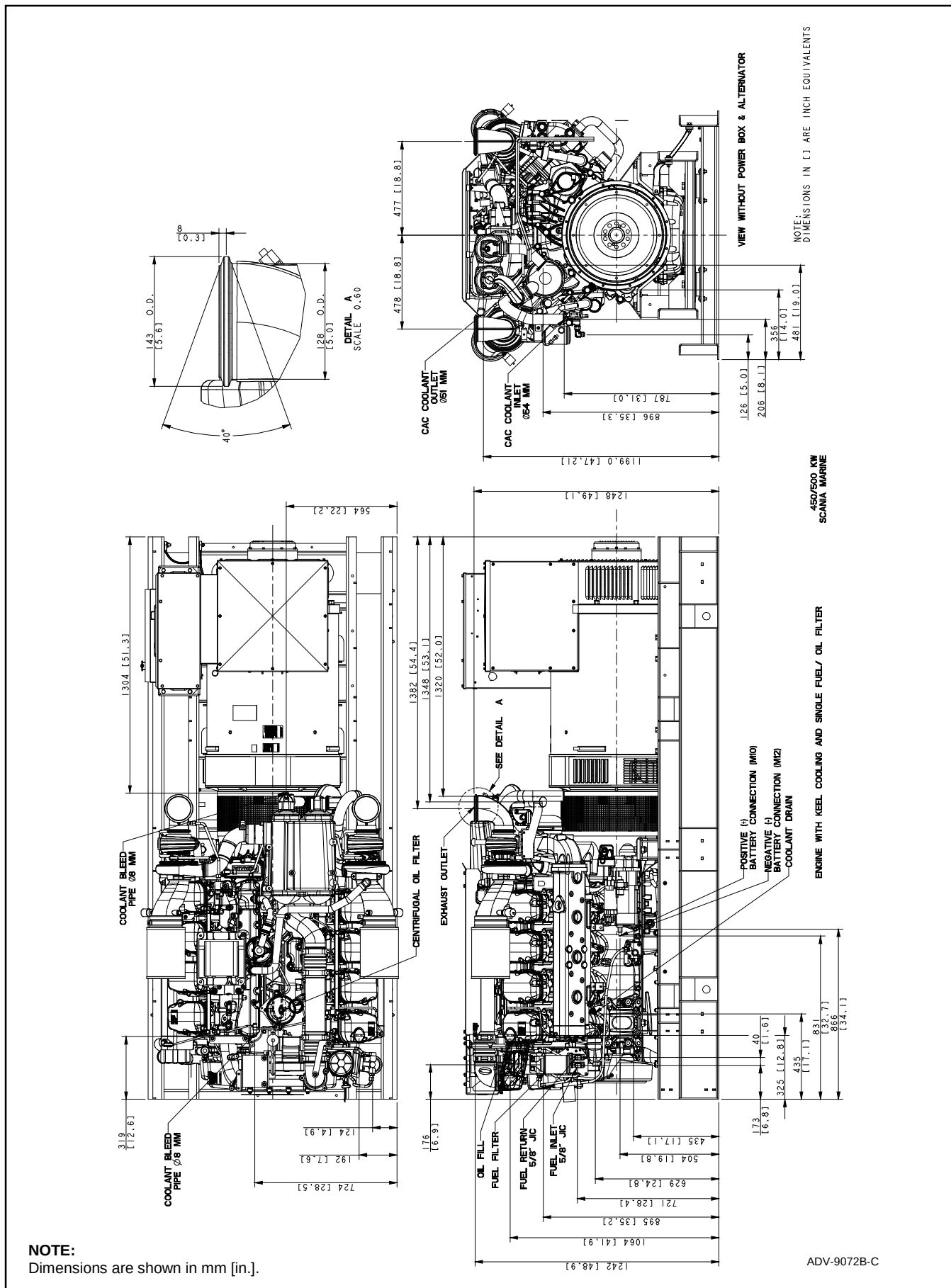


Figure 94 Dimension Drawing, 500EOZCS and 450EFOZCS (Sheet 2 of 3)

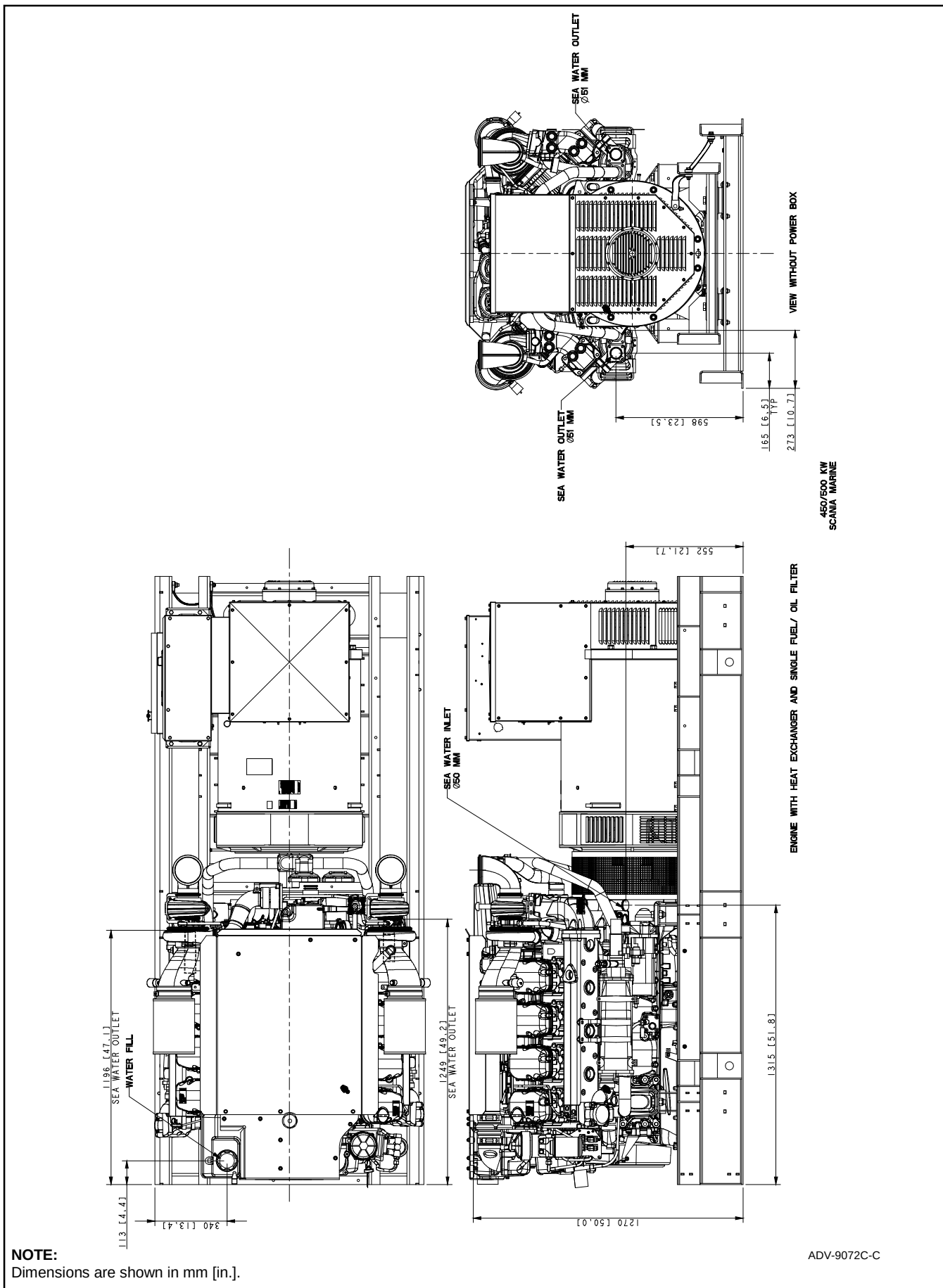
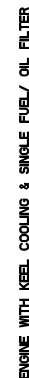


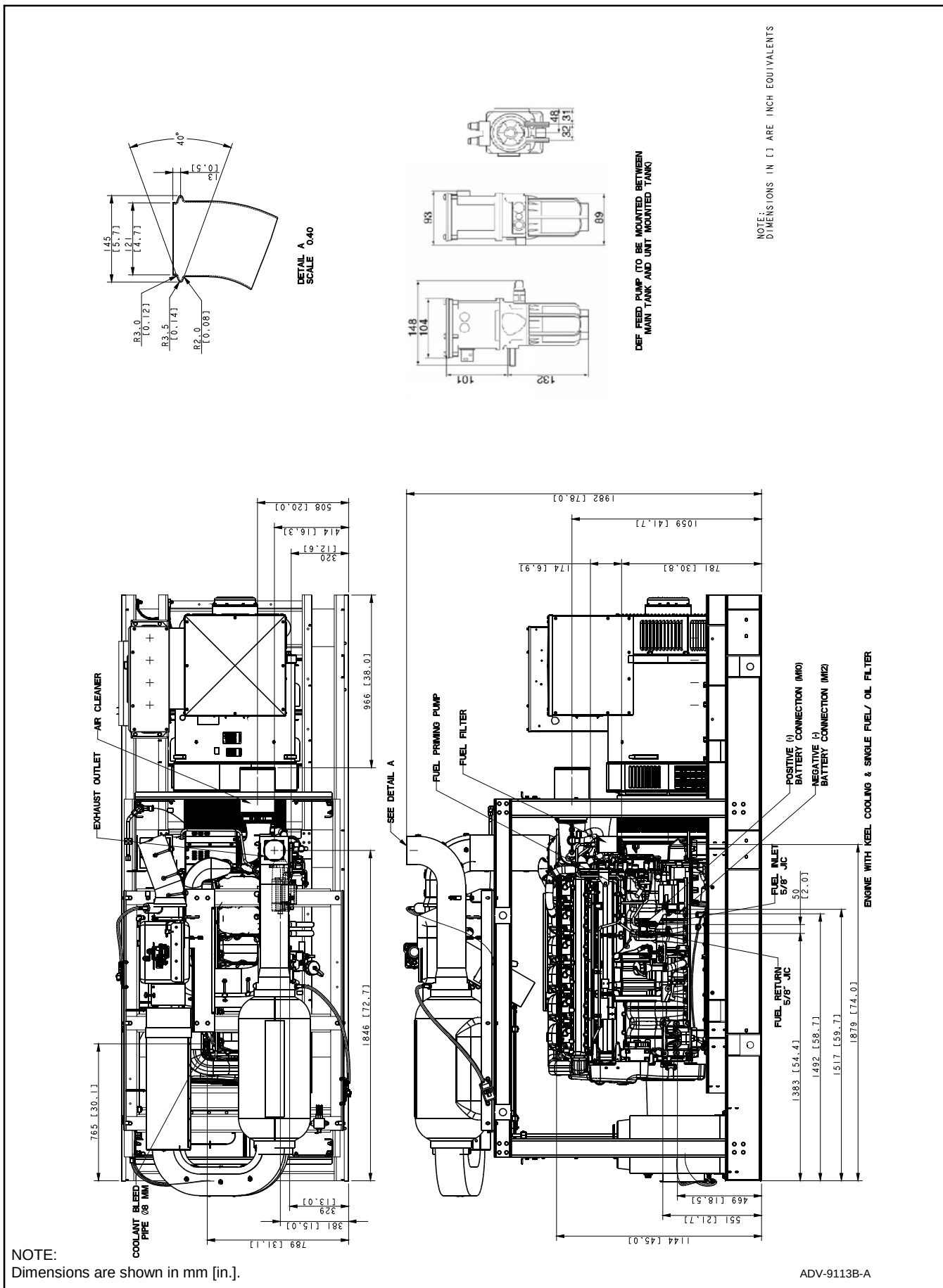
Figure 95 Dimension Drawing, 500EOZCS and 450EFOZCS (Sheet 3 of 3)



NOTE: DIMENSIONS IN [] ARE INCH EQUIVALENTS

ADV-9113A-A

Figure 96 Dimension Drawing, 350EOZCS and 300EFOZCS IMO Tier III Models (Sheet 1 of 3)



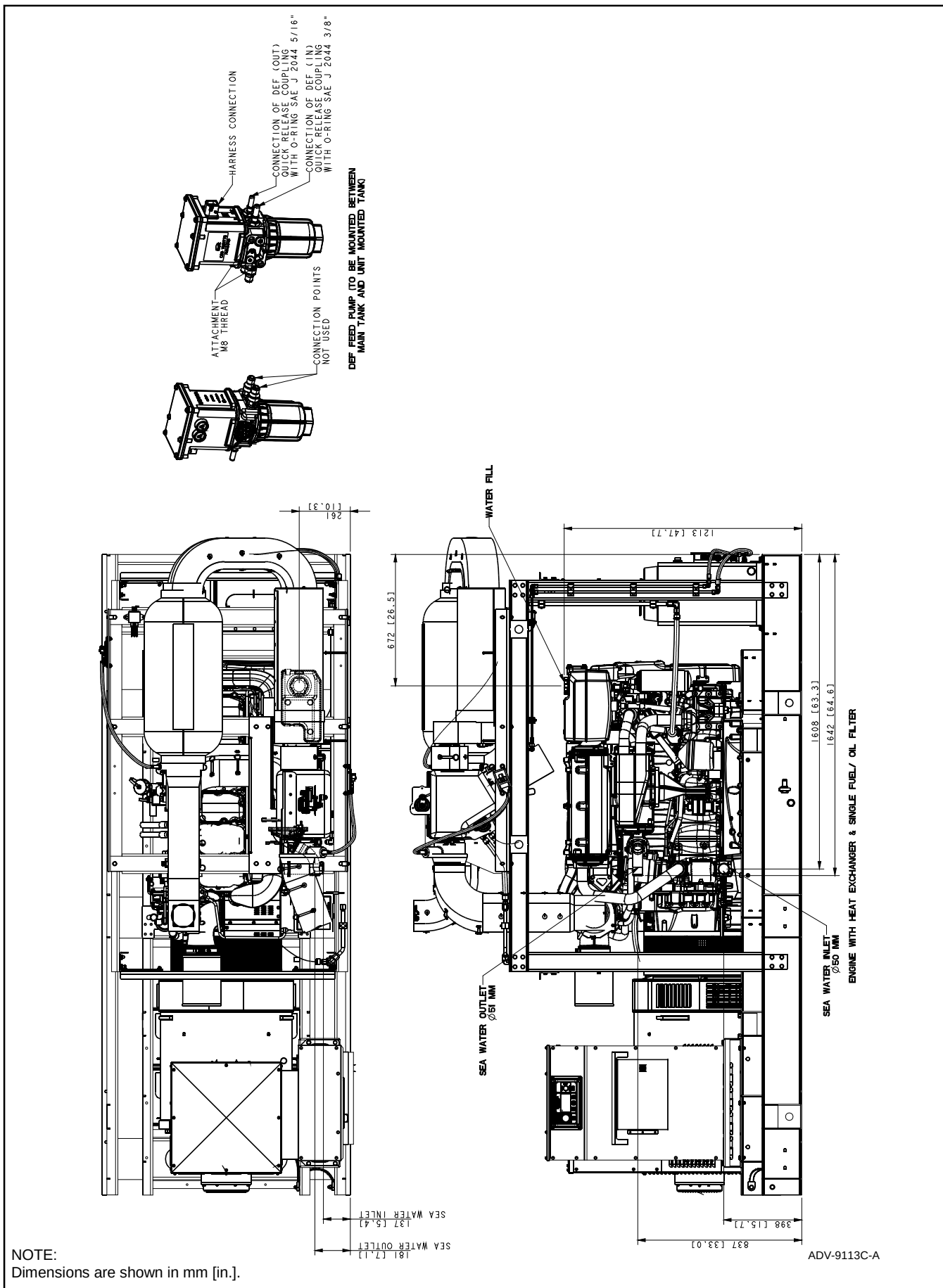


Figure 98 Dimension Drawing, 350EOZCS and 300EFOZCS IMO Tier III Models (Sheet 3 of 3)

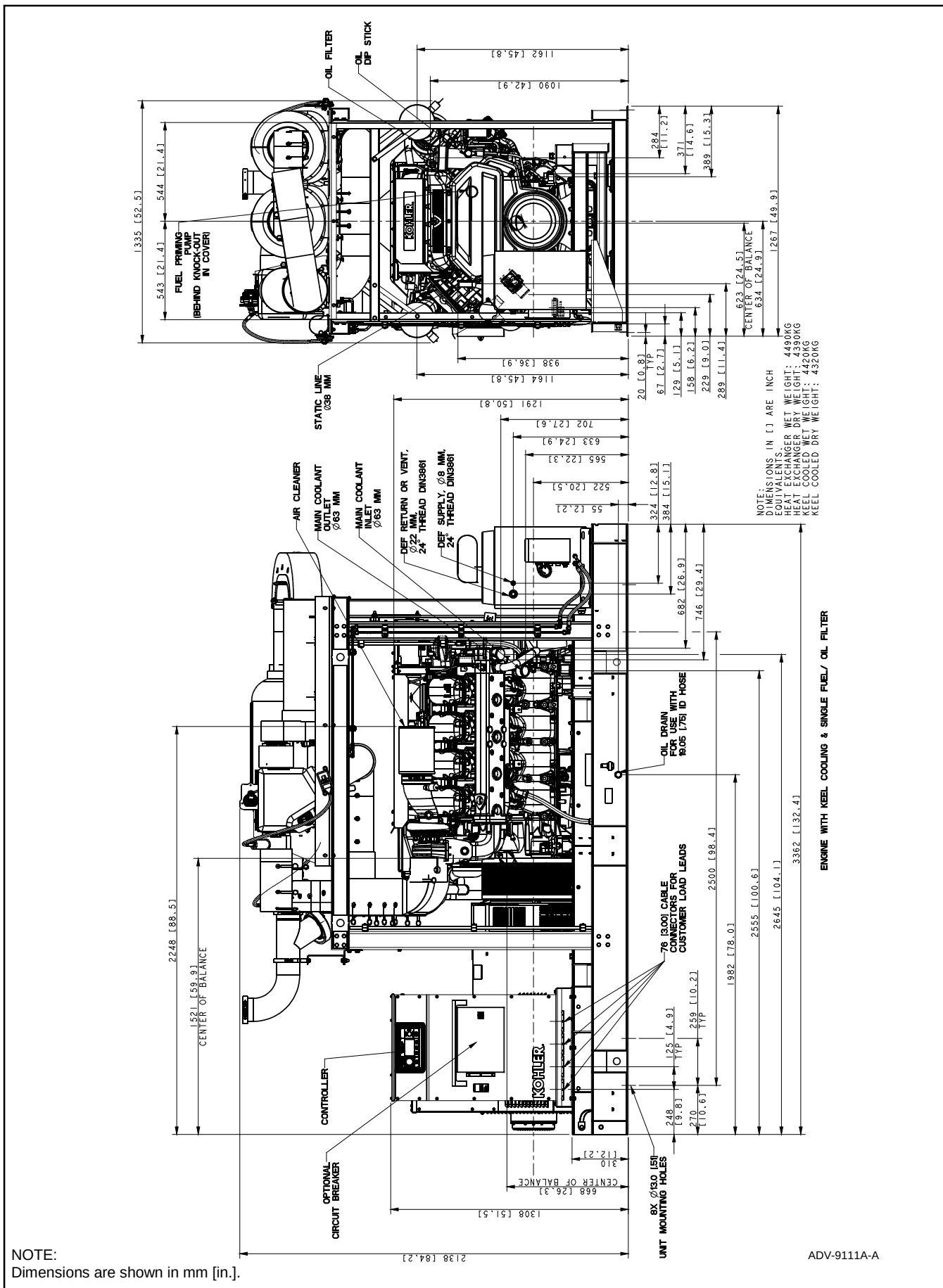


Figure 99 Dimension Drawing, 500EOZCS and 450EFOZCS IMO Tier III Models (Sheet 1 of 3)

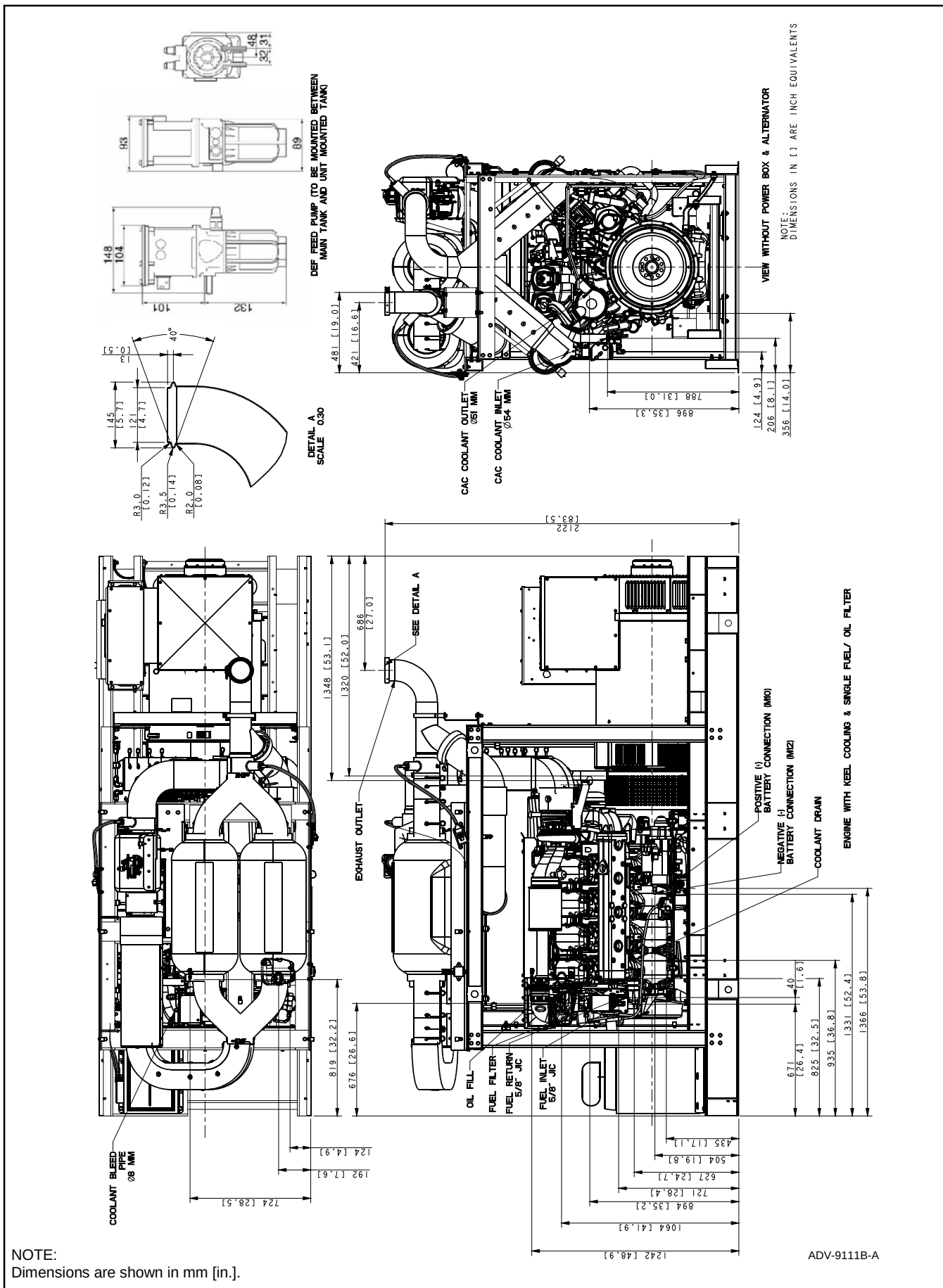


Figure 100 Dimension Drawing, 500EOZCS and 450EFOZCS IMO Tier III Models (Sheet 2 of 3)

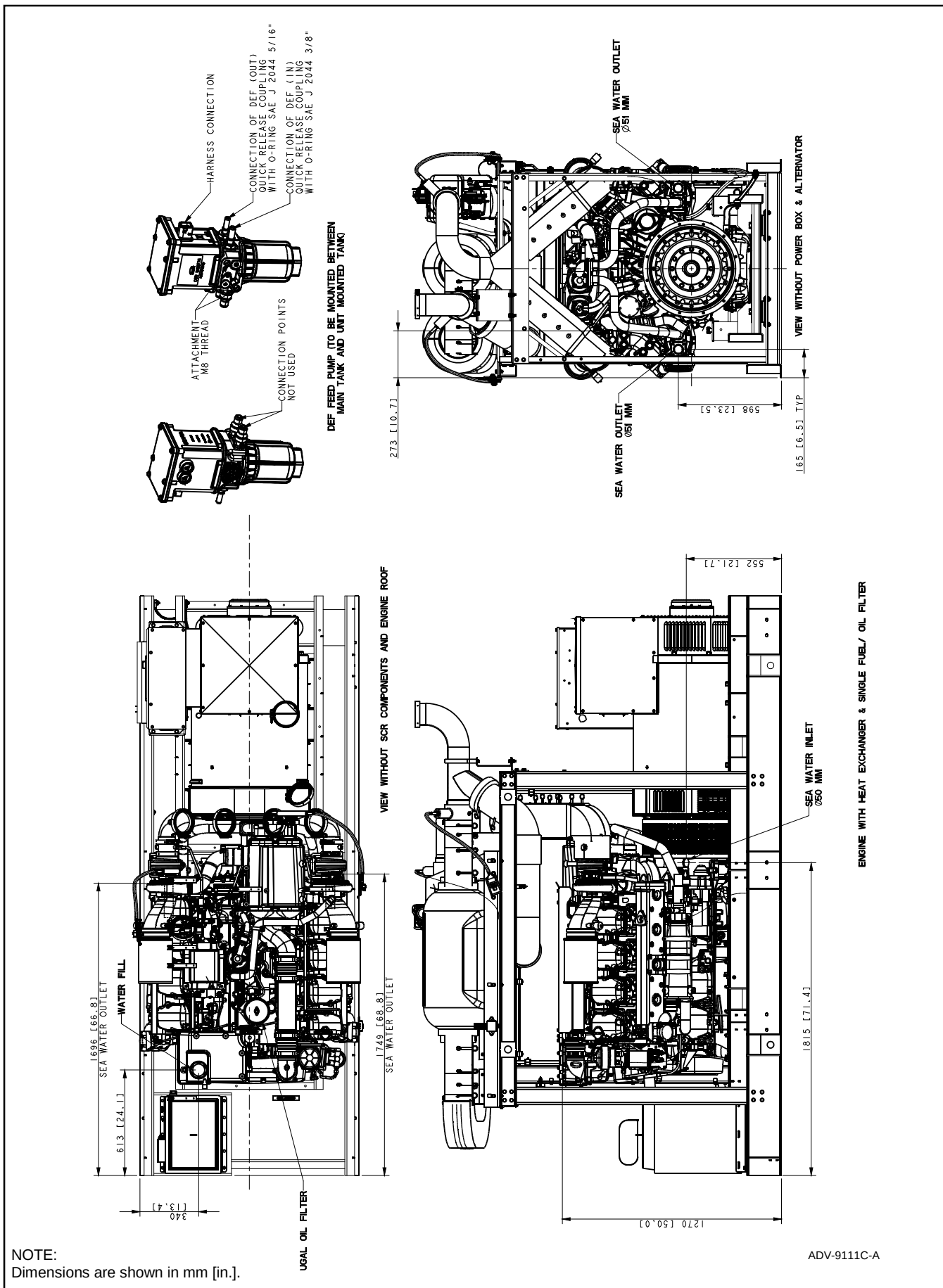
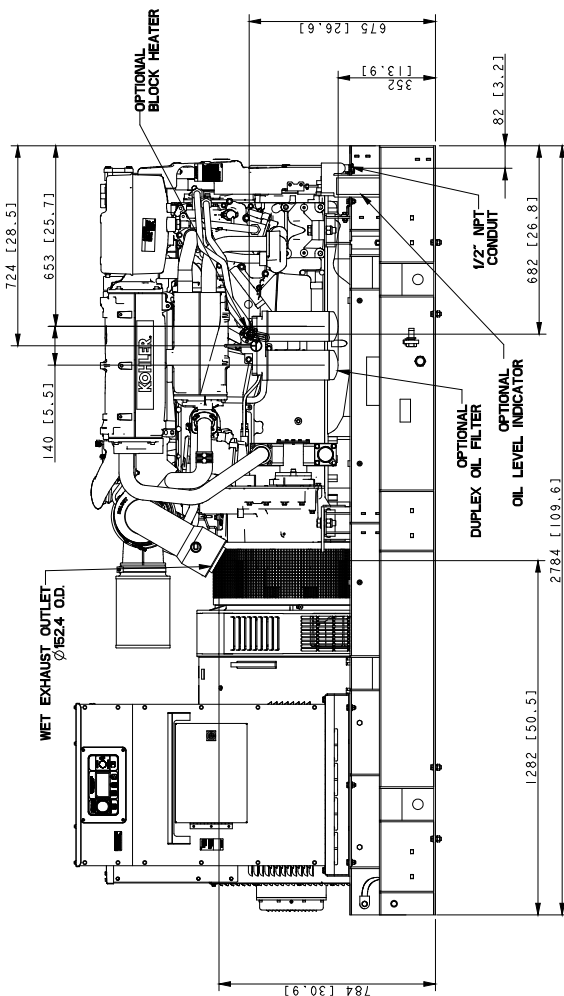
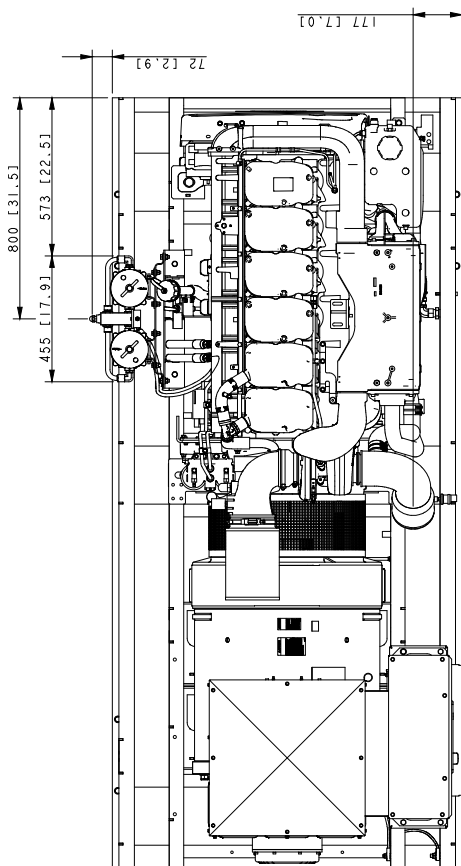
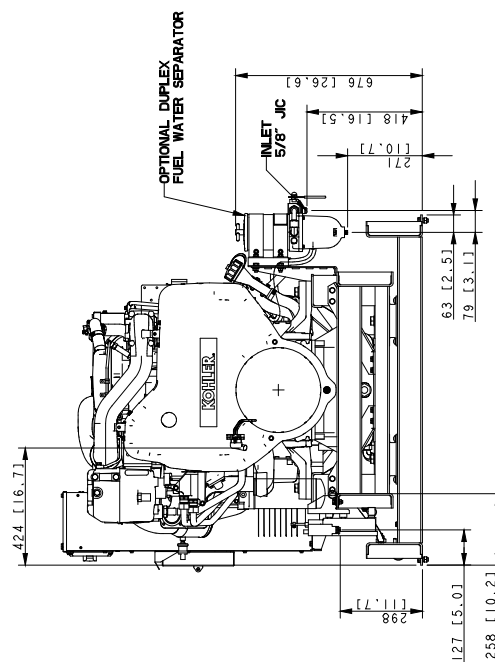


Figure 101 Dimension Drawing, 500EOZCS and 450EFOZCS IMO Tier III Models (Sheet 3 of 3)



ENGINE WITH HEAT EXCHANGER, DUPLEX FUEL/OIL FILTER
AND WET EXHAUST ELBOW



300/350KW
SCANIA MARINE

NOTE:
Dimensions are shown in mm [in.].

ADV-9114A-A

Figure 102 Dimension Drawing, 350EOZCS and 300EFOZCS Accessories (Sheet 1 of 2)

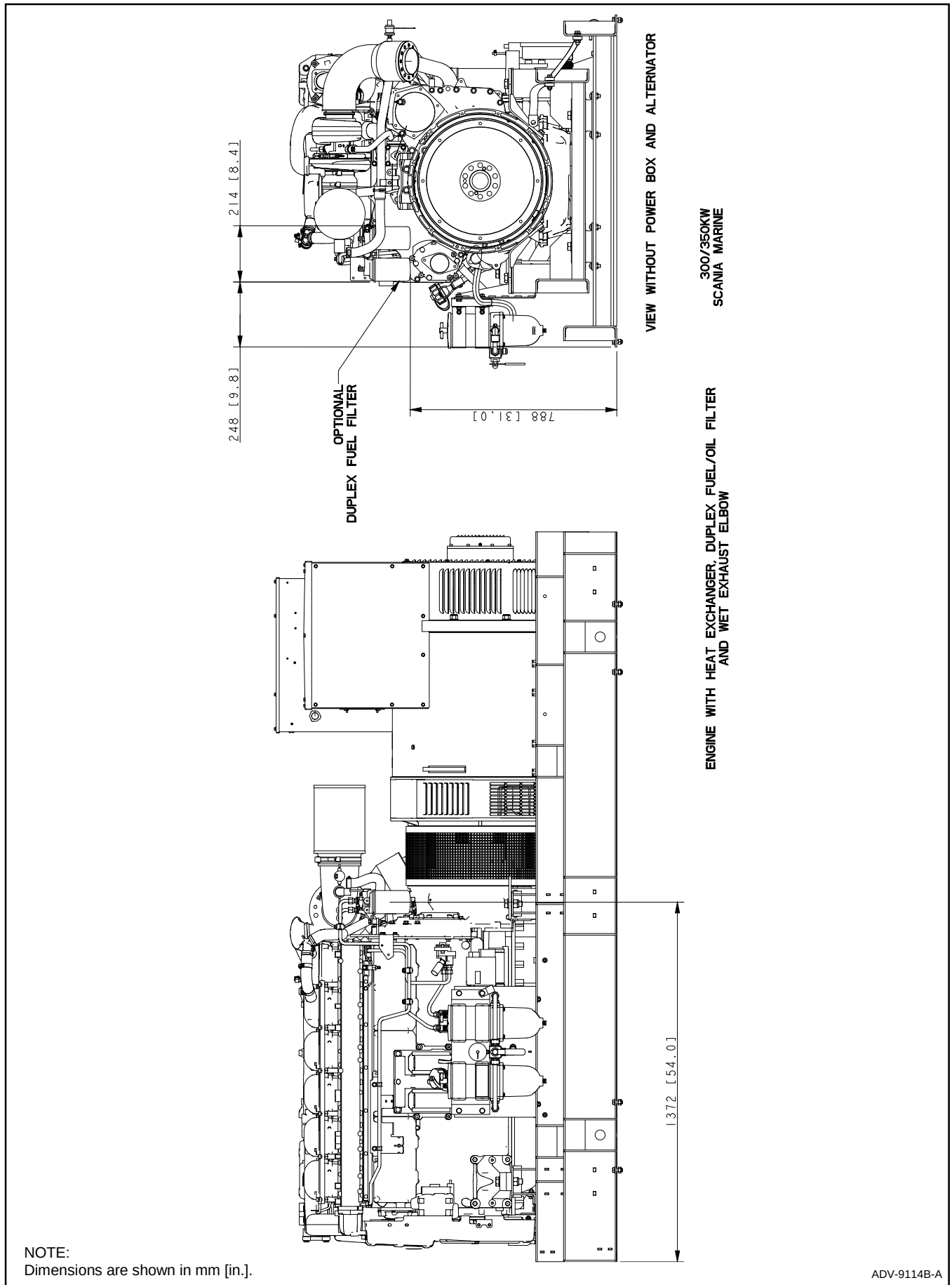
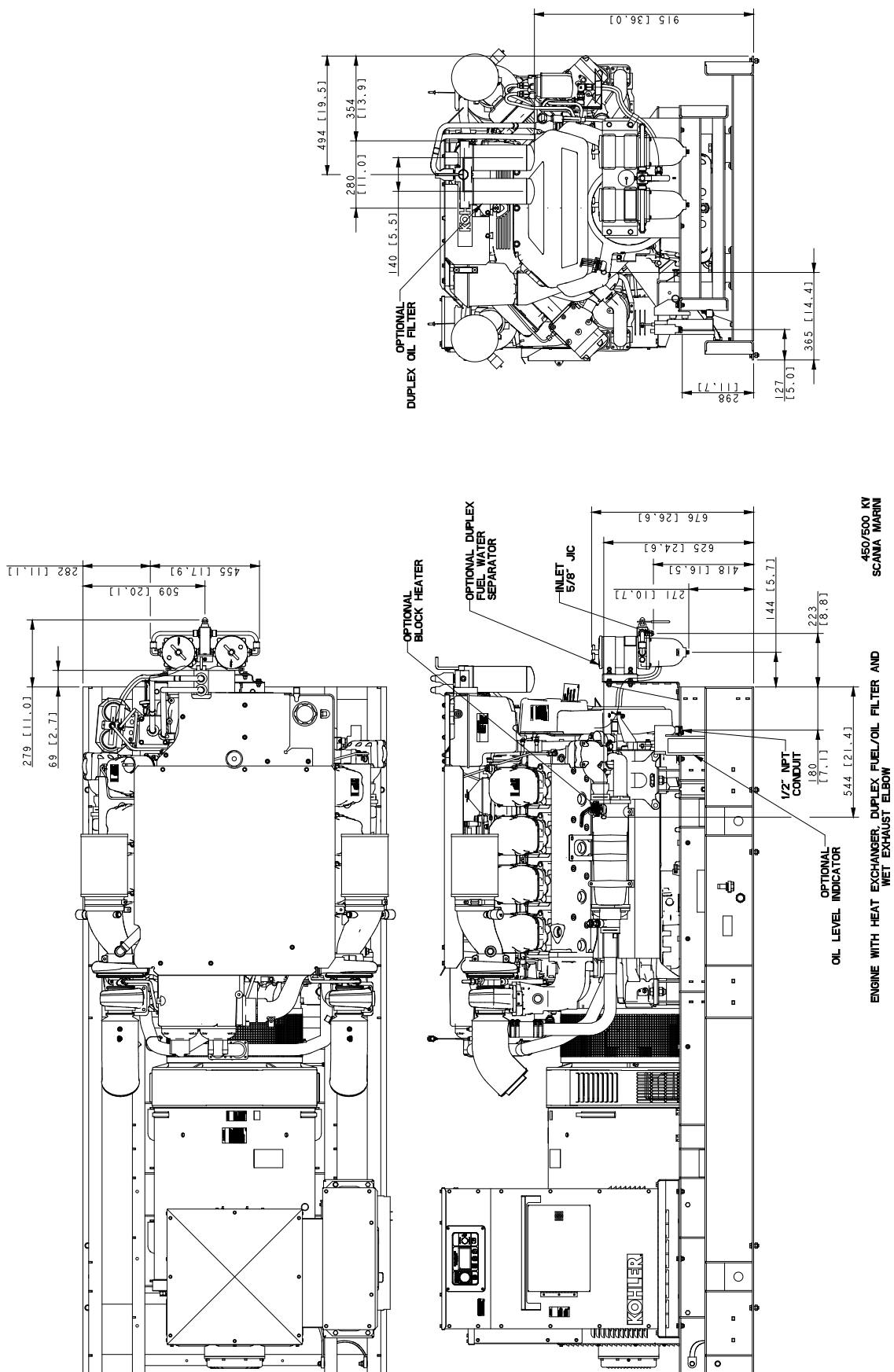


Figure 103 Dimension Drawing, 350EOZCS and 300EFOZCS Accessories (Sheet 2 of 2)



ADV-9112A-A

Figure 104 Dimension Drawing, 500EOZCS and 450EFOZCS Accessories (Sheet 1 of 2)

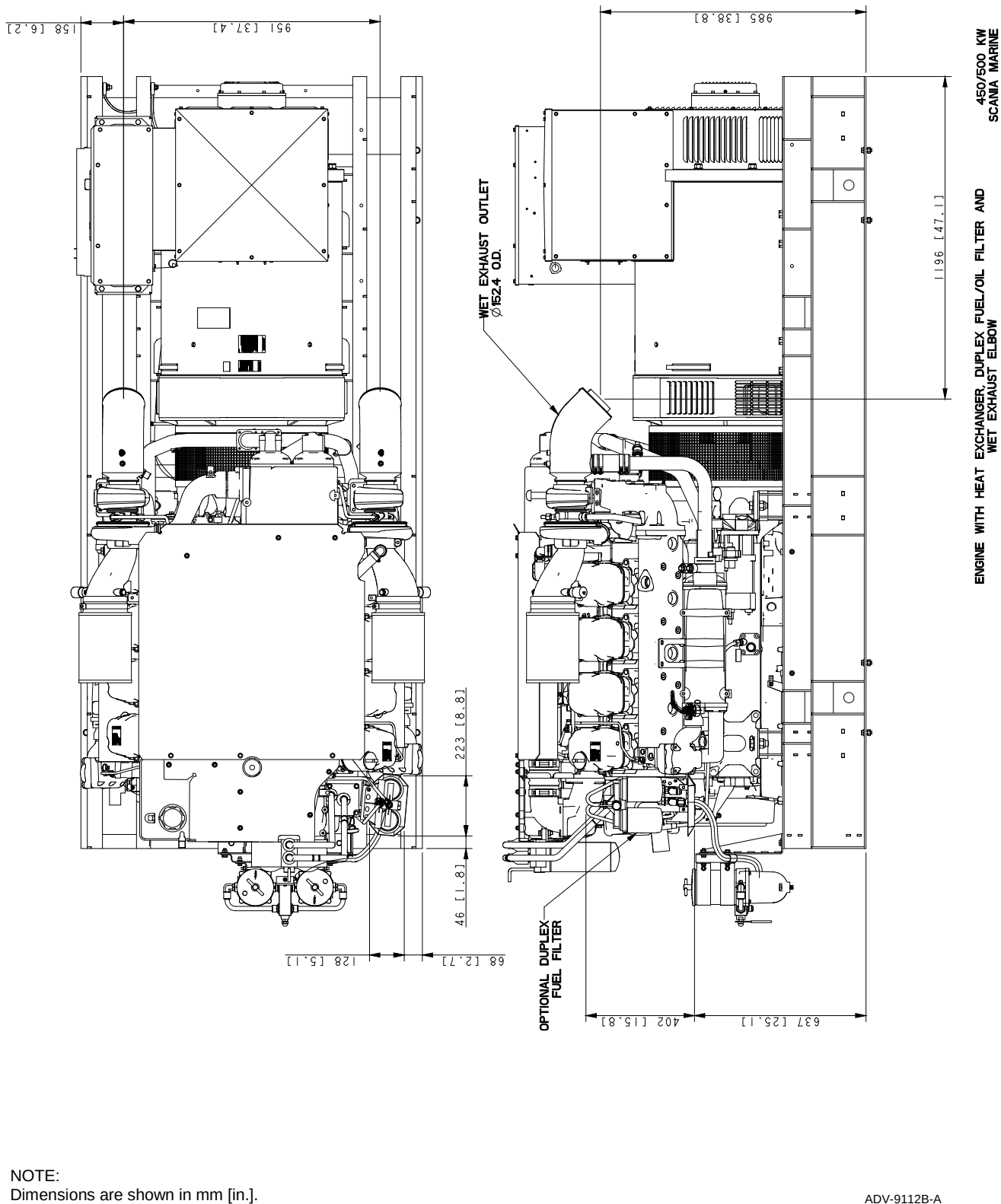


Figure 105 Dimension Drawing, 500EOZCS and 450EFOZCS Accessories (Sheet 2 of 2)

Section 12. Paralleling Generator Sets

 WARNING	Accidental starting. Can cause severe injury or death.
  	Disconnect the battery cables before working on the generator set. Remove the negative (–) lead first when disconnecting the battery. Reconnect the negative (–) lead last when reconnecting the battery.

Disabling the generator set. Accidental starting can cause severe injury or death. Before working on the generator set or equipment connected to the set, disable the generator set as follows: (1) Move the generator set master switch to the OFF position. (2) Disconnect the power to the battery charger. (3) Remove the battery cables, negative (–) lead first. Reconnect the negative (–) lead last when reconnecting the battery. Follow these precautions to prevent starting of the generator set by an automatic transfer switch, remote start/stop switch, or engine start command from a remote computer.

 DANGER	Hazardous voltage. Moving parts. Will cause severe injury or death.
 	Operate the generator set only when all guards and electrical enclosures are in place.

Grounding electrical equipment. Hazardous voltage will cause severe injury or death. Electrocution is possible whenever electricity is present. Ensure you comply with all applicable codes and standards. Electrically ground the generator set, transfer switch, and related equipment and electrical circuits. Turn off the main circuit breakers of all power sources before servicing the equipment. Never contact electrical leads or appliances when standing in water or on wet ground because these conditions increase the risk of electrocution.

Introduction

Read and follow the safety precautions included in this manual. Pay attention to the decals on the equipment and follow the instructions below.

- All personnel involved in handling, site preparation, installation, testing, operation, and maintenance should be thoroughly familiar with the information in this manual and the customer drawings provided before working on this equipment.
- Never make interlocks inoperative or operate the equipment with any safety barriers removed.
- Always assume that all high-voltage parts are energized until it is certain that they are de-energized.
- Use only test equipment rated for the service intended.
- Check interconnection diagrams and make sure there are no potential back feed sources.
- Never disconnect the main trip source of energized equipment.
- Use out-of-service tags and padlocks when working on equipment. Leave tags in place until the work is completed and the equipment is ready to be put back into service.
- The complete assembly arrangement determines if the top or bottom contacts are the line side; both can be energized when the circuit breaker is removed from the compartment.
- Do not use liquid fire extinguishers or water on electrical fires. Before extinguishing fires within the assembly, be absolutely certain that the main power source is disconnected and the main and all feeder breakers are tripped.

The Decision-Maker® 3500 generator set controller provides generator set advanced control, system monitoring, and system diagnostics for paralleling multiple generator sets.

The Decision-Maker® 3500 interfaces the generator set to other power system equipment and other network management systems using standard industry network communications.

The controller uses unique software logic to manage sophisticated functions, such as voltage regulation, synchronizing and load-sharing controls, and protective relays for paralleling up to eight generator sets.

Decision-Maker® 3500 Controller Features Include:

- Isochronous (real and reactive) load sharing with other Decision-Maker® 3500 equipped generator sets.
- Random first-on logic to prevent two or more generator sets from closing to a dead bus.
- Automatic synchronizer with dead bus closing.
- Soft loading and unloading.
- Protective relay functions include:
 - Loss of field
 - Over current
 - Over frequency
 - Over power
 - Over voltage
 - Reverse power
 - Under frequency
 - Under voltage
- Generator management allows unneeded generators to be stopped to conserve fuel.
- Load control logic permits prioritization of supplied loads, allowing critical load to retain power in a failure scenario.

A generator set needs to be configured and set up correctly to work in paralleling applications. This section covers:

- Paralleling Basics
- Paralleling Considerations
- Paralleling Set Up
- Paralleling Troubleshooting
- Generator Management Setup
- Load Add/Shed Configuration

12.1 Paralleling Basics

12.1.1 Why Parallel Generator Sets

Some reasons to parallel generator sets are:

- Redundancy
- Increased power capacity
- Decreased fuel consumption
- Reduced chance of wet stacking/fuel on water
- Increased reliability
- Greater flexibility
- Individual generators can be serviced in prime power applications

12.1.2 Paralleling Functions

There are two methods of paralleling:

1. **PGEN.** The Decision-Maker® 3500 is a full-featured paralleling controller. It offers integrated control for synchronizing, load sharing, protective relays, generator management, and load add/shed. This functionality is performed automatically by the Decision-Maker® 3500 controller. PGEN requires an RS-485 between each of the paralleling generators for paralleling operation.
2. **Remote Speed and Voltage Bias.** The Decision-Maker® 3500 controller is also capable of accepting a speed and voltage bias from an external paralleling control. In these applications, the external paralleling control performs all of the required functionality and the Decision-Maker® 3500 controller merely provides a control interface and protective functions for the generator set.

Note:

For external speed and voltage bias, the PGEN communication's cable should not be connected between generators.

TB13 is located inside the junction box and contains the connection points for external speed and voltage bias control and accommodates 0- 5 volt input for active control. See the table below and the wiring diagrams in the Operation Manual for more information.

	Connection
Speed Bias Negative (-)	TB13-SBN
Speed Bias Positive (+)	TB13-SBP
Speed Bias Negative (-)	TB13-VBN
Speed Bias Positive (+)	TB13-VBP

External paralleling requires the external speed and voltage bias inputs to be enabled. Using SiteTech™, under the **Synchronization Control** parameter change the setting to the following:

External Bias Inputs: True

Note:

For more information on SiteTech™, see TP-6701 SiteTech™ Software Operation Manual.

With the external bias enabled, the engine speed is set based on the voltage between SBP and SBN:

- Voltage < 0.5V: Engine Run Speed
- Voltage = 0.5V: 95% of Engine Run Speed
- Voltage = 2.5V: Engine Run Speed
- Voltage = 4.5V: 105% of Engine Run Speed
- Voltage > 4.5V: Engine Run Speed

With the external bias enabled, the output voltage is set based on the voltage between VBP and VBN:

- Voltage < 0.5V: Voltage Regulator Average Voltage Adjustment
- Voltage = 0.5V: 90% of Voltage Regulator Average Voltage Adjustment
- Voltage = 2.5V: Voltage Regulator Average Voltage Adjustment
- Voltage = 4.5V: 110% of Voltage Regulator Average Voltage Adjustment
- Voltage > 4.5V: Voltage Regulator Average Voltage Adjustment

The Decision-Maker® 3500 controller reads the voltage on the speed and voltage bias inputs every 50 ms (20 times per second) and passes the new target to the voltage regulator and the ECM.

Reactive droop should be enabled on the Decision-Maker® 3500 when paralleling with another generator set (either in simple or intelligent paralleling). The slope should be identical on all generators in the paralleling system (the default is 1.0%). Reactive droop can be configured using either SiteTech™ or the User Interface (UI) at the controller:

Using SiteTech™, under the **Reactive Power Load Sharing** parameter.

Using the UI under the

Generator Info -> Voltage Regulation Menu and **Generator Info -> Paralleling Operation -> Sharing Setup** Menus.

Note:

Non-ECM engines will require an electronic governor (Woodward APECs) and an appropriate Kohler governor calibration in order to permit speed adjustment.

Speed Bias is the amount that the controller is attempting to adjust the output frequency of the generator (100% bias = +5% on the engine speed, - 100% = - 5% on the engine speed). The controller adjusts the Speed Bias to match frequency and phase with the paralleling bus.

Note:

The Speed Bias can also be controlled by an external device if the External Bias Inputs Enabled parameter is true, the Stand Alone Operation parameter is false, no other generators are visible on the PGEN communications channel, and the voltage applied to the speed bias input is between 0.5V and 4.5V.

The External Speed Bias Input (SBP and SBN) is a voltage measuring channel capable of reading from - 10V to 30V DC. The input is normally pulled down to - 3.3V, but can be overridden by applying a voltage to the input.

The voltage that the controller sees on the voltage measuring channels is visible in the **Analog Voltage Input Metered Relative Value** under the **Programmable Analog Voltage Input 108** parameter heading. The input is polarity sensitive.

The Speed Bias is interpreted by the controller as shown in **Figure 106**.

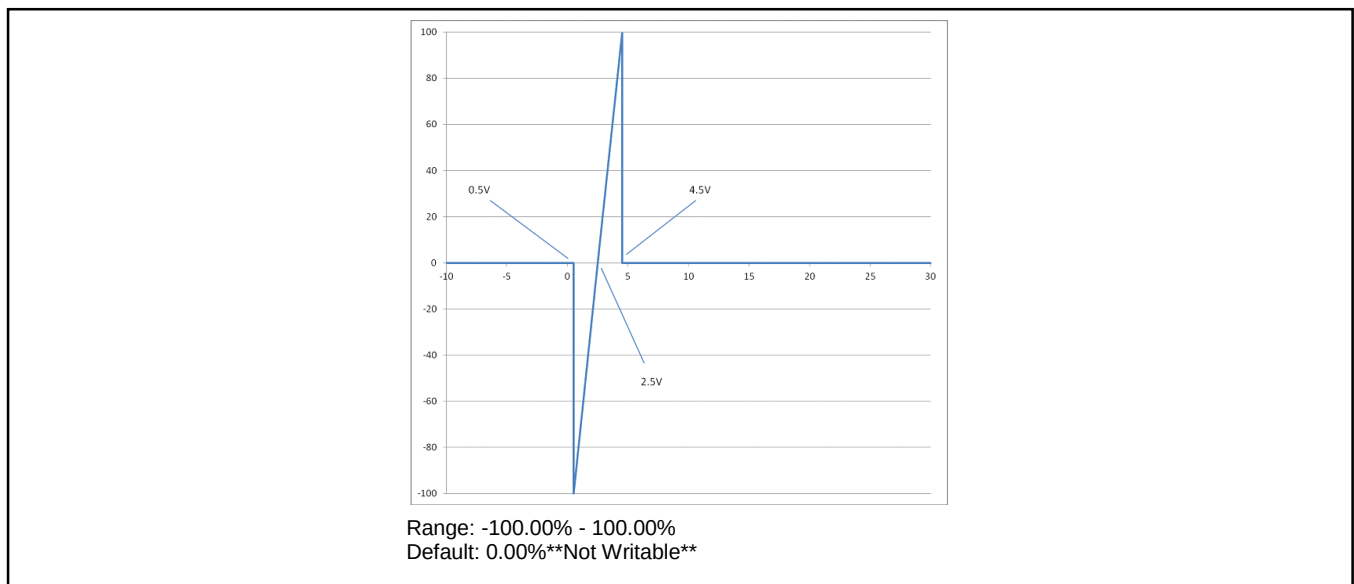


Figure 106 Speed Bias

Voltage Bias is the amount that the controller is attempting to adjust the output voltage (100% bias = +10% on the output voltage, - 100% = - 10% on the output voltage). The controller adjusts the voltage bias to match the generator voltage to the bus voltage.

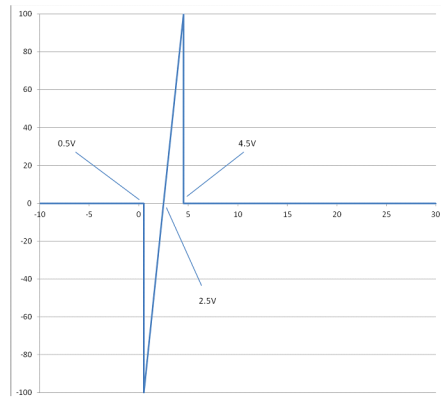
Note:

The Voltage Bias can also be controlled by an external device if the External Bias Inputs Enabled parameter is true, the Stand Alone Operation parameter is false, no generators are visible on the PGEN communications channel, and the voltage applied to the voltage bias input is between 0.5V and 4.5V.

The External Voltage Bias Input (VBP and VBN) is a voltage measuring channel capable of reading from - 10V to 30V DC. The input is normally pulled down to - 3.3V, but can be overridden by applying a voltage to the input.

The voltage that the controller sees on the voltage measuring channels is visible in the **Analog Voltage Input Metered Relative Value** under the **Programmable Analog Voltage Input 107** parameter heading. The input is polarity sensitive.

The Voltage Bias is interpreted by the controller as shown in **Figure 107**.



Range: -100.00% - 100.00%
Default: 0.00%**Not Writable**

Figure 107 Voltage Bias

Synchronizing

Before a generator set can operate in parallel with another generator set, its electrical output must be synchronized (matched) to the power source it will parallel. The parameters that must be matched are:

- Frequency
- Phase Angle
- Voltage
- Phase Rotation (for 3-phase applications)

The synchronizer will issue a breaker close command when the frequency difference, phase angle, and voltage difference are within an acceptable range and the phase rotation matches.

Note:

The Decision-Maker® 3500 synchronizer will not attempt to match voltage, frequency, or phase if the phase rotation of the bus doesn't match that of the generator set.

For PGEN paralleling, the synchronizing is handled within the Decision-Maker® 3500 controller.

For Remote Speed and Voltage Bias paralleling, the synchronizing is handled by an external controller, typically supplied on switchgear.

Real (kW) Load Control

When generator sets are running in parallel (electrically connected), the load controller controls the generator sets so each generator set is supplying its proportional share of power to the load while maintaining rated frequency. This is isochronous load sharing.

The load controller communicates (analog or digital) to the other load controllers and determines how much power each generator set should supply.

For PGEN paralleling, the load controller is within the Decision-Maker® 3500 controller.

For Remote Speed and Voltage Bias paralleling, the load control is performed by an external controller, typically supplied on switchgear.

Reactive (kVAR) Control (Isolated Bus)

When generator sets are paralleled, the voltage output of each generator set must be equal. Reactive power control is needed between the generator sets to ensure that each is supplying its share of the reactive load and to minimize circulating currents. This can be done in one of two ways:

1. **Active Control (Used in PGEN Paralleling and some external paralleling).** The reactive load controller communicates (analog or digital) to the other reactive load controllers to maintain the same proportional kVAR output while maintaining the system's nominal voltage.

2. **Passive Control (Used in Droop Paralleling).** The voltage regulators are operated in droop, biasing the regulator to equalize reactive power output of the generators. There is no active control from the controller.

12.2 Paralleling Considerations

12.2.1 Generator Requirements

Alternator and Connections

Units to be paralleled must have the same frequency, the same number of phases, the same voltage, and the same phase rotation. The latter merely means that the voltages across the terminals must reach their maximum and minimum values in the same order. Otherwise, the magnetic forces would try to turn the rotors in opposite directions.

The pitch of the paralleled alternators needs to be the same or excessive circulating currents may occur.

Engine

If not already equipped, the engine must be up-fitted with an electronic isochronous governor in order to allow paralleling of the unit. This governor allows the Decision-Maker® 3500 controller to control speed, allowing load sharing and synchronizing.

Motorized Paralleling Circuit Breaker

The Decision-Maker® 3500 controller provides control of a single motor-operated breaker to selectively close on or off the bus. For motorized paralleling breakers, there are two options:

- On the generator set, pre-wired from the factory.
- Remotely mounted. Customer needs to wire to status, trip, close, charge motor, and bus sensing. See the wiring diagram in the operation manual for more information.

Note:

The motor operator breaker requires a constant supply voltage of 24- 30VDC. Supply voltages below 24VDC will result in failure of the motor operator breaker.

Speed Control (Required for Paralleling Done Via Remote Speed and Voltage Bias Method)

The Decision-Maker® 3500 controller will accept an input from the paralleling controller. This is the way the paralleling controller adjusts the frequency and controls the power output of the generator set.

The Decision-Maker® 3500 controller has the ability to accept a remote speed adjust input of:

- 0.5 - 4.5 volts $\pm 5\%$ (values supplied outside of this range will default the setting to nominal)

Note:

Some engines may limit this speed adjust to no more than approx. $+3.5\%$.

Voltage Regulator

The voltage regulator is integral to the Decision-Maker® 3500 controller and is capable of accepting remote input for voltage adjustment. It adjusts to:

- 0.5 - 4.5 volts $\pm 10\%$ (values supplied outside of this range will default the setting to nominal)

Generator Set Protection

A reverse power relay senses the direction of power flow. Each generator's Decision-Maker® 3500 controller contains a reverse power relay. If any unit in the system has a malfunction such as a loss of fuel causing real power to flow into the generator, the reverse power relay will sense the reverse power and disconnect the unit from the system. If reverse power relays are not used, units still running will drive the unit that has stopped with the alternator acting as a motor.

Modbus® is a registered trademark of Schneider Electric.

12.2.2 Paralleling Controller—PGEN

Starting and Stopping Generator Set

The Decision-Maker® 3500 controller has supervisory control over paralleling. There are several methods that can be used to start and stop the generator set (consult the operation manual for more detail):

- CAN gauge
- Modbus®
- Kohler SiteTech™ software
- AUTO- RUN/AUTO- OFF button
- RUN button
- Contacts 3 and 4 for remote signal

Frequency and Real (kW) Power

Depending on the state of the paralleling motorized breaker, the Decision-Maker® 3500 controls the frequency or kW output of the generator set by sending a signal to the engine governor over J1939 (CAN).

- **Motorized Paralleling Breaker Open.** The generator set speed (frequency) will vary with this signal. This would be the case while synchronizing.
- **Motorized Paralleling Breaker Closed.** If the generator set parallel motorized breaker is closed and the generator set is operating in parallel with another power source, this signal will control the kW load provided by the generator.

Voltage and Reactive (kVAR) Power

The Decision-Maker® 3500 controls the generator set's output voltage.

The generator set response to the signal varies depending on the state of its paralleling motorized breaker.

- **Motorized Paralleling Circuit Breaker Open.** If the motorized circuit breaker is open, the output voltage will change. This would be the case while synchronizing.
- **Motorized Paralleling Circuit Breaker Closed.** If the motorized circuit breaker is closed and the generator set is operating in parallel with another power source, this signal will control the kVAR load provided by the generator.

12.3 Paralleling Set Up

12.3.1 PGEN Communication Wiring

PGEN Communication Wiring

In order to parallel two or more generator sets using PGEN, a communication wire is required. Use a Belden cable #9841 (or equivalent) shielded twisted-pair communication cable. Connect the shield to ground at one end only. Tighten the connections to 0.5 Nm (4.4 in. lbs.). The PGEN connection between the generator sets is always required when the generator sets connect to a common bus. See **Figure 108**.

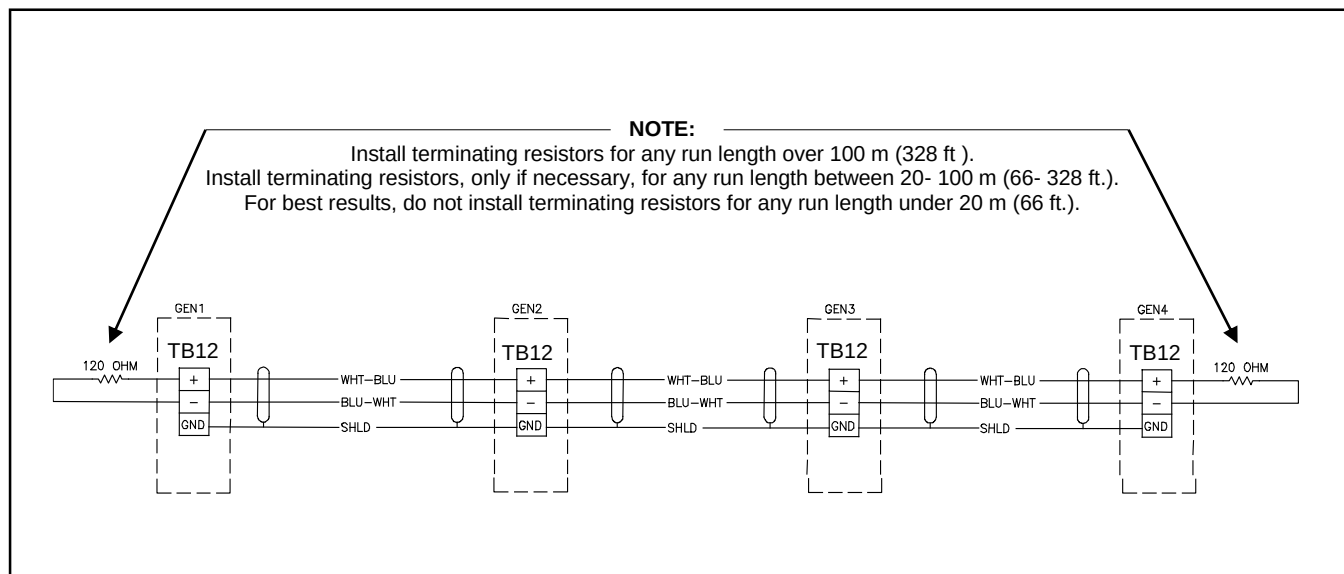


Figure 108 Paralleling System Interconnection Diagram

PGEN connections are made on terminal blocks TB12 and TB13. TB12 and TB13 are located in the generator set junction box. See **Figure 109** for TB12 and TB13 locations. See the operation manual for the complete wiring diagram including PGEN connections.

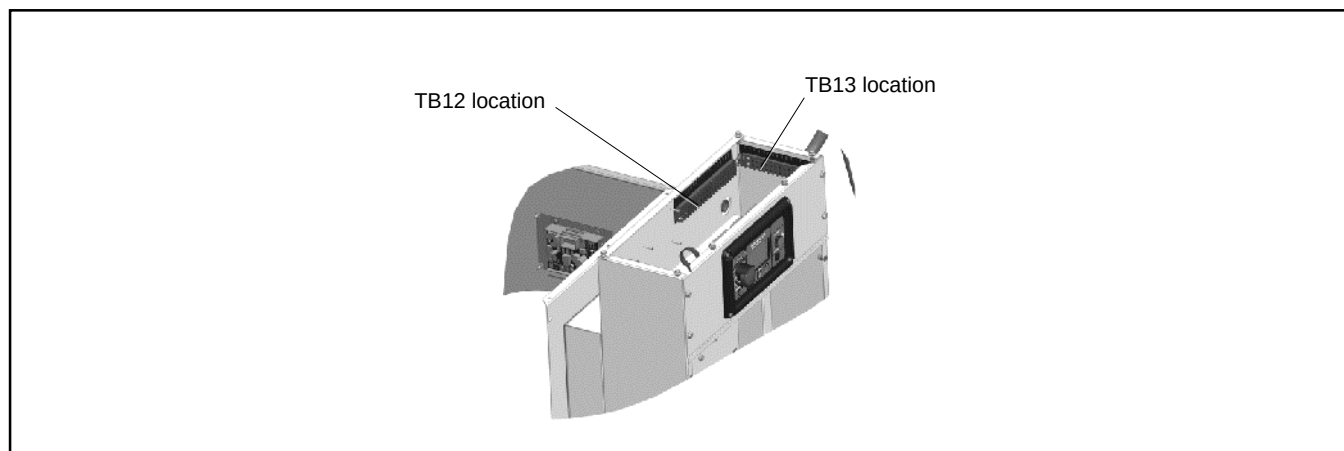


Figure 109 TB12 and TB13 Terminal Block Locations

12.3.2 Paralleling Gain Setting

The Decision-Maker® 3500 controller is preset with factory defaults for each generator model number in the personality profile. These gains should perform adequately for most applications, but it may be necessary to perform adjustment of advanced settings.

The Decision-Maker® 3500 controller uses PID (Proportional, Integral, and Derivative) type gains as explained below:

- **Proportional gain** controls the response time or sensitivity when a change, due to an error, is needed. Too high or too low of a gain value can create instability as it can make the system too sensitive or damped. Too sensitive of a gain value makes the control loop “chase” the target. A small gain makes the control loop slow to respond to a target change. Proportional gain is the primary component in making an output change.
- **Integral gain** controls how aggressive the output change will be. Too high of a gain value can cause an overshoot of the target when an output change is needed. This gain should start small and in some instances will be a fairly small value when compared to the proportional or derivative gains.
- **Derivative gain** controls the overshoot and settling time of an output change. Too low of a gain value can cause “ringing” or oscillation of an output change as the target is met. Derivative gain may not be needed in some installations as the proportional and integral gains do the bulk of the work on an output change. If the system has some instability after an output change that eventually goes away, increase the derivative gain.

Tuning Example

Before beginning ensure that all generator set controllers are connected to a PC via a USB cable and that all controllers are shown in SiteTech™ under the “Manage Parallel Devices” mode located at the top of the SiteTech™ screen.

Note:

For more information on SiteTech™, see TP-6701 SiteTech™ Software Operation Manual.

If the factory-set gains are deemed inadequate, the Real Power Load Sharing gains are most likely the gains that need adjustment. Synchronizing parameters like phase match window synchronization frequency match window, and voltage match window and their associated gains are factory-set and should not need adjustment.

Monitoring Generator Total Real Power (located in the Generator Metering tab in SiteTech™) on all paralleled generator sets simultaneously and observing the behavior of a changing load condition provides an indication of whether an adjustment is needed. If the paralleled generator sets are able to share load at varying load steps without errors, the proportional gain is likely ok. Some shift of load from generator set to generator set is normal, but the actual kW of load movement should be minimized. If a large load movement is observed from generator set to generator set, start by decreasing the integral gain. If the load shift is happening at a high frequency, increase the derivative gain. In general, increasing the derivative gain makes the load shift happen slower. Reducing the integral gain makes the amplitude of the load being shifted smaller.

Reactive Power Load Sharing gains can be adjusted in the same way (monitor Generator Total Reactive Power located in the Generator Metering tab in SiteTech™), but it's unlikely that the factory gains will need any adjustment. Always start with the Real Power Load Sharing gains.

Any of the other Decision-Maker® 3500 controller PID gains can be adjusted using the same method explained above, however note that the derivative gains for most other parameters are disabled from the factory.

Note:

All factory gains are values of 1 so it is simple to revert back to the factory defaults.

12.3.3 Decision-Maker® 3500 Paralleling Sequence of Operation

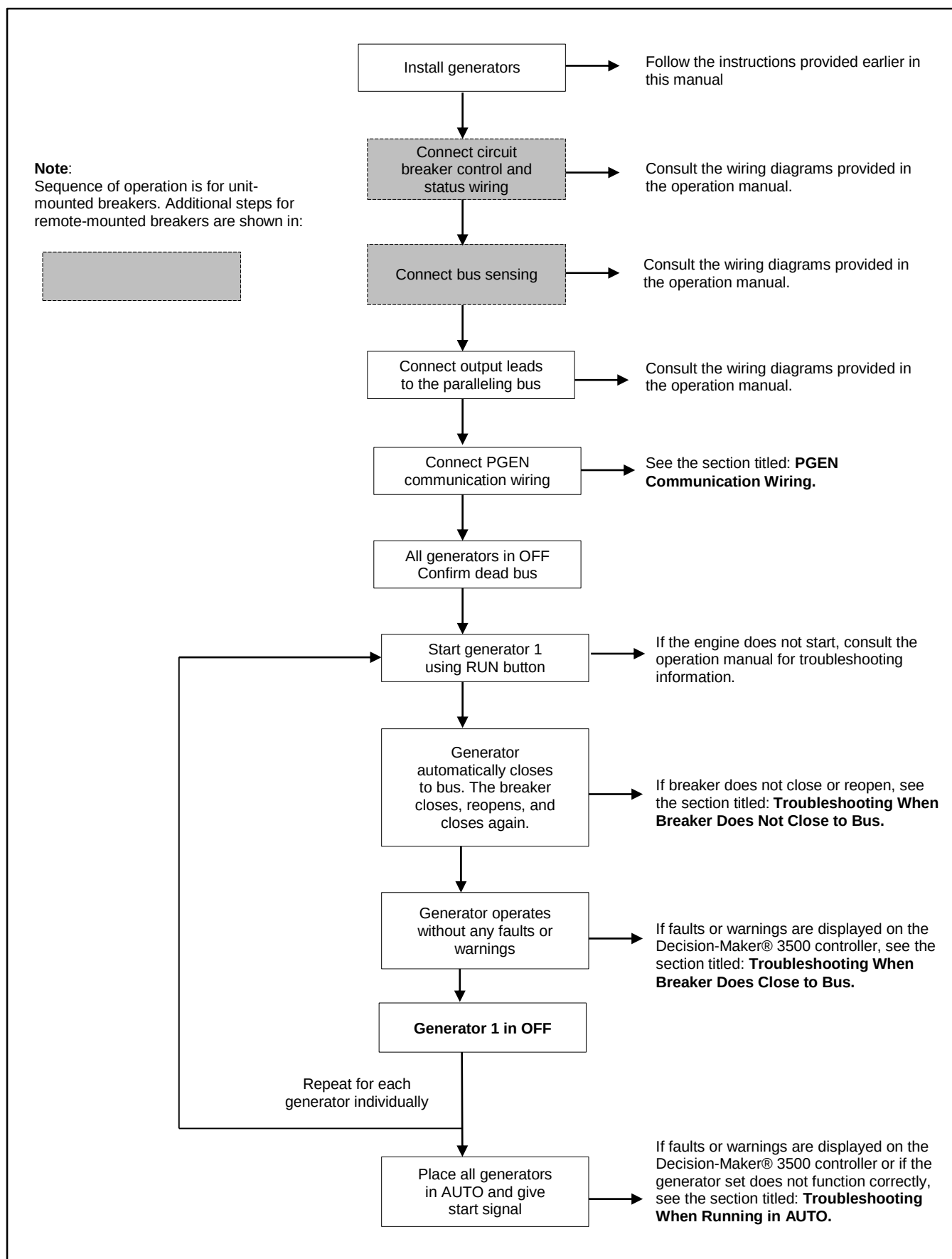


Figure 110 Sequence of Operation

12.4 Troubleshooting When Breaker Does Not Close to Bus

12.4.1 Faults Not Shown

Step	Potential Cause	Explanation	Troubleshooting
1	PGEN communication not operational	The controller must have seen PGEN communication with at least one other node at some time since the last power cycle event before it will close the breaker.	In <i>Controller Config -> Communication Setup</i> , verify the PGEN Nodes Online is at least 2. If so, continue troubleshooting at Step 8 otherwise, continue on to Step 2.
2	Single generator application	There is only one generator on site, but the controller is expecting to see PGEN communication. The controller supports this scenario if the controller is configured in Standalone mode. Standalone mode can be set using the standalone input to the controller or in Kohler SiteTech™.	Configure a digital input to Standalone mode and assert it, or set Standalone mode in Kohler SiteTech™. Note, Standalone mode should only be asserted if there is only one generator set at the site.
3	PGEN wiring not connected correctly	PGEN communicates over an RS-485 connection. RS-485 requires that the network be connected in a daisy-chain configuration, terminated at 120 Ohms at either end of the network and that positive (B) and negative (A) polarity be maintained.	Verify wiring, all PGEN + connections should be connected with daisy-chain wire (Belden #9841 or equivalent). Verify terminations are at the end of the network. Verify that there are no unintentional or loose connections.
4	Baud rate misconfigured	One of the controllers on the network is attempting to communicate at a different baud rate than the other controllers. This results in collisions on the communication bus and incorrect interpretation of the data.	In <i>Controller Config -> Communication Setup</i> , verify that the baud rate of all generators on the network matches. Default is 57,600 baud.
5	Interference	The PGEN network is seeing noise which makes it difficult for the generator controllers to communicate.	Verify that PGEN network uses Belden #9841 or equivalent. Verify that the shield drain for the cable is grounded at only one end.
6	Short circuit in communication wiring	The RS-485 communication wires are short-circuited together.	In <i>Controller Config -> Communication Setup</i> , verify the PGEN Node ID is less than 16. If not, check the PGEN wiring for short circuits. Otherwise, continue troubleshooting to Step 7.
7	Intermittent connection in PGEN wiring	Although the generator controllers can occasionally communicate, the connection is unreliable. This can be caused by a short or open circuit.	It is not uncommon for small communications wire to not connect directly to a terminal block well. Verify there are no loose wiring connections or "whiskers" at the PGEN terminal blocks. "Fork", "ring", or "crow's feet" connectors are preferred for terminal block connections.
8	Unable to establish first-on lock	The generator is trying to close to a dead bus but it is not receiving permission from one of the other nodes to allow it to do so. This can occur if one of the other nodes has seen a node removed from the network.	Cycle power on all generators.

12.4.2 Faults Shown

Step	Potential Cause	Explanation	Troubleshooting
Fault: System Voltage Mismatch Between Generators			
1	System voltage is not equivalent	One of the controllers on the network is configured differently than the other controllers. This will inhibit any of the generators from closing to the bus.	Verify the system voltage of all the generators match the requirements of the site.
Fault: System Frequency Mismatch Between Generators			
1	System frequency is not equivalent	One of the controllers on the network is configured differently than the other controllers. This will inhibit any of the generators from closing to the bus.	Verify the system frequency of all the generators match the requirements of the site.
Fault: Phase Connection Mismatch Between Generators			
1	Phase connection is not equivalent	One of the controllers on the network is configured differently than the other controllers. This will inhibit any of the generators from closing to the bus.	Verify the phase connection of all the generators match the requirements of the site.
Fault: Live Bus Sensed When Dead Bus Expected			
1	Bus is considered to be live	The controller is measuring voltage on the paralleling bus. This will inhibit the breaker from closing.	Check bus for residual voltage (sometimes induced by large transformers or motors). Possibly, adjust the Dead Bus Threshold to accommodate the residual voltage.
2	Bus sensing is not connected	The controller may see voltage on the paralleling bus when the generator is operating and the bus sensing is disconnected.	Verify the bus sensing wiring is connected to the load side of the motor-operated breaker for this generator.
Fault: Close Attempt Fault: Fail to Close			
1	Breaker is unable to close	The controller is attempting to close the circuit breaker but the breaker is not closing.	Watch the ready flag on the motor operator of the circuit breaker, if equipped. If it indicates not ready when the engine is stopped and toggles to the ready state when the generator is trying to close the breaker, the trip coil is acting correctly. Continue at Step 5 otherwise, continue on to Step 2.
2	Trip is not removed from the circuit breaker	The controller is attempting to close the circuit breaker but the breaker is not closing because the trip coil is still energized.	If the ready flag of the motor operator indicates ready when the engine is stopped, continue at Step 3 otherwise, continue on to Step 4.
3	CB trip relay is wired as normally open	The controller is expecting that the trip on the circuit breaker is a normally-closed contact. This is intentional as it holds a trip on the breaker if the controller is removed.	Verify the CB trip relay is wired to hold a trip on the breaker when the relay is not energized.
4	Incorrect wiring between the CB trip relay and the trip coil on the breaker	The CB trip relay is operating correctly but the trip coil on the breaker is remaining energized. This could be due to incorrect wiring between the generator controller and the circuit breaker.	Verify the wiring to the circuit breaker.
5	Close is not applied to the circuit breaker	The breaker trip is removed but the controller is not able to close the breaker.	Verify the wiring between the generator controller and the circuit breaker close coil. Check the close coil to ensure that it is not defective.
6	Breaker is not charged	The breaker is receiving the signal to close but the energizing spring is not charged.	Verify the motor operator is receiving voltage at the appropriate contacts to allow it to wind the spring.
7	Breaker is not powered	The 24V electronics on the circuit breaker require an external 24V source on a 12V generator.	Verify the 24V input which exists on paralleling generators is receiving 24VDC in the correct polarity.
8	Wiring to power is not complete	There is no voltage to the CB close relay on this circuit breaker.	Connect the supply to the CB close relay to either 24V from wire #70 or an external 24VDC supply (with battery storage).
9	Breaker status feedback is not valid, no bus sensing	The breaker closes but the controller does not see a change in status. The controller cannot see the bus is energized as the bus sensing is not connected correctly on any generators on the network.	Verify the wiring on the circuit breaker to ensure that it is connected correctly. Verify bus wiring for all nodes. Verify the generator output is connected to the line side of the generator breaker.

Step	Potential Cause	Explanation	Troubleshooting
Fault: CB Status			
Warning: Bus Sensing Not Connected			
1	Breaker status feedback is not valid, no bus sensing	The breaker closes but the controller does not see a change in status. The controller cannot see the bus is energized as the bus sensing is not connected correctly on this generator, but another generator is connected.	Verify the wiring on the circuit breaker to ensure that it is connected correctly. Verify bus wiring for this generator.
Fault: CB Status or Continuous Breaker Cycling			
1	Breaker status feedback is not valid	The breaker closes but the controller does not see a change in status. The controller sees the bus is now live.	Verify the wiring on the circuit breaker to ensure that it is connected correctly.

12.5 Troubleshooting When Breaker Does Close to Bus

12.5.1 Faults Shown

Step	Potential Cause	Explanation	Troubleshooting
Fault: Close Attempt			
Fault: Fail to Close			
1	Breaker status feedback is not valid, no bus sensing	The breaker closes but the controller does not see a change in status. The controller cannot see the bus is energized as the bus sensing is not connected correctly on any generators on the network.	Verify the wiring on the circuit breaker to ensure that it is connected correctly. Verify bus wiring for all nodes. Verify the generator output is connected to the line side of the generator breaker.
Fault: CB Status			
1	Breaker status feedback is not connected	The breaker closes but the controller does not see a change in status. The controller sees the bus is now live.	Verify the wiring on the circuit breaker to ensure that it is connected correctly.
2	Breaker status is short circuited	The controller sees the breaker is closed even when it is not trying to open it.	Verify connection of the breaker status wiring at the circuit breaker.
3	Breaker status feedback is connected to the wrong contacts	The controller sees open status for the breaker after telling it to close, closed status after telling it to open.	The controller is expecting the breaker status to be an "A" contact. Verify the circuit breaker auxiliary contacts are either: 11 and 14 21 and 24 31 and 34 or 41 and 44. If the breaker status contacts are removable, make sure that they are inserted in one of the OF slots and that the wires go to 1 and 4.
4	Breaker status feedback is connected to a latching contact	The breaker status indicated that it closed when it was triggered to close but it did not indicate that it was open when the breaker opened. This fault will only occur if the bus sensing is connected correctly (the controller sees the voltage go to 0 when the breaker is triggered to open).	Verify the breaker status input to the controller is connected directly to an auxiliary contact on the circuit breaker.
Fault: Bus Phase Rotation Mismatch			
1	All of the bus sensing wires are incorrectly connected	The bus sensing wires must be connected to phase A, phase B, and phase C of the bus. If any two connections are reversed, the controller can detect the reversed connections. This fault will only occur if all three wires are incorrectly connected.	Verify the bus metering connections.
2	The phase connections on the paralleling breaker are inconsistent with the generator	The power leads from the generator to the paralleling circuit breaker must be connected consistently. Phase A from the generator must go to phase A of the line side of the paralleling (motor operated) breaker, phase B from the generator to phase B of the breaker and phase C of the generator to phase C of the breaker.	Verify the output cable connections.
3	Generator sensing is connected incorrectly	The controller measurement leads are not connected to the appropriate output phases or the phases are incorrectly labeled.	Verify the sensing leads from the controller are connected to the appropriate output leads from the generator. L1 should connect to phase A, L2 to phase B, L3 to phase C, L0 to neutral.
4	Breaker to bus wiring is inconsistent	In applications where the bus sensing is taken from a location other than the load side of the paralleling breaker, it is possible to connect the wiring incorrectly between the load side of the output breaker and the paralleling bus.	Verify the cable connections from the paralleling breaker to the paralleling bus.
Fault: Bus Voltage Amplitude Mismatch- Phase A			
1	The phase A voltage of the bus does not match the generator	The voltage measured on the bus sensing for phase A does not match the voltage measured on phase A of the generator.	Verify the bus sensing wire for phase A is connected to phase A of the load side of the paralleling breaker and there are no breaks in the wire.
Fault: Bus Voltage Amplitude Mismatch- Phase B			
1	The phase B voltage of the bus does not match the generator	The voltage measured on the bus sensing for phase B does not match the voltage measured on phase B of the generator.	Verify the bus sensing wire for phase B is connected to phase B of the load side of the paralleling breaker and there are no breaks in the wire.

Step	Potential Cause	Explanation	Troubleshooting
Fault: Bus Voltage Amplitude Mismatch- Phase C			
1	The phase C voltage of the bus does not match the generator	The voltage measured on the bus sensing for phase C does not match the voltage measured on phase C of the generator.	Verify the bus sensing wire for phase C is connected to phase C of the load side of the paralleling breaker and there are no breaks in the wire.
Fault: Bus Voltage Amplitude Mismatch			
1	The bus metering is not connected correctly	The bus metering is not connected to the appropriate lugs of the load side of the paralleling breaker (but there is some voltage present).	Verify the bus sensing wire for all three phases is connected to the appropriate lugs on the load side of the paralleling breaker and there are no breaks in any of the wires.
2	The generator metering is not connected correctly	The generator metering is not connected to the output of the generator.	Verify the generator metering is sensed at the output of the generators. A common mistake is to connect the metering to the center tap voltages V7, V8, V9.
Fault: Phase Angle Mismatch			
1	All of the bus sensing wires are incorrectly connected	The bus sensing wires must be connected to phase A, phase B and phase C of the bus. If any two connections are reversed, the controller can detect the reversed connections. This fault will only occur if all three wires are incorrectly connected.	Verify the bus metering connections.
2	The phase connections on the paralleling breaker are inconsistent with the generator	The power leads from the generator to the paralleling circuit breaker must be connected consistently. Phase A from the generator must go to phase A of the line side of the paralleling (motor operated) breaker, phase B from the generator to phase B of the breaker, and phase C of the generator to phase C of the breaker.	Verify the output cable connections.
3	Generator sensing is connected incorrectly	The controller measurement leads are not connected to the appropriate output phases or the phases are incorrectly labeled.	Verify sensing leads from the controller are connected to the appropriate output leads from the generator. L1 should connect to phase A, L2 to phase B, L3 to phase C, L0 to neutral.
4	Breaker to bus wiring is inconsistent	In applications where the bus sensing is taken from a location other than the load side of the paralleling breaker, it is possible to connect the wiring incorrectly between the load side of the output breaker and the paralleling bus.	Verify cable connections from the paralleling breaker to the paralleling bus.
Fault: Bus Frequency Mismatch			
1	Abnormal condition	Bus frequency is not similar to generator frequency with breaker closed.	Verify bus metering is connected correctly. Reset the controller.
Fault: Bus Sensing Phases A and B are Reversed			
1	The bus sensing for phase A is connected to phase B of the paralleling bus and vice versa	Phase angle from generator to bus is about 180° and bus rotation is backwards.	Verify wiring between bus sensing inputs and load side of paralleling breaker.
2	The wiring between the generator and the paralleling breaker is incorrect	Phase angle from generator to bus is about 180° and bus rotation is backwards.	Verify wiring between generator and paralleling breaker.
3	The generator metering is not connected correctly	Phase angle from generator to bus is about 180° and bus rotation is backwards.	Verify metering connections on the generator. L1 should connect to the phase A output lead. L2 to phase B, L3 to phase C, L0 to neutral.
Fault: Bus Sensing Phases B and C are Reversed			
1	The bus sensing for phase B is connected to phase C of the paralleling bus and vice versa	Phase angle from generator to bus is about - 120° and bus rotation is backwards.	Verify wiring between bus sensing inputs and load side of paralleling breaker.
2	The wiring between the generator and the paralleling breaker is incorrect	Phase angle from generator to bus is about - 120° and bus rotation is backwards.	Verify wiring between generator and paralleling breaker.
3	The generator metering is not connected correctly	Phase angle from generator to bus is about - 120° and bus rotation is backwards.	Verify metering connections on the generator. L1 should connect to the phase A output lead. L2 to phase B, L3 to phase C, L0 to neutral.
Fault: Bus Sensing Phases C and A are Reversed			
1	The bus sensing for phase A is connected to phase C of the paralleling bus and vice versa	Phase angle from generator to bus is about 120° and bus rotation is backwards.	Verify wiring between bus sensing inputs and load side of paralleling breaker.

Step	Potential Cause	Explanation	Troubleshooting
2	The wiring between the generator and the paralleling breaker is incorrect	Phase angle from generator to bus is about 120° and bus rotation is backwards.	Verify wiring between generator and paralleling breaker.
3	The generator metering is not connected correctly	Phase angle from generator to bus is about 120° and bus rotation is backwards.	Verify metering connections on the generator. L1 should connect to the phase A output lead. L2 to phase B, L3 to phase C, L0 to neutral.
Fault: Bus Sensing Not Connected			
1	No wires connect the bus sensing on the generator to the load side of the paralleling breaker	Wiring not connected between load side of the paralleling breaker and the bus metering.	Verify that the bus sensing is connected.
2	No leads connect the generator output to the line side of the paralleling breaker	The leads connecting the output of the generator to the paralleling breaker are not connected.	Verify that the leads connecting the generator to the paralleling breaker are connected.
3	The line circuit breaker is open	The line circuit breaker (at the generator) is open, disconnecting the output from the generator from the line side of the paralleling breaker.	Verify that the line circuit breaker is closed.
Fault: Bus Sensing Connected to Generator Side of Breaker			
1	Bus metering is connected to the wrong side of the paralleling breaker	The controller sees the bus voltage always matches the generator voltage, even when the breaker contacts indicate that the breaker is open.	Verify the bus metering is connected on the load side of the paralleling breaker.
2	Breaker is closed and status feedback is not connected	The controller sees that the bus voltage always matches the generator voltage, even when the breaker contacts indicate that the breaker is open.	Verify the paralleling breaker control wiring is connected correctly and the status feedback is connected to an "A" contact.
Fault: Failure to Open			
1	Wiring between CB trip relay and trip coil is not connected	The CB trip relay is releasing, but the coil in the breaker is not energizing, hence the breaker is not opening.	Verify wiring to the trip coil (A4) is connected correctly.
2	CB trip relay is not receiving 24V power	The CB trip relay is releasing, but there is no voltage to apply to the trip coil. This is most likely to occur when the generator has a 12V battery and there is an external battery bank to operate the circuit breaker.	Verify the CB trip relay has a 24VDC supply which is common to the CB close relay and charge motor.

12.6 Troubleshooting When Running in AUTO

12.6.1 Faults Shown

Step	Potential Cause	Explanation	Troubleshooting
Fault: Generator Phase Rotation Mismatch			
1	This generator is wired with the opposite phase rotation of all the other generators on the paralleling bus	The controller has validated that the bus metering is accurate relative to this generator, if the bus phase rotation is backwards to the generator, the phase rotation must really be different.	Verify wiring between this generator and the paralleling breaker. It may be necessary to reverse two phases between the generator and the paralleling breaker and then to reverse the sensing at the bus to match. This generator should be started and closed to a dead bus again to validate the changes.
2	The wiring between the paralleling breaker and the paralleling bus is incorrectly connected (two phases are reversed)	Voltage from other generators comes into this generator as incorrect phase rotation because the wiring connections from the other generator to the paralleling bus are reversed, even though the rotation of the other generators is identical to the rotation of this generator.	Verify wiring between the paralleling breaker and the paralleling bus. It may be necessary to reverse the connection of two of the leads. This generator should be started and closed to a dead bus again to validate the changes.
3	The generator which is connected to the paralleling bus has the opposite phase rotation of this generator and all others	Voltage from the other generator comes into this generator as incorrect phase rotation because the wiring connections from the other generator to the paralleling bus are reversed, even though the rotation of the other generators is identical to the rotation of this generator.	Verify wiring between the paralleling breaker and the paralleling bus of the other generator. It may be necessary to reverse two phases between the paralleling breaker and the paralleling bus on the other generator. The other generator should be started and closed to a dead bus again to validate the changes.
Fault: Dead Bus Sensed When Live Bus Expected			
1	The wiring was not connected between the load side of the paralleling breaker for this generator and the paralleling bus	This generator controller observed accurate bus voltage when it closed the breaker, the other generator controller did the same, but the bus of this generator is not connected to the bus of the other generator. The other generator is energizing the load, this generator cannot energize the load as there is a disconnected wiring between this generator and the paralleling bus.	Verify wiring between the paralleling breaker and the paralleling bus of this generator.
2	The wiring was not connected between the load side of the paralleling breaker for the other generator and the paralleling bus	This generator controller observed accurate bus voltage when it closed the breaker, the other generator controller did the same, but the bus of this generator is not connected to the bus of the other generator. The other generator is not energizing the load because it is not connected to it—this generator may be able to energize the load, but there is no simple way of telling this without connecting the output of the other generator.	Verify wiring between the paralleling breaker and the paralleling bus of the other generator.
Fault: Bus Voltage Out of Spec			
1	The generators which are connected to the paralleling bus are overloaded	When the generators which are supplying a load are overloaded, their engine speed will decrease, resulting in a decrease in output voltage. Sometimes this decrease in output voltage is sufficient to allow the generators to recover.	Verify the load requirements are met by a single generator. If not, it may be necessary to connect several low priority loads to load shed outputs from the paralleling generators to avoid overloading a single generator.
2	Excessive cable lengths from generators to paralleling bus	Although a single generator can handle the load, the cables which connect the generator to the paralleling bus are too long or too small of gauge, resulting in insufficient bus voltage.	Increase wire size on the generator connection leads.
Fault: Bus Frequency Out of Spec			
1	The generators which are connected to the paralleling bus are overloaded	When the generators which are supplying a load are overloaded, their engine speed will decrease, resulting in a decrease in output voltage. Sometimes this decrease in output voltage is sufficient to allow the generators to recover.	Verify the load requirements are met by a single generator. If not, it may be necessary to connect several low priority loads to load shed outputs from the paralleling generators to avoid overloading a single generator.
Fault: Failure to Synchronize			
1	Varying load requirements drive generator frequency unstable	Heavy variations in the load on a generator will cause the speed of the generator to vary significantly. It can be difficult to synchronize with a generator with continuously changing frequency.	Adjustment of synchronizing dwell time or synchronizing gains may improve ability to synchronize.

Step	Potential Cause	Explanation	Troubleshooting
2	Fuel variations or other environmental factors cause the generator frequency regulation to suffer	When the frequency regulation is impeded by atmospheric conditions or fuel quality, the ability to synchronize may be affected. Not only is the bus varying more than normal, but it is more difficult for the generator to control speed while synching.	It may be necessary to adjust the synchronizing gains.
3	Different sized units or units of different fuel types	The factory synchronizing gains were calibrated for equal-sized units. The response of a large unit to a small one is slightly different than two small units. A diesel generator has significantly better frequency regulation than a natural gas generator.	It may be necessary to adjust the synchronizing gains.
Fault: Generator Voltage Average Line to Line: High Warning			
1	Metering calibration issue	All the generators on the paralleling bus attempt to control to the same voltage. If one has incorrect calibration, it may see this voltage as a much higher level than the other generators, resulting in a protective relay trip.	Verify the controller is measuring voltage accurately. If not, re-calibrate it.
2	Voltage drop on generator connection leads	If the generator is sourcing high current through too small of output leads, the voltage drop in these cables may require the generator to run at an increased voltage to supply the necessary current to the paralleling bus.	Install oversized connecting leads for the generator to minimize voltage drop between the generator and the paralleling bus.
3	Attempting to operate a generator in base-load mode while it is connected to a variable load	The speed bias and voltage bias control real and reactive load in base-load mode against a source with a nearly constant frequency and voltage (such as a utility source). If the generator is disconnected from the utility source, the speed and voltage will deviate to either extreme of the bias range, depending on the target load and the actual load.	Install contacts in series with the base-load mode input to the controller which are disconnected when the utility source is disconnected from the paralleling bus.
Fault: Generator Voltage Average Line to Line: Low Warning			
1	Metering calibration issue	All the generators on the paralleling bus attempt to control to the same voltage. If one has incorrect calibration, it may see this voltage as a much lower level than the other generators, resulting in a protective relay trip.	Verify the controller is measuring voltage accurately. If not, re-calibrate it.
2	Attempting to operate a generator in base-load mode while it is connected to a variable load	The speed bias and voltage bias control real and reactive load in base-load mode against a source with a nearly constant frequency and voltage (such as a utility source). If the generator is disconnected from the utility source, the speed and voltage will deviate to either extreme of the bias range, depending on the target load and the actual load.	Install contacts in series with the base-load mode input to the controller which are disconnected when the utility source is disconnected from the paralleling bus.
Fault: AC Frequency: High Warning			
1	Attempting to operate a generator in base-load mode while it is connected to a variable load	The speed bias and voltage bias control real and reactive load in base-load mode against a source with a nearly constant frequency and voltage (such as a utility source). If the generator is disconnected from the utility source, the speed and voltage will deviate to either extreme of the bias range, depending on the target load and the actual load.	Install contacts in series with the base-load mode input to the controller which are disconnected when the utility source is disconnected from the paralleling bus.
Fault: AC Frequency: Low Warning			
1	Attempting to operate a generator in base-load mode while it is connected to a variable load	The speed bias and voltage bias control real and reactive load in base-load mode against a source with a nearly constant frequency and voltage (such as a utility source). If the generator is disconnected from the utility source, the speed and voltage will deviate to either extreme of the bias range, depending on the target load and the actual load.	Install contacts in series with the base-load mode input to the controller which are disconnected when the utility source is disconnected from the paralleling bus.
Fault: Generator Total Real Power: High Warning			
1	Continuous overload	The generator breaker will trip to protect the generator from damage due to excessive loads.	Ensure that the load is low enough for a single generator to support it.
Fault: Generator Total Real Power: Low Warning			
1	Loss of fuel pressure	The generator breaker will trip to prevent generator operation. Otherwise, power could be absorbed from other generators causing potential damage to the fuel system by operating without lubrication.	Ensure that the generator has sufficient fuel to support load. Connect a fuel level sensor and place Generator Management in Fuel Level Equalization mode.
2	Quick ramp rate settings	The real power may overshoot when in a real power control situation such as base load or system control.	It may be necessary to adjust the load control gains.

Step	Potential Cause	Explanation	Troubleshooting
3	Different sized units or units of different fuel types.	The real power may overshoot when in a real power control situation such as a load ramp or a quickly changing customer load.	It may be necessary to adjust the kW load sharing gains.
4	Different engine speed adjust settings	Setting the Engine Speed Adjust parameter high on a generator will result in that generator providing more real power than the other generators. It is possible to drive the other generators offline in light loading conditions.	Set the engine speed adjustment similarly on all generators.
Fault: Generator Current Average: High Warning			
1	Excessive reactive load	The generator breaker will trip to prevent the generator from damage due to excessive stator current. Note, the controller also has a heat-model-based alternator protection algorithm (which will shut the generator down).	Ensure that the load is low enough for a single generator to support it.
Fault: Generator Total Reactive Power: Low Warning			
1	Different sized units	The reactive power may overshoot when in a power control situation such as a load ramp or a quickly changing customer load.	It may be necessary to adjust the kVAR load sharing gains.
2	Different automatic voltage regulator settings	Setting the Engine Speed Adjust parameter high on a generator will result in that generator providing more real power than the other generators. It is possible to drive the other generators offline in light loading conditions.	Set the voltage regulator average voltage adjustment to the same value on all connected generators.
3	Different voltage calibrations	Because each generator will attempt to match the target output voltage, generators with incorrect calibration may be targeting a different output voltage, thus generating or absorbing VARs.	Verify the controller is measuring voltage accurately. If not, re-calibrate.
4	Failure in voltage regulator or activator board	The generator breaker will trip to prevent the generator from absorbing VARs from the other generators. Providing power while absorbing VARs may cause that alternator to slip a pole—potentially damaging the rotor or crankshaft.	Verify the voltage regulator and activator are ok. Perform load tests to verify.
Fault: Generator Management Enabled: Erroneous Data Received Warning			
1	Two generators that are communicating on the network have different Order Selection modes	Generator management will not operate if any generators on the PGEN network have different Order Selection modes.	Adjust the Order Selection mode on any generator on the network to set the Order Selection mode in all controllers.
2	Two generators that are communicating on the network have different Stability delays	Generator management will not operate if any generators on the PGEN network have different Stability delays.	Adjust the Order Selection mode on any generator on the network to set the Stability delay in all controllers.
3	Two generators that are communicating on the network have different Redundancy Requirements	Generator management will not operate if any generators on the PGEN network have different Redundancy Requirements.	Adjust the Order Selection mode on any generator on the network to set the Redundancy Requirements in all controllers.
4	Two generators that are communicating on the network have different Maximum Run Time Hour Difference Thresholds	Generator management will not operate if any generators on the PGEN network have different Maximum Run Time Hour Difference Thresholds.	Adjust the Order Selection mode on any generator on the network to set the Maximum Run Time Hour Difference Threshold in all controllers.
5	Two generators that are communicating on the network have different Maximum Fuel Level Difference Thresholds	Generator management will not operate if any generators on the PGEN network have different Maximum Fuel Level Difference Thresholds.	Adjust the Order Selection mode on any generator on the network to set the Maximum Fuel Level Difference Threshold in all controllers.

12.7 Generator Management Setup

Generator Management starts and stops generators based on the requirements of the load. The order in which the generators are started or stopped is determined according to one of the following:

- **Manual/Fixed**—The starting order of the generators is determined at the time of configuration (It is adjustable at a later time through the menu on the controller display). The controllers automatically negotiate to ensure that no two units have the same order number - setting the order number on one controller which conflicts with the order of another controller will cause the two controllers to exchange order numbers.
- **Run Time**—The starting order of the generators is determined based on the run time hours on the generators. The generator with the most run time hours will stop first and start last. Generators which are already running are allowed to continue to run until their run time hours exceed stopped the run time hours of a stopped generator by an adjustable threshold.
- **Fuel Level**—The starting order of the generators is determined based on the fuel level remaining in the supply tanks for the generators. This option is only valid if the generators have indication of fuel level.

Typical Applications for Manual Order Selection Mode:

- Units of various sizes are operated in a prime power application and the generator management settings are optimized for minimal fuel consumption.
- An older unit is intended to accumulate most of the run time hours because it is scheduled for replacement soon.
- Some units are quieter or located more remotely than other units, making them more desirable to operate.
- A unit is in need of maintenance but is still operational—this unit can be used if necessary, but should not operate more than is necessary.

Typical Applications for Run Time Order Selection Mode:

- Normal Standby Power systems without special requirements.
- Multiple generator system where all generators are of identical size and age, where the generator run time should remain essentially identical.
- Prime power applications where the generators are all of similar size.

Typical Applications for Fuel Level Order Selection Mode:

- Prime power applications where the generators have individual fuel tanks and have level indication on the fuel tanks.
- Standby applications where the generators have individual fuel tanks and have level indication on the fuel tanks.

12.7.1 Manual Order Selection Setup

The Generator Management order should be configured so that the generator which is preferred to run has the lowest order. If the controllers are communicating over PGEN, changing the order on one generator will cause the order of the other generators to rearrange to accommodate the changed order of the one generator.

The Manual Start order can be changed through the menu on the controller display at any time after the commissioning of the site is complete.

12.7.2 Run Time Order Selection Setup

When Run Time Order Selection Mode is selected, Generator Management will automatically adjust the order of the connected generators based on their run time hours. The order of each should reflect the relative run time of that generator if all the generators are running or all the generators are stopped. The generator with the lowest run time will be started first.

Because a generator will not be accumulating run time when it is stopped, it is necessary to add a stability threshold to each generator which is not running or the generators will start 12 minutes after they stop (0.2 hours). This threshold is called the Generator Management Run Time Threshold.

Configure the threshold to allow the generators to equalize run time without starting and stopping each generator unnecessarily. The factory default is 12.0 hours—one of the running generators will have to have 12.0 fewer hours than the generator that is stopped before the generator will start. Once that generator is online, the generator with the most run time hours will stop.

12.7.3 Fuel Level Selection Setup

When Run Time Order Selection Mode is selected, Generator Management will automatically adjust the order of the connected generators based on their fuel level. The order of each should reflect the relative fuel level of that generator if all the generators are running or all the generators are stopped. The generator with the most fuel will be started first.

Because a generator will not be consuming fuel when it is stopped, it is necessary to add a stability threshold to each generator which is not running or the generators will start as soon as 1% of the running generator's fuel is consumed. This threshold is called the Generator Management Fuel Level Threshold.

Configure the threshold to allow the generators to equalize run time without starting and stopping each generator unnecessarily. The factory default is 10% of fuel level—one of the running generators will have to have 10% less fuel than the generator that is stopped before the generator will start. Once that generator is online, the generator with the least fuel will stop.

12.7.4 Paralleling Parameters

Generator Management Enabled

Set this to true if Generator Management is desired for this application

Generator Management Stability Delay

The Stability Delay is intended to ensure that all loads have returned to their normal demand before Generator Management considers stopping a generator.

All generators will be told to run until the Stability Delay has expired.

Generator Management Minimum Gens Online

The Minimum Gens Online parameter will allow the system to be configured to require at least 1 generator or to require at least 2 generators. If set to 2 Generators, the system will always keep one more generator online than is required.

Note:

The default setting is 2.

Generator Management Min Load Shed Priority

The Minimum Load Shed Priority is the priority which has to be online to allow Generator management to become active (start the stability timer). This parameter should match the maximum load shed priority that is connected to an actual load.

The default setting is 6 (load priority 6 must be online before generator management becomes active).

Generator Start Percentage

The Generator Start Percentage is the percent load on the running generators above which this generator will begin timing for the Generator Start Delay.

The default setting is 80%, this means that the other generators will have more than 80% load on them before this generator will begin timing for the Generator Start Delay.

Generator Stop Percentage

The Generator Stop Percentage is the percent load on the other running generators below which this generator will begin timing for the Generator Stop Delay. The Stop percentage is calculated as if this generator was not running (the percent load on the remaining generators).

The default setting is 60%, this means that the total load on all the running generators is low enough that all the running generators other than this one will have less than 60% load on them if they were supporting the load. The order 1 generator does not stop.

Generator Start kW

The Generator Start kW is calculated based on the Start kW's of each of the generators with a lower order number and the Start percentage for this generator. The Start kW is the total load on the bus above which this generator will begin timing for the Generator Start Delay.

Generator Stop kW

The Generator Stop kW is calculated based on the Stop kW's of each of the generators with a lower order number and the Stop percentage for this generator. The Stop kW is the total load on the bus below which this generator will begin timing for the Generator Stop Delay.

Generator Start Delay

The Generator Start Delay is the time delay in seconds for this generator to start. Because the start delay is actually a curve based on the difference between the actual kW and the start kW of this generator, the start delay is actually the time for the generator to start with a 10% overload.

Generator Stop Delay

The Generator Stop Delay is the time delay in seconds for this generator to stop. Because the stop delay is actually a curve based on the difference between the actual kW and the stop kW of this generator, the start delay is actually the time for the generator to start with 10% less load than the stop kW.

12.8 Load Add/Shed Configuration

The Load Add/Shed configuration (also known as load control) is intended to remove non-critical loads from the generator in the event of a condition where the generator capacity is insufficient to support the load. This allows the critical loads to receive power until the load decreases or the capacity increases.

12.8.1 Load Add/Shed Setup

Generator Maximum Percent Capacity

This is the maximum load on the generator which the Load Add/Shed will automatically allow. If the load exceeds this level, no additional loads will be added until the load decreases below this level. The time to add a load increases as the load approaches this level.

Generator Overloaded Percent

This is the maximum load that the generator will support before it begins to shed load. The time to shed a load decreases as the load on the generator increases.

Load Priority Configuration

The Load Shed priorities are events which can be assigned to programmable IO. Priorities 1 and 2 are defaulted to RDO outputs 3 and 4. The priorities can be configured to outputs on the 14 relay dry contact kit or each controller on the network can be given consecutive assignments to the existing IO.

For Example:

Generator #1—Load Shed Priority 1 and Load Shed Priority 2

Generator #2—Load Shed Priority 3 and Load Shed Priority 4

Generator #3—Load Shed Priority 5 and Load Shed Priority 6

Note:

The load control outputs behave similarly on each of the generators. If an output is configured for Load Shed Priority 1 on all generators, they will all shed and add at the same time.

Note:

The advantage of setting a few load shed outputs on each controller is that if one generator has the battery removed for service, the load control outputs on the other controllers are still able to shed loads (allowing the system to shed non-critical loads and continue supplying critical loads with power). The priorities that are shed may be more important than the priorities that are controlled by the disconnected generator but at least the critical loads will not lose power due to an overload condition.

Appendix A. Generator Selection and Wattage Requirements

Consider total wattage requirements (lights, motors, appliances) when selecting a generator set or when sizing wattage usage in which available space and construction limit the size of the generator set.

Motors

When figuring generator set capacity requirements for loads that include electric motors, consider the high current demanded by the motors during startup. The inrush or starting current is typically 2- 3 times higher than that required when the motor reaches normal operating speed. Allow reserve for inrush demands plus other loads which could be on the line as the electric motor starts. Use **Figure 111** as a guide when selecting generator set capacity requirements involving motor loads.

Motor HP	Starting (Inrush) Watts	Running Watts
1/4	750	330
1/3	1000	400
1/2	1500	600
3/4	2000	750
1	3300	1100
2	4000	2000
3	5000	3000

Figure 111 Motor Requirements

Lighting

To calculate lighting load, add the wattage of each generator set-operated lamp. Note that not all of the lights or lamps are on the generator set AC circuit; some are DC powered by a 12-volt battery. Make sure the calculated total wattage includes only lights actually on the generator set AC circuit.

Air Conditioners

The starting characteristics of air conditioners vary greatly; one 12,000 Btu unit has, for example, lower starting requirements than a 10,000 Btu unit of another variety. When using only one unit, there is usually no starting problem, provided the lighting and appliance load is not too high when starting the unit.

Simultaneous starting of two air conditioning units, however, can present problems if the generator set capacity is marginal. Because of the variation in starting characteristics among air conditioners, this publication makes no statements regarding multiple-motor starting capabilities of the generator set covered. Consider delayed starting or use of easy-starting devices on air conditioner units whenever simultaneously starting more than one motor.

See **Figure 112** for typical air conditioner requirements. Information will vary with manufacturer.

Appliances

Generator sets often furnish AC for appliances such as TV, stereo, electric water heater, etc. With the exception of the resistance-type loads such as the water heater, requirements for appliances are usually low. Do not overlook such loads when figuring total requirements. Allow reserve capacity for anticipated appliance loads to avoid overloading a generator set.

Air Conditioner Size (Btu/Hr.)									
	7,000		9,000		12,000		16,000		24,000
Voltage	115	230	115	230	115	230	115	230	230
Full load amps	9.3	4.8	9.9	5.0	11.8	6.3	16.3	8.0	11.6
Rated load amps	7.7	4.0	7.0	3.5	8.9	4.8	13.0	6.2	10.2
Locked rotor amps	34.0	20.0	40.0	20.0	50.0	31.0	75.0	36.0	56.0
Starting (inrush) watts	3910	4600	4600	4600	5750	7130	8630	8280	12,900
Running watts	886	920	805	805	1020	1100	1500	1430	2350

Figure 112 Typical Marine Air Conditioner Requirements, 60Hz

Appendix B. Abbreviations

A, amp	ampere	blk. htr.	block heater	DAC	digital to analog converter
ABDC	after bottom dead center	BMEP	brake mean effective pressure	dB	decibel
AC	alternating current	bps	bits per second	dB(A)	decibel (A weighted)
A/D	analog to digital	br.	Brass	DC	direct current
ADC	advanced digital control; analog to digital converter	BTDC	before top dead center	DCR	direct current resistance
adj.	adjust, adjustment	Btu	British thermal unit	DEF	diesel exhaust fluid
ADV	advertising dimensional drawing	Btu/min.	British thermal units per minute	deg., °	degree
AGM	absorbent glass mat	C	Celsius, centigrade	dept.	department
Ah	amp-hour	cal.	Calorie	dia.	Diameter
AHWT	anticipatory high water temperature	CAN	controller area network	DI/EO	dual inlet/end outlet
AISI	American Iron and Steel Institute	CARB	California Air Resources Board	DIN	Deutsches Institut fur Normung e. V. (also Deutsche Industrie Normenausschuss)
ALOP	anticipatory low oil pressure	CAT5	Category 5 (network cable)	DIP	dual inline package
alt.	alternator	CB	circuit breaker	DPDT	double-pole, double-throw
Al	aluminum	CC	crank cycle	DPST	double-pole, single-throw
ANSI	American National Standards Institute (formerly American Standards Association, ASA)	cc	cubic centimeter	DS	disconnect switch
AO	anticipatory only	CCA	cold cranking amps	DVR	digital voltage regulator
APDC	Air Pollution Control District	ccw.	Counterclockwise	E ² PROM, EEPROM	electrically-erasable programmable read-only memory
API	American Petroleum Institute	CEC	Canadian Electrical Code	E, emer.	emergency (power source)
approx.	approximate, approximately	cert.	certificate, certification, certified	EATS	Exhaust Aftertreatment System
APU	Auxiliary Power Unit	cfh	cubic feet per hour	ECM	electronic control module, engine control module
AQMD	Air Quality Management District	cfm	cubic feet per minute	EDI	electronic data interchange
AR	as required, as requested	CG	center of gravity	EFR	emergency frequency relay
AS	as supplied, as stated, as suggested	CID	cubic inch displacement	e.g.	for example (exempli gratia)
ASE	American Society of Engineers	CL	centerline	EG	electronic governor
ASME	American Society of Mechanical Engineers	cm	centimeter	EGSA	Electrical Generating Systems Association
assy.	Assembly	CMOS	complementary metal oxide substrate (semiconductor)	EIA	Electronic Industries Association
ASTM	American Society for Testing Materials	com	communications (port)	EI/EO	end inlet/end outlet
ATDC	after top dead center	coml	commercial	EMI	electromagnetic interference
ATS	automatic transfer switch	Coml/Rec	Commercial/Recreational	emiss.	Emission
auto.	Automatic	conn.	Connection	eng.	Engine
aux.	auxiliary	cont.	continued	EPA	Environmental Protection Agency
avg.	average	CPVC	chlorinated polyvinyl chloride	EPS	emergency power system
AVR	automatic voltage regulator	crit.	Critical	ER	emergency relay
AWG	American Wire Gauge	CRM	Common Rail Manifold	ES	engineering special, engineered special
AWM	appliance wiring material	CSA	Canadian Standards Association		
bat.	Battery	CT	current transformer	ESD	electrostatic discharge
BBDC	before bottom dead center	Cu	copper	est.	estimated
BC	battery charger, battery charging	cUL	Canadian Underwriter's Laboratories	E-Stop	emergency stop
BCA	battery charging alternator	cu. in.	cubic inch	etc.	et cetera (and so forth)
BCI	Battery Council International	cw.	Clockwise	exh.	exhaust
BDC	before dead center	CWC	city water-cooled	ext.	external
BHP	brake horsepower	cyl.	Cylinder	F	Fahrenheit, female
blk.	black (paint color), block (engine)	D/A	digital to analog	FDS	Fluid Dosing System

FHM	flat head machine (screw)	in.	inch	Lpm	liters per minute
fl. oz.	fluid ounce	in. H ₂ O	inches of water	LOP	low oil pressure
flex.	flexible	in. Hg	inches of mercury	LP	liquefied petroleum
freq.	frequency	in. Lb.	inch pounds	LPG	liquefied petroleum gas
FS	full scale	Inc.	incorporated	LS	left side
ft.	foot, feet	ind.	Industrial	L _{wa}	sound power level, A weighted
ft. lb.	foot pounds (torque)	int.	internal	LWL	low water level
ft./min.	feet per minute	int./ext.	internal/external	LWT	low water temperature
ftp	file transfer protocol	I/O	input/output	m	meter, milli (1/1000)
g	gram	IP	internet protocol	M	mega (10 ⁶ when used with SI units), male
ga.	gauge (meters, wire size)	ISO	International Organization for Standardization	m ³	cubic meter
gal.	gallon	J	joule	m ³ /hr.	cubic meters per hour
gen.	generator	JIS	Japanese Industry Standard	m ³ /min.	cubic meters per minute
genset	generator set	k	kilo (1000)	mA	milliampere
GFI	ground fault interrupter	K	kelvin	man.	manual
GND, 	ground	kA	kiloampere	max.	maximum
gov.	governor	KB	kilobyte (2 ¹⁰ bytes)	MB	megabyte (2 ²⁰ bytes)
gph	gallons per hour	KBus	Kohler communication protocol	MCCB	molded-case circuit breaker
gpm	gallons per minute	kg	kilogram	MCM	one thousand circular mils
gr.	grade, gross	kg/cm ²	kilograms per square centimeter	meggar	megohmmeter
GRD	equipment ground	kgm	kilogram-meter	MHz	megahertz
gr. wt.	gross weight	kg/m ³	kilograms per cubic meter	mi.	mile
H x W x D	height by width by depth	kHz	kilohertz	mil	one one-thousandth of an inch
HC	hex cap	kJ	kilojoule	min.	minimum, minute
HCHT	high cylinder head temperature	km	kilometer	misc.	miscellaneous
HD	heavy duty	kOhm, kΩ	kilo-ohm	MJ	megajoule
HET	high exhaust temp., high engine temp.	kPa	kilopascal	mJ	millijoule
hex	hexagon	kph	kilometers per hour	mm	millimeter
Hg	mercury (element)	kV	kilovolt	mOhm, mΩ	milliohm
HH	hex head	kVA	kilovolt ampere	MOhm, MΩ	megohm
HHC	hex head cap	kVAR	kilovolt ampere reactive	MOV	metal oxide varistor
HP	horsepower	kW	kilowatt	MPa	megapascal
hr.	hour	kWh	kilowatt-hour	mpg	miles per gallon
HS	heat shrink	kWm	kilowatt mechanical	mph	miles per hour
hsg.	Housing	kWth	kilowatt-thermal	MS	military standard
HVAC	heating, ventilation, and air conditioning	L	liter	ms	millisecond
HWT	high water temperature	LAN	local area network	m/sec.	meters per second
Hz	hertz (cycles per second)	L x W x H	length by width by height	mtg.	mounting
IBC	International Building Code	lb.	pound, pounds	MTU	Motoren-und Turbinen-Union
IC	integrated circuit	lbm/ft ³	pounds mass per cubic feet	MW	megawatt
ID	inside diameter, identification	LCB	line circuit breaker	mW	milliwatt
IEC	International Electrotechnical Commission	LCD	liquid crystal display	μF	microfarad
IEEE	Institute of Electrical and Electronics Engineers	LED	light emitting diode	μF	microfarad
IMS	improved motor starting	Lph	liters per hour		

N, norm.	normal (power source)	PMG	permanent magnet generator	SCR	silicon controlled rectifier (electrical), selective catalytic reduction (exhaust emissions)
NA	not available, not applicable	pot	potentiometer, potential	s, sec.	second
nat. gas	natural gas	ppm	parts per million	SI	<i>Système international d'unités</i> , International System of Units
NBS	National Bureau of Standards	PROM	programmable read-only memory	SI/EO	side in/end out
NC	normally closed	psi	pounds per square inch	sil.	Silencer
NEC	National Electrical Code	psig	pounds per square inch gauge	SMTP	simple mail transfer protocol
NEMA	National Electrical Manufacturers Association	pt.	pint	SN	serial number
NiCd	nickel cadmium	PTC	positive temperature coefficient	SNMP	simple network management protocol
NFPA	National Fire Protection Association	PTO	power takeoff	SPDT	single-pole, double-throw
Nm	newton meter	PVC	polyvinyl chloride	SPST	single-pole, single-throw
NO	normally open	PVC	polyvinyl chloride	spec	specification
no., nos.	number, numbers	PWM	pulse width modulated, pulse width modulation	specs	specification(s)
NPS	National Pipe, Straight	qt.	quart, quarts	sq.	square
NPSC	National Pipe, Straight-coupling	qty.	quantity	sq. cm	square centimeter
NPT	National Standard taper pipe thread per general use	R	replacement (emergency) power source	sq. in.	square inch
NPTF	National Pipe, Taper-Fine	rad.	radiator, radius	SMS	short message service
NR	not required, normal relay	RAM	random access memory	SS	stainless steel
Ns	nanosecond	RDO	relay driver output	std.	standard
OC	overcrank	ref.	reference	stl.	Steel
OD	outside diameter	rem.	Remote	tach.	Tachometer
OEM	original equipment manufacturer	Res/Co ml	Residential/Commercial	TB	terminal block
OF	overfrequency	RFI	radio frequency interference	TCP	transmission control protocol
opt.	option, optional	RH	round head	TD	time delay
OS	oversize, overspeed	RHM	round head machine (screw)	TDC	top dead center
OSHA	Occupational Safety and Health Administration	rly.	Relay	TDEC	time delay engine cooldown
OSHPD	Office of Statewide Health Planning and Development (California)	rms	root mean square	TDEN	time delay emergency to normal
OV	overvoltage	rnd.	Round	TDES	time delay engine start
oz.	ounce	RO	read only	TDNE	time delay normal to emergency
p., pp.	page, pages	ROM	read only memory	TDOE	time delay off to emergency
PC	personal computer	rot.	rotate, rotating	TDON	time delay off to normal
PCB	printed circuit board	rpm	revolutions per minute	temp.	temperature
pF	picofarad	RS	right side	term.	Terminal
PF	power factor	RTDs	resistance temperature detectors	THD	total harmonic distortion
ph., ø	phase	RTU	remote terminal unit	TIF	telephone influence factor
PHC	Phillips® head Crimptiter (screw)	RTV	room temperature vulcanization	tol.	Tolerance
PHH	Phillips® hex head (screw)	RW	read/write	turbo.	Turbocharger
PHM	pan head machine (screw)	SAE	Society of Automotive Engineers	typ.	typical (same in multiple locations)
PLC	programmable logic control	scfm	standard cubic feet per minute	UF	underfrequency

UHF	ultrahigh frequency
UIF	user interface
UL	Underwriter's Laboratories, Inc.
UNC	unified coarse thread (was NC)
UNF	unified fine thread (was NF)
univ.	universal
URL	uniform resource locator (web address)
US	undersize, underspeed
UV	ultraviolet, undervoltage
V	volt
VAC	volts alternating current
VAR	voltampere reactive
VDC	volts direct current
VFD	vacuum fluorescent display
VGA	video graphics adapter
VHF	very high frequency
W	watt
WCR	withstand and closing rating
w/	with
WO	write only
w/o	without
wt.	weight
xfmr	transformer

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Original Instructions (English)

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