HD CONSTRUCTION EQUIPMENT

950106-068012EN

Installation Guide

MARINE ENGINE

PREFACE

- **General Information**

  This installation instruction is designed as a guide for the proper installation of HD Construction Equipment marine diesel engines and to create conditions for faultless operation of the entire system and to prevent installation related malfunctions and possible consequential damage to the engine.

- **Scope**

  This installation instruction applies to all HD Construction Equipment engines for marine propulsion and marine generator.

- **Warranty**

  Warranty claims against HD Construction Equipment Marine Engines will be accepted only if this installation instruction has been complied with.

  If any modification to the engine installation intended by HD Construction Equipment is planned, HD Construction Equipment must be informed in writing, and a new inspection may necessary.

  We reserve the right to make technical modifications in the course of further development.

- **Validity**

  HD Construction Equipment reserves the right to make changes at any time, without notice, in specifications and models and also to discontinue models. The right is also reserved to change any specifications or parts at any time without noticing any obligation to equip same on models manufactured prior to date of such change.

  The continuing accuracy of this manual cannot be guaranteed.

  All illustrations used in this manual may not depict actual models or equipment and are intended as representative views for reference only.

- **Marine Engine Recommendation on Applications**
  - The engine must be able to achieve rated engine speed when operated under fully loaded conditions; Secondary drive loads must be considered engine horse power which could be available to drive the primary load. Therefore any such parasitic load requirements must be deducted when sizing an engine for the primary load.
  - The engine must be used in accordance with the application guidelines for that particular rating; It is important to choose the proper engine rating to provide the optimum performance in a given application. Ratings below show HD Construction Equipment marine engine guidelines on applications.

(1) Heavy duty

- Operation hours : Unlimited per year
- Average load application : Up to 90%
- Percentages of time at full load : Up to 80%
- Typical gear box ratio : 2.5 ~ 6

(Application: Fishing trawler, Tug boat, Pushing vessel, Cago boat, Freighter, Ferry)

(2) Medium duty

- Operation hours : Up to 3,000 hr per year
- Average load application : Up to 70%
- Percentages of time at full load : Up to 30%, 4 hrs per 12 hour operation period
- Typical gear box ratio : 2 ~ 3.5

(Application: Fishing boat, Pilot boat, Escort boat, Passenger boat, Ferry, Cruising Vessel)

(3) Light duty

- Operation hours : Up to 1,000hr per year
- Average load application : Up to 50%
- Percentages of time at full load : Up to 20%, 2hrs per 12 hour operation period
- Typical gear box ratio : 1 ~ 2.5

(Application: Fishing boat, Pilot boat, Escort boat, Passenger boat, Ferry, Cruising Vessel)

- **Other Country Regulation**

Other country may apply additional internal regulation. Please follow their appropriate advice.

Korea	: KR = Korean Resister of Shipping
Sweden	: Navigation Office
Finland	: Navigation Office
Norway	: DNV = Det Norske Veritas
USA	: ABS = American Bureau of shipping
Indonesia	: BKI = Biro Klasifikasi Indonesia
USA	: NMMA = National Marine Manufacturers Association
England	: LR = Lloyds Register of Shipping
France	: BV = Bureau Veritas
Germany	: GL = Germanisher Lloyd
Italy	: RINA = Regislro Italiano Navale
Bulgaria	: BKP = Bulgarian Register of Shipping
China	: CCS = China Classification Society
China Rep.(Taiwan)	: CR = China Corporation Register of Shipping
Spain	: FN = Fidenavis
Croatia	: CRS = Croatian Register of shipping
India	: IRS = Indian Register of Shipping
Japan	: NK = Nippon Kaiji Kyokai
Poland	: PRS = Polski Register Statkow
Portugal	: RP = Rinave Portuguesa
Rumania	: RNR = Registrul Naval Roman
Russia	: MRS = Russian Maritime Register of Sipping
Turkey	: TL = Turk Loydu Vakfi

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HD Construction Equipment

CONTENTS

1. Engine Room

When installing the engine, ensure that there is sufficient space for regular maintenance work and possible engine overhaul after prolonged periods of operation. It must be possible to carry out the following jobs on engine and gearbox without obstruction;

Removing heat exchanger and inter-cooler for cleaning

- Exchanging starter, alternator and water pump
- Filling up with fuel, oil and coolant
- Checking oil and coolant level
- Changing fuel, oil and air filter
- Setting valves, re-tightening cylinder head bolts
- Draining oil and coolant
- Re-tightening and exchanging V - belts
- Maintenance and exchange of battery
- Exchanging injection nozzles
- Changing the sea water pump impeller
- Changing the reduction gear

1.1. Engine Room Ventilation

Calculation of the air requirements for the dissipation of convection and radiation heat can be simplified the following formula:

$$\dot{m} = \frac{\dot{Q} \times 1{,}000}{C_p \times \Delta t}$$

where

$\dot{m}$ Air mass flow rate in kg/h

$\dot{Q}$ Convection and radiation in MJ/h

C_p Specific heat capacity of air = 1 kJ/(kg x degree)

Δt Difference in temperature between heated waste air and cold intake air in degrees Celsius

In order to obtain the air volume flow (m^3/h) the air mass flow (kg/h) must be divided by the air density, which depends on the temperature.

Air density as a function of the temperature at the air pressure of 0.98 kg/cm^2 (1,000 mbar).

Temperature in	Density in kg/m^3
0	1.28
10	1.23
20	1.19
30	1.15
40	1.11
50	1.08

The before-mentioned formula is based on the assumption that the engine room is a heat-tight system, i.e. for the sake of simplicity it is assumed that no thermal energy whatever is dissipated through the hull to the ambient air or water.

In practice, however, such heat losses are likely to occur and depend on the following factors:

- Size and surface area of the engine room
- Difference in temperature between the engine room and the ambient air
- Hull material (thermal conductivity) and hull thickness
- Heat dissipation via pipes (e.g. exhaust pipes)

This heat transfer is therefore hard to estimate qualitatively.

NOTE:
The difference of engine room and ambient air temperature (△t) would be better below than 15°C, but should not exceed maximum 20°C.
△t = (Air temperature of engine room) - (Ambient temperature)

<Conversion Table of Physical Units >

- Temperature

t (degree Celsius)	= T (Kelvin) - 273
T (Kelvin)	= t (degree Celsius) + 273
t (degree Fahrenheit)	= 1.8 x t (degree Celsius) + 32

- Pressure

1 kilo-Pascal (kPa)	= 10 millibar (mbar)
1 hecto-Pascal (hPa)	= 1 millibar (mbar)

- Energy flow

$$\text{Mega - Joule/hour (MJ/h)} \times \frac{1{,}000}{4.187} = \text{Kilocalories/hour (kcal/h)}$$

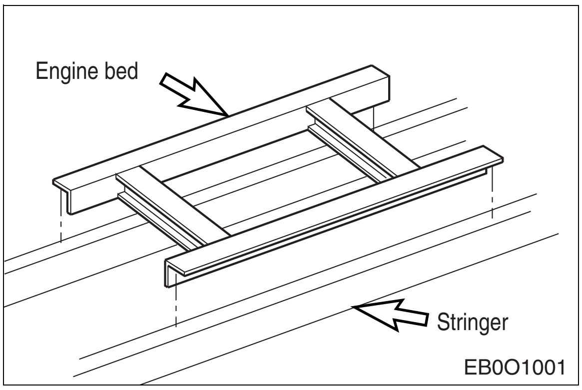
$$\text{Mega - Joule/hour (MJ/h)} \times \frac{1}{3.6} = \text{Kilowatt (kW)}$$

1.2. Engine Foundation

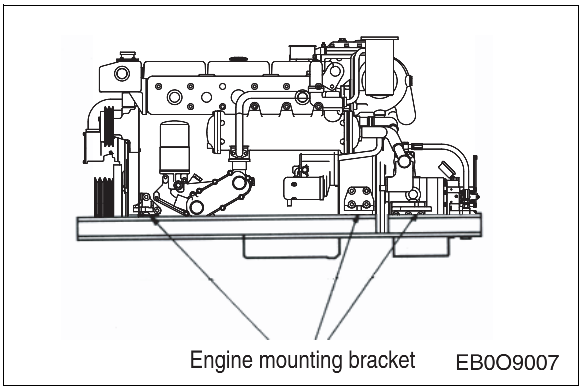
Requirements for the engine foundation are as following;

- The foundation in the vessel should be able to take up propeller thrust in both directions (ahead & astern) and transmit it on to the hull.
- The weight of the drive system as well as all dynamic forces that occur in rough seas must be safely taken up.
- The torsion of the hull owing to rough seas and the load status must not be transferred to the engine. The engine foundation is to be connected to the hull on an area as large as possible.

- Transverse cross bracing on the engine bed and stringers should be used to prevent lateral engine movement on solid mounted systems.



- In order to properly support the weight of the engine and marine gear, a six-point mounting system is recommended on all HD Construction Equipment marine engines.
  When using a six-point mounting system, the engine should be aligned using the mounts at the front and at the marine gear at first. Once the alignment is complete, the next flywheel housing mounts should be added.

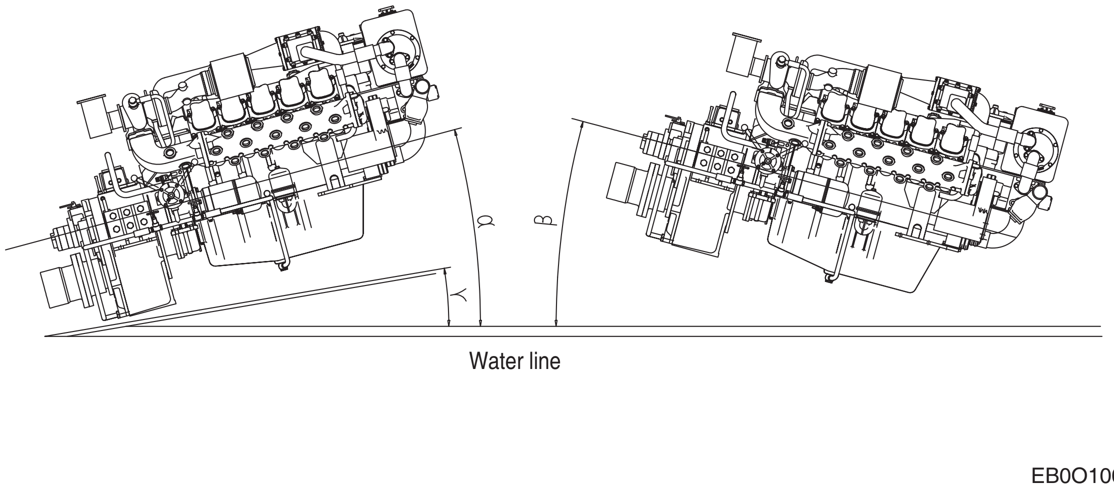


1.3. Max. Permissible Engine Inclination

The installation angle of the engine is an important factor in the construction of the sub-frame.

When the engine is to be installed in longitudinal direction, The maximum permissible inclination must not be exceeded. The maximum permissible inclination is defined as the largest angle that occurs in driving operation, ie, installation inclination plus the ship's maximum trim angle.

The maximum installation angle of the engine is the maximum permissible inclination angle (α) of the boat less the angle of the maximum trim (γ) while the vessel is in motion. ie, the maximum installation angle of the engine is (α - γ).



α = Max. permissible vessel inclination angle; angle towards the flywheel end

β = Angle towards the non flywheel end

γ = Trim of the vessel

<The Maximum Angles of Inclination for the Various Engine are Shown in Below Table>

Engine Model	Max. Oil Pan Permissible Angle of Inclination to the Rear: (α)	Max. Angle of Engine Installation Inclination: (β)
L066TI	30°	5˚
L136/L136T	17°	5˚
L136TI/L086TI	17°	5˚
MD196T/L126TI/4L126TI	17°	5˚
V158TI/4V158TI	17°	5˚
V180TI	25°	5˚
V222TI/4V222TI/4V222C	25°	5˚
4L126/4L086/4L066	17°	5˚
4AD12/4AD08/4AD06	17°	5˚

NOTE: Angle β

The angle of 5˚ toward the non-flywheel and must occur only while the vessel is in motion.

If the installation angle of the engine is greater than that listed upper, the engine may occur any engine damage. That is, connecting rods begin to dip into the oil in oil pan. So, this may also cause high oil consumption, low power and the breather gas increasing and more smokes.
We recommend the engine installation angle to install below 6 degree for HD Construction Equipment marine engines.

1.4. Power Rating

Diesel engines are to be so designed that when running at rated speed their rated power can be delivered as a continuous power. Continuous power means the net brake power which an engine is capable of delivering continusously between the maintenance intervals stated by the engine manufacturer.
To determine the power of all engines used on board ships with an unlimited range of service, the following ambient conditions are to be used:

Classification Societies	Barometric Pressure	Temperatures		Relative Humidity
		Intake Air	Seawater/ Charge Air Coolant	
DNV	According to ISO3046/1			
BV	1,000 mbar	45°C	32°C	60%
GL	1,000 mbar	45°C	32°C	60%
LR	1,000 mbar	45°C	32°C	60%
RINA Propuision	1,000 mbar	15°C	15°C	-
RINA Aux. Service	1,000 mbar	45°C	30°C	-
KR	1,000 mbar	45°C	32°C	60%

Engine driving generators are to be capable of developing 10% for a short period. (15 minutes)

1.5. Inclinations

All components and systems shall be capable to operate in the following trim and pitch positions.

	Angle of inclination 1)													
Installation	ABS		BV		DNV		GL		LR		RINA		KR	
	Stat.	Dyn.	Stat.	Dyn.	Stat.	Dyn.	Stat.	Dyn.	Stat.	Dyn.	Stat.	Dyn.	Stat.	Dyn.
Main and Aux Athwartships	15	22.5	15	22.5	15	22.5	15	22.5	15	22.5	15	22.5	15	22.5
For - and - aft	5	7.5	5	7.5	5	7.5	5	7.5	5	7.5	5	7.5	5	7.5
Emergency Athwartships 3)	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
For - and - aft	10	10	10	10	10	10	10	10	10	10	10	10	10	10

1) Athwartships and for - and - aft inclinations may occur simultaneously.
2) Where the length of the ship exceeds 100 m, the fore - and - aft static angle of inclination may be taken as: (500)°/L where L = length of ship (m).
3) In ships for the carrige of liquefied gases and of chemicals the emergency power supply must also remain operable with the ship flooded to a final athwartships inclination up to maximum 30°.

2. Marine Engine Installation and Vibration Standards

2.1. Purpose and Scope

This standard is intended to define requirements to be followed during marine engine installation process and standardize several factors, including engine vibration, to be considered during marine engine installation in order to eliminate any problem occurred by improper installation practice and ensure the engine performance quality ultimately.

2.2. Related Standard/Specifications and Regulations (References)

2.2.1. Referenced Standard/Regulation

ISO 8528-9

2.2.2. Reference Materials

- Volvo Penta installation guide
- MAN installation guide
- HD Construction Equipment marine engine installation manual

2.3. Term Definition

2.3.1. Marine Gear (Reducer)

As the engine speed (RPM) is too high to be transferred to the propeller directly, this device is used to reduce the speed to a proper level.

2.3.2. Stuffing Box

A stuffing box is used to prevent leakage of steam or water between sliding parts, such as pistons and plungers. In this system, it prevents sea water from entering through the propeller shaft.

2.3.3. Chock Liner

It is fit between the engine mounting bracket and the hull bed frame to maintain a certain clearance.

2.3.4. Fix Liner

It is a thin steel plate welded to the engine bed frame. It is welded to the bed frame surface to which the mounting bracket is to be attached, followed by milled finishing to enhance adhesion.

2.3.5. Chock Fast

It is a type of resin that is set in a mould.

2.3.6. FRP

The FRP (Fiber Reinforced Plastics) is a composite material made of unsaturated polyester matrix reinforced with fibers.

It features formability and corrosion resistance of plastic, light weight and high strength which make it suitable for helmets, bath tubs, boats and more.

Also, its production cost is relatively low and it is widely used for small sized ships.

2.3.7. Stern Tube

It is a cylindrical tube fit to the position where the shaft is protruded out of the hull.

2.3.8. Hull

It is a generic term for main body and upper structure of a boat or ship.

2.3.9. Keel

It is a long framework along the centerline of the hull from stem to stern.

2.3.10. Jack Bolt

This bolt is used to widen the gap between flanges. In this system, it widens the gap between the engine mounting bracket and bed frame.

2.3.11. Reamer Bolt

This bolt is fitted into a hole that is smoothened using a reamer, and it is also smoothened for tight fit of its axial portion to the hole.

2.3.12. Lignum-Vitae, Cutlass, Thordon

Lignumvitae (for Domestic Model)
(Hard Wood from South America
Coated with Paraffin)

Cutlass (for Export)
(Rubber Covered by Shell)

Thordon
(Synthetic Resin)

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2.4. Installation Methods (Input/Procedure/Output)

2.4.1. Overview

Correct installation of a marine engine is important as much as the structure of a hull. Improper installation not only can affect engine performance and service life directly, but also it can result in an accident. Incorrect or incomplete installation of an engine can result in damage to the main bearing and even to the crankshaft. Once engine installation is completed, it is permanent except under special circumstances. If an engine is not installed correctly with caution, it may experience chronic failure and even cause a fatal accident. To prevent such problems, the following basic guidelines should be followed during installation.

2.4.2. Marine Engine Installation

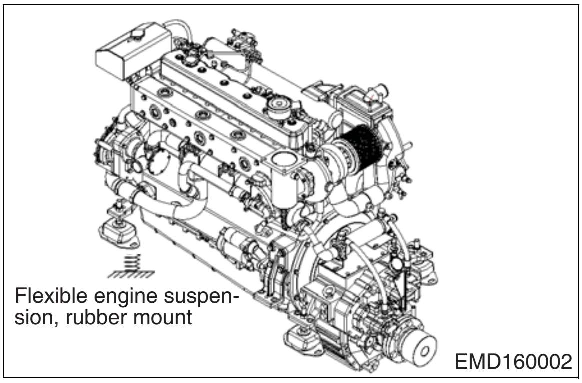
1) Engine installation

There are two methods for engine installation. The flexible mounting method uses a rubber mount between the engine and engine bed while the rigid mounting method fixes the engine and engine bed directly.

a) Flexible mounting

The flexible mounting method (rubber mount) can be used for low gear reduction ratio.

At high gear reduction ratio, torsional force and propeller's thrust can be applied to the rubber mount excessively. In order for the rubber mount to reduce engine vibration effectively, the engine bed should have enough strength.



Also, the engine bed and the engine mounting bracket should be maintained parallel within 2 mm of clearance to avoid unbalance due to abnormal deformation which can be occurred while installing the rubber mount. Abnormal deformation of the rubber mount can increase vibration level and shorten its service life.

The flexible mount should be supported at four positions, two on the front side and the other two on the marine gear. The rubber mount applied to the marine gear should be selected properly to withstand thrust of the propeller.

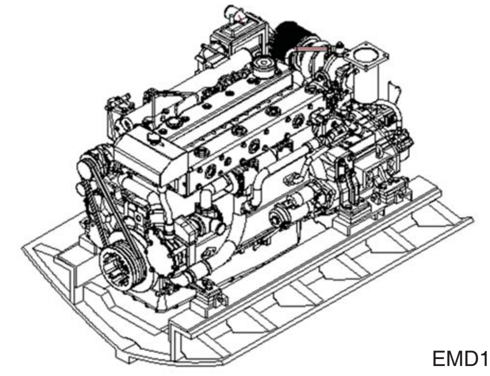
CAUTION:

Never use the flexible mount to adjust the tilted engine bed. As the rubber mount is compressed during its installation, the engine should be left for 24 hours after installation before adjusting its height so that it can be seated by itself. Incorrect use of the rubber mount can cause abnormal vibration and even can damage engine components.

CAUTION:
With the flexible mount installed, other related components should be connected flexibly as well. The propeller shaft should be equipped with the flexible stuffing box or flexible shaft coupling, and the engine's fuel line, exhaust line and cooling line should be flexible as well.

b) Rigid mounting

The rigid mounting method is commonly used especially for commercial purpose and large vessels. For the rigid mounting method, an iron or steel shim or chock liner is fitted between the engine mounting bracket and engine bed and this assembly is bolted to the engine bed for tight adhesion. Therefore, the adhesion level of the engine mount, chock liner and mounting liner, and the strength of the engine bed are critical in this method. If these factors are not within the specifications, abnormal deformation in the connection related to engine mounting can be occurred, resulting in excessive vibration or deformation and leading to shortened service life of the engine and hull.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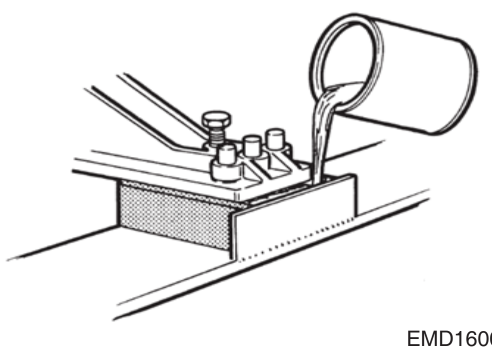
While shims or chock liners are generally used for engine support, a proper approved moulding compound (chockfast for example) can be used as well. However, in this case, the engine alignment should be already completed before application.

With the rigid mounting method, a flexible shaft coupling may be used between the propeller shaft and engine to prevent their misalignment due to deformation of the hull structure.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CAUTION:
Only rigid mounting is described in this manual as it is widely used in FRP ships.

c) Matching mount and propeller shaft

A stainless propeller shaft can be manufactured in various diameter sizes.

The dimensions of a shaft are determined based on the engine power, gear ratio and its material.

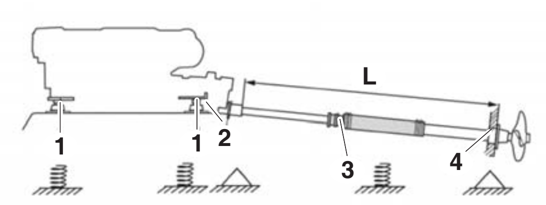
CAUTION:
A flexible shaft coupling should not be used with a flexible stuffing box.
This can cause a vibration problem.

The following three combinations are recommended:

(1) Flexible Mount + Flexible Shaft Seal

In this case, a flexible shaft coupling should not be used.

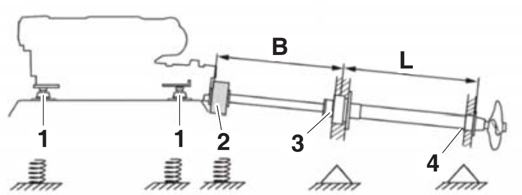
Number	Name
1	Fixed Engine Mounting
2	Fixed Shaft Coupling
3	Flexible Mounted Shaft Seal
4	Water Lubricated Stern Bearing
L	Maximum Distance Between Support Points



- L: Contact the shaft manufacturer.

(2) Flexible Mount + Fixed Shaft Seal

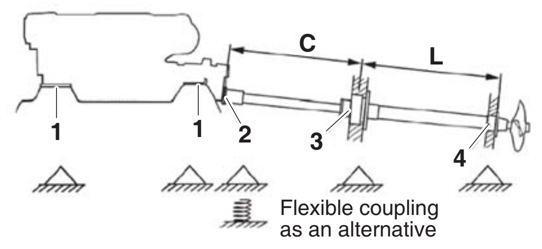
Number	Name
1	Flexible Engine Mount
2	Fixed Shaft Coupling
3	Fixed Front Stern Bearing and Shaft Seal
4	Water Lubricated Stern Bearing
L	Maximum Distance Between Support Points
B	Distance Between Marine Gear Flange and Support Point



- L: Contact the shaft manufacturer.
- B: The recommended minimum value is 6 ~ 10 x shaft diameter.
- For the maximum values of B and L, contact the manufacturers.

(3) Flexible Mount + Fixed Shaft Seal

Number	Name
1	Fixed Engine Mounting
2	Fixed Shaft Coupling (Flexible Coupling Can be Used As Well)
3	Fixed Front Stern Bearing and Shaft Seal
4	Water Lubricated Stern Bearing
L	Maximum Distance Between Support Points
C	Distance Between Marine Gear Flange and Support Point



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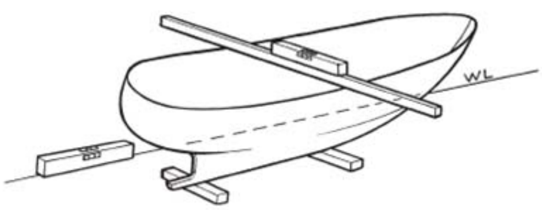
- L: Contact the shaft manufacturer.
- The minimum value for C is 10 ~ 14 x shaft diameter.
- For the maximum value of C, contact the manufacturer.

2.4.3. Preparation for Engine Installation

1) Adjusting ship alignment

Before installing the engine, align the hull in the horizontal direction to facilitate installation process. Calculate the waterline of the hull and set it parallel to the ground.

A water level can be helpful. When manufacturing the hull bottom, make sure that the engine bed surface is parallel to it and it is exactly on the centerline of the propeller. A guide sleeve with the same diameter of the propeller shaft can be inserted to the stern tube for easier alignment of the engine bed.



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2) Basic mounting tips

As load should be distributed as much as possible, the engine bed should be designed to be robust in all directions. To block noise and vibration as much as possible, the engine bed, including the rib (crossmember) should be fixed to the hull with the maximum possible scope.

When installing the engine, align the propeller according to its specification, then align the propeller shaft with the marine gear output coupling before securing the engine mounting.

(1) Engine bed

The location of the engine bed is determined based on the location of the propeller shaft.

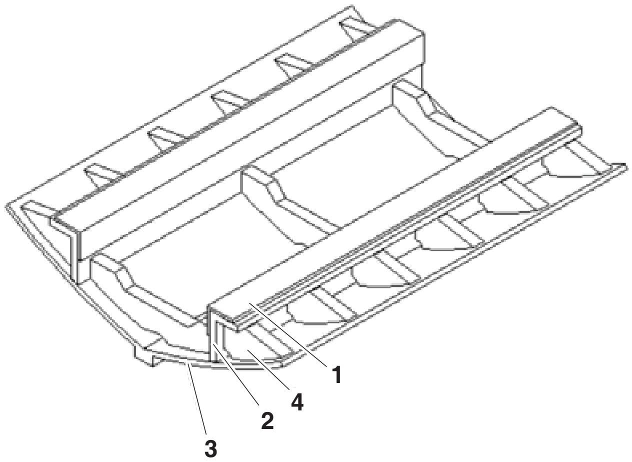
As the propeller shaft position is determined by the propeller position, comprehensive examination should be performed. Measure the engine bed position with caution and drill holes to the stern so that the stern bearings can be inserted into them with some margin. The engine bed should be robust enough to absorb engine torque, propeller's thrust and moving mass that are occurred while sailing in a wild sea. To prevent excessive height of the engine bed, its design height should include the thickness of the shim and chock liner. Also, there should be a path to pump out water around the engine bed with a bilge pump. When designing the engine bed, there should be enough space below the engine for engine movement. If possible, the engine bed should be designed to be lifted separately with the marine gear and flexible coupling disengaged.

When designing the engine bed, the engine and boat design drawings should be utilized to check the engine's footprint and height on the engine bed and mounting position related to the propeller shaft.

The engine height is different between the flexible mounting type and the rigid mounting type, and the inclination of the engine bed is determined according to the one of the propeller shaft.

The engine bed can be divided into the steel bed and FRP bed. The FRP bed is fixed to the hull and acts as a base structure to support the engine. It should be securely fixed to the hull with the rib (cross member) to prevent bending and torsion by deformation and to absorb vibration from the engine effectively.

The steel bed is bolted onto the FRP bed securely.



1. Steel bed: thickness 15 ~ 20 mm
2. FRP steel
3. Hull
4. Rib

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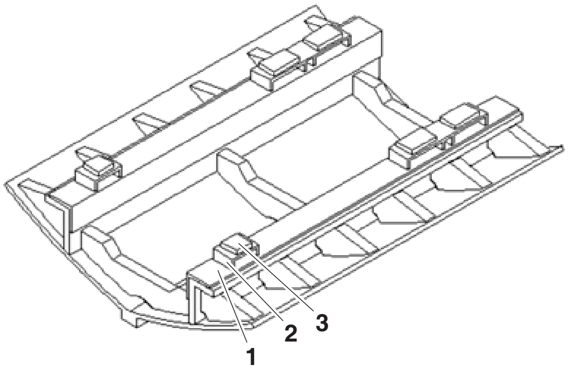
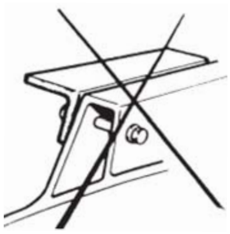
(2) Bracket and fixed liner

After placing the engine onto the bed, install the bracket and fixed liner to align and secure the shaft center and face center. The bracket should be welded to the steel bed securely to prevent deformation while the fixed liner is installed to the position where the engine mounting bracket will be installed to. The fixed liner is "fixed" to the bracket by welding and its top should be plane by milled finishing. The bracket is installed onto the steel bed and it should maintain robustness enough to withstand dynamic load and movement of the engine during operation.



1. Steel bed: thickness 15 ~ 20 mm
2. Bracket: thickness 15 ~ 20 mm
3. Fixed liner



If the bracket is fixed to the side of the bed as shown in the left figure, the structure is not robust enough to support the engine and it cannot absorb vibration from the engine effectively.

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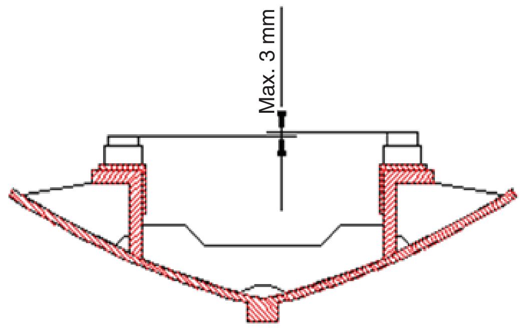
(3) Required flatness for rigid mounting

The maximum allowable difference of the height between the left and right sides of the engine mounting surface is 3 mm.

When using the rigid mounting method for engine installation, it is important that the dimensions of the engine bed are maintained the same. In other words, when sailing in a wild sea, anchoring or setting sail, deformation is occurred in the hull.



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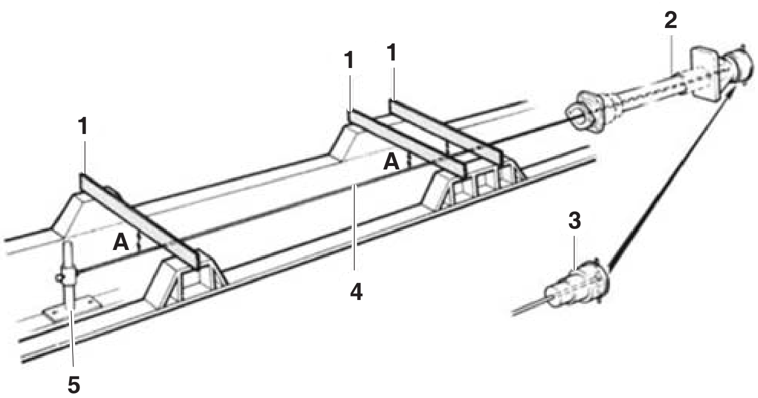
To keep the flatness below the allowable limit under these conditions, torsional rigidity and bending rigidity of the engine bed are critical.

The difference of the height (A) between the stern tube center and the bracket or fixed liner top in the engine mounting surface direction should be within 2 mm. Make sure that the it is horizontal to the hull using the measuring point.



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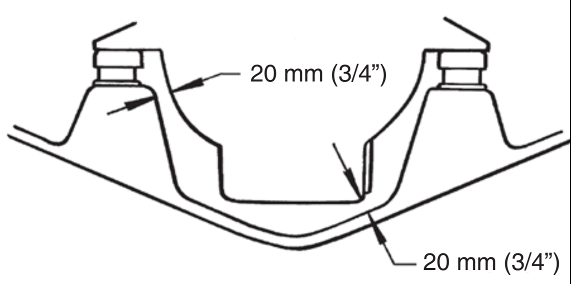
(4) FRP hull

The engine bed should be designed and manufactured to be absolutely robust in the lateral, longitudinal and vertical directions in order to distribute load to the hull as much as possible. The engine bed is generally made in a box type structure.



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The engine bed, including the rib (cross member), should be fixed to the hull securely to block noise and vibration as much as possible.

The engine bed can be engaged to the hull with precise measurements after manufacturing it separately, or it can be made directly onto the hull. It is important to use several layers of fiberglass to connect the engine bed to the hull widely.

When designing the engine compartment, make sure that there is enough space for the flywheel housing and oil tanks on the bottom and side. There should be at least 20 mm of clearance.

3) Engine alignment

Alignment of a marine engine has certain procedures: determining the allowable engine mounting angle and propeller position, aligning the shaft center and face center of the propeller flange and marine gear flange, and securing the engine.

Alignment of an marine engine involves two steps: alignment at the dock and alignment in the sea.

After initial alignment is performed at the dock and the ship is launched, the alignment state should be confirmed again in 24 hours.

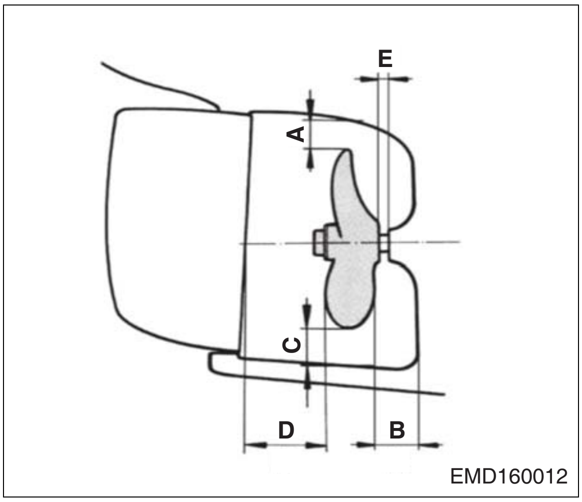
As the hull is deformed at the dock, the ship should be launched to restore the hull form to its original shape before aligning the shaft center.

(1) Determining propeller position

The position of the propeller has a direct effect not only to the engine alignment state, but also the sailing speed, noise, vibration and propeller's service life.

If the outside diameter of the propeller and the clearance from the stern form are out of the specifications, water (shock wave) propelled from the rotating propeller hits the bottom of the hull. This water shock wave generates noise and vibration, leading to cavitation in the hull and abnormal vibration in the engine.

Most ships have 10 to 15% of the propeller outside diameter as the clearance.



A = 0.10 ~ 0.15 x propeller diameter

B = 0.15 x propeller diameter

C = 0.10 x propeller diameter

D = 0.08 x propeller diameter

E = approximately propeller shaft diameter

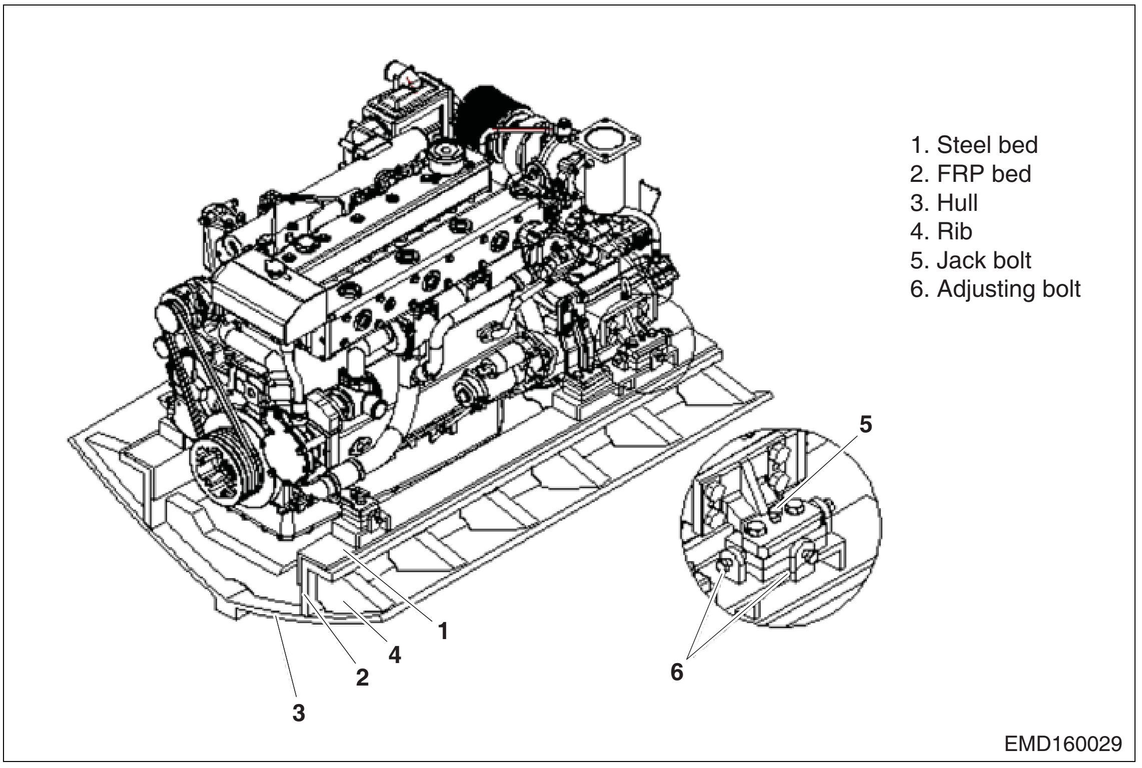
(2) How to align shaft center

Position the engine with the propeller flange and marine gear flange facing at each other.

Use the adjusting bolt (6) and jack bolt (5) to align the engine and propeller shaft roughly.

Install the adjusting bolt (6) and jack bolt (5) to the engine front and marine gear as illustrated.

Make the final alignment, referring to the description on the shaft center measurement in the next section.



(3) How to measure shaft center

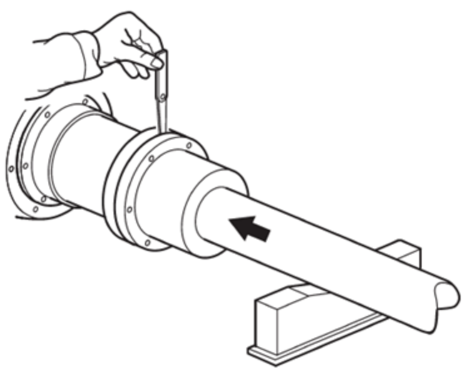
After engine bed and propeller shaft installation is completed and other preparation work is done, install the engine and marine gear. When measuring the shaft center, the propeller shaft should be supported without sag and it should be secured tightly so that it is not pushed over the intended limit even in the shaft direction. Initial alignment of the engine can be performed either on the dock or in the sea. However, for the final alignment, the ship should be left on the sea at least 24 hours so that its form is restored to the original state.

There are two methods for alignment as follows:

Method 1

Check that the propeller shaft flanges are parallel as shown in the figure above. Move the flanges together so that the guide is engaged between the propeller shaft flanges. Also, make sure that the flanges are parallel so a 0.1 mm feeler gauge cannot be fitted into a gap at any point between the flanges while applying force onto the flanges together. Then, turn the flanges 90°, 180°and 270° to check their parallel state at these three positions.

The maximum permissible gap in the method 1 is 0.1 mm.



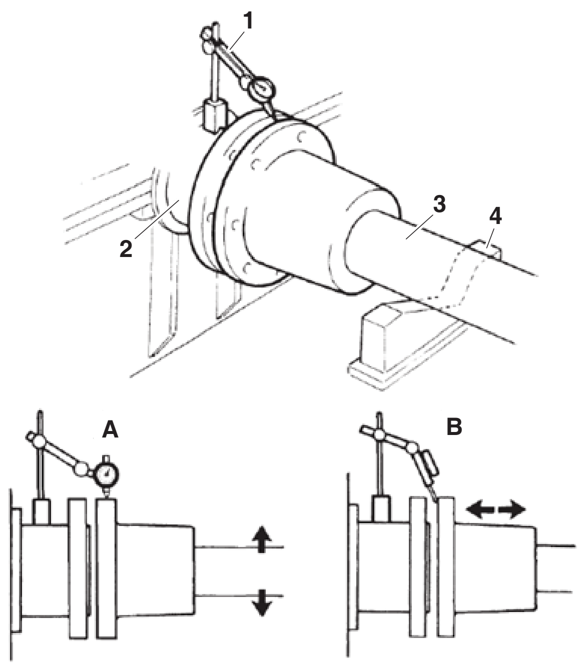
EMD160014

CAUTION:

Perform the overall inspection to confirm that the flanges are applying pressure to each other. When the engine is installed onto the rubber mount, its alignment should be performed same for the rigid mounting type.

Method 2

This method is generally more accurate, but it needs enough space to fix a dial gauge to the marine gear flange and turn the flange.



1. Dia Indicator with Magnetic Foot
2. Flange on Marine Gear
3. Propeller Shaft
4. Support

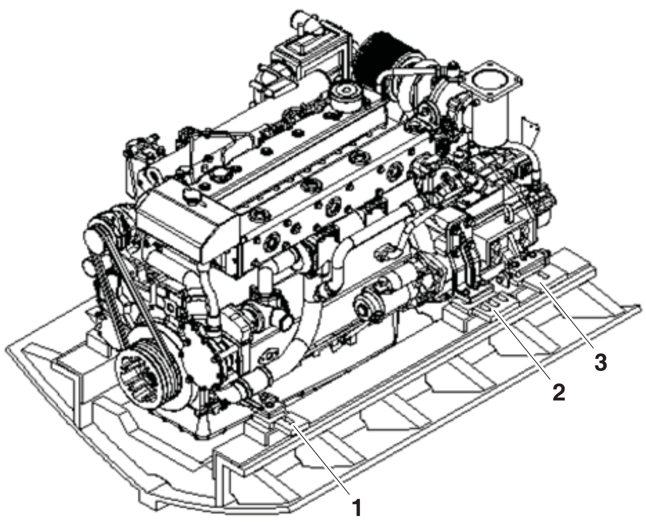
A. Checking Deviation in Circumferential Direction (Shaft Center)
B. Checking Deviation of Contact Surface (Face Center)

EMD160030

The flange should be checked using a dial gauge as shown in the figure above.
The propeller shaft should be pushed back for approx. 10 mm and should be centered and supported properly without sag. Also, it should be fixed in the axial direction.
Turn the marine gear flange and measure the first radial deviation as A.
After repositioning the marine gear, use the rocker gauge for the flange mating surface to measure the axial deviation as B.
The allowable maximum deviation (TIR: Total indicator range) for these two deviations is 0.1 mm.

CAUTION:
After the shaft center is checked at the dock initially and the ship is launched, it should be checked again in 24 hours.
As the hull is deformed at the dock, the ship should be launched to restore the hull form to its original shape before aligning the shaft center.

(4) Seating engine
This process is to ensure stable seating of the engine onto the engine bed by fitting a shim or chock liner between the engine mounting bracket and fixed liner after aligning the shaft center and face center between the engine and propeller according to the specifications.
Its purpose is to prevent vibration and movement of the engine during navigation so utmost care should be taken for this process.

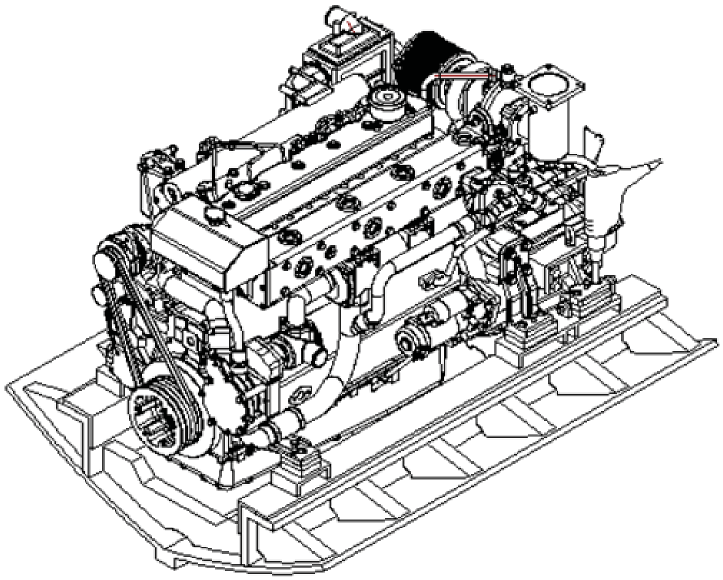


1. Engine Front Chock Liner
2. Engine Rear Chock Liner
3. Marine Gear Chock Liner

EMD160019

The shim or chock liner should be milled or polished to the precise size for good contact to the surface when performing the final alignment of the engine with the propeller shaft.
Its contact area should be at least 80% to absorb vibration from the engine effectively.
It should be made of iron or steel, not soft material such as aluminum and copper.

(5) Drilling engine mounting holes



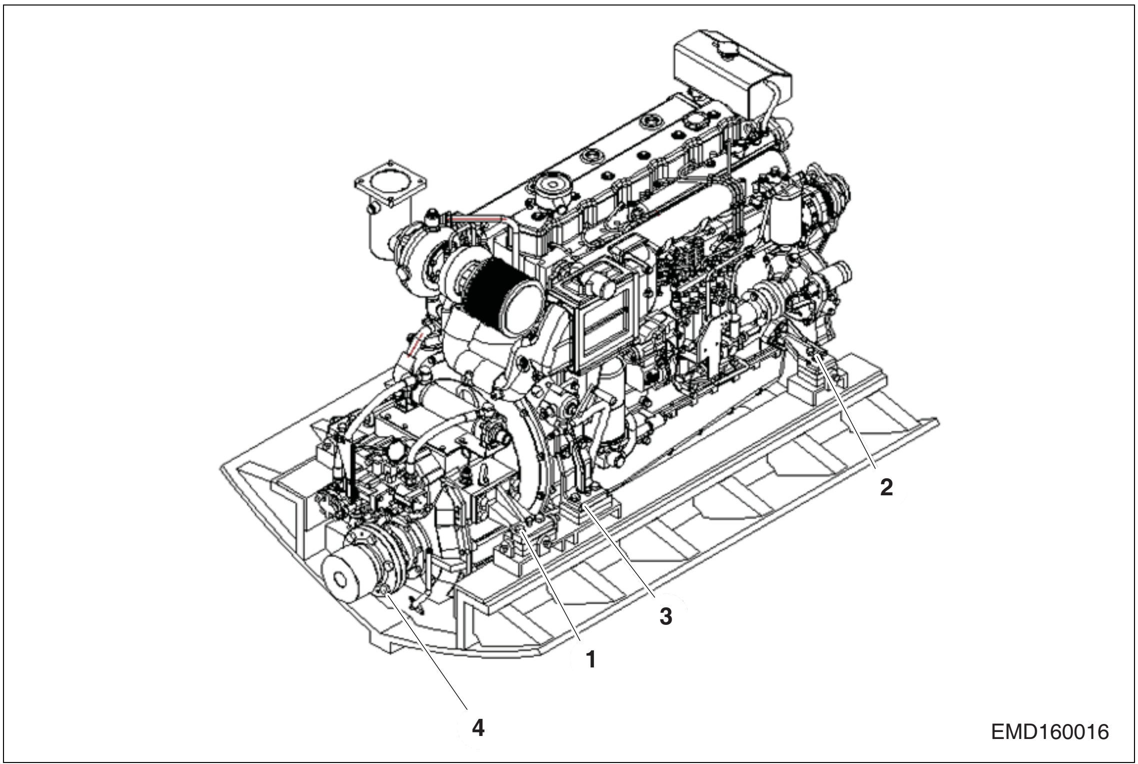
EMD160020

This process is to fix the engine onto the engine bed after confirming the engine alignment status. It is important as it has direct influence to proper distribution of the engine's dynamic load and propeller's thrust and engine bed's absorption performance of engine's vibration during operation. Align the chock liner, fixed liner and engine mounting bracket and drill the engine mounting holes into them simultaneously, referring to the holes on the bracket. It is possible to drill holes onto the engine front and rear mounts after measured on the engine bed. However, holes should be drilled simultaneously on the marine gear side and should be reamed for reamer bolts. As the marine gear mount receives thrust from the propeller, it should be fixed securely to prevent any movement by thrust.

HD Construction Equipment's specifications for mounting bolt holes are as follows:

- In-line engine : Ø17
- V-type engine : Engine front and rear Ø17, Marine gear Ø26 H7 reamer hole

(6) Fixing engine



To fix the engine, fix (1) marine gear mount, (2) engine front mount, (3) engine rear mount and (4) propeller coupling in order as shown in the figure.

As the marine gear mount receives thrust from the propeller, it should be fixed securely with reamer bolts to prevent any movement. Then, fix other sections according to the installation procedures. As the engine rear mount is a critical section, check the contact state of the chock liner and shim again before fixing it.

If fixing the engine rear mount by excessive force, the engine cylinder block can be deformed, leading to deformation of the crankshaft. This can result in serious problems such as increased engine vibration and shortened engine service life.

HD Construction Equipment's specifications for mounting bolts are as follows:

- In-line engine : M16 8.8T, tightening torque 20 kg.m
- V type engine : engine front and rear mounts M16 8.8T, tightening torque 20 kg.m
  Marine gear M24_Ø26 reamer bolt 8.8T, tightening torque 74 kg.m

(7) Maintenance

A Lignum-vitae bearing (main material: wood), and a Thordon or Cutlass bearing(main material: rubber) are used as the propeller shaft bearing for the marine engine. Therefore, these kinds of bearings experience wear and deformation eventually while the hull is also deformed due to environments and other external factors.

Due to these conditions, the shaft center is changed, so periodic inspection and adjustment are required to ensure stable performance and durability of the engine.

2.5. Marine Engine Vibration Standard

2.5.1. Overview

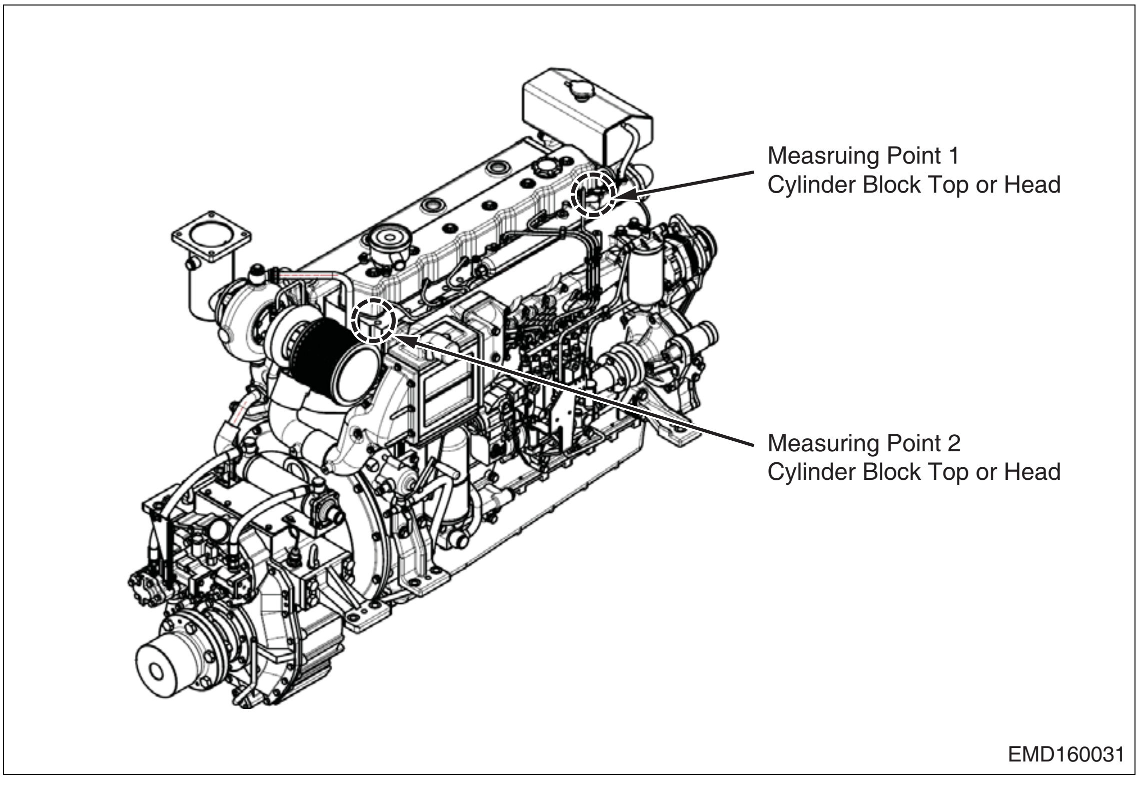
Correct installation of a marine engine is important as much as the structure of a hull. Improper installation not only can affect engine performance and service life directly, but also it can result in an accident. Once engine installation is completed, it is permanent except under special circumstances. If an engine is not installed correctly with caution, it may experience chronic failure and even cause a fatal accident. Once the engine is installed, it is hard to tell if it is correctly installed with naked eyes. Therefore, the installation state should be indirectly checked by measuring vibration of the engine.

2.5.2 .Measuring vibration

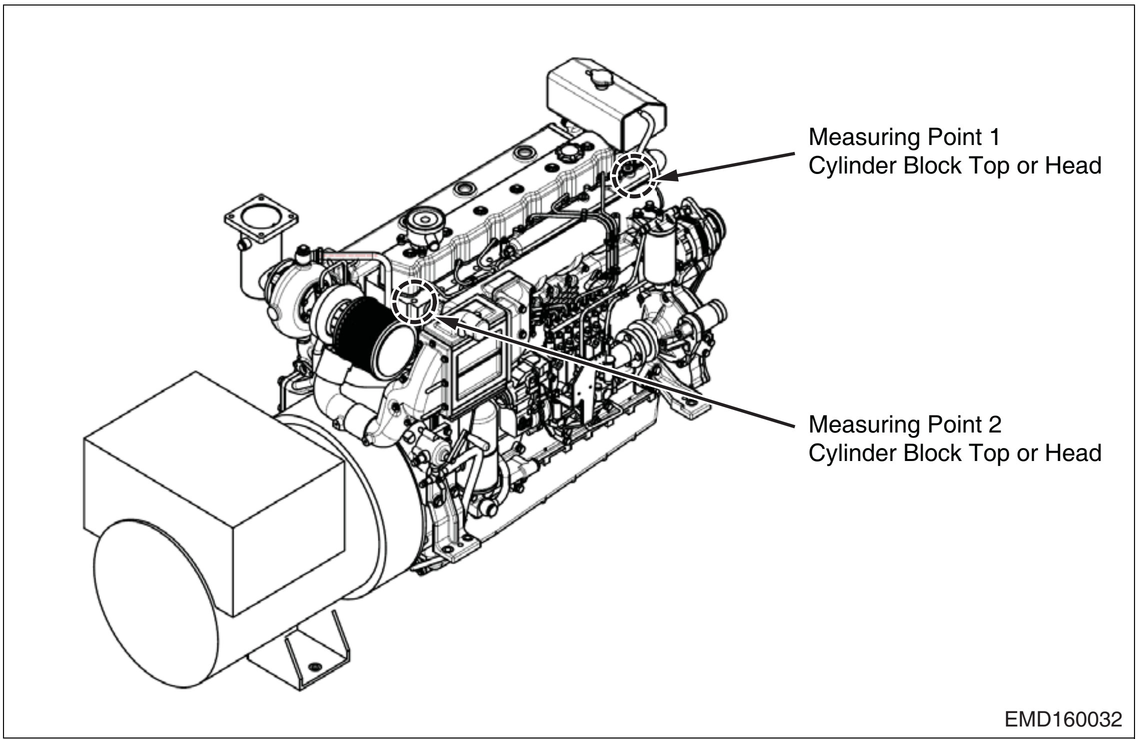
1) Attaching vibration measuring device

To measure vibration, a measuring device should be attached to the engine. Attach the measuring device to the position marked in the following figure. There are two front and rear measuring points: top right section of the cylinder head or cylinder block.

(1) Main engine's measuring point



(2) Generator engine's measuring point



2) How to measure vibration

After attaching the measuring device, perform measurement as follows:

(1) For the main engine, take measurement in waters where a straight course can be maintained.

(2) Starting engine: After starting the engine, warm it up sufficiently and ensure safety before measurement.

(3) Measuring vibration: Operate the measuring device to measure the vibration value.

- Measurement section: 0 ~ 200 Hz
- Measurement load: main engine - measuring at 75%, 90% and 100% of rated RPM
  Auxiliary engine (generator set): measuring at 75%, 90% and 100% of rated RPM
- Measurement unit: m/s^2

(4) Recording vibration value: Write down the measured data onto the attached marine engine vibration measurement report.

If the measuring device measures RMS (Root mean square) values, multiply the measured RMS value by $\sqrt{2}$ to obtain the peak value.

3) Evaluating measured data

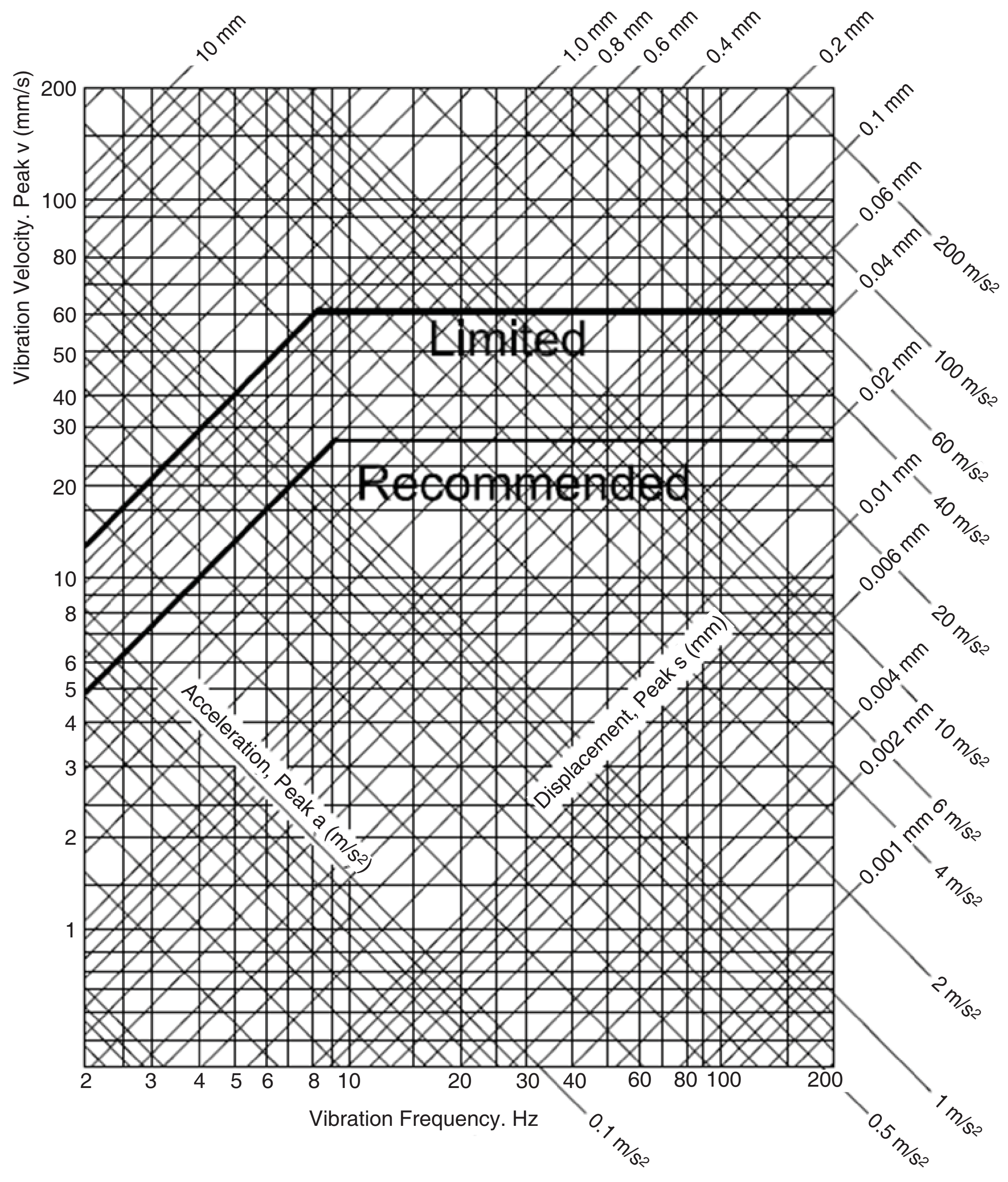
Vibration control standard

The HD Construction Equipment marine engine's vibration control standard is based on ISO 8528-9. The engine should be installed correctly to comply with the control standard. If excessive vibration over the standard is occurred, the engine performance and service life can be deteriorated.

(1) Vibration control standard graph

The measured engine vibration value should not be over the limit marked on the corresponding graph.

If vibration is over the limit, the engine performance and service life can be deteriorated.



EMD160021

2.5.3. Check point

Marine engine installation and vibration standards - Marine engine installation and vibration measurement report	Doc No.	
	Page	3/4

1. General information

1) Owner:

2) Ship name:

3) Region:

4) Date:

5) Shipyard:

6) Ship material □ FRP □ Steel □ Wood □ Others

7) Registered tonnage:

8) Type of business:

2. Engine specifications

1) Engine model:

2) Engine rated power and engine rated RPM:

3) Reducer model

4) Reduction ratio

5) Generator make

6) Generator model

7) Generation power and power factor

3. Engine and generator mounting

1) Main engine □ Rigid □ Flexible □ Others

2) Generator set

4. Engine mounting inspection

		Left			Right		
Front	Becket	□ Yes	□ No	Thickness	□ Yes	□ No	Thickness
	Fixed liner	□ Yes	□ No	Thickness	□ Yes	□ No	Thickness
	Steel bed	□ Yes	□ No	Thickness	□ Yes	□ No	Thickness
	Chock liner	□ Yes	□ No	Thickness	□ Yes	□ No	Thickness
	Stud bolt	□ Yes	□ No	Spec.	□ Yes	□ No	Spec.
	Others						
Rear	Becket	□ Yes	□ No	Thickness	□ Yes	□ No	Thickness
	Fixed liner	□ Yes	□ No	Thickness	□ Yes	□ No	Thickness
	Steel bed	□ Yes	□ No	Thickness	□ Yes	□ No	Thickness
	Chock liner	□ Yes	□ No	Thickness	□ Yes	□ No	Thickness
	Stud bolt	□ Yes	□ No	Spec.	□ Yes	□ No	Spec.
	Others						
Marine	Becket	□ Yes	□ No	Thickness	□ Yes	□ No	Thickness
Gear	Fixed liner	□ Yes	□ No	Thickness	□ Yes	□ No	Thickness
	Steel bed	□ Yes	□ No	Thickness	□ Yes	□ No	Thickness
	Chock liner	□ Yes	□ No	Thickness	□ Yes	□ No	Thickness
	Reamer bolt	□ Yes	□ No	Spec.	□ Yes	□ No	Spec.
	Others						

Marine engine installation and vibration standards - Marine engine installation and vibration measurement report	Doc No.	
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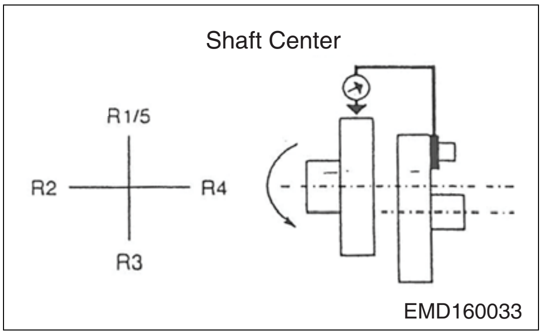
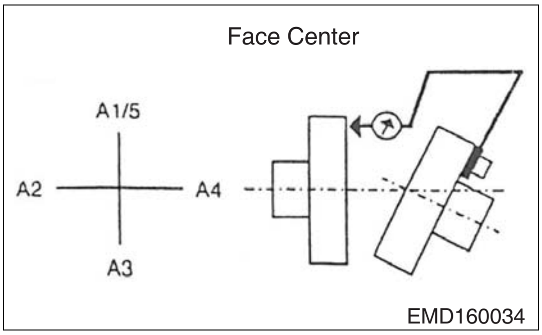
5. Checking shaft center/face center alignment





R1				
R2				
R3				
R4				
R5				

A1				
A2				
A3				
A4				
A5				

6. Vibration measurement

Measur-ing Point	Engine Load	Peak Overall Values (2 Hz ~ 200 Hz)								
		Direction of Measurement								
		Axial (x)			Transverse (y)			Vertical (z)		
1	75%									
2										
1	90%									
2										
1	100%									
2										

* If the measuring device measures RMS (Root Mean Square) values, multiply the measured RMS value by √2 to obtain the peak value.

7. Others

____
____
____
____
____
____
____
____

8. Inspection

Inspector ____________________ Owner ____________________

3. Front Power-take-off

3.1. Marine Installation Requirements

- Belt-driven accessories must be mounted on the engine when a flexible mounting system is used.
- Brackets used to mount accessories must provide adequate strength to hold the static and dynamic load of the accessory and avoid resonant vibration within the normal operating range of the engine.
- Variance in accessory loads must be considered when selecting accessory drive location and capacity. Design service factors given in the installation recommendations should be used when determining accessory loads.
- Belt-driven equipment must be held in alignment to a tolerance of 1 mm in 200 mm (1/16 inch in 12 inches).
- The total power taken off at the front of the crankshaft cannot exceed the maximum capacity of the FPTO clutch and the total power absorbed from the engine may not exceed the specified value of each model.
- All exposed rotating components must have a protective guard.

3.2. Front Power Take-off Clutches

More power may be taken from a direct drive at the front of the crankshaft than any other accessory drive location. Many HD Construction Equipment marine engines can be fitted with FPTO clutch for driving accessories such as a winch, fire pump, hydraulic pumps or generator.

All direct driven equipment will have some effect on torsional vibration. Excessive torsional vibration in a system can result in excessive noise, gear failure, main bearing wear or, in the most severe cases, crankshaft failures.

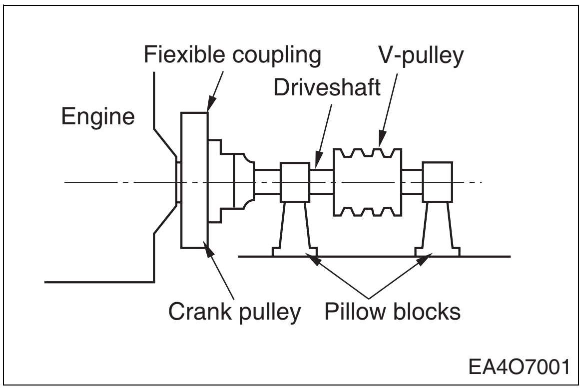
The total power taken off at the front of the crankshaft cannot exceed the capacity of the FPTO clutch and the total required power from the engine may not exceed the values in the list below.

This is the maximum amount of power that can be transmitted through the particular clutch.

3.2.1. For maximum FPTO power

For front power take-off in engine, install a flexible coupling to the engine front crank shaft pulley and connect drive shaft and Vpulley by supporting them with two pillow blocks as shown in Fig. It is a standard procedure to support driveshaft and Vpulley with two pillow blocks by using flexible coupling for connection to engine.

HD Construction Equipment recommends you this type to use front power take-off. (FPTO)



When the front PTO is installed, be sure to take deflection reading. Radial run-out should be no more than 0.02 mm.

Be sure to limit the front PTO output within the maximum allowable horsepower as specified for each model in figure below.

<Maximum Allowed Torque of Overall Power Extraction>

Model	Rotational Torque (kg.m)
L066TI	42
L136/L136T/L136TI	60
L086TI	
MD196TI	80
L126TI/4L126TI	80
V158TI/4V158TI	

Model	Rotational Torque (kg.m)
V180TI	140
V222TI/4V222TI/4V222C	
4L066C	59
4L086C	82
4L126C	100

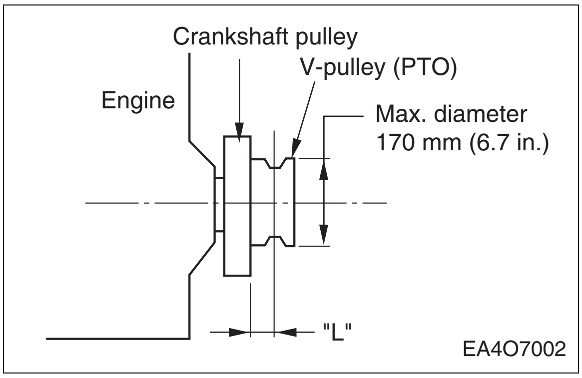
(Load represents when there is no propeller load)

NOTE:
Upper listed loads represent allowable maximum torque.

3.2.2. For Small Cross Drive Power

(No supporting bearing on front side of PTO pulley)

HD Construction Equipment does not recommend this type arrangement, which is not standard procedure. However, If the FPTO as in figure have to apply the drive arrangement, the distance between the coupling end face of engine pulley and the centerline through pulley groove is not greater than 60 mm. The distance is indicated as "L" in the figure.



<Maximum Allowed Torque of Open Type>

(L = Max. 60 mm)

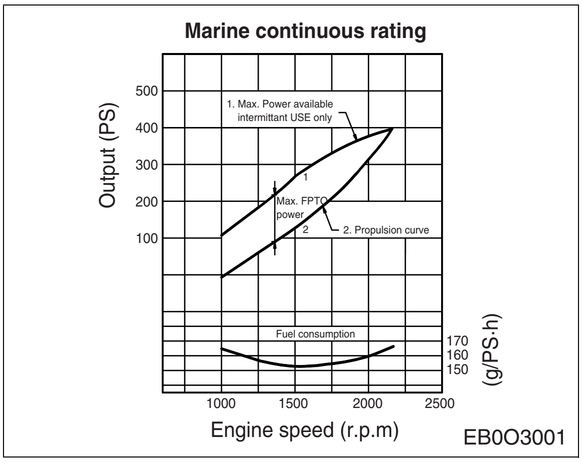
Model	Rotational Torque (kg.m)
L066TI	21
L136/L136T/L136TI	30
L086TI	
MD196TI	50
L126TI/4L126TI	50

Model	Rotational Torque (kg.m)
V158TI/4V158TI	88
V180TI	
V222TI/4V222TI/4V222C	
4L066C	37
4L086C	51
4L126C	62

(Load represents when the propeller is running with engine)

NOTE:
Upper listed loads represent allowable maximum torque.

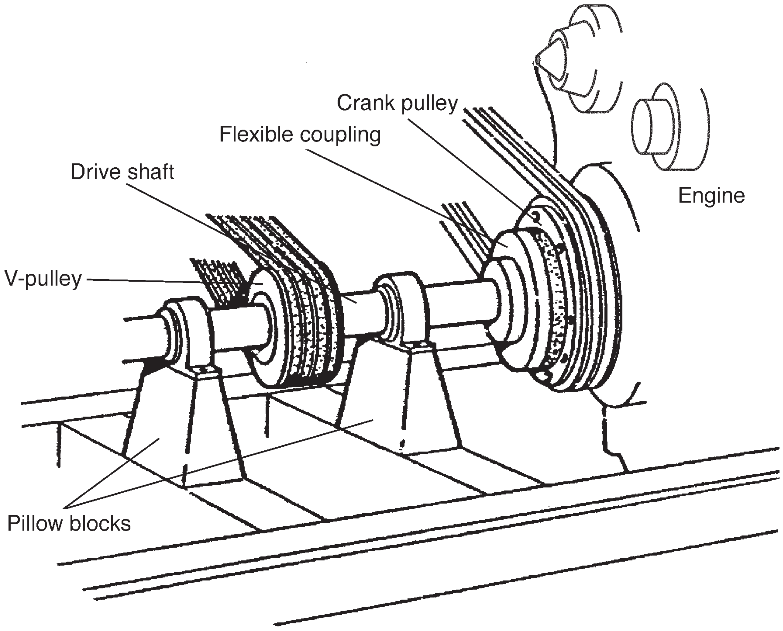
Additionally, the total power(Load) required by the propeller and FPTO cannot exceed curve #1 on the power curve at any given rpm. If the propeller is engaged, this means that the max. power available at the front is equal to the distance between curves #1 and #2.



3.3. Belt Drives

HD Construction Equipment marine engines usually have belt drives for an alternator, sea water pump and at least one or two free(grooves of) drive pulleys for other accessories. Many engines also have crankshaft pulleys available for driving accessories. All of HD Construction Equipment marine engine drives are available with either A or B type V-belts that are designed to ISO 3046 standards.

If two power take-offs are at the same time, make sure that the resultant radial forces are as small as possible. The combination of companion flange and V-belt pulley can be used for such a multi power take-off, as shown in below figure. It is advisable to shield V-belts and flanges properly, to avoid accidents.



NOTE:
New belts require a run-in period of 10 ~ 15 minutes under tension and should then be retensioned. This allows for the initial stretch of the belt and will help prevent it from jumping the pulley. Brackets used to mount accessories must provide adequate strength to hold the static and dynamic load of the accessory and avoid resonant vibration within the normal operating range of the engine.

If a bracket has a natural frequency within the operating range of the engine, operation at that speed will result in resonant vibration and failure of the bracket. So HD Construction Equipment has no control over the design or material of the component, they are not responsible for any damage resulting from the failure of a non-HD Construction Equipment supplied part.

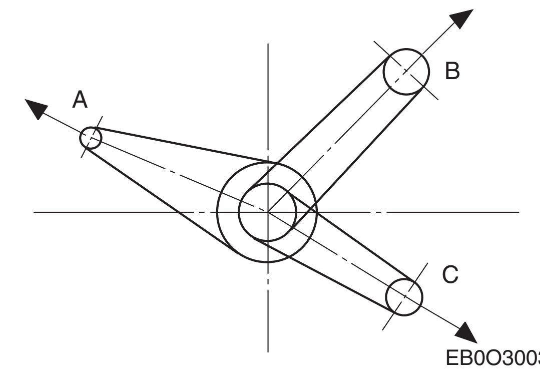
When accessories are mounted on the engine, the mounting bracket should be attached to a basic part of the engine such as the cylinder block or cylinder head whenever possible.

Accessories should not be mounted where they must be removed for normal engine maintenance or where they are supported through a gasketed joint.

NOTE:
Variance in accessory loads must be considered when selecting accessory drive location and capacity. Design service factors given in the installation recommendations should be used when determining accessory loads.

Since engine-driven accessories will have experience fluctuations in the load during normal operation, the rated load of the accessories should be multiplied by a design service factor when determining the load imposed on the engine by the accessory.
The direction as well as the load is important when considering belt driven accessories. The load capacity of crankshaft pulleys and other drive locations will vary at different angles due to the loading capability of the bearings.

If two or more accessories are being driven from a single multigroove pulley, the accessories should be arranged to have opposing belt pulls so that the resulting force on the drive shaft is kept to a minimum.
Additional pulley grooves or increasing the belt size may exceed the safe loading of the crankshaft or drive location.
Therefore the overloading should not be allowed to prevent any malfunction.
Any device rigidly attached to the front of the crank, other than an approved option, must be analyzed for the effects on crank bending, side-pull loading, mean and vibratory torques, and the capability of the crank bolted joint capacity.



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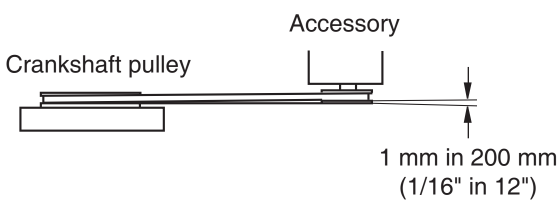
NOTE:
Belt driven equipment must be held in alignment to a tolerance of 1 mm in 200 mm (1/16 inch in 12 inches).

Misalignment between the belt-driven equipment and the engine will result in bending forces on the shafts involved, wearing of the belt, belt jumping and can result in bearing or belt failure. This can usually be checked with a straight edge.



EB0O3004

4. Exhaust System

The purpose of the exhaust system is to carry the exhaust gas from the engine to the atmosphere with minimal flow restriction. Marine applications have two types of exhaust systems, wet and dry.

4.1. Marine Installation Requirements

- Thermal insulation or guards must be installed on dry exhaust systems.
- Dry exhaust piping must not be installed near combustible material.
- The exhaust system components must not impose excessive stresses on the exhaust manifold or turbocharger due to weight, inertia, relative motion of the components or dimensional change due to thermal growth.
- The exhaust system must automatically prevent the entrance of water into the engine or turbocharger whether it is from spray, rain, washing or any other source.
- The exhaust gas must be dispersed so that it does not detrimentally affect the air cleaner function, the engine ambient environment or the crew or passengers.

4.2. Dry Exhaust Systems (without Sea Water Injection)

Depending on the temperature, the standard value for longitudinal expansion of steel pipes is **1 mm per meter and 100˚C**.

It is not permissible to channel exhaust gases of several engines into one system. Multiengine systems are required to have a separate exhaust system for each and every engine to prevent exhaust gases from penetrating from one running engine into another one.

For V-type engines it is recommended that the exhaust gases of both cylinder rows be combined via an Y-pipe type.

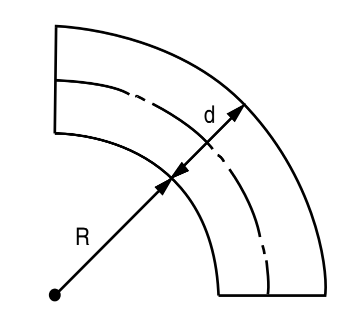
Owing to high exhaust temperatures of several hundred degrees Celsius, exhaust pipes heat up. For reasons of safety the pipes must be fitted with suitable anti-heat protection.

In order to prevent the engine room from heating up too much, a fireproof fuel and lubricatingoil-repellent insulation is recommended.

To minimize exhaust gas back pressure, avoid sharp turns and manifolds.

Design pipe bends with large radius only ($R/d \geq 1.5$). If silencers are installed, ensure that the max. permissible exhaust gas back pressure is not exceeded.

Any bends in the exhaust system should be made as smooth as possible. Sharp bends can drastically increase the exhaust back pressure.



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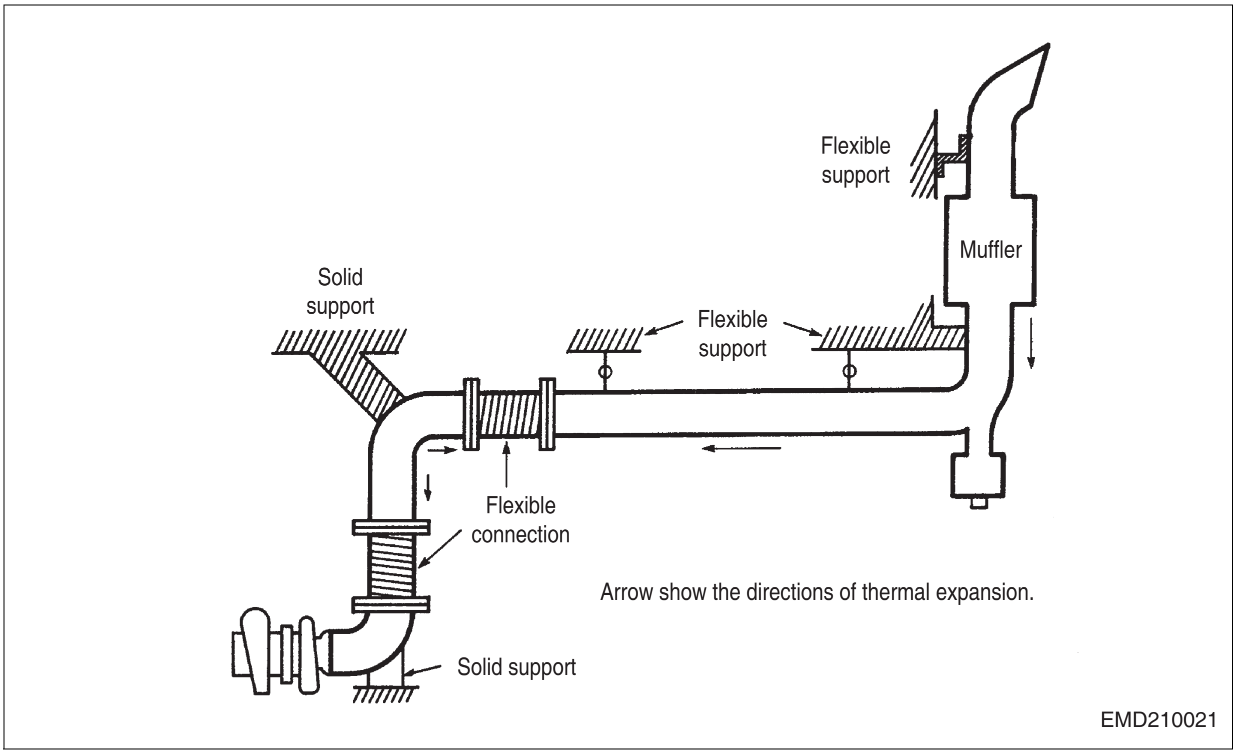
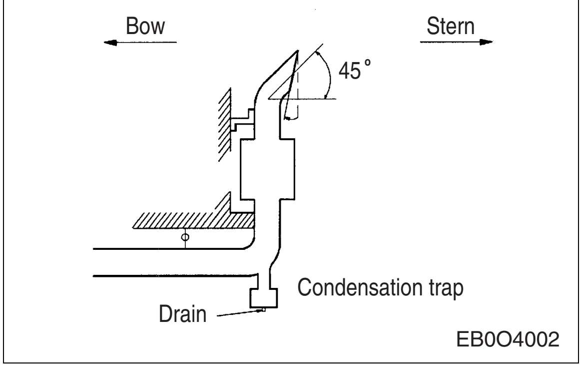
Dry exhaust systems use steel or iron pipe for the exhaust piping, stainless steel flexible sections, and steel for the mufflers. Due to the high exhaust temperatures and the thermal conductivity of the metal components they can be very dangerous unless certain precautions are taken.
One more flexible exhaust connection must under initial tension be installed between the engine and the exhaust system.
A flexible exhaust connection must be installed in the exhaust piping within 1.2 m (4 feet) of the engine exhaust outlet.



If the exhaust system has both long vertical and horizontal sections, separate flexible exhaust sections must be used to absorb the thermal growth in each direction. The horizontal flexible sections should be installed as far away from the vertical piping as possible to avoid collecting soot and condensation in the bellows. If water enters the turbocharger or engine it will damage the turbocharger and, if it enters the exhaust manifold, may cause a hydraulic lock and engine failure upon start-up.
Condensation water collects in the exhaust system and under any circumstances water (rain, spray) must not penetrate into the exhaust system of the engine.

For this reason the water collector with a drainage device must be installed near the engine if long exhaust pipes are laid at an ascending angle.
This can usually be accomplished in a dry exhaust system by using a 45 degrees or greater bend at the top of the piping. The pipe should also have a slight overhang to make the entrance of water more difficult.



The exhaust outlet should face the stern of the boat so that any water that comes over the bow will not enter the exhaust system.

The actual exhaust piping size may vary depending upon the complexity of the routing and the silencer used in the system.

The below table is showed the MINIMUM dry exhaust outlet pipe diameters for various engine models and ratings when total exhaust piping length is below 5 m. Add the diameter additional 5 mm every 5 m increasing. The actual exhaust piping size may vary depending upon the complexity of the routing and the silencer used in the system.

Engine Model	Minimum Dry Exhaust Inner Diameter (mm)
L066TI	76
L136/L136T/L136TI	
L086TI/4L066C	115
MD196TI	
L126TI/4L126C/4L086C	115

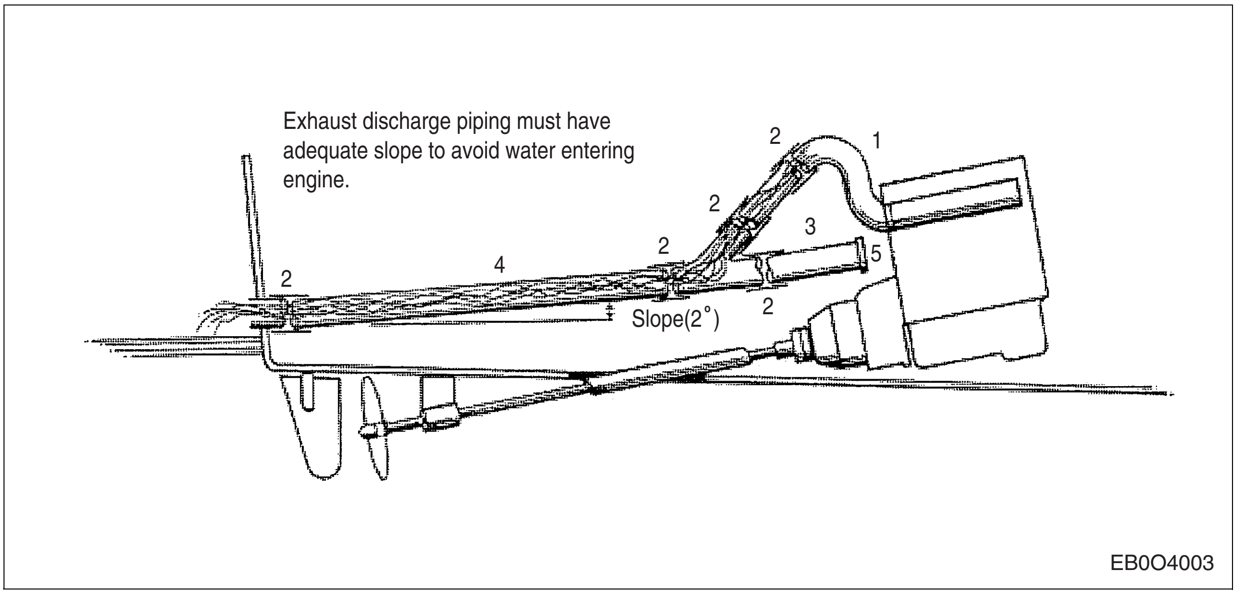
Engine Model	Minimum Dry Exhaust Inner Diameter (mm)
V158TI/4V158TI	145
V180TI	
V222TI/4V222TI/ 4V222C	

4.3. Wet Exhaust System (with Sea Water Injection)

In a wet exhaust, sea water is sprayed into the exhaust pipe. Heat is transferred from the exhaust gases to the sea water and the exhaust gas temperature drops low enough.

A pipe bend (swan neck) is required in the exhaust pipe system followed by a downward sloping exhaust pipe to prevent water from penetrating into the engine. The pipe bend must be mounted immediately downstream of the engine. Following picture shows an example of a swan neck for sea water injection into the exhaust pipe. The diameter of the exhaust pipe behind the sea water inlet must be 25% larger than that of the pipe bend. Any bends in the exhaust system should be made as smooth as possible. Sharp bends can greatly increase the back pressure and should be avoided.

<Schematic Diagram for Sea Water Injection>



Wet Exhaust System
(Engine Should Be Mounted Above Water Line)

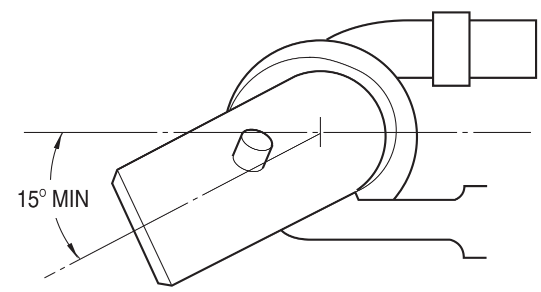
1) The water cooling exhaust elbow: sea water cools elbow, then discharges through peripheral slot at discharge end of elbow into exhaust pipe.
2) The rubber exhaust hose flexible connection: must be oil and heat resistant.
3) Backwater surge chamber: prevents sea water surging into engine exhaust when vessel at rest with stern exposed to oncoming waves.
4) Exhaust pipe: should have slight downward gradient toward discharge end.
5) End cover plate: available for inspection and cleanup purposes.

4.3.1. Design of water injection

In a wet exhaust system, sea water is sprayed into the exhaust pipe at some point downstream of the turbocharger.

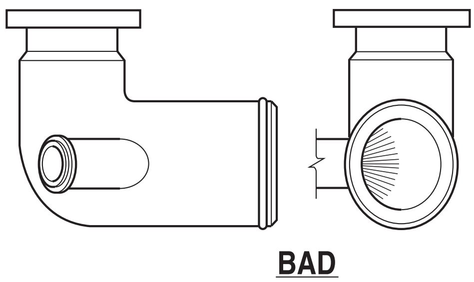
If a water injection elbow is used, the elbow should be directed downward at a minimum of 15 degrees to prevent the water being injected from getting back into the turbocharger and should have a

pipe tap (1/8") for exhaust restriction measurements. Heat is transferred from the exhaust gases to the sea water and the exhaust gas temperature drops low enough to allow the use of hard rubber hose, fiberglass tube or other corrosion resistant materials downstream of the water injection.



EB0O4006

Wherever water is injected in the exhaust system, it is important that an even spray pattern is achieved. If the spray pattern is uneven, parts of the exhaust piping may not be sufficiently cooled. This can result in failure of the exhaust piping system due to overheating and a possible safety hazard from high surface temperatures.

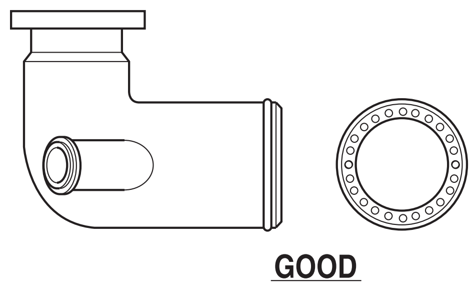


EB0O4004

NOTE:
Upper listed loads represent allowable maximum torque.

HD Construction Equipment recommends using evenly distributed holes with an 8 mm (0.31 in) diameter with the number of holes being dependent upon the sea water flow. The following equation can be used to determine the number of holes:

$$\text{No. of holes} = \frac{\text{Lit./min (Sea Water Flow)}}{10}$$



EB0O4005

4.3.2. Location of Water Injection

If the engine is installed at a deep position and the exhaust gas outlet at the system is located just above or even below the water line, a pipe bend (swan neck) must be integrated into the pipe. This prevents water from flowing into the engine when the ship reverses or the water is rough.

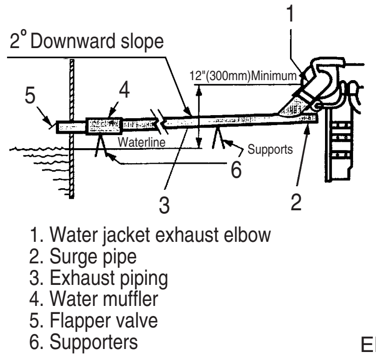
Therefore, all exhaust outlets should be located above the loaded water line.

A flapper valve may also be installed at the exhaust outlet to help prevent water from entering the exhaust system while the boat is at rest.

The location of the water injection should be at least 300 mm (12 inches) from any sharp bends to prevent a water buil-up that would result in high back pressure and the pipe bends should be made as smooth as possible in the exhaust system.

The diameter of the exhaust piping will have a large effect on the exhaust back pressure in the system.

The minimum wet exhaust outlet pipe diameter is at least 1.25 times bigger than that of dry exhaust outlet pipe. the actual wet pipe sizing may vary depending on the complexity of the pipe routing.



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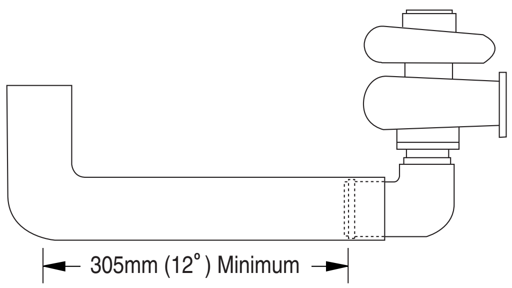


EB0O4014

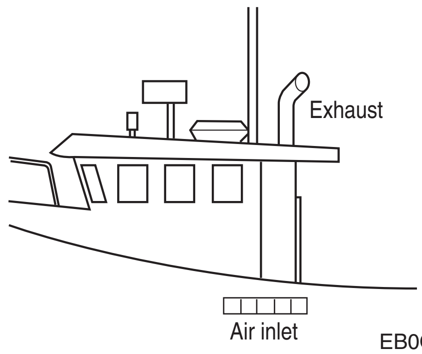
Engine Model	Minimum Dry Exhaust Inner Diameter (mm)
L066TI	76 x 1.25
L136/L136T/L136TI	
L086TI/4L066C	115 x 1.25
MD96TI	

Engine Model	Minimum Dry Exhaust Inner Diameter (mm)
L126TI/4L126C/4L086C	115 x 1.25
V158TI/4V158TI	
V180TI	145 x 1.25
V222TI/4V222TI/4V222C	

4.4. Direction of Exhaust Outlet

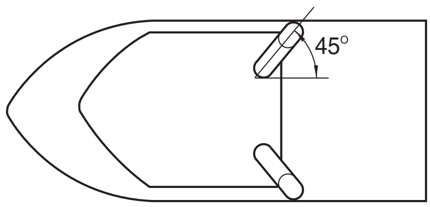
All exhaust outlets should be located aft and above all air Intake locations so as to prevent exhaust gases from re-entering the engine room.

The exhaust outlet should be high enough above the deck or far enough aft so that the exhaust gases are dispersed into the atmosphere without adversely affecting the passengers or crew.



EB0O4008

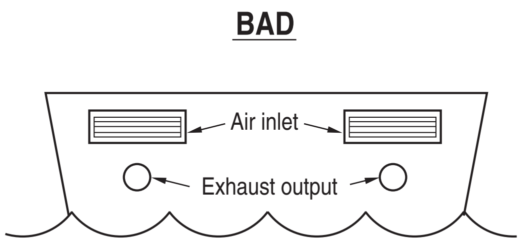
The exhaust outlet should also be angled out to the side of the vessel to allow the exhaust gas to disperse and not be drawn back onto the deck.



EB0O4009

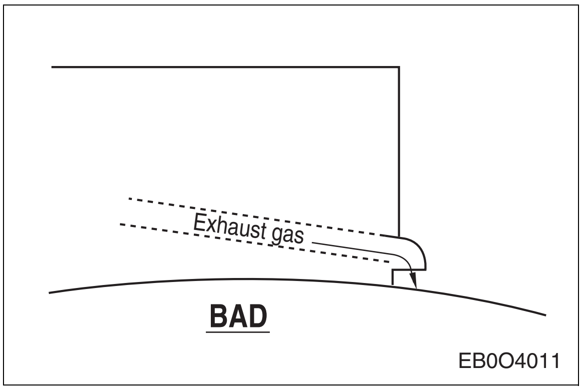
NOTE:
The exhaust gas must be dispersed so that it does not detrimentally affect the air cleaner function, the engine ambient environment or the crew or passengers.

All exhaust outlets should be a sufficient distance from all intake and exhaust ventilation areas so as to prevent exhaust gases from re-entering the engine room.

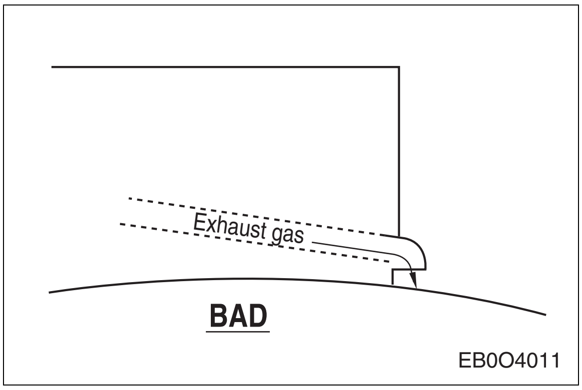


EB0O4010

The exhaust outlets should not be angled directly into the water as this will result in higher noise levels and the sudden quenching of the exhaust gases may result in a visible film of carbon deposits on the water.



Whenever possible, it is recommended that the exhaust outlets be situated on the side of the vessel. As the air flows around the vessel, a slight vacuum will be created at the stern side. If the exhaust outlets are located on the transom, the exhaust gas may be drawn back onto the deck of the boat. Locating the outlets on the side will help prevent this from occurring.



4.5. Permissible Back Pressure

The permissible exhaust back pressure measured immediately downstream of the collecting pipe is:

1. Mechanical type engine
   - Natural aspiration engine: 11 kPa
   - Turbocharger engine: 8 kPa
2. Electronic type engine

Back Pressure (kPa)	IMO-T2		IMO-T3	
	Propulsion	Auxiliary	Propulsion	Auxiliary
DL06	10	7	15	7
LD08	10	7	15	7
DX12	10	7	30	18
DX22	10	5	30	16

To exceed these values results in impermissible exhaust temperatures and thermal stress as well as unsatisfactory engine power and excessive smoke development.

For this reason it is indispensable that the exhaust back pressure be measured when the engine is commissioned and, if necessary, the exhaust system is re-dimensioned.

A vacuum at the exhaust gas outlet (e.g. caused by the flow behavior in an underwater exhaust) leads to an increase in ignition pressures in turbocharged engines and is therefore to be avoided.

4.6. Designing the Exhaust System

We recommend that, if possible, the maximum permissible back pressure value (= pressure drop) be not fully exploited when the exhaust system is designed. The exhaust pipe diameter, the number of manifolds, the silencers and the pipe routing are to be selected so that 75% of the maximum value is not exceeded when the engine is new.

The total back pressure (total pressure drop) Δp in the exhaust system is calculated as follows:

- $\Delta p = \Delta pR \times L + \Delta pK \times nK + \Delta pS$

Explanation of the formula:

- ΔpR = Back pressure (pressure drop) per 1 m of pipe
- L = Length of pipe in m
- ΔpK = Back pressure (pressure drop) per 90" manifold
- nK = Number of manifolds
- ΔpS = Back pressure (pressure drop) in silencer

4.6.1. Example of a Dry Exhaust System Calculation

A dry exhaust system with a pipe length of 5 m, two 90˚ manifolds and a silencer is planned for a vessel. The clear diameter is to be 120 mm.

Is this system adequately designed for a turbocharger diesel engine with an exhaust gas mass flow of 1,300 kg/h.

The following values can be found in the tables:

- Back pressure per 1 m of pipe = 0.3 kPa
- Back pressure per 90˚ manifold = 0.51 kPa

For back pressure data in manifold, contact manufacturer.

A value of 5 hPa is assumed.

The total back pressure Δp is calculated as follows: (1 kg/cm^2 = 98 kPa = 980 hPa)

- $\Delta p = \Delta pR \times L + \Delta pK \times nK + \Delta pS$
- Δp = 3.0 hPa x 5 + 5.1 hPa x 2 + 5hPa = 30.2 hPa

The calculated value is within the permissible area (10 ~ 80 hPa).

4.6.2. Example of a Wet Exhaust System Calculation

A wet exhaust system with a pipe length of 7 m and four 90˚ manifolds is planned. The clearance diameter is 100 mm.

Is this system adequately designed for a diesel engine with an exhaust gas mass flow of 1,300 kg/h

The following values can be found in the tables:

- Back pressure per 1 m of pipe = 8 hPa
- Back pressure per 90˚ manifold = 10.6 hPa

As the exhaust gas noises are well silenced by the water injection, no silencer is installed.

The total back pressure Δp is calculated as follows:

- Δp = 8.0hPa x 7 + 10.6hPa x 4 = 98.4hPa

The calculated value is above the maximum permissible back pressure of 80 hPa (mbar).
For this reason an exhaust system with a larger diameter is required.
Checking the same system but with a clear diameter of 120 mm:
The back pressures per 1 m of pipe and a 90˚ manifold can be gathered from the following tables.

The total back pressure Δp is calculated as follows:

- Δp = 3.0hPa x 7 + 5.1 hPa x 4 = 41.4 hPa(mbar)

The calculated value is in the permissible area. Downstream of the sea water inlet into the exhaust pipe the diameter is to be enlarged by 25%. From there onwards it must be 150 mm.
The calculation method is an aid to designing the exhaust system. However, when an engine is commissioned an exhaust back pressure check is necessary in any event.

4.7. Measuring the Pressure Drop

4.7.1. Unit of Measurement

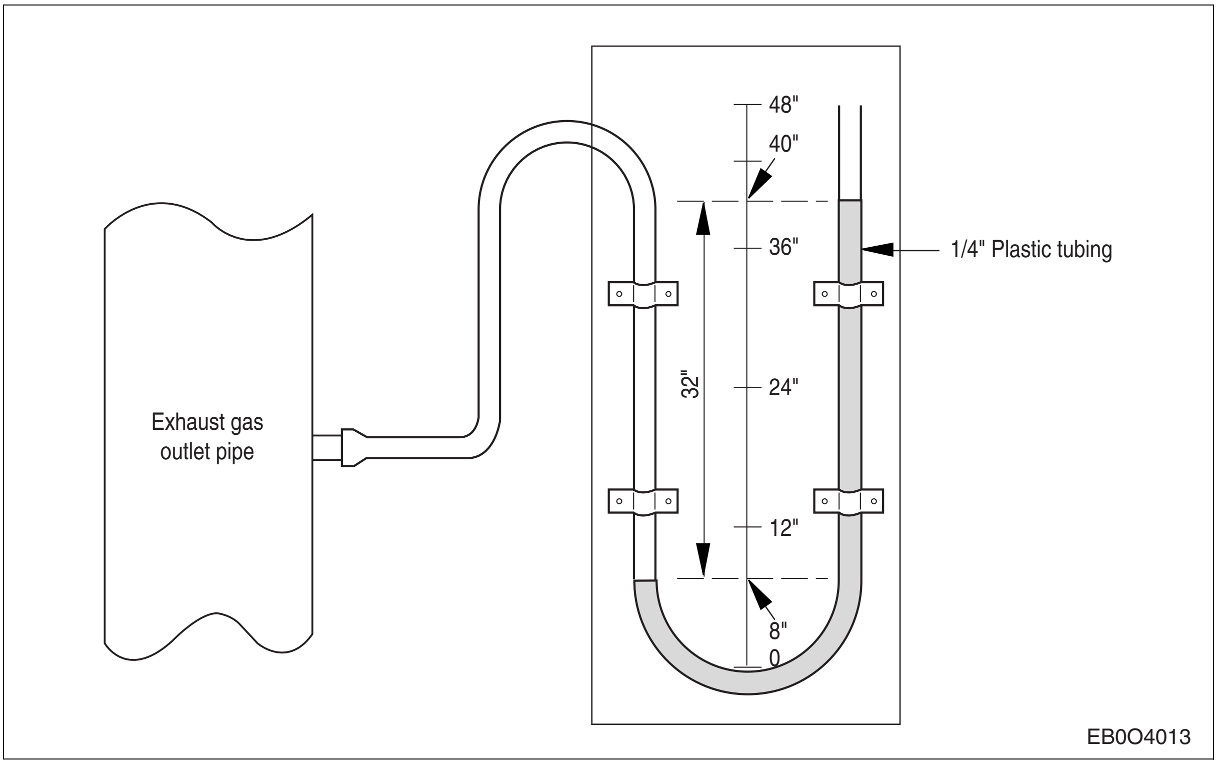
1 hPa = 1 mbar = 10 mm water column

4.7.2. Measuring Instrument

The simplest measuring instrument is a U-pipe manometer filled with water. If the U-pipe manometer is filled with mercury, the reading of the liquid's difference in height given in mm is to be multiplied by 13.6 to obtain the result in mm head of water.
1 mm Hg = 13.6 mm head of water = 1.33 mbar

4.7.3. Measuring Arrangement

The quantity to be measured is the static pressure, i.e. the measuring connection must fit on the inside flush with the pipe wall.
Select a straight part of the pipe or the neutral fiber of the pipe bend for the measurement.
This can be nothing more than a piece of clear plastic tubing of any diameter greater than 1/4", fixed in a U-shaped loop to a board about 4 feet long. The board is marked off in inches as below figure. Set up the board on end and half fill the tubing with water.
If the overall pressure drop of the exhaust system is to be measured, a point immediately downstream of the engine's exhaust gas collecting pipe or the turbocharger is to be selected for the measurement.



NOTE:
During the measuring operation the engine must run at continuous maximum power and speed.

Note the level of the water in the tube with the engine at rest. Then crank the engine and the exhaust back pressure will push the water down one side of the tubing and up the other.
The difference between two levels, measured in inches, is the back pressure in inches of water column.

Average back pressure (pressure drop) in kPa per 1 m exhaust pipe, depending on the fexhaust gas mass flow in kg/h and the clear diameter in mm (1 kPa = 10 mbar)

<Average Back Pressure (Pressure Drop)>

Table 1) in kPa per 1 m of exhaust pipe (1 kPa =10 hPa = 10 mbar)

Exhaust Gas Mass Flow * (kg/h)	Diameter in mm						
	80	100	120	140	160	180	200
200	0.06	0.02	0.01	-	-	-	-
300	0.14	0.04	0.02	0.01	-	-	-
400	0.25	0.08	0.03	0.01	0.01	-	-
500	0.39	0.12	0.05	0.02	0.01	-	-
600	0.56	0.17	0.06	0.03	0.01	0.01	-
700	0.76	0.23	0.09	0.04	0.02	0.01	0.01
800	0.99	0.3	0.12	0.05	0.03	0.01	0.01
900	1.26	0.38	0.15	0.06	0.03	0.02	0.01
1,000	1.55	0.47	0.18	0.08	0.04	0.02	0.01
1,100	1.88	0.57	0.22	0.1	0.05	0.03	0.02
1,200	2.23	0.68	0.26	0.11	0.06	0.03	0.02
1,300	-	0.8	0.3	0.13	0.07	0.04	0.02
1,400	-	0.93	0.35	0.16	0.08	0.04	0.02
1,500	-	1.07	0.4	0.18	0.09	0.05	0.03
1,600	-	1.21	0.46	0.2	0.1	0.05	0.03
1,700	-	1.37	0.52	0.23	0.11	0.06	0.04
1,800	-	1.53	0.58	0.26	0.13	0.07	0.04
1,900	-	1.71	0.65	0.29	0.14	0.08	0.04
2,000	-	1.89	0.72	0.32	0.16	0.08	0.05
2,100	-	2.01	0.79	0.35	0.17	0.09	0.05
2,200	-	2.29	0.87	0.38	0.19	0.1	0.06
2,300	-	-	0.95	0.42	0.21	0.11	0.06
2,400	-	-	1.04	0.46	0.22	0.12	0.07
2,500	-	-	1.12	0.5	0.25	0.13	0.08
2,600	-	-	1.22	0.54	0.26	0.14	0.08
2,700	-	-	1.31	0.58	0.29	0.15	0.09
2,800	-	-	1.41	0.62	0.31	0.16	0.09
2,900	-	-	1.51	0.67	0.33	0.18	0.1
3,000	-	-	1.62	0.71	0.35	0.19	0.11
3,100	-	-	1.73	0.76	0.38	0.2	0.11
3,200	-	-	1.84	0.81	0.4	0.21	0.12
3,300	-	-	1.96	0.86	0.42	0.23	0.13
3,400	-	-	2.08	0.92	0.45	0.24	0.14
3,500	-	-	2.2	0.97	0.48	0.26	0.15
3,600	-	-	-	1.03	0.5	0.27	0.15
3,700	-	-	-	1.08	0.53	0.29	0.16
3,800	-	-	-	1.14	0.56	0.3	0.17
3,900	-	-	-	1.2	0.59	0.32	0.18
4,000	-	-	-	1.27	0.62	0.33	0.19
4,100	-	-	-	1.33	0.65	0.34	0.2
4,200	-	-	-	1.4	0.68	0.36	0.21

* For mass flow values, see each engine technical data of the appendix page in this manual.

<Average Back Pressure (Pressure Drop)>

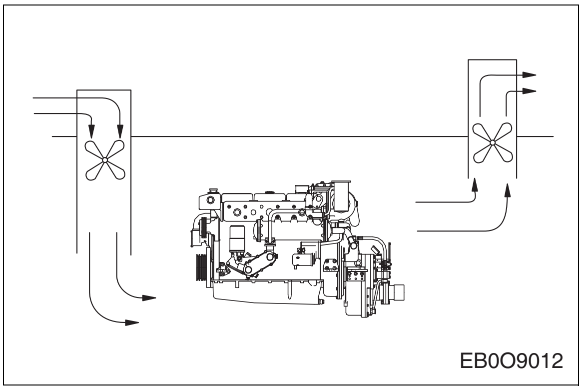
Table 2) in kPa per 90° bend (R/d = 1.5): 1 kPa =10 hPa = 10 mbar

Exhaust Gas Mass Flow * (kg/h)	Diameter in mm						
	80	100	120	140	160	180	200
200	0.06	0.03	0.01	0.01	-	-	-
300	0.14	0.06	0.03	0.02	0.01	-	-
400	0.24	0.1	0.05	0.03	0.02	0.01	-
500	0.38	0.16	0.08	0.04	0.03	0.02	0.01
600	0.55	0.23	0.1	0.06	0.04	0.02	0.02
700	0.75	0.31	0.15	0.08	0.05	0.03	0.02
800	0.98	0.4	0.19	0.11	0.06	0.04	0.03
900	1.23	0.51	0.25	0.13	0.08	0.05	0.03
1,000	1.52	0.62	0.3	0.16	0.1	0.06	0.04
1,100	1.84	0.76	0.36	0.2	0.12	0.07	0.05
1,200	2.19	0.89	0.43	0.23	0.14	0.09	0.06
1,300	-	1.06	0.51	0.28	0.16	0.1	0.07
1,400	-	1.22	0.59	0.32	0.19	0.12	0.08
1,500	-	1.41	0.68	0.37	0.22	0.13	0.09
1,600	-	1.6	0.77	0.42	0.24	0.15	0.1
1,700	-	1.8	0.87	0.47	0.28	0.17	0.11
1,800	-	2.02	0.98	0.53	0.31	0.19	0.13
1,900	-	-	1.09	0.59	0.34	0.22	0.14
2,000	-	-	1.2	0.65	0.38	0.24	0.16
2,100	-	-	1.33	0.72	0.42	0.26	0.17
2,200	-	-	1.46	0.79	0.46	0.29	0.19
2,300	-	-	1.59	0.86	0.5	0.31	0.21
2,400	-	-	1.73	0.94	0.55	0.34	0.23
2,500	-	-	1.88	1.02	0.6	0.37	0.24
2,600	-	-	2.04	1.1	0.65	0.4	0.26
2,700	-	-	-	1.18	0.69	0.43	0.28
2,800	-	-	-	1.27	0.75	0.47	0.31
2,900	-	-	-	1.37	0.8	0.5	0.33
3,000	-	-	-	1.46	0.86	0.54	0.35
3,100	-	-	-	1.56	0.91	0.57	0.37
3,200	-	-	-	1.66	0.97	0.61	0.4
3,300	-	-	-	1.77	1.04	0.65	0.42
3,400	-	-	-	1.88	1.1	0.69	0.45
3,500	-	-	-	1.99	1.17	0.73	0.48
3,600	-	-	-	2.1	1.23	0.77	0.5
3,700	-	-	-	2.22	1.3	0.81	0.53
3,800	-	-	-	-	1.37	0.86	0.56
3,900	-	-	-	-	1.45	0.9	0.59
4,000	-	-	-	-	1.52	0.95	0.62
4,100	-	-	-	-	1.59	1	0.65
4,200	-	-	-	-	1.66	1.05	0.68

* For mass flow values, see each engine technical data of the appendix page in this manual.

5. Intake System

5.1. Air Intake



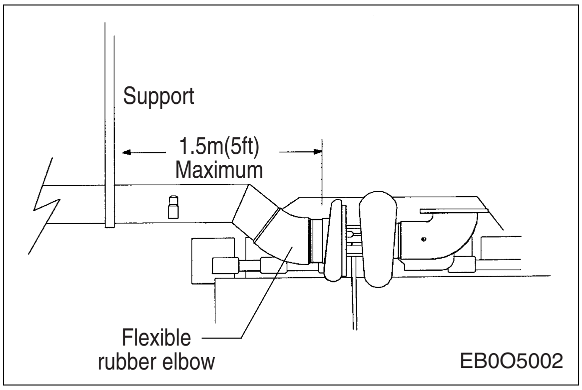
If it is not possible to install sufficient ventilation ports to maintain the required engine room temperature, blowers and exhaust fans can be used to circulate fresh air through the engine room. The inlet blowers must have a capacity of two times the engine's rated air consumption listed on the engine technical data of the last sheet in this manual. Exhaust fans should be from one-half to one times the rated air consumption of the engines to carry away the excess heat.

With both engine mounted and remote mounted air cleaners, there should be enough ventilation to keep the engine room temperature below 60°C (140°F). Temperatures above this may cause a deterioration in the hoses and/or wiring on the engine.

Maintaining reasonable engine room temperatures can be aided by insulating as many hot surfaces as possible (i.e. exhaust piping, turbocharger, muffler, heating system).

Any breaks or leaks in the air system after the air cleaner will allow dirt to enter the engine and decrease engine life.

Relative movement between the engine air cleaner and air inlet requires flexibility in the pipe components and flexible connections. Any deflections must occur in the rubber components and not in the rigid piping.



On turbocharger engines a flexible connection must be provided between the compressor casing and the first piping support. The first support should be less than 1.5 meters (5 feet) from the turbocharger.

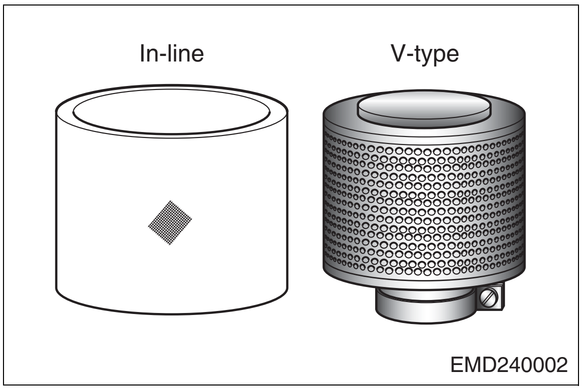
HD Construction Equipment marine engines have air filter with urethane rubber type as below figure.

After the installation of the engine if a work that produces dust is carried out on the interior ship fittings, the air filter must be cleaned before the engine is commissioned.

1) Air filter element

If there is a lot of dust, the element needs to be cleaned.

- In-line engine: Remove the sponge element and shake it clean. If it is damaged, replace it with a new one.
- V-type engine: Rinse it out in fuel or washing oil. To dry it, shake it out thoroughly, then apply engine oil thinly and evenly all over the element surface. Applying oil further improves filtration capacity.



2) Vacuum after air filler

The maximum permissible partial vacuum at maximum power and rated engine speed is:

- Clean Air Filter: 2.94 kPa (300 mmH2O)
- Dirty Air Filter: 6.18 kPa (630 mmH2O)

If this value is exceeded, the filter element must be cleaned or the filter element must be replaced new one.

5.2. Engine Room Ventilation

When the engine runs for an extended period of time, the surface of its components becomes hot and radiates heat that increases the temperature in the engine room.

In order to keep the temperature in the engine room at the proper level, it should be equipped with a ventilation system.

- **Engine room temperature = ambient temperature + 15°C (max. 20°C)**

To prevent parts that have poor resistance to high temperature, such as hoses and wires, from deformation or durability deterioration, the temperature in the engine room should never exceed 60°C (140°F) under any circumstances.

The air filter, in particular, should be installed outside of the engine room. When the temperature of the fuel delivered to the engine is maintained at 38°C (100°F), an engine power drop can be prevented, and, especially in the winter, its power can be enhanced.

5.3. Radiant Heat to be Removed

Depending on the engine model, the amount of heat to be removed is up to 5% of the heat input supplied with the fuel. If silencers or long exhaust pipes are also located in the engine room, the heat dissipation of these components must be taken into consideration too.

High air inlet temperatures will lead to high thermal stresses, high exhaust temperatures, poor engine performance, worse fuel economy and shorter engine life. Derating may occur at the engine room temperature of 45°C (113°F), and output degradation may occur when the hardware limit condition is reached.

5.4. General Note on Air Guidance

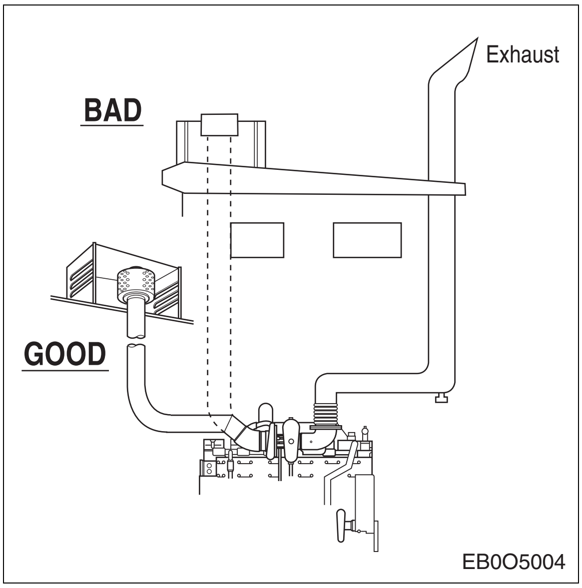
High air inlet restriction will lead to decreased airflow through the engine for combustion. This in turn will lead to a decrease in power, performance and engine life as well as an increase in smoke.

⚠ **The air inlet location, air piping and engine room ventilation must be designed so that the air inlet temperature measured at the inlet connection to the manifold or turbocharger is not more than 17°C (30°F) above the outside ambient temperature at rated speed and load.**

5.4.1. Guidance of the Air Filter for Engine Room Outside Installation

The air cleaner should be mounted in an area that is free of dirt, dust, fish scales or other debris that may clog the filter during regular operation, net handling or deck operations.
If the exhaust and air Intake are both above the vessel, the exhaust should be located higher and aft of the intake. If the exhaust gas is drawn back into the intake, the air cleaner can quickly become clogged.

If the air cleaner is to be remote mounted, the inlet location should be outside the engine room. The inlet should be located so that a supply of fresh air or near the ambient temperature is always available.
Locations with high inlet air temperature should be avoided. Areas to consider as heat sources are exhaust components, mufflers, air conditioner and refrigeration condensers, boilers and heating system components and auxiliary engines. Air inlets should be louvered or pointed forward to increase air circulation through the engine room.

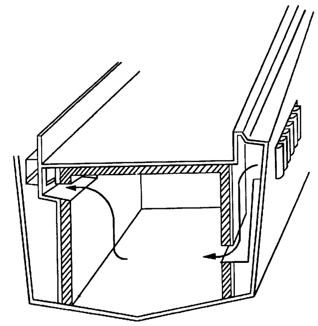


5.4.2. Intake & Exhaust Ventilation Ports of the Engine Room

⚠ **Marine engines with engine mounted air cleaners may draw air from the engine room.**
Engine rooms with natural draft ventilation must have vent openings of adequate size and location to insure an ample supply of air at a reasonable temperature to the engine, and carry away heat from the machinery in the engine room.

A water or condensation trap should be located prior to the air cleaner on remote mounted systems. The air cleaner should be easily serviced without removing other parts of the air system and should be checked at air cleaner service intervals or if the air inlet restriction increases unexpectedly.
Good circulation in the engine room is a key factor in keeping down the engine room temperature at a low level.

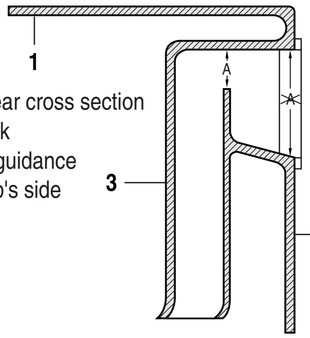
The inlet vents should be ducted to the bottom of the engine room to promote bottom up circulation of the fresh air and to clear fumes and moisture from the bilge.
The exhaust vents should be located near the top of the engine room to carry away the hot air in the engine room.



Note:
In planning the ventilation ports, two-thirds of the area should be used for intake air and one third of the area should be for exhaust ventilation.

5.5. Clear Cross Section

The clear cross section A of the air inlet orifice refers to the narrowest point in the entire air-guiding system.
The table on shows the guideline values for the clear cross section A of the air inlet orifice. They are based on an assumed flow rate of 1.5 m/s. The ventilation cross sections can be further reduced by means of electric fans switched on above a certain engine room temperature by electrical temperature switches.



<Clear Cross Sections>

Engine Model	Rated Output (kW/ps)	Clear Cross section A (m^2)
L066TI	132 / 180	0.15
L136	118 / 160	0.12
L136T	147 / 200	0.16
L136TL	177 / 240	0.17
L136TI	169 / 230	0.18
L086TIH	210 / 285	0.22
L086TIM	232 / 315	0.27
L086TIL	265 / 360	0.32
MD196TI	235 / 320	0.29
L126TIH	265 / 360	0.30
L126TIM	294 / 400	0.32
4L126TIC	294 / 400	0.32
4L126TIH	331 / 450	0.36
4L126TIM	364 / 495	0.39
4L126TIL	401 / 545	0.43

Engine Model	Rated Output (kW/ps)	Clear Cross section A (m^2)
V158TIH	353 / 480	0.38
V158TIM	397 / 540	0.44
V158TIL	500 / 680	0.52
V180TIH	441 / 600	0.47
V180TIM	478 / 650	0.50
V180TIL	603 / 820	0.62
V222TIH	530 / 720	0.55
V222TIM	588 / 800	0.60
V222TIL	736 / 1,000	0.72
4V158TIH	390 / 530	-
4V158TIM	441 / 600	-
4V158TIL	588 / 800	-
4V222TIH	588 / 800	-
4V222TIM	647 / 880	-
4V222TIL	883 / 1,200	-

Engine Model	Rated Output (kW/ps)	Clear Cross section A (m^2)
4L066CASC	184 /250	0.2
4L066CASH	210 /285	0.22
4L066CASM	221 /300	0.26
4L086CASC	235 /320	0.29
4L086CASH	265 /360	0.3
4L086CASM	279 /380	0.31
4L126CASC	331 /450	0.36
4L126CASH	368 /500	0.39
4L126CASM	405 /550	0.43
4V222CASC	596 / 810	-
4V222CASH	664 / 903	-
4V222CBSH	588 / 800	-
4V222CCSH	530 / 720	-

Engine Model	Rated Output (kW/ps)	Clear Cross section A (m^2)
4V222CASM	809 / 1,100	-
4V222CASL	908 / 1,235	-
4V222CBSL	846 / 1,150	-
4V222CAKC	596 / 810	-
4V222CAKH	664 / 903	-
4V222CBKH	588 / 800	-
4V222CCKH	530 / 720	-
4V222CAKM	809 / 1,100	-
4V222CAKL	908 / 1,235	-
4V222CBKL	846 / 1,150	-
4V222CAKC	596 / 810	-
4V222CAKH-II	736 / 1,000	-
4V222CASH-II	736 / 1,000	-

* Engine power is based on maximum power

In fast vessels ventilators switched on via a thermo-switch once the critical engine room temperature has been reached may be additionally necessary for ventilation with the back pressure from the headwind.

<Engine Room Ventilation>
Calculation of the air requirements for the dissipation of convection and radiation heat can be simplified the following formula:

$$\dot{m} = \frac{\dot{Q} \times 1,000}{C_p \times \Delta t}$$

$\dot{m}$ Air mass flow rate in kg/h

$\dot{Q}$ Convection and radiation in MJ/h

C_p Specific heat capacity of air = 1 kJ/(kg x degree)

Δt Difference in temperature between heated waste air and cold intake air in degrees Celsius

In order to obtain the air volume flow (m^3/h) the air mass flow (kg/h) must be divided by the air density, which depends on the temperature.
Air density as a function of the temperature at the air pressure of 0.98 kg/cm (1000 mbar).

Temperature (°C)	Density (kg/m^3)
0	1.28
10	1.23
20	1.19
30	1.15
40	1.11
50	1.08

The before-mentioned formula is based on the assumption that the engine room is a heat-tight system, i.e. for the sake of simplicity it is assumed that no thermal energy whatever is dissipated through the hull to the ambient air or water.

6. Cooling System

6.1. Marine Installation Requirements

- Remote mounted expansion tanks must be mounted above the highest point in the cooling system.
- The cooling system must be designed and installed so that the maximum jacket water temperature does not exceed 93°C (199°F) under any operating conditions.
- The engine cooling system must be properly treated with an ethylene or propylene glycol/water solution and/or DCA-4.
- The pressure at the water pump inlet must be greater than atmospheric when the engine is run at rated speed with a coolant temperature of 76°C to 93°C (169°F to 199°F), and the system filler cap removed.
- The expansion tank volume must provide for a minimum excess coolant volume that is equal to 20% of the engine coolant capacity listed on the "Engine technical data" of the last sheet in this manual and 5% of the total coolant in keel cooler system volume.
- The system must vent during initial fill to allow filling of the total cooling system volume to 95% of its full capacity.
- When installing the hull cooler (keel cooler), the coolant pressure drop between the coolant inlet and outlet of the hull cooler should not exceed 0.4 kg/cm^2.
- Cooling system vent lines must not be fed together.
- Once the engine starts, it should be possible to remove the air inside the coolant through the air bleed line, and the air bleed line should be constructed so that, even during the normal operation, it should be possible to remove the air bubbles inside the coolant.

6.2. Selection of Piping Materials

- Dissimilar metals must not be combined randomly. If a precious metal is combined with base metal, the base metal is destroyed by galvanic corrosion. Moist or even salty atmosphere accelerates this process.
- The baser a metal, the more negative is its electrical potential. Two different metals have a galvanic difference in potential which strives to be cancelled out if a connection is established between the metals (direct contact or conductive water). The metals listed below are arranged according to their difference in potential, starting off with the most precious metal (platinum) down to the basest metal (magnesium).
- The farther apart two metals appear in this list the greater are the problems to be expected owing to galvanic corrosion.

Grade	Metal
Precious	Platinum
↑	Titanium
	Silver
	Nickel
	Cupro-nickel
	Lead
	Stainless steel
	Tin bronze
	Copper
	Tin
	Brass alloys
	Nickel cast-iron
	Low-alloy steels
	Shipbuilding steel
↓	Aluminum alloys
	Zinc
Base	Magnesium

6.3. Cooling Circuit

All HD Construction Equipment marine engines have indirect cooling circuit cooled the engine coolant in the heat exchanger by sea water.
The temperature of engine coolant is ususlly normal between 76°C and 90°C.
And the sea water entry temperature is designed up to 32°C (305 K).
River/sea water is sucked in by the sea water pump and fed through the heat exchanger, where it absorbs the heat conducted away by the engine coolant.
After that, the sea water flows to the outside of the boat through inter-cooler and reduction gear oil cooler.
In case of most inter-cooled engines, sea water flows to inter-cooler at first and heat exchanger and then gear box oil cooler, finally flow out the vessel outside.

6.4. Engine Cooling System

6.4.1. Expansion Tank

Cooling water expands owing to the heat caused by engine operation. The engine coolant will expand approximately 5% between its high and low temperatures. In order to compensate this expansion, an expansion tank must be installed.
The expansion tank volume must have enough capacity to accommodate this plus additional capacity for any evaporation or minor leaks. That is equal to 20% of the engine coolant capacity listed on the "Engine technical data" of the appendix page in this manual" and 5% of the total coolant in keel cooler system volume.

The following formula is used to calculate the minimum required deaeration expansion tank size:

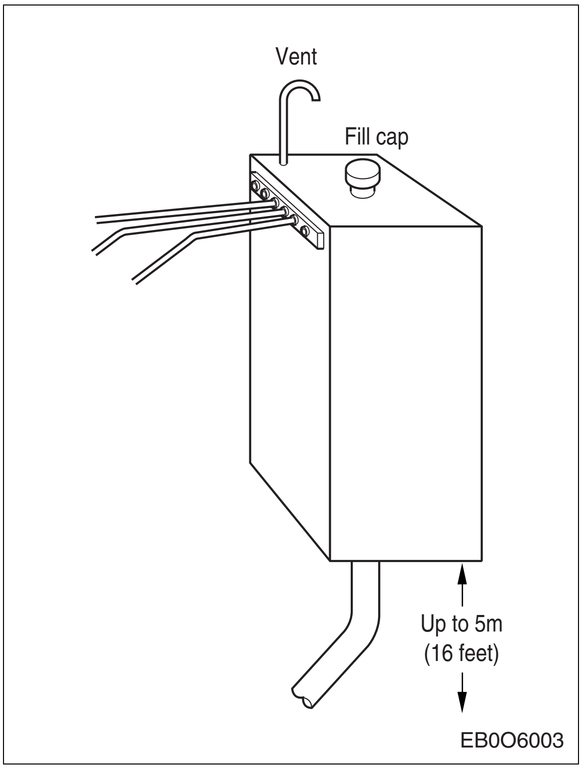
$$V = \frac{T}{18} + \frac{E}{4.5}$$

Where: V = Minimum Expansion Tank Volume (Lit.)
T = Total System Coolant Volume including engine (Lit.)
E = Engine Coolant Volume (Lit.)

For the heat exchanger cooled engines, the expansion tank system has been properly sized for HD Construction Equipment supplied heat exchanger. If a customer is using a different heat exchanger or wishes to build their own expansion tank, the equation shown above should be used.

6.4.2. Air Vents System (Keel Cooler Type)

All HD Construction Equipment engines have venting provisions at the thermostat housing and water outlet connection. 0ther vent locations on a particular engine are shown on some engine installation drawings. These include the turbocharger(water cooled), exhaust manifold, inter-cooler and any other locations requiring vents.



Additional vents are also required to allow air to escape from the top of the keel cooler during initial engine coolant filling.

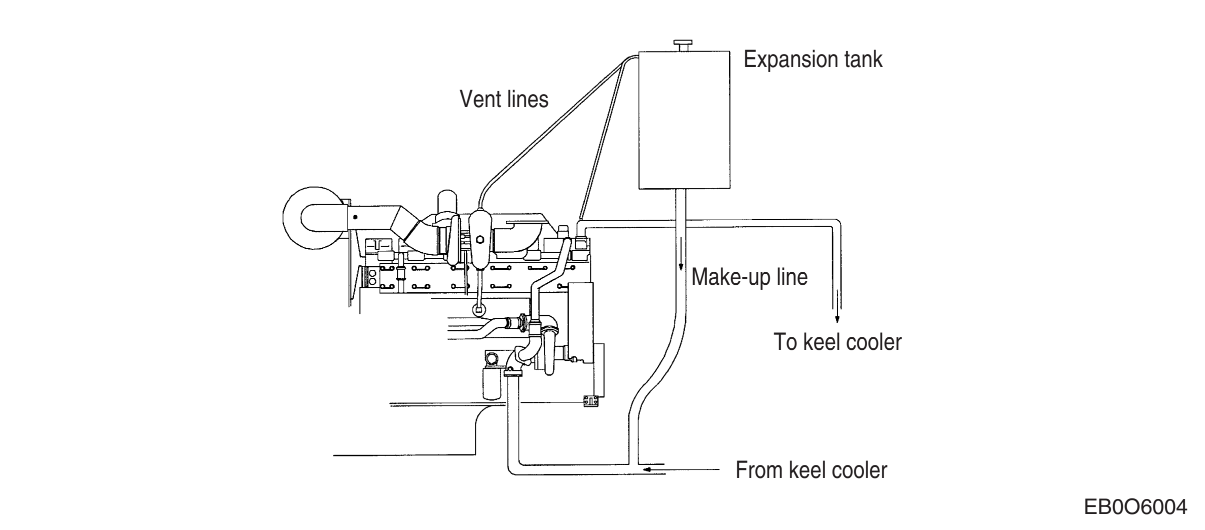
Expansion tanks more than 5 meters (16 feet) above the engine crankshaft are not recommended.

Expansion tanks that do not require a pressure cap must have a vent tube from the top of the tank to allow air and gases to escape from the cooling system and a fill cap. The vent must have a gooseneck to prevent dust and debris from contaminating the cooling system.

The engine vent system provides a continuous flow of water through the expansion tank as a method of removing air and gases from the engine coolant. The highest points in the engine coolant circuit are the best vent locations,

Since air will always travel to the highest point in the cooling system, it is necessary to have the bottom of a remote mounted expansion tank above any other point in the cooling system.

The bottom of the tank must be above all vent locations on the engine at any vessel trim and operating angle and all vent lines must have a continuous upward run to prevent air traps from forming.



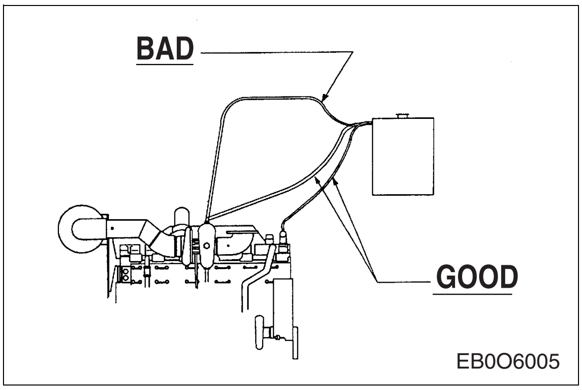
If air becomes trapped in the engine cooling system it can lead to isolated hot spots in the engine and water pump cavitation.

This will decrease engine life and may cause engine or component failures.

A deaeration system consists of a properly designed expansion tank, vents and make-up line.

All vent lines must be installed with a continuous upward run from the engine or keel cooler to the expansion tank at all vessel operating angles.

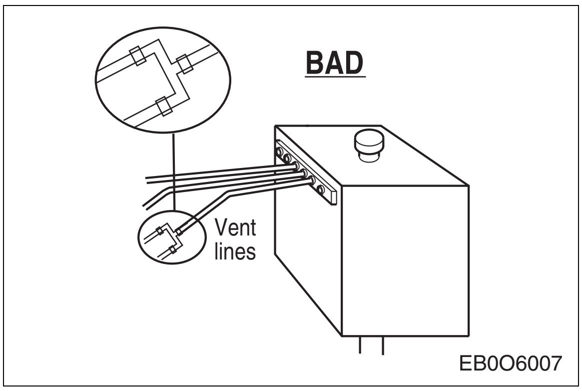
Engine power levels must be reduced if high ambient temperatures raise the engine coolant temperature above 93°C (199°F).



⚠ **Cooling system vent lines must not be fed together.**

Since vent lines run from points of different pressures, teeing the vent lines together may result in reduced vent water flow and inadequate venting of the system.

Each vent line must be connected to the expansion tank without using Tee's or other fittings that would join the vent line together in a common vent. Joining the vents into a common line will reduce the total vent water flow and may result in aerated water flowing back into the engine.



The engine must have a closed cooling system.

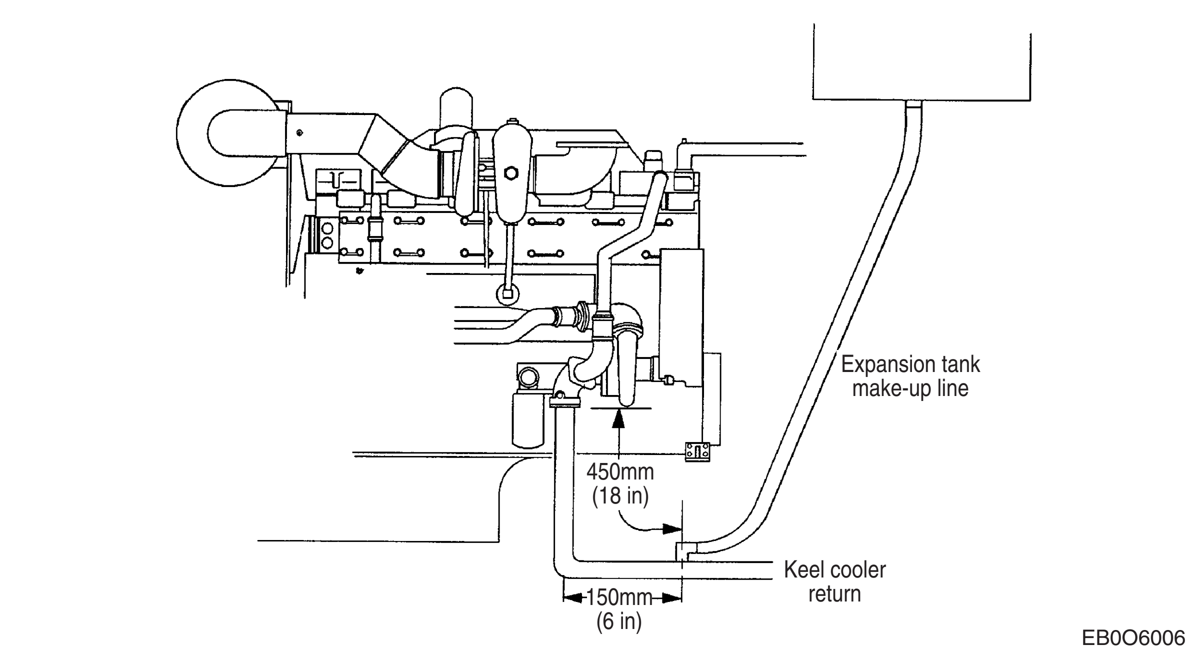
Since vent lines run from points of different pressures, teeing the vent lines together may result in reduced vent water flow and inadequate venting of the system.
Each vent line must be connected to the expansion tank without using Tee's or other fittings that would join the vent line together in a common vent. Joining the vents into a common line will reduce the total vent water flow and may result in aerated water flowing back into the engine.

Expansion Tank Height	
Above Engine Meter (Feet)	Minimum Pressure Cap kg/cm^2 (psi)
0 to 1.5 (0 to 5)	0.9 (13)
1.5 to 4 (5 to 13)	0.5 (7)
3 to 7 (10 to 23)	0.3 (4)
6 to 9 (20 to 30)	Fill Cap & Vent

6.4.3. Make-up lines

The deaerated water return, or make-up line, connection is located in the bottom of the expansion tank. The purpose of the make-up line is to provide a means for filling the engine water line and to feed the water from the vent lines back to the engine after it has been deaerated during operation. The make-up line is plumbed from the bottom of the expansion tank to the engine water inlet line. The make-up line should not be plumbed to the water pump housing or body. When the make-up water enters the engine water inlet line, the turbulence created in the flow may cavitate the water pump. Therefore, the line should be plumbed at least 450 mm (18 inches) from the engine water pump inlet connection and at least 150 mm (6 inches) from any bends or elbows in the piping. This will reduce the chances of pump cavitation. The size of the make-up line is also important. The line must be large enough to allow proper coolant fill and to provide adequate return flow from the expansion tank without allowing air back into the system. The size of the make-up will depend on the number and size of the vent lines. In general, the cross-sectional area of the make- up line should be 3 ~ 4 times the sum of the vent line areas.

Cooling system vent lines must not be fed together.



6.5. Engine Coolant

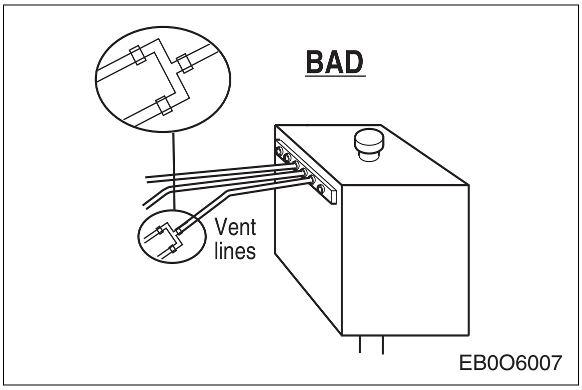
Correctly prepared coolant is of particular importance for trouble-free engine operation.

Coolants that are unsuitable or inadequately or wrongly prepared may cause failure of coolant circuit units and components as a result of cavitation and/or corrosion damage.

6.5.1. Antifreeze Agent

HD Construction Equipment recommends to use a coolant that is 50% water and 50% ethylene or propylene glycol antifreeze. This mixture raises the boiling point of the coolant and prevents vapor pockets from forming in the engine as well as lowers the freezing temperature.

The antifreeze will also provide additional protection from cavitation and liner erosion.



The engine cooling system must be treated with an ethylene or propylene glycol/water solution and/or DCA-4.

The antifreeze concentration may be increased to 60% ethylene/propylene glycol for operation below -37°C (-34°F).

HD Construction Equipment recommends to use the pre-charge DCA elements for cooling system. Since keelcooling systems have a much larger coolant volume, an additional DCA charge must be added at initial fill. The following table lists the additional amounts of DCA4 required for various sized systems. Spin-on cartridges are available with 2 to 23 units of DCA. Larger coolant volumes are treated with DCA liquid or powder.

DCA Concentration with 50% Water/50% Anti-freeze Mix.

Cooling System Size		Required Liquid or Units of DCA4	
Liters	US Gallons	Pints or US Gallons	Units
19 ~ 25	5 ~ 7	2 pints	10
26 ~ 40	8 ~ 11	3 pints	15
41 ~ 55	12 ~ 15	4 pints	20
56 ~ 75	16 ~ 20	5 pints	25
76 ~ 115	21 ~ 30	1.00	40
116 ~ 190	31 ~ 50	1.50	60
191 ~ 285	51 ~ 75	2.25	90
286 ~ 380	76 ~ 100	3.00	120
381 ~ 570	101 ~ 150	4.50	180
571 ~ 760	151 ~ 200	6.00	240
761 ~ 950	201 ~ 250	7.50	300
951 ~ 1,140	251 ~ 300	9.00	360
1,141 ~ 1,330	301 ~ 350	10.50	420
1,131 ~ 1,515	351 ~ 400	12.00	480

6.5.2. Anti-corrosion agent

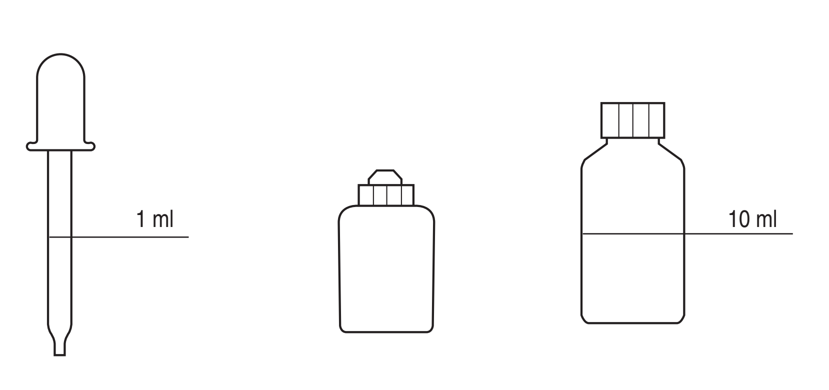
At this moment only the "Fleetguard DCA 4 Fluid" agent is cleared in accordance with this standard. Notwithstanding the manufacturer's data the following instructions must be adhered to:

- Keeping a concentration of 0.8 to 1.5 DCA 4 units per 4 liters of water; this corresponds to 240 ~ 450 ml fluid per 10 liters of water (2.4 to 4.5% by volume).
- Change of the entire coolant after one year or after 1500 operating hours, depending on which limit has been reached earlier.
- A mixture of antifreeze and DCA 4 is not permissible. When changing from antifreeze to Fleetguard DCA 4 Fluid or vice versa, the entire coolant must be drained. Flushing is not necessary.

The Fleetguard DCA 4 Fluid concentration must be checked with the Fleetguard test kit, HD Construction Equipment part no. 60.99901-0038, after every 300 operating hours:

6.5.3. Test kit instructions

1) Collect coolant sample from the drain device of heat exchanger or cylinder block. Do not collect from the coolant recovery or overflow system. Coolant must be between 10˚C and 55˚C when tested. Room temperature is preferred.



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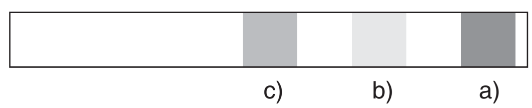
2) Remove on strip from bottle and replace cap immediately. Do not touch the pads on the end of the strip. Discard kit if unused strips have turned brown for the nitrite test pad.
3) Dip strip in coolant sample for one second, remove, and shake strip briskly to remove excess liquid.
4) 45 seconds after dipping strip compare and record results in the following order.
   a) Compare FREEZEPOINT (end pad) to color chart and record result.
   a) Next compare MOLYDATE (middle pad) to color chart and record result.
   a) Finally compare NITRITE test to color chart and record result.



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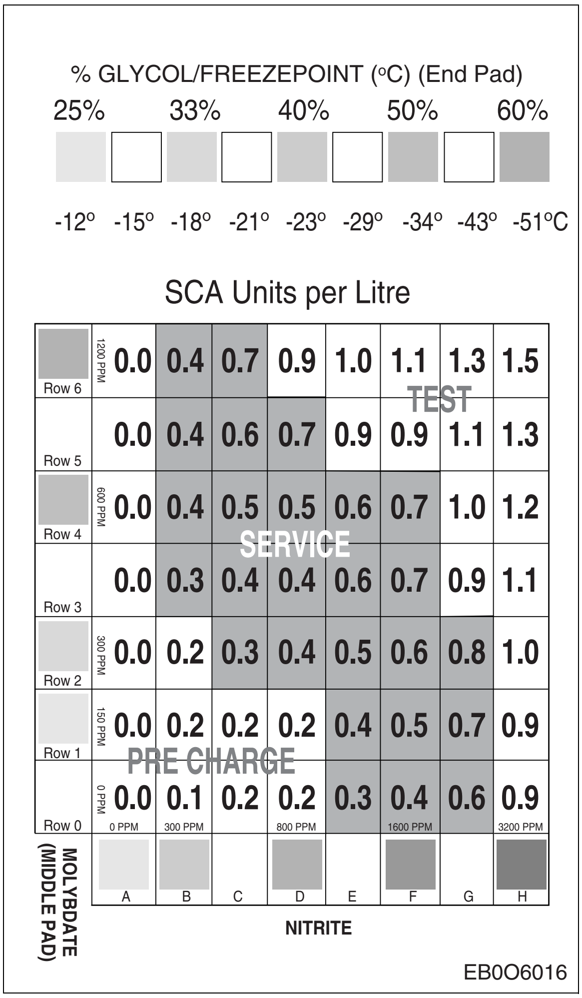
5) All three readings must be completed no later than 75 seconds after dipping strip.
6) It is okay to estimate a value between color blocks, but if uncertain about the color match, pick the lower numbered block. (example: if nitrite color is not F, use column E)
7) Determine where the MOLYDATE level intersects the NITRITE level on the chart. The amount of SCA units per liter in the cooling system is given where the MOLYBDATE row intersects the NITRITE column.
8) For best results follow test times carefully. Use a stopwatch or clock with a sweep second hand. Comparing the test strip to the color chart too soon before, or too late after, the required test time will result in incorrect readings and improper treatment and could result in liner pitting and engine damage.
9) All readings should be recorded on the truck maintenance record for future reference.



6.5.4. Treatment Instructions (Not for ES Coolant)

- Below 0.3 units per liter
  Replace service filter and add the specified amount of DCA4 liquid as stated in service chart. Follow precharge instructions.
- 0.3 to 0.8 units per liter
  Continue to replace service coolant filter and add specified amount of DCA4 liquid as stated in service chart.
- Above 0.8 units per liter
  Do not replace service filter or add DCA4 liquid until the concentration falls below 0.8 units per liter. Test at every subsequent oil drain interval.

6.5.5. Maintenance and Repair

- Any coolant loss must be replenished with a mixture of antifreeze and water with the same concentration required for summer and/or winter operation.
- Every other year coolant must be replaced. It is essential that during this period of time the antifreeze concentration does not sink below 35 ~ 40% by coolant volume.

6.5.6. Engine Coolant Treatment

- Treat undiluted anti-corrosion agent and or antifreeze as dangerous waste.
- When disposing of spent coolant comply with the regulations of the relevant local authorities.

6.6. Sea Water Lines

6.6.1. Sea Water Pump

Depending on the model of the HD Construction Equipment marine engine, the following saltwater pump impeller is implemented on the engine.

Discontinued Model ( )

- Rubber impeller type: (L034)/(L034TI)/(L066TI)/L136/L136T/L136TI/L086TI/MD196T/MD196TI/
  L126TI/4L066C/4L086C - - - - - - - - - - - In line type
  V158TI/V180TI/V222TI/4V222C - - - - - - - - - - - - V series type

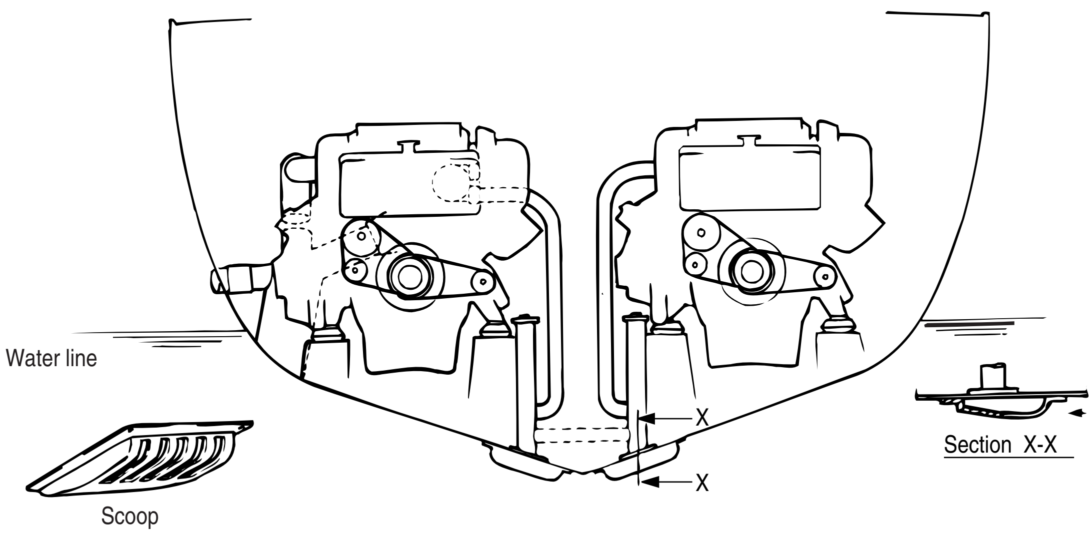
Note:
Sea water pump of bronze type have to install a sea water strainer to prevent small debris from clogging bronze impeller side gap. Also we recommend to install the sea water strainer for our all engines.

6.6.2. Sea Water Entry

In most cases sea water enters the vessel through a scoop whose entrance port must be minimum two times the cross section of the suction pipe. The entrance port must be located so far below the water line that the sea water pump does not suck in air under any circumstances.

An indication of sufficient sea water supply in high speed planing boats is the reduction in partial volume in the suction line as the boat gains speed, ideally, until overpressure is reached.

If the partial volume increases while the vessel is in motion, the sea water supply is inadequate.



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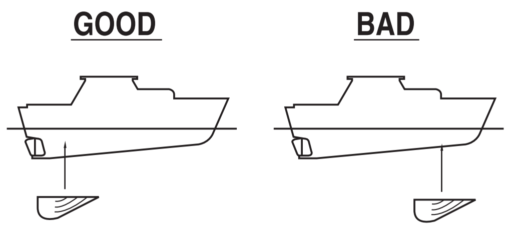
Guideline values for the maximum permissible partial volumes are:

- while the vessel is stationary: 0.3 kg/cm^2 (0.3 bar) at set nominal speed
- at maximum speed: 0.05 kg/cm^2 (0.05 bar)

The sea water inlet must be in a location that provides a solid water flow to the sea water pump at all times and in all operating conditions. If air is ingested in the sea water system it can cause failure of the sea water pump and result in overheating the engine.



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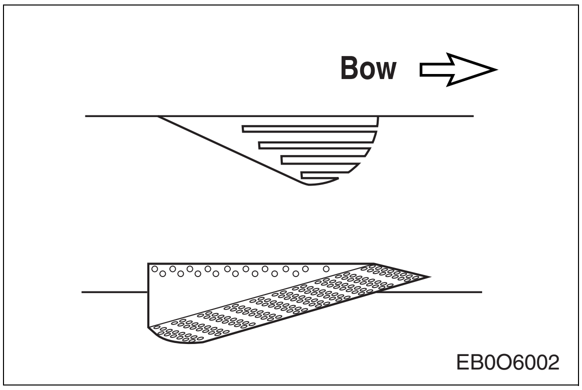
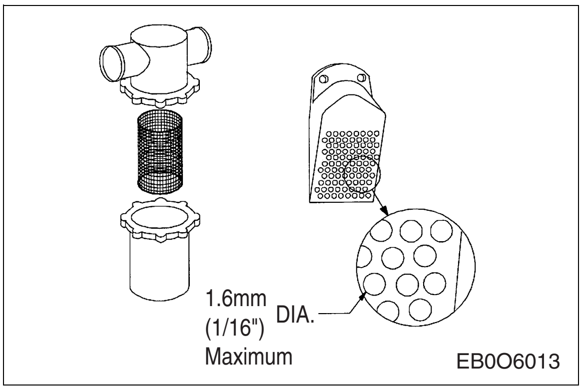
If a scoop is used on the bottom of the hull at the sea water inlet it should be positioned as shown in the right figure.



Note:
The cooling system must remove entrained air at engine start-up, and must continuously remove air that enters to the cooling system during normal operation.

6.6.3. Sea Water Filter

In many places (harbors, rivers, coastal waters) water contains sand and suspended matter. To prevent that matter from clogging the heat exchanger and the intercooler and to prolong the service life of the sea water pump, a sea water filter must be Installed between shut-off valve and sea water pump. Debris in the sea water system can lead to sea water pump damage or clogging of the heat-exchanger. This will in turn result in overheating and possible failure of the engine.



HD Construction Equipment recommends selecting a filter whose pressure drop in the new condition is not above 0.1 kg/cm^2 (100 mbar) and using of strainer in the sea water system prior to the sea water pump in addition to a scoop on the bottom of the hull.

This strainer can be checked for clogging and must be serviced more easily.

If a scoop is used on the bottom of the hull it must be able to handle the volume of sea water flow listed on the "Engine technical data" of the appendix page in this manual.

6.6.4. Piping of Sea Water Line

All components of HD Construction Equipment marine engines carrying sea water are made of copper & bronze and hoses. In order to prevent galvanic corrosion, material for the sea water pipes along the hull must be selected accordingly The minimum sea water piping registration are listed below. The line size may have to be larger if the piping is especially long or has several bends that would increase the intake restriction.

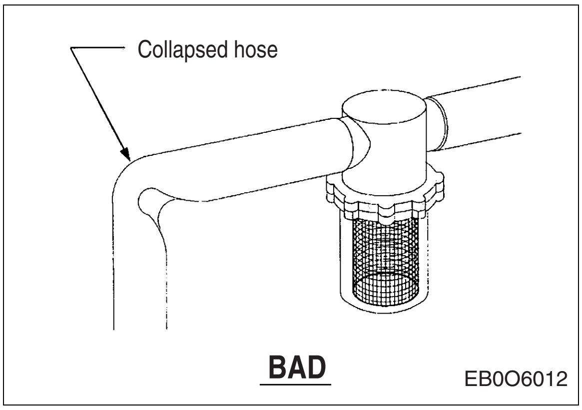
Stop	Within 0.3 bar
Operate	Within 0.015 bar

Engine Model	Min. Sea Water Piping Line Size (Diameter mm)
(L034/L034TI/L066TI)	35
L136/L136T/L136TI/L086TI	50
MD196T/MD196TI/L126TI	60
4L126C	56
V158TI/4V158TI/V180TI/V222TI/4V222TI	75
4V222C	76.3

Note:
Although a boat has two engines, each engine should have its own sea water inlet or outlet individually. This will prevent all engines from overheating in the vessel if a sea water inlet should become plugged.

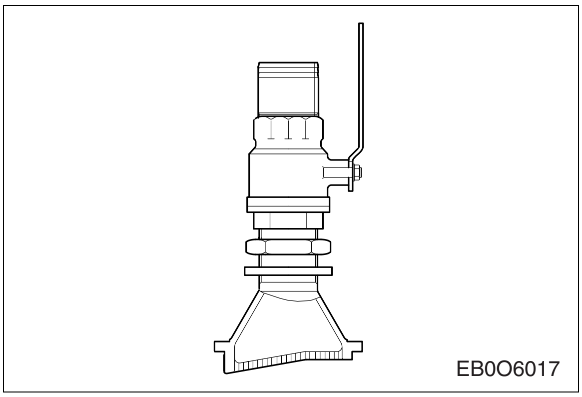
<Suction Side>

The piping from the sea water inlet on the bottom of the hull to the sea water pump should be short and as free of sharp bends as possible. Any sharp bends will cause an increase in the inlet restriction.



Immediately downstream of the sea water entrance port in the hull a shut off valve must be fitted to allow repairs or the replacement of components of the sea water pipe line below its water line. The clear cross sections of both the sea water suction lines and the shut off valve must not be smaller than the inlet cross section at the sea water pump inlet.

The through keel fittings and shut-off valve connections should be at least as large as the sea water piping and any scoop used on the bottom of the hull should be sized for the sea water flow of the engine.



The suction line from the sea water inlet to the sea water pump must be absolutely tight and stable, i.e. it must not contract under the low suction pressure of the sea water pump. The line is to be kept as short as possible.

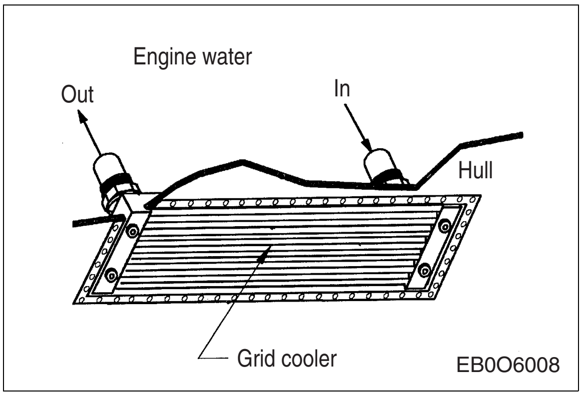
<Deliver Side> Discontinued Model ( )

HD Construction Equipment marine engines (except L034/L034TI/L066TI/L136/L136T/L136TI/L086TI marine engine) must install two kinds of the sea water outlet pipes, that is, for heat exchanger (or inter cooler) and for marine gear oil cooler respectively.

The heated sea water can be pumped out through outlets in the hull after cooling the coolant in heat exchanger or the hot air in inter-cooler and the oil in marine gear oil cooler.

6.7. Keel Cooler

Keel cooling is a cooling system that uses a group of tubes, or channels in direct contact with the surrounding water to transfer heat from the coolant to the water. This cooling method is often used in regions where the saltwater line inlet can be blocked by dust, ice or other floating materials in saltwater or freshwater or the tube inside the heat exchanger can be damaged by puncture due to a large amount of foreign materials.

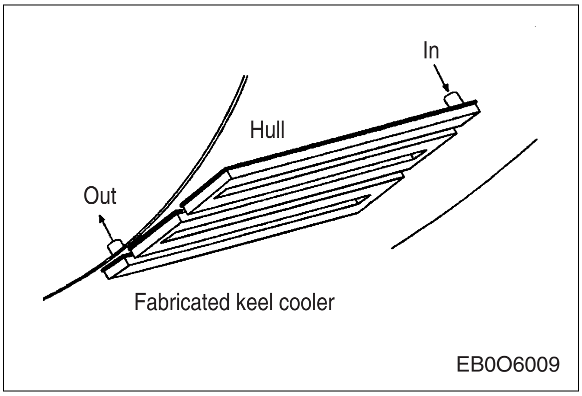


An alternative to keel cooling is the use of keel pipe cooling, with the cooling containers being replaced by pipes fixed to the outboard side of the hull.
These pipes can run either parallel to the keel or be designed similar to bilge keels.
As in keel cooling systems, avoid sharp edges and turns as well as reductions in pipe cross sections to minimize pressure drops in the system.
A drawback of keel cooling is its proneness to destroy when hitting the sea- or riverbed and the ship's increased resistance coefficient. As all pipes are located on the outer side of the keel, the system must be checked for leaks before the ship is launched.
Keel coolers may be manufactured units or fabricated. The manufactured type of keel cooler, or grid cooler, is generally much more compact and efficient than a fabricated unit. They are made of a "grid" of tubes that is attached to the bottom of the hull with an Inlet and outlet connection for the engine fresh water. The manufacturer of the unit should be consulted for proper siting and installation.

6.7.1. Kinds of keel cooler

<Fabricated Keel Cooler>

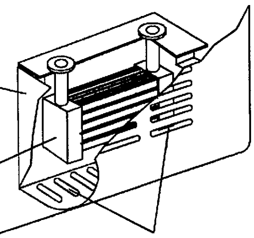
Fabricated keel coolers will generally be a series of pipes or channels that are welded to tile bottom of the keel. This is used instead of a heat exchanger. The engine coolant pump feeds engine coolant through the keel cooling sells where it gives off heat to the surrounding river or sea water. These types tend to be less efficient and therefore, larger than a manufactured unit.



<Box Type Keel Cooler>

The other type of keel cooler that is used is a box cooler. This type uses a box or sea chest that sits inside the keel with openings to allow sea water to flow through it. The tube bundle sits inside the box and carries the engine water. These units are useful since they can be checked or serviced without pulling the boat out of the water and the cooler is protected from any impact with foreign objects.

The manufacturer of the box cooler should be consulted for proper sizing and installation of the unit.



6.7.2. Keel cooler location

The keel cooler should be installed below the waterline far enough to avoid the aerated water close to the surface. Good keel cooler performance requires a constant water flow over the cooler. Locations that are in the water flow and flush on the keel are preferred over side locations and recessed installations. Recessed and shielded installations must allow for unobstructed sea water flow over the keel cooler tubes.

Slow moving boats should have the keel coolers installed close to the propeller to benefit from movement of water through the propeller. Dredges and other vessels that will be operated with little movement through the water should have the keel coolers installed on an incline or vertically to promote water circulation by convection.

Keel coolers should not be located in areas that at exposed to pounding seas, keel flexing or excessive vibration. The bow of a ship is subjected to tremendous water forces and is generally a poor location for a keel cooler. The area of the ships bottom adjacent to the keel is the strongest section and is the best keel cooler location.

6.7.3. Design of keel cooler system

The keel cooling area must be of a certain size to ensure that coolant heat is conducted away under all operating conditions.

This cooling area depends, among other things, on the planned top speed of the vessel which, for a given engine rating, results from the propeller system installed and the size and design of the hull.

Guideline values for the design of the keel cooling area as a function of the amounts of coolant heat to be dissipated and the speed of the ship can be found in tables on the following pages.

The amounts of heat to be dissipated at maximum power output can be obtained from the "Technical data " sheet in the appendix page of this manual.

Guideline values for cooling areas in keel cooling systems in m² for the engine coolant circuit. (River or sea water temperature = 32°C)

Amount of Heat to be Dissipated from the Engine Coolant Circuit in MJ/h*	Cooling area in m² for ships at a top speed of:			
	0	**8**	**15**	**≥20 (knots)**
	0	**15**	**28**	**37 (km/h)**
200	5.5	1.0	0.9	0.8
400	11.0	1.9	1.75	1.6
600	16.5	2.8	2.6	2.3
800	22.0	3.75	3.5	3.1
1,000	27.4	4.75	4.3	4.0
1,200	-	5.6	5.25	4.7
1,400	-	6.5	6.0	5.5
1,600	-	7.5	7.0	6.25
1,800	-	8.5	7.75	7.0
2,000	-	9.5	8.75	8.0
2,200	-	10.3	9.1	8.7
2,400	-	11.2	9.9	9.5
2,600	-	12.2	10.7	10.3

* See engine technical data of the appendix page in this manual.

Design data: a) River or sea water temperature: 32°C
b) Cooling cell height: 20 mm
c) Cooling flow rate in cooling system: 1 ~ 2 m/s
d) Keel made of steel with thermal conductivity: 50 W/K x m
e) For safety reasons (influence of paint layers, encrustation of keel with foreign matter, deposits in cooling system) only 60% of the cooling areas were utilized.

Guideline values for cooling areas in keel cooling systems in m^2 for the engine coolant circuit. (River or sea water temperature = 20°C)

Amount of Heat to be Dissipated from the Engine Coolant Circuit in MJ/h*	Cooling area in m^2 for ships at a top speed of:			
	0	**8**	**15**	**≥20 (knots)**
	0	**15**	**28**	**37 (km/h)**
200	4.5	0.8	0.7	0.65
400	9.0	1.6	1.4	1.3
600	13.4	2.4	2.1	2.0
800	17.9	3.2	2.8	2.6
1,000	22.3	4.0	3.5	3.3
1,200	-	4.8	4.2	4.0
1,400	-	5.6	4.9	4.7
1,600	-	6.5	5.6	5.3
1,800	-	7.25	6.3	6.0
2,000	-	8.0	7.0	6.7
2,200	-	8.8	7.7	7.25
2,400	-	9.6	8.4	8.0
2,600	-	10.4	9.1	8.7

* See engine technical data of the appendix page in this manual.

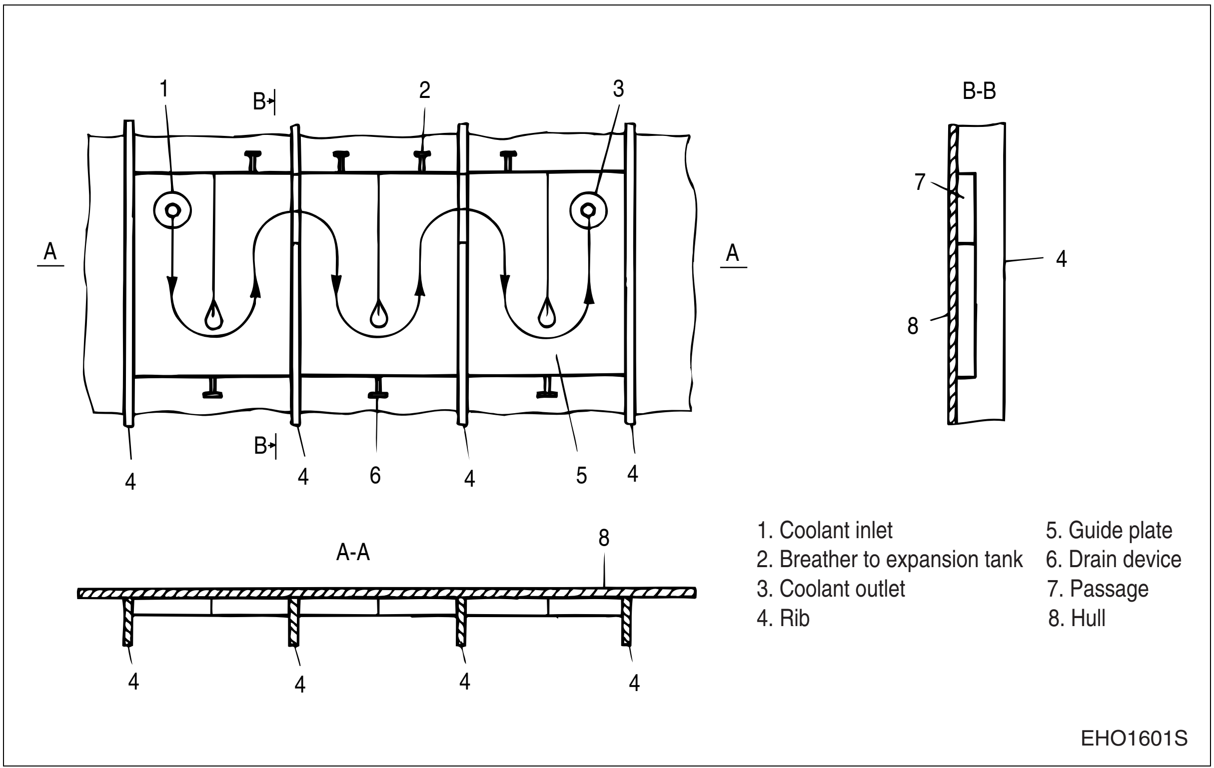
Design data: a) River or sea water temperature: 20°C
b) Cooling cell height: 20 mm
c) Cooling flow rate in cooling system: 1 ~ 2 m/s
d) Keel made of steel with thermal conductivity: 50 W/K x m
e) For safety reasons (influence of paint layers, encrustation of keel with foreign matter, deposits in cooling system) only 60% of the cooling areas were utilized.

<Design of Keel Cooler>

Keel coolant cell heights of over 20 mm are to be avoided, as the heat transfer occurs only within a small boundary layer. In addition, great heights result in large cross sections and, consequently, in flow rates that are too low, which leads to a deterioration of the heat transfer.

Not any small value for the free cross section of the cooling system can be chosen, as otherwise the pressure drop will be too high. Flow resistance in the cooling system can be effectively reduced by the use of deflectors at the turns. The coolant is usually circulated by engine water pump.

<Example: Schematic Diagram of a Keel Cooling System>



Note:

Good bleeding of each and every cell section to the expansion tank is decisive for system's reliability.

6.7.4. Commissioning the Keel Cooling System

Before commissioning, remove any kind of dirt from the cooling system (forging scales, welding beads etc.) and check for leaks.

Ensure that the system is thoroughly bled when filling it up.

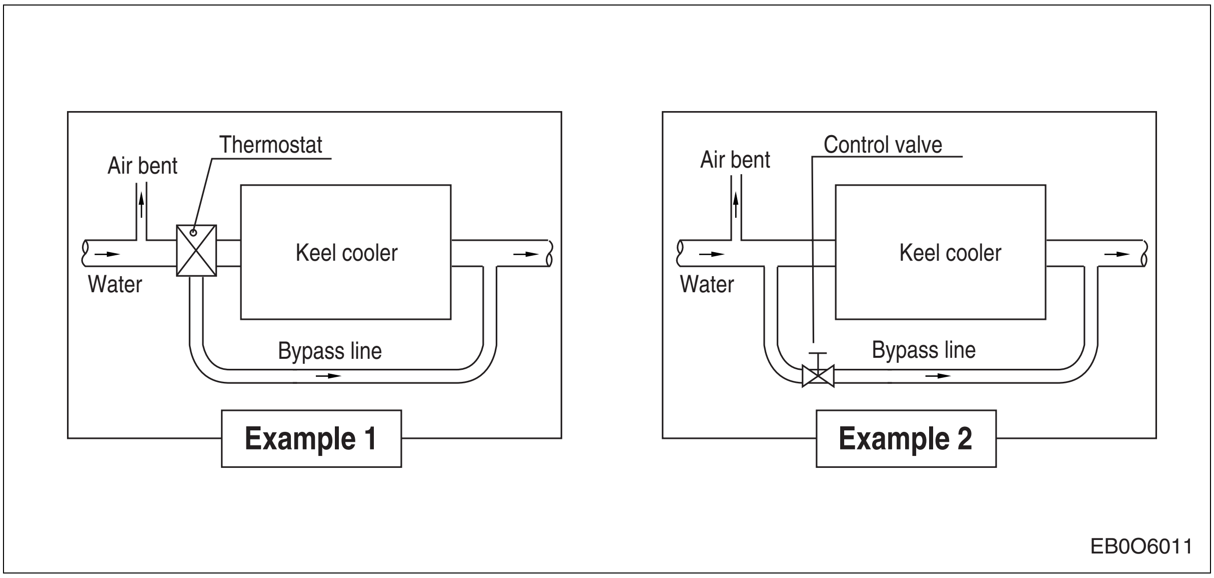
6.7.5. Engines with Inter-cooler

A second cooling system with a separate pump must be installed for the keel-cooler.

The circulating pump may be procured by the shipyard itself but must meet the following minimum delivery requirements:

Note:
Refer to "engine technical data" of the appendix page in this manual for "Amounted of heat to be dissipated from Intercooler" each model.

Alternatively, the sea water pump only can be used for inter cooler cooling separately.



Guideline values for cooling areas in keel cooling systems in m² for the engine coolant circuit. (River or sea water temperature = 20°C)

Amount of Heat to be Dissipated from the Intercooler Circuit in MJ/h*	Cooling area in m² for ships at a top speed of:			
	0	**8**	**15**	**≥20 (knots)**
	0	**15**	**28**	**37 (km/h)**
50	5.7	1.3	1.2	1.1
100	11.4	2.5	2.25	2.15
150	17.0	3.8	3.4	3.2
200	22.7	5.0	4.5	4.3
250	28.5	6.3	5.6	5.4
300	-	7.6	6.7	6.5
350	-	8.8	7.8	7.5
400	-	10.1	9.0	8.6
450	-	11.3	10.1	9.7
500	-	12.6	11.2	10.7
550	-	13.9	12.3	11.8
600	-	15.1	13.4	12.9
650	-	16.4	14.6	14.0

* See engine data of the appendix page in this manual.

Design data:
a) River or sea water temperature: 20°C
b) Cooling cell height: 20 mm
c) Cooling flow rate in cooling system: 1 ~ 2 m/s
d) Keel made of steel with thermal conductivity: 50 W/K x m
e) For safety reasons (influence of paint layers, encrustation of keel with foreign matter, deposits in cooling system) only 60% of the cooling areas were utilized.

<Calculation Formula of Rated Power at Inter-cooler System>

The maximum permissible inlet temperature of the inter-cooling agent into the inter-cooler is 32°C.

If this requirement cannot be met, proceed as follows:

The output must be reduced as per the formula below:

$$P = -\frac{1}{3} \times t_{a3} + 110$$

Key: P = Power in% of rated power

t_{a3} = Inlet temperature of the coolant into the inter-cooler in °C

Example: One engine with a maximum output of 300 kW at 2,000 rpm

The coolant inlet temperature into the inter-cooler is 60°C.

$$P = -\frac{1}{3} \times 60 + 110 = 90$$

The engine can now be operated with only 90% of its max. output, i.e. 0.9 x 300 = 270 kW.

The above formula does not apply to these engine models. If an inter-cooling agent entry temperature of 32°C cannot be achieved, a heat exchanger cooling system must be installed greater

7. Lubricating System

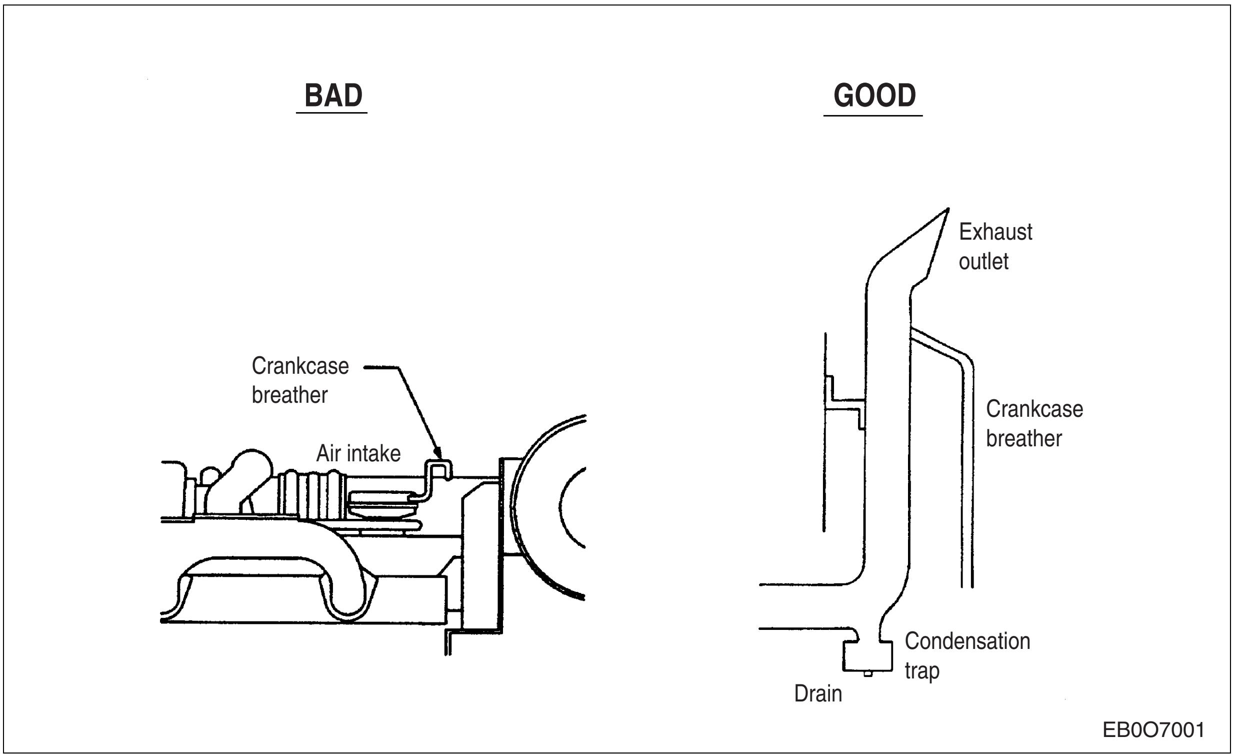
7.1. Marine Installation Requirements

- When oil filter is changed, HD Construction Equipment genuine parts are to be used.
- The oil dipstick must be marked with the high and low oil level when the boat is in the water and at its normal trim if the engine installation angle is over 6 degree.
- The lubricating oil used in the engine must meet the specifications listed in "engine technical data" of the appendix page in this manual.

All HD Construction Equipment marine engines have full flow lubricating oil filter type. Engine oil filter should not be modified from engine.

7.2. Engine Blow-by Gas Vent

During normal operation a small amount of combustion gas escapes past the piston compression rings into the crankcase. This blow-by gas is vented out through the engine breathers. Most of the oil mist and vapor is removed by the breathers and drains back into the engine.



However, some oil vapor is carried through the breathers by the blow-by gases. Engines that operate in an open area just allow the gases and oil vapor to escape at the breather.

On boats the gases and oil vapor should be piped out of the engine room. Vessels with dry exhaust systems can vent the blow-by into the exhaust flow. The blow-by should be vented into the exhaust at the outlet of the exhaust piping. Routing the blow-by too close to the turbocharger outlet will pressurize the crankcase and result in excessive blow-by gas.

Crankcase vent plumbing should have a continuous upward slope to prevent oil build-up in the vent lines. Drain fittings are required at the bottom of long vertical runs to remove accumulated oil.

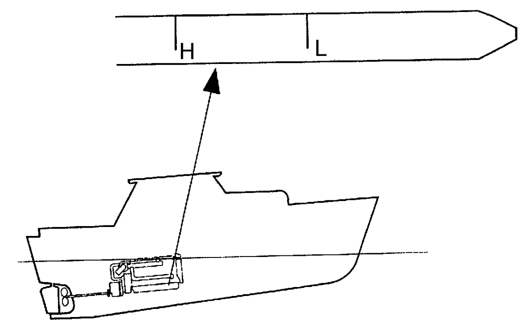
Blow-by gases should not be vented to the atmosphere near the engine all intake or directly into air cleaners or turbochargers. The oil build-up that occurs will plug the air cleaner element and may cause turbocharger failures, loss of power and decrease the effectiveness of the inter-cooler air fins.

7.3. Lube Oil Drain Pump

The engine oil pan is normally not accessible in a marine application of boat. Lube oil drain pump is mounted on all HD Construction Equipment marine engines to a standard part because the drain plugs of oil pan and marine gear are difficult to access in the boat.

7.4. Oil Dipstick Level Gauge

⚠ **The lubricating oil dipstick must be marked with the high and low oil level when the vessel is in the water and at its normal trim if the engine installation angle is over 6 degree.**



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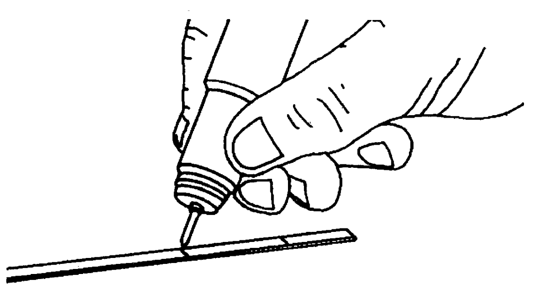
Since the installation angle of a marine engine may vary greatly among vessels, the high and low oil levels on the dipstick will also vary as the engine angle changes.
The capacity of lube oil can be referred to "Engine technical data" of the appendix page in this manual.
Dipstick should be re-marked by engraving on the lube oil capacity of each engine. Be sure to check and mark the oil levels between Max. and Min. when the boat is commissioning at first. Please note that stamping or notching will weaken the dipstick and the tip of the dip-stick may break off in the oil pan.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8. Fuel System

- The fuel injection system operates at high pressures. Accordingly, the system must be handled and serviced with care, and the safety regulations must always be followed.
- The electric controlled common rail fuel injection system should never be removed, installed or inspected while the engine is running or immediately after stopping the engine; inspections and service work should be performed at least 30 seconds to one minute after stopping the engine.
- During service work and inspections, make sure that the workspace is clean before performing any work to prevent foreign matter from entering the fuel system; keep any unnecessary removal and installation to a minimum; and in the case of parts which must be reused during removal and installation, take the necessary measures to prevent foreign matter from entering the parts after removing them and clean them before reusing them for installation.
- The normal performance of O-rings and sealing washers used on high-pressure fuel pipes and in the fuel system cannot be guaranteed if they are reused; make sure to use new parts.
- When assembling high-pressure fuel pump, common rails, injectors, and high-pressure fuel pipes, take care to prevent damage due to impacts, etc. resulting from carelessness and make sure to assemble them precisely.

8.1. Fuel Circuit

Fuel is sucked from the tank by the supply pump and fed to the inlet chamber of the injection pump via the fuel water separator filter.
The fuel supply pump supplies more fuel than is actually needed for the combustion.
The delivered surplus fuel flows back to the tank via a fuel return line.

8.1.1 Fuel Lines

Should prevent the fuel against heating up. Heated fuel is expanded and especially lighter.
As a result, less fuel mass is injected, which causes the power to drop. For this reason fuel line from the tank to the engine must not be laid near or attached to hot engine parts.
The inner line cross sections must not be smaller than that of the injection pump inlet pipe and should select the flame-resistant material for this fuel lines.
Prior to commissioning the fuel system (tank and pipe-work) the entire system must be flushed out with diesel fuel. If the fuel return restriction is too high, excess fuel will be put in the cylinder.
This will cause high cylinder pressures, high temperatures, increased smoke, poor performance and a decrease in the engine life.

Note:
The lubricating oil dipstick must be marked with the high and low oil level when the vessel is in the water and at its normal trim if the engine installation angle is over 6 degree.

The fuel return line size required for an engine will depend on the engine return flow rate, the length of the line, the number of bends and the number and type of fittings.
The following table lists the minimum line sizes which will NORMALLY meet the maximum allowable return line restriction limit. However, larger line sizes may be required when several bends, valves or fittings are used in the fuel plumbing. Whatever line size is used, the fuel return line restriction must not exceed the 102 mm Hg (0.14 kg/cm^2).

Engine Model	Supply Line I.D.	Return Line I.D.
L066TI	ø10 mm	ø10 mm
L136/L136T/L136TI/L086TI/MD196T/L126TI/4L126C	ø10 mm	ø10 mm
V158TI/4V158TI/V180TI/V222TI/4V222TI	ø12 mm	ø12 mm
4L066C/4L086C	Min. ø10 mm	Min. ø10 mm
4V222C	Min. ø18 mm	Min. ø18 mm

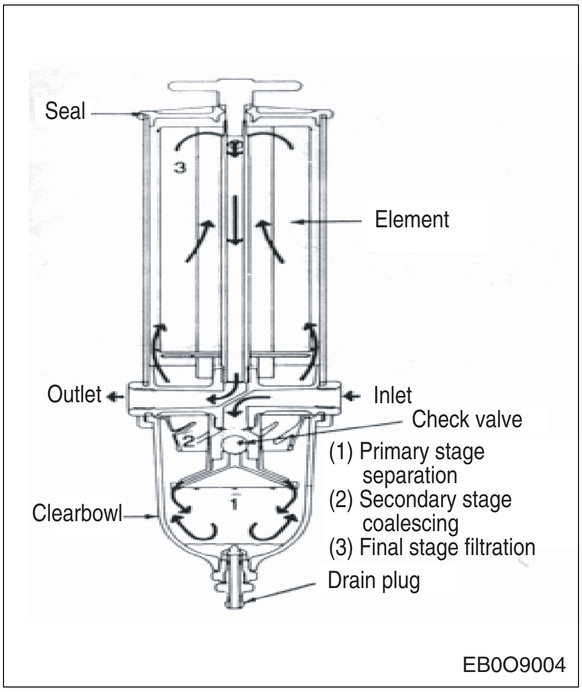
The fuel line should supply clean fuel not mixed with air bubbles and water to the fuel injection system.

Therefore, the water separator should be installed between the fuel tank and the fuel filter as shown below.

Not only does fuel cool down some of the heat generated from the injection nozzle tips during combustion, it also lubricates the fuel Injection pump and the injection nozzles.

If fuel containing water is supplied, the lubricating action for the pump and the injection nozzles is hampered, and as a result, related parts may get damaged. Therefore, the water contained in fuel must be removed by installing a water separator before the fuel is supplied to the injection pump.

Only the genuine parts shipped by HD Construction Equipment should be installed for the water separator.

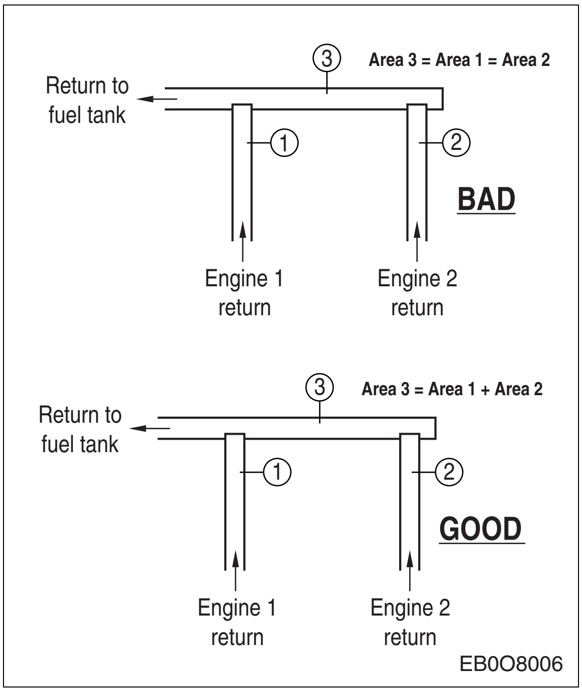


8.1.2. Valves

Valves installed in the fuel supply should have low flow resistance and not be a source for the entry of air into the fuel system. These requirements are best met with a plug type valve. Globe valve and other types of packed valves may be used, but they require periodic repacking to maintenance an air tight seal. Some valves are not designed to seal in a suction line, and therefore, cannot be used in the fuel supply line.

When a manual shut-down valve is used, the linkage should completely open and close the valve under all conditions.

Selector valve ports should be at least as large as the fuel supply line's inner diameter. All values used in the fuel system should be clearly marked as to their function and position (open/close).



The fuel supply and return line must be routed without loops. Any loops in the fuel plumbing will cause pressure surges in the line and result in engine speed instability.

Whenever multiple engines are used, each engine should have separate fuel supply and return lines. Running two or more engines with common fuel lines can result in idle surge and speed stability problems. Pressure pulses in the return line of one engine may affect the operation of other engines that share the common return line. This can be overcome by using a common return line whose cross-sectional area is equal to the sum of the area of each of the individual return lines.

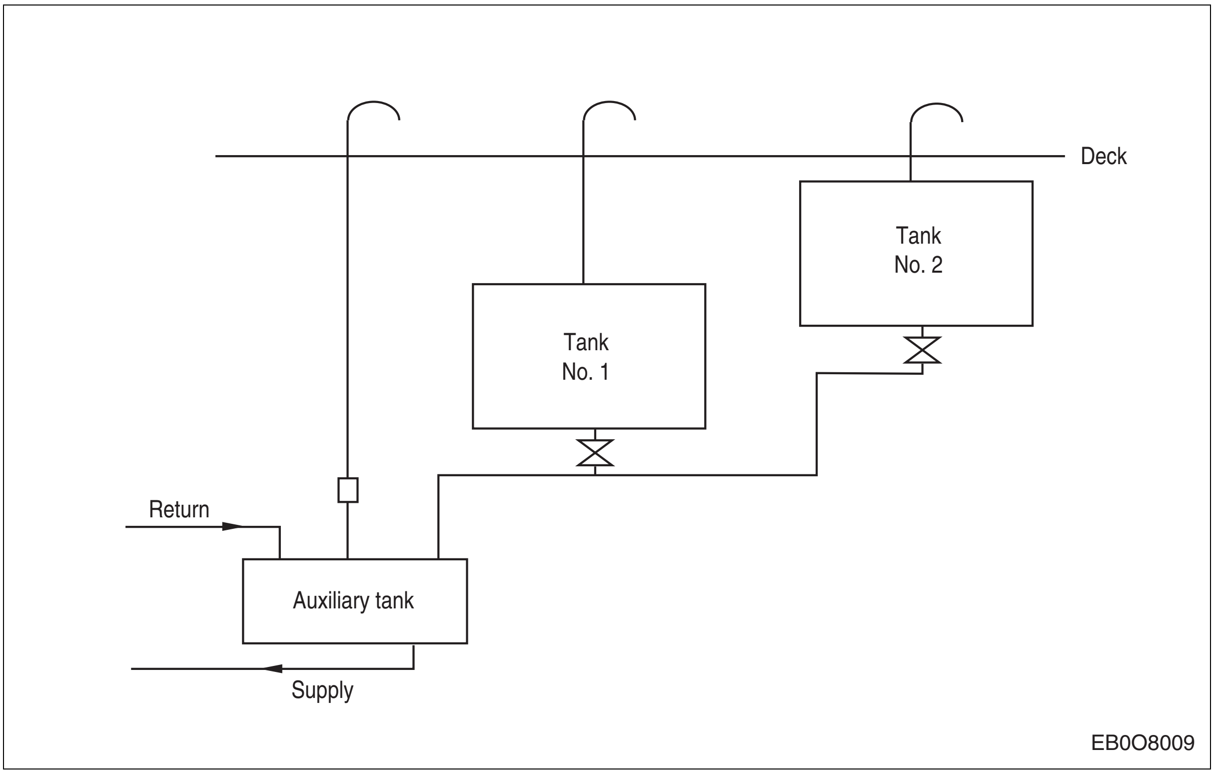
<Air Vent Line>

The vent line should terminate above the deck in a protected location. A gooseneck at the top is recommended to keep dirt and water from entering the fuel tank through the vent line.

Fuel tanks can be made of terneplate or phosphate coated steel, aluminum or fiberglass.

Galvanized or zinc plated steel tanks or piping should never be used in a diesel fuel system.

All auxiliary tanks should have vents routed to a point that is above the highest possible fuel level in the main tanks. This will prevent accidental flooding of the bilge if the float tank (No. 1) is overfilled.

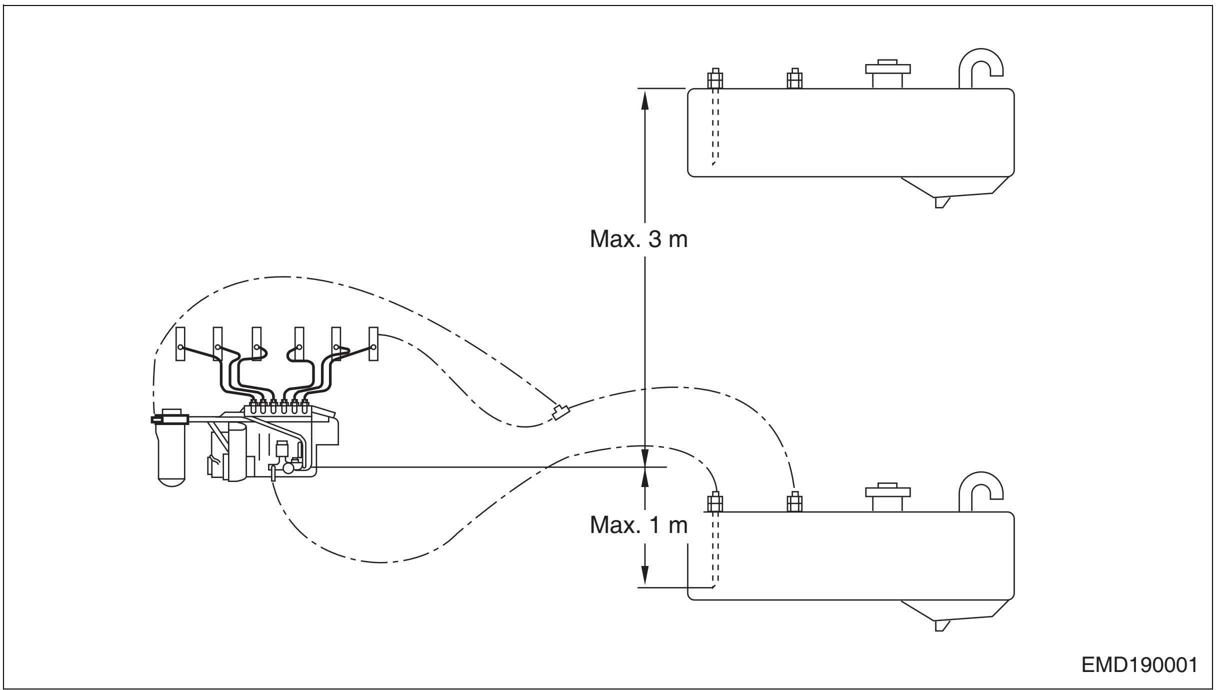


8.1.3. Installing the Fuel Tank in a Ship

When installing the fuel tank in a ship, install it in a position at a similar height to the engine. If such a position is not available, follow the instructions below.

As the maximum suction height of the HD Construction Equipment fuel supply pump is 1 m, the fuel tank should not be positioned below this point. Also, if the mounting position of the tank is far from the engine due to an additional fuel filter installed between the tank and fuel supply pump, obstacles or limited mounting space, the piping between them becomes longer, resulting in higher resistance in the piping.

Therefore, the mounting height should be lowered in such cases.

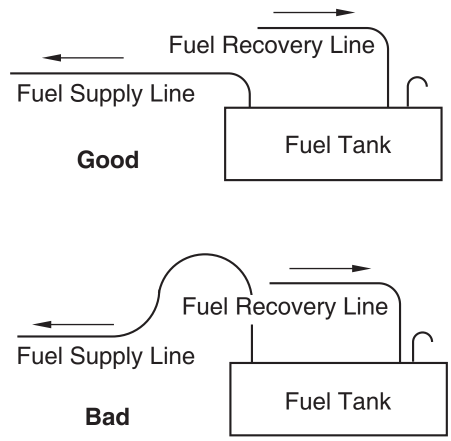


Engine Model	Fuel Supply (Max. Restriction)	Fuel Return (Max. Allowable Pressure)
L066TI/L136TI/M086TI/ MD196TI/L126TI/4L126C	120 mbar	600 mbar
V158TI/4V158TI/V180TI/ V222TI/4V222TI	360 mbar	600 mbar
4L066C/4L086C/4V222C	0.5 ~ 1.0 bar(abs.)	1.2 bar(abs.)

Since the amount of fuel supplied for combustion is two to three times greater than the actual amount of fuel needed for combustion, the amount remaining after injection is returned to the fuel tank through the return pipe. Therefore, if the fuel return line is restricted or has excessive resistance, this remaining fuel is led into the combustion chamber, leading to incomplete combustion and therefore increasing fuel consumption, as well as causing exhaust gas and engine overheating.

To prevent this, at least one fuel return line should be always kept open at all times.

When installing a fuel supply line on the tank, there should be no sharp bends or slack parts to prevent air pockets from forming in the line. If the fuel line is slack, abnormal pressure jumps are created in it. When the nozzles spray fuel in this state, the fuel line cannot supply fuel evenly, causing unstable engine speed.



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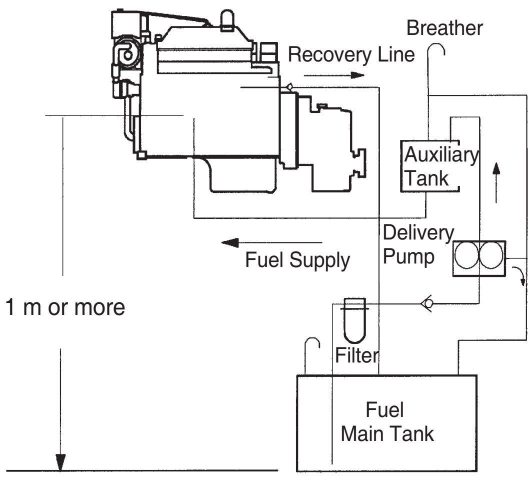
1) If the fuel tank is positioned more than 1 m below the injection pump

   For HD Construction Equipment engines, if the height of the fuel tank is over 1 m lower than the inlet of the fuel injection pump, fuel cannot be supplied smoothly, so an additional fuel transfer pump is required in such cases to ensure smooth fuel supply to the engine.

   As shown in the figure, the auxiliary fuel tank is installed on the fuel supply line to ensure a continuous supply of fuel from the main fuel tank to the engine.

   This system requires a transfer pump that can be run continuously to supply fuel with up to 0.6 ㎏/㎠ of the regulated pressure to the auxiliary tank. Thus, fuel can be continuously supplied from the main tank to the auxiliary tank, and then to the fuel injection pump.



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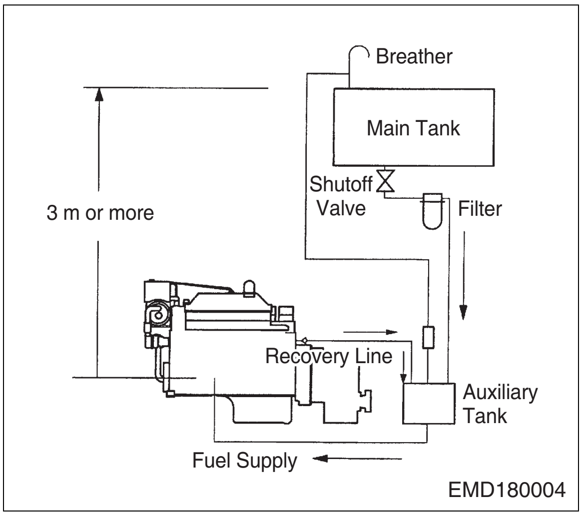
Any auxiliary tank should be equipped with an overflow line and air outlet.

The fuel line should be set up so that overflowing fuel is automatically returned to the main fuel tank through the overflow line in case the auxiliary tank overflows due to a problem in the fuel line.

2) If the fuel tank is positioned more than 3 m over the injection pump

If the position of the fuel tank is over 3 m higher than the fuel supply pump, an auxiliary tank should be added and the fuel return line should be connected to the auxiliary tank. In such cases, fuel cut-off valves should be installed on the fuel supply line and fuel return line to prevent fuel from overflowing during engine repairs.



8.2. Fuel Tank

The fuel tank must be able to store fuel cleanly and safely and must be structured to satisfy the following requirements so as not to affect the components of the engine injection system.

- Material
  Zinc (Zn), copper (Cu), lead (Pb), sodium (Na) and calcium (Ca) cause chemical reactions with water in fuel and biodiesel, thereby forming various corrosive acids, sludge and viscous substances. When this occurs, it causes premature clogging of the primary fuel filter, seizure of injectors, corrosion and wear of fuel system components, including the injection system, leading to excessive maintenance expenses resulting from engine failure. Hence, when the use of these materials cannot be avoided, make sure to apply a phosphate film or trivalent chromium plating to prevent the materials from coming into direct contact with fuel.
- Air Intake/Discharge System
  When fuel is delivered to the engine, a reduction in pressure equivalent to the volume occupied by the fuel in the tank occurs, leading to a fluctuation in the volume of fuel as a result of a change in the fuel temperature. Hence, if the fuel tank is an enclosed structure, excessive static/negative pressure is formed, causing abnormal engine operation. Accordingly, the fuel tank must be equipped with an air intake/discharge system to constantly maintain atmospheric pressure, while the ports through which air is drawn in or discharged must be connected by means of extension hoses or tubes to a clean environment with minimal dust, moisture, insects, etc. or a suitable air filter must be installed to prevent such foreign matter from entering the system. When air inlets and outlets are installed in extremely dusty or humid areas, the service life of the primary and secondary fuel filters severely reduced, while wear and corrosion of injection system components are accelerated, resulting in a shortened service life and excessive maintenance expenses.
- Port for Draining Condensate and Cleaning Foreign Matter
  Inside the fuel tank, foreign matter entering through the air inlet and outlet ports as well as condensate on the inner wall of the tank resulting from the difference in temperature between fuel and ambient air form deposits continuously. The fuel tank must be equipped with a cleaning port for periodically removing and cleaning condensate and foreign matter to prevent foreign matter and condensate deposits in the tank from entering the engine fuel system.
- Cleaning and maintaining the fuel tank
  After filling the tank with the recommended fuel, draining any condensation accumulated on the bottom of the tank completely and keeping the fuel full help to enhance engine performance.

CAUTION:
Check whether the fuel supply valve is open. (If used)

As the fuel tank cools after stopping the engine, condensation forms and can contaminate the fuel. In order to prevent this, add fuel to the tank after running the engine each day.
In maritime regions, most fuel contamination is caused by moisture and the reproduction of microorganisms. Generally, contamination arises from handling fuel improperly and not following common sense. If fuel contains moisture, it is easy for microorganisms to reproduce and coat the bottom of the tank in a black slime. Hence, it is important to keep the amount of moisture in the fuel storage tank to a minimum.

In order to remove contaminated fuel from the fuel tank, install a water separator to gather the moisture and foreign materials in the tank. Drain the contaminated, foreign matter accumulated here every day and change the engine fuel filter several times until the fuel system is clean.

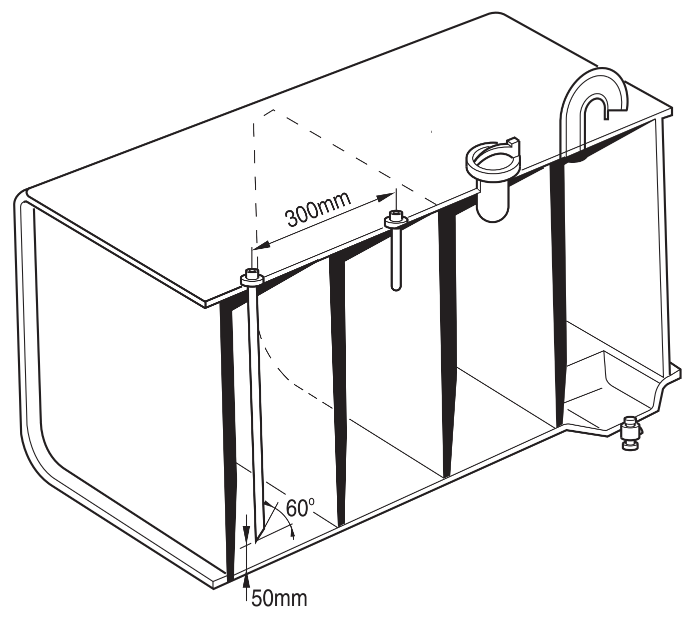
8.2.1. Tank Capacity

The required fuel tank capacity is determined by the engine power, the fuel consumption and the required radius of action. The following equation can be used for a rough-and-ready estimate.
In addition, a sufficiently large amount of reserved fuel must be taken into consideration too.

$$V = \frac{P \times b_e \times t}{830}$$

Where: V = Tank capacity in liter (lit.)
P = Engine power in kilowatt at cruising speed (kW)
t = Operating period in hours (hr)
b_e = Specific fuel consumption at full load in gram per kilowatt and hour.(g/kW.h)
A guideline value of 220 g/kWh is sufficiently precise for the estimate.

8.2.2. Tank Manufacturing



The tank must be made of fuel- and corrosion-resistant material. We recommend special sheet steel as tank material. Under no circumstances must galvanized sheet metal be used.
The tank must be made stable. We recommend the use of baffles to prevent fuel from sloshing when the ship is pitching through rough waters and air from being sucked in. The tank bottom must have a depression with a drainage device where dirt and condensation water can collect.

Condensation water in the fuel tank provides the basis for the growth of micro-organisms in diesel fuel. These micro-organisms cause premature filter blockages and corrosion damage, which is why condensation water collected in the tank and in the filter must be drained regularly.
The suction line inlet to the engine should be approx. 50 mm above the tank bottom.
We recommend that the fuel return line from the engine to the tank be located as far away from the suction line as possible and extend as far into the tank as the suction line.
The filling line must have an adequate cross section, lead to the tank without sharp turns and close securely.
In addition, the tank must be equipped with a bleeding line to the deck.
Ensure that even in adverse conditions no water (spray, rain) can penetrate.
Having completed the tank assembly, remove all dirt, forging scales and welding beads from the tank and check it for leaks.

8.2.3. Fuel Requirements

Fuel quality is an important factor in obtaining satisfactory engine performance, long engine life, and acceptable exhaust emission levels. HD Construction Equipment engines are designed to operate on most diesel fuels marketed today. In general, fuels meeting the properties of ASTM
Designation D975 (grades 1-D and 2-D) have provided satisfactory performance.
HD Construction Equipment recommends to use Number 2-D diesel fuel for maximum fuel economy whenever possible. When temperatures are below -7°C (20°F), use Number 1-D fuel. If Number 1-D fuel is not available, the mixture of one kerosene to two gallons of Number 2-D fuel can be used.
Once kerosene has been added, the engine should be run for several minutes to mix the fuel.

8.3. Fuel Specifications

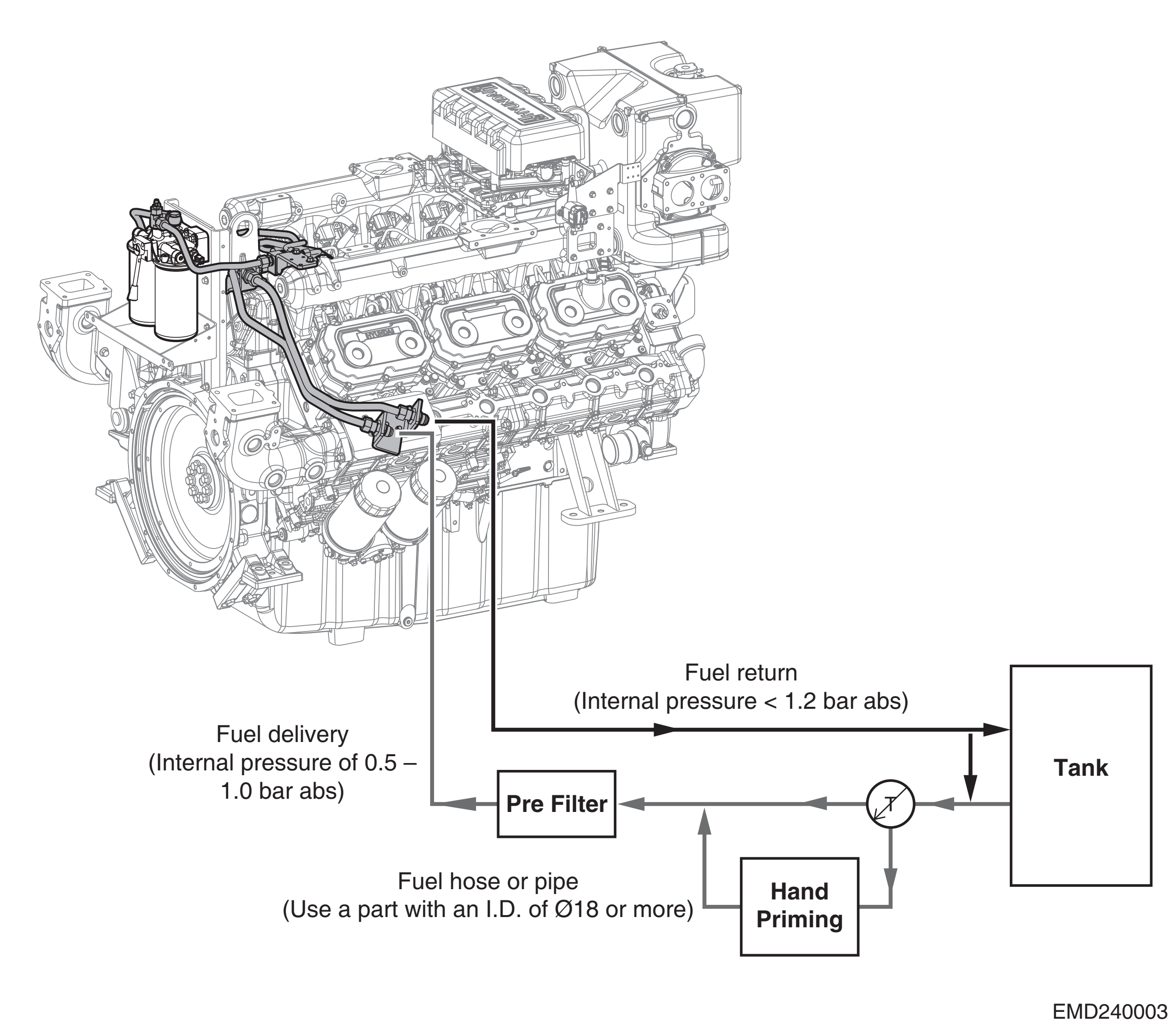
- Allowable Fuel Under Warranty
  1) Korea: Article 115 Schedule 33 'Ultra-Low-Sulfur Diesel' of the Clean Air Conservation Act
  2) Europe: EN590:2013 AC:2014, EN16734:2016
  3) North America: ASTM D975-15C Grade 1D or 2D
  4) Japan: JIS K2204:2007 (lubricity $\leq$ 520μm, FAME max. 5%)
  5) China: GB252:2015 and GB19147:2013
  6) India: IS 1460 2005 Amm. 10 BS III or BS IV
  7) Brazil: ANP69/2014
  8) Russia: GOST R32511-2013 (excluding Articles 3 and 4)
  9) HVO (Mechanic engine is not allowed, electronic engine is certified.)
- Characteristics and effects of 7% or higher biodiesel: If the amount of biodiesel in the fuel exceeds 7%, the oxidation stability decreases below that of ordinary diesel and the fuel reacts more easily with oxygen in the air, resulting in problems such as the formation of sludge and deposits, reduced lubrication, increased microbes, and excessive water in the fuel. If this foreign matter enters the engine, problems requiring high maintenance costs may occur, including premature clogging of the primary/secondary fuel filters, corrosion of fuel system components, and wear of components of the high-pressure injection system. Hence, biodiesel must be stored only for less than six months from the date when it was manufactured and less than three months of being added to the generator set. Using fuel which has exceeded this storage period can cause critical damage to fuel system components, so make sure to follow these guidelines.

  In addition, if the fuel tank and fuel line components contain copper, lead, tin or zinc, the biodiesel oxidizes more quickly, resulting in engine damage due to fuel within a very short period of time or premature clogging of the primary/secondary fuel filters.
- Water and Foreign Matter in Fuel

  The fuel and fuel tank must be kept free of moisture. Water in fuel causes the following problems.
  1) Incomplete combustion
  2) Nozzle clogging
  3) Injection pump damage
  4) Piston damage

  Moisture also accelerates the growth of mold or microbes in the fuel tank, thereby clogging the fuel filter. In winter, moisture can freeze and block the delivery of fuel.

8.4. Requirements



8.4.1. Primary Fuel Filter

A primary fuel filter, two piping connecting adapters, and two fuel filter plugs are provided as separate accessories along with the engine.

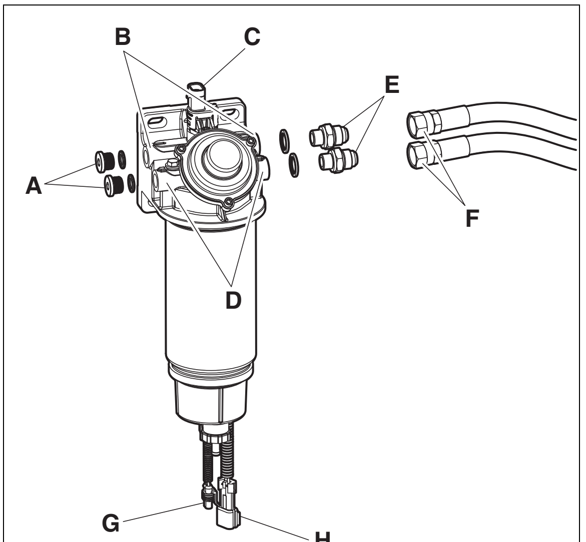
Remove the plugs for preventing foreign matter from entering the fuel inlet/outlet of the primary fuel filter and tighten the connecting adapters provided to the specified torque. (Adapter tightening torque: 2.0 ~ 2.5 kg.m)

According to the installation location of the primary fuel filter, one connecting adapter per port in the both inlet/outlet ports is used, and the fuel filter plugs are assembled in the remaining ports.

When tightening the hose, tighten it with the hex. portion of the adapter secured with a spanner to prevent it from turning along with the hose. (Hose tightening torque: 7.0 kg.m ±10%)

8.4.2. Running the Primary Fuel Filter (Oil-Water Separator) Heater

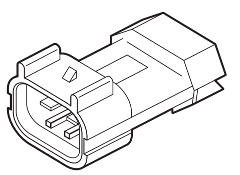
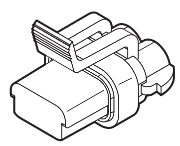
In winter and in cold temperatures, the paraffin in diesel forms a gel and blocks the surface of the cartridge in the primary fuel filter, resulting in restricted fuel flow. In such cases, engine start-up may be delayed/ impossible, the engine rpm may be unstable after engine start-up, or the engine may turn off. To prevent this phenomenon, turn the keyswitch on to run the heater mounted on the primary fuel filter (oil-water separator) three minutes before starting the engine to remove the paraffin from inside the primary fuel filter and the paraffin gel entering continuously from the fuel tank.



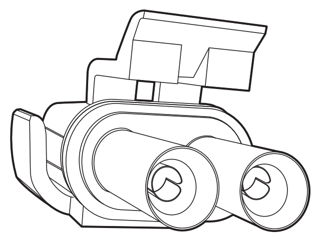
EMD210009

Number	Name
A	Fuel filter plug
B	Fuel inlet port
C	Fuel heater connector
D	Fuel outlet port
E	Fuel adapter SAE J516 37˚ CONE 7/8-14 UNF
F	Fuel hose
G	Water-in-fuel sensor connector
H	Fuel heater connector

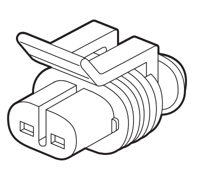
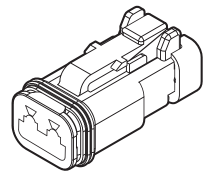
- Fuel heater
  - Fuel heater specifications (for one heater)
    Operating voltage: DC24V
    Operating power: 200 W
    Operating temperature: On under 7 ±4°C, Off over 24 ±°C

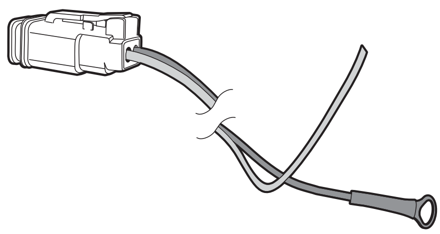
Primary Fuel Filter	Harness connecting part
	
15300002(DELP HI)	15300027(DELP HI)

- Fuel heater (DX22)
  Heater Lead Wire:
  Connector Housing Packard #12103584
  Pin PACKRAD #12124581-L
  Operating power: 195 W (X2)
  Operating temperature: 2 ±5°C On, 24 ±°C


EMD240005

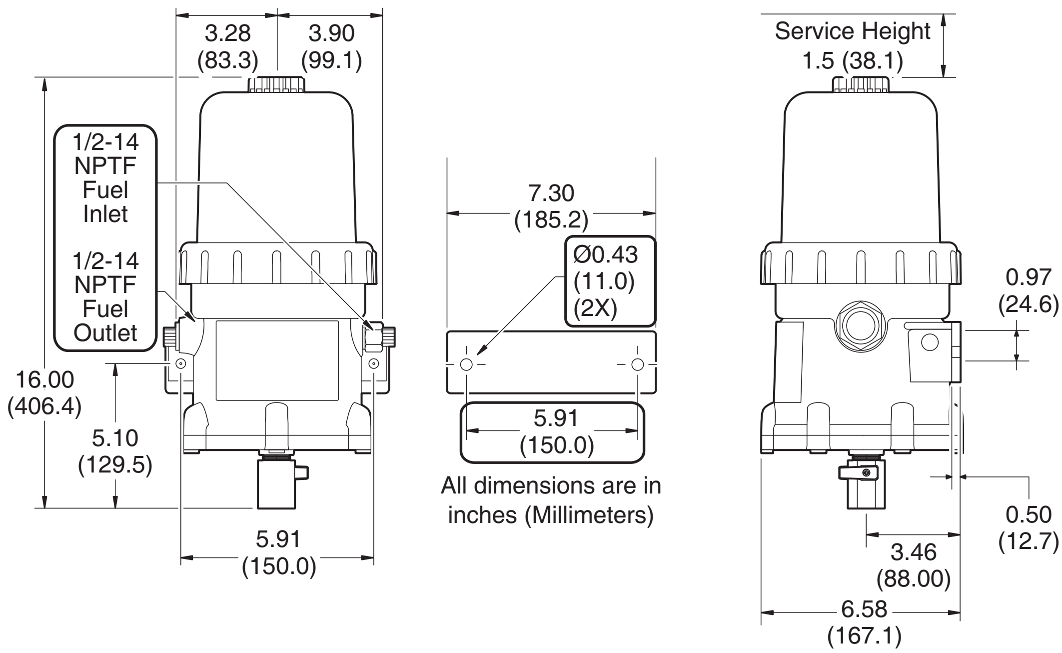
- Water-in-fuel sensor
  - Water storage capacity of the primary fuel filter
    Start of electrical connection with water in fuel sensor switch: 210 ml
    Maximum water capacity: 500 ml
  - Water in fuel sensor switch specifications
    Operating voltage: 5 ~ 50 VDC or VAC
    Resistance: 82 kΩ ±2% @ 25°C
- Water-in-fuel sensor (DX22)
  - DEUTSCH DT06-2S for harness
    (Provided with the filter.)
  - Start of electrical connection with water in fuel sensor switch: 490 ml
  - Operating voltage: 5 ~ 50 VDC or VAC

Primary Fuel Filter	Harness connecting part
	
DEUTSCH DT04-2P	DEUTSCH DT06-2S



EMD240006

- Water-in-fuel sensor (DX22)
  - With regard to the lubrication and cooling of fuel injection system components, fuel must be supplied to the engine in a clean state without any air or moisture, and if fuel containing moisture enters the engine, it can drastically reduce the service life and cause high maintenance costs due to wear and corrosion of injection system components, so the following genuine pre-filter must be installed between the fuel tank and the engine.
  - Cummins FH386
  - Fuel Inlet/Outlet Port Hole Tap Spec.(1/2-14 NPTF)



EDX22190137

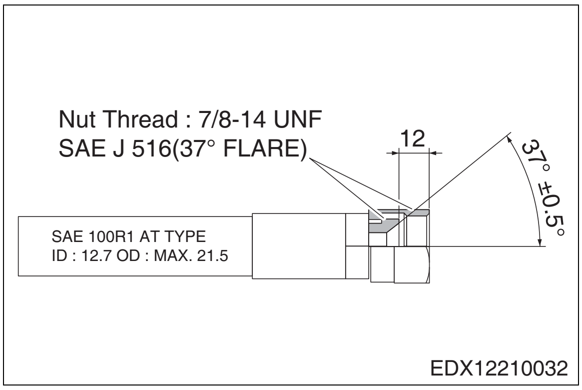
8.4.3. Fuel Lines Connected to the Engine

Since the fuel lines connecting the engine and the fuel tank must be flexible enough to withstand vibrations while the engine is running, it is recommended to use hoses.

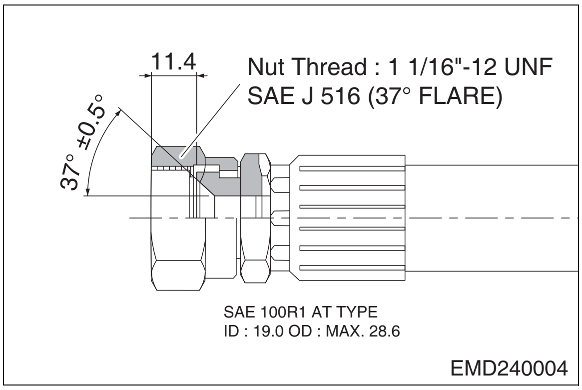
Install it to a necessary location according to the location of the primary fuel filter and the fuel tank.

When additional fuel hoses of different lengths are required, use the fuel hose specifications provided to order hoses of the desired length from a hose supplier.

- Hose
  SAE 100R1 AT Type I.D. Ø12.7,
  O.D. max. Ø21.5
- Hose Coupling
  SAE J516 37° Flare, 7/8-14 UNF



- Hose (DX22)
  SAE 100R1 AT Type I.D. Ø19.0,
  O.D. max. Ø28.6
- Hose Coupling (DX22)
  SAE J516 37° Flare, 1 1/16"-12UNF



9. Propulsion System

9.1. Marine Gear Ratio Selection

- Marine gear ratio selection is important and will affect both engine life and vessel performance. Propeller speed must be properly balanced with the power applied to it like vessel speed, propeller size, and propeller pitch and the secondary loads.
- Another important part of proper engine application is to choose the proper marine gear ratio and propeller size. Therefore, the marine gear ratio and propeller size must be chosen to allow the engine to achieve rated speed under fully loaded conditions.

Note:
HD Construction Equipment recommends to install the gearbox ratio as next application.

- Heavy duty: 2.5 ~ 6, Medium duty: 2 ~ 3.5, Light duty 1 ~ 2.5
- Engine movement must be restrained sufficiently to prevent damage from physical contact between the engine components and adjoining structures; and the movement must not exceed the flexural limits of connecting systems.
- The propeller shaft flange bore and face alignment must be within the marine gear manufacturer's limits.

9.2. How to Select the Right Propeller System

If you want to get the best performance out of your boat, you need to select the propeller and the gear ratio that will suit your particular boat, engine and speed range.
Below you will find a brief description of how propeller systems are designed. It is not just the engine capacity which determines the speed of the boat ; it depends just as much on the efficiency of the reverse gear and the propeller system.
Using the right propeller system will not only give you good fuel economy and higher speed; you will also experience greater comfort, with less noise and vibration.

9.2.1. Planing Boats

In planing boats over 20 knots, the size of the propeller depends on the engine power.
To transfer the power from the engine to the water, you need approximately 7 ~ 8 cm^2 propeller blade surface per kW shaft power. If the shaft is at an angle in relation to the flow of the water, this requirement may be considerably greater: 8 ~ 15 cm^2/kW is reasonable, depending on the angle of the shaft and the water flow.
At a shaft power of 400 kW, therefore, the propeller blade surface may need to be 400 kW x 9 cm^2/kW = 3,600 cm^2.
This surface may be divided over three, four or five blades.
This efficiency of a propeller blade diminishes when it becomes far too wide in relation to its length. This means that if the propeller diameter is limited in size (as is often the case), it is better to select several narrower blades (four of five) rather than three wide ones, for example.
The angle of the propeller shaft should be as small as possible. Shaft angles of less than 12˚ do not usually cause any major problems, but shaft angles of more than 14 ~ 15˚ should be avoided. The dis-

tance between the bottom of the boat and the propeller blades should be at least 12 ~ 13% of the diameter of the propeller. When you have selected the diameter of the propeller, you are ready to go on to select the pitch. Propeller blades should no travel faster than 60 ~ 70 knots through the water at 70% of the maximum propeller diameter.
This means that the speed of the propeller revolutions must be reduced when the engine capacity is greater, which requires a larger blade surface and therefore a greater diameter.
The relations between pitch and diameter should be:

$$\text{Pitch} = \frac{\text{Pitch Ratio}}{\text{Diameter}}$$

0.9 ~ 1.15 at 20 knots
1.0 ~ 1.3 at 30 knots
1.05 ~ 1.35 at 35 knots

Generally, a larger propeller with narrow blades and low revolutions is more efficient than a small, high-speed revolving propeller. When the boat's speed goes above 24 ~ 28 knots, the resistance of the shafts, rudders and propeller supports starts to become so great that the greater efficiency of the propeller is not beneficial.
The resistance on the propeller system can be reduced by reducing the shaft diameter, selecting stronger materials and reducing the rudders and surfaces of the propeller supports.
Lower gear ratios also mean thinner shafts. It is necessary to find a balance between propeller efficiency, water resistance of the shaft, etc.

9.2.2. Displacement and Semi-planing Boats

Boats of less than 15 knots need propellers which are as large as possible.
For example, in a trawler it is possible to save 20 ~ 30% fuel or to gain 20% greater thrust when trawling by increasing the propeller diameter by 50% and reducing the propeller speed by 40%.
The blade surface of the propeller is designed according to the minimum of 0.17 m^2 perton of thrust.
As described above, a large, slow - moving propeller is preferable. At a speed of 12 knots, for example, a three - blade propeller with a 50% blade area will achieve an efficiency rate of approximately 57% if the propeller blade cuts through the water at 50 knots with 70% of its diameter. At a blade speed of 70 knots, approximately only 47% efficiency is achieved.

The formula:

$$\text{T Newton} = \frac{\text{Propeller Efficiency x Shaft Output in kW x 1,944}}{\text{Diameter}}$$

Can be used to calculate the thrust and, therefore, the blade surface.
Three - blade propellers are often more efficient for large, solw - moving propellers than four - blade or five - blade propellers.
However, four - blade propellers usually produce less vibration, which is often preferable.
In general, there is a tendency towards four - blade propellers.
A suitable pitch ratio at 10 knots is 0.7 ~ 0.9 and at 15 knots 0.8 ~ 1.05.

As the best pitch ratio varies according to the speed of the boat, it is necessary to decide whether the propeller should be at its best when trawling, e.g. with a pitch ratio of 0.7, or whether it should be better when not trawling with a slightly higher pitch ratio.
Adjustable propellers are an excellent solution for trawlers, tugs and freighters.

As a very rough estimate, the bollard pull thrust can be calculated using the formula

- Adjustable propeller (kp)' 13 ~ 14 x hp
- Fixed propeller (kp)' 11 ~ 12 x hp

An adjustable propeller fitted to "the right boat" (up to 10 knots) can therefore save a lot of fuel.

9.2.3. Speed Range Between 15 and 20 knots

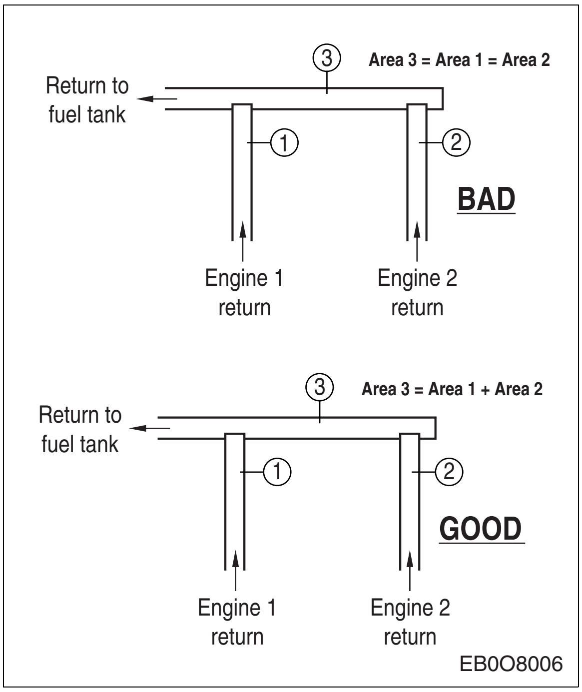
Within this speed range, a large slow propeller is preferable to a small, fast one.
The blade surface is designed as a compromise between kW/cm^2 and m^2/ton of tractive force.
The above description is very general and describes only superficially how propellers are designed.

9.2.4. Controllable Pitch Propellers

If controllable pitch propellers are to be used, the maximum pitch on the propeller should be determined under fully loaded conditions. The vessel should be taken out fully loaded and the pitch slowly increased until the engines are operating at rated speed at full throttle. This is the maximum amount of pitch that should be used under any operating conditions.

9.3. Propeller Selection

Your dealer has chosen a propeller designed to deliver top performance and economy under most conditions. To obtain the maximum percentage of available horsepower (A), the engine rpm at full throttle should be in the specified full throttle operating rage (B).
Refer to specifications in Performance Curve.
If the engine's full throttle RPM with a normal load is below the specified on the low side of the range (C), use a propeller with less pitch to increase the RPM. Should the engine's full throttle RPM want to exceed the specified range (D), the engine RPM is limited by the governor. Use a propeller of higher pitch to stop the limiting by the governor.



Note:
Engine damage can result from incorrect propeller selection which;

- **(C) Prevents engine RPM from attaining the specified "Full Throttle Operating Range". When the engine is laboring, install lower pitch propeller.**
- **(D) Allows engine RPM above the specified "Full Throttle Operating Range". Engine RPM can be limited by the governor, install a higher pitch propeller.**

9.4. Power Drive with Fixed Pitch Propeller

The power of a marine diesel engine varies as shown by the power curve approx. in proportion to the engine speed. The power take-up of a propeller, however, varies according to the propeller law

$$P_1 : P_2 = N_1^3 : N_2^3$$

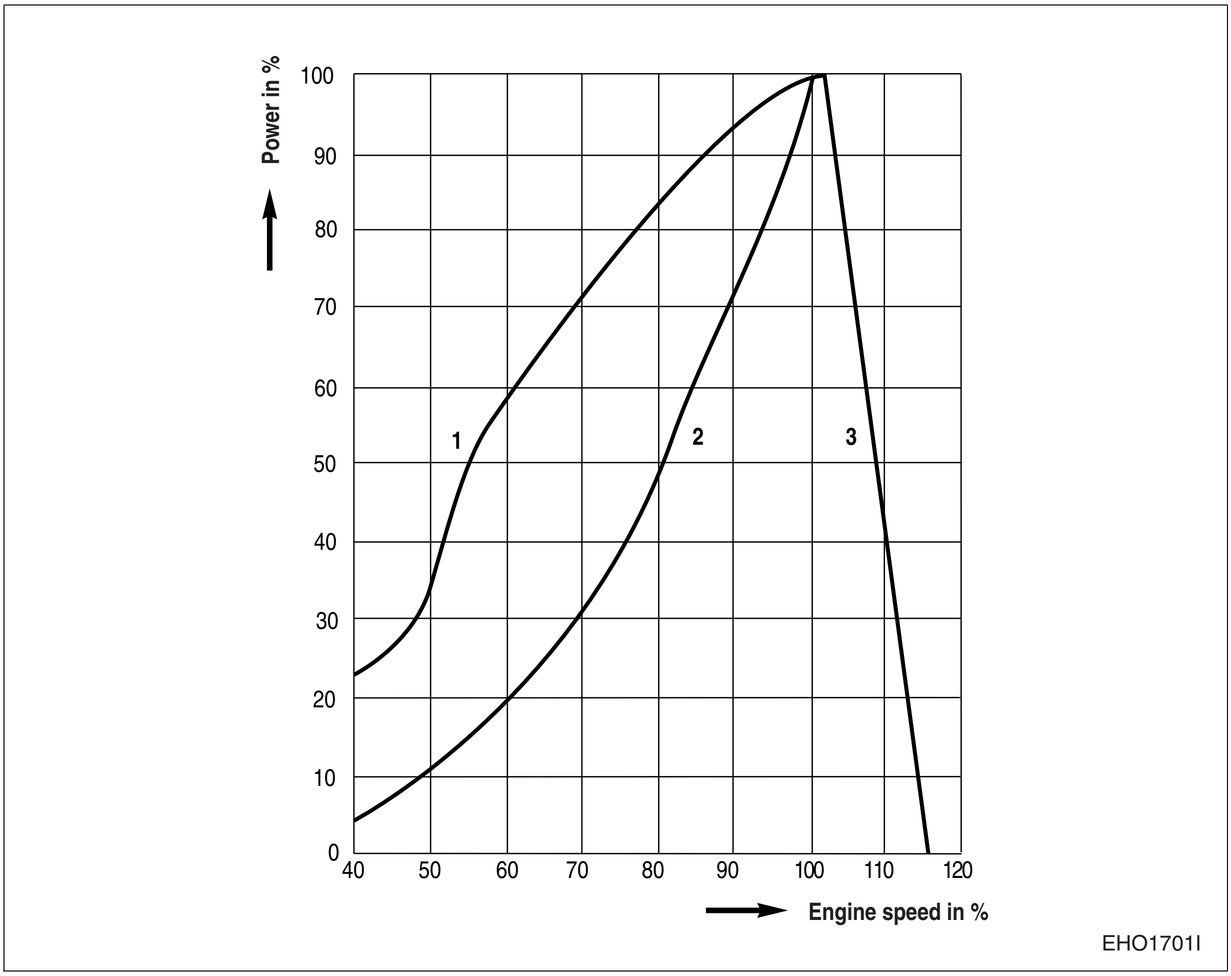
with the third power of the engine speed, i.e. if the propeller speed and, consequently, the ship speed (P) is to be doubled, the power input (n) has to be increased eightfold (23 = 8).
The diagram and the table on the next page give in percent the power ratings and the engine speeds which belong together according the propeller law. These figures are theoretical values which allow only rough-and-ready estimates and apply to ships with displacement hulls without trawling device (trawl nets for fishing, barges) in calm, deep shipping channels.
This means that a ship's curve of resistance depends on the overall tractive resistance of the ship, the propeller design and the individual water conditions.

<Example>
According to the model plate the power of an engine is 185 kW at 1,800 rpm.
What is the power that can be transmitted by the propeller if the engine speed is reduced by 200 rpm to 1,600 rpm?

<Solution>

The rated engine speed of 1,800 rpm is 100%. Consequently, the engine speed of 1,600 rpm is 89% of the rated speed. Both the diagram and the table on the next page show that with 89% of the rated engine speed 70% of the power i.e. 10% of 185 kW, which equals 130 kW, can still be transmitted by the propeller.

- **Engine power as a function of engine speed with propeller drive (theoretical propeller curve)**



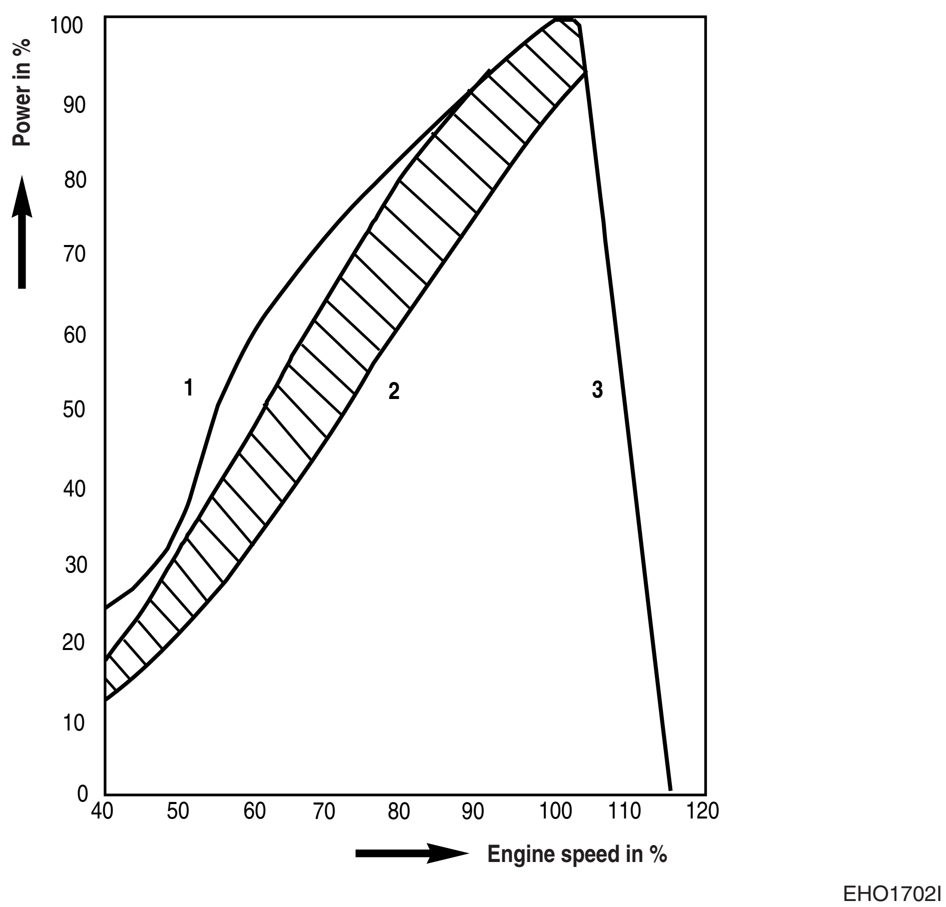
1. Engine Power Curve
2. Power Take-up Of Propeller
3. Breakaway Curve

Power P (%)	Engine Speed N (%)
15	53
20	58
25	63
30	66
35	71
40	73

Power P (%)	Engine Speed N (%)
45	77
50	79
55	82
60	84
65	87
70	89

Power P (%)	Engine Speed N (%)
75	91
80	93
85	95
90	97
95	98
100	100

In practice there can be considerable differences between the theoretical power take-up of the propeller and the actual tractive resistance.



1. Engine Power Curve
2. Tractive Resistance Range of Some High-speed Planing Boats
3. Breakaway Curve

The actual resistance curves show that, in contrast to the theoretical power requirement of the propeller, a relative large amount of power is already transmitted in the lower engine speed range, which in the case of light boats can produce high speeds even at idling speed.
This could render maneuvers in narrow harbors or travelling in canals at crawling speed difficult.
There are several possibilities of reducing propeller speed independently of the engine speed, thus improving the slow travelling properties of fast boats:

- **Reduction gear with trolling device:**
  Propeller speed is reduced by the clutch discs slip. The clutch oil pressure (for pressing the clutch discs against one another) is lowered during the trolling operation while at the same time an increased amount of oil for lubrication and removing friction heat is pumped through the clutch discs.
  Trolling device can be only supplied to all models optionally by gear box maker.
  These models as follows: L066TI/L136/L136T/L136TI/L086TI/MD196T/MD196TI/L126TI/V158TI/
  4V158TI/V180TI/V222TI/4V222TI/4V222C

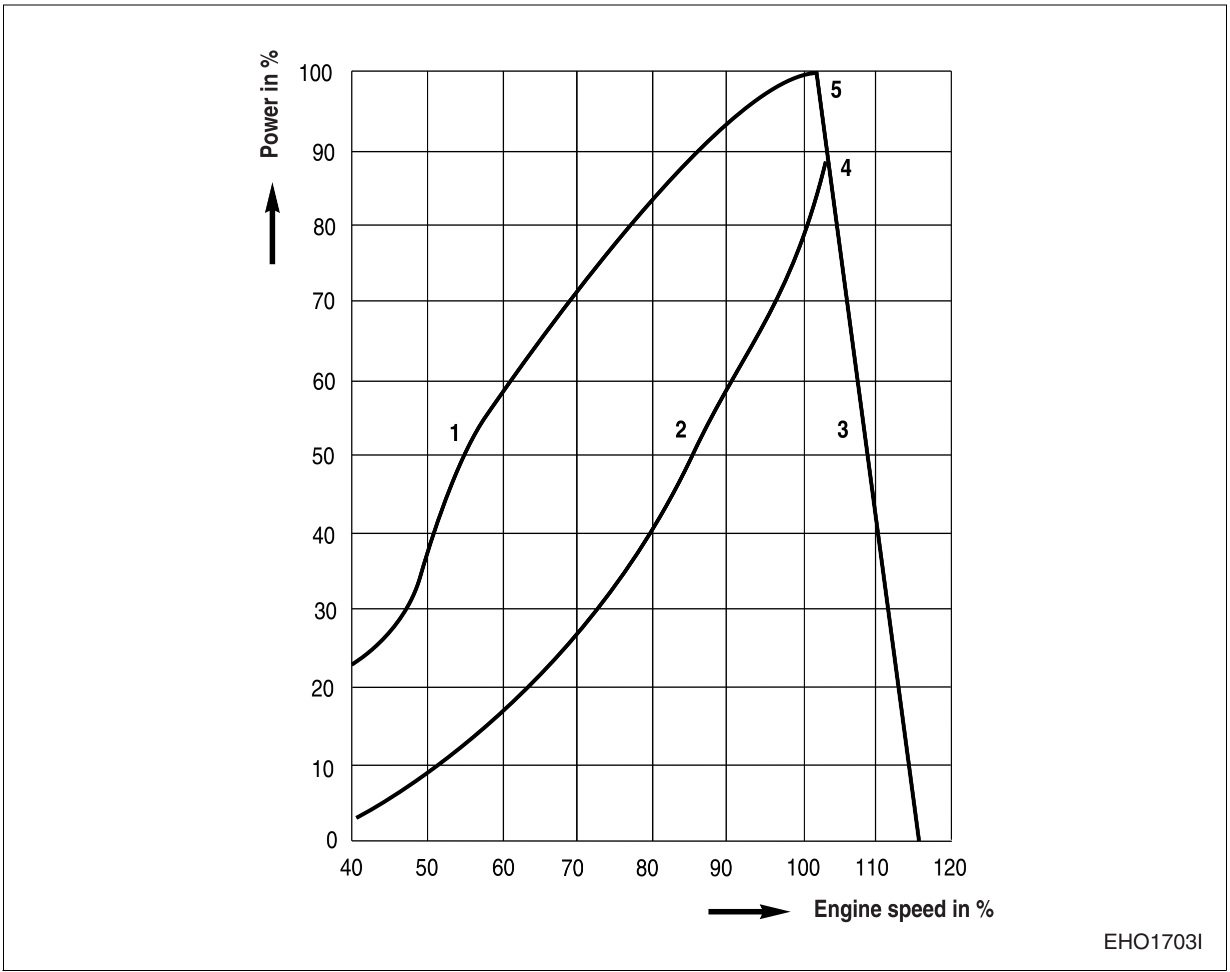
9.5. Designing of the Propeller

The propeller design is of paramount importance for achieving the highest ship speed or thrust possible at a given power output. It depends on the type of ship (displacement, planing or semi-planing), the shape of the hull and the operating conditions (non-towing ship or tug).

More detail design of the propeller can be made by the propeller maker.

The propeller should be planned for 90% of the rated power and must be designed in such a way that in a trial run with the new, fully equipped ship in laden condition the engine speed is 100 rpm above the rated speed.

This guarantees that rated engine speed is achieved if the tractive resistance (encrustation) increases any further.

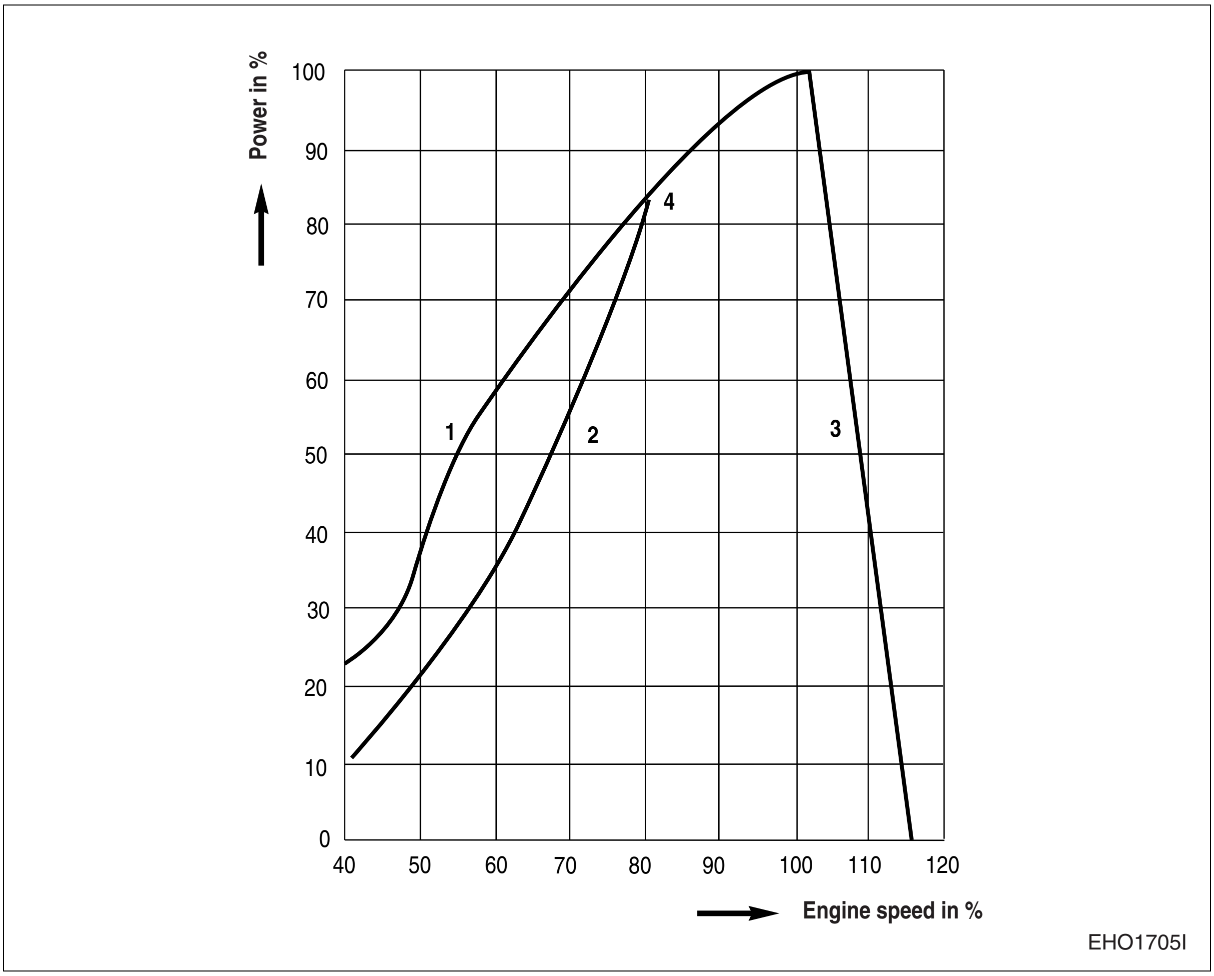


1. Engine Power Curve
2. Tractive Resistance Curve
3. Breakaway Curve
4. Operating Point, New Condition (Inspection, Trial Run)
5. Operating Point, with Further Increase in Tractive Resistance

9.5.2. Propeller Too Large

The power take-up of the propeller is higher than the engine power. Consequently, the engine cannot achieve its rated speed and is therefore overloaded.

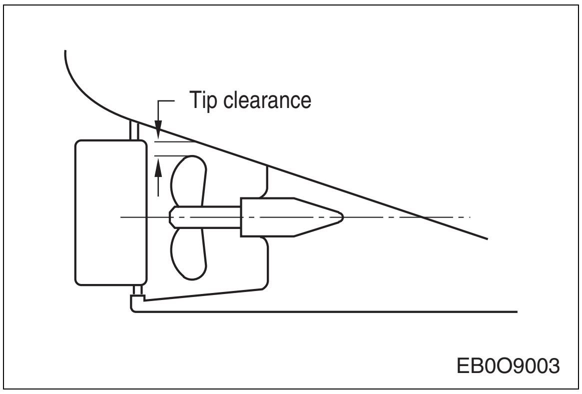
Overloading may result in the development of black smoke, which in the long run is likely to cause damage to the engine and excessive wear.



1. Engine Power Curve
2. Tractive Resistance Curve
3. Breakaway Curve
4. Operating Point if the Propeller is Too Big

9.6. Propeller Tip Clearance

Sufficient propeller tip clearance is necessary to prevent water hammering against the bottom of the hull. Inadequate tip clearance will result in noise vibration, and cavitation throughout the vessel. Most boats typically require tip clearance between 10 to 15% of propeller diameter.



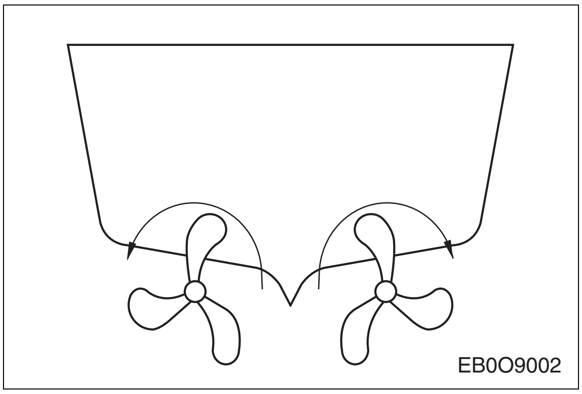
- **Typical Propeller Diameters**

units: mm (inch)

Max. Propeller Swing without Tip Clearance	Maximum Allowable Propeller Diameter	
	10% Tip Clearance	15% Tip Clearance
381 (15)	279 (11)	305 (12)
406 (16)	305 (12)	330 (13)
432 (17)	330 (13)	356 (14)
457 (18)	356 (14)	381 (15)
483 (19)	356 (14)	406 (16)
508 (20)	381 (15)	406 (16)
533 (21)	406 (16)	432 (17)
559 (22)	432 (17)	457 (18)
584 (23)	432 (17)	483 (19)
610 (24)	457 (18)	508 (20)
635 (25)	483 (19)	533 (21)
660 (26)	508 (20)	533 (21)
686 (27)	533 (21)	559 (22)
711 (28)	533 (21)	584 (23)
737 (29)	559 (22)	610 (24)
762 (30)	584 (23)	635 (25)

$$\text{Max Allowable Propeller Diameter} = \frac{\text{Max. Propeller Swing Without Tip Clearance}}{1 + [2\ (\text{Tip Clearance Percentage}/100)]}$$

9.7. Propeller Rotation in Twin Engine Applications



Engine rotation is viewed from the front of the engine, looking at the engine crank pulley side. Propeller rotation is viewed from behind the boat, looking forward at the propeller. Therefore, a right hand rotation

engine and a left hand rotation propeller are turning in the same direction.

HD Construction Equipment marine engines are available in standard right hand rotation only. Twin engine installations should have the propellers turning in opposite directions.

The normal recreational boat arrangement has the right hand (clockwise) turning propeller on the starboard (right) side of the boat and the left hand (counterclockwise) turning propeller on the port (left) side of the boat.

The propeller rotation is determined by the marine gear. Some gears allow for full power in either direction of rotation. The rotation in forward is set at the marine gear. Marine gears that are designed for a specific direction of rotation must be installed on the proper side of the boat.

HD Construction Equipment marine gears have the strength fully that they can be used for long periods of time in reverse position of the gear shift lever under full load at rated rpm because of designing both forward gear/shaft and reverse gear/shaft equally.

So all marine gears supplied by HD Construction Equipment can be used for the port propeller.

10. Electrical System

10.1. Electric Circuit

The circuit diagrams depend on the engine models and the extent of delivery and are tailormade for orders and dispatched together with the usual documents such as wiring diagram etc. while the order is processed but on some available models.

- The installed battery capacity must not be less than that specified for that particular engine.
- The maximum resistance in the starting circuit must not exceed 0.002 Ohms.
- If the alternator is not supplied with the engine, the installer must assume responsibility for adequate mounting.
- A functioning hour meter must be maintained on the engine.

Note:
When you work like any repairing jobs in the engine room you should pay attention to not occurring any electric circuit shortage (spark).

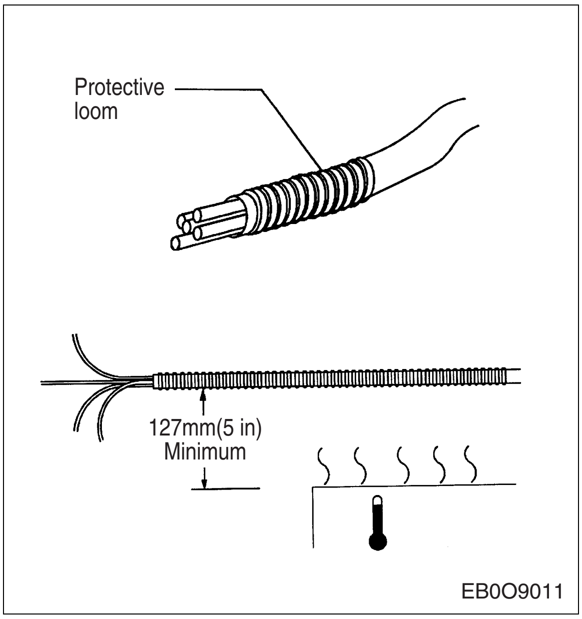
10.1.1. Electrical Wiring

Overcharging or undercharging reduces battery life.

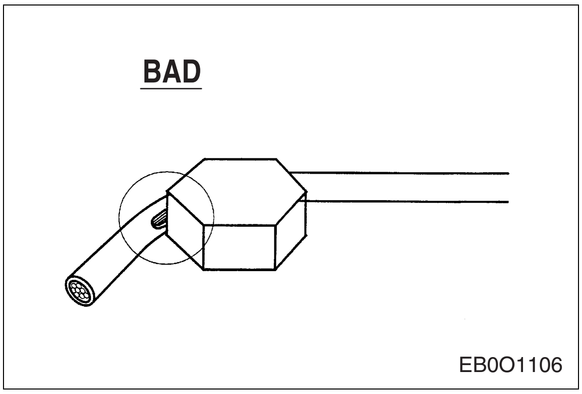
Because of operating and environmental conditions, wiring on marine applications needs special precaution. Connections should be made with corrosion resistant hardware and be shielded as much as possible. All wiring should be in protective looms, conduit or tape and be routed away from heat sources, such as the exhaust piping, and above bilge water level.

Proper routing arid clipping of electrical wiring is extremely important.

Leads should be routed away over 150 mm from heat sources such as the exhaust piping and should be above the bilge water level. Listed below are basic guidenlines which should be followed when designing or installing wiring systems.



- On any surface likely to see movement from vibration or normal deflections, such as the frame or stringer to engine, wires must not rub against surrounding parts or each other. If they must rub a surface, they should be banded or clipped to it.
- Under no circumstances should the wire contact sharp edges, screw, bolts or nuts.



10.1.2. Cause of Electrolytic Corrosion

One of the most important causes of corrosion of metal parts in salt water is interference current from the ship's electrical system. These currents may be very weak and are often hard to detect. However, if they are active over prolonged periods of time, they may cause heavy corrosion.
Electrolytic corrosion may be prevented by a suitable electrical wiring.
Marine engine installations require special grounding of electrical system components to minimize electrolytic corrosion from stray currents and to minimize radio interference.
On metallic the boats the hull may serve as the common bonding conductor and a separate bonding system may not be required.

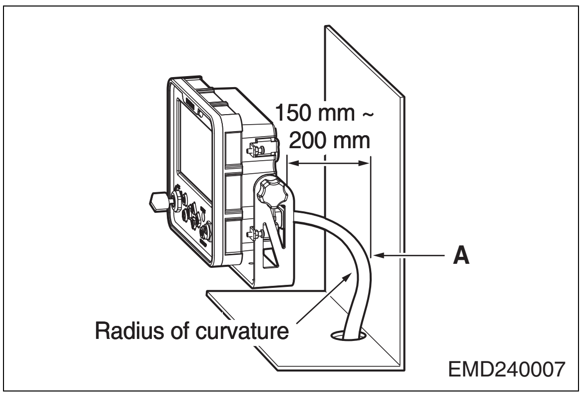
10.2. Electric Components

10.2.1. Gauge Panel

All HD Construction Equipment marine engines covered in this manual are available with remote mounted instrument panels and some kinds of different gauge panels on each model that is standard, deluxe, dual type also one pole(earth return), two pole(insulated return) type engine electric wires optionally.

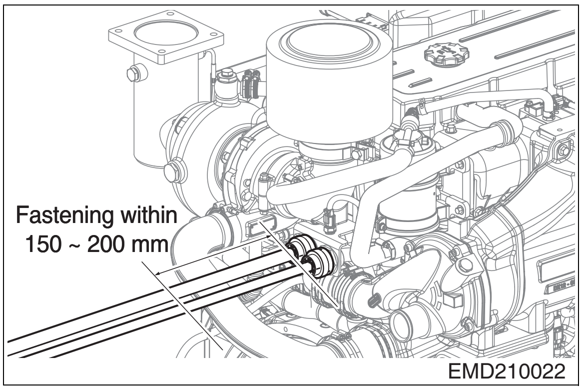
Note:
Instrument panels should not be mounted on the engine due to engine vibration.

The wiring branches must be secured in order to minimize tension in the 150 ~ 200 mm section (A) behind the wire harness during the installation of the digital panel, and the radius of curvature of the bent wire harness must be over 90°.



10.2.2. Cautions when installing the harness (engine harness - panel & aftertreatment assembling guide)

Maintain the curvature radius at 90° or higher, and fasten the harness within the 150 ~ 200 mm so that the interference to related parts can be avoided.



10.2.3. Battery

The starting and electrical system must be designed so that the engine will start readily under the most severe ambient conditions ordinarily encountered. In order to achieve this objective, the installer must exercise good judgment in the selection and application of the electrical system components. These recommendations are offered as a guide to obtain a reliable system.

Note:
The installed battery capacity must not be less than that specified for that particular engine.

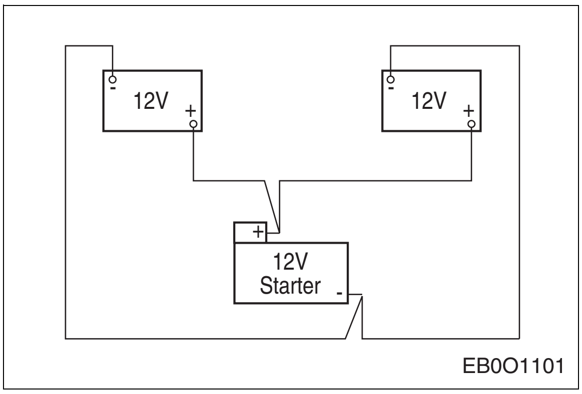
On any engine there must be enough power available to the starter to ensure quick, reliable starts under any operating condition. The temperature of the environment in which the vessel operators will greatly affect the power required for starting, so the worst case condition for the vessel should be used and considered.

Note:
The installed battery capacity must not be less than that specified for that particular engine.

Battery voltage or current capacity can be increased by connecting batteries in different combinations of series and parallel arrangements.

1) The batteries in parallel

If the batteries are connected in parallel, the system current will be equal to the sum of the current for the two batteries and trip system voltage will be the same as the individual voltages of the batteries. (Refer to the figure.)

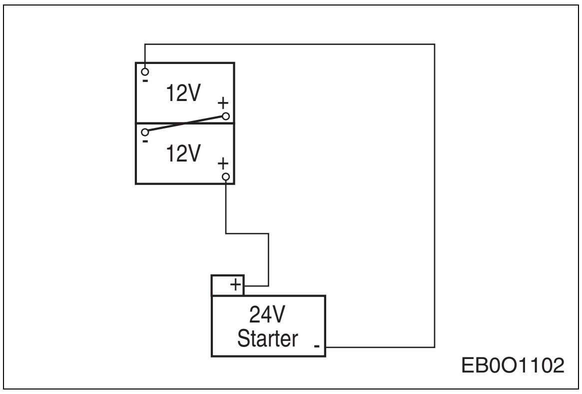


Parallel Circuit

V = V1 = V2, I = I1 + I2

2) The batteries in series

Connecting the batteries in series will increase the system voltage, but not the current. The voltage will be equal to the sum of the two battery voltages and the current will be equal to the current of either individual battery.



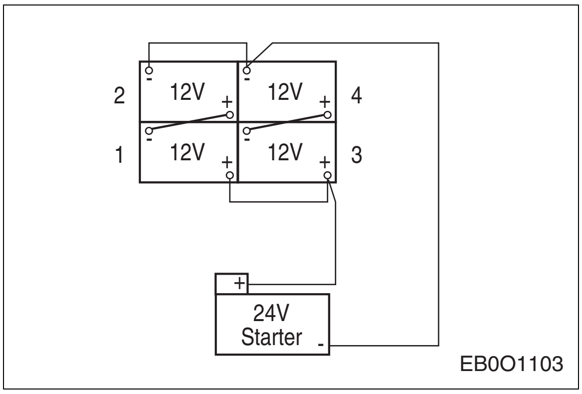
Series Circuit

V = V1 = V2, I = I1 + I2

3) The batteries in series and parallel

If the batteries are connected in series and parallel, then both the system voltage and current will increase.

Note:
The maximum resistance in the starting circuit must not exceed 0.002 Ohms.



Series - Parallel Circuit

V = V1 + V2 = V3 + V4, I = I1 + I3 = I2 + I4

If the circuit resistance is too high, the starting motor will not receive an adequate supply of electrical energy and will not provide reliable cranking over the range of conditions encountered in service.
The maximum starting circuit resistance for the engines covered in this manual is 0.002 Ohms.
The table below lists the maximum length of typical cables in the cranking circuit necessary to meet this requirement.

<Battery to Cranking Motor Cable Sizes>

Battery to Cranking Motor Cable Sizes			
Maximum Circuit Resistance	**Maximum Length Cable in Cranking Circuit**		**Remarks**
	#00	**#000**	
0.002 Ω	6.0 m	8.0 m	Single Battery
			Single Cranking Motor
0.002 Ω	6.0 m	8.0 m	Dual Battery
			Dual Cranking Motor

This table lists the cable diameter and cross - sectional area for the sizes listed above.

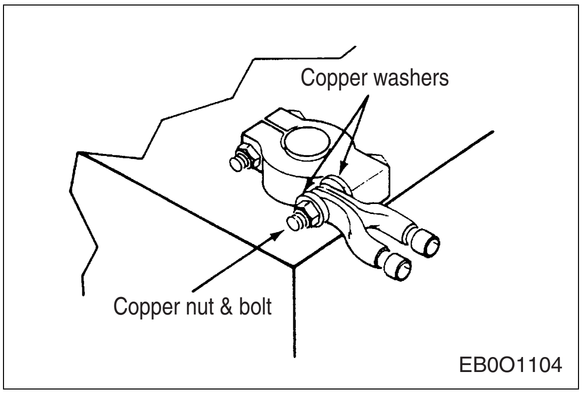
Cable Size (AWG)	Cable Diameter (mm)	Cable Area (mm^2)
#0	7.8	47.8
#00	8.4	55.4
#000	9.2	66.5
#0000	10.0	78.5

Starting motor circuit resistance will be affected by cable size and length, the number of connections in the system and the possible presence of additional contactors in the wiring arrangement.

CAUTION:
The battery connected to the propulsion engine should not be connected to the auxiliary engine or the battery for other generators.
An independent battery system should be established, and if it is connected to other batteries, it may lead to permanent damage or malevolent effects due to noise.

10.2.4. Starter Circuit Wiring

The starter cable terminals should have soldered connections. Rosin flux should be used for soldering electrical connections. Acid flux solders will cause deterioration of the electrical connection.
Connecting two strands of cable, such as two #00 or two #000 should be carefully done in order to assure that both wires have a good connection with the battery. Next figure shows one method used to connect two cables to a battery. Tinning the stainless steel washers and cable connectors with solder will reduce the chances of problems due to corrosion. The use of a non-conductive grease at the connection will also help prevent corrosion.
The cable to battery connections should use the maximum available contact area of the battery post. Clamps must be positioned squarely on the battery post or stud with clean surface and securely fastened. Stacked terminal connections which have only point or line contact will not be satisfactory.



Note:
If the alternator is not supplied with the engine, the installer must assume responsibility for adequate mounting.

Since the integrity of customer supplied alternator mounting cannot be assured, HD Construction Equipment is not responsible for any problems associated with an improperly mounted alternator that was not supplied with the engine. If the customer wishes to supply and mount their own alternator, they should contact the local HD Construction Equipment distributor for assistance.

10.2.5. Alternator Wiring

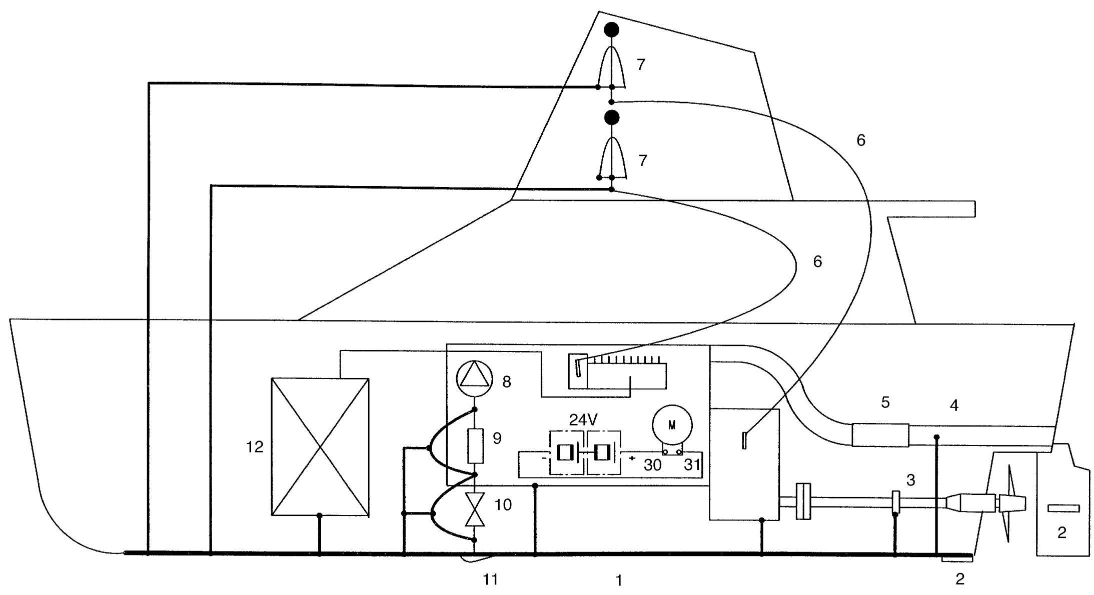
Unless special protective devices are used, an alternator system can be damaged by the connection of a charged battery to the alternator in reverse polarity. If a reverse connection is made while attempting to start an engine that has a dead battery or when connecting a newly changed battery, the low resistance path through the rectifier will burn up the diodes.

It is recommended that one battery lead be shorter than the other so that once the battery is properly set in place it is impossible to misconnect it.

Most alternators include heavy duty voltage regulators. Generally, the range will be as follows:

System Voltage	Low	Normal	High
24 Volt	28.1 V	28.5 V	28.9 V

10.2.6. Explanations on the Subsequent Wiring Diagram



EB0O1112

The following wiring diagram depicts the wiring of the engine and its most important components to prevent electrolytic corrosion. The earthing cables in the diagram are indicated in bold print.

A copper band connected to the hull (1) runs in longitudinal direction along the hull and is connected with zinc anodes (2). More anodes are located e.g. on the rudder blade.

The propeller shaft is connected with the hull via a slip ring (3).

Control cables (6) are laid from the adjusting lever of the Injection pump and from the reversing lever of the gearbox to the deck control instruments (7) that are also to be connected to the hull.

If a sea water injection system is fitted, that part of the exhaust gas pipe (4) that contains sea water is in most cases connected with a hose connection (5) and must therefore also be connected to the hull.

The pipe connections between the sea water pump (8), sea water filter (9), shut-off valve (10) and scoop (11) must also be "earthed".

For safety reasons (sparking owing to electrostatic charging) the steel tank (12) is also connected to the hull.

CAUTION:
The engine GND circuit (propulsion engine/auxiliary engine/other units) should be separated from each other.
Each system's ground should be independent from each other, and if they are connected to each other, it may lead to permanent damage or malevolent effects due to noise.

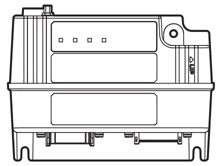
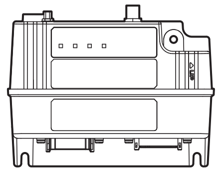
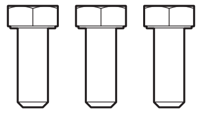
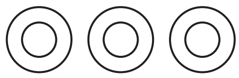
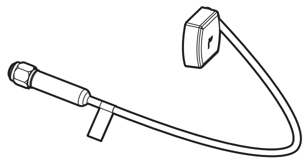
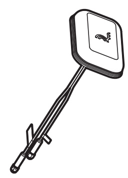
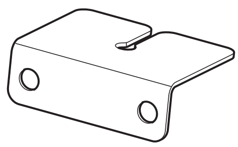
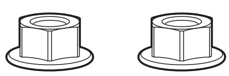
In addition, the following is to be heeded for commissioning engines:

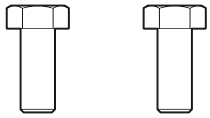
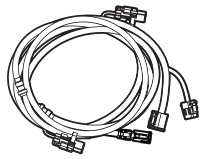
Only authorized specialist personnel must inspect the installation and commission the engine.

- Never operate the engine while it is dry, i.e. without lubricant or coolant.
- Do not use any additional starting aids (e.g. start pilot) for starting the engine.
- Only use operating materials (engine oil, antifreeze and anti-corrosion agents) approved by HD Construction Equipment. Ensure cleanliness. Diesel fuel must be free of water
- Do not immediately switch off hot engine but let it idle for about 5 minutes without load so that a temperature equalization can be brought about.
- Never fill overheated engine with cold coolant
- Do not fill up with engine oil above the max. level on the dipstick. Do not exceed the engine's maximum permissible operating inclination(12degree).
- Non-compliance with these instructions may cause severe engine damage.
- Always ensure that control and monitoring devices (charging, control, oil pressure, coolant temperature) work faultlessly.
- Never operate the sea water pump while it is dry in danger of frost empty sea water pump when the engine is shut down.

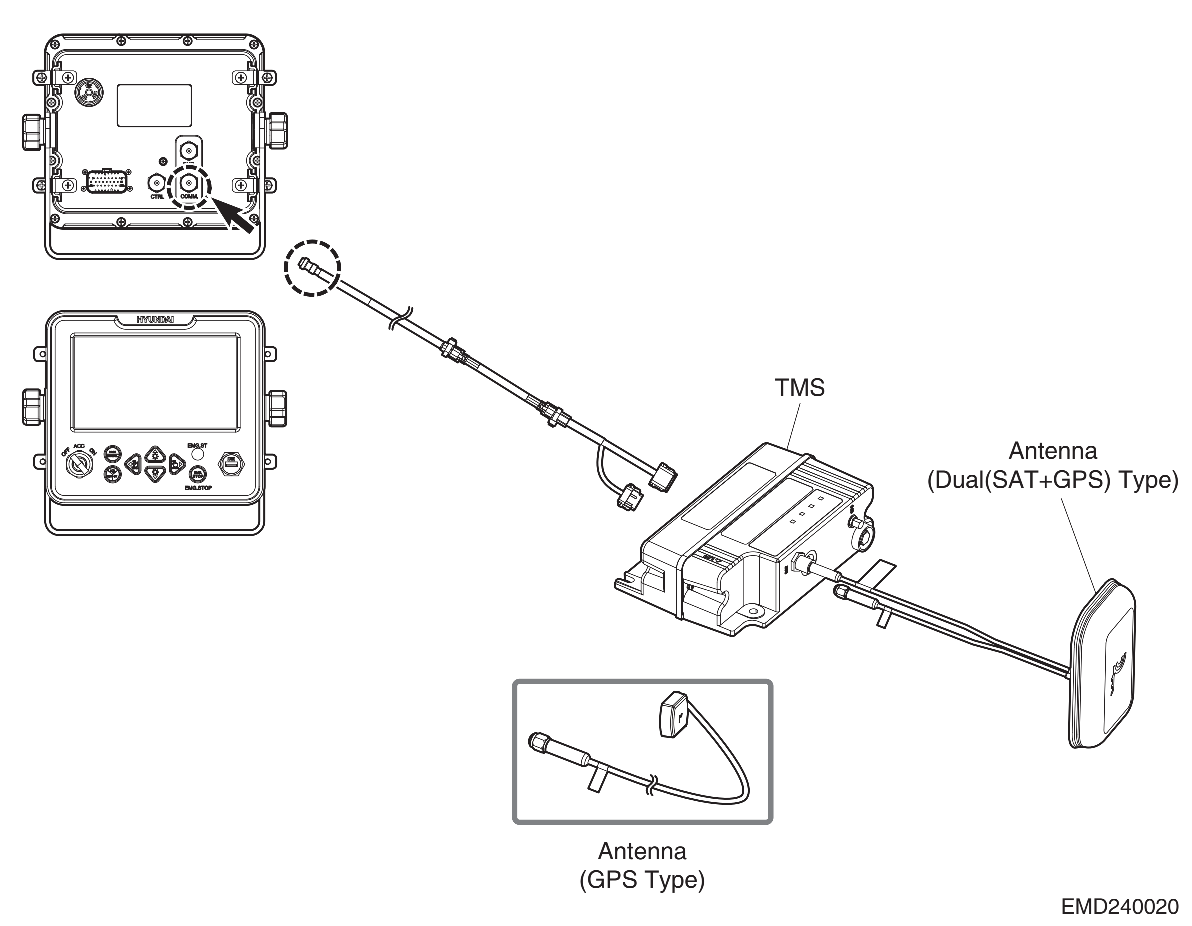
10.3. TMS 3.0 Installation Guide (for the Marine Engine) (Option)

10.3.1. Preparation

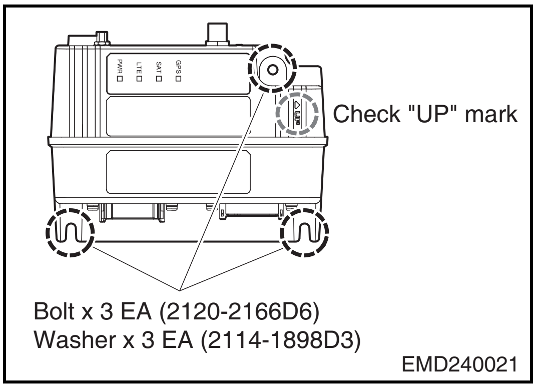
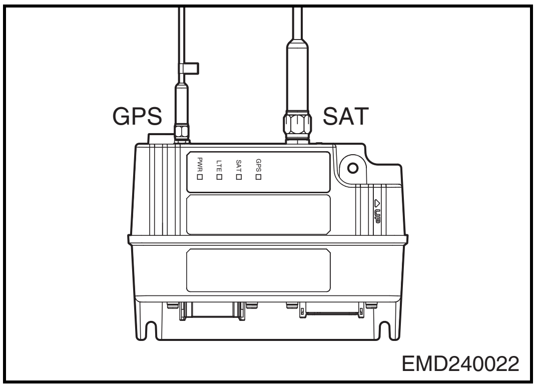
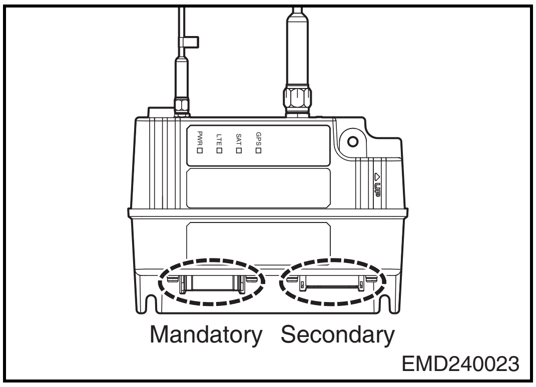
NO.	Parts Name	Parts No	Qty	Photos
1	TMS module (LTE)	300611-01929 (Base)	1	
2	TMS module (LTE & SAT)	300611-01930	1	
3	TMS fixing bolt	2120-2166D6	3	
4	TMS fixing washer	2114-1898D3	3	
5	Antenna	300703-00045 (Base)	1	
6	Antenna	300703-00046	1	
7	Antenna bracket	110406-09535	1	
8	Antenna fixing nut	43DM12	2	

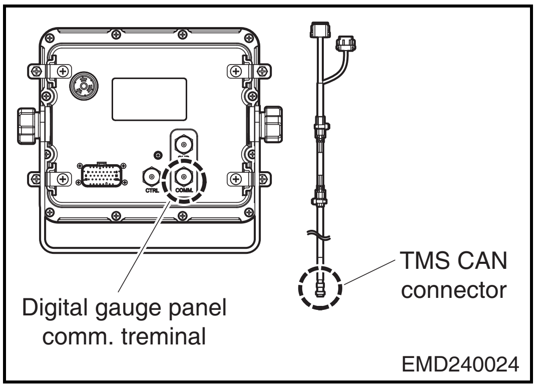
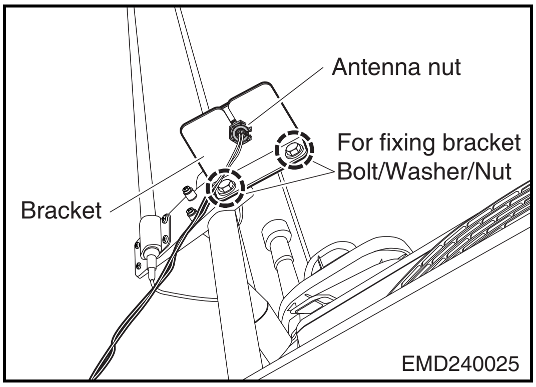
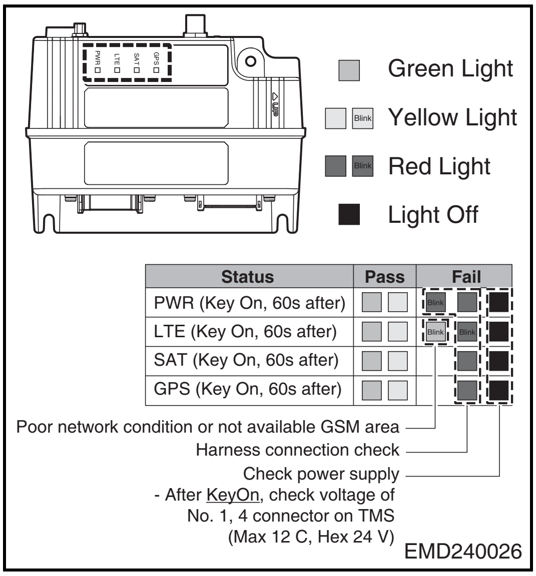
NO.	Parts Name	Parts No	Qty	Photos
9	Antenna fixing plain Washer	2114-1898D17	2	
10	Antenna fixing bolt	2120-2166D32	2	
11	Antenna fixing spring washer	2114-2031D6	2	
12	TMS cable	310207-13597 (2 m) 310207-13598 (3 m) 310207-13599 (5 m) 310207-13716 (7.5 m)	1	

10.3.2. Installation Layout



10.3.3. Installation Procedure

<table>
<tr><th>Steps</th><th>Detailed Description</th><th>Reference</th></tr>
<tr><td>Pre inspection</td><td>1. Disconnect the battery power before installing the TMS module
2. Install the TMS module in a location that does not directly contact moisture and salt
3. Avoid installation near fire, oil, and sharp objects</td><td></td></tr>
<tr><td>Step-A</td><td>Install the TMS module in the bridge.
("UP" mark faces up)</td><td rowspan="2">
</td></tr>
<tr><td>Step-A-1</td><td>Fix the TMS module using bolt 3 EA and Washer 3 EA.
(M6 X 1.0P/
Bolt tightening torque: 1.0 kg.m)</td></tr>
<tr><td>Step-B</td><td>Connect the antenna cable terminal 2 EA to the TMS module (Antenna cable 3.5 m).</td><td>
</td></tr>
<tr><td>Step-C</td><td>Connect the TMS cable connector 2 EA to the TMS module.</td><td>
</td></tr>
</table>

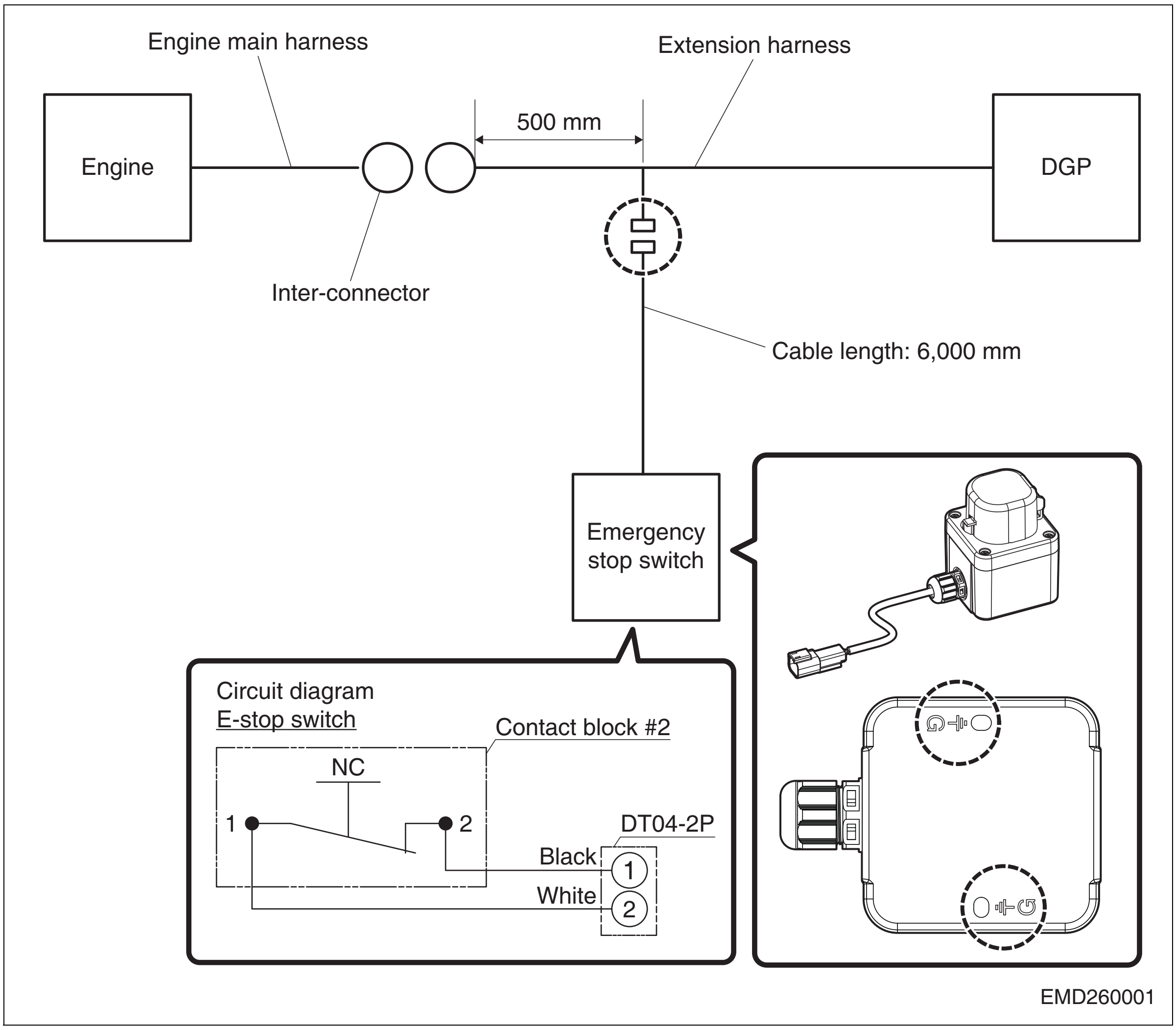
<table>
<tr><th>Steps</th><th>Detailed Description</th><th>Reference</th></tr>
<tr><td>Step-D</td><td>Assemble the digital gauge panel comm. Terminal and the TMS CAN connector</td><td>
</td></tr>
<tr><td>Step-E</td><td>Install antenna with bracket outside the bridge
※ If there is an iron plate on top of antenna or installed in an enclosed space, it may cause communication failure, so install it in a place where communication is smooth.</td><td rowspan="3">
</td></tr>
<tr><td>Step-E-1</td><td>Loosen the nut 1 EA assembled with the antenna, attach the antenna to the bracket, and fix the nut again.</td></tr>
<tr><td>Step-E-2</td><td>Fix the antenna with bracket using a bolt 2 EA, spring washer 2 EA, plain washer 2 EA, and nut 2 EA.
(M12 X 1.75P/
Nut tightening torque: 10.5 kg.m)</td></tr>
<tr><td>Post installation check</td><td>Check the LED of the TMS module 1 minute after the key-on to check the installation status.
1. If the TMS module LED is red, check the connection status of harness and antenna.
2. If the cause is not found, record it for 1 minute and contact the administrator.</td><td>
</td></tr>
</table>

10.3.4. Notice

1) Do not connect the engine wiring and the wiring of high-power electronic equipment (Ex: inverter) to the same battery.
   - High-power electronic equipment must use independent batteries.
2) When using engine diagnostic equipment, remove the TMS connector.
   - It does not work at the same time and may cause diagnostic equipment malfunction.
3) Design the wiring so that sufficient voltage is supplied to the TMS terminal.
   - TMS operating voltage: +9 V ~ +32 V
4) Do not remove the TMS terminal and harness arbitrarily.
5) The TMS terminal has a built-in lithium-ion battery, so be careful when handling it, such as subjecting it to excessive shock.
6) Avoid harmful environments.
   - Operates normally under dust proof living/waterproof rating (IP67) and operating temperature (-30° ~ +70°). but is unsuitable for use in environments exposed to salt water and high temperatures.

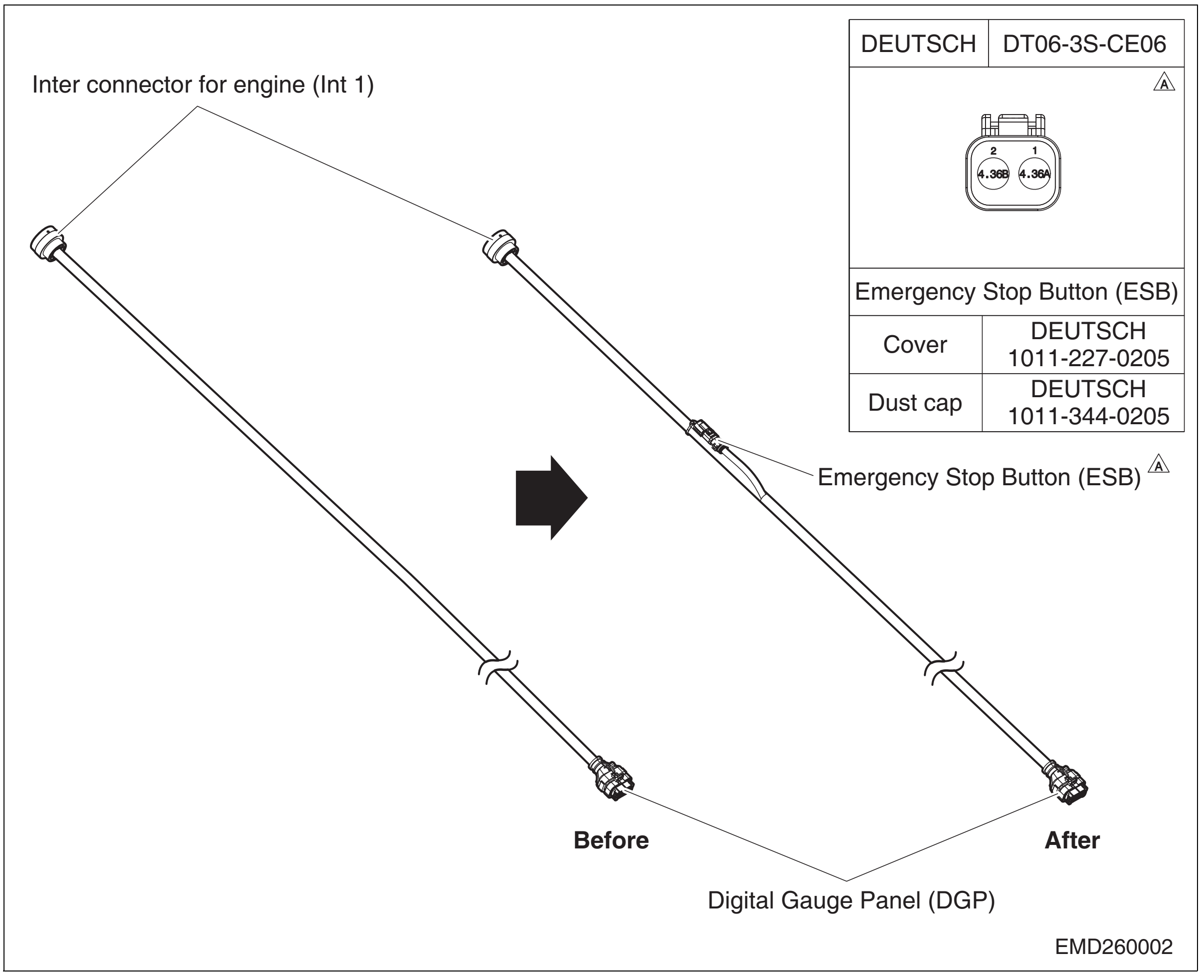
10.4. Emergency Stop Switch

- Applicable engine: DL06/DL08/DX12/DX15/DX22 (electronic marine engine)
- Wiring diagram



- Wire length can be grounded within 6,000 mm, and it can be installed in an easily accessible location.
- As shown in the drawing, grounding can be secured at two points using M4 grounding bolts (Stainless-SUS316 recommended).
  (G mark on the bottom of the switch.)
- It can only be connected to an 8-inch panel engine.

• Extension wire



Panel	Length	Part Number Before	Part Number After Change
8 Inch	1.5 M	310207-13620	310207-13620A
8 Inch	2.5 M	310207-13621	310207-13621A
8 Inch	5 M	310207-13622	310207-13622A
8 Inch	7.5 M	310207-13623	310207-13623A
8 Inch	10 M	310207-13624	310207-13624A
8 Inch	12 M	310207-13625	310207-13625A
8 Inch	15 M	310207-13626	310207-13626A
8 Inch	20 M	310207-13627	310207-13627A
8 Inch	30 M	310207-13628	310207-13628A
8 Inch	40 M	310207-13630	310207-13630A

10.5. Safety Management Instructions

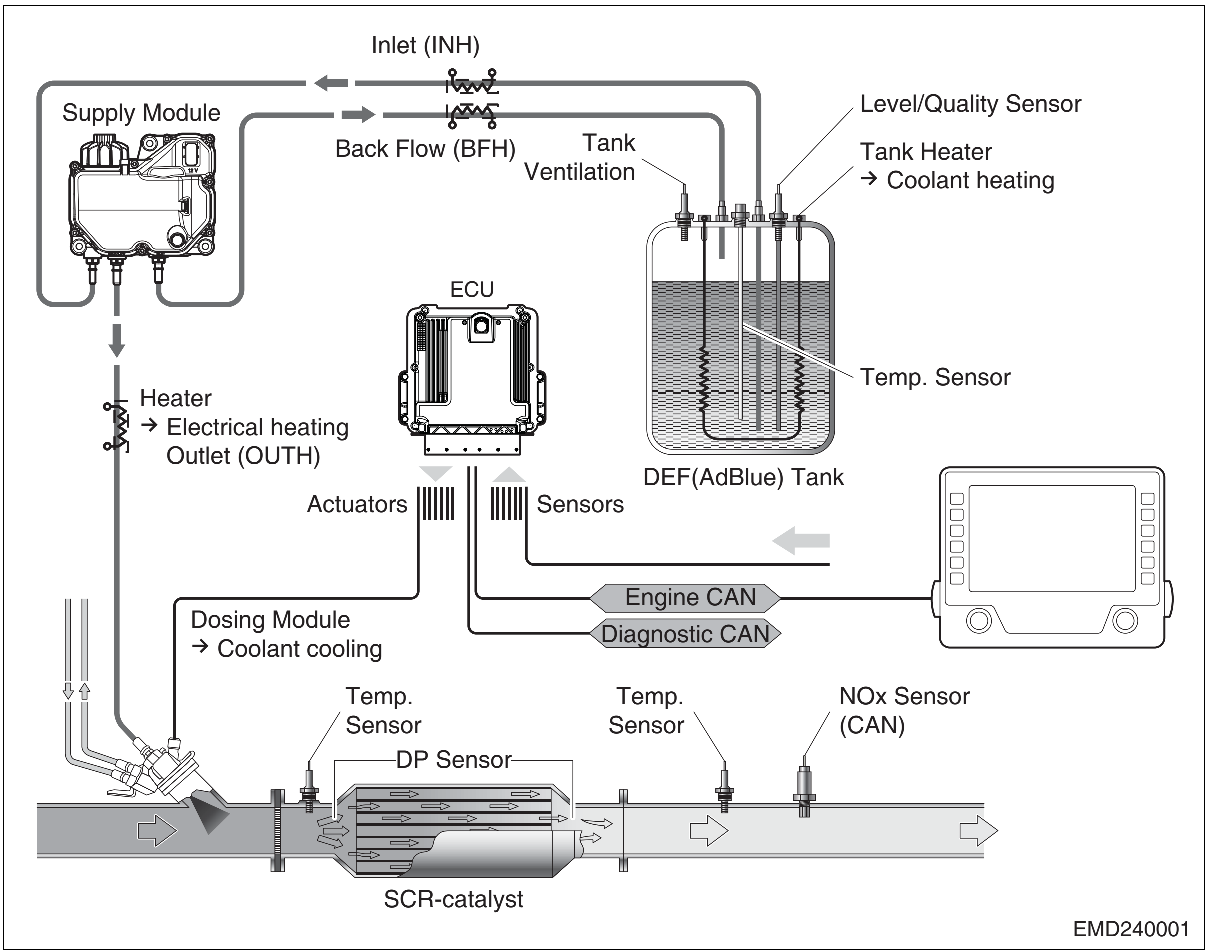
The initial engine test run must be conducted in the presence of an A/S expert designated by HD Construction Equipment or in the presence of such experts.
Please be sure to check the following important information:

- Make sure that oil, coolant, fuel, and antifreeze are used as specified.
- When starting the engine, check again whether the wiring is properly connected.
- After running the engine, do not stop it quickly. run the engine at idle for about 5 minutes and then stop it.
- Do not add cold coolant while the engine is hot.
- When installing the engine, do not exceed the maximum allowable inclination angle.
- Always keep an eye on the instrument panel to check that it is operating normally.
- In winter, as freezing may occur, replenish 35 ~ 50% of antifreeze and drain coolant to prevent sea-water lines from freezing.
  When running again, check for frost or ice and then remove it.
- If do not follow these instructions may result in serious engine damage.

11. SCR (Selective Catalytic Reduction) System

This chapter defines the information and installation of the SCR system, including the DEF (Diesel Emission Fluid, Urea Water Solution 32.5%, AdBlue) injection system, to satisfy the IMO, Tier3 emissions regulations.

- Refer to the image below for the whole schematic diagram of the SCR system.
- The SCR system is a device that sucks up and pressurizes the DEF from the DEF tank using the Supply Module (DEF Pump), sends it to the Dosing Module (DEF Injection Device) connected to the exhaust pipe, and injects the DEF at the Dosing Module based on the control of the ECU (Engine Control Unit).
- By receiving the data from various sensors installed in the SCR system, the ECU controls the DEF injection, monitors any failures on related parts, and displays fault codes. In addition, if it is determined that the DEF has frozen, related parts can be operated or heat is applied to the DEF hose to de-freeze the DEF.
- Installed in the SCR system are the following sensors for the operation and monitoring of the system.
  - Exhaust Temperature Sensor: 2 ea, each of which is installed at the inlet and outlet of the SCR muffler.
  - NOx Sensor: 1 ea, installed at the outlet of the SCR muffler.
  - DP (Differential Pressure) Sensor: 1 ea, measuring the differential pressure of both ends of the SCR catalyst.
  - DEF Level/Concentration Sensor (Urea Level/Quality Sensor): 1ea, installed in the DEF tank.
  - DEF Temperature Sensor (Urea Temp Sensor): 1ea, installed in the DEF tank.



11.1. DEF (Diesel Exhaust Fluid, Urea Water Solution 32.5%, AdBlue)

- To satisfy the IMO Tier3 emissions regulations, the DEF in the SCR system must use products with the urea concentration at 32.5%, and the regulations on the components of the product should follow ISO 22241-1:2006 (E).
- While the DEF is colorless, odorless, and harmless fluid, its freezing point is -11°C, and if it is frozen, its volume expands by about 9%, and therefore, the DEF tank should have the remaining capacity over 10%.
- Shown in Table 1 is the scope of the DEF temperature allowed in the SCR system.
- The recommended DEF temperature in the DEF tank is between 4 and 60°C, and if the DEF temperature exceeds 60°C, the DEF concentration may increase due to the evaporation, and at the worst case, the crystallization of the DEF may block the DEF hose.
- Table 2 shows the materials that need to be handled with caution when storing and using the DEF. Caution must be taken as, if the DEF makes contact with the listed materials, it gets contaminated and cannot be usable.
- Table 3 shows the duration for which the DEF can be used based on the storing temperature.

Table 1 Urea operation temperature

Classification	Temperature	Remarks
Supply module Inlet	-5 ~ 70°C	Recommended under 60 degrees
Atmospheric conditions	-30 ~ 80°C	

Table 2 Prohibited material for Urea storage and contact.

Materials forming compounds as a result of reaction with ammonia, which may negatively interfere with the SCR system: carbon steels, zinc coated carbon steels, mild iron
Non ferrous metals and alloys (copper, copper alloys, zinc, lead)
Solders containing lead, silver, zinc or copper
Aluminum, aluminum alloys
Magnesium, magnesium alloys
Plastics or metals coated with nickel

Table 3 Possible days for Urea storage (Depending on storage temperature)

Constant ambient storage temperature(?)	Minimum shelf life (months)
≤ 10	36
≤ 25	18
≤ 30	12
≤ 35	6

11.2. Fuel

- To satisfy the IMO Tier3 emissions regulations, only the fuel with the sulfur content at or below 0.1% should be used.
- If the sulfur content exceeds the above standard, it may cause a negative impact on the SCR catalyst, resulting in not being able to meet the IMO Tier3 emissions regulations, and therefore, caution must be taken.

11.3. Supply Scope

- Shown in Table 4 is the supply scope of the SCR system.
- The part number required for the installation of the SCR system on ships is for reference, and the electronic part book should be referenced.

Table 4. Supply Scope

Part Name	Part Number*	HD Construction Equipment	Vessel	Comment
Supply Module	300628-00628A	○		Assembled in DEF Tank
Dosing Module	300630-00044B	○		Assembled in SCR muffler
SCR Muffler (DX12) SCR Muffler (DL06/08)	240103-01997B 240103-01996B	○		
DEF Tank	450106-00345A	○		
Exhaust Gas Temperature Sensor	301317-00262	○		2ea (assembled in SCR muffler)
Differential Pressure Sensor	301309-00343	○		1ea (assembled in SCR muffler)
NOx Sensor	301308-01131	○		1ea (assembled in SCR muffler)
Urea Hose (Pressure Line)	420108-02722	○		
Urea Hose (Suction Line)	420108-02720	○		Assembled in DEF Tank
Urea Hose (Backflow Line)	420108-02721	○		Assembled in DEF Tank
Hose (for Urea Tank heating)	X		○	Refer to Installation guide
Hose (for Dosing module cooling)	X		○	Refer to Installation guide
Coolant Control Valve (for Tank heating)	300701-00084B	○		

11.4. SCR Muffler Installation

- The weight of the SCR muffler is about 105 kg (DX12), and sufficient mounting should be considered to withstand the weight or the dynamic load.
- The catalyst inside the SCR muffler is made with fragile material and should not be installed in a unrecommended way. (Example: vertical installation of the muffler, installation of the muffler in a unstable location, etc.)
- The mounting should prevent movements or rotations in any direction and should not make contact with other engine parts or ship parts.
- The SCR muffler should not be exposed to strong impact or vibration.
- The SCR muffler's vibration level should be at or below 1 g (rms), and the maximum g value should be at or below 5 g (Peak).
- The mounting should not use the same frame on which the engine is installed. If the same frame is used for both the mounting and the engine, the vibration of the engine will deliver to the SCR muffler, affecting the durability of each part of the SCR muffler.
- The SCR muffler should be installed on a strong frame or on the floor, and should be fixed using the bolt holes of the SCR muffler bracket. (Refer to Fig. 1, it should be fixed with M14 bolts at 10 to 12 kgfm.)
- Sea water may cause contamination of the SCR catalyst or corrosion of the sensors attached in the SCR muffler, and therefore, in principle, the SCR muffler should be installed in the engine compartment.
- The surface temperature of the SCR muffler may rise up to 200°C, and thus, inflammable parts, fuel or engine oil should be placed away from the SCR muffler for safety. Also, sufficient insulation should be considered to prevent such risks.
- If the SCR muffler is installed in the engine compartment, it may affect the temperature in the engine compartment, causing negative effect. Therefore, if the engine compartment temperature rises over 60°C, the exhaust pipes or the SCR muffler should be insulated or the engine intake air should be changed to the external intake air so as not to affect engine performance. (Refer to intake system installation part)
- If the SCR muffler is installed outside the engine compartment, it should be protected from sea water, etc. In case of installing any protective equipment, the thermal threshold of the various sensors in the SCR muffler should be considered to offer sufficient ventilation. (Refer to Fig.2)

NOTE:

Protection method must be considered not to over sensor's temperature limit (120°C)

- Shown in Table 5 is the size of the SCR muffler.

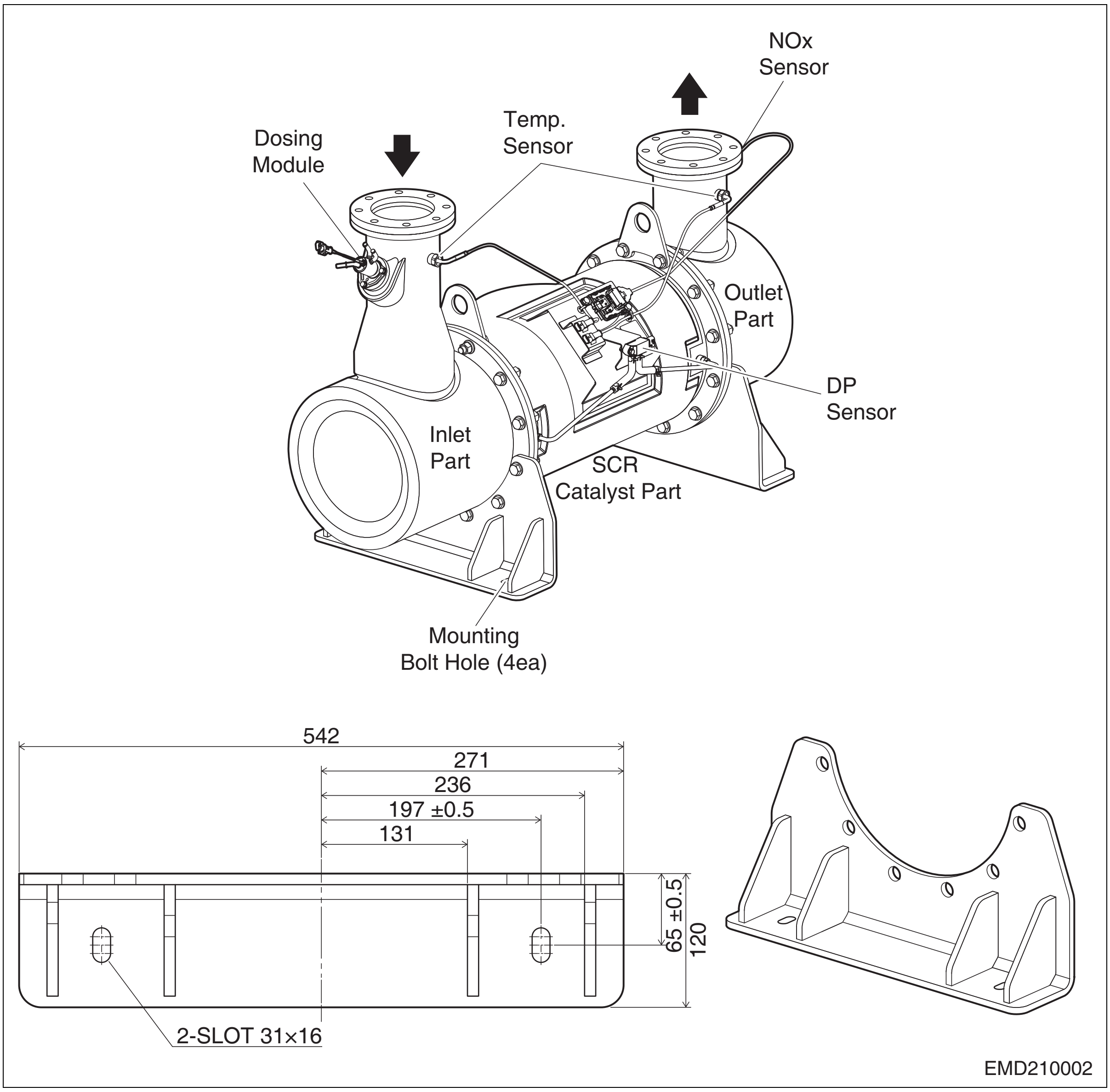


Fig. 1 SCR Muffler (for IMO Tier3) & SCR muffler Bracket

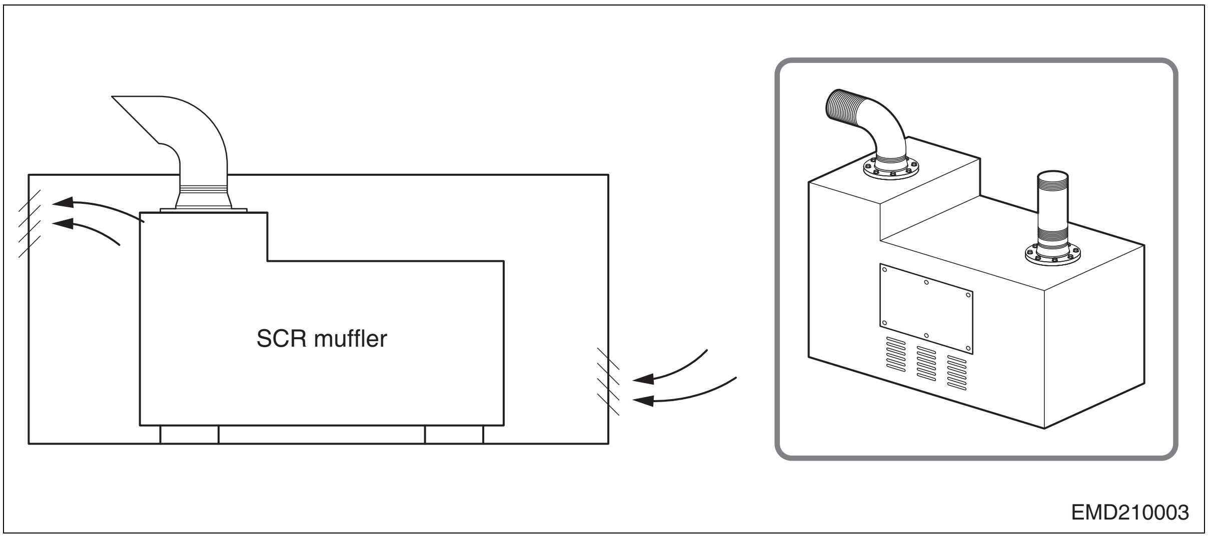


Fig. 2 SCR Muffler Protection (for example)

Table 5. SCR muffler size

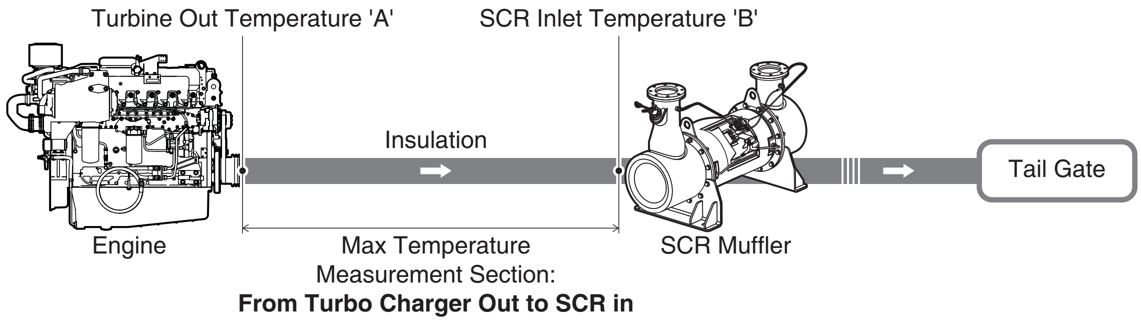
Item	DX22	DX12	DL08	DL06
Diameter* (mm)	330	330	←	←
Length* (mm)	1,150	1,150	1,040	←
Height* (mm)	775	775	775	←
Weight* (kg)	105	105	97	←
Part No.**	240103-02684	240103-01997B	240103-01996B	←

* Muffler size/weight is reference data and must check the real size/weight.

** This part number will be changed for improving part's quality without any notice.

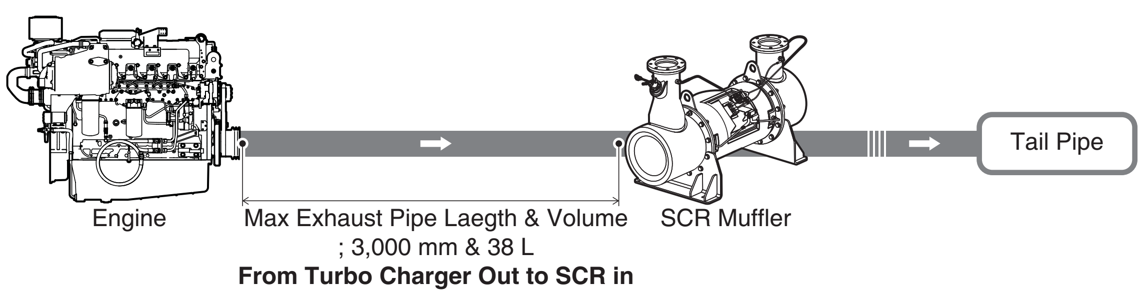
11.5. SCR Muffler Tubing

- The exhaust pipes connecting the engine and the SCR muffler should satisfy the "Dry Exhaust System Guide" in the Installation Guide.
- Since the temperature of the exhaust gas from the engine is very high at several hundreds °C, sufficient insulation material should be used to wrap the exhaust pipe so as to promote safety and maximum efficiency of the SCR catalyst.
  Max. exhaust gas temperature drop: 50°C @ rated power



EMD210004

- The efficiency of the SCR catalyst is negatively affected as the exhaust gas temperature drops, and thus, the distance from the outlet of the engine's turbocharger to the inlet of the SCR muffler should be within 3,000 mm. (The volume of the exhaust pipe should be at or below 38 liter.)



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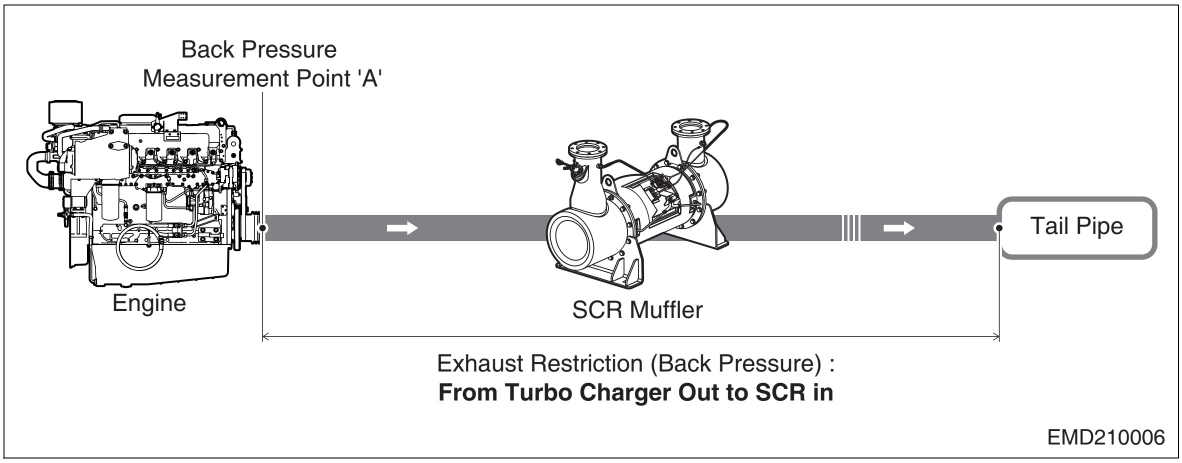
- If the exhaust pipe or tail pipe dangles to the SCR muffler, force is applied to the entrance/outlet part of the SCR muffler, and therefore, it should be avoided. (Refer to the Dry Exhaust System Guide.)
- One or more bellows should be installed between the outlet of the turbocharger and the inlet of the SCR muffler, and in particular, bellows should be installed in the exhaust pipe connected to the outlet of the engine's turbocharger, within 1.2 m from the engine. (Refer to the Dry Exhaust System Guide.)
- The exhaust gas back pressure from the exhaust pipe should satisfy the following criteria.
  Max. exhaust back pressure (kPa)
  DL06/DL08: 15 ±1 kPa (Propulsion), 7 ±1 kPa (Auxiliary)
  DX12: 30 ±1 kPa (Propulsion), 14 ±1 kPa (Auxiliary)
  DX22 (IMO Tier-2): 10 ±1 kPa (Propulsion), 5 ±1 kPa (Auxiliary)
  DX22 (IMO Tier-3): 30 ±1 kPa (Propulsion), 16 ±1 kPa (Auxiliary)



- While the inlet and outlet of the SCR muffler can be rotated by within 60° clockwise or counter-clockwise to connect the SCR muffler and the exhaust pipe, the temperature sensor and NOx sensor in the SCR muffler should be detached and re-attached after having rotated the inlet and outlet pats.

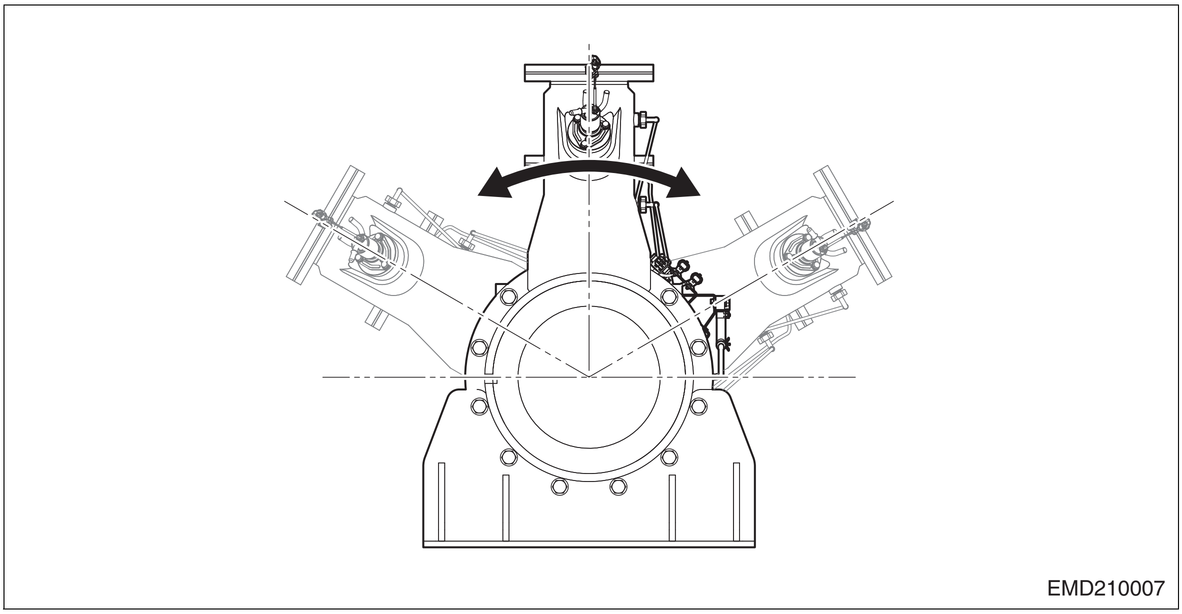


Fig. 3 SCR Muffler' permissible Inlet/Outlet part rotation

- Additional flanges and gaskets are supplied to connect the inlet/outlet pipes of the SCR muffler, and therefore, those should be used in connecting the inlet/outlet of the SCR muffler.

- To prevent contamination of the SCR catalyst and corrosion by the DEF, exhaust pipes in stainless 304, 439, and 409AL should be used for the connection of the turbocharger and the SCR muffler. (Stainless 304, 439, 409AL)
- If brass, copper, zinc or soft iron is used for the exhaust pipe, the DEF may be changed or contaminated and those materials should not be used.

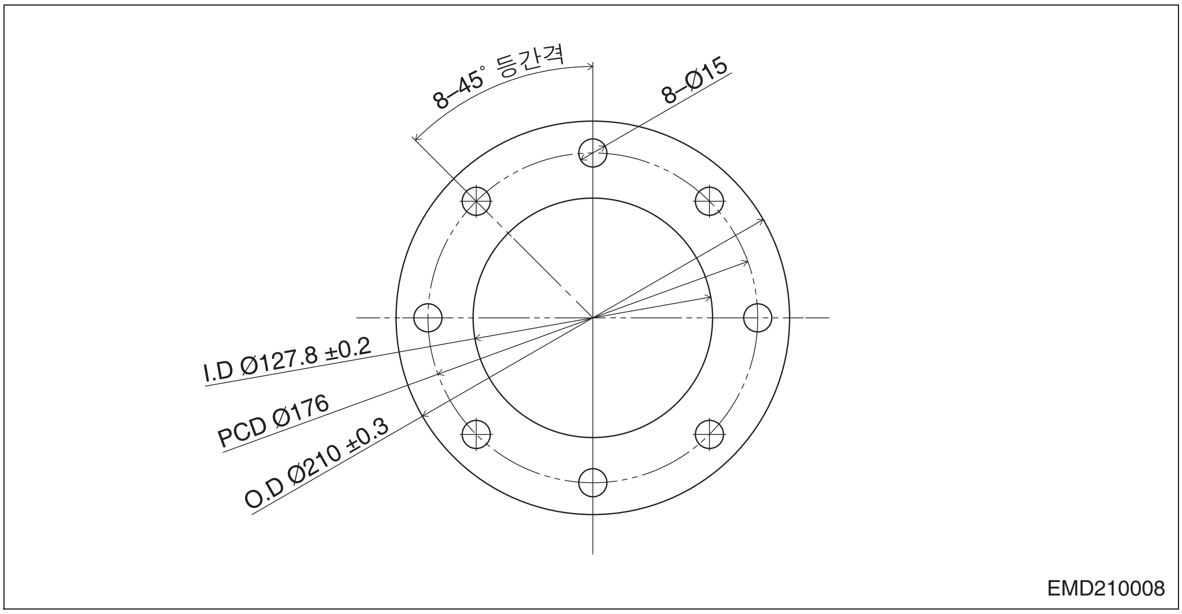


Fig. 4 Flange for SCR muffler Inlet/Outlet

11.6. Installation of the DEF Injection System (Dosing System)

11.6.1. Installation of the DEF Pump (Supply Module) and the DEF Injection Module (Dosing Module)

- If a HD Construction Equipment DEF tank is not used, the location of the DEF tank and pump should be satisfied as in the following figure. If the DEF tank is higher or lower than the DEF pump, the supply module and dosing module should be installed within 1,000 mm, respectively. In addition, the siphon of at least 100 mm should be created in the DEF pump to prevent the freezing of the DEF pump. (Refer to Fig. 5)
- If a HD Construction Equipment DEF tank is used, these criteria need not be considered.

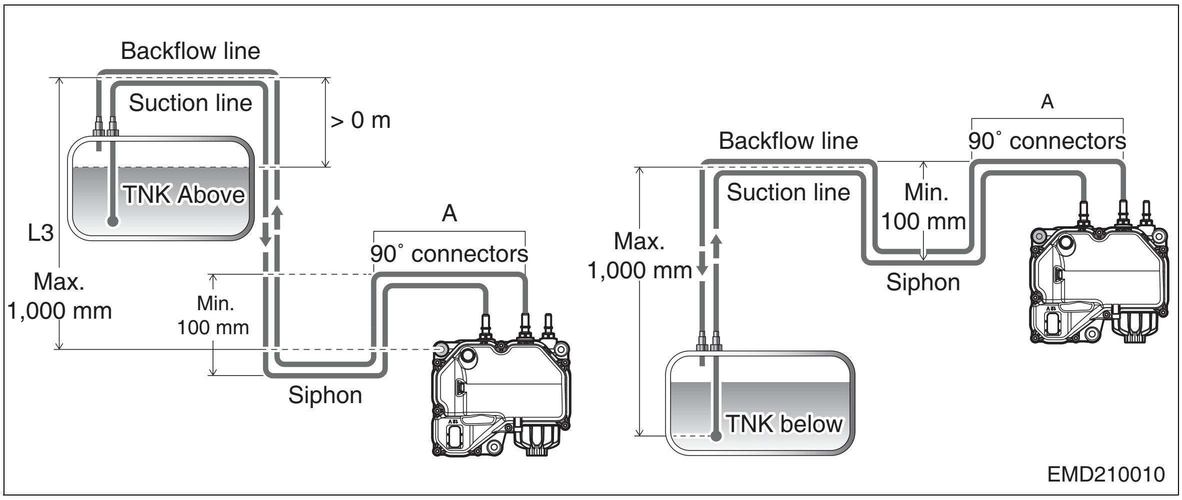


Fig. 5 The position of Supply module against Urea tank

- If the location of the DEF pump/tank and the DEF injection module (installed in the SCR muffler) is either higher or lower than that of the DEF pump, each of the modules should be installed within 1,000 mm, and the siphon of at least 100 mm should be created to prevent the freezing of the DEF injection module. (Refer to Fig. 6)

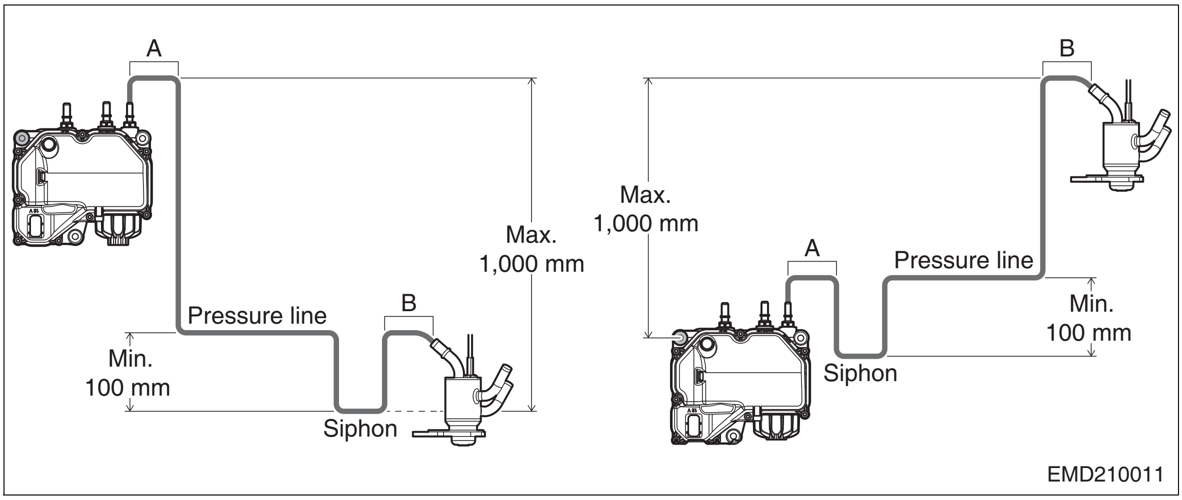


Fig. 6 The position of Supply module against Dosing module

- The harness of the DEF injection module should be fixed within 150 mm from the DEF injection module. (Refer to Fig. 7)

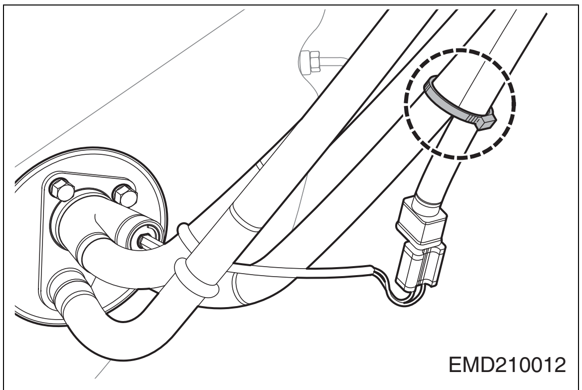


Fig. 7 Dosing Module Wire Harness Fixing (for example)

11.6.2. DEF Tank Installing and Tubing

- To prevent damage by vibration, the DEF tank should be fixed on a sturdy structure like a frame, etc. (It should be fixed with M10 bolts by 6 to 7 kg.m.)
- The DEF tank mounting should not use the same frame on which the engine is installed. o If the same frame is used for both the mounting and the engine, the vibration of the engine will deliver to the DEF tank, affecting the durability of each part of the DEF tank.
- The DEF tank should be installed vertically.

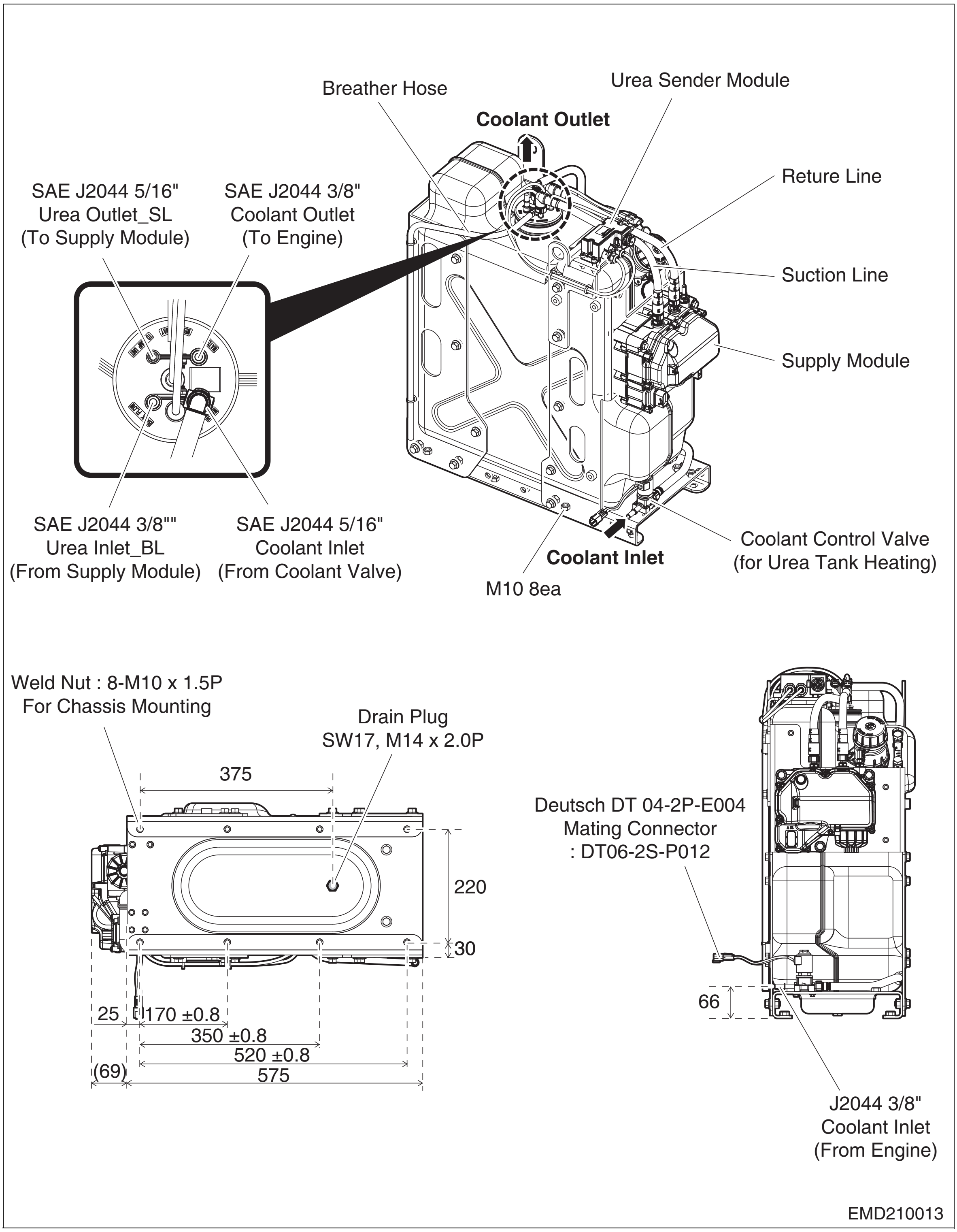


Fig. 8 DEF Tank (Port & Bracket)

- The DEF hoses connect the DEF to the DEF tank, the DEF pump (supply module), and the DEF dosing module.
- The material for the DEF hoses is PA11 (Nylon 11 or Polyamide 11), which does not affect the property of the DEF. Do not use any materials shown in 8.1, which are prohibited to be used for the DEF hoses and others making contact with the DEF.
- The DEF hoses consist of the suction hose that connects the DEF tank and the DEF pump (supply module), the back flow hose, and the pressure hose, and the suction hose and the back flow hose are assembled with the DEF pump on the DEF tank and are supplied together.
- To prevent the freezing of the DEF, the DEF hoses are installed with heating elements, and hose heating is controlled by ECU.
- In principle, the DEF hoses should use the ones supplied by HD Construction Equipment, and the use of other hoses should be checked by HD Construction Equipment.
- Shown in Table 5 are the DEF hose part number, length, and connector type.

Table 5 DEF Hose Specification

	Pressure Hose	**Suction Hose**	**Back Flow Hose**
Part No*	420108-02722	420108-02720	420108-02721
Length (mm)	4,000 ±10	440	441
Inner Diameter(mm)	6	6	6
Connector	Quick Connector (J2044 5/16")	Quick Connector (Tank Side, J2044 5/16") Quick Connector (DEF Pump Side, J2044 3/8")	Quick Connector (J2044 3/8")

* This part number might be changed for improving part's quality without any notice.

- Since the freezing point of the DEF tank is -11°C, a coolant heating tube is installed in the DEF tank to prevent freezing. If the DEF is frozen, the engine coolant flows through the pipe to melt the frozen DEF. Thus, the inlet and outlet of the DEF tank coolant pipes should be connected to the engine. Shown in Table 6 are the related connecting hoses.
- Since the DEF injection module (dosing module) is also attached to the exhaust pipe, it can malfunction due to the heat from the exhaust gas, and therefore, it needs to be cooled by the engine coolant. Therefore, as shown in Fig. 9, the coolant hose needs to be connected. Shown in Table 6 are the related connecting hoses.

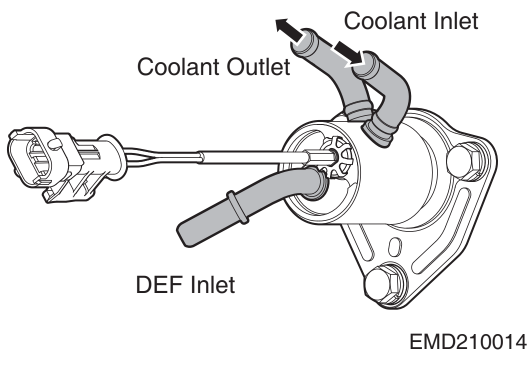


Fig. 9 Dosing Module Cooling

- The system design for the DEF tank heating and the cooling of the DEF injection module (dosing module) in the SCR system is shown in Fig. 10. (Black: DEF hose)

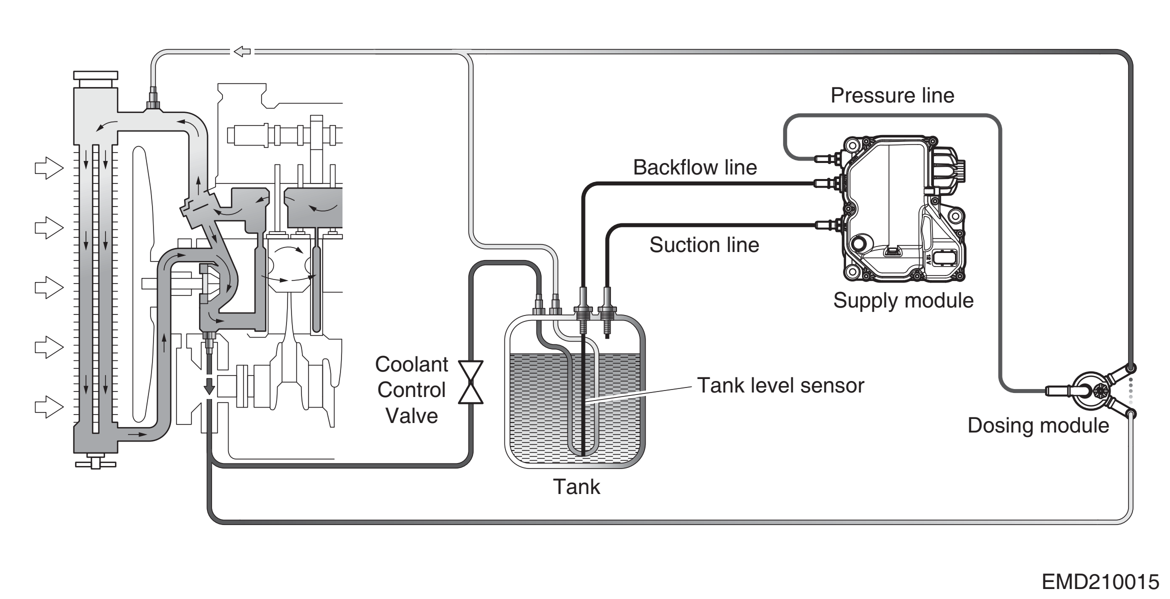


Fig. 10 The system diagram of Urea Tank heating & Dosing Module cooling

Table 6 SCR system tubing Specification

Item	Connection Type
Engine ↔ Urea Tank**	Quick Connector (J2044 3/8")
Engine ↔ Dosing Module**	Inner ø: 7mm, Out ø*: 13mm, Material: NBR
Supply Module ↔ Dosing Module	Quick Connector (J2044 5/16")

* Recommend

** These Connection Tubes are not HD Construction Equipment supply parts

- Shown in Fig. 11~13 are the connections of the DX12, DL08, and DL06 engine coolants to the DEF tank and DEF injection module (dosing module).

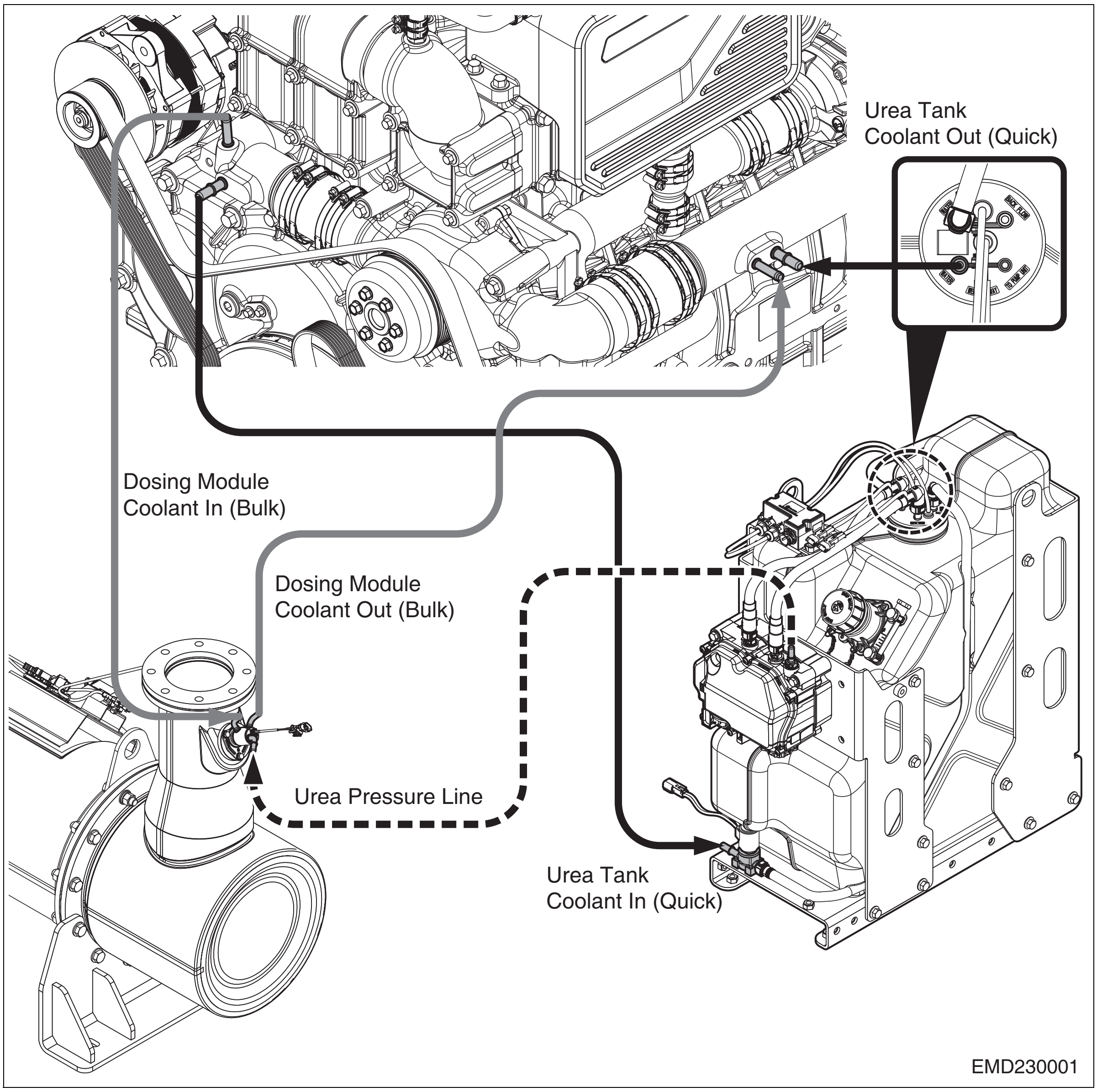


Fig. 11 Urea Tank heating & Dosing Module cooling Hose connection (DX12)

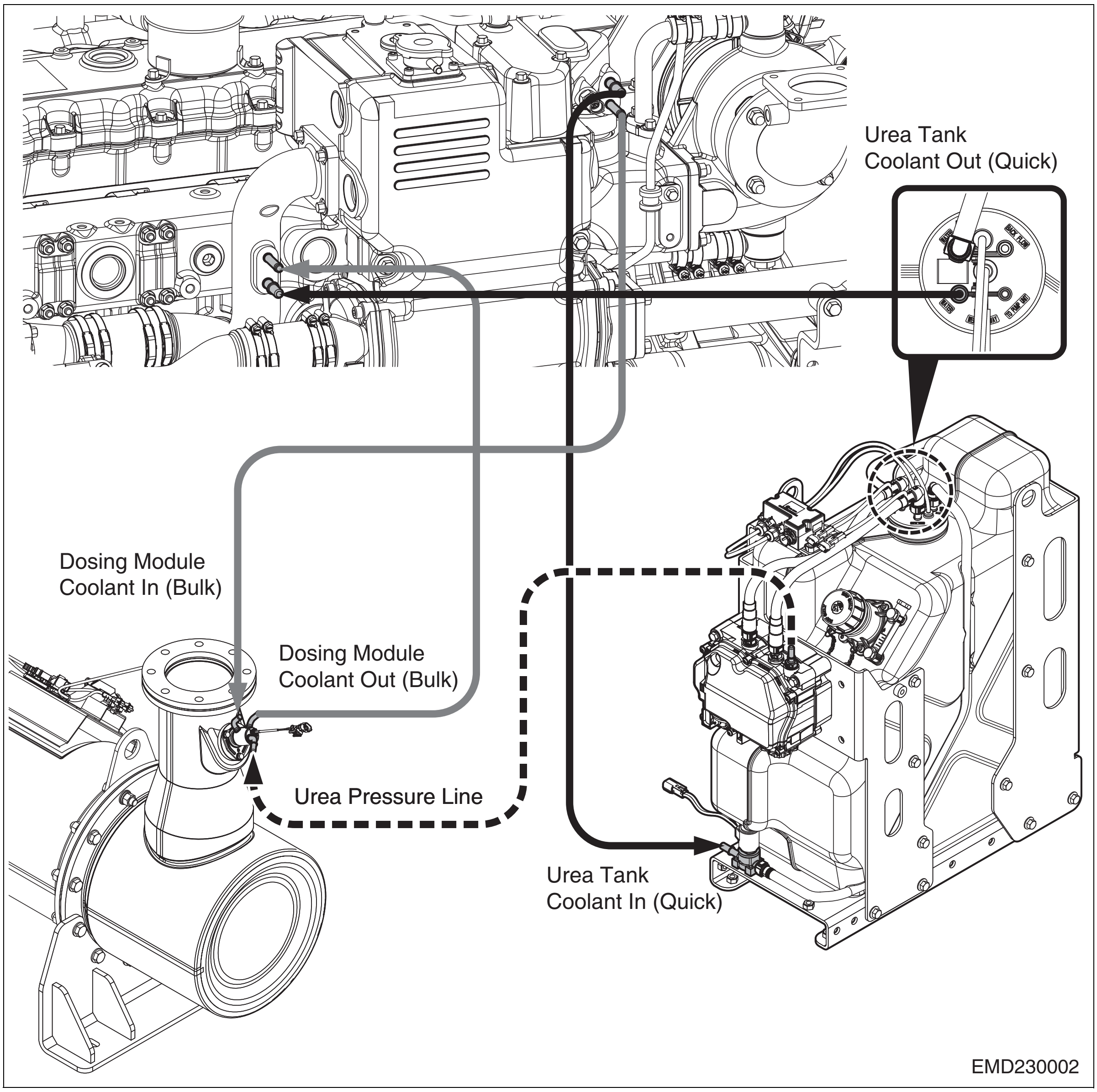


Fig. 12 Urea Tank heating & Dosing Module cooling Hose connection (DL06)

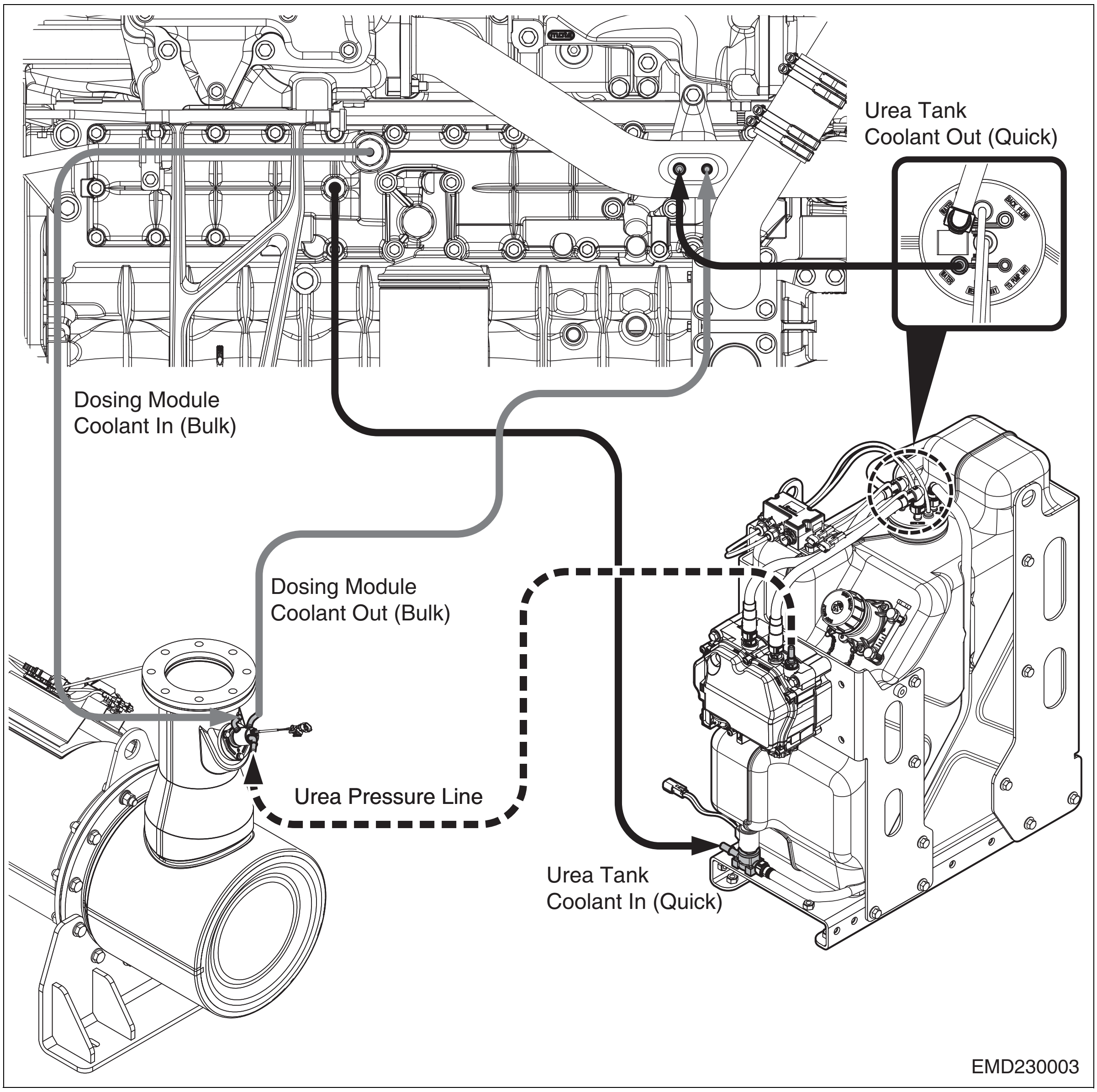


Fig. 13 Urea Tank heating & Dosing Module cooling Hose connection (DL08)

Appendix

Conversion Tables (1/2)

Units	To convert	Into	Multiply by	Reference
Length	mm	inch	0.03937	
	cm	foot	0.03281	
	m	yard	1.09361	
	km	mile	0.62137	1 ft = 12 in.
	inch	mm	25.4	1 yd = 3 ft. = 36 in.
	foot	cm	30.48	
	yard	m	0.5144	
	mile	km	1.6093	
Area	cm^2	in.^{2}	0.155	
	m^2	ft^2	10.76	
	km^2	mile^2	0.3861	
	are	acre	0.0247	1 ft^2 = 144 in.^{2}
	in.^{2}	cm^2	6.4516	1 yd^2 = 9 ft^2 = 1,296 in.^{2}
	ft^2	m^2	0.0929	
	mile^2	km^2	2.59	
	acre	are	40.4686	
Volume				• Great Britain (UK)
	cm^3	in.	0.06102	1 fl oz = 0.028413 dm^3
	dm^3 (liter)	in.^{3}	61.0236	1 pt = 4 gills = 0.56826 dm^3
	dm^3 (liter)	ft^3	0.03531	1 qt = 2 pt = 1.13652 dm^3
	m^3	ft^3	35.315	1 gal = 34 qt = 4.5461 dm^3
	m^3	yd^3	1.30795	
	in.^{3}	cm^3	16.3871	• United States (US)
	in.^{3}	dm^3 (liter)	0.01639	1 ft oz = 0.029574 dm^3
	ft^3	m^3	0.02832	1 liq = 4 gills = 0.47318 dm^3
	yd^3	m^3	0.76456	1 liq qt = 2 liq pl = 0.94635 dm^3
				1 gal = 231 in.^{3} = 4 liq qt = 3.7854 dm^3
Weight (Units of mass)	g	oz	0.03527	
	kg	lb	2.2046	1 lb = 16 oz = 453.592 g
	oz	g	28.3495	= 0.45359 kg
	lb	kg	0.45359	
Force	gf	N (newton)	0.009807	
	kgf	N	9.80665	1 pdℓ (poundal)
	1bf	N	4.44822	= 0.138255 N = force which
	N	gf	101.972	accelerates a mass of lb by 1 ft/s^2
	N	kgf	0.101972	
	N	lbf	0.224809	

Conversion Tables (2/2)

Units	To convert	Into	Multiply by	Reference
Pressure and Stress	kgf/cm^2	Bar	0.98066	1 at = 1 kgf/cm^2 1 Pa = 1 N/m^2 10 m H_2O = 1 kgf/cm^2 1 mmHg = 1 Torr 1 kg/cm^2 = 98 kPa = 980 hPa 760 mmHg = 1,013 mbar = 1,013 hPa
	kgf/cm^2	N/m^2 (Pa)	98066.5	
	kgf/cm^2	$lbf/in.^2$	14.2233	
	$lbf/in.^2$	Bar	0.0689	
	lbf/in^2	N/m^2 (Pa)	6894.76	
	Bar	kgf/cm^2	1.01972	
	N/m^2 (Pa)	kgf/cm^2	1.097×10^{-5}	
	lbf/in^2	kgf/cm^2	0.070331	
	Bar	$lbf/in.^2$	14.5037	
	N/m^2 (Pa)	$lbf/in.^2$	1.4504×10^{-4}	
Energy	J	kcal	238.8×10^{-6}	
	J	kWh	277.8×10^{-9}	
	J	BTU	947.8×10^{-6}	
	kcal	BTU	3.9683	
	BTU	kcal	0.252	
Work	kgfm	Nm	9.80665	
	lbft	Nm	1.356	
	kgfm	1bft	7.233	
	lbft	kgfm	0.138	
	Nm	kgfm	0.102	
	Nm	1bft	0.738	
Power	kW	P.S	1.3596	1 PS = 75 kg·m/sec 1 HP = 550 lb·ft/sec
	kW	HP	1.3410	
	PS	kW	0.7355	
	HP	kW	0.7457	
	PS	HP	0.98632	
	HP	PS	1.01387	
Velocity	m/sec	ft/min	196.86	
	ft/min	m/sec	0.0051	
	km/h	mile/h	0.62137	
	mile/h	km/h	1.09361	
Acceleration	m/sec^2	ft/sec^2	3.281	
	ft/sec^2	m/sec^2	0.3048	
Fuel Consumption	g/PS-h	g/kW-h	1.3596	
	g/HS-h	g/kW-h	1.3410	
	lb/PS-h	g/kW-h	599.96	
	lb/HS-h	g/kW-h	608.277	
	g/kW-h	g/PS-h	0.7355	
	g/kW-h	g/HS-h	0.7457	
	g/kW-h	lb/PS-h	0.00167	
	g/kW-h	lb/HS-h	0.00164	
Temperature	°C	°F	°C = 5/9 (°F - 32)	
	°C	K (Kelvin)	°C = K - 273.15	
			°F = 1.8 × °C + 32	
	°F	°C	°F = °R - 459.67	
	°F	°R (Rankine)	°F = °R - 459.67	
	K	°C	K = °C + 273.15	
	°R	°F	°R = °F + 459.67	

Heat Balance

DE12 Engine

Engine Models		MD196T	MD196TI	L126TI		AD196T		AD196TI		AD126TI		Remarks
				H	M	F	S	F	S	F	S	
Rating output	PS	260	320	360	400	210	246	235	270	280	336	
Engine speed	rpm	2,000	2,000	2,000	2,100	1,500	1,800	1,500	1,800	1,500	1,800	
Combustion air	m³/h	865	1,310	1,344	1,445	650	760	670	930	1,050	1,255	
Coolant capacity	Liter	24	24	24	24	24	24	24	24	24	24	
Coolant circulation	Liter/min	342	342	342	360	260	310	260	310	260	310	
Heat dissipated from cooling circuit	MJ/h	430	510	580	610	325	380	375	440	455	550	
Heat dissipated from inter cooler	MJ/h	-	66	73	82	-	-	50	56	59	69	
Sea water flow rate	Liter/min	260	260	290	305	220	265	220	265	220	265	
Exhaust temperature	°C	510	430	366	414	410	410	410	410	420	420	
Exhaust mass flow	kg/h	1,090	1,300	1,620	1,751	820	960	830	1,140	1,260	1,520	
Exhaust volume flow	m³/h	1,325	1,575	3,025	3,269	995	1,165	1,522	2,113	2,355	2,830	
Radiation, convection	MJ/h	100	107	112	133	75	88	80	90	89	107	

NOTE:

1. **The pressure drop in the external coolant loop (from the coolant outlet to the coolant inlet) must not exceed 0.5 bar.**
2. **If marine gear is used, 4% in heat rejection will be added for it's marine gear oil cooler.**
3. **The temperature difference between engine jacket water outlet and inlet must not exceed 8°C.**
4. **Max. permissible inlet cooling water temp. to inter cooler and marine gear oil cooler from keel cooler is 40°C.**

DX12 Engine (Mechanical)

Engine Models		Propulsion				Auxiliary		Emergency		
		4L126TIC	4L126TIH	4L126TIM	4L126TIL	4AD126TI	4AD126TI	4AD126TI	4AD126TI	4AD126TI
Continuous rating (B.H.P)	PS	400	450	495	545	350	410	350	350	410
	kW	294	330.8	363.8	400.6	257.3	301.4	257.3	257.3	301.4
Engine speed	rpm	1,800	2,000	2,100	2,200	1,500	1,800	1,500	1,500	1,800
Combustion air	m3/h	1,358	1,558	1,691	1,846	1,059	1,402	1,059	1,059	1,402
Coolant capacity (Max/Min)	Lit.	42/40	42/40	42/40	42/40	42/40	42/40	32/30	32/30	32/30
Coolant circulation	Lit/min	355	395	415	434	295	355	295	295	355
Heat dissipated from cooling circuit	MJ/h	615	628	680	848	604	708	604	604	708
Heat dissipated from inter cooler	MJ/h	220	205	234	292	104	190	104	104	190
Sea water flow rate	Lit/min	353	395	410	425	300	353	-	-	-
Exhaust temperature	°C	402	359	364	389	446	411	446	446	411
Exhaust mass flow	kg/h	1,663	1,906	2,095	2,277	1,211	1,714	1,211	1,211	1,714
Exhaust volume flow	m3/h	2,923	3,135	3,474	3,939	2,234	2,931	2,234	2,234	2,391
Radiation, convection	MJ/h	125	125	151	151	92	92	92	92	92

NOTE:

1. **The pressure drop in the external coolant loop (from the coolant outlet to the coolant inlet) must not exceed 0.5 bar.**
2. **If marine gear is used, 4% in heat rejection will be added for it's marine gear oil cooler.**
3. **The temperature difference between engine jacket water outlet and inlet must not exceed 8°C.**
4. **Max. permissible inlet cooling water temp. to inter cooler and marine gear oil cooler from keel cooler is 40°C.**

2 Valve

Engine Models		V158TI			V180TI			V222TI			AD158TI		AD180TI		AD222TI		Remarks
		H	M	L	H	M	L	H	M	L	F	S	F	S	F	S	
Rating output	PS	480	540	680	600	650	820	720	800	1000	410	480	485	600	606	720	
Engine speed	rpm	1,800	2,100	2,300	1,800	2,100	2,300	1,800	2,100	2,300	1,500	1,800	1,500	1,800	1,500	1,800	
Combustion air	m^3/h	2,350	2,780	3,970	2,890	3,190	4,785	3,450	4,040	5,995	2,010	2,350	2,335	2,890	2,905	3,450	
Coolant capacity	Liter	85	85	85	90	90	90	95	95	95	85	85	90	90	95	95	
Coolant circulation	Liter/ min	495	585	640	495	585	640	495	585	640	412	495	412	495	412	495	
Heat dissipated from cooling circuit	MJ/h	890	1,060	1,405	1,130	1,320	1,690	1,340	1,570	2,070	830	890	1,005	1,130	1,225	1,340	
Heat dissipated from inter cooler	MJ/h	190	223	290	242	273	349	287	330	428	173	190	206	242	255	287	
Sea water flow rate	Liter/ min	375	460	510	445	530	580	445	530	580	313	375	370	445	370	445	
Exhaust gas temperature	°C	385	400	450	400	410	435	385	385	455	385	385	400	400	385	385	
Exhaust mass flow	kg/h	1,842	2,168	2,821	2,347	2,643	3,383	2,786	3,214	4,153	1,575	1,842	1,895	2,347	2,345	2,786	
Exhaust volume flow	m^3/h	3,610	4,250	5,530	4,600	5,180	6,630	5,460	6,300	8,140	3,085	3,610	3,720	4,600	4,596	5,460	
Radiation, convection	MJ/h	139	171	225	182	204	256	215	242	328	134	139	156	182	189	215	

NOTE:

1. **The pressure drop in the external coolant loop (from the coolant outlet to the coolant inlet) must not exceed 0.5 bar.**
2. **If marine gear is used, 20% in heat rejection will be added for it's marine gear oil cooler.**
3. **The temperature difference between engine jacket water outlet and inlet must not exceed 8°C.**
4. **Max. permissible inlet cooling water temp. to inter cooler and marine gear oil cooler from keel cooler is 40°C.**

4 Valve

Engine Models		4V158TI			4V222TI			4AD158TI		4AD222TI		Remarks
		H	M	L	H	M	L	F	S	F	S	
Rating output	PS	530	600	800	800	880	1,200	442	530	667	800	
Engine speed	rpm	1,800	2,100	2,300	1,800	2,100	2,300	1,500	1,800	1,500	1,800	
Combustion air	m³/h	2,595	3,089	4,671	3,833	4,444	7,194	2,165	2,595	3,195	3,833	
Coolant capacity	Liter	94	94	120	103	103	103	94	94	103	103	
Fresh water flow	Liter/min	495	585	640	495	585	640	412	495	412	495	
Heat dissipated from cooling circuit	MJ/h	979	1,179	1,653	1,485	1,729	2,479	816	979	1,238	1,485	
Heat dissipated from inter cooler	MJ/h	210	248	342	318	364	513	175	210	265	318	
Raw water flow	Liter/min	445	530	580	445	530	580	330	445	330	445	
Exhaust gas temperature	°C	410	420	475	410	420	490	410	410	410	410	
Exhaust mass flow	kg/h	2,034	2,409	3,319	3,129	3,578	4,951	1,695	2,034	2,610	3,129	
Exhaust volume flow	m³/h	3,986	4,722	6,506	6,133	7,013	9,702	3,324	3,986	5,424	6,133	
Radiation, convection	MJ/h	154	190	265	239	267	393	128	154	199	239	

NOTE:

1. **The pressure drop in the external coolant loop (from the coolant outlet to the coolant inlet) must not exceed 0.5 bar.**
2. **If marine gear is used, 20% in heat rejection will be added for it's marine gear oil cooler.**
3. **The temperature difference between engine jacket water outlet and inlet must not exceed 8°C.**
4. **Max. permissible inlet cooling water temp. to inter cooler and marine gear oil cooler from keel cooler is 40°C.**

D1146 Engine

Engine Models		L136	L136T		L136TI	L086TI			AD136		AD136T		AD136TI		AD086TI		Remarks
			H	L		H	M	L	F	S	F	S	F	S	F	S	
Rating output	PS	160	200	240	230	285	315	360	105	126	145	170	157	188	205	253	
Engine speed	rpm	2,200	2,200	2,500	2,200	2,100	2,300	2,500	1,500	1,800	1,500	1,800	1,500	1,800	1,500	1,800	
Combustion air	m³/h	450	770	1,005	850	1,050	1,130	1,470	295	355	560	655	585	695	755	935	
Coolant capacity	Liter	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	
Coolant circulation	Liter/ min	250	250	290	250	250	270	290	175	210	175	210	175	210	175	210	
Heat dissipated from cooling circuit	MJ/h	276	312	338	460	600	710	780	185	220	285	335	315	375	435	535	
Heat dissipated from inter cooler	MJ/h	-	-	-	47	54	64	77	-	-	-	-	47	47	39	48	
Sea water flow rate	Liter/ min	180	180	195	180	180	185	195	135	145	135	145	135	145	135	145	
Exhaust temperature	°C	520	450	470	450	390	430	470	445	490	420	430	435	450	400	390	
Exhaust mass flow	kg/h	560	960	1,260	1,060	1,310	1,410	1,840	368	442	696	816	725	865	945	1,165	
Exhaust volume flow	m³/h	680	1,170	1,520	1,280	1,580	1,710	2,220	447	435	848	995	875	1,045	1,135	1,405	
Radiation, convection	MJ/h	68	76	92	86	98	106	120	45	54	60	71	59	71	72	88	

NOTE:

1. **The pressure drop in the external coolant loop (from the coolant outlet to the coolant inlet) must not exceed 0.35 bar.**
2. **If marine gear is used, 20% in heat rejection will be added for it's marine gear oil cooler.**
3. **The temperature difference between engine jacket water outlet and inlet must not exceed 8°C.**
4. **Max. permissible inlet cooling water temp. to inter cooler and marine gear oil cooler from keel cooler is 40°C.**

DB58 Engine

Engine Models		L066TI	AD066TI		Remarks
		H	F	S	
Rating output	PS	180	130	150	
Engine speed	rpm	2,200	1,500	1,800	
Combustion air	m^3/h	700	700	700	
Coolant capacity	Liter	23	23	23	
Coolant circulation	Liter/min	150	150	150	
Heat dissipated from cooling circuit	MJ/h	335	335	335	
Heat dissipated from inter cooler	MJ/h	33	33	33	
Sea water flow rate	Liter/min	140	140	140	
Exhaust temperature	°C	400	400	400	
Exhaust mass flow	kg/h	870	870	870	
Exhaust volume flow	m^3/h	1,050	1,050	1,050	
Radiation, convection	MJ/h	78	78	78	

NOTE:

1. **The pressure drop in the external coolant loop (from the coolant outlet to the coolant inlet) must not exceed 0.35 bar.**
2. **If marine gear is used, 20% in heat rejection will be added for it's marine gear oil cooler.**
3. **The temperature difference between engine jacket water outlet and inlet must not exceed 8°C.**
4. **Max. permissible inlet cooling water temp. to inter cooler and marine gear oil cooler from keel cooler is 40°C.**

Marine Engine Electronic (DL06 PROPULSION)

4L066C		IMO Tier2											Remarks
		CD			HD					MD			
Engine Models		4L066CA (C)	4L066CB (C)	4L066CC (C)	4L066CA (H)	4L066CB (H)	4L066CC (H)	4L066CD (H)	4L066CE (H)	4L066CA (M)	4L066CB (M)	4L066CC (M)	
Rating output	PS	250	220	176	286	250	230	176	130	300	270	240	
Engine speed	rpm	1,800	1,800	1,800	2,100	2,100	2,100	2,100	2,100	2,300	2,300	2,300	
Combustion air	m³/h	654	620	580	876	860	847	708	608	1,006	990	955	
Coolant capacity	Liter	26	26	26	26	26	26	26	26	26	26	26	
Coolant circulation	Liter/min	287	287	287	338	338	338	338	338	369	369	369	
Heat dissipated from cooling circuit	MJ/h	441	388	311	483	423	389	297	220	534	480	427	
Heat dissipated from inter cooler	MJ/h	79	69	56	127	111	102	78	58	160	144	128	
Sea water flow rate	Liter/min	276	276	276	328	328	328	328	328	346	346	346	
Exhaust temperature	°C	419	407	370	387	361	350	313	287	391	345	335	
Exhaust mass flow	kg/h	808	816	699	1,076	1,083	1,014	842	721	1,232	1,237	1,141	
Exhaust volume flow	m³/h	1,722	1,730	1,416	2,191	2,144	1,980	1,566	1,298	2,528	2,386	2,176	
Radiation, convection	MJ/h	40	35	28	46	40	37	28	21	50	45	40	

NOTE:

1. **The pressure drop in the external coolant loop (from the coolant outlet to the coolant inlet) must not exceed 0.5 bar.**
2. **If marine gear is used, 4% in heat rejection will be added for it's marine gear oil cooler.**
3. **The temperature difference between engine jacket water outlet and inlet must not exceed 8°C.**
4. **Max. permissible inlet cooling water temp. to inter cooler and marine gear oil cooler from keel cooler is 40°C.**

Marine Engine Electronic (DL06 AUXILIARY)

4L066C		IMO Tier2								Remarks
		50Hz				60Hz				
Engine Models		4AD066CA (F)	4AD066CB (F)	4AD066CC (F)	4AD066CD (F)	4AD066CA (S)	4AD066CB (S)	4AD066CC (S)	4AD066CD (S)	
Rating output	PS	209	175	136	109	250	190	163	136	
Engine speed	rpm	1,500	1,500	1,500	1,500	1,800	1,800	1,800	1,800	
Combustion air	m^3/h	512	460	395	360	654	612	546	498	
Coolant capacity	Liter	26	26	26	26	26	26	26	26	
Coolant circulation	Liter/min	239	239	239	239	287	287	287	287	
Heat dissipated from cooling circuit	MJ/h	374	313	243	195	441	335	288	240	
Heat dissipated from inter cooler	MJ/h	55	46	36	29	79	60	51	43	
Sea water flow rate	Liter/min	231	231	231	231	276	276	276	276	
Exhaust temperature	°C	478	461	405	359	419	416	369	340	
Exhaust mass flow	kg/h	635	561	479	434	808	743	659	600	
Exhaust volume flow	m^3/h	1,472	1,281	1,026	881	1,722	1,604	1,335	1,173	
Radiation, convection	MJ/h	33	27	21	17	40	30	26	22	

NOTE:

1. **The pressure drop in the external coolant loop (from the coolant outlet to the coolant inlet) must not exceed 0.5 bar.**
2. **If marine gear is used, 4% in heat rejection will be added for it's marine gear oil cooler.**
3. **The temperature difference between engine jacket water outlet and inlet must not exceed 8°C.**
4. **Max. permissible inlet cooling water temp. to inter cooler and marine gear oil cooler from keel cooler is 40°C.**

Marine Engine Electronic (DL08 PROPULSION)

4L086C		IMO Tier2						Remarks
		CD		HD		MD		
Engine Models		4L086CA(C)	4L086CB(C)	4L086CA(H)	4L086CB(H)	4L086CA(M)	4L086CB(M)	
Rating output	PS	320	280	360	320	380	330	
Engine speed	rpm	1,800	1,800	2,000	2,000	2,100	2,100	
Combustion air	m³/h	1,011	950	1,143	1,098	1,178	1,110	
Coolant capacity	Liter	28	28	28	28	28	28	
Coolant circulation	Liter/min	336	336	376	376	382	382	
Heat dissipated from cooling circuit	MJ/h	526	460	628	557	676	588	
Heat dissipated from inter cooler	MJ/h	170	149	233	207	253	220	
Sea water flow rate	Liter/min	358	358	386	386	388	388	
Exhaust temperature	°C	370	352	382	330	387	321	
Exhaust mass flow	kg/h	1,283	1,171	1,407	1,400	1,465	1,495	
Exhaust volume flow	m³/h	2,550	2,273	2,832	2,615	2,966	2,757	
Radiation, convection	MJ/h	53	46	60	54	63	55	

NOTE:

1. **The pressure drop in the external coolant loop (from the coolant outlet to the coolant inlet) must not exceed 0.5 bar.**
2. **If marine gear is used, 4% in heat rejection will be added for it's marine gear oil cooler.**
3. **The temperature difference between engine jacket water outlet and inlet must not exceed 8°C.**
4. **Max. permissible inlet cooling water temp. to inter cooler and marine gear oil cooler from keel cooler is 40°C.**

Marine Engine Electronic (DL08 AUXILIARY)

4L086C		IMO Tier2			Remarks
		50Hz	60Hz		
Engine Models		4AD086CA(F)	4AD086CA(S)	4AD086CB(S)	
Rating output	PS	271	320	272	
Engine speed	rpm	1,500	1,800	1,800	
Combustion air	m^3/h	816	1011	953	
Coolant capacity	Liter	28	28	28	
Coolant circulation	Liter/min	276	336	336	
Heat dissipated from cooling circuit	MJ/h	469	526	447	
Heat dissipated from inter cooler	MJ/h	105	170	145	
Sea water flow rate	Liter/min	305	358	358	
Exhaust temperature	°C	388	370	317	
Exhaust mass flow	kg/h	1,035	1,283	1,160	
Exhaust volume flow	m^3/h	2,118	2,550	2,131	
Radiation, convection	MJ/h	43	53	45	

NOTE:

1. **The pressure drop in the external coolant loop (from the coolant outlet to the coolant inlet) must not exceed 0.5 bar.**
2. **If marine gear is used, 4% in heat rejection will be added for it's marine gear oil cooler.**
3. **The temperature difference between engine jacket water outlet and inlet must not exceed 8°C.**
4. **Max. permissible inlet cooling water temp. to inter cooler and marine gear oil cooler from keel cooler is 40°C.**

Marine Engine Electronic (DX12 PROPULSION)

4L126C		IMO Tier2				Remarks
		CD	HD			
Engine Models		4L126CA(C)	4L126CA-II(H)	4L126CA(H)	4L126CB(H)	
Rating output	PS	450	550	500	400	
Engine speed	rpm	1,800	2,100	2,000	2,000	
Combustion air	m³/h	1,233	1,501	1,368	1,300	
Coolant capacity	Liter	38	38	38	38	
Coolant circulation	Liter/min	389	458	437	437	
Heat dissipated from cooling circuit	MJ/h	781	1008	893	714	
Heat dissipated from inter cooler	MJ/h	140	241	191	153	
Sea water flow rate	Liter/min	322	374	355	355	
Exhaust temperature	°C	405	440	390	332	
Exhaust mass flow	kg/h	1,569	1,912	1,741	1,708	
Exhaust volume flow	m³/h	3,248	4,141	3,514	3,196	
Radiation, convection	MJ/h	68	90	86	69	

NOTE:

1. **The pressure drop in the external coolant loop (from the coolant outlet to the coolant inlet) must not exceed 0.5 bar.**
2. **If marine gear is used, 4% in heat rejection will be added for it's marine gear oil cooler.**
3. **The temperature difference between engine jacket water outlet and inlet must not exceed 8°C.**
4. **Max. permissible inlet cooling water temp. to inter cooler and marine gear oil cooler from keel cooler is 40°C.**

Marine Engine Electronic (DX12 AUXILIARY)

4L126C		IMO Tier2			Remarks
		50Hz	60Hz		
Engine Models		4AD126CA(F)	4AD126CA(S)	4AD126CB(S)	
Rating output	PS	390	455	381	
Engine speed	rpm	1,500	1,800	1,800	
Combustion air	m³/h	916	1,218	1,212	
Coolant capacity	Liter	38	38	38	
Coolant circulation	Liter/min	324	389	389	
Heat dissipated from cooling circuit	MJ/h	655	770	644	
Heat dissipated from inter cooler	MJ/h	115	137	114	
Sea water flow rate	Liter/min	269	322	322	
Exhaust temperature	°C	451	400	344	
Exhaust mass flow	kg/h	1,168	1,558	1,535	
Exhaust volume flow	m³/h	2,571	3,201	2,929	
Radiation, convection	MJ/h	61	68	57	

NOTE:

1. **The pressure drop in the external coolant loop (from the coolant outlet to the coolant inlet) must not exceed 0.5 bar.**
2. **If marine gear is used, 4% in heat rejection will be added for it's marine gear oil cooler.**
3. **The temperature difference between engine jacket water outlet and inlet must not exceed 8°C.**
4. **Max. permissible inlet cooling water temp. to inter cooler and marine gear oil cooler from keel cooler is 40°C.**

Marine Engine Electronic (DX22 PROPULSION)

4V222C		IMO Tier2								Remarks
		CD	HD				MD	LD		
Engine Models		4V222C ASC	4V222C ASH	4V222C BSH	4V222C CSH	4V222C ASH-II	4V222C ASM	4V222C ASL	4V222C BSL	
Rating output	PS	810	903	800	720	1000	1100	1235	1150	
Engine speed	rpm	1,800	1,800	1,800	1,800	1,800	2,100	2,300	2,300	
Combustion air	m³/h	2,342	2,540	2,310	2,139	2,814	3,292	3,688	3,624	
Coolant capacity	Liter	108	108	108	108	108	108	108	108	
Coolant circulation	Liter/min	687	687	687	687	687	782	842	842	
Heat dissipated from cooling circuit	MJ/h	1,266	1,400	1,252	1,135	1,553	1,675	1,966	1,814	
Heat dissipated from inter cooler	MJ/h	290	321	287	260	356	510	657	606	
Sea water flow rate	Liter/min	568	568	568	568	568	603	587	587	
Exhaust temperature	°C	412	420	411	403	416	389	406	383	
Exhaust mass flow	kg/h	2,832	3,057	2,800	2,594	3,421	3,874	4,310	4,221	
Exhaust volume flow	m³/h	5,244	5,684	5,178	4,762	6,309	6,697	7,441	7,192	
Radiation, convection	MJ/h	162	179	160	145	199	223	246	227	

NOTE:

1. **The pressure drop in the external coolant loop (from the coolant outlet to the coolant inlet) must not exceed 0.5 bar.**
2. **If marine gear is used, 4% in heat rejection will be added for it's marine gear oil cooler.**
3. **The temperature difference between engine jacket water outlet and inlet must not exceed 8°C.**
4. **Max. permissible inlet cooling water temp. to inter cooler and marine gear oil cooler from keel cooler is 40°C.**

Marine Engine Electronic (DX22 AUXILIARY)

4V222C		IMO Tier2			Remarks
		50HZ HD	60HZ HD		
Engine Models		4AD222CASF	4AD222CASS	4AD222CASS-II	
Rating output	PS	752	903	1,000	
Engine speed	rpm	1,500	1,800	1,800	
Combustion air	m³/h	1,870	2,523	2,741	
Coolant capacity	Liter	108	108	108	
Coolant circulation	Liter/min	572	687	687	
Heat dissipated from cooling circuit	MJ/h	1,423	1,396	1,551	
Heat dissipated from inter cooler	MJ/h	142	320	356	
Sea water flow rate	Liter/min	493	568	568	
Exhaust temperature	°C	466	419	413	
Exhaust mass flow	kg/h	2,285	3,051	3,343	
Exhaust volume flow	m³/h	4,621	5,647	6,160	
Radiation, convection	MJ/h	143	179	199	

NOTE:

1. **The pressure drop in the external coolant loop (from the coolant outlet to the coolant inlet) must not exceed 0.5 bar.**
2. **If marine gear is used, 4% in heat rejection will be added for it's marine gear oil cooler.**
3. **The temperature difference between engine jacket water outlet and inlet must not exceed 8°C.**
4. **Max. permissible inlet cooling water temp. to inter cooler and marine gear oil cooler from keel cooler is 40°C.**

Marine Engine Electronic (DX22 PROPULSION)

4V222C		IMO Tier3								Remarks
		CD	HD				MD	LD		
Engine Models		4V222C AKC	4V222C AKH	4V222C BKH	4V222C CKH	4V222C AKH-II	4V222C AKM	4V222C AKL	4V222C BKL	
Rating output	PS	810	903	800	720	1,000	1,100	1,235	1,150	
Engine speed	rpm	1,800	1,800	1,800	1,800	1,800	2,100	2,300	2,300	
Combustion air	m³/h	2,097	2,329	2,069	1,962	2,464	3,005	3,455	3,327	
Coolant capacity	Liter	108	108	108	108	108	108	108	108	
Coolant circulation	Liter/min	687	687	687	687	687	782	842	842	
Heat dissipated from cooling circuit	MJ/h	1,288	1,441	1,274	1,154	1,551	1,740	2,038	1,883	
Heat dissipated from inter cooler	MJ/h	295	330	292	265	356	530	681	629	
Sea water flow rate	Liter/min	568	568	568	568	568	603	587	587	
Exhaust temperature	°C	455	467	451	439	511	463	485	462	
Exhaust mass flow	kg/h	2,566	2,854	2,537	2,402	3,031	3,599	4,120	3,936	
Exhaust volume flow	m³/h	4,654	5,162	4,560	4,316	5,468	5,944	6,749	6,344	
Radiation, convection	MJ/h	165	184	163	148	199	232	255	236	

NOTE:

1. **The pressure drop in the external coolant loop (from the coolant outlet to the coolant inlet) must not exceed 0.5 bar.**
2. **If marine gear is used, 4% in heat rejection will be added for it's marine gear oil cooler.**
3. **The temperature difference between engine jacket water outlet and inlet must not exceed 8°C.**
4. **Max. permissible inlet cooling water temp. to inter cooler and marine gear oil cooler from keel cooler is 40°C.**

Marine Engine Electronic (DX22 AUXILIARY)

4V222C		IMO Tier3			Remarks
		50HZ HD	60HZ HD		
Engine Models		4AD222CAKF	4AD222CAKS	4AD222CAKS-II	
Rating output	PS	752	903	1,000	
Engine speed	rpm	1,500	1,800	1,800	
Combustion air	m^3/h	1,709	2,301	2,452	
Coolant capacity	Liter	108	108	108	
Coolant circulation	Liter/min	572	687	687	
Heat dissipated from cooling circuit	MJ/h	1,485	1,443	1,551	
Heat dissipated from inter cooler	MJ/h	148	331	356	
Sea water flow rate	Liter/min	493	568	568	
Exhaust temperature	°C	515	470	510	
Exhaust mass flow	kg/h	2,128	2,819	3,018	
Exhaust volume flow	m^3/h	4,276	5,046	5,444	
Radiation, convection	MJ/h	149	185	199	

NOTE:

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