Installation

Marine Propulsion
Diesel Engines

D E
1(1)

D5 - D16 series

Installation

Marine Propulsion Diesel Engines D5, D7, D9, D11, D12, D16

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Printed on environmentally-friendly paper

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Introduction

This Installation Manual contains the information you will need to install your Volvo Penta product correctly. Check that you have the correct Installation Manual.

Read the *Safety precautions* and the *General information* in the installation manual carefully before servicing or operating the engine.

Important

The following special warning symbols are found in this manual and on the engine.

⚠ **WARNING!** Danger of personal injury, damage to property or mechanical malfunction if the instructions are not followed.

⚠ **IMPORTANT!** Possible damage or mechanical malfunction in products or property.

NOTE! Important information to facilitate work processes or operation.

Below is a list of the risks that you must always be aware of and the safety measures you must always carry out.

⚠ Plan in advance so that you have enough room for safe installation and (future) dismantling. Plan the engine compartment (and other compartments such as the battery compartment) so that all service points are accessible. Make sure it is not possible to come into contact with rotating components, hot surfaces or sharp edges when servicing and inspecting the engine. Ensure that all equipment (pump drives, compressors for example) has protective covers.

⚠ Make sure the engine is immobilized by not connecting the electrical system or turning off the power supply to the engine at the main switch (breakers), and locking the switch (breakers) in the OFF position for as long as work continues. Set up a warning notice at the engine control point or helm.

⚠ As a rule, no work should be done on a running engine. However, some work e. g. adjustments, requires a running engine. Approaching an engine that is running is a safety risk. Loose clothing or long hair can fasten in rotating parts and cause serious personal injury. If working in proximity of a running engine, careless movements or a dropped tool can result in personal injury. Take precautions to avoid hot surfaces (exhaust pipes, turbochargers, charge air manifolds, starting elements etc.) and hot liquids in supply lines and hoses in engines that are running or have just been turned off. Reinstall all protective parts removed during service operations before starting work on the engine.

⚠ Ensure that the warning or information decals on the product are always visible. Replace decals which are damaged or painted over.

⚠ Turbocharged engines: Never start the engine without installing the air cleaner (ACL). The rotating compressor parts in the turbocharger can cause serious personal injury. Foreign objects entering the intake ducts can also cause mechanical damage.

⚠ Never use starting spray in the air intake. Use of such products could result in an explosion in the air intake pipe. There is a danger of personal injury.

⚠ Do not open the filler cap for the engine coolant (freshwater cooled engines) when the engine is hot. Steam or hot engine coolant can be ejected and any pressure in the system will be lost. Open the filler cap slowly and release coolant system pressure (freshwater cooled engines), if the filler cap or drain cock must be opened, or if a plug or engine coolant line must be removed on a hot engine. Steam or hot coolant can be ejected.

⚠ Hot oil can cause burns. Avoid skin contact with hot oil. Ensure that the oil system is depressurised before starting work on it. Never start or run the engine without the oil filler cap in place because of the risk of oil being ejected.

⚠ If the boat is in the water, stop the engine and close the bottom valve before carrying out operations on the cooling system.

⚠ Only start the engine in an area that is well ventilated. Beware, the gases are poisonous to breathe in. When operating in an enclosed space, use exhaust extraction to lead the exhaust and crankcase gases away from the place of work.

⚠ Always wear protective goggles if there is a risk of splinters, grinding sparks and splashes from acid or other chemicals. Your eyes are extremely sensitive and an injury to them can result in loss of sight!

⚠ Avoid skin contact with oil! Long term or repeated skin contact with oil can lead to the loss of natural oils from the skin. This leads to irritation, dry skin, eczema and other skin problems. Old oil is more dangerous to your health than new. Use protective gloves and avoid oil-soaked clothes and rags. Wash regularly, especially before meals. Use special skin creams to help clean and to stop your skin drying out.

⚠ Most chemicals intended for the product (engine and reverse gear oils, glycol, gasoline and diesel), or chemicals intended for the workshop (degreasing agent, paints and solvents) are harmful to your health. Read the instructions on the packaging carefully! Always follow protective measures (using a protective mask, goggles, gloves etc.). Make sure that other personnel are not unknowingly exposed to harmful substances, in the air that they breathe for example. Ensure that ventilation is good. Deal with used and excess chemicals as directed.

⚠ Be extremely careful when tracing leaks in the fuel system and when testing injectors. Wear protective goggles. The jet from an injector is under very high pressure and fuel can penetrate deep into tissue, causing serious injury with a risk of blood poisoning.

⚠ All fuels and many chemicals are inflammable. Keep away from naked flames or sparks. Gasoline, some solvents and hydrogen from batteries in the correct proportions with air are very inflammable and explosive. Do not smoke! Maintain good ventilation and take the necessary safety measures before welding or grinding in the vicinity. Always keep a fire extinguisher accessible in the workplace.

⚠ Store oil and fuel-soaked rags and old fuel and oil filters properly. Oil-soaked rags can, in certain circumstances, ignite spontaneously. Old fuel and oil filters are environmentally harmful and should be delivered, with used lubrication oil, contaminated fuel, paint, solvents and degreasing agents, to a proper refuse station for environmentally harmful material for destruction.

⚠ Ensure that the battery compartment is designed according to current safety standards. Never allow an open flame or electric sparks near the battery area. Never smoke in proximity to the batteries. The batteries give off hydrogen gas during charging which when mixed with air can form an explosive gas. This gas is easily ignited and highly volatile. Incorrect connection of the battery can cause sparks sufficient to cause an explosion with resulting damage. Do not shift the connections when attempting to start the engine (spark risk) and do not lean over any of the batteries.

⚠ Always ensure that the Plus (positive) and Minus (negative) battery leads are correctly installed on the corresponding terminal posts on the battery. Incorrect installation can result in serious damage to the electrical equipment. Refer to the wiring diagrams.

⚠ Always use protective goggles when charging and handling the batteries. The battery electrolyte contains extremely corrosive sulphuric acid. If this should come in contact with the skin, immediately wash with soap and plenty of water. If battery acid comes in contact with the eyes, flush immediately with water and obtain medical assistance.

⚠ Turn the engine off and turn off the power at the main switches (breakers) before carrying out work on the electrical system.

⚠ Clutch adjustments must be carried out with the engine turned off.

⚠ Use the lifting eyes fitted on the engine/reverse gear when lifting the drive unit. Always check that the lifting equipment used is in good condition and has the load capacity to lift the engine (engine weight including reverse gear and any extra equipment installed).

To ensure safe lifting and avoid damage to components installed on the top of the engine use an adjustable lifting beam. All chains and cables must run parallel to each other and as perpendicular as possible to the upper side of the engine.

If extra equipment is installed on the engine which alters its centre of gravity a special lifting device is required to obtain the correct balance for safe handling.

Never carry out work on an engine suspended on a hoist.

⚠ Never work alone when installing heavy components, even when using secure lifting equipment such as a lockable block and tackle. Most lifting devices require two people, one to see to the lifting device and one to ensure that the components do not get caught and damaged.

⚠ The components in the electrical system, the ignition system (gasoline/petrol engines) and in the fuel system on Volvo Penta products are designed and manufactured to minimise risks of fire and explosion. Engines should not run in environments containing explosive media.

⚠ Always use fuels recommended by Volvo Penta. Refer to the Operators's Manual. Use of fuels that are of a lower quality can damage the engine. On a diesel engine poor quality fuel can cause the fuel control rack to stick causing the engine to overspeed with resulting risk of damage to the engine and personal injury. Poor fuel quality can also lead to higher maintenance costs.

General information

About the Installation Manual

This publication is intended as a guide for the installation of Volvo Penta marine diesel engines for inboard use. The publication is not comprehensive and does not cover every possible installation, but is to be regarded as recommendations and guidelines applying to Volvo Penta standards. Detailed Installation Instructions are included in most of the accessory kits.

These recommendations are the result of many years practical experience of installations from all over the world. Departures from recommended procedures etc. can however be necessary or desirable, in which case the Volvo Penta organisation will be glad to offer assistance in finding a solution for your particular installation.

It is the sole responsibility of the installer to ensure that the installation work is carried out in a satisfactory manner, it is operationally in good order, the approved materials and accessories are used and the installation meets all applicable rules and regulations.

This Installation Manual has been published for professionals and qualified personnel. It is therefore assumed that persons using this book have basic knowledge of marine drive systems and are able to carry out related mechanical and electrical work.

Volvo Penta continuously upgrades its products and reserves the right to make changes. All the information contained in this manual is based on product data available at the time of going to print. Notification of any important modifications to the product causing changes to installation methods after this date will be made in Service Bulletins.

Plan installations with care

Great care must be taken in the installation of engines and their components if they are to operate satisfactorily. Always make absolutely sure that the correct specifications, drawings and any other data are available before starting work. This will allow for correct planning and installation right from the start.

Plan the engine room so that it is easy to carry out routine service operations involving the replacement of components. Compare the engine's Service Manual with the original drawings showing the dimensions.

It is very important when installing engines that no dirt or other foreign matter gets into the fuel, cooling, intake or turbocharger systems, as this can lead to faults or engine seizure. For this reason,, the systems must be sealed. Clean supply lines and hoses before connecting them to the engine. Remove protective engine plugs only when making a connection to an external system.

Certified engines

The manufacturer of engines certified for national and local environmental legislation (Lake Constance for example) pledges that this legislation is met by both new and currently operational engines. The product must compare with the example approved for certification purposes. So that Volvo Penta, as a manufacturer, can pledge that currently operational engines meet environmental regulations, the following must be observed during installation:

- Servicing of ignition, timing and fuel injection systems (gasoline) or injector pumps, pump settings and injectors (diesel) must always be carried out by an authorised Volvo Penta workshop.
- The engine must not be modified in any way except with accessories and service kits developed for it by Volvo Penta.
- Installation of exhaust pipes and air intake ducts for the engine compartment (ventilation ducts) must be carefully planned as its design may affect exhaust emissions.
- Seals may only be broken by authorised personnel.

⚠ **IMPORTANT!** Use only by Volvo Penta approved parts.

Using non-approved parts will mean that AB Volvo Penta will no longer take responsibility for the engine meeting the certified design.

All damage and costs caused by the use of non-approved replacement parts will not be covered by Volvo Penta.

Seaworthiness

It is the boat builder's duty to check that the security requirements applying to the market in which the boat is sold are met. In the USA for example, these are the US Federal Regulations for pleasure boats described in Title 46. The requirements described below apply to the EU principles. For information and detailed descriptions of the safety requirements that apply to other markets, contact the authority for the country concerned.

From 16 June 1998, pleasure boats and certain associated equipment marketed and used within the EU must bear CE labels to confirm that they meet the safety requirements stipulated by the European Parliament and Council of Europe's directive for pleasure boats. The normative requirements can be found in the standards drawn up to support the directive's objective of uniform safety requirements for pleasure boats in EU countries.

Certificates that grant the right for CE label use and confirm that boats and equipment meet safety requirements are issued by approved notified bodies. In many Member States the classification societies have become the notified bodies for pleasure boats, e.g. Lloyd's Register, Bureau Veritas, Registro Italiano Navale, Germanischer Lloyd, etc. In many cases completely new institutions have been approved as notified bodies. The directive also allows boat builders and component manufacturers to issue assurances of compliance with the requirements of the directive. This requires the manufacturer to store the prescribed product documentation in a place that is accessible to the monitoring authority for at least ten years after the last product is produced.

Life boats and boats for commercial activities are approved by classification societies or by the navigation authority for the boat's registered country.

Joint liability

Each engine consists of many components working together. One component deviating from its technical specification can cause a dramatic increase in the environmental impact of an engine. It is therefore vital that systems that can be adjusted are adjusted properly and that Volvo Penta approved parts as used.

Certain systems (components in the fuel system for example) may require special expertise and special testing equipment. Some components are sealed at the factory for environmental reasons. No work should be carried out on sealed components except by authorised personnel.

Remember that most chemical products damage the environment if used incorrectly. Volvo Penta recommends the use of biodegradable degreasing agents for cleaning engine components, unless otherwise indicated in a Workshop Manual. Take special care when working on board boats to ensure that oil and waste are taken for destruction and not accidentally are pumped into the environment with bilgewater.

Conversion factors

	Metric to U.S. or IMP. conversion factors:			**U.S. or IMP. to metric conversion factors:**		
	To convert from	**To**	**Multiply by**	**To convert from**	**To**	**Multiply by**
Length	mm	inch	0.03937	inch	mm	25.40
	cm	inch	0.3937	inch	cm	2.540
	m	foot	3.2808	foot	m	0.3048
Area	mm^2	sq.in.	0.00155	sq. in.	mm^2	645.2
	m^2	sq. ft.	10.76	sq. ft.	m^2	0.093
Volume	cm^3	cu. in.	0.06102	cu. in.	cm^3	16.388
	litre, dm^3	cu. ft.	0.03531	cu. ft.	litre, dm^3	28.320
	litre, dm^3	cu. in.	61.023	cu. in.	litre, dm^3	0.01639
	litre, dm^3	imp. gallon	0.220	imp. gallon	litre, dm^3	4.545
	litre, dm^3	U.S. gallon	0.2642	U.S. gallon	litre, dm^3	3.785
	m^3	cu. ft.	35.315	cu.ft.	m^3	0.0283
Force	N	lbf	0.2248	lbf	N	4.448
Weight	kg	lb.	2.205	lb.	kg	0.454
Power	kW	hp (metric) [1)]	1.36	hp (metric) [1)]	kW	0.735
	kW	bhp	1.341	bhp	kW	0.7457
	kW	BTU/min	56.87	BTU/min	kW	0.0176
Torque	Nm	lbf ft	0.738	lbf ft	Nm	1.356
Pressure	Bar	psi	14.5038	psi	Bar	0.06895
	MPa	psi	145.038	psi	MPa	0.006895
	Pa	mm Wc	0.102	mm Wc	Pa	9.807
	Pa	in Wc	0.004	in Wc	Pa	249.098
	KPa	in Wc	4.0	in Wc	KPa	0.24908
	mWg	in Wc	39.37	in Wc	mWg	0.0254
Energy	kJ/kWh	BTU/hph	0.697	BTU/hph	kJ/kWh	1.435
Work	kJ/kg	BTU/lb	0.430	BTU/lb	kJ/kg	2.326
	MJ/kg	BTU/lb	430	BTU/lb	MJ/kg	0.00233
	kJ/kg	kcal/kg	0.239	kcal/kg	kJ/kg	4.184
Fuel consump.	g/kWh	g/hph	0.736	g/hph	g/kWh	1.36
	g/kWh	lb/hph	0.00162	lb/hph	g/kWh	616.78
Inertia	kgm^2	$lbft^2$	23.734	$lbft^2$	kgm^2	0.042
Flow, gas	m^3/h	cu.ft./min.	0.5886	cu.ft./min.	m^3/h	1.699
Flow, liquid	m^3/h	US gal/min	4.403	US gal/min	m^3/h	0.2271
Speed	m/s	ft./s	3.281	ft./s	m/s	0.3048
	mph	knots	0.869	knots	mph	1.1508
Temp.	°F=9/5 x °C + 32			°C=5/9 x (°F – 32)		

[1)] All hp figures stated in the catalogue are metric.

Engine application ratings

The engines covered by this manual are mainly used for five different operating conditions, **Rating 1 – Rating 5,** as described below.

Even at a very early stage, the output requirements and operating conditions for the installation concerned should be carefully specified so that a suitable engine with the right setting and convenient equipment can be ordered. This can avoid time concerning modifications at a later stage.

The rating on each product states the toughest application allowed. Of course, the product can also be used in an application with a higher rating.

Rating 1

Heavy duty commercial

For commercial vessels with displacement hulls in heavy operation. Unlimited number of running hours per year.

Typical boats: Bigger trawlers, ferries, freighters, tugboats, passenger vessels with longer journeys.

Load and speed could be constant, and full power can be used without interruption.

Rating 2

Medium Duty Commercial

For commercial vessels with semi planing or displacement hulls in cyclical operation. Running hours less than 3000 h per year.

Typical boats: Most patrol and pilot boats, coastal fishing boats in cyclical operation, (gillnetters, purse seiners, light trawlers), passenger boats and costal freighters with short trips.

Full power could be utilised max 4 h per 12 h operation period. Between full load operation periods, engine speed should be reduced at least 10% from the obtained full load engine speed.

Rating 3

Light Duty Commercial

For commercial boats with high demands on speed and acceleration, planing or semi planing hulls in cyclical operation. Running hours less than 2000 h per year.

Typical boats: Fast patrol, rescue, police, light fishing, fast passenger and taxi boats etc.

Full power could be utilised maximum 2 h per 12 h operation period.

Between full load operation periods, engine speed should be reduced at least 10% from the obtained full load engine speed.

Rating 4

Special Light Duty Commercial

For light planing crafts in commercial operation. Running hours less than 800 h per year.

Typical boats: High speed patrol, rescue, navy, and special high speed fishing boats. Recommended speed at cruising = 25 knots.

Full power could be utilised max 1 h per 12 h operation period. Between full load operation periods, engine speed should be reduced at least 10% from the obtained full load engine speed.

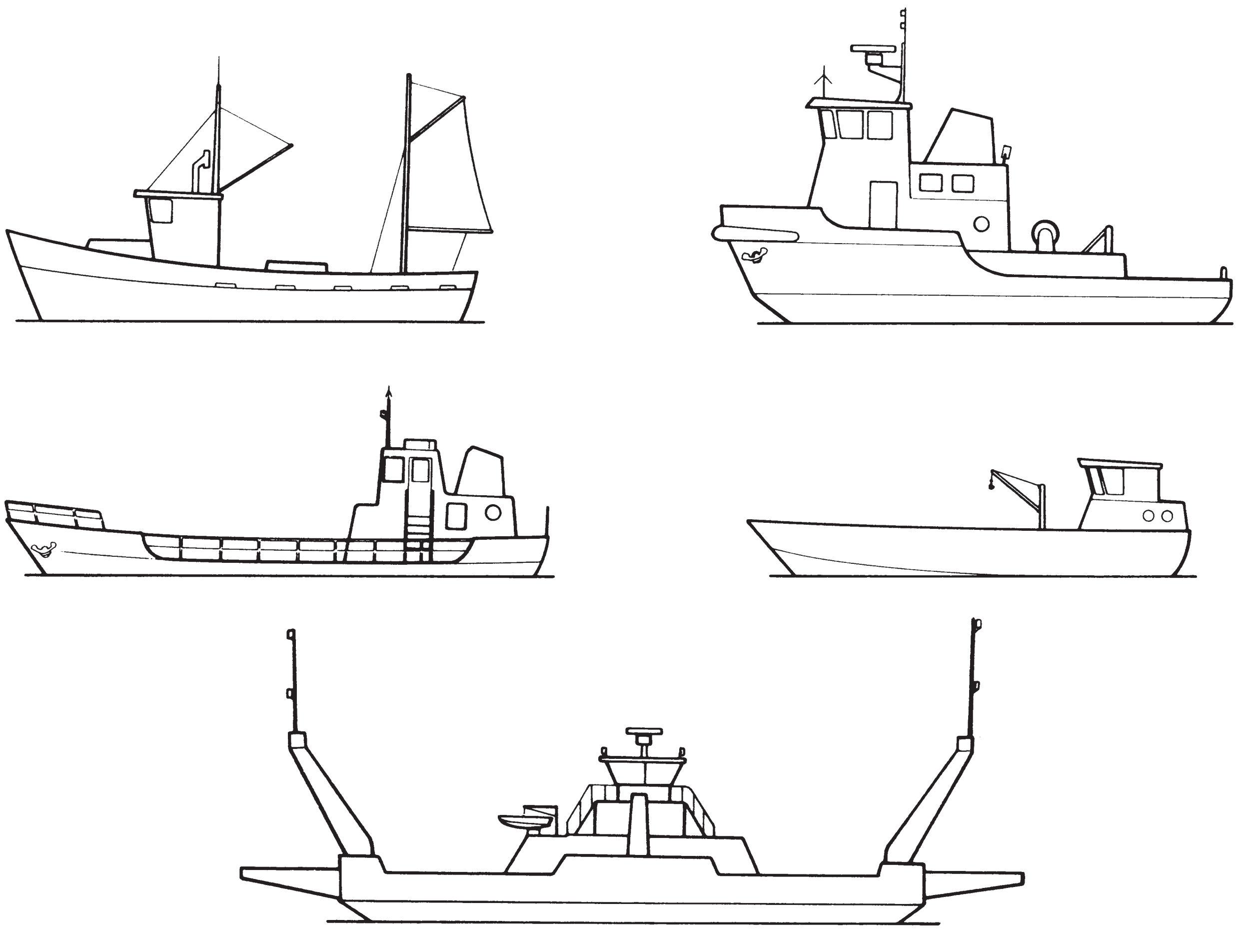
Rating 5

Pleasure Duty

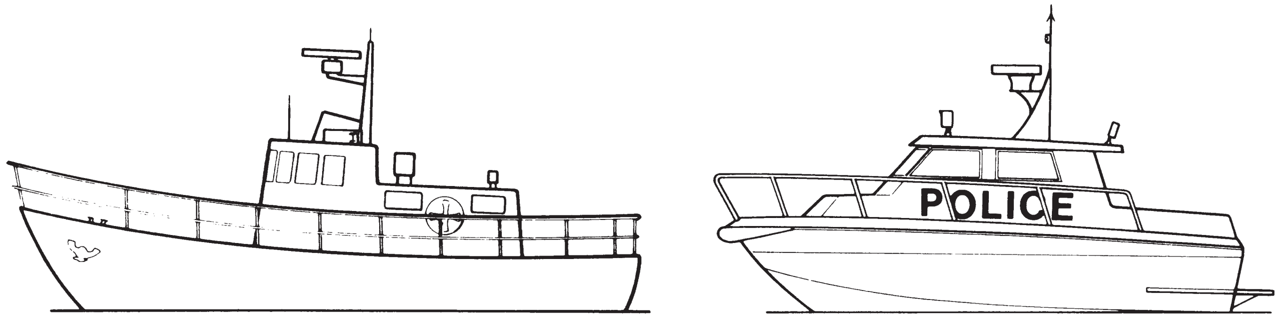
For pleasure craft applications only, which presumes operation by the owner for his/ her recreation. Running hours less than 300 h per year.

Full power could be utilised maximum 1 h per 12 h operation period.

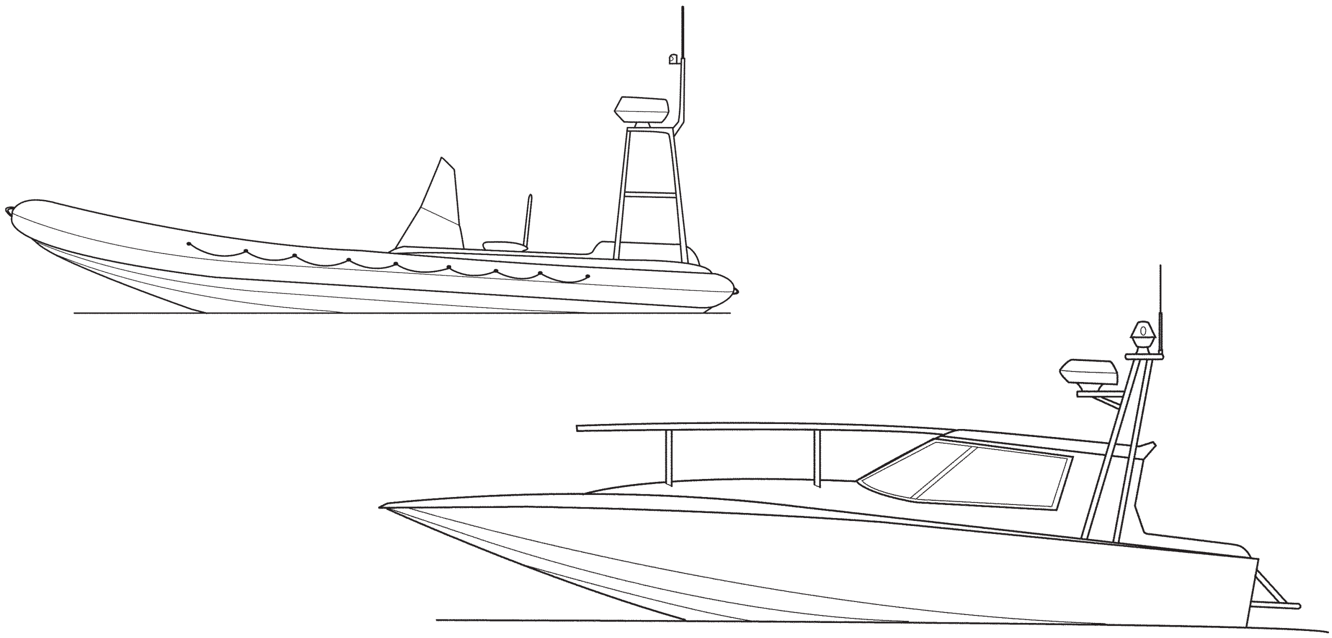
Between full load operation periods, engine speed should be reduced at least 10% from the obtained full load engine speed.



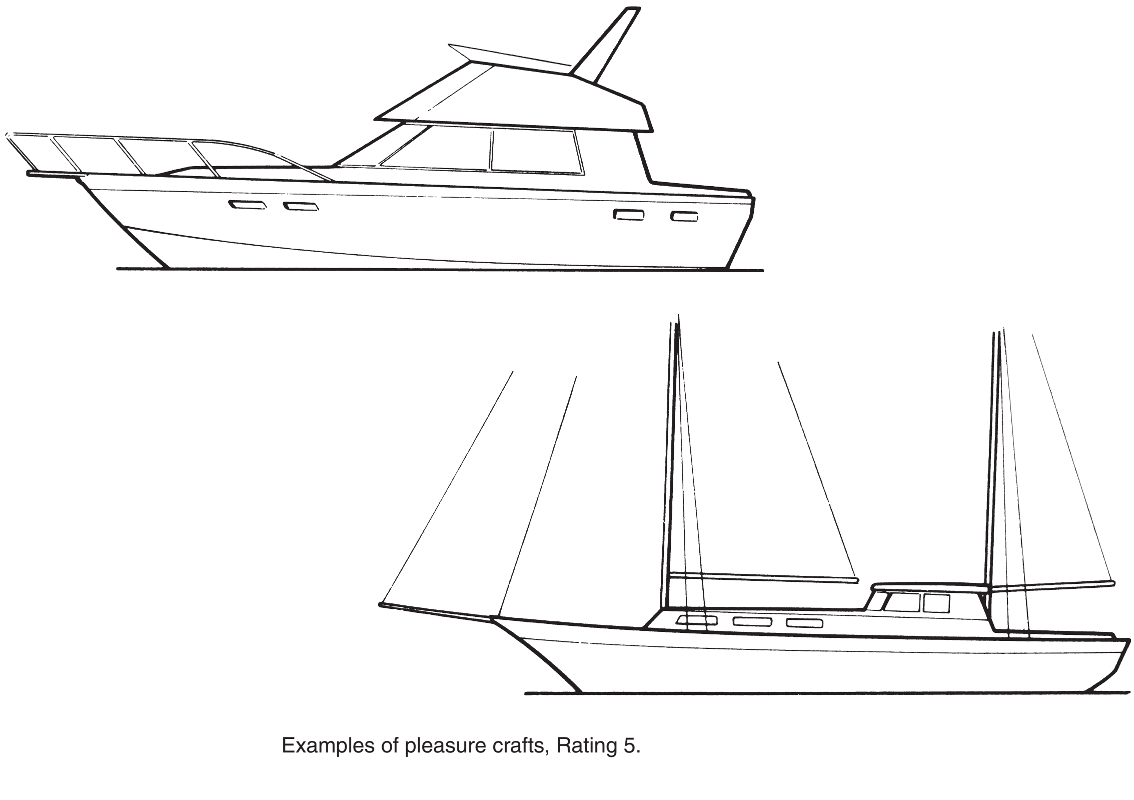
Examples of boats for medium and heavy duty commercial operation, Rating 1–2.



Examples of boats for light and medium duty commercial operation, Rating 2–3.



Examples of boats for light duty and special light duty commercial operation, Rating 3–4.



Examples of pleasure crafts, Rating 5.

Marine engine environment

The marine engine and its environment

Marine engines, like engines for cars and trucks, are rated according to one or more power norms. The output is indicated in kW, usually at maximum engine speed.

Most engines will produce their rated power provided they have been tested under the conditions specified by the power norm and have been properly run in. Tolerances according to ISO standards are usually ± 5%, which is a reality that must be accepted for line produced engines.

Measuring output

Engine manufacturers normally assign an engine's output to the flywheel, but before the power reaches the propeller, losses occur in the transmission and in the propeller shaft bearings. The amounts of these losses are 4-6%.

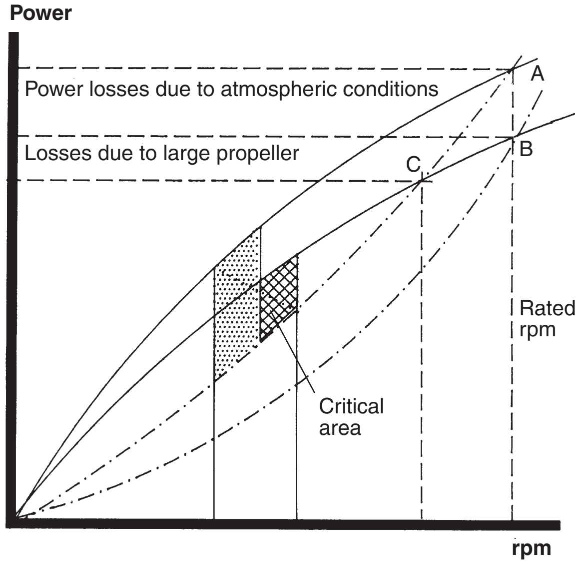
All major marine engine manufacturers indicate engine power according to ISO 8665 (supplement to ISO 3046 for leisure boats), based on ISO 3046, which means that the propeller shaft power will be given. If an exhaust system is optional, engine tests are conducted with a backpressure of 10 kPa. If all engine manufacturers followed the same test procedure it would be easier for a boat producer to compare products from various suppliers.

Engine performance

Engine output is affected by a number of different factors. Among the more essential are barometric pressure, ambient temperature, humidity, fuel thermal value, fuel temperature (not EDC engines) and backpressure. Deviation from normal values affects diesel and petrol engines differently.

Diesel engines use a large amount of air for combustion. If the mass flow of the air is reduced, the first sign is an increase in black smoke. The effect of this is especially noticeable at planing threshold speed, where the engine must produce maximum torque.

If the deviation from normal mass flow is substantial, even a diesel engine will lose power. In the worse case the reduction could be so large that the torque is not sufficient to overcome the planing threshold.



The above figure illustrates the consequences of climate variation.

Point **A** is where rated power from the engine is equal with the power absorbed by the propeller. Selection of the propeller size at this point is correctly located for utilising max. rated power at a certain weather and load condition.

If atmospheric conditions cause the power to drop to point **B**, the propeller curve will cross the output curve from the engine at point **C**. A secondary performance loss has occurred because the propeller is too large. The propeller reduces the rpm from the engine.

By replacing the propeller with a smaller one, the power curve of the engine will cross at point B, making it possible to regain previous rpm, but at reduced power.

For planing or semi-planing boats, the planing threshold ("hump" speed), which mostly occurs at 50 - 60% of max. speed, is the critical area. In this section it is important that the distance between the engine max. power curve and the propeller curve is large enough.

Other factors affecting performance

It is important to keep the exhaust backpressure at a low level. The power losses caused by backpressure are directly proportional to the increase of backpressure, which also increases the exhaust temperature. Thermal values differ between markets and influence engine output. Environmental fuel, which is compulsory in some markets, has a low thermal value. Engine output may be reduced up to 8% compared with fuel specified in the ISO standard.

The weight of the boat is another important factor affecting boat speed. Increased boat weight has a major effect on boat speed, especially on planing and semi-planing hulls. A new boat tested with half filled fuel and water tanks and without a payload easily drops 2-3 knots in speed when tested fully loaded with fuel, water and equipment for travelling comfort. This situation arises because the propeller is often selected to give maximum speed when the boat is tested at the factory. It is therefore advisable to reduce propeller pitch by one or more inches when encountering hot climate and user load conditions. The top speed will be somewhat reduced but the overall conditions will improve and provide better acceleration, even with a heavily loaded boat.

With this in mind it is important to remember that fibreglass boats absorb water when they rest in water, making the boat heavier over time. Marine growth, an often overlooked problem, also has a serious effect on boat performance.

Propeller selection

Naval architects, marine engineers or other qualified people should choose the propeller. The required engine performance data to make the proper propeller selection is available in technical literature.

With regard to the propeller selection it is important to achieve correct engine RPM. For this purpose we recommend Full Throttle Operating Range.

In order to achieve good all-round performance the propeller should be selected within this range.

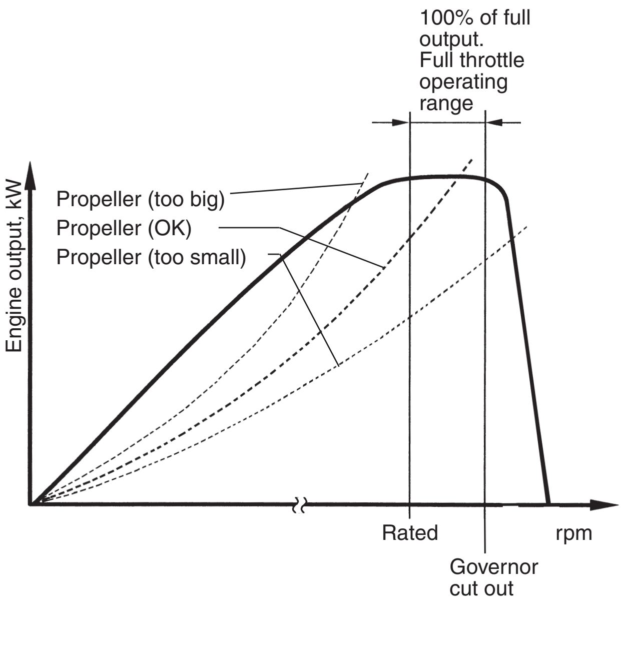
When the prototype and first production boat is built, a Volvo Penta representative and a boat manufacturer should undertake a fully loaded trial of the vessel as near as possible to the conditions that the boat will meet in the field. The most important conditions are:

- Full fuel and water on board
- Ballast evenly distributed throughout the boat to represent the owners's equipment including such things as outboards, inflatable dinghies etc.
- Genset/air conditioning equipment and all domestic appliances fitted.
- Adequate number of people onboard.

Once the vessel is subjected to these conditions a full engine/propeller trial should be undertaken where all engine parameters are checked, i.e. engine rpm, fuel consumption, rel. load, ref. rpm (EDC) boost pressure, exhaust temperatures, engine space temperatures etc.

When the correct propeller has been established based on the tests, the engine rpm should be within the " Full Throttle Operating Range" at full load.

However, it is advisable to reduce pitch some more to handle varying weather conditions and marine growth. For this reason boat manufacturers must follow the actual situation of their differing markets.

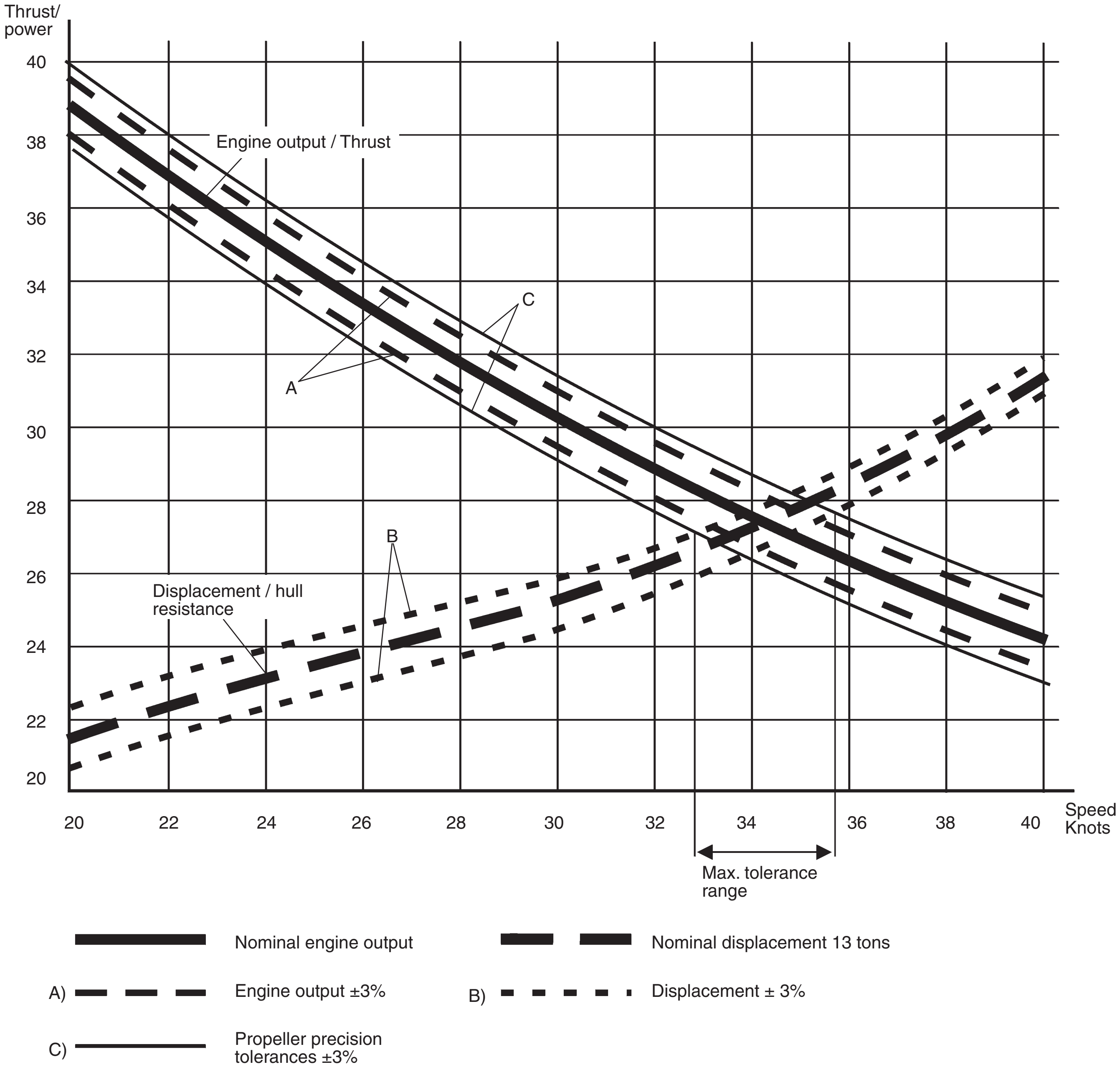


Full throttle operating range

The performance of any marine engine is largely dependent upon the correct matching of the propeller to the horsepower available from the engine. All Volvo Penta engines have an operating speed range where the engine develops its rated horsepower, this is titled "Full Throttle Operating Range". A propeller that has been sized to demand the rated horsepower of the engine will allow the engine to operate at its rated speed. Should the propeller load be less than the rated horsepower the engine will operate above the specified range. A propeller load that is greater than the engines rated horsepower will result in the engine not being able to reach the rated rpm and will therefore overload the engine.

An engine in a newly launched vessel is likely to be exposed to the lightest loads. This is because the total displacement of the vessel has yet to be reached, the hull has not become fouled and all onboard systems are running at optimal efficiency. It is therefore important that after launching and on sea trials the engine be able to achieve slightly more than the rated rpm under normal conditions.

Typical sample of a planing hull and how displacement and engine output tolerances effects performance



Production tolerances

In order to ensure optimal performance of the vessel and long engine life, correct propeller size is essential. Selecting the correct propeller will enable the engine to develop its full power and provide the performance that is expected.

There are a number of factors with their tolerances that can greatly affect the performance of the vessel. These must be recognised for correct engine/propeller selection. These factors are:

A) Engine power can vary within international power standard tolerances.

B) The calculated hull resistance/displacement may vary within certain limits.

C) The power absorbed by the propeller with regard to propeller manufacture precision tolerances generally affects engine rpm.

General information about classification

The classification procedures outlined below are general and can be changed from time to time by the Classification Societies.

The classification procedure was originated for the purpose of introducing similar and comparable rules and regulations for, among other things, production and maintenance of ships and their machinery and equipment. As a result of these rules and regulations "safety at sea" could be improved and better documentation could be introduced for insurance matters.

The government authorities in most countries concerned with shipping have authorized the **Classification Societies** to handle these rules and make sure they are followed. The classification procedure dates from long ago. It can be noted that Lloyd's Register of Shipping, London, was founded as early as 1760.

The major Classification Societies are:

- Det norske Veritas (DnV)
- Lloyd's Register of Shipping (LR)
- Bureau Veritas (BV)
- American Bureau of Shipping (ABS)
- Germanischer Lloyd (GL)
- Registro Italiano Navale (RINA)
- Russian Maritime Register of Shipping, (RMRS)
- China Classification Society (ZC)
- Korean Register of Shipping (KR)
- Nippon Kaiji Kyokai (NK)

As examples of **government authorities** responsible for ships' seaworthiness we can note the following:

Sjöfartsverket, Sweden (National Maritime Administration), Sjöfartsdirektoratet, Norway, Statens Skibtilsyn, Danmark, Department of Transport, England.

The Classification Societies have established their rules so that the authorities' requirements are covered. The authorities, however, have requirements for lifeboats that are not included in the rules of the Classification Society.

In 1974 an International Convention for the Safety of life at sea (SOLAS) was adopted by the International Maritime Organisation (IMO). This document ratifies uniform rules for life saving equipment on board lifeboats and rescue boats.

NOTE! This installation manual does not give full information concerning classification. Please contact an authorised classification society for complete information.

Classified engine, range of use

An engine with equipment that is used in a classified vessel must be approved by the Classification Society, which handles matters relating to ships' seaworthiness. The rules apply for instance to the propulsion engine, auxiliary engine, power take off, reverse gear, shaft and propeller.

This means that if an installation needs to be classified it must be stated clearly when addressing inquiries and quotation requests to AB Volvo Penta.

Special rules for different operational conditions

The Classification Societies have, in general, different rules relating to the following:

Varying shipping conditions e.g:

- Shipping in tropical water
- Coastal shipping
- Ocean shipping
- Operation in ice (several different classes)

Type of load e.g:

- Passenger shipping
- Tanker shipping
- Reefer shipping

Type of manning e.g:

- Unmanned machine room
- Manned machine room

These rules are adapted so that each vessel can be assumed to function faultlessly in the area or type of operation for which it is approved.

Type approval

To be able to classify an engine, the type of engine must first be type approved. In such cases, where Volvo Penta is concerned, an application for type approval is sent to the Classification Society in question, followed by the required drawings, data and calculations.

After certain tests, checks and possible demands for supplementary information, the engine is type-approved for a specified maximum power at a given rated speed. This type approval must not however be considered as a classification; it is only a certificate that states that the engine type with specified power can be classified. Final classification can only be given when all components are approved and the installation and test run in the vessel are completed and found to be in order by the local surveyor.

Procedure for classification (Product orientated)

To earn a classification certificate, the engine, its components, **the installation and the test run must be approved by a surveyor from the Classification Society in question.** The surveyor can, after final inspection and with certificates from the built-in machinery, issue the final certificate for the vessel. (Thus the final certificate cannot be issued by AB Volvo Penta).

Usually the procedure is initiated as a result of a request from a customer or dealer who has to deliver an engine in a classified installation. For these orders Volvo Penta normally starts with a "type approved engine". During production of such an engine the surveyor checks the production if there is no quality assurance system agreement.

Separate certificates are issued for the following components:

- Crankshaft, connecting rods,
- heat exchanger, oil cooler,
- turbocharger, coupling,
- reverse gear, propeller and shaft,
- generator, alternator.

The surveyor then checks the pressure testing and test running of the engine, after which a certificate for the engine itself is issued.

Torsional Vibration Calculations (TVC) must be carried out for the complete installation of the engine in the vessel and approved by the Classification Society.

These calculations are carried out to check that no critical torsional vibrations occur in the speed range in which the engine is operated.

The procedure can differ somewhat depending on the Classification Society in question.

Simplified rules for engines produced in series (Process orientated classification)

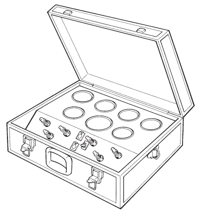
Most Classification Societies can use simplified classification procedures based on a well implemented Quality Assurance System at the Engine Manufacturer.

As Volvo Penta fulfills Quality Assurance based on Swedish standard SS-ISO 9001, AB Volvo Penta has been approved by the Classification Societies below:

- Lloyd’s Register of Shipping (LR)
- Registro Italiano Navale (RINA).

Installation tools and literature

Special tools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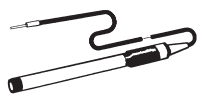
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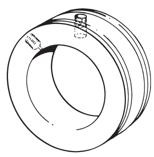
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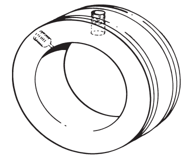
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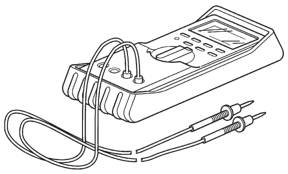
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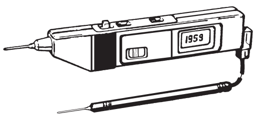

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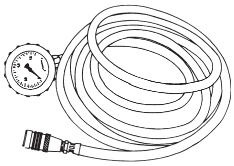
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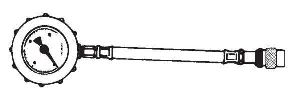
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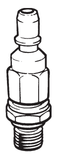
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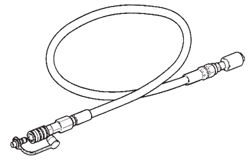
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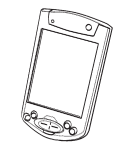
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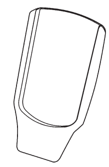

3838621

885151 Box with gauges and connections. For measuring pressures and exhaust temerature.

885156 Calomel electrode. For measuring galvanic and stray current (use in combination with multimeter P/N 9812519).

885309 Flange D5. For measuring exhaust backpressure and temperature.

885164 Flange D7. For measuring exhaust backpressure and temperature.

9812519 Multimeter.

9988452 Digital probe tester.

9996065 Manometer. For measuring fuel feed pressure, not D9/D11/D12.

9996398 Manometer D9/D11/D12/D16. For measuring fuel feed pressure.

9996666 Connection D9/D11/D12/D16. For measuring fuel feed pressure.

9998494 Hose and nipple D9/D11/D12/D16. For measuring fuel feed pressure.

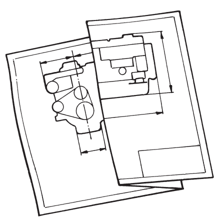
3838620 VODIA tool*. For reading fault codes in clear text.

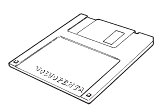
3838621 Docking station for the VODIA tool*. Connects the VODIA tool to the engine.

*Order via VODIA WEB on Volvo Penta Partner Network

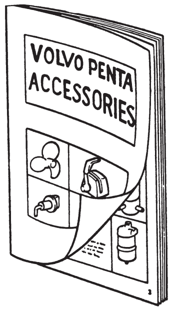
Dimension drawings

Drawings for current program, leisure and commercial applications are available at:
http://www.volvopenta.com





Publications

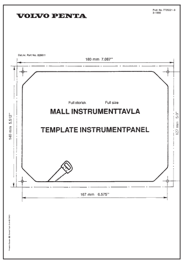


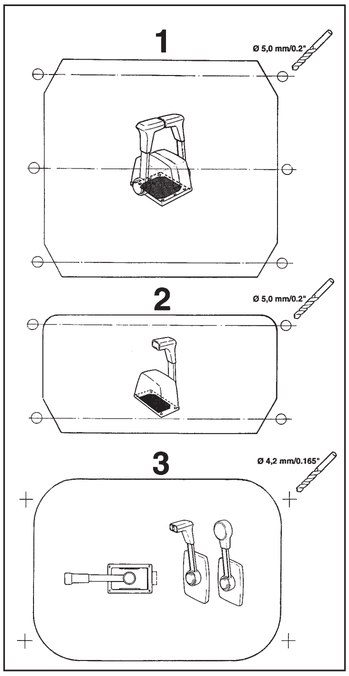
- *Installation, Electronic Vessel Control EVC*
- *Installation, Marine Commercial Control MCC*
- *Marine Electrical Systems, Part 1*
- *Inboard propellers and speed calculation*
- *Installation, Water Jet*
- *Sales Guide Marine Propulsion Diesel Engines*
- *Volvo Penta Accessories & Maintenance Parts*
- *Workshop Manuals*
- *Operator's Manuals*

Templates

- *Instrument panels*
- *Controls*

Installation instructions and templates are included in the kits.

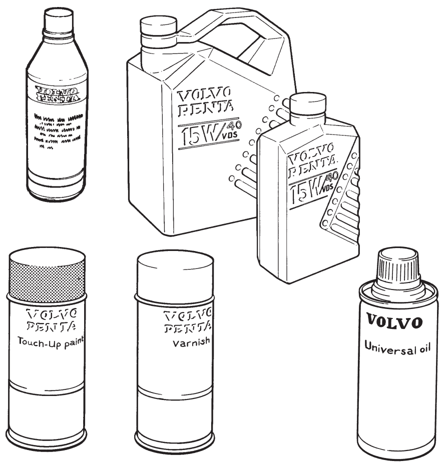




Chemicals

A wide range of chemical products are available from Volvo Penta. Some examples are:

- Oil and coolant
- Sealant and grease
- Touch-up paint
- Refer to "Volvo Penta Accessories & Maintenance Parts"

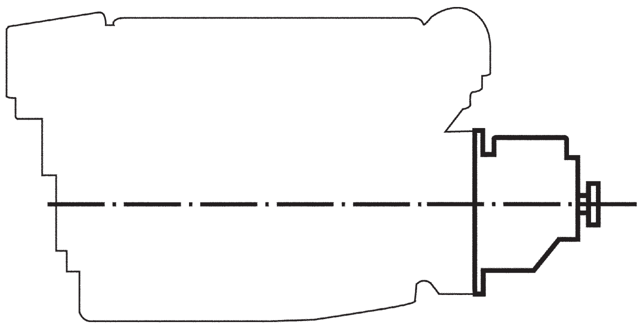


Design concepts of propulsion systems

There are different types of engines, reverse gears and front drive systems, depending on the available space and other requirements during the installation.

Follow the manufacturer's instructions when installing components and equipment not supplied by Volvo Penta.

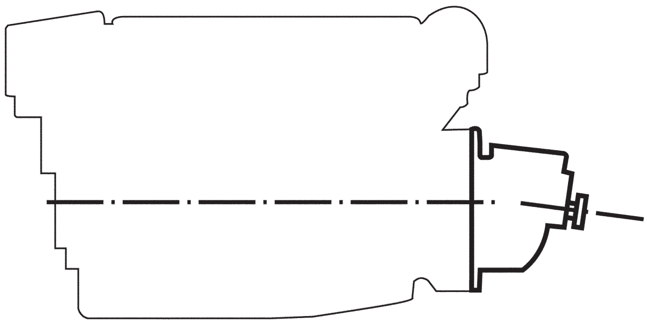
Reverse gear, various types



Coaxial

The engine's crankshaft and the reverse gear's output shaft are on the same level. The propeller shaft and crankshaft are in-line.

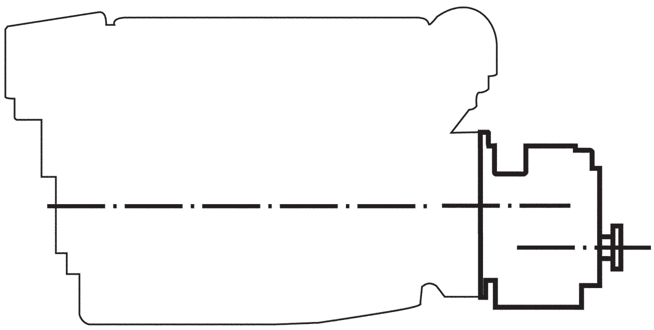
The engine and reverse gear form one unit. The compressive forces from the propeller are absorbed by an axial bearing in the reverse gear.



Coaxial down angle

The extension of the engine crankshaft centre line is angled in the reverse gear. The angle of the propeller shaft deviates from the angle of the crankshaft.

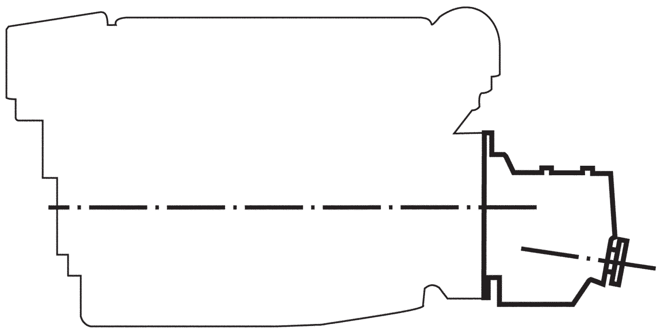
The engine and reverse gear form one unit. The compressive forces from the propeller are absorbed by an axial bearing in the reverse gear.



Drop centre, parallel

The engine's crankshaft and the reverse gear's output shaft are parallel. The output shaft is on a lower level than the crankshaft.

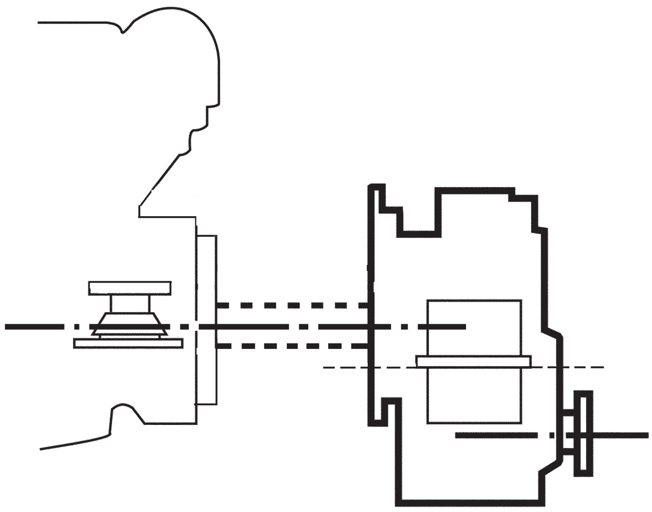
The engine and reverse gear form one unit. The compressive forces from the propeller are absorbed by an axial bearing in the reverse gear.



Drop centre, down angle

The engine's crankshaft and the reverse gear's output shaft are on different levels. The angle of the propeller shaft deviates from the angle of the crankshaft.

The engine and reverse gear form one unit. The compressive forces from the propeller are absorbed by an axial bearing in the reverse gear.



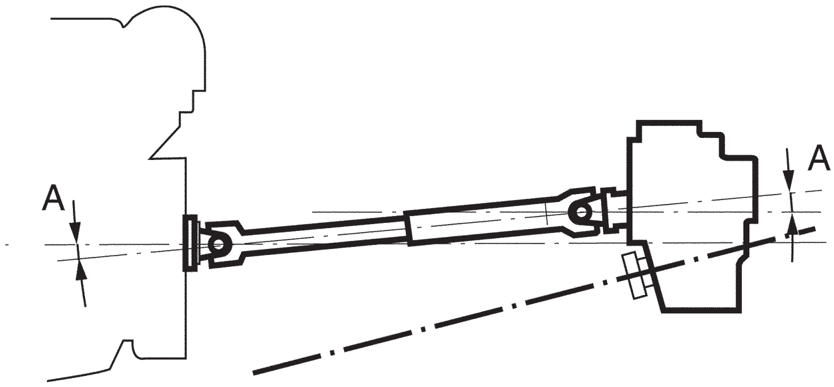
Remote reverse gear

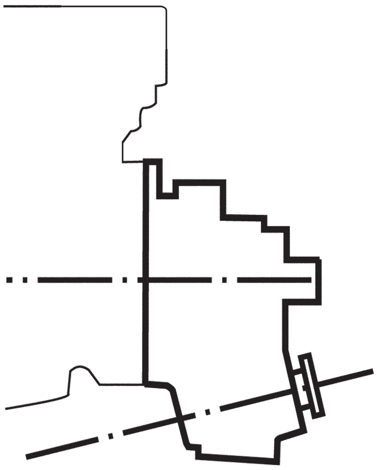
The reverse gear is separated from the engine and mounted on the engine bed or on a separate bed. Torque is transferred via a flexible coupling through a shaft. The angle of the propeller shaft can deviate from the angle of the crankshaft.

The remote reverse gear must first be installed and carefully aligned nominated by the propeller shaft.

Then the couplings are fitted and the engine is aligned to the reverse gear. For final location and to prevent possible shock loads, lugs must be welded in front of and behind the brackets on each side. Wedges are then driven in and secured by welding when alignment is completely finished.

V-drive, various types





Close coupled V-drive

The engine and reverse gear form one unit. The axial forces from the propeller are absorbed by an axial bearing in the reverse gear.

Remote V-drive

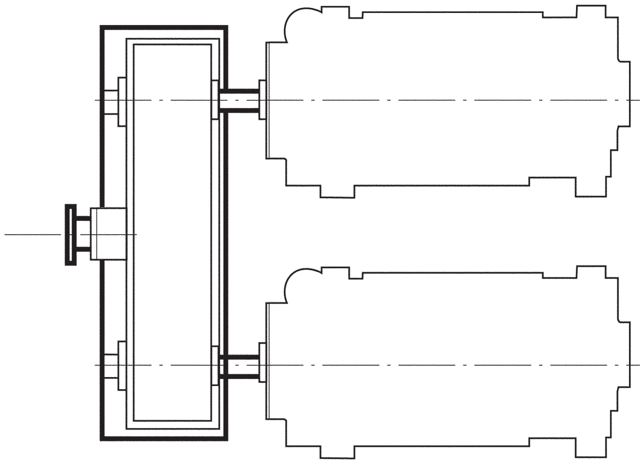
The reverse gear is separated from the engine and mounted on a separate bed. Torque is transferred via the propeller shaft, as illustrated in the diagram, or via a flexible coupling.

The axial forces from the propeller are absorbed by an axial bearing in the reverse gear.

The remote V-drive must first be installed and carefully aligned according to the propeller shaft. Then the shaft and couplings are fitted and the engine is aligned to the reverse gear. For final location and to prevent possible shock loads, lugs must be welded in front of and behind the brackets on each side. Wedges are then driven in and secured by welding when alignment is completely finished.

For the application of cardan shafts, follow the installation instructions from the cardan shaft supplier. A rule of thumb share the joint angle, where A ≈ A.

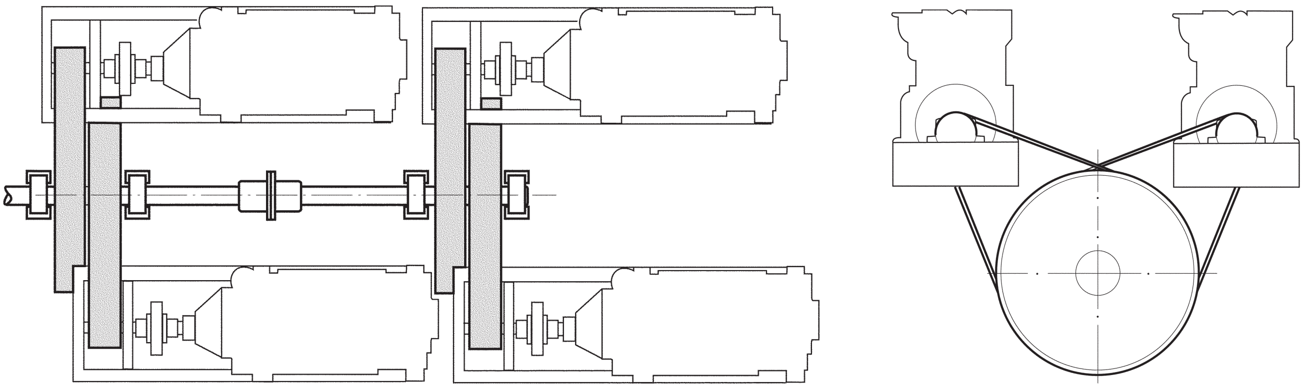
Twin engine package - Twin gear



The twin engine package over one marine gear is a concept used by Volvo Penta over a period of time. The concept is based of the utilisation of the commonality of two high volume produced high speed marine diesel engines power over the twin marine gear to one common propellershaft. The twin gears are available from a limited number of manufacturers for fixed and controllable pitch propellers.

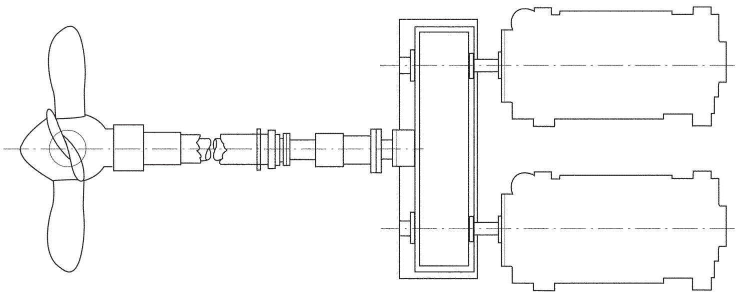
Volvo Penta does not market these gears as a marine engine package. If this application concept is considered attractive, further information and support can be acquired from Volvo Penta Sales Organisation.

Multi-belt transmission



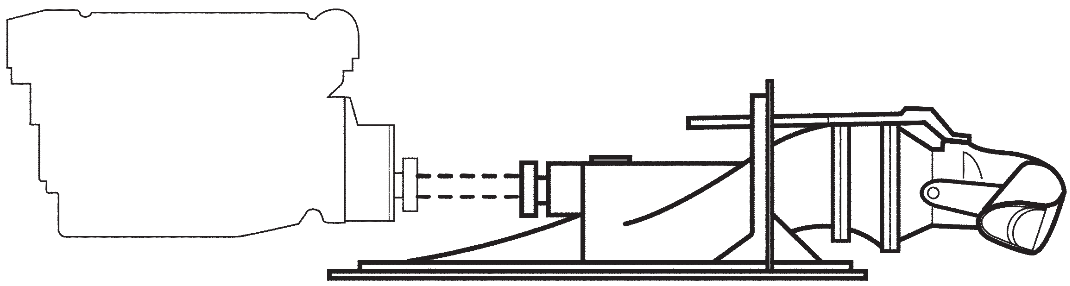
Another transmission concept is the multi- belt utilising a number of diesel engines driving a common shaft to a remote marine gear. The engines in this application are normally disengagable by a clutch. The concept is proven very functional to obtain the total power requirement beyond the conventional single or twin installation. The system can theoretically operate a marine gear for either a fixed or a controllable pitch propeller. Volvo Penta does not market this concept as a whole but could provide considerable know-how through the sales organisation if this system solution is considered.

Controllable pitch



Controllable pitch is used as an alternative to a fixed propeller. The pitch of the propeller blade is normally regulated by means of a built-in function in the reverse gear.

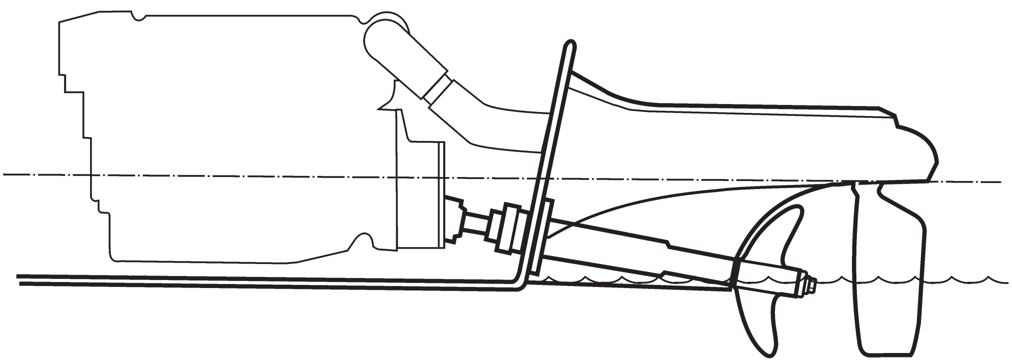
Water Jet



Water Jet drives work according to principles of jet propulsion. A jet of water is generated whose thrust sets the vessel in motion.

There are different types of water jets, a direct drive or one with a marine gearbox enabling clutch in/out and backflushing the system for cleaning purposes. See ***Installation, Water Jet.***

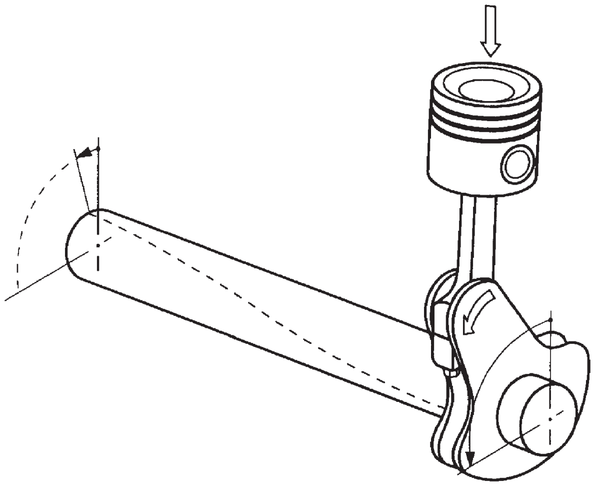
Surface drive



A number of surface piercing propeller systems are available on most markets. These systems are aimed at high speed applications where the systems are highly efficient. The systems are available with rudder arrangements or steerable drive unit. At planing speed the propeller operates with half of its diameter submerged. At lower speed the propeller is usually submerged and due to its high pitch torque, has greater absorption in comparison to a conventional propeller.

Torsional vibrations and TVC calculations

Torsional vibrations



Torsional vibrations occur due to forces on the crankshaft caused by the piston and connecting rod during the power stroke. These forces tend to deflect the crankshaft, including angular displacement of the shaft.

- The frequency is the time rate of torsional vibrations
- The amplitude is the angular displacement due to torsional vibrations.
- The critical speed is the speed at which the amplitude of the vibrations in a shaft are maximum and could result in stresses that exceed the safe limit of the material.
- Torsional vibrations may also be caused by torque vibrations at the propeller.

Torsional vibration approvals

The object of a Torsional Vibration Calculation (TVC) is to locate the critical speed points and to ensure that these critical speeds are outside the operating range of the engine.

Disregarding the torsional compatibility of the engine and driven equipment may fracture the crankshaft and flywheel bolts and overheat the vibration damper.

Since compatibility of the installation is the system designer's responsibility; it is also his responsibility to obtain the theoretical torsional vibration analysis.

Volvo Penta standard propulsion packages would generally not require TVCs unless front end PTO is utilised. TVCs are recommended for all heavy duty commercial applications. In classified installations, a TVC must be performed.

Torsional analysis data

Volvo Penta will do a torsional analysis on receipt of the necessary details from the customer. The following technical data is required to perform a torsional analysis:

A. Operating speed ranges. Lowest speed to highest speed.

B. Maximum power output.

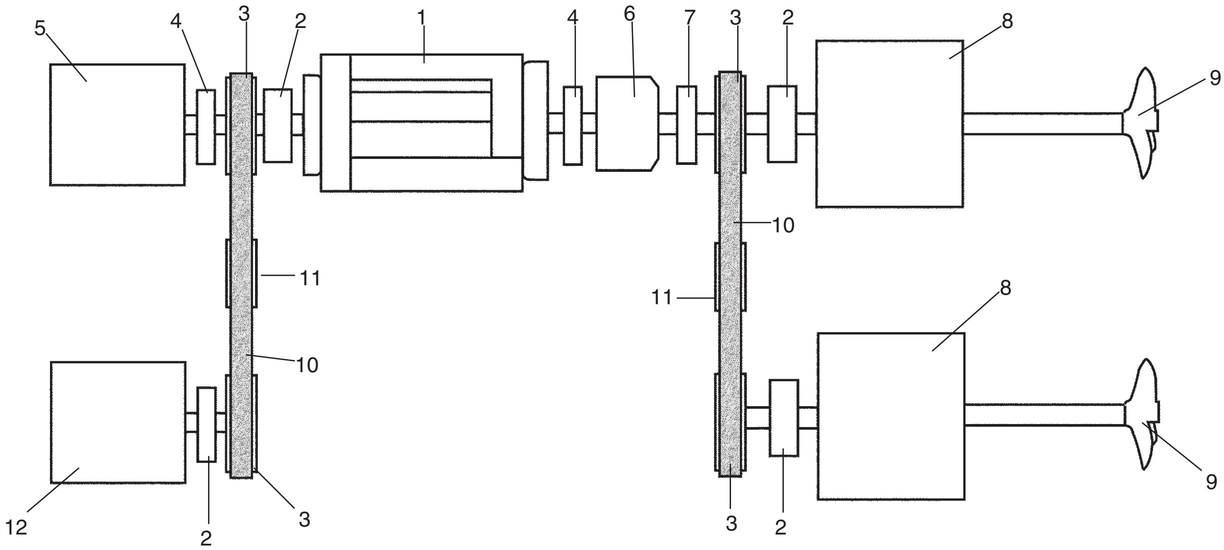
C. Detailed drawing of rotating components.

D. Inertia of rotating components and location of masses.

E. A general layout drawing is needed for more complicated installations.

For the purpose of TVCs, most drive line manufacturers provide shaft drawings, with moment of inertia and their position on the shaft diameters.

Example of a complex masselastic system



1. Engine
2. Coupling, disengagable
3. Pulley
4. Coupling
5. Pump, compressor etc. with the same rpm as engine
6. Reduction gear, reverse gear
7. Flange coupling
8. Alternator, compressor
9. Propeller shaft and propeller
10. Belt
11. Belt tensioner
12. Pump, compressor

The Drive package, i.e. engine, flexible coupling, and reverse gear, supplied by Volvo Penta has as one unit the lowest possible torsion vibration level in terms of standard propeller systems. A Torsional Vibration Calculation (TVC) must be conducted by Volvo Penta if other combinations are to be used. Incorrectly selected components in the drive package can result in abnormally high stress of the engine's crankshaft.

Routines for handling TVC

When a **Torsional Vibration Calculation** is requested, it can be carried out by Volvo Penta.

The following procedure should be followed:

1. All necessary documents should be sent to the ***Quality System and Classification Department***, which will issue an order number that will be the reference number for future communication regarding the matter.
2. All communication in TVC matters should be directed to the Quality System and Classification Department. The responsibility for internal handling is on Quality System and Classification Department at the production unit in Göteborg.
3. The cost for TVC will be charged according to the following principle: If the received documentation is complete from the beginning a basic calculation will be charged according to the price list.

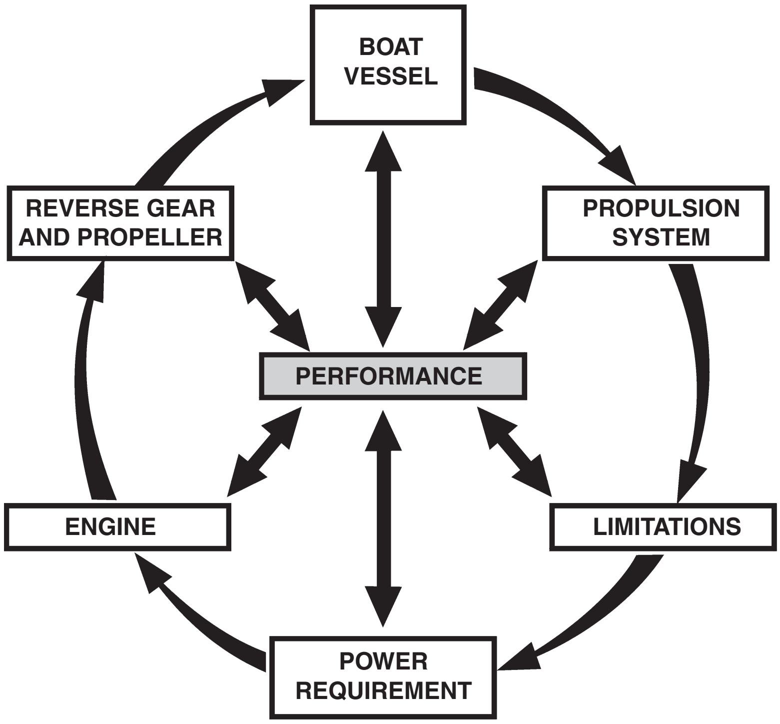
   Each additional operation, e.g. recalculation due to missing or wrong information or complex calculations, will be charged at actual cost.

   It is therefore of extreme importance that the documents for the calculation are complete and that no information is missing.

General arrangement and planning

Choice of engine

To provide the best performance and characteristics of an installation it is important to elaborate and iterate the information shown in the illustration below. Trial and error is often needed to finally find the essential set of "performance" requirements the installation aims to fulfil. Analysis of each contribution may vary depending on the dominating priorities such as top speed, economy, safety, etc. Consult Volvo Penta literature and computer programs or contact the Volvo Penta organisation for assistance.



Performance requirements

What are the top speed and cruising speed requirements?

The boat/vessel

Define the category of hull type:

- Displacement
- Semi-planing
- Planing

Consider the boat size and estimate weight, LCG (Longitudinal Centre of Gravity) etc. Drawing information (line drawings) is requested, in the best case resistance data from tank tests.

Propulsion system

Search for the most suitable propulsion system and engine geometry. Think about the characteristics of different propulsion systems.

Limitations

Consider possible limitations such as engine and propeller dimensions.

Power requirement

Use the data to define the required power. Do not forget to consider power losses due to PTOs, climate, fuel qualities etc.

Engine

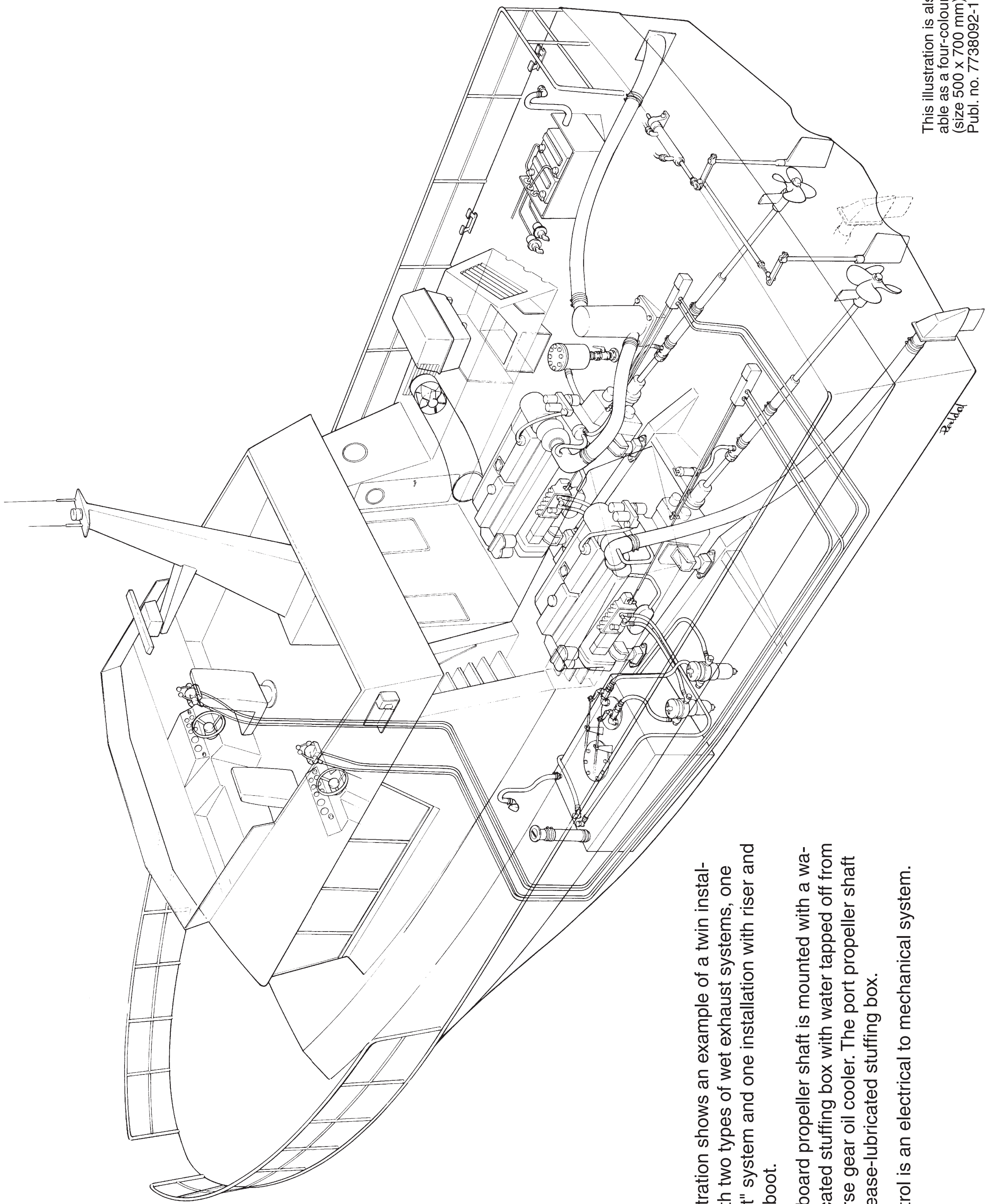
Consult Volvo Penta sales literature for the corresponding engine, giving minimum required power at the correct duty rating. Check the available reverse gear ratios.

Reverse gear and propeller

Calculate for the optimum gear ratio as well as propeller type and size.

Installation example

This illustration is also available as a four-colour poster (size 500 x 700 mm). Publ. no. 7738092-1



The illustration shows an example of a twin installation with two types of wet exhaust systems, one "Aqua-lift" system and one installation with riser and exhaust boot.

The starboard propeller shaft is mounted with a water-lubricated stuffing box with water tapped off from the reverse gear oil cooler. The port propeller shaft has a grease-lubricated stuffing box.

The control is an electrical to mechanical system.

Plan the engine room so as not to hinder engine servicing work. Compare with the instruction book and make sure that all filter replacesments, oil changes and other servicing measures can be carried out normally. Also ensure that it is possible to install and remove the engine.

Before starting any installation work, make sure that up-to-date dimensional drawings for the engine and its equipment are used. Dimensional drawings provide all the necessary measurements for installation, such as the distance from the centre of the crankshaft to the engine brackets (reverse gear brackets) and to the centre line of the propeller shaft.

Note that the small silhouette drawings on leaflets and brochures should **not** be used for this purpose.

The engine and drive line should be installed in such a way as to minimise noise and vibrations, i.e. air noise and body noise (vibrations).

Vibrations from the engine and propeller are transmitted via the suspension and engine bed out in the hull. Other channels are via the exhaust pipe, coolant pipes, fuel pipes, cabling, and control cables.

Pressure shocks from the propeller are transmitted through the water into the hull. Pulsating force on the propeller goes into the hull via the support brackets, bearings and seals.

If the propeller is at a large angle this pulsating pressure and force can be considerable. Use of an incorrect propeller can result in cavitation, which also causes noise and vibrations.

Torsional vibrations from correctly selected components in the drive package are often negligible.

NOTE! Always consider international and local requirements.

1. Engine room layout

Only use updated and approved dimensional drawings. Study the drawings carefully. Consider soundproofing material, the engine's movements when running and accessibility for servicing and repairs.

For twin installations, the distance between the engines should be sufficient to allow easy performance of inspection and service work.

2. Weight distribution

Consider the weight distribution of the boat so that it is evenly distributed even with different levels of fuel and water in the tanks. Place heavy units so that the boat is balanced around the centre of gravity according to the designer's recommendations.

NOTE! Pay special attention to obtain the best centre of gravity possible. This has a major influence on performance in planing boats.

3. Choice of engine suspension type

Choose the appropriate type of engine suspension based on comfort requirements, type of use and engine/reverse gear arrangement.

The two major systems are fixed or flexible. In the fixed system, the engine/reverse gear is directly bolted to the engine bed. While in flexible systems, the engine/reverse gear is installed on flexible mounts. Volvo Penta offers flexible mounts for a large variety of engine/reverse gear combinations.

Select a shaft system depending on the type of coupling (rigid or flexible), shaft support, stuffing box etc.

4. Fuel system

Determine the type of fuel system. Choose to use fuel hoses or fuel pipes. Consider classification rules.

Decide where to place extra water separating fuel filters and plan for the routing of fuel hoses and pipes, fuel filler and venting hoses, shut off devices etc. Fuel feed and return hoses or pipes should be placed low in the engine room so as not to transmit extra heat to the fuel.

5. Cooling system

Determine the type of cooling system. Chose where to place seawater intakes and seawater filters. Plan the routing of hoses.

6. Exhaust system

Determine the type of exhaust system, wet or dry. Plan the installation of the exhaust line components, such as silencer and hoses.

7. Electrical system

Plan the routing of cabling and check the length of instrument cable harnesses. Decide where to place fuse boxes and main switches.

Avoid joints and cable connections where there is risk of moisture or water. Do not make any joints or connections behind fixed bulkheads or similar which are difficult to reach after finishing the boat.

8. Electrochemical corrosion

The potential problem of galvanic and stray current corrosion must be considered when planning electrical installation and choosing the equipment to be used. Plan for protected anodes.

9. Air supply, ventilation and soundproofing

Carefully study sizes of sufficient duct area and pay attention to optimise the design of air inlet.
Plan the routing of the ducts (hoses) for the engine's air consumption and ventilation so that they do not impede installation of the batteries, fuel tanks, etc.

Sound insulation in the engine room is of great importance to keep the sound level as low as possible. Sufficient space for soundproofing material must also be planned for. A condition for good sound insulation is a sealed engine room with ducts as the only openings.

10. Controls and steering

Plan for the routing of control cables, steering systems, Dual station units (DS–units), etc. Allow accessibility for servicing and replacement.

When using mechanical control cables it is of great importance to route the cables with as few bends as possible to achieve smooth handling.

11. Power take-off

In order to operate miscellaneous small auxiliary apparatus, power take-offs can be fitted from an additional pulley or on the drive gear casing.

If greater outputs are needed, a mechanical power take-off can be fitted on the front end of the crankshaft.

The outputs permitted from the power take-offs are described in the sales literature.

Propeller theory

To get the best performance out of your boat, you need to select the propeller and gearing 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 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 but you will also experience greater comfort, with less noise and vibration.

The following description is very general and describes only superficially how propellers are designed. The propeller manual ***Propellers*** gives more detailed information.

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.

The 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 or 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 distance between the bottom of the boat and the propeller blades should be at least 10% 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:

$$P/D = \frac{\text{Pitch}}{\text{Diameter}}$$

0.90–1.15 at 20 knots
1.00–1.30 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 exceeds 24–28 knots, the resistance of the shafts, rudders and propeller supports increase to a level where the improved 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 on the shaft, etc.

Displacement and semi-planing boats

Boats of less than 15 knots need propellers that 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 (0.26 in^2) per ton 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:

$$T \text{ (Newton)} = \frac{\text{propeller efficiency x shaft output (kW) x 1944}}{\text{speed of boat (knots)}}$$

can be used to calculate the thrust.

Three-blade propellers are often more efficient for large, slow-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 (N) 95–105 x kW
Fixed propeller (N) 80–90 x kW

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

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.

Propeller and performance computer program

Over the last year, Volvo Penta has been developing computer programs for calculating speed, gear ratios and propellers. This is excellent for predicting speed and propellers simply and safely.

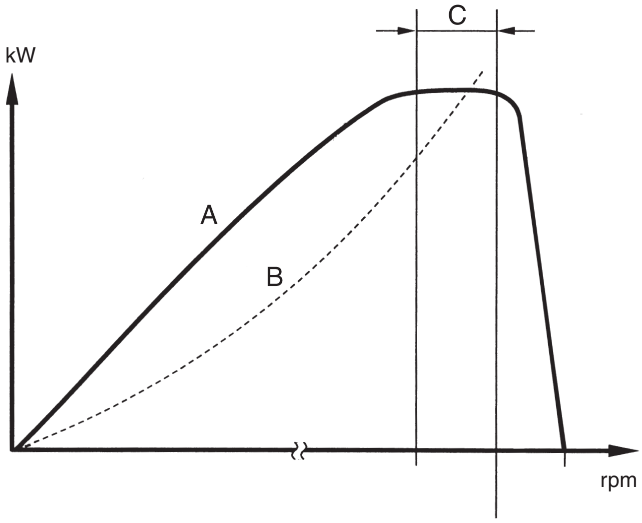
The estimated speed in the individual computer programs is based on the experience gained from a number of installations.

Propeller calculations

Theoretical speed and propeller calculations are made using well-established methods and a number of practical test results, but are still a result of approximations and estimations. We believe that for a standard type of boat they can give you a reasonable good estimation, provided that correct and complete input is available. However the Volvo Penta organisation can not take any responsibility for the final result which only can be found out during a sea trial.

Propeller selection

The combination of ratio, shaft diameter and propeller size can be calculated by using ***the Volvo Penta computer program.*** Calculation of the correct propeller size can be done by the Volvo Penta organisation if so desired. In this case all details of the boat (preferably drawings) must be provided in good time.



A = Engine full load curve
B = Propeller load curve (propeller OK)
C = Recommended max operating range

The propeller should be chosen with the greatest of care. Consider the space between the hull and skeg. Refer to propeller recommendations and propeller shaft angles, and the recommendation for free space between the propeller and hull. See information on the following page.

On planing boats the bottom over the propeller is often rather flat. The hull can be reinforced on the inside to reduce noise and vibrations caused by the propeller blade pulses.

For the best propeller efficiency, the angle of the propeller shaft in relation to the water line should be as small as possible. The larger the shaft angle the lower the efficiency. Shaft angles exceeding 12° should be avoided if possible. This means that with the boat lying still, the propeller angle should not exceed 12°. This applies especially to planing boats. Larger shaft angles may affect the speed, sound and vibrations negatively.

Check the shaft angle. If the shaft angle exceeds 12°, the use of a smaller propeller should be considered. This can be compensated by more blades.

The keel or the propeller shaft brackets in front of the propeller should have a profile creating a minimum of drag and turbulence. Also the shape of a tunnel is very important. A poor tunnel design can create a lot of turbulence in the propeller and reduce the boat's buoyancy at the stern.

Ensure that there is sufficient space between the propeller, hull, keel, skeg and the rudder. It should be possible to move the propeller shaft at least 200 mm (8") aft to allow the removal of the reverse gear or coupling. Also make sure that any transverse bulkhead does not impede its removal. Sufficient clearance, approx. 1 x the shaft diameter, must be provided between the propeller and the stern bearing to prevent the propeller from pressing against the stern bearing. Allowance should also be made for rope cutters if they are to be fitted. See figures on this page, position (**E**).

The minimum distances to the hull, keel, skeg and rudder.

∅ = Propeller diameter

A = 0.10 x ∅

B = 0.15 x ∅

C = 0.10 x ∅

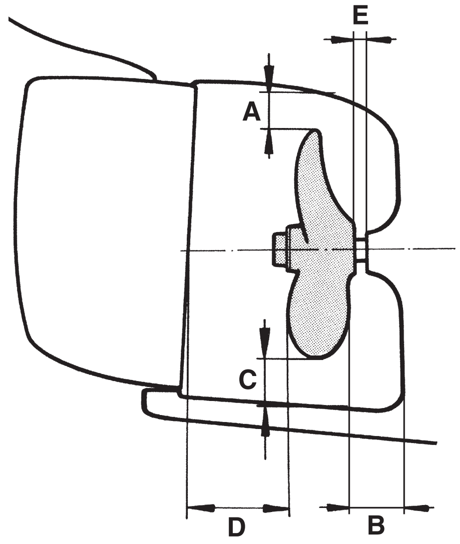
D = 0.08 x ∅

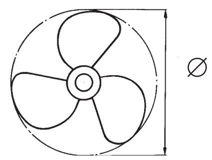
E = Approx. 1 x shaft diameter

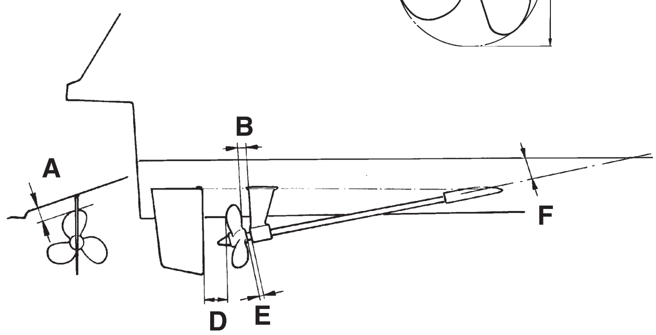
F = Shaft angle. Shaft angles exceeding 12° should be avoided.

Example: The measurement (**A**) for a boat with a propeller diameter 30" (762 mm) is 0.10 x 762 = 76 mm (0.10 x 30" = 3") minimum.

The measurement (**A**) must never be less than 50 mm (2"). For classification, the requirements of the respective classification body must be followed.







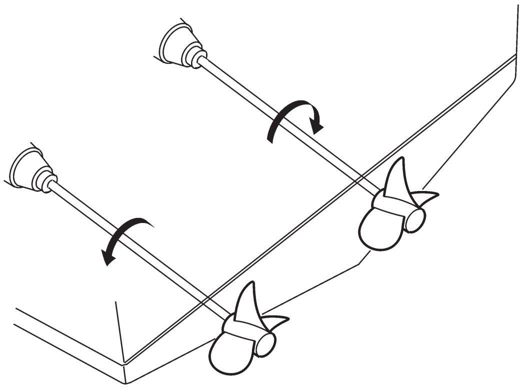
Single and twin installations

The most effective method of propulsion is generally achieved with a single installation. If more power is required than is possible with a single installation, two engines, each with a separate propeller shaft can be fitted.

Improved manoeuvring is gained in two engine installations and separate propellers as the power output can be controlled separately and independently for each engine. One engine can be run reverse and the other ahead when for example manoeuvring at low speed.

Two or more engines coupled to a common transmission and one propeller is a third possibility.

Propeller rotation



For a single installation, a right or left-hand rotating propeller can be chosen. The rotation direction is sometimes dependent of the type of reverse gear being used.

For twin installation, the starboard propeller should always rotate clockwise and the port propeller anti-clockwise seen from the aft forward. Otherwise there is a risk that air bubbles will be drawn down into the water between the two propellers which can cause ventilation.

Choice of reduction ratio

The propeller shaft usually has lower speed than the engine. This is normally achieved with the reduction in the reverse gear.

As a rule the largest possible ratio should be chosen for slow-going displacement boats. It then follows that the propeller diameter can also be relatively large with high thrust within the applicable speed range. Depending on the hull type and speed range, a smaller ratio can be chosen for higher speed, if required. See the table. This is to obtain highest thrust within the respective speed range. If the ratio is chosen outside of the recommendations the thrust can be lower than the optimum calculated power. The boat's top speed is not necessarily affected.

A check must always be done that the hull has sufficient space for the propeller according to information in chapter ***Propeller selection***.

In order to select the optimal gear ratio a calculation have to be made. The following tables could serve as guidelines.

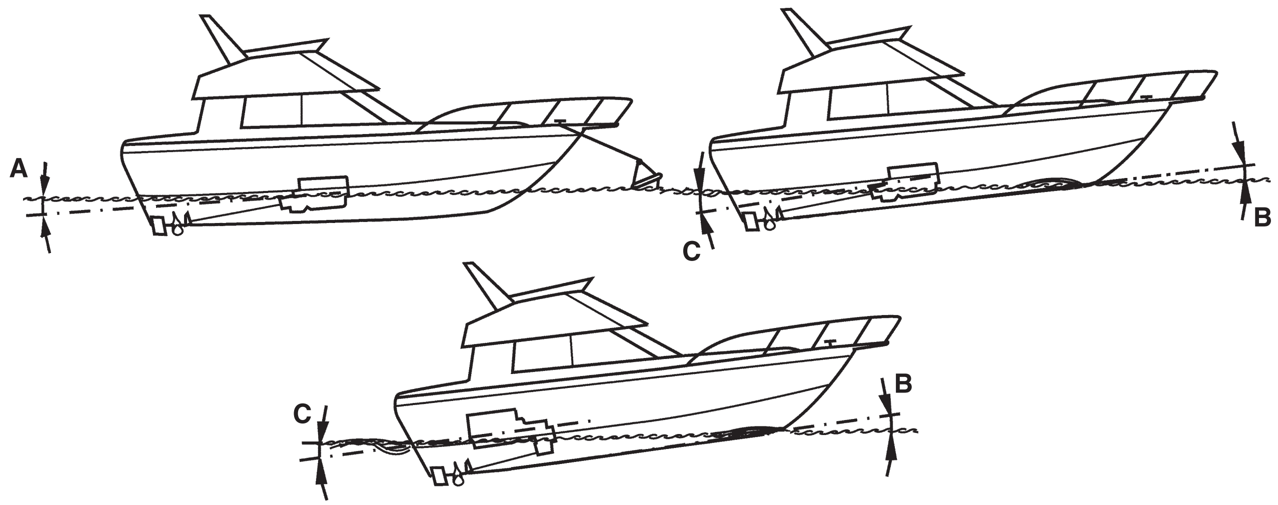
D5/D7 engine revolution range 1900–2300 rpm with conversional shaft/propeller system

Ratio, approx.	Main type of operation	Speed range
4:1–3:1	Work boats, Displacem. boats, High pulling power, Towing, Trawling	4–8 kn.
3:1–2.0:1	Work boats, Displacement boats, Low speed planing boats, mainly free run	6–10 kn.
2.5:1–1.5:1	Semi-planing to planing boats, Patrol boats, Sport fishing and Pleasure boats	10–15 kn.

D9/D12/D16 engine revolution range 1800–2800 rpm with conversional shaft/propeller system

Ratio, approx.	Main type of operation	Speed range
6:1–3:1	Work boats, Displacem. boats, High pulling power, Towing, Trawling	4–12 kn.
3:1–2.5:1	Work boats, Displacement boats, Low speed planing boats, mainly free run	8–17 kn.
2.5:1–2:1	Semi-planing to planing boats, Patrol boats, Sport fishing and Pleasure boats	16–26 kn.
2:1–1.5:1	Planing boats, Patrol boats, Sport fishing, and Pleasure boats	25–35 kn.
1.5:1–1:1	High speed planing boats, high performance, Pleasure boats and similar	35–45 kn.

Engine inclination



To ensure that the engine is sufficiently lubricated and cooled, it is important that the maximum engine inclination is not exceeded. The engine inclination must be checked.

Care should be taken to avoid having the front end lower than the flywheel end, i.e. in excess of permitted negative inclination, since this can affect lubrication of the engine and venting of the cooling system.

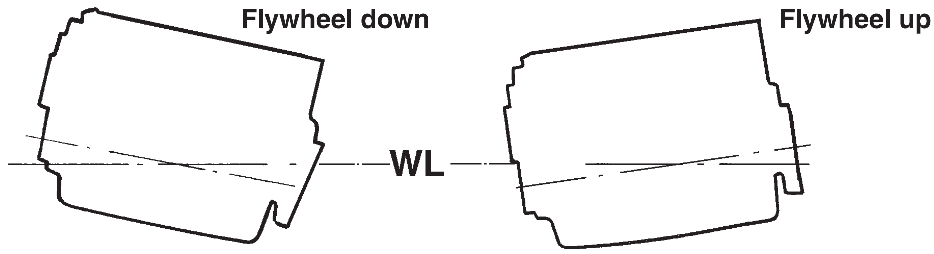
Each engine type has a **maximum permitted engine inclination** while the boat is under way. This inclination includes both the installation inclination and the trim angle that the boat/engine has when going through the water.

A = The engine's static inclination.

B = The boat's trim angle under way.

C = Total inclination of engine under way, maximum permissible inclination (A+B).

Max. engine inclination



	Static (A)		Under way (C)	
Engine	**Flywheel down**	**Flywheel up**	**Flywheel down**	**Flywheel up**
D5/D7, standard sump	10	0	15	0
D5/D7, shallow sump	5	0	10	0
D9, shallow sump	6	0	12	5
D9, V-drive system	5	0	5	10
D9, deep sump	13	0	18	5
D11, standard sump	7	0	17	10
D12, shallow sump	8	0	13	5
D12, deep sump	13	0	18	5
D16, standard sump	11	0	18.5	7.5

Weight distribution

General

The centre of gravity has a major influence on the boat's static and dynamic stability. It is therefore important to consider this for the both when loaded and unloaded.

Planing and semi-planing hulls

For planing and semi-planing hulls especially it is important that heavy equipment such as engines, fuel tanks, water tanks and batteries are positioned in a way as to obtain the best possible trim of the boat in the water.

Consider the weight distribution of the boat so that it is evenly distributed even with different levels of fuel and water in the tanks.

It is an advantage to install the fuel tanks away from the warm engine room. The batteries should be placed in a separate, well ventilated area if possible.

Figure A

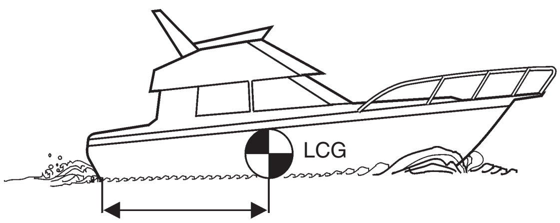
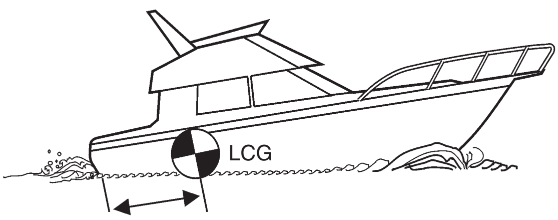


Figure B

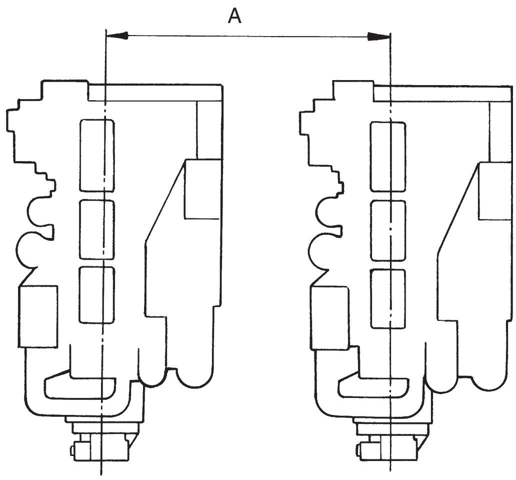


LCG = Longitudinal Centre of Gravity

Figure A represents an installation with good weight distribution and with a good trim angle.

Figure B represents a wrong type of installation with a subsequent bad running attitude.

Engine centre distance, twin installation



For twin installations, consideration must be given to the minimum distance between the engines to allow sufficient accessibility for service work. Larger distance also gives better manoeuvring capacities.

Check for a suitable distance by using the dimensional drawing.

Generally, the following minimum measurements between the engine's centre-lines (**A**) are recommended:

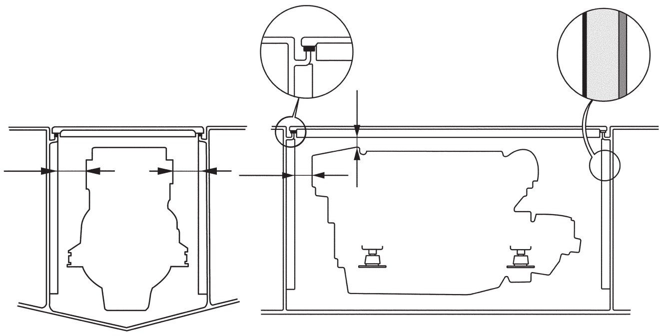
D5/D7	1050 mm (41")
D9/D11	1200 mm (47")
D12	1250 mm (49")
D16	1350 mm (53")

For installation of several engines on one propeller shaft the distance between the engines is mainly determined by the gears or belt transmissions with which the engines are joined together. The requirement for access for inspection, service and repairs is still applicable.

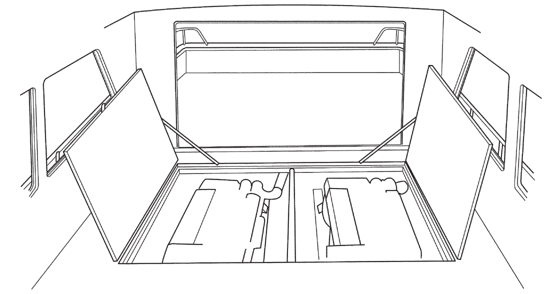
Accessibility for checking, maintenance and repairs

When designing the engine room always pay attention to the accessibility needed to allow proper service and repairs to the engine. Also ensure that the complete engine can be removed without damage to the boat structure.

A written instruction may be of major help if engine removal is necessary at a later stage.



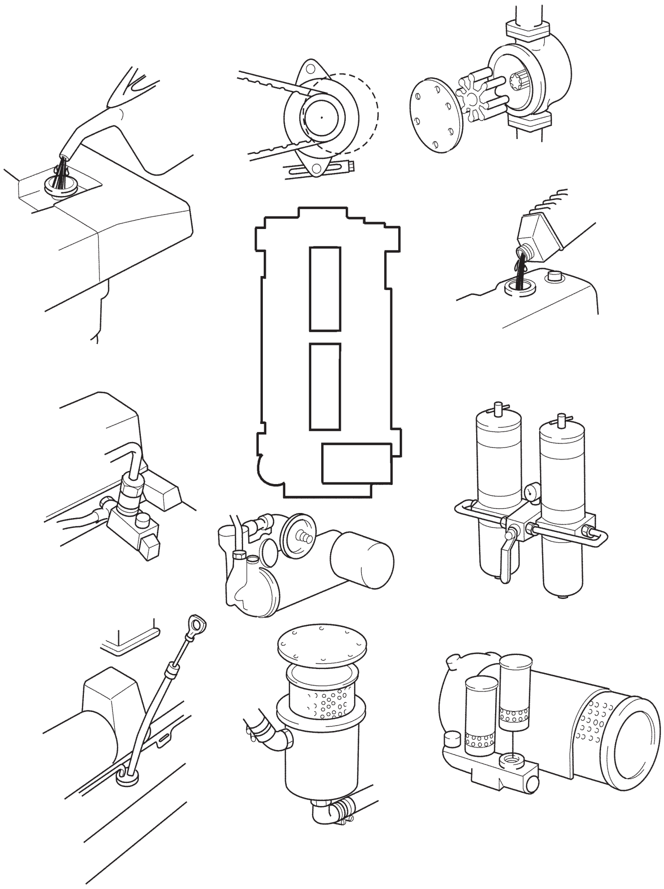
NOTE! There must also be sufficient space for the soundproofing material. Study the dimensional drawings of the relevant engine carefully.



Accessibility for maintenance

Some areas that normally require access for maintenance:

- Oil change and refill
- Change of oil filters
- Change of fuel filters
- Venting fuel system
- Change of air filter
- Check of belt tension
- Change of belts
- Removal of valve cover
- Change of seawater impeller
- Cleaning of water filter
- Venting cooling system



Accessibility for repairs

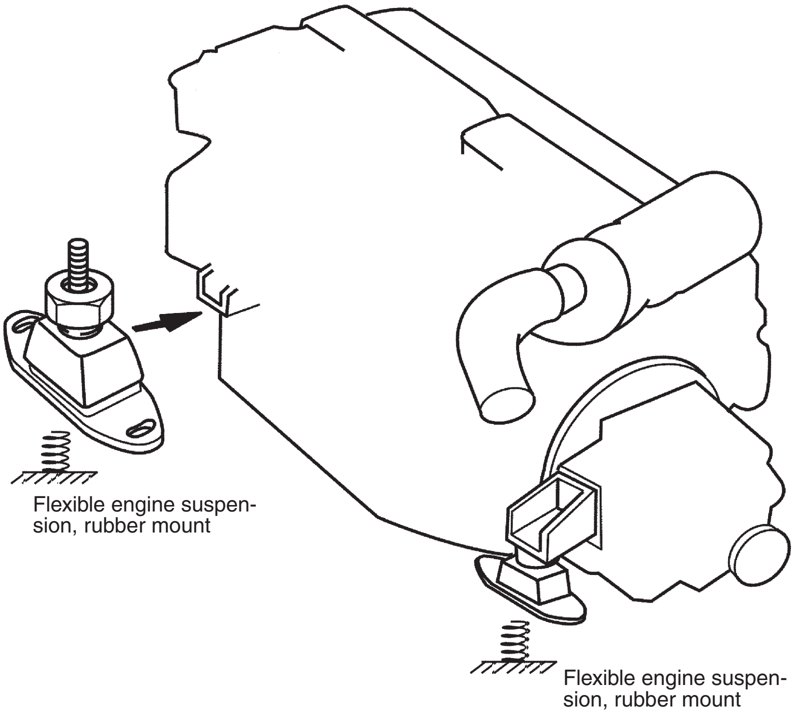
Some areas that may require access for repairs:

- Lower crank case inspection covers (if fitted)
- Removal of injectors
- Removal of cylinder head
- Removal of charge air cooler
- Removal of oil coolers
- Removal or change of electrical components
- Removal of flywheel and vibration damper
- Removal or change of reverse gear
- Removal of propeller shaft
- Engine removal

Selection of engine suspension

There are two types of engine suspension; flexible mounting with rubber mounts and rigid mounting.

Flexible mounting



Flexible engine suspension (rubber mounts) can be used together with low gear ratios. With higher ratios, the torsion forces and propeller axial force become excessive for the rubber mounts.

One condition for rubber mounts to be effective dampers is that the engine bed is sufficiently rigid. The bed must also be parallel to engine feet to avoid tensions being built into the engine suspension. Tensions can increase the vibration level and also shorten the life span of the mounts.

NOTE! The elasticity of the rubber mounts must never be utilised to compensate for an inclined bed.

Flexible engine mountings provide good insulation from vibration between the engine and the bed frame, thus contributing to a low noise level. Dimensions for flexible mountings, see chapter ***Building the engine bed.***

There are two types of rubber mounts: mounts that are adjustable in the vertical plane, and mounts with a fixed height that must be shimmed to the correct height.

The rubber mounts are compressed during installation, therefore the engine should rest on the rubber mounts for 12 hours before the height is adjusted.

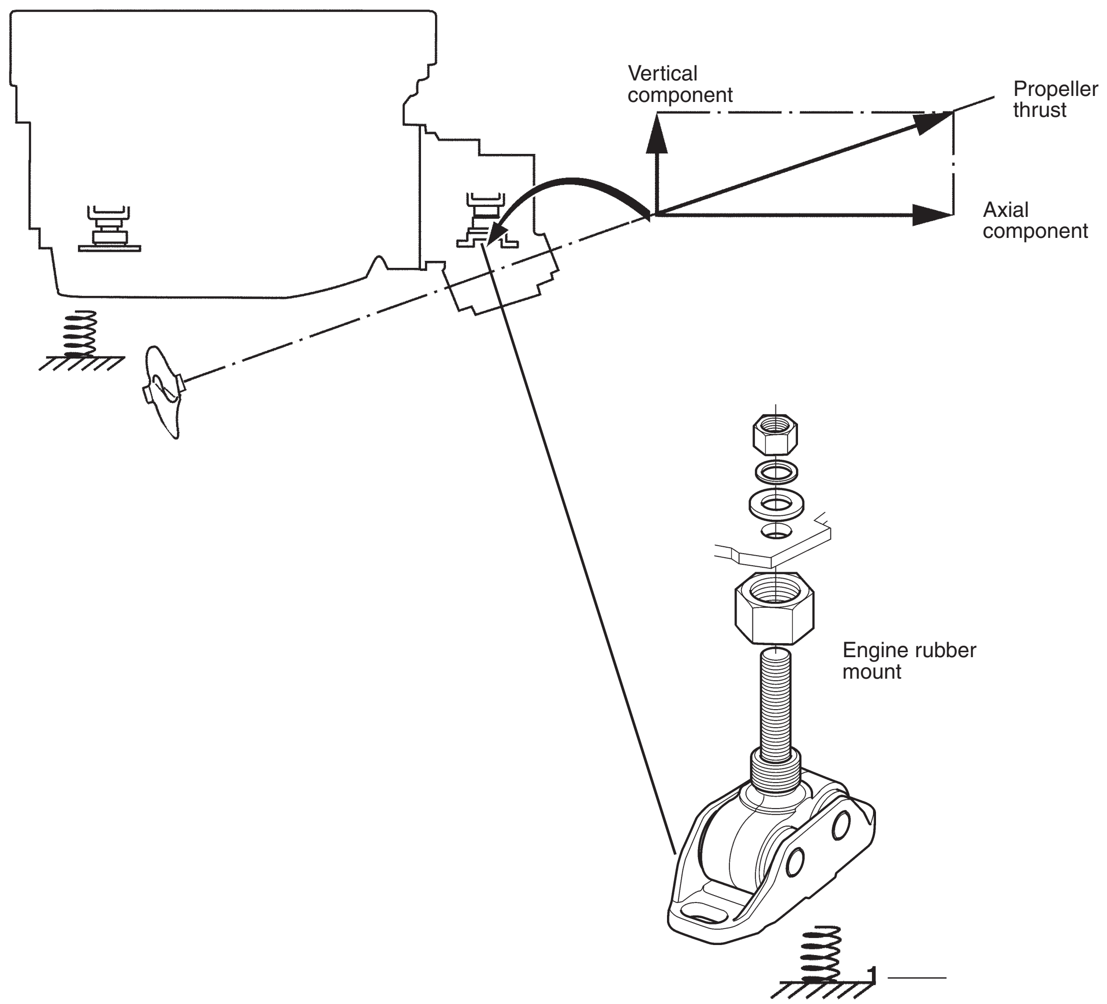
Always follow the recommendations of Volvo Penta when selecting the engine suspension. The use of incorrect rubber mounts can result in abnormal vibrations, which in turn can cause damage to engine components and also reduce the degree of comfort.

NOTE! When flexible engine suspension is selected, all the connection of components to the engine must be flexible.

The propeller shaft must have a flexible stuffing box, or alternatively a flexible shaft coupling.

The engine's connections for fuel lines, exhaust and coolant must be flexible.

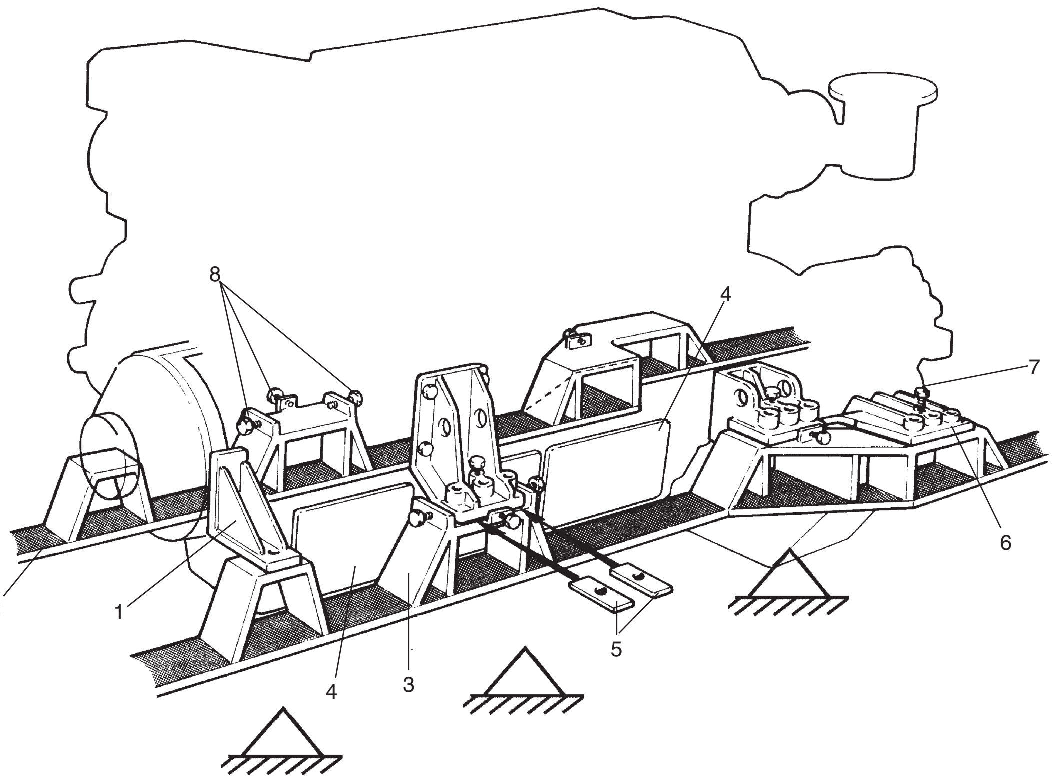
V-drive



In all installations with a down angle propeller shaft there will be a lifting force transmitted from the propeller shaft. In an installation of an engine with a V-drive this force could be higher than that from the weight of the engine and gear box.

This will create a lifting force to the engine mounts fitted at the same end as the gear box. Therefore all engines with a close coupled V-drive must be equipped with mounts that are designed for this type of installation at the rear end.

Rigid mounting



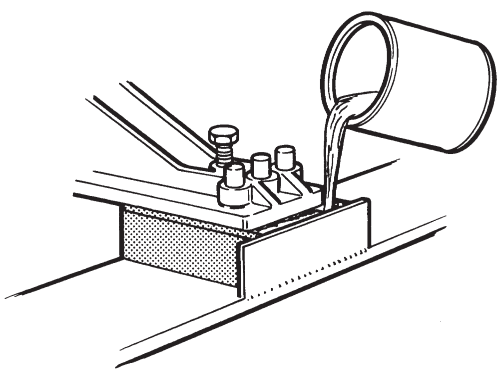
1. Support bracket for front power take-off
2. Steel bed frame (U-member or L-member, thickness 0.47–0.6" = 12-15 mm)
3. Front mounting bracket (about 10" = 250 mm high)
4. Inspection covers
5. Sheet steel shims (about 0.4" = 10 mm thick)
6. Rear mounting brackets (about 10" = 250 mm high)
7. Adjustment bolts (4 pcs) for engine heightwise position. To be removed after completed installation
8. Bolt to adjust engine lateral position

Rigid mounting is often used for commercial service and heavy hulls. The vibration of the drive package is not particularly noticeable with a large hull.

It is very important that the bed is level where the engine mounts rest since otherwise there is a risk of building tensions into the suspension joint.

With rigid mounting, the engine mounts are bolted to the engine bed with 10 mm (0.4") thick shims. The shims need to be milled to the correct size in conjunction with the final alignment together with the propeller shaft.

An approved type of moulding compound (e.g. Shockfast) can be used instead of shims, but only when the engine has the correct alignment.



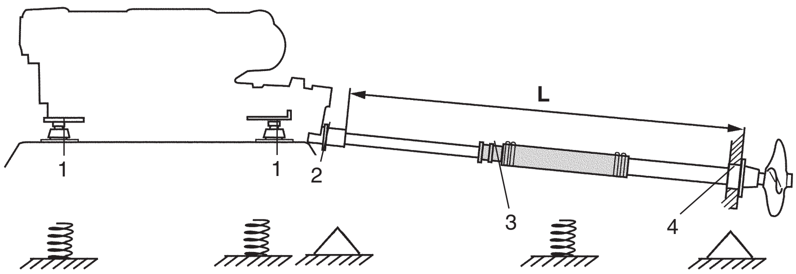
A flexible shaft coupling can be used to absorb changes that may occur in the alignment of the engine / propeller shaft as a result of deformation of the hull structure.

Engine suspension vs propeller shafting

NOTE! A flexible shaft coupling must never be fitted together with a flexible mounted stuffing box. This can cause vibration problems.

Stainless steel propeller shafts are available in different diameters. The shaft dimension should be chosen based on the engine power output, gear ratio and propeller shaft material.

The following installation alternatives and combinations are recommended:

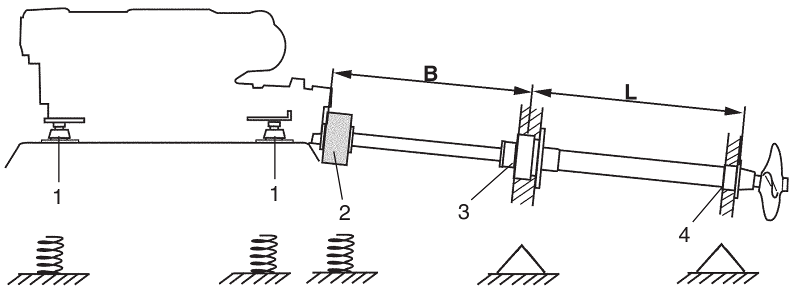


1. Engine with flexible mounts and flexible shaft seal

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

1. Flexible engine mountings
2. Fixed shaft coupling
3. Flexible mounted shaft seal
4. Water lubricated stern bearing

L. Maximum distance between support points. For calculation see page 50.

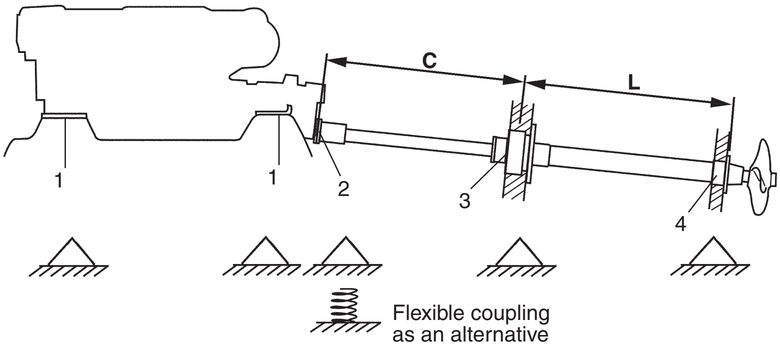


2. Engine with flexible mounts and fixed shaft seal

1. Flexible engine mountings
2. Flexible shaft coupling
3. Fixed front stern bearing and shaft seal
4. Water lubricated stern bearing

L. Distance between support points. For calculation L max see page 50.

B. Distance reverse gear flange – support point.
Recommended B min is 6-10 x shaft diameter.
B max is calculating in the same way as L max.



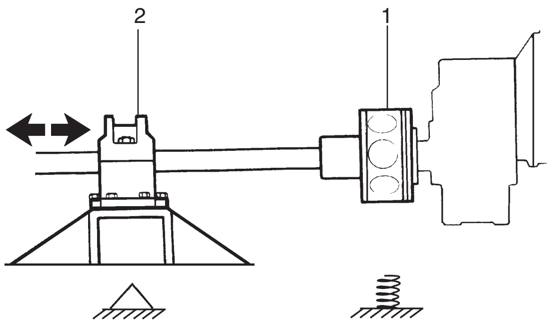
3. Engine with fixed mounts and fixed shaft seal

1. Fixed engine mountings
2. Fixed shaft coupling. (Flexible coupling as an alternative.)
3. Fixed front stern bearing and shaft seal
4. Water lubricated stern bearing

L. Distance between support points. For calculation L max see page 50.

C. Distance reverse gear flange – support point.
Regarding C min see page 50.
C max is calculated in the same way as L max.

Axial thrust bearing



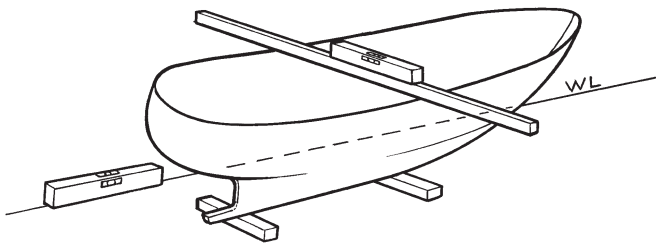
1. Flexible coupling
2. Thrust bearing

All reverse gears from the genuine Volvo Penta range are fitted with built-in axial bearings for axial forces from the propeller shaft. No extra thrust bearings need to be fitted under normal load conditions. In the case of ice going vessels with excessive pulsating axial forces, an additional thrust bearing is recommended in the propeller shaft system. In such cases, a flexible coupling must always be fitted between the reverse gear and the thrust bearing so as to eliminate axial stresses between the two thrust bearings.

If the unsupported propeller shaft length is too long, a separate support bearing should be fitted. A support bearing cannot absorb axial stresses.

Engine foundation

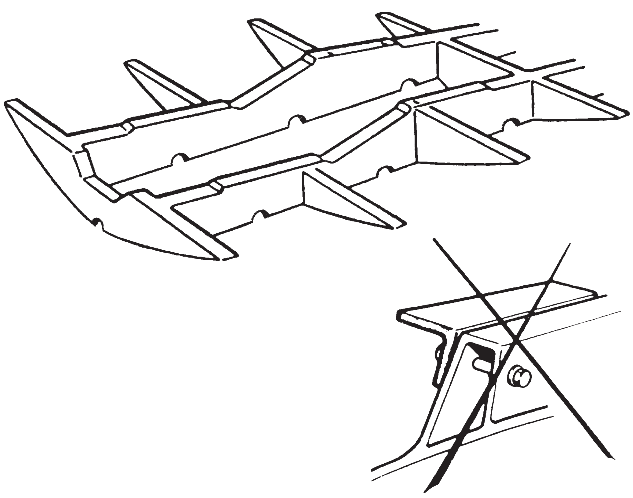
Aligning the boat



The installation work is made easier if the hull is aligned horizontally before starting. Block up the hull so that the calculated water lines, both longitudinal and transverse, are parallel with the horizontal plane. A spirit level is a good help.

Check when manufacturing the bed that the upper bed plane, the mating plane, is parallel and correctly positioned in relation to the centre line of the propeller shaft. A guide sleeve with the same diameter as the propeller shaft can be used in the stern tube to help with the alignment of the bed.

General



The engine bed should be dimensioned so that it is rigid in all directions to distribute the load as much as possible into the hull. The greatest possible area of the engine bed, and with cross members, must be fastened to the hull to give the best noise and vibration insulation.

Plane requirements, rigid mounting

It is very important that the engine bed is dimensionally stable when the engine has a rigid mounting. The maximum height deviation (movement) between the engine's attachment plane must be within 3 mm (0.12"). In other words it is important that the bed is so torsionally and bending rigid that the plane requirements are not exceeded as a result of movements in the hull in rough sea, or when the boat is put on shore or into the sea.

Design

The bed should have a design basis that enables it to absorb by an adequate margin the engine torque, the compressive force of the propeller, and the dynamic forces (mass forces) that occur during movement in rough sea.

When designing the bed it is important that there is sufficient space under the engine for the movement of the engine, and that there is also access to the inspection covers (certain engine versions).

If possible the bed should be designed so that the reverse gear and flexible coupling can be dismantled and lifted out separately.

The engine bed can be built separately and then carefully measured and bonded into the hull, or be built up directly in the hull.

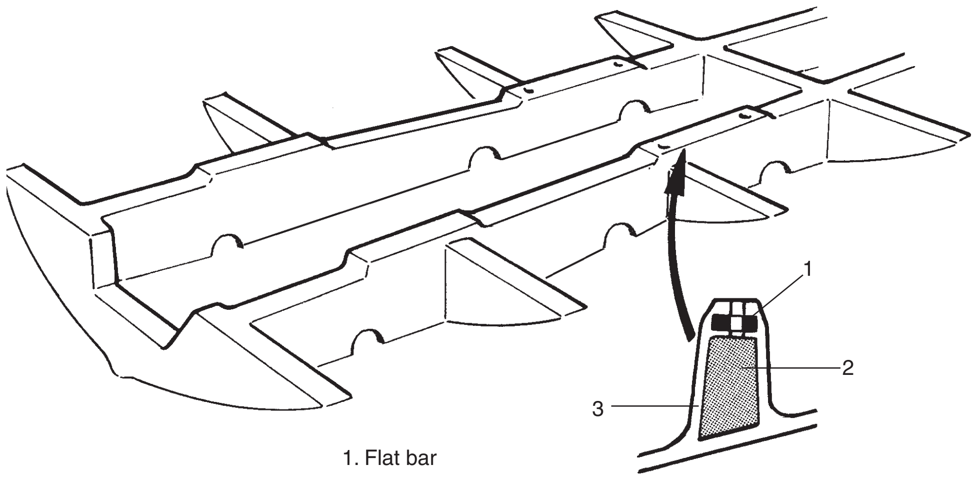
When designing the bed the dimensional drawings for the engine and the boat should if possible be used to check the space round the engine and the height and position of the bed in relation to the propeller shaft. The height depends on whether a flexible engine suspension is to be used or whether the engine is to have a rigid suspension, and the inclination of the bed should correspond with the inclination of the propeller shaft. The height should include a shim of 10 mm (0.4") avoiding the bed being too high.

It is important to drain any water around the engine bed to the location of the bilge pump.

The figure to the left shows an example of a well-designed engine bed.

Fibreglass hull

Example of an engine bed in a fibreglass hull.



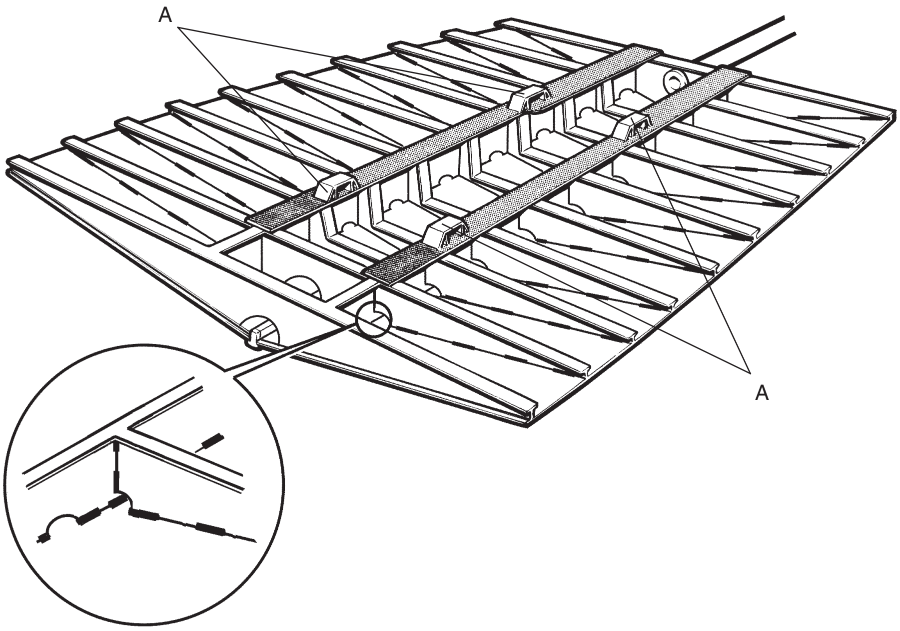
1. Flat bar
2. Spacer material
3. Fibreglass

The engine bed in fibreglass should be designed so that it is rigid, both vertically, longitudinally and transversely, to distribute the load as far as possible to the hull. The bed is often built as a box construction. As much of possible of the engine bed, including cross members, should be attached to the hull to ensure the best possible noise and vibration insulation.

The engine bed can be built up separately and then carefully measured and bonded to the hull, or be built up directly in the hull. It is important that the bed connects to the hull with a large radius built up of several layers of fibreglass.

Steel, aluminium or wooden hull

Example of engine bed in a steel or aluminium hull.



The bed frame in a steel or wooden boat should be designed as a welded steel structure. The plate thickness should be sufficient to achieve a dimensionally stable structure.

In a steel boat, the engine bed plane is welded to each frame rib along their entire length.

In a wooden boat, the bed should be bolted to the frame ribs with bolts and nuts.

The length of the engine bed should be extended as far as possible to distribute the load.

If the engine has an extra PTO in the front end that requires extra support, the bed should be designed to accommodate this support. There must be space in front of the PTO so that it can be dismantled.

Take into consideration and calculate brackets and foundations etc. for other systems, fuel and exhaust systems etc., and for extra equipment.

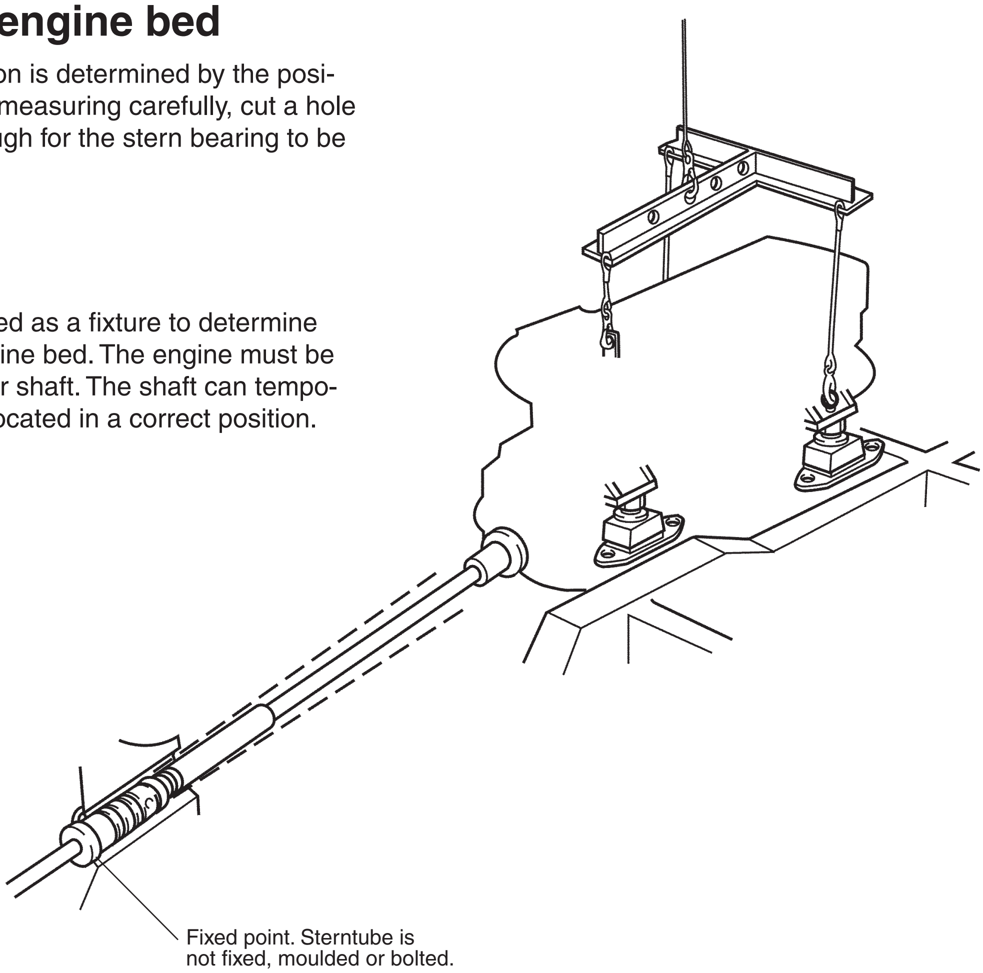
NOTE! If the engine in question is equipped with inspection covers it is highly recommended (if classified, a must) to build mounting brackets (A) high enough to ensure accessability.

Building the engine bed

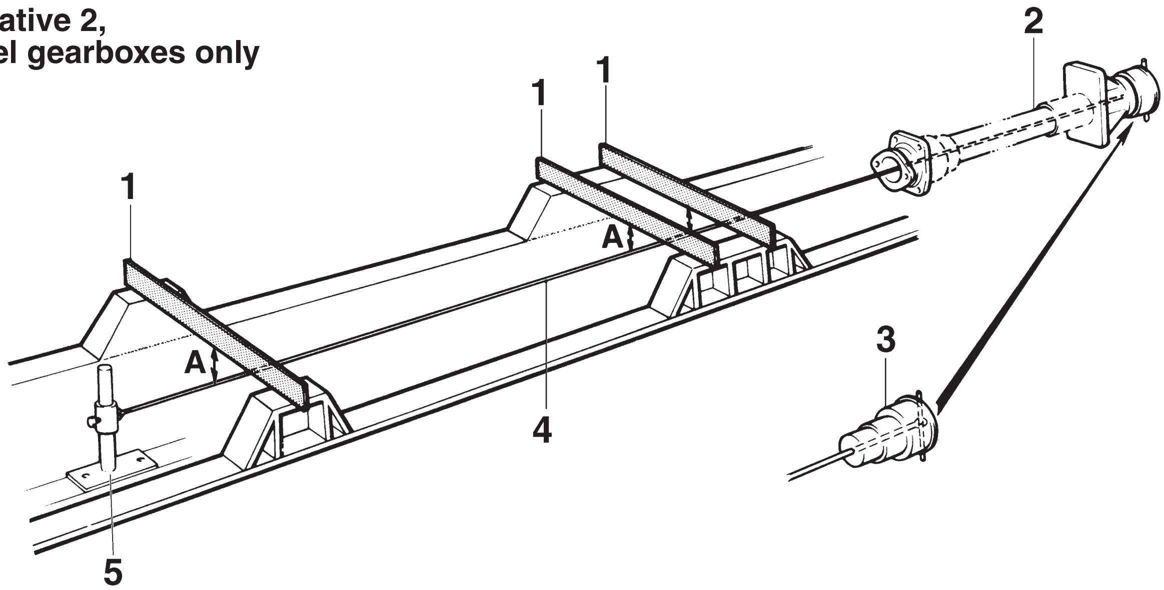
The engine bed position is determined by the position of the shaft. After measuring carefully, cut a hole in the stern large enough for the stern bearing to be put loosely in place.

Alternative 1

The engine can be used as a fixture to determine the position of the engine bed. The engine must be aligned to the propeller shaft. The shaft can temporary be installed and located in a correct position.



Alternative 2, parallel gearboxes only

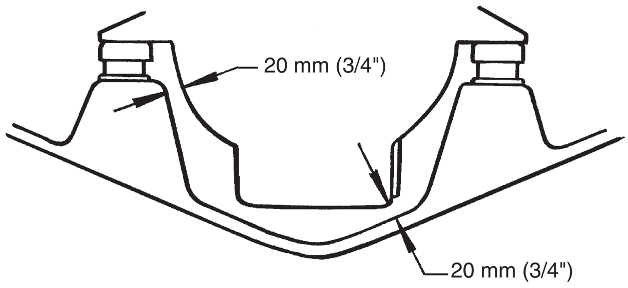


Another method to fix the engine bed without a fixture or the engine is to apply a line from the rear end (3) centered in the stern tube (2) to a fixed point (5) forward of the engine bed. The measurement (A) should be equal to the rulers (1) within 0-2 mm (0-0.08"). See figure.

Ensure that the rulers are horizontal athwartship.

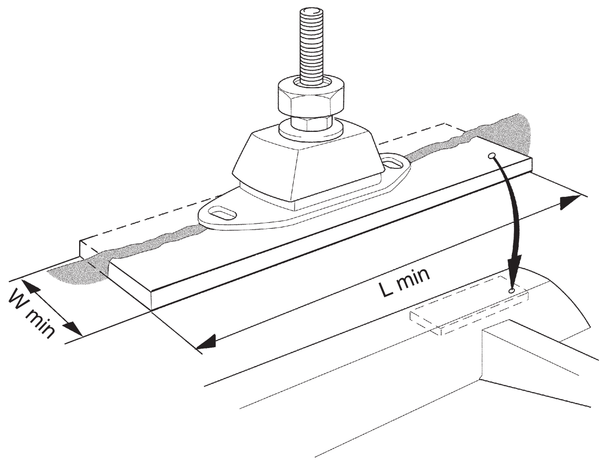
Alternative 3

In serial production or frequent installation work a fixture could be manufactured to position the bed planes.

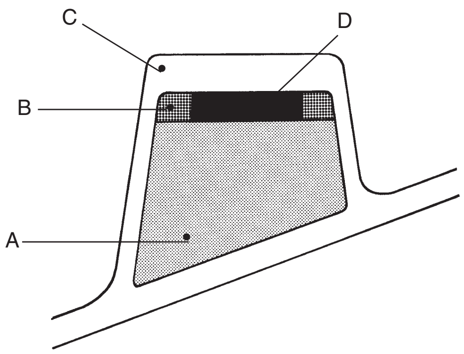


When designing the engine bed, make sure that the space for the flywheel housing, the bottom and sides of the sump, etc. have a recommended clearance of at least 20 mm (3/4").

Flexible mounting



Fibreglass engine bed



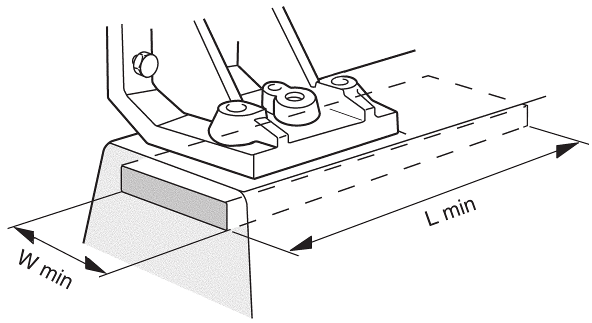
A = Spacer material
B = Filler (rounding of corners)
C = Fibreglass, approx. 10–15 mm (0.4–0.6")
D = Flat bar, galvanized, approx. 10–12 mm (0.4–0.5")

To reduce noise and vibrations, the engine bed should be filled with a material that does not absorb water.

Build up the engine bed with spacer material (A) so that the underside of the engine mounts/engine rubber mounts almost rest against the bed. Divinycell, for example, can be used as spacer material. There must be room for flat bars and fibreglass.

Build in drain channels to allow water to drain to the location of the bilge pump.

Rigid mounting



A 10–12 mm (0.4–0.5") thick galvanised flat bar with a minimum length (L min) of 300 mm (12") and a minimum width (W min) of 100 mm (4") should be built into the engine bed.

Finish up the engine bed with filler material and coat the bed with sufficient amount of layers of fibreglass.

Seal the surface with gelcoat

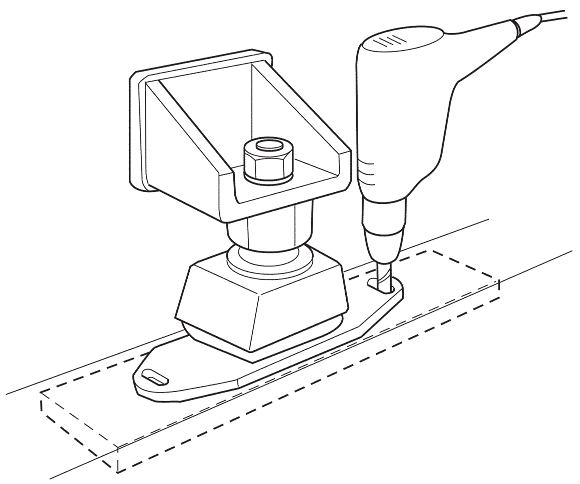
Drilling holes for engine suspension

Bolt holes could, of course, be drilled and tapped (threaded) by accurate measurements and fixtures at other stages than outlined in this chapter. In serial production and other frequent installations, more sophisticated methods may be desired and used.

NOTE! If the engine and engine mounts are used as a drill rig, the holes to the engine mounts/rubber mounts should be drilled in conjunction with installing the engine in the boat.

See also chapter ***Engine installation***.

Flexible mounting



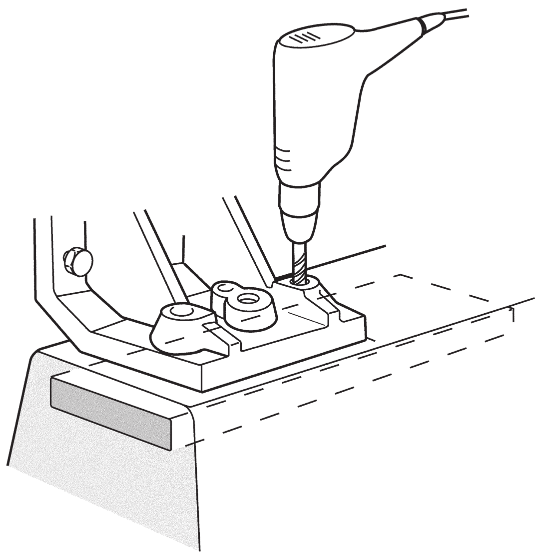
Align the engine to the propeller shaft and mark up for the holes of the engine mounts.

Drill and thread the holes in the bed and flat bars. Recommended bolt diameter for Volvo Penta elastic mounts is 5/8" alternatively M16.

Rigid mounting

NOTE! See chapter ***Rigid engine mounting*** and current engine drawings.

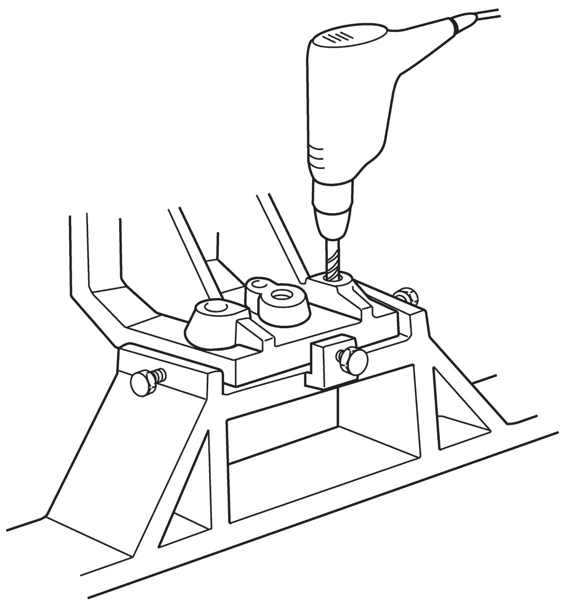
Fibreglass engine bed



Align the engine to the propeller shaft and mark up for the holes of the engine brackets.

Drill and thread the holes in the engine bed and flat bars.

Steel engine bed



Check engine bed parallelity.

Fix the engine in correct position. Align the engine to the propeller shaft and mark up for the holes of the engine brackets.

Drill holes in engine bed.

Propeller shaft systems

Propeller shafts

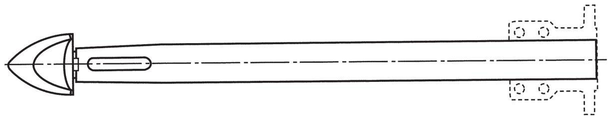
When selecting a propeller shaft for a particular application, there are many points to be taken into consideration. Shaft material and shaft sizes must suit the individual vessel designs and application.

The shaft material must have good strength and be corrosion resistant. A stronger material is beneficial in many sport cruiser applications, because a smaller diameter results in less underwater resistance and turbulence.

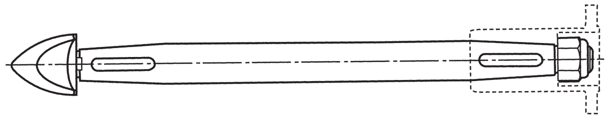
Depending on the length, the shaft may need to be supported with bearings. The minimum distance between the propeller shaft coupling to the first rigid bearing should be 10-14 x the shaft diameter. The distance should be sufficient to allow engine movements without excessive stresses to the shaft system. The maximum distance between bearings is determined by shaft critical speed. This can be calculated based on the type of installation and shaft properties.

During installation of the shaft, it is of great importance to protect the precision straightness and fine surface finish. When lifting shafts it is best to use slings with spreaders to distribute weight more evenly to avoid straightness problems.

Always check the straightness of the propeller shaft. The run-out of the shaft from 100% straightness must not exceed 0.3 mm per metre (0.0036" per foot).



Single tapered shaft



Double tapered shaft

Shafts that are tapered at both ends, double tapered shafts, can be machined to be reversible. This effectively doubles the life of the shaft as it can be turned around when seals and bearings have made wearing marks in the shaft. Before the shaft is installed, check the fit of the coupling to the shaft taper.

Propeller shaft dimensions and bearing distances

The propeller shaft will be subject to both bending and torsional forces and must be dimensioned with regard to this. Also a certain safety margin must also be applied. The maximum bearing distance has a major influence for the calculation of shaft dimensioning.

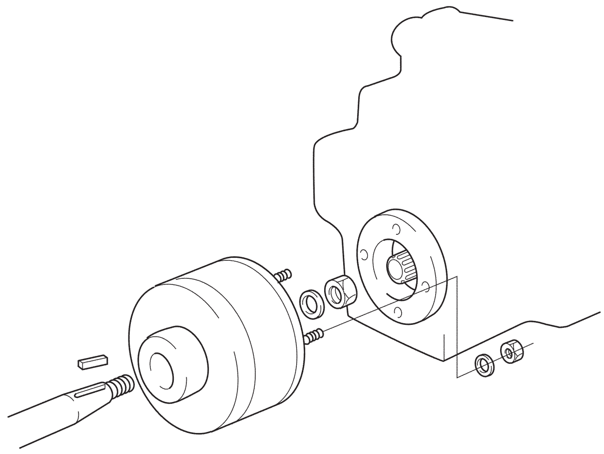
To determine the propeller shaft dimension and bearing distance, use the Volvo Penta computer program or consult the shaft supplier.

Flexible propeller shaft coupling

Together with a flexible mounted engine and a fixed stuffing box, the propeller shaft must be fitted with a flexible propeller shaft coupling. See combinations in chapter ***Selection of engine suspension***.

NOTE! The alignment of the engine is just as important with the above propeller equipment as for a rigid shaft connection. The flexible stuffing box and propeller shaft coupling are not designed to absorb a constant angle deviation.

The flexible propeller shaft coupling could be fitted as shown in the figure.



Shaft seals

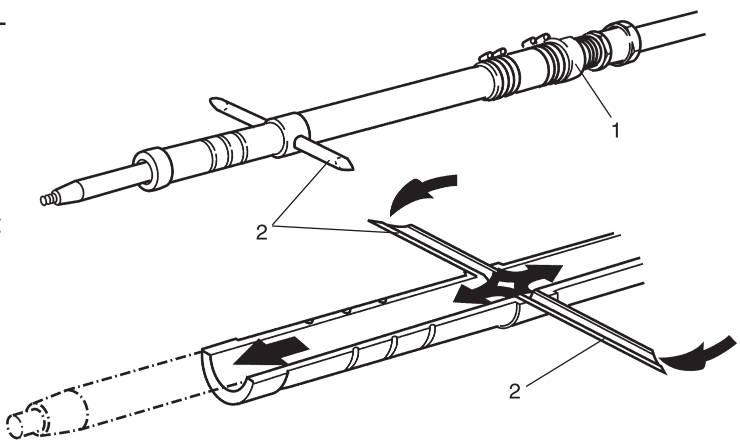
There are different methods of lubrication for the shaft seal. The two most common are water and grease lubricated seals. Ensure easy access for maintenance and inspection of the seal. Some seals require a certain clearance to the gearbox coupling in order to permit replacement of packing without disconnecting the shaft.

Water lubricated shaft seal

With water lubricated seal the water has two purposes, lubricating and cooling the seal. Water could be supplied to the water lubricated shaft seal in different ways.

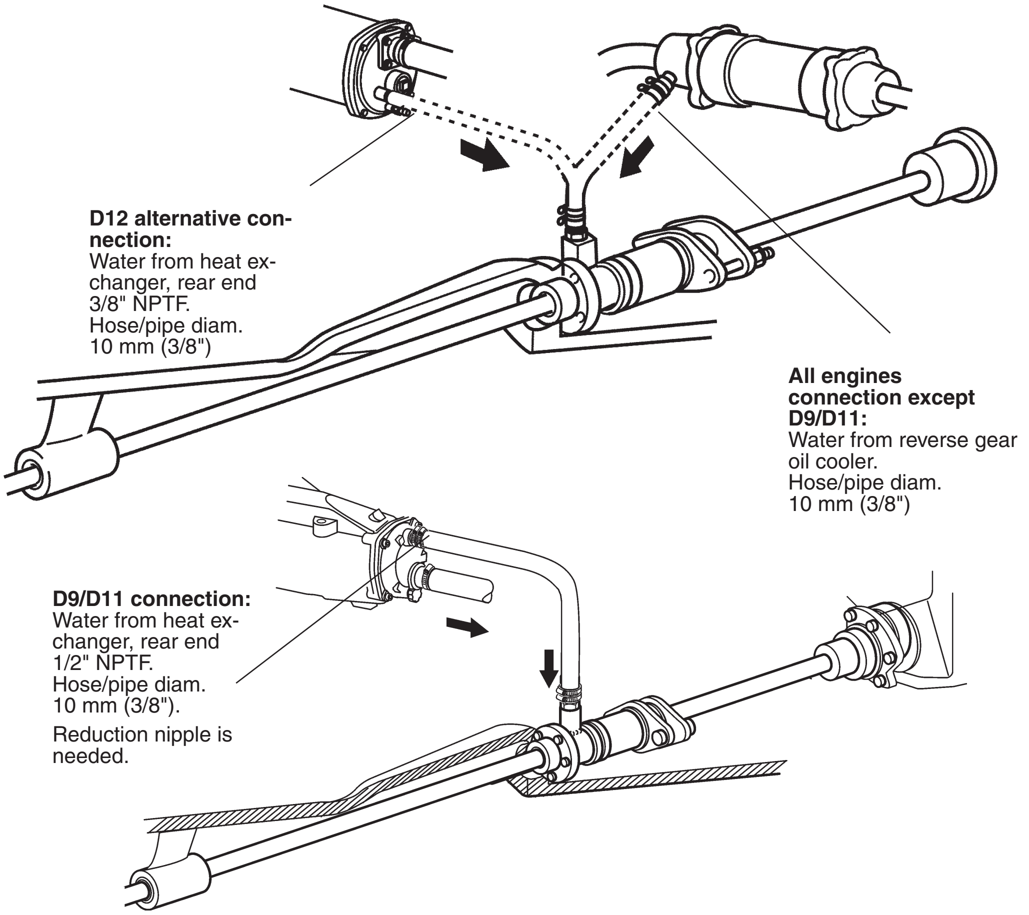
One way, which is suitable in displacement boats, is to feed it from water pick up pipes in the stern tube. The feed pipes should be designed to build up pressure through the boats motion in water.

It is important to check that the water lubrication is adequate, also at full speed, while test running a new installation. Make sure that the pipes (**2**) allow enough water to flow in.



1. Shaft seal
2. Water pick up pipes

Connection to gearbox oil cooler

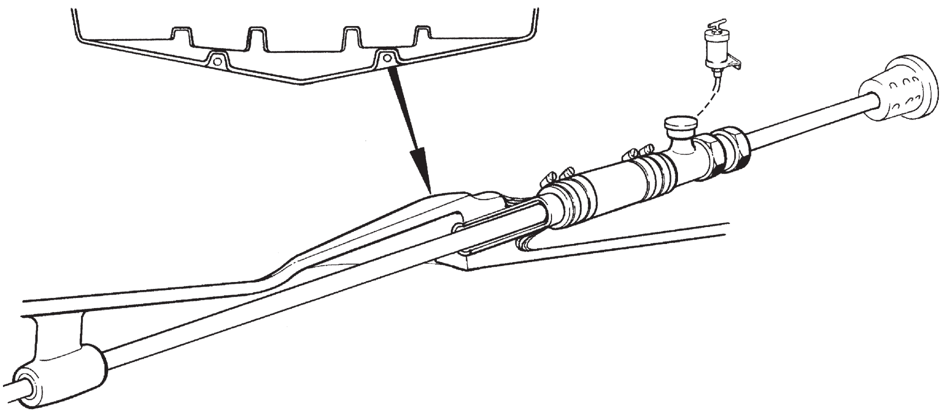


Another way, which is common in planing boats, is to feed the shaft seal with water taken from the cooling system of the engine. Make sure to take the water after the cooling circuit of the engine and not bleed off too much water in a boat with wet exhaust system. If too much water is lost through the outlet to the shaft seal, the exhaust hose might be overheated. A guideline is to install a 10 mm (3/8") hose from the reverse gear oil cooler.

It is important to check that the water lubrication is adequate, also at full speed, while testing a new installation.

NOTE! For D16, the oil cooler is delivered separately. For installation instructions, contact Volvo Penta.

Grease lubricated shaft seal

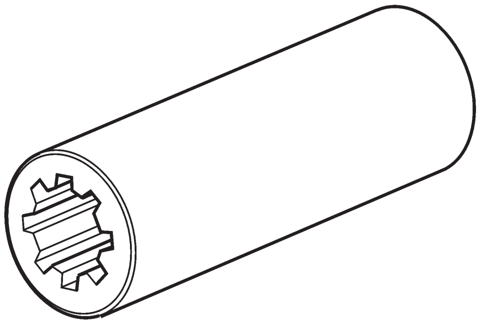


The grease is injected either with a grease cup fitted to the seal assembly or from a remote greaser. The bolt holding the seal should not be overtightened as this may cause overheating and excessive wear on the propeller shaft.

Shaft bearings

There are different types of shaft bearings. Choose the type which suits the application and use. The shaft bearings could be fitted in a propeller shaft bracket, front and/or rear end of the stern tube or in a separate support bearing.

Cutlass bearings



The most common type, especially for medium and faster boats. The bearing is made of rubber with a shell of brass. The design of the bearing is to create a film of water, upon which the propeller shaft floats. Normal play between shaft and bearing is 0,1% of the shaft diameter. Bearings fitted in, for example, p-brackets are normally self-lubricated but for bearings in stern tubes is it important to ensure the water supply.

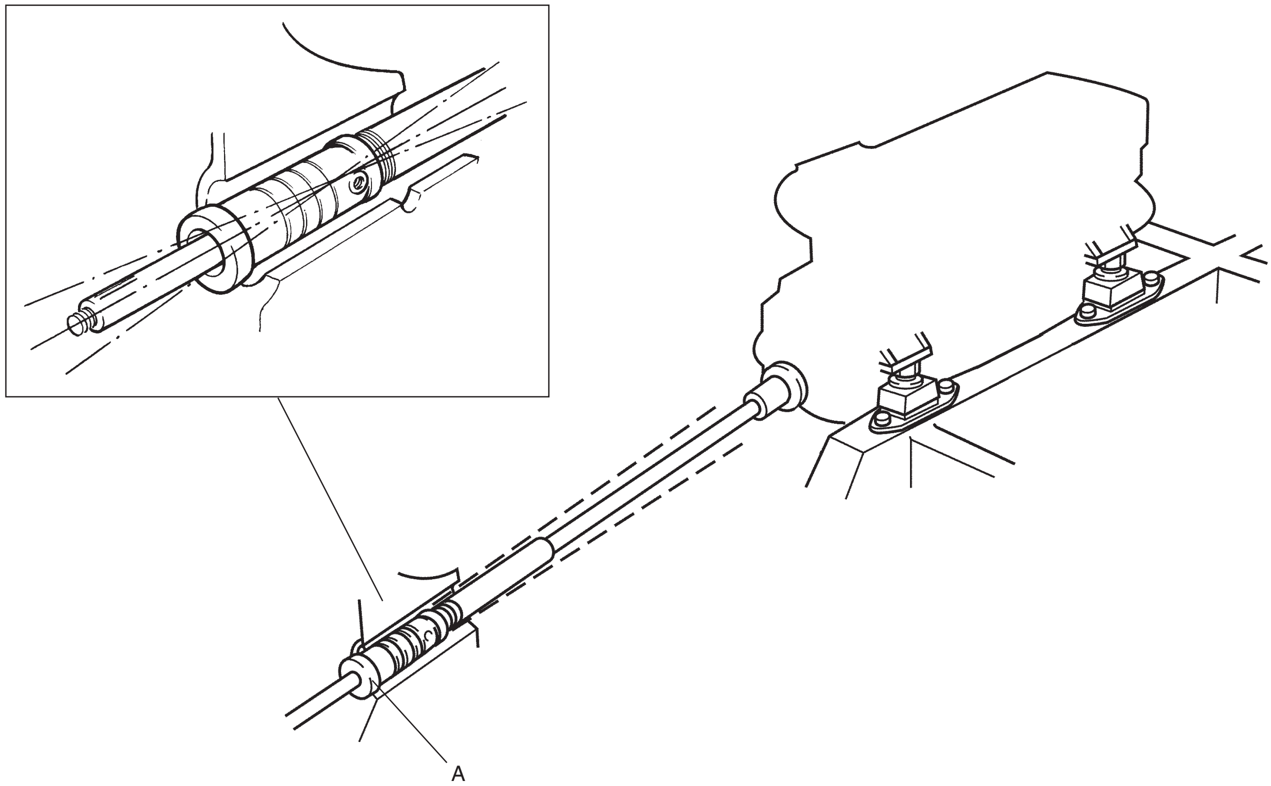
Metal bearings

Metal bearings are often fitted inside a stern tube or a separate support bearing and grease lubricated. They could be combined with grease lubricated shaft seals.

Bearing boxes

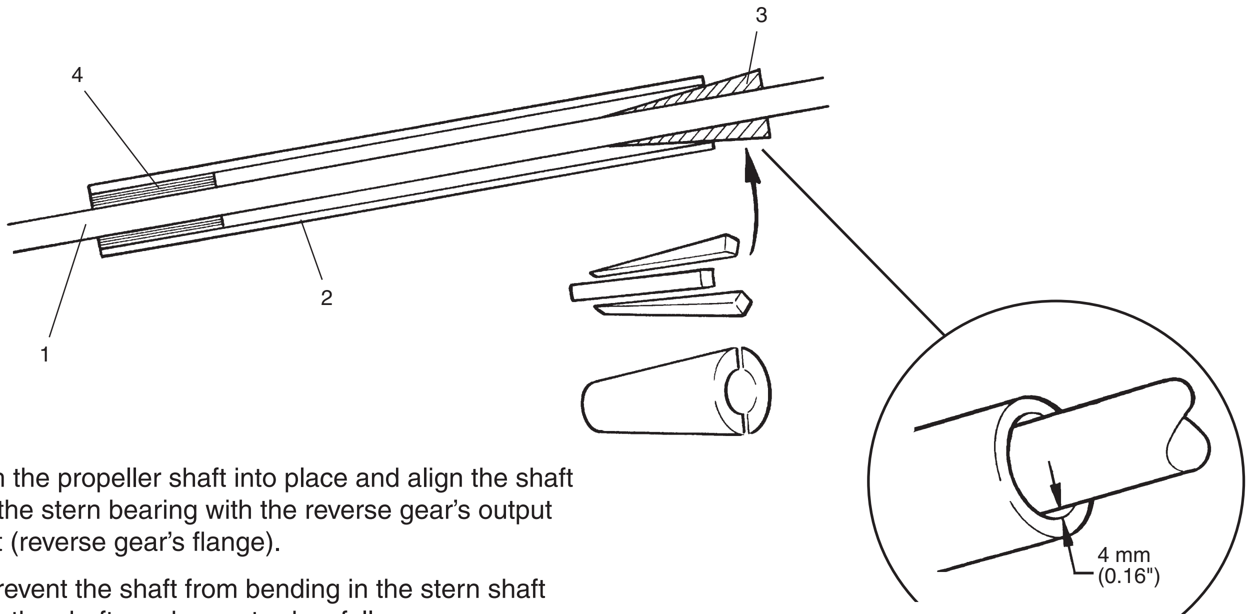
Bearing boxes use ball or roller bearings. The bearing box can be lubricated with grease or oil. Some bearing boxes can also take an axial thrust.

Installation of stern tube and shaft bearing



The fix point (A) is determined by required propeller size etc.The engine can be used as a fixture to decide the location of the stern tube and bearing. The engine must be adjusted to its nominal position.

In serial productio tailor-made fixtures are often used instead of the engine to locate the stern bearing.



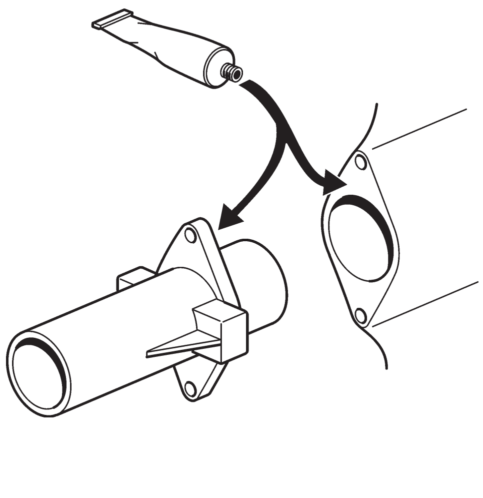
The clearance between the propeller shaft and tube for a flexible mounted engine should be min. **4 mm (0.16")**.

Push the propeller shaft into place and align the shaft and the stern bearing with the reverse gear's output shaft (reverse gear's flange).

To prevent the shaft from bending in the stern shaft tube, the shaft can be centred as follows:

- Install the shaft bearing (**4**).
- Centre the shaft (**1**) in the propeller shaft tube (**2**) using wedge-formed guides (**3**).
- Check that the shaft is not bent in front of the tube; support the shaft if necessary.

After alignment has carefully been done, the stern bearing can be bolted or bonded in place.

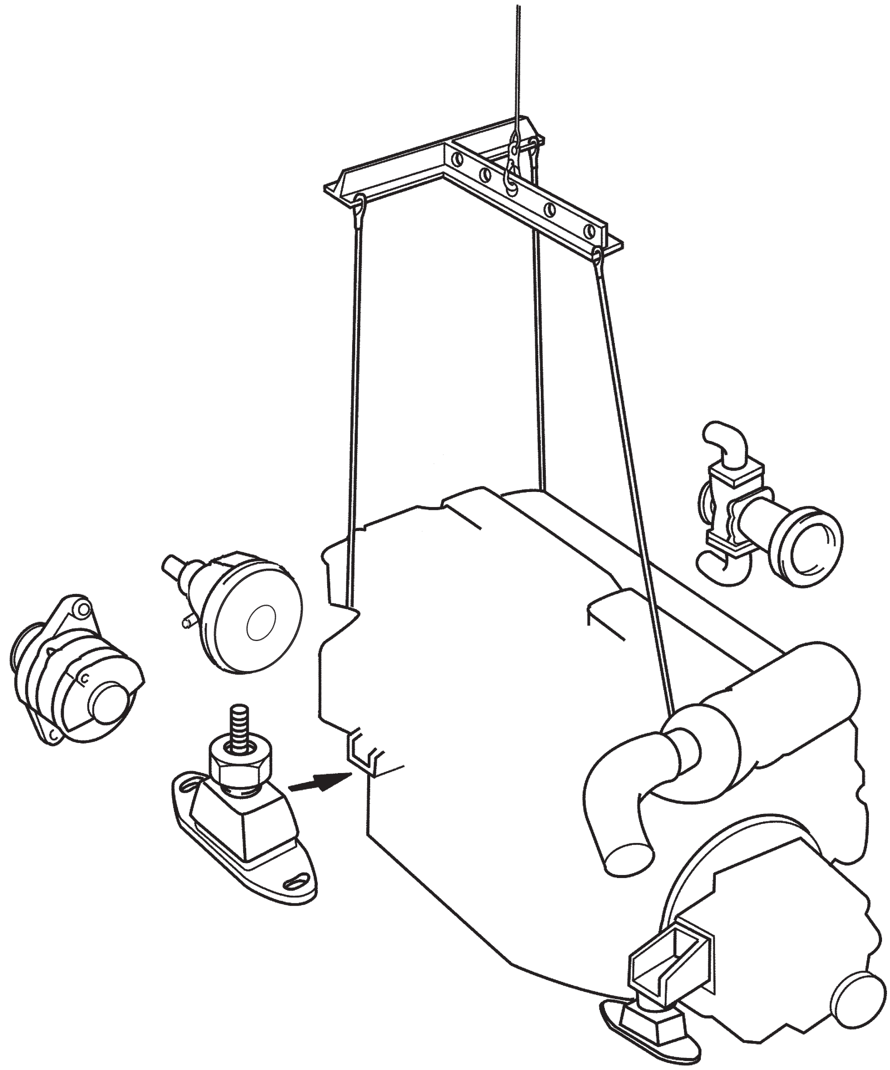


If the stern bearing is to be bolted to the stern, the contact surface for the bearing flange must be sanded flat first. Apply sealing compound, e.g. silicon rubber, and tighten the bolts holding the bearing.

NOTE! The alignment must be checked after bonding.

Engine installation

Preparing the engine



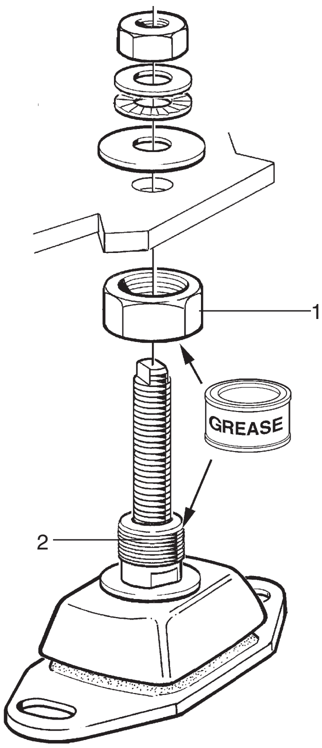
NOTE! Installations in the engine room for the cooling system, exhaust system, electrical system etc. should be as complete as possible before the engine is installed.

Install extra equipment and accessories on the engine, such as extra alternator, hot water outlet, power take-off etc. before engine is installed. The figure above shows a flexible mounted engine.

NOTE! All engines are delivered from Volvo Penta without engine oil and coolant. Check that the oil plug and draining cocks for coolant, hot water cocks etc. are closed.

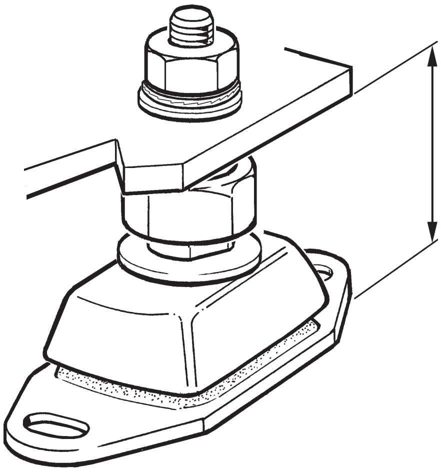
Fill oil and coolant. See chapters ***Coolant*** and ***Filling with coolant***. Check for leakages.

If the engine is flexible mounted:



Install the rubber mounts on the engine brackets.

Grease the adjusting nut (1) and adjusting screw (2). Use grease part no. 1141644.

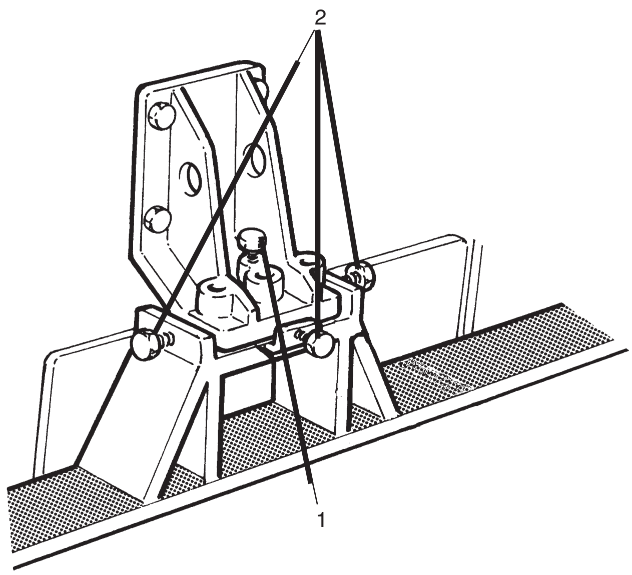


Adjust the rubber mounts to **nominal height** (A) without using tightening tools (see following pages).

Lift the engine into the boat and on to the bed. The lifting device should also be available when making the alignment to the propeller shaft later on.

If the engine is rigid mounted:

Lift the engine into the boat and on to the bed. The lifting device should also be available when making the alignment to the propeller shaft later on.



Install adjustment bolts for vertical adjustment (1) in the engine brackets. Tighten the bolts until they are in contact with the bed plane.

Install adjustment bolts for lateral adjustment (2).

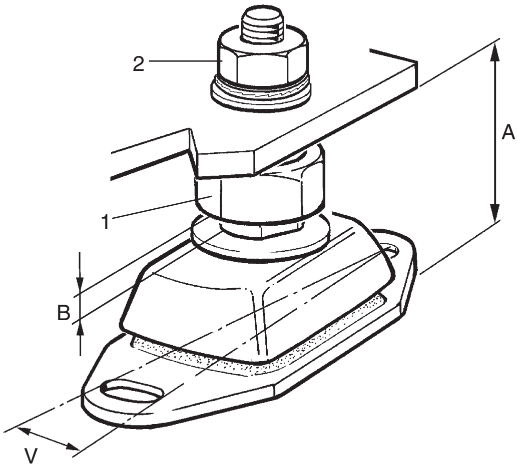
Flexible engine mounting

Installing the engine on the engine bed with mounts of type 1

Before adjustments can be made, the engine must rest on the rubber mounts for at least twelve hours but prefferrably more than two days.

Never use rubber mounts other than those intended for each particular engine type.

This chapter explains the procedure using a mount which is adjustable in the vertical plane with a nut. Mounts adjusted with shims follow in principle the same procedure, but use shims to adjust the engine height.



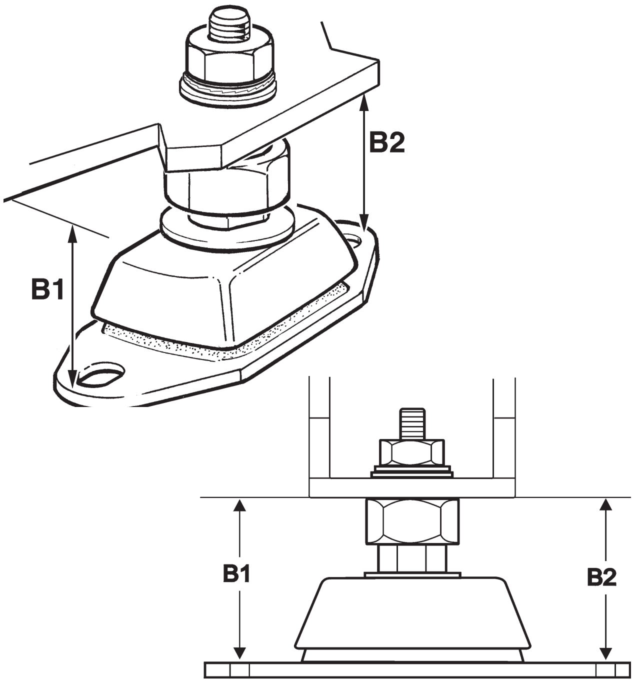
A = Nominal height
D12: 130 mm ±8 mm (5.1±0.27")
All other engines: 117 mm ±8 mm (4.6±0.31")

V = Lateral adjustment ±8 mm (0.30 ")
B = To verify height adjustment, 0-16 mm (0–0.62")

Height adjustment is carried out using the adjustment nut (1).

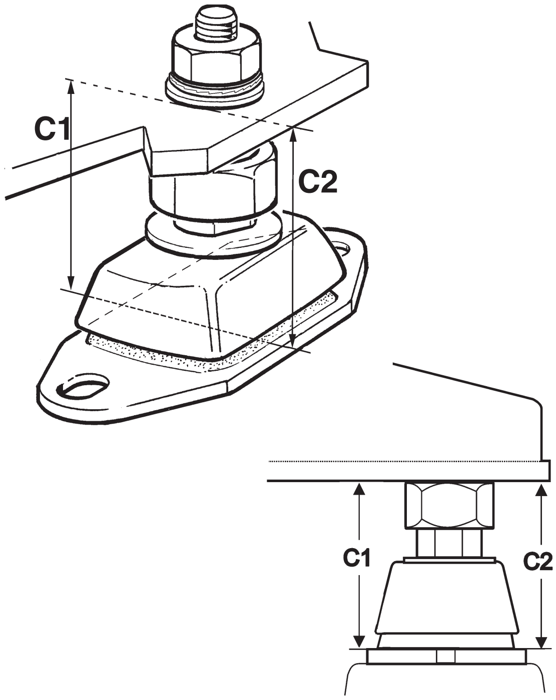
NOTE! Verify that the mount is not adjusted too high. The distance (B) between the big washer and the adjustment nut (1) must not exceed 20 mm (0.8").

Lateral adjustment is carried out using the slip-shaped holes in the base of the rubber mounts. These can be turned facing forward or backwards, whichever allows the best accessibility. The basic position of the rubber mounts is at the intermediate position with the base plate holes in the bed's longitudinal line.



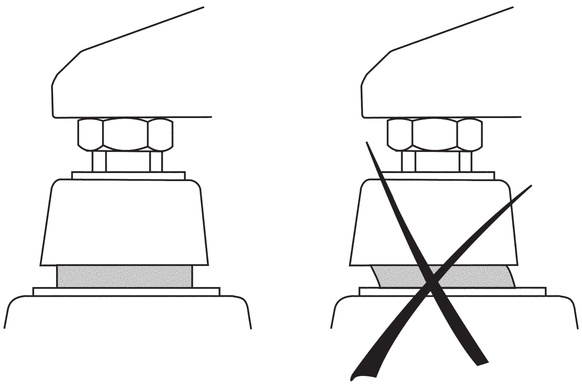
Check any deviation in engine bed parallelity.

Measure distances B1 and B2. The difference must not exceed 3 mm (0.12") for each rubber pad.

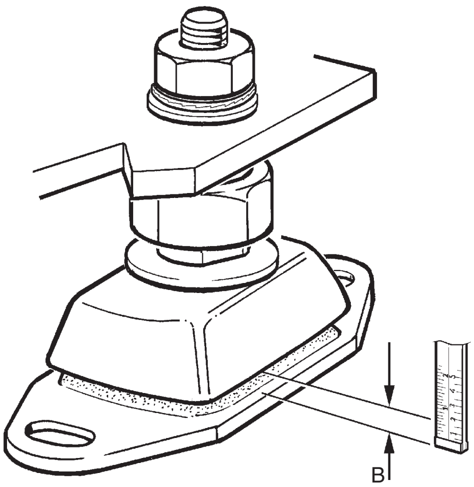


The difference between rubber pads must not exceed 1.5 mm (0.06") for dimensions C1 and C2. Angular misalignment between the bed plane and the engine brackets is adjusted by correcting the bed plane beneath the foot of the rubber pad.

Align the engine to the propeller shaft. See chapter ***Alignment***.

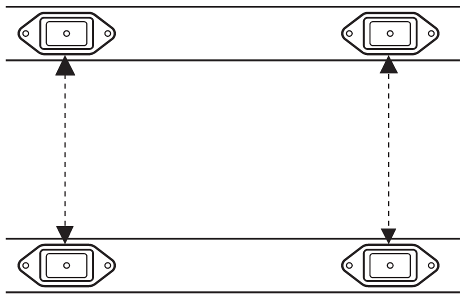


NOTE! Make sure that the rubber mounts are installed so that no pre-load or side forces occur after the engine has been installed and aligned with the propeller shaft.

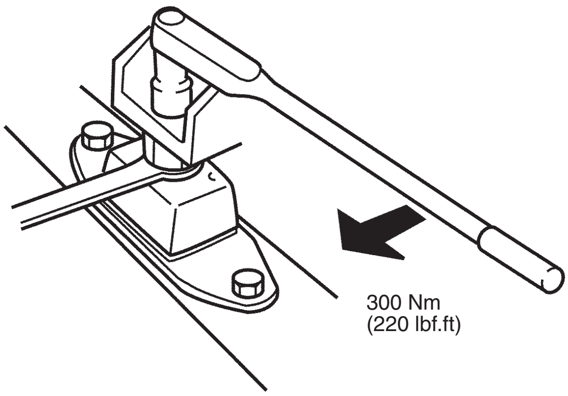


When the engine is installed, the load on the front pair of mounts as well as the load on the rear pair of mounts must be equal.

Measure the compression (B) of the mounts on all sides. The difference between port and starboard mount must not exceed 2 mm (0.08").



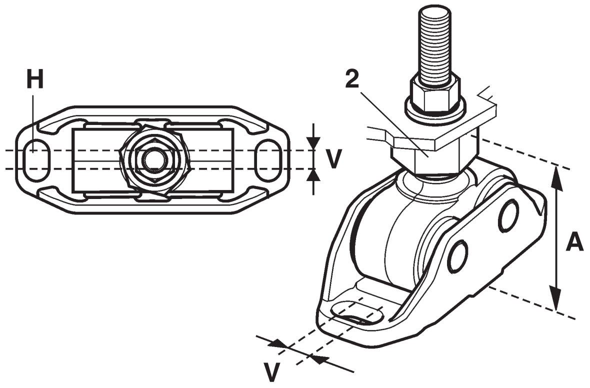
Compare front and rear mounts sidewise in pairs. Adjust as necessary.

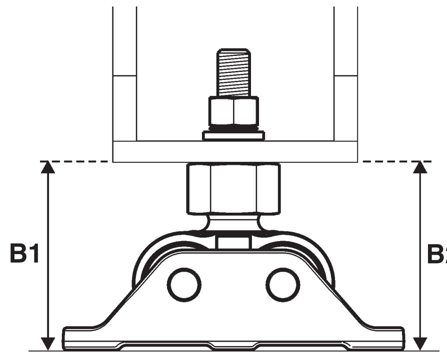


After alignment to propeller shaft and verification of engine bed parallelity and loading on mounts, tighten upper nut on engine mounts.

Tightening torque: **300 Nm (220 lbf.ft)**.

Installing the engine on the engine bed with mounts of type 2





Before installation, check that the engine bed is flat, as described in the applicable installation manual. The engine must have rested on the rubber mountings for at least twelve hours before any adjustments can be made.

Never use any type of rubber mounting, other than the ones which have been specially developed for the type of engine being installed.

The D12 mounts are delivered with a 15 mm (0.67") spacer to give the same install height as with the privious type of mounts.

Nominal height (excluding spacer):
115 ±10 mm (4.5 ±0.39")

Adjust the height with the adjustment nut (2).

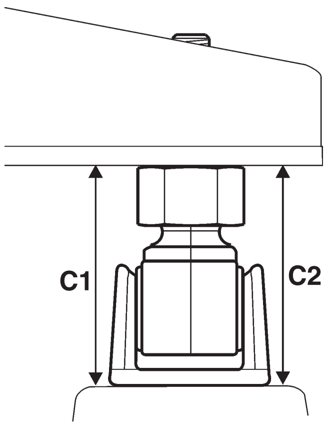
NOTE! The maximum height 125 mm (4.9") may not be exceeded

Side adjustment (V): ±7 mm (0.28")

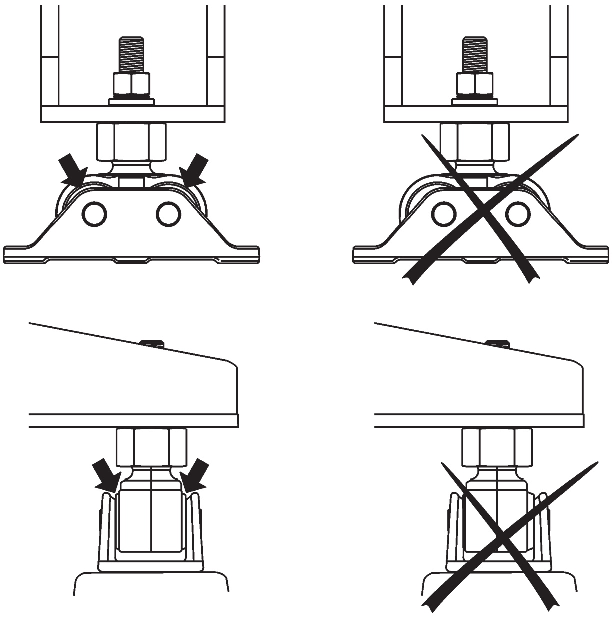
Side adjustment is done by using the slotted holes (H) on the base plate of each anchorage. To start off with, the rubber anchorages should be placed in the center of the slots, with the slots aligned parallel to the length of the engine bed.

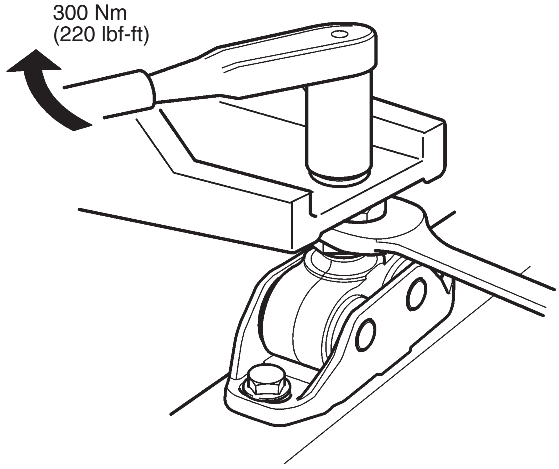
Check whether there is any deviation from parallelism in the engine bed.

Re-measure distances B1 and B2. The difference must not exceed 3 mm (0.12") in any anchorage.



Also measure dimensions C1 and C2 on the side edges of the rubber mountings. These must not exceed 1.5 mm (0.060"). Angle errors between the engine bed plane and the engine mountings should be adjusted by correcting the bed plane under the feet of the rubber mountings.

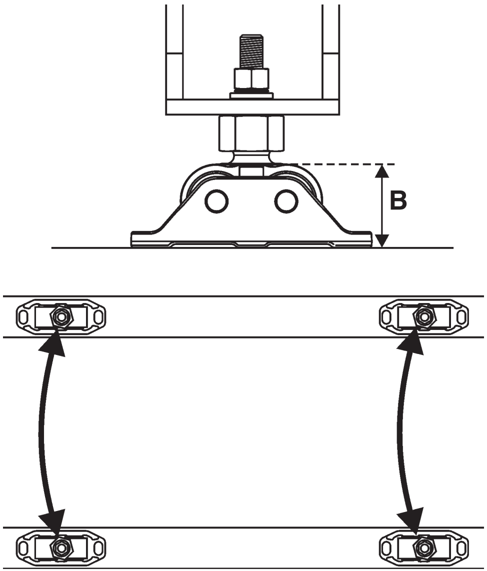




NOTE! Check that the rubber mountings are installed so that they are not left under tension or side forces when the engine has been installed and aligned in relation to the propeller shaft.

Tighten the top nut on each engine bed after alignment in relation to the propeller shaft. Check parallelism of the engine bed and check the loading of the mountings.

Tightening torque: **300 Nm (220 lbf.ft)**.

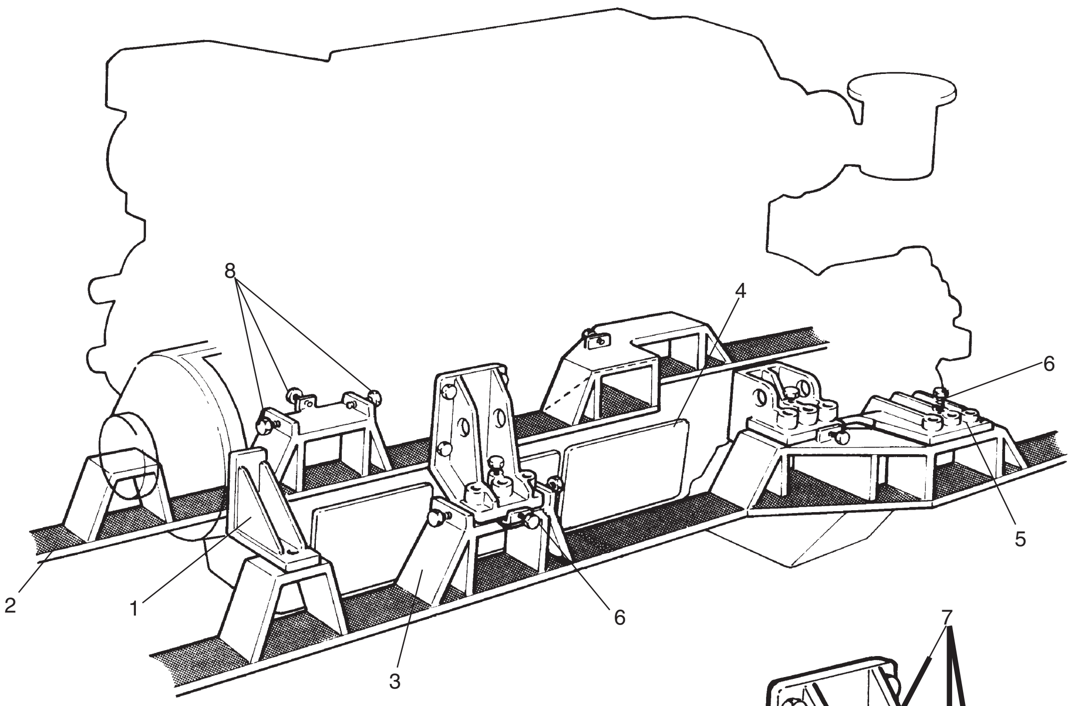


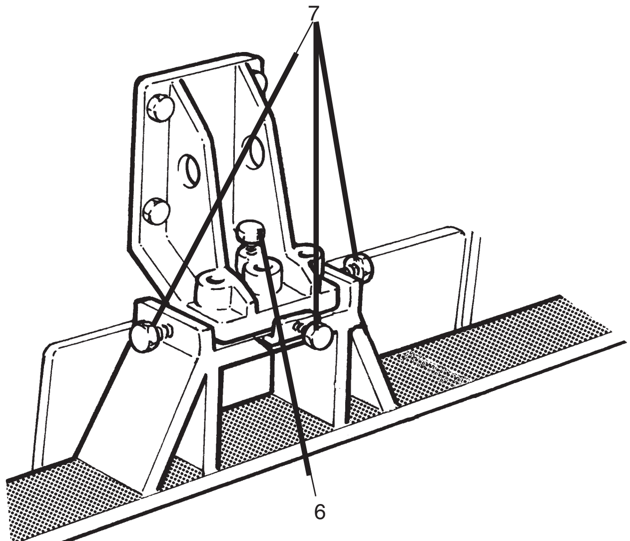
When the engine has been installed, the two front mountings should be equally loaded, as should the two rear mountings be.

Measure the compression (B) of the engine mountings on each side. The difference between port and starboard mountings must not exceed 1 mm (0.04").

Compare the sideways alignment of the front and mountings of the front and rear mountings as pairs. Adjust as necessary.

Rigid engine mounting





1. Support bracket for front power take-off
2. Steel bed frame
3. Front mounting bracket
4. Inspection covers
5. Rear mounting brackets
6. Adjustent bolts (4 pcs) for engine vertical position. To be removed after completed installation
7. Bolt to adjust engine lateral position

Make a rough alignment of the engine to the propeller shaft with adjusting bolts (7, 8). Always attempt to have even load on the height adjustment bolts (8) on port and starboard side.

Make the final alignment see chapter ***Alignment***.

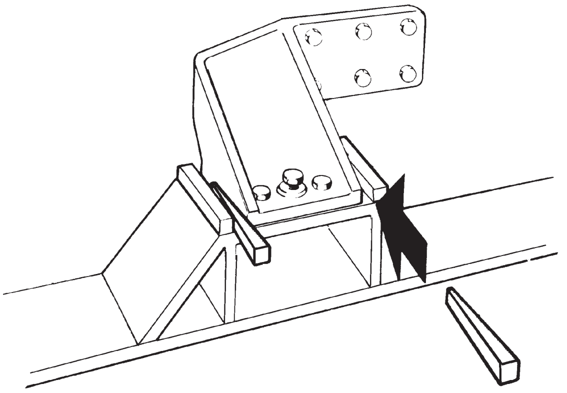
Verify that there is some space clearance between the bed and the engine brackets for later alignments.

Check that the engine is standing on all four height adjustment bolts (6) using a 0.10 mm (0.04") filer gauge. Try also to obtain an even load on the two bolts on the front port and starboard bracket as well as the two bolts on the rear port and starboard bracket.

Fixing positions

After final control and possible alignment and adjustment, the engine and reverse gear must be fixed in their correct locations with the aid of either wedges or tapered guide pins. Holes are drilled through diagonally opposed engine and reverse gear brackets and the bed. A suitable size for the tapered guide pins is 0.3-0.4" = 8-10 mm.

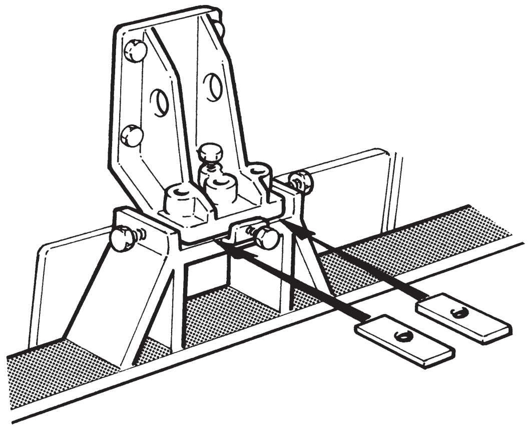
NOTE! This description is general. For more detailed information see installation drawings for each engine.

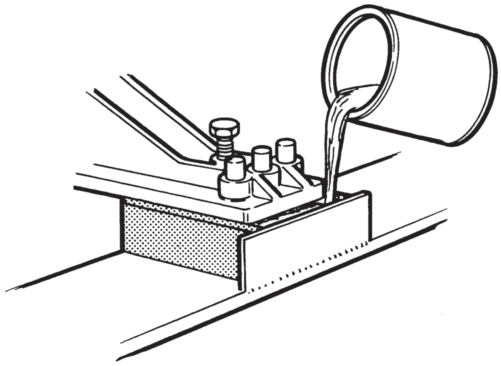


If wedges are used, which is recommended for commercial use, the wedges must be welded and the surplus part cut off.

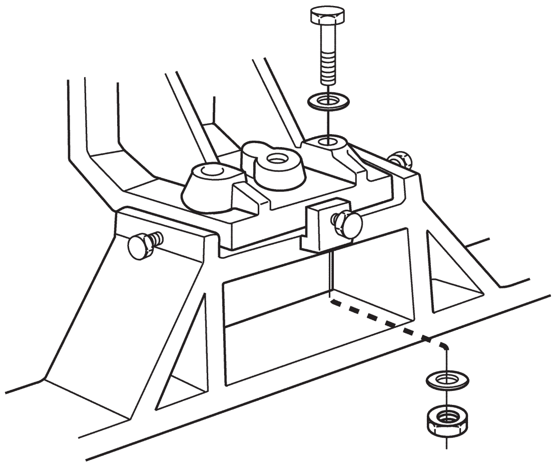
After the boat has been taken into use, check at regular intervals to ensure that no change has occurred in alignment due to changes in the shape of the hull.

Poor alignment between the engine and the propeller shaft can cause vibrations in the hull, reverse gear damage, rapid wear of propeller shaft thrust bearings, propeller shaft, bearing sleeve, etc.





After the correct amount of shims have been added or the moulding compound has hardened but before tightening the bolts check with a filer gauge that the clearance is less than 0.10 mm (0.00394").



Tightening torques, 8:8 :

Bolt dimension	Nm	(lb.ft.)
12 mm	80	(59)
14 mm	140	103)
16 mm	230	(170)
18 mm	300	(220)
20 mm	440	(324)
22 mm	600	(442)
24 mm	750	(553)

Alignment

When the bed frame is finally in position, the propeller shaft installed and other preparatory work completed, the engine and reverse gear can be installed.

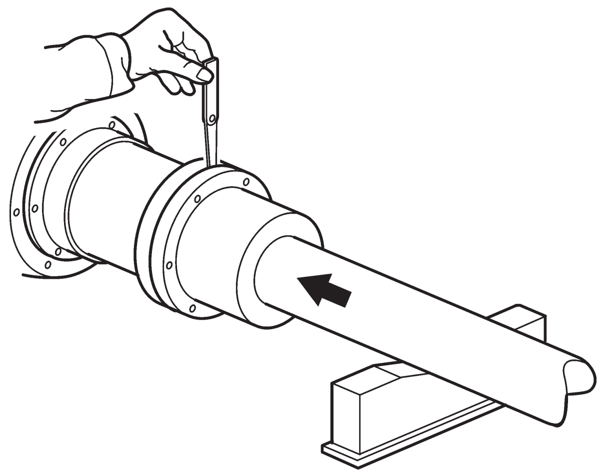
Engines with a closed coupled reverse gear are lifted into position together with their gears.

The first alignment of the engine can be made no matter whether the boat is ashore or afloat. Before final alignment is started, however, the boat should have been afloat for some days so that the hull is subjected to the loading it has in its final form.

Checking flanges

There are two ways of making the alignment:

Method 1



Checking parallel position of flanges
1. Feeler gauge with thickness of 0.1 mm (0.004").

Check that the propeller shaft flanges are parallel as shown in the figure above. Move the flanges together so that the guides engage with each other. Then check, with the flanges pressed against each other, that they are parallel so that it is not possible to insert an 0.1 mm (0.004") feeler gauge at any point between the flanges. Then turn the flanges through 90°, 180° and 270° and repeat the check in the new positions.

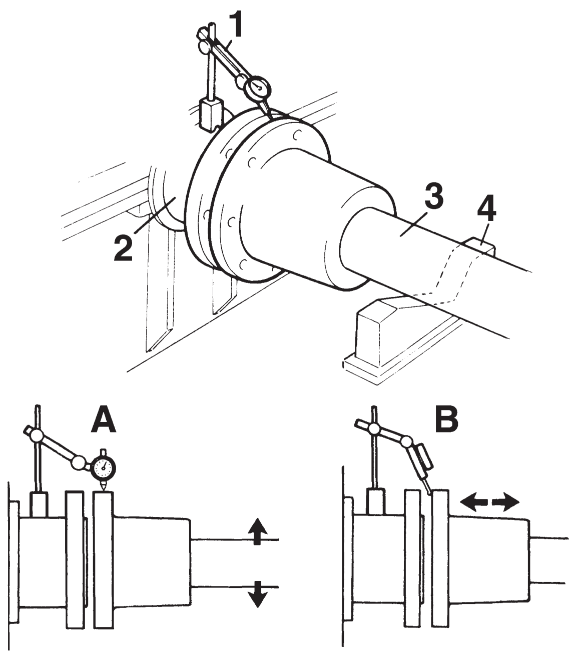
NOTE! Make sure that the flanges are pressed against each other throughout the entire check.

When the engine is fitted on rubber mountings, alignment must be carried out with the same care as in the case of fixed mountings.

⚠ **IMPORTANT!** The alignment should be rechecked a few days after launch with the boat completed and rigged (sailing yachts).

Method 2

This method is normally more accurate but requires enough space to turn the dial indicator around fitted to the reverse gear flange.



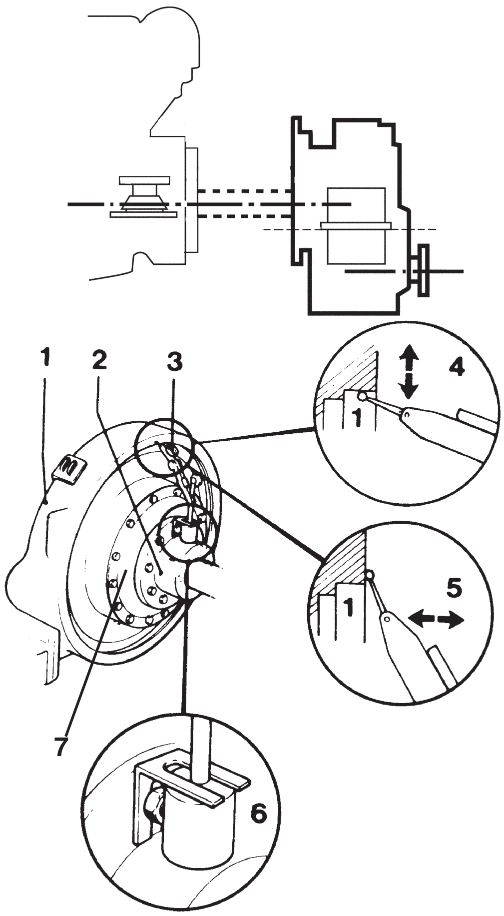
1. Dial indicator with magnetic foot
2. Flange on reverse gear
3. Propeller shaft
4. Support
A. Checking radial deviation
B. Checking axial deviation (rocker gauge)

The flanges are checked using a dial indicator as shown in the figure above.

The propeller shaft must then be pushed aft by about 10 mm (0.4") and well supported so that the shaft is thoroughly centred. The shaft must also be fixed axially.

Turn the reverse gear flange and first measure the radial deviation as shown at A. Adjust the reverse gear position, then measure the axial deviation according to B with a rocker gauge against the flange contact surface. The greatest permissible deviation in both cases is 0.1 mm (0.004").

Remote reverse gear, alignment



1. Engine flywheel cover
2. Hub on flexible coupling
3. Dial indicator
4. Measurement of radial throw (max 0.008" = 0.2 mm)
5. Measurement of axial throw (max 0.008" = 0.2 mm)
6. Attachment of dial indicator foot
7. Elastic coupling

Drill all the holes for the brackets, fit the shims or spacers and then tighten the engine and reverse gear in position. Make sure that all adjuster bolts for the vertical position are unscrewed so that the brackets rest on the shims or spacers. The adjuster bolts are then removed.

After the boat has been launched, check alignment once again. The boat should have been in the water for some days and should be loaded with all the tanks full. The hull is always flexible and does not have the same shape when laid up ashore as when it is floating in the water.

If subsequent adjustment is necessary, brass shims can be placed under the brackets.

Fuel system

General

Installation of the fuel system components - fuel tanks, cocks, fuel piping and extra fuel filters, etc., must be carried out very carefully to assure the engine has a sufficient supply of fuel and that demands concerning perfect sealing and fire safety are satisfied.

Plan the location of the tanks very carefully before starting work. Use good quality cocks to avoid fuel leakage. A leaking fuel system always implies a great risk of operational disturbances and the danger of fire.

Utilize high grade material and high quality components.

The cocks should preferably be fitted outside the engine room or be remote controlled.

The amount of fuel can be subdivided between several tanks to keep the centre of gravity low and also provide certain trimming possibilities for the hull.

If the tanks are built in, the surrounding space should be provided with ventilation.

NOTE! Local legislation may apply which in all override the engine manufacturers literature and recommendations.

Be sure not to bend the high pressure pipes between injection pump and injectors and do not stand on the engine due to risk of bending the high pressure pipes.

Do not clamp anything to the high pressure pipes, and keep the original clamping intact on the engine. Otherwise there will be a risk of broken pressure line and fire.

When working with the fuel system it is important to keep it free from dirt.

Fuel tanks

If possible, the tanks should be located so that they are at the same level or somewhat higher than the engine. If they are placed lower, due attention must be paid to the maximum suction height of the feed pump which is 1.5 m (4’9") for D5/D7 and 2 m (4’9") for all other engines. Note that the suction height must be calculated from the lower end of the suction pipe, i.e. 25 mm (1") above the bottom of the tank.

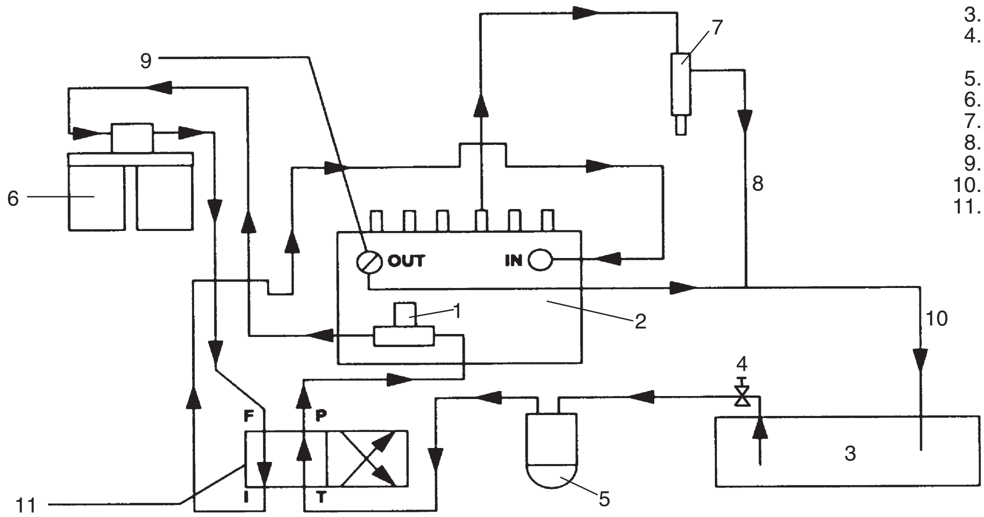
The return pipe should be installed about 10 mm (0.4") above the tank bottom and minimum 300 mm away from the suction pipe, to prevent air from entering when the engine is switched off.

If the tanks are located lower than the level permitted by the suction height of the fuel feed pump, then the fuel is to be pumped up to a day tank by means of a hand pump or power pump. Return fuel from the engine is taken in this case to the day tank.

Shut-off valves should be fitted on the fuel and return line, if the fuel tank's maximum level is higher than 2.5 m (8'3") for D5/D7 above the injection pump of the engine . For D9/D11/D12/D16 engines it must not be higher than the cylinder head of the engine.

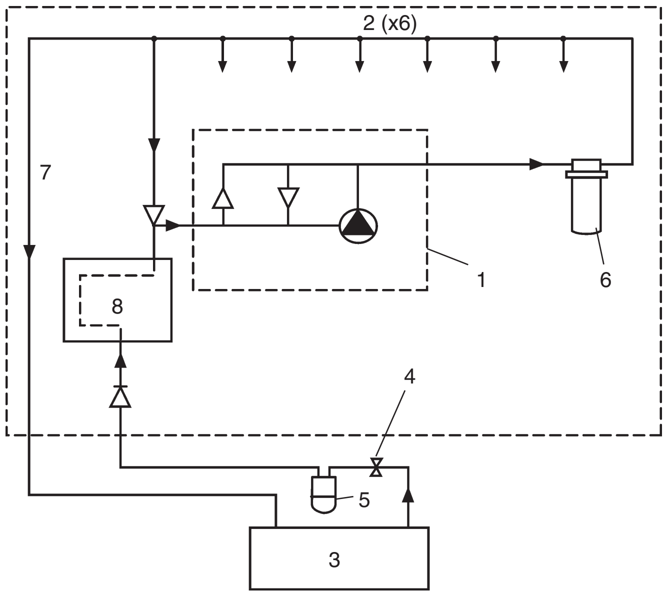
The valves should be shut off during permanent engine stop. There is otherwise a risk that fuel may leak through the injection pump to the lubricating system.

Example of fuel system, D5/D7



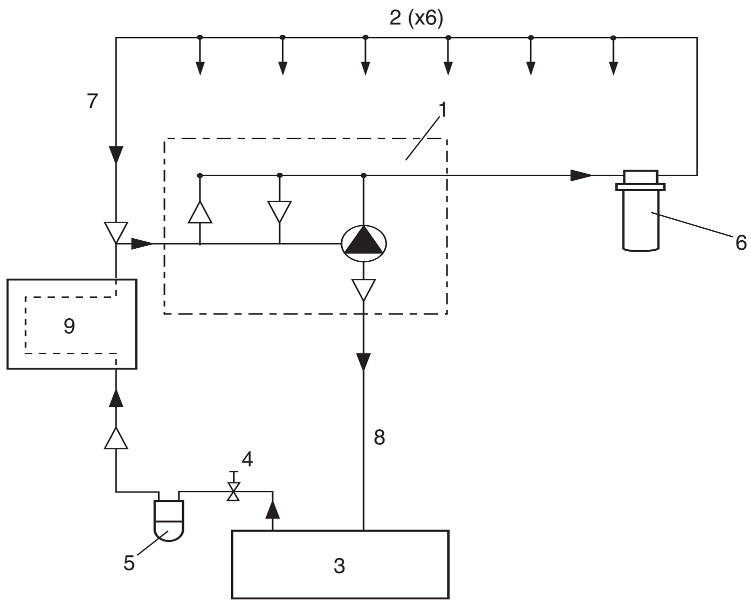
1. Feed pump
2. Fuel injection pump
3. Fuel tank
4. Shut-off valve (optional, se section 'Fuel tanks')
5. Primary filter and water separator
6. Fuel fine filter
7. Injector
8. Leak off line
9. Overflow valve
10. Return to tank
11. Engine stop valve

Example of fuel system, D9



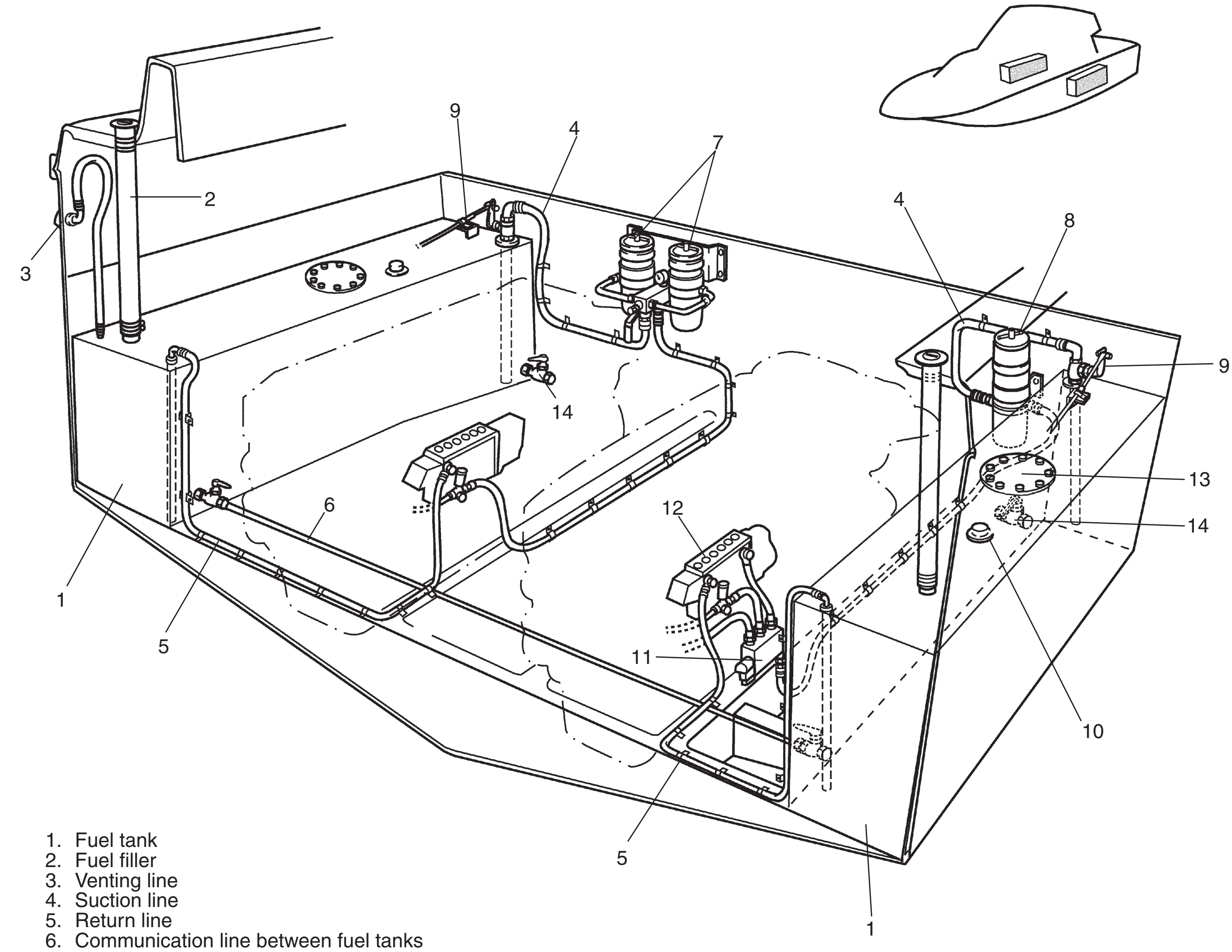
1. Feed pump
2. Injector unit (6pcs)
3. Fuel tank
4. Shut-off valve (optional, se section 'Fuel tanks')
5. Primary filter and water separator
6. Fuel fine filter and water separator
7. Deaeration line (Return to tank)
8. Electronic Control Module (ECM)

Example of fuel system, D12



1. Feed pump
2. Injector unit (6pcs)
3. Fuel tank
4. Shut-off valve (optional, se section 'Fuel tanks')
5. Primary filter and water separator
6. Fuel fine filter and water separator
7. Leak off line
8. Return to tank
9. Electronic Control Module (ECM)

Double fuel tanks



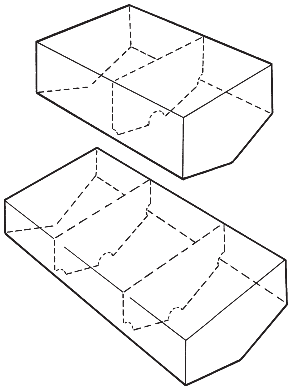
1. Fuel tank
2. Fuel filler
3. Venting line
4. Suction line
5. Return line
6. Communication line between fuel tanks
7. Double fuel pre-filter
8. Single fuel pre-filter
9. Remote controlled fuel shut-off valve
10. Fuel level gauge
11. Fuel shut-off valve, engine
12. Injection pump (not D9/D12/D16)
13. Inspection hatch
14. Draining cock

Double tanks as shown in the figure should be connected at bottom by means of pipelines fitted with shut-off cocks. The lower connecting pipe should have an internal diameter of at least 1" so that the tanks can be filled from either side of the boat. Other fuel tank shapes that are adapted to the installation geometry are of course acceptable. Whatever shape is chosen, it is important to design the tank to provide a low part where water and sludge can be drained

NOTE! An extra fuel filter with water separator must be installed for all Volvo Penta engines.

If a day tank is installed, then it is advisable to connect the return line to this tank.

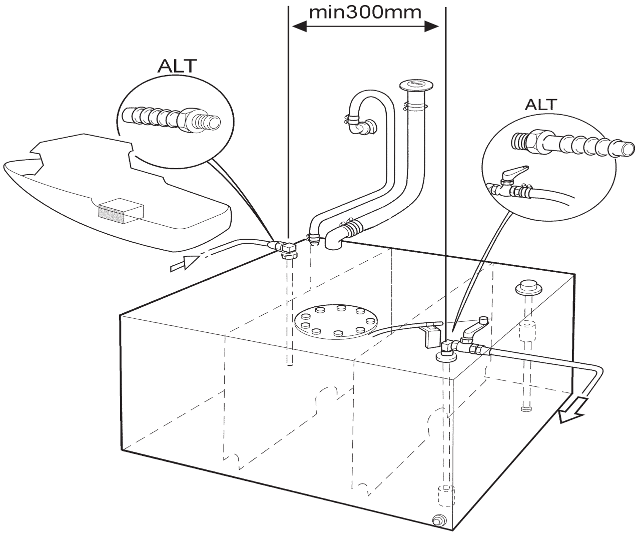
A shut-off valve must be installed in the supply pipe, between the tank and the filter. This tap should be able to be shut from a location outside the engine room.



Stainless steel or aluminum sheet metal is a suitable material for fuel tanks.

NOTE! All tanks must be provided with at least one baffle plate for each 150 litres (37 gallons) of volume. Check if there are special restrictions about volumes and baffle plates.

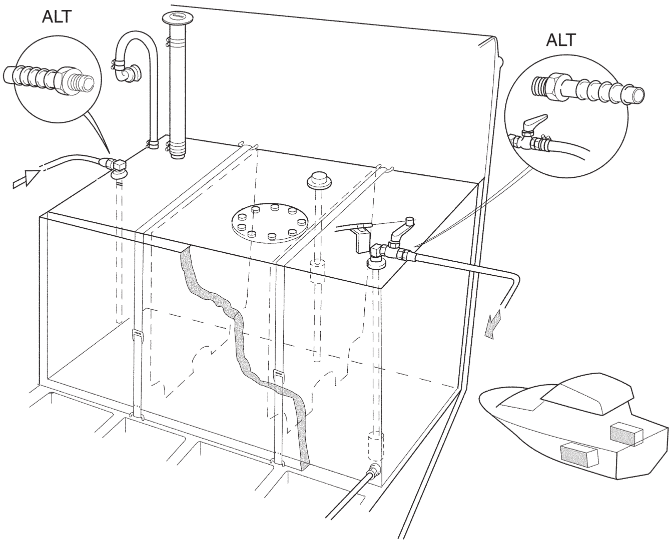
Filling and venting connections must **not** be positioned on the side of the tank.



The fuel tank has connections for filling, venting, suction line, return line, sender for tank gauge and an inspection hatch with cover. The suction line and the return line should be separated as shown in the figure to prevent air and hot fuel from the return line to be sucked back into the engine.

A shut-off valve must be installed in the suction line as close to the tank as possible. The shut-off valve may have a remote controlled shut-off function by means of a push-pull cable for example. Certain markets require electrically controlled shut-off valves.

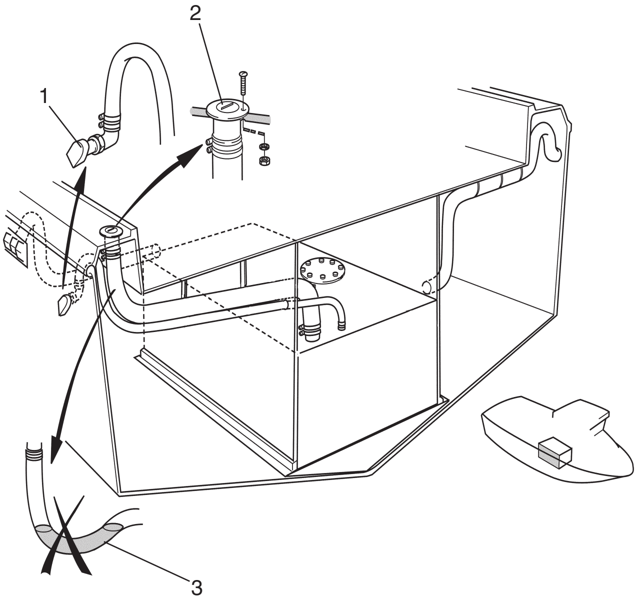
The fuel return line on diesel engines must be drawn back to the bottom of the tank in order to avoid air from entering the fuel system when engine is stopped.



Position the tank on some kind of soft bedding. Do not position the tank on wooden blocks or on other type of uneven bedding. This might cause abnormal stresses with subsequent risks of cracking in the tank.

Install the fuel tank in the boat. Secure the tank by clamping, to prevent it from moving in rough sea. The tank shouls be located in a cold compartment of its own in order to avoid heating of the fuel or spreading of the fuel to other parts of the boat in case of leakage.

In boats where space is at a premium, the tank can be tailored to suit the space underneath the gunwale or some other similar space.



The tank must be properly vented. The tank venting line (1) should have an inner diameter of minimum 12 mm (1/2"). Raise the hose internally to create a water lock.

The filler fitting (2) should be adapted for a minimum 50 mm (2.0") hose connection. The hose between the deck fitting and the tank must overlap the tubing at either end with at least 75 mm (3.0") and be locked with two hose clamps. The hose clamps must be made of a corrosion-resistant material.

Common ground for the fuel tank, filling etc. is not generally necessary for diesel installations. Local authorities, however, could demand this on boats in general.

NOTE! Install the filler and venting hoses, preventing traps (3) being formed.

NOTE! The fuel filler fitting and venting must be installed in a way that prevents overfilling and fuel entering air intakes.

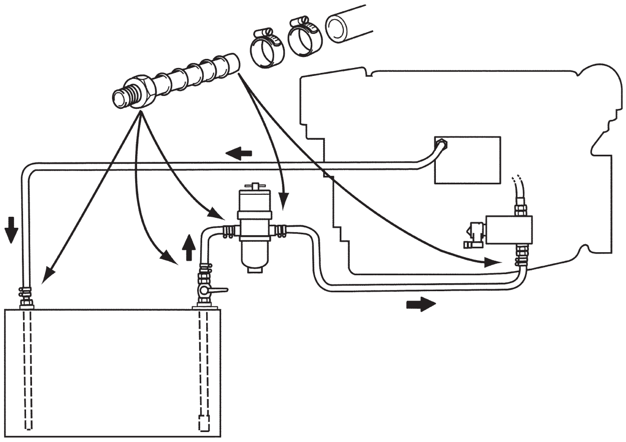
Piping

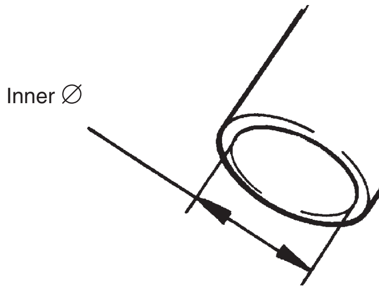
All fuel lines should be led and properly clamped near bottom of the boat to avoid heat radiation.

NOTE! The D5 and D7 has a high fuel flow and therefor must the fuel lines have a large diameter. To small piping will reduce the power output.

Rubber hoses

The figures show the most common types of connections for fuel pipes. Make sure to use the correct dimension of approved flexible hose.





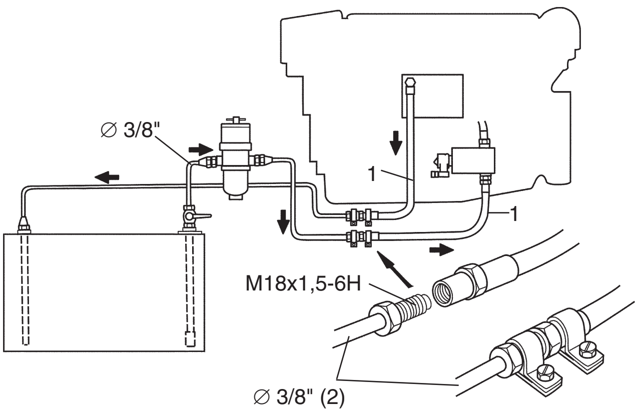
From tank to fuel line connection point

	<6 m (20')	**>6 m (20')**
D5/D7	12 mm (1/2")	14 mm
D9/D11/D12/D16	10 mm (3/8")	10 mm (38")
Fuel return line dimensions		
All engines	10 mm (3/8")	10 mm (3/8")

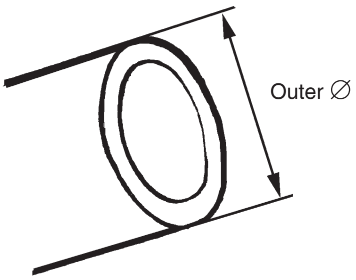
NOTE! Classification Societies and some registration bodies (i.e. river authorities) do not permit rubber hoses for fuel lines, or require hoses to conform to certain specifications. Check if the boat is to be used in these areas.

Clamp the fuel line. Distance between clamps should be approx. 300 mm (12").

Copper piping



The figure shows a transition from flexible fuel hoses (1) to copper pipe (2). Thread M18x1.5.



Required minimum copper pipe diameters, see table below.

From tank to fuel line connection point

	<6 m (20')	**>6 m (20')**
D5/D7 D9/D11/D12/D16	14 mm 10 mm (3/8")	16 mm 12 mm (1/2")

Fuel return line dimensions

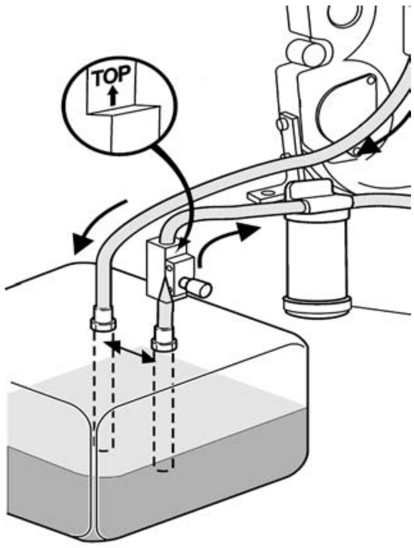
D5/D7 D9/D11/D12/D16	12 mm (1/2") 10 mm (3/8")	12 mm (1/2") 10 mm (3/8")

Clamp the fuel line. Distance between clamps should be approx. 300 mm (12").

Priming pump for D5/D7

D5/D7 has no engine mounted priming pump. To be able to vent the fuel system, if the tank is located below the engine, a prime pump must be installed on a bulkhead or similar between fuel tank and prefilter.

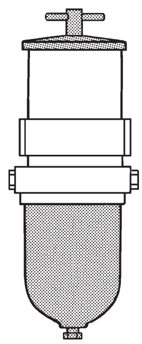
NOTE! It's important to install the pump with the arrow upwards according to the picture below.

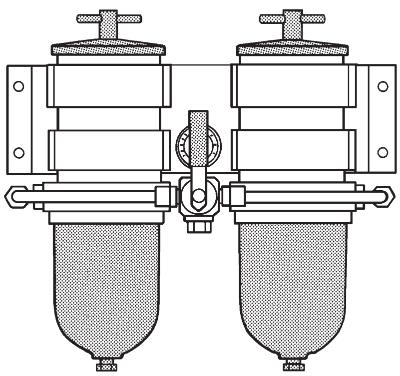


Fuel pre-filters

Single or double filters

The filter shall be installed on the suction side of the feed pump, between the feed pump and the fuel tank, and should be located at a height between the base of the fuel tank and the feed pump, to reduce the resistance in the supply pipe.





Install the filter vertically on a bulkhead or bracketing, where it is not affected by engine vibration and in such a manner that it is protected as much as possible from fire in the engine room. The location should also facilitate inspections and insert replacement.

⚠ **IMPORTANT!** Always select a fuel filter for the correct fuel flow quantity. D5/D7 has a high fuel flow quantity.

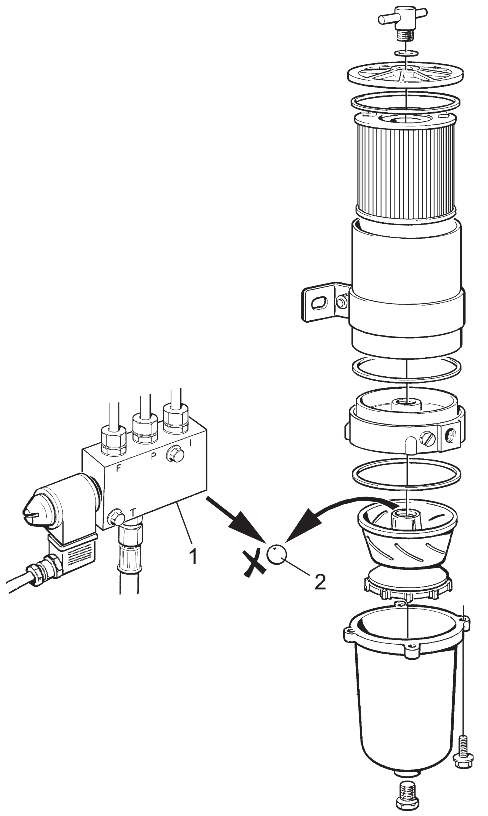
NOTE! Free space is required above the filter lid to permit the insert to be changed, min. 130 mm (5") up to 260 mm (10") depending on type of filter.

Classified installations and sometimes local authorities demand fire resistant material in the fuel filters. Sightglass made of glass or plastic might not be approved.

Filtration

Three progressive stages – separation, coagulation and filtration ensure that fuel arrives at the engine free from contamination. Water and other impurities are collected in the bowls beneath, from where they can be simply drain off by means of a drain valve. Recommended filter insert 10 micron to have an even change interval between engine mounted filter and the pre filter.

The double filter has a pressure gauge showing the pressure drop. The flow can be directed through left-hand, right-hand or both filters, thus making it possible to change filter elements with the engine running.



The filter thereby complies with Classification Association standards for propulsion engine fuel systems.

NOTE! When fuel pre filters are used together with a fuel shut-off valve (1), the non-return valve (2) in the fuel pre filter must be removed if fitted. See figure.

If this is not done, the stop fuction will not work because there will not be sufficient negative pressure in the injection pump.

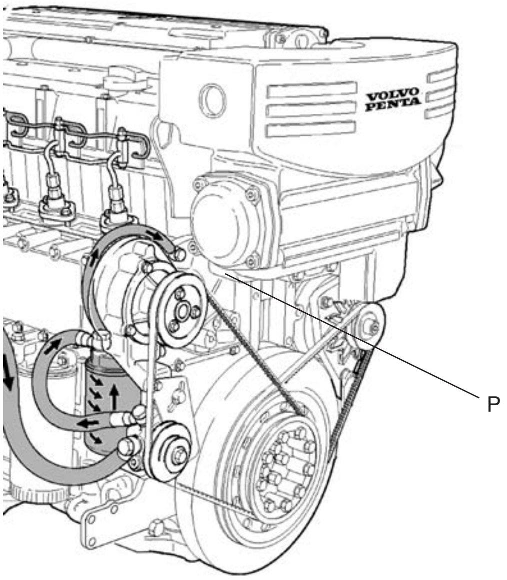
Checking feed pressure

The pressure is measured after the fuel has passed the filter cartridge.

When checking, engine speed is first increased, after which the speed is reduced so that the pressure can be read off at low idling speed. The feed pressure must not be less than 280 kPa (40.6 psi) for D5/D7 & D16, 300 kPa for D9/D11 and 100 kPa (14.5 psi) for all other engines.

Low feed pressure may be the result of a blocked filter, defective overflow valve or defective feed pump. Ensure that the components follow recommendations and do not cause the excessive pressure level.

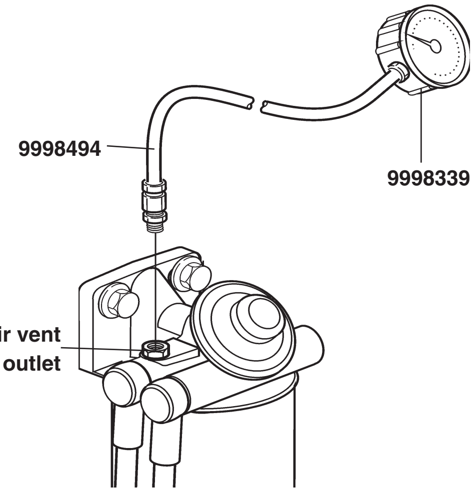
NOTE! The overflow valve must not be adjusted. Replace the valve if necessary.



D5/D7:

Measure the feed pressure at the fuel inlet hollow screw on the front of the engine block (P), by using manometer **999 6398** with nipple **999 6066** and a long hollow screw (44 mm) with a new copper washer (969011).

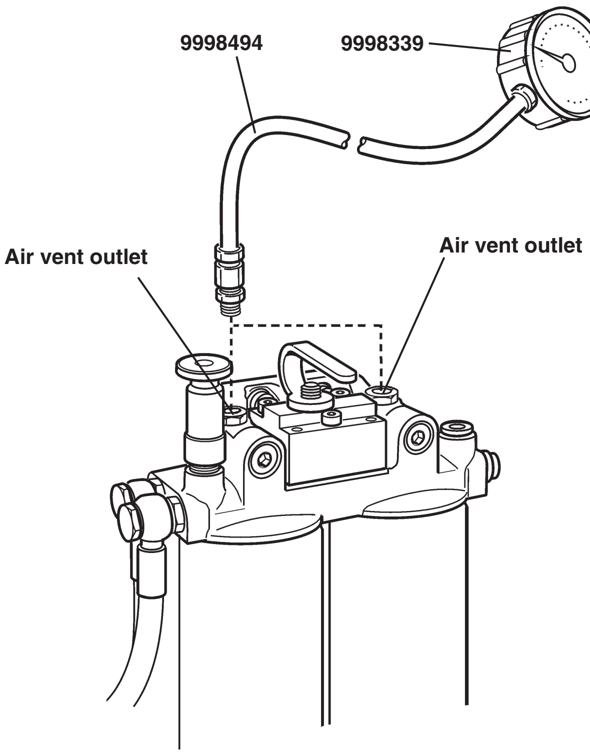
NOTE! The feed pressure shold be **min 280 kPa** (40.6 psi)



D9/D11/D12/D16:
The hose and nipple **999 4894** and the manometer **999 8339** are connected to the air vent outlet on the filter cover.

NOTE! Single filter not available for D16.

⚠ **IMPORTANT!** Shut-off valves should be fitted on the fuel and return line, if the fuel tank maximum level is higher than the cylinder head of the engine.
The valves should be shut off during permanent engine stop. There is otherwise a risk that fuel may leak through the injection pump/ injectors to the lubricating system.



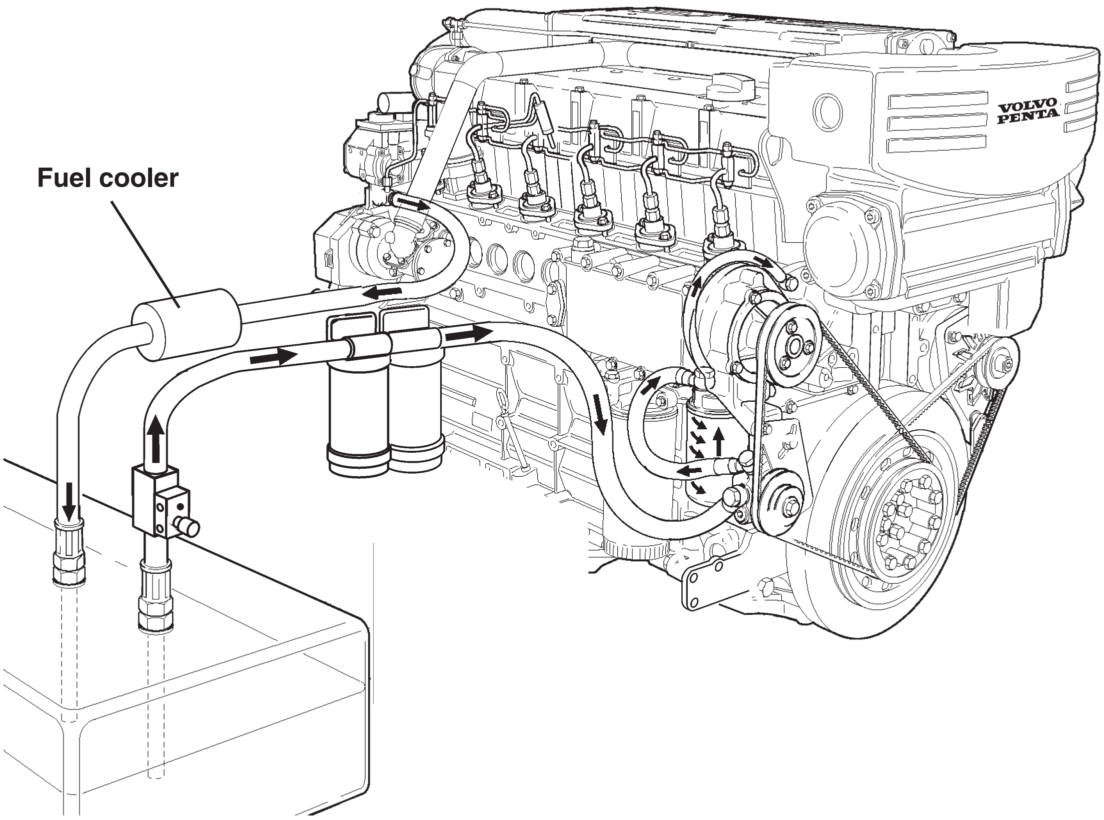
Fuel cooler for D5/D7

Increasing the fuel temperature above 40°C (measured at the inlet to the injection pump) leads to a decrease in power of approx. 1.5 % per 5°C, and at higher temperatures, to vapour bubble formation and backfiring. The maximum permissible **continuous fuel temperature** is **75°C**, whereas a short-term fuel temperature of up to 90°C can be tolerated at the feed pump inlet in special cases depending on the power setting of the engine and the fulfilment of emission values.

Today, modern engines with high pressure injection require a lower fuel temperature level. Through design and material selection when building the fuel tank and its mounting position in the unit (good venting, avoiding additional heating), the fuel temperature characteristics can be influenced. Safe and defined heat dissipation can also ensured by an accordingly dimensioned fuel cooler.

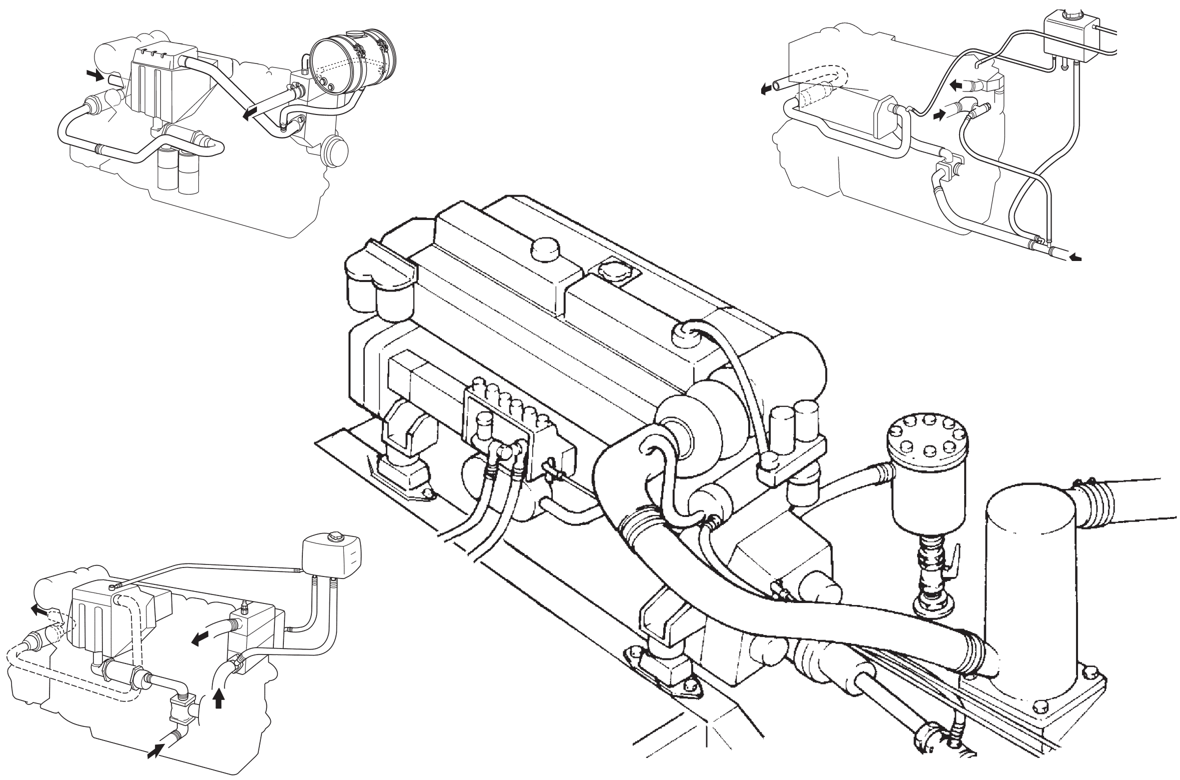
Theses kind of fuel coolers are integrated into the cooling system of the engine (air side) and are flowed through by returning fuel. The fuel cooler flow resistance must not be higher than 15 kPa (2.2 psi).
The overall resistance of return system including fuel cooler must not exceed 50 kPa (7.2 psi).

The cooler size should be approx. 2 - 4 kW.



Cooling system

General



The installer of the cooling system is responsible for ensuring that the cooling system operates in accordance with these installation instructions.

The cooling system must be dimensioned generously enough to ensure that fouling and repainting do not adversely affect its cooling performance even after a long period of service.

Use genuine Volvo Penta accessories and spare parts wherever possible. Make sure that parts not supplied by Volvo Penta do not restrict or reduce pressures and flow in the engine. Lines with an excessively small bore, unsuitable routing, incorrect connections etc will cause restrictions and lead to abnormal engine temperatures.

The pipe and hose diameters stated in these installation instructions are to be treated as recommendations. The only way to tell whether an installation is correct is to check pressures, temperatures and flows with the engine running. In case of doubt, contact the Volvo Penta organisation.

To reduce corrosion to a miniumum, use the correct combinations of materials in pipes, valves etc. plus a correctly sized and pressurized expansion tank.

Electrolytic corrosion may occur when two different materials surfaces are close and connected via water or moisture.

When the engine is connected to an external cooling system, such as a central cooling system, keel cooling or a radiator, the pH of the coolant is extremely important in order to protect the various materials in the cooling system.

Always use Volvo Penta coolant in a mixture of anti-freeze or anti-rust agent. The coolant used affects the cooling performance of the engine.

NOTE! For more information about the cooling system, see section ***Coolant mixture***.

Seawater system

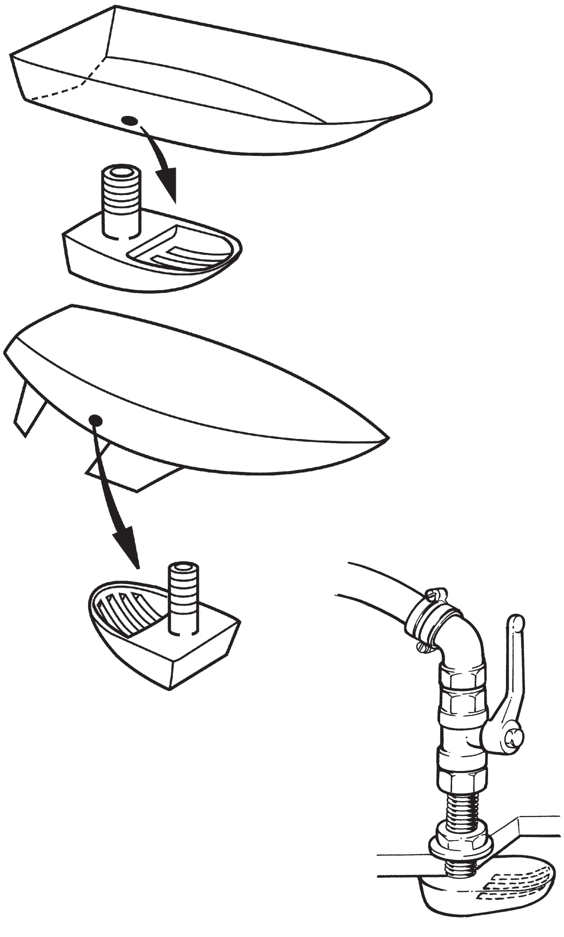
A standard feature of Volvo Penta diesel engines is a closed cooling system, with freshwater circulating in the cooling ducts and heat exchanger(s) of the engine. In the heat exchanger(s), the engine coolant is cooled by seawater.

Seawater circuit

The seawater is circulated in the system by the rubber impeller of the seawater pump.

Seawater intake, sea cock, filter and seawater circuit

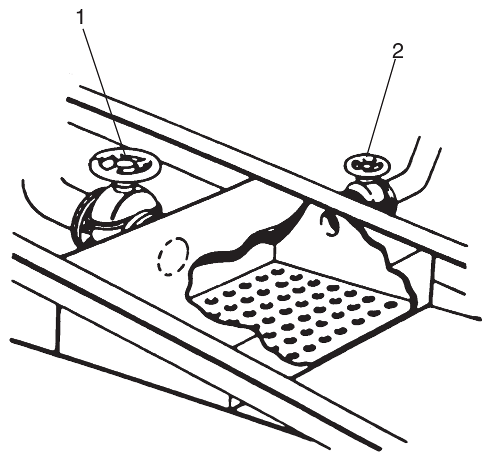
The seawater intake must be positioned so that the seawater line to the pump is as short as possible. In addition, the intake must be positioned so that air is not drawn into the system at the planing threshold of the boat or when rolling at sea.



NOTE! The greatest permitted suction head for the pumps are 2 m (6.6") for D5/D7 and 3 m (10') for all other engines.

The seawater intake, valve and strainer must have sufficient flow area. For planing crafts, a sloted water intake is recommended.

To avoid the seawater becoming blocked when passing through ice, the intake can be designed as shown in the illustration.

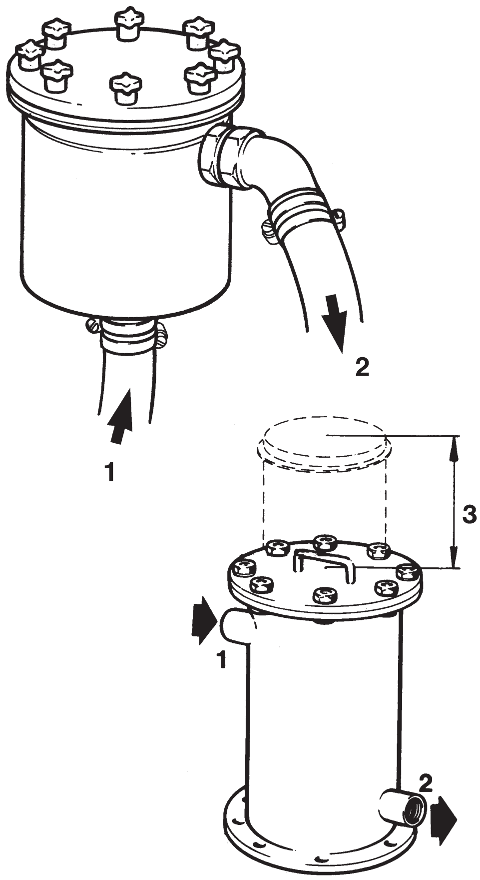


1. Valve for seawater intake.
2. Valve for flushing with hot water.

The sea cock must be easily accessible, and in certain cases it is a requirement that the valve is capable of being closed from outside the engine compartment.

In highly contaminated water and off coasts where there is sand and sludge in the water, these substances are drawn into the seawater pump and will reduce the life of the pump and the impeller. Fouling and clogging of the seawater system contribute to reduced cooling performance thus damaging the engine. A seawater filter helps to extend the life of the pump and reduces fouling of heat exchangers, oil cooler and aftercooler.

Flow area of the seawater intake



Minimum flow area of seawater intake = 1.5 x hose inner cross section area.

Seawater filter

1. Inlet via sea cock.
2. Outlet to seawater pump.
3. Clearance for removal of filter basket, about 550 mm.

The seawater filter, as illustrated, is positioned so that it is easily accessible for servicing, and far enough above the waterline to ensure that water cannot flow in, even if the sea cock is not closed.

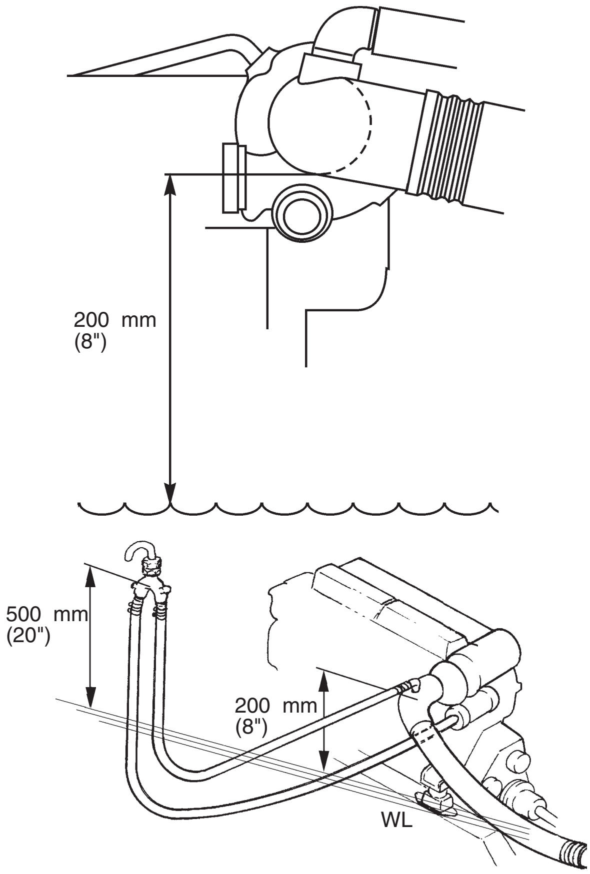
For necessary seawater flow see ***Sales Guide Marine Propulsion Diesel Engines*** for each engine type.

Any bends in the suction line must be swept and the line must be correctly dimensioned to avoid any unnecessary restrictions. Recommended materials for the suction line are rubber hose, copper pipe or acid-resistant stainless steel pipe.

Connections above the waterline are to be made with high-quality rubber hose with several layers of fabric to resist hose collapse under suction. Double stainless steel hoseclamps must be used at both ends of the hose.

Dimensions of hoses

Dimensions of hoses and pipes for seawater to and from the engine, see drawings for each engine type.

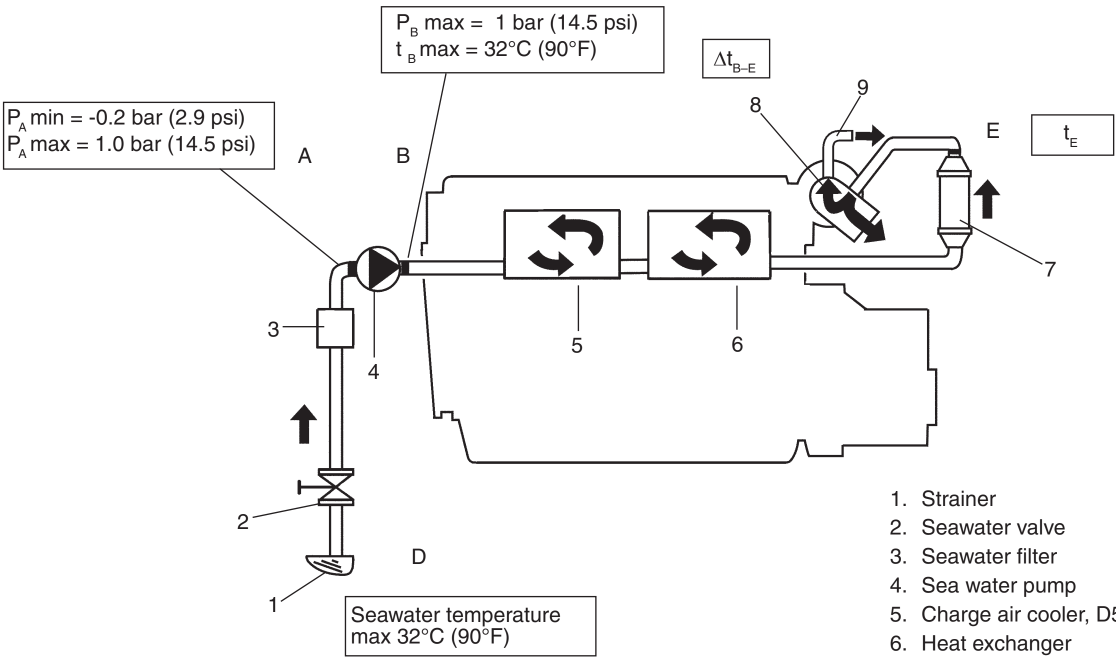


Anti-siphoning valve

An anti-siphoning valve (vacuum valve) should be fitted in cases where the engine is installed so deep in the boat that the distance between the exhaust pipe flange (lower part) and waterline is less than **200 mm (8")**. When correctly fitted the valve prevents siphoning, that is stopping seawater from entering the engine.

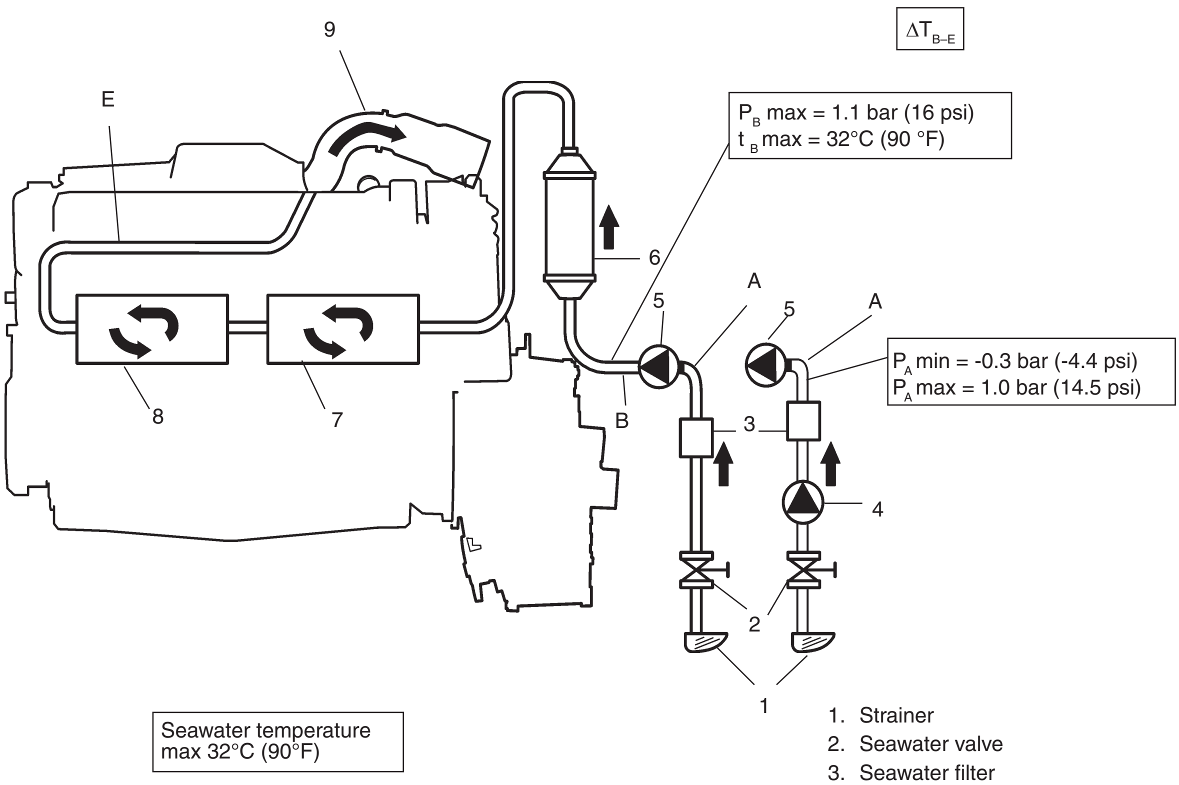
Height position of the anti-siphoning valve should be at least 500 mm (20") above waterline. See also chapter ***Exhaust system***, ***Wet exhaust line***.

D5/D7



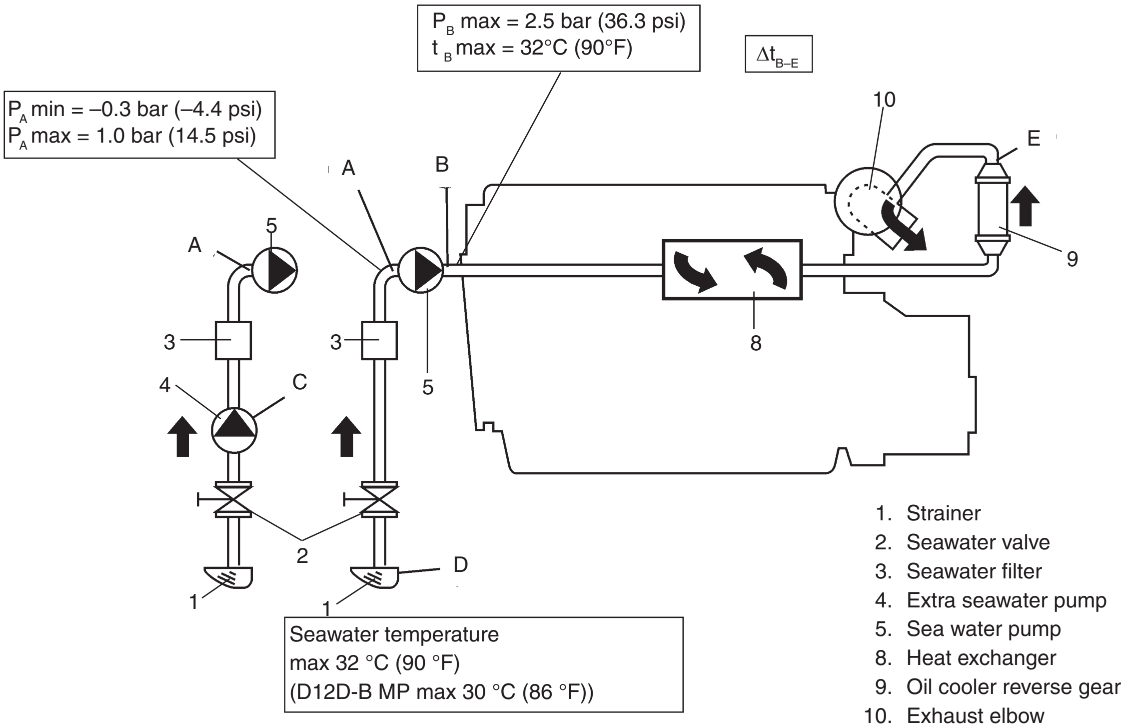
1. Strainer
2. Seawater valve
3. Seawater filter
4. Sea water pump
5. Charge air cooler, D5/D7 TA
6. Heat exchanger
7. Oil cooler reverse gear
8. Exhaust elbow
9. Bypass, only D5

D9/D11



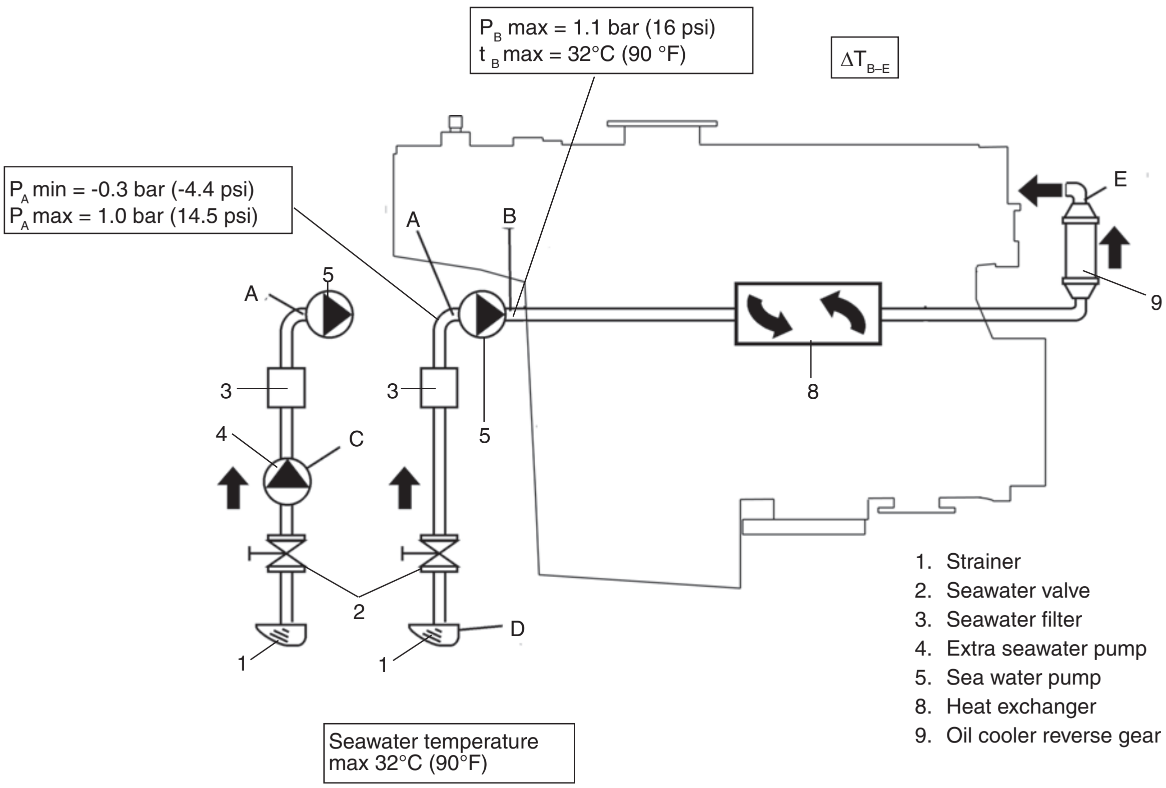
1. Strainer
2. Seawater valve
3. Seawater filter
4. Extra seawater pump
5. Sea water pump
6. Oil cooler reverse gear
7. Charge air cooler
8. Heat exchanger
9. Exhaust elbow

D12



1. Strainer
2. Seawater valve
3. Seawater filter
4. Extra seawater pump
5. Sea water pump
8. Heat exchanger
9. Oil cooler reverse gear
10. Exhaust elbow

D16



1. Strainer
2. Seawater valve
3. Seawater filter
4. Extra seawater pump
5. Sea water pump
8. Heat exchanger
9. Oil cooler reverse gear

⚠ **IMPORTANT!** To ensure there are no leaks in the cooling system, carry out a simple pressure test before bringing the installation into service.

The following pressure conditions must be fullfilled according to figures on previous page:

A. The pressure on the seawater suction side of the pump (P_A), measured immediately before the pump, and with the engine running at max. rpm, must not be less than 0.2 bar (2.9 psi) for D5/D7 and –0.3 bar (–4.4 psi) for all other engines. It must not be higher than 1.0 bar (14.5 psi).

B. The pressure after the seawater pump ($P_B$max) must not be exceed 1 bar (14.5 psi) for D5/D7 and 2.5 bar (36.3 psi) for all other engines.

C. When the engine is installed higher than the maximum suction head of the pump, 3 m (9'), an extra seawater pump must be installed.

D. The seawater intake, the valve, the strainer hoses and piping must have sufficient flow area to avoid restriction losses. Any bends in the line must be swept, to avoid unnecessary restriction losses. Copper pipe is recommended. It should be arranged in a U-bend to reduce stresses, and must be connected with reinforced rubber hose. To prevent collapse, the hose must have several layers of fabric.

E. The temperature increase of the seawater, Δt_{B-E} and the pressure increase, ΔP_A give a good understanding of the function of the system. For temperature increase, see table on page 81.

Where a genuine Volvo Penta seawater pump is replaced with a different type of pump, the flow must be measured.

A flowmeter is installed in the outgoing seawater line after the reverse gear oil cooler, and the seawater flow is checked with the engine running at max. speed.

For the recommended seawater flows for the various engines at different speeds, see ***Sales Guide Marine Propulsion Diesel Engines*** for each engine type and rpm.

Volvo Penta standard cooling systems are designed for a max. seawater temperature of **32°C (90°F)**.

Temperature increase (ΔT_{B-E}) across the seawater circuit of the engine including reverse gear oil cooler at nominal power.

Engine	Rating	ΔT_{B-E} according to figure on pages 78 - 79 °C	(°F)
D5A T, 1900 rpm	1	8–10	(15–18)
2300 rpm	1	7–9	(13–17)
1900 rpm	2	10–12	(18–22)
2300 rpm	2	9–11	(17–20)
D5A TA, 1900 rpm	1	9–11	(17–20)
2300 rpm	1	9–11	(17–20)
1900 rpm	2	10–12	(18–22)
2300 rpm	2	10–12	(18–22)
D7A T, 1900 rpm	1	11–13	(20–24)
2300 rpm	1	11–13	(20–24)
1900 rpm	2	12–14	(22–26)
2300 rpm	2	11–13	(20–24)
D7A TA, 1900 rpm	1	12–14	(22–26)
2300 rpm	1	13–15	(24–27)
1900 rpm	2	14–16	(26–29)
2300 rpm	2	15–18	(27–33)
D7C TA, 1900 rpm	1	14–16	(26–29)
2300 rpm	1	13–15	(24–27)
1900 rpm	2	16–19	(29–35)
2300 rpm	2	16–19	(29–35)
D9 (221 kW)	1	10–12	(18–22)
D9 (261 kW) 1800 rpm	1	13–15	(24–27)
D9 (261 kW) 2200 rpm	1	12–14	(22–26)
D9 (313 kW)	2-3	15–18	(27–33)
D9 (368 kW)	4	17–19	(31–35)
D9 (425 kW)	5	20–24	(36–44)
D11 (493 kW)	5	21–25	(38–45)
D12 (294 kW)	1	11–13	(20–24)
D12 (331 kW)	1	13–15	(24–27)
D12 (405 kW)	2	17–20	(31–36)
D12 (452 kW)	3	15–18	(27–33)
D12 (478 kW)	4	16–19	(29–35)
D12 (496 kW)	5	16–19	(29–35)
D12 (515 kW)	5	13–16	(24–29)
D12 (525 kW)	5	15–18	(27–33)
D12 (570 kW)	5	17–20	(31–36)
D16 (363 kW)	1	n.a.	n.a.
D16 (404 kW)	1	n.a.	n.a.
D16 (441 kW)	1	n.a.	n.a.
D16 (478 kW)	1	n.a.	n.a.
D16 (551 kW)	2	n.a.	n.a.

Minimum seawater flow at different engine speed

- Lower flow than recommended causes insufficient cooling performance.
- Higher flow than recommended causes cavitation in the heat exchangers and pipes.

See ***Sales Guide Marine Propulsion Diesel Engines*** for each engine type and rpm.

Freshwater system

The freshwater is circulated via the cooling ducts and heat exchanger of the engine by a centrifugal pump.

On D12 and D16 engines also the charge air cooler is integrated in the freshwater circuit.

As long as the coolant is cold, the thermostat(s) remain closed, preventing the coolant from passing to the heat exchangers. Instead the coolant flows in a bypass duct directly back to the suction side of the pump. This ensures that the engine rapidly reaches its working temperature. The thermostats also prevent the engine temperature from falling at low load and in cold weather.

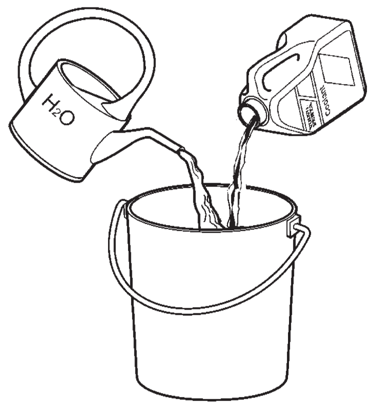
Coolant mixture

⚠ **WARNING!** All glycol is hazardous and harmful to the environment. Do not consume!
Glycol is flammable.

⚠ **IMPORTANT!** Ethylene glycol must not be mixed with other types of glycol.

Mix: 40 % "Volvo Penta Coolant" (conc. coolant) and 60 % water.

Note! D9 CAC-circuit: 20 % "Volvo Penta Cool ant" (conc. coolant) and 80 % water.



This mixture protects the engine against internal corrosion, cavitation and frost damage down to -28 °C (-18°F). (Using 60 % glycol lowers the freezing point to -54 °C (-65°F)). Never mix more than 60 % concentrate (Volvo Penta Coolant) in the cooling liquid, this will give reduced cooling effect and increase the risk of overheating, and will give reduced freezing protection.

⚠ **IMPORTANT!** Coolant must be mixed with **pure** water, use **distilled - deionized water**. The water must fulfill the requirements specified by Volvo Penta, see "Water quality".

⚠ **IMPORTANT!** It is extremely important that the correct concentration of coolant is added to the system. Mix in a separate, clean vessel before adding into the cooling system. Ensure that the liquids mix properly.

Water quality

ASTM D4985:

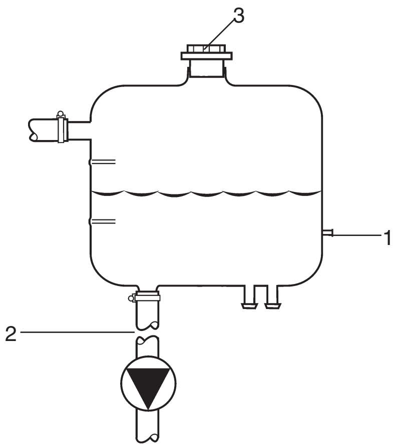
Total solid particles	< 340 ppm
Total hardness:	< 9.5° dH
Chloride	< 40 ppm
Sulfate	< 100 ppm
pH value	5,5–9
Silica (acc. ASTM D859)	< 20 mg SiO_2/l
Iron (acc. ASTM D1068)	< 0.10 ppm
Manganese (acc. ASTM D858)	< 0.05 ppm
Conductivity (acc. ASTM D1125)	< 500 µS/cm
Organic content, COD_{Mn} (acc. ISO8467)	< 15 mg $KMnO_4$/l

Filling with coolant

NOTE! Coolant should be filled with the engine stopped and cold.

NOTE! For filling D12D-B MP with coolant, see ***Operator's Manual***.

External systems: When external systems are connected to the engine's cooling system, the valves to the systems should be opened and the units vented during filling.



NOTE! Adjust coolant level in accordance with the pressure in the system. Measure pressure in the expansion tank and **below** coolant level. Test outlet (1) alternative test point (2).

Cold engine:	0 kPa (0 psi)
Warm engine:	Approx. 10 kPa (1.5 psi) below release pressure of the pressure cap (3).

D5/D7/D9/D11/D16: The cooling system has no venting nipples. It is automatically vented.

Fill until the system is completely filled up, including the expansion tank.

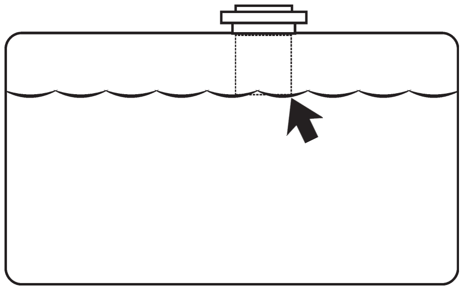
Start the engine and let it run without load at 1000–1500 rpm for 15–20 minutes. Check coolant level.

D12: Open all venting nipples when filling. Fill at the rate of approximately 10 – 15 l/min (2.5 – 4.0 US gal/min).

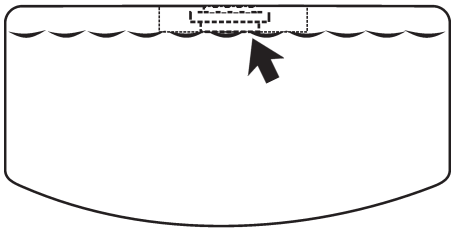
Close the venting nipple(s) as no bubbles can be seen in the coolant.

Fill until the system is completely filled up, including the expansion tank.

Start the engine and let it run without load at 1000–1500 rpm for 15–20 minutes. Check coolant level.



D5/D7: The coolant level should reach the lower edge of the filler pipe. The level must be visible from top of the compensationtank.



D9/D11/D12/D16: The coolant level should reach the lower edge of the filler pipe. All D9/D11 and D16 engines are equipped with low coolant level alarm.

⚠ **IMPORTANT!** The engine must not be started until the system has been vented and completely filled.

⚠ **WARNING!** Do not open the pressure cap or the venting nipples on a hot engine. Steam or hot water can spray out and the pressure thus lost.

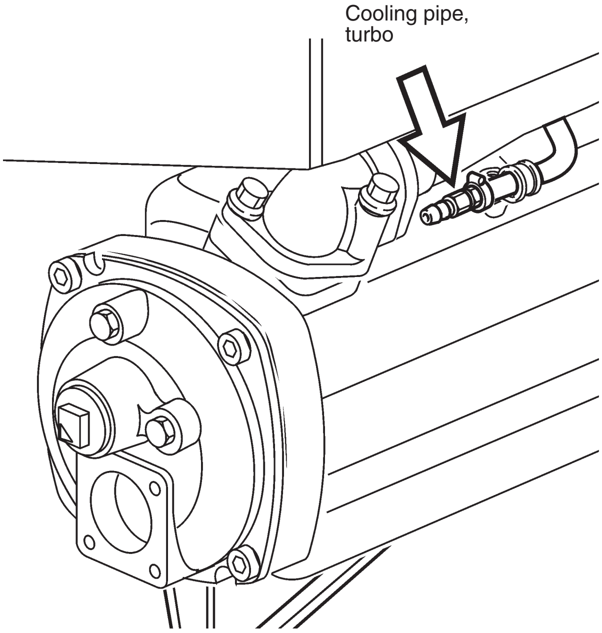
Venting nipples

D5/D7/D9/D11/D16

D5/D7/D9/D11/D16 has no venting nipples. The cooling system is automatically vented.

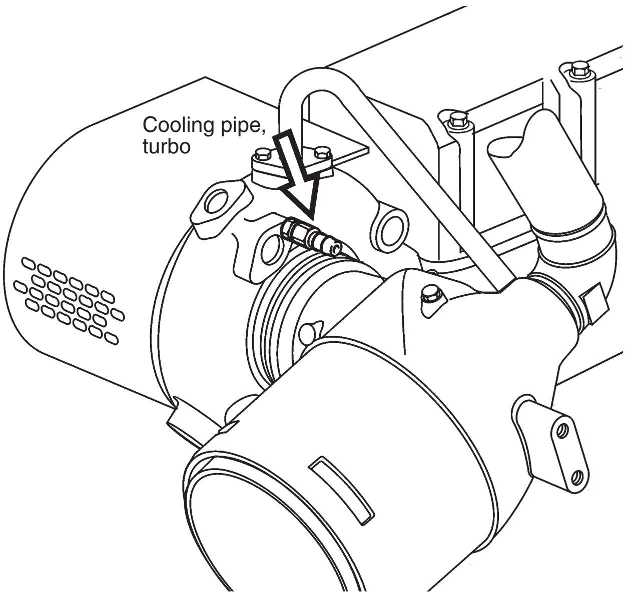
D12D-A MP, D12D-B MH

All cooling systems



D12D-B MP

All cooling systems



External cooling

General

When the boat is operating in waters where there is a lot of sand and sludge, or in ice, it is advisable to fit a closed cooling system (keel cooling system).

There are several possible cooling system arrangements:

- skin cooling
- pipe assemblies (keel cooling)
- double bottom (skin cooling)
- external cooling tanks (box cooling)

The principle of an external cooling installation is that the standard circulation pump of the engine also circulates coolant in the external cooler.

It is important to use the correct materials in the coolers. Use Volvo Penta coolant, a mixture of anti-freeze.

A number of factors must be taken into account when calculating and designing the external cooling system.

- Volvo Penta does not market external cooling systems or components for such systems.
- Volvo Penta does market engines suitable for connection to external cooling systems.
  Tables in this chapter list the pressures and flows that must be taken into account when calculating the system as well as a description of the cooling system.
- It is essential to choose the correct pipe dimension and length for pipe coolers, and the correct tank height and width for double-bottom coolers, with regard to backpressure, flows and heat to be dissipated.
- The system must not include any sharp bends or tanks that end abruptly.
- When calculating pipe length and tank area, factors to be taken into account are:
  1. Engine technical data
  2. Power and rpm
  3. Type of operation
  4. Minimum hull speed at full rated power
  5. Maximum seawater temperature
  6. Cooler dimensions
  7. Materials in cooler
  8. Thickness of paint on cooler
  9. Exhaust system, wet or dry
  10. If using power take-off under 0 knot condition, what are the power and rpm at which the engine will be loaded?
  11. The concentration of antifreeze and its effect on the cooling capacity are stated in section ***Coolant***.
  12. To extend service life, especially on the D12, it is recommended to install a fresh water filter between the external circuit and the engine.
- If the normal expansion tank of the engine is too small, an extra expansion tank must be installed. Position the tank at the highest point of the engine cooling system. The volume of the expansion tank should be equivalent to about 15% of the total volume of the keel cooling system. See chapter ***Extra expansion tank*** for further details.
- The extra expansion tank must be connected to the suction side of the circulation pump of the engine via a static pressure line.

  There must be means of venting inbetween the standard expansion tank and the extra tank, as well as between the keel cooler and the expansion tank. See chapter ***Extra expansion tank*** for further details.
- Where an intercooled Volvo Penta engine is to have keel cooling and it proves difficult to keep the coolant temperature of the engine below the maximum permitted level, the keel cooling system can be divided into two circuits. The engine's seawater pump is utilised to circulate the coolant of the intercooler circuit and the circulation pump of the engine can then be used to circulate the coolant of the engine circuit.
- Where the pressure drop in the cooling system is too high for the engine circulation pump to achieve the correct flow, an extra pump can be connected to the system.

Central cooling system

The principle for connecting engines to a central cooling system is the same as for a keel cooled engine. See chapter ***Function diagrams***.

The parameters given for Volvo Penta marine engines under the heading ***External cooling*** also apply when the engine is connected to a central cooling system.

Depending on the design of the central cooling system, high static and dynamic pressures may occur.

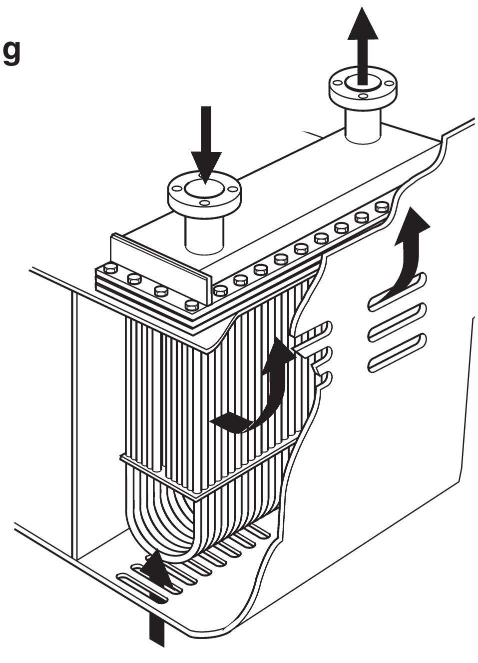
Pressure limits for central cooling system

Pressure before coolant circulation pump
Pmax = 100 kPa (14.5 psi)

NOTE!

- Max pressure before circulation pump is 100 kPa (14.5 psi).
- Min pressure before circulation pump when engine is cold = 0 kPa (0 psi).
- Min pressure before circulation pump when engine is warm = 30 kPa (4.4 psi).
  See ***Expansion tank, function diagram*** .
- Pressure before seawater pump
  P max = 100 kPa (14.5 psi)
- In cases where seawater pump is excluded, max. permitted pressure before charge air cooler = 250 kPa (36.3 psi)
- In cases where the maximum coolant pressure of the engine is exceeded, a heat exchanger capable of handling the higher pressure must be connected in between the engine and the central cooling system.

Box cooling



An extra expansion tank for the engine must also be connected to the system. For further details see under chapter ***Extra expansion tank***.

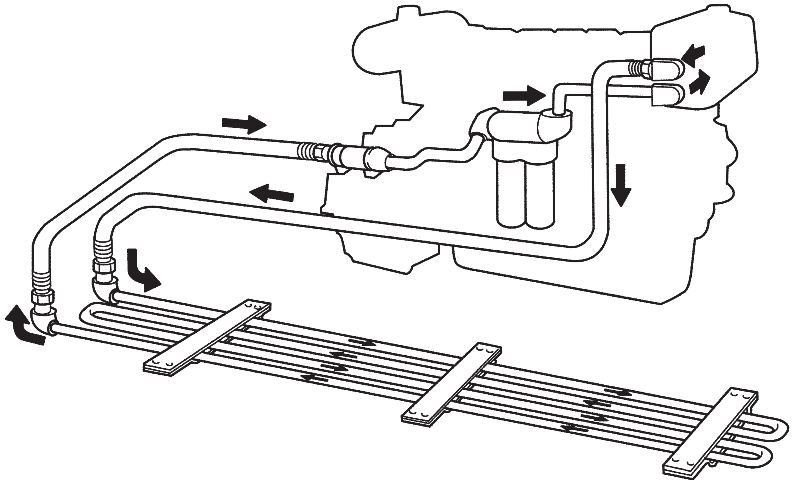
Depending on system temperatures in the central cooling system it may be possible to use the seawater-cooled version of an engine. However, the installation parameters laid down for Volvo Penta seawater cooled engines must be observed.

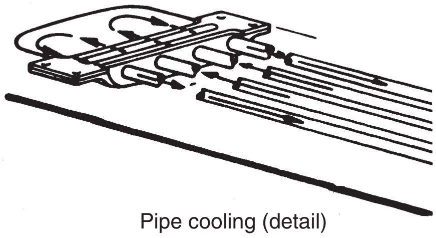
In central cooling systems with several engines, each engine must be fitted with coolant inlet and outlet valves for service reasons.

⚠ **IMPORTANT!** When an engine is connected to a central cooling system, the composition of the coolant and its pH are extremely important. See chapter ***Coolant***.

NOTE! Always use Volvo Penta anti-freeze or anti-rust agent. Both are available in concentrated form. Mixing with other makes of coolants can give impaired corrosion protection, which may damage the engine or block the cooling system.

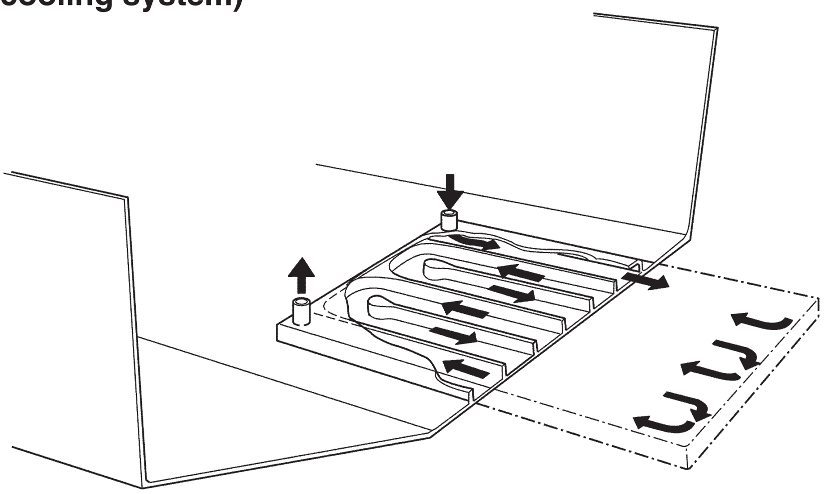
Keel cooling
(Pipe cooling system)

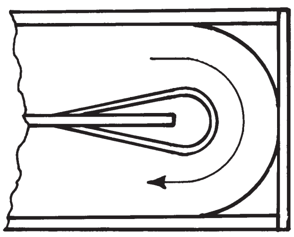




Pipe cooling (detail)

Keel cooling
(Skin cooling system)





Skin cooling (detail)

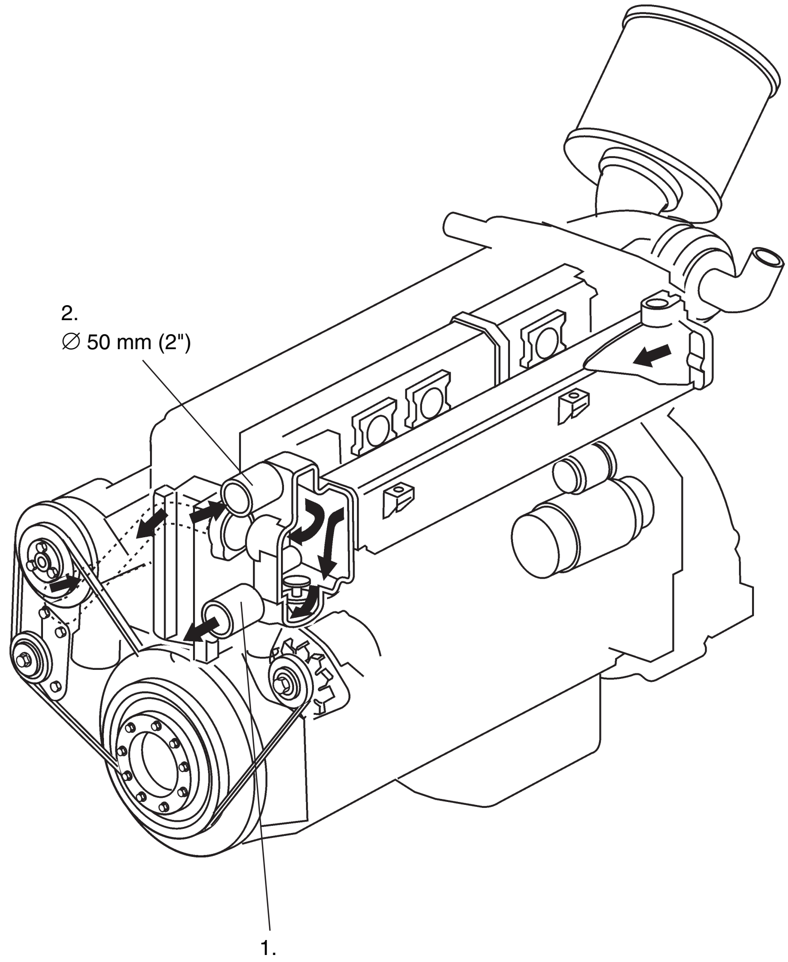
Coolant flow and connections for engines adapted for external cooling

Engines adapted for external cooling differ from seawater cooled engines. The seawater pump and the heat exchanger(s) have been removed. The engines have been fitted with connections for the external cooling system.

The figures below show the connections on the engines and the inner diameter of the hoses.

D5/D7

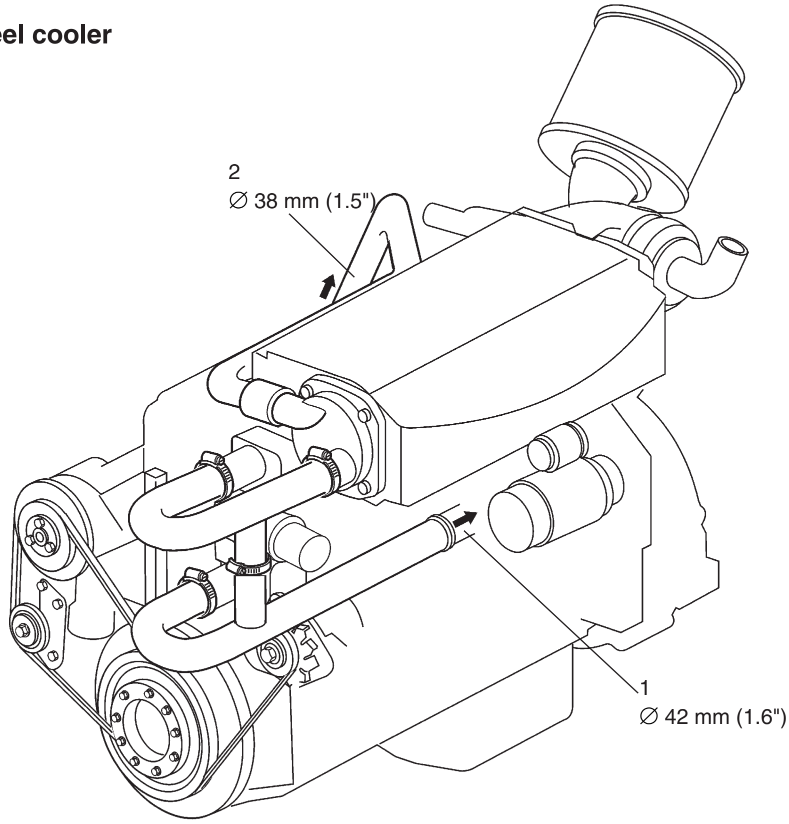
One circuit keel cooling



1. To keel cooler
2. From keel cooler

D5/D7

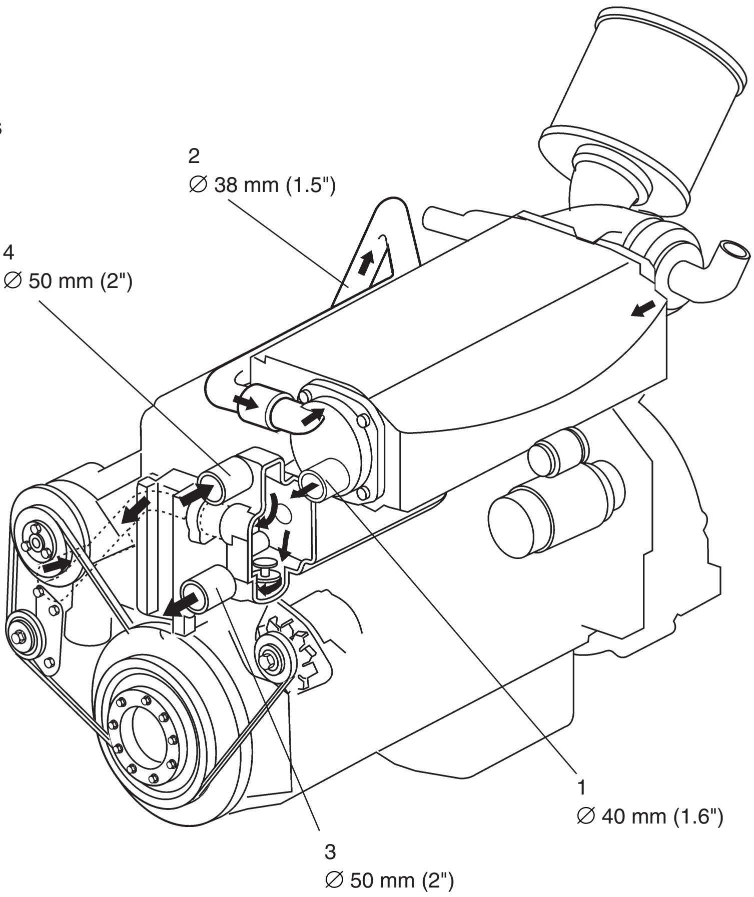
Two circuit system with one keel cooler



1. To keel cooler
2. From keel cooler

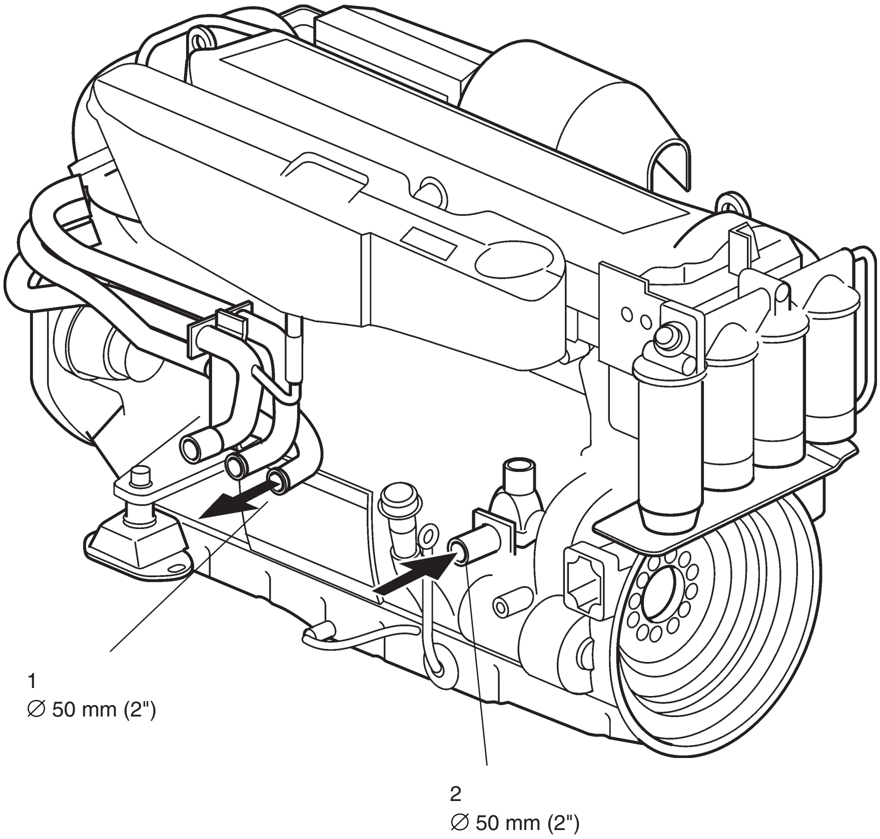
D5/D7

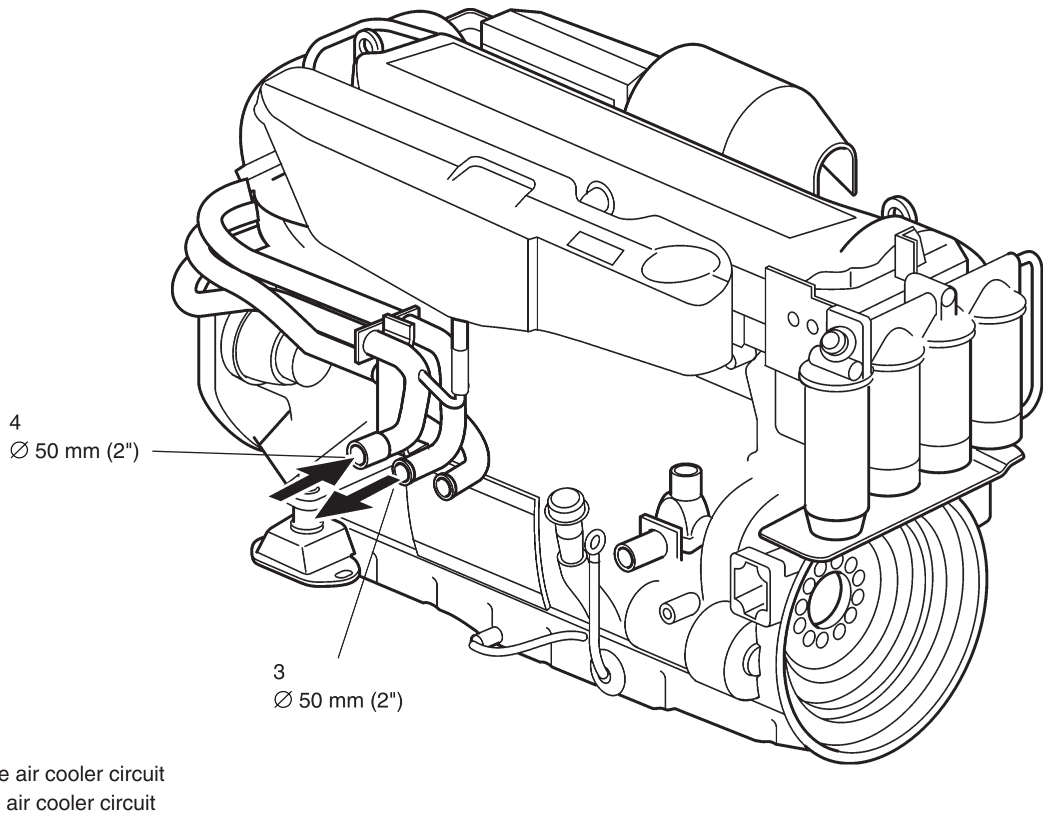
Two circuit system with two keel coolers



1. To keel cooler, charge air cooler circuit
2. From keel cooler, charge air cooler circuit
3. To keel cooler, engine coolant circuit
4. From keel cooler, engine coolant circuit

D9
Two circuits keel cooler

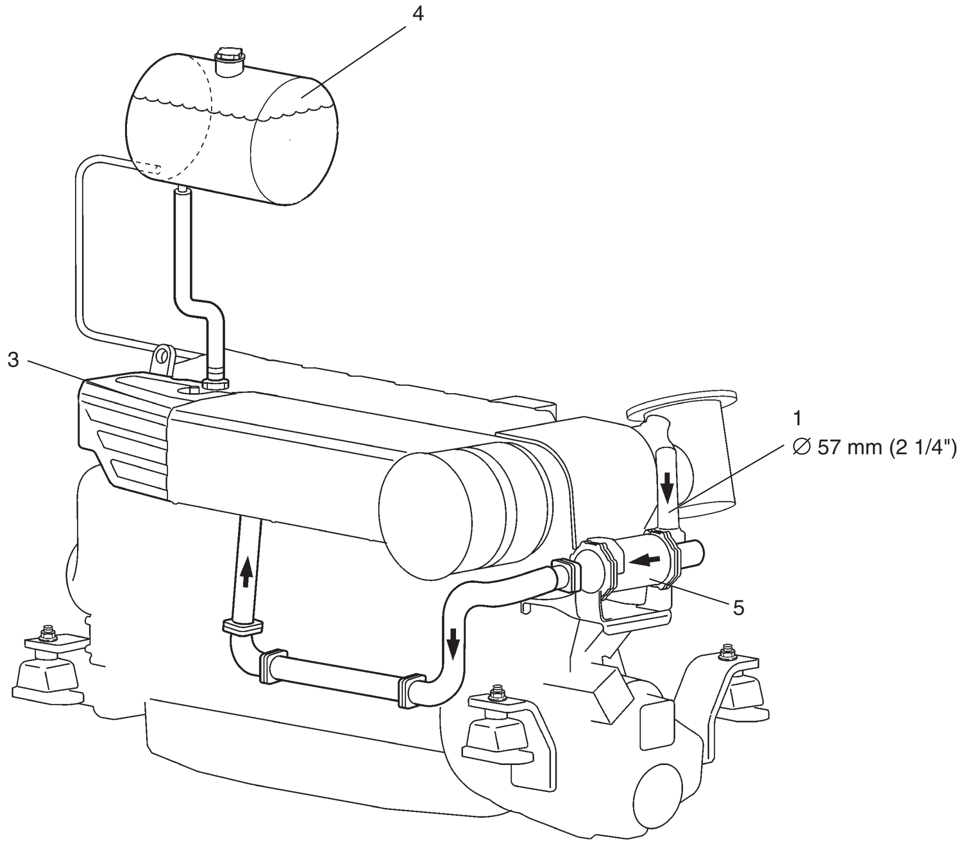




1. To the keel cooler, charge air cooler circuit
2. From keel cooler, charge air cooler circuit
3. To keel cooler, engine coolant circuit
4. From keel cooler, engine coolant circuit

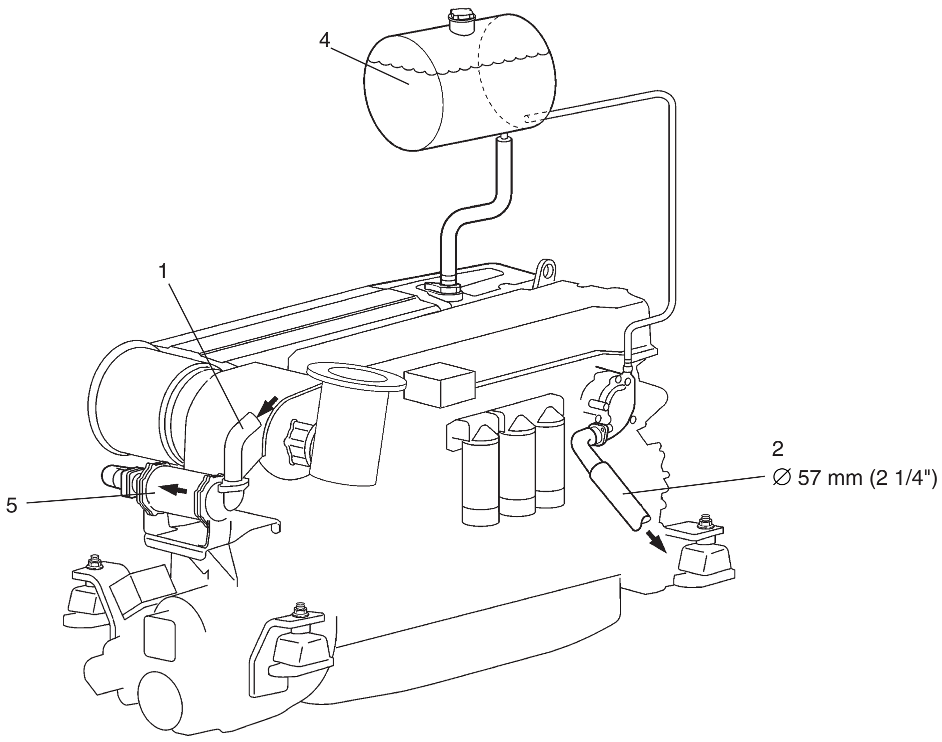
D12
One circuit keel cooler

Port side



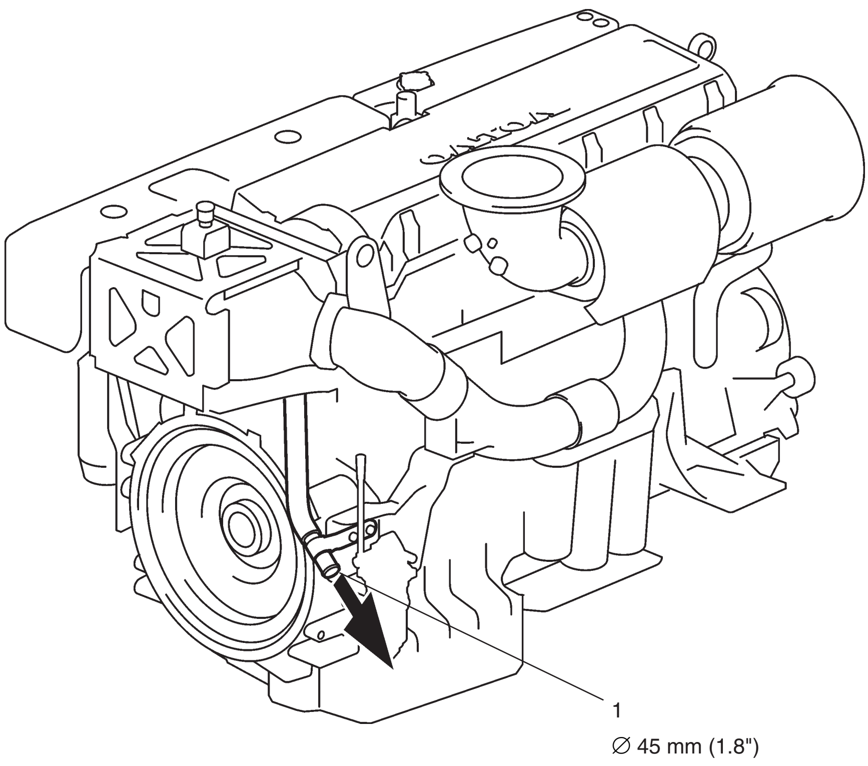
1. From keel cooler
2. To keel cooler
3. Standard expansion tank
4. Extra expansion tank
5. Reverse gear oil cooler

Starboard side

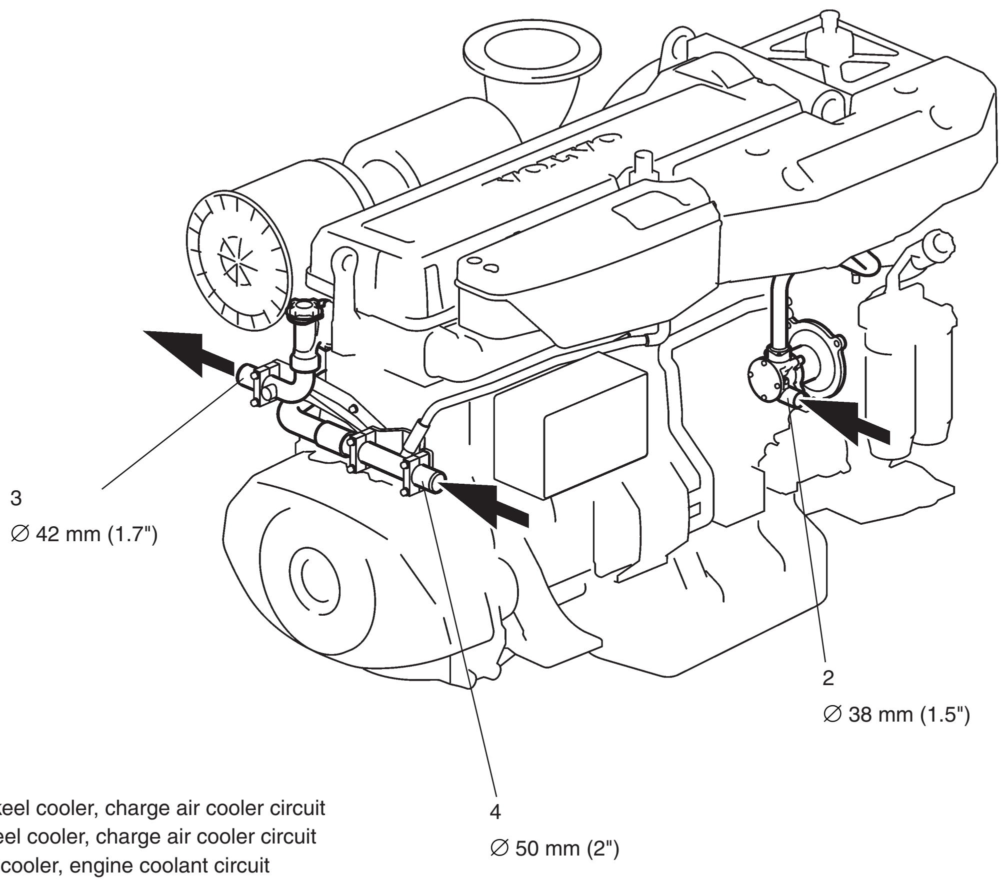


D16
Two circuit keel cooler

Starboard side



Port side



1. To the keel cooler, charge air cooler circuit
2. From keel cooler, charge air cooler circuit
3. To keel cooler, engine coolant circuit
4. From keel cooler, engine coolant circuit

Max. capacity of the freshwater system in keel cooled engines

This table shows engine volume excluding heat exchanger and the max. permitted total cooling system volume with standard expansion tank, including keel cooler and other circuits such as an engine heater circuit or a cabin heater circuit.

NOTE! If these values are exceeded, larger expansion tank must be installed.

Engine	Engine volume liter (US gal.)	Total system volume max. liter (US gal.)	Engine	Engine volume liter (US gal.)	Total system volume max. liter (US gal.)
D5A T	11 (2.9)	63 (16.6)	D9[1)]	33 (8.7)	73 (19.3)
D5A TA	11 (2.9)	63 (16.6)	D12	44 (11.6)	135 (35.6)
D7A T	14 (3.7)	63 (16.6)	D16[1)]	39 (10.3)	59 (15.6)[2)]
D7A TA	14 (3.7)	63 (16.6)			
D7C TA	14 (3.7)	63 (16.6)			

[1)] Volumes for engine circuit only

[2)] For D16 an extra expansion tank on the LT circuit should always be used.

Dimensioning of external cooling systems. Heat rejection from freshwater system in kW

For additional data on temperature, pressure and coolant flow, see ***Sales Guide Marine Propulsion Diesel Engines***.

NOTE! For all systems: If reverse gear is used, add 4% in heat rejection for reverse gear oil cooler.

D5/D7 -T. One circuit with one keel cooler
D5/D7 -TA. Two circuit with one keel cooler
D5/D7 -TA. Two circuit with two keel coolers

Parameters, kW	Rating	D5A T	D5A TA	D7A T	D7A TA	D7C TA
Total heat rejection (engine/charge air cooler)						
1900 rpm	1	64 / –	74 (63 / 11)	89 / –	101 (85 / 16)	111 (92 / 19)
	2	76 / –	84 (71 / 13)	98 / –	116 (96 / 20)	128 (103 / 25)
2300 rpm	1	70 / –	85 (67 / 18)	105 / –	125 (98 / 27)	135 (103 / 32)
	2	75 / –	98 (77 / 21)	111 / –	146 (113 / 33)	164 (125 / 39)

D12. One circuit system

Parameters, kW	Rating	2300 rpm	2100 rpm	1900 rpm	1800 rpm
Total heat rejection (engine/charge air cooler)	4 (650 hp)	430 (301 / 129)	–		
	3 (615 hp)	–	398 (276 / 122)		
	2 (550 hp)			409 (283 / 126)	
	1 (450 hp)				298 (209 / 89)
	1 (400 hp)				253 (177 / 76)

D9/D16

Please refer to ***Sales Guide Marine Propulsion Diesel Engines***.

Max. temperature increase, ΔT_{max}
- across the engine circuit, T1–T2 (T5–T6 on D12C)
- across the charge air cooler circuit, T3–T4

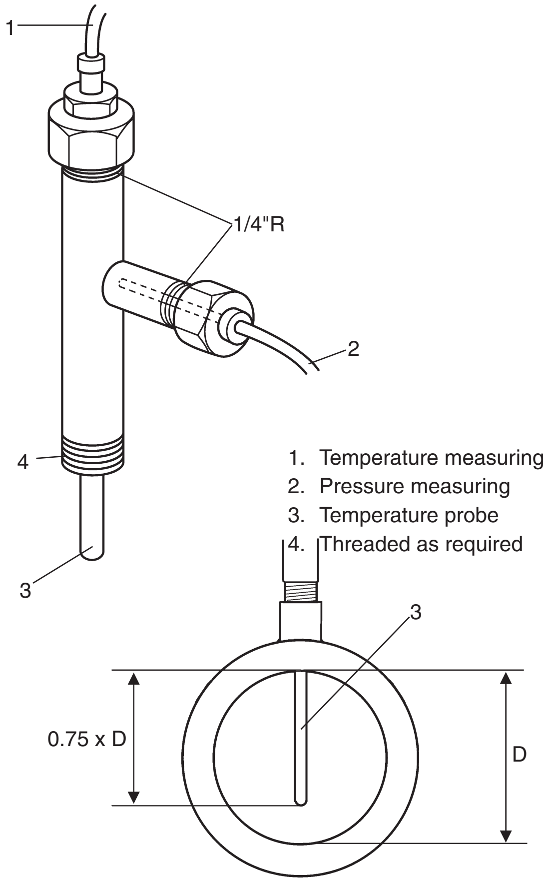
See also chapter *Function diagrams, external cooling* for each engine type.

Engine	Rating	ΔT_{max} engine circuit T1–T2 (T5–T6 D12)			ΔT_{max} charge air cooler circuit T3–T4		
			°C	(°F)		°C	(°F)
D5A T, 1900 rpm	1	≤	8	(15)		—	—
D5A T, 2300 rpm	1	≤	8	(15)		—	—
D5A T, 1900 rpm	2	≤	10	(18)		—	—
D5A T, 2300 rpm	2	≤	9	(17)		—	—
D5A TA, 1900 rpm	1	≤	8	(15)	≤	2	(4)
D5A TA, 2300 rpm	1	≤	7	(13)	≤	3	(6)
D5A TA, 1900 rpm	2	≤	9	(17)	≤	2	(4)
D5A TA, 2300 rpm	2	≤	8	(15)	≤	3	(6)
D7A T, 1900 rpm	1	≤	12	(22)		—	—
D7A T, 2300 rpm	1	≤	11	(20)		—	—
D7A T, 1900 rpm	2	≤	13	(24)		—	—
D7A T, 2300 rpm	2	≤	12	(22)		—	—
D7A TA, 1900 rpm	1	≤	11	(20)	≤	2	(4)
D7A TA, 2300 rpm	1	≤	10	(18)	≤	3	(6)
D7A TA, 1900 rpm	2	≤	12	(22)	≤	2	(4)
D7A TA, 2300 rpm	2	≤	12	(22)	≤	3	(6)
D7C TA, 1900 rpm	1	≤	12	(22)	≤	2	(4)
D7C TA, 2300 rpm	1	≤	11	(20)	≤	3	(6)
D7C TA, 1900 rpm	2	≤	13	(24)	≤	2	(4)
D7C TA, 2300 rpm	2	≤	13	(24)	≤	3	(6)
D9	Please refer to ***Sales Guide Marine Propulsion Diesel Engines***.						
D12 (294 kW)	1	≤	26	(47)	≤	11	(20)
D12 (331 kW)	1	≤	28	(51)	≤	11	(20)
D12 (405 kW)	2	≤	26	(47)	≤	11	(20)
D12 (452 kW)	3	≤	25	(45)	≤	11	(20)
D12 (478 kW)	4	≤	25	(45)	≤	10	(18)
D16	Please refer to ***Sales Guide Marine Propulsion Diesel Engines***.						

Measuring pressure in keel cooling systems

Gauge connections

T-nipple for measuring pressure and temperature



The T-nipple is used when measuring both pressure and temperature in the cooling circuit. The tool is not stocked by Volvo Penta.

Note that it is important to place the probe correctly in the coolant flow. See figure above.

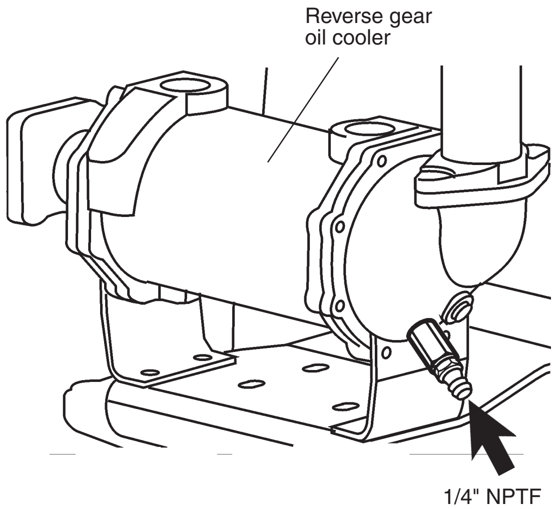
D5/D7/D9/D16

Pressure before and after keel cooler

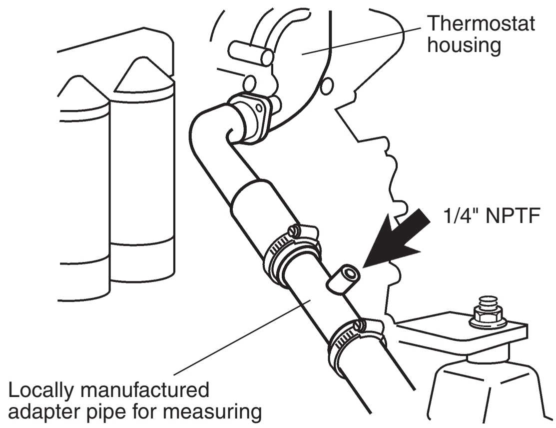
Connections for measuring pressure in the cooling circuit on D5/D7/D9/D16 has to be built into the circuit of the boat, close to the connections to the engine.

D12

Pressure before keel cooler



Pressure after keel cooler



Cut the hose and fit a piece of pipe in between. Fit a connection with an internal thread, 1/4" NPTF, on the pipe to connect a manometer.

Measuring temperature in keel cooling systems, Gauge connections

NOTE! Before installation is carried out, the internal freshwater temperature to and from the keel cooler must be checked. The temperature gauge connections of the engines are shown in the illustrations below.

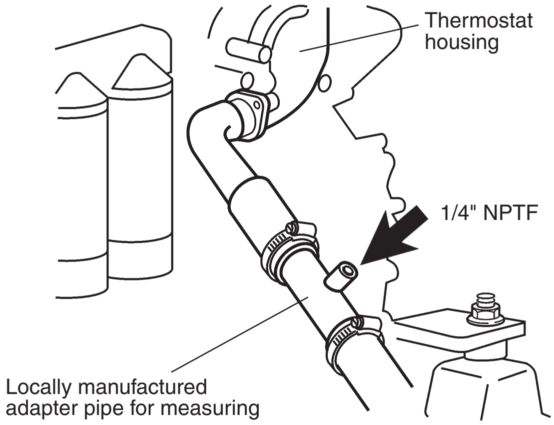
D5/D7/D9/D16

Temperature before and after keel cooler

Connections for measuring temperature in the cooling circuit on D5/D7/D9/D16 has to be built into the circuit of the boat, close to the connections to the engine.

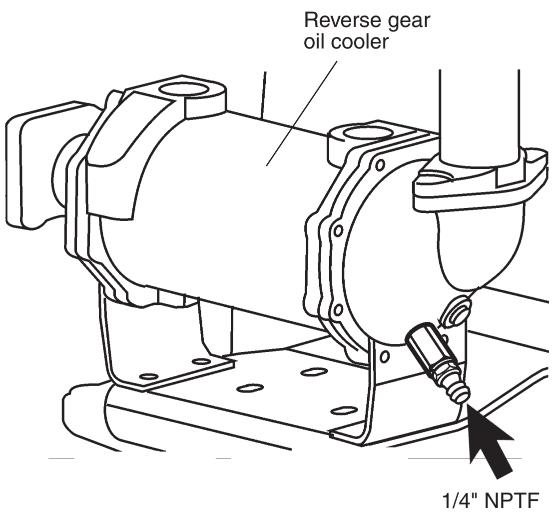
D12

Coolant temperature from keel cooler



Cut the hose and fit a piece of pipe in between. Fit a connection with an internal thread, 1/4" NPTF, on the pipe to connect a temperature meter.

Coolant temperature to keel cooler



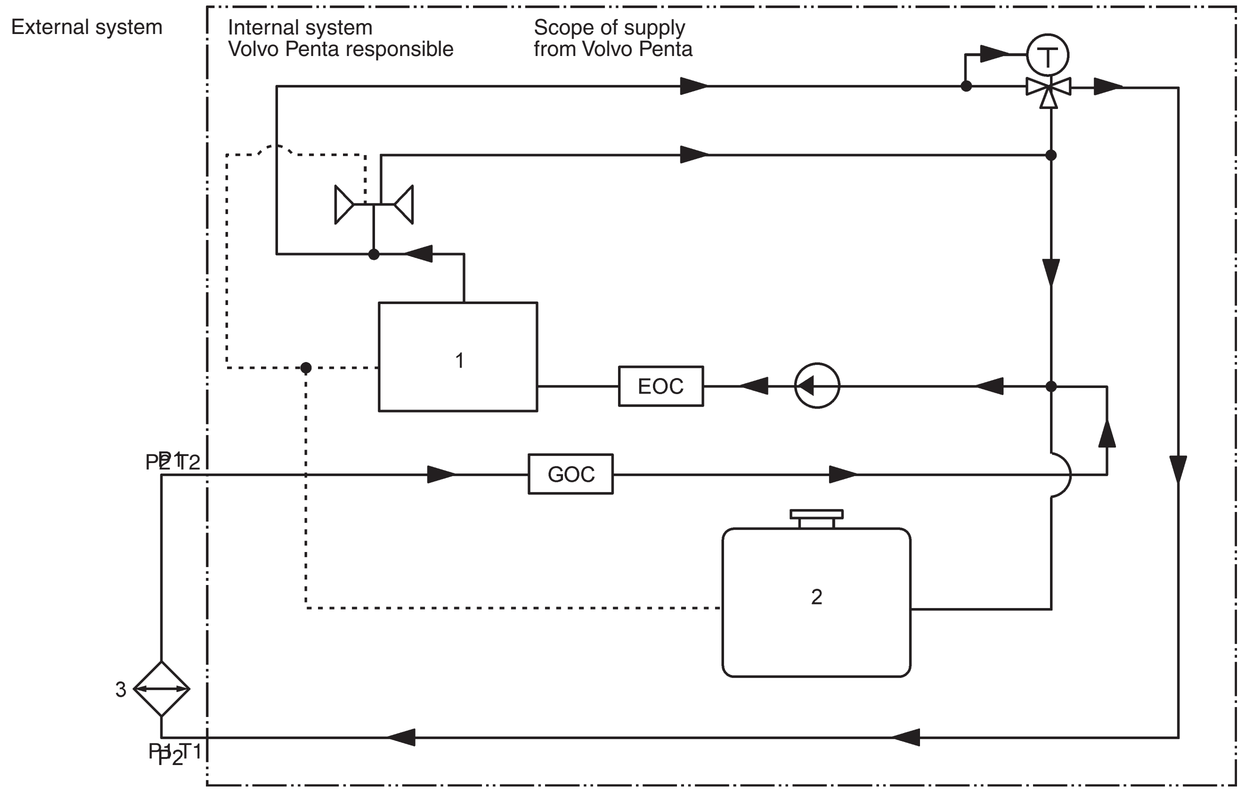
Function diagrams, external cooling

Components, such as oil coolers for reversing gear, expansion tank etc. are not always supplied by Volvo Penta. These components are not the responsibility of Volvo Penta.

The border of Scope of supply from Volvo Penta/Volvo Penta responsibility is marked in the diagrams by
— - — - —

Internal temperature increase across the engine circuit (keel cooler 1, T1–T2) and the charge air cooler circuit (keel cooler 2, T3–T4) see table on page 94 for each engine type.

D5/D7 -T
External cooling. One circuit system

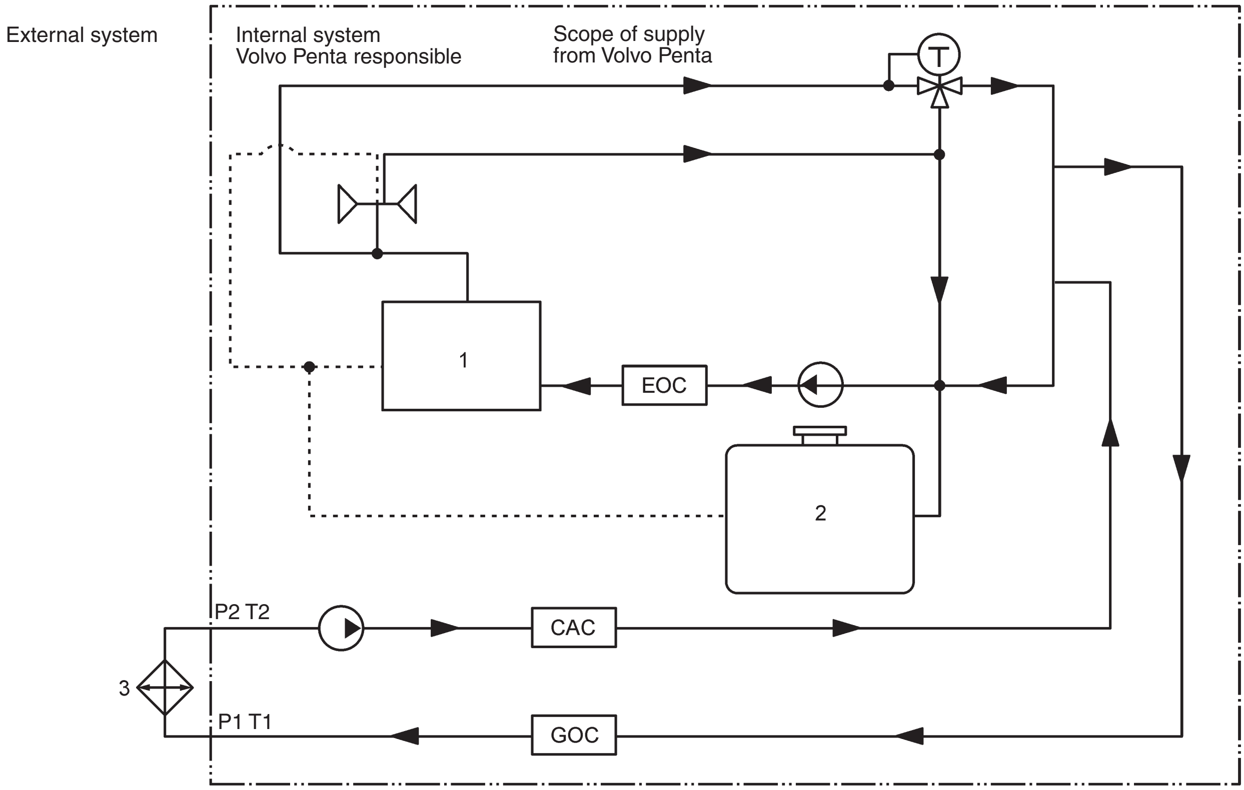


1. Engine
2. Expansion tank
3. Keel cooler, engine circuit

- EOC – Engine oil cooler
- CAC – Charge air cooler
- GOC – Reverse gear oil cooler
- Connection, flange or thread for valve
- Thermostatic valve
- Circulation pump
- Seawater pump
- Air vent nipple
- Restriction
- Cooler
- Turbo

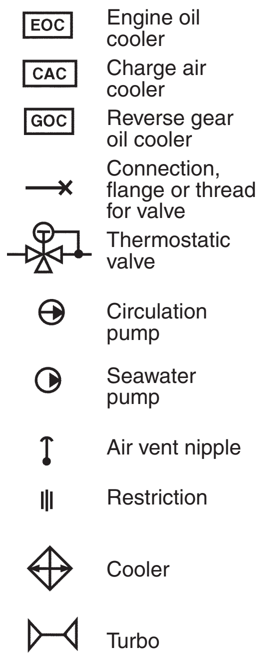
For temperatures, max pressure drop and flow, see Technical data in ***Sales Guide Marine Propulsion Diesel Engines***.

D5/D7 -TA
External cooling. Two circuit system with one keel cooler

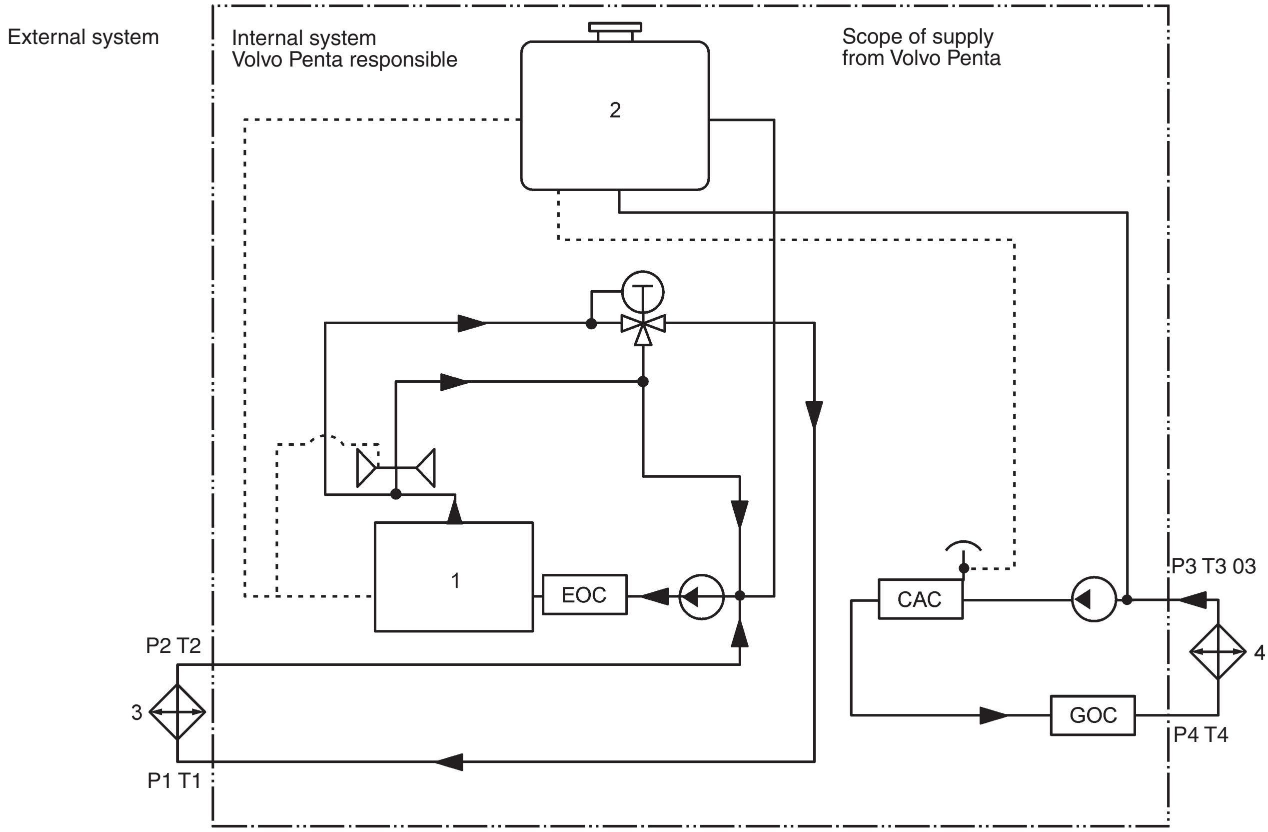


1. Engine
2. Expansion tank
3. Keel cooler, engine circuit

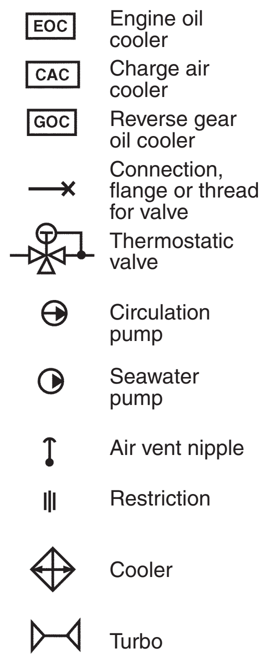
For temperatures, max pressure drop and flow, see Technical data in ***Sales Guide Marine Propulsion Diesel Engines***.



D5/D7 -TA
External cooling. Two circuit system with two keel coolers

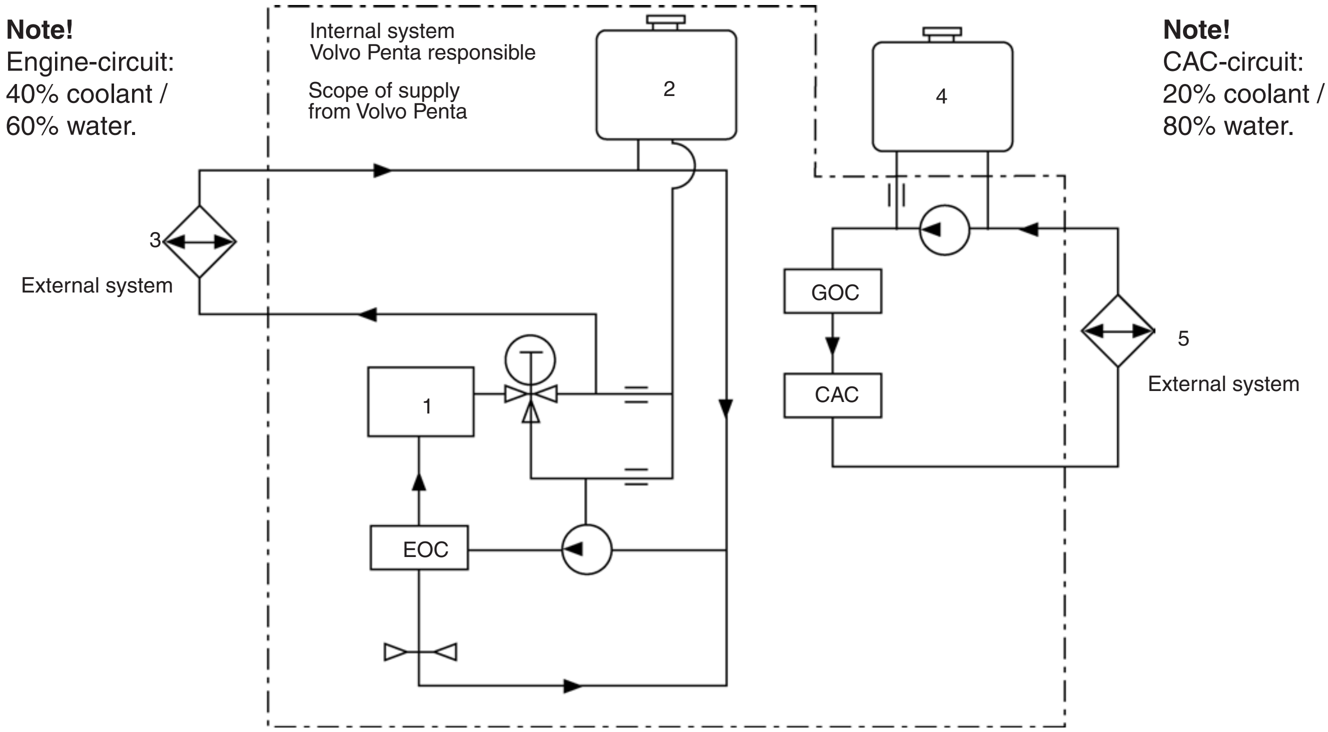


1. Engine
2. Expansion tank
3. Keel cooler, engine circuit
4. Keel cooler, charge air cooler circuit

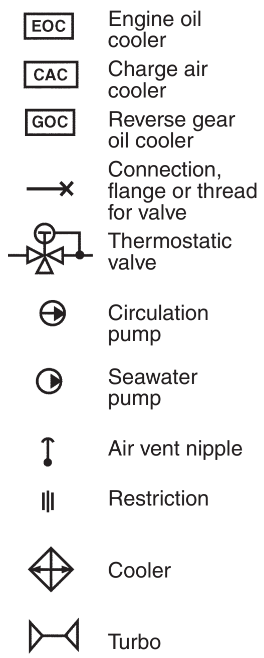


For temperatures, max pressure drop and flow, see Technical data in ***Sales Guide Marine Propulsion Diesel Engines***.

D9
External cooling. Two circuit system with two keel coolers

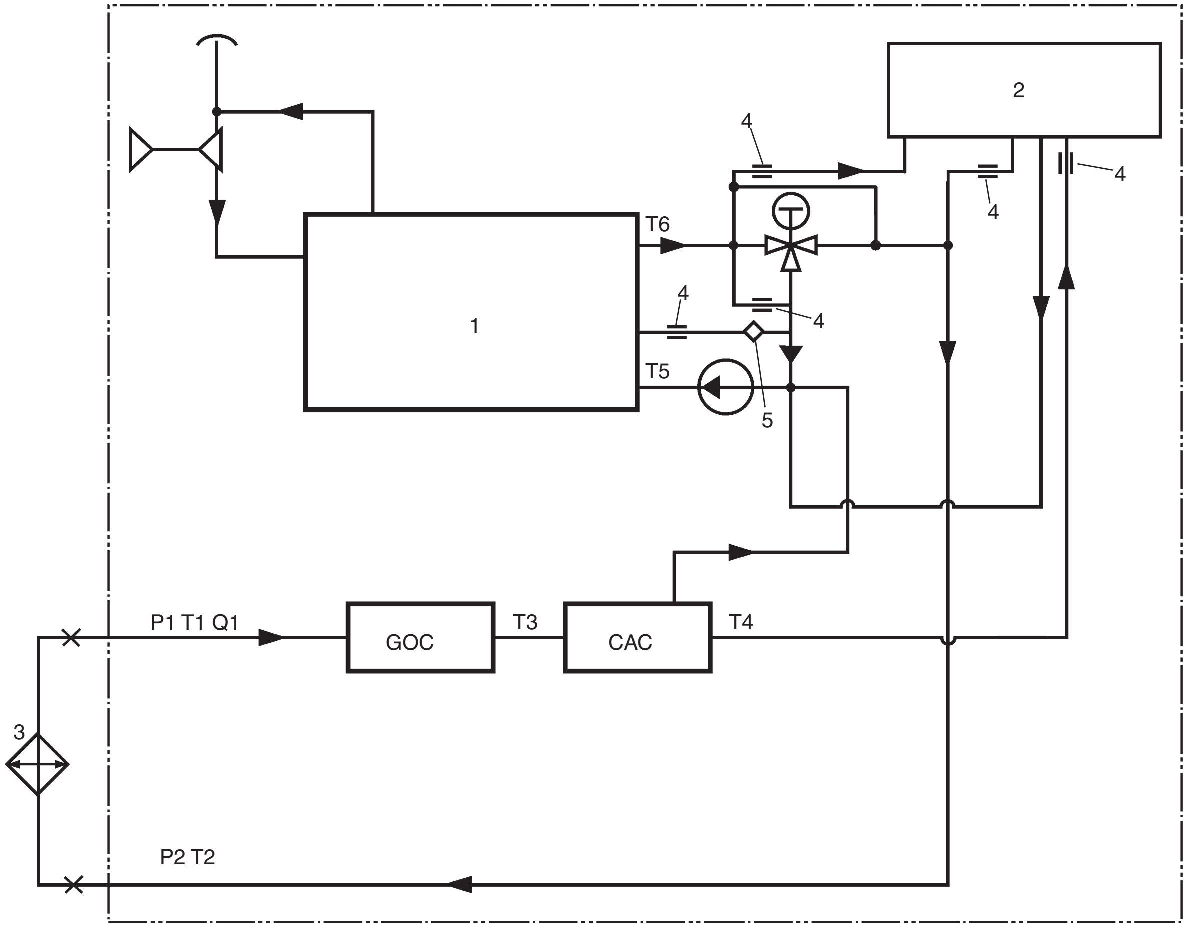


1. Engine
2. Expansion tank, engine circuit
3. Keel cooler, engine circuit
4. Expansion tank, charge air cooler circuit (option)
5. Keel cooler, charge air cooler circuit



For temperatures, max pressure drop and flow, see Technical data in ***Sales Guide Marine Propulsion Diesel Engines***.

D12
External cooling. One circuit system



External system

Internal system
Volvo Penta responsible

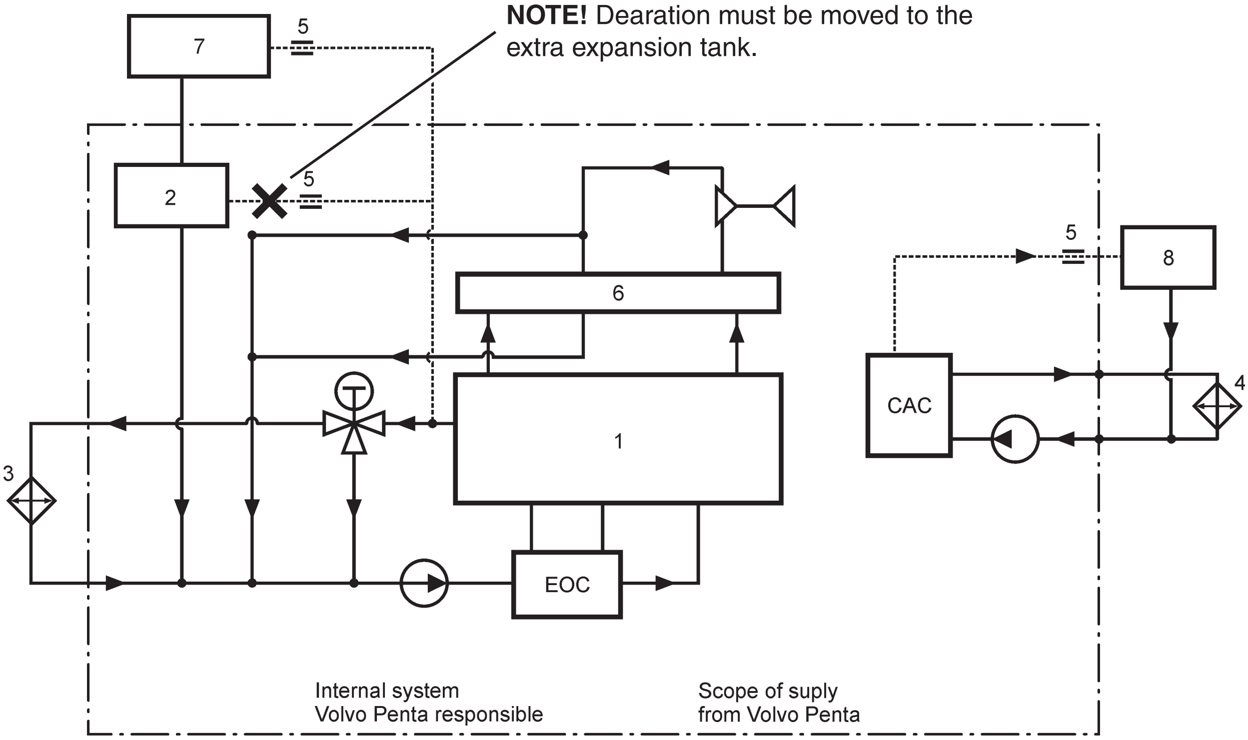
Scope of supply
from Volvo Penta

1. Engine
2. Expansion tank
3. Keel cooler
4. Restriction
5. Coolant filter

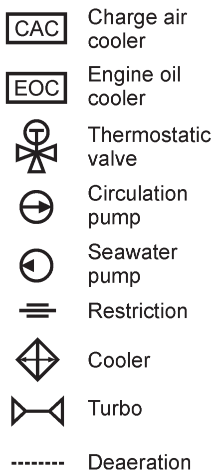
For temperatures, max pressure drop and flow, see Technical data in ***Sales Guide Marine Propulsion Diesel Engines***.

EOC — Engine oil cooler
CAC — Charge air cooler
GOC — Reverse gear oil cooler
Connection, flange or thread for valve
Thermostatic valve
Circulation pump
Seawater pump
Air vent nipple
Restriction
Cooler
Turbo

D16
External cooling. Two circuit system



1. Engine
2. Expansion tank (Engine mounted)
3. Keel cooler - Engine cooler
4. Keel cooler - Charge air cooler
5. Restriction
6. Exhaust manifold
7. HT exp.tank (Extra expansion tank)**
8. LT exp.tank (Extra expansion tank)*



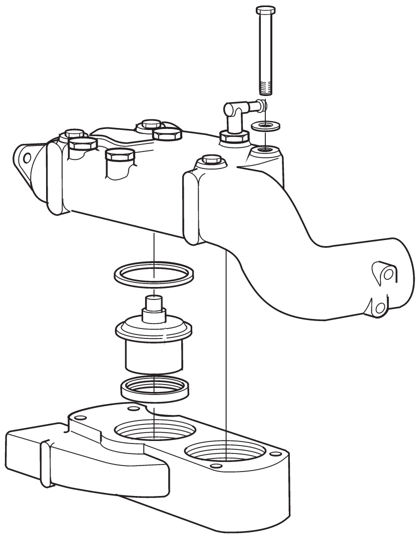
For temperatures, max pressure drop and flow, see Technical data in ***Sales Guide Marine Propulsion Diesel Engines***.

* LT exp tank is not incl. in delivery. Size should be adapted to circuit volume

** HT extra exp. tank must be installed when system volume exceeds 20 ltr. Not incl. in delivery. Size should be adapted to circuit volume

NOTE! Dearation must be moved to the extra expansion tank, refer to schematic.

Thermostats, external cooling



Two different types of thermostats are used in Volvo Penta marine engines - disk thermostats and piston thermostats.

D5/D7, D9, D12 and D16 have piston thermostats.

NOTE: If an engine is connected to a **central cooling system**, which requires full flow through the engine, and the system has its own thermostat, the thermostat(s) of the engine must be forced fully open.

The following table shows opening temperatures for the various thermostats and the gap of the opening when fully open.

⚠ **IMPORTANT!** Do not run an engine without thermostats.

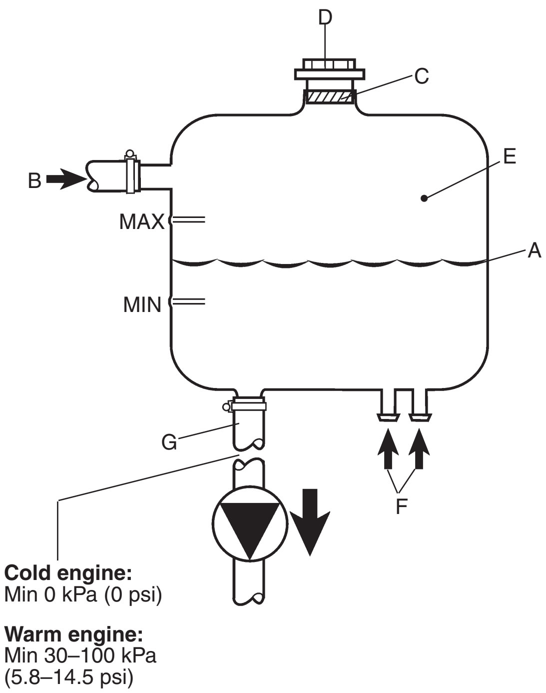
Thermostat data

Engine:		D5/D7	D9	D12	D16
No. of thermostats		1	1	1	1
Opening temp.	°C (°F)	83 (181)	86 (187)	76 (169)	86 (187)
Fully open	°C (°F)	95 (203) 84* (183)	96 (205)	86 (185)	96 (205)
Opening with fully open therm.	mm (inch)	8 (0.32)	16 (0.63)	16 (0.63)	16 (0.63)

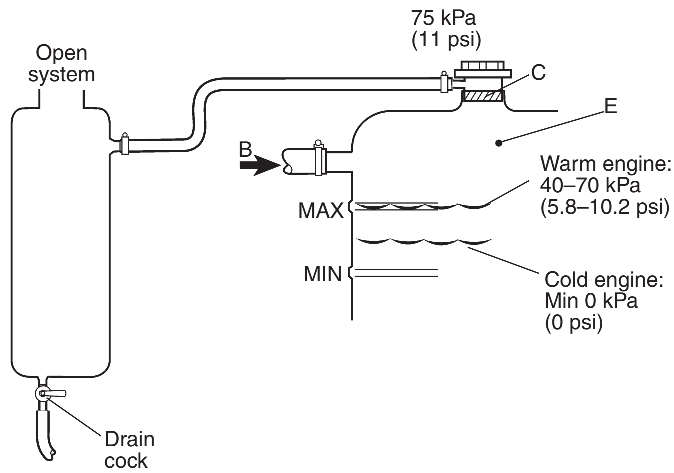
*) Two thermostats (blue marking) open at 76°C and are fully open at 90°C. The third thermostat (red marking) opens at 70°C and is fully open at 84°C.

Expansion tank, function diagram

Correctly designed system



Recovery tank correctly connected



A Coolant level before start up. Max. filling level with cold engine.
Coolant level is not to pass below the MIN mark with cold engine.
Coolant level is not to pass the MAX mark with warm engine.

B Connection for hose from thermostat housing.

C Low pressure relief valve. See next page.

D Pressure cap 75 kPa (11 psi). See chapter ***Extra expansion tank***.

E Expansion volume.

F Deaeration from engine / radiator.

G Connected to the suction side of the seawater / coolant pump.

- It is advisable not to surpass the in-between level when engine is cold. This minimizes the "throw out" if an undesired quick stop occurs.

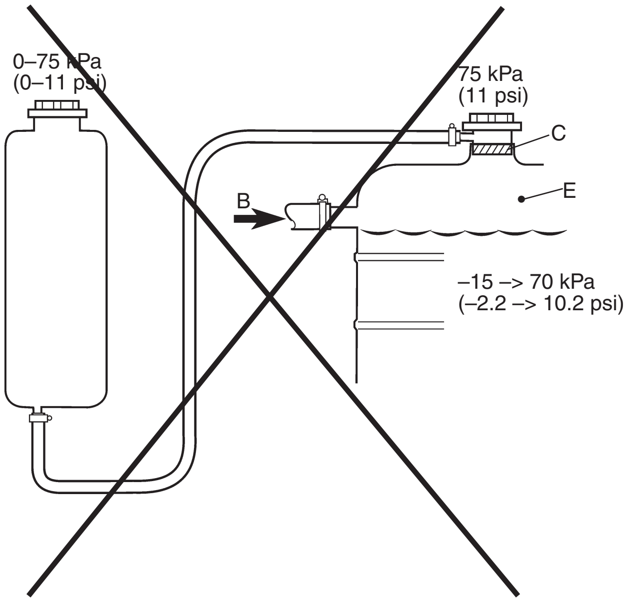
  With a correctly designed cooling system the pressure cap prevents ventilation. Avoid opening the pressure cap. If necessary, always open cap when the engine is cold.

- Connection (**B**) is to be connected before the thermostat with the hose continuously inclining in order to ensure deairing when filling up coolant after the system has been drained.

  In the case of an existing manual drain cock the hose is to be connected to the bottom of the tank and connection (**B**) blanked (sealed off).

NOTE! A restriction of 2.5 – 3.0 mm (0.10 – 0.12") is to be fitted in each deairing hose. Locate the restriction in an inclining part of the hose.

Recovery tank incorrectly connected. Unacceptable system, fatal to the engine

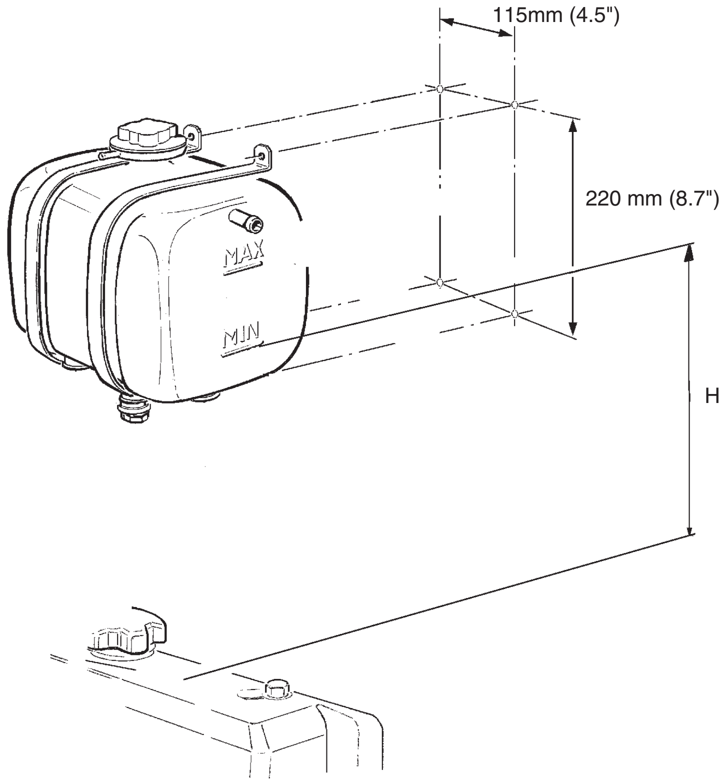


⚠ **IMPORTANT!**

- If there is too little expansion volume (**E**) an underpressure will be created when charged after an idling period, thus causing cavitation of the jacket pump.
- During idling the thermostats close, the coolant is cooled off and contracting. The pressure cap has a low pressure relief valve (**C**) which opens up around –15 kPa (–2.2 psi). It is not healthy for a jacket pump to operate with an inlet pressure of 0 kPa (0 psi) and below, since cavitation is likely to occur.

Extra expansion tank

All engines



Type of pressure cap and opening pressure depending on height

Height (H) engine valve cover – MIN mark		Type of pressure cap
– 2.0 m	(– 6.5')	75 kPa (10.9 psi)
2.0 – 5.0 m	(6.5 – 16.5')	50 kPa (7.3 psi)
5.0 – 7.0 m	(16.5 – 23.0')	30 kPa (4.4 psi)
7.0 – 10.0 m	(23.0 – 33.0')	Open system

NOTE! If you select an in-house manufactured expansion tank, you should use a Volvo Penta pressure cap. Choose the type of cap in accordance with table above.

Heat exchanger cooled engines. Capacity of the freshwater standard system and extra circuits

Extra circuits, such as hot water circuits and cabin heaters, may be added to the freshwater system. See table for maximum increase of freshwater system by an extra circuit.

⚠ **IMPORTANT!** When the volume is **further** increased, the cooling system has to be equipped with a larger expansion tank. Please contact the Volvo Penta organisation for more information.

Permitted volumes with standard expansion tank:

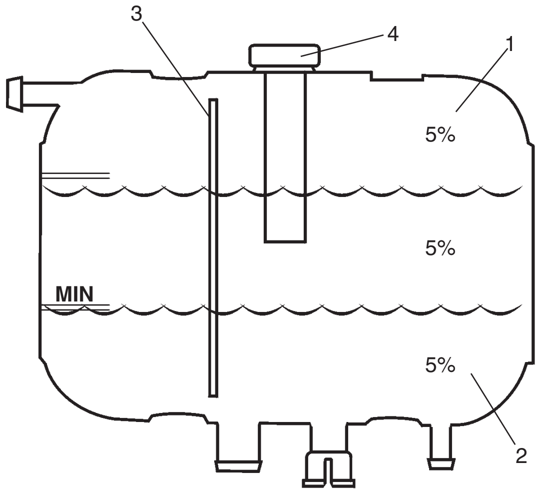
Engine including heat exchanger	Engine volume lit (US gal.)	Extra circuit volume lit (US gal.)
D5	21 (5.6)	63 (16.6)
D7	26 (6.9)	63 (16.6)
D9/D11	39 (10,3)	40 (10,6)
D12 300-650	60 (15.8)	75 (19.8)
D12 675-800	65 (17.2)	77 (20.3)
D16	56 (14.8)	20 (5.2)

When an extra expansion tank is installed the engine's expansion tank must be completely filled with coolant.

NOTE! The keel cooled version of D9 and D16 must always have an extra expansion tank.

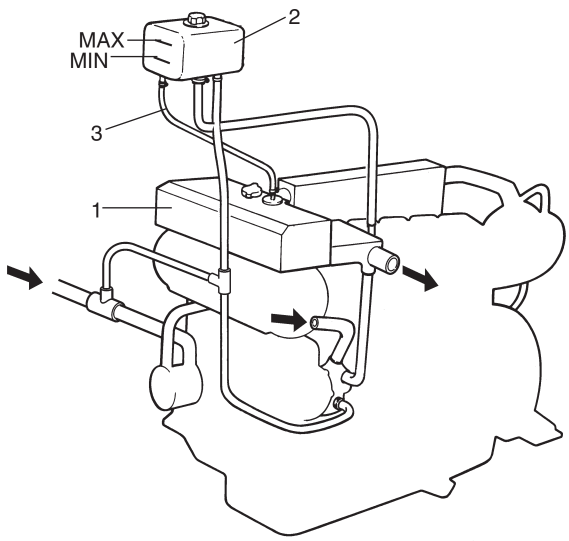
The expansion tank volume in the extra tank should be 15% of the **total capacity** of the cooling system. Of this volume:

5% is meant for coolant expansion when hot (expansion volume),
5% is meant for the difference between MAX and MIN levels
5% is reserve volume.



1. Expansion volume, 5%
2. Reserve volume, 5%
3. Divider
4. Pressure cap

A divider can be used to improve deairing of the expansion tank.



1. Engine expansion tank
2. Extra expansion tank
3. Separate venting hose

The expansion tank of the engine must have a separate vent (3) to the extra tank connected below MIN level.

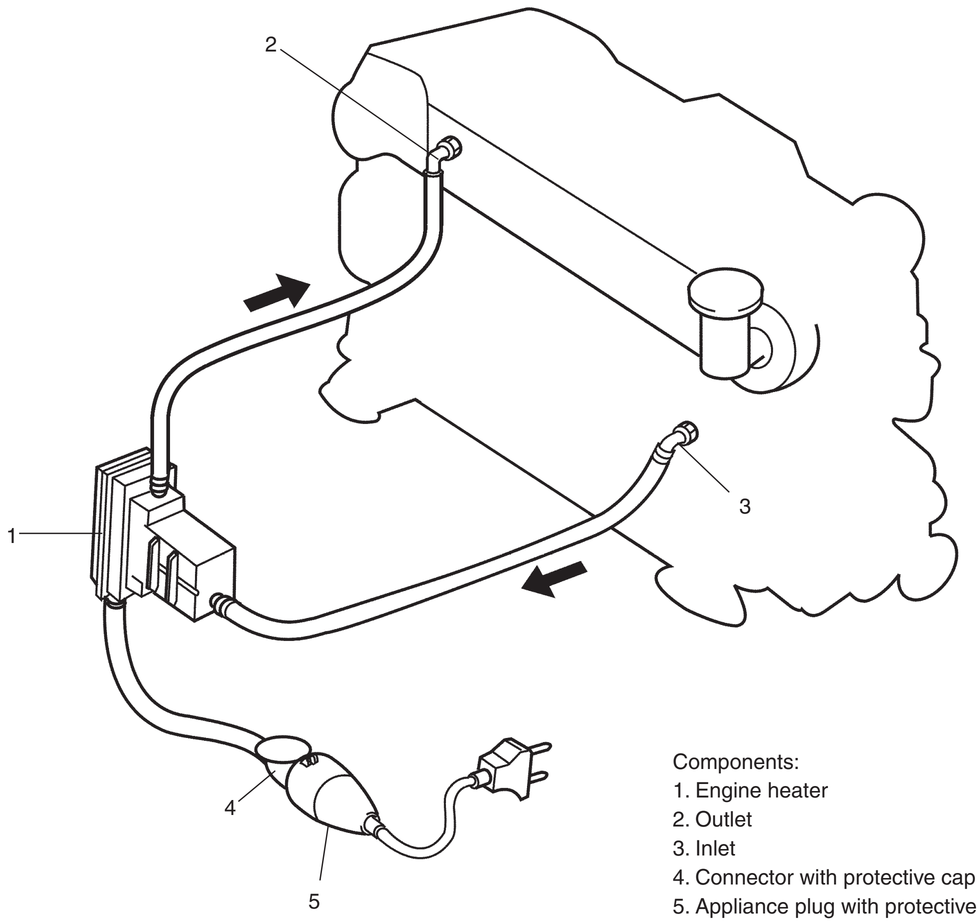
NOTE! If there are no manual venting nipples, the hose (3) must be continously inclining.

The hoses must be able to withstand temperatures up to 115°C (240°F).

The engine's pressure cap is replaced with a sealed cap. The standard engine venting hose from the thermostat housing can be connected to the extra expansion tank below the MIN level to facilitate venting when topping up with coolant.

To improve pressurisation of the cooling system it is recommended to keep the temperature high in the expansion tank. If the tank is located in a cold place, the tank should be in a sheltered position and insulated.

Engine heater



Components:
1. Engine heater
2. Outlet
3. Inlet
4. Connector with protective cap
5. Appliance plug with protective cap

Cold starting is one of the most important determining factors regarding the service life of an engine. Frequent cold starts followed by extended periods of idling significantly increase wear on the engine. An engine heater extends the service life of the engine and the batteries. The heater lowers emissions during start up and prevents hunting.

The engine heater warms and circulates coolant through the engine block. It is important that the engine heater is of the right type, is correctly connected and maintains the engine coolant at the right temperature.

The heater should have its own circulation pump and be located in a protected area.

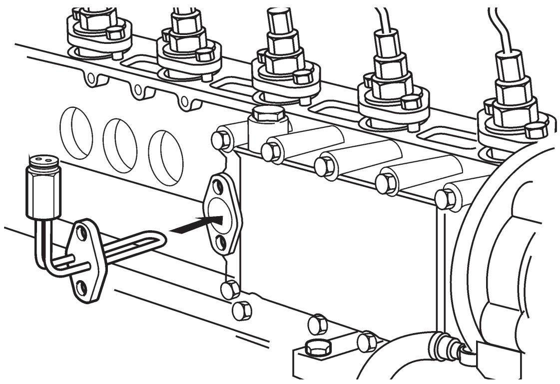
The figures on the following two pages show, for each engine model, connecting points for a separately mounted heater.

An engine mounted engine heater can be provided for D5/D7. A separately mounted heater should not be used.

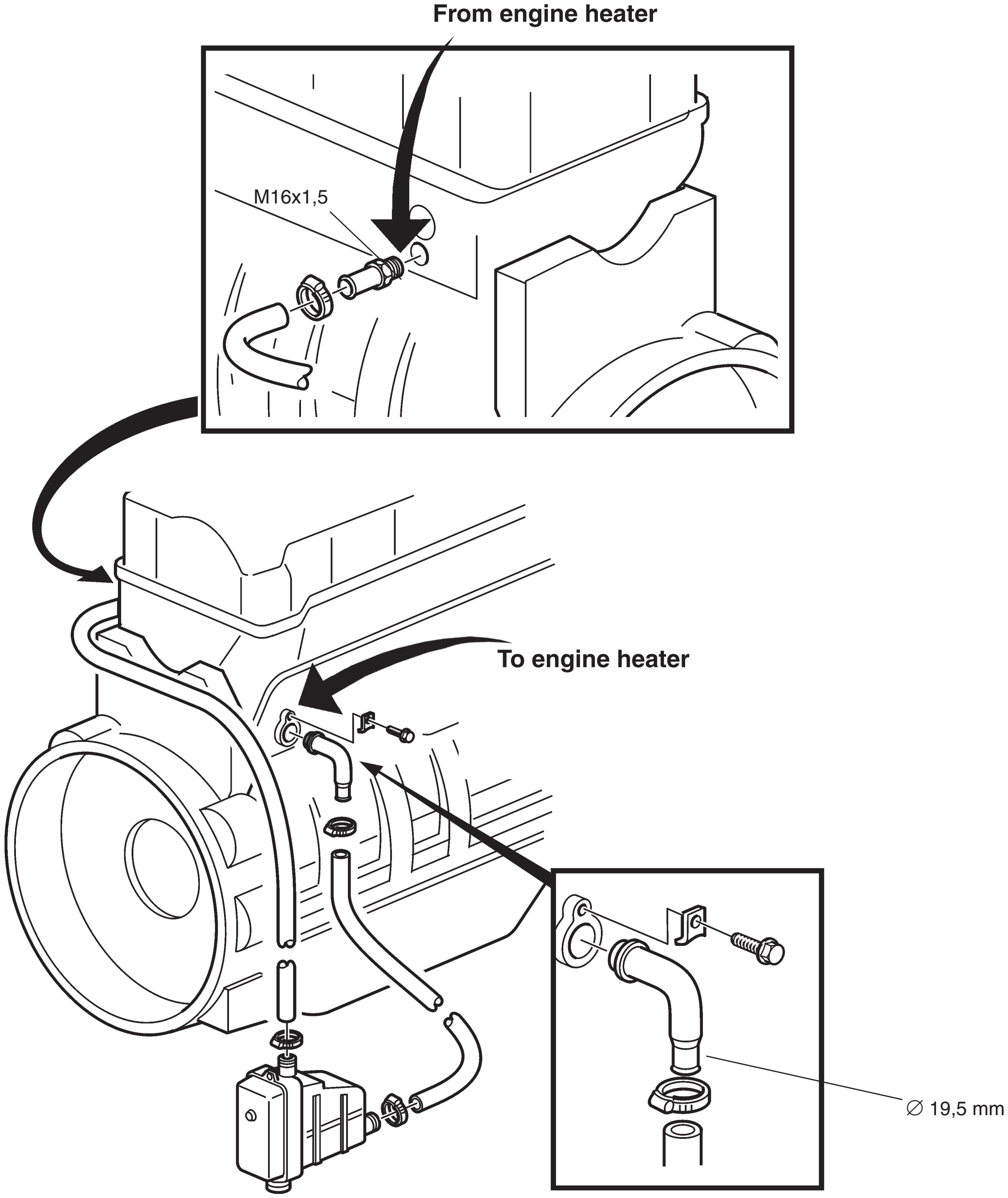
NOTE! The rating of the engine heater shall be chosen so that the incoming coolant temperature in the engine does not exceed 70°C (158°F).

NOTE! To avoid galvanic corrosion, it is very important that the engine heater is correctly protected. Please see 161, Protection against galvanic corrosion.

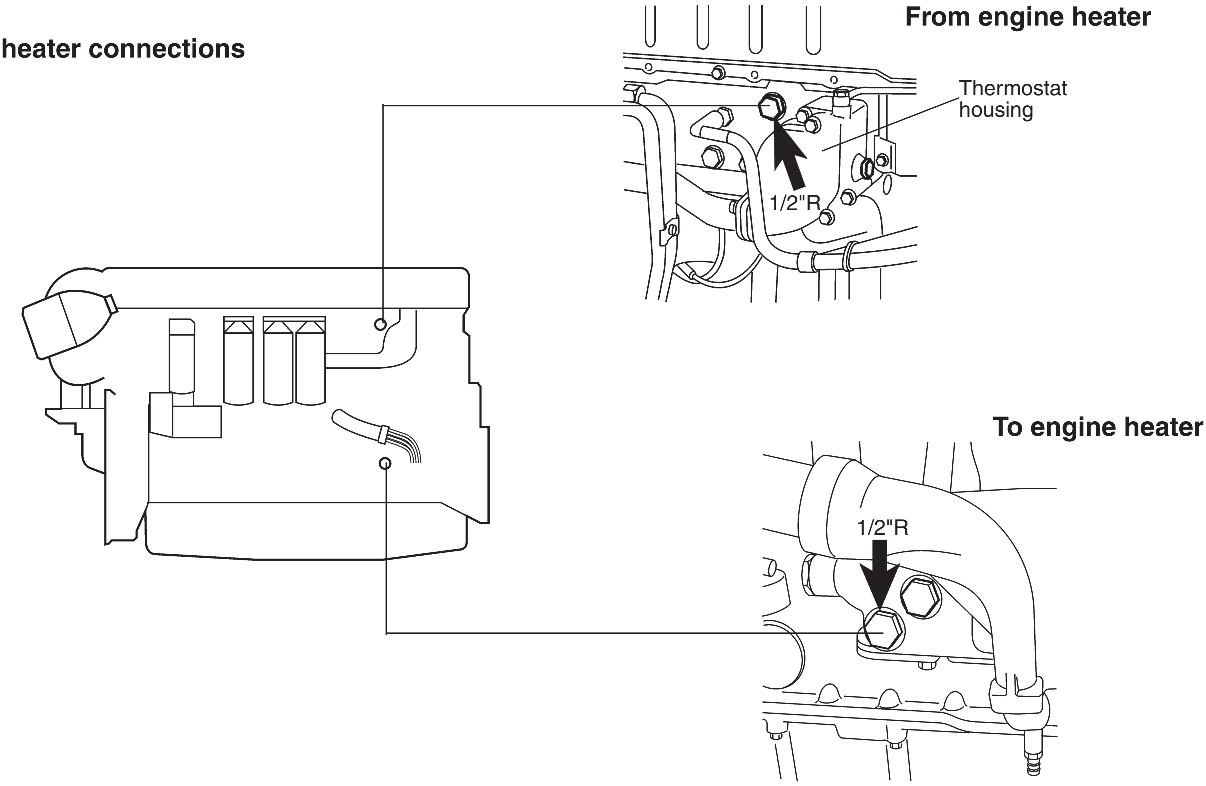
D5/D7
An engine mounted engine heater can be provided for the D5 and D7 engines.



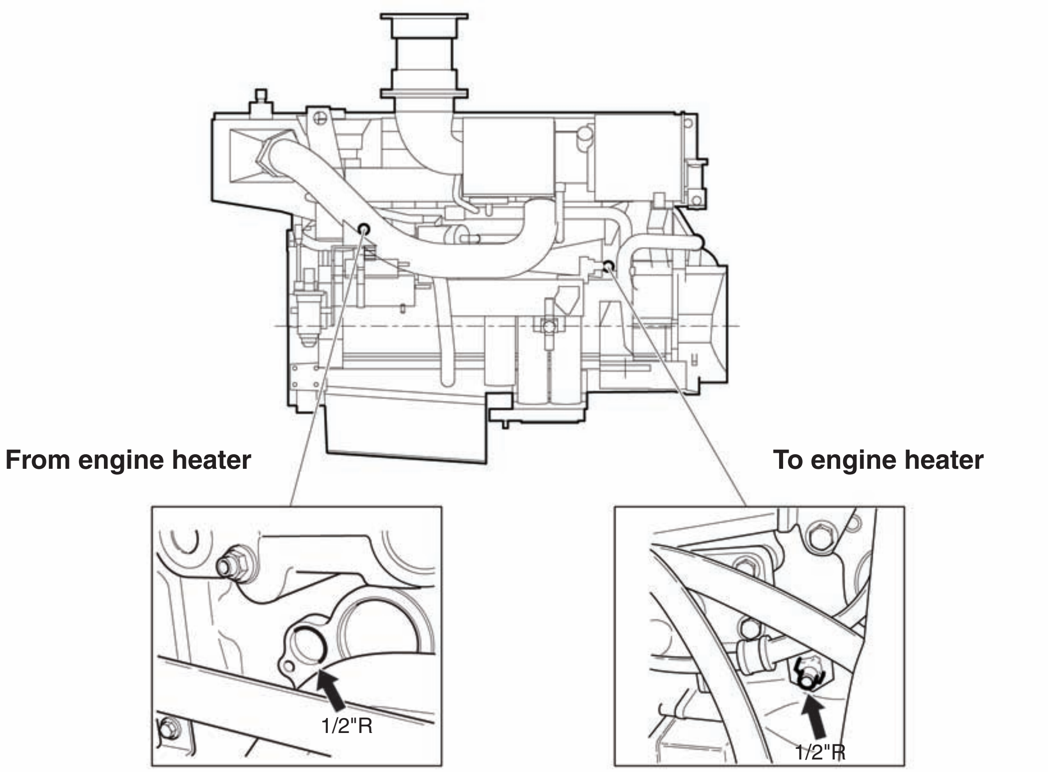
D9/D11
Engine heater connections



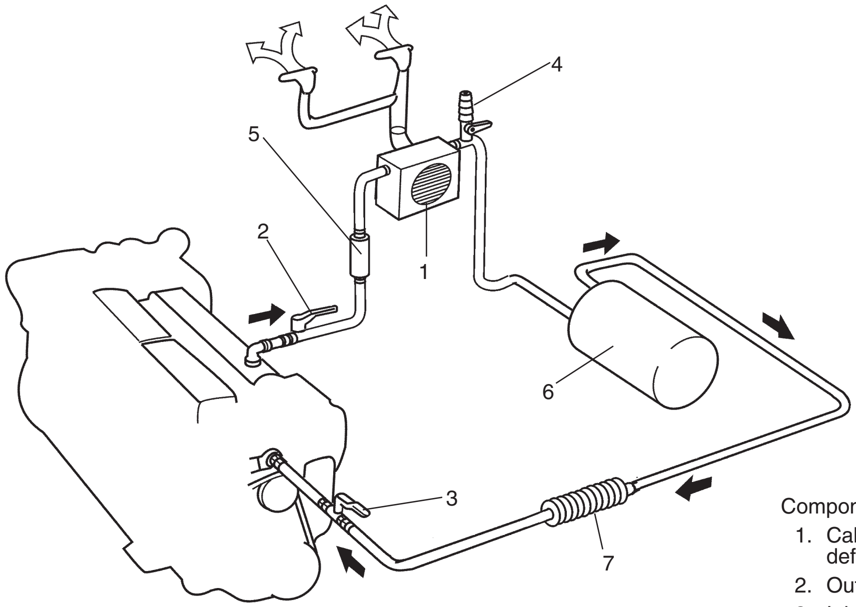
D12
Engine heater connections



D16
Engine heater connections



Hot water connections



Components:
1. Cabin heater with defroster unit
2. Outlet valve
3. Inlet valve
4. Venting nipple
5. Hose thermostat
6. Calorifier
7. Radiator

General

A cabin heater and/or a calorifier can be connected to the freshwater circuit of the engine. When a cabin heater is installed, it must always have a manual venting nipple (4) at its highest point. The system is vented once pressurized.

In large heating systems, a hose thermostat (5) should be mounted in the line of the hot water circuit. This ensures that the engine quickly reaches its operating temperature. Volvo Penta stocks suitable thermostats.

The illustrations on the following two pages show where, on each type of engine, coolant can be tapped off for the hot water circuit.

Max. freshwater capacity

For freshwater capacities see information in chapter ***Extra expansion tank***.

Shut-off valves

Volvo Penta recommends that shut-off valves (2, 3) are installed in the extra cooling circuit on both the supply and return sides to be shut off for service and repair or during warm seasons.

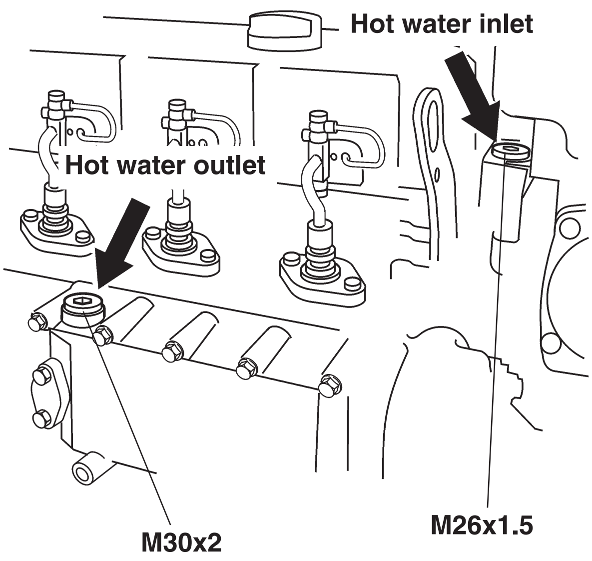
Locate the valves as close to the engine as possible and with a hoose between.

Mounting

Calorifier, cabin heater etc. may be fitted max. 2.5 m (8') above MIN level of the expansion tank.

D5/D7
Hot water connections

Inlet and outlet - from hot water circuit



D5/D7

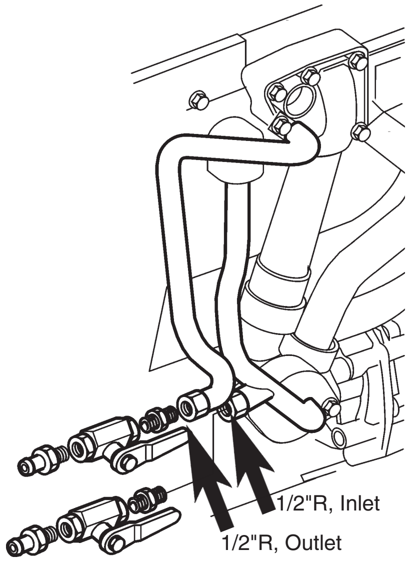
When dimensioning the heat exchanger for heating, it must be observed that the coolant tap on the engine only can allow a limited water flow and temperature drop.

Max allowed water flow	18 l/min.
Max allowed temperature drop	30°C (86°F)

The external circuit must be designed to restrict the flow to not exceed the allowed flow. The external circuit is by-passing the engine cooling circuit, to great flow may cause engine overheating.

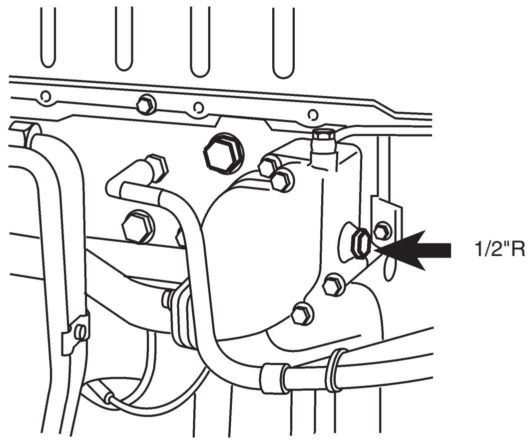
If the heating is designed so that it can dissipate more heat whit the available quantity of coolant, the engine cannot reach its appropriate temperature despite a closed thermostat. This must be avoided by heating dimensioning.

D9/D11
Hot water connections

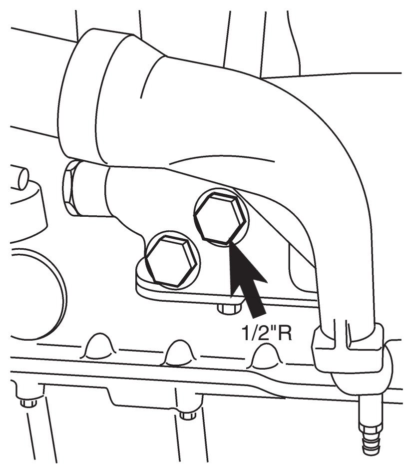


D12
Hot water connections

Outlet - to hot water circuit

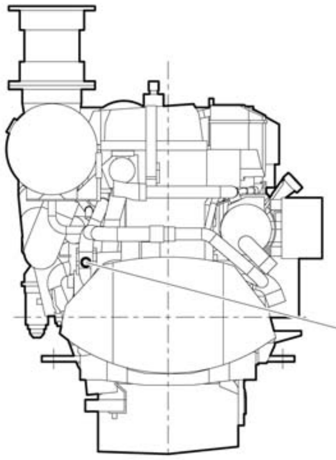


Inlet - from hot water circuit

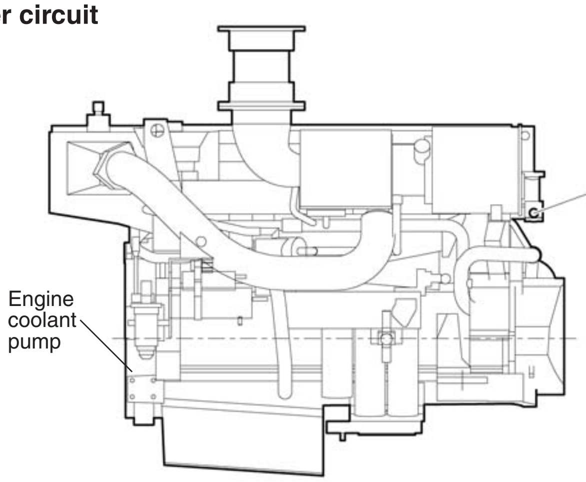


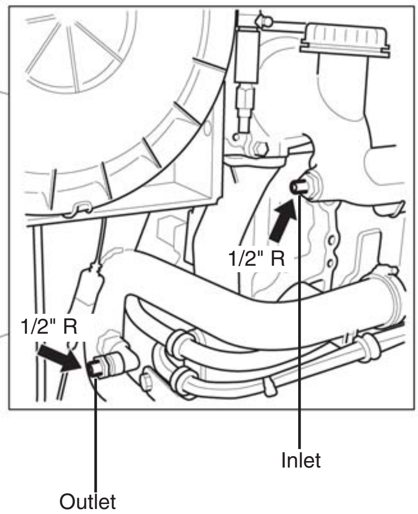
D16
Hot water connections

Inlet - from hot water circuit



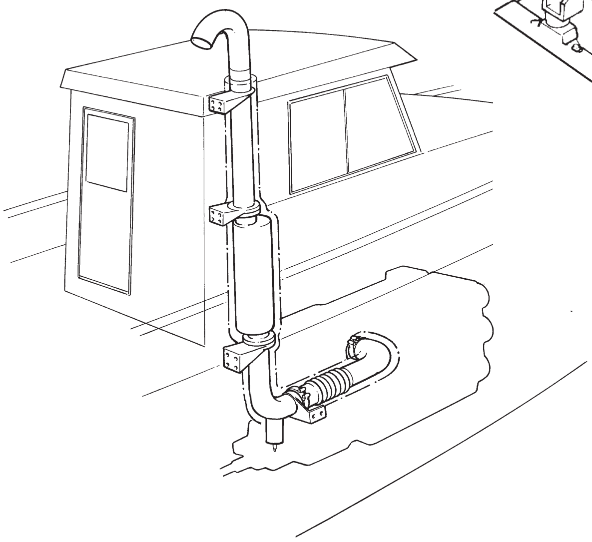
Outlet - to hot water circuit

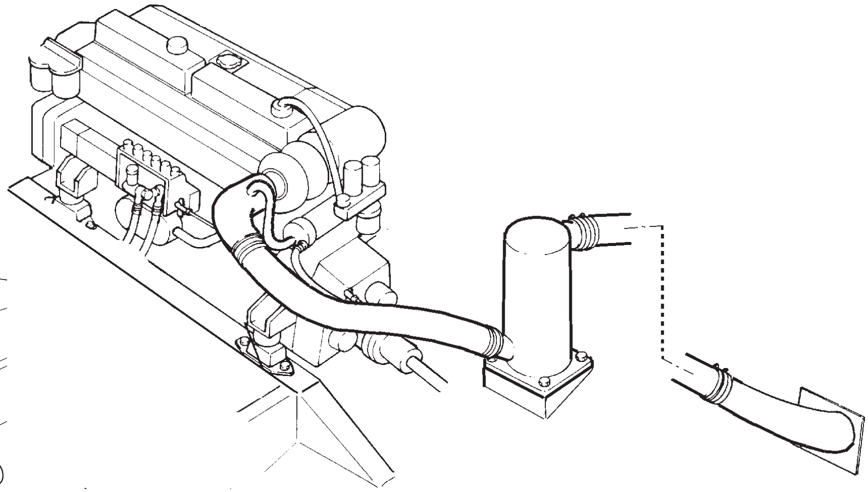




Exhaust system

Dry exhaust system





Wet exhaust system

General

Exhaust systems for marine engines can be divided in two categories :

- Wet exhaust line
- Dry exhaust line, insulated

Most of the boats/vessels in Volvo Penta power range with inboard engines are equipped with wet exhaust systems. Water is injected into the system to cool the exhaust gas and the mixture passes out together with the exhaust.

A wet system has several advantages compared with a dry system. The water lowers the exhaust temperature considerably after the point where the water is fed into the system, enough to permit the use of a flexible rubber hose. A flexible hose is usually easier to install than pipes, is not affected by corrosion or stress and absorbs the vibration from a flexibly mounted engine. A wet exhaust system does not need insulation either and radiates less heat.

The importance of using a wet exhaust is to make a proper design and make sure the coolant cannot enter backwards into the engine.

⚠ **IMPORTANT!** The exhaust system should be designed and installed in such a way that the exhaust emissions are taken out of the boat without any harmful backpressure for the engine and so that there is no risk of overheating any adjacent parts of the boat. The demand for silencing must also be met and the system arranged in such a way as to prevent the gases from entering the boat. All exhaust systems must be installed in such a way that water cannot force its way back into the engine when the engine has been switched off.

When designing the exhaust system, note that the backpressure must not exceed the values in the table in chapter Backpressure.

The dry exhaust system for inboard diesel engines is mainly used for slower vessels, commercial operation. A dry system is neccessary in cold climates with temperatures below 0°C (32°F). The dry system in general requires less maintenance and has longer service life. Insulation of the system is usually required as temperatures are dangerously high and heat radiation into the engine room is negative for engine operation.

Volvo Penta does not market complete wet or dry exhaust systems but provides some of the key components.

⚠ **IMPORTANT!** Vessel manufacturers should note that U.S. federal regulations applicable to U.S. vessels require the installation of an exhaust sampling port in the exhaust system that could be used for connection to an exhaust emissions measuring device. This applies to engines certified according to U.S. EPA 40 CFR part 94 regulations.

Where Volvo Penta have not added a sample port, for example when an inadequate amount of the exhaust system is supplied to make such an installation practical, the vessel manufacturer is responsible to ensure that the required sample port is installed. Failure to comply with this requirement may constitute an act that is prohibited under federal law and may subject the vessel manufacturer to federal penalties.

Vessel manufacturers should ensure that they carefully follow instructions concerning an exhaust sampling port as required under controlling federal regulations. Failure to do so could be a violation of the prohibited acts set forth at 40 CFR 94.1103, potentially subjecting the vessel manufacturer to federal penalties, and could make it unlawful to sell or place the vessel into service.

Instructions to comply with this requirement can be provided by Volvo Penta upon request.

"Wagon-back effect"

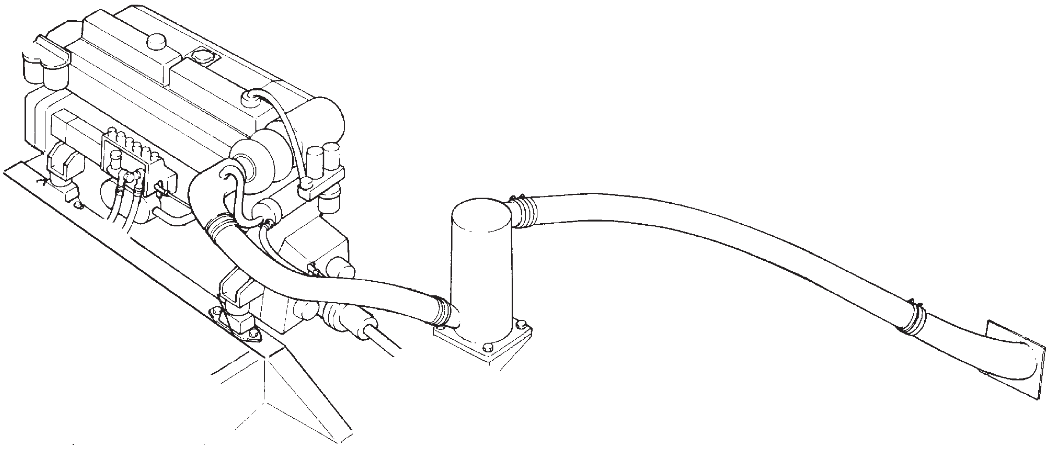
As long as we continue to use combustion engines as sources of power, we will always be faced with the problem of exhaust emissions. Even though the level of exhaust emissions from modern combustion engines has now been minimised, smoke and fumes are still given off when fuel is burnt.

When we also have a sheer body in motion, another problem arises. It is the phenomen we call the Wagon-back effect".

On a boat with a sheer, broad transom and high superstructure, the result of the "wagon-back effect" is that the exhaust fumes are drawn up towards the afterdeck, dirtying the cockpit and creating unpleasant conditions for those on board. The problem originates with what is known as recirculating air. When a boat moves forward and creates a backward current of air, an underpressure forms in the boat and the exhaust fumes are drawn into it.

To avoid such a problem, it is of outmost importance to design and locate the exhaust outlet properly.

Wet exhaust line



General

The expression "wet exhaust line" implies that the outgoing coolant is taken into the exhaust line for cooling and silencing purposes.

Complete wet exhaust elbows are offered for most Vovo Penta engines. In other cases, elbows can be specially made.

A wet exhaust line is particulary suitable with a flexible mounted engine since it can mostly be made of oil and heat-resistant rubber exhaust hose. Thus it would be the most comfortable system for noise reduction.

The geometry of the vessels and the engine rooms varies from spacious volumes to very compact and tailor-made systems.

Usually the marine engine manufacturers do not market complete wet exhaust systems. The OEM, shipyard, boat manufacturers etc. are the ones who design, chose components and experiment to develop a final exhaust system that complies with all subsupplier requirements.

The recommendation in this section should be regarded as emperical framework and reflects a total system with maximum length of **10 meters (33') and maximum 4 x 90° bends**.

All systems with silencers, especially the "Aqua-lifts" contribute to the system's total backpressure. The contribution of each silencer must be carefully estimated and calculated as well as sea-trialed and verified by measurements.

NOTE! U.S. federal regulations applicable to U.S. vessels require the installation of an exhaust sampling port in the exhaust system. See chapter **General** under **Exhaust system.**

Dimensioning the exhaust line

The exhaust line must be dimensioned so as to avoid harmful backpressure. This is particulary important in the case of turbocharged engines. Too high backpressure means output losses and can cause operating disturbances like power losses, increased smoke level and shorter service life. For recommendations see diagram in chapter **Backpressure**.

Exhaust elbow diameter

The table below indicates standard wet exhaust connection diameters. Note that the complete system might require larger diameters depending on length, silencer and outlet configuration.

Engine	Volvo Penta standard exhaust elbow connection diameter
D5	3"/ 68 mm
D7	4"/ 107 mm
D9/D11	6"/ 150 mm
D12	8"/ 200 mm

The silencer is fitted in a suitable place as close to the engine as possible. The silencer should always be placed lower than the exhaust elbow.

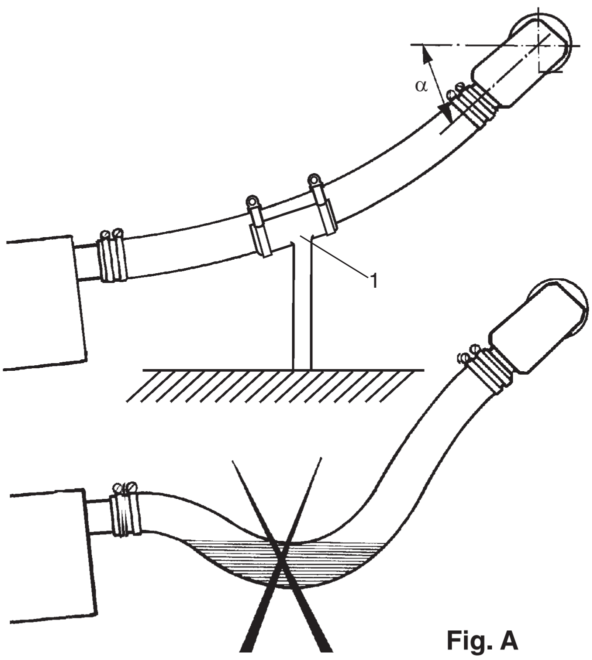


Fig. A

Exhaust elbow angle (α) relative to water line, fig. A should be min:

D5	15°
D7	10°
D9/D11	elbow angle is fixed
D12	15°

The elbow angle is important to obtain a water spray all around the outlet. This is to avoid overheating of the top of the exhaust hose.

It is very important to install a flexible hose to the exhaust elbow. This hose must be flexible enough to allow the engine to move without creating stress on elbow or its connection.

The hose must be arranged with a continuos inclination into the silencer throughout the whole distance, see figure A.

If the hose between elbow and silencer has such a length or design it must be supported (1) to avoid a "sack", see figure A.

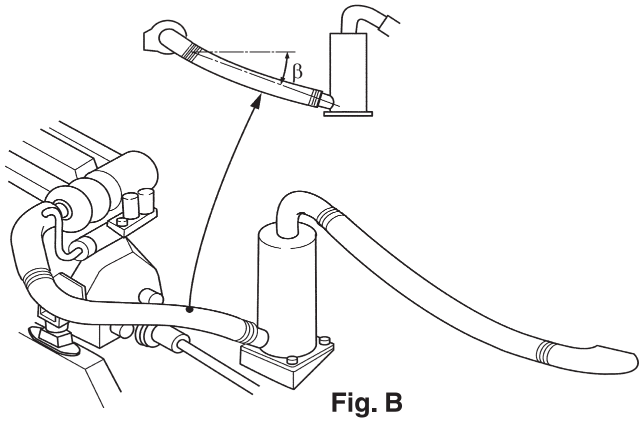


Fig. B

Inclination angle (β) figure B
from elbow to silencer should be min:
Longitudinal inclination 4° (according to figure B)

Longitudinal inclination,
systems without silencer 10°
Transverse inclination 10° (according to figure C)

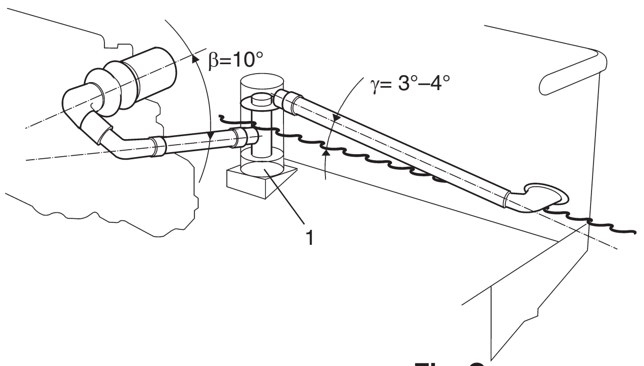


Fig. C

Transverse inclination (β) figure C:
The inclination should be minimum 10°.
This presumes that the coolant can be collected in the silencer inlet. See figure C position (1).

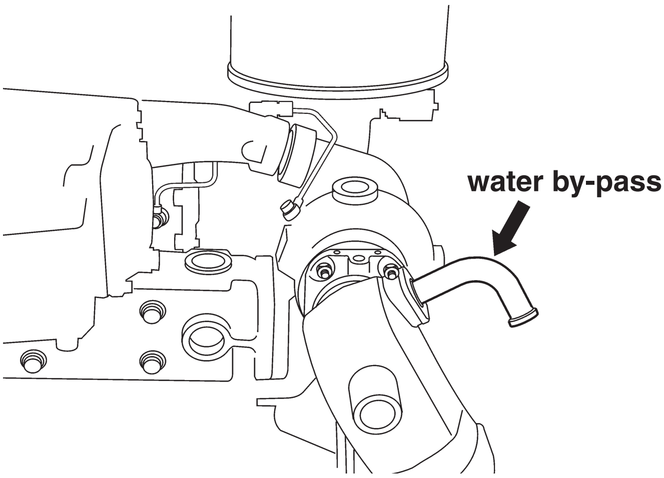
Exhaust systems without silencers should have an **average** inclination of min. 10°.

Inclination angle (γ) figure C, longitudinal exhaust line from silencer to exhaust outlet:
The minimum permissible fore and aft inclination (γ) between the silencer and the exhaust outlet in the hull is 50–70 mm/m (2–2 3/4"/3.3'), 3°–4°. See figure C.

For sailing yachts see principal system figure D on the following page.

Water by-pass for D5

A water by-pass hose must always be installed on D5 to obtain allowed back pressure. The hose should be installed on the exhaust elbow and the water outlet through the hull.



Principal system for sailing yachts

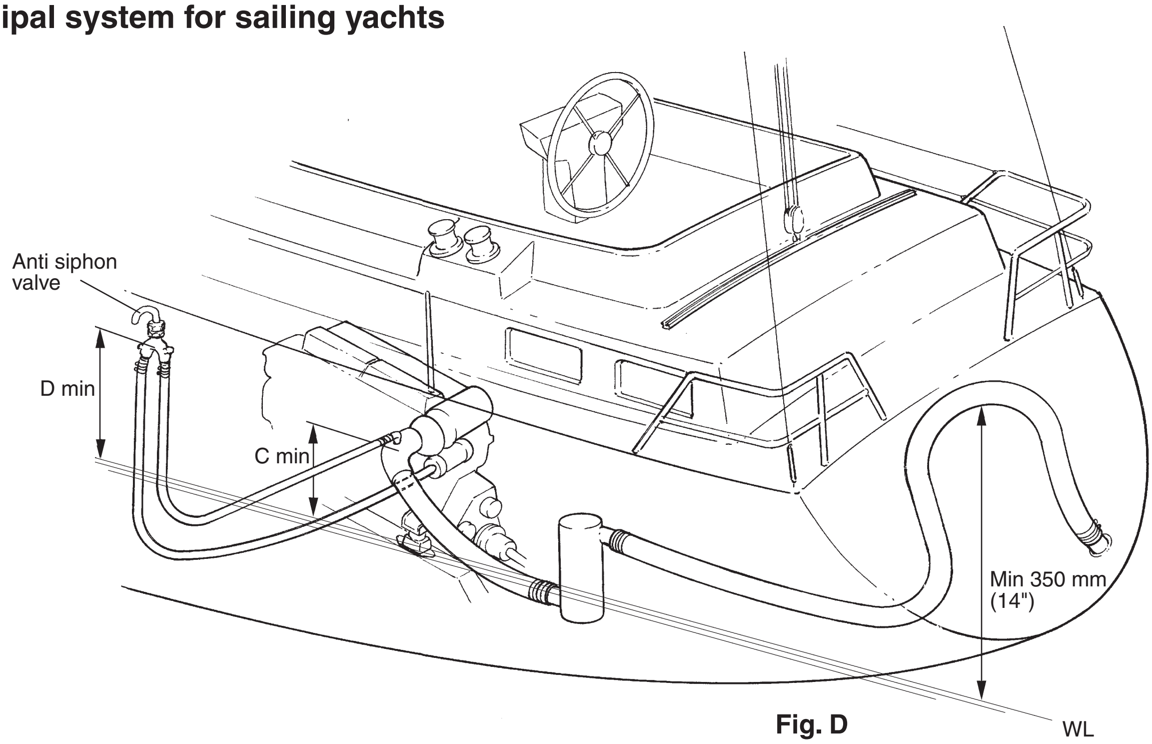


Fig. D

Principal system, figure D

To prevent water from entering from the rear, the last part of the exhaust line should be arranged in a bend (swan neck) reaching up to at least **350 mm (14")** above the water surface when the boat is loaded.

Use stainless hose clips. If the hose passes through bulkheads or similar it must be protected against chafing.

Anti-siphon valve

Measure C min and D min:
The height of exhaust elbow above water line (C min), see fig. D, should be **200 mm (8")**. If less a vacuum valve is needed in the cooling system to avoid siphon action that could result in water ingress through the exhaust system.

The height of anti-siphon valve above water line (D min) should be at least **500 mm (20")**.

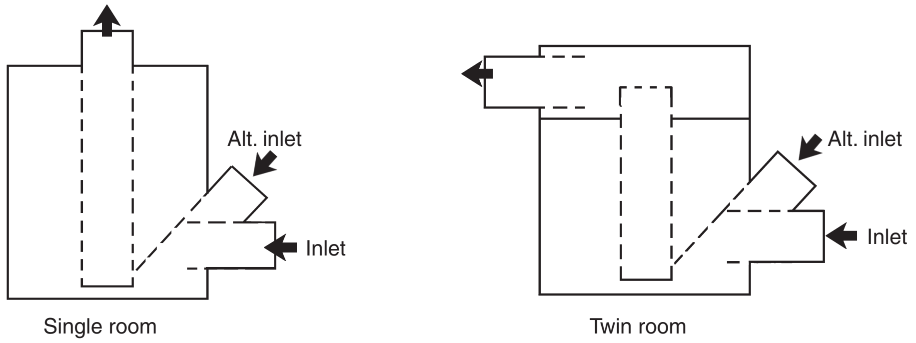
A suitable position of the valve is as close as possible to the centre line of the boat.

Silencers

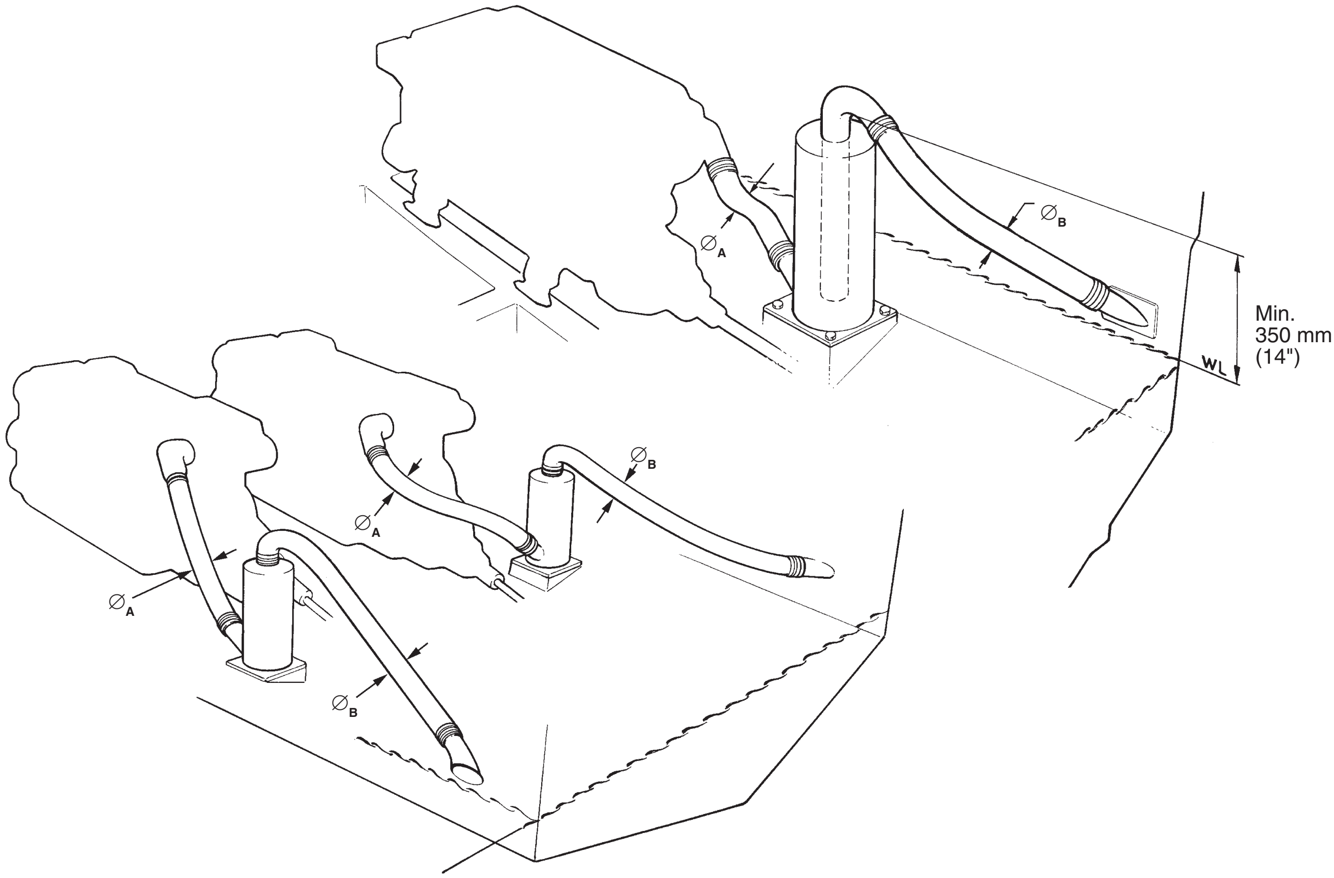
There are various types of silencers depending on the type of installation. Two very common types are:

- Aqua-lift silencers
- In-line silencers

Aqua-lift silencers, principle outlines of various types



Exhaust system Aqua-lift silencer, wet exhaust line in motor boats

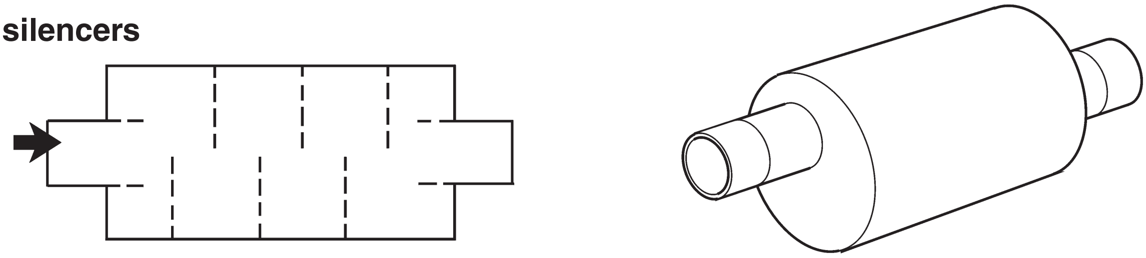


The figure shows an example of an engine with the Aqua-lift silencer system. The silencer should have sufficient volume to suit the engine power and space available. The **inner diameters** of the exhaust hoses ($\varnothing_A$ and $\varnothing_B$) should be chosen to suit the engine power, to give low exhaust backpressure.

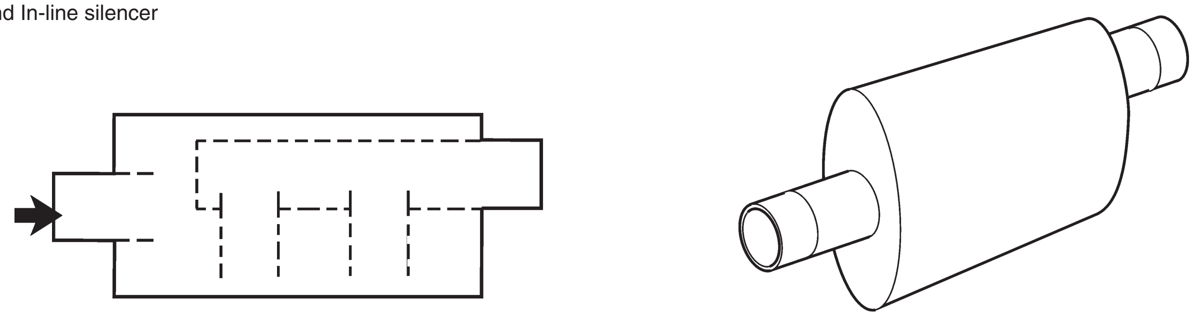
See table on in this chapter under section "Recommended hose diameters" for dimensioning hoses for and after the silencer.

The minimum height between the lower edge of the silencer exhaust outlet and the water line is at least **350 mm (14")**. See figure above.

In-line silencers

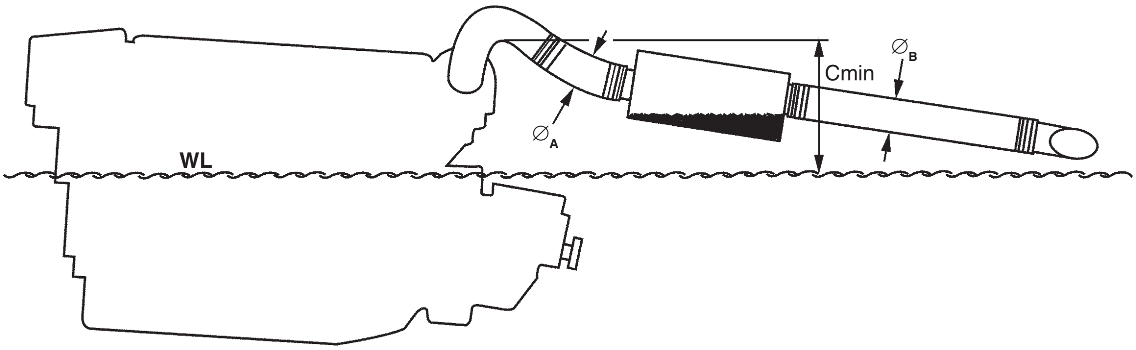


Round In-line silencer



Oval In-line silencer

Exhaust system In-line silencer, wet exhaust line



An in-line silencer is most suitable when the exhust outlet is located high in relation to the water line so an acceptable downward inclination can be acheived. The importance is that the system is drained when the engine is shut off.

Recommended hose diameter (innerdiameter) $\varnothing_A$ and $\varnothing_B$ see table on the following page.

NOTE! An in-line system is not recommended when height (Cmin) exhaust elbow – waterline is less than **350 mm (13.7")**.

Recommended hose diameters elbow - silencer ($\varnothing_A$) and silencer outlet ($\varnothing_B$), Aqua-lift and in-line systems

Engine	Exhaust hose inner diameter ($\varnothing_A$)	Exhaust hose inner diameter ($\varnothing_B$)
D5	4"/102 mm	5"/127 mm
D7	5"/127 mm	6"/152 mm
D9/D11	6"/150 mm	8"/200 mm
D12	8"/200 mm	8"/200 mm

NOTE! As a rule of thumb multiply $\varnothing_A$ x 1.4 to estimate $\varnothing_B$.
Rounding to rubber hose standard diameters.

Wet exhaust elbow D9/D11

The elbow angle is fixed. It is possible to make small adjustments to the exhaust outlet position by rotating the fixed elbow.

Note! It is very important that the exhaust outlet is not pointing upwards. In that case there is a big risk that water will return into the exhaust elbow and reach the turbo.

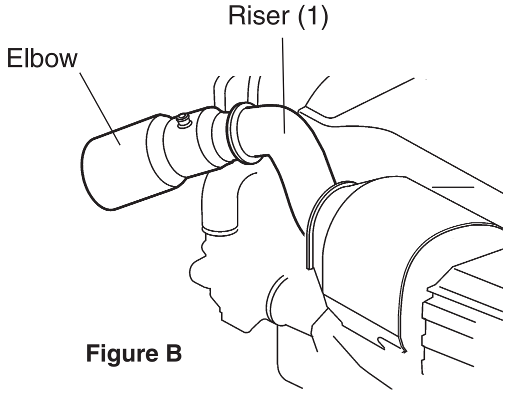


Figure B

Exhaust riser

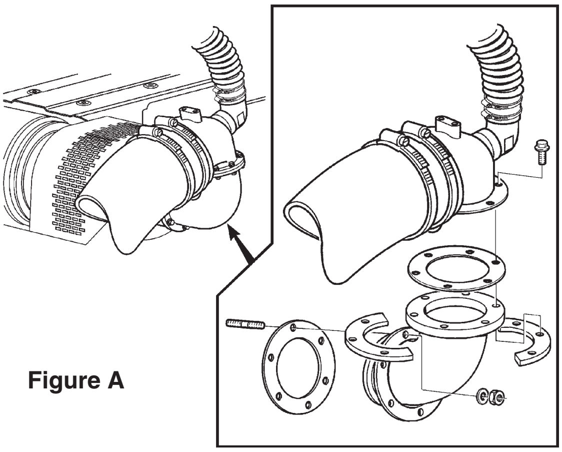


Figure A

Figures A and C show a Volvo Penta multi-purpose riser fitted on a D12 engine. This riser can be used on both port and starbord engine in a twin engine installation. The riser is continuosly adjustable in the vertical and the horizontal plane for each installation purpose.

A riser is also available for D9/D11 engines. It is of dry type and is shown in figure B (1) together with the wet exhaust elbow.

NOTE! The dry part of the riser, see figure B and C (1), should be insulated with proper heat insulation material, see figure C (2).

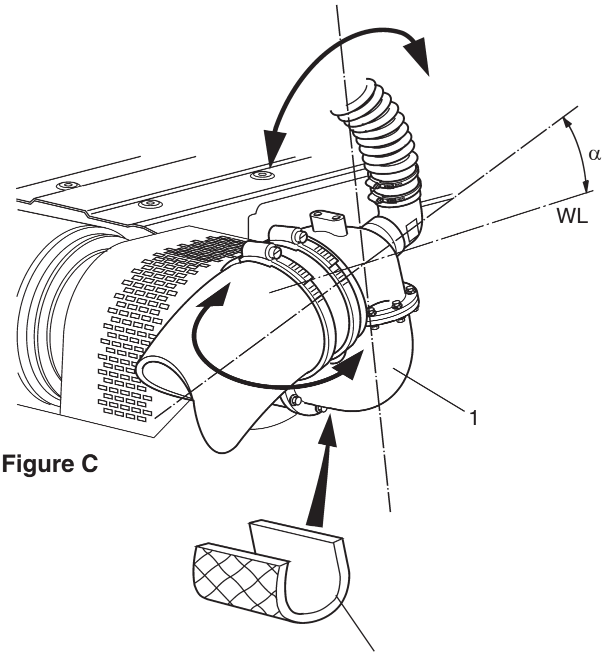
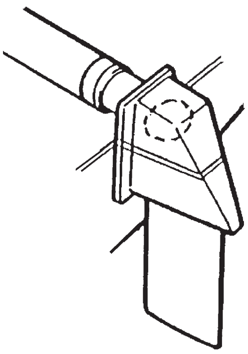


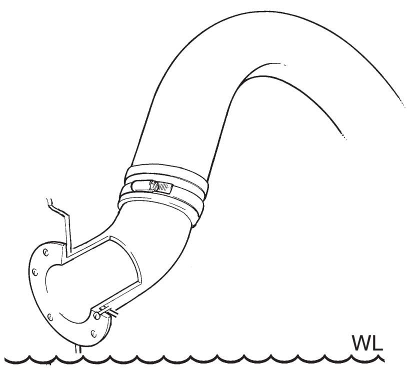
Figure C

Minimum exhaust elbow angle (α) relative to water line (WL) is dependent on engine type. See figure and table in chapter **Wet exhaust line, Dimensioning the exhaust line**.

Exhaust outlet - through-hull fittings



The through-hull fittings are placed at a suitable point above the waterline with a loaded boat. If the through-hull fitting opens below the water-line a shut-off valve must be installed at the outlet, or a rigid pipe connected. This must reach at least **350 mm (14")** above the water-line with a loaded boat.

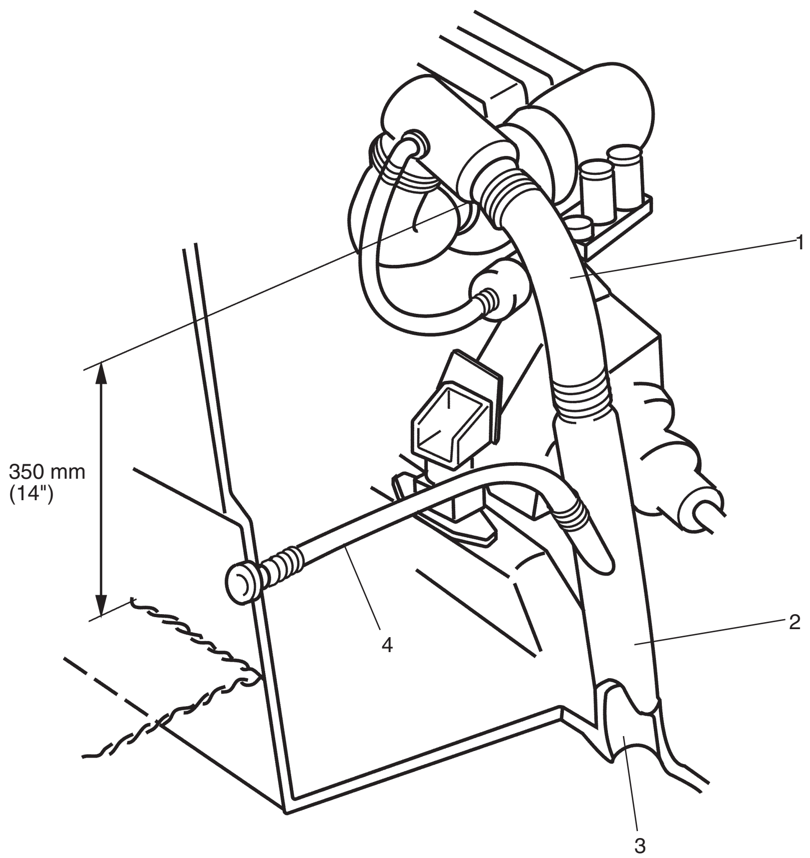


This type of outlet is a kind of standard component and should not be located at flat transoms. See section **"Wagon-back effect"** in chapter **Exhaust system, General**.

Exhaust outlet through boat bottom – concept design

Principle sketch, exhaust outlet through bottom

In some installations an exhaust outlet through the bottom of the boat might be the prefered alternative.



1. Exhaust hose
2. Exhaust pipe (Full strength pipe)
3. Exhaust outlet
4. By-pass outlet

In such an installation a full strength pipe (metal, grp, or similar) must go from the hull up to a level above the static water line when the boat is moored in order to avoid needing a shut-off valve.

Incline the pipe slightly backwards and design the outlet in the bottom to avoid water being pushed up the pipe if the boat is towed or running with one engine only.

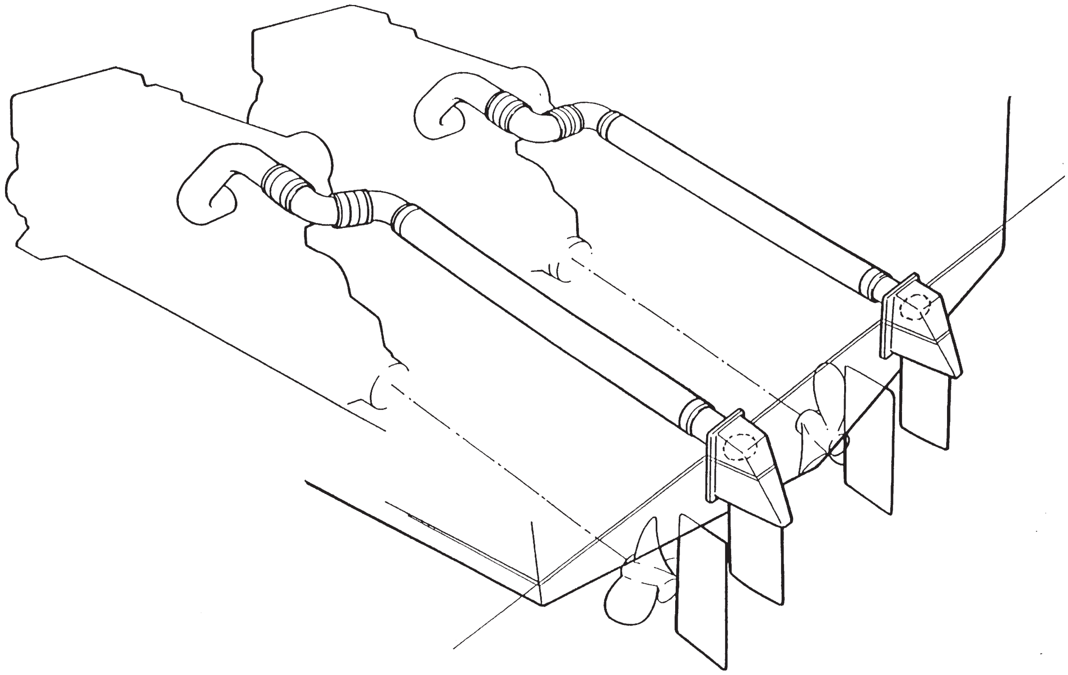
Position the outlet in the bottom in a way so the exhaust gases will not create negative turbulance flowing into the propeller or trim tabs, not even when the boat is turning, as this will affect the performance of the boat.

A by-pass outlet should be installed from the exhaust pipe, above the water line, to an outlet above the water line to avoid high backpressure when starting the engine and reduce the low idling pressure pulses to the hull, which create noise.

Often a riser is needed to obtain the correct distance (350 mm / 14") to water line (WL), see **Exhaust riser** in chapter **Wet exhaust line**.

Air turbulence behind the boat – Exhaust boot

Principle scetch of an exhaust boot system



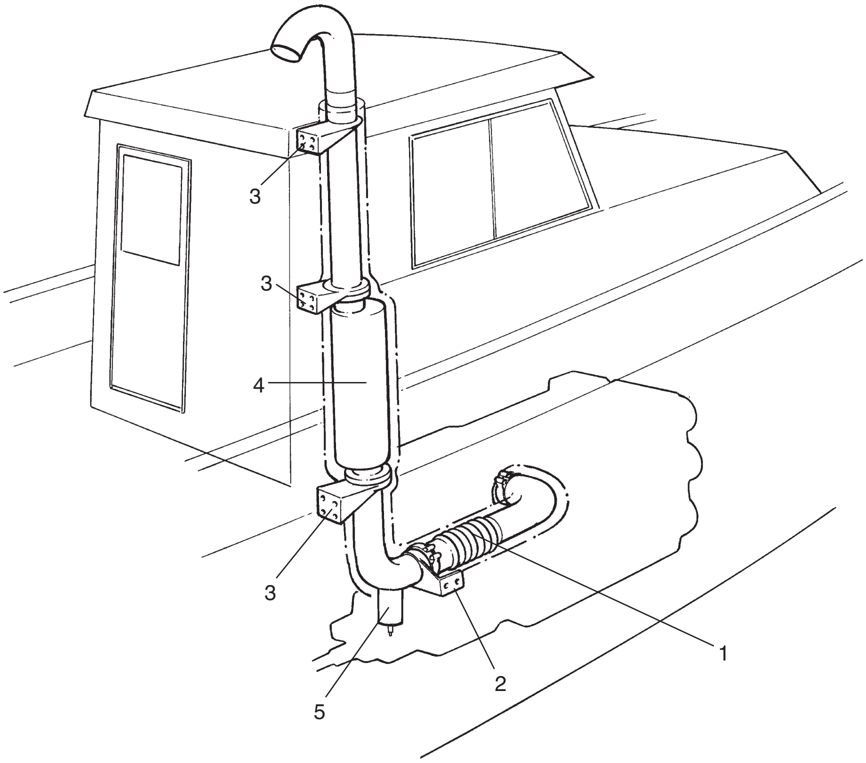
When a boat, especially a boat with a sheer, broad transom and high superstructure, moves forward and creates a backward current of air, an underpressure forms in the boat and the exhaust fumes are drawn towards it.

To minimise this problem, the flow of the propeller can be utilised to release the exhaust fumes far from the boat transom. The outlets of the boots are preferably positioned in line with the propeller shaft just behind the propeller and rudder. This way the exhaust emissions are carried into the currents of water aft of the propeller. See **"Wagon-back effect"** in chapter **Exhaust system, General**.

This slipstream system can be profiled to meet the requirements of individual boat builders.

Volvo Penta has considerable know-how in the application of custom-made exhaust boots, and can provide conceptual design drawings of a hydrodynamically developed boot for local manufacturing in GRP/FRP.

Dry exhaust line



Introduction

The exhaust system should be planned at the layout stage of the installation. The main objectives are to:

- ensure a that the backpressure of the complete system is below the maximum limit determined by the engine manufacturer.
- keep weight off the engine manifold and turbocharger by supporting the system.
- allow for thermal expansion and contraction.
- provide flexibility if the engine is set on anti-vibration mountings.
- reduce exhaust noise.

The figure shows an example of how a dry exhaust line can be designed and installed. The line should preferably be made of acid-proof stainless steel pipe, but a satisfactory service life can also be obtained with other stainless steel pipe. Copper pipes must not be used for diesel engines. Due to the high temperatures, 400°C–500°C (842°F–932°F) in the dry exhaust line, it must be insulated with insulating material to avoid the risk of fire and personal injury.

The line must also be provided with a flexible compensator (1) to absorb heat expansion and vibration from the engine. The compensator is fitted on the engine exhaust pipe flange as straight and stress-relieved as possible.

The exhaust line must be insulated throughout its whole length. Note that the movements of the compensator must not be obstructed. After the compensator, the exhaust line, including silencer (4), must be suspended by flexible brackets (2, 3) so that the movements caused by heat expansion are not obstructed.

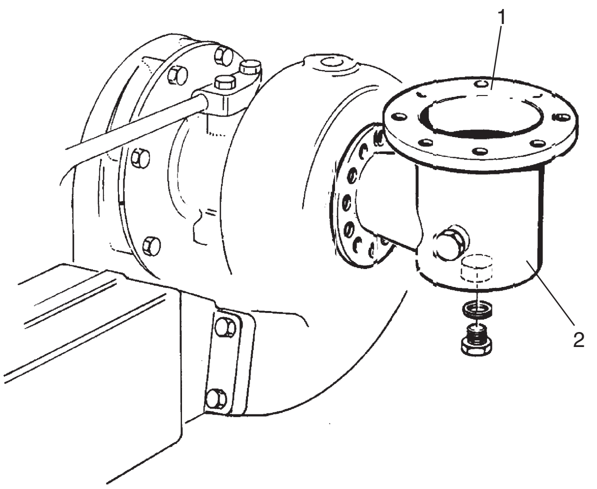
The exhaust outlet is placed in a suitable position with good margin of clearance above the water-line with loaded boat and with insulation against the hull side to prevent heat damage.

An arrangement for draining condensation water should be fitted at the lowest point of the line (5) and as close to the engine as possible.

When dimensioning the exhaust line, note that the backpressure in the complete exhaust system must not exceed the values shown in table in chapter **Backpressure**.

NOTE! U.S. federal regulations applicable to U.S. vessels require the installation of an exhaust sampling port in the exhaust system. See chapter **General** under **Exhaust system.**

Condensation water collector



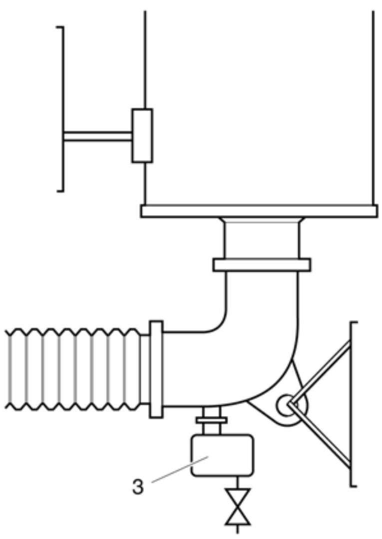
1. Exhaust elbow
2. Condensation water collector for D5/D7/D9/D12

The exhaust gases from a combustion engine always include water vapour. This water vapour can condense and form water, which in the worst cases, can run into the engine when it is switched off.

Rain or condensed water that enters into the engine can cause severe damage. Long exhaust lines should therefore be fitted with a water drain (yard supply), which should be located as close to the engine as possible.

When the exhaust line is inclined downwards towards the engine, a condensation water collector (position 2 and 3) must always be fitted. It must be located at the lowest pont of the final installation.

The condensation water collector must be fitted with a cock or drain plug at the bottom.



Example: Fitting of condensation water collector for D16.

Insulated exhaust systems

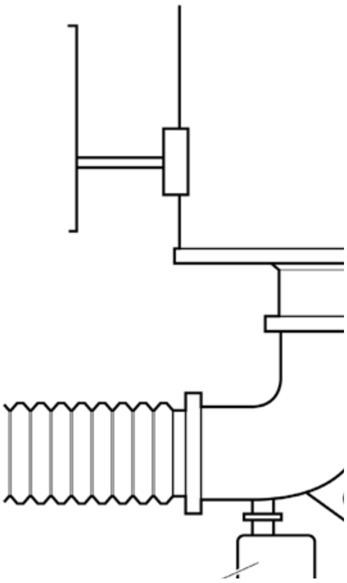
Due to the high temperatures that arise in a dry exhaust pipe (400–500°C) it is sometimes necessary to insulate it. Thereby the temperature in the engine room can be kept low and personal injuries can be avoided. The insulation also helps to keep the noise level low.

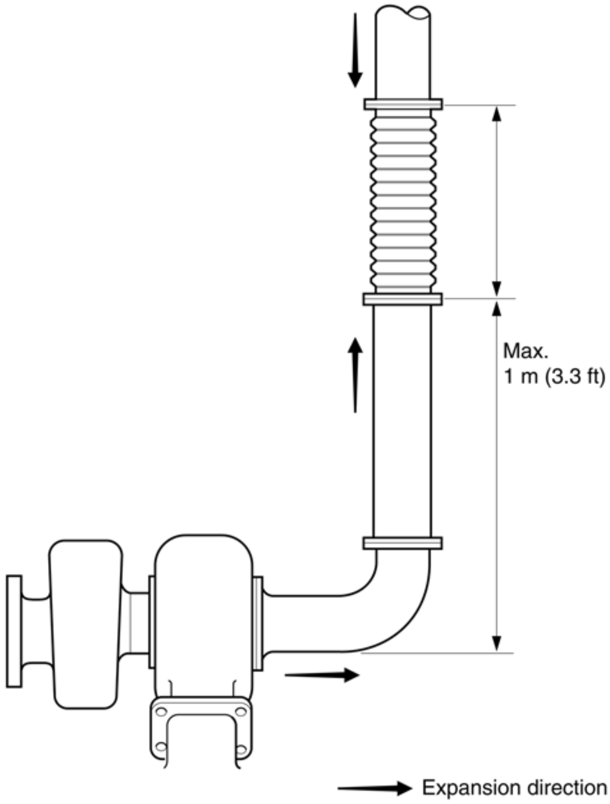
Insulation of long lines will affect the exhaust back-pressure and therefore the exhaust pipe diameter must be increased.

Exhaust outlet position

The outlet of the exhaust pipe must be designed so that rain water cannot enter the exhaust system. Fit an elbow, hood or self-closing cover to the end. The exhaust outlet must be in such a position that there is no possibility of hot gas entering any air inlet opening.

Flexible exhaust compensator





Exhaust pipes are isolated from the engine movements usually via a flexible compensator.

The compensator should be fitted to the exhaust elbow. In special cases the compensator can be installed up to max. 1 m (3.3 ft) from the exhaust outlet.

Flexible exhaust compensators have three functions:

- Isolate vibrations and weight of exhaust piping from the engine
- Compensate for thermal expansion of the exhaust piping
- Compensate for lateral movement when the engine starts and stops, if the engine is on flexible engine mounts.

The flexible pipe is available to take up large axial movements, small radial movements but no twisting movements.

It must not be bent. The flexible compensator can be fitted in different positions, but should preferably be fitted vertically.

The fixture for the exhaust line should be designed to prevent that radial movements, generated by pressure pulses in the line are transfered into the compensator.

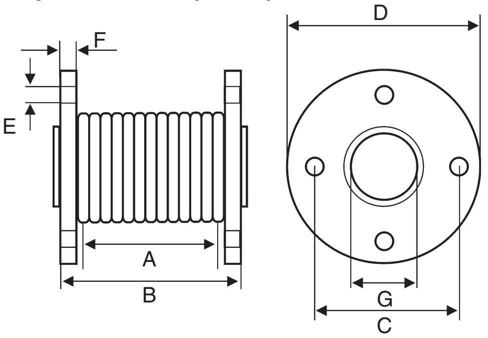
Thermal growth of exhaust piping must be planned to avoid excessive load on supporting structures. The expansion of one meter of steel pipe per rise in temperature of 100°C (212 °F) is approx. 1.2 mm (0.05"). It is therefore important to place supports to allow expansion away from engine, avoid strains or distortions to connected equipment, and to allow equipment removal without additional support.

Long pipe runs are sectioned with expansion joints. Each section is fixed at one end and allowed to expand at the other.

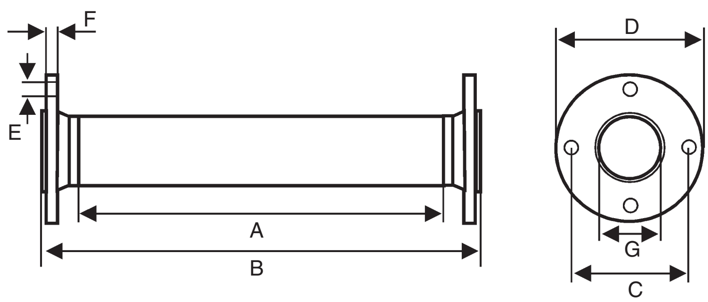
Measurements mm (in)

Pos. in fig.	Description		Compensator type			
		4" (short)	4" (long)	5"	6"	7"
A	Hose length	185 (7.3)	500 (19.7)	500 (19.7)	500 (19.7)	250 (9.8)
B	Total nominal length	145 (5.7)	590 (23.2)	590 (23.2)	590 (23.2)	280 (11.0)
C	Screw circle diam.	170 (6.7)	170 (6.7)	200 (7.9)	225 (8.7)	261 (10.3)
D	Outer diam. flange	210 (8.3)	210 (8.3)	254 (10.0)	265 (10.4)	305 (12.0)
-	No. of holes in flange	4	4	4	4	8
E	Diam. holes in flange	17 (0.67)	18 (0.71)	18 (0.71)	18 (0.71)	18 (0.71)
F	Flange thickness	16 (0.63)	14 (0.55)	14 (0.55)	14 (0.55)	15 (0.61)
G	Inner diameter	100 (4.0)	100 (4.0)	128 (5.0)	150 (6.0)	195 (7.7)

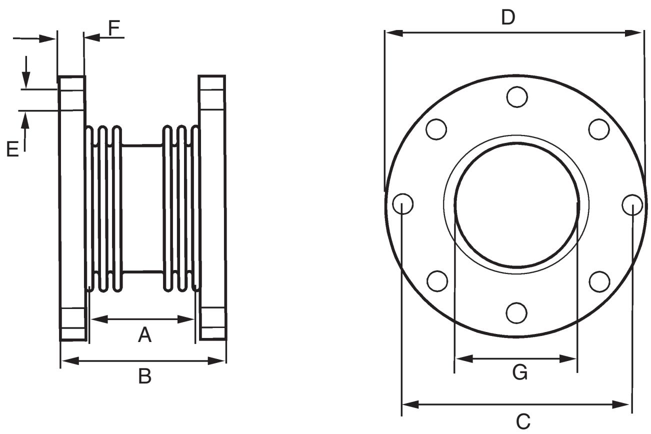
Compensator 4" (short)



Compensator 4" (long), 5" and 6"



Compensator 7"

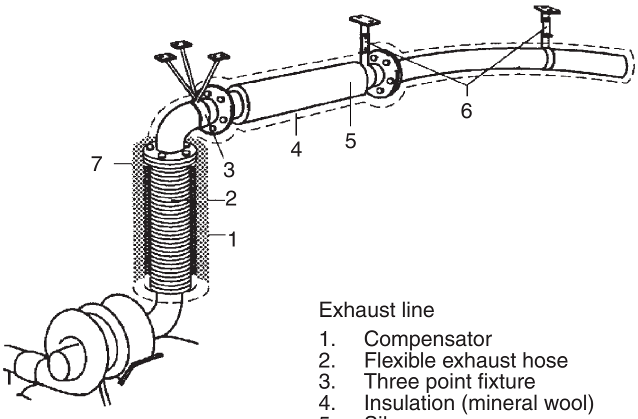


Installation data

Compensator type	Total nominal length B	Flexibility mm (in) Radial	Axially
4" (short)	185	±3 (±0.12)	+3, –5 (+0.12, –0.20)
4" (long)	590	±5 (±0.20)	+5, –10 (+0.20, –0.40)
5"	590	±5 (±0.20)	+5, –10 (+0.20, –0.40)
6"	590	±5 (±0.20)	+5, –16 (+0.20, –0.63)
7"	280	±15 (±0.6)	+24 (0.94)

Silencer

There are generally two types of silencers described as either absorptive or reactive.



Exhaust line

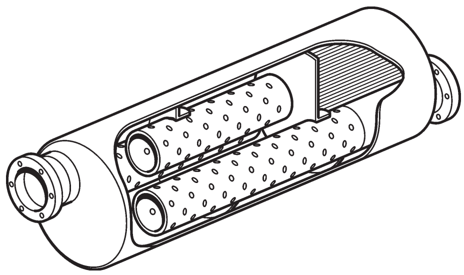
1. Compensator
2. Flexible exhaust hose
3. Three point fixture
4. Insulation (mineral wool)
5. Silencer
6. Flexible attachment
7. Glass fibre fabric

Absorptive type

These work on the principle of absorbing noise by means of an absorbent lining inside the silencer and normally provide attenuation over a broad frequency range.

An absorptive silencer is generally designed as a straight through and would only create a marginally greater backpressure than similar length of straight pipe.

Expansion (reactive) silencers



These work on the principle of reflecting and thus containing sound within the silencer. There are internal baffle plates fitted to divide the silencer into sections, which can be individually tuned to a specific frequency. A reactive silencer creates a relatively high backpressure due to the torturous gas flow path, i.e. through the baffle plates, which reverses flow.

Volvo Penta HD silencers combine reactive and absorptive type of silencing.

Silencer location

The reactive silencer is fitted as close to the exhaust manifold as is practical to prevent noise break-out through pipe work.

Insulation of long lines will affect the exhaust backpressure and therefore the exhaust pipe diameter must be increased.

Calculation of HD silencer backpressure

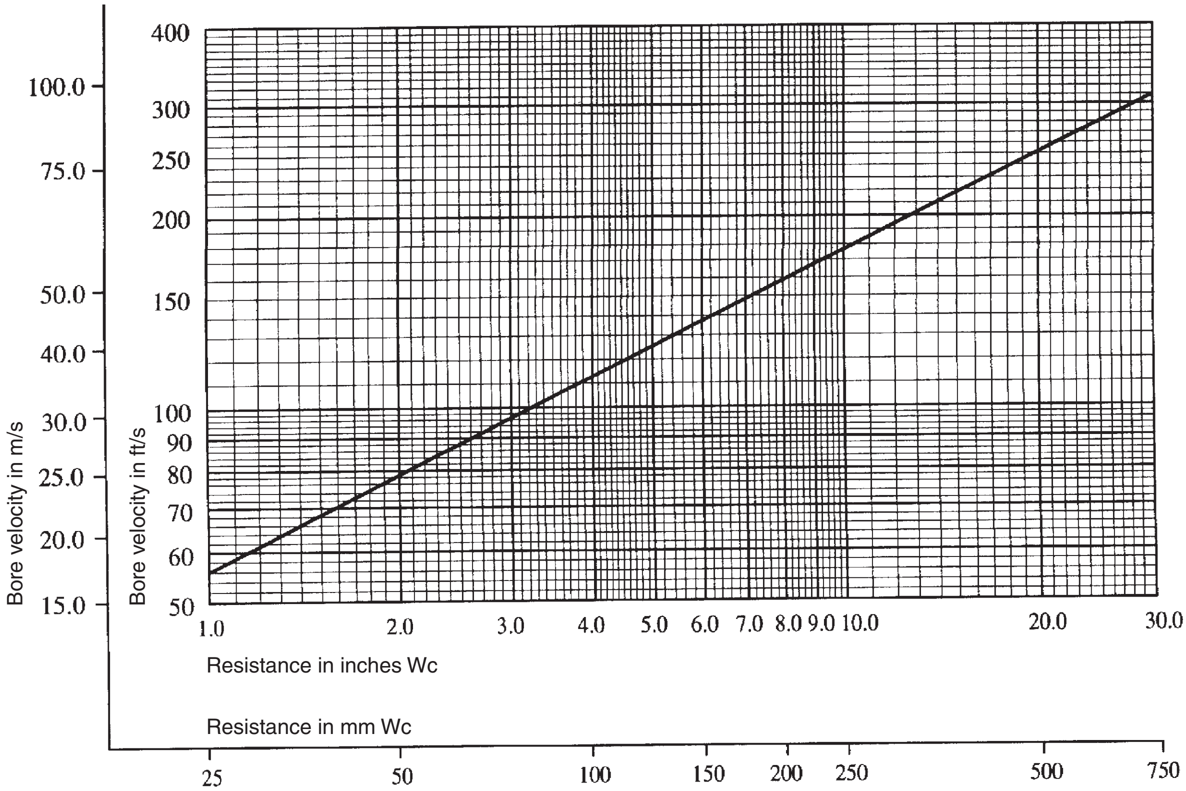
To calculate the backpressure for Volvo Penta HD silencers use the following formulas:
See **Sales Guide Marine Propulsion Diesel Engines Technical Data**.

$$\text{Bore velocity} = \frac{\text{Exhust gas flow } (m^3/\text{min})}{\text{Area of pipe } (m^2) \times 60} \quad (m/s)$$

$$\text{Backpressure} = \frac{\text{Resistance from graph (mm Wc)} \times 673}{T + 273} \quad (\text{mm Wc})$$

T = engine exhaust temperature (°C), 1 mm Wc = 0.0098 kPa

Velocity/Resistance curve at 400 °C



Backpressure - exhaust pipe - calculation

Using the value of the exhaust gas flow and having calculated the backpressure for a certain silencer (HD) you will be able to determine the resistance to flow in a straight exhaust pipe.

The following formula is recommended:

$$P = 6.32 \times \frac{L \times Q^2}{D^5} \times \frac{1}{(T + 273)}$$

where:

P = is backpressure through the exhaust pipe in Pa

L = is total equivalent length of straight pipe in metres

Q = is exhaust gas flow in m^3/s

D = is pipe diameter in metres

T = is exhaust gas temperature °C

NOTE! When the bends are used in the exhaust system pressure loss is expressed in equivalent straight length of pipe.

For equivalent straight length see the table below:

Pipe diameter (inches)	Bend 45 deg. (m/bend)	Bend 90 deg. (m/bend)
3.5	0.57	1.33
4	0.65	1.52
5	0.81	1.90
6	0.98	2.28
7	1.22	2.70

Adding the pressure losses through the silencer to the loss through the pipe work will give the total backpressure incurred by the exhaust system. This must not exceed the figure quoted in the **Sales Gulde Marine Propulsion Diesel Engines** against the appropriate engine and rating.

Example:

Engine: D12MH

Power: 294 kW / 1800 rpm

Silencer: 7" HD

Calculation of pressure loss through the silencer.

$$\text{Bore velocity (m/s)} = \frac{Q\ (m^3\ /min)}{\text{Pipe area}\ (m^2) \times 60}$$

$$Q\ (\text{flow}) = 2952\ m^3/h = \frac{2952\ m^3/h}{3600\ s} = \frac{2952}{3600} = 0.82\ m^3/s$$

– the value originates from **Technical Data** in **Sales Guide Marine Propulsion Diesel Engines**.

$$\text{Pipe area} = \frac{\pi \times D^2}{4}\ m^2$$

D = 7" = 0.175 m

Pipe area will be

A = 0.0240 m^2

Bore velocity = 34.1 m/s

From the diagram on previous page, one will find the resistance in mm Wc.
The resistance is approx 99 mm Wc.
The pressure loss will be calculated according to the formula:

$$\text{Pressure loss (mm Wc)} = \frac{\text{Resistance from graph (mm Wc)} \times 673}{T\ °C + 273} = \frac{99 \times 673}{293 + 273} = 118\ \text{mm Wc}$$

T = Exhaust gas Temperature

T = 293 °C (See **Technical Data** in **Sales Guide Marine Propulsion Diesel Engines**.)

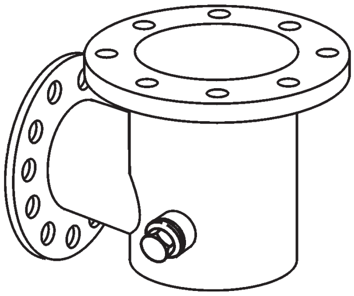
Pressure loss will be:

P_{loss} = 118 mm Wc = 1.157 kPa

The pressure loss through the silencer is 1.873 kPa

NOTE! Check that the total backpressure (silencer backpressure and piping backpressure) is within the limits in table in chapter **Backpressure**.

Exhaust elbows



For dimensions of exhaust elbows see current **Sales Guide Marine Propulsion Diesel Engines**.

Multiple exhaust outlets

If more than one engine is being installed, the exhaust from the engines must not be taken into the same flue.

The reason is that if one engine is stopped when others are running, exhaust gases with condensate and carbon will be forced into the exhaust system of the stopped engine and then into the engine cylinders which can cause corrosion.

If a flap valve of good quality is fitted in each exhaust line near the intersection, multi-engine installations on one exhaust line can sometimes be acceptable.

To calculate the total diameter of a common exhaust pipe use the following formula:

$D_{total} = D \times K$

where:

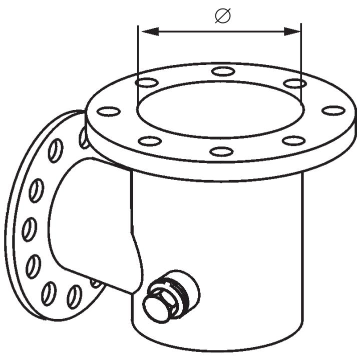
D is exhaust pipe diameter for one engine

K is a factor

Number of engines	Factor K
2	1.32
3	1.55
4	1.74
5	1.90
6	2.05

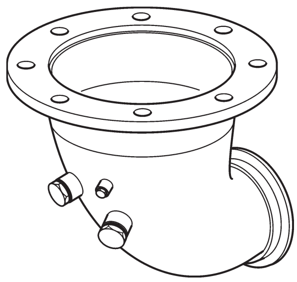
Factor K = $\sqrt[5]{(\text{number of engines})^2}$

Standard system size



Exhaust system diameter (∅)

Engine	Dry exhaust line
D5	3"/68mm
D7	4"/107mm
D9	7"/175 mm
D11	7"/175 mm
D12	7"/175 mm
D16	7"/175 mm



D16

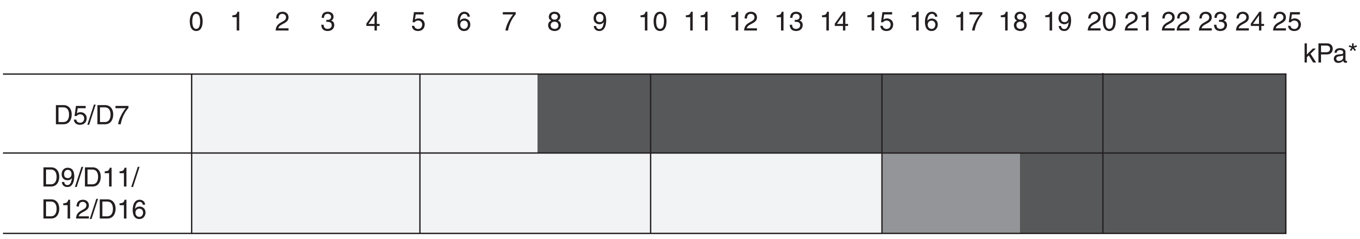
Backpressure

The exhaust system will produce a certain resistance to the exhaust gas flow. This resistance or backpressure must be kept within specified limits. Excessive backpressure can cause damage and will lead to:

- Loss of power output
- Poor fuel economy
- High exhaust temperature

These conditions produce overheating and excessive smoke from the installation, and reduce the service life of the valves and turbocharger.

Max. allowed backpressure in exhaust pipe at rated rpm, kPa*



*) 1 kPa = 100 mm wc

No performance losses
(Relative to technical data. Maximum allowed backpressure for emission certified engines.)

Small performance losses
(Not approved backpressure for exhaust emission certified engines.)

Not acceptable

Measuring exhaust backpressure

After the exhaust line has been installed, the backpressure must always be checked. This can be easily done with the aid of a transparent plastic hose connected to a measuring flange (see chapter **Special tools**) occasionally installed in the exhaust line.
The back-pressure can also be checked with the aid of a suitable pressure gauge.

When testing is carried out, the engine should be run under full loading a sufficiently long period to obtain a stable value.

Measuring procedure

Wet exhaust system

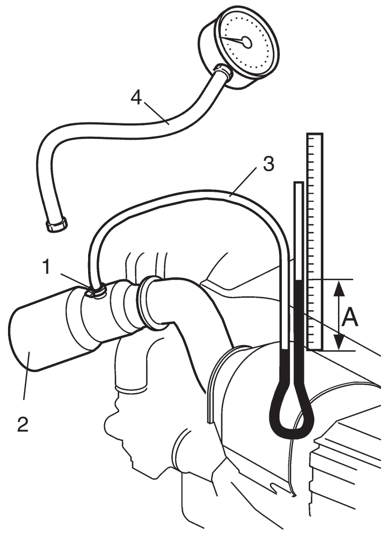
- Remove the exhaust pipe from the turbocharger exhaust output. Clean the mating surface.
- Install the measuring flange (1) to the turbine housing flange (only if measuring flange is needed).
- Install the exhaust elbow pipe (2) on the measuring flange or the nipple. Use V clamps or bolts depending on the engine type and exhaust system.
- Connect a transparent plastic hose (3) to the measuring flange or the nipple as illustrated. Alternatively, connect a manometer (4) calibrated to 24 kPa (3.5 psi, 2440 mm wc**)** with pressure hose and a suitable nipple (if needed) to the measuring flange or the nipple.

The difference between the water column levels (A) shows the exhaust line back-pressure in mm or inches water column.

- Run the engine at full load and max. rpm for several minutes and check that the backpressure does not exceed permitted value.

Max permissible exhaust backpressure in exhaust line, see table **Max. allowed backpressure in exhaust pipe at rated rpm, kPa**.

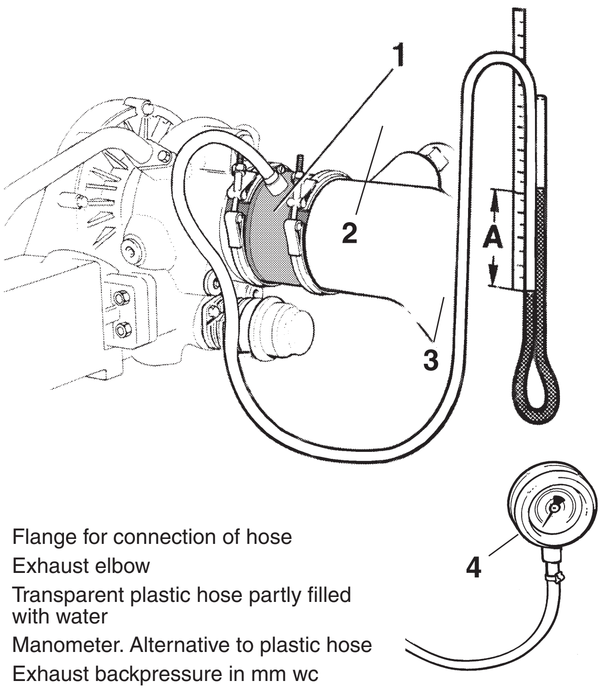
D9/D11
Wet exhaust line (picture with riser)



1. Nipple for connection of hose
2. Exhaust elbow
3. Transparent plastic hose partly filled with water
4. Manometer. Alternative to plastic hose

A. Exhaust backpressure in mm wc

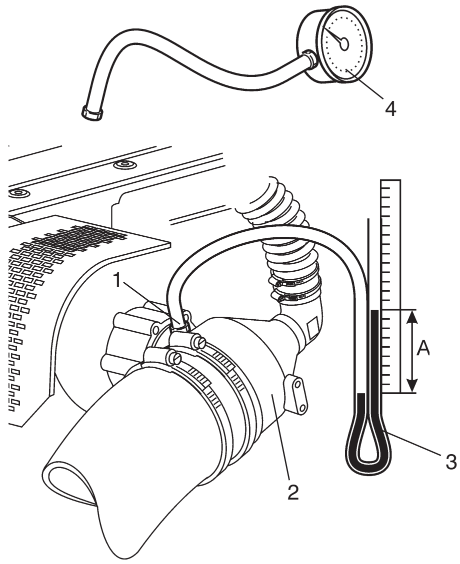
D5/D7
Wet exhaust line



1. Flange for connection of hose
2. Exhaust elbow
3. Transparent plastic hose partly filled with water
4. Manometer. Alternative to plastic hose

A. Exhaust backpressure in mm wc

D12
Wet exhaust line



1. Nipple for connection of hose
2. Exhaust elbow
3. Transparent plastic hose partly filled with water
4. Manometer. Alternative to plastic hose

A. Exhaust backpressure in mm wc

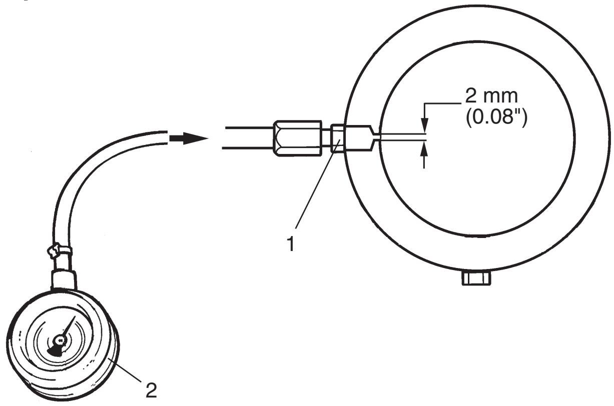
Measuring procedure

Dry exhaust system

- Connect a manometer calibrated to 24 kPa (3.5 psi, 2440 mm wc) with pressure hose and a suitable nipple to the exhaust elbow.
  Alternatively, connect a transparent plastic hose with a suitable nipple to the exhaust elbow.
- Run the engine at full load and max. rpm for several minutes and check that the backpressure does not exceed permitted value.

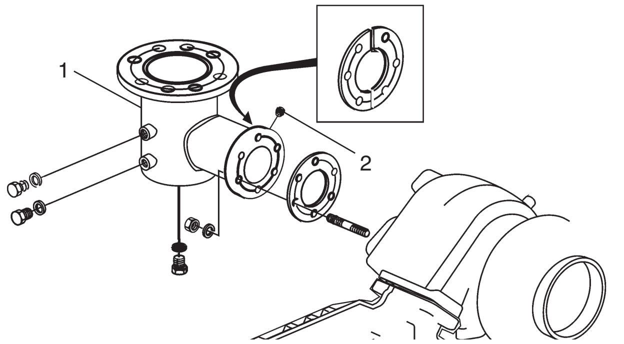
Max permissible exhaust backpressure in exhaust line, see table **Max. allowed backpressure in exhaust pipe at rated rpm, kPa**.

Dry exhaust line



1. Nipple for connection of manometer, 1/8" NPTF
2. Manometer

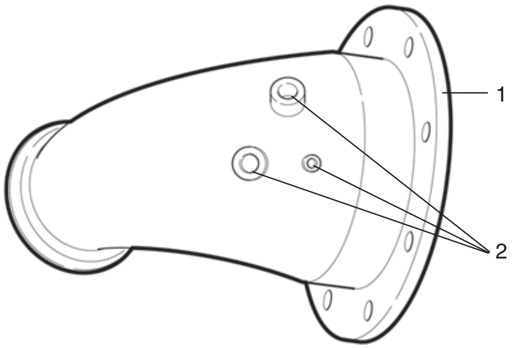
D9/D11/D12
Dry exhaust line



1. Exhaust elbow
2. Nipple for connection of manometer or hose

   Transparent plastic hose partly filled with water (see previous page position 3). Exhaust backpressure in mm wc (A).
   See figures for wet exhaust line.

D 16
Dry exhaust line

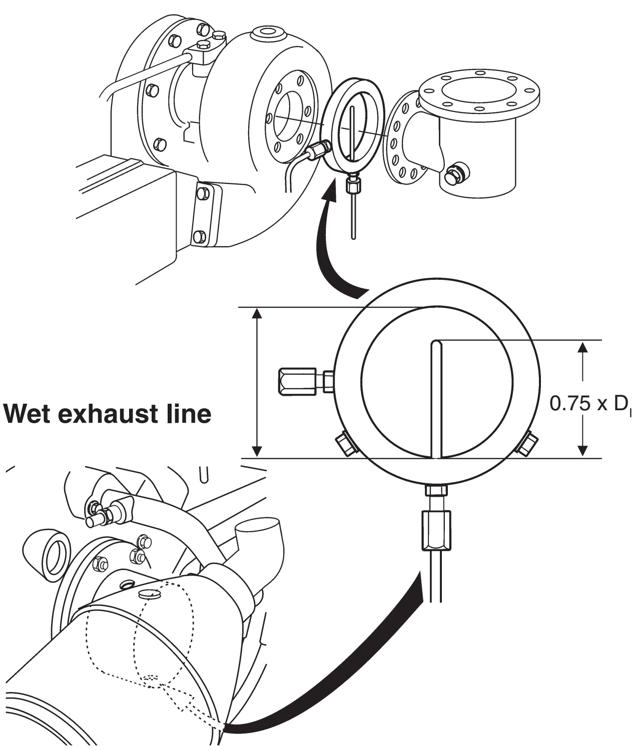


1. Exhaust elbow
2. Nipple for connection of manometer or hose

   Transparent plastic hose partly filled with water (see previous page position 3). Exhaust backpressure in mm wc (A).

Measuring exhaust temperature

Dry exhaust line



Wet exhaust line

Dry and wet exhaust line

Control measuring of the exhaust temperatue is sometimes needed to ensure the thermal conditions of the installation and in some cases the engine. It is important that the measurements are accurate. One important factor when taking these measurements is to position the probe correctly in the gas flow. See figure.

With an accurate measurement (± 2%), comparison can be made with the technical data for verification provided that compensation is made for atmospheric conditions. Exhaust monitoring guages are normally less accurate.

Electrical system

Electrical installation

General

The electrical installation has to be planned very carefully and carried out with the utmost care. Seek simplicity when designing the electrical system.

The wires and connectors used in the installation have to be of a type approved for marine use. The wires should be routed in a protective sheath and clamped properly.

Make sure that the wires are not installed too close to heated parts of the engine or close to another source of heat. The wires must not be subject to mechanical wear. If necessary, route the wires through protective tubing.

Minimize the number of joints in the system. Make sure that cables, and joints in particular, are accessible for inspection and repair.

It is recommended to supply a wiring diagram of the complete electrical system with the boat. This will simplify fault tracing and installation of additional equipment considerably.

NOTE! Make sure that no joints in the engine room are placed deep down. All cable joints should be located higher up than the alternator.

Batteries

Battery terminology

Capacity

Capacity is measured in Ampère-hours (Ah). The starter battery capacity (Ah) is usually stated as the 20 hour capacity of the battery, i.e. the battery can be discharged at a constant current for 20 hours to a final voltage of 1.75 V/cell. For example: If a battery can produce 3 A for 20 hours, its capacity is 60 Ah.

The cold cranking amperage (CCA) measures the starting performance of the battery. The society of Automotive Engineers (SAE) has specified the following test: A battery at a temperature of –18° C (0°F) must be able to deliver a current equal to the cold cranking amps for 30 seconds with the voltage remaining above1.2 V/cell or 7.2 V for a 12 V battery. There are other CCA tests defined by DIN, IEC, EN etc. These tests will give different CCA values compared with the SAE test.

Battery capacity is affected by temperature. Battery capacity is specified at +20°C (68°F). Cold considerably reduces a battery's ability to release its energy. The following table shows the difference in capacity between +20°C (68°F) and -18°C (0°F).

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

Connecting batteries

If a boat has more than one battery, observe the following for each connection method:

Parallel connection:

Two (or more) 12V batteries are connected in parallel so that the capacity is increased. The boat's system voltage is the same as the rated voltage of the battery.

- The batteries must have the same nominal voltage.
- The batteries may have different capacities.
- The batteries do not need to be of the same age.

When two batteries are connected in parallel, the voltage remains the same but the capacity is the sum of the capacities. When charged, each battery receives a charge lower than that stated on the charger. To find out the charge current supplied to each battery, measure the charging current to each battery with an ammeter.

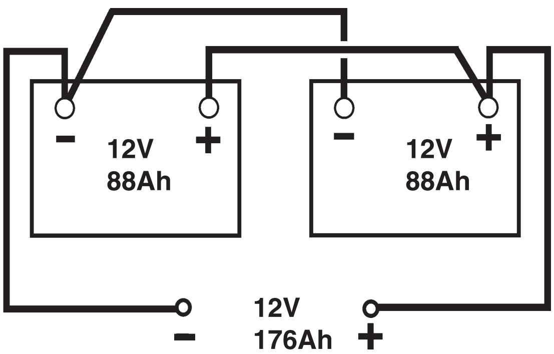
Series connection:

Two 12 V batteries are connected in series so that the system voltage in the boat is 24 V.

⚠ **WARNING!** Always check the boat's system voltage before connecting. A particular engine type may be available for 12 V and 24 V configurations.

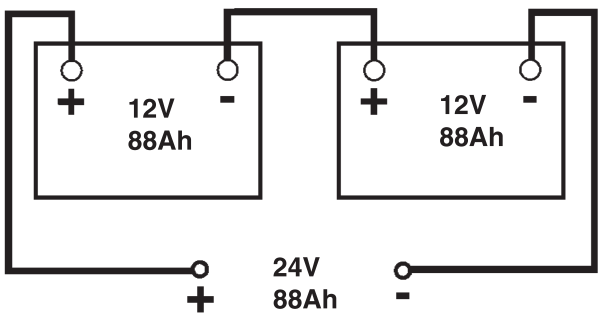
- The batteries must be similar (same capacity and voltage).
- The batteries must be the same age since the charge current required to produce a certain voltage changes with the age of the battery.
- There must not be unequal loading (equipment should load both batteries - not just one). A small load such as a radio connected across only one battery can quickly destroy the batteries.

Two batteries connected in series retain the capacity but double the voltage. During charging, each battery receives the current supplied by the charger. The total battery voltage must not exceed the battery voltage marked on the charger.



Example: When two 12 V batteries each with a capacity of 88 Ah are connected in parallel, the voltage will be 12 V and the total capacity 176 Ah.

If one of two batteries connected in parallel has a short-circuited cell, the nominal system voltage will be approx. 10 V.



Example: When two 12 V batteries are connected in series, with a capacity of 88 Ah, the voltage is 24 V and the capacity 88 Ah.

When two 12 V batteries are connected in series and one battery has a short-circuited cell, the resting voltage across the two batteries will be approx. 23 V.

Battery dimensioning

Cranking current

Cranking current for engines at +5°C (41°F).

12V system
D5/D7 .... 650 A
D9 .... 700 A

24V system
D5/D7 .... 320 A
D9/D11 .... 340 A
D12 .... 500 A
D16... 900 A

As a guideline the breakaway current can be calculated as 2–2.5 times cranking current.

Selecting battery size

When selecting battery size, it is vital to look at both momentary and long-term capacity.

- The rating norm for long-term capacity (batteries marked with Ah) the C20 norm is used.

  C20 means the amount of current able to take out from the battery during 20 h.

  Ex. 1: 60Ah = 20 h X 3A

  Ex 2: 100Ah = 20 h X 5A

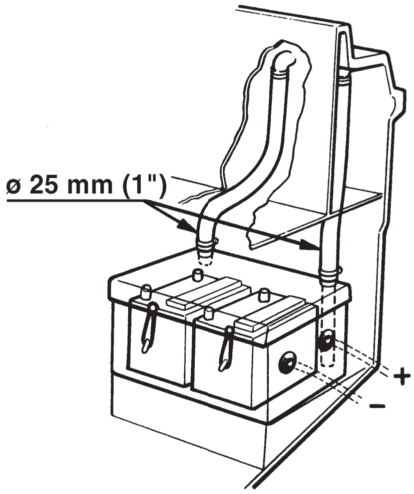
The battery sizes listed below are recommended for Volvo Penta engines at a temperature down to +5°C. Battery voltage is 12V.

Engine	V	Capacity, min	Ah max
D5/D7	12V	88	170
D5/D7	24V	2x66	2x115
D9	12V	140	2x220
D9/D11	24V	2x105	2x180
D12	24V	2x140	2x220
D16	24V	2x140	2x220

The battery capacity will decrease with approx. 1% per degree, from +20°C, which has to be considered at extreme conditions in temperature

NOTE! The list above specifies batteries per engine. E.g. for a twin D9, 24V a total of four 105Ah batteries should be installed.

Battery installation



Install the batteries in a tight-fitting box. Vent the box with 25 mm (1") hoses. The ventilation hose must end up outside the boat to allow the detonating gas, produced by batteries, to escape.

The batteries should be fastened and only allowed to move max 10 mm (3/8").

⚠ **WARNING!** The batteries, if they are not the closed type, may only be installed in the engine compartment if they are installed in a separate sealed and well ventilated battery box. Battery gas is easily ignited and highly volatile. Sparks or open flames can cause explosion or fire.

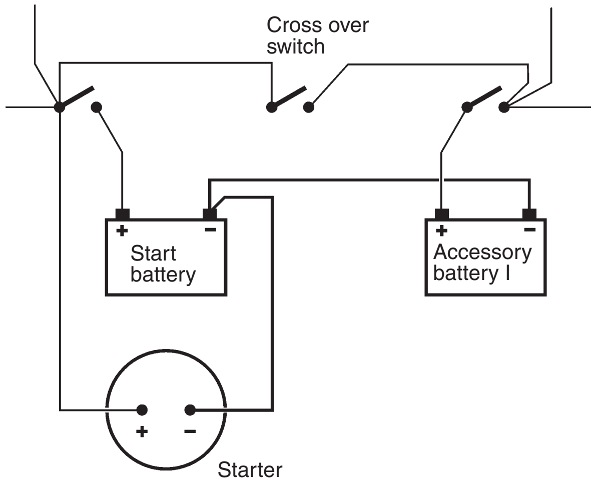
Accessory battery

The use of a separate battery group for accessories is mandatory.

Volvo Penta recommends using a charge distributor to feed the accessory batteries.

Cross-over switch

The use of a cross-over switch between the accessory battery and the starter battery is recommended.



Starting battery cable area

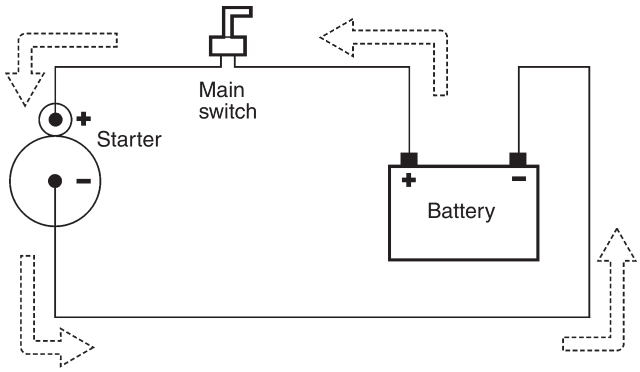
Volvo Penta recommends cable areas as below, to provide sufficient power from the battery to the starter motor.

Measure the **total cable length** from the battery positive (+) terminal via the main switch to the starter motor positive (+) terminal and from the starter motor negative (–) terminal back to the battery negative (–) terminal .

Thereafter select the recommended cable area according to the table on the next page for **both** the negative (–) cable and the positve (+) cable.

Since the cable has to absorb generated heat, the cross section area should not be less than 50 mm².

Keep the positive and negative wires to the starter motor at approximately equal lengths and use the same dimensions



NOTE! If the vessel may operate in colder temperature than +5 °C, the cable size must be increased.

	Cable core area (mm²)	50	70	95	120
	Cable core area[1] (AWG)	1/0	2/0	3/0	4/0
Engine	**Electrical System**	**Total cable length m (ft)**			
D5/D7	12V	N/A	0–4.2 (0–13.8)	4.2–5.4 (13.8–17.6)	5.4–7.2 (17.6–23.6)
D5/D7	24V	0–13.0 (0–42.6)	13.0–17.8 (42.6–55.8)	17.8–23.0 (55.8–75.4)	23.0–31.0 (75.4–101.6)
D9	12V	0–5.0 (0–16.4)	5.0–8.0 (16.4–26.2)	8.0–10.0 (26.2–32.8)	10.0–13.0 (32.8–42.6)
D9/D11	24V	N/A	0–8.0 (0–26.2)	8.0–10.0 (26.2–32.8)	10.0–13.0 (32.8–42.6)
D12[2]	24V	N/A	0–13.2 (0–42.8)	13.2–16.0 (42.8–52.4)	16.0–22.0 (52.4–72.2)
D16	24V	0–4.4 (0–14.4)	4.4–6.4 (14.4–21.0)	6.4–8.4 (21.0–27.6)	8.4–11.0 (27.6–36.0)

[1]) AWG (American Wire Gauge)

[2]) Values based on battery capacity 140 Ah

Comparison cable core area (mm²) / diameter (mm) according to Volvo standard

Cable core area, mm²	50	70	95	120
Cable core diameter, mm	12	14	16	18
Cable diameter, mm	15	17	19	21

Power supply

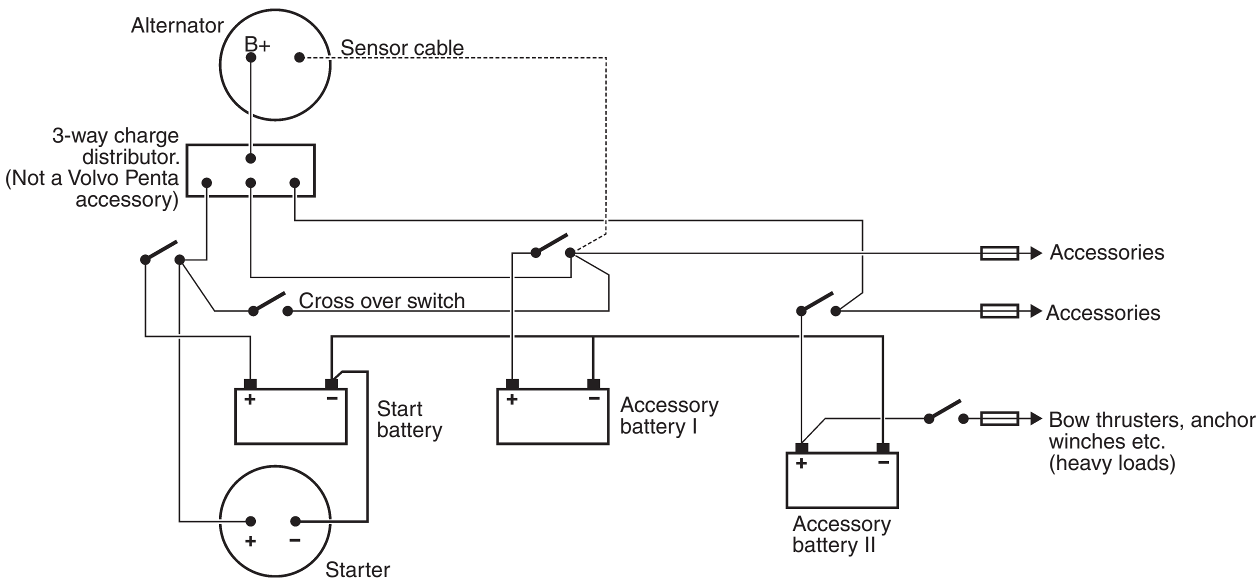
All engines covered in this manual have a two-pole electrical system. This means that each electrical component on the engine has an insulated DC negative return. The alternator, starter motor and all sensors are electrically isolated from the engine block and the positive and negative poles of the batteries must be connected to the starter motor terminal.

Charge distributor 12V and 24V. Engine and boat.

The charge distributor automatically provides charging of two battery circuits, independent of each other. One circuit is used for starting the engine and the other circuit for other electrical equipment. This means that if you empty the accessory battery, you will still be able to start the engine from the start battery.

How to calculate the cable area is described in the installation instruction included in the charging distributor kit.

Recommended single installation

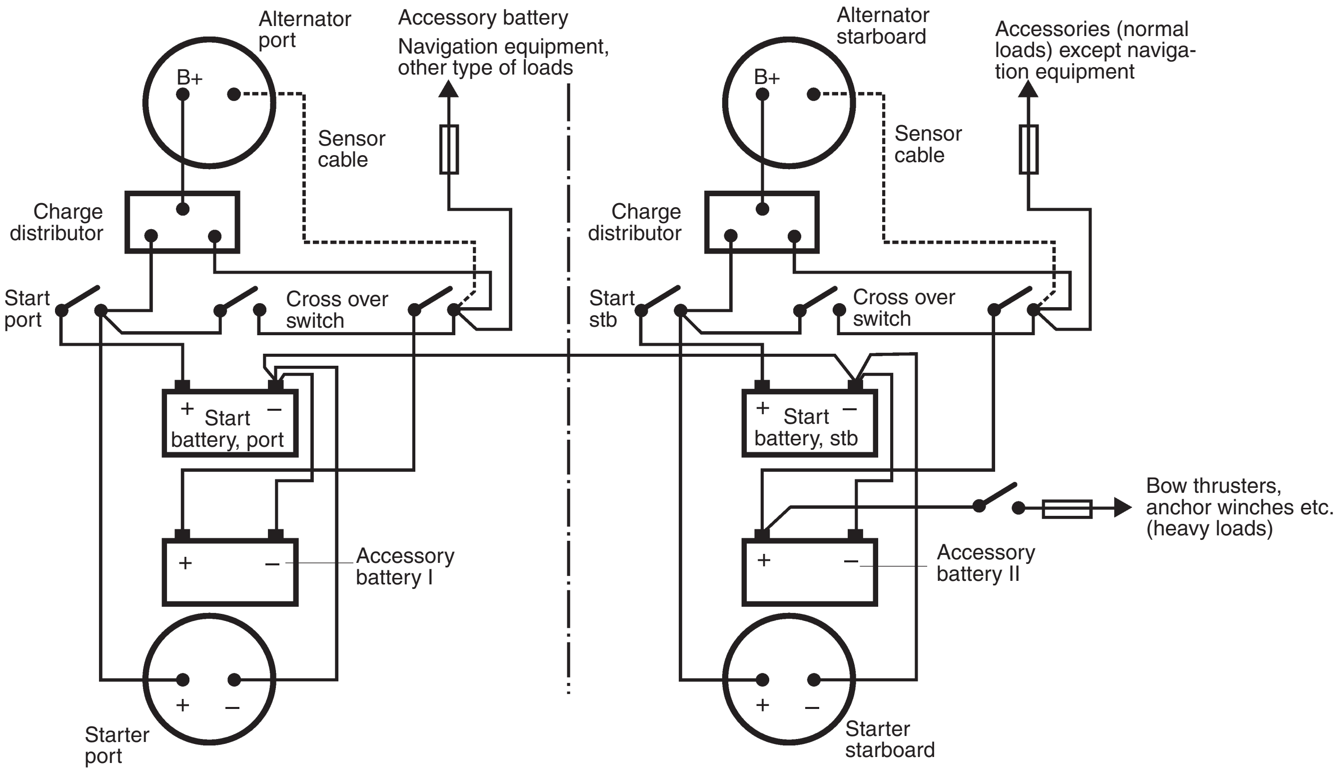


- **NOTE**! No equipment is connected to the starting battery group.
- Two separate accessory battery groups.

  Navigation equipment is connected to accessory battery I.
- Bow and stern thrusters, anchor winches and other heavy electrical loads are connected to accessory battery II. This to prevent voltage drop in equipment connected to accessory battery I, such as navigation instruments.

  NOTE! Heavy electrical loads should have a separate switch connected directly to the accessory battery positive (+) terminal.
- All other equipment, lamps, fans, refrigerators etc. (navigation instruments excepted) can be connected either to accessory battery I or II.
- On D9, D11, D12 and D16 the sensor cable is factory mounted on the starter motor. If accessory batteries are used, re-route the cable according to the picture.

Recommended twin installation
Two accessory battery groups (single failure tolerant system)



- Separate starting battery group for each engine (driveline).

  NOTE! No equipment connected to the starting battery group.
- Two separate accessory battery groups.

  Navigation equipment is connected to the port accessory battery.

  NOTE! Navigation equipment should not be connected to the starting battery group.
- Bow and stern thrusters, anchor winches and other heavy electrical loads are connected to the starboard accessory battery (II). This to prevent voltage drop in equipment connected to the port accessory battery, such as navigation instruments.
- Connect the sensor cables from the alternator to the accessory battery groups.

  NOTE! Heavy electrical loads should have a separate switch connected directly to the accessory battery positive (+) terminal.
- All other equipment, lamps, fans, refrigerators etc. (except navigation instruments) can be connected either to the port or starboard accessory battery.
- On D9, D11, D12 and D16 the sensor cable is factory mounted on the starter motor. If accessory batteries are used, re-route the cable according to the picture.

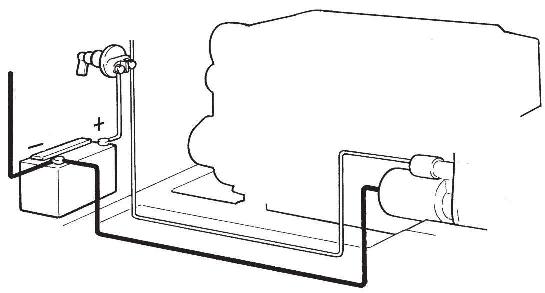
Single failure tolerant system

If a short circuit appears in one of the drivelines, this will not affect the other driveline.

Power module D9/D11/D12/D16

The power module monitors power supply to the control unit, the EVC system (on D12, also exhaust temperature sensor and sea water pressure sensor).

If the power module is connected to a backup battery group, the unit automatically chooses the battery group with the highest voltage. The unit is equipped with a fully automatic circuit breaker function, which cuts the current if overloaded.



NOTE! If the engine is stopped the starter motor does not automatically switch over to backup battery group.

The connection for back up battery is located on the right hand side of the engine below the start motor. It is a two-pole connection marked "1" and "2" where "1" is positive and "2" is negative. The wires to the connection are red and black, where red is positive and black is negative.

If the back-up power functionality is not needed, the power module can be left unconnected.

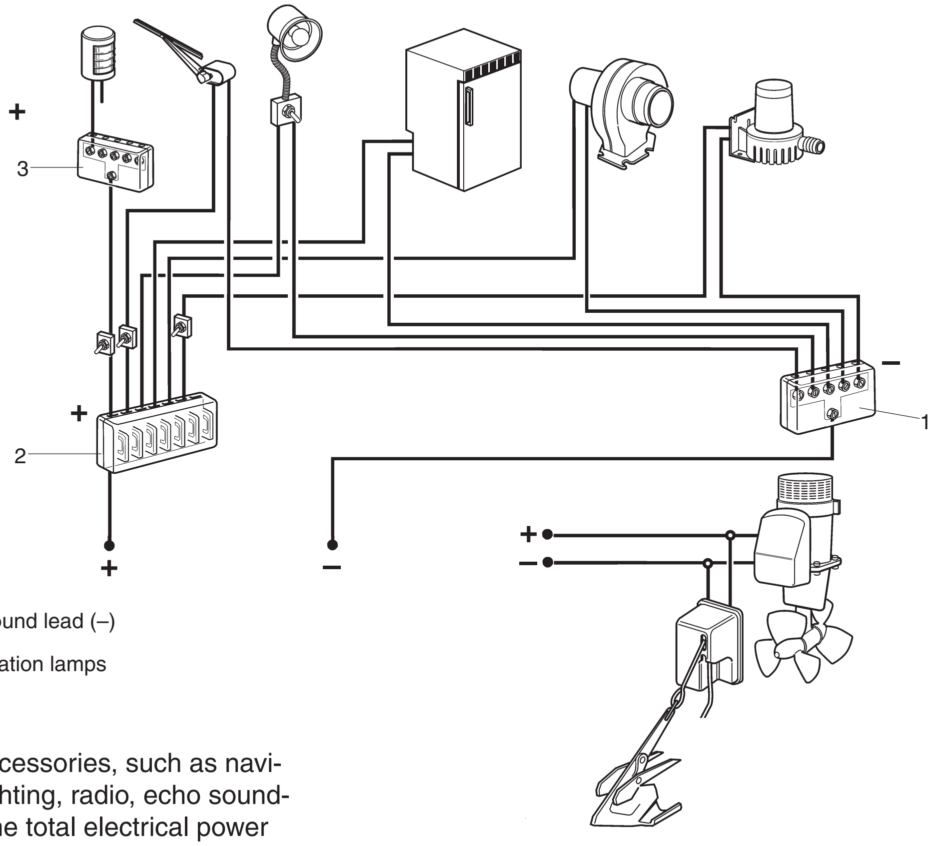
Main switch

A main battery switch should be installed on the positive side. The bulkhead transitions for both the positive and negative cables must be provided with grommets. Position the main switch outside the engine room but as close to the engine as possible, to reduce cable length.

Requirements, main switch

Normal voltage	Nominal capacity Contin-uous	During 5 sec.	Working temp and storage Min	Max	Dimension terminal spade tags	Standard	Protection degree CEI529 standard
≤48V	300A	3000A	–40°C –40°F	+85°C +185°F	M10	SAE J1171	IP 68

Accessories



1. Junction box for ground lead (–)
2. Fuse box (+)
3. Junction box, navigation lamps

Before installing optional accessories, such as navigation instruments, extra lighting, radio, echo sounder etc., carefully calculate the total electrical power consumption of these extras in order to be sure that the charging capacity in the boat is sufficient.

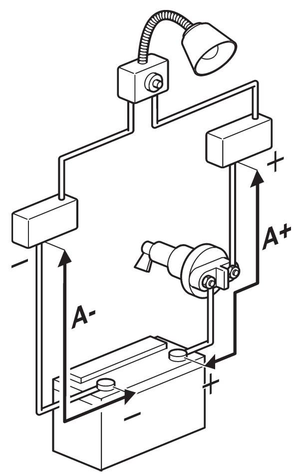
The above diagram indicates how this extra equipment can be installed in the boat. Clamp the leads at close intervals and preferably mark the leads at the fuse and junction boxes (1–3) with the purpose of each lead, i.e. communication radio, refrigerator, navigation lamps etc.

Position the electrical system control panel in a place free from moisture with easy access and close to the instrument panel.

If a 220 V system is installed, this area of the control panel must be clearly identified.

NOTE! Make sure all components used are suitable for a marine environment. Spray all electrical equipment with a moisture-repellent spray.

Calculating the supply cable area

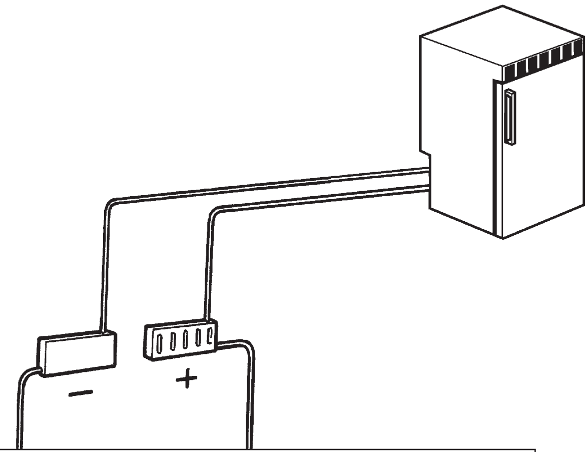


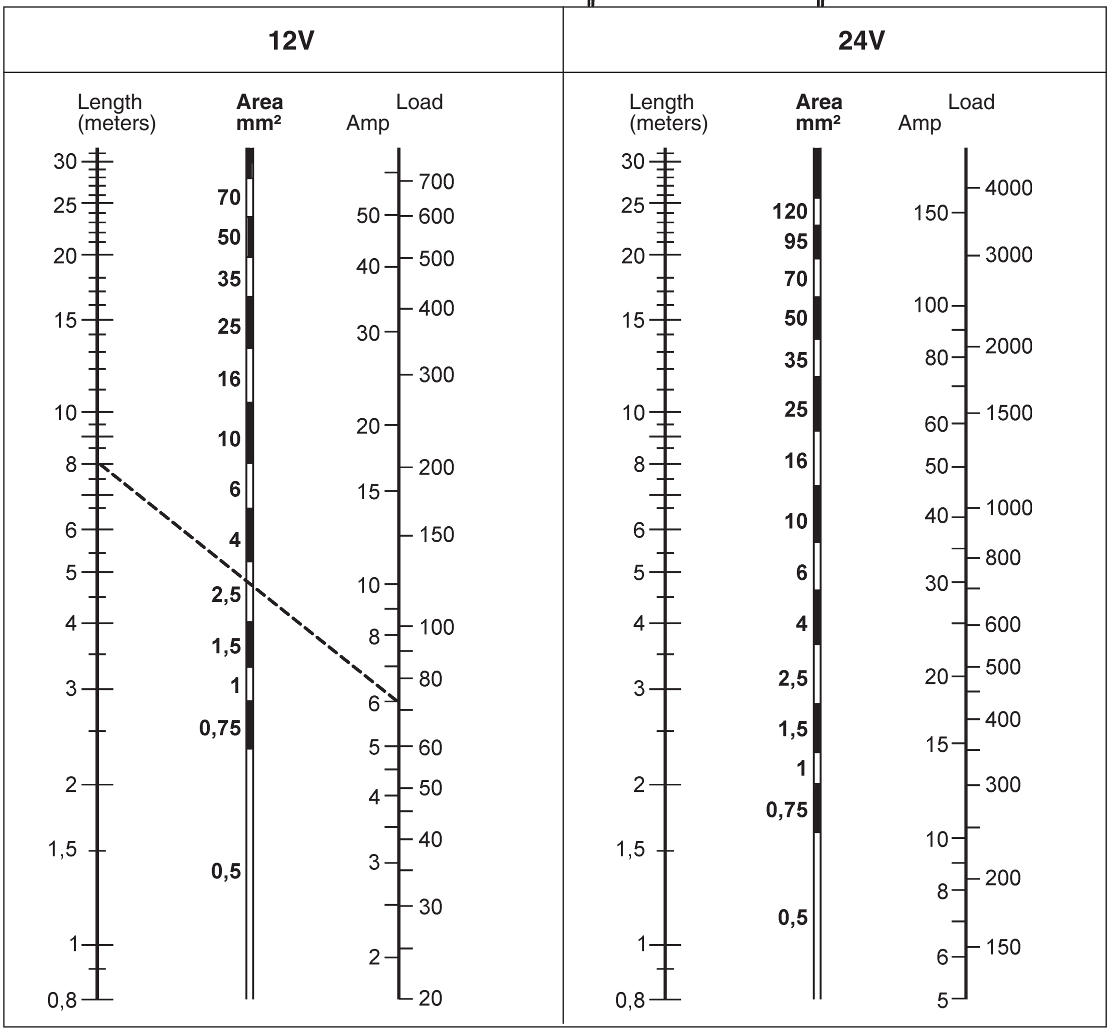
Please note that the length and the area of the supply cables (**A+, A–**) dependends on the number of accessories connected to it.

- Add up all accessories (loads)
- Measure the **total length** on the positive (+) and negative (–) sides of the supply cable (**A+, A–**).
- Please refer to the table on the next page. The table will give you the area of the supply cables.

Calculating the cable area for power loads

- Measure the distance from the terminal block to the accessory.
- Multiply the distance by two.
- Calculate the area in accordance with the table below.





Example: If a 12 V refrigerator consumes 70 W and the distance between the terminal block and the refrigerator is 4 meters, a straight line should be drawn between the figure 8 (4 x 2) on the meter scale and figure 70 on the load scale.

The line passes the area scale in the 2.5 space. 2.5 is equal to the needed area (2.5 mm²).

The calculation is based on the max. permissible total voltage drop in all cables between the positive terminal to the load and the load back to the negative terminal.

Total voltage drop when using the table above:

12 V system 0.4 V

24 V system 0.6 V

Relationship between AWG, inch, mm and mm²

AWG	Diameter		Area
No	inches	mm	mm²
22 21 20	0,0253 0,0285 0,032	0,6438 0,7229 0,8118	0,3255 0,4104 0,5176
19 18 17	0,036 0,04 0,045	0,9116 1,024 1,15	0,6527 0,8231 1,039
16 15 14	0,051 0,057 0,064	1,291 1,45 1,628	1,309 1,651 2,082
13 12 11	0,072 0,081 0,091	1,828 2,053 2,305	2,624 3,31 4,173
10 9 8	0,102 0,114 0,129	2,588 2,906 3,264	5,26 6,633 8,367
7 6 5	0,144 0,162 0,182	3,665 4,115 4,621	10,54 13,3 16,77
4 3 2	0,204 0,229 0,258	5,189 5,827 6,544	21,15 26,67 33,63
1 0 2/0	0,289 0,325 0,365	7,348 8,251 9,266	42,41 53,47 67,43
3/0 4/0	0,41 0,46	10,4 11,68	84,95 107,2

Extra alternators

For information about extra alternators see **Sales Guide Marine Propulsion Diesel Engines** and the **Power take-off** chapter in this publication.

EVC–Electronic Vessel Control

For in formation about how to install the EVC system see manual **Installation, Electronic Vessel Control EVC**.

Battery charging

⚠ **IMPORTANT**! Always connect the battery charger directly to the battery positive (+) and negative (–) poles.

When a battery charger is used in a 12 V system, the battery voltage rises quickly to around 12.9 V, and then rises slowly to 13.8–14.4 V when gas starts to form. The charge current should be reduced by the charger when gas starts to appear. Charging at a high rate and intensive gassing results in the following:

- The life of the battery is reduced
- The capacity is reduced
- There is a risk of a short circuit in the battery
- There is a risk of explosion

The following parameters determine the duration of the charge period:

- The state of discharge when charging is commenced.
- The capacity of the charger (how much current can be supplied from the charger).
- The size of the battery (capacity in Ah).
- The temperature of the battery. Longer charging is required if the battery is cold. The battery cannot absorb a high charge current at low temperature.

It is better to charge at 10 A for 5 hours than 50 A for 1 hour even if the total charge is 50 Ah in both cases. The battery has difficulty in absorbing a high current.

NOTE! A moderate amount of gas is normal. Towards the end of charging, the voltage rises quickly to 15–16 V. This value is not exceeded even if charging is continued.

Risk of explosion

Gas is formed in the battery during charging. A short circuit, naked flames or sparks in the vicinity of the battery can cause a powerful explosion. Ensure proper ventilation, especially if the battery is charged in a closed area.

⚠ **WARNING**! Always disconnect the charge current before removing the cable clamps.

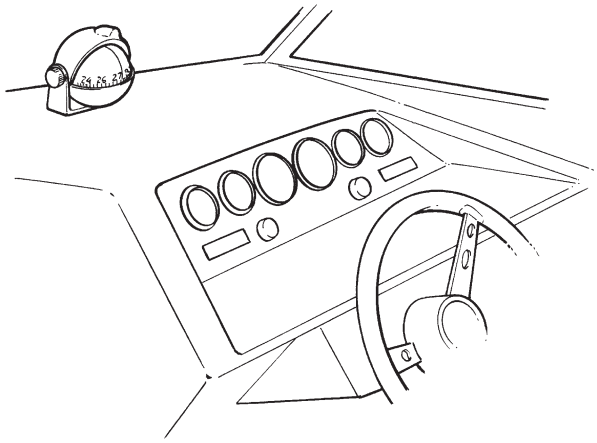
Charge state

The charge state is the level to which the battery is charged. This state can be measured either by measuring the specific gravity of the battery acid in each cell or by measuring the off-load voltage of the cell. The latter cannot be done on modern batteries since the cells' electrical connections are enclosed and therefore not accessible for measurement.

Measuring the off-load voltage across the poles gives entirely wrong information if any cell(s) should be defective. The specific gravity of the battery acid should be measured with a hydrometer instead. Specific gravity varies with temperature. The lower the temperature the higher the specific gravity.

The battery is fully charged when the acid density is 1.28 g/cm3 at +25°C (77°F). A battery filled with tropical acid is fully charged when the acid specific gravity is 1.24 g/cm3 at +25°C (77°F).

Instruments Non EVC engines

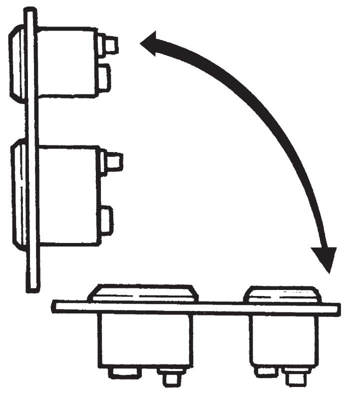


This manual covers normal instruments. Special instruments and senders might be required for some installations, for example classified systems.

Select a position where the instruments will be unobstructed and easily readable.

NOTE! The safe distance for the compass location (to avoid magnetic interference) from the rev counter is **0.3 m (1 ft)**. If the compass is placed closer, compensation must be made. Also see installation instructions regarding the compass.

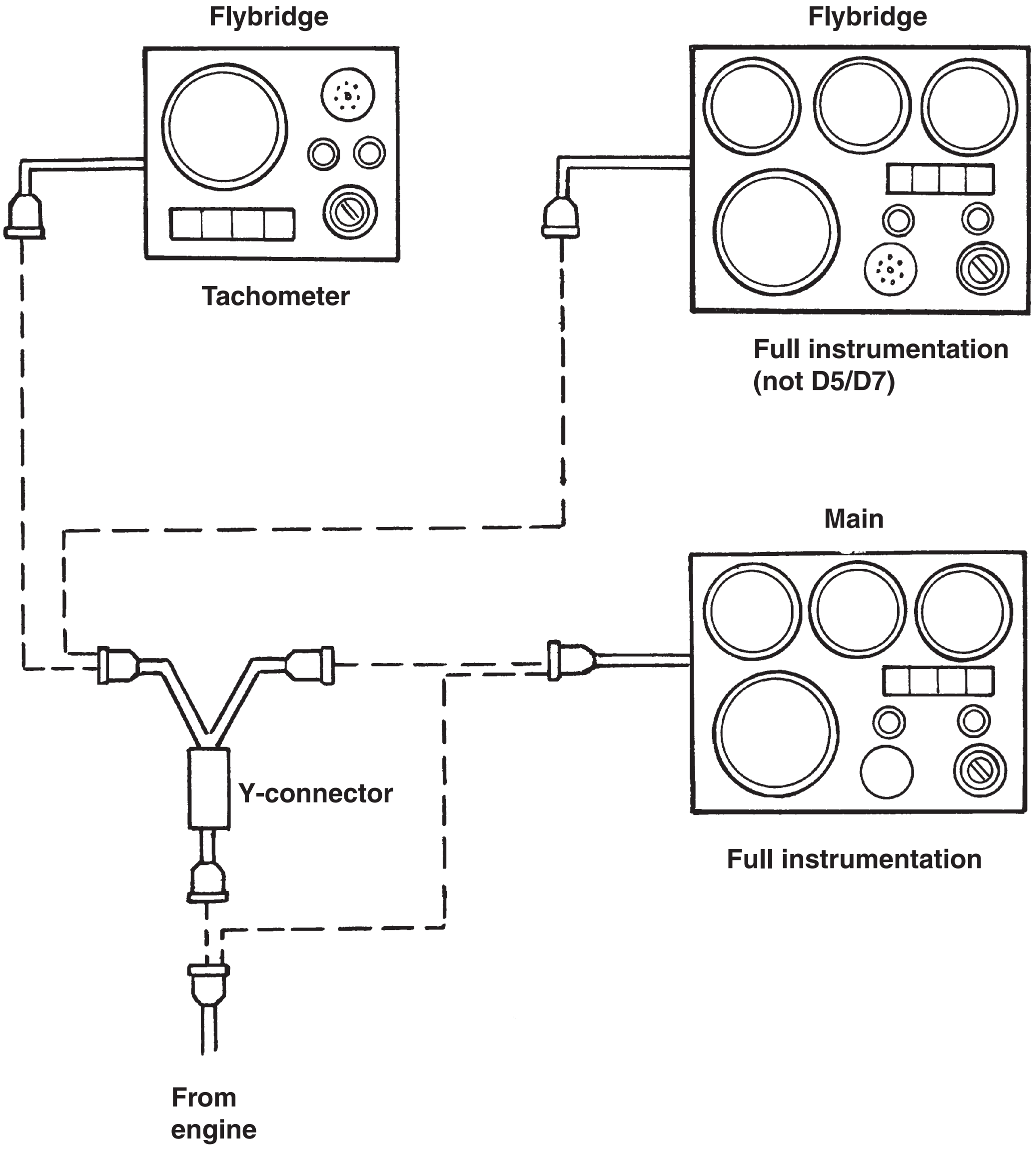
Check to make sure that there is sufficient space underneath for the instruments and leads. Attach the template (if needed) on the selected position.

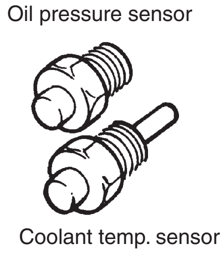


Make sure the panel is accessible for inspection and repair.

The instruments can be installed from a horizontal plane (lying) to the vertical plane (standing). Other angles (inclinations) lead to reduced accuracy and risk of greater wear (shorter life span) of the instruments.

Complete instrument panels for one or two stations



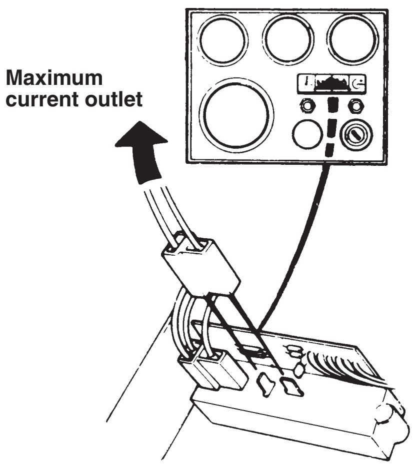


NOTE! When two panels, full instrumentation are used, make sure an electrical system with oil pressure sender and coolant temperature sender for two instruments is used.

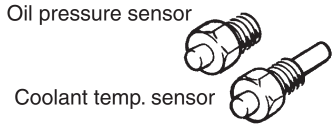
Power supply

Extra outlets: Connect additional outlets on rear side of the alarmpanel. These outlets can be used for additional instruments, audio, etc.

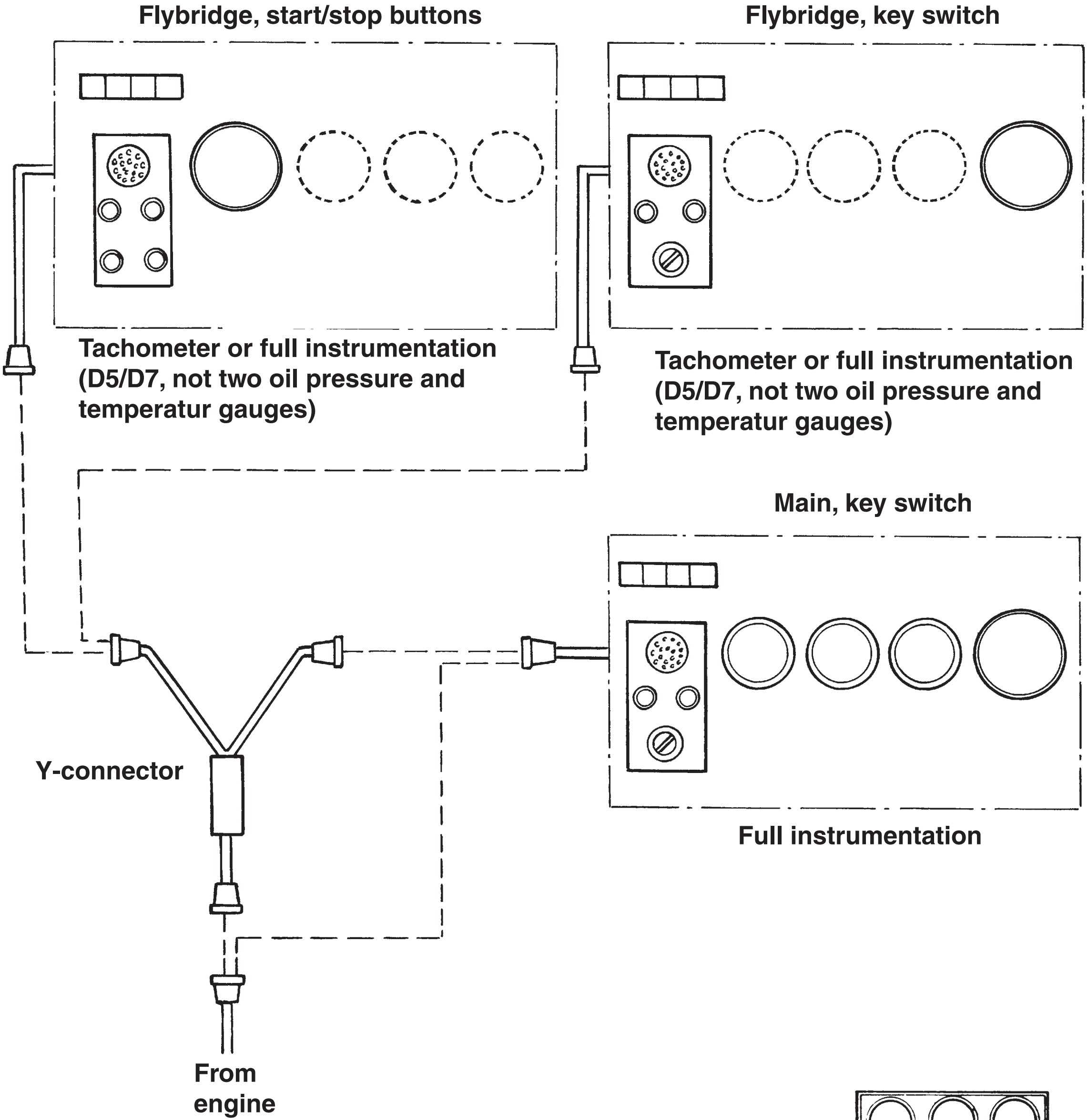
NOTE! Maximum current outlet for both instrument panels together: **5 Amps**.



Instrument kits for customised dashboards



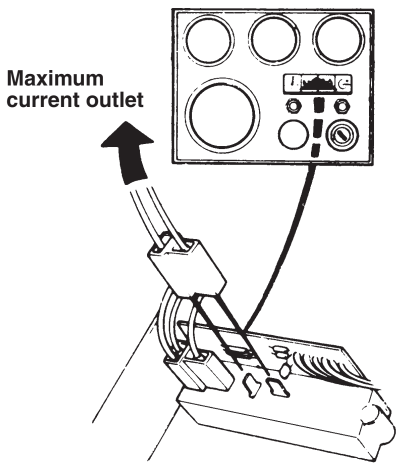
NOTE! When two panels, full instrumentation are used, make sure an electrical system with oil pressure sender and coolant temperature sender for two instruments is used.



Power supply

Extra outlets: Connect additional outlets on rear side of the alarmpanel. These outlets can be used for additional instruments, audio, etc.

NOTE! Maximum current outlet for both instrument panels together: **5 Amps**.

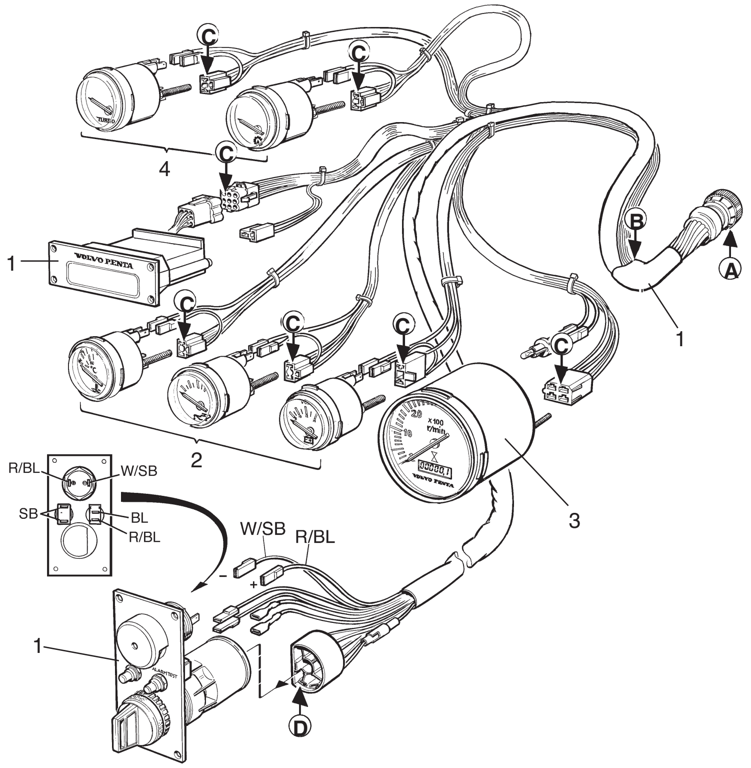


Instrument kit – key switch

1. Panel kit

Available as option:

2. Instrument kit (temperature, oil, volt)
3. Tachometer kit
4. Instrument kit (boost pressure, oil pressure reverse gear)



Harness lengths:

A → B 180 mm

A → C 760 mm

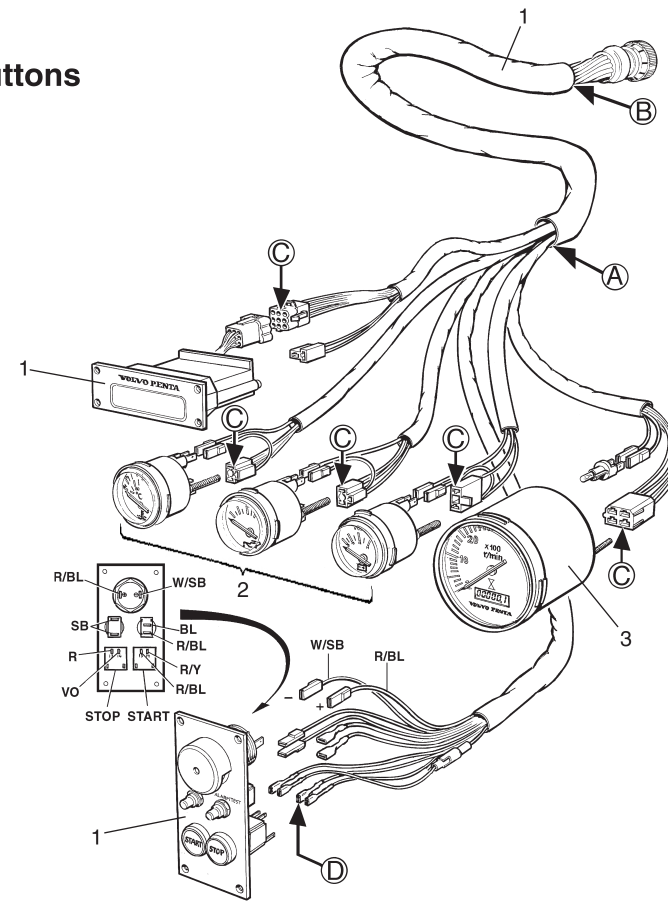
A → D 3280 mm

Instrument kit – flybridge – start/stop buttons

1. Panel kit

Available as option:

2. Instrument kit (temperature, oil, volt)
3. Tachometer kit



Harness lengths:

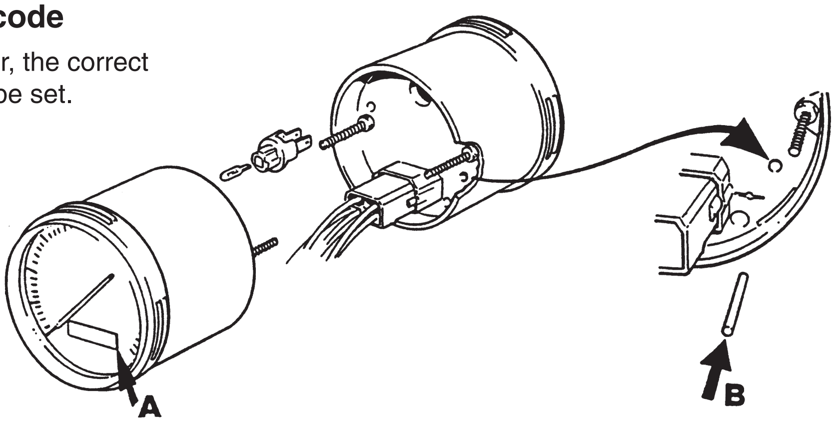
A → B 500 mm

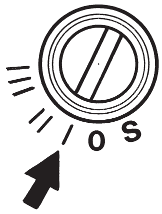
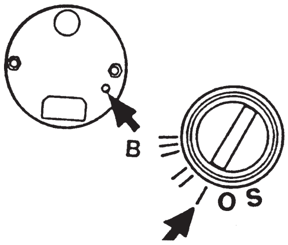
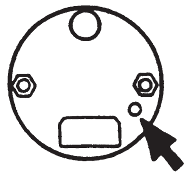
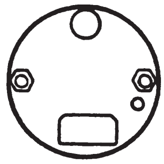
A → C 580 mm

A → D 1600 mm

Universal tachometer, 12V/24V.
Instructions–how to set the code

Before you start using the tachometer, the correct code for the respective engine must be set.

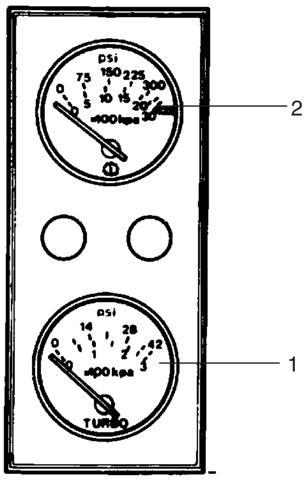


Setting steps		Shown on display A	Descriptions
Connected to system voltage		COdE	**Important!** For tachometers that are already coded pin B **must be pressed in** when the voltage is turned on.
Press in pin B and release pin B. Pin B is not included in the tachometer kit.		Cd1	
Press in pin B.		Cd5	Codes are scrolled at 1 second intervals
Remove pin B when the correct code is displayed*.		Cd3	This is your code. Compare with code table.
* **IMPORTANT!** Wait for 10 seconds with the unit connected to system voltage to confirm the code setting		0.0	Switches to hours counting

Code table

Code	Code shown on display	Signal sender	Engine
24	Cd24	Inductive	D5/D7

Extra instruments



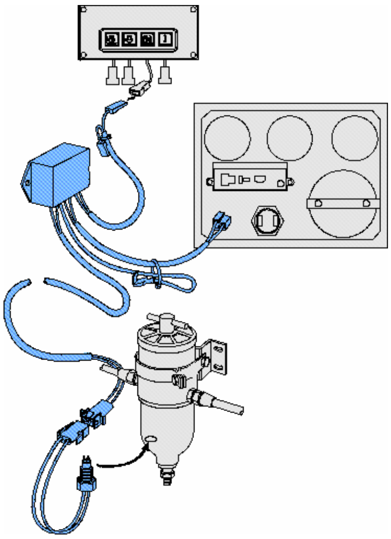
Additional instruments are available to monitor engine boost pressure (1) and oil pressure (2) in the gearbox.

The wiring harness to the these instruments are included in the instrument panels and panel kit for separately mounted instruments.

On D5/D7 the senders have to be ordered separately for fitting on the engine.

Other instruments, such as water and fuel tank gauges and senders, etc. are also available as accessories.

Water in fuel filter alarm



Volvo Penta offers the option of installing an indication for water in the fuel pre-filter. The sender can be connected to an indicator or to a second alarm panel.

External stop relay

D12D-A MP

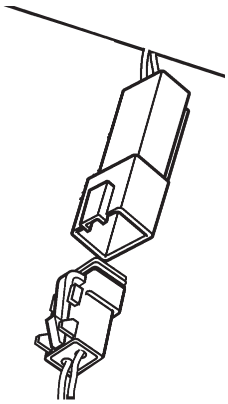
The auxiliary stop can be controlled remotely by installing two relays in series with the auxiliary stop wiring.

The function can be used for a third party fire extinguishing system. Please contact Volvo Penta for further information.

D9/D11/D12D-B MP/D16

The D9, D11, D12D-B MP, and D16 engines are equipped with a relay that can be remotely controlled by third party equipment, e.g. a fire extinguishing system. The engine shuts down when the relay is energized.

NOTE! Leave the external stop connector unconnected if the functionality is not to be used.



Connecting the external stop relay

- Locate the two-pole connector on the right hand side of the engine.
- Connect the accessory cable kit.

Fault codes presented on Vodia when external stop relay is activated (D9, D11, D12D-B MP and D16):

MID128, PPID 6, FMI 11

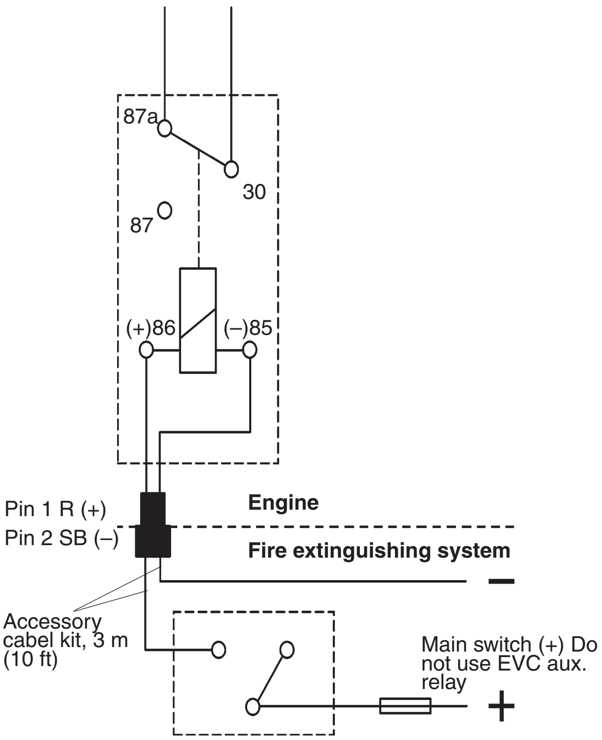
Fire extinguishing system

Before the fire extinguishing system deploys, it should turn off the engine(s). By connecting the engine shut down functionality of the fire extinguishing system to the external stop relay, the engine can be shut down in case of fire.

Recommended installation

(Default functionality on D9/D11/D12D-B)

Active (+) when shut down (energize to stop)

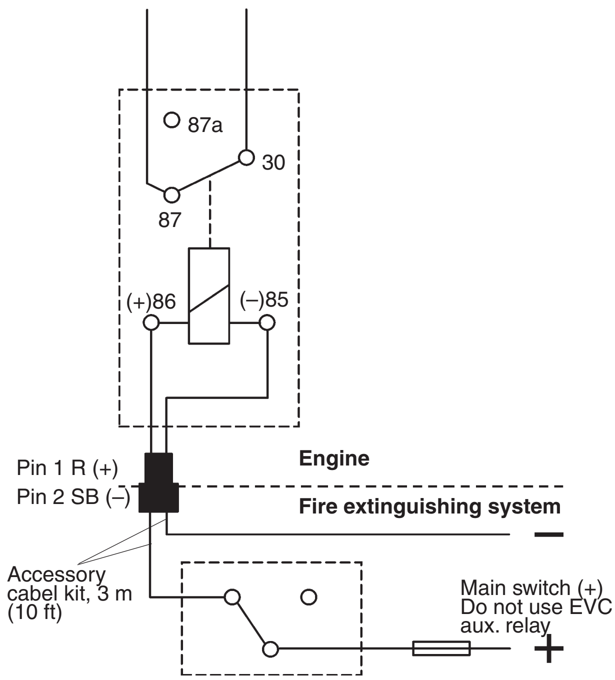


Alternative installation

Not active (+) when shut down (energize to run)

NOTE! When there is a need for a hold function of the relay with active plus (+) from the fire shut down system when engine is running and **no** active plus (+) to shut down the system, cables have to be connected in the relay socket according to figure. Special tool is needed.

Terminal 85 is connected to battery (–) and terminal +86 to the fire extinguishing system.

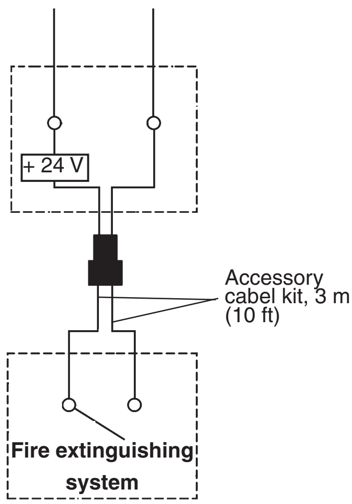


Classified installations

(Default functionality on D9-D16)

Active (+) when shut down (energize to stop)

NOTE! For alternative functionality –
Not active (+) when shut down (energize to run), use VODIA to change configuration.



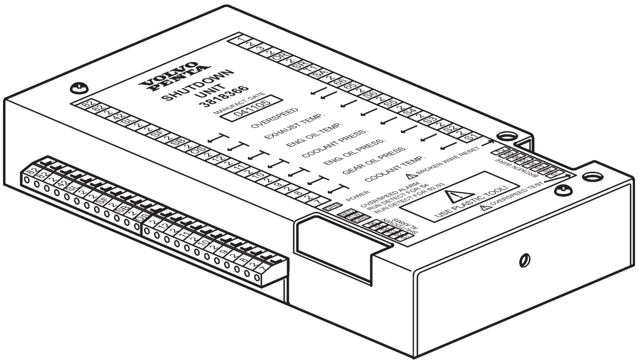
Classified electrical systems, MCC

Below is a general introduction to the MCC. For more information, see **Installation, Marine Commercial Control MCC**.

MCC

The Volvo Penta Marine Commercial Control (MCC) is a control and monitoring system for marine applications. The Marine control unit (MCU), Engine Control Unit and Power Module, together with the Shutdown unit (SDU), provides completely redundant engine control.

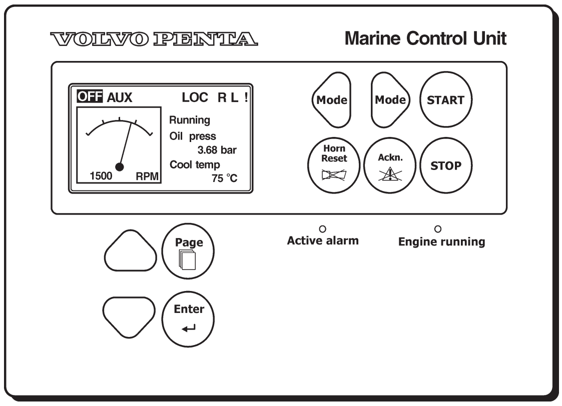
SDU



The Volvo Penta Marine Commercial Control protects the engine using the Volvo Penta shutdown unit (SDU). The SDU is a stand-alone hard wired system for engine protection with separate hard-wired senders and switches inputs and Fuel stop outputs, providing a completely redundant protection system.

- 6 shutdown channels and overspeed shutdown
- All channels equipped with broken wire detection
- Broken wire reset button
- Test button for overspeed shutdown test
- DIN 35-rail mounting

MCU



The MCU communicates with Engine Management System via the CAN serial line using standard J1939 and J1587 communication protocols and controls and monitors the engine in 4 different applications – Propulsion, emergency, auxiliary and combined.

Equipped with a powerful graphic display with icons, symbols and bar-graphs for intuitive operation, together with high functionality this sets new standards in engine controls.

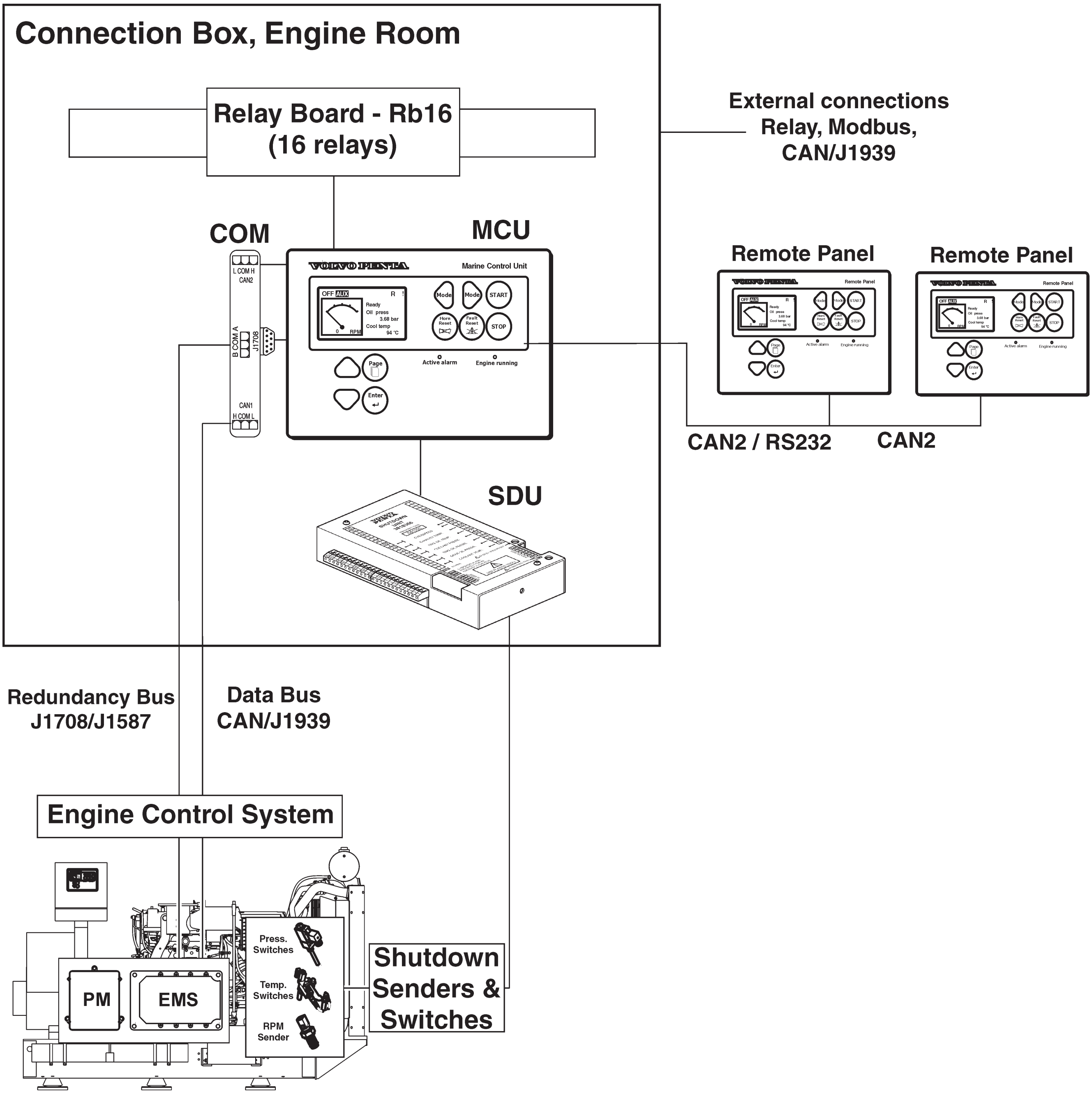
Functions

- On screen alarm list indication
- Event and time driven engine history for back tracing
- Running hours meter, number of starts counter
- Configurable 14 binary inputs and 14 binary outputs and 8 analog inputs
- Magnetic pick-up speed measurement (+redundant channel)
- Extension units for more I/O and Remote Display panel
- Password protection
- 4 operational modes – emergency, auxiliary, harbor and propulsion
- 10 languages selectable on MCU

Communication

- RS232 / Modbus RTU
- J1939, J1587

MCC system overview



Terminology

MCC .... Marine Commercial Control, name of the over all system.

MCU .... Marine Control Unit, the central control unit of the system.

SDU .... Shudown Unit, for engine protection. Activates a fuel shut-off valve to shut down the engine. Separated from the engine control system, all functions hard wired.

COM .... Communication Module, for J1708/J1587 and CAN2 bus (for RP and other extension modules).

RP .... Remote Panel, additional display panel for remote monitoring.

EMS .... Engine Management Systemmonitors engine status and handles engine speed and torque governing and overall control of fuel injection and emission control algorithms.

PM .... Power Module, handles power distribution and power management. It also monitors power supply and switches to secondary power.

Technical data MCU

General

Power supply

Voltage range	8-36V DC
Consumption	0,34A at 8VDC
	0,12A at 24VDC
Battery voltage measurement tolerance	2 % at 24V
Real Time Clock (RTC) battery life-cycle	10 years

NOTE! RTC battery flat causes wrong Date&Time information only.

Operating conditions

Operating temperature	-20 - +70 °C
Storage temperature	-30 - +80 °C
Humidity	95% without condensation
Flash memory data retention time	10 years
Protection front panel	IP65

Dimensions and weight

Dimensions	180x120x50mm
Weight	800g

Binary inputs

Number of inputs	14
Input resistance	4.7 kW
Input range	0-36 VDC
Switching voltage, closed contact indication	0-2 V
Max voltage for open contact indication	8-36 V

Binary open collector outputs

Number of outputs	14
Maximum current (outputs BO1, BO2)	1A
Maximum current (outputs BO3 - BO14)	0,5 A
Maximum switching voltage	36 VDC

Group 1 AI1 – AI4

Number of inputs	4 unipolar
Resolution	10 bits
Jumper selectable range	V, W, mA
Maximal resistance range	2500 W
Maximal voltage range	4,0 V
Maximal current range	0 – 20 mA
Resistance measurement tolerance	± 2 % ± 2 W out of measured value
Voltage measurement tolerance	± 1 % ± 1mV out of measured value
Current measurement tolerance	± 1 % ± 0,5mA out of measured value

Group 2 AI5 – AI8

Number of inputs	4 bipolar
Resolution	(up to 16) bits
Jumper selectable range	V, ohm, mA, thermocoupler
Maximal resistance range	2500 W
Maximal voltage range	± 1000 mV or 100mV
Maximal current range	± 0 - 20 mA active, 0 - 20 mA passive
Resistance measurement tolerance	± 0,5 % ± 2 W out of measured value
Voltage measurement tolerance	± 0,5 % ± 1mV out of measured value
Current measurement tolerance	± 0,5 % ± 0,5mA out of measured value

RS232 interface

Maximal distance	10m
Speed	19.2kBd

Electrochemical corrosion

General

NOTE! Please refer to the **Marine Electrical Systems Part 1** manual, chapter **Electrochemical corrossion** for more detailed information.

Electrochemical corrosion

Electrochemical corrosion of metals can cause very serious and expensive damage to propellers, propeller shafts, rudders, keels and other equipment fitted to the boat.

The types of corrosion that are particularly significant for boats are:

- Galvanic corrosion
- Crevice and deposit corrosion
- Stray current corrosion

Galvanic and stray current corrosion are of major importance when doing the installation work. It may be caused by mistakes in the electrical installation or choice of wrong materials in submerged components.

The damaging effects of electrochemical corrosion start as soon as the boat is launched. Since corrosion takes place "out of sight" below the surface of the water, damage can be severe and is often not detected until the boat is brought up on land.

Consequently, drives and propellers should be protected against corrosion by the use of sacrificial anodes made of zinc, aluminum, magnesium or iron. This protection may not be sufficient if electrical equipment is connected incorrectly or incorrect material is used in external boat equipment.

Galvanic corrosion

A boat that lies in the water constitutes a galvanic element, since different metals (or metal alloys) such as steel and bronze are in electrical contact with each other while in the same electrolyte, namely salt water. This produces galvanic corrosion.

In popular terms, this can be compared with the similar electrochemical process that goes on in a battery, called a galvanic element. In a non-battery context the result of this process is called galvanic corrosion.

There must be be certain conditions for galvanic currents to occur: The metals need to be in an electrolyte and galvanically connected to each other. A corrosion current will then flow from the metal with the lower potential (the anode) to the metal with the higher potential (the cathode). Two chemical reactions are needed for this; oxidation and reduction. Oxidation (release of electrons) takes place at the anode and reduction (absorption of electrons) takes place at the cathode.

Metals susceptible to corrosion

All metals can be physically listed in a galvanic potential series. This indicates the metal's normal potential (voltage) in relation to a reference electrode when each material is immersed in a particular electrolyte.

The following is a voltage series for metals. The electrolyte is seawater at a temperature range of +10°C to +26.7°C (50°F – 80°F). The water flow rate is 2.4 – 4.0 m/s (7.8-13.1 ft/s).

The reference electrode is silver-silver chloride (Ag-AgCl).

Graphite	+0.19 to +0.25 V
Stainless steel 18-8, Mo, in a passive state *	±0.00 to -0.10 V
Stainless steel 18-8 in a passive state *	-0.05 to -0.10 V
Nickel	-0.10 to -0.20 V
Nickel aluminum bronze	-0.13 to -0.22 V
Lead	-0.19 to -0.25 V
Silicon bronze (Cu, Zn, Si, Mn, Sn)	-0.26 to -0.29 V
Manganese bronze (Cu, Zn, Sn, Fe, Mn)	-0.27 to -0.34 V
Aluminum brass (Cu, Zn, Al)	-0.28 to -0.36 V
Soft solder (Pb, Sn)	-0.28 to -0.37 V
Copper	-0.30 to -0.57 V
Tin	-0.31 to -0.33 V
Red brass (Cu, Zn)	-0.30 to -0.40 V
Yellow brass (Cu, Zn)	-0.30 to -0.40 V
Aluminum bronze	-0.31 to -0.42 V
Stainless steel 18-8, Mo, in an active state **	-0.43 to -0.54 V
Stainless steel 18-8 in an active state **	-0.46 to -0.58 V
Cast iron	-0.60 to -0.71 V
Steel	-0.60 to -0.71 V
Aluminum alloys	-0.76 to -1.00 V
Galvanized iron and steel	-0.98 to -1.03 V
Zinc	-0.98 to -1.03 V
Magnesium and magnesium alloys consumed	-1.60 to -1.63V

* Metals are in a passive state when the metal has a thin, reaction-inhibiting coating. This coating is not present in an active state.

** Still water.

From the table, we can see that steel has about -0.65 V and aluminum around -0.85 V in the voltage series. The higher up in the voltage series (the greater potential), the more noble the metal. If these metals are connected together in a galvanic element, the less noble metal will be consumed by the more noble metal-galvanic corrosion arises.

In our case, the aluminum will corrode.

The further the metals are apart in the galvanic voltage series, the greater the (corrosive) effect will be on the less noble metal if they are connected together in a galvanic element.

Definitions

One-pole system

In a 1-pole system the engine block itself is used as a negative return for all electrical components on the engine block.

Two-pole system

All engines covered in this manual have a two-pole electrical system. This means that each electrical component on the engine has an insulated DC negative return. The alternator, starter motor and all sensors are electrically isolated from the engine block and the positive and negative poles of the batteries must be connected to the starter motor terminal.

Isolation Transformer

A transformer with galvanically separated input and output windings.

Galvanic isolator

A device installed in series with the AC grounding conductor of the shore power cable to prevent low voltage DC galvanic current flow, but permit the passage of alternating current normally associated with the AC grounding conductor.

Ground fault circuit interrupter (GFCI)

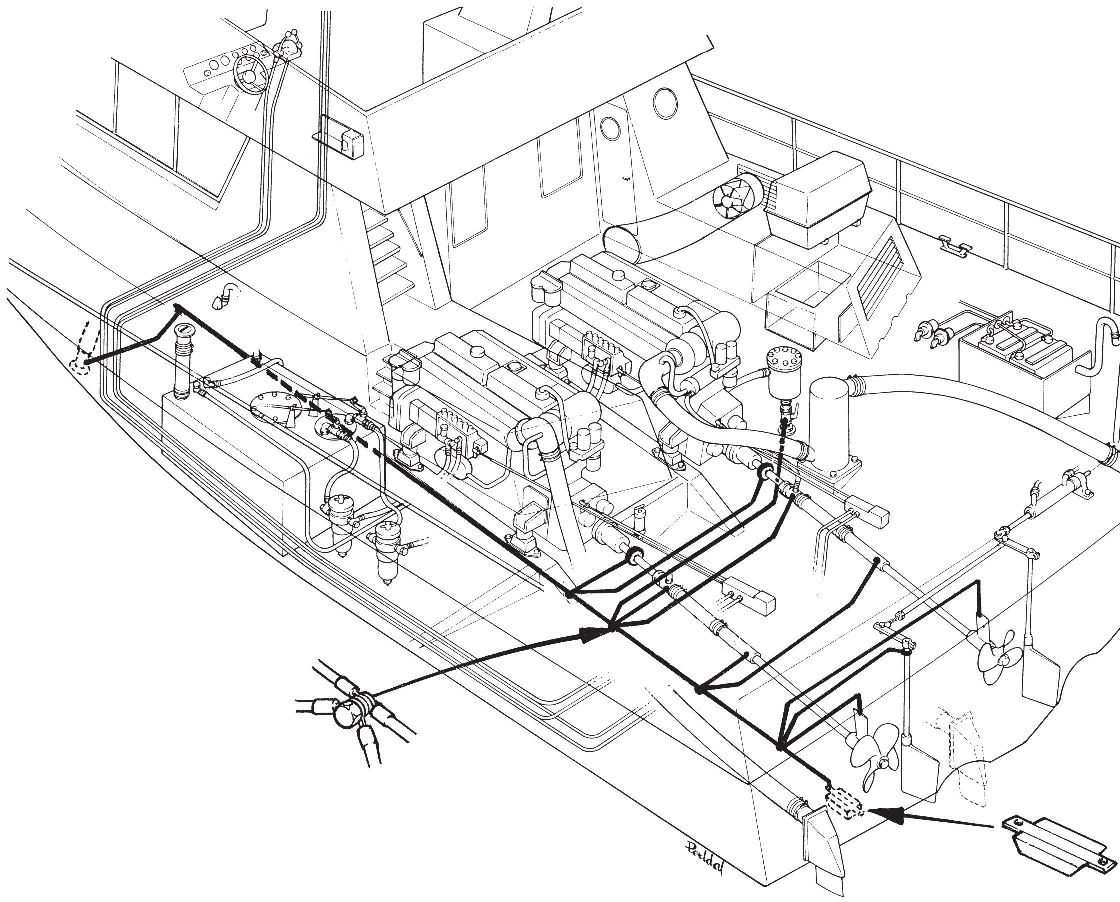
A device for the protection of personnel. The GFCI de-energize a circuit, when a current to ground exceeds a predetermined value.

Protection against electrochemical corrosion

It is important that components submerged in the water such as through-hull fittings, swim ladders etc. are protected from galvanic corrosion. Our recommendation is to bond all of them to a transom mounted, protective anode, normally made of zinc. Trim tabs may have their own protection.

NOTE! This bonding system with its individual components should normally have no contact with the negative circuit of the boat's electrical system.

Local recommendations, e.g. ABYC, may state that the battery negative terminal should be connected to the bonding galvanic circuit. If you decide to connect the bonding galvanic circuit to the battery negative (–) terminal, you must also connect the engine block with a cable large enough to carry the cranking engine current, as described in ABYC chapter E-11.

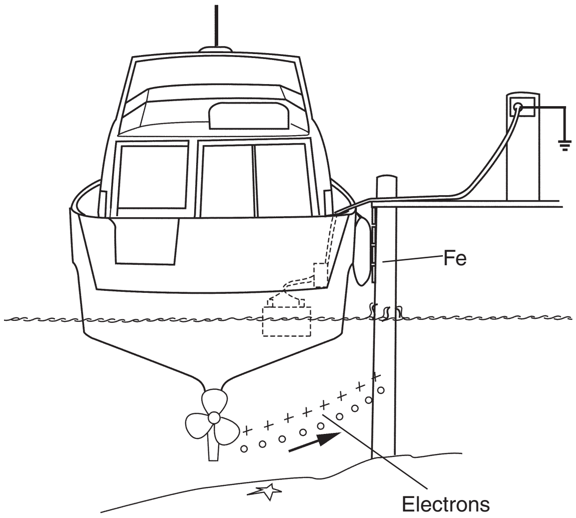


Protection against electro-static discharge and lightning

For advice on the prevention of hazards due to electrostatic discharge or lightning, please refer to relevant publications by national and international standardization bodies such as the International Electrotechnical Commission and the American Boat and Yacht Council.

In particular, the publications IEC 60092-507:2000 Electrical installation in ships Part 507: Pleasure craft, and ABYC Standards and guidelines H-33 and E-4 may prove helpful.

Stray current and shore power corrosion



Stray current corrosion is similar to galvanic corrosion in the way it acts but differs in the way it is caused. In galvanic corrosion, it is the potential differences on the metal that initiates corrosion. As the name implies, stray current corrosion is caused by stray currents.

Stray currents can arise as a result of faults in the boat's electrical system, such as connections and splices that are exposed to moisture or bilge water, equipment that is faulty as a result of damage or wear, or an electrical system that is incorrectly connected.

Stray current corrosion can also be caused by stray currents from neighboring boats or equipment for connecting to a shore based power supply at quays.

Shore power and generator installation

Recommended installations

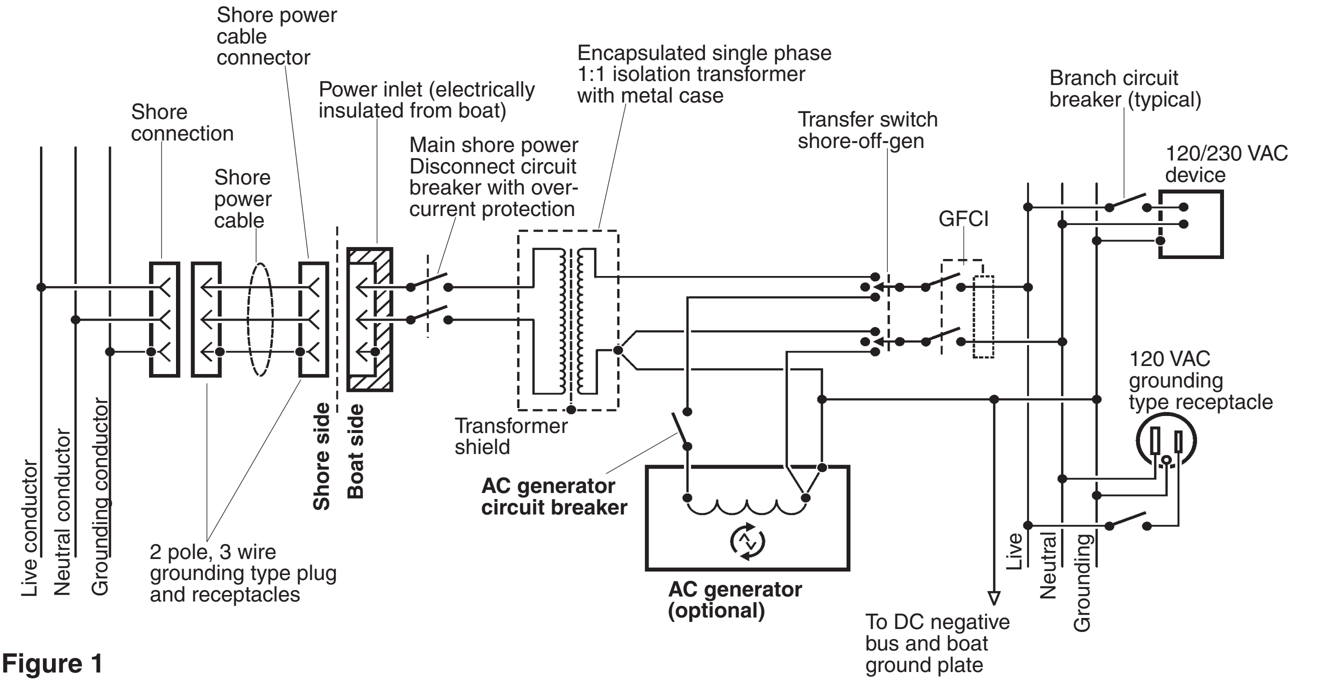


Figure 1
Single-phase, 120/230 VAC system

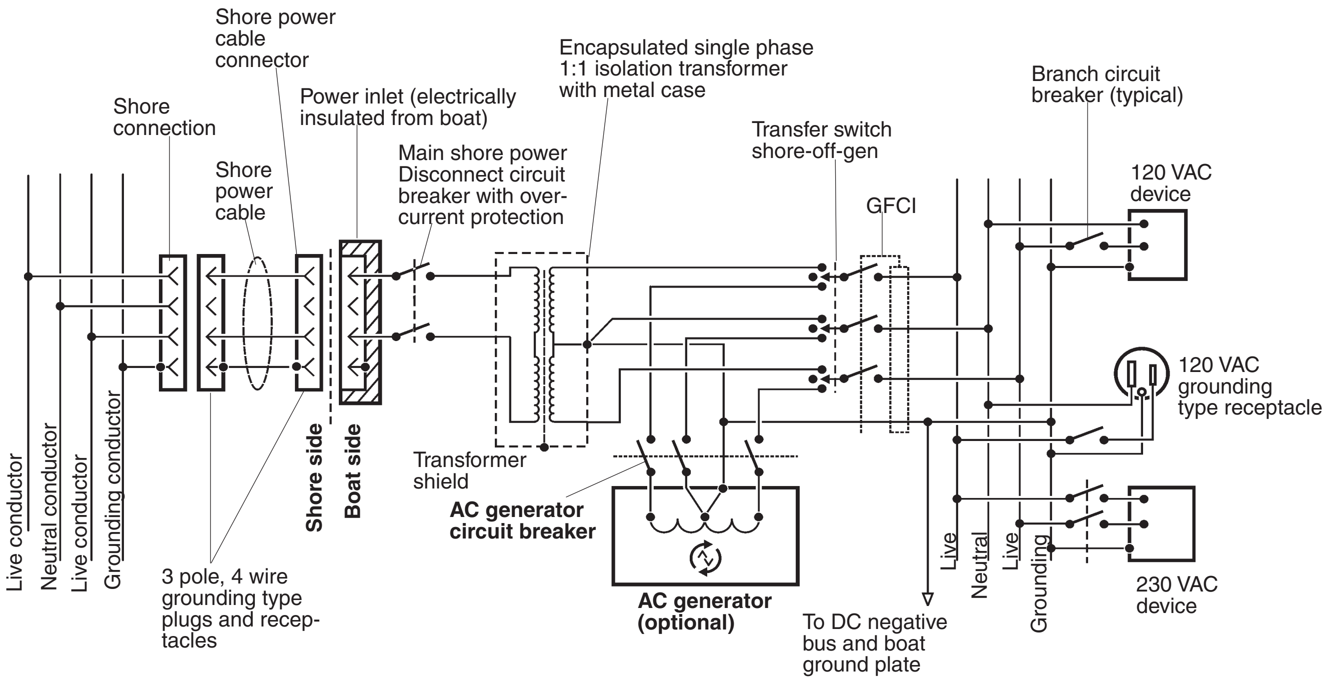


Figure 2
Single-phase, 230 VAC input, 120/230 VAC output

Taking into account considerations of personnel safety and care of the equipment, Volvo Penta gives the following recommendations regarding shore power alternating current (AC) installations:

Installations should be made according to figure 1 or figure 2. Figure 1 shows a single-phase installation for either 230VAC or 120VAC. Figure 2 shows a 230VAC input, 120/230VAC output installation.

Figures 1 and 2 are based on ABYC E-11 diagrams 8 and 11 but require a ground fault circuit interrupter and an isolation transformer. Figures 1 and 2 are considered best practice and are in harmonywith recommendations from ABYC and ISO, and provide protection against electrochemical corrosion and electrical shock.

The safety related components are important for the following reasons:

Isolation transformer

The isolation transformer galvanically separates the shore power from the boat. This minimizes the risk of galvanic and stray current corrosion.

Ground Fault Circuit Interrupter (GFCI)

Arcing faults between a live conductor and ground can be sustained at relatively low current levels and does not trigger circuit breakers. Furthermore, even very low current levels represent danger to personnel. A GFCI must be installed on the secondary side of the isolation transformer as a ground fault protection in the boat. The GFCI trip sensitivity and trip time must comply with local standards.

The GFCI placed on the secondary of the isolation transformer ensures ground fault protection on the boat. This is an addition to ABYC E-11, that ensures a higher degree of protection against electrical shock.

Ground plate

To ensure safety of personnel, a common ground plate below the waterline must be connected to the AC and DC electrical system.

Shore power and battery charging

When shore power is connected (120V–230V), the shore safety ground (earth) must not be connected to the engine or any other ground point on the boat. The safety ground must always be connected to the connection cabinet's ground (earth) terminal ashore. The safety ground should not be connected to the negative connection on the output side (12/24V), i.e. it must be galvanically separated.

⚠ **WARNING!** Installation and work using shore connected equipment may only be carried out by an electrician who is qualified to work on mains voltage installations. Incorrect installation can result in danger to life.

Prevention of stray currents during installation

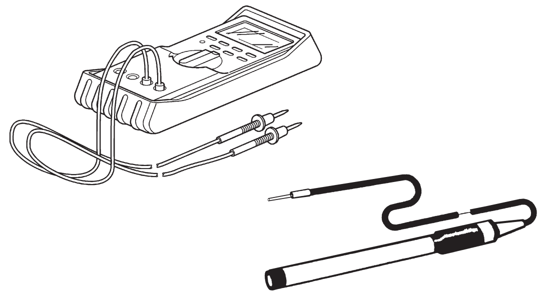
A proper installation will reduce the risk of stray current problems later in the boat's service life.

- All DC circuits must have an insulated return cable. Consequently, a metal keel must not be used as a return conductor.
- All splices in the circuit such as socket housings and terminal blocks shall be installed so that they are not exposed to moisture or bilge water. The same applies to switch panels, fuse holders etc.
- Cables shall be routed as high as possible above the bilge water in a keel. If a cable must be routed where it is exposed to water, it must be housed in a watertight conduit and the connections must also be watertight.
- Cables which can be subject to wear must be installed in self-draining conduits, sleeves, cable channels etc.
- For battery and main switch installation, please refer to the **Electrical System** chapter.
- Engines and drivelines must not be used as a ground (earth) for radio, navigation or other equipment where separate ground cables are used.
- All separate ground (earth) cables (ground connections for radio, navigation equipment, echo sounder etc.) must be linked to a common ground (earth) point, i.e. a cable that does not normally act as a return for equipment.
- If shore based power is connected (120V/230V), the safety ground (earth) must not be connected to the engine or any other ground point on the boat. The safety ground must always be connected to the connection cabinet's shore ground terminal.
- Transformers connected to a shore base current supply, such as a battery charger, shall have the protection ground (earth) on the input side (120/230V) connected but the negative connection on the output side (12/24V) not connected, i.e. galvanically separated.

⚠ **WARNING!** Installation and work on shore connected equipment may only be carried out by an electrician who is qualified to work on installations with voltage higher than 50V AC.

Checking electrochemical corrosion

Measuring galvanic currents and stray currents in water



Volvo Penta has produced a method for measuring galvanic currents and stray currents using a calomel electrode.

The calomel electrode (Ag/AgCl), **885156**, is a reference electrode which shall be connected to the multimeter **9812519**. The multimeter is used to measure potential differences.

NOTE! If other multimeters are used, accuracy is required to 1 mV.

Depending on the method used, the measurement result can provide a mean voltage value for the entire measurement object, such as a shaft line or the voltage which an individual component produces.

Examples of such point checks are rudders, water intakes etc.

NOTE! The calomel electrode can be used in water with a varying salt content or in freshwater.

The process measures the potential difference between the measurement object and the calomel electrode. The calomel electrode has a known constant electrode potential. Thus the potential differences recorded must always be related to a particular reference electrode and the same electrolyte, i.e. the same water and water temperature. The water flow rate must also be the same if results from different measurements are to be compared.

Measurement theory

Anodic protection operates by sending out an electric current, the protection current, to oppose the corrosion current. When the protection current rises and the corrosion current falls, the potential of the protected object falls. When a given potential is reached, the corrosion current will have disappeared and the object has complete cathodic protection.

Thus a given electrode potential for the metal provides a guide as to when cathodic protection is in place and whether it is sufficient. The calomel electrode can measure whether this protection potential is provided.

Checking galvanic electricity, calomel electrode.

Connect the calomel electrode, special tool **885156** to the multimeter, special tool **9812519.**

Connect the multimeter to a good ground (earth) connection. Set the multimeter for DC measurement.

Carefully remove the protective sleeve from the probe tip. The protective sleeve is filled with a saturated salt solution (NaCl). Dry the tip with a clean paper tissue or equivalent after measurement and before putting it back.

Dip the electrode in water approximately 30 cm (12") from the **propeller and propeller shaft**. The measurement result is the mean value for the complete shaft line. The result should lie between (minus) -900 mV and -1100 mV.

To check individual components, move the electrode so that the tip is directed towards the surface, approximate 5 mm (0.2") away from the surface where the component is fitted.

The measurement result here should also lie between –900 and –1100 mV.

If the result exceeds this (i.e. is a more positive value such as –800), the proportion of "noble" metals such as stainless steel, bronze etc., is too great for the zinc anodes to overcome the corrosion current. The number of anodes should be increased.

The result may also be from stray currents caused by incorrect or incorrectly connected (+) cable or (+) cables exposed to bilge water.

There is excess protection if the multimeter gives a result less than –1100 mV. This could also be caused by stray currents from separate ground (earth) cables for VHF radio or other equipment fitted with separate ground (earth) cables which are incorrectly connected.

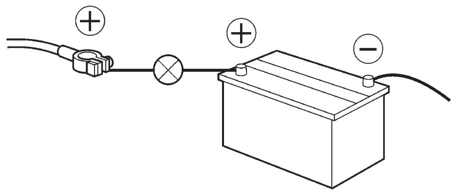
The reason may also be that the anodes provide too much protection current, such as magnesium anodes in salt water.

Checking for leakage from the electrical system

A simple way of testing the boat's electrical integrity is to employ the following procedure:

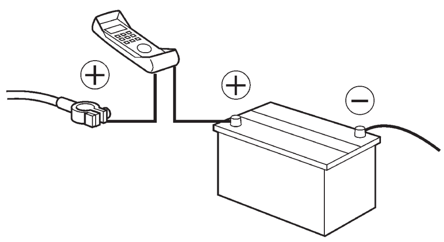
First check that fuses and circuit breakers are fitted and intact, that the battery main switches are on, and that all other switches and appliances are off. Theoretically, there should be no current flowing from the battery. Any flow will indicate a leak.

1. To check if any current is leaking.



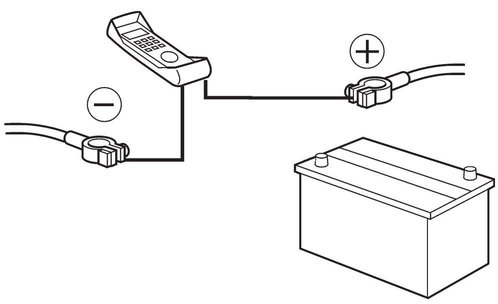
Lift off the positive battery terminal connector and connect a 12 volt, 3W test lamp between the positive terminal and the loosened connector. If there is no leak, the lamp will fail to light. A faint glow indicates a small leak, and a bright light means that you have a more serious leak. You can also use a Voltmeter for this test. Note that some equipment may consume current even when it is switched off (clock or radio), which will cause the lamp to light. Such equipment must be disconnected.

2. To check how much current is flowing.



Use a multimeter, and set it to read "DC Amps". Connect the red test lead to the battery positive terminal, and the black lead to the loosened connector. The meter will now show how much current is leaking. If you do not get a reading, change to the ”DC mAmps” scale.

3. Double-check to see the resistance in the circuit.



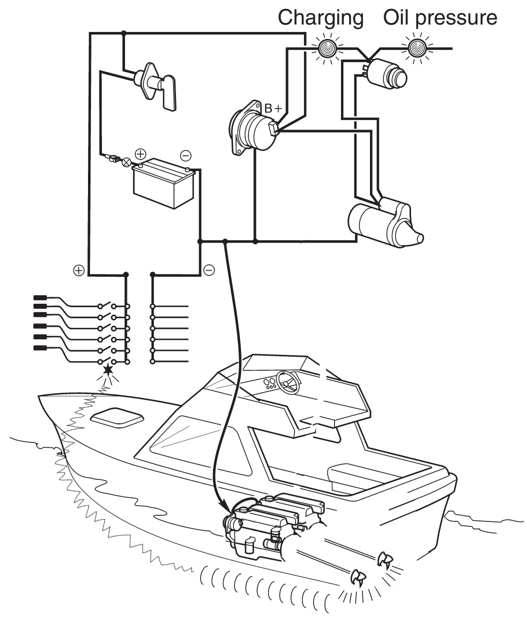
Set the multimeter to Ohms. Connect the black test lead to the loosened negative connector, and the red test lead to the loosened positive connector. You should now see a reading of the resistance of the circuit.

NOTE! Certain equipment may also cause a current drain when shut off, such as a radio, clock or automatic bilge pump. This equipment must be disconnected.

The rough guide below indicates what these readings means in practical terms:

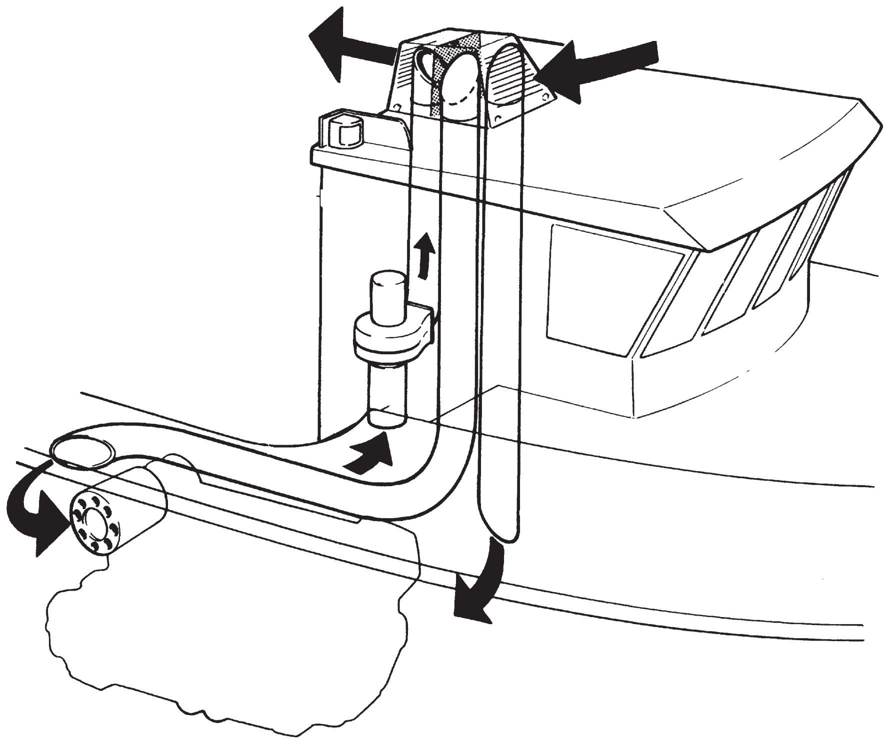
- 10.000 Ohm up to open circuit– A next to perfect circuit, no problems.
- 5.000 Ohm – There is a small leak.
- 1.000 Ohm – There is a leak that must be found and corrected.
- 500 Ohms or less – A heavy leak. Disconnect the battery terminals. Repair as soon as possible.

4. To find the leak.



With the test lamp connected as step 1 above, loosen one fuse at a time and put it back again. When you remove a fuse and the test lamp goes out, then you have found the circuit that is causing the problem. Trace the circuit until the fault is found, and repair it.

Engine room, ventilation and soundproofing



Introduction

Engine performance

Engine power is affected by a number of different factors. Among the most important ones are air pressure, air temperature and exhaust backpressure. Deviations from the normal values affect engine performance and function.

Diesel engines require excess air. Deviations from the normal values show up first of all with an increase in black smoke. This can be particularly noticeable at the planing threshold when the engine must give its greatest possible torque.

If the deviations from the normal values are great, the diesel engine will lose power. This power loss can be so great that a planing boat cannot pass through the planing threshold.

For the engine to function properly and give full power, it is absolutely necessary that both the inlet and outlet air ducts are sufficiently dimensioned and installed correctly.

Two main conditions must be fulfilled:

A. The engine must get enough air (oxygen) to allow for the combustion of the fuel.

B. The engine room must be ventilated, so that the temperature can be kept down to an acceptable level.

Ventilation is also important to keep the engine's electrical equipment and fuel system at a low temperature, and for certain general cooling of the engine.

If personnel are to be present in the engine room, the ventilation installation must be adapted accordingly.

NOTE! All valid safety regulations and legal requirements for each country must be followed. Each classification society has its own regulations that must be followed when required.

Engine power output and air temperature

The engine's stated power output applies at an air temperature of +25°C (+77°F), air pressure of 750 mm Hg, relative humidity 30%, fuel temperature +40°C (+104°F) and seawater temperature of +32°C (+90°F). (According to International test standards).

Adequate air supply and ventilation makes it possible to obtain as high a power output as possible together with a long engine life.

If the inlet air for the engine cannot be kept below +25°C (+77°F), the **power output drops** by up to 1.5% for turbocharged engines and 1.0% for turbocharged engines with aftercooler for every +10°C (+18°F) increase in air temperature. For normally aspirated engines, this figure can be up to 2%. In those places in the world where the air temperature is constantly at or above +45°C (+113°F), diesel engines must be de-rated, i.e. the injection pump adjusted to a lower injection quantity.

However, the driver can reduce the throttle **when operating temporarily** in such hot areas and thus avoid these types of unfavourable operating conditions.

⚠ **IMPORTANT**! In those cases where operation is at full throttle and the injection pump is not adjusted (de-rated) despite high air temperature, the result will be very smoky exhaust, increased thermal load and greatly increased engine wear and consequently greatly increased operating costs.

Engine power output at high altitudes above sea level

In most cases, marine engines are run at or near sea level. There are, however, some lakes that are situated at high altitudes above sea level.

There is loss of power when operating at high altitudes due to the fact that the air density (and therefore oxygen content) decreases as altitude increases. This results in smoky exhaust and the turbocharger operating at abnormally high speeds with increased wear.

The loss of power is, however, not important until approx 500 m (1640 ft) above sea level.

At altitudes of more than 500 m (1640 ft) above sea level, there is a loss of power of approx 0.1% per 100 m (328 ft).

De-rating should be done for high altitudes (reduced fuel quantity) according to the following:

Altitude above sea level, metres (feet)	Reduced fuel quantity%
1000 (3280)	4
1500 (4920)	8
2000 (6560)	12
2500 (8200)	17

NOTE! De-rating is not possible on electronic controlled engines!

NOTE! Electronic controlled engines are not suitable for running at altitudes exceeding:

Rating 5	1500 m (4920 ft)
Rating 1-4	2500 m (8200 ft)

NOTE! Emission certificates have not been verified by Volvo Penta for altitudes above 1500 m (4920 ft)

Dimension of air intakes and ducts

When installing is planned, the following basic facts should be kept in mind:

All combustion engines, irrespective of make or type, require a certain minimum amount of oxygen (or air) for the combustion process. Diesel engines, however, work with a somewhat larger air surplus than carburetor engines.

All engines also emit a certain amount of radiant heat to the environment, i. e. to the engine room.

The specific radiant heat is less for modern compact engines than for older and less compact engines. Modern, compact engines have a great advantage in this respect.

Channels or ducts for inlet and outlet air

It is advantageous if the inlet and outlet air ducts can be planned for at the construction stage, where they can be placed in the hull or superstructure. This will avoid the need for separate ducts.

For an installation, it is relatively simple to design a system to provide the engine with enough air for the combustion, but it is considerably more difficult to lead the radiant heat away.

The engine itself sucks in air very effectively and, naturally, will take in air from any direction. Should the inlet or outlet air ducts be underdimensioned, the engine will consequently suck air from both ducts and no ventilation air will go out through the outlet air ducts. This causes dangerously high engine room temperatures.

Most of the radiant heat from the engine must be transported out of the engine room. This is an **absolute requirement** to keep the engine room temperature below the permitted maximum limit.

Fans

To ventilate the engine room more effectively and thus keep the engine room temperature at a low level, a **suction fan** must normally be installed in the outlet air duct.

Fans must never be installed in the inlet air ducts, as this could lead to overpressure in the engine room with the risk of gas or air leaking out into other parts of the boat.

For diesel engines, the fan can very well be thermostat controlled and should start at approx. +60°C (+140°F) engine room temperature, measured at the engine room.

Engine room temperature

Remembering that the engine's performance figures apply at a test temperature of **+25°C (+77°F)**, it is important that the inlet air temperature is kept as low as possible. There is always a loss of power with increased temperatures, and if the engine's inlet air is **constantly above +45°C (+113°F),** the engine must be **de-rated.**

Engines without after cooler

≤ 25°C (77°F)	> 25°C (77°F)	> 45°C (113°F)
Full power output	Loss of power 3% per 5°C	De-rating

Engines with after cooler

≤ 25°C (77°F)	> 25°C (77°F)	> 45°C (113°F)
Full power output	Loss of power 1–2% per 10°C	De-rating

The temperature of the inlet air at the air filters must not be higher than +25 °C (+77 °F) for full power output. During sea trial the air temperature in the air filter should not exceed **20 °C (36 °F)** above ambient temperature.

The temperature of the engine itself is rather high in some places. Certain separate electric components, such as charging regulators and relays, should therefore be fitted on bulkheads or elsewhere where the temperature is relatively low.

The **maximum temperature** for areas where electric components are fitted is **+70 °C (+158 °F).** The starter motor and alternator however, have their given locations.

Engine room depression

Volvo Penta recommends that the depression in the engine room does not exceed 0.5 kPa (0.07 psi) at full speed. A small vacuum in the engine room is not harmful but will prevent gases from being pushed out from the engine room into the boat.

Engine's air consumption

The engine consumes a certain amount of air in the combustion process. This requires a minimum internal area of air supply ducting. The area can be calculated by using the formula:

A = 1.9 × engine power output

A = Area in cm^2

Engine output in kW

The value applies for non-restricted intake and up to 1 m (3.3 ft) duct length with only one 90 degree bend. The bending radius should be at least twice the dia.

If longer ducts or more bends are used, the area is corrected by multiplying by a coefficient from **Table 1** below.

Number of bends	Metres (ft) duct length				
	1 (3.3)	2 (6.6)	3 (9.8)	4 (13.1)	5 (16.4)
1	1	1.04	1.09	1.13	1.20
2	1.39	1.41	1.43	1.45	1.49
3	–	1.70	1.72	1.74	1.78

Table 1.

Engine room ventilation

To keep the engine room temperature down to the permitted values, a great deal of the radiant heat must be transported out of the engine room, in other words be ventilated away.

The same dimension must be chosen for the inlet and outlet ducts to achieve low flow speeds and low noise levels.

The area for the inlet/outlet air supply is calculated using the formula:

Inlet air = 1.65 × engine power output

Outlet air = 1.65 × engine power output

Areas in cm^2 and engine power output in kW.

These values must be corrected according to **Table 1** with regard to bends and duct length.

The ambient air temperature (outdoor air temperature) is assumed to be +30°C (86°F). Correction factors as per **Table 2** shall be used where applicable.

Ambient air temperature °C (°F)	Correction factor
+20 (+68)	0.7
+30 (+86)	1.0
+40 (+104)	1.4

Table 2.

Fan selection

The fan must be dimensioned for air flow volume according to the following:

Flow m^3 / min = 0.07 × engine power output in kW.

This volume flow is corrected by a factor from the table.

The total pressure increase through the fan should be 10 mm (0.394") wat.col. (100 pa).

These two values, flow and total pressure increase, are sufficient for the selection of a fan. If the fan is fitted directly to the bulkhead, i. e. without a connection pipe, the value of the total pressure increase can be reduced to 7 mm (0.276") w.col. (70 pa). This means that a somewhat smaller fan can be used.

Calculation of air ducts, example 1, two diesel engines, 294 kW (400 hp)

Calculation of areas for **two engines** at 294 kW **each** with a non-restricted air supply and an ambient air temperature of +30°C (+86°F).

For each engine the following is obtained:

Area, engine's air consumption:

1. 1.9 × 294 = 558 cm² (87 sq.in).

   According to **figs 1 and 2** on the following page, ex 1, this corresponds to a duct with a diameter of 265 mm (10.5") for **one** engine.

Area ventilation, engine room:

1. **Inlet, engine room:** Area = 1.65 × 294 = 485 cm² (75 sq.in). According to **fig. 2** this gives a diameter of 250 mm (9.8") for a single engine.
2. **Outlet, engine room:** Area = 1.65 × 294 = 485 cm² (75 sq.in). According to **fig. 2** this gives a diameter of 250 mm (9.8") for a single engine.
3. **Extraction fan capacity** 0.07 × 294 = 20.6 m³/min (728 ft³/min).
4. **NOTE!** As this is a twin installation figures have to be doubled.

Calculation of air ducts, example 2, diesel engine, 441 kW (600 hp)

Calculation of areas for **one** engine with 2 m (6.6 ft) duct length, 2 bends and an ambient air temperature of +20°C (+68°F).

Area for engine's air consumption:

1. 1.9 × 441 = 838 cm² (130 sq.in).

   Correction for air temperature = 0.7 from **Table 2**, and correction for duct length and bends = 1.41 from **Table 1**.

   This gives 838 × 0.7 × 1.41 = 827 cm² (128 sq.in). According to **fig. 2** this gives a duct diameter of 330 mm (13").

Area ventilation, engine room:

1. **Inlet, engine room:** Area = 1.65 × 441 = 728 cm² (113 sq.in). According to **fig. 2**, this gives a duct diameter of 302 mm (12").
2. **Outlet, engine room:** Area = 1.65 × 441 = 728 cm² (113 sq.in). According to **fig. 2** this gives a duct diameter of 302 mm (12").
3. **Correction** (inlet and outlet) for air temperature = 0.7 from **Table 2**, and correction for duct length and bends = 1.41 from **Table 1**.

   This gives 728 × 0.7 × 1.41 = 719 cm² (112 sq.in). According to **fig. 2** this gives a duct dia of 300 mm (11.8") for each inlet and outlet.
4. **Extraction fan capacity** 0.07 × 441 = 31 m³/min (1095 ft³/min).

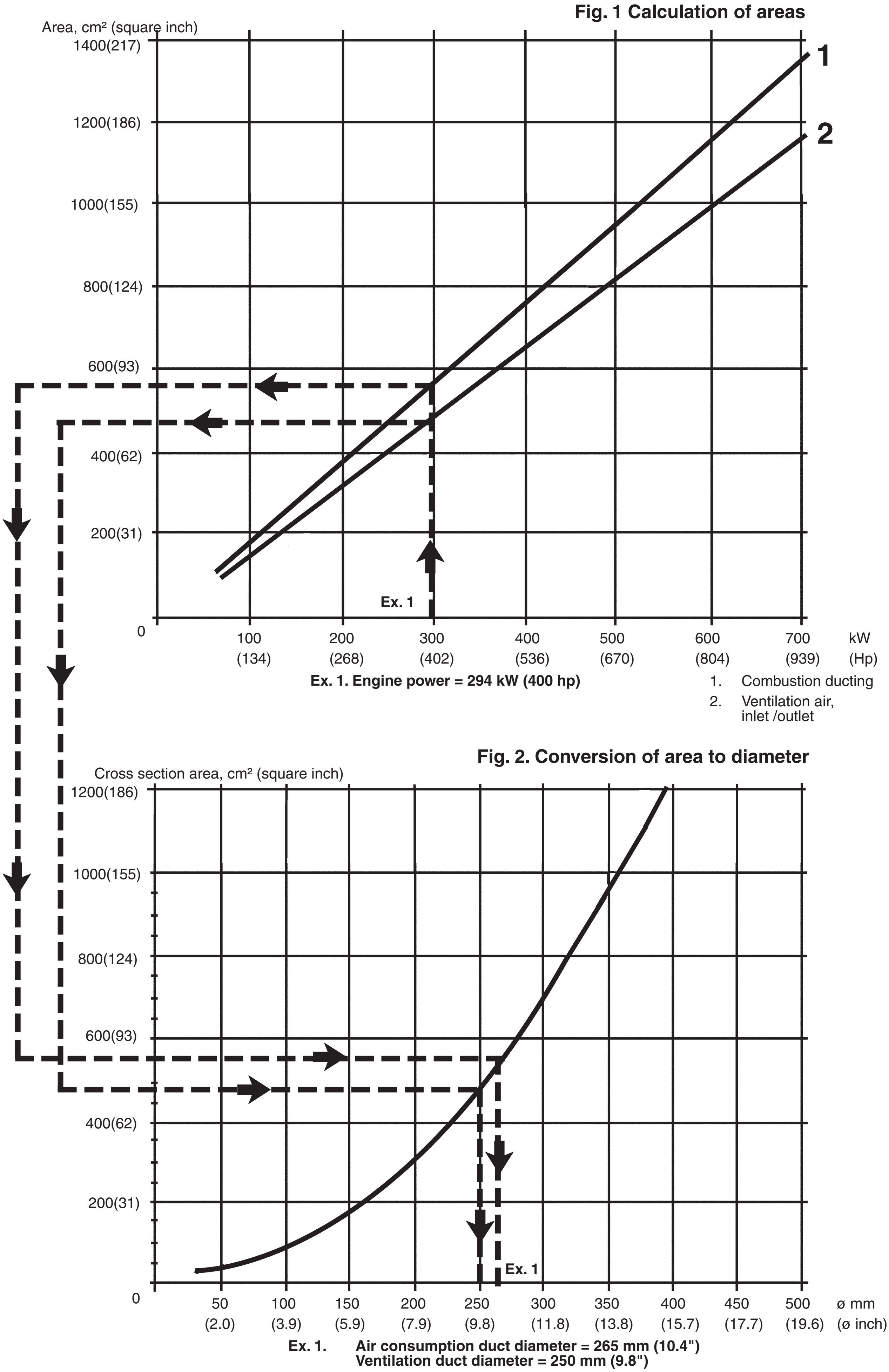
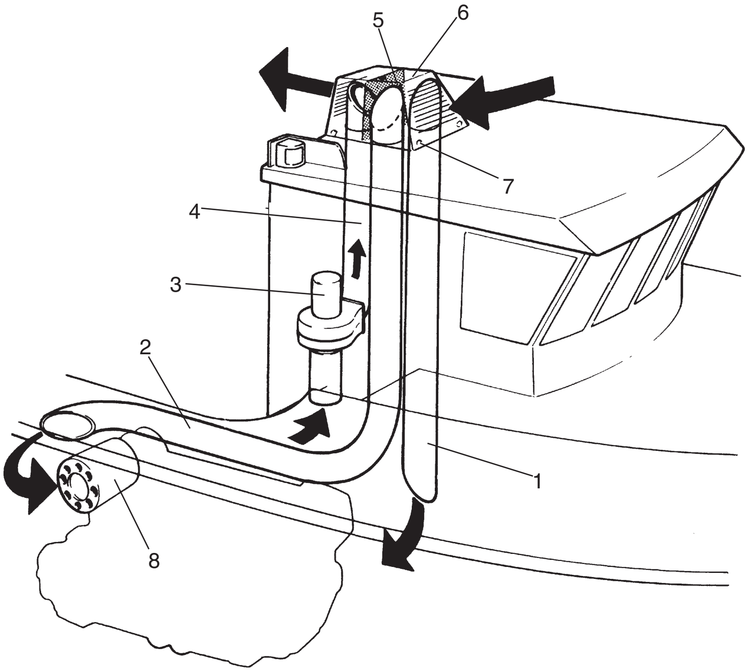
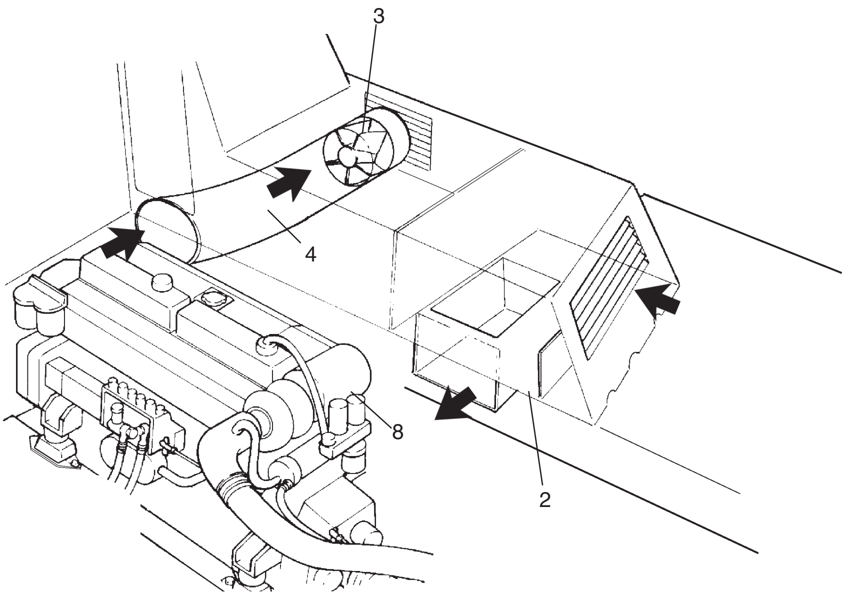


Fig. 1 Calculation of areas
Area, cm² (square inch)
1400(217)
1200(186)
1000(155)
800(124)
600(93)
400(62)
200(31)
0
1
2
Ex. 1
100 (134)
200 (268)
300 (402)
400 (536)
500 (670)
600 (804)
700 (939)
kW (Hp)
Ex. 1. Engine power = 294 kW (400 hp)
1. Combustion ducting
2. Ventilation air, inlet /outlet
Fig. 2. Conversion of area to diameter
Cross section area, cm² (square inch)
1200(186)
1000(155)
800(124)
600(93)
400(62)
200(31)
0
Ex. 1
50 (2.0)
100 (3.9)
150 (5.9)
200 (7.9)
250 (9.8)
300 (11.8)
350 (13.8)
400 (15.7)
450 (17.7)
500 (19.6)
ø mm (ø inch)
Ex. 1. Air consumption duct diameter = 265 mm (10.4")
Ventilation duct diameter = 250 mm (9.8")

Location of ventilators and air intakes



1. Inlet duct, engine room
2. Air inlet duct, open end in engine room
3. Suction fan
4. Outlet air duct
5. Intermediary partition
6. Water trap
7. Draining holes
8. Engine air filter



NOTE! Air intakes or outlet holes must never be installed in the transom. The air in this area is mixed with water and exhausts and must therefore never be allowed to enter the boat.

Function of air intakes

Air intakes and outlets must function well, even in bad weather, and must therefore have efficient water traps. Soundproofing must usually be built in.

The air intake and outlet should be placed as far away from each other as possible so that a good through-flow is obtained.

If the intake and outlet are too close, the air can recirculate resulting in poor ventilation.

Location of air ducts

The channels or ducts for the engine air supply should be routed up as close as possible to the air filters, but with a minimum distance of 20–30 cm (8–12"), to definitely prevent water from entering the engine. See figures in chapter **Location of ventilators and air intakes**.

For diesel engines the incoming ventilation air duct should open out low down in the engine room, but not so low that any bilge water can block the air supply. The outlet ducts should be located diagonally across on the other side of the engine.

All channels and ducts must be routed so that the least possible flow resistance is obtained. The bends must not be sharp, but softly rounded. The smallest radius is twice the diameter. **Restrictions must always be avoided**.

The ducts should be cut obliquely at the ends to get the best flow.

In certain countries there are regulations in this respect, which must be followed.

Soundproofing

The drive package must be installed in such a way as to minimise noise and vibration. The noise that occurs is airborne noise and structural noise (vibration).

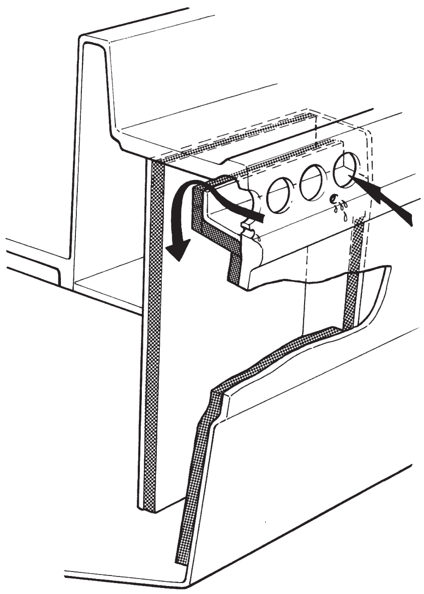
Structural noise

Vibration from the engine is transmitted via the engine mountings and the engine bed to the hull. Other routes are via the transmission and propeller systems, exhaust pipe, coolant pipes, fuel pipes, electrical cables and control cables.

Pressure pulses from the propeller are transmitted through the water and into the hull. Pulsed force on the propeller enters the hull via support blocks, bearings and seals.

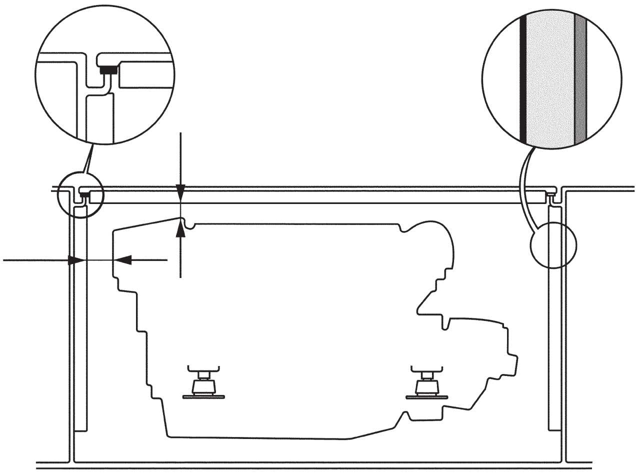
Airborne noise

This section refers to airborne noise from the engine bay. The most important measure to lower airborne noise from the engine room is to seal the room properly. Further improvements in noise level reduction can be achieved by sound insulation material and by designing sound traps for the air inlets.



The engine installation should be soundproofed in order to obtain a noise level that is as low as possible. Build the engine compartment with sound traps. Different types of sound traps can be selected. The figure reflects a type that is also provided with drainage.

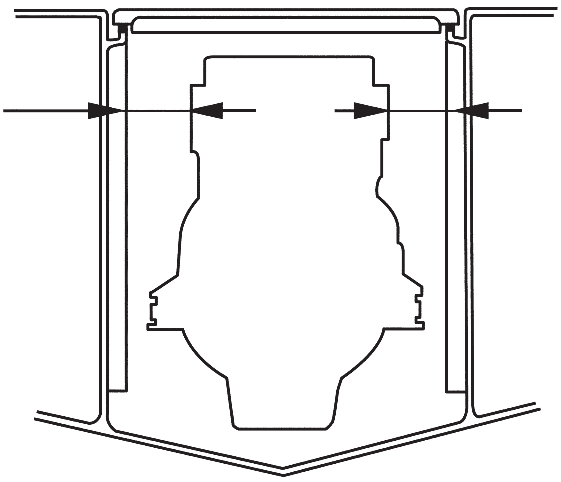
Furthermore, due consideration must be given to the thickness of the insulation material.



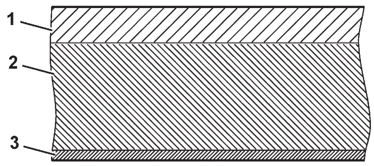
Make sure the necessary room is available for service and repair. Also make sure that all hatches are properly sealed off.

Greatest possible care must be given to the task of screening the sound source as well as possible. Screen all the way down to the hull but leave a small distance to prevent bilgewater from penetrating insulation material.

Cracks, openings etc. must be carefully sealed off with insulation material. In cases where the engine is installed under the floor, dress all bulkheads and floorboards.



Prior to installing the insulation material, make sure that there is sufficient room for checking, service and repair and for the engine movements during operation.

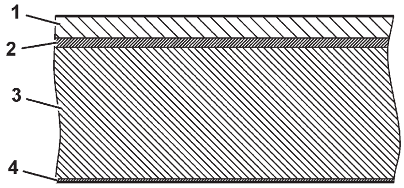


Above you can see an example of the build-up of an insulation sheeting. This type of insulation material is glued to the frame.

NOTE! The insulation sheeting is turned differently, owing to the type of the material in the frame, i.e. GRP or wood.

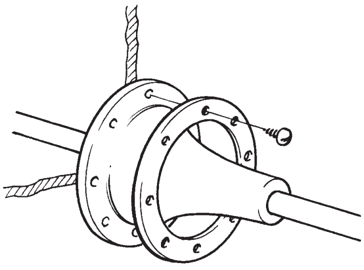
Insulation material, being applied on wood (plywood):

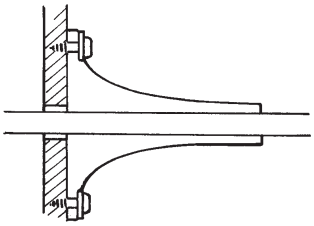
1. Wood (plywood)
2. Flame-proof absorption sheeting.
3. Flame-proof, reflecting soundproofing foil.



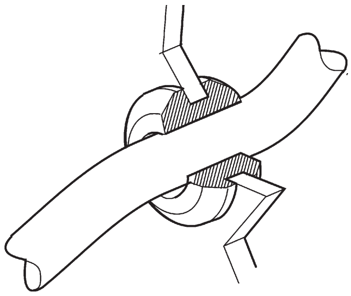
Insulation material applied on GRP:

1. GRP
2. Iron-PVC, thickness 2.5 mm (0.1")
3. Flame-proof absorption sheeting
4. Flame-proof, reflecting soundproofing foil

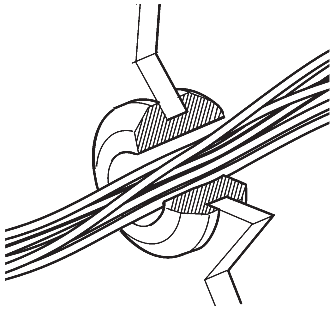




Shift cables, throttle cables and electrical wires coming through bulkheads can perferably be drawn through a tube or a grommet, sealing off properly. At the same time the cables are protected against wear.

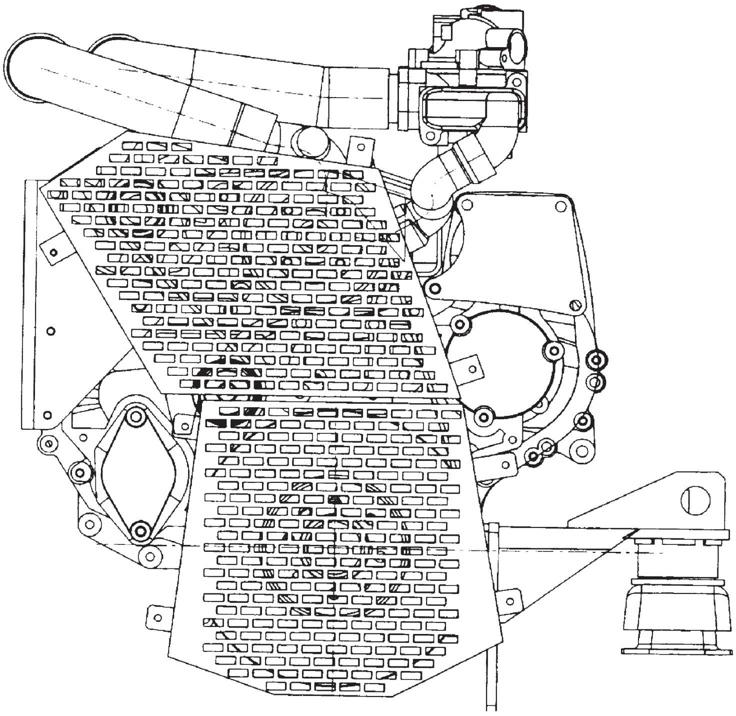


Fuel hoses going through a bulkhead should rest in a grommet where they pass through the bulkhead. The grommet seals off and protects the hose against sharp edges, which might cause leakage.



Other cables, electrical wires, battery leads etc can be drawn through a rubber hose or through a special PVC-tube (electrical), being built onto the bulkhead of GRP. Possible clearance between the tubing and the wires can be sealed off with some kind of insulation material or sealing compound.

Belt guards and protections



Installation requirements

Unless the engine is protected by a cover or its own enclosure, exposed moving or hot parts of the engine that could cause personal injury must be effectively shielded.

Belt guards which can be fitted on the engine, are available as optional equipment from Volvo Penta. Protections can also be built in the engine room by the boat builder.

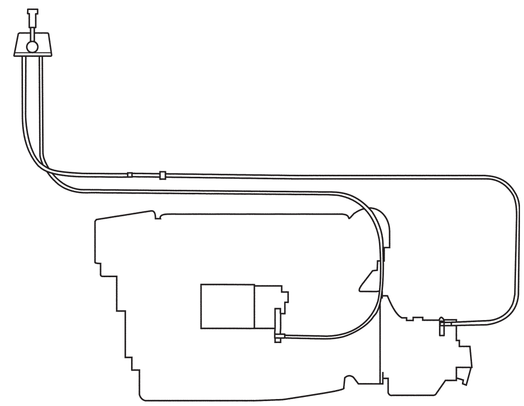
Controls

General

If the boat is to be manoeuvred and operated in a convenient and safe manner, then the operating station should be arranged in such a way that the controls, steering and instruments, navigational equipment and alarm systems are located practically. This applies to each operating station.

The control could be either a single lever control or two lever control. On a single lever control both shifting and speed is operated with the same lever. In a two lever control there is one lever for shifting and one for speed.

1



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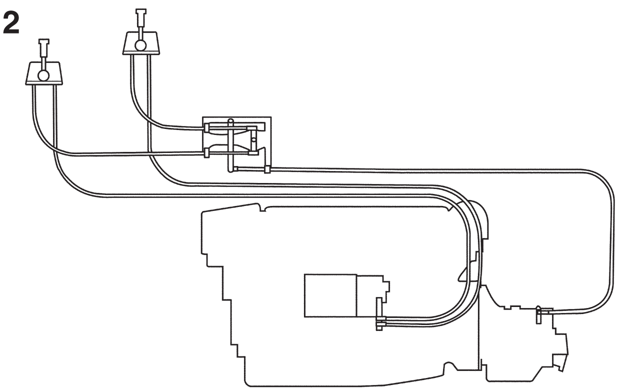

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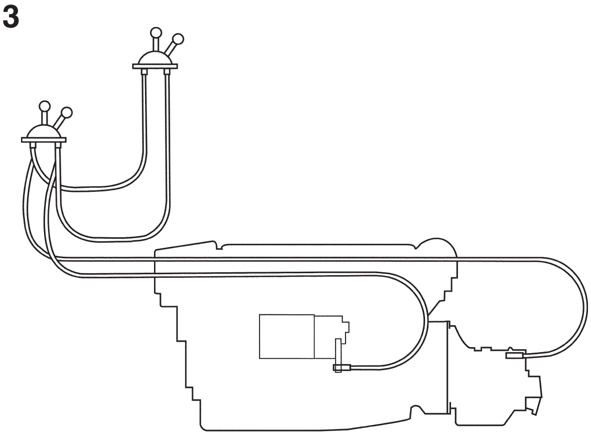

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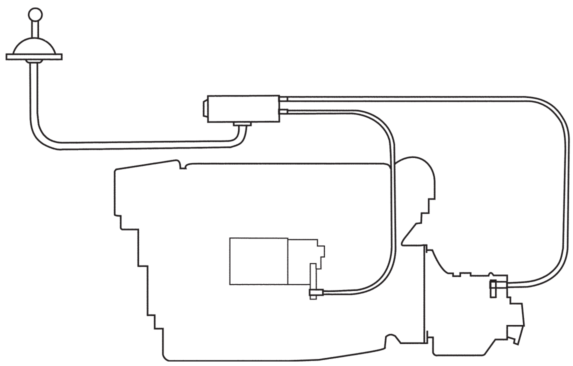


Example showing different control systems

1. Single lever control - mechanical
2. Single lever control - two stations - mechanical - DS-unit
3. Two lever control - two stations - mechanical - serial connected
4. Single lever control - electrical to mechanical

For wire information see **Installation, Electronic Vessel Control EVC**.

There are several types of control system alternatives available:

Mechanical control systems

With a mechanical control system communication between the engine/reverse gear is done with push-pull cables. This type of system could require a little more effort and be less distinct, especially with long cable lengths and more than one control station.

This installation manual mainly covers this type of installation.

Electrical control systems

In fully electrical systems, the control communicates with the engine via electrical signals and can only be used on electrically governed engines, as the Volvo Penta EVC engines.

It offers very simple installation as well as smooth handling with long cables and several control stations. For further details about installation of EVC control systems see **Installation, Electronic Vessel Control EVC**.

Electrical to mechanical control systems

In electrical to mechanical control systems, the electrical control communicates with actuators usually located in the engine room via electrical wires. The actuator transforms the electrical signal to a mechanical movement. From the actuator, a push-pull cable runs to the engine/reverse gear and there installation is done the same way as with a mechanical control system.

Hydraulic and pneumatic controls.

The principle behind communication between control and engine/reverse gear is to use hoses or pipes with hydraulic oil or air. Hydraulic and pneumatic control systems give advantages similar to those of an electrical control system. They are rather easy to install in boats with several control stations. They also require very little effort to use in installation with several control stations or long distances.

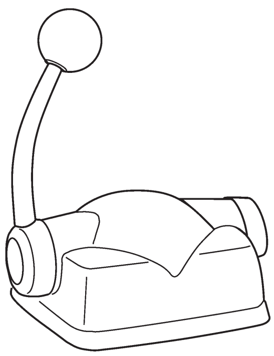
Alternative operating stations

The controls must be duplicated for each operating station. In a mechanical control, the switch-over for shifting with controls for the different operating stations can be carried out automatically if a dual station unit is installed.

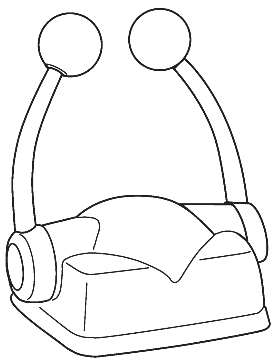
The speed control cables from the two controls are connected at the fuel injection pump by means of a speed control kit. See **Connecting the speed control cable** in chapter **Controls**.

Controls

These controls are for top mounting. Side mounted controls are available but not so common in vessels or boats of this size.



Single engine, single lever control, EVC

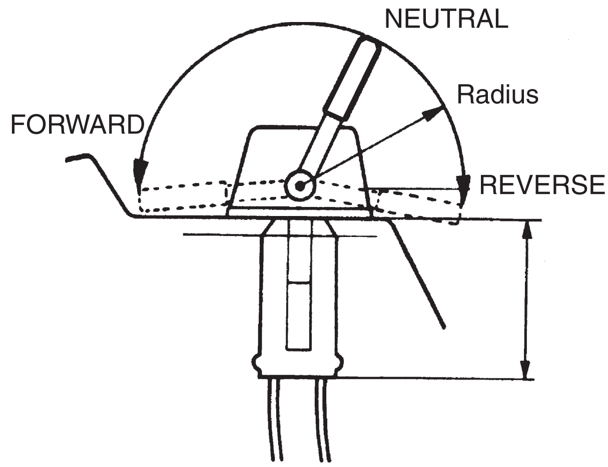


Twin engine, single lever control, EVC

The engine can only be started if the control lever is in the neutral/upright position.

Location of the controls

The following must be considered before cutting holes for the controls.



When selecting the location for the control it is important to take into consideration whether there is sufficient space for the control lever movement and sufficient space underneath the panel for the control mechanism.

There must be enough room for full stroke of the control lever for FORWARD and sufficient space for operating REVERSE.

The lower part of the control must not come so close to the steering control or other components that they are affected in any way.

There must be sufficient space under the control to permit installation of the control cables to the engine and reverse gear with as few and smooth bends as possible.

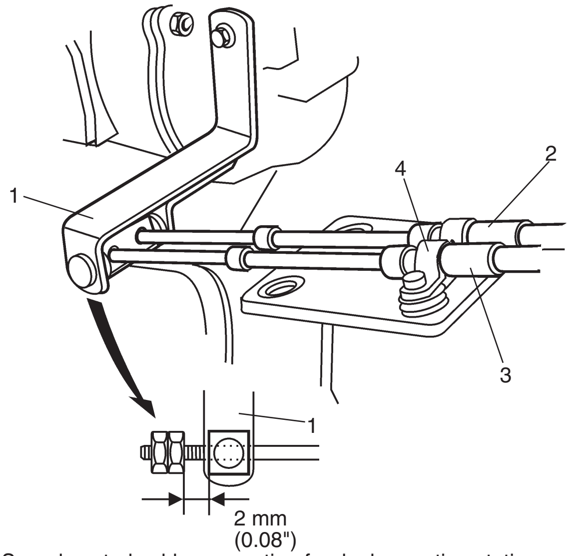
Connecting

Connecting the speed control cable

To increase of the engine speed, the speed control cable must have a pulling movement on all engines.

The speed control cable is connected at the fuel injection pump as shown in the figure below. Connections should be made so as to obtain the largest possible stroke on the control cable to provide the smoothest control procedure. The pump lever, however, must always be in contact with the full speed stop at full throttle.

When double cables are connected as shown in figure, the cables run freely through their attachments to the pump lever.



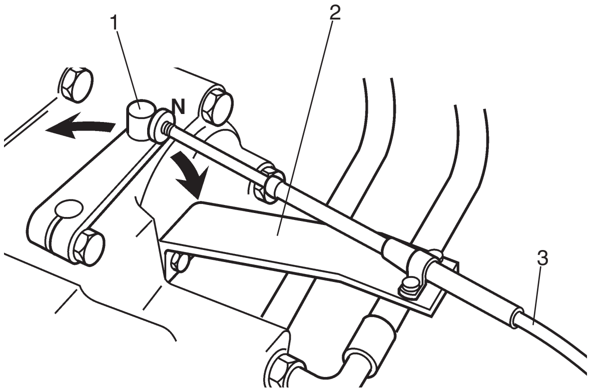
Speed control cable connection for dual operating stations

1. Lever on fuel injection pump
2. Speed control cable from upper operating station
3. Speed control cable from lower operating station
4. Cable clamp

NOTE! The nuts on the ends of the cables must be locked against each other when the pump lever and control levers are simultaneously at their idling and neutral positions respectively.

Gear cable connection

Always connect the cable to the reverse gear lever so that the neutral position is obtained on the reverse gear when the control is set to NEUTRAL.



1. Connection
2. Bracket
3. Control cable

Install the shifting cable and make sure the cable is connected in the control for the required rotation of the propeller shaft. See table on the following page.

Connecting the neutral safety switch

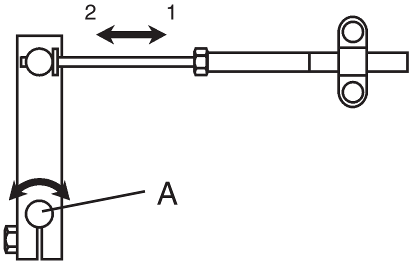
In most controls, a neutral safety switch can be installed. With this switch, the engine can only be started when the control is in the neutral position.

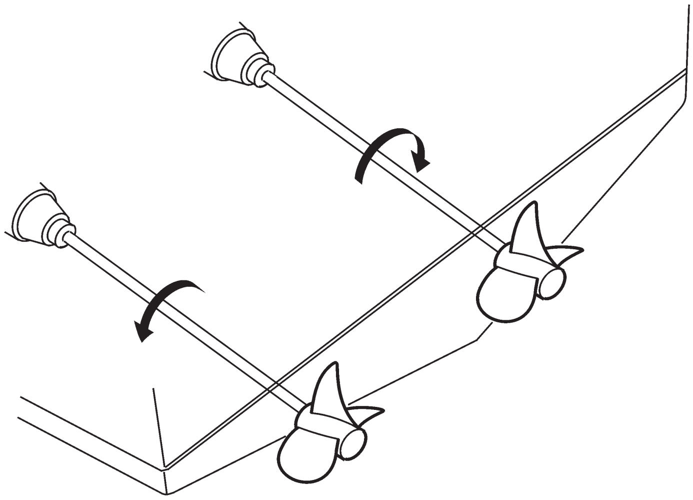
Install the switch on the yellow/red wire going to the no. 50 terminal on the key switch. The circuit should be closed in the neutral position.

Local legislation might apply making neutral switches compulsory.

In the case of twin installations, the starboard propeller must rotate to the right and the port propeller to the left in forward gear.

Install the shifting cable and make sure the cable is connected for the required rotation of the propeller shaft. See table below. 'To alter the direction of the cable movement, change the position where the cable is attached in the control.



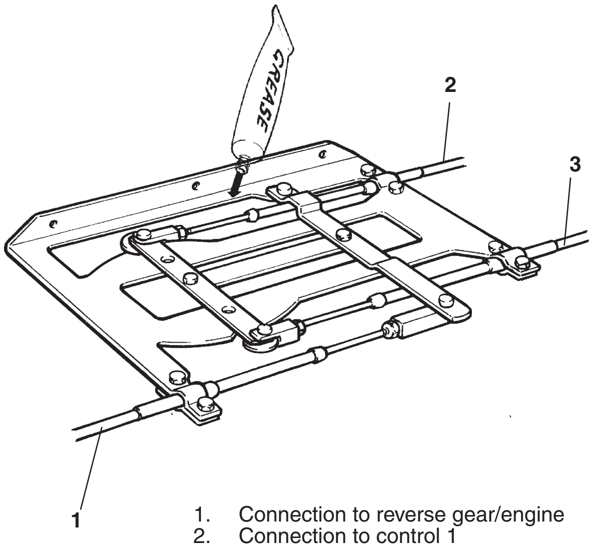


Shifting cable movement at reverse gear with standard bracket.
Pulling (1), pushing (2). See figure.
Direction within brackets is the way the shaft to the shifting lever (A) on the reverse gear rotates.

Reverse gear	Left hand propeller rotation:		Right hand propeller rotation:	
ZF45	**Pulling**	(Clockwise)	**Pushing**	(Anticlockwise)
ZF220/ZF220A	**Pulling**	(Clockwise)	**Pushing**	(Anticlockwise)
ZF220IV	**Pushing**	(Anticlockwise)	**Pulling**	(Clockwise)
ZF280/ZF280A	**Pushing**	(Anticlockwise)	**Pulling**	(Clockwise)
ZF280IV	**Pulling**	(Clockwise)	**Pushing**	(Anticlockwise)
ZF301A	**Pulling**	(Anticlockwise)	**Pushing**	(Clockwise)
ZF302IV	**Pushing**	(Anticlockwise)	**Pulling**	(Clockwise)
ZF350A	**Pulling**	(Clockwise)	**Pushing**	(Anticlockwise)
MG5061	**Pushing**	(Clockwise)	**Pulling**	(Anticlockwise)
MG5062V	**Pushing**	(Clockwise)	**Pulling**	(Anticlockwise)
MG507	**Pushing**	(Anticlockwise)	**Pulling**	(Clockwise)
MG5091	**Pulling**	(Anticlockwise)	**Pushing**	(Clockwise)
MG5111	**Pulling**	(Anticlockwise)	**Pushing**	(Clockwise)
MG5114	**Pushing**	(Anticlockwise)	**Pulling**	(Clockwise)
MG514	**Pulling**	(Anticlockwise)	**Pushing**	(Clockwise)
MG516	**Pushing**	(Clockwise)	**Pulling**	(Anticlockwise)

DS-unit, gear shift

If two single lever controls are installed in parallel in a mechanical control system and connected to one reverse gear, a DS-unit or similar must be installed.



1. Connection to reverse gear/engine
2. Connection to control 1
3. Connection to control 2

Choose a suitable place for the DS-unit as close to the reverse gear as possible and in a dry and easily accessible position. The DS-unit can be mounted vertically, horizontally or up side down. Horizontal is preferred.

A DS-unit is not needed when two lever controls are installed in series.

Final check

Check, without starting the engine, after final connection of cabling that the lever on the pump is at idling and the lever for the reverse gear is in the neutral position when the control is in NEUTRAL.

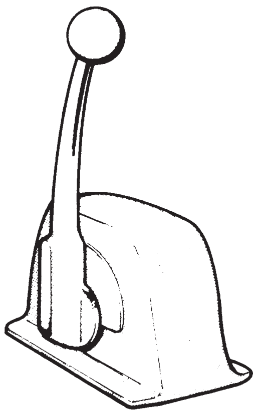
Then move the control to full speed and FORWARD position. Check that the pump lever is against the full speed stop and that the reverse gear lever is in the FORWARD position. Also check the REVERSE position.

Trolling valve

Trolling valves can be fitted on most reverse gears as an accessory.

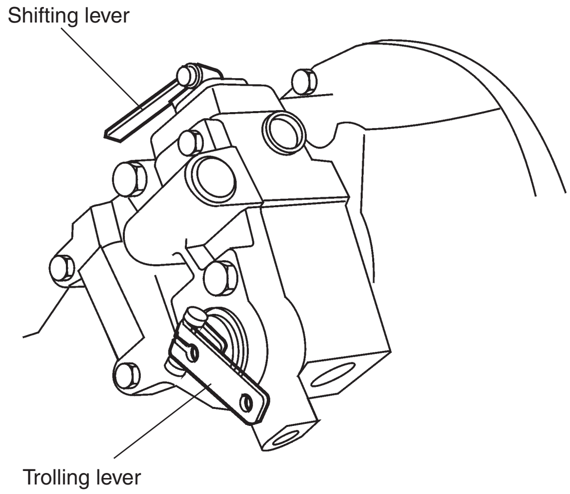
The trolling valve will reduce the oil pressure on the disc pack, which will make it slip in a controlled way. The speed of the propeller shaft can be reduced up to 80% compared to in a non-slipping condition. There is normally an engine rpm limit up to which the trolling valve can be used. A larger oil cooler is sometimes fitted to keep the oil temperature stable. It is highly recommended to use a thermostat on the gear box oil cooler.

The benefit of the trolling valve is reduction of the idling speed of the boat or the option of increasing engine rpm at low boat speed, for example in order to use pumps etc. during fishing.

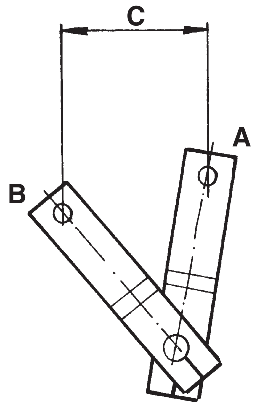


For operating a trolling valve, a single-acting control with a pushing movement shall be used.

Install the control cable the same way as the gear-shift control cable. Mark the control TROLLING VALVE, and the positions DISENGAGED and ENGAGED.



When operating with the trolling valve engaged, speed should be kept low in accordance with the instructions provided by the manufacturer.

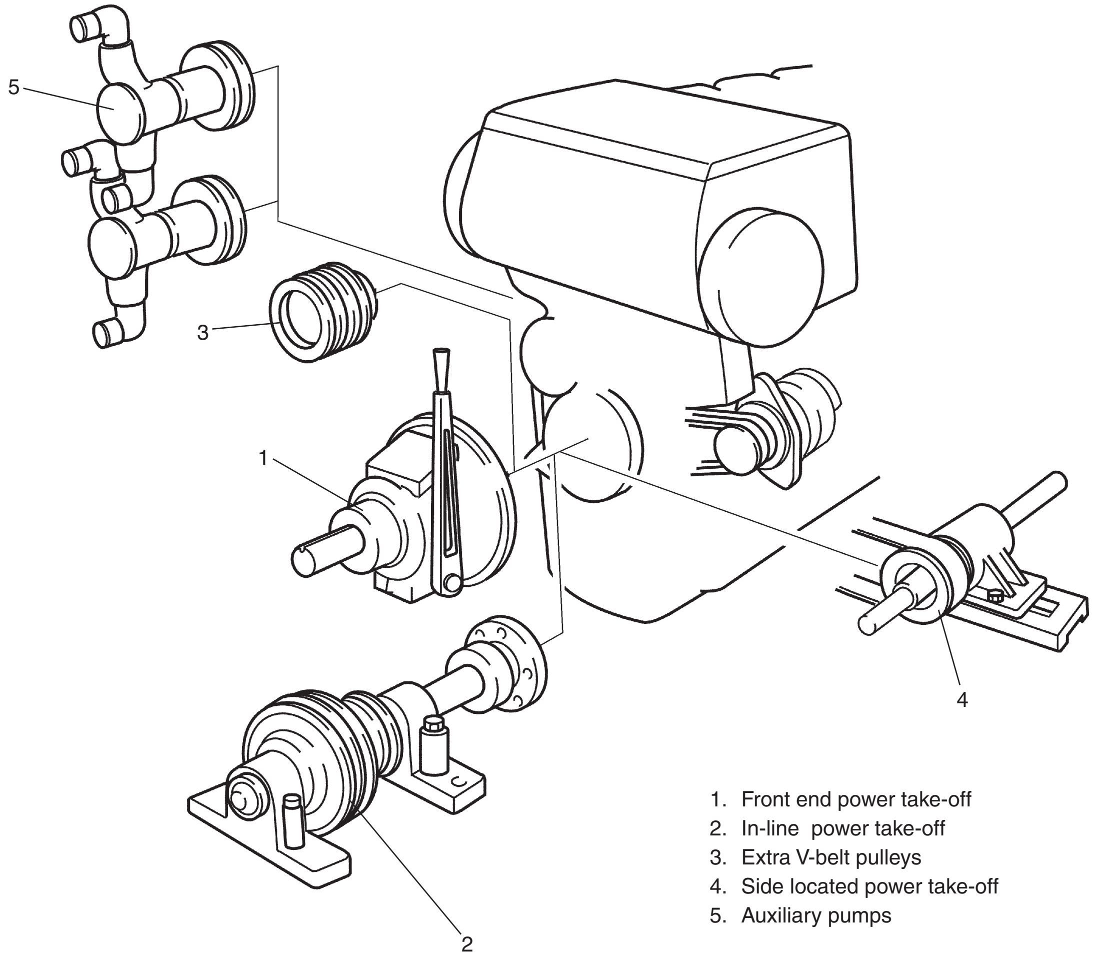


Position A: Maximum slipping
Position B: Trolling fuction off

Verify that the required travel (C) is achived.

For correct measurements consult Volvo Penta organisation or the gearbox manufacturer.

Power take-off



1. Front end power take-off
2. In-line power take-off
3. Extra V-belt pulleys
4. Side located power take-off
5. Auxiliary pumps

General

In order to operate miscellaneous small auxiliary apparatus, there is the option of fitting power take-offs on the auxiliary drive gear casing or a sidemounted power take-off on the starboard side at the front.

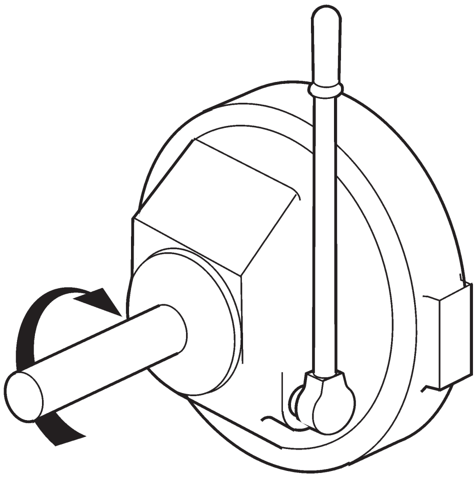
If greater outputs are needed, a mechanical power take-off can be fitted on the front end of the crankshaft. Either via a common standard over-centre clutch or an extra shaft connection (in-line).

Various configurations of PTO can be built. The most common are described in this chapter.

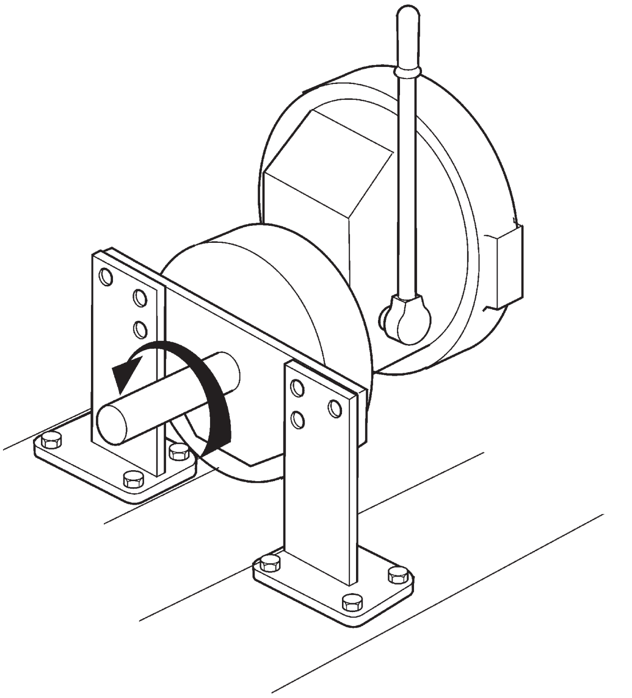
Always see the current Sales Guide for the PTO options Volvo Penta is marketing for each engine size and rating.

The outputs permitted from the power take-offs are described later in this chapter.

Disconnectable power take-off, crankshaft



Power take-off, ratio **1:1**. Direction of rotation: Clockwise.



Power take-off with reduction gear, ratio **2.8:1**. Direction of rotation: Anti-clockwise. Including support device.

A power take-off fitted with a reduction gear must be fitted with a support device. See figure.

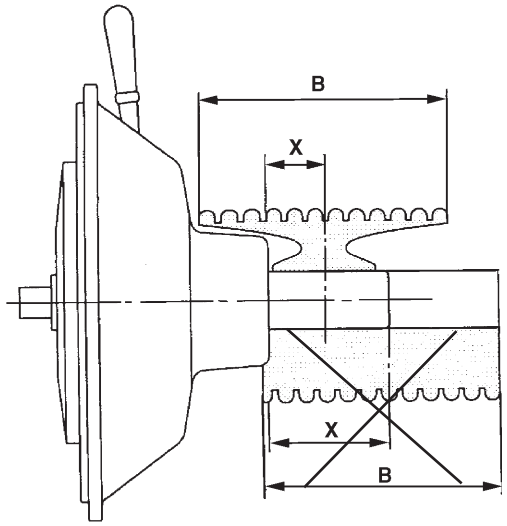
Disconnectable power take-offs are required if the load is on from start or if it is required to disengage the load while the engine is running.

Volvo Penta offers a range of power take-offs.

The over-centre toggle action assures smooth and progressive engagement, locking the PTO securely into the driving position.

Always try to have the pulley hub installed as close as possible to the power take-off housing. It is under no circumstances permissible to install the pulley with its centre further out on the shaft than half the length of the free shaft.

The pulley should be formed in accordance with the figure. This type of pulley can be placed in such a way that part of the pulley covers the bearing housing, thus reducing the x-value, whereby the side load can be increased.



If direct drive is used without a belt transmission or if some output consumer is to be connected directly to the crankshaft, TVCs must always be made first.

Calculations are carried out by AB Volvo Penta on request.

Determine the output requirement, the maximum torque and the engine speed required for the driven equipment.

Calculate torque is obtained by using the formula

$$Mv = \frac{716.2 \times Ne}{n}$$

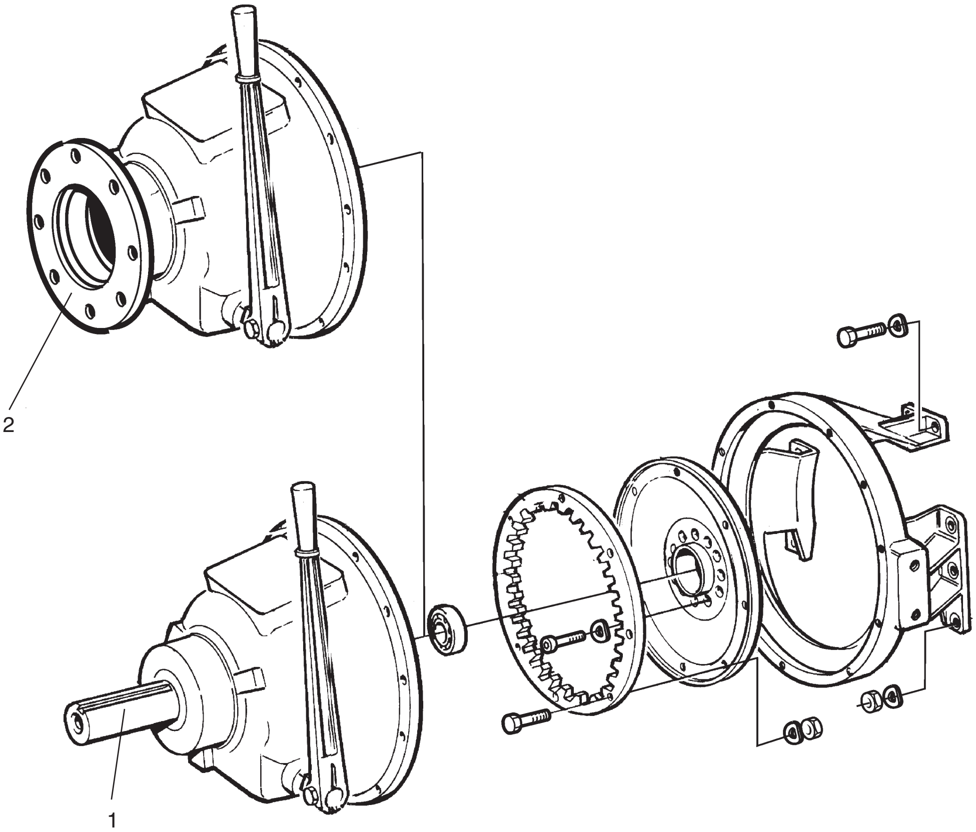
Mv = Torque (kpm)
Ne = Output (hp)

n = r/min

Check that the output requirement does not exceed the maximum permitted from the power take-off.

Front mounted, disengagable PTO.

The clutches are of disengagable design, intended for driving winches, bilge pumps or other optional equipment.



Engine	PTO connecting flange size	Clutch make, type	Output	Max torque Nm (lbf. ft.)
D12	SAE3	Twin Disc SP 211-11.5"	Stub-shaft (1)	1000 (738)

Flywheel and flywheel housing, SAE standard

Engine	Standard	Option
D5	SAE 3	SAE 1, 2
D7A T	SAE 3	SAE 1, 2
D7A/C TA	SAE 2	SAE 1, 3
D9 R1-R2	SAE 1	—

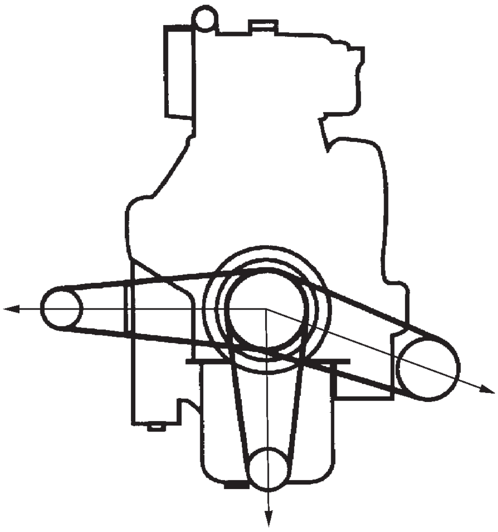
Engine	Standard	Option
D9 R3-R5	SAE 2	—
D11	SAE 2	—
D12	SAE 1	—
D16	SAE 1	SAE 0

SAE bell housing dimensions

SAE No.	A mm (in.)	B mm (in.)	C mm (in.)	No.	Bolt holes Diam. mm (in.)
00	787,4 (31.00)	850.9 (33.50)	882.7 (34.75)	16	13.5 (17/32)
0	647.7 (25.75)	679.5 (26.75)	711.2 (28.00)	16	13.5 (17/32)
1/2	584.2 (23.00)	619.1 (24.38)	647.7 (25.50)	12	13.5 (17/32)
1	511.2 (20.12)	530.2 (20.87)	552.5 (21.75)	12	11.9 (15/32)
2	447.7 (17.62)	466.7 (18.38)	488.9 (19.25)	12	10.3 (13/32)
3	409.6 (16.12)	428.6 (16.87)	450.8 (17.75)	12	10.3 (13/32)
4	361.9 (14.25)	381.0 (15.00)	403.2 (15.87)	12	10.3 (13/32)
5	314.3 (12.38)	333.4 (13.12)	355.6 (14.00)	8	10.3 (13/32)
6	266.7 (10.50)	285.7 (11.25)	308.0 (12.12)	8	10.3 (13/32)

NOTE! See **Sales Guide Marine Propulsion Diesel Engines** for complete information about flywheel housing measurements.

Power take-off positions



Accessories such as water pumps, steering pumps, etc can be driven from various PTO positions on the engine. These positions will vary, depending on engine type, but generally accessories can be:

1. Mounted on the engine, and belt driven from a PTO groove on the crankshaft pulley. If the accessory is mounted remotely from the engine, provision must be made for engine movement, e.g. by use of a spring loaded jockey pulley.
2. Mounted on the front or back of the timing case, and gear driven from the timing gears.

Belt driven power take-off Crankshaft pulley, front end

The amount of power available from the crankshaft pulley depends on the distance of the PTO pulley from the face of the cylinder block, and the direction of the resultant loads acting on the pulley.

It also depends on the pulley diameter and engine speed.

Crank pulleys are available for each engine type, some with an integral PTO groove, and some accepting a "bolt-on" PTO pulley.

Tightening Torque

If the crankshaft pulley type is changed, it must be ensured that the correct tightening torque for that pulley is applied.

The tightening torque values are specified in the Workshop Manual for each engine type.

V-belt transmissions

V-belt transmissions are easily adaptable for different ratios (by using differently sized pulleys). This type of transmission provides a flexible transmission, it has a low noise level and is relatively free of maintenance.

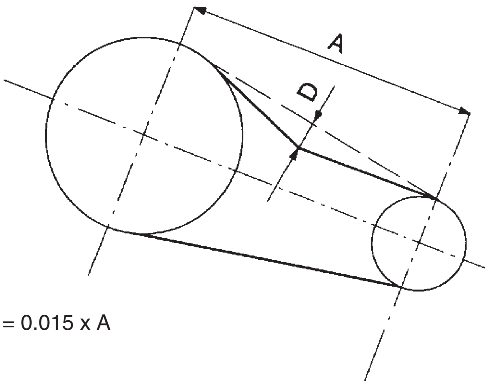
The alignment, however, must be done carefully and the V-belt tension must be easy to adjust.

Belt tension

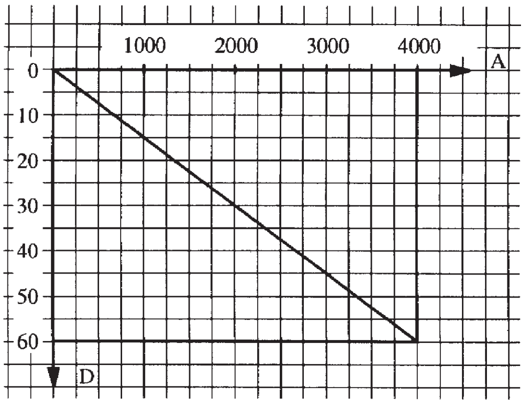
The correct tension must be applied to any PTO belt driving arrangement, as insufficient installation tension could cause belt slippage at high powers and high speeds, reducing belt life etc.

With a PTO drive from the crankshaft, excessive belt tension will result in higher side loads than necessary, which could result in crankshaft failure.

A practical way of estimating the fan belt tension is by applying pressure in the centre of the longest run of belt between any two pulleys, and adjusting the tension until the belt deflects by a given amount. (See figure).



D = 0.015 x A



A = Distance between pulleys in mm.
D = Deflection in mm.

In multi-belt installations, where two or more belts are used between two pulleys, belts matched in length must be used to ensure correct load sharing and best possible life.

Idler pulleys

Idler pulleys used for tensioning the V-belts should be on the slack side of the belt, and not smaller than the minimum diameter recommended by the manufacturer for a particular belt.

The use of too small a pulley will severely reduce belt life.

A suitable spring loaded pulley is preferable to one that is adjusted and clamped, as it can enable the correct installation tension to be used. This is increasingly more important with larger PTO values, as more installation tension is required to avoid slippage, resulting in a higher side loading/bending moment on the crankshaft.

NOTE! A spring loaded idler pulley is also very important where there could be relative movement between a flexibly mounted engine and driven equipment mounted on a separate chassis.

Power output from front end of crankshaft

Power can be taken out, for in-line duty, from the front end of the crankshaft. The limit for this power is the bolted joint between the damper/pulley and polygon hub. In the **Sales Guide Marine Propulsion Diesel Engines** you will find the max. permissible torque for our engine range. There are however a number of things that have to be considered before the installation.

Alignment of the engine

It is of utmost importance to align the engine to the unit which is to be driven.

The stress on the crankshaft, engine mounts, drive shaft and coupling might otherwise be big enough to cause interruptions in the operation. Check to make sure that the drive shaft is straight prior to beginning alignment work.

Imbalance in the driven unit and in the drive shaft and the coupling can cause noise and vibrations. This is why these components have to be balanced. The alignment is facilitated if adjustment screws are installed on the engine feet.

After alignment, the distance between the frame and each bracket is measured.

Then steel shims with the correct measurement are installed.

Crankshaft end thrust

If anything is fitted to the engine that imposes an axial end loading on the crankshaft, it must be ensured that the end loading of the crankshaft does not exceed the maximum allowable values for the particular engine type.

The manufacturer should be contacted for details of the operating end thrust of their equipment if this information is not known.

Torsional vibration

The diesel engine, plus its driven equipment (driven from either front or rear) is made up of rotating masses connected by a series of shafts. This forms a torsional mass-elastic system, which will vibrate at its own natural frequency when acted upon by an exciting torque.

A resonant condition will occur when the frequency of the exciting torque is equal to the natural frequency of the system, or one of its harmonics.

This condition will result in high vibratory stress, which can lead to damage of the crankshaft or any driven shafting. It is therefore necessary to ensure that the characteristics of the total system, i.e. engine and driven machinery (including front end PTO if fitted) are such that excessive torsional vibration stresses will not occur.

As a general guide, all axially driven inertia should be as low as possible in order to minimise the effects of vibratory torque. Driven equipment which introduces damping into the system will have a beneficial effect on the torsional vibration characteristics.

The use of a flexible coupling in the system will have a similar beneficial effect, and coupling manufacturers are usually able to give guidance in this respect.

D5/D7 Moment of inertia

On D5/D7 it is important not to exceed allowed moment of inertia for additional component mounted on front of the crank shaft.

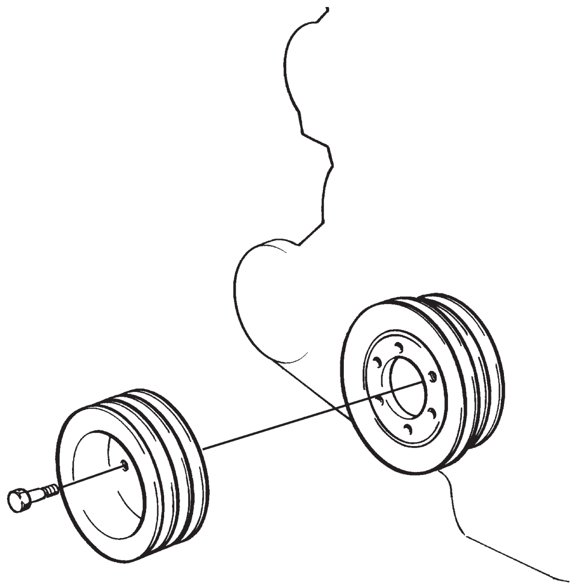
Allowed max moment of inertia		
Engine	1900 rpm	2300rpm
D5A T	0.53 kgm^2	0.24 kgm^2
D5A TA	0.51 kgm^2	0.22 kgm^2
D7A T	0.64 kgm^2	0.64 kgm^2
D7A TA	0.54 kgm^2	0.44 kgm^2
D7C TA	0.26 kgm^2	0.19 kgm^2

Below you can find a guidline for the moment of inertia for some additional equipment.

Pulley for 140A extra alternator	0.1514 kgm^2
3-belt pulley	0.0334 kgm^2
Pulley on stub shaft*	0.040 kgm^2

*estimated weight 8 kg

Extra V-belt pulleys



In order to calculate speed and diameter, the following formula can be used:

RD × N = rd × n

RD = The driving belt pulley pitch diameter

rd = The driven belt pulley pitch diameter

N = The speed of the driving shaft

n = The speed of the driven shaft

The pitch diameter is given in the catalogues of the pulley belt suppliers.

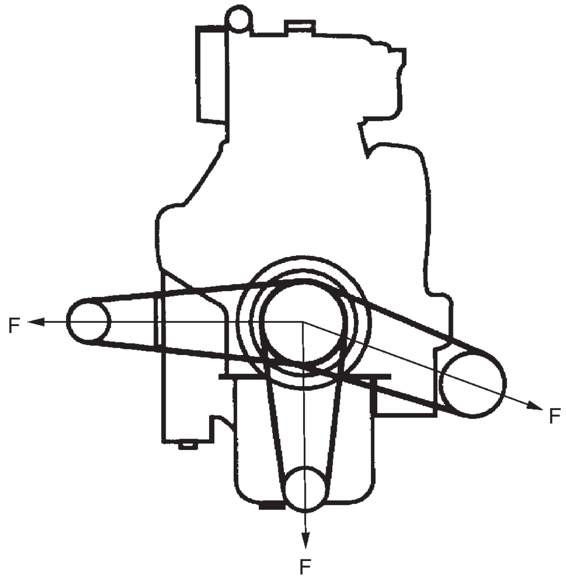
Front end V-belt pulleys Belt pulley on crankshaft

Extra belt pulleys are available for bolting to the front end of the crankshaft.

Information regarding Volvo Penta standard front end pulleys is published with its dimensions in the **Sales Guide Marine Propulsion Diesel Engines**.

Direction of the side loads

The engine can usually accept a greater side load below the crankshaft than above. Where this is the case the belt drive should be arranged, if possible, so that the driven equipment is below the crankshaft centre line.



If two or more belt drives are required and can be arranged in opposite directions, the effects will tend to cancel each other out and minimise the overall side load on the crankshaft.

Unsupported power take-off pulley

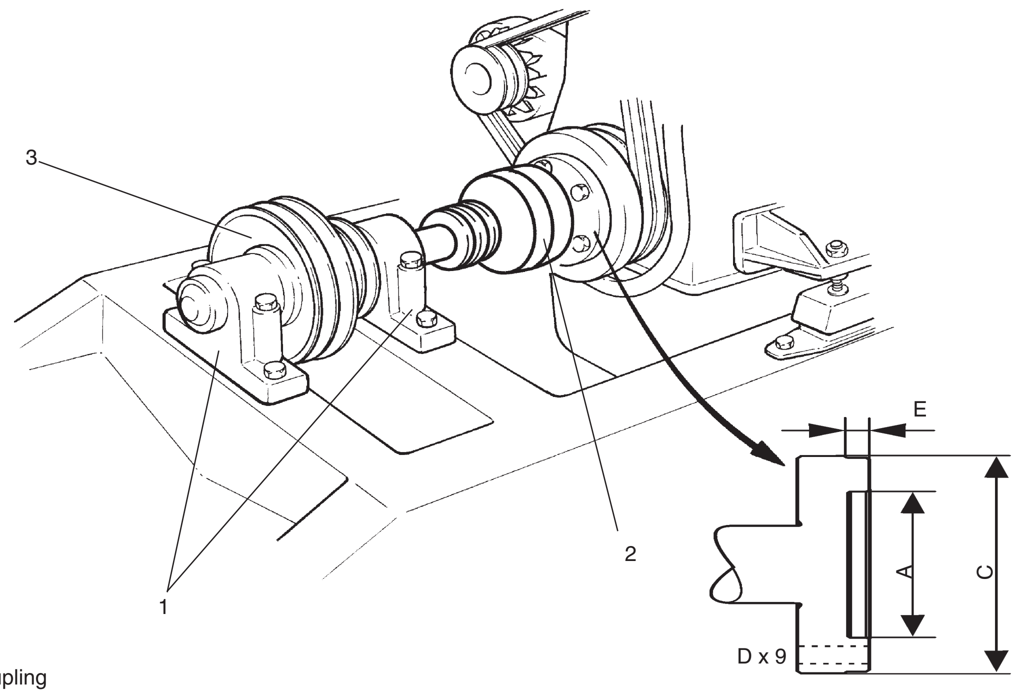
When it is essential to have an unsupported power take-off pulley, the design can be checked and approved by Volvo Penta.

The following information must be provided:

1. The engine specification
2. A drawing of the drive arrangements which should include the following:

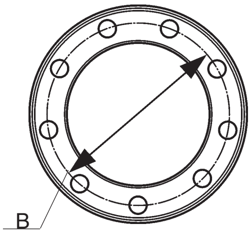
a. the effective diameter of all pulleys in the system.
b. the distance of the power take-off belt(s) from the front or rear face of the cylinder block.
c. the number, size and type of belts used.
d. the position of the driven equipment in relation to the engine.
e. the method of tensioning the belt(s), for example, adjustable fixed pulley, spring loaded jockey pulley, etc.
f. the maximum and continuous power requirements of the equipment.

In-line power take-off

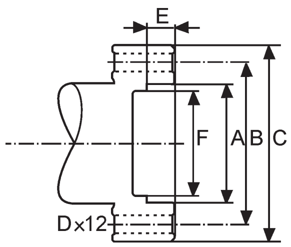


1. Bearings
2. Flexible coupling
3. Belt pulley

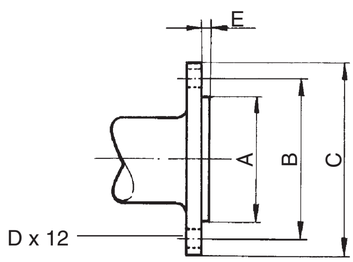
The figure shows one concept of how to utilise the crankshaft power in-line when all side thrusts are taken up by the bearings (1). The torque figures are maximum levels. Flexible coupling (2) must be calculated by Volvo Penta.



D5/D7



D9/D16



D12

Concept of a front Power Take-off with drive shaft

Engine	Max torque Nm (lbf. ft.)	A mm (inches)	B	C	D	E	F
D5A T	395 (291)	95 (3.74)	118 (4.65)	140 (5.51)	11.2x9 (0.44x9)	8.0 (0.32)	– –
D5A TA	490 (361)	95 (3.74)	118 (4.65)	140 (5.51)	11.2x9 (0.44x9)	8.0 (0.32)	– –
D7A T	535 (394)	95 (3.74)	118 (4.65)	140 (5.51)	11.2x9 (0.44x9)	8.0 (0.32)	– –
D7A TA	725 (535)	95 (3.74)	118 (4.65)	140 (5.51)	11.2x9 (0.44x9)	8.0 (0.32)	– –
D7C TA	810 (597)	95 (3.74)	118 (4.65)	140 (5.51)	11.2x9 (0.44x9)	8.0 (0.32)	– –
D9*	1000 (738)	84 (3.31)	114 (4.49)	138 (5.43)	12,6x12 (0.50x12)	20 (0.79)	74 (2.91)
D12	1000 (738)	85 (3.35)	114 (4.49)	140 (5.51)	11.0x12 (0.43x12)	10 (0.39)	– –
D16**	1100 (811)	84 (3.31)	114 (4.49)	140 (5.51)	12.6x12 (0.43x12)	6.5 (0.26)	65 (2.56)

*) Outer pulleys on crankshaft must be fitted.

**) Data for flexible coupling VKE 3414.

PTO D9 including flexible coupling

The PTO system that include flexible coupling gives possibility to gain, under the normal circumstances, max torque at the engines front end. Vibratory torque limit that is set up by values that can be carrying out by the bolt connection is satisfied with this PTO system. Both the dynamical and the statical part of the torque amplitude is possible to transmit over the bolt connection.

The flexible coupling that has been analyzed (VKE 3414) can be thermally overloaded in the case with engine misfiring. The vibratory torque for the flexible coupling is also above adequate limit for the case with engine misfiring. This moment is limited to 1000 Nm witch correspond to the power of 190 kW at 1800 rpm and 230 kW at 2200 rpm.

Please contact Volvo Penta for verifications of the PTO that include flexible coupling other than VKE 3414.

PTO D16 including flexible coupling

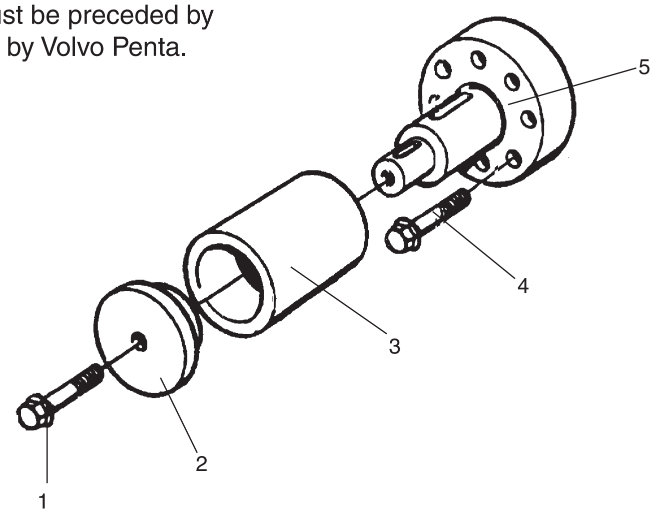
Please contact Volvo Penta for verifications of the PTO that include flexible coupling other than VKE 3414.

Stub shafts and V-belt pulleys

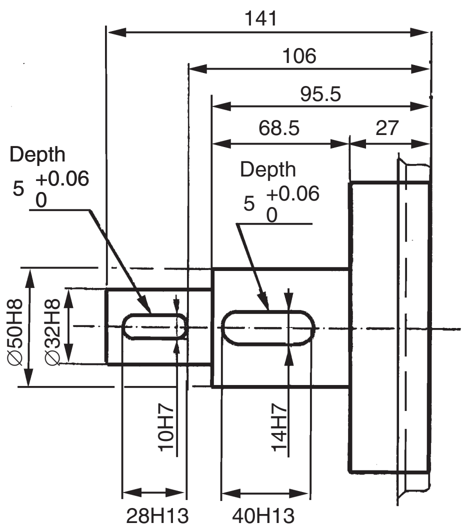
Stub shaft system D5/D7

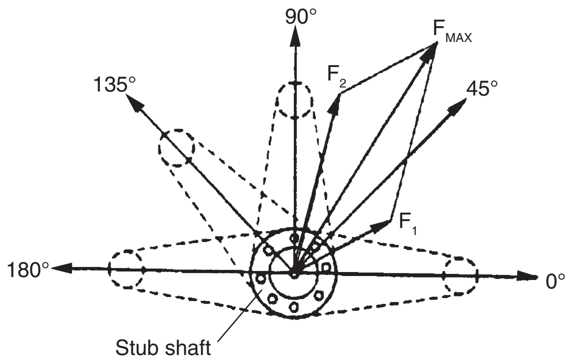
If a flexible joint is to be used, it must be preceded by a torsion vibration calculation done by Volvo Penta.

1. Bolt to stub shaft
2. Cover
3. Intermediate cylinder. Will be cut to proper length
4. Bolt to crankshaft
5. Stub shaft



Stub shaft D5/D7

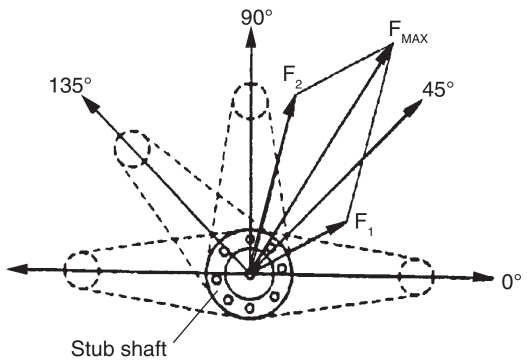


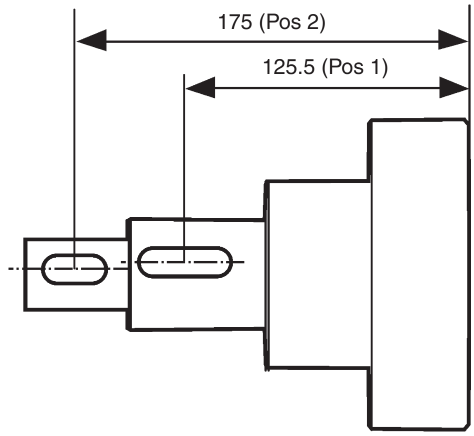


$$P(kW) = \frac{F(N) \times \varnothing d\ (m) \times (rpm)}{3.2 \times 10^4}$$

	F_{max} (N)	
Angle	Pos1	Pos2
0°	5900	5200
45°	3100	2800
90°	3100	2800
135°	3100	2800
180°	5400	4800

Stub shaft D9





$$P(kW) = \frac{F(N) \times \varnothing d\,(m) \times (rpm)}{3.2 \times 10^4}$$

	D9-300 R1		D9A-355 R1		D9A-355 R1		D9A-425 R2/R3		D9-500 R4	
	221 kW/1800 rpm		261 kW/1800 rpm		261 kW/2200 rpm		313 kW/2200 rpm		368 kW/2600 rpm	
	F_{max} (N)		F_{max} (N)		F_{max} (N)		F_{max} (N)		F_{max} (N)	
Angle	Pos1	Pos2	Pos1	Pos2	Pos1	Pos2	Pos1	Pos2	Pos1	Pos2
0°	2590	2050	2590	2050	3420	2710	3420	2710	3120	2480
45°	1740	1370	1740	1370	1680	1330	1680	1330	820	650
90°	1380	1090	1380	1090	1250	990	1250	990	510	410
135°	1700	1350	1700	1350	1480	1170	1480	1170	690	550
180°	3210	2540	3210	2540	3160	2500	3160	2500	2270	1800

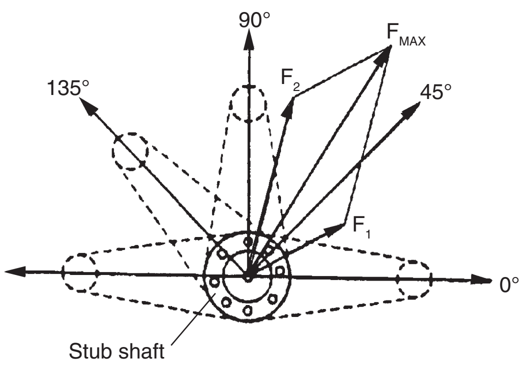
PTO with stubshaft

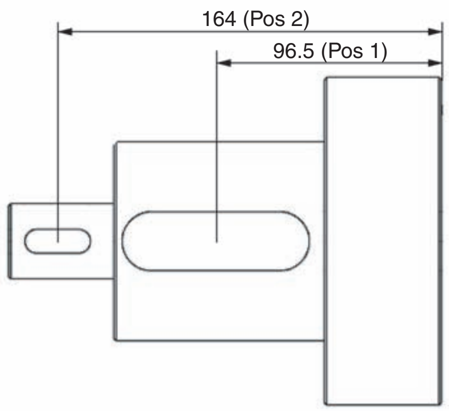
For the system with the stubshaft torque amplitude values are delimited in relation to the added lumped inertia J1 on the engine's front end. Corresponding power that is possible to deliver at the engine's front end is limited to values that are below engine's full load curve for some of the values for J1 (J1=0.2-0.8).

Engines working according the propeller load excitation curve

J1 [kgm2]	P[kW], R1 261kW@1800rpm	P[kW], R2 313kW@2200rpm	P[kW], R1 261kW@2200rpm	P[kW], R1 221kW@1800rpm
0.1	261	309	261	221
0.2	225	281	261	221
0.4	138	241	261	169
0.6	83	224	247	131
0.8	24	187	196	87

Stub shaft
D16





$$P(kW) = \frac{F(N) \times \varnothing d\ (m) \times (rpm)}{3.2 \times 10^4}$$

D16-500 - 750

368 kW - 559 kW

	F_{max} (N)	
Angle	Pos1	Pos2
0°-180°	3100	2500

PTO with stubshaft

For the system with the stubshaft torque amplitude values are delimited in relation to the added lumped inertia J1 on the engine's front end. Corresponding power that is possible to deliver at the engine's front end is limited to values that are below engine's full load curve for some of the values for J1 (J1=0.1-0.6).

Engines working according the propeller load excitation curve

J1 [kgm2]	P[kW] R1 368 - 479kW@1800rpm	P[kW] R2 551kW@1900rpm
0.1	551	551
0.2	551	551
0.3	551	551
0.4	548	548
0.5	516	516
0.6	- *	- *

* Crankshaft damper heat load is above allowable levels.

Auxiliary drives

Gear driven power take-off from timing case

The engine specifications must be appropriate for the power take-off equipment to be fitted.

Weight
The weight of the extra equipment to be bolted on to the timing cases must be considered. A support bracket from the cylinder block should be used for heavy equipment.

Cyclic torque
Some equipment, i.e. hydraulic pumps, impose high cyclic torque variations on the timing gears. This means that max torque in accordance with the data given in the **Sales Guide Marine Propulsion Diesel Engines** can not be utilised.

Miscellaneous
In the case of engines fitted with keel cooling, no seawater pump is used for systems only requiring circulation pump. A power take-off can then be located in the place of the seawater pump at the rear. A driving gearwheel must be fitted in the power take-off in the same way as for the seawater pump.

In the case of the 74-engines, a power take-off cannot be fitted on the front of the auxiliary drive gear casing when the engine is fitted with a power take-off driven from the crankshaft.

Check that the output requirement does not exceed the maximum permissible output according to the specifications in the sales literature.

⚠ **IMPORTANT!** Any power take-off equipment attached directly to timing case must be approved by Volvo Penta.

Things to remember concerning power take-off at the timing gears

- The limiting factor for the life of the gears is torque.
- If a higher torque than listed is utilised, the lifetime of the gears will be reduced.
- Remember the formula:

P = M x v

P = Output in W

M = Torque in Nm

v = Angel speed = $\frac{\pi \times n}{30}$ in RAD/s

n = Driven apparatus speed in rpm

This means that if the same output (P) is utilised at a lower engine speed, the torque will be higher and thus resulting in shorter life for the gears.

Example:

P = 15.3 kW

M = 73 Nm

n = 2000 rpm

Now, if we want to utilise the same power at 1800 engine rpm, what is the torque?

First the compressor speed must be calculated:

Crankshaft gear (Z = 30) / Compressor gear (Z = 33)

30/33 = 0.909 (compr. gear ratio)

1800 x 0.909 = 1636 rpm.

$$15300 = M \times \frac{\pi \times 1636}{30}$$

<u>M = 89.3 Nm</u>

Example:

What is the max permissible power for the servo pump gear at 1500 rpm (engine speed) for a 7 l engine?

Max. torque M = 38 Nm

According to the Sales Guide:

Servo pump speed ratio = 1.58 : 1

1500 x 1.58 = 2370 rpm

$$P = 38 \times \frac{\pi \times 2370}{30}$$

P = 9431 W = 9.4 kW

Timing gear wheel ratio and maximum torque

	Crankshaft (A) – Transmission wheel (B–F)							
	A–B		A–C		A–D		A–E	
Engine	Ratio	Max.torque Nm (lb.ft.)	Ratio	Max.torque Nm (lb.ft.)	Ratio	Max.torque Nm (lb.ft.)	Ratio	Max.torque Nm (lb.ft.)
D5/D7	1.1:30	64.5 (7.8)	1.1:30	64.5 (7.8)	1:1.12	187.5 (138.3)	*	*
D12	1:0.76	55 (40)	0.71:1	—	1:0.60	30 (22)	*	*

*) PTO occupied or not applicable.

Ratio

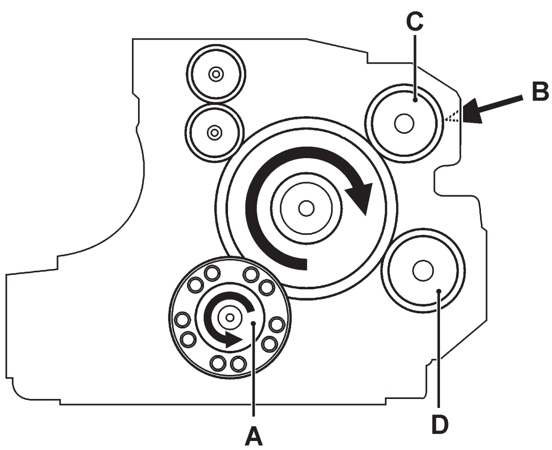
Driven (wheel) speed = crankshaft/ratio number.

Example:
A = 1800 rpm, ratio = 0.91
Driven wheel speed = 1800/0.91 = 1978 rpm

NOTE! PTO application to timing gears requires correct material combination of the gears. Use only by Volvo Penta approved gear wheels.

Transmission wheel positions

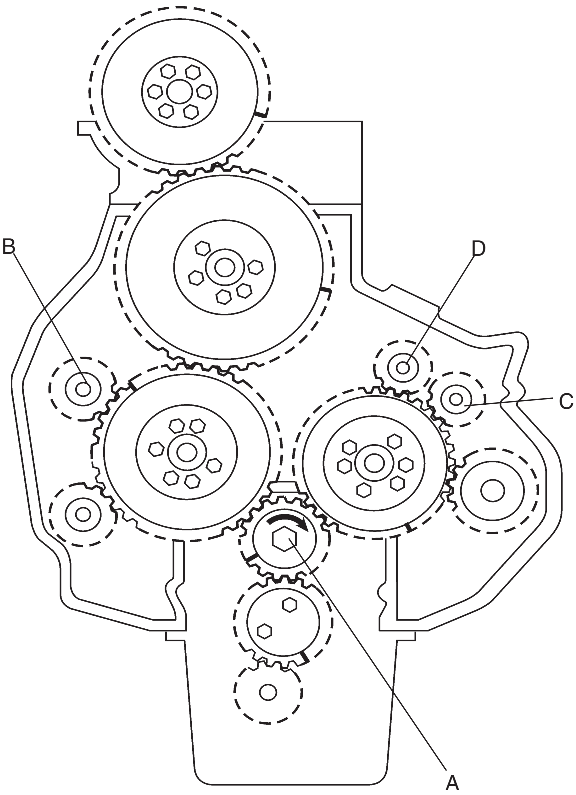
D5/D7



Timing gear positions, seen from flywheelside.
A. Crankshaft gear
B. Drive gear for seawater pump (impeller type)
C. Drive gear for coolant pump and alternator
D. Drive gear for seawater pump (Gilkes-type)
Drive gear free for PTO connection

Transmission wheel positions

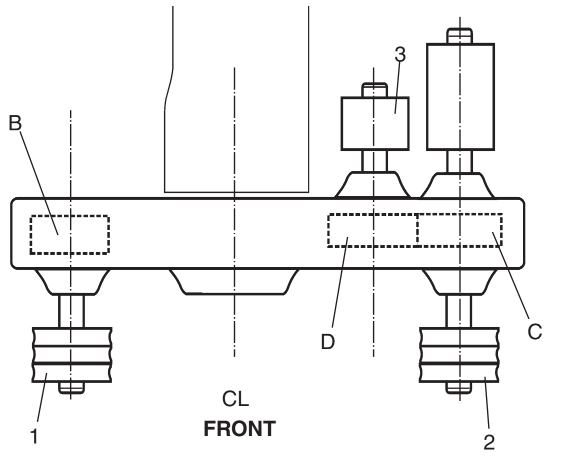
D12



Timing gear positions, seen from front side.

A. Crankshaft gear
B. Drive gear free for PTO connection
C. Drive gear for feed pump, alternator and extra equipment
D. Drive gear for hydraulic pump (Extra equipment)

Power take-off on engine auxiliary drive gear casing

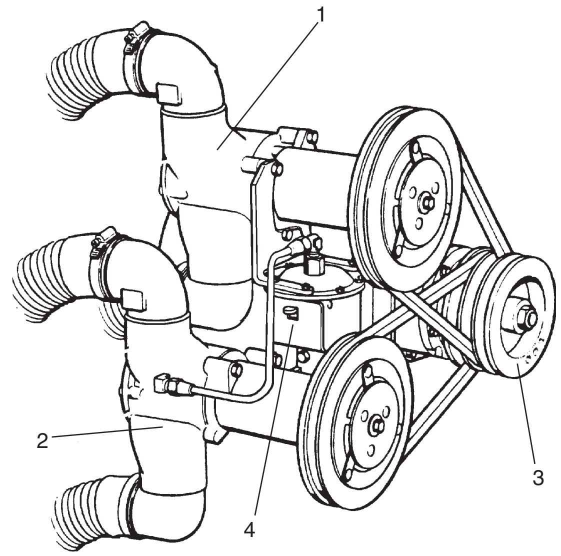


Power take-off on auxiliary drive gear casing

B. Drive gear for PTO connection
1. Power take-off front, starboard side. (Drive gear B)
C. Drive gear for feed pump, alternator or extra equipment
2. Power take-off port (Drive gear C)
D. Drive gear for hydraulic pump (Extra equipment)
3. Power take-off hydraulic pump
CL Crankshaft centre line

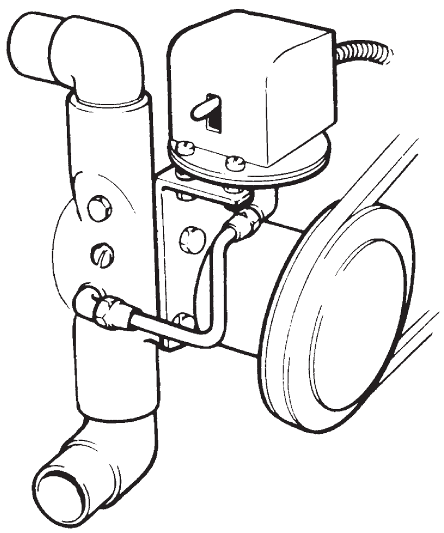
Flush and bilge pumps

Different types of pumps can be fitted to dispose of bilgewater and for flushing purposes. Furthermore, when changing oil in the reverse gear and the engine, it can be convenient to have an electrically powered oil scavenging pump.



Bilge and flush pump (2"). Switched on and off electrically. Vacuum gauge for automatic disconnecting

1. Bilge pump
2. Flushing pump
3. Power take-off
4. Vacuum switch



Bilge pump (2"). Switched on and off electrically. Vacuum gauge for automatic disconnecting.

Disengageable 2" bilge pumps and 2" flushing pumps can be fitted on the engines. The pumps are mounted to a power take-off at the back of the timing gear casing.

The pumps are of the impeller type with rubber impeller. The power is transferred through an electromagnetic clutch.

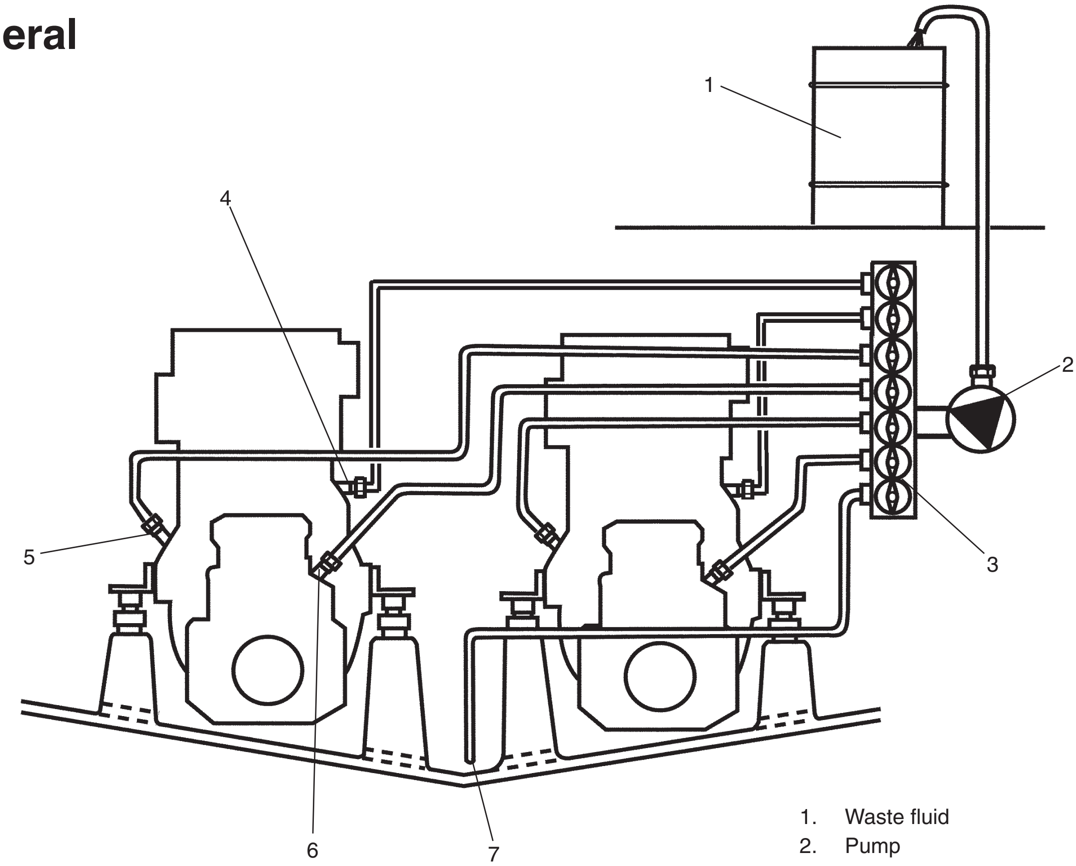
The connection time of the bilge pump is monitored by a vacuum switch. At start, the switch is held down for approx. 20 seconds. The vacuum switch breaks the current to the magnetic coupling when the pumping medium is finished.

The flushing pump is used for many service purposes such as deck flushing, fish washing etc.

The **Sales Guide Marine Propulsion Diesel Engines** describes speeds, dimensions and capacity.

Oil and coolant drain systems

General



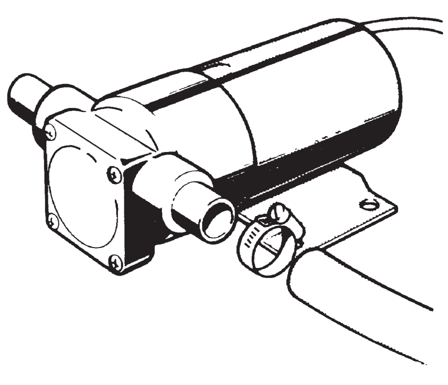
1. Waste fluid
2. Pump
3. Valve block
4. Coolant drain connection
5. Engine oil drain connection
6. Reverse gear oil drain connection
7. Pipe to drain the bilge

Engine installations in boats and vessels, carry the potential for negative impact on the environment. The liquids necessary are harmful and should be handled in a safe way.

The figure above shows a concept of how this could be solved via a central waste pump connected to the important positions in the engine room.

The systems must comply with local ruling and legislation.

Oil draining pump



Apart from the fixed hand-operated draining pumps on certain engines, an electrically powered draining pump for oil is also available as extra equipment. This pump is installed in a suitable position by using a bracket. The pump can be run in the desired direction by changing the polarity of the cables.

The oil hoses should be connected up only when changing oil so as to avoid the risk of accidental draining.

Launching the boat

Check before launching:

- Install the batteries in their compartment and attach the battery leads.
- Check that all valves at through hull fittings are closed.
- Check that the fitted propeller has the correct diameter and pitch before launching. Check also that the propeller has the correct rotation (right or left).
- Launch the boat.

Check before starting the engine:

- Open valves at through hull fittings one by one.
- Check for leakages in hull and through hull fittings.
- Open valves for external systems, keel cooling, hot water circuit etc.
- That all drain cocks are closed and all drain plugs are installed.
- Engine oil. The oil capacity, oil quality and viscosity. See **Operators's Manual**.
- Reverse gear oil.
  The oil capacity, oil quality and viscosity. See **Operators's Manual**.

  NOTE! Since the marks on the dipstick apply at operating temperature with the engine idling and the control in neutral, the correct level before starting must be judged by experience.

- Coolant level. Filling of coolant see chapter **Coolant** and **Filling with coolant**.
- Fill up with fuel.
  Fuel pre-filter:
  Remove the lid and fill the filter with clean diesel fuel. Install the lid and tighten it by hand. Wipe off any diesel fuel which may have collected on the heat shield. Check that the tap handle is in the open position (all on) if a twin filter has been installed.
- Open the fuel cocks and vent the fuel system-
  Oil level in hydraulic steering system or power take off equipment (if fitted)
- Engine alignment after the boat is completed and rigged. (Preferably after 12 hours in water.)
  See chapter **Engine installation**.

Starting the engine

- Starting procedures:
  See **Operators's Manual** for each engine.

Check while the engine is running at idling

- Leakage in fuel system and cooling system.
  Check pipes and hoses. See **Operators's Manual**.
- Instruments and gauges are working and showing correct values. See **Operators's Manual.**
- Oil level in reverse gear when engine has reached operating temperature. See **Operators's Manual**.
- Equipment such as navigation lights, instruments etc. is working correctly. See **Operators's Manual**.

Stop the engine. Check:

- Engine oil level.
- Coolant level.
- Water level in wet exhaust system.

  The level shall be **well below** the lower edge of silencer inlet so that there will be no risk of water entering into the engine exhaust system. Follow the design limit from the silencer manufacturer.

Sea trial

Check when test running the boat:

- Instruments
  Check engine rpm, oil pressure, coolant temperature and charging voltage. See **Operators's Manual.**
- Check engine installation for water, coolant, oil and fuel leaks.
- Check if the maximum engine speed can be obtained, see the **Operators's Manual**. Should the maximum engine speed not be obtained, the wrong size propeller might be installed. Also, the boat might be loaded in a way that results in a bad running attitude position in the water.
- Exhaust backpressure. See chapter **Exhaust system, Backpressure**.
- Keel cooling system for leakages and coolant circulation (temperature and pressure, inlet and outlet). See **Cooling system, External cooling**.
- Grease propeller shaft bearings and seals: These should be at a low temperature and without leakes.

Check over the whole speed range:

- That the engine room temperature is kept at an acceptable level.
- Abnormal noise and vibrations.
- Verify that the steering and controls are correctly connected and correspond to the boat's movement.

References to Service Bulletins

Group	No.	Date	Concerns

Notes

Notes

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Do you have any complaints or other comments about this manual? Please make a copy of this page, write your comments down and post it to us. The address is at the bottom of the page. We would prefer you to write in English or Swedish.

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