Technical Documentation

Project Guide

Design Specification: ..... **Propulsion**
Plant No. **L21/31**
Date **2026-10-27**

2026-10-27

While remaining the same legal entity, MAN Energy Solutions has been renamed to Everllence and its products are being rebranded from “MAN” and/or “MAN Energy Solutions” to “Everllence”. As this is an ongoing process, any reference to “MAN” and/or “MAN Energy Solutions” is actually a reference to “Everllence”.

All data provided in this document is non-binding. This data serves informational purposes only and is especially not guaranteed in any way. Depending on the subsequent specific individual projects, the relevant data may be subject to changes and will be assessed and determined individually for each project. This will depend on the particular characteristics of each individual project, especially specific site and operational conditions.

Original instructions

L21/31

2026-10-27

Everllence
H. Christoffersensvej 6
4960 Holeby
Denmark

Phone +45 54 69 31 00
www.everllence.com

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Introduction to project guide

Introduction

Our project guides provide customers and consultants with information and data when planning new plants incorporating four-stroke engines from the current Everllence engine programme. On account of the modifications associated with upgrading of our project guides, the contents of the specific edition hereof will remain valid for a limited time only.

Every care is taken to ensure that all information in this project guide is present and correct.

For actual projects you will receive the latest project guide editions in each case together with our quotation specification or together with the documents for order processing.

All figures, values, measurements and/or other information about performance stated in the project guides are for guidance only and shall not be used for detailed design purposes or as a substitute for specific drawings and instructions prepared for such purposes. Everllence makes no representations or warranties either express or implied, as to the accuracy, completeness, quality or fitness for any particular purpose of the information contained in the project guides.

Everllence will issue an installation manual with all project related drawings and installation instructions when the contract documentation has been completed.

The installation manual will comprise all necessary drawings, piping diagrams, cable plans and specifications of our supply.

Everllence four-stroke small bore engines – all emission requirements

Besides focus on power density and fuel economy, Everllence is committed to a steady reduction of the environmental impact of our engines.

IMO Tier II

Applying well-proven methods to achieve a cleaner and more efficient combustion process, Everllence has significantly decreased NO_x emissions. Our four-stroke engines are IMO Tier II compliant with internal engine measures alone.

IMO Tier III

For operation in emission control areas (ECA), Everllence has developed a comprehensive range of selective catalytic reduction (SCR) systems that tremendously reduce NO_x levels surpassing IMO Tier III requirements.

Everllence is the first manufacturer to successfully produce and offer IMO Tier III compliant four-stroke marine engines based on a fully modular SCR kit covering our entire four-stroke engine portfolio. In 2014, Everllence was awarded the first IMO Tier III EIAPP certificate together with the classification society DNV-GL.

Everllence' standard SCR system is available in fourteen different sizes covering our entire portfolio of four-stroke engines. Customised SCR systems are offered on demand.

Everllence has developed a complete range of SCR systems that work perfectly with our engines for maximum system efficiency. The intelligent exhaust gas temperature control allows significant savings in fuel consumptions as compared to third-party supplier systems. Everllence SCR systems work with

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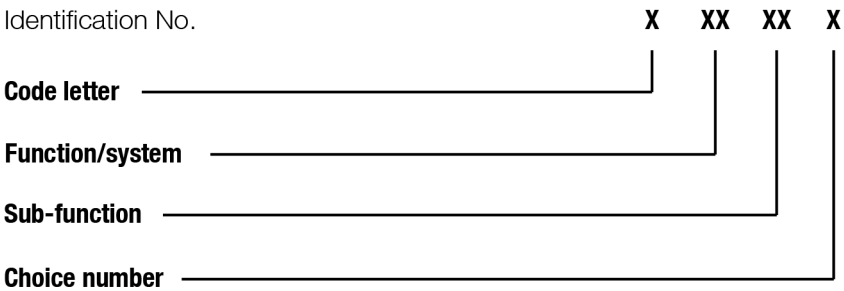
MGO, MDO and HFO with up to 3.5% sulphur. Our modular system comes in 14 different sizes to match all power demands. Some notable benefits of standardisation are significant cost reduction and simplification of installation.

NOTICE **Stated SFOC/SGC values are valid for currently applicable rules acc. IMO MARPOL ANNEX VI/NTC 2008, 2023 Edition. They are subject to change regarding the upcoming IMO MARPOL ANNEX VI/NTC rules as proposed in IMO PPR 11/8, to be approved at MEPC 82 (September 2024).**

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Code numbers



Code letter: The code letter indicates the contents of the documents:

B	:	Basic Diesel engine / built-on engine
D	:	Designation of plant
E	:	Extra parts per engine
G	:	Generator
I	:	Introduction
P	:	Extra parts per plant

Function/system number: A distinction is made between the various chapters and systems, e.g.: Fuel oil system, monitoring equipment, foundation, test running, etc.

Sub-function: This figure occurs in variants from 0-99.

Choice number: This figure occurs in variants from 0-9:

0	:	General information	1	:	Standard
2-8	:	Standard optional	9	:	Optional

Further, there is a table of contents for each chapter and the pages follow immediately afterwards.

Drawing No: Each document has a drawing number including revision number i.e. 1643483-5.5.

Release date: The release date of the document Year.Month.Date. This is the date the document has been created.

NOTICE

When referring to a document, please state both Drawing No including revision No and Release date.

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Safety precautions

General

Correct operation and maintenance, which is the aim of this book, are crucial points for obtaining optimum safety in the operation of the engine. The general measures mentioned here should therefore be routine practice for all operators.

The basic safety instructions are addressed to all users. They inform users about the risks not described elsewhere in the instruction book. They contain important information on how the affected users must protect themselves from such risks. The basic safety instructions provide information on the safety concept and the minimum requirements for the safety use of the Everllence products.

General maintenance guidelines

- Read and follow all instructions given in work cards.
- Only use original spare parts.
- Only use appropriate tools.
- Always inspect the engine when maintenance work is completed.

Cross-referencing in the manual

Many places in the instruction manual contain cross-referencing between work cards and procedures, for example "See work card X".

When switching to the work card being referenced, always check and follow the safety precautions listed for the work card being referenced.

A work procedure must never be carried out unless all safety precautions have been read and understood.

Operational Staff

Operation and maintenance of Everllence engines is to be carried out exclusively by qualified professional personnel.

Stays in the engine area is to be limited to only necessary operations.

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Minimum personal safety equipment requirements:

1. Safety shoes.
2. Hearing protection.
3. Boiler suit or other similar protective wear.
4. Always check data sheets and work cards if additional personal protection is needed for specific work procedures.

Additional personal safety equipment:

1. Use eye protection when working on or near pressurised equipment.
2. Use gloves when working on hot surfaces, or when handling parts with sharp edges.
3. Use helmet if lifting a load more than 2 metres above staff, or if there is overhead obstacles.
4. Use harness when working at heights over 2 metres, or if footing is unstable or unsafe.





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Signs / Nameplates

Signs and nameplates mounted on the engine are not to be removed, painted over, or in any other way be made unreadable. This includes safety signs, signs with serial numbers, signs with instructions, etc

Special Dangers

Various situations may lead to risk of serious injury. The following recommendations must always be observed:

- Keep clear of the space below a crane with load.
- Before opening of valves, always observe which way liquids, gases or flames will move, and keep clear.
- Dismantling of parts may cause the release of springs.
- Removal of plugs may cause the release of pressurised fluids or gasses.
- Blow-off from safety valves will discharge hot liquids, gasses and flash flame, observe which way liquids, gases or flames will spray, and keep clear.
- Do not stand near turbo chargers in case of any abnormal running.
- Do not stand near crankcase doors or relief valves – nor in corridors near doors to the engine space – if an alarm sets off for oil mist, high lube oil temperature, no piston cooling oil flow, or scavenge box fire.
- Do not step on valves, valve handles or instrumentation during maintenance work.
- Lock and tag valves which are closed during maintenance work.

⚠ WARNING **It is of the upmost importance that the shutdown function is working properly. Therefore, the shutdown function must be tested at regular intervals according to the planned maintenance programme in the Instruction Manual.**

Fire

⚠ WARNING



Fire hazard

Risk of fire due to discharge from relief valves.

- Keep the areas around the relief valves free of oil, grease, and so forth, to prevent the risk of fire caused by the emitted hot air/gas if the relief valves open.

Do not weld or use naked lights in the engine room until it has been ascertained that no explosive gases, vapour, or liquids are present.

If the crankcase is opened before the engine has cooled down, welding and the use of naked flames will result in the risk of explosions and fire. The same applies to inspection of oil tanks and of the spaces below the floor.

Attention is furthermore drawn to the danger of fire when using paint and solvents with a low flash point. Porous insulating material, soaked with oil from leakage, is flammable and should be renewed.

Warning and information signs, symbols

Warning and information signs and safety-relevant symbols provide following information:

- Indications of possible hazards (e.g. pressure, explosion, etc.)
- Warnings and prohibitions against unsafe behavior
- Mandatories for safety-related behavior
- Fire protection and firefighting,
- Signposting of evacuation and emergency escape routes

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Warning and information signs as well as safety-relevant symbols can also be attached directly to components. They must be complete and easy to read or identify at all times.

Section warning messages

Section warning messages instructions apply to an entire chapter, a section or several paragraphs in a document and are prepended to the descriptive text.

Definition of signal words for personal injury

⚠ DANGER

Designation of a danger with a high risk level,
which – if not avoided – will result in death or serious injury.

⚠ WARNING

Designation of a danger with a medium risk level,
which – if not avoided – can result in death or serious injury.

⚠ CAUTION

Designation of a danger with a low risk level,
which – if not avoided – may result in minor or moderate injury.

Note of environmental or property damage

NOTICE

Description of an action or situation,
which – if not avoided – can result in damage to the environment or property.

Special user note

Special user note
User notes contain helpful tips and additional information.

User notes are not used to designation of a danger.

Safety precautions for maintenance

Before carrying out maintenance work, stop and block the engine according to the safety precautions given on the specific work card.
Other safety precautions than listed below may apply.

●	Shut-off starting air
●	Stop lub. oil circulation

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●	Shut-off cooling oil
●	Engine stopped
●	Shut-off cooling water
●	Shut-off fuel oil
●	Press Blocking - Reset

Safety precautions at running engine

●	Stay clear of any rotating parts
●	Do not work on any pressurized systems

Safety precautions for overhauling of components in work shop

●	No engine related safety precautions

Data Sheet Signs

Data sheets may include warning signs for special dangers that could arise in connection with the maintenance procedures.

Warning signs		Mandatory action signs	
General warning sign		General mandatory action sign	
Explosive material		Wear ear protection	
Drop (fall)		Wear eye protection	
Slippery surface		Wear safety footwear	
Electricity		Wear protective gloves	
Overhead load		Wear face shield	
Hot surface		Wear head protection	
Crushing		Wear mask	

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Warning signs		Mandatory action signs	
Overhead obstacle		Wear respiratory protection	
Flammable		Wear safety harness	
Crushing of hands		Disconnect before carrying out maintenance	
Pressurised cylinder		Wear antistatic footwear	
Pressurised device		Use gas detector	
Falling objects		No open flame, Fire, open ignition source and smoking prohibited	
Low temperature/ freezing			

Alarm messages

All alarm messages must be responded and acted upon accordingly.

- Serious alarms can lead to automatic power reduction and a complete shutdown.
- In the case of alarm messages, an error check and troubleshooting must be carried out immediately.
- The operating and maintenance personnel must know the alarm system and be able to adequately respond to the alarm messages.

Cleanliness

- All areas should be always clean and tidy.
- Remove oil spills immediately with suitable cleaning agents.
- Dispose of oil-soiled or contaminated cleaning agents properly.
- In case of danger of dust or dirt entries stop the ventilation system. If necessary, close the ventilation ducts, windows and skylights.
- Ensure that no dirt enters the product during maintenance.
- All work that can cause contamination or entry of metal chips or grinding dust must not be carried out close to the product.
- Clean the product regularly to detect possible leaks quickly and easily.

Compressed air for maintenance work

Compressed air for maintenance work is dangerous due to its high pressure. Improper use can lead to serious personal injury.

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- Use suitable personal protective equipment.
- In particular, protect eyes, ears and open areas of skin.
- Do not blow compressed air in the direction of people.
- Do not use compressed air to clean any worn clothing.

Danger of injury due to manual engine turning

Before engaging the turning gear, ensure that the starting air supply is shut off, the main starting and slow turning valves are blocked, and that the indicator cocks are open.

When the turning gear is engaged, check that the indicator lamp "Turning gear in" has switched on.

The turning gear remote control is a critical device and should always be kept in optimal working condition. Any fault on the device or cable must be rectified before use.

When operating the turning gear it is important to note the following points:

- The turning gear must be operated by the remote control and only by the person working on the engine.
- Warnings must be given before each turning.
- Operation of the turning gear from the switchboard must not take place while maintenance work is in progress inside the engine.
- Block the turning gear remote control or place a "Do not touch" sign.

External Equipment

Observe the safety instructions, operating and work manuals of external equipment.

Work on electrical installations

- Disconnect power supply.
- Secure re-connection by "Lockout and Tagout".
- Check that there is no operating voltage.
- Ensure protection from nearby live parts.
- Potential-free signal must be used when external signals are connected to Everllence control system.
- Enclosures may contain more than one power supply.
  In this case, label the enclosure with "Warning - more than one power supply".
- All terminals/cables must be labeled according to the wiring diagram.

ATEX installations

After completion of ATEX installation, an initial inspection of the material and installation must be carried out according to EN 60079-14 and EN 60079-17.

Handling electrical wiring and cables

- Route all wiring and cables that is at risk of elevated temperatures so that they are protected against external excessive heat.
- The minimum distance between control lines and power supply cables (up to 690 V AC) is 150 mm.

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- The minimum distance between low-voltage and medium-voltage power lines is 300 mm.
- Special requirements such as necessary shielding must always be observed. Any such instructions specified in the drawings are binding.
- See the cable manufacturer's specifications for the minimum bending radius of the cables.
- Cables of intrinsically safe circuits (for EX zones) should always be laid in their own cable duct and must not be laid together with signal and power cables. Maintain minimum distance. The shell colour is light blue.

Handling hoses and pipes

Hoses and pipes pose hazards due to the media they are used to transport:

- Flammable liquids or gaseous media
- Hot liquid or gaseous media
- Liquid or gaseous media under high pressure

Liquid or gaseous media escaping in an uncontrolled manner may cause serious injuries. Liquid media and vapours may be very hot, which can cause serious burns if they escape. Leaking gaseous media may cool very rapidly, which may cause frostbite.

Improper handling may result in explosions, fire or serious injury (burns, skin and eye injuries due to liquid or gaseous media escaping suddenly under high pressure).

Always observe the following safety precautions when handling hoses and pipes:

- Observe the maintenance schedule, particularly the specified replacement intervals.
- All lines, hoses and bolted connections must be regularly checked for leakages and externally visible damage. Repair any damage immediately. Avoid chafing and repair if necessary.
- Before opening or dismantling any piping, cylinders, tanks, valves or connections, make sure that the system is depressurised or drained.
- Ensure that all piping, cylinders, tanks, valves and connections are suitable for the intended media, temperature and pressure ranges.
- Allow pipes carrying hot liquids or gases to cool down before opening.
- Replace insulating material contaminated with flammable liquids immediately.
- Install all flexible hose connections so that they are free of torsional forces.

Handling of flammable materials

To prevent dangers related to handling of flammable materials, the following measures must be taken:

- A high air exchange rate reduces the risk of fires.
- For conventional applications, the volume of air in an enclosed space shall be completely replaced at least five times per hour.
- For applications with highly flammable materials such as gas, oxygen, etc., the air volume shall be completely replaced at least twelve times per hour.
- In the case of highly flammable gaseous materials, ensure that the pipework is permanently technically sealed. Take organisational measures to ensure that no leaks occur.

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- Ensure that no naked flames are generated and that smoking is prohibited.
- If open flames cannot be avoided, e.g. during welding work, make sure that no flammable substances or atmospheres are present in the working environment.
- Pipes for hot and flammable liquids (e.g. lube oil) shall be routed at an appropriate distance from heat-sensitive materials.
- Close hot open surfaces with thermally insulating covers to prevent ignition of dripping media.

Hazardous materials

All risks must be identified in a risk assessment. Safety measures must be implemented in relation to the activity and in consideration of the safety data sheets before work begins.

- Always follow the manufacturer's specific instructions, i.e. the material safety data sheet (MSDS)
- Use protective gloves, goggles, breathing mask, and any other recommended protective gear stated in the material safety data sheet
- Read the material safety data sheet regarding first aid measures in the event of skin contact
- When handling harmful materials it is important to ensure proper ventilation and shielding if needed
- In the event of leaks or spillage, spread binding agents immediately. Dispose of the binding agents according to the material safety data sheet

Hot and cold surfaces

During operation, high surface temperatures can occur, which can cause burns if touched. Individual components and piping systems may contain gases or volatile liquids. Due to the expansion of gases or evaporation of liquids they can become very cold.

- Wear suitable personal protective equipment.
- Avoid direct contact with hot and cold surfaces.

Hot works

Hot work permit is mandatory for all hot works. In particular, hot works on tanks or piping systems with potential explosive material can lead to an explosion. Before any hot work on tanks or piping systems, it must be determined by a qualified specialist (for example an engineer or service technician) that these tanks or piping systems do not contain any explosive material.

Freezing

If there is a risk of damage due to freezing when the plant is out of service, engines, pumps, coolers, and pipe systems should be emptied of cooling water.

Safety valve

Beware of unexpected opening of safety valves and its exhaust opening in top of the cylinder top cover as hot liquids, gasses and flash flame will be discharged.

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Risk of explosion in the cylinder crankcase

By mechanical atomization and subsequent evaporation of the lubricating oil on hot components or by the entry of unburned gases during operation, it may lead to the formation of explosive atmosphere in the cylinder crankcase.

- Danger area around the engine must be clearly marked and recognizable.
- During operation, the operating and maintenance personnel may only be in the vicinity of the engine for the duration of the necessary work.
- The opening of the cylinder crankcase cover is generally prohibited during operation.
- Work on the engine may be performed 20 minutes after engine stop.
- Surveillance sensors must be replaced as soon as possible after a failure or damage.
- Check the oil mist detectors according to the operating instructions.

Explosion relief valve

If there is an event of an oil mist- or gas explosion in the engine, the explosion relief valves protect personnel and equipment. The explosion relief valve opens immediately to protect the engine of damage. It is designed to relieve the excess pressure during an explosion, avoid flame escape and to close rapidly after an explosion.

- The area around the explosion relief valves must always be clear.
- Danger of burns due to hot parts! Do not touch the relief valve after an explosion.
- Work on the explosion relief valve must only be carried out with the shut-down and cooled down engine. Note the cooling time for the engine and components.
- The security seal on the explosion relief valve must not be removed.
- Disassembling the flame arrester is forbidden.
- While working on the explosion relief valve, appropriate protective clothing and gloves must be used.
- Damaged explosion relief valve must be replaced.
- After an explosion: A restart of the engine is only permissible if the cause of the fault has been determined and eliminated. The explosion relief valves must be checked for proper function and replaced if necessary.

Hazard zone around relief

Relief valves are installed on the crankcase covers and exhaust pipes and are designed to protect persons and equipment in case of an oil mist or gas explosion.

During engine operation, the presence of personnel in the hazard zones around the relief valves is prohibited.

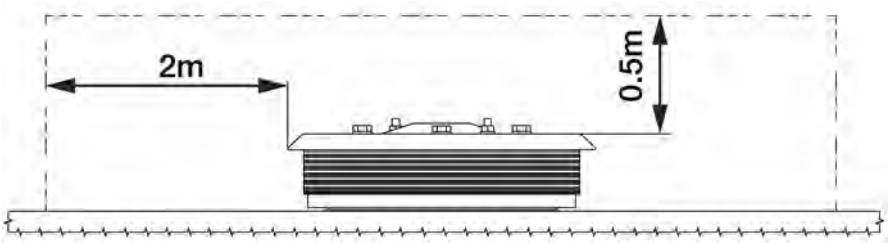


Figure 1: Hazard zone around a relief valve

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Fuel nozzle testing

The removal of fuel valves (or other valves in the cylinder head) may cause oil to run down to the piston crown; if the piston is hot, an explosion may then blow out the valve. When testing fuel valves with the hand pump, do not touch the spray holes, as the jet may pierce the skin.

⚠ DANGER



Impacting second fuel components during lift

Risk of second fuel leakage

- Due to the risk of damaging second fuel components on the engine during lifts, the engine room crane should not be used during second fuel operation.
  - ⇨ Movement of, and lift of heavy equipment around and above the engine, is only to be done with the engine stopped or operating in fuel oil, ensuring the engine is in second fuel standby or purged of second fuel before beginning lift.

Lifting tools and load handling equipment

The use of lifting tools and load handling equipment may only be carried out by trained operating personnel.

- Depending on the load and situation, suitable lifting tools and load handling equipment and attachments should be selected.
- Before using cranes, check the functionality, i.e. slow and fast movement/ lifting and end stop functionality. In case of double jib cranes also check that the two cranes lift at the same speed.
- Before each use, lifting tools and load handling equipment must be checked for damage.
- Do not use lifting tools and load handling equipment that are not clearly identified, that are damaged, that are not marked with the Work Load Limit (WLL).
- All operations such as striking, lifting, moving, landing and separating of lifting tools and load handling equipment must be carefully considered and carried out with due care.
- Before lifting a load, the weight and center of gravity must be uniquely determined.
- Always use all intended and available lifting points when lifting loads.
- For loads without existing anchor points, the anchor points must be determined.
- Secure loads against slipping by fixing with suitable means.
- To avoid damaging load handling equipment use edge protectors for sharp edges.

Pay attention to reducing the maximum load capacity

0° – 30° = 50 % load per sling leg	30° – 60° = 75 % load per sling leg	90° – 120° = 100 % load per sling leg	above 120° **prohibited**

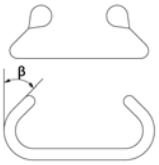
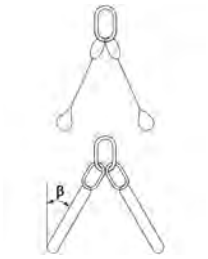
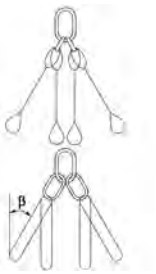
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Reduction of the load capacity by the sling angle

At the synthetic web slings pay attention to the maximum load!

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WLL of sewn webbing component	Colour of sewn webbing component	Working load limits (WLL) in tonnes								
		Straight lift	Choked lift	Basket hitch			Two leg sling		Three and four leg slings	
										
				Parallel	β = 0 - 45°	β = 45 - 60°	β = 0 - 45°	β = 45 - 60°	β = 0 - 45°	β = 45 - 60°
		M = 1,0	M = 0,8	M = 2,0	M = 1,4	M = 1,0	M = 1,4	M = 1,0	M = 2,1	M = 1,5
1,0	Violet	1,0	0,8	2,0	1,4	1,0	1,4	1,0	2,1	1,5
2,0	Green	2,0	1,6	4,0	2,8	2,0	2,8	2,0	4,2	3,0
3,0	Yellow	3,0	2,4	6,0	4,2	3,0	4,2	3,0	6,3	4,5
4,0	Grey	4,0	3,2	8,0	5,6	4,0	5,6	4,0	8,4	6,0
5,0	Red	5,0	4,0	10,0	7,0	5,0	7,0	5,0	10,5	7,5
6,0	Brown	6,0	4,8	12,0	8,4	6,0	8,4	6,0	12,6	9,0
8,0	Blue	8,0	6,4	16,0	11,2	8,0	11,2	8,0	16,8	12,0
10,0	Orange	10,0	8,0	20,0	14,0	10,0	14,0	10,0	21,0	15,0
Over 10.0	Orange									
M = Mode factor for symmetrical loading. Handling tolerance for slings or parts of slings indicated as vertical = 6°										

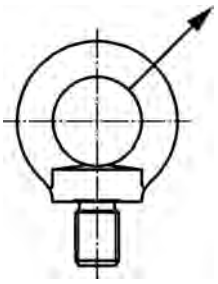
Shackles

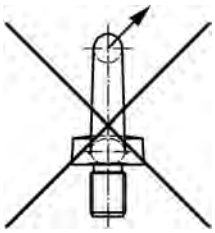
Screw pins to be tightened to full contact.

Eye screw / Eye nut

Tighten to full contact without any gap. Be aware of loading direction.

Lateral loading is prohibited in all cases!

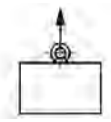
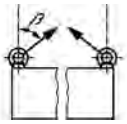
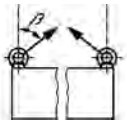
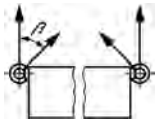




Prohibited lateral load

Load capacity depending on the load direction

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Installation position to thread axis:	vertical			horizontal
Direction of loading:	axial	obliquely		laterally
				
Opening angle:	0°	β ≤ 45°	β > 45°– 60°	β ≤ 45°
Load capacity in %:	100 %	75 %	50 %	

Hooks

Only hooks with safety latches are allowed for lifting.

Chain tackles

Be aware of lifting angle.

Lighting

Sufficient lighting must be permanently installed in suitable places.

- For poor or unlighted areas, a portable work light must be available.
- For maintenance and repair work only portable safety lamps may be used.

Order at the workplaces

Equipment required for operation, maintenance and servicing must be stored properly after use. For example:

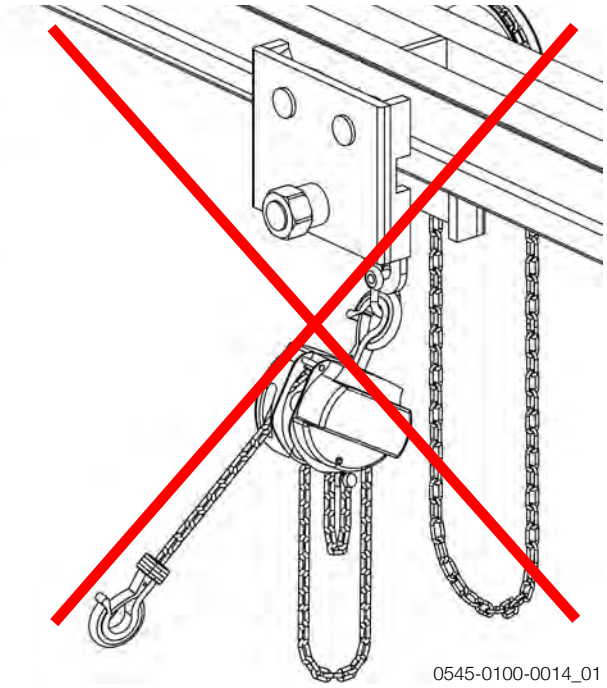
- Hand tools should be securely fastened and placed on easily accessible tool panels.
- Special tools should be securely fastened close to the area of use.
- Components, tools, aids, etc. should not be on the ground, on platforms, on catwalks, when they are no longer needed.

Travelling trolley

Before use, inspect the travelling trolley and ensure that the travelling trolley is properly maintained.

⚠ CAUTION The travelling trolley must only be used for vertical lifts and NOT for tilted lifts.

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Sealing materials

When removing O-rings, sealing rings, and other rubber or plastic-based sealants exposed to high temperatures, precautions should be taken by using protective neoprene or PVC gloves.

Spare parts

Only use spare parts approved by Everllence.

- Heavy and large spare parts should be stored near the place of use.
- Spare parts must be professionally secured against unintentional movement.
- The safe transport of spare parts must be ensured by means of suitable lifting tools and load handling equipment.
- Spare parts must be protected against harmful influences such as corrosion or mechanical effects.

Splash guard

It is required that fuel oil and lubrication oil lines and flanged connections must be screened or otherwise suitably protected to avoid oil onto hot surfaces, air intakes, electrical installations or other sources of ignition. Splash guard removed in connection with maintenance or repair work must be reinstalled again when the work has been carried out.

Stay under suspended loads prohibited

Improper transport of loads can lead to serious personal injury.

- Never work or stay under a suspended load.
- Use suitable personal protective equipment.
- Use suitable means of transport, lifting tools and load handling equipment and use as intended.
- Always use all intended and available lifting points when lifting loads.

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Tools

All tools supplied by Everllence comply with European standards.

- A completeness check of the tools must be carried out before and after each maintenance and repair work.
- Before each use, it must be ensured that the tool is in a technically safe condition.
- Do not use damaged tools.
- If tools are to be used in areas where specific certificates, special markings or approvals are required, the operator must ensure that the tools meet the requirements.

Marking of piping systems



Marking of piping systems

The following marking of piping systems is a recommendation of Everllence. The final color scheme is to be decided between owner, engine builder and shipyard, as such the following should only be seen as guidelines.

Piping systems containing media that directly or indirectly pose potential hazards to safety are marked by Everllence according to DIN ISO 14726. This marking identifies the medium by certain main colours, a text informs about the medium and its effect. Arrows indicate the flow direction.

Piping systems for fuels with a low flash point are painted in the main colour of flammable gases (yellow) or covered with tape rolls.

System	Medium	Label	Colour name	Colour	RAL	Note
Starting	Non-flammable gases	Starting air 30 bar	Grey		7001	
Exhaust	Waste media [a]	Exhaust gas	Black		9005	
Lube	Oils other than fuels	Lubricant 6 bar	Orange		2003	Apply actual pressure
Hydraulic	Oils other than fuels	Hydraulic oil 30 bar	Orange		2003	Apply actual pressure
Fuel	Fuel	HFO / MDO / MGO / etc.	Brown		8001	
Flammable gases	Low Flashpoint Fuel	Methanol	Yellow		1021	Full painted pipes
Flammable gases	Low Flashpoint Fuel	LPG	Yellow		1021	Full painted pipes
Flammable gases	Low Flashpoint Fuel	Ethan	Yellow		1021	Full painted pipes
Flammable gases	Low Flashpoint Fuel	Methan	Yellow		1021	Full painted pipes

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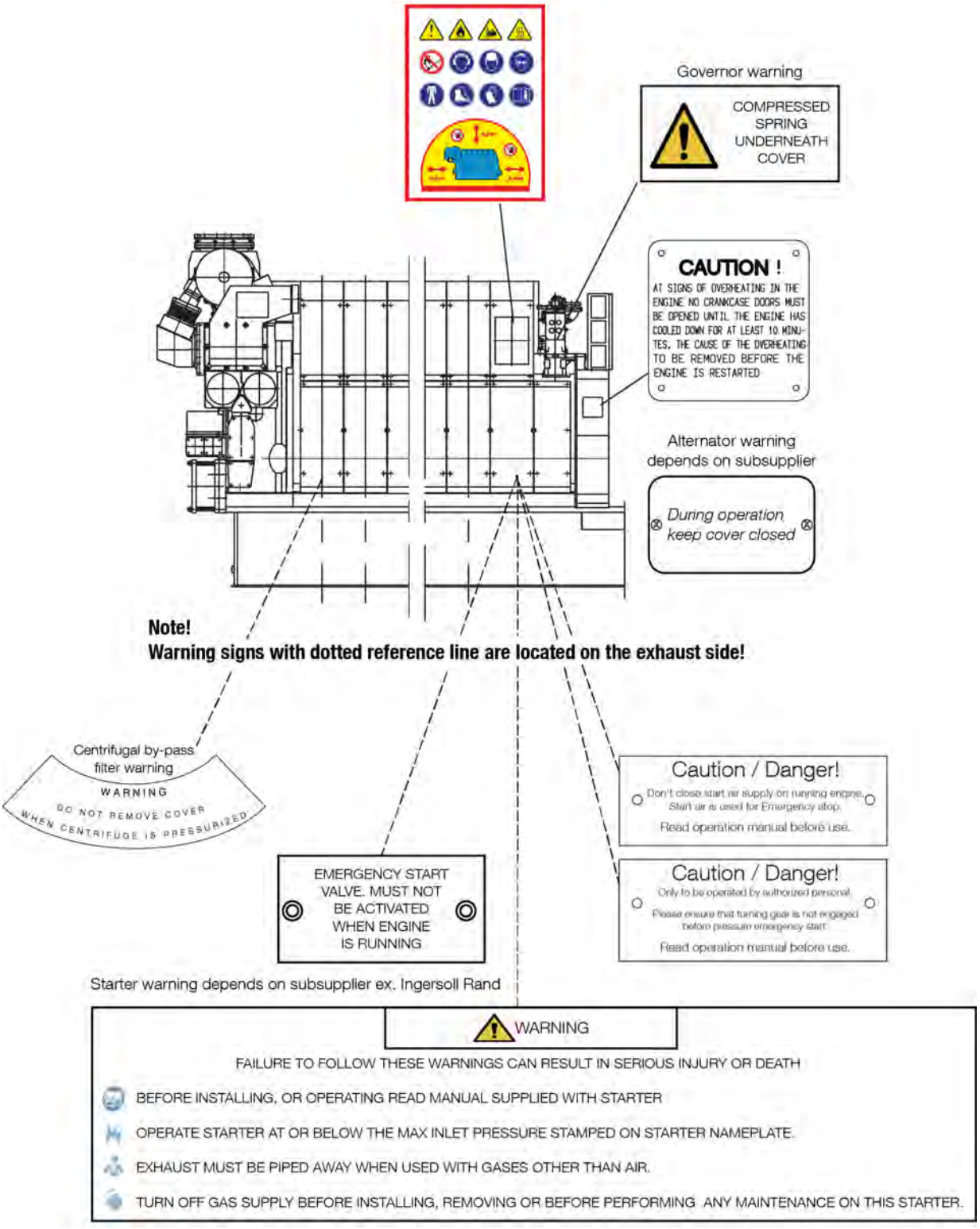
System	Medium	Label	Colour name	Colour	RAL	Note
Flammable gases	Low Flashpoint Fuel	Ethanol	Yellow		1021	Full painted pipes
EGR	Acids, alkalis	NaOH	Violet		4001	
SCR	Acids, alkalis	Urea	Violet		4001	
Gas system flushing	Non-flammable gases	Nitrogen	Grey		7001	
Sea water	Sea water [b]	Sea water	Green		6018	
Cooling	Fresh water	Fresh water with inhibitor high / low temperature	Blue		5015	
Heating	Steam	Steam	Silver		9006	
Fire fighting	Fire fighting	CO2	Red		3000	
Working air	Non-flammable gases	Working air 10 bar	Grey		7001	Apply actual pressure
Control	Non-flammable gases	Control air max. 10 bar	Grey		7001	
Ventilation	Air in ventilation systems	Venting	White		9010	
Waste media	Waste media [a]		Black		9005	

[a] Examples: black water, grey water, waste oil, exhaust gas.
[b] For ships with mixed navigation (sea-river ships): all outside waters..

Table 1: Main colors for media and their label text/remarks

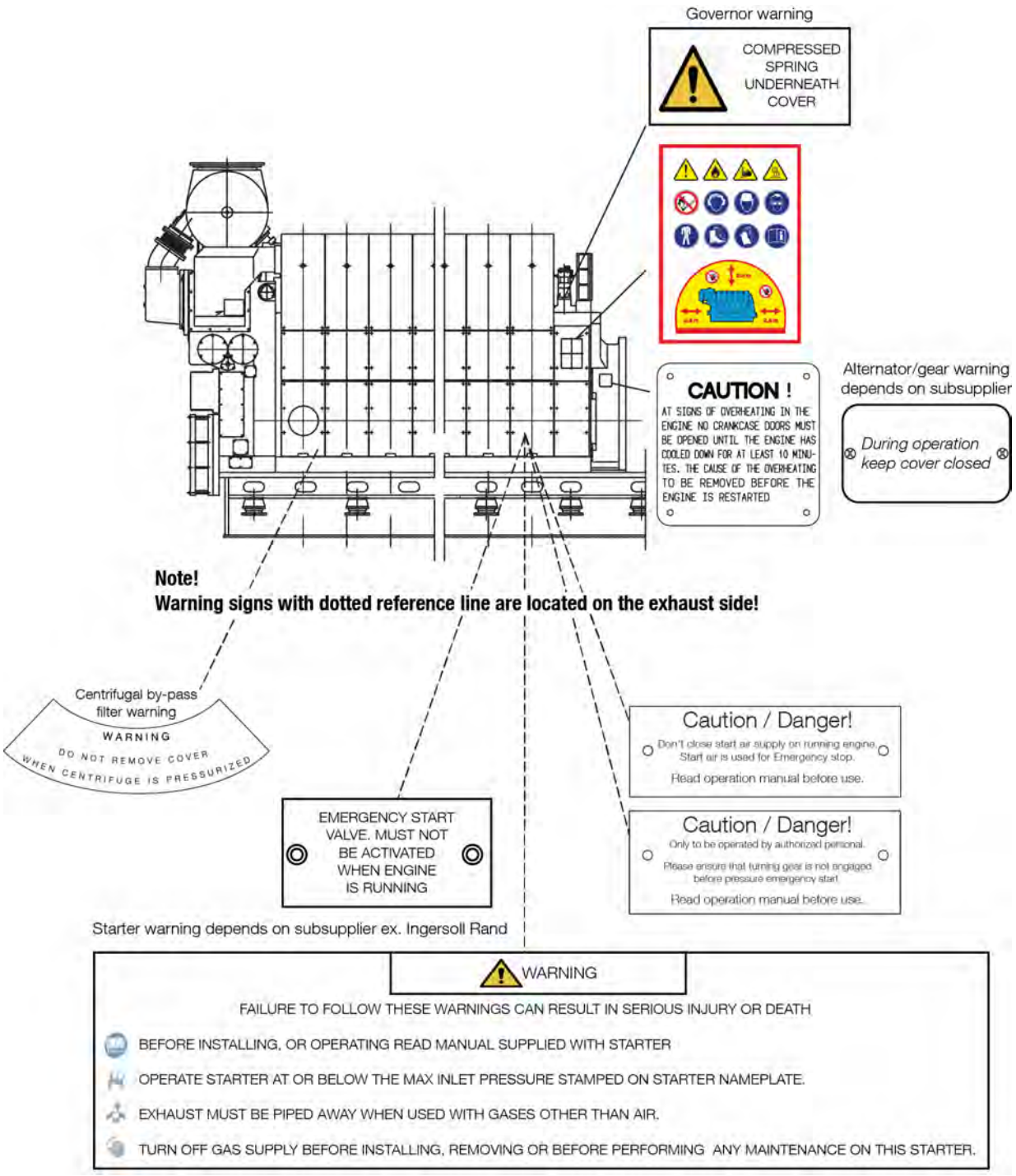
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Placement of warning signs L16/24, L16/24S



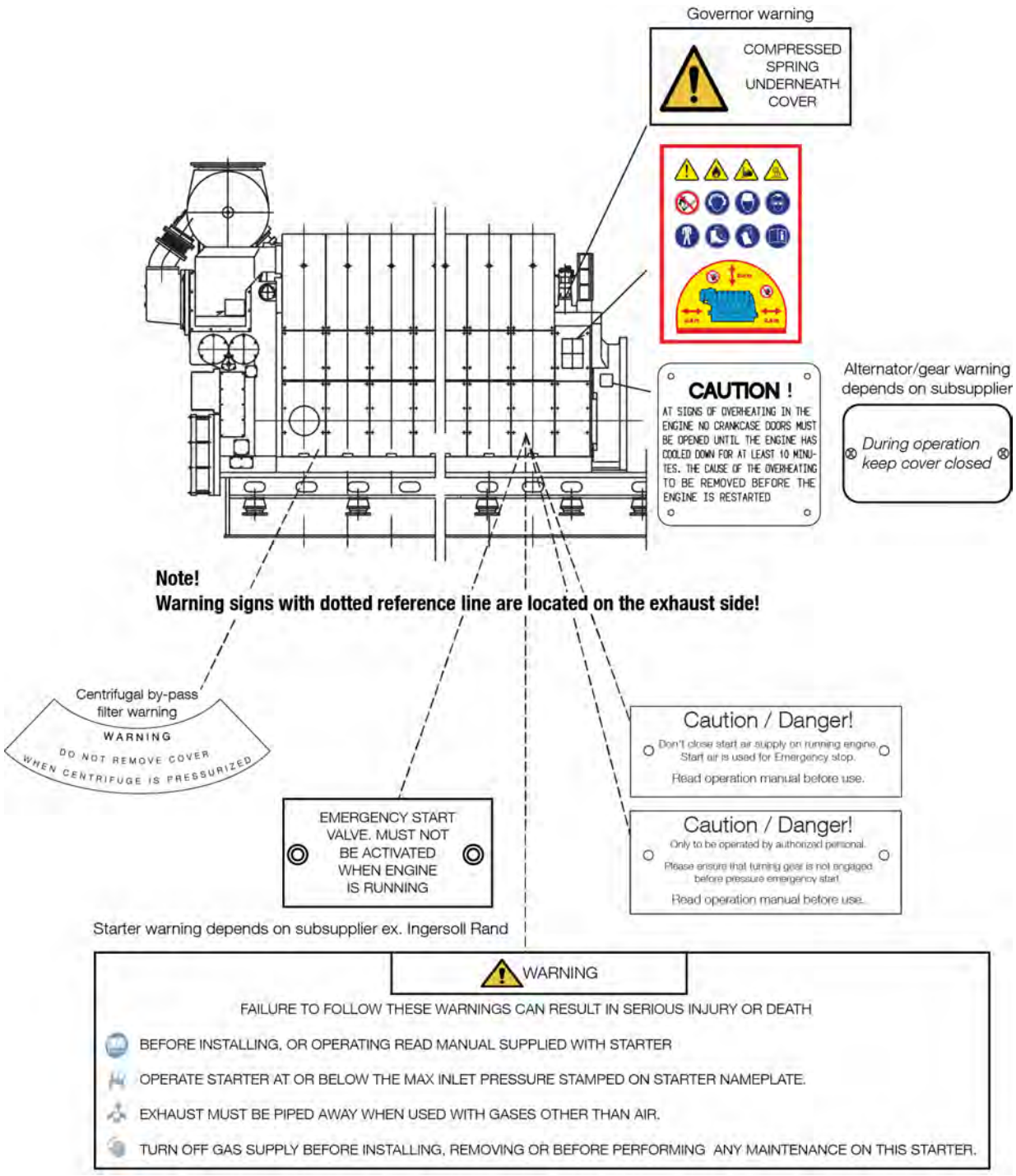
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Placement of warning signs
L21/31, L21/31S, L21/31 Mk2, L21/31 Mk1.1, L21/31DF-M



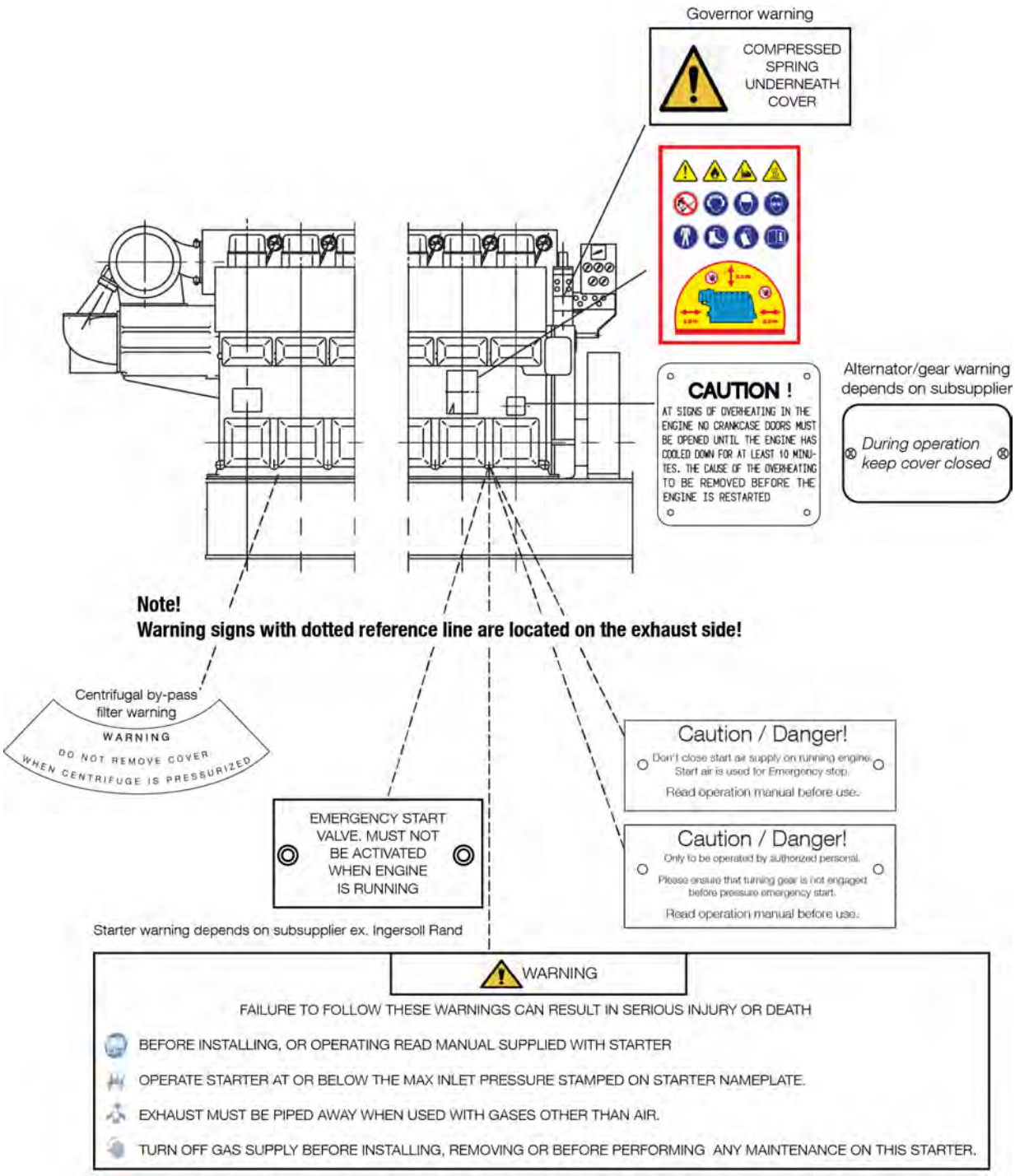
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Placement of warning signs
L27/38, L27/38S, L27/38 Mk2



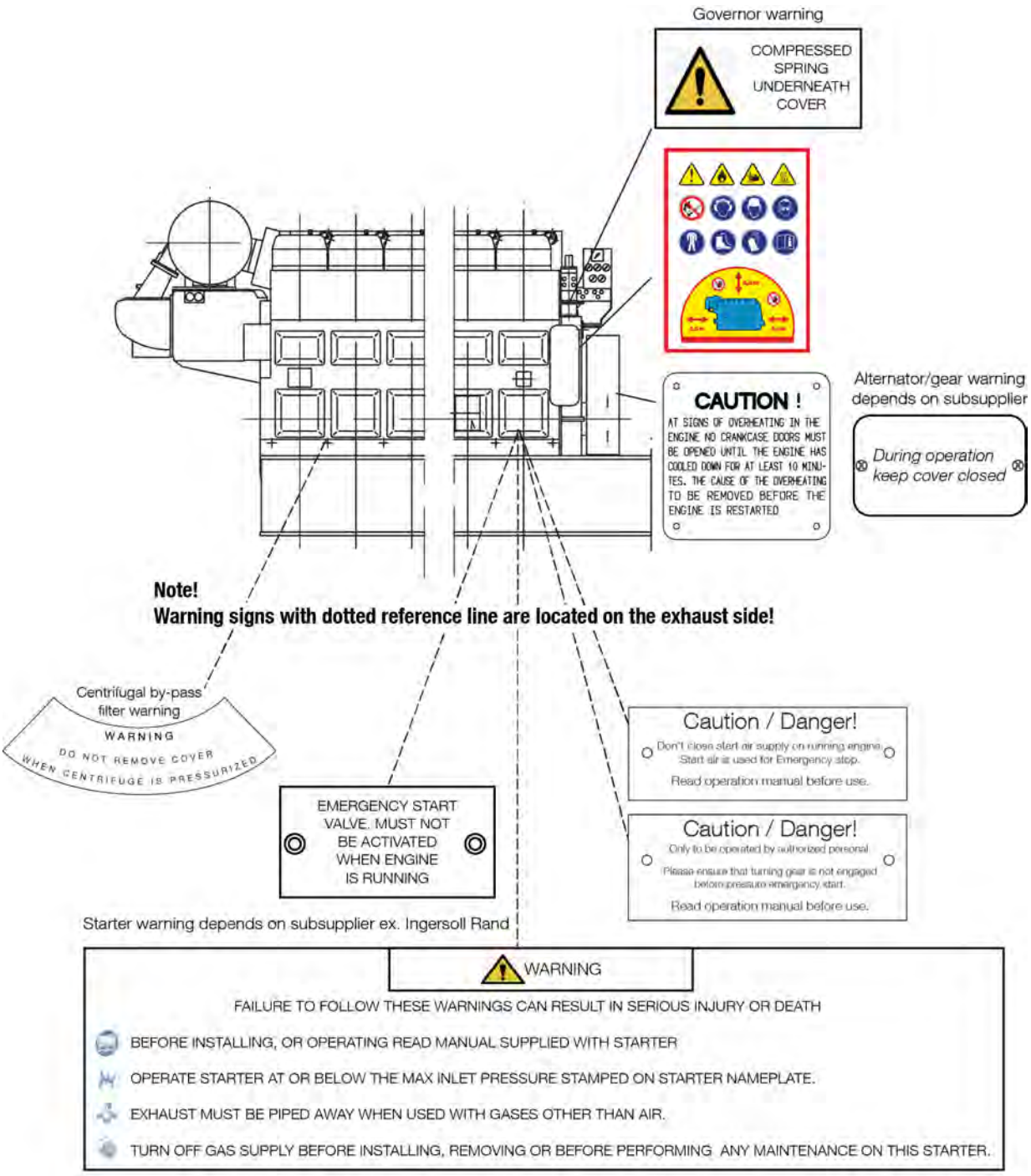
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Placement of warning signs
L23/30A, L23/30H, L23/30H Mk2, L23/30H Mk3, L23/30S, L23/30DF



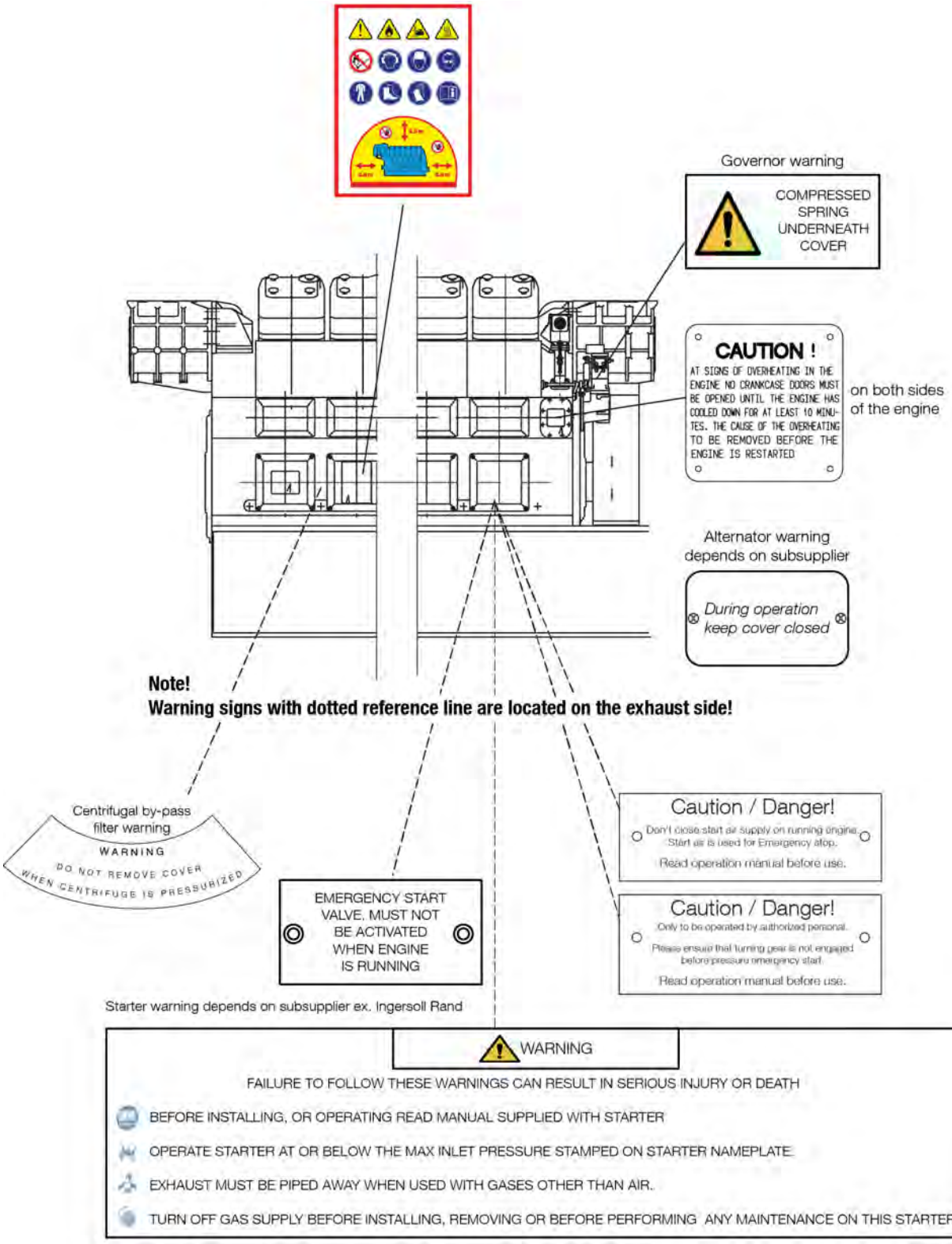
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Placement of warning signs
L28/32A, L28/32H, L28/32S, L28/32DF



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Placement of warning signs
V28/32S



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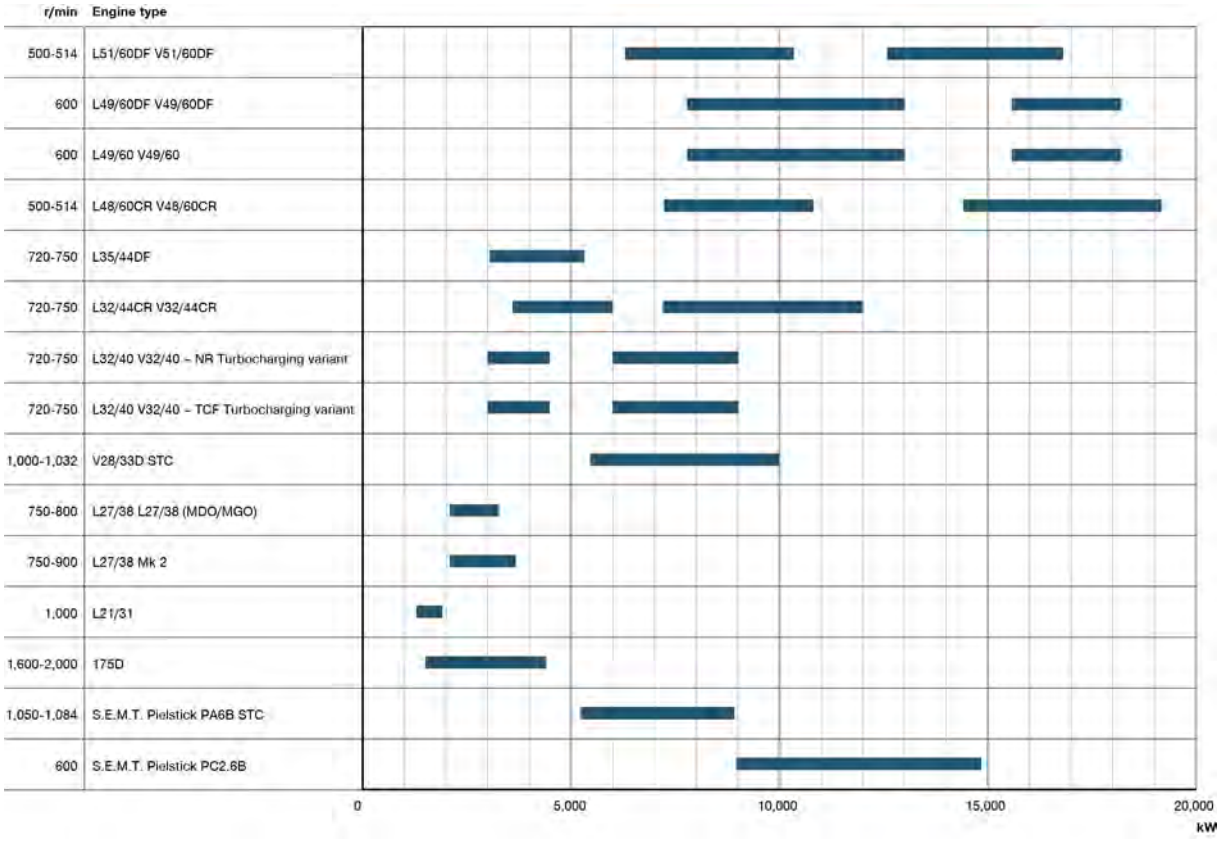
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Marine engine programme

Description

Four-stroke diesel engine programme for marine applications complies with IMO Tier II/III, Propulsion engines.



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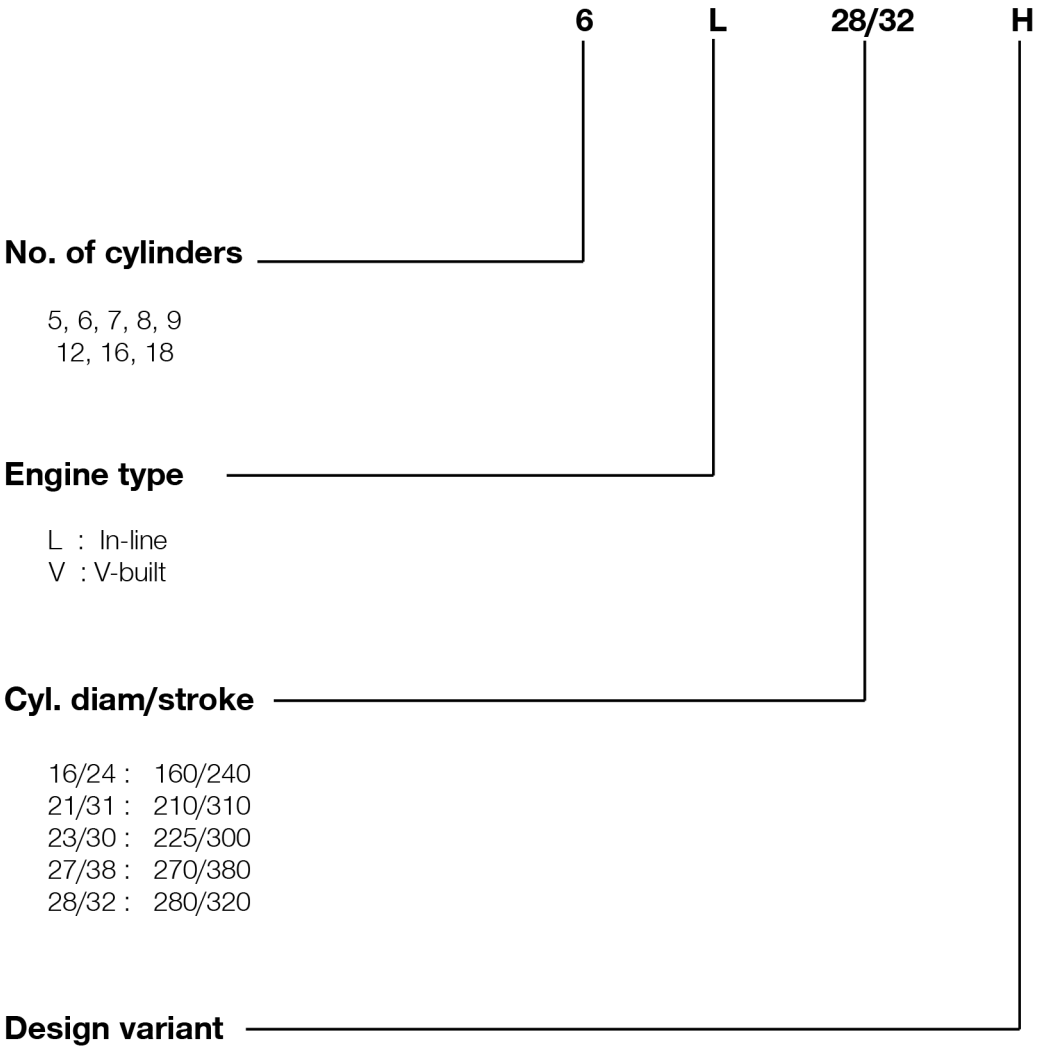
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Key for engine designation

Key for engine designation

The engine types of the Everllence programme are identified by the following figures:

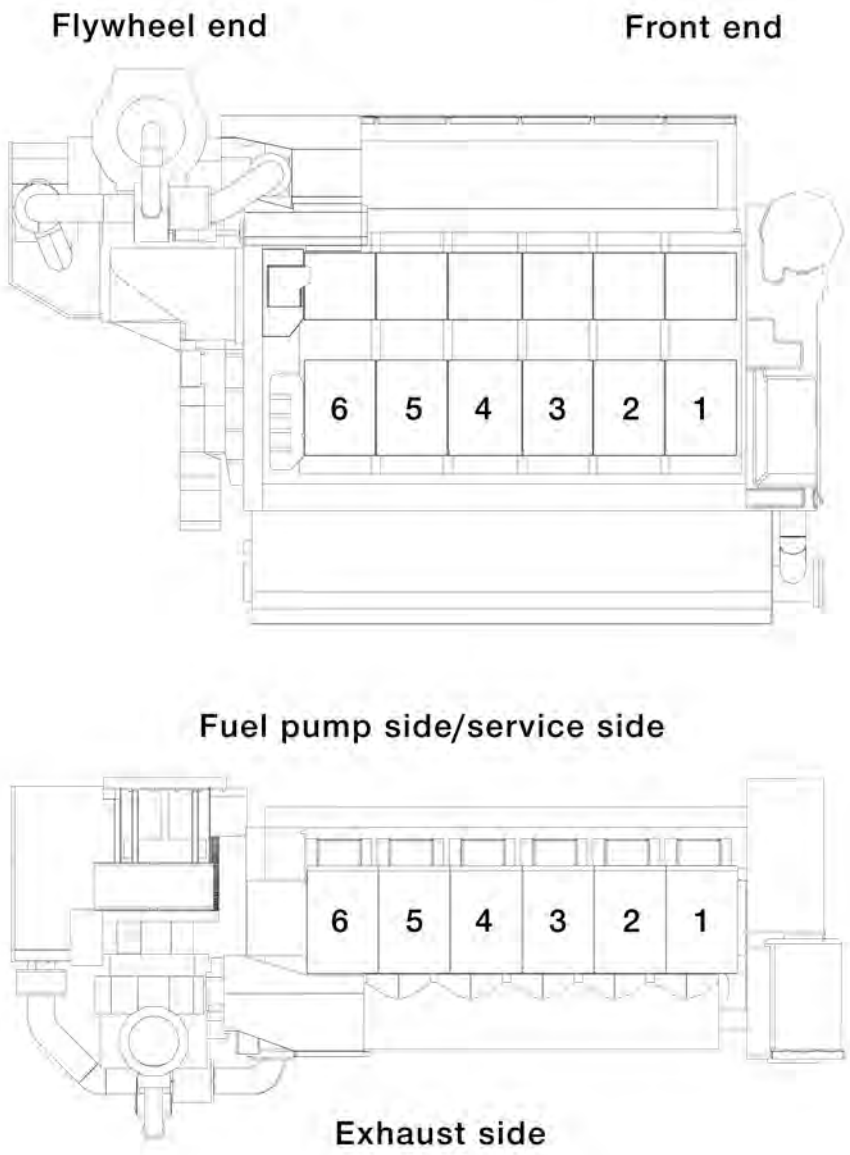


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Designation of cylinders

General

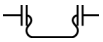


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Symbols for piping

General

No	Symbol	Symbol designation	No	Symbol	Symbol designation
1. GENERAL CONVENTIONAL SYMBOLS			2.13		Blank flange
1.1		Pipe	2.14		Spectacle flange
1.2		Pipe with indication of direction flow	2.15		Orifice
1.3		Valves, gate valves, cocks and flaps	2.16		Orifice
1.4		Appliances	2.17		Loop expansion joint
1.5		Indicating and measuring instruments	2.18		Snap coupling
1.6		High-pressure pipe	2.19		Pneumatic flow or exhaust to atmosphere
1.7		Tracing	3. VALVES, GATE VALVES, COCKS AND FLAPS		
1.8		Enclosure for several components as-sembled in one unit	3.1		Valve, straight through
2. PIPES AND PIPE JOINTS			3.2		Valve, angle
2.1		Crossing pipes, not connected	3.3		Valve, three-way
2.2		Crossing pipes, connected	3.4		Non-return valve (flap), straight
2.3		Tee pipe	3.5		Non-return valve (flap), angle
2.4		Flexible pipe	3.6		Non-return valve (flap), straight screw down
2.5		Expansion pipe (corrugated) general	3.7		Non-return valve (flap), angle, screw down
2.6		Joint, screwed	3.8		Safety valve
2.7		Joint, flanged	3.9		Angle safety valve
2.8		Joint, sleeve	3.10		Self-closing valve
2.9		Joint, quick-releasing	3.11		Quick-opening valve
2.10		Expansion joint with gland	3.12		Quick-closing valve
2.11		Expansion pipe	3.13		Regulating valve

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2.12		Cap nut	3.14		Ball valve (cock)

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No	Symbol	Symbol designation	No	Symbol	Symbol designation
3.15		Butterfly valve	3.37		3/2 spring return valve contr. by solenoid
3.16		Gate valve	3.38		Reducing valve (adjustable)
3.17		Double-seated changeover valve	3.39		On/off valve controlled by solenoid and pilot directional valve and with spring return
3.18		Suction valve chest	4. CONTROL AND REGULATION PARTS		
3.19		Suction valve chest with non-re-turn valves	4.1		Fan-operated
3.20		Double-seated changeover valve, straight	4.2		Remote control
3.21		Double-seated changeover valve, angle	4.3		Spring
3.22		Cock, straight through	4.4		Mass
3.23		Cock, angle	4.5		Float
3.24		Cock, three-way, L-port in plug	4.6		Piston
3.25		Cock, three-way, T-port in plug	4.7		Membrane
3.26		Cock, four-way, straight through in plug	4.8		Electric motor
3.27		Cock with bottom connection	4.9		Electromagnetic
3.28		Cock, straight through, with bot-tom conn.	4.10		Manual (at pneumatic valves)
3.29		Cock, angle, with bottom connec-tion	4.11		Push button
3.30		Cock, three-way, with bottom connection	4.12		Spring
3.31		Thermostatic valve	4.13		Solenoid
3.32		Valve with test flange	4.14		Solenoid and pilot directional valve
3.33		3-way valve with remote control (actuator)	4.15		By plunger or tracer
3.34		Non-return valve (air)	5. APPLIANCES		
3.35		3/2 spring return valve, normally closed	5.1		Mudbox
3.36		2/2 spring return valve, normally closed	5.2		Filter or strainer

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No	Symbol	Symbol designation	No	Symbol	Symbol designation
5.3		Magnetic filter	6. FITTINGS		
5.4		Separator	6.1		Funnel / waste tray
5.5		Steam trap	6.2		Drain
5.6		Centrifugal pump	6.3		Waste tray
5.7		Gear or screw pump	6.4		Waste tray with plug
5.8		Hand pump (bucket)	6.5		Turbocharger
5.9		Ejector	6.6		Fuel oil pump
5.10		Various accessories (text to be added)	6.7		Bearing
5.11		Piston pump	6.8		Water jacket
5.12		Heat exchanger	6.9		Overspeed device
5.13		Electric preheater	7. READING INSTR. WITH ORDINARY DESIGNATIONS		
5.14		Air filter	7.1		Sight flow indicator
5.15		Air filter with manual control	7.2		Observation glass
5.16		Air filter with automatic drain	7.3		Level indicator
5.17		Water trap with manual control	7.4		Distance level indicator
5.18		Air lubricator	7.5		Recorder
5.19		Silencer			
5.20		Fixed capacity pneumatic motor with direction of flow			
5.21		Single acting cylinder with spring returned			
5.22		Double acting cylinder with spring returned			
5.23		Steam trap			

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List of Symbols

General			
Pipe dimensions and piping signature **Pipe dimenesions**			
A : Welded or seamless steel pipes.			B : Seamless precision steel pipes or Cu-pipes.
Normal Diameter DN	Outside Diameter mm	Wall Thickness mm	Stated: Outside diameter and wall thickness i.e. 18 x 2 **Piping** ▬▬▬▬: Built-on engine/Gearbox ▬▬▬▬: Yard supply Items connected by thick lines are built-on engine/ gearbox.
15 20 25 32 40 50 65 80 90 100 125 150 175 200	21.3 26.9 33.7 42.4 48.3 60.3 76.1 88.9 101.6 114.3 139.7 168.3 193.7 219.1	In accordance with classification or other rules	

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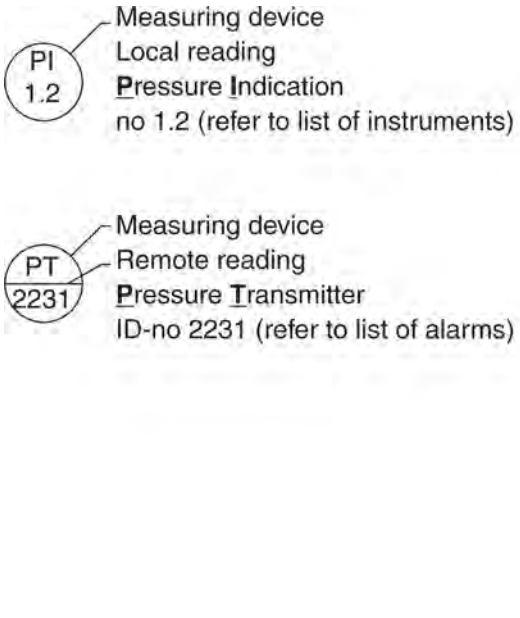
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Symbols for piping

Description

General					
	Pump, general	DIN 2481		Ballcock	
	Centrifugal pump	DIN 2481		Cock, three-way, L-port	
	Centrifugal pump with electric motor	DIN 2481		Double-non-return valve	DIN 74.253
	Gear pump	DIN 2481		Spectacle flange	DIN 2481
	Screw pump	DIN 2481		Spectacle flange, open	DIN 2481
	Screw pump with electric motor	DIN 2481		Spectacle flange, closed	DIN 2481
	Compressor	ISO 1219		Orifice	
	Heat exchanger	DIN 2481		Flexible pipe	
	Electric pre-heater	DIN 2481		Centrifuge	DIN 28.004
	Heating coil	DIN 8972		Suction bell	
	Non-return valve			Air vent	
	Butterfly valve			Sight glass	DIN 28.004
	Gate valve			Mudbox	
	Relief valve			Filter	
	Quick-closing valve			Filter with water trap	ISO 1219
	Self-closing valve			Typhon	DIN 74.253
	Back pressure valve			Pressure reducing valve (air)	ISO 1219
	Shut off valve			Oil trap	DIN 28.004
	Thermostatic valve			Accumulator	
	Pneumatic operated valve			Pressure reducing valve with pressure gauge	

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Specification of letter code for measuring devices

1st letter	Following letters
D : Density E : Electric F : Flow L : Level M ; Moisture P : Pressure S : Speed T : Temperature V : Viscosity Z : Position (ISO 3511/I-1977(E))	A : Alarm D : Difference E : Transducer H : High I : Indicating L : Low N : Closed O : Open S : Switching, shut down T : Transmitter X : Failure C : Controlling Z : Emergency/safety acting
The presence of a measuring device on a schematic diagram does not necessarily indicate that the device is included in our scope of supply. For each plant. The total extent of our supply will be stated formally.	

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General

Specification of ID-no code for measuring signals/devices

1st digit	2nd digit
Refers to the main system to which the signal is related.	Refers to the auxillary system to which the signal is related.
1xxx : Engine	x0xx : LT cooling water
2xxx : Gearbox	x1xx : HT cooling water
3xxx : Propeller equipment	x2xx : Oil systems (lub. oil, cooling oil, clutch oil, servo oil)
4xxx : Automation equipment	x3xx : Air systems (starting air, control air, charging air)
5xxx : Other equipment, not related to the propulsion plant	x4xx : Fuel systems (fuel injection, fuel oil)
	x5xx :
	x6xx : Exhaust gas system
	x7xx : Power control systems (start, stop, clutch, speed, pitch)
	x8xx : Sea water
	x9xx : Miscellaneous (shaft, stern tube, sealing)

The last two digits are numeric ID for devices referring to the same main and aux. system.

Where dublicated measurements are carried out, i.e. multiple similar devices are measuring the same parameter, the ID specification is followed by a letter (A, B, ...etc.), in order to be able to separate the signals from each other.

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Basic symbols for piping

2237	Spring operated safety valve										
2238	Mass operated Safety valve										
2228	Spring actuator										
2284	Float actuator										
2229	Mass										
2231	Membrane actuator										
2230	Piston actuator										
2232	Fluid actuator										
2223	Solenoid actuator										
2234	Electric motor actuator										
2235	Hand operated										
	Basic Symbol										
	Valves	584	585	593	588	592	590	591	604	605	579

584: Valve general
585: Valve with continuous regulation
593: Valve with safety function
588:Straight-way valve
592: Straight-way valve with continuous regulation
590:Angle valve
591: Three-way valve
604: Straight-way non return valve
605: Angle non-return valve
579: Non-return valve, ball type

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	I - bored											
	L - bored											
	T - bored											
2237	Spring operated safety valve											
2238	Mass operated Safety valve											
2228	Spring actuator											
2284	Float actuator											
2229	Mass											
2231	Membrane actuator											
2230	Piston actuator											
2232	Fluid actuator											
2223	Solenoid actuator											
2234	Electric motor actuator											
2235	Hand operated											
	Basic Symbol											
	Valves	594	595	586	587	599	600	601	602	607	608	606

594: Straight-way reduction valve
595: Angle reduction valve
586: Gate valve
587: Gate valve with continuous regulation
599: Straight-way cock
600: Angle cock
601: Three-way cock
602: Four-way cock
607: Butterfly valve
608: Butterfly valve with continuous regulation
606: Non-return valve, flap type

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No	Symbol	Symbol designation	No	Symbol	Symbol designation
Miscellaneous			972		Pipe threaded connection
582		Funnel	xxx		Blind
581		Atomizer	**Tanks**		
583		Air venting	631		Tank with domed ends
6.25		Air venting to the outside	771		Tank with conical ends
299		Normal opening/ closing speed	yyy		Electrical insert heater
300		Quick opening/ closing speed	**Heat exchanger**		
613		Orifice with diffuser	8.03		Electrical preheater
612		Orifice	8.08		Heat exchanger
611		Sight glass	792		Nest of pipes with bends
615		Silencer	798		Plate heat exchanger
617		Berst membrane	**Separators**		
629		Condensate relief	761		Separator
580		Reducer	764		Disc separator
589		Measuring point for thermo element	**Filters**		
1298		Air relief valve	669		Air filter
Couplings/ Flanges			671		Fluid filter
167		Coupling	**Coolers**		
955		Flanged connection	16.03		Cooling tower
971		Clamped connection	16.06		Radiator cooler

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No	Symbol	Symbol designation	No	Symbol	Symbol designation
Chimney			**Pumps**		
838		Chimney	708		Centrifugal pump
Expansion joints			697		Piston pump
2285		Expansion bellow	704		Piston pump - radial
4.1		Expansion pipe	700		Membrane pump
4.1.1.1		Loop expansion joint	702		Gear pump
4.1.1.2		Lyra expansion joint	705		Screw pump
4.1.1.3		Lens expansion joint	706		Mono pump
4.1.1.4		Expansion bellow	703		Hand vane pump
4.1.1.5		Steel tube	**Motors**		
4.1.1.6		Expansion joint with gland	13.14		Electrical motor AC
Compressors			13.14		Electrical motor AC
716		Piston compressor	13.14		Electrical motor AC
725		Turbo axial compressor	13.15		Electrical motor DC
726		Turbo dial compressor	13.15		Electrical motor DC
720		Roots compressor	13.15		Electrical motor DC
722		Screw compressors	13.15		Electrical motor DC
Ventilators			13.15		Electrical motor DC
637		Fan general	13.15		Electrical motor DC
638		Fan - radial	632		Turbine
639		Fan - axial	633		Piston engine

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List of capacities

L21/31 Propulsion - 1000 rpm - 215 kW/cyl - 2 strings

Number of cylinders		5	6	7	8
Engine performance					
Engine load	%	100			
Engine output	kW	1290	1505	1720	1935
Heat to be dissipated [1]					
HT-string					
Charge air cooler (HT stage)	kW	410	465	516	564
Jacket cooling	kW	190	227	266	305
LT-string					
Charge air cooler (LT stage)	kW	279	316	352	387
Lube oil cooler [2]	kW	220	259	300	340
Heat radiation (engine)	kW	39	46	53	59
Engine room temperature	°C	55			
CW - Cooling water					
HT-string					
CW temp. after cooling system (HT)	°C	65.0			
CW temp. before cooling system (HT)	°C	82.0	82.5	83.1	83.6
LT-string					
CW temp. after cooling system (LT)	°C	38.0			
CW temp. before cooling system (LT)	°C	46.6	48.0	49.3	50.6
Air data					
Temperature of charge air					
at compressor outlet	°C	258	259	259	260
at charge air cooler outlet	°C	53.5	55.7	57.5	59.0
Air flow rate	kg/kWh	7.41			
Charge air pressure (abs.)	bar	4.25	4.27	4.28	4.30
Air consumption per start, incl. jet assist [3]					
10 bar air starter	Nm^3	1.2	1.4	1.6	1.8
30 bar air starter	Nm^3	2.1	2.4	2.7	3.0
Exhaust gas data [4]					
Mass flow	t/h	9.8	11.5	13.1	14.7
Exhaust gas temperature at turbine inlet	°C	556	558	560	562
Exhaust gas temperature at turbine outlet	°C	360	361	363	364

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Number of cylinders		5	6	7	8
Heat content	kW	502	591	681	772
Reference temp. for exhaust heat content	°C	190			
Exhaust gas back pressure at T/C outlet (max.)	mbar	50			
Pumps					
Engine driven pumps					
HT-string circuit	m^3/h	50.0			
LT-string circuit	m^3/h	50.0			
Lube oil circuit	m^3/h	60.0		84.0	
External flow [5]					
HT CW flow from and to cooling system	m^3/h	31.0	34.6	37.9	41.0
LT CW flow from and to cooling system	m^3/h	50.0			
External pumps [6]					
HT CW pump [2.5 bar]	m^3/h	40			
LT CW pump [2.5 bar]	m^3/h	35			
Lube oil pump [4.5 bar]	m^3/h	45		65	
Diesel oil pump [3.5 bar at fuel oil inlet B3]	m^3/h	0.97	1.13	1.29	1.45
Fuel oil supply pump [4 bar discharge pressure]	m^3/h	0.47	0.54	0.62	0.70
Fuel oil circulating pump [8 bar at fuel oil inlet B3]	m^3/h	0.98	1.14	1.31	1.47
Temperature setpoints					
HT CW engine outlet (nominal) [7]	°C	79			
LT CW engine outlet (nominal) [8]	°C	35			
Lube oil engine inlet (nominal)	°C	66			
Reference conditions		*Tropic*			
Air temperature	°C	45			
Relative humidity	%	60			
Air pressure	bar	1			

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Remarks to capacities

1) Tolerances (heat to be dissipated): +10 % for rating coolers, -15 % for heat recovery from HT- or LT- or lube oil system.
2) Addition required for separator heat (e.g. 30 kJ/kWh).
3) Starting air system consumption is based on start using SaCoS (manual start would require less amount of air). Starting jet assist consumption depends on specific turbo charger present: TCR14,16 0.40-0.65 Nm^3; TCR18,20 0.65-0.80 Nm^3.
4) Tolerances (exhaust gas data): ±20 °C for temperature at turbine outlet, ±5 % for flow quantity.
5) Stated external flow (from engine to system) is considered with stated exemplary "CW temp. behind cooling system". This CW temperature depends on cooler size and seawater temperature. Please be aware, that due to engine internal thermostat, only certain amount of total flow through engine will be available at external system.
6) Tolerances (external pumps - delivery capacities): must be considered by manufacturers.
7) HT CW flows first through HT stage charge air cooler, and then through water jacket and cylinder head. Subsequently, water temperature is regulated by mechanical thermostat.
8) LT CW flows first through LT stage charge air cooler, and then through lube oil cooler. Subsequently, water temperature is regulated by mechanical thermostat.

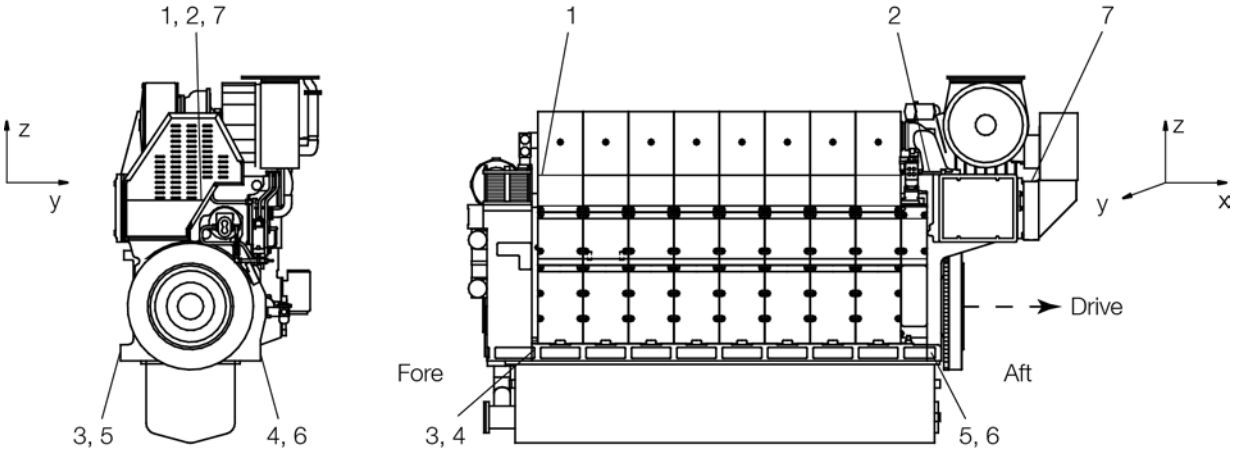
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Vibration limits and measurements

Propulsion

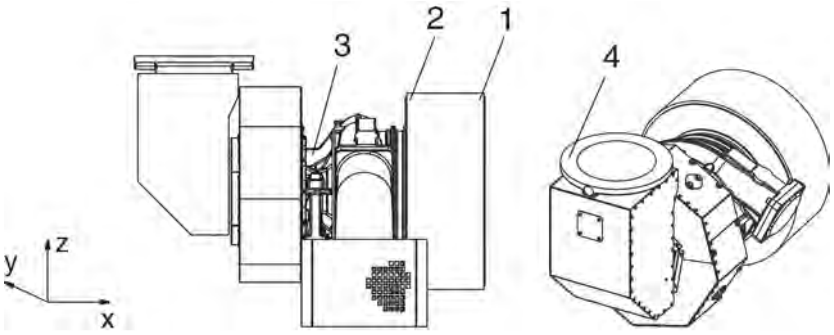


Measurement point	Description	Limit		Measurement point	Description	Limit
1	Frame uppper edge, Fore	35		5	Frame lower edge Front A-side	35
2	Frame, Aft	35		6	Frame lower edge Front B-side	35
3	Frame lower edge Aft A-side	35		7	Turbocharger, foot	35
4	Frame lower edge Aft B-side	35				

Date	Running Hours	Load %	Vertical (z)										
			1	2	3	4	5	6	7	8	9	10	11
		100											
			Crosswise (y)										
		100											
			Longitudinal (x)										
		100											

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Turbocharger



Vibration acceleration measuring point, see the project guide for turbocharger.

Turbocharger type		Recommendation						Contact engine builder					
		Meas. pt (1)		Meas. pt (2+3)		Meas. pt (4)		Meas. pt (1)		Meas. pt (2+3)		Meas. pt (4)	
	f (Hz)	mm/s	g	mm/s	g	mm/s	g	mm/s	g	mm/s	g	mm/s	g
TCR10	3-300	45	2.9	35	2.2	45	2.9	100	6.4	50	3.2	90	5.8
TCR12 NR12			2.6		2.0		2.6		5.8		2.9		5.2
TCR14 NR14, NR15, NR17			2.0		1.6		2.0		4.5		2.2		4.0
TCR16 NR20			1.7		1.4		1.7		3.8		1.9		3.5
TCR18 NR20, NR24			1.4		1.1		1.4		3.2		1.6		2.9
TCR20 NR24, NR26			1.2		0.9		1.2		2.6		1.3		2.3
TCR22			0.9		0.7		0.9		1.9		1.0		1.7

Turbocharger vibration limit values - measuring point

Date	Running Hours	Load %	Vertical (z) (Turbocharger oriented)											
			1	2	3	4	5	6	7	8	9	10	11	12
Shop test		100												
			Crosswise (y) (Turbocharger oriented)											
		100												
			Longitudinal (x) (Turbocharger oriented)											
		100												

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Exhaust gas components

Exhaust gas components of medium speed four-stroke diesel engines

The exhaust gas is composed of numerous constituents which are formed either from the combustion air, the fuel and lube oil used or which are chemical reaction products formed during the combustion process. Only some of these are to be considered as harmful substances.

For the typical exhaust gas composition of a Everllence four-stroke engine without any exhaust gas treatment devices, please see tables below (only for guidance). All engines produced currently fulfil IMO Tier II.

Carbon dioxide CO_2

Carbon dioxide (CO2) is a product of combustion of all fossil fuels.

Among all internal combustion engines the diesel engine has the lowest specific CO2 emission based on the same fuel quality, due to its superior efficiency.

Sulphur oxides SO_x

Sulphur oxides (SO_x) are formed by the combustion of the sulphur contained in the fuel.

Among all propulsion systems the diesel process results in the lowest specific SOx emission based on the same fuel quality, due to its superior efficiency.

Nitrogen oxides NO_x

The high temperatures prevailing in the combustion chamber of an internal combustion engine causes the chemical reaction of nitrogen (contained in the combustion air as well as in some fuel grades) and oxygen (contained in the combustion air) to nitrogen oxides (NO_x).

Carbon monoxide CO

Carbon monoxide (CO) is formed during incomplete combustion.

In Everllence four-stroke diesel engines, optimisation of mixture formation and turbocharging process successfully reduces the CO content of the exhaust gas to a very low level.

Hydrocarbons HC

The hydrocarbons (HC) contained in the exhaust gas are composed of a multitude of various organic compounds as a result of incomplete combustion. Due to the efficient combustion process, the HC content of exhaust gas of Everllence four-stroke diesel engines is at a very low level.

Particulate matter PM

Particulate matter (PM) consists of soot (elemental carbon) and ash.

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Main exhaust gas constituents	approx. [% by volume]	approx. [g/kWh]
Nitrogen N_2	74.0 - 76.0	5,020 - 5,160
Oxygen O_2	11.6 - 13.2	900 - 1,030
Carbon dioxide CO_2	5.2 - 5.8	560 - 620
Steam H_2O	5.9 - 8.6	260 - 370
Inert gases Ar, Ne, He ...	0.9	75
Total	> 99.75	7,000

Additional gaseous exhaust gas constituents considered as pollutants	approx. [% by volume]	approx. [g/kWh]
Sulphur oxides SO_x[1]	0.07	10.0
Nitrogen oxides NO_x[2]	0.07 - 0.10	8.0 - 10.0
Carbon monoxide CO[3]	0.006 - 0.011	0.4 - 0.8
Hydrocarbons HC[4]	0.01 - 0.04	0.4 - 1.2
Total	< 0.25	26

Additional suspended exhaust gas constituents, PM[5]	approx. [mg/Nm³]		approx. [g/kWh]	
	operating on		operating on	
	MGO[6]	HFO[7]	MGO[6]	HFO[7]
Soot (elemental carbon)[8]	50	50	0.3	0.3
Fuel ash	4	40	0.03	0.25
Lube oil ash	3	8	0.02	0.04

Note!
At rated power and without exhaust gas treatment.

1) SO_x, according to ISO-8178 or US EPA method 6C, with a sulphur content in the fuel oil of 2.5% by weight.
2) NO_x according to ISO-8178 or US EPA method 7E, total NO_x emission calculated as NO_2.
3) CO according to ISO-8178 or US EPA method 10.
4) HC according to ISO-8178 or US EPA method 25A.
5) PM according to VDI-2066, EN-13284, ISO-9096 or US EPA method 17; in-stack filtration.
6) Marine gas oil DM-A grade with an ash content of the fuel oil of 0.01% and an ash content of the lube oil of 1.5%.
7) Heavy fuel oil RM-B grade with an ash content of the fuel oil of 0.1% and an ash content of the lube oil of 4.0%.
8) Pure soot, without ash or any other particle-borne constituents.

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Description of sound measurements

General

Purpose

This should be seen as an easily comprehensible sound analysis of Everllence GenSets. These measurements can be used in the project phase as a basis for decisions concerning damping and isolation in buildings, engine rooms and around exhaust systems.

Measuring equipment

All measurements have been made with Precision Sound Level Meters according to standard IEC Publication 651or 804, type 1 – with 1/1 or 1/3 octave filters according to standard IEC Publication 225. Used sound calibrators are according to standard IEC Publication 942, class 1.

Definitions

Sound Pressure Level: $L_P = 20 \times \log P/P_0$ [dB]

where P is the RMS value of sound pressure in pascals, and P_0 is 20 µPa for measurement in air.

Sound Power Level: $L_W = 10 \times \log P/P_0$ [dB]

where P is the RMS value of sound power in watts, and P_0 is 1 pW.

Measuring conditions

All measurements are carried out in one of Everllence' test bed facilities.

During measurements, the exhaust gas is led outside the test bed through a silencer. The GenSet is placed on a resilient bed with generator and engine on a common base frame.

Sound Power is normally determined from Sound Pressure measurements.

New measurement of exhaust sound is carried out at the test bed, unsilenced, directly after turbocharger, with a probe microphone inside the exhaust pipe.

Previously used method for measuring exhaust sound are DS/ISO 2923 and DIN 45635, here is measured on unsilenced exhaust sound, one meter from the opening of the exhaust pipe, see fig.1.

Sound measuring "on-site"

The Sound Power Level can be directly applied to on-site conditions. It does not, however, necessarily result in the same Sound Pressure Level as measured on test bed.

Normally the Sound Pressure Level on-site is 3-5 dB higher than the given surface Sound Pressure Level (L_{pf}) measured at test bed. However, it depends strongly on the acoustical properties of the actual engine room.

Standards

Determination of Sound Power from Sound Pressure measurements will normally be carried out according to:

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ISO 3744 (Measuring method, instruments, background noise, no of microphone positions etc) and ISO 3746 (Accuracy due to criterion for suitability of test environment, K2>2 dB).

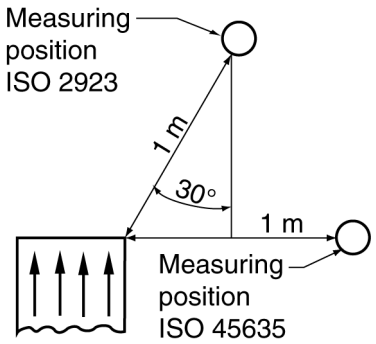


Figure 1: .

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Description of structure-borne noise

Introduction

This paper describes typical structure-borne noise levels from standard resiliently mounted Everllence small-bore engines. The levels can be used in the project phase as a reasonable basis for decisions concerning damping and insulation, engine rooms and surroundings in order to avoid noise and vibration problems.

References

References and guidelines according to ISO 9611 and ISO 11689.

Operating condition

Levels are valid for standard resilient mounted engine on flexible rubber support of 55° sh (A) on relatively stiff and well-supported foundations.

Frequency range

The levels are valid in the frequency range 31.5 Hz to 4 kHz.

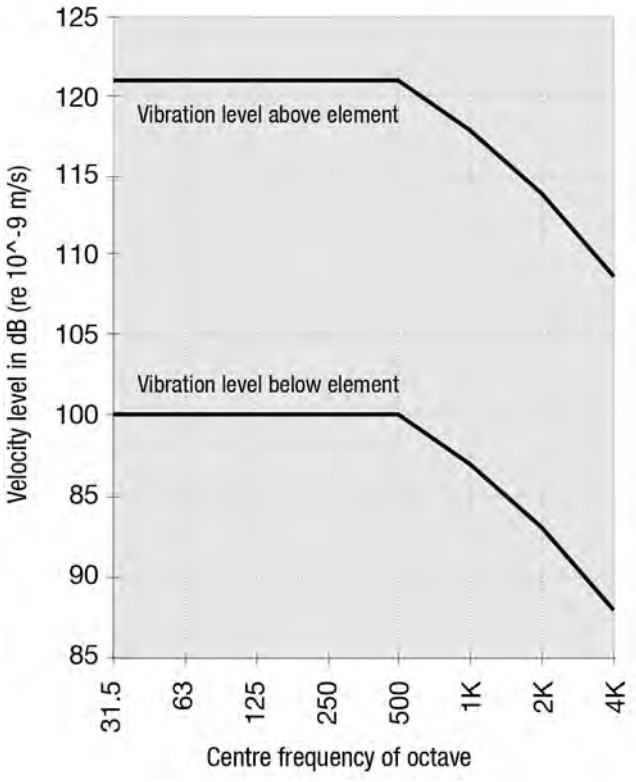


Figure 1: Structure-borne noise on resiliently mounted engine.

Stiffness according to minimum requirement, see "*Recommendations concerning steel foundations for resilient mounted GenSets, B 20 01 0*"

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Foundation for engine

External forces and moments

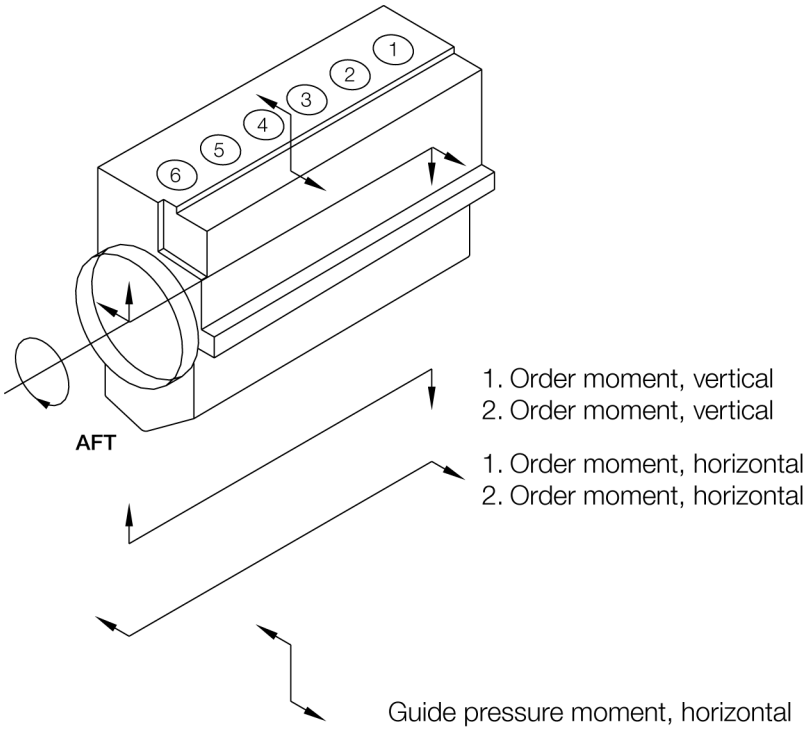


Figure 1: .

Engine Type	rpm	1 order moment		2 order moment		Free forces		Guide pressure moment	
		Horizontal kNm	Vertical kNm	Horizontal kNm	Vertical kNm	Horizontal kN	Vertical kN	kNm	Hz
6L21/31	1000	0	0	0	0	0	0	14.18 11.05	50 1000
7L21/31	1000	0	9.33	0	7.95	0	0	24.76 3.84	58.3 116.7
8L21/31	1000	0	0	0	0	0	0	20.90 2.22	66.7 133.3
9L21/31	1000	0	6.76	0	4.33	0	0	19.66 1.03	75 150

The details given in this chapter are important for dimensioning the engine foundation and the aft structure of the vessel.

The forces and moments, arising due to weight, and operation of the engine must be taken into consideration when designing the engine foundation. For information on forces and moments, *see fig 1*.

We recommend the clearance between the tanktop and oil pan of the engine to be min 15 mm, when the engine/reduction gear is placed on the top plates without chocks.

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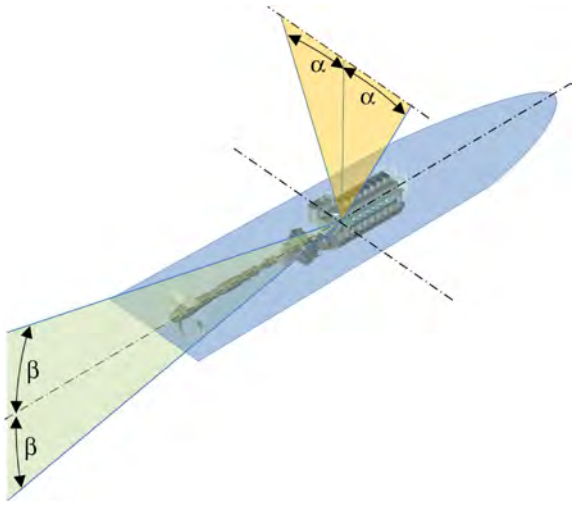
Inclination of engines

Description

All engines are as standard designed for and approved by leading classification societies to be in accordance with IACS's demands for inclination of ships, that means the following angles (°) of inclination.

Max. permissible angle of inclination [°] [1]					
Application	Athwartships α		Fore and aft β		
	Heel to each side (static)	Rolling to each side (dynamic)	Trim (static) [2]		Pitching (dynamic)
			L < 100 m	L > 100 m	
GenSet/ Main engines	15	22.5	5	500/L	7.5

[1] Athwartships and fore and aft inclinations may occur simultaneously.
[2] Depending on length L of the ship.



α Athwartships β Fore and aft

Figure 1: Angle of inclination.

NOTICE

For higher requirements contact Everllence. Arrange engines always lengthwise of the ship.

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Green Passport

Green Passport

In 2009 IMO adopted the „Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships, 2009“.

Until this convention enters into force the recommendatory guidelines “Resolution A.962(23)” (adopted 2003) apply. This resolution has been implemented by some classification societies as “Green Passport”.

Everllence is able to provide a list of hazardous materials complying with the requirements of the IMO Convention. This list is accepted by classification societies as a material declaration for “Green Passport”.

This material declaration can be provided on request.

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General description

Design criteria for L21/31

Decisive parameters for a propulsion engine are the requirements for a compact engine design and long term reliability in operation.

However, other requirements as mentioned below, have been given high priority:

- Long time between overhauls (TBO)
- No unscheduled maintenance and repair work
- Unrestricted heavy fuel oil operation
- Low fuel and lub oil consumption rates, fulfilling legal emission limit values
- High maintenance and operation friendliness
- Good acceleration and part load behaviour
- Easy installation, rigidly or resiliently seated

Engine frame and crankshaft

The monobloc nodular cast iron engine frame forms the most vital part of the engine. Through-going main bearing tie rods and the deeply positioned cylinder head tie rods maintain a static preloading of the casting, thereby absorbing dynamic loads attained from gas and mass forces, with a high safety margin. All tie rods are tightened hydraulically.

Well supported main bearings carry the crankshaft with generously dimensioned journals. The combination of a stiff frame design and the carefully balanced crankshaft ensure that the engine is running smoothly and free of vibrations.

Front-end box

A unique feature is the introduction of the front-end box, arranged at the free end of the engine. It contains integrated ducts for cooling water and lubricating oil systems as well as pumps (plug-in units), thermostatic valve elements, lub oil cooler and the automatic back-flushing lub oil filter.

In order to reduce the engine installation length, external pipe connections are arranged on the sides of the front-end box.

The optional PTO is located on the front-end.

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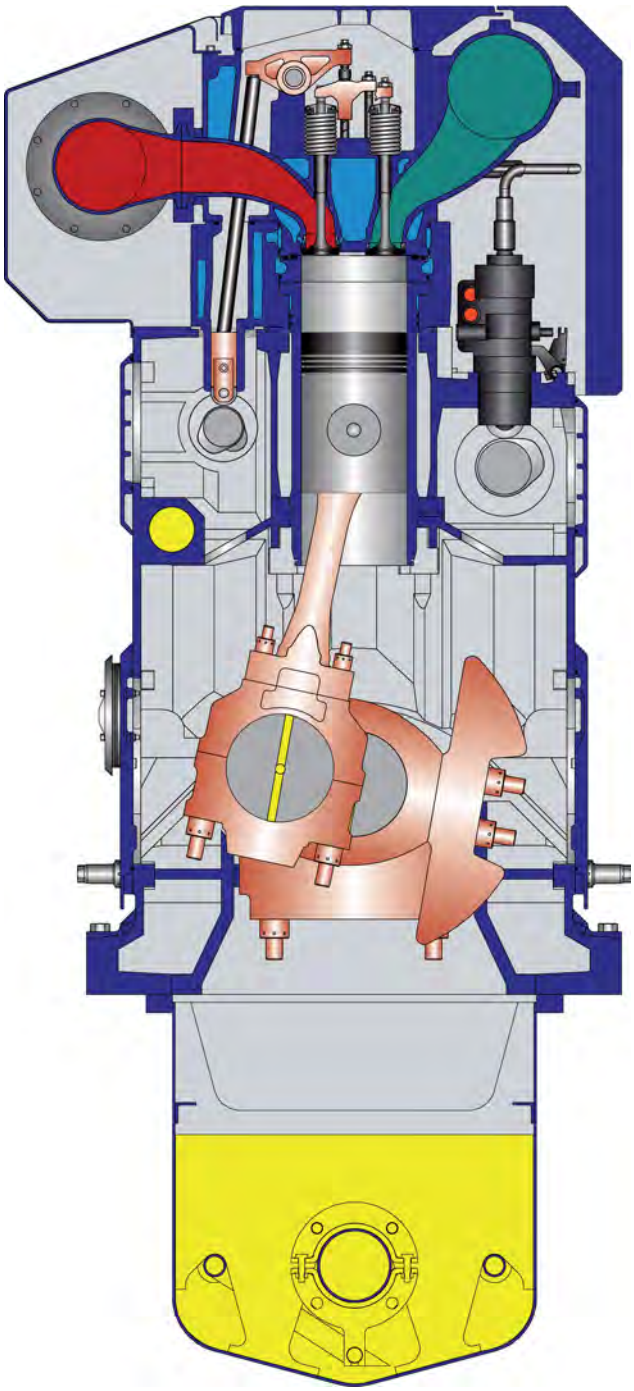


Figure 1: Sectional view of the L21/31 engine

Cylinder unit

The cylinder unit incorporating cylinder head, water jacket, piston and connecting rod can either be withdrawn/ installed as a complete unit or as individual components, depending on the available space conditions.

The cylinder liner features a flame ring in the top. The purpose is to control the coke deposits on the piston top land and thereby avoid bore polishing of the cylinder liner. This will ensure optimal ring performance and low lub oil consumption.

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The piston is a composite piston with steel crown and a nodular cast iron body. A wear resistant chrome layer on the piston rings ensures long TBOs.

The robust connecting rod is of the marine head type with the joint above the marine head and fitted with hydraulically tightened units. During piston withdrawal, the marine head remains on the journal, saving dismantling space and at the same time protecting the journal.

The “cross-flow” cylinder head in nodular cast iron has two inlet valves and two exhaust valves – all rotating in order to minimize wear and to equalize temperatures. Together with the direct cooled exhaust valve seat rings, a reliable operation is ensured.

Turbocharging, charge air cooler

The turbocharging system is based on the constant pressure principle, using the newly developed radial flow type Everllence turbochargers.

Starting air system

The engine is started by means of a built-on air starter, controlled from the instrument panel on the engine or from the remote control system.

In case of electric power failure, an emergency starting facility can be activated. A cranking device is fitted on the engine.

Lubricating oil system

The engine features an entirely closed lub oil system which ensures easy installation on board and no risk of dirt entering the lub oil circuit.

The helical gear type lub oil pump is mounted in the front-end box, with suction from the oil pan.

Via a pressure regulator, the oil flows through the lub oil plate cooler and the full-flow automatic backflushing lub oil filter. This solution eliminates exchange of filter cartridges as well as the waste disposal problem.

The back-flush oil is drained to the sump. A purifier is to be connected to maintain proper condition of the lub oil.

An integrated thermostatic valve ensures a constant lub oil temperature to the engine.

Cooling water system

The cooling water system is based on separate low and high temperature systems. Both circuits are cooled by fresh water.

HT system

The water is circulated by the HT pump through the first stage of the charge air cooler, the jacket water collar, cylinder heads and thermostatic valve, through the high temperature cooler, back to the HT pump. Nearly 100% of the heat removed from the high temperature system can be utilized for heat recovery.

LT system

The water is circulated by the LT pump through the second stage of the charge air cooler, the lub oil coolers (for engine and gearbox), the high temperature cooler, and finally through the central cooler and back to the LT pump.

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L21/31 Propulsion

The concept

Many years of experience with the propulsion concept, together with customers' requirements for reliability, economy and technical advancement has resulted in this attractive 1000 rpm engine with a cylinder output of 215 kW.

Combined with gearboxes, CP propellers and control systems, the L21/31 is a fully integrated propulsion package for tugs, fishing vessels, small ferries and coasters requiring an output ranging from 1290–1935 kW.

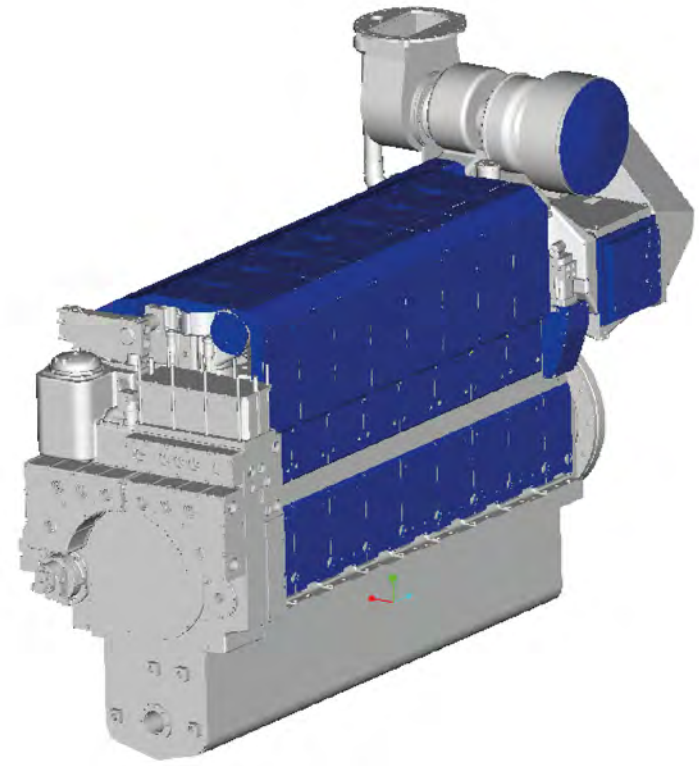


Figure 1: the L21/31 propulsion engine

Installation aspects

The development target and design philosophy were to achieve the shortest possible propulsion system by optimizing the combination of engine, flexible coupling and gearbox.

Low dismantling height for cylinder head, piston and cylinder liner is ensured thanks to the marine head connecting rod.

The engine front-end box incorporates cooling water pumps, thermostatic valves, lubricating oil pump, lubricating oil cooler and the automatic lubricating oil filter.

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100% PTO is possible from either end of the engine and additionally a small 40 kW PTO is optional on the front-end box for driving a seawater pump or similar.

The turbocharger is located on the engine's aft-end box utilising the space above the compact gearbox, resulting in a very low exhaust gas outlet flange position.

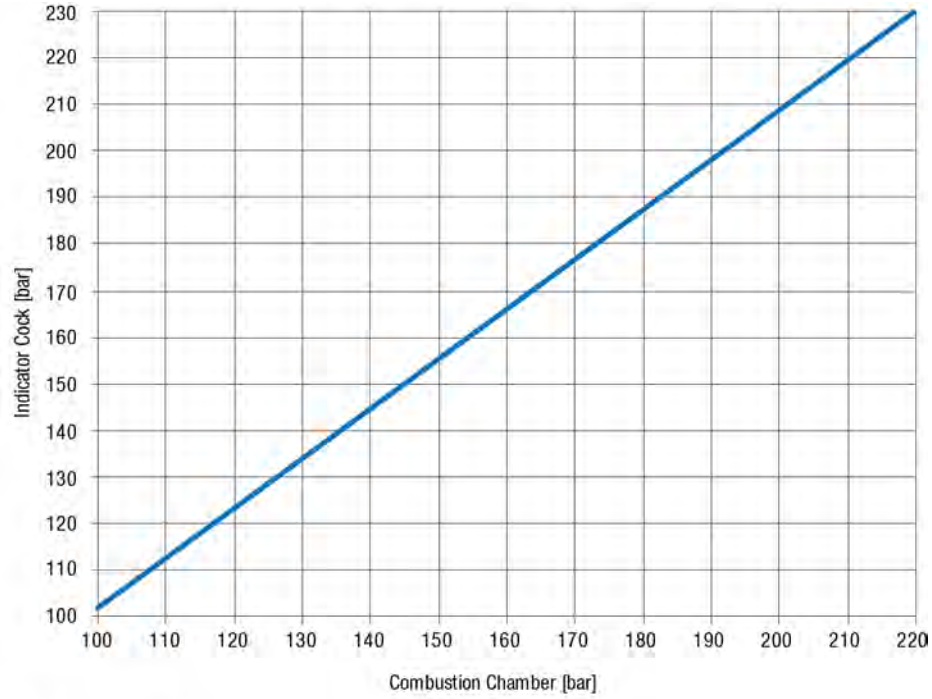
The engine can be delivered for clockwise rotation (standard) or anticlockwise rotation, seen from the flywheel end.

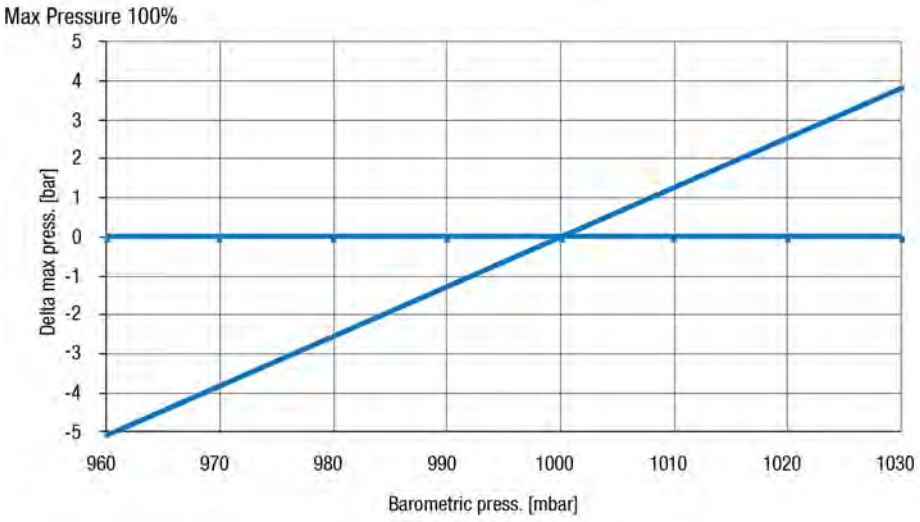
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Firing pressure comparison

Firing pressure comparison

Engine type	Output kW/cyl	Engine speed rpm
GenSet 5 cyl 6-9 cyl	 200 220	 900/1000 900/1000
Propulsion 6-9 cyl	 215	 1000





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Main dimensions

6L21/31

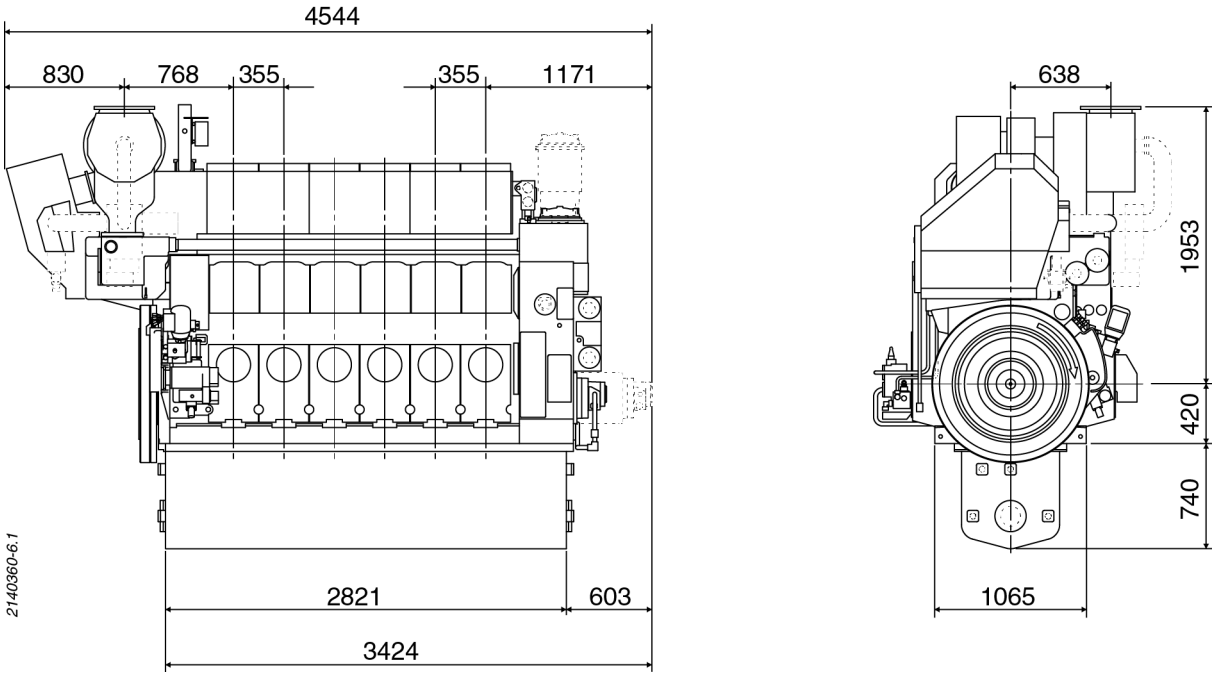


Figure 1: Engine type 6L21/31

7L21/31

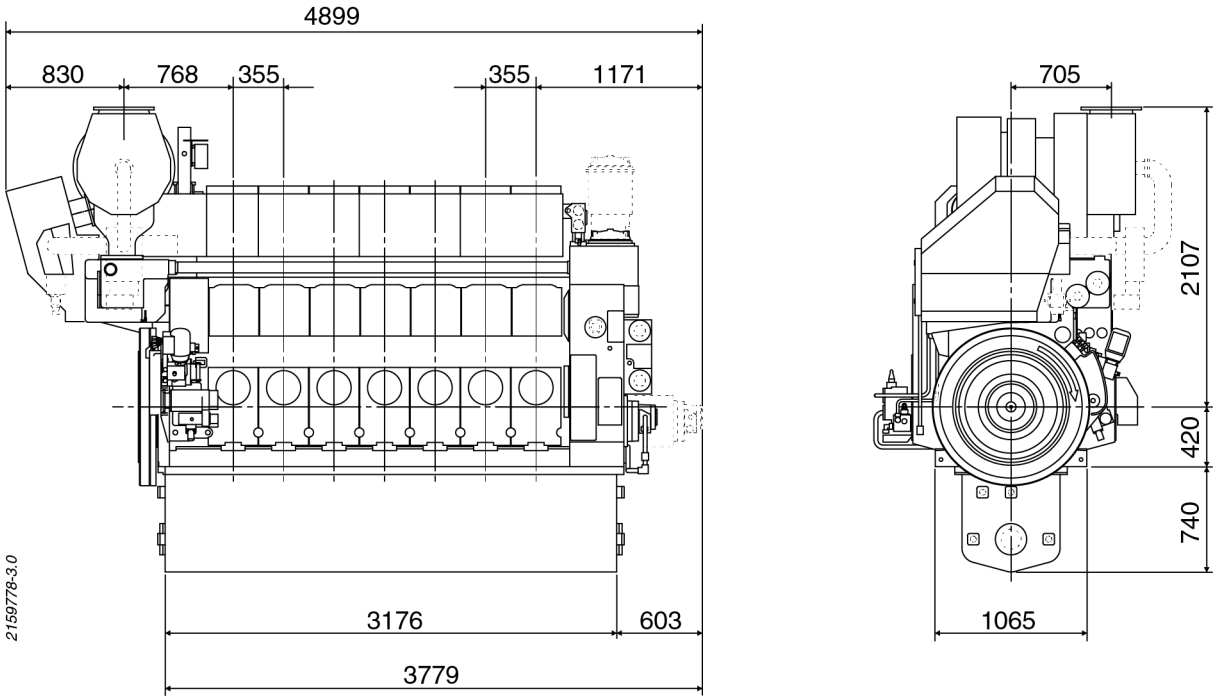


Figure 2: Engine type 7L21/31

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8L21/31

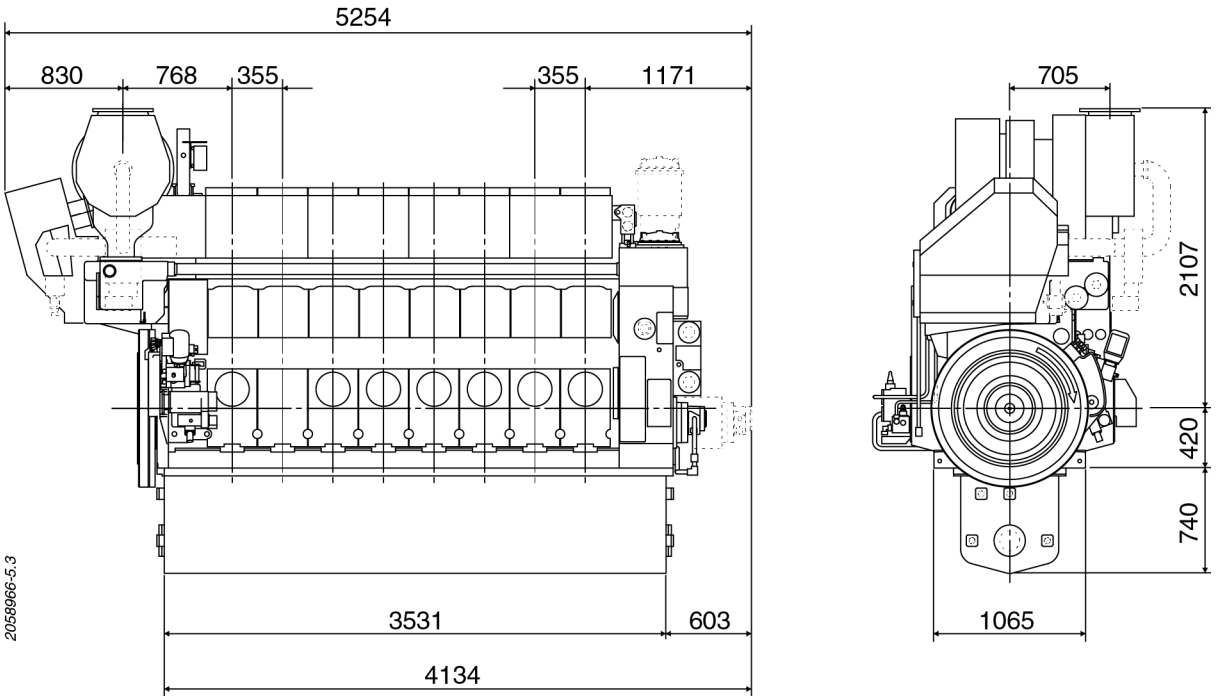


Figure 3: Engine type 8L21/31

9L21/31

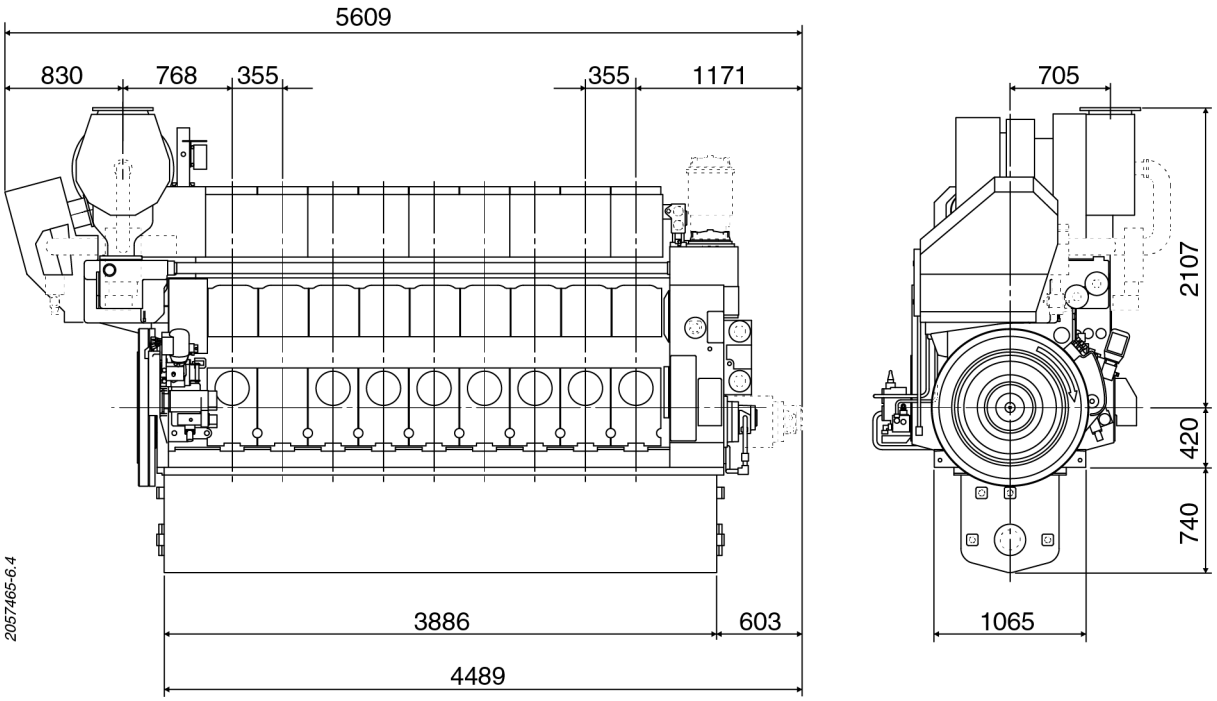
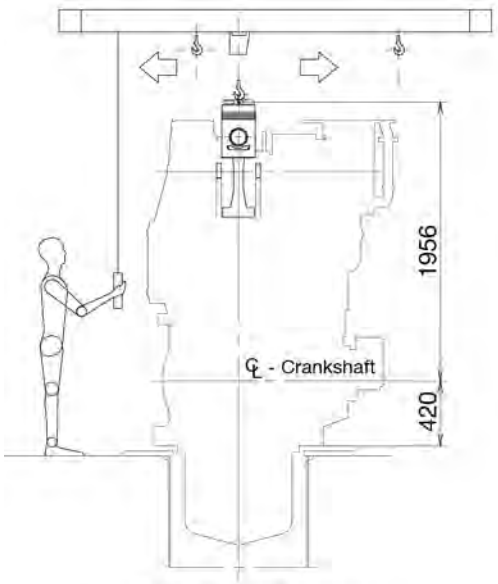


Figure 4: Engine type 9L21/31

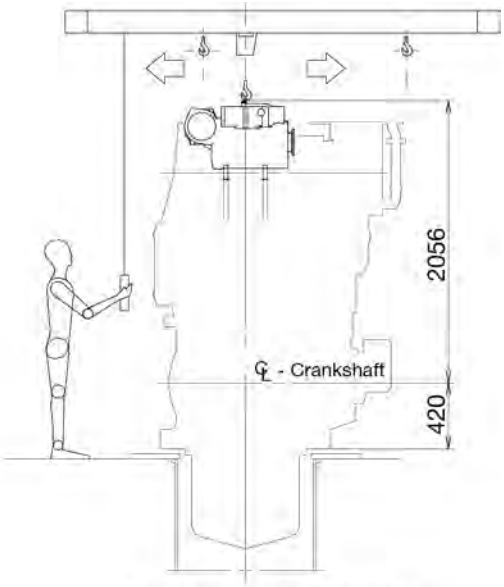
Space requirements

Dismantling space

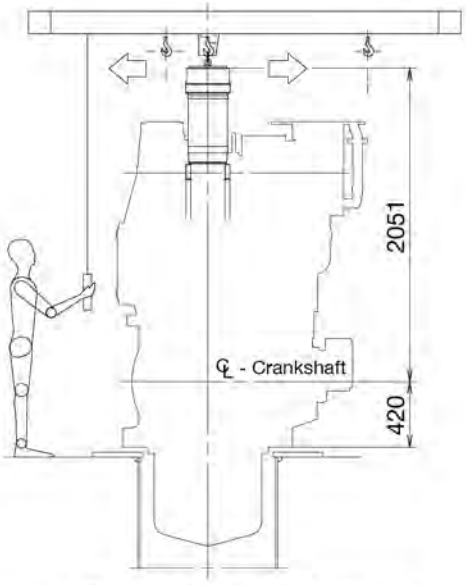
Sufficient space for pulling the pistons, cylinder liners, cylinder heads, and charging air cooler must be available.



Lifting height for pistons

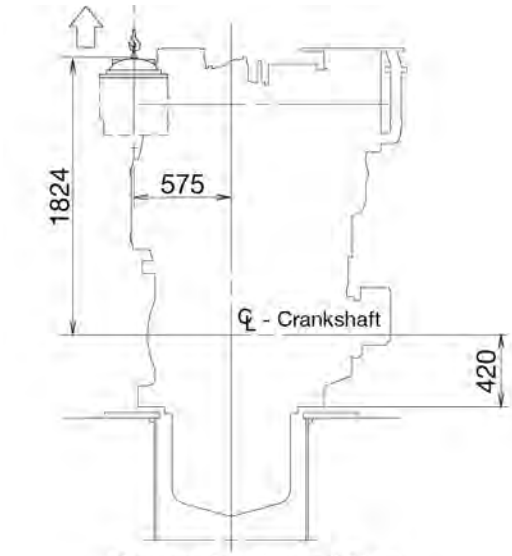


Lifting height for cylinder heads

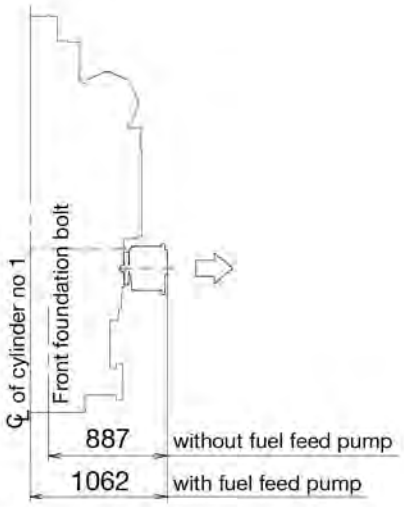


Lifting height for cylinder liners

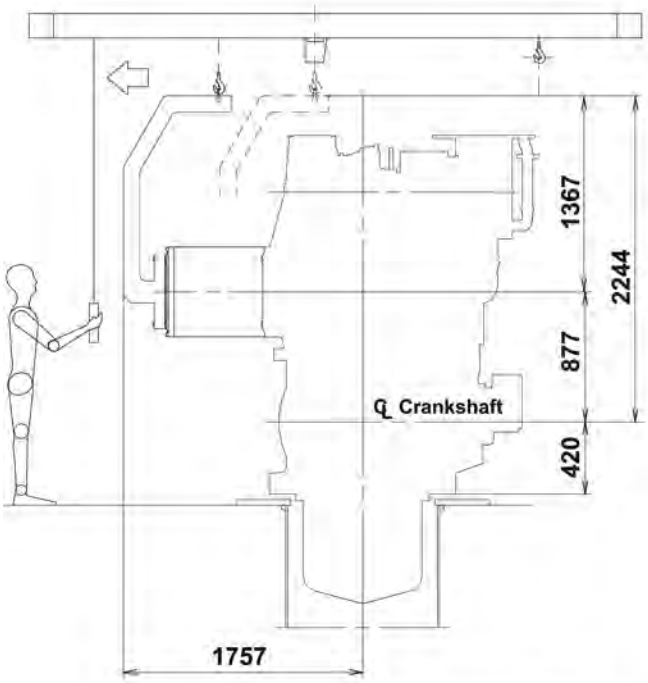
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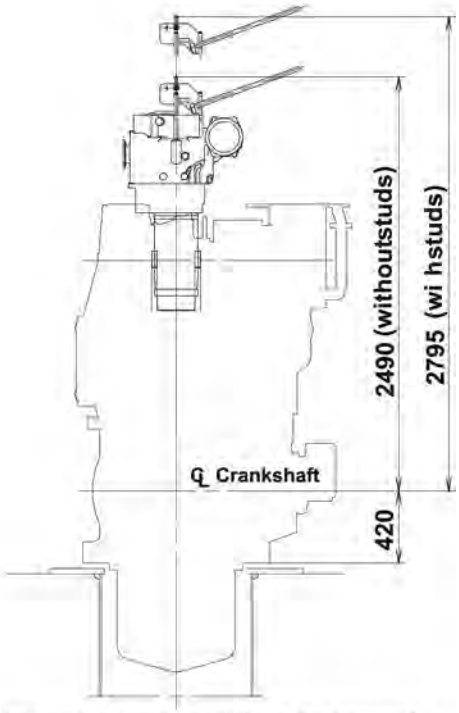
Dismantling lub. oil filter



Dismantling lub. oil pump



Dismantling charging air cooler

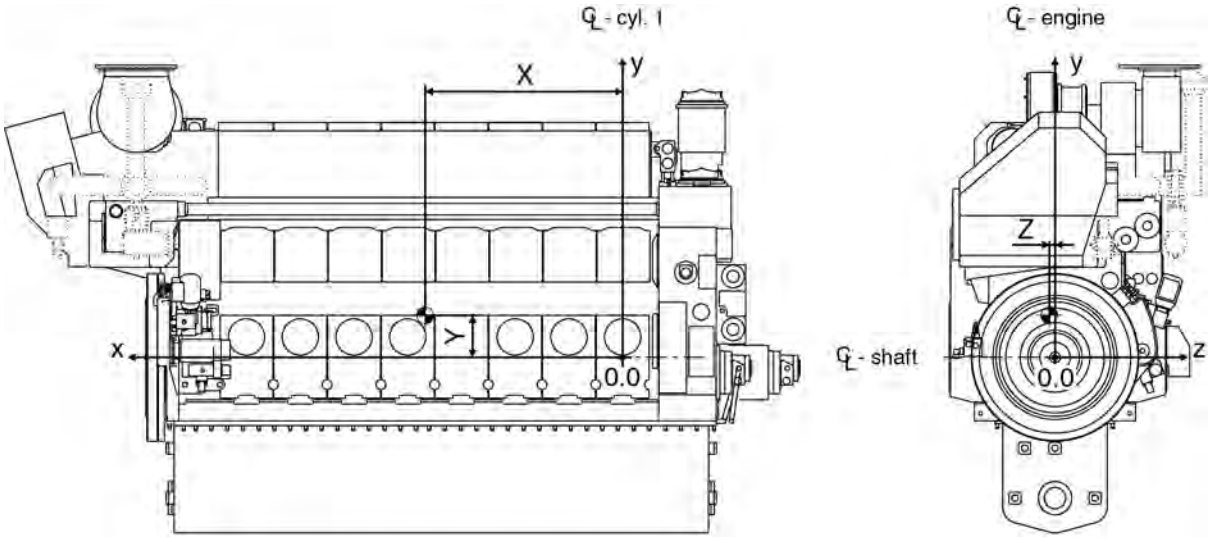


Dismantling complete cylinder unit

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Weight and centre of gravity

Weight and centre of gravity



Engine type	X - mm	Y - mm*	Z - mm	Wet weight of engine tons *	Dry weight of engine tons**
6L21/31	1010	278	0	17.0	16.0
7L21/31	1180	278	0	18.7	17.5
8L21/31	1365	278	0	20.3	19.0
9L21/31	1535	278	0	22.0	20.5

* Incl. lubricating oil and water
** Excl. lubricating oil and water

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PTO on engine front

PTO on fore end of engine

The engine can be supplied with a PTO on the fore end, as an adapted extension to the crankshaft, see fig 1.

The PTO can be dimensioned to transmit the full engine power. If a plant is to be supplied with PTO it must be planned in co−operation with us. For carrying out the torsional vibration analysis of the complete propulsion system, all necessary information concerning the PTO is needed.

Generally, a flexible coupling between the PTO and the generator and/or driven machinery will be necessary and this coupling must be selected to transmit the PTO requirements, accommodate and absorb any vibrations which may be present. Usually a toothed coupling will not be allowed.

The PTO-arrangement for the driven equipment may only cause a small axial force to the engine crankshaft. − Typically below 1500 kN.

The temperature expansion factor must be avoided. The crankshaft guide bearing is located in the aft end of the engine. Due to that the PTO−shaft can move forward (out the engine) up to 2 mm in extreme conditions.

This deflection may cause the flexible coupling between the crankshaft and the driven equipment to create an additional axial force, which must be taken into consideration when the PTO−arrangement is being designed.

Please ask our project plant department for advise. An additional small PTO of max 40 kW is available on the engine fore end. It can either be used for a sea water pump, or for a hydraulic pump for the steering gear.

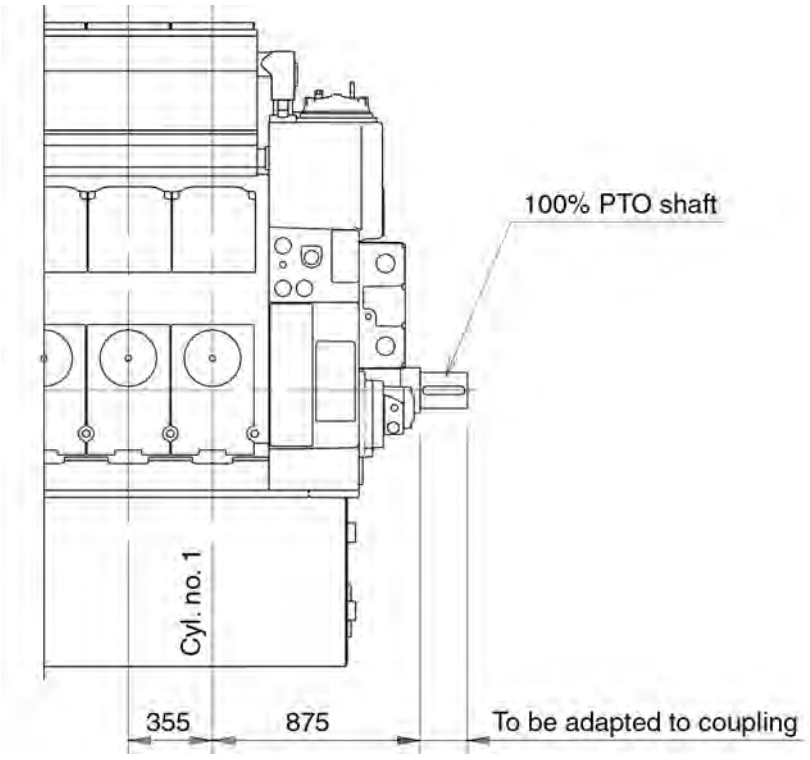


Figure 1: PTO arrangement

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Fuel oil system

General

The engine can be equipped with different equipment depending on fuel oil quality.
The standard engine, for operation on MDO (Marine Diesel Oil), is equipped with built-on:

- Fuel oil primary pump
- Double filter with paper inserts
- Lubrication of fuel oil pumps
- Fuel oil pumps with leak oil seal
- Uncooled fuel injection valves

The MDO built-on equipment is designed for single engine installation. For multi engine installations it is recommended to have either two separate fuel supplies or the built-on pumps have to be replaced by electrical pumps.

The standard engine, for operation on HFO (Heavy Fuel Oil), is equipped with built-on:

- Fuel oil duplex filter
- Fuel oil back pressure valve
- Lubrication of fuel oil pumps
- Fuel oil pumps without leak oil seal
- Uncooled fuel injection valves
- Equipment for cleaning of turbocharger turbine side during operation

The built-on equipment is designed for use of fuel oil modules, normally referred to as booster modules. For multi engine installations a common fuel oil feed system should cover all engines.

Fuel oil quality

For fuel oil quality and injection viscosity, *see fuel specifications 010.000.023*.

Velocity recommendations for fuel oil pipes:

Marine Diesel Oil:	Suction pipe:	0.5 - 1.0m/s
	Delivery pipe:	1.5 - 2.0 m/s
Heavy Fuel Oil:	Suction pipe:	0.3 - 0.8 m/s
	Delivery pipe:	0.8 - 1.2 m/s

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Fuel oil system - MDO

Fuel oil system for operation on gas/diesel oil

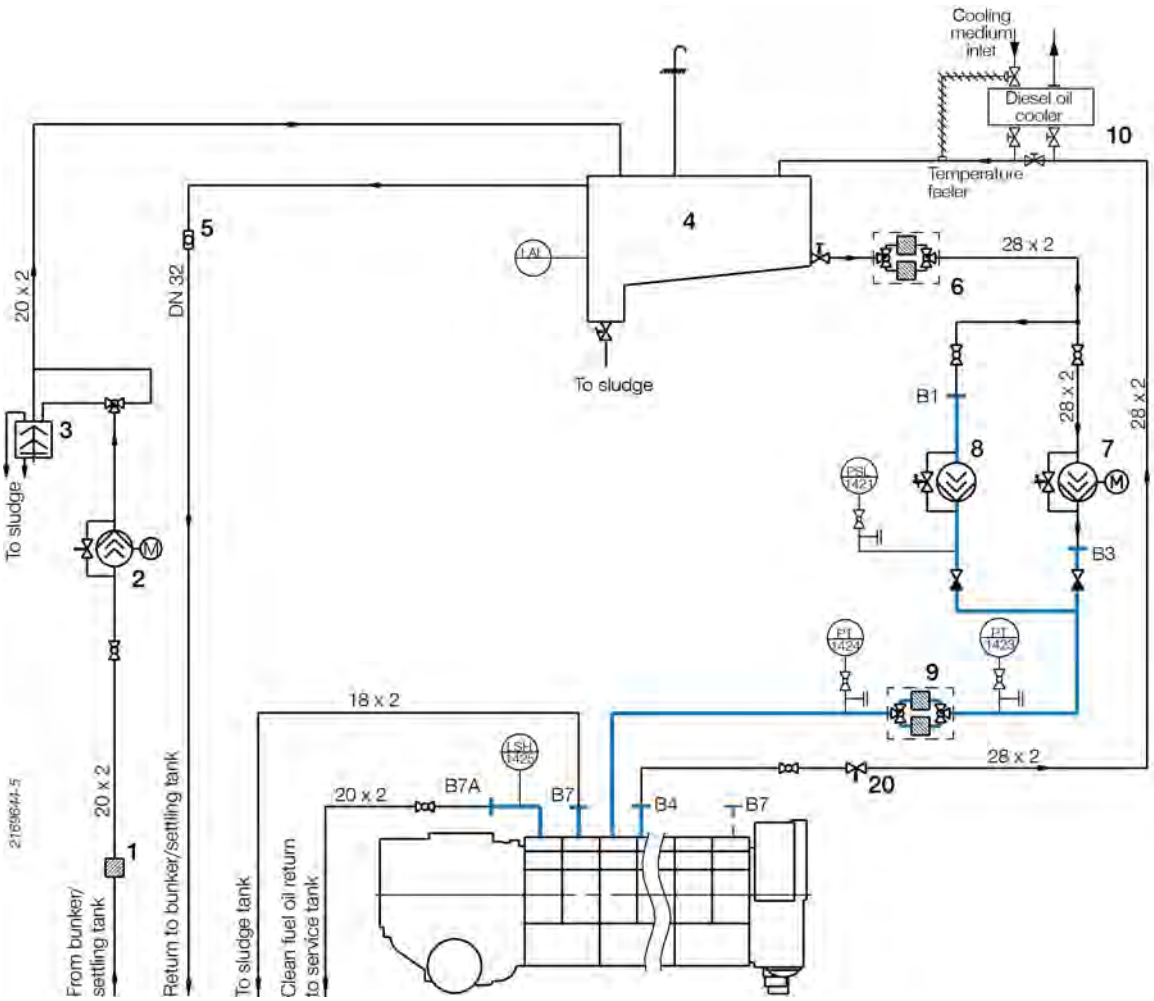


Fig 6.1 Fuel oil system – MDO

Item	Description
1	Prefilter for purifier
2	Transfer pump
3	Purifier
4	MDO service tank
5	Sightglass for MDO overflow
6	Duplex filter (magnetic insert)
7	Primary stand-by pump
8	Primary pump
9	Duplex filter (paper insert)
10	MDO/MGO diesel oil cooler
20	Pressure regulating valve

Connections:

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B1	Fuel oil primary pump - suction
B3	Fuel oil primary stand-by pump - pressure
B4	Fuel oil circulation to service tank
B7	To sludge tank
B7A	Clean fuel oil return to service tank (with alarm)

Shut-off valve at B4 is to be placed as close to the connections as possible

Service tank (item 4):
Min capacity in m^3 for 8 hours operation:

L21/31	With separator or settling tank	L27/38	With separator or settling tank
6 cyl engine	2.4	6 cyl engine	3.9
7 cyl engine	2.6	7 cyl engine	4.6
8 cyl engine	3.2	8 cyl engine	5.2
9 cyl engine	3.6	9 cyl engine	5.9

The lowest oil level of the service tank must be min 500 mm above centerline of crankshaft.

Fuel oil storage

The storage and handling system comprises of bunker tanks, pipe systems and transfer systems

Cleaning systems

The cleaning system normally comprises of a settling tank, pipe system and equipment for cleaning of the MDO prior to use in the engine.

The settling tank should be designed to provide the most efficient sludge and water separation. The tank should be provided with baffles to reduce mixing of sludge with the fuel. The bottom of the tank should have a slope toward the sludge drain valve(s), and the pump suction must not be in the vicinity of the sludge space.

We recommend that the capacity of a single settling tank is sufficient to ensure minimum 24 hours operation.

Prefilter, item 1

To protect the purifier pump (item 2), a prefilter should be inserted before the pump.

Design data:

- Capacity: see oil pump, item 2
- Mesh size: 0.8 - 1.0 mm

Oil pump to separator, item 2

The pump can be driven directly by the separator or by an independent motor.

Design data:

- Capacity: According to separator

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- Pressure: Max 2.5 bar
- Temperature: Max 50°C

Separator, item 3

For engines operating on MDO we recommend cleaning of the oil by a separator to remove water. For the blended fuel oil (M3 in accordance to BS MA100 fuel oil specification) which can be expected in some bunker places, the separator is also an important cleaning device. We recommend the automatic self-cleaning type.

As a guideline for the selection of separator, the following formula can be used:

Design data:

- Capacity: V = C x (24/T)
- V: The nominal capacity of the separator in litres/hour
- C: Consumption at MCR in liters/hour
- T: Daily separating time, depending on separator (20_22 hours)

Guidance given by the manufacturer of the separator must be observed.

If aux engines are fed from the same fuel oil system, the fuel oil consumption has to include all engines.

Pre-heating is normally not necessary, but a separation temperature of approx 40-50 °C is recommended for better separation. Some Marine Diesel Oils have a high content of “paraffin” which cloggs up filters and can cause unintended engine stopping. To avoid this preheating can be necessary.

A heat exchanger and a thermostatic valve using the main engine HT cooling water as heating media can be installed, if necessary.

The fuel oil separator should be installed and constantly circulating the fuel between settling tank and service tank. Separator must not be selected too small for the purpose. It is recommended to be approximately 4 times bigger than the requested capacity flow of the supply system to have optimum cleaning efficiency. Correct viscosity/temperature is also important for efficiency of separator.

The automatic back-flush filter with a change-over cock and bypass simplex filter and with integrated heating chamber has a mesh size of 10 microns (absolute/sphere passing mesh). The automatic back-flush filter permits a continuous operation even during back-flushing without any pressure drops or interruptions of flow. If the filter inserts are clogged, an automatic cleaning is started. The filter is equipped with a visual differential pressure indication and two differential pressure contacts to monitor the clogging of the filter. Back-flushing medium is discharged discontinuously to a sludge tank or back to the settling tank.

Automatic back-flush filter will also extend the cleaning intervals considerably of the filter elements in the fuel oil filter duplex (safety filter).

For more information of separator unit, *see B 12 15 0, 3700643-9 Separator unit*.

Service tank, item 4

The service tank shall be dimensioned to contain purified MDO for operating minimum 8 hours at MCR.

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Attention must be paid that the fuel oil inlet pipe is connected to the side of the tank in a position to avoid sludge and water contamination of the MDO.

A vent pipe from the tank should be led up to the deck level minimum 500 mm above the tank. Precaution should be taken that water does not enter the tank through the vent pipe.

To ensure satisfactory suction when starting up the main engine, the lowest oil level in the service tank should be at least 500 mm above the suction to the primary pump.

Duplex suction filter, item 6

A duplex suction filter with magnetic inserts should be installed in the suction line of the fuel oil primary pump to protect the pump. The filter should be designed for the capacity of the built-on primary pump with a mesh size of 0.5–0.8 mm.

Stand-by primary pump, item 7

Design data:

- Capacity: 3 x MCR consumption
- Pressure: 2.5 bar

Duplex filter, item 9

Engines are equipped with a fuel oil filter duplex (safety filter) with a fineness of maximum 25 microns (absolute/sphere passing mesh). The filter is with star-pleated filter elements and allows change-over during operation without pressure loss. The filter is compact and easy to maintain, requiring only manual cleaning when maximum allowable pressure drop is reached. The filter is equipped with a visual differential pressure indication and two differential pressure contacts to monitor the clogging of the filter. When maximum pressure drop is reached, the standby filter chamber is brought on line simultaneously as the dirty one is isolated by means of the change-over valve. After venting, the dirty element can be removed, cleaned and refilled to be the standby filter chamber.

Fuel oil consumption

For calculating the necessary tank size, purifier, stand-by pumps, etc, the consumption stated in the planning data, based on engine MCR, should be used. These values include an addition for engine driven pumps plus 5% tolerance in accordance with ISO requirements.

MDO/MGO Diesel oil cooler, item 10

Fuel oil temperatures before engine / fuel oil injection pumps (MDO/MGO):

- If the fuel oil temperature before engine / fuel injection pumps exceeds 40° C or the viscosity is below 2,0 cSt cooler must be built-in, in order to ensure the lubricating properties for the injection pumps.

Circulation of MDO/MGO over engine will heat up the fuel. In warmer regions will diesel oil cooler be needed.

Diesel cooler can also be installed on inlet string upstream engine.

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Notes

We recommend that the total pressure drop in the piping system is calculated in order to ensure that the pump capacity is sufficient and the flow velocity is as recommended by us.

We should be pleased to review your piping diagrams and give our comments and recommendations. The shipyard is responsible for the choice of method, design and execution.

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Fuel oil system - HFO

Fuel oil system for operation on heavy fuel oil

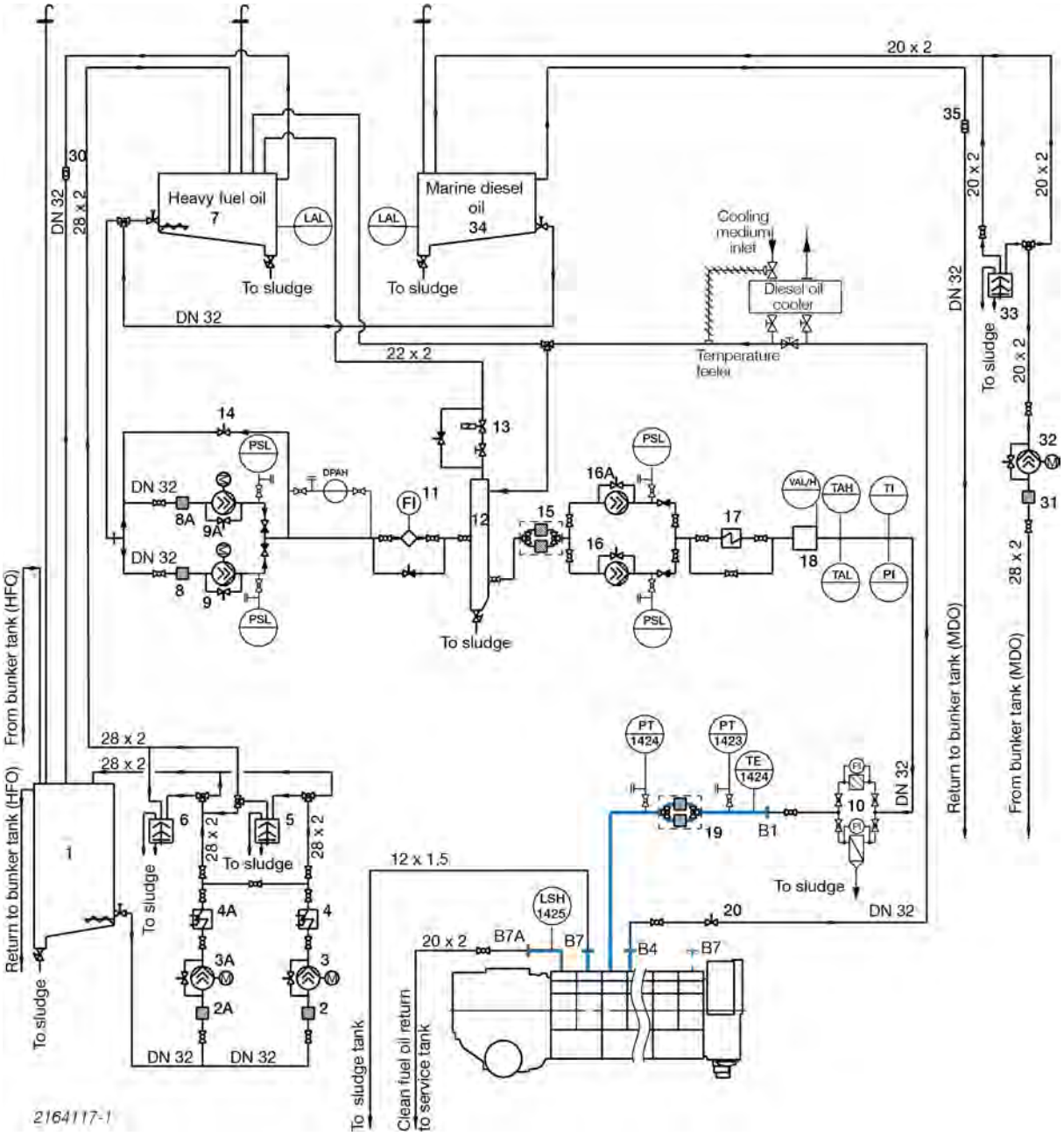


Figure 1: Fuel oil diagram - HFO

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Fuel oil system

Item	Description		Item	Description
1	HFO settling tank		14	Supply pressure control valve
2	Prefilter for separator		15	Duplex filter (magnetic insert)
3	Transfer pump for separator		16	Fuel oil booster pump
4	Preheater for separator		17	Final preheater
5	HFO separator		18	Viscosity control equipment
6	HFO separator		19	Fuel oil filter duplex (safety filter)
7	HFO day tank		20	Booster pressure regulating valve
8	Prefilter for HFO supply pump		30	Sight glass, HFO day tank overflow
9	Fuel oil supply pump		31	Prefilter for MDO transfer pump
10	Automatic back-flush filter		32	MDO transfer pump
11	Flow indicator		33	MDO separator
12	Mixing tank		34	MDO separator
13	Automatic de-aeration valve		35	Sight glass, MDO day tank overflow

Connections				
B1	Fuel oil inlet engine		B7	To sludge tank
B4	Fuel oil circulation to service tank		B7A	Clean fuel oil return to service tank (with alarm)

NOTICE

All tanks and pipes for heated oil must be insulated.

Shut-off valve at B4 is to be placed as close to the connection as possible

Final preheater (item 17):

- Standard
  - Steam heated final preheater
- Optional
  - Electrical, thermal oil heated final preheater

MDO-tank (item 34):

- Min oil level in MDO-tank is to be approx. 500 mm above inlet pipe (item 10)

Pressure regulating valve (item 20):

- The pressure regulating valve is to be adjusted to a pressure of 4 bar. The relief valve for booster pumps (items 16 and 16A) are adjusted to a pressure somewhat higher.

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Fuel oil storage

The storage and handling system comprises of bunker tanks, pipe systems and transfer systems

Tank design

There need to be a separate tank for all fuels available high-sulphur HFO, low-sulphur LSHFO, Distillate, etc.

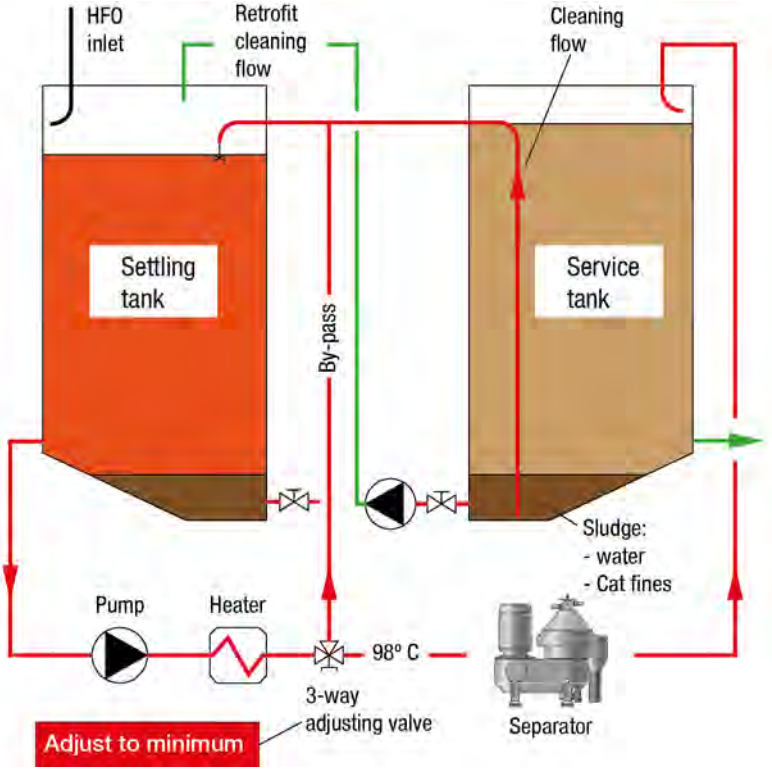
In all fluids a natural settling of particles, takes place. This results in a higher concentration of particles in the bottom of the tanks. Due to this phenomenon it is important that the various fuel tanks are designed and operated correctly.

Tanks must be designed with a sloped bottom toward drainage outlet for easy collection of the settled particles. There must be drain valves in each tank for removing water and particles. Appropriate access should be provided for personnel to enable tank maintenance operations to be conducted safely.

The overflow pipe in the service tank must go to the bottom of the service tank to enable re-circulation; thus contributing to leading the highest particle concentration back to the settling tank. **Overflow as a simple hole from tank to tank is not permitted**.

Cat fines have a higher density than fuel oil and they tend to settle in the bottom of the service tanks. They might enter the engines in periodically high concentrations during rolling and pitching of the vessel in rough weather. Such a phenomenon can result in heavily cat fines attacks and engine damage.

Tank material and/or surface treatment have to be selected that it not will contaminate or change properties of fuel.



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Fuel supply system

The common fuel supply system is a low pressurized system, consisting of “DIESELswitch”, HFO supply pumps with pressure control valves, venting tank and de-aerating valve.

Pump capacity is minimum fuel consumption for all engines in system running 100% load. *See “List of capacities” for each engine types*.

The fuel oil is led from one of the service tanks to one of the electrically driven supply pumps (*with redundancy*). It delivers the fuel oil with an adjusted pressure of approximately 4 bar to the fuel circulation system.

The venting pipe is connected to the service tank via an automatic de-aeration valve that will release any gases present.

Fuel circulation system

From the low-pressure supply fuel system the fuel oil is poured with return fuel from engines and led to one of the electrically driven circulating pumps (with redundancy), through preheater, diesel cooler, and equipment for controlling the viscosity, (e.g. “Viscorator”).

Pump capacity is minimum 3 times fuel consumption for all engines in system running 100% load. See “List of capacities” for each engine types.

The circulating pumps will always be running; even if the propulsion engine and one or several of the engines are stopped. Circulation of heated heavy fuel oil through the fuel system on all the engine(s) keep them ready to start with preheated fuel injection pumps.

The surplus amount of fuel oil is re-circulated in the engine and back through the venting pipe. To have a constant fuel pressure to the fuel injection pumps during all engine loads a spring-loaded pressure relief valve is installed (Valve 20 "Booster pressure regulating valve")

Fuel circulation pressure has to be 8-9 bar at fuel oil inlet. Back-pressure in the circulation-system is approximately 4 bar (from supply system).

Fuel oil pressure for engine must be minimum 8 bars and can be up to 16 bar. It is therefore recommended to distribute fuel to GenSet(s) before main engine.

Fuel preheater and diesel cooler should safely manage to control temperature. Clogging point, cloud and pour point of the bunkered fuel need to be considered in every operating areas and ambient temperatures.

Depending on system layout, viscosity, and volume in the external fuel oil system, unforeseen pressure fluctuations can be observed. In such cases it could be necessary to add pressure dampers to the fuel oil system. For further assistance, please contact Everllence.

Settling tank, item 1

The settling tanks should be designed to provide the most efficient sludge and water separation. Each tank should be provided with baffles to reduce mixing of sludge with the fuel. The bottom of the tank should be with a slope toward the sludge drain valve(s), and the pump suction must not be in the vicinity of the sludge space.

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We recommend that the capacity of each settling tank should be sufficient to ensure minimum 24 hours operation.

The temperature of the oil settling tanks should be as high as possible to help the dirt to settle. The temperature should be below 75°C in order to avoid the formation of asphaltenes, and min 7°C above the pour point of the oil to ensure pumpability.

Prefilter, items 2 and 2A

To protect the separator pumps, items 3 and 3A, a prefilter should be inserted before the pumps.

Design data:

- Capacity: See oil pump, items 3 and 3A
- Mesh size: 0.8-1.0 mm

Oil pump to separator, items 3

The pumps can be driven directly by the purifier or by an independent motor.

Design data:

- Capacity: According to separator
- Pressure: Max 2.5 bar
- Temperature: Max 70°C

Preheater before separator, items 4 and 4A

The preheater must be able to raise the temperature of the oil from approx 60°C to approx 98°C, which is the temperature of the oil for purifying.

Design data:

- Capacity: $P = v \times t/1710$

- P: Capacity of the preheater in kW
- v: Flow through preheater in litres/hour
- t: Temperature difference approx 40°C (engine operating)

Max pressure: 4 bar

Max pressure loss: 0.5 bar

The specific load on heating surface for an electric preheater is recommended not to exceed 1.2 W/cm^2.

Separator, items 5 and 6

The fuel oil separator should be installed and constantly circulating the fuel between settling tank and service tank. Separator must not be selected too small for the purpose. It is recommended to be approximately 4 times bigger than the requested capacity flow of the supply system to have optimum cleaning efficiency. Correct viscosity/temperature is also important for efficiency of separator.

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The automatic back-flush filter with a change-over cock and bypass simplex filter and with integrated heating chamber has a mesh size of 10 microns (absolute/sphere passing mesh). The automatic back-flush filter permits a continuous operation even during back-flushing without any pressure drops or interruptions of flow. If the filter inserts are clogged, an automatic cleaning is started. The filter is equipped with a visual differential pressure indication and two differential pressure contacts to monitor the clogging of the filter. Back-flushing medium is discharged discontinuously to a sludge tank or back to the settling tank.

Automatic back-flush filter will also extend the cleaning intervals considerably of the filter elements in the fuel oil filter duplex (safety filter).

If aux engines are supplied from the same fuel oil system, the fuel oil consumption has to include all engines.

For more information of separator unit, see B 12 15 0, 3700643-9 Separator unit.

HFO service tank, item 7

The service tank should be dimensioned to contain purified HFO for operating for at least 12 hours.

The tank must be insulated and the oil temperature in the tank should be kept at minimum 60 °C. Depending on separating temperature and tank insulation the temperature may rise to above 90°C.

Attention must be paid that the fuel oil inlet pipe is connected to the side of the tank in a position to avoid sludge and water contamination of the HFO.

The feed from the service tank to the mixing pipe is to be connected in a suitable distance above the bottom of the service tank to avoid sludge and water contamination in the pipe.

A vent pipe from the tank should be led up to the deck level minimum 500 mm above the tank. Precaution should be taken that water does not enter the tank through the vent pipe.

Prefilters, items 8 and 8A

The pressure pumps (items 9 and 9A) must be protected by prefilters.

Design data:

- Capacity: See capacity for pressure pump
- Temperature: Max 90°C
- Mesh size: 0.8-1.0 mm

Pressure pumps, items 9 and 9A

The HFO system must be pressurised to avoid gas separation in the fuel oil piping. Pressurising is maintained by the pumps installed between the HFO service tank and the automatic filter.

Design data:

- Type: Screw or gear pump with relief valve
- Capacity: 1.6 x MCR consumption
- Pressure: 4 bar

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- Temperature: Max 90°C

Viscosity at normal operation: Max 140 cSt (corresponding to 70°C)

Viscosity for dimensioning of el–motor: 1000 cSt

Pressure regulating valve, item 14

The pressure regulating valve is to be adjusted to a pressure of approx 4 bar and the relief valve setting for supply pumps, items 9 and 9A, is adjusted to a higher pressure.

If the capacity of the pressure pumps (items 9 and 9A) exceeds the fuel oil consumption too much, or if the plant often operates at low load, the surplus oil by-passed by the pressure regulating valve has to be cooled down by a by-pass oil radiator, to avoid unintended heating of the fuel supply.

Automatic back-flush filter (hot side), item 10

The automatic back-flush filter with a change-over cock and bypass simplex filter and with integrated heating chamber has a mesh size of 10 microns (absolute/sphere passing mesh). The automatic back-flush filter permits a continuous operation even during back-flushing without any pressure drops or interruptions of flow. If the filter inserts are clogged, an automatic cleaning is started. The filter is equipped with a visual differential pressure indication and two differential pressure contacts to monitor the clogging of the filter. Back-flushing medium is discharged discontinuously to a sludge tank or back to the settling tank.

This will also extend the cleaning intervals of the filter elements in the fuel oil filter duplex (safety filter) considerably.

Design data:

Capacity	MCR consumption
Pressure	8-16 bar
Temperature	Max 150°C
Mesh size	10 µm absolute (main supply)
	35 µm absolute (by-pass supply)

Fuel oil consumption measuring, item 11

For engines with pressurised HFO system a fuel consumption meter can be fitted between the automatic filter (item 10) and the mixing tank (item 12). A spring loaded valve has to be installed in parallel. In case of the measuring device, the valve will open and ensure fuel supply to the engine.

Mixing pipe, item 12

The main purpose of the mixing pipe is to ensure good ventilation of gas from the hot fuel oil.

Furthermore, the mixing pipe ensures a gradual temperature balance by mixing the hot returned oil from the engine with the oil from the daily service tank thereby reducing the heat requirements from the final preheater.

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The mixing pipe should be dimensioned to contain fuel oil for 10-15 minutes operation at MCR load, and in any case not less than 50 litres.

Minimum diameter of mixing pipe: 200 mm.

Because the capacity of the fuel oil primary pump is higher than the consumption of the engine, the surplus oil from engine flange connection B4 must be returned to the mixing pipe and must be adequately insulated.

The flange connection B2 must be connected to a drain tank and not to the mixing pipe.

Prefilter, item 15

To protect the fuel oil circulation pumps a duplex prefilter is recommended between the mixing pipe (item 12) and the circulating pumps (items 16 and 16A).

Design data (depending on fuel type):

- Capacity: See the planning data
- Operating temperature: Max 150°C
- Pressure: Max 10 bar
- Pressure drop by clean filter: Max 0.05 bar
- Pressure drop by dirty filter: Max 0.1 bar
- Mesh size: 0.5 – 0.8 mm

HFO circulating pump, items 16 and 16A

The pressurised HFO system has a high degree of recirculation.

Design data (depending on fuel type):

- Capacity: Min 3 × MCR consumption
- Pressure: 8 bar
- Operating temperature: Max 150°C
- Viscosity at normal operation:
  - 25 cSt (corresponding to 110°C)
- Viscosity for dimensioning of el-motor:
  - 250 cSt (corresponding to 60°C)

Preheater, item 17

In order to heat the HFO to the proper viscosity before the injection valves (12±2 cSt), the oil is led through a preheater.

The temperature of the HFO is regulated by an automatic viscosity control unit to 85-150 °C (depending on the viscosity).

The specific load on heating surface for an electric preheater is recommended not to exceed 1.2 W/cm2.

Based on the minimum temperature of the oil from the HFO service tank to be 60 °C and because the fuel must be heated to temperatures indicated in the table below (corresponding to a viscosity of 12±2 cSt plus an addition of 5°C to compensate for heat loss before injection) the capacity of the preheater in kW should be minimum:

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The above capacities include a safety margin of 15% but the necessary capacity depends on the actual fuel and condition. We will be pleased to carry out calculations for a specific condition on request.

Fuel type final temp	IF 80 t= 110 °C kW	IF 180 t=131 °C kW	IF 380 t=147 °C kW
6L27/38	18	25	30
7L27/38	21	29	35
8L27/38	25	33	40
9L27/38	28	38	45

Viscosity control equipment, item 18

This equipment is required for all types of fuel to ensure the optimum viscosity of approx 12±2 cSt at the inlet to the fuel injection pump. The viscosimeter should be of a design which is not affected by pressure peaks produced by the injection pumps. For efficient operation, the pipe length between the HFO preheater and the viscosity control equipment should be as short as possible (or in accordance with the manufacturer's instruction).

The viscosity control equipment should be able to switch over to thermostatic control in case of malfunctioning.

Fuel oil filter duplex (safety filter), item 19

Engine attached fuel oil filter duplex (safety filter), with a fineness of max. 25 microns (absolute/sphere passing mesh). The fuel oil filter duplex (safety filter) is with star-pleated filter elements and allows change-over during operation without pressure loss. The filter is compact and easy to maintain, requiring only manual cleaning when maximum allowable pressure drop is reached. The filter is equipped with a visual differential pressure indication and two differential pressure contacts to monitor the clogging of the filter. When maximum pressure drop is reached, the standby filter chamber is brought on line simultaneously as the dirty one is isolated by means of the change-over valve. After venting, the dirty element can be removed, cleaned and refilled to be the standby filter chamber.

Fuel oil consumption

For calculating the necessary size of tank, separators, stand-by pumps, etc, the consumption stated in the planning data, based on engine MCR, should be used.

The consumption includes an addition for engine driven pumps plus 5% tolerance in accordance with ISO requirements.

The conversion from kg/hour to litres/hour is based on a fuel with density of 950 kg/m^3 for IF 80 and 980 kg/m^3 for IF 380.

The low calorific heat value of the heavy fuel oil corresponds to 40,225 kJ/kg.

See "*Calculation of specific fuel oil consumption (SFOC)*"

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Operation on distillate

The distillate to the engine is recommended to be supplied by a separate pipeline from the service tank through a distillate booster pump. The capacity of the distillate booster pump must be minimum three times higher the amount of distillate consumed by the diesel engines at 100% load. *See list of capacities for each engine type*.

The system is designed in such a way that the fuel type for the engine can be changed independently of the fuel supply to the propulsion engine. As an option the engine plant can be delivered with the fuel changing system consisting of a set of remotely controlled, pneumatically actuated 3-way fuel changing valves “V1-V2” for each engine and a fuel changing valve control box common for all engines.

A separate fuel changing system for each engine gives the advantage of individually choosing distillate or HFO mode. Such a changeover may be necessary if the engine have to be:

- Entering SECA area
- Stopped for a prolonged period
- Stopped for major repair of the fuel system, etc.
- In case of a blackout / emergency start.

With the introduction of stricter fuel sulphur content regulations the propulsion engine as well as the engine increasingly have to be operated on distillate fuels, i.e. marine gas oil (MGO) and marine diesel oil (MDO). To maintain the required viscosity at the engine inlet, it is necessary to install a cooler in the fuel system. The lowest viscosity suitable for the main engine and the GenSets is 2 cSt at engine inlet.

Vessel that constantly will enter/exit SECA area, and has multiple engine installation, it is recommended not to change between fuels, but to select some engine for HFO and some engine for distillate fuels. The change-over procedure will then be starting/stopping engine and not changing between fuels.

Distillate pump capacity need to be minimum for one engine (see description D 10 05 0 "List of capacities"). If 2 or more engines need to run distillate (ie. entering SECA) then distillate pump capacities must be adjusted accordingly.

If the fuel type for complete system both the propulsion engine and GenSet have to be changed from HFO to MDO/MGO/Distillate and vice versa, the 3-way valve (*“DIESELswitch”*) just after the service tanks has to be activated.

The change-over between HFO and MDO/MGO/Distillate needs to be done very thoroughly with high attention to temperature/viscosity. Incorrect handling can damage the engine.

An MDO separator must be installed upstream of the MDO service tank. Separation temperature must be in the range 40 – 50°C. Most solid particles (*sand, rust and catalyst particles*) and water can be removed, and the cleaning intervals of the filter elements can be extended considerably.

It is possible, however not our standard/recommendation, to install a common MGO/MDO back-flush filter for all engines.

Emergency start

MGO/MDO must be available in emergency situations. If a blackout occurs, the engines can be started up on MGO/MDO in three ways:

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1. Pneumatic driven MGO/MDO circulation pump with air supply from starting air bottles. Air consumption of the pump must be included in calculation of starting air consumption and sizes of starting air bottles according to classification rules in this regard.
2. Electrical driven MGO/MDO circulation pump connected to the emergency switchboard.
3. MGO gravity tank (*100 - 200 litres*) can be arranged above the engine. With no pumps available, it is possible to start up the engine if a gravity tank can be installed minimum 8 metres directly above the engine. However, only if the connection to the engine is as directly as possible, meaning change-over valve “V1-V2” should be placed as near as possible to the engine.

Sampling points

Points for taking fuel oil samples are recommended in following locations:

1. After the fuel oil service tank. Before any fuel change-over valve.
2. Before and after any fuel filters and/or separator to verify the filter effectiveness
3. Before each engine fuel inlet pipe.

Sampling points should be provided at locations within the fuel system that enable samples of fuel to be taken in a safe manner.

Position of a sampling point should be placed such that the fuel sample is representative of the oil fuel quality passing that location within the system.

The sampling points should be located in positions away from any heated surface or electrical equipment.

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Fuel water emulsion

Introduction

Water added to the combustion have been used for many years in different ways and on a number of different engines.

The water does not harm or disturb the life span or overhaul intervals of the engine if it complies with our guidelines.

The effect of water in the combustion is mainly a reduction of the combustion temperature and in this way reducing NO_x, but it also has other effects that will be described in this document.

We do not recommend FWE or any other water-based systems, there are better alternatives available today like SCR.

Typical system

There are three basic systems:

- Direct water injection into cylinder, DWI-system.
- Water supplied together with charge air, HAM-system.
- Water mixed into the fuel, FWE-system.

Above mentioned systems have different advantages and disadvantages.

Direct water injection (DWI)

Water injected directly into the cylinder do not affect the charge air or fuel supply system and can be deactivated fast. In this respect, it is a standalone system not affecting the base engine operation, but water nozzle and piping must be added. The nozzle is typically placed in the cylinder head.

DWI can cause water to touch the cylinder surface and explode from the surface which collapses the oil film with fatal consequences. To minimize this risk the pressure must be high to ensure the water is sufficient atomized in the cylinder.

DWI must be switched off before the engine is cooled down and stopped, and the system must secure that leaks from the water system will not enter the engine during standstill.

DWI gives no restriction in power output.

Humid air motor (HAM)

In a HAM-engine large amount of water (Sweet water) is sprayed into the charge air after the compressor, the water will evaporate and cool the charge air sufficient and eliminate the need of a charge air cooler.

Before the moist air enters the scavenging channel, free water must be extracted with a water-mist-catcher. Any droplet left might land on the cylinder surface with the same implications as for direct water injection.

If HAM is not active the power output must be reduced because there are no cooling of the charge air.

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HAM must be switched off during low/idle load and before the engine is stopped. It must be secured that no free water accidently enters the engine during standstill.

No restriction in power output as long as HAM is active.

Fuel water emulsion (FWE)

FWE is the most common system and therefore this system will be explained in more details, some of the topics might be relevant for DWI and HAM too.

In a FWE system water is mixed into the fuel before the engine and therefore not implicating the engine systems with additional components.

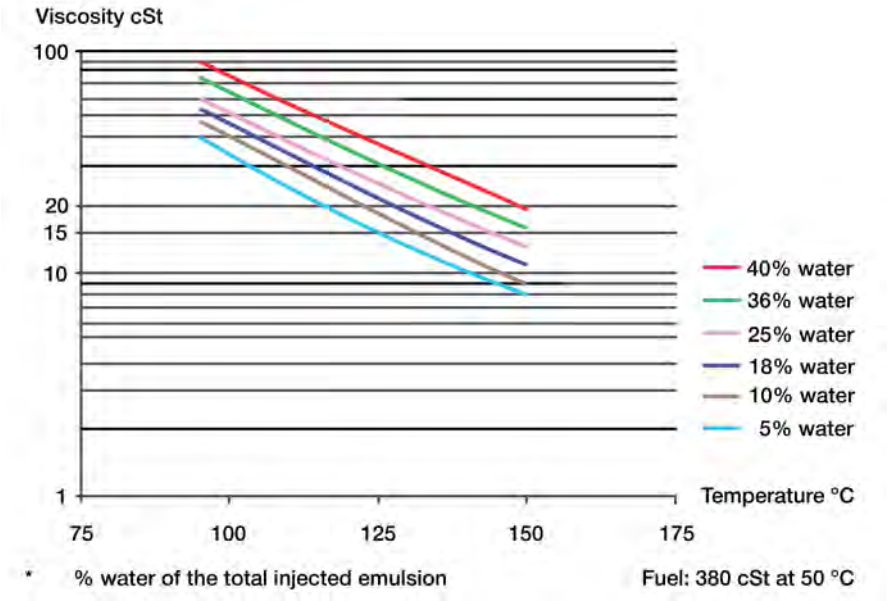
Water can be emulsified into the fuel in many different ways, it is important that the water is uniform distributed in the fuel and with as small droplets as possible.

Homogenizer, ultrasonic device and other emulsification systems are on the market, even the engine itself do a good homogenizing of the water into the fuel by the fuel pump when pressure are released at the end of the injection stroke.

Any fuel can be emulsified with water, but some are very unstable. MGO/water emulsions are unstable and will often require a chemical emulsifier to keep the water attached to the fuel in a sufficient time.

Most HFO is stable for a sufficient time, in general higher viscosity give more stability.

When water is emulsified into fuel the viscosity will increase, this means that the advice temperature in the bunker slip supplied at bunker delivery must be recalculated according to the diagram below.



Viscosity as a function of temperature with different percentiles of water content.

When fuel and water emulsion is injected into the combustion chamber the mixture will explode and the fuel drops will be smaller and burn faster, this is good for the fuel consumption and cleanness of the combustion chamber.

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The water will evaporate and adopt energy from the combustion, this adoption energy lower the temperature and reduces NO_x, the evaporated water is present as steam in the cylinder and will expand together with the normal combustion gas and return some of the energy to the engine.

During the expansion some of the energy will be returned to the engine process, but the water will not condensate, therefore the condense heat will be lost.

The temperature before the turbine typical decreases 25°C at full load with a water content of 25%.

At 4-6% m/m water addition there seems to be an optimum for fuel consumption and at 8-10% there are a breakeven compared to consumption without water. At higher water contents the heat losses by evaporating is larger than the gain in the combustion.

The reduction in NO_x continues with increasing water content.

For electronic controlled fuel injection, the engine can be operate with the FWE system as long at the fuel pump, nozzle and fuel cam can handle the increased viscosity and mass that has to be injected. The cam and roller can be overloaded at high load with increased amount of fuel/water.

At a mechanical controlled fuel system the load is blocked by a physical stop device. The stop device does not detect whether the fuel is with or without water, it acts as a physical restriction on maximum allowed fuel pump index. As a consequence the engine will get 20% less fuel at full load if the water content is 20%, and therefore have 20% lower maximum output.

This topic must be addressed to the classification society by the customer in order not to violate the class required available power for the given installation.

The increased viscosity can lead to the maximum pressure being exceeded above the design limit. This may be solved by introducing a new fuel nozzle. This requires an amendment to the technical file and in some cases a new NOx certification. If nozzles with larger holes are introduced to compensate for the increased viscosity and injected volume black smoke can be expected at lower loads when running on fuel without water.

Special attention must be given to the temperature and pressure in the fuel system. If the pressure are too low in combination with increased temperature to compensate for viscosity the water might evaporate in the system and cause cavitation.

The water may increase the ignition delay. High amount of water in the emulsion and/or low load operation might result in white smoke.

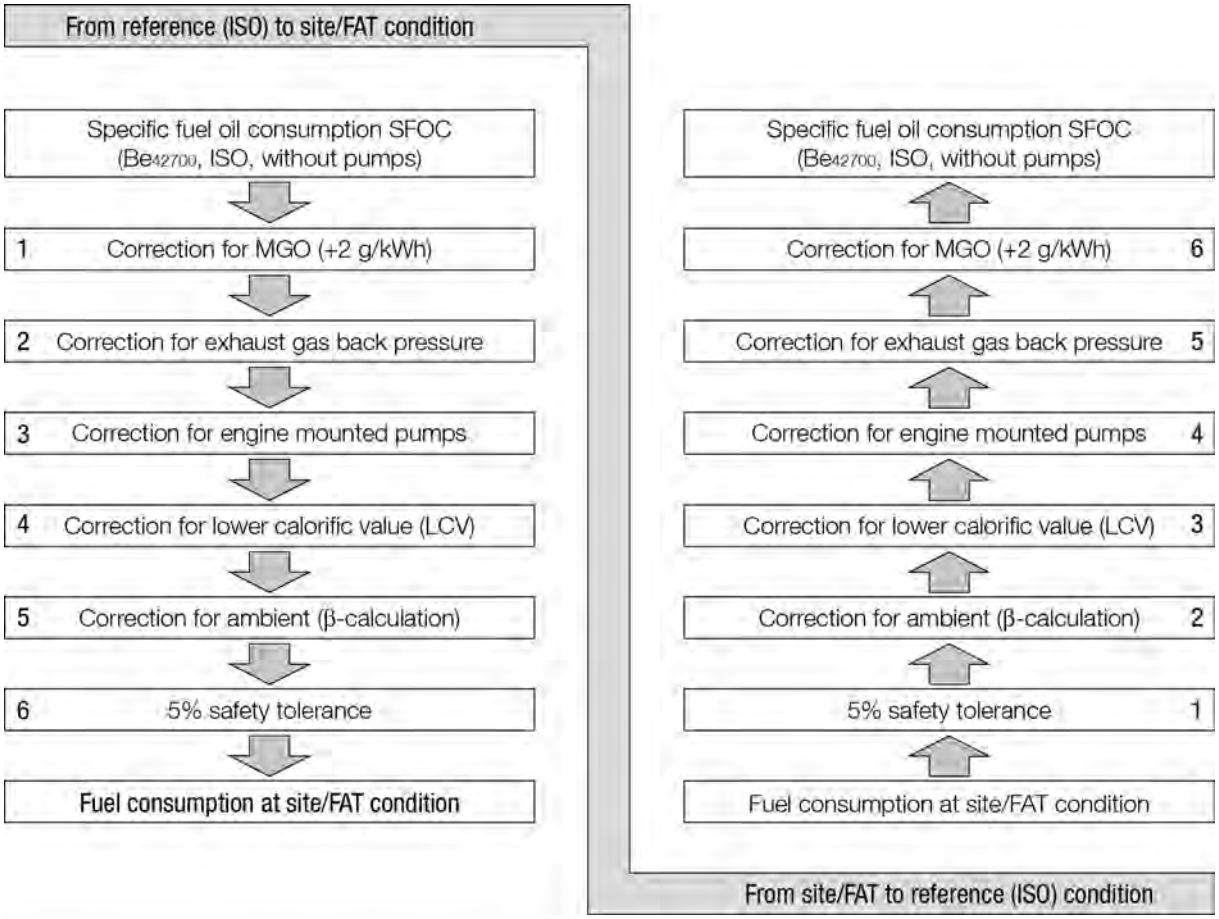
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Calculation of specific fuel oil consumption (SFOC)

General

Figure describes the standardized calculation order for conversion of SFOC from Reference condition (ISO) to Site/FAT condition, and from Site/FAT condition to Reference condition (ISO).



Following description is focussed on how to calculate a conversion from site/FAT condition to reference condition ISO.

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Fuel consumption (kg/h):

Fuel oil consumption is measured by a measuring tank. Recommended is that a recently calibrated electronic weight is measuring the fuel consumption. Measuring time should minimum have duration of 10 minutes. Values are stated in kg/h.

The leakage oil (kg/h) is measured over minimum 10 min and subtracted from measured fuel consumption.

$$BeO = (\textit{Fuel oil}) - (\textit{Leak oil})$$

Leak oil

Please find below diagram for different engine types running on MGO.

The mentioned values are measured under controlled condition on a test bed using new fuel injection pump / fuel injection valve, and taking into consideration that temperature, viscosity, clearance, oil condition, oil quality etc can differ and thereby affect the leak oil amount.

Tolerance of the values is +/-25%.

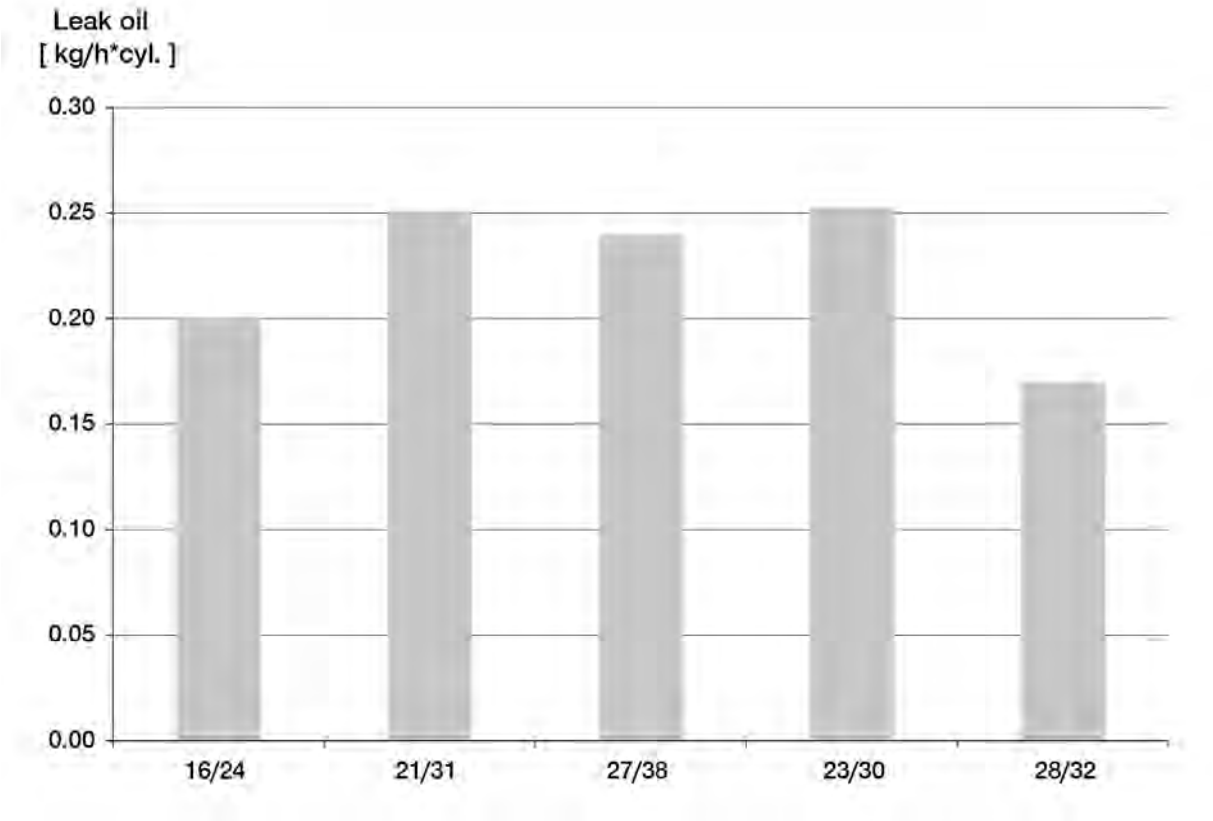


Figure 1: Leak oil on full load for MGO operation (for guidance only)

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1) Safety tolerance 5%

Safety tolerance 5% is subtracted from fuel consumption

$$Be1 = \frac{Be0}{1 + (SFOC\ tolerance/100)}$$

2) Correction for ambient (β-calculation)

In accordance to ISO-Standard ISO 3046-1:2002 *"Reciprocating internal combustion engines – Performance, Part 1: Declarations of power, fuel and lubricating oil consumptions, and test methods – Additional requirements for engines for general use"* Everllence specifies the method for recalculation of fuel consumption dependent on ambient conditions **for 1-stage turbocharged engines** as follows:

$$\beta = 1 + 0.0006 \times (t_x - t_r) + 0.0004 \times (t_{bax} - t_{bar}) + 0.07 \times (p_r - p_x)$$

The formula is valid within the following limits:

+ Ambient air temperature	5°C – 55°C
+ Charge air temperature before cylinder	25°C – 75°C
+ Ambient air pressure	0.885 bar – 1.030 bar

$$Be2 = \frac{Be1}{\beta}$$

β Fuel consumption factor

t_{bar} Engine type specific reference charge air temperature before cylinder, see »Reference conditions« in »*Fuel oil consumption for emissions standard*«.

Legend		Reference	Site/FAT
Specific fuel consumption	[g/kWh]	b_r	b_x
Ambient air temperature	[°C]	t_r	t_x
Charge air temperature before cylinder	[°C]	t_{bar}	t_{bax}
Ambient air pressure	[bar]	p_r	p_x

Example

Reference values:

br = 200 g/kWh, tr = 25°C, tbar = 40°C, pr = 1.0 bar

At site:

t_x = 45°C, t_{bax} = 50°C, p_x = 0.9 bar

ß = 1+ 0.0006 (45 – 25) + 0.0004 (50 – 40) + 0.07 (1.0 – 0.9) = 1.023

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$b_x = ß \times b_r = 1.023 \times 200 = 204.6$ g/kWh

3) Correction for lower calorific value (LCV)

Whenever LCV value rise 427 kJ/kg the SFOC will be reduced with 1%

$$LCV\ f = \frac{LCV}{42700}$$

$$Be3 = Be2 * LCV\ f$$

4) Correction for engine mounted pumps

Engine type 16/24, 27/38

With built-on pumps, the SFOC will be increased in [%] by:

Lubricating oil main pump	$1.2 \times \left(\frac{110}{load\ \% + 10} \right)$ %
LT Cooling water pump	$0.7 \times \left(\frac{110}{load\ \% + 10} \right)$ %
HT Cooling water pump	$0.7 \times \left(\frac{110}{load\ \% + 10} \right)$ %

Engine type 21/31

5 cyl. engine

Lubricating oil main pump	$1.13 \times \left(\frac{110}{load\ \% + 10} \right)$ %
LT cooling water pump	$0.93 \times \left(\frac{110}{load\ \% + 10} \right)$ %
HT cooling water pump	$0.93 \times \left(\frac{110}{load\ \% + 10} \right)$ %

6, 7, 8, 9 cyl. engine

Lubricating oil main pump	$1.10 \times \left(\frac{110}{load\ \% + 10} \right)$ %
LT cooling water pump	$0.71 \times \left(\frac{110}{load\ \% + 10} \right)$ %
HT cooling water pump	$0.71 \times \left(\frac{110}{load\ \% + 10} \right)$ %

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Engine type
23/30, 28/32

With built-on pumps, the SFOC will be increased in [%] by:

Lubricating oil main pump	$0.5 \times \left(\frac{110}{\text{load \%} + 10} \right)$ %
LT Cooling water pump	$0.7 \times \left(\frac{110}{\text{load \%} + 10} \right)$ %
HT Cooling water pump	$0.7 \times \left(\frac{110}{\text{load \%} + 10} \right)$ %

$$Be4 = \frac{Be3}{1 + LO\,f + LT\,f + HT\,f}$$

5) Correction for exhaust gas back pressure

Increased negative intake pressure before compressor leads to increased fuel oil consumption, calculated as increased air temperature before turbocharger:

U = (-20 [mbar] – $p_{\text{Air before compressor}}$ [mbar]) x 0.25 [K/mbar] with U ≥ 0

Increased exhaust gas back pressure after turbine leads to increased fuel oil consumption, calculated as increased air temperature before turbocharger:

O = ($p_{\text{Exhaust after turbine}}$ [mbar] – 50 [mbar]) x 0.25 [K/mbar] with O ≥ 0

Charge air blow-off for exhaust gas temperature control (ex. plants with catalyst) leads to increased fuel oil consumption:
For every increase of the exhaust gas temperature by 1° C, due to activation of charge air blow-off device, an addition of 0.05 g/kWh to be considered.

6) Correction for MGO (+2 g/kWh)

When engine is running MGO the fuel consumption can be increased by up to +2 g/kWh due to lower energy content and longer injection duration.

SFOC can in some case also be reduced by inverted fuel values of MGO.

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Description for biofuels

Biofuels

Biofuels are similar to diesel and gasoline fuels in many parameters. They can be used in combustion engines with relatively simple adaptation measures to the engine parameters.

Everllence four-stroke small bore has many engines in service running on various biofuels with excellent operation experience.

Liquid biofuels used in Everllence 4-stroke small bore engines

Several types of liquid biofuels have already been tested on engines:

Non-transesterified biofuel

From a chemical point of view vegetable oil and animal fat are of the same composition. These are large molecules based on three fatty acids bound to glycerin. The viscosity is typically more in the range of heavy fuel oil and much higher compared to diesel fuel. Dependent on the fatty acids such fuels can have a quite high pour point. Similar to HFO is preheating required to achieve the injection viscosity.

Critical components in such fuels can be acids (from free fatty acids) causing corrosion in the fuel system. This must be controlled by keeping the TAN (total acid number) in a specified limit. Besides acids such fuels can contain gums. These components can cause deposits in the fuels system. Limitations for the phosphorus content and the carbon residue shall avoid such issues.

Long storage is not recommended as such fuels are sensitive to microbiological degeneration.

- Findings on engines with non-transesterified biofuel:
  - Blockage of leakage system. Trace heating necessary
  - Increased built up of deposits within combustion chamber and exhaust gas system
  - Reduction in maximum power output
  - Increased wear on parts of the injection system may influence the TBO.

Transesterified biofuel – FAME (fatty acid methyl ester)

Specifications like EN 14214 ensure high quality of FAME fuels. It is important to know that the energy content is significantly lower compared to diesel fuel. Depending on the engine type the maximum output of the engine might be reduced. Long storage is not recommended as such fuels are sensitive to microbiological degeneration.

Fuels not complying with EN 14214 are regularly offered on the market. Such fuels still contain a significant amount of glycerin components and have a higher tendency to build up deposit in the fuel system.

- Findings on engines with transesterified biofuel:
  - - Reduced engine load
  - - Deposits within fuel oil filters
  - - Increased wear on parts of the injection system may influence the TBO.

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FAME diesel fuels from four different feedstock on a Medium Speed Single Cylinder Engine were investigated. Additionally two blended fuels were tested. The FAME content within the fuel influences the emission behavior, as the figure shows for the nominal load point. With increasing FAME content the NOx emissions remain constant compared to HFO.

A significant decrease of the soot emissions was observed (see Figure 1).

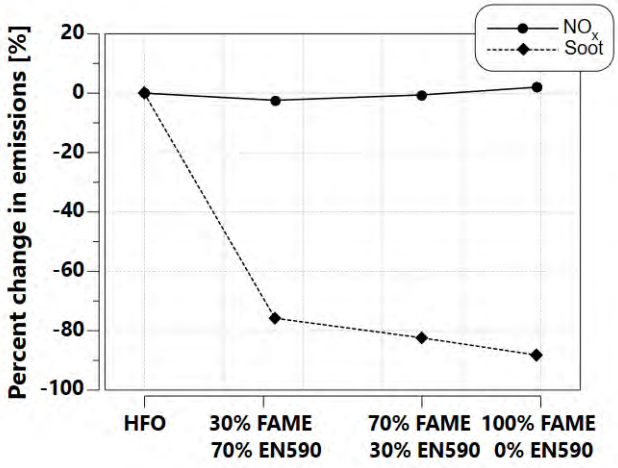


Figure 1: Emission behavior with FAME.

Diagrams in Figure 2 show the NOx and soot emission trends for FAME fuels and blends compared to DMA (MGO) as reference. With increasing FAME-content, a slight increase of the NOx emissions was observed. For all investigated B100 fuels an increase below 10% of the NOx emissions and a significant reduction (up to 50%) of the soot emissions, compared to DMA, was measured.

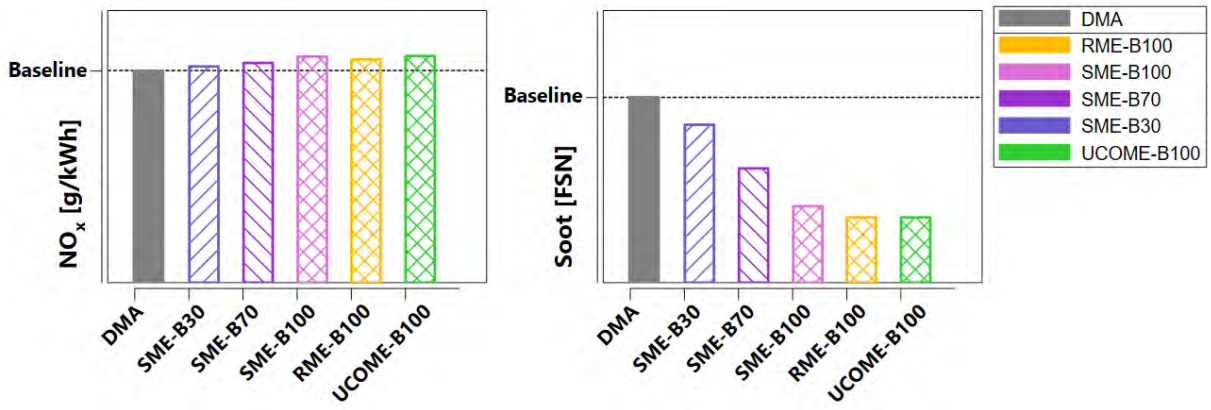


Figure 2: NOx and soot emission trends

HVO (hydrogenated vegetable oil)

HVO (hydrogenated vegetable oil) can be produced from the same base stock like the other fuels mentioned (vegetable oil, cooking oil, animal fat) but in a completely different process. HVO is derived by treatment with hydrogen resulting in a fuel that is chemically quite similar to high performance diesel fuel, consisting of pure hydrocarbons. HVO is comparable to synthetic diesel fuel like GtL. Compared to fossil diesel fuel HVO contains hardly any aromatic components causing very good combustion properties.

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Although the energy content (per mass) is higher compared to fossil diesel the volumetric energy content is lower, caused by a low density. This can reduce the maximum possible output of the engine. Similar to distillate, then be aware of viscosity due to increasing temperature with fuel circulating over engine. Fuel cooler will be needed in the fuel string.

To comply with the regular fuel specifications like ISO 8217 or EN 590 and to ensure sufficient lubricity of the fuel, the supplier could possible add lubricity additives.

- Findings on engines with HVO:
  - First tests with HVO show significant improvements in emissions compared to HFO operation. NOx emissions are reduced by up to 29%, SOx emissions by almost 100%, and particle matters by up to 72% compared to HFO operation.
  - Observed leakages due to the lower viscosity of the fuel is in the same range as with MGO, load stability in the lower operating range is comparable to HFO, even slightly better.

Operation with biofuel

Please contact Everllence at an early stage of project.

Requirements on plant side

Biofuel has to be divided into 3 categories.

Category 1

Transesterified biofuel

For example:

- Biodiesel (FAME)

Esterified biofuel is comparable to MDO (ISO-F-DMB/ ISO-F-DMC), therefore standard layout of fuel oil system for MDO-operation to be used.

Category 2

Non-transesterified biofuel and pour point below 20°C

For example:

- Vegetable oil
- Rape-seed oil

Non-transesterified biofuel with pour point below 20°C is comparable to HFO (ISO-F-RM), therefore standard layout of fuel oil system for HFO-operation to be used.

Category 3

Non-transesterified biofuel and pour point above 20° C

For example:

- Palm oil
- Stearin
- Animal fat
- Frying fat

⚠ CAUTION Non-transesterified biofuel with a pour point above 20° C carries a risk of flocculation and may clog up pipes and filters unless special precautions are taken.

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Therefore the standard layout of fuel oil system for HFO-operation has to be modified concerning following aspects:

- In general no part of the fuel oil system must be cooled down below pour point of the used biofuel.
- Fuel cooler for circulation fuel oil feeding part => to be modified.
  In this circuit a temperature above pour point of the biofuel is needed without overheating of the supply pumps.
- Sensor pipes to be isolated or heated and located near to main pipes.
- To prevent injection nozzles from clogging indicator filter size 0.010 mm has to be used instead of 0.034 mm.

Additionally

- Fuel oil module to be located inside plant (to be protected against rain and cold wind).
- A second fuel type has to be provided of category 1 or 2.
  Due to the risk of clogging it is needed before each stop of the engine, to change over to a second fuel type of category 1 or 2 and to operate the engine until the danger of clogging of the fuel oil system no longer exists.

Requirements on engine

- Injection pumps with special coating and with sealing oil system.
- Fuel pipes and leak fuel pipes must be equipped with heat-tracing (not to be applied for biofuel category 1). Heat-tracing to be applied for biofuel category 2 outside covers of injection pump area and for biofuel category 3 also inside injection pump area.
- Nozzle cooling to be applied for biofuel category 2 and 3.
- Charge air temperature before cylinder 55° C to minimize ignition delay.

Please be aware

- Depending on the quality of the biofuel, it may be necessary to carry out one oil change per year (this is not taken into account in the details concerning lubricating oil consumption).
- An addition to the fuel oil consumption is necessary:
  2 g/kWh addition to fuel oil consumption (see chapter fuel oil consumption)
- Engine operation with fuels of low calorific value like biofuel, requires an output reduction:
  - LCV ≥ 38 MJ/kg Power reduction 0%
  - LCV ≥ 36 MJ/kg Power reduction 5%
  - LCV ≥ 35 MJ/kg Power reduction 10%

Gaseous biofuels used in engines

Biogas

Biogas is a gas mixture produced by the natural decomposition of organic material in the absence of air and is produced naturally or as part of an industrial process to intentionally produce biogas as a fuel. The methane number value of the used biogas must be in accordance with the Everllence gas specification for gaseous fuels.

- Findings on engines with biogas:
  - The use of biogas has been tested successfully on our engines without any limitations in operation. Compared to LNG or SNG biogas may have an influences to the lifetime of engine components.
  - Increased wear on parts of the injection system may influence the TBO.

Synthetic natural gas (SNG)

SNG is similar to natural gas produced from organic material such as coal, propane or biomass (biomethane). Everllence has tested the world's first container ship to run on climate-neutral liquefied synthetic natural gas (SNG). With this project.

- Findings on engines with SNG:
  - Measurements on the mentioned vessel have shown that the greenhouse gas emissions with blended proportion of synthetic natural gas were 27% lower compared to operation with conventional LNG.

    Compared with HFO, the reduction in emissions was even around 34%.
  - With straight SNG operation, it is expected to cut CO2-emissions by up to 80%.

Implications on engines with the use of biofuels

The different calorific values of biofuels have a significant impact on engine efficiency due to their different ignition and combustion capabilities. Therefore we would like to remind you on the standard test method IP541/06, described in our PCI 398 from December 2018:

PCI No. 398
- Possible impacts of the IMO 2020 Sulphur Cap on four stroke engines (Dec. 2018)

This method enables an index called the estimated cetane number (ECN). Figure 3 shows the recommended operational reference ranges for the ECN parameter. Critical is a fuel with an ECN less than 20, especially in the low-load range.



Figure 3: ECN operational reference ranges (CIMAC Fuel quality guide 2011)

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Automatic back-flush filter

Automatic back-flush filter

To protect the GenSets from foreign particles in the fuel (cat fines attack), must a common automatic back-flush filter be installed in the circulation line, just before the branching to the individual GenSets.

The automatic back-flush filter with a change-over cock and by-pass simplex filter and with integrated heating chamber, has a mesh size of 10 microns (absolute/sphere passing mesh).

The automatic back-flush filter permits a continuous operation even during back flushing without any pressure drops or interruptions of flow. If the filter inserts are clogged, an automatic cleaning is started. The filter is equipped with a visual differential pressure indication and two differential pressure contacts to monitor the clogging of the filter. Back flushing medium is discharged discontinuous to a sludge tank or back to the settling tank.

Filter specification

Range of application	:	Heavy fuel oil 700 cSt @ 50°C
Max. operating pressure	:	16 bar
Test pressure	:	According to class rule
Max. operating temperature	:	160°C
Nominal width of connection flanges	:	DN40, DN65, DN80, DN100 or DN125
Grade of filtration	:	10 microns (absolute/sphere passing mesh)
Cleaning	:	Sequential reverse-flow back-flushing, assisted by compressed air
Back-flushing control	:	Differential pressure-dependent or time-dependent
Pressure drop at clean filter	:	≤ 0.2 bar
Filter to be cleaned at a pressure drop	:	0.38 bar ± 10%
Alarm contact switches at differential pressure	:	0.5 bar ± 10%
Compressed air	:	4-10 bar

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Specification L16/24

1000 rpm	Booster circuit				
Qty. engines	5L16/24	6L16/24	7L16/24	8L16/24	9L16/24
1	DN40	DN40	DN40	DN40	DN40
2	DN40	DN40	DN40	DN40	DN40
3	DN40	DN40	DN40	DN65	DN65
4	DN40	DN65	DN65	DN65	DN65

1200 rpm	Booster circuit				
Qty. engines	5L16/24	6L16/24	7L16/24	8L16/24	9L16/24
1	DN40	DN40	DN40	DN40	DN40
2	DN40	DN40	DN40	DN40	DN40
3	DN40	DN40	DN65	DN65	DN65
4	DN40	DN65	DN65	DN65	DN65

Specification L21/31 + Mk2

900 rpm	Booster circuit				
Qty. engines	5 cyl. engine	6 cyl. engine	7 cyl. engine	8 cyl. engine	9 cyl. engine
1	DN40	DN40	DN40	DN40	DN65
2	DN65	DN65	DN65	DN65	DN65
3	DN65	DN65	DN65	DN65	DN80
4	DN65	DN65	DN80	DN80	DN80

1000 rpm	Booster circuit				
Qty. engines	5 cyl. engine	6 cyl. engine	7 cyl. engine	8 cyl. engine	9 cyl. engine
1	DN40	DN40	DN40	DN40	DN65
2	DN65	DN65	DN65	DN65	DN65
3	DN65	DN65	DN65	DN65	DN80
4	DN65	DN65	DN80	DN80	DN80

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Specification L27/38

720 rpm	Booster circuit				
Qty. engines	5L27/38	6L27/38	7L27/38	8L27/38	9L27/38
1	DN40	DN40	DN65	DN65	DN65
2	DN65	DN65	DN65	DN65	DN65
3	DN65	DN65	DN65	DN80	DN80
4	DN65	DN80	DN80	DN80	DN100

750 rpm	Booster circuit				
Qty. engines	5L27/38	6L27/38	7L27/38	8L27/38	9L27/38
1	DN40	DN40	DN65	DN65	DN65
2	DN65	DN65	DN65	DN65	DN65
3	DN65	DN65	DN65	DN80	DN80
4	DN65	DN80	DN80	DN80	DN100

Specification L23/30H + Mk2

720/750 rpm	Booster circuit			
Qty. engines	5 cyl. engine	6 cyl. engine	7 cyl. engine	8 cyl. engine
1	DN40	DN40	DN40	DN40
2	DN40	DN40	DN40	DN65
3	DN40	DN65	DN65	DN65
4	DN65	DN65	DN65	DN65

900 rpm	Booster circuit		
Qty. engines	6 cyl. engine	7 cyl. engine	8 cyl. engine
1	DN40	DN40	DN40
2	DN40	DN65	DN65
3	DN65	DN65	DN65
4	DN65	DN65	DN65

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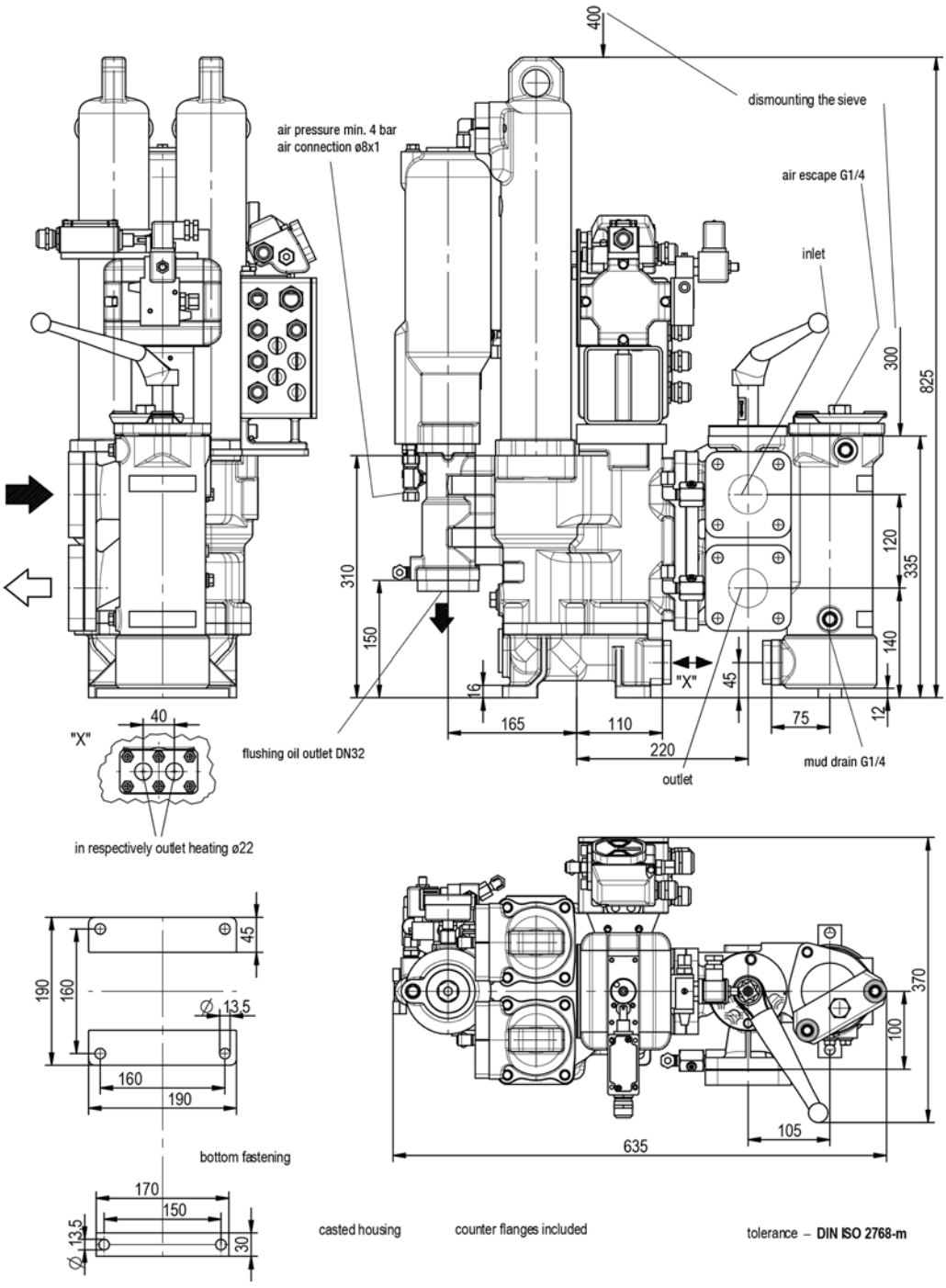
Specification L28/32H

720 rpm	Booster circuit				
Qty. engines	5L28/32H	6L28/32H	7L28/32H	8L28/32H	9L28/32H
1	DN40	DN40	DN40	DN40	DN40
2	DN40	DN65	DN65	DN65	DN65
3	DN65	DN65	DN65	DN65	DN65
4	DN65	DN65	DN65	DN65	DN80

750 rpm	Booster circuit				
Qty. engines	5L28/32H	6L28/32H	7L28/32H	8L28/32H	9L28/32H
1	DN40	DN40	DN40	DN40	DN40
2	DN40	DN65	DN65	DN65	DN65
3	DN65	DN65	DN65	DN65	DN65
4	DN65	DN65	DN65	DN65	DN80

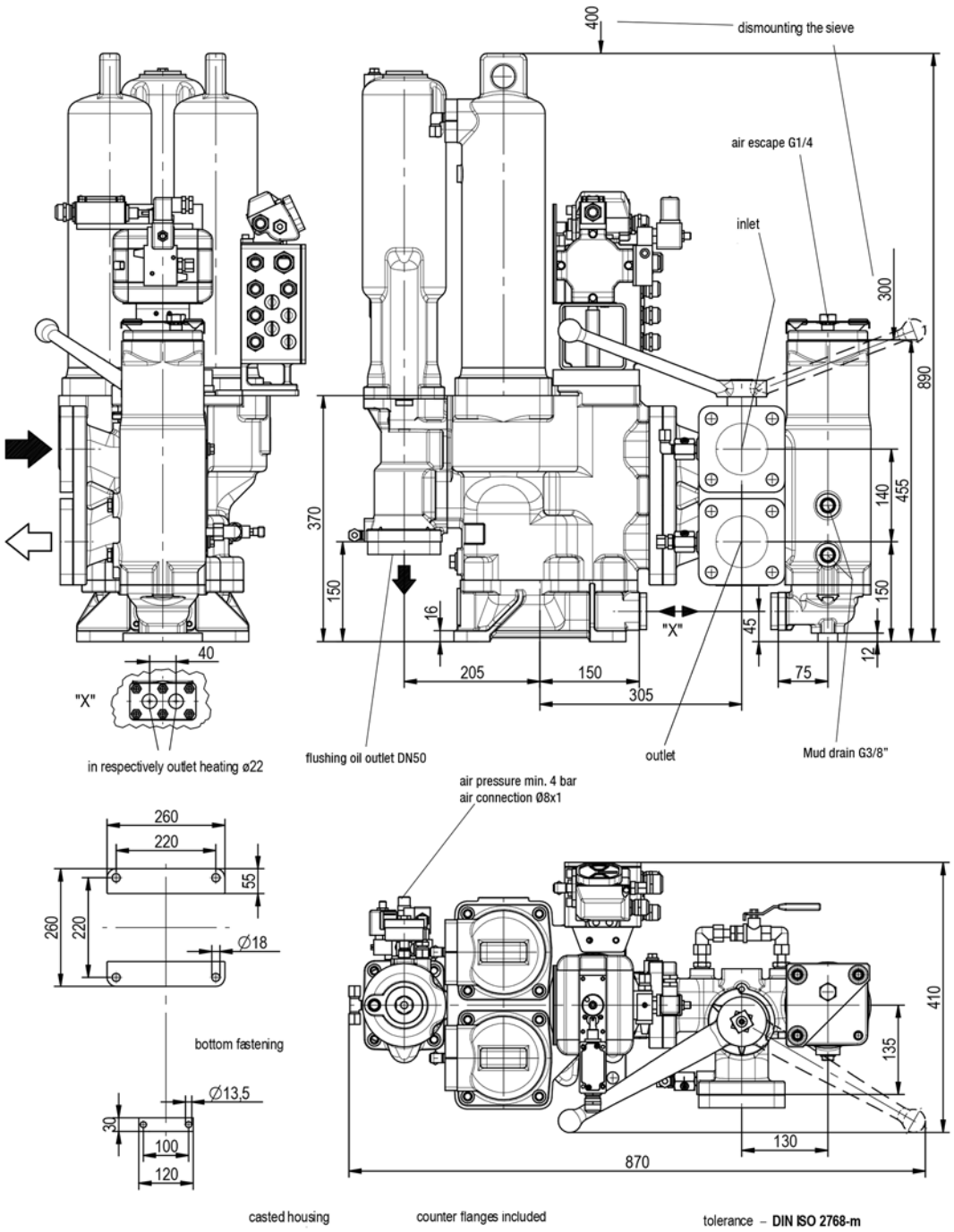
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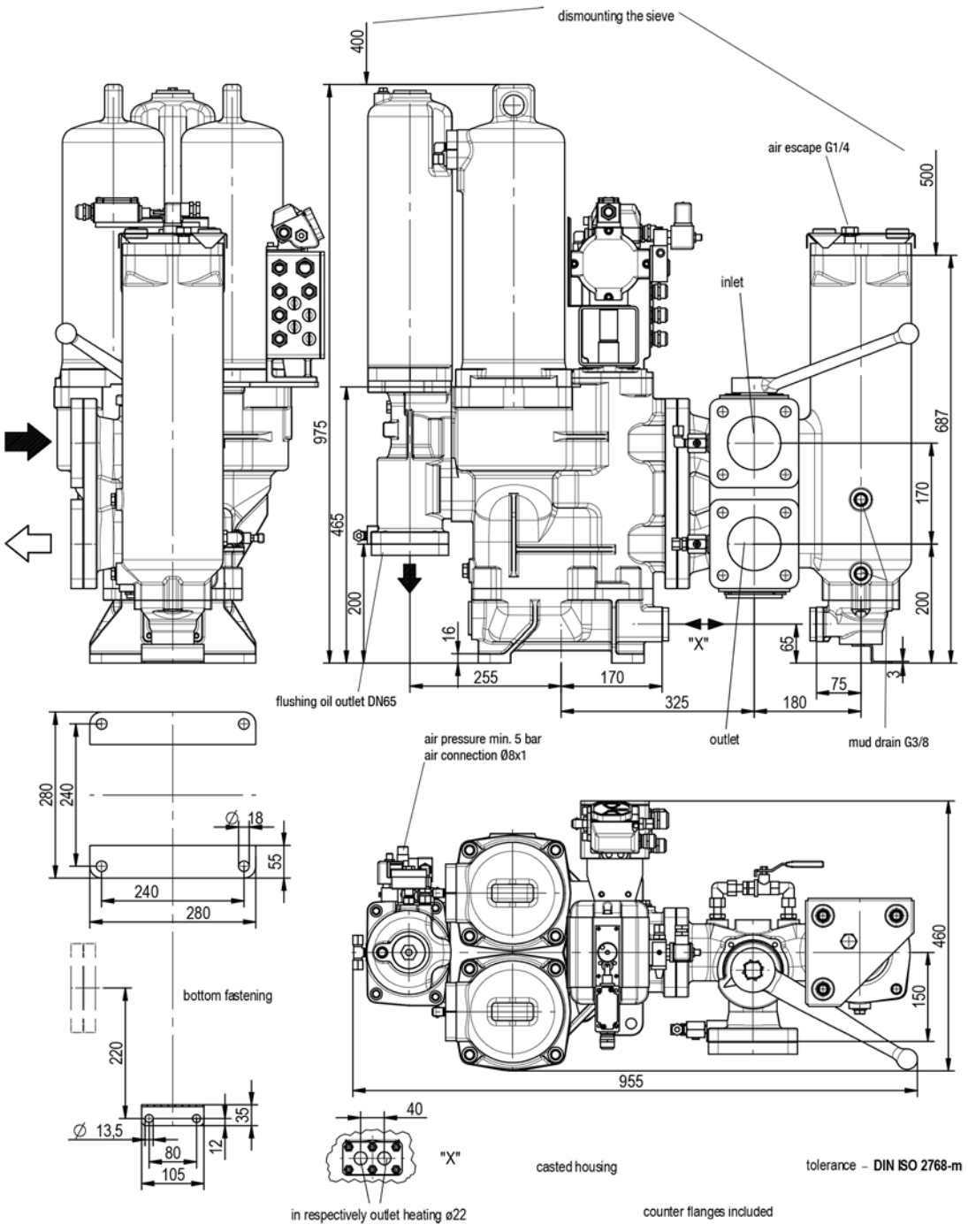


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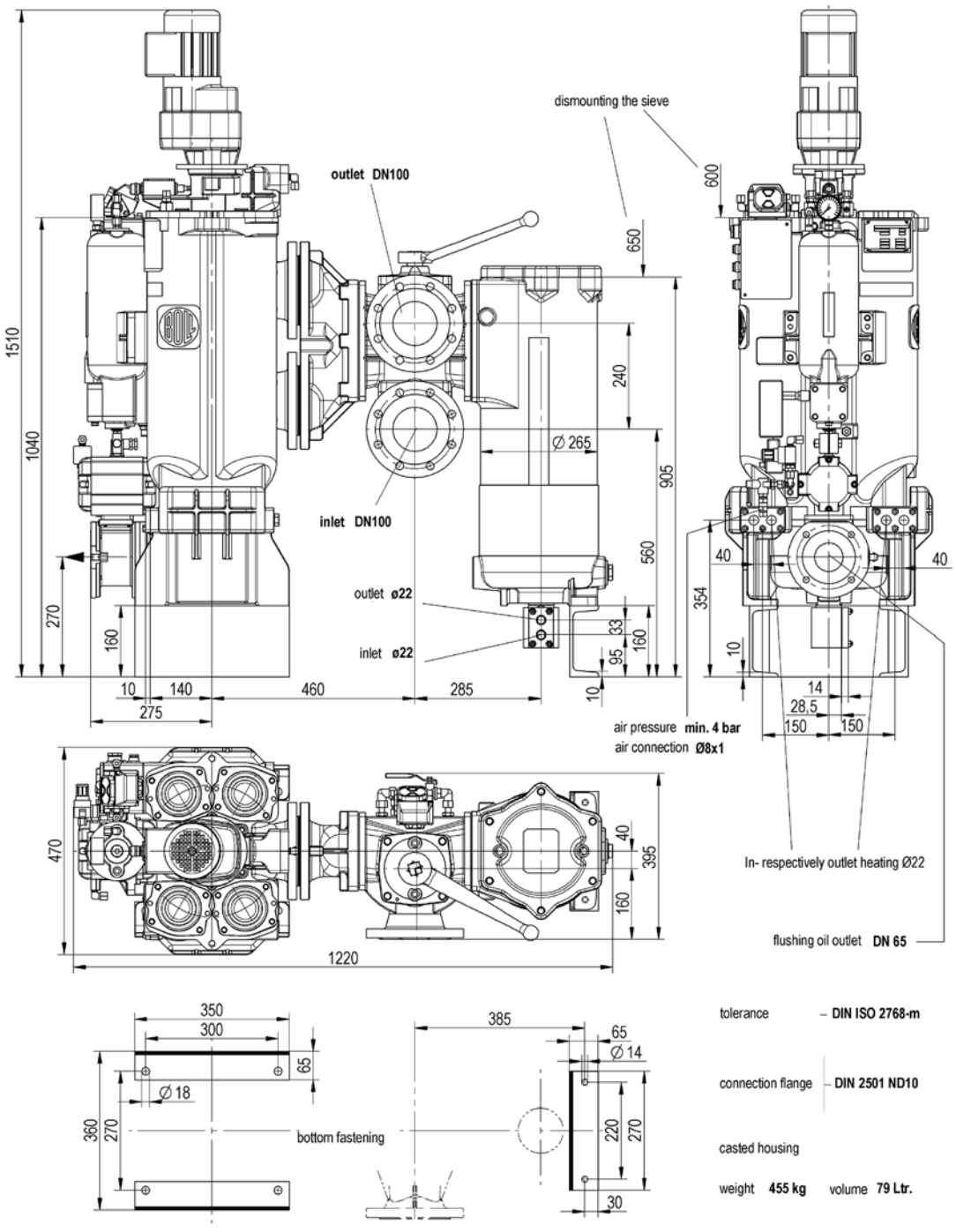


DN80 - Typ 6.72.1



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DN100 - Typ 6.64.1



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Residual fuel (HFO) specification

General information

Four-stroke diesel engines from Everllence can be powered with any residual fuel recovered from crude oil that fulfils the requirements specified in the table Residual fuel requirements, provided that the engine and the fuel management system are designed accordingly. It is also referred to as: Residual fuels (RM), FAME Residual fuels (RF). In order to ensure a favourable ratio between fuel costs, spare parts and also repair and servicing expenditure, we recommend observing the following points.

Selection of suitable fuel

Unsuitable or adulterated fuel generally results in a shortening of the service life of engine parts/components, damage to these and to catastrophic engine failure. It is therefore important to select the fuel with care in terms of its suitability for the engine and the intended application. Through its combustion, the fuel influences the emissions behaviour of the engine.

Specifications and approvals

The fuel quality varies regionally and depends on climatic conditions. All requirements from ISO 8217:2024 apply

The following values must be maintained at the engine inlet:

Property	Unit		Limit value[1)]	Standard[2)]
Kin. viscosity at 50° C[3)]	mm/s	Max. Min.	700 1.9	EN ISO 3104, ASTM D7042, ASTM D445, DIN EN 16896
Kin. viscosity at 100°C[3)]	mm/s	Max.	55	EN ISO 3104, ASTM D7042, ASTM D445, DIN EN 16896
Density at 15°C	kg/m^3	Max.	1010	ISO 3675, ISO 12185
Water content[4)]	% (m/m)	Max.	0.20	DIN 51777, ASTM D6304, DIN ISO 3733
Sulphur content[5)]	% (m/m)	Max.	5.0	ISO 8754, ISO 14596, ASTM D4294
Flashpoint[6)]	°C	Min.	60.0	ISO 2719
Acid number	mg KOH/g	Max.	2.5	ASTM D664
Carbon residue (CCR)	% (m/m)	Max.	20.0	EN ISO 10370
Ash content	% (m/m)	Max.	0.150	ISO 6245
Hydrogen sulphide	mg/kg	Max.	2.0	IP 570
Total sediment (aged)	% (m/m)	Max.	0.10	ISO 10307-2
Asphaltene content	% (m/m)	Max.	2/3 x CCR	Factory standard, DIN 51595
Fatty acid methyl ester content[7)]	% (m/m)		Report	ASTM D7963, IP 631, DIN EN 14078, DIN EN 14103
Pour point[8)]	°C	Max.	30	ISO 3016

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Property	Unit		Limit value[1)]	Standard[2)]
Vanadium	mg/kg	Max.	450	IP 501, IP 470, ISO 14597, DIN EN 15944 DIN 51790-6
Sodium	mg/kg	Max.	100 and 1/3 x vanadium	IP 501, IP 470
Aluminium and silicone[9)]	mg/kg	Max.	15	IP 501, IP 470, DIN ISO 10478
Calcium Zinc	mg/kg mg/kg	Max. Max.	30 15	IP 501, IP 470
Calcium Phosphorus	mg/kg mg/kg	Max. Max.	30 15	IP 501, IP 470, IP 500
CCAI[10)]		Max.	870	

Table 1: Residual fuel requirements

Remarks:

[1)] Engine inlet requirement: Additional parameters defined for ISO 8217. The entire ISO 8217:2024 document is mandatory. The fuel mixture at the engine inlet must be homogeneous. The fuel mixture is homogeneous if the p-value according to ASTM D7060 is at min. 1.20. Other processes (e.g. ASTM D7112 or ASTM D7157) can also be used to check the homogeneity of the fuel mixture. Furthermore, the fuel must be fit for use and must not contain substances in a concentration that contributes to further contamination of the air and/or may impair the safety of personnel or the performance of the machine.

[2)] Always reference the latest edition.

[3)] If FAME is present in the HFO (RF), the max. viscosity is limited to 500 mm2/s at 50°C.
Specific requirements of the injection system must be taken into account.

[4)] According to ISO 8217:2024, the bunker product (before purification) may contain max. 0.50% water.

[5)] Local laws and regulations must be observed independently of the maximum possible sulphur content.

[6)] Additional requirements (e.g. SOLAS) must be observed. Applicable laws must be adhered to.

[7)] When using RF (FAME according to EN 14214 or ASTM D6751* and their mixtures with HFO), prior consultation with Everllence is required.
The FAME must either be in accordance with EN 14214 or with ASTM D6751 as well as with increased oxidation stability of at least 8 hours (EN 15751). For additional information see FAME mixtures.

[8)] The pour point must be suitably selected by the operating company in accordance with the design of the fuel system and on the basis of the requirements at the place of use.

[9)] The bunker product (prior to purification) may contain max. 60 mg/kg Al and Si.

[10)] This method is only applicable to ‘straight run’ residual oils. The increasing complexity of refinery processes means that the CCAI method does not correctly reproduce the ignition behaviour for all residual oils. A test device (fuel combustion analyser; FCA) based on the constant volume combustion method measures the ignition delay to determine the ignition quality of a fuel and this measurement is converted

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into the cetane number (ECN: Estimated Cetane Number). It was discovered that residual fuels with a low ECN number cause malfunctions and can even lead to engine damage. An ECN > 20 can be considered acceptable.

Fuels that do not comply with the above-mentioned standards must be queried with Everllence.

Residual fuel (HFO)

Origin/refinery process

The quality of the residual fuel depends to a large extent on the quality of the crude oil and the refining process used. For this reason, residual fuels of the same viscosity can have significantly different properties depending on the bunker spaces. Residual fuel can consist of a mixture of residual oil, distillates and FAME. Residual oils and distillates generally originate from modern refining processes, such as CatCracker or Visbreaker. These processes can have an adverse affect on the stability of the fuel and on the ignition and combustion properties. These factors also have a considerable effect on the preparation of the residual fuel and the operating results of the engine.

The engine operator is responsible for selecting the corresponding residual fuels.

Important

The fuel properties in the table Residual fuel requirements, even if they meet the requirements mentioned there, may not be sufficient to determine the ignition and combustion properties and stability of the fuel. This means that the operational performance of the engine may depend on properties that are not defined in the specification. This particularly applies to the oil property that causes formation of deposits in the combustion chamber, injection system, gas pipes and exhaust system. A number of fuels have a tendency towards incompatibility with lubricating oil which leads to deposits being formed in the fuel injection pump that can cause a blockage of the pumps. It may therefore be necessary to exclude specific fuels that could cause problems.

Mixtures

The admixture of engine oils (ULO – used lube oil), of additional materials that have not been produced from mineral oils (example coal tar oil) and of residual products from chemical or other processes such as solvents (polymers or chemical waste) is not permitted. Among other things, this is due to the following reasons: abrasive and corrosive effects, unfavorable combustion characteristics, lack of compatibility with mineral oils and, not least, harmful effects on the environment. The fuel order must state explicitly what is no permissible, since this restriction is not contained in the generally utilized fuel specifications.

The admixture of engine oils (ULO – used lube oil) to the fuel represents a particular hazard since the additives of the lubricating oil work as emulsifiers. This means that dirt, water and cat fines are transported as a fine suspension. They hence prevent the necessary cleaning of the fuel. We and other manufacturers have discovered that serious consequential damage to the engine and turbocharger components may result due to excess wear.

The admixture of chemical waste products (e.g. solvents) to the fuel is prohibited for environmental reasons by the resolution of the IMO Marine Environment Protection Committee of 1 January 1992.

Leaked oil collectors

Leaked oil collectors that collect leaked oil, return pipes, and overflow pipes of the lubricating oil system must not be connected to the fuel tank. Leaked oil pipes should be drained into slurry tanks.

Fuels that do not comply with the above-mentioned standards must be queried with Everllence.

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Additional information

The following information will clarify the correlation between the quality of the residual fuel, fuel preparation, engine operation and the operating results.

Viscosity/injection viscosity

Residual fuels with higher viscosity can be of lower quality. The maximum permissible viscosity depends on the available pre-heating equipment and the capacity (flow rate) of the separator.

The prescribed injection viscosity of 12-14 mm^2/s and the corresponding fuel temperature upstream of the engine must be complied with. Only in this way can a suitable atomisation and mixture formation be ensured and therefore low-residue combustion. This also prevents mechanical overload of the injection system at the same time. The prescribed injection viscosity and/or the required fuel oil temperature upstream of the engine can be found in the viscosity temperature diagram.

Residual fuel preparation

Fault-free engine operation depends to a considerable extent on the care with which the residual fuel was prepared. Particular attention should be paid to ensuring that inorganic foreign matter with a strongly abrasive effect (catalyst particles, rust, sand) are effectively separated. It has been shown in practice that wear as a result of abrasion in the engine increases considerably if the aluminium and silicon content is higher than 15 mg/kg.

Viscosity and density have an influence on the cleaning effect. This must be taken into account when designing and installing the cleaning system.

Vanadium/Sodium

If the vanadium/sodium ratio is unfavourable, the melting point of the ash may fall in the operating area of the exhaust valve which can lead to high-temperature corrosion. Most of the water and water-soluble sodium compounds it contains can be removed by pre-treating the residual fuel in the settling tank and in the separators.

The risk of high-temperature corrosion is low if the sodium content is one third of the vanadium content or less. It must also be ensured that sodium does not enter the engine in the form of seawater in the intake air.

If the sodium content is higher than 100 mg/kg, this is likely to result in a higher quantity of salt deposits in the combustion chamber and exhaust-gas system. This will impair the function of the engine (including the suction function of the turbocharger).

Under certain conditions, high-temperature corrosion can be prevented using a fuel additive that increases the melting point of residual fuel ash (see also Additional information).

Ash

Fuel ash consists for the greater part of vanadium oxide and nickel sulphate (see above chapter for more information). Residual fuel containing a high proportion of ash in the form of foreign matter, e.g. sand, corrosion compounds and catalyst particles, accelerates the mechanical wear in the engine. Catalyst particles produced as a result of the catalytic cracking process may be present in the residual fuel. In most cases, these catalyst particles are aluminium silicates causing a high degree of wear in the injection system and the engine.

Flashpoint

National and international regulations for transport and storage involving the use of fuel must be considered in regard to the flashpoint. In general, a flashpoint of above 60 °C is specified for fuels of diesel engines.

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Low-temperature performance

The pour point is the temperature at which the fuel can no longer flow (but can be pumped). Since many residual fuels with low viscosity have a pour point above 0°C, the bunker facility must also be pre-heated. The entire fuel system must be designed in such a way that the residual fuel can be pre-heated to around 10°C above the pour point.

Pump properties

If the viscosity of the fuel is higher than 700 mm^2/s (cSt), or the temperature is not at least 10°C above the pour point, pump problems will occur. For more information, also refer to section Low-temperature behaviour.

Combustion properties

If the proportion of asphaltene is more than two thirds of the coke residue (Conradson), combustion may be delayed which in turn may increase the formation of combustion residues, leading to such as deposits on and in the injection nozzles, large amounts of smoke, low output, increased fuel consumption and a rapid rise in ignition pressure as well as combustion close to the cylinder wall (thermal overloading of lubricating oil film). If the ratio of asphaltenes to coke residues reaches the limit 0.66, and if the asphaltene content exceeds 8%, the risk of deposits forming in the combustion chamber and injection system is higher. These problems can also occur when using unstable residual fuels, or if incompatible residual fuels are blended. This would lead to an increased separation of asphalt (see section Compatibility).

Ignition quality

Nowadays, to achieve the prescribed reference viscosity, cracking-process products are used as the low viscosity ingredients of residual fuels although the ignition characteristics of these may also be poor. The cetane number of these compounds should be > 35. If the proportion of aromatic hydrocarbons is high (more than 35%), this also adversely affects the ignition quality.

The ignition delay in residual fuels with poor ignition characteristics is longer, the combustion is also delayed which can lead to thermal overloading of the oil film at the cylinder liner and also high cylinder pressures. The ignition delay and accompanying increase in pressure in the cylinder are also influenced by the end temperature and compression pressure, i.e. by the compression ratio, the charge-air pressure and charge-air temperature.

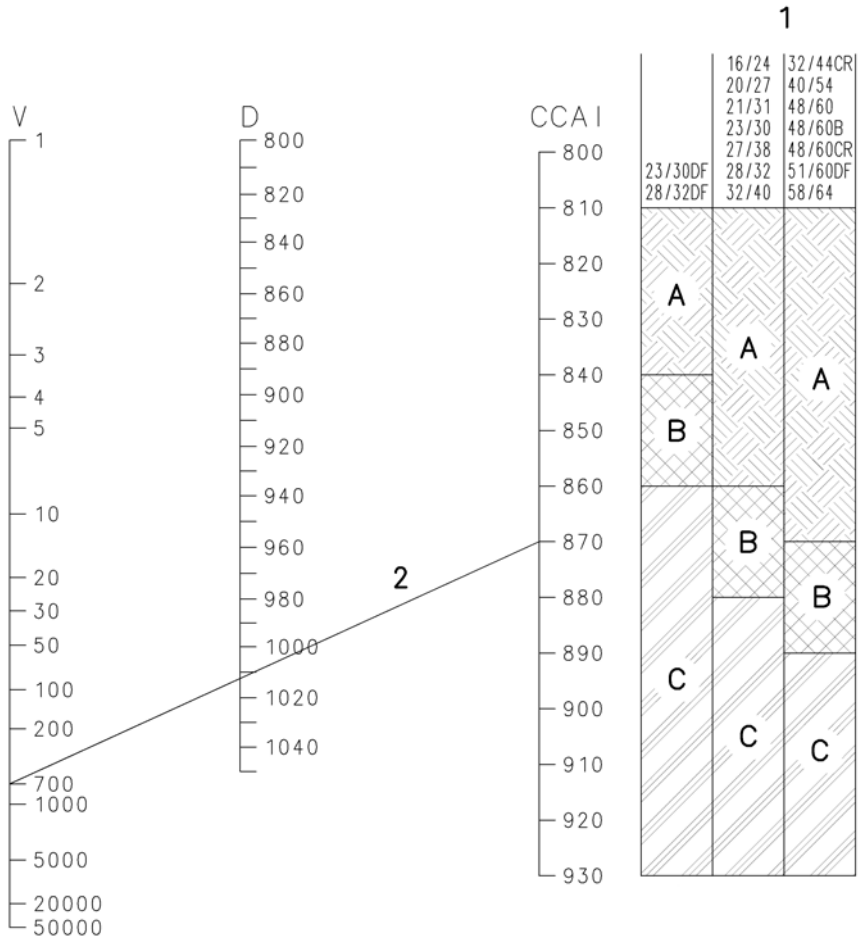
The disadvantages of using fuels with poor ignition characteristics can be limited by pre-heating the charge air in partial load operation and reducing the output for a limited period. However, a more effective solution is a high compression ratio and operational adjustment of the injection system to the ignition characteristics of the fuel used, as is the case with Everllence.

The ignition quality is one of the most important properties of the fuel. This value appears as CCAI in ISO 8217. This method is only applicable to ‘straight run’ residual oils. The increasing complexity of refinery processes has the effect that the CCAI method does not correctly reflect the ignition behaviour for all residual oils.

A test instrument based on the Fuel Combustion Analyser (FCA) method has been developed, which is used in some fuel testing laboratories (FCA according to IP 541).
The ignition quality of a fuel is determined as the ignition delay in the instrument and converted into an instrument-dependent cetane number (ECN: Estimated Cetane Number). It has been determined that residual fuels with a low ECN number cause operating problems and may even lead to damage to the engine. An ECN > 20 can be considered acceptable.

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As the liquid components of the residual fuel have a decisive influence on the ignition quality, and flow properties determine the combustion quality, the system operator is responsible for obtaining a fuel that is suitable for the diesel engine. Also see illustration entitled Nomogram for determining the CCAI – assigning the CCAI ranges to engine types.



V Viscosity in mm^2/s (cSt) at 50°C

D Density [in kg/m^3] at 15°C

CCAI Calculated Carbon Aromaticity Index

1 Engine type

A Normal operating conditions

B The ignition characteristics can be poor and require an adjustment to the engine or the operating conditions.

C Any problems identified can even lead to engine damage after a short operating period.

2 The CCAI is calculated from the density and viscosity of the residual fuel.

The CCAI can be calculated with the help of the following formula:

$$CCAI = D - 141 \log \log (V+0.85) - 81$$

Figure 1: Nomogram for determining the CCAI and assigning the CCAI ranges to engine types

Sulfuric acid corrosion

The engine should be operated with cooling water temperatures as specified in the operating manual for the respective load. If the temperature of the components that are exposed to acidic combustion products is below the acid dew point, acid corrosion can no longer be sufficiently prevented, even in the case of alkaline lubricating oil.

If the lubrication oil quality and the engine cooling system fulfil the specified requirements, the BN values stated in section 010.005 Engine – Operating Instructions 010.000.023-11 are sufficient.

Stability

The fuel must be a homogeneous mixture when entering the engine. Precipitation of any fuel components is not permissible! Experience has shown that stability decreases with continued storage and the given conditions. It is hence of great interest to the operator that the fuel has the maximum possible stability reserve so that it can provide a homogeneous fuel mixture at all times when entering the engine (see table Residual fuel requirements).

Compatibility

The supplier must guarantee that the residual fuel is homogeneous and remains stable even after the usual storage time. If different bunker oils are mixed, this may lead to separation that is connected with sludge build-up in the fuel system and where large quantities of sludge can be deposited in the separator, clog up the filter, prevent atomisation and lead to residue-rich combustion.

Cases like this can be traced back to incompatibility or instability. The fuel storage tanks should therefore be drained as much as possible before they can be bunkered again, in order to avoid incompatibilities.

Contamination

The fuel must not contain any substances that can lead to instability or deposits, otherwise engine operation may be impaired or engine damage may occur. With the help of an analysis according to ASTM D7845 (GC-MS), such substances can be partially detected and analysed. The fuel should be free of all substances listed in ASTM D7845, or their concentration should be below the limit of quantification noted therein. Proportions above the limit of quantification of all substances listed in ASTM D7845 can cause problems in engine operation. The combination of different substances could also cause problems with the engine even in a small amount.

Mixing residue fuels

If residual fuel for the main engine is blended with distillate fuel (e.g. DMA, FAME) or other residual fuels, to obtain the required quality, it is essential that the components are compatible (see section Compatibility). The compatibility of the resulting mixture must be tested over the entire mixing range. Reduced long-term stability due to consumption of the stability reserve can be a result. If a mixture of different fuels is planned or unavoidable, the stability reserve of the fuel must be sufficient to ensure that non-homogeneous fuels are not produced when blending.

Mixture with synthetic fuel

We strongly advise against using a mixture of HFO and synthetic fuel (in accordance with EN 15940). The reason is that the HFO contains asphaltenes, which are held in solution by the aromatics contained in HFO. Synthetic fuel is purely paraffinic (does not contain any aromatics) and therefore cannot hold asphaltenes in solution. This means that when synthetic fuel is added to HFO, these aromatics precipitate, deposits form or fuel filters become clogged or, in the worst case scenario, the injection system fails.

Additives for residual fuels

Everllence-Engines can also be economically operated without additives. It is up to the customer to decide whether or not the use of additives is beneficial. The supplier of the additive must guarantee that the engine operation will not be impaired by using the product.

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As a rule, the use of fuel additives during the warranty period must be avoided.

Residual fuels with low sulphur content

From the perspective of an engine manufacturer, there is no lower threshold for the sulphur content of residual fuel. We have not identified any issues that can be traced to the sulphur content with the low-sulphur residual fuels that are currently commercially available.

If the engine is not constantly operated with low-sulphur residual fuel, the lubricating oil must be selected accordingly for the highest sulphur content of the utilised fuels.

FAME mixtures

FAME admixtures (RF20 to RF500)

When using RF (FAME according to EN 14214 or ASTM D6751* and their mixtures with HFO), prior consultation with Everllence is required. In addition, the following should be observed:

- The fuel mixture at the engine inlet must be homogeneous. The fuel mixture is homogeneous if the p-value according to ASTM D7060 is at least 1.20. Other processes (e.g. ASTM D7112 or ASTM D7157) can also be used to check the homogeneity of the fuel mixture. Furthermore, the fuel must be fit for use and must not contain substances in a concentration that contribute to further contamination of the air and/or may impair the safety of personnel or the performance of the machine.
- If RF is to be used with other fuels and blending cannot be avoided, contact your fuel supplier to ensure the compatibility of these fuels.
- After switching to RF, pay attention to the delta pressure indicators/alarms of the filters, as they can become clogged by residues dissolved by RF.
- Heating is installed and active in the fuel supply system to prevent deposits or blockages to the pipes.
- The temperature resistance of the fuel must be guaranteed up to 150°C.
- Storage and leakage handling of FAME fuels, FAME mixtures with residual fuels and distillate fuels must be separated from each other in order to avoid incompatibility reactions due to the mixing of larger amounts of different fuels.
- Due to the typically lower calorific value or energy content of RF, it may result in deviations to the specified engine output, operating behaviour, load application, specific fuel consumption and emissions.
- Fuels may cause harmful reactions with metals such as zinc or copper. We highly recommend getting in contact with your tank and heating oil system supplier.
- The sealing materials used must be suitable for RF. NBR seals are not suitable and must not be used.
- RF reacts to air and this may lead to microbial growth. Ensure that the atmospheric oxygen ventilation is kept to a minimum. A nitrogen buffer is ideally installed in the fuel tank.
- RF tends to attract water. This increases the risk of microbial growth. Correctly adjust the separator to the new fuel type.
- If free water appears in the fuel tanks, it is important to drain this water immediately.
- If there is a possibility of dead volume in the fuel system, it is strongly recommended to flush these areas regularly (weekly) to prevent bacterial growth (e.g., in the area of the fuel filters by briefly switching the filter chambers).

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- Long standstill periods (e.g. emergency power units) must be avoided due to microbial growth. To prevent damage, it is recommendable to only operate applications with fuel which is free of FAME.
- The entire fuel system must be purged with fuel which is free of FAME prior to longer standstill periods.
- Since FAME has a higher evaporation temperature, it accumulates in the lubricating oil. Regular analysis of all the lubricating oil is highly recommended. The lubricating oil needs to be replaced if a FAME content of 12% is reached.
- RF may cause a layer to form, such a phenomenon leads to increased consumption of lubricating oil. If such an increase in lubricating oil consumption values is detected, please contact your Everllence PrimeServ department.

In any case, it is the responsibility of the operating company to adhere to the legal requirements (e.g. SOLAS) and agree on these with the relevant authorities.

* as well as with increased oxidation stability of at least 8 hours (EN 15751).

Cold suitability

The cold suitability of the fuel is determined by the climatic requirements at the place of installation. It is the responsibility of the operating company to choose a fuel with sufficient cold suitability.

The cold suitability of a fuel may be determined and assessed using the following standard:

- Pour point as per ISO 3016

Analyses

To ensure sufficient cleaning of the fuel by the separator, regular functional testing must be conducted by means of sampling upstream and downstream of the separator.

The examination of fuel samples is essential for safe engine operation. Examinations can be performed in the Everllence Laboratory PrimeServLab for our customers.

To guarantee the safety of the crew and to obtain a representative sample, sampling must take place in accordance with valid Everllence operating instructions.

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Residual fuel (HFO) specification

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Marine diesel oil (DMB, DFB) specifications

General information

Marine diesel oil as a heavy distillate is available for marine applications only. Another names are: Marine diesel oil, DMB, DFB. It is made from crude oil and may contain synthetic components (e.g. BtL, CtL, GtL and HVO). The fuel is treated the same as residual fuel in the supply chain. This means that it is possible for the fuel to be blended with high-viscosity residual fuel residue, e.g. in a bunker vessel, and it might therefore contain residue from crude oil processing. This can affect the properties of the fuel.

Selection of suitable fuel

Unsuitable or adulterated fuel generally results in a shortening of the service life of engine parts/components, damage to these and to catastrophic engine failure. It is therefore important to select the fuel with care in terms of its suitability for the engine and the intended application. Through its combustion, the fuel influences the emissions behaviour of the engine.

Specifications and approvals

The fuel quality varies regionally and depends on climatic conditions. All requirements from ISO 8217:2024 apply.

For information on the use of up to 7% FAME (DFB), see FAME (fatty acid methyl ester) additive of 0.5 to 100% (DFA).

The following values must be maintained at the engine inlet:

Property	Unit		Limit value[1)]	Standard[2)]
Appearance[3)]	–	–	Free from contamination	visually
Kinematic viscosity at 40 °C[4)]	mm^2/s	Max. Min.	11.0 2.0	ISO 3104, ASTM D7042, ASTM D445, DIN EN 16896
Density at 15 °C	kg/m^3	Max. Min.	900.0 820.0	ISO 3675, ISO 12185
Water content	% (m/m)	Max.	0.02	DIN 51777, DIN EN 12937, ASTM D6304
Cetane number		Min.	35	EN ISO 5165, IP541, EN 15195, EN 16715, EN 17155
Sulphur content[5)]	% (m/m)	Max.	1.50	EN ISO 8754, EN ISO 14596, ASTM D4294, DIN 51400-10
Flashpoint[6)]	°C	Min.	60.0	ISO 2719
Acid number	mg KOH/g	Max.	0.5	ASTM D664
Sediment content[7)]	% (m/m)	Max.	0.10	ISO 2719
Carbon residue	% (m/m)	Max.	0.30	ISO 10370
Ash content	% (m/m)	Max.	0.010	ISO 6245

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Property	Unit		Limit value[1)]	Standard[2)]
Lubricity (WSD)	µm	Max.	520	ISO 12156-1, ASTM D6079
Corrosion effect on copper	Class	Max.	1	ISO 2160
Hydrogen sulphide	mg/kg	Max.	2.0	IP 570
FAME[8)]-content DMB	% (V/V)	Max.	0.5	ASTM D7963, IP 579, DIN EN 14078
FAME[8)]-content DFB	% (V/V)	Max.	7.0	ASTM D7963, IP 579, DIN EN 14078
Pour point[9)] winter quality	°C	Max.	0	ISO 3016
Pour point[9)] summer quality	°C	Max.	6	ISO 3016
Oxidation stability DMB	g/m^3	Max.	25	ISO 10307-1
Oxidation stability[10)] DFB	h	Min.	8.0	ISO 10370
Na, K, Ca, P, Cu, Zn, Si	mg/kg	Max.	free from	DIN EN 16476

Table 1: Requirements for diesel fuel (DMB/DFB)

Remarks:

[1)] The fuel must be suitable for the intended application. It must not contain any substance in a concentration that causes additional air pollution, is harmful for personnel, jeopardises ship safety and/or has an adverse effect on machine performance. The fuel must be free from non-ferrous metals according to DIN EN 16476. The fuel must not contain any waste oil.

[2)] Always in relation to the currently applicable edition.

[3)] Only possible with clear samples. If the sample is not clear or contains visible contamination, the check must be completed mandatorily for the entire sediment.

[4)] Specific requirements of the injection system must be taken into account

[5)] Local laws and regulations must be observed independently of the maximum possible sulphur content.

[6)] Additional requirements (e.g. SOLAS) must be observed. Applicable laws must be adhered to.

[7)] If the sample is not clear and bright, the total sediment by hot filtration shall be required.

[8)] The FAME must either be in accordance with EN 14214 or with ASTM D6751 as well as with increased oxidation stability of at least 8 hours (EN 15751).

[9)] 10 °C below the lowest temperature in the fuel system.

[10)] If there is more than 2% (V/V) FAME, an analysis as per EN15751 must additionally be carried out.

Approved fuels

The following fuels are approved for use if the fuel complies with table Requirements for diesel fuel (DMB/DFB):

- Class ISO F-DMB according to ISO 8217:2024
- Class ISO F-DFB according to ISO 8217:2024 with additional requirement regarding oxidation stability

Fuels that do not comply with the above-mentioned standards must be queried with Everllence.

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Viscosity

In order to ensure sufficient lubrication, a minimum level of viscosity must be ensured at the fuel injection pump. The specified maximum temperature required to maintain a viscosity of more than 1.9 mm^2/s upstream of the fuel injection pump depends on the fuel viscosity. The temperature of the fuel upstream of the fuel injection pump must not exceed 45 °C in any case. The lubricity requirement for the fuel upstream of the engine is a maximum of 520 µm WSD in each case according to ISO 12156-1.

Contamination

We recommend installing a separator upstream of the fuel filter. Separation temperature 40–50°C. Most solid particles (sand, corrosion and catalytic converter fragments) and water can thus be removed and the cleaning intervals for the filter elements can be significantly extended.

FAME (Fatty acid methyl ester) additive up to max. 7 %

Using fuels with biofuel admixture based on fatty acid methyl ester (FAME) of max. 7 vol. % is possible.
The FAME must comply with the requirements stipulated in EN 14214 or ASTM D6751.*

It is the responsibility of the operating company that the fuel always complies with all requirements in table Requirements for diesel fuel (DMB/DFB).

Applications with longer standstill periods (e.g. emergency power units) can be affected by fuel ageing. To prevent damage, it is recommendable to only operate these applications with fuel which is free of FAME or to purge the entire fuel system with fuel which is free of biodiesel prior to longer standstill periods.

FAME blends typically contain a higher water content. This higher water content must be reduced by appropriate means in order to adhere to the maximum permissible water content at the engine inlet.

In any case, it is the responsibility of the operating company to adhere to the legal requirements (e.g. SOLAS).

Everllence is not liable for damage caused to the engine or subsequent damage resulting from this caused by FAME fuel blends.

* as well as with increased oxidation stability of at least 8 hours (EN 15751)

Cold suitability

The cold suitability of the fuel is determined by the climatic requirements at the place of installation. It is the responsibility of the operating company to choose a fuel with sufficient cold suitability.

The cold suitability of a fuel may be determined and assessed using the following standards:

- Limit of filterability (CFPP) as per EN 116
- Pour point as per ISO 3016
- Cloud point as per EN 23015

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To be able to draw a reliable conclusion, it is recommended to perform all three stated procedures.

Analyses

The examination of fuel samples is essential for safe engine operation. Examinations can be performed in the Everllence Laboratory PrimeServLab for our customers.

To guarantee the safety of the crew and to obtain a representative sample, sampling must take place in accordance with valid Everllence operating instructions.

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Diesel fuel (DMA, DFA) specifications

General information

Diesel fuel is a middle distillate refined from crude oil. It is also referred to as: gas oil, marine gas oil (DMA), DFA, diesel oil. It should not contain any residue from crude oil refining.

Selection of suitable fuel

Unsuitable or adulterated fuel generally results in a shortening of the service life of engine parts/components, damage to these and to catastrophic engine failure. It is therefore important to select the fuel with care in terms of its suitability for the engine and the intended application. Through its combustion, the fuel influences the emissions behaviour of the engine.

Specifications and approvals (DMA)

The fuel quality varies regionally and depends on climatic conditions. All requirements from ISO 8217:2024 apply

The following values must be maintained at the engine inlet:

Property	Unit		Limit value[1)]	Standard[2)]
Appearance	-	-	Clear, bright and free from visible contamination	visual
Kinematic viscosity at 40° C[3)]	mm^2/s	Max. Min.	6.0 2.0	ISO 3104, ASTM D7042, ASTM D445, DIN EN 16896
Density at 15°C	kg/m^3	Max. Min.	890.0 820.0	ISO 3675, ISO 12185
Water content	% (m/m)	Max.	0.02	DIN 51777, DIN EN 12937, ASTM D6304
Cetane number		Min.	40	EN ISO 5165, IP541, EN 15195, EN 16715, EN 17155
Sulphur content[4)]	% (m/m)	Max.	1.0	ISO 8754, ISO 14596, ASTM D4294, DIN 51400-10
Flashpoint[5)]	°C	Min.	60.0	ISO 2719
Acid number	mg KOH/g	Max.	0.5	ASTM D664
Carbon residue[6)]	% (m/m)	Max.	0.30	ISO 10370
Ash content	% (m/m)	Max.	0.010	ISO 6245
Lubricity (WSD)	µm	Max.	520	ISO 12156-1, ASTM D6079
Corrosion effect on copper	Class	Max.	1	EN ISO 2160
Hydrogen sulphide	mg/kg	Max.	2.0	IP 570
FAME[7)]-content	% (V/V)	Max.	0.5	ASTM D7963, IP 579, DIN EN 14078
Oxidation stability	g/m^3	Max.	25	EN ISO 12205

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Property	Unit		Limit value[1)]	Standard[2)]
Sediment content[8)]	% (m/m)	Max.	0.01	ISO 10307-1
CFPP	°C		10°C below the lowest temperature in the fuel system	DIN EN 116, IP 309, IP 612
Pour Point[9)] winter grade	°C	Max.	-6	ISO 3016
Pour Point[9)] summer grade	°C	Max.	0	ISO 3016
Na, K, Ca, P, Cu, Zn, Si	mg/kg	Max.	free from	DIN EN 16476

Table 1: Requirements for diesel fuel (DMA)

Remarks:

[1)] The fuel must be suitable for the intended application. It must not contain any substance in a concentration that causes additional air pollution, is harmful for personnel, jeopardises ship safety and/or has an adverse effect on machine performance. The fuel must be free from non-ferrous metals according to DIN EN 16476. The fuel must not contain any waste oil.

[2)] Always refer to the currently applicable edition.

[3)] Specific requirements of the injection system must be taken into account

[4)] Independent of the maximum permissible sulphur content, local laws and regulations must be adhered to

[5)] Additional requirements (e.g. SOLAS) must be observed. Applicable laws must be adhered to.

[6)] Determined at 10% distillation residue

[7)] The FAME must either be in accordance with EN 14214 or with ASTM D6751 as well as with increased oxidation stability of at least 8 hours (EN 15751). For information on the use of fuels with more than 0.5% FAME see section FAME (fatty acid methyl ester) additive of 0.5 to 100% (DFA)

[8)] If the sample is not clear and bright, complete sedimentation through hot filtration and the determination of water content is required

[9)] 10°C below the lowest temperature in the fuel system

The following fuels are approved for use if the fuel complies with table Requirements for diesel fuel (DMA):

- Classes ISO F-DMA & DMZ according to ISO 8217:2024
- Diesel fuel as per EN 590:2022 with additional requirement regarding flashpoint > 60 °C in SOLAS regulated areas
- Diesel fuel no. 2-D as per ASTM D975-21 with additional requirement regarding flashpoint > 60 °C in SOLAS regulated areas

Fuels that do not comply with the above-mentioned standards must be queried with Everllence.

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Viscosity

In order to ensure sufficient lubrication, a minimum level of viscosity must be ensured at the fuel injection pump. The specified maximum temperature required to maintain a viscosity of more than 1.9 mm^2/s upstream of the fuel injection pump depends on the fuel viscosity. The temperature of the fuel upstream of the fuel injection pump must not exceed 45 °C in any case. The lubricity requirement for the fuel upstream of the engine is a maximum of 520 µm WSD in each case according to ISO 12156-1.

Military fuel specification

The fuels of type F-75 or F-76 as per NATO STANAG 1385 can be used if they fully comply with the standards or limit values listed in the table Requirements for diesel fuel (DMA) pursuant to ISO 8217:2024 and the minimum permissible viscosity upstream of the injection pump with the corresponding temperature is adhered to.

Synthetic fuels (DIN EN 15940)

When using synthetic fuels according to DIN EN 15940 with a density of less than 820 kg/m^2 at 15 °C, prior consultation with Everllence is required.

Synthetic fuels such as HVO, BTL, CTL, GTL according to DIN EN 15940, can be produced from renewable electrical energy and CO_2 or from the same basic material such as FAME fuels (vegetable oil, cooking oil, animal fat) but in a completely different procedure. Synthetic fuels are produced by means of hydrogen treatment, with a fuel being generated which has a very similar chemical structure to high-performance diesel fuel and consists of paraffinic hydrocarbons. In contrast to fossil diesel fuel, synthetic fuel barely contains any aromatic components, which causes very good combustion properties.

Although the energy content (per mass unit) is higher in comparison with fossil diesel fuel, the volumetric energy content is lower due to the lower density (typically approx. 780 kg/m^3 at 15°C). This may lead to deviations in the specified engine output, operating behaviour, load application and emissions as well as deviations in the specific fuel consumption.

The lubricity of synthetic fuels is relatively low. In order to meet fuel specifications (requirements on diesel fuel) and guarantee sufficient lubricity of the fuel, the fuel supplier needs to add a lubricity additive or FAME.

The lower flashpoint limit is too low at a minimum of 55°C. The additional requirement relating to flashpoint min. 60 °C in SOLAS regulated areas must be observed.

We strongly advise against using a mixture of HFO and synthetic fuel (in accordance with EN 15940). The reason is that the HFO contains asphaltenes, which are held in solution by the aromatics contained in HFO. Synthetic fuel is purely paraffinic (does not contain any aromatics) and therefore cannot hold asphaltenes in solution. This means that when synthetic fuel is added to HFO, these asphaltenes precipitate, deposits form or fuel filters become clogged or, in the worst case scenario, the injection system fails.

FAME (fatty acid methyl ester) additive of 0.5 to 100% (DFA)

The following values must be maintained at the engine inlet:

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Diesel fuel (DMA, DFA) specifications

Property	Unit		Limit value[1]	Standard[2]
Appearance	-	-	Clear, bright and free from visible contamination	visually
Kinematic viscosity at 40° C[3]	mm^2/s	Max. Min.	6.0 2.0	ISO 3104, ASTM D7042, ASTM D445, DIN EN 16896
Density at 15°C	kg/m^3	Max. Min.	890.0 820.0	ISO 3675, ISO 12185
Water content	% (m/m)	Max.	0.02	DIN 51777, DIN EN 12937, ASTM D6304
Cetane number		Min.	40	EN ISO 5165, IP541, EN 15195, EN 16715, EN 17155
Sulphur content[4]	% (m/m)	Max.	1.0	ISO 8754, ISO 14596, ASTM D4294, DIN 51400-10
Flashpoint[5]	°C	Min.	60.0	ISO 2719
Acid number	mg KOH/g	Max.	0.5	ASTM D664
Carbon residue[6]	% (m/m)	Max.	0.30	ISO 10370
Ash content	% (m/m)	Max.	0.010	ISO 6245
Lubricity (WSD)	µm	Max.	520	ISO 12156-1, ASTM D6079
Corrosion effect on copper	Class	Max.	1	EN ISO 2160
Hydrogen sulphide	mg/kg	Max.	2.0	IP 570
FAME[7]-content	% (V/V)	Min.	0.5	ASTM D7963, IP 579, DIN EN 14078
Oxidation stability	h	Min.	8	EN 15751
Sediment content[8]	% (m/m)	Max.	0.01	ISO 10307-1
CFPP	°C		10°C below the lowest temperature in the fuel system	DIN EN 116, IP 309, IP 612)
Pour Point[9] winter grade	°C	Max.	-6	ISO 3016
Pour Point[9] summer grade	°C	Max.	0	ISO 3016
Na, K, Ca, P, Cu, Zn, Si	mg/kg	Max.	free from	DIN EN 16476

Table 2: Requirements for diesel fuel (DFA)

Remarks:

[1] The fuel must be suitable for the intended application. It must not contain any substance in a concentration that causes additional air pollution, is harmful for personnel, jeopardises ship safety and/or has an adverse effect on machine performance. The fuel must be free from non-ferrous metals according to DIN EN 16476. The fuel must not contain any waste oil.

[2] Always refer to the currently applicable edition.

[3] Specific requirements of the injection system must be taken into account

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[4] Independent of the maximum permissible sulphur content, local laws and regulations must be adhered to

[5] Additional requirements (e.g. SOLAS) must be observed. Applicable laws must be adhered to.

[6] Determined at 10% distillation residue

[7] The FAME must either be in accordance with EN 14214 or with ASTM D6751 as well as with increased oxidation stability of at least 8 hours (EN 15751).

[8] If the sample is not clear and bright, complete sedimentation through hot filtration and the determination of water content is required

[9] 10°C below the lowest temperature in the fuel system

When using DFA (FAME according to EN 14214 or ASTM D6751* or their mixtures with DMA), prior consultation with Everllence is required. In addition, the following should be observed:

- Due to the typically lower calorific value or energy content of FAME fuels and their mixtures with DMA (DFA), it may result in deviations to the specified engine output, operating behaviour, load application, specific fuel consumption and emissions.
- The sealing materials used must be suitable for DFA. NBR seals are not suitable and must not be used.
- DFA tends to attract water. The risk of microbial growth is therefore increased. For this reason, the water content needs to be kept as low as possible. The maximum water content must not be exceeded. Everllence recommends draining water from the fuel tank every day.
- If there is a possibility of dead volume in the fuel system, it is strongly recommended to flush these areas regularly (weekly) to prevent bacterial growth (e.g., in the area of the fuel filters by briefly switching the filter chambers).
- Long standstill periods (e.g. emergency power units) must be avoided due to microbial growth. To prevent damage, it is recommendable to only operate applications with fuel which is free of FAME (DMA).
- The fuel reacts to air and this may lead to microbial growth. Ensure that the atmospheric oxygen ventilation is kept to a minimum. A nitrogen buffer is ideally installed in the fuel tank.
- The entire fuel system must be purged with fuel which is free of FAME (DMA) prior to longer standstill periods.
- If DFA is to be used with other fuels and mixing cannot be avoided, contact your fuel supplier to ensure the compatibility of these fuels.
- It is recommended that wherever possible a heat tracing system is installed in the fuel supply system, in order to prevent deposits or blockage of the lines.
- As DFA have a higher evaporation temperature than standard DMA qualities, these are enriched in lubricating oil. Regular analysis of all the lubricating oil is highly recommended. The lubricating oil needs to be replaced if a FAME content of 12% is reached.
- DFA may cause a layer to form, such a phenomenon leads to increased consumption of lubricating oil. If such an increase in lubricating oil consumption values is detected, please contact your Everllence PrimeServ department.
- Fuels may cause harmful reactions with metals such as zinc or copper. We highly recommend getting in contact with your tank and heating oil system supplier.

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- After switching to DFA, pay attention to the delta pressure indicators/ alarms of the filters, as the residues dissolved by DFA can clog the filters.
- In any case, it is the responsibility of the operating company to adhere to the legal requirements (e.g. SOLAS) and agree on these with the relevant authorities.

* as well as with increased oxidation stability of at least 8 hours (EN 15751)

Cold suitability

The cold suitability of the fuel is determined by the climatic requirements at the place of installation. It is the responsibility of the operating company to choose a fuel with sufficient cold suitability.

The cold suitability of a fuel may be determined and assessed using the following standards:

- Limit of filterability (CFPP) as per EN 116
- Pour point as per ISO 3016
- Cloud point as per EN 23015

To be able to draw a reliable conclusion, it is recommended to perform all three stated procedures.

Analyses

The examination of fuel samples is essential for safe engine operation. Examinations can be performed in the Everllence Laboratory PrimeServLab for our customers.

To guarantee the safety of the crew and to obtain a representative sample, sampling must take place in accordance with valid Everllence operating instructions.

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Non-standardised fuels

General information

Non-standardised fuels are fuels that are not based on mineral oil or comply with ISO 8217, and fuels that contain larger proportions of bio-fuels (fatty acid methyl ester). Such bio-fuel components are typically produced from oleiferous plants or used cooking oil. Residues from bio-fuel production can also be included.

In order to use a fuel like this, a Non-Standard Fuel Request (NSR) must be submitted. This request must be approved before the fuel can be used.

Selection of suitable fuel

Unsuitable or adulterated fuel generally results in a shortening of the service life of engine parts/ components, damage to these and to catastrophic engine failure. It is therefore important to select the fuel with care in terms of its suitability for the engine and the intended application. Through its combustion, the fuel influences the emissions behaviour of the engine.

Specifications

The fuel quality varies regionally and is dependent on climatic conditions.

The following fuels can be considered:

- Fatty acid methyl esters as per DIN EN 14214 and ASTM D6751
- Distillate fuels with fatty acid methyl esters > 7% and max. 30% as per DIN EN 16734, DIN EN 16709 and ASTM D7467
- Distillate fuels with > 30% fatty acid methyl ester content

The following values must be maintained at the engine inlet (applies for transesterified bio-fuels/FAME and their mixtures with distillate fuels; it may not be possible to perform all analyses):

Property	Unit		Limit value	Standard[1)]
Kin. viscosity at 40°C[2)]	mm^2/s	Max.	11.00	ISO 3104, ASTM D7042, ASTM D445, DIN EN 16896
		Min.	2.000	
Density at 15°C	kg/m^3	Max.	900.0	ISO 3675, ISO 12185
		Min.	820.0	
Cetane index & cetane number	—	Min.	40	ISO 4264 & ISO 5165
Sulphur content[3)]	%(m/m)	Max.	1.00	ISO 8754, ISO 14596, ASTM D4294, DIN 51400-10
Flash point[4)]	°C	Min.	60.0	ISO 2719
Hydrogen sulphide	mg/kg	Max.	2.00	IP 570
Acid number	mg KOH/g	Max.	0.5	ASTM D664
Corrosion on copper	Class	Max.	1	ISO 2160

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Non-standardised fuels

Property	Unit		Limit value	Standard[1)]
Oxidation stability[5)]	h	Min.	8 h (FAME content 70–100%) 15 h (FAME content 40–70%) 20 h (FAME content 7–40%)	EN 15751
Fatty acid methyl ester (FAME) content[6)]	% (V/V)	Max.	7.0–100%	ASTM D7963, IP 579, EN 14078
Carbon residue[7)]	%(m/m)	Max.	0.40	ISO 10370
Appearance	—	—	Clear and free from visible contamination	—
Water content	%(m/m)	Max.	0.20	DIN 51777, DIN EN 12937; ASTM D6304
Ash content	%(m/m)	Max.	0.010	ISO 6245
Total glycerine content	%(m/m)	Max.	0.25	EN 14105
Methanol content	%(m/m)	Max.	0.20	EN 14110
Monoglycerides	%(m/m)	Max.	0.70	EN 14110
Diglycerides	%(m/m)	Max.	0.20	EN 14110
Triglycerides	%(m/m)	Max.	0.20	EN 14110
Iodine value	%(m/m)	Max.	120	EN 14111
Linolenic acid methyl ester	%(m/m)	Max.	12	EN 14103
Polyunsaturated (> 4) fatty acids	%(m/m)	Max.	1.00	EN 15779
Alkali metals (Na+K)	%(m/m)	Max.	5.0	EN 14108
Alkaline earth metals	%(m/m)	Max.	5.0	EN 14538
Phosphorous content	%(m/m)	Max.	4.0	EN 14107
Lubricity[8)]	µm	Max.	520	ISO 12156-1; ASTM D6079

Remarks:

[1)] Always reference to the latest edition

[2)] Specific requirements of the injection system must be taken into account

[3)] Independent of the maximum permissible sulphur content, local laws and regulations must be adhered to

[4)] SOLAS specification. A lower flash point is possible for non-SOLAS-regulated applications

[5)] If there is more than 2% (V/V) FAME, an analysis as per EN 15751 is an additional requirement

[6)] The FAME must either comply with EN 14214 or with ASTM D6751

[7)] Determined at 10% distillation residue

[8)] Diameter of the corrected wear scar (WS)

Table 1: Specification for transesterified bio-fuel

The following values must be complied with at the engine inlet (does not apply for non-transesterfied bio-fuels):

Characteristics / properties	Characteristics / unit	Test method
Density at 15 °C	900 - 930 kg/m^3	DIN EN ISO 3675, EN ISO 12185

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Characteristics / properties	Characteristics / unit	Test method
Flash point	> 60°C	DIN EN 22719
Lower fuel value	> 35 MJ/kg (typically: 37 MJ/kg)	DIN 51900-3
Viscosity/50 °C	< 40 cSt (corresponds to viscosity / 40 °C < 60 cSt)	DIN EN ISO 3104 ASTM D7042
Estimated cetane number	> 40	IP 541
Carbon residue	< 0.4%	DIN EN ISO 10370
Sediment content	< 200 ppm	DIN EN 12662
Oxidation resistance (110 °C)	> 5 h	EN ISO 6886, EN 14112
Percentage of monoglycerides	< 0.70% (m/m)	EN14105
Percentage of diglycerides	< 0.20% (m/m)	EN14105
Percentage of triglycerides	< 0.20% (m/m)	EN14105
Percentage of free glycerin	< 0.02% (m/m)	EN14105
Phosphorus content	< 15 ppm	ASTM D3231
Na and K content	< 15 ppm	DIN 51797-3
Ash content	< 0.01%	DIN EN ISO 6245
Water content	< 0.5%	EN ISO 12537
Iodine value	< 125 g/100 g	DIN EN 14111
TAN (total acid number)	< 5 mg KOH/g	DIN EN ISO 660
Cold Filter Plugging Point	10 °C below the lowest temperature in the fuel system	EN 116

Table 2: Specification for non-transesterified biofuel

⚠ WARNING

Handling operating materials

Handling operating materials can lead to serious personal injury and environmental damage.

- Observe the safety data sheets of the operating material manufacturer.

Tests

Analysis of samples

To ensure sufficient cleaning of the fuel by the separator, regular functional testing must be conducted by means of sampling upstream and downstream of the separator.

Analysis of residual fuel samples is essential for safe engine operation. We can analyse fuel for customers at the Everllence laboratory PrimeServLab.

To guarantee the safety of the crew and to obtain a representative sample, sampling must take place in accordance with valid Everllence work instructions.

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Viscosity-temperature diagram (VT diagram)

Explanations of viscosity-temperature diagram

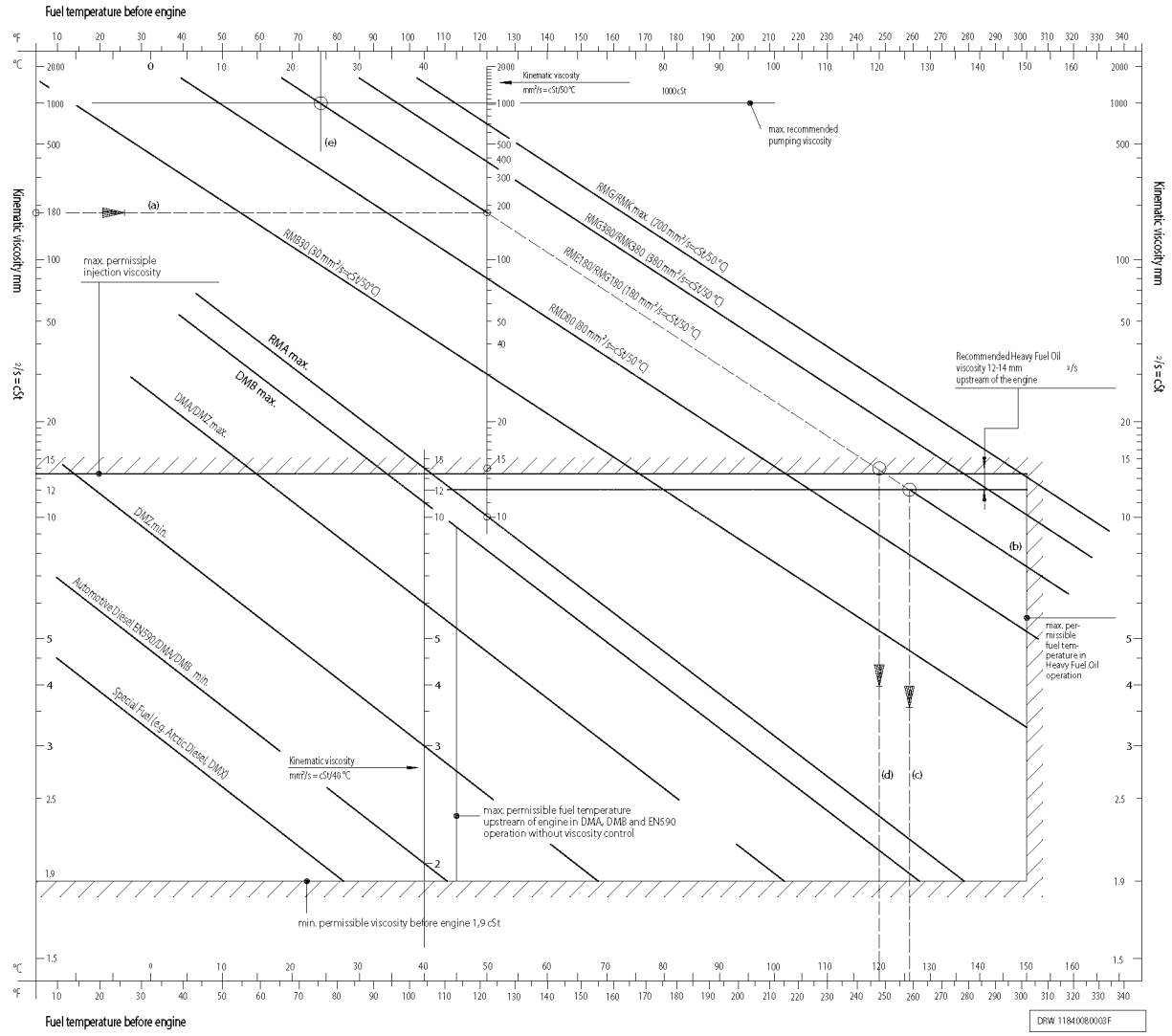


Figure 1: Viscosity-temperature diagram (VT diagram)

In the diagram, the fuel temperatures are shown on the horizontal axis and the viscosity is shown on the vertical axis.

The diagonal lines correspond to viscosity-temperature curves of fuels with different reference viscosities. The vertical viscosity axis in mm²/s (cSt) applies for 40, 50 or 100 °C.

Determining the viscosity-temperature curve and the required preheating temperature

Example: residual fuel with 180 mm²/s at 50°C

Prescribed injection viscosity in mm²/s	Required fuel temperature at the engine inlet[1)] in °C
≥ 12	126 (line c)
≤ 14	119 (line d)

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Prescribed injection viscosity in mm²/s	Required fuel temperature at the engine inlet[1)] in °C
[1)] For these figures, the temperature drop from the last pre-heating device to the fuel injection pump is not taken into account.	

Table 1: Determining the viscosity temperature trend and the required pre-heating temperature

Residual fuel with a viscosity of 180 mm²/s at 50 °C can reach a viscosity of 1,000 mm²/s at 24 °C (line e) – this is the maximum permissible viscosity of fuel that the pump can deliver.

A residual fuel discharge temperature of 152 °C is reached when using a recent state-of-the-art preheating device with 8 bar saturated steam. At higher temperatures there is a risk of residues forming in the preheating system – this leads to a reduction in heating output and thermal overloading of the residual fuel. Asphalt is also formed in this case, i.e. quality deterioration.

The residual fuel lines between the outlet of the last preheating system and the injection valve must be suitably insulated to limit the maximum drop in temperature to 4 °C. This is the only way to achieve the necessary injection viscosity of 14 mm²/s for residual fuels with a reference viscosity of 700 mm²/s at 50 °C (the maximum viscosity as defined in the international specifications such as ISO CIMAC or British Standard). If residual fuel with a low reference viscosity is used, the injection viscosity should ideally be 12 mm²/s in order to achieve more effective atomisation to reduce the combustion residue.

The delivery pump must be designed for residual fuel with a viscosity of up to 1,000 mm²/s. The pour point also determines whether the pump is capable of transporting the residual fuel. The bunker facility must be designed so as to allow the residual fuel to be heated to roughly 10 °C above the pour point.

NOTICE

Viscosity

The viscosity of gas oil or diesel oil (marine diesel oil) upstream of the engine must be at least 1.9 mm²/s. If the viscosity is too low, this may cause seizing of the pump plunger or nozzle needle valves as a result of insufficient lubrication.

This can be avoided by monitoring the temperature of the fuel. Although the maximum permissible temperature depends on the viscosity of the fuel, it must never exceed the following values:

- 45 °C at the most with DMA and DMB

A fuel cooler must therefore be installed.

If the viscosity of the fuel is < 2 cSt at 40 °C, consult the technical service of Everllence in Augsburg.

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Lubricating oil system

General

The engine features an entirely closed wet sump lub oil system, ensuring easy installation and no risk of dirt entering the lub oil circuit.

The helical gear type lub oil pump is installed in the front-end box and draws the oil from the sump.

Via a double check valve with connection for stand-by pump, the oil flows to the pressure regulator, through the built-on lub oil plate cooler and the integrated automatic lub oil filter to the engine.

The back-flush oil from the filter is drained to the sump. A separator must be connected to maintain proper condition of the lub oil.

Integrated thermostatic elements ensure a constant lub oil temperature to the engine.

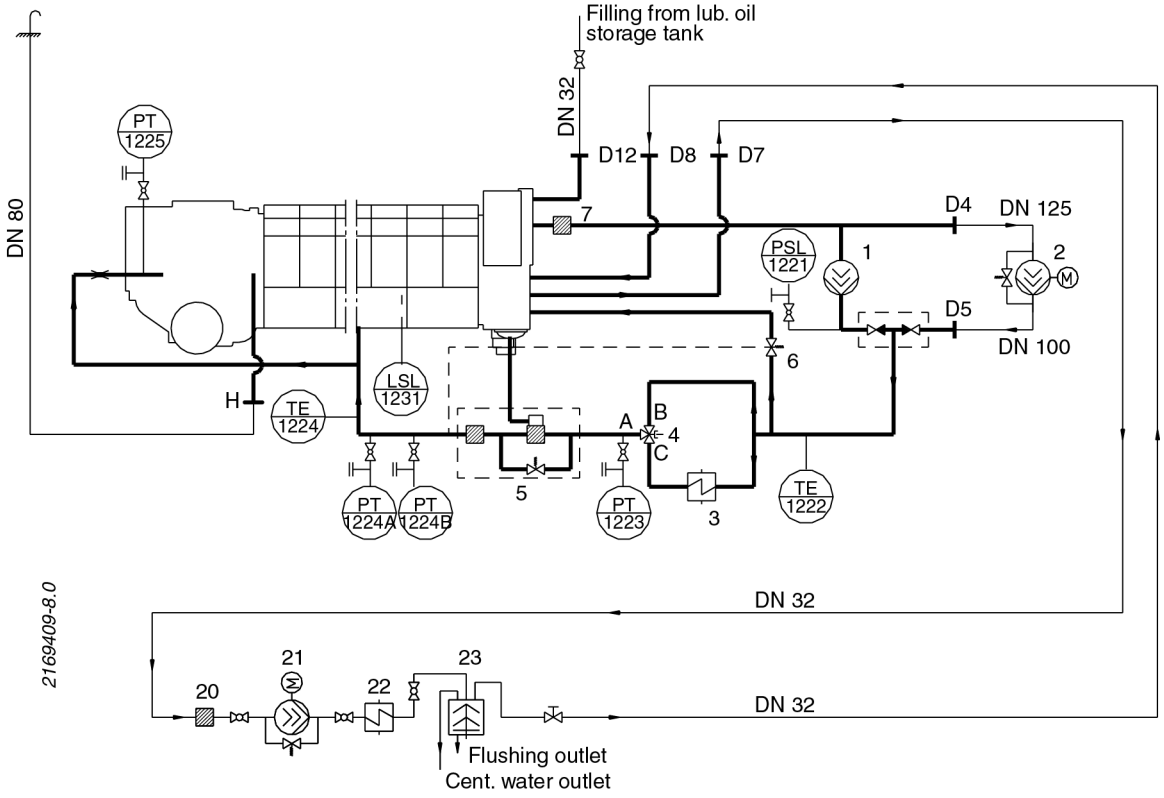
Lubricating oil requirements

Only lub oils meeting the requirements in the “List of Lubricating Oils” may be used.

Within the guarantee period, only lub oils approved by us should be used, unless a written statement has been given.

Lubricating oil system

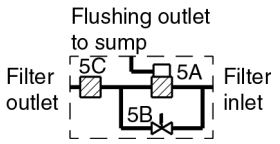
The lub oil system is the same for both MDO and HFO operation.



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Item	Description		Item	Description
1	Engine driven lub oil pump, attached		7	Strainer (magnetic insert)
2	Electrical lub oil pump, stand-by		20	Prefilter for lub. oil separator
3	Lub oil cooler		21	Lub oil separator pump
4	Thermostatic valve		22	Preheater for lub. oil separator
5	Automatic backflush filter		23	Lub oil separator
6	Lub oil presure control valve			

Connections				
D4	Lub oil stand-by pump, suction		D8	Lub oil from separator
D5	Lub oil stand-by pump, pressure		D12	Filling of lub oil
D7	Lub oil to separator		H	Venting of crankcase

Automatic backflush filter (ITem 5:				
			5A	Backflush filter unit, 30 µm
			5B	Pressure controlled by-pass valve
			5C	Back-up filter in line, 50 µm

Lub oil stand–by pump, item 2

To ensure good suction conditions for the lub oil pump, the pump should be placed as low as possible.

The suction pipe should be as short and with as few bends as possible in order to prevent cavitation of the pump.

The lub oil stand-by pump also acts as a priming pump for the engine prior to start.

Design data

Capacity

- See list of capacity

Viscosity at normal operation:

- 40 cSt (corresponding to 70 °C)

Max viscosity for dimensioning of el-motor:

- 150 cSt (corresponding to 40 °C for SAE 40 oil)

The turbocharger is connected into the same piping system and must not be primed for more than 5 minutes. The motor starter for the stand-by pump must be fitted with time and auxiliary relays limiting the stand-by pump to run for 5 minutes only or frequent converter for adjustment of flow.

For multi-engine installation a smaller prelubricating pump similar to GenSet can be installed.

When we are to supply the motor starter, the function described is built-in. When the motor starter is not included in our scope of supply, a drawing showing the components and connections required will be forwarded.

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Lub oil cooler, item 3

The lub oil cooler with stainless steel plates is built-on to the engine. All connections are integrated in cooler/front-end box.

The heat dissipation appears from the planning data.

Lub oil thermostatic valve, item 4

The integrated thermostatic valve has 4 elements and controls the inlet temperature to the engine. The nominal set-point is 66 °C. Manual override is featured when required by the classification society concerned.

Automatic lub oil, back-flushing filter, item 5

The built-on automatic lub oil filter has 2 filtering stages:

Primary filter

Contains several filter candles with a filter mesh of 25 microns corresponding to a nominal filtration degree of 20 microns.

The back-flushing facility operates continuously by means of the oil pressure. The back flushing oil is led to the oil sump.

The pressure drop across the filter candles is approx 0.2 bar with clean filter.

In case the pressure drop exceeds 2 bar, by-pass valves in the filter will open.

Secondary filter

The filtered oil is always passing the secondary filter with a filter mesh of 50 microns. This filter also acts as a safety filter in case the by-pass valves are open.

Lub oil pressure control valve, item 6

The control valve ensures a correct lub oil pressure also in case of operation with the lub oil stand-by pump.

Strainer with magnetic insert, item 7

The strainer is part of the suction pipe in the oil sump.

Prefilter, item 20

To protect the separator pump, item 21, a prefilter should be inserted before the pump.

Design data:

- Capacity: See oil pump, item 21
- Mesh size: 0.8-1.0 mm

Lub oil pump to separator, item 21

The pump can be driven directly by the separator or by an independent motor.

Design data:

- Capacity: V = F x P

  V: Pump capacity in litres/hour

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F: MDO/MGO : 0.21 / HFO : 0.29 / LSFO : 0.21 - 0.29

P: Power of the engine in kW at MCR

- Pressure: Max 2.5 bar
- Temperature: Max 95°C

Preheater before lub oil separator, item 22

The preheater must be able to raise the temperature of the oil from approx 65°C to approx 95°C, which is the temperature of the oil for separation.

- Capacity: C = V x t/1800

  C: Capacity of the preheater in kW

  V: Flow through preheater in litres/hour - defined from the capacity of the separator.

  t: Temperature difference 35°C (engine operating)
- Max pressure 4 bar
- Max pressure loss 0.5 bar

Specific load on heating surface for an electric preheater must not exceed 0.8 W/cm^2 .

Lub oil preheating

In case engine stopped for a larger period it can be required to install a pre-heater which can maintain at least 40 °C in case engine has a longer stand still period.

Slow circulation over lub oil cooler on preheated engine should be sufficient.

Preheating the lub oil to 40 °C is effected by the preheater of the separator via the free-standing pump.

The preheater must be enlarged in size if necessary, so that it can heat the content of the service tank to 40 °C within 4 hours.

Bypass cleaning equipment

Bypass cleaning equipment is mandatory when running on HFO and recommend when running distillate.

In diagram is shown separator, but there are other options, *please see "B 12 15 0, Treatment and maintenance of lubricating oil*".

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Crankcase ventilation

Crankcase ventilation

The crankcase ventilation is not to be directly connected with any other piping system. It is preferable that the crankcase ventilation pipe from each engine is led independently to the open air. The outlet is to be fitted with corrosion resistant flame screen separately for each engine.

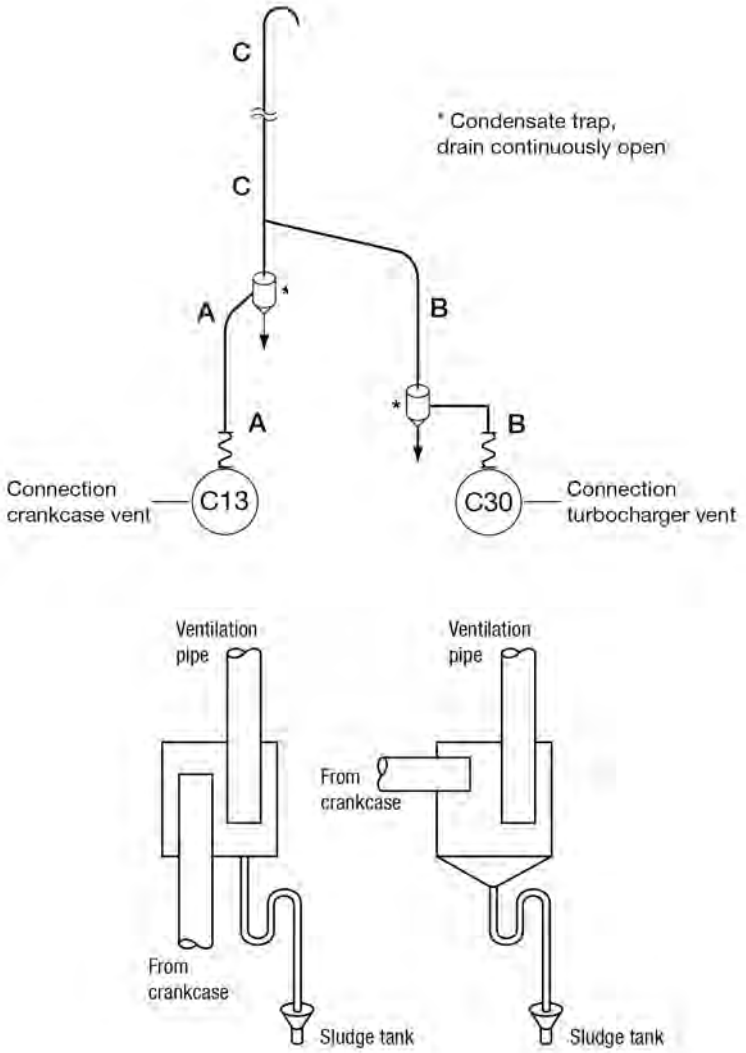


Figure 1: Crankcase ventilation

However, if a manifold arrangement is used, its arrangements are to be as follows:

1) The vent pipe from each engine is to run independently to the manifold and be fitted with corrosion resistant flame screen within the manifold.

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2) The manifold is to be located as high as practicable so as to allow a substantial length of piping, which separates the crankcase on the individual engines.
3) The manifold is to be vented to the open air, so that the vent outlet is fitted with corrosion resistant flame screen, and the clear open area of the vent outlet is not less than the aggregate area of the individual crankcase vent pipes entering the manifold.
4) The manifold is to be provided with drainage arrangement.

The ventilation pipe must be designed to eliminate the risk of water condensation in the pipe flowing back into the engine and should end in the open air:

- The connection between engine (C13 / C30) and the ventilation pipe must be flexible.
- The ventilation pipe must be made with continuous upward slope of minimum 5°, even when the ship heel or trim (static inclination).
- A continuous drain must be installed near the engine. The drain must be led back to the sludge tank.

Engine	Nominal diameter ND (mm)		
	A	B	C
L16/24, L16/24S	50		65
L21/31, L21/31S, L21/31 Mk 1.1 L21/31 Mk 2, L21/31DF-M	65	40	80
L23/30H**, L23/30S**	50	-	65
L23/30DF, L23/30H***, L23/30H Mk 2, L23/30H Mk 3	50	25	65
L27/38, L27/38S, L27/38 Mk2	100	-	100
L28/32DF	50	40	65
L28/32H**, L28/32S**	50	-	65
L28/32H***, L28/32S***	50	40	65
V28/32H	100	-	125
V28/32DF	100	-	125
V28/32S	100	-	125
Turbo application : ** NR, *** TCR			

Table 1: Pipe diameters for crankcase ventilation

- Dimension of the flexible connection, *see pipe diameters in table 1*.
- Dimension of the ventilation pipe after the flexible connection, *see pipe diameters in table 1*.

The crankcase ventilation flow rate varies over time, from the engine is new/major overhauled, until it is time to overhaul the engine again.

The crankcase ventilation flow rate is in the range of 3.5 – 5.0 ‰ of the combustion air flow rate [m^3/h] at 100 % engine load.

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If the combustion air flow rate at 100 % engine load is stated in [kg/h] this can be converted to [m³/h] with the following formula (Tropic Reference Condition) :

$$\frac{287.04\ [Nm/(kg \bullet K)] \bullet \text{Mass flow}\ [kg/h] \bullet 318.16\ [°K]}{1\ [bar] \bullet 100000\ [N/m^2]}$$

Example :

Engine with a mechanical output of 880 kW and combustion air consumption of 6000 [kg/h] corresponds to :

$$\frac{287.04\ [Nm/(kg \bullet K)] \bullet 6000\ [kg/h] \bullet 318.16\ [°K]}{1\ [bar] \bullet 100000\ [N/m^2]}$$

$$= 5479\ [m^3/h]$$

The crankcase ventilation flow rate will then be in the range of 19.2 – 27.4 [m³/h]

The maximum crankcase pressure measured at 100% engine load must not exceed 3.0 (mbar) = 30 (mmWc). Normal values 8–18 mmWC. *See work card M5031101*.

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Lubricating oil (SAE 40) specification for residual fuel operation (HFO)

General

The specific power achieved by modern diesel engines and the use of fuels that are increasingly reaching the very limits in terms of quality place higher requirements on the lube oil and necessitate careful selection of the lube oil.

Medium alkalinity lubricating oils have a proven track record as lubricants for the moving parts and turbocharger cylinder and for cooling the pistons. Lubricating oils of medium alkalinity contain additives that, in addition to other properties, ensure a higher neutralization reserve than with fully compounded engine oils (HD oils).

International specifications do not exist for medium alkalinity lubricating oils. A test operation is therefore necessary for a corresponding long period in accordance with the manufacturer's instructions.

Only lubricating oils that have been approved by Everllence may be used.

The list of the currently approved lubricating oils is available at Lubrication.

Specifications

Additional requirements

Fresh oil must not contain water or other contaminants.

Lubricating oil selection

Engine	SAE class
16/24, 21/31, 27/38, 23/30, 28/32, 32/40, 32/44CR, 35/44DF, 48/60CR, 49/60, 49/60DF, 51/60DF, 51/60R, 51/60R-DF-M	40

Table 1: Viscosity (SAE class) of lubricating oils

Neutralisation properties (BN)

At the present level of knowledge, an interrelation between the expected operating conditions and the BN number can be established. However, the operating results are still the overriding factor in determining which BN number provides the most efficient engine operation.

Table Base number to be used for various operating conditions indicates the relationship between the anticipated operating conditions and the BN number.

Approx. BN of fresh oil (mg KOH/g oil)	Engines/operating conditions
20	Marine diesel oil (DMB) of a lower quality and with a high sulphur content or residual fuel with a sulphur content of less than 0.50%
30	Generally 16/24, 21/31, 23/30, 28/32 under normal operating conditions. For engines 27/38, 32/40, 32/44CR, 35/44DF, 48/60CR, 49/60, 49/60DF (marine application) and 51/60DF operating with 100% residual fuel with a sulphur content < 1.5% only.
40	Under unfavourable operating conditions and where the corresponding requirements for the oil service life and cleaning capacity exist, 16/24, 21/31, 23/30 and 28/32. In general 27/38, 32/40, 32/44CR, 35/44DF, 48/60CR, 49/60, 49/60DF (marine application) and 51/60DF for operation with residual fuel, provided the sulphur content is over 1.5%.

Lubricating oil (SAE 40) specification for residual fuel operation (HFO)

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Approx. BN of fresh oil (mg KOH/g oil)	Engines/operating conditions
50	32/40, 32/44CR and 48/60CR, if the oil service life or engine cleanliness is insufficient with a BN number of 40 (high sulphur content of fuel, extremely low lubricating oil consumption).

Table 2: Base number to be used for various operating conditions

Operation with low-sulphur fuel

To comply with the emissions regulations, the sulphur content of fuels used nowadays varies. Fuels with low-sulphur content must be used in environmentally-sensitive areas (e.g. SECA). Fuels with higher sulphur content may be used outside SECA zones. In this case, the BN number of the lube oil selected must satisfy the requirements for operation using fuel with high-sulphur content. A lube oil with low BN number may only be selected if fuel with a low sulphur content is used exclusively during operation.
However, the practical results demonstrate that the most efficient engine operation is the factor ultimately determining the permitted additive content.

Oil for mechanical/hydraulic speed governors

Multigrade oil 5W40 should ideally be used in mechanical-hydraulic controllers with a separate oil sump, unless the technical documentation for the speed governor specifies otherwise. If this oil is not available when filling, 15W40 oil may be used instead in exceptional cases. In this case, it makes no difference whether synthetic or mineral-based oils are used.

The military specification applied for these oils is NATO O-236.

Experience with the drive engine L27/38 has shown that the operating temperature of the Woodward controller UG10MAS and corresponding actuator for UG723+ can reach temperatures higher than 93 °C. In these cases, we recommend using synthetic oil such as Castrol Alphasyn HG150.

Hydraulic oil for engines with VVT controller

Hydraulic oil HLP 46 (DIN 51502) or ISO VG 46 (DIN 51519) must be used according to the specification DIN 51524-2. Mixing hydraulic oils from different manufacturers is not permitted.

Lubricating oil additives

It is not permissible to use any other additives in conjunction with the lubricating oil or to mix oils of different brands (oils from different manufacturers and different brands of the same manufacturer) since this can reduce the effectiveness of already existing additives, which have been carefully matched to one another and the base oil.

Oil during operation

There are no prescribed oil change intervals for Everllence medium speed engines. The oil properties must be analysed monthly. The oil must therefore be suitable for the intended purpose and meet the defined limit values as per the table. If this is the case, the oil can continue to be used. See section Limit values for used lubricating oil.

The quality can only be maintained if it is purified via a separator or an otherwise suitable device.

Temporary operation with distillate fuel

Due to current and future emissions regulations, the use of residual fuel in designated areas is not possible. Instead of this, a low-sulphur diesel fuel must be used in these areas.

If the duration of the operation with low-sulphur diesel fuel is limited to less than 1,000 h, a lubricating oil that is intended for residual fuel operation (BN 30–55 mg KOH/g) can continue to be used during this time.

If the temporary operation with low-sulphur diesel fuel lasts longer than 1,000 h and is then operated with residual fuel again after that, a lubricating oil with a BN of 20 must be used. If the BN 20 lubricating oil is from the same

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brand as the lubricating oil used in the HFO operation with high BN (40 or 50), no oil change is required for the switch. It is sufficient to use BN 20 oil to top up the used lubricating oil.

If you want to use residual fuel again, you must switch back in good time to a lubricating oil with a higher BN (30–55). If the lubricating oil with the higher BN is from the same brand as the BN 20, the switch can also be made without changing oil. To do this, approx. 2 weeks before operating again with residual fuel, use the lubricating oil with the higher BN (30–55) to top up the consumed lubricating oil.

	Limit value	Procedure
Viscosity at 40 °C	110–220 mm²/s	ASTM D7042, ASTM D445, DIN EN 16896 or ISO 3104
Base number (BN)	at least 50 % of fresh oil	ISO 3771
Flash point (PM)	at least 185 °C	ISO 2719
Water content	max. 0.2 % (max. 0.5 % for brief periods)	DIN 51777 or ASTM D6304
n-heptane insoluble	max. 1.5 %	DIN 51592 or IP 316
Metal content	dependent on engine type and operating conditions	–
Guide value only Fe Cr Cu Pb Sn Al	 max. 50 ppm max. 10 ppm max. 15 ppm max. 20 ppm max. 10 ppm max. 20 ppm	ASTM D5185 or DIN 51399-1

Table 3: Limit values for used lube oil

Tests

A monthly analysis of lube oil samples is mandatory for safe engine operation. We can analyse samples for customers in the Everllence PrimeServLab.

To guarantee the safety of the crew and to obtain a representative sample, sampling must take place in accordance with valid Everllence work instructions.

NOTICE

No liability when using these oils

Everllence is not liable for any problems that occur when using these oils.

Lubricating oil (SAE 40) specification for residual fuel operation (HFO)

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Lubricating oil (SAE 40) specification for residual fuel operation (HFO)

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Lubricating oil (SAE 40) specification for operation with DMA/DMB, DFA, DFB

General

The specific power achieved by modern diesel engines and the use of fuels that are increasingly reaching the very limits in terms of quality place higher requirements on the lube oil and necessitate careful selection of the lube oil.

Lubricating oils contain additives that, amongst other things, ensure dirt absorption capability, cleaning of the engine and the neutralisation of acidic combustion products.

Only lubricating oils that have been approved by Everllence may be used. These are listed under Lubrication.

Specifications

The doped lubricating oil must have the following properties:

Neutralisation capacity

The neutralisation capacity (DIN ISO 3771) must be so high that the acidic products produced during combustion are neutralised. The reaction time of the additives must be matched to the process in the combustion chamber.

Additional requirements

Fresh oil must not contain water or other contaminants.

Lubricating oil selection

Engine	SAE class
16/24, 21/31, 27/38, 23/30, 28/32, 32/40, 32/44CR, 35/44DF, 48/60CR, 49/60, 49/60DF, 51/60DF, 51/60R, 51/60R-DF-M	40

Table 1: Viscosity (SAE class) of lubricating oils

Oil quality

Only lubricating oils approved by Everllence may be used. Lubricating oils of military specification O-278 can be used if they are listed under Lubrication in the list of currently approved lubricating oils.

The operating conditions of the engine and the quality of the fuel determine the additive fractions the lube oil should contain. If marine diesel oil with a high sulphur content of 1.0 up to 1.5 weight % is used, a base number (BN) of approx. 20 should be selected. However, the operating results that ensure the most efficient engine operation ultimately determine the additive content.

Oil for mechanical/hydraulic speed governors

Multigrade oil 5W40 should ideally be used in mechanical-hydraulic controllers with a separate oil sump, unless the technical documentation for the speed governor specifies otherwise. If this oil is not available when filling, 15W40 oil may be used instead in exceptional cases. In this case, it makes no difference whether synthetic or mineral-based oils are used.

The military specification applied for these oils is NATO O-236.

Experience with the drive engine L27/38 has shown that the operating temperature of the Woodward controller UG10MAS and corresponding actuator for UG723+ can reach temperatures higher than 93 °C. In these cases, we recommend using synthetic oil such as Castrol Alphasyn HG150.

Lubricating oil (SAE 40) specification for operation with DMA/DMB, DFA, DFB

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Lubricating oil additives

It is not permissible to use any other additives in conjunction with the lubricating oil or to mix oils of different brands (oils from different manufacturers and different brands of the same manufacturer) since this can reduce the effectiveness of already existing additives, which have been carefully matched to one another and the base oil.

Selection of lubricating oils/ warranty

Most oil manufacturers are in close, permanent contact with engine manufacturers and can therefore specify which oil from their own product line is approved by the engine manufacturer for the specific application. Irrespective of this information, the lubricating oil manufacturers are liable for the quality and properties of their products. If you have any questions, we would be more than happy to provide you with additional information.

Oil during operation

There are no prescribed oil change intervals for Everllence medium speed engines. The oil properties must be analysed monthly. The oil must therefore be suitable for the intended purpose and meet the defined limit values as per the table. If this is the case, the oil can continue to be used. See section Limit values for used lubricating oil.

The quality can only be maintained if it is purified via a separator or an otherwise suitable device.

Tests

A monthly analysis of lube oil samples is mandatory for safe engine operation. We can analyse samples for customers in the Everllence PrimeServLab.

To guarantee the safety of the crew and to obtain a representative sample, sampling must take place in accordance with valid Everllence work instructions.

⚠ WARNING

Handling operating materials

Handling operating materials can lead to serious personal injury and environmental damage.

- Observe the safety data sheets of the operating material manufacturer.

The list of the currently approved lubricating oils is available at Lubrication.

NOTICE

No liability when using these oils

Everllence is not liable for any problems that occur when using these oils.

	Limit value	Procedure
Viscosity at 40 °C	110–220 mm²/s	ASTM D7042, ASTM D445, DIN EN 16896 or ISO 3104
Base number (BN)	at least 50 % of fresh oil	ISO 3771
Flash point (PM)	at least 185 °C	ISO 2719
Water content	max. 0.2 % (max. 0.5 % for brief periods)	DIN 51777 or ASTM D6304
n-heptane insoluble	max. 1.5 %	DIN 51592 or IP 316

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	Limit value	Procedure
Metal content	dependent on engine type and operating conditions	–
Guide value only Fe Cr Cu Pb Sn Al	 max. 50 ppm max. 10 ppm max. 15 ppm max. 20 ppm max. 10 ppm max. 20 ppm	ASTM D5185 or DIN 51399-1

Table 2: Limit values for used lube oil

Lubricating oil (SAE 40) specification for operation with DMA/DMB, DFA, DFB

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Lubricating oil (SAE 40) specification for operation with DMA/DMB, DFA, DFB

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Specific lubricating oil consumption - SLOC

General

Engine type	RPM	SLOC [g/kWh]	[1] Max. [l/cyl 24h]
L16/24, L16/24S	1000/1200	0.4 - 0.8	2.5
L21/31, L21/31S, L21/31 Mk1.1, L21/31 Mk2, L21/31DF-M	900/1000	0.4 - 0.8	5.0
L23/30H, L23/30DF	720/750	0.4 - 0.8	2.9
L23/30H Mk2, L23/30S	720/750	0.4 - 0.8	3.2
L23/30H Mk3	720/750	0.4 - 0.8	3.8
L23/30H, L23/30DF, L23/30S-DF, L23/30A	900	0.4 - 0.8	3.6
L23/30H Mk2, L23/30S	900	0.4 - 0.8	4.0
L23/30H Mk3	900	0.4 - 0.8	4.5
L27/38, L27/38S, L27/38 Mk2 (330/340 kW/cyl)	720/750/800	0.4 - 0.8	7.5
L27/38 (350/365 kW/cyl)	720/750/800	0.4 - 0.8	8.2
L27/38 Mk2 (410 kW/cyl)	900	0.4 - 0.8	9.3
L28/32H, L28/32S, L28/32DF, L28/32S-DF	720/750	0.4 - 0.8	4.7
L28/32A	775	0.4 - 0.8	5.5
V28/32S	720/750	0.4 - 0.8	5.2

In the Engine performance data calculation program Everllence-Projedat the figures 0.6+20% g/kWh are used as an average SLOC value for calculation of Operation Expenses (OPEX), “Total cost of ownership” etc. When the engine is new or newly overhauled the SLOC can be lower than 0.4 g/kWh without causing concerns.

Increased SLOC values might be observed just before overhaul. Note “*1) Max Lubrication oil consumption per cyl per 24 hours*”

Description

Please note

- Only maximum continuous rating (P_{MCR} (kW)) should be used in order to evaluate the SLOC.
- During engine running-in the SLOC may exceed the values stated.

The following formula is used to calculate the SLOC:

$$\text{SLOC [g/kWh]} = \frac{\text{(lubricating oil added - A1 - A2 [dm}^3\text{] x } \rho_{\text{lub oil}} \text{ [kg/m}^3\text{]}}{\text{run.hrs.period x } P_{MCR} \text{ [kW]}}$$

In order to evaluate the correct engine SLOC, the following circumstances must be noticed and subtracted from the engine SLOC:

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A1:

- Desludging interval and sludge amount from the lubricating oil separator (or automatic lubricating oil filters). The expected lubricating oil content of the sludge amount is 30%.

The following does also have an influence on the SLOC and must be considered in the SLOC evaluation:

A2:

- Lubricating oil evaporation
- Lubricating oil leakages
- Lubricating oil losses at lubricating oil filter exchange

The lubricating oil density, ρ @ 15°C must be known in order to convert ρ to the present lubricating oil temperature in the base frame. The following formula is used to calculate ρ:

$$\rho_{lub\ oil}\ [kg/m^3] = \rho_{lub\ oil\ @\ 15°C}\ [kg/m^3] - 0.64 \times (t_{lub\ oil}\ [°C] - 15)$$

The engine maximum continuous design rating (P_{MCR}) must always be used in order to be able to compare the individual measurements, and the running hours since the last lubricating oil adding must be used in the calculation. Due to inaccuracy *) at adding lubricating oil, the SLOC can only be evaluated after 1,000 running hours or more, where only the average values of a number of lubricating oil addings are representative.

NOTICE

***) A deviation of ± 1 mm with the dipstick measurement must be expected, which corresponds uptill ± 0.1 g/kWh, depending on the engine type.**

Plant / Ship
Lube oil consumption

Engine type:_____ **Engine # :**_____

Lube oil brand/type:_____

Density @15 C:_____ **[kg/m3]**

Date	Run. hrs [h]	Add. Lube oil [dm³]	A1 + A2 [dm³]	L.O.Temperature [°C]	SLOC [g/kWh]	Remarks

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Separator unit

Separator unit

Continuous lubricating oil cleaning during engine operation is mandatory. An optimal lubricating oil treatment is fundamental for a reliable working condition of the engine.

If the lubricating oil is circulating without a separator unit in operation, the lubricating oil will gradually be contaminated by products of combustion, water and/or acid. In some instances cat-fines may also be present.
In order to prolong the lubricating oil lifetime and remove wear elements, water and contaminants from the lubricating oil, it is mandatory to use a by-pass separator unit.
The separator unit will reduce the carbon residue content and other contaminants from combustion on engines operated on HFO, and keep the amount within Everllence recommendation, on condition that the separator unit is operated according to Everllence recommendations.

When operating a cleaning device, the following recommendations must be observed:

- The optimum cleaning effect is achieved by keeping the lubricating oil in a state of low viscosity for a long period in the separator bowl.
- Sufficiently low viscosity is obtained by preheating the lubricating oil to a temperature of 95°C - 98°C, when entering the separator bowl.
- The capacity of the separator unit must be adjusted according to Everllence recommendations.

Slow passage of the lubricating oil through the separator unit is obtained by using a reduced flow rate and by operating the separator unit 24 hours a day, stopping only for maintenance, according to maker's recommendation.

Lubricating oil preheating

The installed heater on the separator unit ensures correct lubricating oil temperature during separation. When the engine is at standstill, the heater can be used for two functions:

- The oil from the sump is preheated to 95 – 98 °C by the heater and cleaned continuously by the separator unit.
- The heater can also be used to maintain an oil temperature of at least 40 °C, depending on installation of the lubricating oil system.

Cleaning capacity

Normally, it is recommended to use a self-cleaning filtration unit in order to optimize the cleaning period and thus also optimize the size of the filtration unit. Separator units for manual cleaning can be used when the reduced effective cleaning time is taken into consideration by dimensioning the separator unit capacity.

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The centrifuging process in separator bowl

Efficient lubricating oil cleaning relies on the principle that - provided the through-put is adequate and the treatment is effective - an equilibrium condition can be reached, where the engine contamination rate is balanced by the centrifuge separation rate i.e.:

- Contaminant quantity added to the lubricating oil per hour = contaminant quantity removed by the centrifuge per hour.

It is the purpose of the centrifuging process to ensure that this equilibrium condition is reached, with the lubricating oil insolubles content being as low as possible.

Since the cleaning efficiency of the centrifuge is largely dependent upon the flow rate, it is very important that this is optimised.

A centrifuge can be operated at greatly varying flow rates (Q).

Practical experience has revealed that the content of insolubles, before and after the centrifuge, is related to the flow rate as shown in Fig. 1.

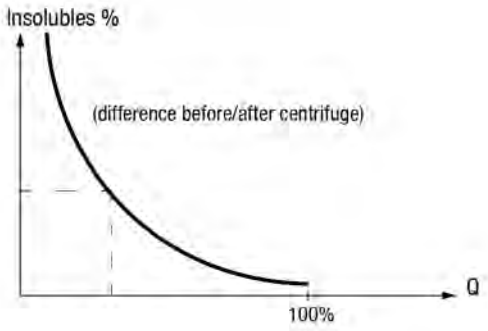


Figure 1: .

Fig. 1 illustrates that the amount of insolubles removed will decrease with rising flow rate (Q).

It can be seen that:

- At low flow rate (Q), only a small portion of the lubricating oil is passing the centrifuge/hour, but is being cleaned effectively.
- At high flow rate (Q), a large quantity of lubricating oil is passing the centrifuge/hour, but the cleaning is less effective.

Thus, by correctly adjusting the flow rate, an optimal equilibrium cleaning level can be obtained (Fig. 2).

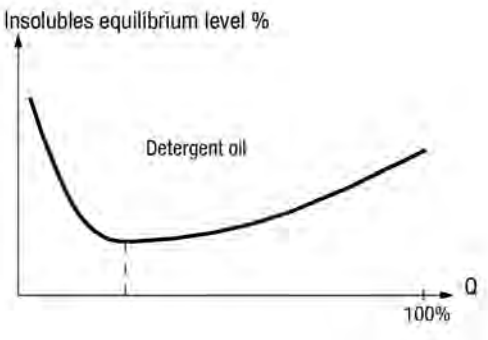


Figure 2: .

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This minimum contamination level is obtained by employing a suitable flow rate that is only a fraction of the stated maximum capacity of the centrifuge (*see the centrifuge manual*).

The most important factor is the particle size (risk of scratching and wear of the bearing journals). In general the optimum centrifuge flow rate for a detergent lubricating oil is about 25% of the maximum centrifuge capacity.

Operation flow

In order to calculate the required operation flow through the separator unit, Everllence recommends to apply the following formula:

$$Q = \frac{P \times 1.36 \times n}{t}$$

Q	=	required operation flow [l/h]
P	=	MCR (maximum continuous rating) [kW]
t	=	actual effective separator unit separating time per day [hour] (23.5 h separating time and 0.5 h for sludge discharge = 24 h/day)
n	=	number of turnovers per day of the theoretical oil volume corresponding to 1.36 [l/kW] or 1 [l/HP]

The following values for "n" are recommended:

n	=	6 for HFO operation (residual)
n	=	4 for MDO operation
n	=	3 for distillate fuel

Example 1

For multi-engine plants, one separator unit per engine in operation is recommended.

For example, for a 1,000 kW engine operating on HFO and connected to a self-cleaning separator unit, with a daily effective separating period of 23.5 hours, the calculation is as follows:

$$Q = \frac{1000 \times 1.36 \times 6}{23.5} = 347 \text{ l/h}$$

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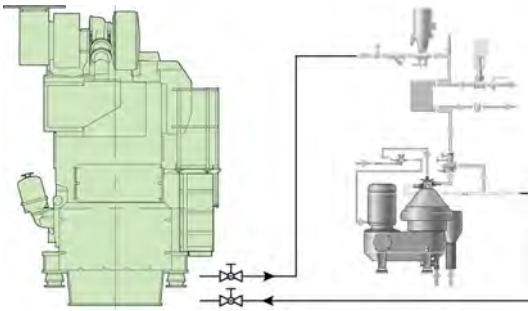


Figure 3: One separator per engine plant

Example 2 (GenSet)

As an alternative, one common separator unit for three engines can be installed, with one in reserve if possible.

For the calculation in this example it is necessary include the combined average power demand of the multi-engine plant. The load profile experienced for the majority of merchant vessels is that the average power demand is around 43-50% of the total GenSet power installed. With three identical engines this corresponds to 1.3-1.5 times the power of one engine.

- Bulk carrier and tankers : ~1.3 times the power of one engine
- Container vessel : ~1.5 times the power of one engine

For example, for a bulk carrier with three 1,000 kW engines operating on HFO and connected to a common self-cleaning separator unit, with a daily effective separating period of 23.5 hours, the calculation is as follows:

$$Q = \frac{1.3 \times 1000 \times 1.36 \times 6}{23.5} = 451 \text{ l/h}$$

Bulk carrier and tankers

Separator unit installation

With multi-engine plants, one separator unit per engine in operation is recommended (*see figure 3*), but if only one separator unit is in operation, the following layout can be used:

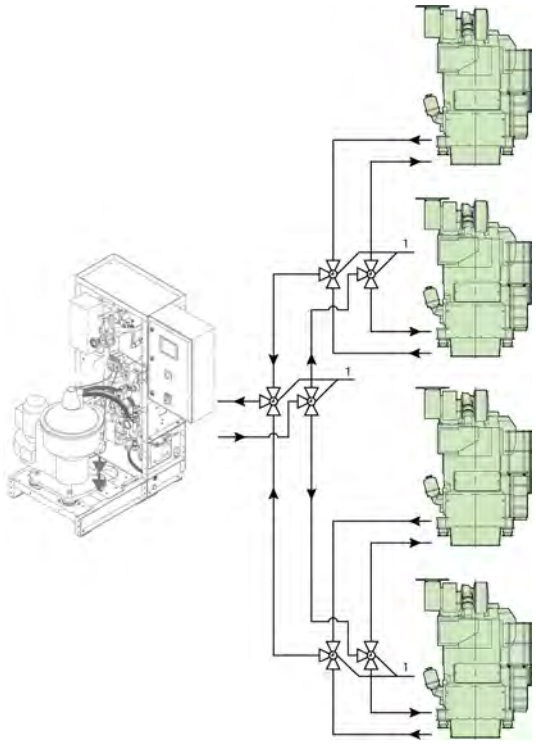
- A common separator unit (*see figure 4*) can be installed, with one in reserve, if possible, for operation of all engines through a pipe system, which can be carried out in various ways. The aim is to ensure that the separator unit is only connected to one engine at a time. Thus there will be no suction and discharging from one engine to another.

It is recommended that inlet and outlet valves are connected so that they can only be changed over simultaneously.

With only one engine in operation there are no problems with separating, but if several engines are in operation for some time it is recommended to split up the separation time in turns on all operating engines.

With 2 out of 3 engines in operation the 23.5 hours separating time must be split up in around 4-6 hours intervals between changeover.

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1 Interconnected valves

Figure 4: One common separator unit for multi-engine installation

Stokes' law

The operating principles of centrifugal separation are based on Stokes' Law.

$$V = \frac{d^2 (\rho_p - \rho_l) r\omega^2}{18\mu}$$

V	=	settling velocity [m/sec]
$r\omega^2$	=	acceleration in centrifugal field [m/sec^2]
d	=	diameter of particle [m]
ρ_p	=	density of particle [kg/m^3]
ρ_l	=	density of medium [kg/m^3]
μ	=	viscosity of medium [kg/m, sec.]

The rate of settling (V) for a given capacity is determined by Stokes' Law. This expression takes into account the particle size, the difference between density of the particles and the lubricating oil, and the viscosity of the lubricating oil.

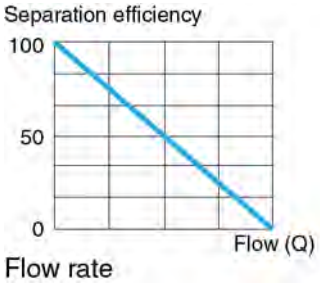
Density and viscosity are important parameters for efficient separation. The greater the difference in density between the particle and the lubricating oil, the higher the separation efficiency. The settling velocity increases in inverse proportion to viscosity. However, since both density and viscosity vary with temperature, separation temperature is the critical operating parameter.

Particle size is another important factor. The settling velocity increases rapidly with particle size. This means that the smaller the particle, the more challenging the separation task. In a centrifuge, the term ($r\omega^2$) represents the centrifu-

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gal force which is several thousand times greater than the acceleration due to gravitational force. Centrifugal force enables the efficient separation of particles which are only a few microns in size.

The separation efficiency is a function of:

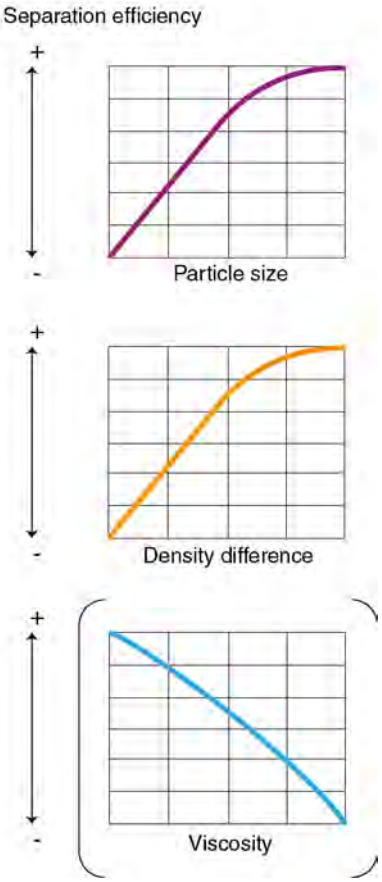


Flow rate



Settling area

Settling velocity



Operating parameters

Various operating parameters affect separation efficiency. These include temperature, which controls both lubricating oil viscosity and density, flow rate and maintenance.

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Temperature of lubricating oil before separator unit

It is often seen that the lubricating oil pre-heaters are undersized, have very poor temperature control, the steam supply to the pre-heater is limited or the temperature set point is too low.

Often the heater surface is partly clogged by deposits. These factors all lead to reduced separation temperature and hence the efficiency of the separator unit. In order to ensure that the centrifugal forces separate the heavy contaminants in the relatively limited time that they are present in the separator bowl, the separator unit must always be operated with an inlet temperature of 95-98°C for lubricating oil.

A control circuit including a temperature transmitter and a PI-type controller with accuracy of ±2°C must be installed. If steam-heated, a correctly sized steam valve should be fitted with the right KvS value. The steam trap must be a mechanical float type. The most common heaters on board are steam heaters. This is due to the fact that steam in most cases is available at low cost.

Most ships are equipped with an exhaust boiler utilizing the exhaust gases to generate steam.

A large proportion of smaller tonnage does, however, use electric heaters.

It is essential to keep the incoming oil temperature to the separator unit steady with only a small variation in temperature allowed (maximum ±2°C).

The position of the interface between oil and water in the separator bowl is a result of the density and the viscosity of the oil, which in turn depends on the temperature.

Flow rate

It is known that separation efficiency is a function of the separator unit's flow rate. The higher the flow rate, the more particles are left in the oil and therefore the lower the separation efficiency. As the flow rate is reduced, the efficiency with which particles are removed increases and cleaning efficiency thus improves. It is, however, essential to know at what capacity adequate separation efficiency is reached in the specific case.

In principle, there are three ways to control the flow:

- Adjustment of the built-in safety valve on the pump.

  This method is NOT recommended since the built-on valve is nothing but a safety valve.

  The opening pressure is often too high and its characteristic far from linear.

  In addition, circulation in the pump may result in oil emulsions and cavitation in the pump.
- A flow regulating valve arrangement on the pressure side of the pump, which bypasses the separator unit and re-circulates part of the untreated lubricating oil back to the treated oil return line, from the separator unit and NOT directly back to the suction side of the pump.

  The desired flow rate is set manually by means of the flow regulating valve. Further, the requirement for backpressure in the clean oil outlet MUST also be fulfilled, helping to maintain the correct interface position.
- Speed control of the pump motor with a frequency converter or a 2-speed motor.

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This is a relatively cheap solution today and is a good alternative for flow control.

Maintenance

Proper maintenance is an important, but often overlooked operating parameter that is difficult to quantify. If the bowl is not cleaned in time, deposits will form on the bowl discs, the free channel height will be reduced, and flow velocity increases. This further tends to drag particles with the liquid flow towards the bowl's centre resulting in decreased separation efficiency.

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Treatment and maintenance of lubricating oil

General

During operation of trunk engines the lubricating oil will gradually be contaminated by small particles originating from the combustion.

Engines operated on heavy fuels will normally increase the contamination due to the increased content of carbon residues and other contaminants.

Contamination of lubricating oil with either freshwater or seawater can also occur.

A certain amount of contaminants can be kept suspended in the lubricating oil without affecting the lubricating properties.

The condition of the lubricating oil must be kept under observation (on a regular basis) by analyzing oil samples. *See Section B 12 15 0 / 504.04 "Criteria for Cleaning/Exchange of Lubricating Oil"*.

The condition of the lubricating oil can be maintained / re-established by exchanging the lubricating oil at fixed intervals or based on analyzing oil samples.

The moving parts in the engine are protected by the built-on lubricating oil filter.

Operation on distillate fuels, Marine diesel oil (MDO), Marine gas oil (MGO), Low, Very low & Ultra low sulphur fuel oil (LSFO), (VLSFO), (ULSFO)

We recommend to install a built-on centrifugal filter as an additional filter to the built-on lubricating oil filter.

It is advisable to run bypass cleaning equipment continuously for engines operated on distillate fuels.

Operation on residual fuels, Heavy fuel oil (HFO) Low, Very low & Ultra low sulphur heavy fuel oil (LSFO), (VLSFO) (ULSFO)

HFO-operated engines require effective lubricating oil cleaning. In order to ensure a safe operation it is necessary to use supplementary cleaning equipment together with the built-on lubricating oil filter.

We recommend to install a built-on centrifugal by-pass filter as an additional filter to the built-on lubricating oil filter.

It is also mandatory to run cleaning equipment continuously for engines operated on residual fuels, as an optimal lubricating oil treatment is fundamental for a reliable working condition. Therefore it is mandatory to clean the lubricating oil with a bypass cleaning equipment, so that the wear rates are reduced and the lifetime of the engine is extended.

Bypass cleaning equipment

As a result of normal operation, the lubricating oil contains abraded particles and combustion residues which have to be removed by the bypass cleaning system and to a certain extent by the built-on lubricating oil filter as well.

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With automatic mesh filters this can result in an undesirable and hazardous continuous flushing. In view of the high cost of cleaning equipment for removing micro impurities, this equipment is only rated for a certain proportion of the oil flowing through the engine since it is installed in a bypass.

The bypass cleaning equipment is operate continuously when the engine is in operation or at standstill.

For cleaning of lubricating oil the following bypass cleaning equipment can be used:

- Separator unit
- Decanter unit
- Self cleaning automatic bypass mesh filter
- Bypass depth filter

The decanter unit, the self-cleaning automatic bypass mesh filter and the bypass depth filter capacity must be adjusted according to maker's recommendations.

If the selected bypass cleaning equipment cannot remove water it is recommended to have portable separator available.

In case full flow filtration equipment is chosen, this must only be installed as in-line cleaning upstream to the built-on lubricating oil filter.

The most appropriate type of equipment for a particular application depends on the engine output, the type and amount of combustion residues, the annual operating time and the operating mode of the plant. Even with a relatively low number of operating hours there can be a great deal of combustion residues if, for instance, the engine is inadequately preheated and quickly accelerated and loaded.

Check of lubricating oil system

For cleaning of the lubricating oil system after overhauls and inspection of the lubricating oil piping system the following checks must be carried out:

1. Examine the piping system for leaks.
2. Retighten all bolts and nuts in the piping system.
3. Move all valves and cocks in the piping system. Lubricate valve spindles with graphite or similar.
4. Blow through drain pipes.
5. Check flexible connections for leaks and damages.
6. Check manometers and thermometers for possible damages.
7. Centrifugal by-pass filter can be used as indicator of lubricating oil system condition.
   Define a cleaning interval (ex. 100 hours). Check the sludge weight. If the sludge weight is raising please check separator and lubricating oil system condition in general.

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Deterioration of oil

Oil seldomly loses its ability to lubricate, i.e. to form a friction-decreasing oil film, but it may become corrosive to the steel journals of the bearings in such a way that the surface of these journals becomes too rough and wipes the bearing surface.

In that case the bearings must be renewed, and the journals must also be polished. The corrosiveness of the lubricating oil is either due to far advanced oxidation of the oil itself (TAN) or to the presence of inorganic acids (SAN). In both cases the presence of water will multiply the effect, especially sea water as the chloride ions act as an inorganic acid.

Signs of deterioration

If circulating oil of inferior quality is used and the oxidative influence becomes grave, prompt action is necessary as the last stages in the deterioration will develop surprisingly quickly, within one or two weeks. Even if this seldomly happens, it is wise to be acquainted with the signs of deterioration.

These may be some or all of the following:

- Sludge precipitation in the separator unit multiplies
- Smell of oil becomes acrid or pungent
- Machined surfaces in the crankcase become coffee-brown with a thin layer of lacquer
- Paint in the crankcase peels off or blisters
- Excessive carbon is formed in the piston cooling chamber

In a grave case of oil deterioration the system must be cleaned thoroughly and refilled with new oil.

Oxidation of oils

At normal service temperature the rate of oxidation is insignificant, but the following factors will accelerate the process:

High temperature

If the coolers are ineffective, the temperature level will generally rise. A high temperature will also arise in electrical pre-heaters if the circulation is not continued for 5 minutes after the heating has been stopped, or if the heater is only partly filled with oil.

Catalytic action

Oxidation of the oil will be accelerated considerably if catalytic particles are present in the oil. Wear particles of copper are especially harmful, but also ferrous particles and rust are active. Furthermore, the lacquer and varnish oxidation products of the oil itself have an accelerating effect. Continuous cleaning of the oil is therefore important to keep the sludge content low.

Water washing

Water washing of HD oils (heavy duty) must not be carried out.

Water in the oil

If the TAN is low, a minor increase in the fresh water content of the oil is not immediately detrimental while the engine is in operation. Naturally, it should be brought down again as quickly as possible (below 0.2% water content, which is permissible, *see description "B 12 15 0/504.04 criteria for exchange of lube oil*"). If the engine is stopped while corrosion conditions are unsatisfactory, the crankshaft must be turned ½ - ¾ revolution once every hour by means of the

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turning gear. Please make sure that the crankshaft stops in different positions, to prevent major damage to bearings and journals. The lubricating oil must be circulated and separated continuously to remove water.

Water in the oil may be noted by steam formation on the sight glasses, by appearance, or ascertained by immersing a piece of glass or a soldering iron heated to 200-300°C in an oil sample. If there is a hissing sound, water is present. If a large quantity of water has entered the lubricating oil system, it has to be removed. Either by sucking up sediment water from the bottom, or by replacing the oil in the sump. An oil sample must be analysed immediately for chloride ions.

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Criteria for cleaning/exchange of lubricating oil

Replacement of lubricating oil

The expected lubricating oil lifetime in operation is difficult to determine. The lubricating oil lifetime is depending on the fuel oil quality, the lubricating oil quality, the lubricating oil consumption, the lubricating oil cleaning equipment efficiency and the engine operational conditions.

In order to evaluate the lubricating oil condition a sample should be drawn on regular basis at least once every three month or depending on the latest analysis result. The lubricating oil sample must be drawn before the filter at engine in operation. The sample bottle must be clean and dry, supplied with sufficient identification and should be closed immediately after filling. The lubricating oil sample must be examined in an approved laboratory or in the lubricating oil suppliers own laboratory.

A lubricating oil replacement or an extensive lubricating oil cleaning is required when the Everllence exchange criteria's have been reached.

Evaluation of the lubricating oil condition

Based on the analysis results, the following guidance are normally sufficient for evaluating the lubricating oil condition. The parameters themselves can not be jugded alonestanding, but must be evaluated together in order to conclude the lubricating oil condition.

1. Viscosity

Limit value:

	Normal value	min. value	max. value
SAE 30 [cSt@40° C]	95 - 125	75	160
SAE 30 [cSt@100° C]	11 - 13	9	15
SAE 40 [cSt@40° C]	135 - 165	100	220
SAE 40 [cSt@100° C]	13.5 - 15.0	11	19

Unit	:	cSt (mm^2/s)
Possible test method	:	ASTM D-445, DIN51562/53018, ISO 3104

Increasing viscosity indicates problems with insolubles, HFO contamination, water contamination, oxidation, nitration and low load operation. Decreasing viscosity is generally due to dilution with lighter viscosity oil.

2. Flash point

Min. value	:	185° C
Possible test method	:	ASTM D-92, ISO 2719

Normally used to indicate fuel dilution.

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3. Water content

Max. value	:	0.2 %
Unit	:	Weight %
Possible test method	:	ASTM D4928, ISO 3733

Water can originate from separator, contaminated fuel oil, an engine cooling water leak or in minor amount formed as part of the combustion process. If water is detected also Sodium, Glycol or Boron content should be checked in order to confirm engine coolant leaks.

If ship installation have no separator unit it is recommend to have a portable separator available to remove water.

4. Base number

Min. value	:	The BN value should not be lower than 50% of fresh lubricating oil value, but minimum BN level never to be lower than 10-12 at operating on HFO!
Unit	:	mg KOH/g
Possible test method	:	ASTM D-2896, ISO 3771

The neutralization capacity must secure that the acidic combustion products, mainly sulphur originate from the fuel oil, are neutralized at the lube oil consumption level for the specific engine type. Gradually the BN will be reduced, but should reach an equilibrium.

5. Total acid number (TAN)

Max. value	:	3.0 acc. to fresh oil value
Unit	:	mg KOH/g
Possible test method	:	ASTM D-664

TAN is used to monitor oil degradation and is a measure of the total acids present in the lubricating oil derived from oil oxidation (weak acids) and acidic products of fuel combustion (strong acids).

6. Insolubles content

Max. value	:	1.5 % generally, depending upon actual dispersant value and the increase in viscosity
Unit	:	Weight %
Possible test method	:	ASTM D-893 procedure B in Heptane, DIN 51592

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Additionally test	:	If the level in n-Heptane insolubles is considered high for the type of oil and application, the test could be followed by a supplementary determination in Toluene.

Total insolubles is maily derived from products of combustion blown by the piston rings into the crankcase. It also includes burnt lubricating oil, additive ash, rust, salt, wear debris and abrasive matter.

7. Metal content

Metal content	Remarks	Attention limits
Iron	Depend upon engine type and operating conditions	max. 50 ppm
Chromium		max. 10 ppm
Copper		max. 15 ppm
Lead		max. 20 ppm
Tin		max. 10 ppm
Aluminium		max. 20 ppm
Silicon		max. 20 ppm

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Criteria for cleaning/exchange of lubricating oil

Description

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Cooling water system

Cooling water diagram

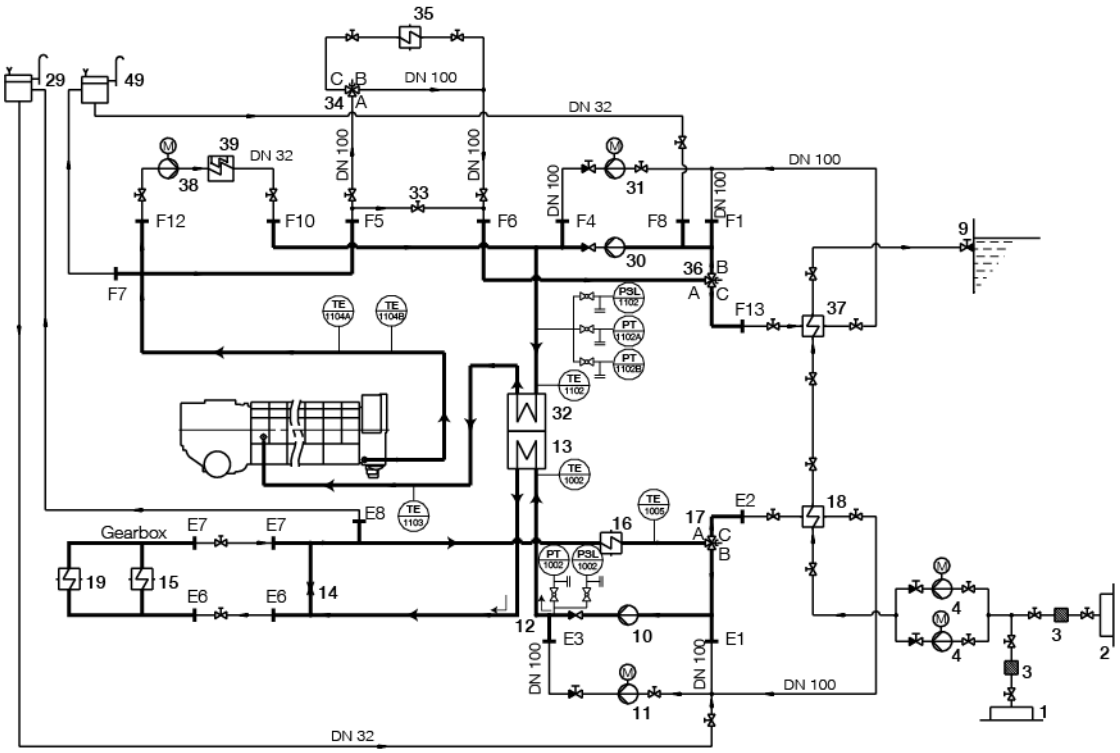


Figure 1: Cooling water diagram

Item	Description		Item	Description
1	Seachest low		19	Diesel oil cooler
2	Seachest high		29	LT expansion tank
3	Sea water filter		30	HT pump
4	Sea water pump		31	HT stand-by pump
9	Overboard discharge valve		32	Charging air cooler HT section
10	LT pump		33	Adjustment valve for heat recovery
11	LT standby pump		34	Thermostatic valve for heat recovery
12	Regulating valve for charge air preheating (optional, only L27/38)		35	Heat recovery
13	Charging air cooler, LT section		36	HT thermostatic valve
14	Orifice for cooling water to gearbox		37	HT fresh water cooler
15	Gear oil cooler		38	Circulating pump for preheater
16	Engine lubricating oil cooler		39	Preheater
17	LT thermostatic valve		49	HT expansion tank
18	Central cooler			

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Connections	
E1	LT cooling water - inlet
E2	LT cooling water - outlet (to cooler)
E3	LT cooling water stand-by pump - pressure
E6	LT cooling water to auxiliary cooler
E7	LT cooling water from auxiliary cooler
E8	LT cooling water tp expansion tank (venting)
F1	HT cooling water - inlet
F4	HT cooling water stand-by pump - pressure
F5	HT cooling water to heat recovery system
F6	HT cooling water from heat recovery system
F7	HT cooling water to expansion tank (venting)
F8	HT cooling water from expansion tank
F10	Engine preheating - inlet
F12	Engine preheating - outlet
F13	HT cooling water - outlet (to cooler)

Sea water filters (item 3):
We recommend a filter with max 3 mm meshsize to prevent clogging of the central cooler.

Thermostatic valves (items 17, 34 and 36): A, B and C refer to port position (diverting mode)
A, B and C refer to port position (diverting mode)

Expansion tank (items 29 and 49):
The lowest water level in the expansion tanks should be min 6 meters above center-line of crankshaft. Inlet to expansion tank to be beneath the lowest water level.

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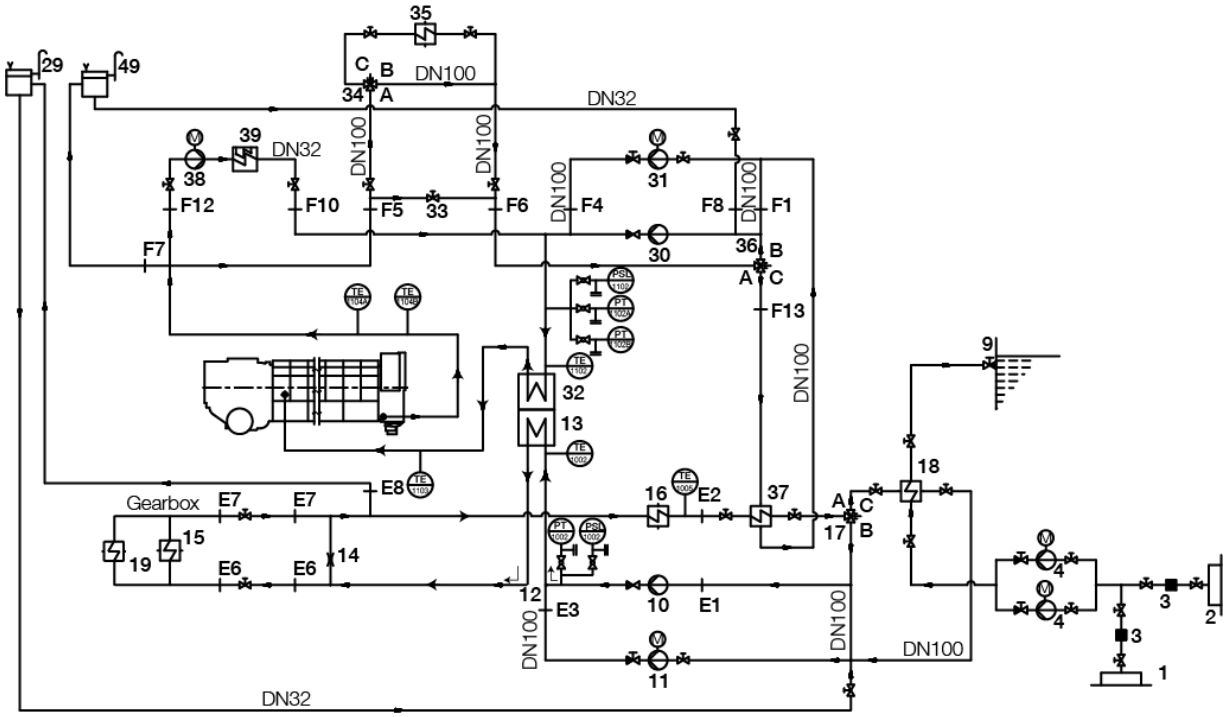


Figure 2: Cooling water diagram

Item	Description		Item	Description
1	Seachest low		19	Diesel oil cooler
2	Seachest high		29	LT expansion tank
3	Sea water filter		30	HT pump
4	Sea water pump		31	HT stand-by pump
9	Overboard discharge valve		32	Charging air cooler HT section
10	LT pump		33	Adjustment valve for heat recovery
11	LT standby pump		34	Thermostatic valve for heat recovery
12	Regulating valve (optional)		35	Heat recovery
13	Charging air cooler, LT section		36	HT thermostatic valve
14	Orifice for cooling water to gearbox		37	HT fresh water cooler
15	Gear oil cooler		38	Circulating pump for preheater
16	Engine lubricating oil cooler		39	Preheater
17	LT thermostatic valve		49	HT expansion tank
18	Central cooler			

Connections	
E1	LT cooling water - inlet
E2	LT cooling water - outlet (to cooler)
E3	LT cooling water stand-by pump - pressure

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Connections	
E6	LT cooling water to auxiliary cooler
E7	LT cooling water from auxiliary cooler
E8	LT cooling water tp expansion tank (venting)
F1	HT cooling water - inlet
F4	HT cooling water stand-by pump - pressure
F5	HT cooling water to heat recovery system
F6	HT cooling water from heat recovery system
F7	HT cooling water to expansion tank (venting)
F8	HT cooling water from expansion tank
F10	Engine preheating - inlet
F12	Engine preheating - outlet
F13	HT cooling water - outlet (to cooler)

Sea water filters (item 3):
We recommend a filter with max 3 mm meshsize to prevent clogging of the central cooler.

Thermostatic valves (items 17, 34 and 36): A, B and C refer to port position (diverting mode)
A, B and C refer to port position (diverting mode)

Expansion tank (items 29 and 49):
The lowest water level in the expansion tanks should be min 6 meters above centerline of crankshaft. Inlet to expansion tank to be beneath the lowest water level.

Cooling Water System

The engine is designed for freshwater cooling only. Therefore the cooling water system has to be arranged as a centralised or closed cooling water system. All recommendable types are described in the following.

The engine design is almost pipeless, i.e. the water flows through internal cavities inside the front-end box and the cylinder units. The front-end box contains all large pipe connections. On the aft-end, the water to the gear oil cooler has to be connected by the yard.

The engine is equipped with built-on freshwater pumps for both the high and low temperature cooling water systems. To facilitate automatic start-up of stand-by pumps, non-return valves are standard.

Thermostatic valve elements, which control the high and low temperature cooling water system, are also integrated parts of the front-end box.

In case the HT cooler as alternative is a part of the LT cooling water system the LT thermostatic valves are to be replaced by “dummies” inside the front-end box and an external thermostatic valve housing is required to be placed in the LT circuit just after the HT freshwater cooler.

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The engine is equipped with a two stage charge air cooler. The first stage is placed in the high temperature cooling water system. The charging air temperature after the turbocharger is at its maximum, making a higher degree of heat recovery possible, when the heat is dissipated to the high temperature cooling water.

The second stage of the charge air cooler is placed in the low temperature system.

It will cool the charging air further down before entering the combustion chamber.

For special applications i.e. sailing in arctic waters with low air temperatures and direct air intake from deck, a regulating system can be applied to control the water flow to the second stage of the charge air cooler in order to increase the charging air temperature, at low load.

Water quality

The fresh water used as coolant, should be as clean as possible.

The pH value should be between 6.5 and 8 at 20°C.

The total hardness of the water must be max 10°dH (German hardness degrees). If the hardness is higher, the water should be diluted with some soft water.

The contents of chlorine, chloride, silicate and sulphate must be as low as possible and must not exceed the following values:

- Chlorine: 10 PPM
- Chloride: 50 PPM
- Silicate: 150 PPM
- Sulphate: 100 PPM

The fresh water must be treated with additives in order to reduce the risk of corrosion in the engine. Anti corrosive agents are not included in our usual scope of supply. The freshwater cooling system should be treated prior to carrying out sea trials.

There are two basic types of chemical additives:

- Chromate base
- Nitrite base or similar

Additives of chromate base are often considered to be more effective, but we advise against using them due to their extreme poisonousness and they are not permitted if a freshwater generator is incorporated in the plant.

For information on additives recommended by us, please refer to “Cooling water inhibitors”, which can be forwarded on request.

New engines, supplied by us are cleaned and nitrated. Providing the freshwater inhibiting is correctly maintained then future cleaning of the system should hardly be necessary. However if it should be required, we would be pleased to assist with recommendations for degreasing, de-scaling with acid and inhibiting.

Velocity recommendations for freshwater and sea water pipes:

- Freshwater
  - Suction pipe : 2.0 - 2.5 m/s
  - Delivery pipe: 2.0 - 2.5 m/s

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- Sea water
  - Suction pipe : 1.0 - 1.5 m/s
  - Delivery pipe: 1.5 - 2.5 m/s

Central cooling water system

Sea water filter, item 3

Design data

Capacity	:	See sea water pump
Pressure drop across clean filter	:	max 0.05 bar
Pressure drop across dirty filter	:	max 0.1 bar
Mesh size	:	3-5 mm
Free filter hole area	:	min two times the normal pipe area

Sea water pumps, item 4

The pumps should always be installed below sea water level when the ship is unloaded.

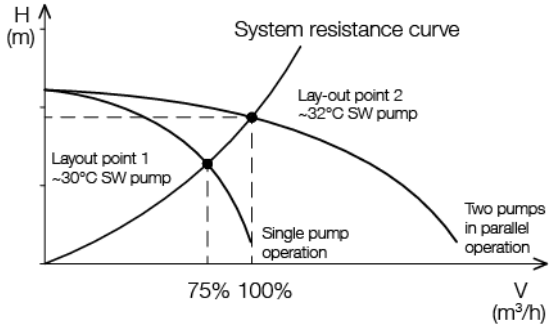


Figure 3: Pump characteristic

The pumps in parallel, layout point 2 see figure 3, are as standard designed to fulfil:

Capacity	:	Determined by the cooler manufacturer. Approx 100 - 175% of fresh water flow in the cooler, depending on the central cooler.
Pressure	:	1.8 - 2.0 bar
Sea water temperature	:	max 32° C

The volume of sea water required to circulate through a known sized cooler to remove a known amount of heat, is very sensitive and dependent on the sea water temperature.

The relation between sea water temperature and the necessary water flow in the central cooler is shown in figure 4.

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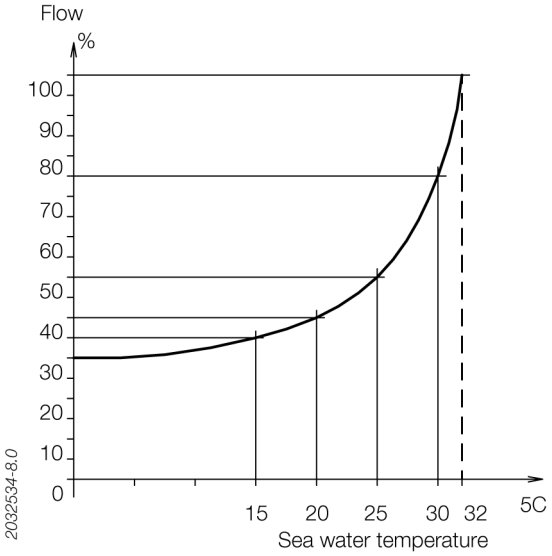


Figure 4: Necessary water flow

Depending on the actual characteristic of the system resistance curve and the pump characteristic curve, the sea water flow with only one pump in service will be approx 75%. This means that the cooling capacity can be obtained with only one pump until reaching a sea water temperature of approx 30°C.

The back pressure in single pump operation must be observed as a low back pressure may lead to unfavourable operation and cavitation of impeller. We are pleased to advise on more specific questions concerning the layout of pumps and location of orifices, etc.

Central cooler(s), item 18

If we are to supply the central cooler(s), it will be a plate cooler with titanium plates.

Design data		
Heat transfer	:	See list of capacities
Pressure drop LT	:	max 0.5 bar
Pressure drop SW	:	max 0.5 bar standard max 1.0 bar if HT cooler is in LT system

Two central coolers in parallel

For an extra investment of 20-25% for the central cooler a much greater safety margin can be achieved by installing two central coolers each of 50% required capacity, operating in parallel instead of one cooler at 100% capacity.

With such flexibility it is possible to carry out repair and maintenance during a voyage especially in temperate climates where the sea water temperature is below the design temperature.

LT freshwater pump, Item 10

The built-on low temperature pump is of the centrifugal type. The maximum back pressure in the low temperature section with clean cooler must not exceed 2.5 bar.

For multi engine installations with a common centralised cooling water system the built-on pumps should be replaced with common electrically driven pumps for full flow.

Design data	:	See list of capacities

LT stand-by pump, item 11

The stand-by pumps should be of the centrifugal type.

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Design data

Capacity	:	See list of capacities, for the built-on freshwater pump
Pressure	:	See list of capacities, for the built-on freshwater pump

HT sea water cooler, item 37

The HT sea water cooler will be a plate cooler in titanium as standard.

Design data

Heat transfer	:	See list of capacities
Pressure drop HT	:	max 0.5 bar
Pressure drop SW	:	max 0.5 bar

HT fresh water cooler (option)

The HT cooler can as an alternative be installed as a part of the LT cooling water system. This will require a separate thermostatic valve for the LT cooling water system.

The HT freshwater cooler will be a plate cooler in stainless steel.

Design data

Heat transfer	:	See list of capacities
Pressure drop HT	:	max 0.5 bar
Pressure drop LT	:	max 0.5 bar

LT thermostatic valve, item 17

The temperature of the LT cooling water to the charge air cooler is normally controlled by thermostatic valve elements of the expanding agent type.

The function of the thermostatic valve is to maintain the outlet temperature of the low temperature water within 29°C to 41°C depending on operating conditions, by re-circulating the water to the suction of the pump or let it in through the central cooler (item 18).

The re-circulated water is led directly to the suction side of the built-on pumps.

Expansion tanks, items 29 and 49

Separate expansion tanks for the LT and HT system should be installed to accommodate for changes of volume due to varying temperatures and possible leakage in the LT and HT systems. The separated HT and LT systems facilitates trouble shooting.

The minimum water level in the expansion tank should be no less than 6 m above the centre line of the crankshaft. This will ensure sufficient suction head to the freshwater pump and reduce the possibility of cavitation, as well as local “hot spots” in the engine.

The expansion tank should be equipped with a vent pipe and flange for filling the tank with water and inhibitors.

The vent pipe should be installed below the minimum water level to reduce oxidation of the cooling water due to splashing from the vent pipe.

Volume	:	min 10% of water volume, however, min 100 litres

HT stand-by pump, item 31

The stand-by pumps should be of the centrifugal type.

Design data

Capacity	:	See list of capacities, for the built-on freshwater pump

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Pressure : See list of capacities, for the built-on freshwater pump

Temperature : max 95° C

Circulating pump for preheater, item 38

For preheating the engine a pump should be installed to circulate high temperature cooling water trough the preheater.

Design data

Capacity : $m = \frac{Q \times 3.6}{C_p \times t}$ m³/h

Q : Heat radiation from engine in kW, see below
C_p : Specific heat for water 4.187 kJ/kg° C
t : The desired temperature drop across engine = 5° C

Pressure : max 2 bar

Temperature : max 85° C

Preheater, item 39

The engine must be fitted with preheating facilities. Preheating is required to avoid producing unnecessary shock loads that may arise as a result of temperature differences if the engine is started from cold.

Design data

Preheating temperature MDO engine : min 40° C

Preheating temperature HFO engine : 60 - 70° C

The heating power required for electrical preheating is stated below:

Engine type	Heating power	Engine type	Heating power
6L21/31	7 kW	6L27/38	9 kW
7L21/31	8 kW	7L27/38	10.5 kW
8L21/31	9 kW	8L27/38	12 kW
9L21/31	10 kW	9L27/38	13.5 kW

The figures are based on raising the engine temperature to 40°C (20-60°C) for a period of 10 hours including the cooling water contained within the engine.

The preheater can be of the electrical type. If sufficient central heating capacity is available, a plate type heat exchanger can be installed. It is important that the inhibited fresh water, used in the main engine cooling system, is not mixed with water from the central heating system.

Thermostatic valve for heat recovery, item 34

If the heat recovery is below 25% of the heat rejection from engine jacket water the heat recovery equipment (item 35) can be connected in series with the HT freshwater cooler.

By utilisation of more than 25% of the heat in the HT cooling water section, an additional thermostatic valve, item 34, should be installed for bypassing of the HT fresh water cooler thus avoiding unnecessary cooling after the heat recovery equipment (item 35).

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Connection of heat recovery or freshwater generator

By layout of the freshwater generator we recommend that no more than 90% of the heat available at MCR is utilised due to safety margins, part load operation and deviations in ambient conditions.

The expected obtainable freshwater production using a normal generator of the single vacuum evaporator type can be estimated.

Design data

Capacity	:	m = 0.03 x Q m^3/24h
Pressure	:	max 2.5 bar
Pressure drop	:	max 0.5 bar
Temperature	:	80° C

Different arrangements of central cooling systems

There are many variations of centralised cooling systems and we are available to discuss various changes to suit an owner's or builder's specific wishes.

For each plant, special consideration should be given to the following design criteria: Sea water temperatures, pressure loss in coolers, valves and pipes, pump capacities etc, for which reason these components have not been specified in this guide.

Closed cooling systems

Several systems have been developed to avoid sea water. The benefits are:

- Minimising the use of expensive corrosion resistant pipes, valves and pumps
- Sea water pumps at reasonable costs
- No cleaning of plate type central heat exchangers

Such systems are advantageous in the following conditions:

- Sailing in shallow waters
- Sailing in very cold waters
- Sailing in corrosive waters (e.g. some harbours)
- Sailing in water with high contents of solids (dredging and some rivers)

A disadvantage of most closed cooling water systems is the poor heat transfer coefficient.

LT coolers with very small temperature differences between the cooling water and the sea or raw water, require a relatively large heat exchanger to enable sufficient heat transfer.

Everllence propulsion engine is a high efficient main engine calling for high efficient coolers. Therefore some designs cannot be recommended.

We are available to offer advice for specific cooler types, but the final responsibility for design, pressure losses, strength and system maintenance remains with the yard and the ship owner. We reserve the right not to accept proposed coolers, which seems to be insufficient for its purpose.

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Also when using other types of closed cooling water systems the HT and LT cooling water systems have to be separated.

Box cooler

The box cooling system has through many years proven to be a reliable closed cooling water system. The box cooler is a pre-manufactured tube bundle for mounting in a sea chest.

The movement of the sea water across the heat exchanger is initiated by the movement of the heated sea water upwards because of the lower density compared with that of the surrounding water. This means that the heat transfer is less dependant on the ship's speed, compared to coolers mounted on the shell of the vessel. However the speed of the vessel does have some influence on the cooling area. For vessels sailing at below 3 knots at MCR, i.e. tugs, dredgers etc, the speed has to be considered when designing the cooler.

The temperature of the sea water has influence on the heat exchanger efficiency as well. We recommend that a temperature of 25°C or 32°C is used, depending on the vessel's operating area.

The tube bundle is normally of corrosion resistant material with a non-metallic coating. The coating protects the vessel from galvanic corrosion between the sea chest and the box cooler. Uncoated coolers may be used, but special consideration has to be given to the galvanic separation of the box cooler and the hull.

In waters with mussels and shell fish these might want to live on the tube bundle, which the different box cooler manufacturers have different solutions to avoid.

If the box cooler is supplied by us, it consists of a steel frame for welding to the hull, a tube bundle and a topbox, delivered complete with counter flanges, gaskets and bolts.

Design data

Heat transfer	:	See list of capacities
Pressure drop through all coolers	:	max 0.5 bar
Min vessel speed at MCR	:	Normally more than 3 knots

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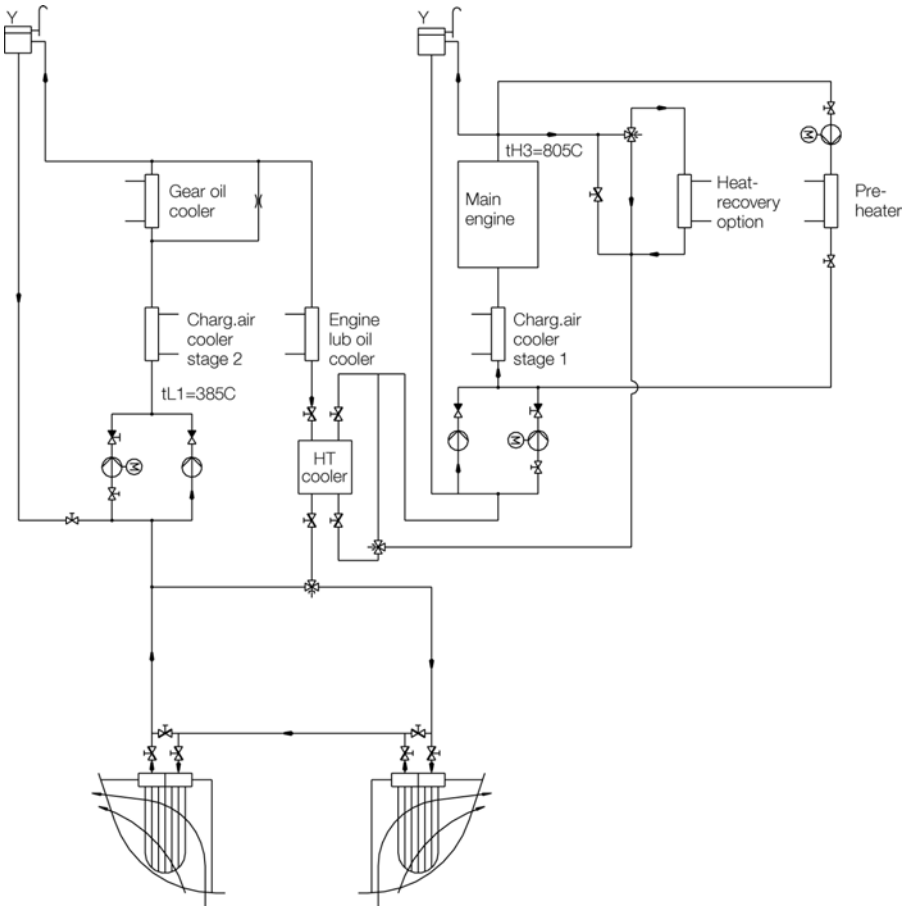


Figure 5: Box cooling diagram

Other cooler types

Some traditional, low efficient coolers fitted to the hull and often referred to as keel cooling, skin cooling or tank cooling is not recommended for Everllence propulsion engine. The layout of such coolers is difficult and changes due to lack of efficiency is very complicated and expensive. The low temperature difference between the sea water and the LT cooling water results in a very big cooling water surface. Depending on the design of the cooler, the waterflow around the hull and to the propeller will be disturbed, causing increased hull resistance and lower speed for the same power.

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Specification of engine coolant

Preliminary Remarks

The engine coolant is of the following composition: Water for heat removal and coolant additive for corrosion protection.

As is also the case with the fuel and lubricating oil, the engine coolant must be carefully selected, handled and checked. Otherwise, corrosion, erosion and cavitation may occur at the walls of the cooling system in contact with water, and deposits may form. Deposits obstruct the transfer of heat and can cause thermal overloading of the cooled parts. The plant must be treated with an anti-corrosion agent before bringing it into operation for the first time. The concentrations prescribed by the engine manufacturer must always be observed during subsequent operation. The above especially applies if a chemical additive is added.

Requirements

Limit values

The properties of the untreated coolant must comply with the following limit values:

Characteristic/property	Characteristics	Unit
Type of water	Distilled or fresh water, free from impurities.	–
Overall hardness	max. 10	dGH[1)]
pH value	6.5 – 8	–
Chloride ion content	max. 50	mg/l[2)]

Table 1: Characteristics of coolant that must be complied with

[1)] 1 dGH (German hardness) ≙ 10 mg CaO in 1 liter water ≙ 17.8 mg $CaCO_3$/l

≙ 0.357 mval/l ≙ 0.178 mmol/l

[2)] 1 mg/l ≙ 1 ppm

Testing equipment

The manufacturers of anticorrosive agents supply user-friendly testing equipment.

Instructions on how to inspect the coolant can be found in work instruction 010.000.002-03 in the engine work instructions “010.005.000 MDC090 Maintenance instructions engine” in the folder 010_Engine system.

Additional information

Distillate

If distilled water (from a fresh water generator, for example) or fully desalinated water (from ion exchange or reverse osmosis) is available, this should ideally be used as the engine coolant. These waters are free of lime and salts, which means that deposits that could interfere with the transfer of heat to the coolant, and therefore also reduce the cooling effect, cannot form. However, these waters are more corrosive than normal hard water as the thin film of lime scale that would otherwise provide temporary corrosion protection does not form on the walls. This is why distilled water must be handled particularly carefully and the concentration of the additive must be regularly checked.

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Hardness	The total hardness of the water is the combined effect of the temporary and permanent hardness. The proportion of calcium and magnesium salts is of overriding importance. The temporary hardness is determined by the carbonate content of the calcium and magnesium salts. The permanent hardness is determined by the amount of remaining calcium and magnesium salts (sulphates). The temporary (carbonate) hardness is the critical factor that determines the extent of limescale deposit in the cooling system. Water with a total hardness of > 10°dGH must be mixed with distilled water or softened.

Damage to the coolant system

Corrosion	Corrosion is an electrochemical process that can widely be avoided by selecting the correct water quality and by carefully handling the water in the engine cooling system.
Flow cavitation	Flow cavitation can occur in areas in which high flow velocities and high turbulence is present. If the steam pressure is reached, steam bubbles form and subsequently collapse in high pressure zones which causes the destruction of materials in constricted areas.
Erosion	Erosion is a mechanical process accompanied by material abrasion and the destruction of protective films by solids that have been drawn in, particularly in areas with high flow velocities or strong turbulence.
Stress corrosion cracking	Stress corrosion cracking is a failure mechanism that occurs as a result of simultaneous dynamic and corrosive stress. This may lead to cracking and rapid crack propagation in water-cooled, mechanically-loaded components if the coolant has not been treated correctly.

Treatment of engine coolant

Formation of a protective film	The purpose of treating the engine coolant using anticorrosive agents is to produce a continuous protective film on the walls of cooling surfaces and therefore prevent the damage referred to above. In order for an anticorrosive agent to be 100 % effective, it is extremely important that untreated water satisfies the requirements in the paragraph Requirements.
Treatment prior to initial commissioning of engine	Treatment with an anticorrosive agent should be carried out before the engine is brought into operation for the first time to prevent irreparable initial damage.

NOTICE

Treatment of the coolant

The engine may not be brought into operation without treating the coolant.

Additives for coolants

Only the additives approved by Everllence and listed under the section entitled Approved coolant additives may be used.

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Only in closed circuits

Additives may only be used in closed circuits where no significant consumption occurs, apart from leaks or evaporation losses. Observe the applicable environmental protection regulations when disposing of coolants containing additives. For more information, consult the additive supplier.

Chemical additives

Sodium nitrite and sodium borate based additives, etc., have a proven track record. Galvanized iron pipes or zinc sacrificial anodes must not be used in cooling systems. This corrosion protection is not required due to the prescribed coolant treatment and electrochemical potential reversal can occur due to the coolant temperatures which are normally present in engines nowadays. If necessary, the pipes must be deplated.

Anti-corrosion oil

It is not permissible to use anti-corrosion oils in cooling circuits of Everllence engines.

Anti-freeze agents

If temperatures below the freezing point of water in the engine cannot be excluded, an anti-freeze agent that also prevents corrosion must be added to the cooling system or corresponding parts. Otherwise, the entire system must be heated.

Adequate corrosion protection is achieved by adding the anti-freeze agents listed under Approved coolant additives, provided that the specified minimum concentration is maintained. This concentration prevents freezing at temperatures down to -22°C and ensures adequate corrosion protection. However, the quantity of anti-freeze agent actually required always depends on the lowest temperatures that are to be expected at the place of operation.

Anti-freeze agents are generally based on ethylene glycol or propylene glycol. A suitable chemical anticorrosive agent must be added if the concentration of the anti-freeze agent prescribed by the user for a specific application does not provide an appropriate level of corrosion protection, or if the concentration of anti-freeze agent used is lower due to less stringent frost protection requirements and does not provide an appropriate level of corrosion protection. Since the anti-freeze agents specified under Approved coolant additives also contain corrosion inhibitors which are not generally compatible with other anti-corrosion agents, only pure ethylene glycol or propylene glycol may be used as anti-freeze in such cases.

The simultaneous use of a nitrite-free coolant additive with ethylene glycol or propylene glycol is not permitted, as it is no longer possible to monitor the concentration of the corrosion inhibitor in such a mixture.

Anti-freeze reduces the coolant's ability to absorb heat. In some cases, the cooling effect of the coolant is not sufficient for certain operating conditions. The standard version of Everllence does not require the use of antifreeze. If anti-freeze is to be used, please consult with Everllence beforehand.

Before an anti-freeze agent is used, the cooling system must be thoroughly cleaned.

If the coolant contains an emulsifiable slushing oil, anti-freeze agent must not be added as otherwise the emulsion would break up and oil sludge would form in the cooling system.

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Biocides

If you cannot avoid using a biocide because the coolant has been contaminated by bacteria, observe the following steps:

- You must ensure that the biocide to be used is suitable for the specific application
- The biocide must be compatible with the sealing materials used in the coolant system and must not react with these
- The biocide and its decomposition products must not contain corrosion-promoting components. Biocides whose decomposition products contain chloride or sulphate ions are not permitted.
- Biocides that cause foaming of coolant are not permitted.
- Biocides should not be used continuously, but only as a spot treatment

Prerequisite for effective use of an anticorrosive agent

Clean cooling system

As contamination significantly reduces the effectiveness of the additive, the tanks, pipes, coolers and other parts outside the engine must be free of rust and other deposits before the engine is started up for the first time and after repairs of the pipe system.

The entire plant must therefore be cleaned using a suitable cleaning agent while the engine is switched off (see work instructions 010.000.001-01 and 010.000.002-04 in the engine work instructions “010.005.000 MDC090 Maintenance instructions engine” in the 010_Engine System folder).

Loose solid matter in particular must be removed by flushing the system thoroughly as otherwise erosion may occur in locations where the flow velocity is high.

The cleaning agents must not corrode the seals and materials of the cooling system. In most cases, the supplier of the coolant additive will be able to carry out this work and, if this is not possible, will at least be able to provide suitable products to do this. If this work is carried out by the engine operator, he should use the services of a specialist supplier of cleaning agents. The cooling system must be flushed thoroughly after cleaning. Once this has been done, the engine coolant must be immediately treated with anticorrosive agent. Once the engine has been brought back into operation, the cleaned system must be checked for leaks.

Regular checks of the coolant condition and system

Treated coolant can become contaminated during operation and the additive can lose some of its effectiveness. It is therefore advisable to check the cooling system and the condition of the coolant regularly. To detect leaks in the lubricating oil system, regular checking of the water in the expansion tank is recommended. Signs of oil in the water include discoloration or a visible oil film on the surface of the water sample.

Check the additive concentration using the test kits provided by the additive manufacturer at least once per week. The results must be recorded.

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NOTICE

Concentration of chemical additives

The chemical additives must be added in the specified concentration. See section Permitted coolant additives.

Concentrations that are too low can lead to corrosion and must be avoided. Concentrations that are slightly higher do not cause damage. Concentrations that are more than double the recommended concentrations should be avoided.

Analyses

A cooling water sample must be taken every 2 - 6 months and sent to an independent laboratory or to the engine manufacturer's chemical laboratory, which is the PrimeServLab, where a complete analysis is performed. A sample of 0.25 l is required for the analysis.

If chemical additives or antifreeze are used, the coolant should be replaced at the latest after three years.

To guarantee the safety of the crew and to obtain a representative sample, sampling must take place in accordance with valid Everllence work instructions.

In the case of high concentrations of solids (rust), the water must be changed completely and the entire system must be cleaned carefully.

Deposits in the cooling system may be caused by fluids that enter the coolant, break-up of the emulsion, corrosion in the system, and limescale deposits due to high water hardness. An increase in the concentration of chloride ions is generally an indication that seawater has entered the system. The specified maximum of 50 mg chloride ions per kg must not be exceeded, as the risk of corrosion is otherwise too high. If exhaust gas enters the coolant, this can result in a sudden drop in the pH value and/or an increase in the sulfate content.

Loss of water must be compensated for by topping up with water that meets the quality requirements specified in the section Requirements. The concentration of the anticorrosive agent must then be checked and corrected if necessary.

Checks of the coolant are required in particular after repairs or maintenance work that involve draining the coolant.

Protective Measures

Anticorrosive agents contain chemical compounds that can pose a risk to health or the environment if incorrectly used. Comply with the directions in the manufacturer's material safety data sheets.

Avoid prolonged direct contact with the skin. Wash hands thoroughly after use. If larger quantities spray and/or soak into clothing, remove and wash clothing before wearing it again.

If chemicals come into contact with eyes, rinse them immediately with plenty of water and seek medical advice.

Anticorrosive agents are generally harmful to the water cycle. Observe the relevant statutory requirements for disposal.

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Auxiliary engines

If the coolant system used in a Everllence two-stroke main engine is used in a marine engine of type 16/24, 21/ 31, 23/30H, 27/38 or 28/32H, the coolant recommendations for the main engine must be observed.

Permissible coolant additives

A list of currently approved coolant additives and their concentrations can be found under Lubrication .

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Coolant system cleaning

Summary

Remove contamination/residue from operating fluid systems, ensure/re-establish operating reliability.

Coolant systems containing deposits or contamination prevent effective cooling of parts. Contamination and deposits must be regularly eliminated.
This comprises the following:
Cleaning the system and, if required,
removal of limescale deposits,
flushing the system.

Cleaning

The coolant system must be checked for contamination at regular intervals. Cleaning is required if the degree of contamination is high. This work should ideally be carried out by a specialist who can provide the right cleaning agents for the type of deposits and materials in the cooling circuit. The cleaning should only be carried out by the engine operator if this cannot be done by a specialist.

Oil sludge

Oil sludge caused by lubricating oil that has entered the cooling system, or a high concentration of corrosion inhibitors, can be removed by flushing with fresh water to which a small amount of detergent has been added. Table Detergents for removing oil sludge contains a list of suitable detergents in alphabetical order. Products from other manufacturers may be used provided their properties are comparable. The manufacturer's instructions for use must be strictly adhered to.

Manufacturer	Product
Drew	HDE - 777
Nalfleet	MaxiClean 2
Unitor	Seaclean, Seaclean Plus

Table 1: Detergents for removing oil sludge

Limescale and rust deposits

Limescale and rust deposits can form if the water is particularly hard or if the concentration of the corrosion inhibitor used is too low. A thin layer of limescale does not need to be removed, as experience shows that it protects against corrosion. However, limescale deposits thicker than 0.5 mm impede heat transfer to such an extent that it leads to thermal overload of the components being cooled.

Rust that has been flushed out can have an abrasive effect (for example, on the seals of water pumps). Together with the components responsible for water hardness, they form what is known as iron sludge, which settles mainly in areas with low flow velocity.

Generally speaking, products designed to dissolve limescale are also suitable for removing rust. Table Cleaning agents for removing limescale and rust deposits contains a list of suitable cleaning agents in alphabetical order.
Products from other manufacturers may be used, provided their properties

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are comparable. The manufacturer's instructions for use must be strictly adhered to. Before cleaning, check that the cleaning agent in question is suitable for the materials to be cleaned. The products listed in Table Cleaning agents for removing limescale and rust deposits are also suitable for stainless steel.

Manufacturer	Product
Drew	Ferroclean
Nalfleet	Nalco 8344, 73190
Unitor	Metal Brite

Table 2: Cleaning agents for removing limescale and rust deposits

Only in an emergency

Limescale deposits may only be removed using aqueous hydrochloric acid or aminosulphonic acid in exceptional cases where no specialist cleaning agents are available that can be used without causing problems. The following must be observed when using these agents:

- Stainless steel heat exchangers must never be treated with diluted hydrochloric acid.
- Cooling systems containing non-ferrous metals (aluminium, red brass, brass, etc.) must be treated with deactivated aminosulphonic acid. This acid should be added to the water at a concentration of 3–5%. The temperature should be 40–50 °C.
- Diluted hydrochloric acid may only be used for cleaning steel pipes. The use of hydrochloric acid as a cleaning agent in systems always carries the risk that acid residues will remain in the system even after neutralisation and flushing. Such residues promote pitting corrosion. We therefore recommend that cleaning be carried out by a specialist company.

When limescale deposits dissolve, carbon dioxide bubbles form, which can prevent the cleaning agent from reaching the scale. Therefore, it is absolutely necessary to circulate the water with the cleaning agent, so that the gas bubbles can be flushed away and escape. The length of the cleaning process depends upon the thickness and composition of the deposits. Guideline values can be found in Table Cleaning agents for removing limescale and rust deposits.

Following cleaning

The cooling system must be flushed several times once it has been cleaned using cleaning agents. Replace the water during this process. If acids are used to carry out the cleaning, neutralise the cooling system afterwards with suitable chemicals then flush. The system can then be refilled with water that has been prepared accordingly.

NOTICE

Only carry out cleaning procedure with cooled engine

Only begin the cleaning procedure when the engine has cooled down. Hot engine parts may not come into contact with cold water. After refilling the cooling system, open the venting pipes. Blocked venting pipes prevent the air from escaping and may cause thermal overload of the engine.

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⚠ WARNING

Danger of chemical burns

From cleaning agents poisonous gases and fumes can develop, which may cause light to severe person injuries.

- Wear protective clothing
- Provide adequate ventilation
- Do not inhale developed gases and fumes
- Observe Safety Data Sheets or Operating Instructions of the relevant manufacturer

The applicable instructions for disposing of cleaning agents or acids are to be observed.

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Coolant inspecting

Summary

Acquire and check typical values of the operating media to prevent or limit damage.

The fresh water used to fill the coolant circuits must satisfy the specifications. The coolant in the system must be checked regularly in accordance with the maintenance schedule.
The following work/steps is/are necessary:
Acquisition of typical values for the operating fluid,
evaluation of the operating fluid and checking the anticorrosive agent concentration.

Tools/equipment required

Devices for testing fresh water quality

The following can be used:

- The water test kit with all the necessary instruments and chemicals for determining water hardness, pH value and chloride content (available from Mar-Tec Marine, Hamburg).

Equipment for testing the concentration of additives

When using chemical additives, use testing equipment in accordance with the supplier's recommendations.

Testing the typical values of water

Short specification

Typical value/property	Water for filling and topping up (without additives)	Water in circulation (with additives)
Type of water	Fresh water, free of foreign matter	Treated coolant
Overall hardness	≤ 10 dGH[1)]	≤ 10 dGH[1)]
pH value	6.5 - 8 at 20 °C	≥ 7.5 at 20 °C
Chloride ion content	≤ 50 mg/l	≤ 50 mg/l[2)]

Table 1: Quality specifications for coolants (short version)

[1)] dGH German hardness

1 dGH = 10 mg/l CaO
= 17.8 mg/l $CaCO_3$
= 0.178 mmol/L

[2)] 1 mg/l = 1 ppm

If the testing kit provided by the additive supplier includes an option for determining the typical values of fresh water, it may be used.

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Testing the concentration of rust inhibitors

Short specification

Anti-corrosion agent	Concentration
Chemical additives	according to the quality specification in chapter 010.000.023-14 of the engine operating instructions "010.005.000 MDC020 Operating instructions engine" in the folder 010_Engine System
Antifreeze	according to the quality specification in chapter 010.000.023-14 of the engine operating instructions "010.005.000 MDC020 Operating instructions engine" in the folder 010_Engine System

Table 2: Concentration of coolant additives

Testing the concentration of chemical additives

The concentration should be tested every week, and/or according to the maintenance schedule, using the testing instruments, reagents and instructions of the relevant supplier.

Chemical anti-corrosion agents can only provide effective protection if the concentration is precisely maintained. In this context, the concentrations recommended by Everllence (quality regulations in chapter 010.000.023-14 of the engine operating instructions "010.005.000 MDC020 Operating instructions engine" in the folder 010_Engine System) must be observed under all circumstances. These recommended concentrations may deviate from those specified by the manufacturer.

Testing the concentration of anti-freeze agents

The concentration must be checked in accordance with the manufacturer's instructions or the test can be outsourced to a suitable laboratory. If in doubt, Everllence should be consulted.

Regular water samplings

Small quantities of lube oil in coolant can be found by visual check during regular water sampling from the expansion tank.

Test

Regular analysis of coolant is very important for safe engine operation. We can analyse fuel for customers at the Everllence PrimeServLab laboratory.

To guarantee the safety of the crew and to obtain a representative sample, sampling must take place in accordance with valid Everllence work instructions.

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Specification of compressed air

General

For compressed air quality observe the ISO 8573-1. Compressed air must be free of solid particles and oil (acc. to the specification).

Requirements

Compressed air quality of starting air system

The starting air must fulfil at least the following quality requirements according to ISO 8573-1.

Purity regarding solid particles	Quality class 6
Particle size > 40µm	max. concentration < 5 mg/m^3
Purity regarding moisture	Quality class 7
Residual water content	< 0.5 g/m^3
Purity regarding oil	Quality class X

Additional requirements are:

- The air must not contain organic or inorganic silicon compounds.
- The layout of the starting air system must ensure that no corrosion may occur.
- The starting air system and the starting air receiver must be equipped with condensate drain devices.
- By means of devices provided in the starting air system and via maintenance of the system components, it must be ensured that any hazardous formation of an explosive compressed air/lube oil mixture is prevented in a safe manner.

Compressed air quality in the control air system

Please note that control air will be used for the activation of some safety functions on the engine – therefore, the compressed air quality in this system is very important.

Control air must meet at least the following quality requirements according to ISO 8573-1.

- Purity regarding solid particles — Quality class 5
- Purity regarding moisture — Quality class 4
- Purity regarding oil — Quality class 3

For catalysts

The following specifications are valid unless otherwise defined by any other relevant sources:

Compressed air quality for soot blowing

Compressed air for soot blowing must meet at least the following quality requirements according to ISO 8573-1.

- Purity regarding solid particles — Quality class 3
- Purity regarding moisture — Quality class 4
- Purity regarding oil — Quality class 2

Compressed air quality for reducing agent atomisation

Compressed air for atomisation of the reducing agent must fulfil at least the following quality requirements according to ISO 8573-1.

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- Purity regarding solid particles — Quality class 3
- Purity regarding moisture — Quality class 4
- Purity regarding oil — Quality class 2

NOTICE

Clogging of catalysts

To prevent clogging of catalysts and catalyst lifetime shortening, the compressed air specification must always be observed.

For gas valve unit control (GVU)

Compressed control air quality for the gas valve unit control (GVU)

Compressed air for the gas valve unit control (GVU) must meet at least the following quality requirements according to ISO 8573-1.

- Purity regarding solid particles — Quality class 2
- Purity regarding moisture — Quality class 3
- Purity regarding oil — Quality class 2

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Starting air system

General

The compressed air system on the engine consists of a starting system, starting control system and safety system. Further, the system supplies air to the jet system and the stop cylinders on each fuel injection pump.

The compressed air is supplied from the starting air receivers (30 bar) through a reduction station, where from compressed air at max. 10 bar is supplied to the engine. The reduction station should be located as near the starting air receiver as possible.

To avoid dirt particles in the internal system, a strainer equipped with a drain valve is mounted in the inlet line to the engine.

Starting System

The engine is started by means of a built-on air starter, which is a turbine motor with gear box, safety clutch and drive shaft with pinion. Further, there is a main starting valve.

Control System

The air starter is activated electrically with a pneumatic 3/2-way solenoid valve. The valve can be activated manually from the starting box on the engine, and it can be arranged for remote control, manual or automatic.

For remote activation the starting coil is connected so that every starting signal to the starting coil goes through the safe start function which is connected to the safety system mounted on the engine.

Further, the starting valve also acts as an emergency starting valve which makes it possible to activate the air starter manually in case of power failure.

Safety System

As standard the engine is equipped with an emergency stop. It consists of one on-off valve, see diagram, which activates one stop cylinder on each fuel injection pump.

Air supply must not be interrupted when the engine is running.

Pneumatic Start Sequence

When the starting valve is opened, air will be supplied to the drive shaft housing of the air starter.

The air supply will - by activating a piston - bring the drive pinion into engagement with the gear rim on the engine flywheel.

When the pinion is fully engaged, the pilot air will flow to, and open the main starting valve, whereby air will be led to the air starter, which will start to turn the engine.

When the RPM exceeds approx. 158, at which firing has taken place, the starting valve is closed whereby the air starter is disengaged.

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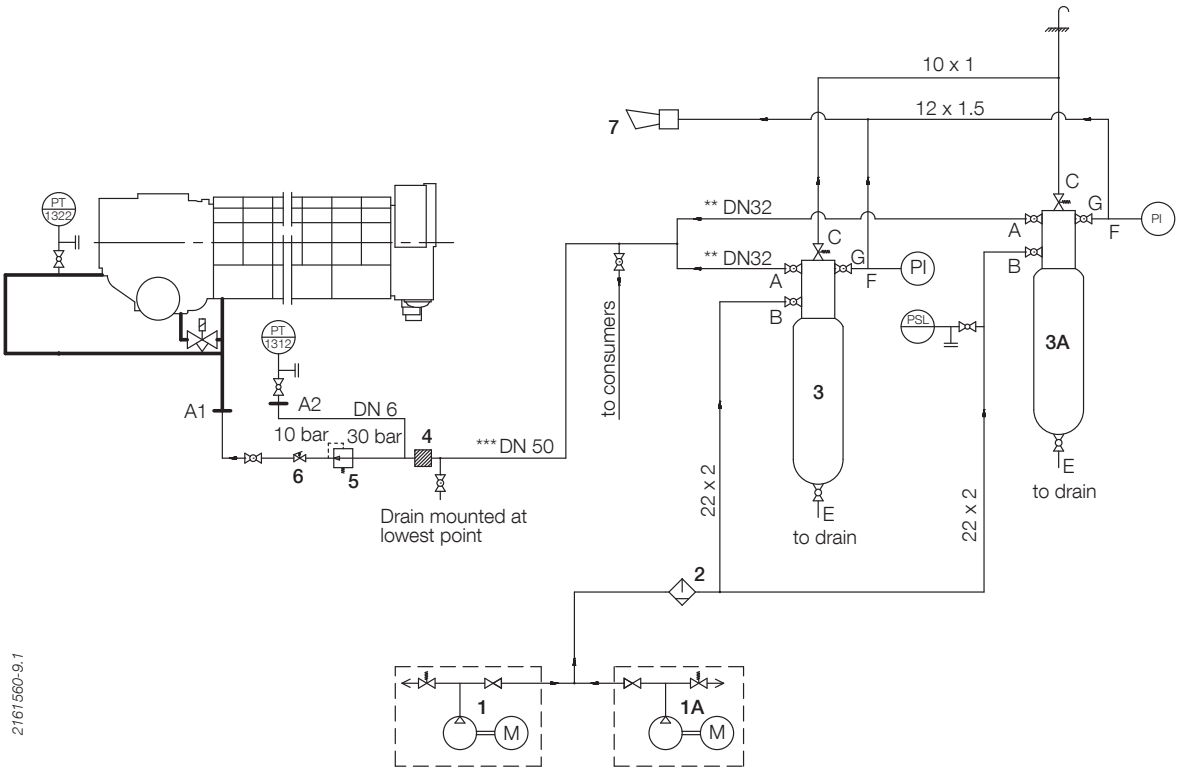


Fig 1 Starting air diagram

Item	Description
1	Compressor
1A	Compressor
2	Filter with water trap
3	Starting air receiver
3A	Starting air receiver
4	Filter
5	Pressure reducing valve
6	Self closing safety valve
7	Typhon

Connections:	
A1	Starting air - inlet
A2	Starting air - before pressure reducing valve

**
The pipe length between receiver and main engine starting air pipe is to be as short as possible

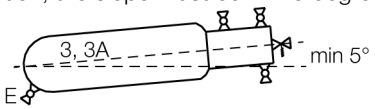
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max 10 m from air receiver to engine

The pressure switch for aut. START/STOP of the compressor (items 1 and 1 A) should be connected to the charging air pipe as close as possible to the starting air receiver (items 3 and 3A) to compensate for pressure peaks from the compressor.

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Starting air receiver (items 3 and 3A): 'A', 'B', 'C', 'E', 'F' and 'G' refer to corresponding connections on the starting air receiver, if supplied by Everllence, Frederikshavn.

Vertical installation of the starting air receiver is recommended. For horizontal installation, the slope must be min 5 degrees as shown.



Compressor, items 1 and 1A

According to most classification societies, two or more air compressors must be provided. At least one of the air compressors must be driven independently of the main engine and must supply at least 50 % of the required total capacity.

The pressure switch (PSL) for aut start/stop of the compressors 1 and 1A is to be connected to the charging air pipe as close as possible to the starting air receiver, to compensate for pressure peaks from the compressor. If the pipe is short, a buffer tank or damper is recommended.

All of the starting air receivers, items 3 and 3A, should be pressurized to 30 bar for approx 60 minutes.

All of the starting air receivers, items 3 and 3A, should be pressurized to 30 bar for approx 60 minutes.

Compressors are to be installed with total capacity sufficient for charging air receivers of capacities specified from atmospheric to full pressure in the course of one hour.

Two or more compressors of total capacity as specified are to be installed'.

Calculation (example):

$$P = \frac{30 * V}{1000} \ (m^3/h)$$

The compressor capacities are calculated as follows:

$$P = \frac{V \times 30}{1000}$$

P [Nm^3/h]	Total volumetric delivery capacity of the compressors
V [litres]	Total volume of the starting air receivers at 30 bar service pressure

P = Total capacity of the compressors (m^3/h)
V = Total volume of the starting air receiver (dm^3) at service pressure of 30 bar)

Example: 1 x 250 ltr + 1 x 500 ltr

$$P = \frac{30 * 750}{1000} = 22.5 \ (m^3/h)$$

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Filter with water trap, item 2

A filter with water trap should be installed in the charging air pipe between the compressors and the starting air receivers.

Starting air receiver, items 3 and 3A

The starting air receiver should, preferably, be vertically installed and secured to a bulkhead, thus ensuring easy access to the water drain valve. If space conditions do not permit vertical mounting, the receiver may be minimum 5° off the horizontal, with the drain valve at the lowest position.

Two starting air receivers are standard equipment for each plant. Table on next page describe minimum values of starting air capacity.

Pressure reducing valve, item 5

As standard the engines are fitted with a 10 bar air starter. Therefore the air supply needs to be reduced from 30 bar to 10 bar before inlet engine.

If the engine is fitted with a 30 bar air starter (option), there will be a pressure reducing valve for stop air pressure installed.

If a pressure drop should occur, it is alarmed by the pressure switch (PT 1322) on the engine control system. To have this indication there need to be a pipe from before the pressure reducing station to location of pressure switch (PT 1322).

Starting air and charging air pipe

The starting and charging air pipes are to be installed with a slope towards the starting air receiver, preventing possible condensed water from running into the air starting motor or the compressors. A drain valve has to be installed at the lowest position of the starting air pipe, as shown in fig 1.

Dimensioning starting air receivers, compressors

Starting air receivers

The starting air supply is to be split up into not less than two starting air receivers of nominally the same size, which can be used independently of each another.

The engine requires compressed air for starting, for the jet assist function as well as several pneumatic controls. The design of the pressure air receiver directly depends on the air consumption and the requirements of the classification societies.

Calculation for starting air receiver of engines with jet assist and Slow Turn:

$$V = (V_{st} \times f_{Drive} \times (z_{st} + Z_{Safe}) + \frac{V_{Jet}}{5_{sec}} \times z_{Jet} \times t_{Jet})/(P_{max} - P_{min})$$

V [litre]	Required receiver capacity
V_{st} [litre]	Air consumption per nominal start

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f_{Drive}	Factor for drive type (1.0 = diesel-mechanic, 1.5 = alternator drive)
z_{st}	Number of starts required by the classification society
z_{Safe}	Number of starts as safety margin
V_{Jet} [litre]	Assist air consumption per jet assist
z_{Jet}	Number of jet assist procedures[1)]
t_{Jet} [sec.]	Duration of jet assist procedures
p_{max} [bar]	Maximum starting air pressure (normally 30 bar)
p_{min} [bar]	Minimum starting air pressure (10 bar)
[1)] The required number of jet maneuvers has to be checked with yard or ship owner. To make a decision, consider the information in section 'Jet assist' .	

If other consumers (i.e. auxiliary engines, ship air etc.) which are not listed in the formula are connected to the starting air receiver, the capacity of starting air receiver must be increased accordingly, or an additional separate air receiver has to be installed.

Jet assist

General

Jet assist is a system for acceleration of the turbocharger. By means of nozzles in the turbocharger, compressed air is directed to accelerate the compressor wheel. This causes the turbocharger to adapt more rapidly to a new load condition and improves the response of the engine. Jet assist is working efficiently with a pressure of 18 bar to max. 30 bar at the engine connection.

Jet assist activating time: 3 seconds to 10 seconds (5 seconds in average).

Air consumption

The air consumption for jet assist is, to a great extent, dependent on the load profile of the ship. In case of frequently and quickly changing load steps, jet assist will be actuated more often than this will be the case during long routes at largely constant load.

Layout of starting air vessels and compressor – Guiding values for consideration of jet assist activation

For the layout of starting air vessels and compressors add the air consumption of these jet assist activation to the air consumption of the considered starts.

The data in following table is not binding. The required number of jet activations have to be checked with yard or ship owner.

Application	Recommended no. of jet assist with average duration	
	Per hour	In rapid succession
General drive	None[1)]	None[1)]
Diesel-mechanical drive without shifting clutch	None[1)]	None[1)]
Diesel-mechanical drive with shifting clutch	3 x 5 sec	2 x 5 sec

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Application	Recommended no. of jet assist with average duration	
	Per hour	In rapid succession
Diesel-mechanical drive with shaft-driven alternator (> 50 % MCR)	2 x 5 sec	2 x 5 sec
Electric propulsion	3 x 5 sec	2 x 5 sec
Electric propulsion offshore applications – Semisub production/drilling applications and drillships[2)]	(10 x 5 sec)	(5 x 5 sec)
Ships with frequent load changes (e.g. ferries)	3 x 5 sec	3 x 5 sec
Auxiliary engine	3 x 5 sec	2 x 5 sec
High-torque applications	2 x 20 sec	2 x 20 sec

[1)] According the necessity of the application "jet assist" please check figure Load application. If the curve "without jet assist" is sufficient, jet assist can be omitted.

[2)] For these applications please contact Everllence for a project specific estimation.

Table 1: Guiding values for the number of jet assist maneuvers dependent on application

Dynamic positioning for drilling vessels, cable-laying vessels, off-shore applications

When applying dynamic positioning, pulsating load application of > 25 % may occur frequently, up to 30 times per hour. In these cases, the possibility of a specially adapted, separate compressed air system has always to be checked.

Air supply

Generally, larger air receivers are to be provided for the air supply of the jet assist.

For the design of the jet assist air supply the temporal distribution of events needs to be considered, if there might be an accumulation of events.

In each case the delivery capacity of the compressors is to be adapted to the expected jet assist requirement per unit of time.

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Combustion air system for arctic operation

General

Engine operation under arctic conditions

Machinery for ships to operate in arctic areas must be able to stand up to extremely low ambient temperatures (such as down to minus 60°C).

Artic condition is defined as:

Air intake temperatures of the engine below 0 °C.

If engines operate under arctic conditions (intermittently or permanently), the engine equipment and plant installation have to hold certain design features and meet special requirements. They depend on the possible minimum air intake temperature of the engine and the specification of the fuel used.

Minimum air intake temperature of the engine, t_x:

- Category 1
  $0\ °C > t_x > -15\ °C$
- Category 2
  $-15\ °C \geq t_x > -60\ °C$

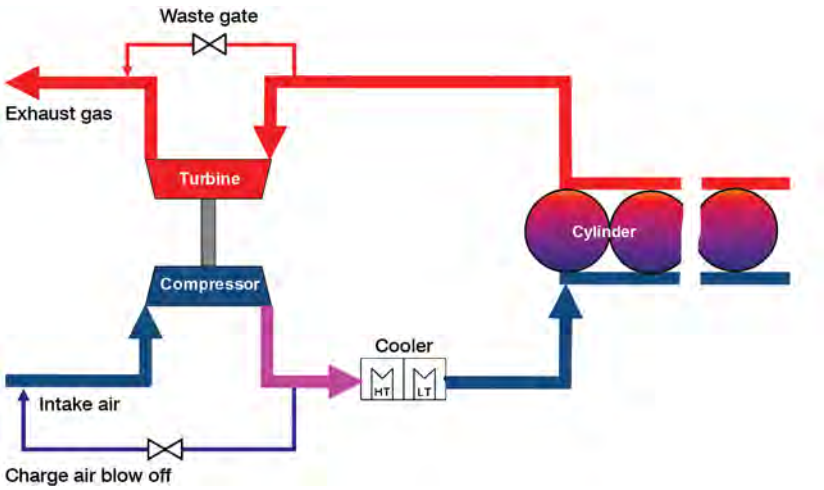


Figure 1: Diagram

In order not to undercool the engine room, the diesel engines cannot be supplied with combustion air from the engine room. They must be connected to an air trunk system taking in air of low temperature from the outside.

If not compensated for, the low air temperature could cause two problems for the engine performance; (namely) a too high combustion pressure and a too low charge air temperature.

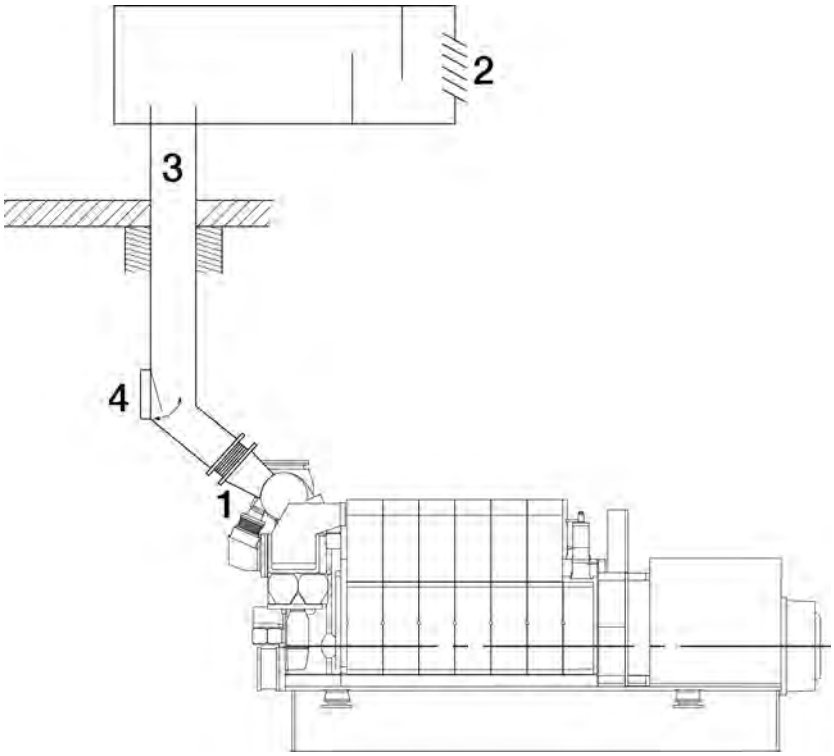
With air of low temperature and consequently high density the turbocharger will supply the engine with such a large amount of charge air (by weight) that the combustion pressure during engine operation in the high load range will become unacceptably high.

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This problem can be compensated for by blowing off a certain amount of air from the engine air inlet bend returning it back to the air inlet bend of the turbocharger, *see fig. 1.* This recirculation will not only adjust the charge air amount but also raise the air inlet temperature.

When running Everllence SCR besides charge air blow off there can also be waste gate for regeneration.

Starting the engine on arctic temperatures is difficult and sometimes impossible at extreme cold temperature. It is recommended that a bypass changeover flap with air intake filter is installed in the pipe connection from the louver to the turbocharger on the engine. The changeover flap is to be open during start of the engine, and thereby heated air from the engine room is entering the turbocharger. When the engine has reached a cooling water temperature of more than 50 degrees, the bypass changeover flap is closed, and thereby the air is supplied from the outside louver.



1 Combustion air duct connected
2 Louver*
3 Combustion air duct
4 Changeover flap with air filter (outside- / inside air) for starting in cold climate

Figure 2: Engine room ventilation, air duct connected to the turbocharger

*Always to be equipped with a filter when an air duct is connected to the turbocharger according to "Specification of intake air", 010.000.023-17.

Plant installation

- Cooling down of engine room due to cold ambient air can be avoided by supplying the engine directly from outside with combustion air. For this the combustion air must be filtered. See D010.000.023-17, Specification

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of intake air. Moreover a droplet separator and air intake silencer become necessary. According to classification rules it may be required to install two air inlets from the exterior, one at starboard and one at portside.

- Cold intake air from outside is preheated in front of the cylinders in the charge air cooler. HT water serves as heat source. Depending on load and air temperature additional heat has then to be transferred to the HT circuit by a HT preheating module
- It is necessary to ensure that the charge air cooler cannot freeze when the engine is out of operation (and the cold air is at the air inlet side). HT-cooling water preheating will prevent this. Additionally it is recommentded tho prepare the combustion air duct upstream of the engine for the installation of a blanking plate, necessary to be installed in case of malfunction on the HT-cooling water preheating system.

Category 1

- Charge air blow-off is activated at high engine load with low combustion air temperature. With a blow-off air duct installed in the plant, it can be recirculated in the combustion air duct upstream of the engine. Alternatively, only if blow-off air is deviated downstream of the charge air coolers and is cold (depending on engine type), blow-off air can be directly released in the engine room. Then a blow-off air silencer installed in the plant becomes necessary.
- Alternatively engine combustion air and engine room ventilation air can be supplied together in the engine room, if heated adequately and if accepted by the classification company.

Category 2

- Please contact Everllence.

Instruction for minimum admissible fuel temperature

- In general the minimum viscosity before engine of 2.0 cSt must not be undershoot.
- The fuel specific characteristic values “pour point” and “cold filter plugging point” have to be observed to ensure pumpability respectively filterability of the fuel oil.
- Fuel temperatures of ≤ –10 °C are to be avoided, due to temporarily embrittlement of seals used in the engines fuel oil system. As a result they may suffer a loss of function.

Minimum engine room temperature

- Ventilation of engine room

  The air of the engine room ventilation must not be too cold (preheating is necessary) to avoid the freezing of the liquids in the engine room systems.
- Minimum power house/engine room temperature for design ≥ +5 °C.

Coolant and lube oil systems

- Coolant and lube oil system have to be preheated for each individual engine, see section Starting conditions.

  See also the specific information regarding special arrangements for arctic conditions, see section Lube oil system and Water systems.
- Maximum permissible antifreeze concentration (ethylene glycol) in the engine cooling water.

  An increasing proportion of antifreeze decreases the specific heat capacity of the engine cooling water, which worsens the heat dissipation from the engine and will lead to higher component temperatures.

  Therefore, the antifreeze concentration of the engine cooling water systems (HT and LT) within the engine room, respectively power house, should be below a concentration of 40 % glycol. Any concentration of > 55 % glycol is forbidden.
- If a concentration of anti-freezing agents of > 50 % in the cooling water systems is required, contact Everllence for approval.

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- For information regarding engine cooling water see section Specification for engine supplies.

Insulation

The design of the insulation of the piping systems and other plant parts (tanks, heat exchanger, external intake air duct etc.) has to be modified and designed for the special requirements of arctic conditions.

Heat tracing

To support the restart procedures in cold condition (e.g. after unmanned survival mode during winter), it is recommended to install a heat tracing system in the pipelines to the engine.

NOTICE

A preheating of the lube oil has to be ensured. If the plant is not equipped with a lube oil separator (e.g. plants only operating on MGO) alternative equipment for preheating of the lube oil must be provided. For plants taken out of operation and cooled down below temperatures of +5 °C additional special measures are required – in this case contact Everllence.

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Engine ventilation

Description

The air intake to the engine room should be dimensioned in such a way that a sufficient quantity of air is available not only for the main engine, auxiliaries, boilers etc, but also to ensure adequate ventilation and fresh air when work and service are in progress.

We recommend the ventilation capacity should be min 50% more than required air consumption (in tropical conditions more than 100% should be considered) for main engine, auxiliaries, boilers etc.

It is important that the air is free of oil and sea water to prevent fouling of the ventilators and filters.

The air consumption of the main engine appears from the planning data.

Approx 50% of the ventilating air should be blown in at the level of the top of the main engine close to the air inlet of the turbocharger. Air should not be blown directly onto heat emitting components or directly onto electric or other water sensitive apparature.

A small airflow should be evenly distributed around the engine and reduction gear in order to dissipate radiated heat.

With closed engine room and all air consuming equipment operating, there should always be positive air pressure in the engine room.

Surplus air should be led up through the casing via special exhaust openings. Alternatively extraction fans should be installed.

Fire arresting facilities must be installed within the casings of the fans and ventilation trunkings to retard the propagation of fire.

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Specifications of intake air (combustion air)

General

The quality and condition of intake air (combustion air) have a significant effect on the engine output, wear and emissions of the engine. In this regard, not only are the atmospheric conditions extremely important, but also contamination by solid and gaseous foreign matter.

Mineral dust in the intake air increases wear. Chemicals and gases promote corrosion.

This is why effective cleaning of intake air (combustion air) and regular maintenance of the air filter are required.

When designing the intake air system, the maximum permissible overall pressure drop (filter, silencer, pipe line) of 20 mbar must be taken into consideration.

Exhaust turbochargers for marine engines are equipped with silencers and air filters as a standard.

Requirements

Liquid fuel engines: As minimum, inlet air (combustion air) must be cleaned by an ISO Coarse 45% class filter as per DIN EN ISO 16890, if the combustion air is drawn in from inside (e.g. from the machine room/engine room). If the combustion air is drawn in from outside, in the environment with a risk of higher inlet air contamination (e.g. due to sand storms, due to loading and unloading grain cargo vessels or in the surroundings of cement plants), additional measures must be taken. This includes the use of pre-separators, pulse filter systems and a higher grade of filter efficiency class at least up to ISO ePM10 50% according to DIN EN ISO 16890.

Gas engines and dual-fuel engines: As minimum, inlet air (combustion air) must be cleaned by an ISO COARSE 45% class filter as per DIN EN ISO 16890, if the combustion air is drawn in from inside (e.g. from machine room/engine room). Gas engines or dual-fuel engines must be equipped with a dry filter. Oil bath filters are not permitted because they enrich the inlet air with oil mist. This is not permissible for gas operated engines because this may result in engine knocking. If the combustion air is drawn in from outside, in the environment with a risk of higher inlet air contamination (e.g. due to sand storms, due to loading and unloading grain cargo vessels or in the surroundings of cement plants) additional measures must be taken. This includes the use of pre-separators, pulse filter systems and a higher grade of filter efficiency class at least up to ISO ePM10 50% according to DIN EN ISO 16890.

In general, the following applies:

The inlet air path from air filter to engine shall be designed and implemented airtight so that no false air may be drawn in from the outdoor.

The concentration downstream of the air filter and/or upstream of the turbocharger inlet must not exceed the following limit values.

The air must not contain organic or inorganic silicon compounds.

Properties	Limit	Unit [1)]
Dust (sand, cement, CaO, Al_2O_3 etc.)	max. 5	mg/Nm^3

Specifications of intake air (combustion air)

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Specifications of intake air (combustion air)

Properties	Limit	Unit [1]
Chlorine	max. 1.5	
Sulphur dioxide (SO_2)	max. 1.25	
Hydrogen sulphide (H_2S)	max. 5	
Salt (NaCl)	max. 1	
[1] One Nm^3 corresponds to one cubic meter of gas at 0 °C and 101.32 kPa.		

Table 1: Typical values for intake air (combustion air) that must be complied with

⚠ WARNING

Explosion due to flammable intake air

Severe personal injury due to the explosion of flammable intake air.

- Intake air must not be explosive.
- Intake air must not contain flammable gases.
- Intake air must not be drawn in from ATEX zones.

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Turbocharger - make Everllence

Description

The engines are as standard equipped with a turbocharger of the radial type Everllence NR/S and TCR.

The rotor, comprising compressor, turbine wheel and shaft, is supported in floating plain bearing bushes.

The turbine wheel is an integrated part of the shaft.

Gas admission casing with gas outlet diffusor matched to the exhaust pipe arrangement and a turbine nozzle ring made of a special wear resistant material.

Air intake silencer with filter, and compressor casing with one outlet.

Lubrication of the two plain bushes is an integrated part of the engine lubricating oil system.

The turbocharger has no water cooling.

Propulsion					
No. cyl.	**5**	**6**	**7**	**8**	**9**
L21/31 - 1000rpm	-	TCR16-42x	TCR18-42x	TCR18-42x	TCR18-42x
L27/38 - 800 rpm	-	TCR18-42x	TCR20-42x	TCR20-42x	TCR20-42x
L27/38 Mk2 - 900 rpm	-	TCR18-42x	TCR20-42x	TCR20-42x	TCR20-42x
28/32A	-	NR24/R	NR24/R	NR24/R	NR26/R

L16/24					
No. cyl.	**5**	**6**	**7**	**8**	**9**
1000 rpm	TCR12-42x	TCR12-41x	TCR12-41x	TCR14-41x	TCR14-41x
1200 rpm	TCR12-42x	TCR12-41x	TCR14-41x	TCR14-41x	TCR14-41x

L21/31					
No. cyl.	**5**	**6**	**7**	**8**	**9**
900 rpm	TCR16-42x	TCR16-42x	TCR18-42x	TCR18-42x	TCR18-42x
1000 rpm	TCR16-42x	TCR16-42x	TCR18-42x	TCR18-42x	TCR18-42x

L21/31 Mk2					
No. cyl.	**5**	**6**	**7**	**8**	**9**
900 rpm	TCR14-42x	TCR16-42x	TCR16-42x	TCR16-42x	TCR18-42x
1000 rpm	TCR14-42x	TCR16-42x	TCR16-42x	TCR18-42x	TCR18-42x

L27/38					
No. cyl.	**5**	**6**	**7**	**8**	**9**
330 kW @ 720 rpm	TCR18-42x	TCR18-42x	TCR20-42x	TCR20-42x	TCR20-42x
330 kW @ 750 rpm	TCR18-42x	TCR18-42x	TCR20-42x	TCR20-42x	TCR20-42x
350 kW @ 720 rpm	-	TCR18-42x	TCR20-42x	TCR20-42x	TCR20-42x
350 kW @ 750 rpm	-	TCR18-42x	TCR20-42x	TCR20-42x	TCR20-42x

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L27/38 Mk2				
No. cyl	**6**	**7**	**8**	**9**
720 rpm	TCR18-42x	TCR20-42x	TCR20-42x	TCR20-42x
750 rpm	TCR18-42x	TCR20-42x	TCR20-42x	TCR20-42x
900 rpm	TCR18-42x	TCR20-42x	TCR20-42x	TCR20-42x

L23/30H + Mk2					
No. cyl	**5 ECR**	**5**	**6**	**7**	**8**
720 rpm	TCR14-42x	TCR14-41x	TCR14-41x	TCR16-41x	TCR16-41x
750 rpm	TCR14-42x	TCR14-41x	TCR14-41x	TCR16-41x	TCR16-41x
900 rpm	-	-	TCR16-41x	TCR16-41x	TCR16-41x

L23/30H Mk3					
No. cyl	**5**	**6**	**7**	**8**	**9**
720 rpm	TCR14-41x	TCR14-41x	TCR16-42x	TCR16-41x	TCR16-41x
750 rpm	TCR14-41x	TCR14-41x	TCR16-42x	TCR16-41x	TCR16-41x
900 rpm	-	TCR16-41x	TCR16-41x	TCR16-41x	TCR18-41x

L23/30DF				
No. cyl	**5**	**6**	**7**	**8**
720 rpm	TCR14-42x	TCR14-41x	TCR14-41x	TCR16-41x
750 rpm	TCR14-42x	TCR14-41x	TCR14-41x	TCR16-41x
900 rpm	-	TCR14-41x	TCR14-41x	TCR16-41x

L28/32DF					
No. cyl.	**5**	**6**	**7**	**8**	**9**
720 rpm	TCR14-41x	TCR16-41x	TCR16-41x	TCR18-41x	TCR18-41x
750 rpm	TCR14-41x	TCR16-41x	TCR16-41x	TCR18-41x	TCR18-41x

L28/32H (update to TCR are in progress)					
No. cyl.	**5**	**6**	**7**	**8**	**9**
720 rpm	NR20/R	NR20/R	TCR18-41x	TCR18-41x	NR24/S
750 rpm	NR20/R	NR20/R	NR24/R	NR24/R	NR24/S

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Exhaust gas system

Exhaust pipe

It is important that the exhaust piping is as short and with as few sweep bends as possible.

Sharp bendings and small diameter exhaust pipes produce high back pressures which will affect the engine combustion.

The exhaust back pressure should not exceed 250 mm WC at MCR. An exhaust gas velocity of max 35 m/sec at MCR through the exhaust system is usually acceptable, but depends on the actual installation and flow resistance.

Each engine must have its own separate exhaust system to avoid fouling of the turbocharger when an engine is not in operation.

We will be pleased to assist in making a calculation of the exhaust back pressure.

The gas outlet from the turbocharger, expansion bellows, connecting piece, exhaust pipes and silencers must be insulated with suitable material. The insulation should be protected by a thin metal plating and comply with class and national authority requirements.

Care must be taken when installing silencers with spark arresters to ensure that the access doors are situated to permit ease of removal for cleaning.

The minimum dimensions of the exhaust pipes are stated in the planning data.

Exhaust pipe mounting

When the exhaust system is designed, consideration must be given to the radiation of heat and noise.

Because the exhaust system is subject to considerable thermal fluctuations, it is necessary to incorporate flexible as well as rigid suspension points.

In order to compensate for thermal expansion in the longitudinal direction, expansion bellows must be inserted as shown. Depending on the actual exhaust piping system, it may be necessary to insert extra expansion bellows. The expansion bellows should preferably be placed at the rigid suspension points.

The exhaust piping must exert no force on the gas outlet of the turbocharger.

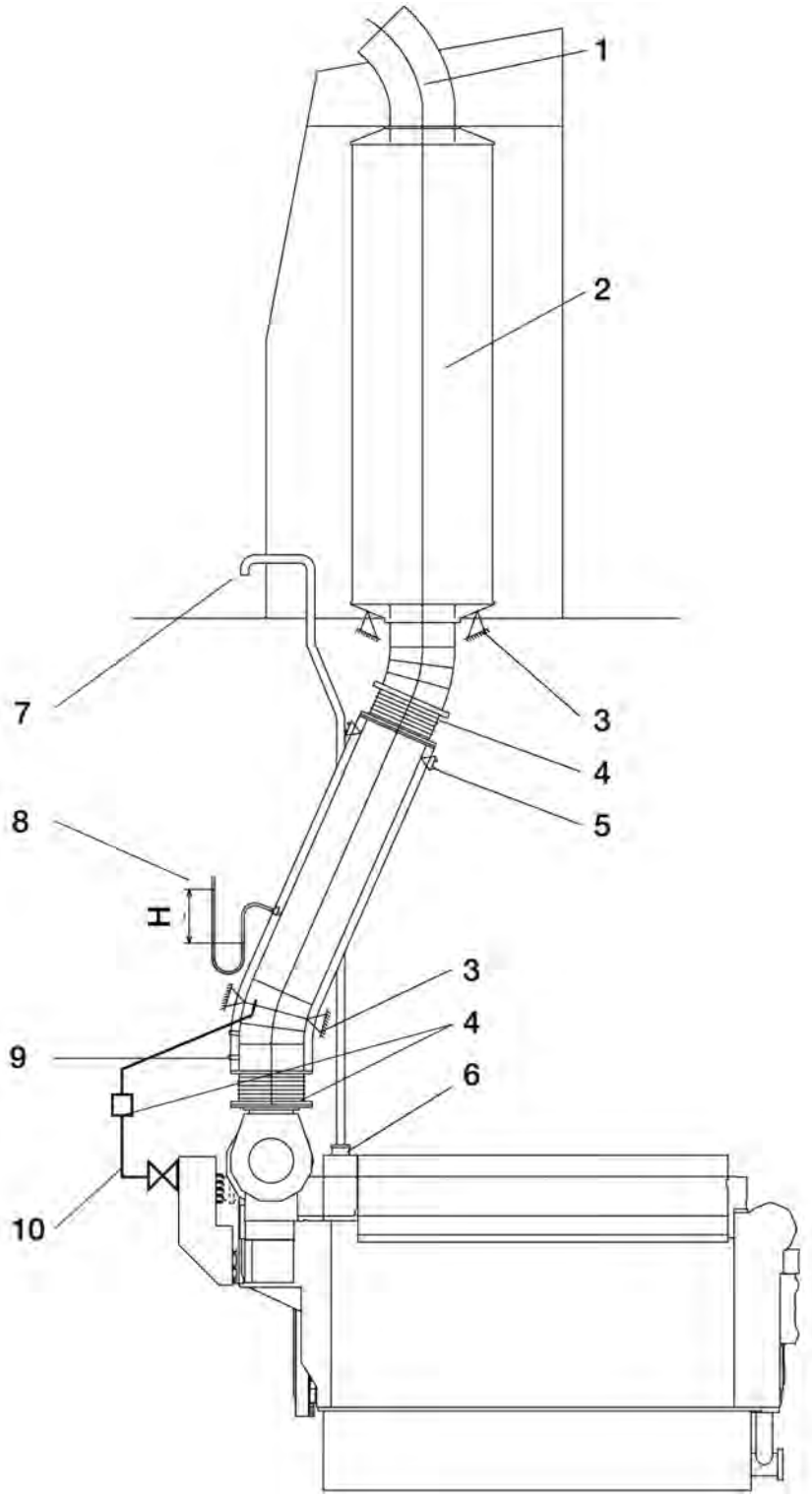
The pipe work should be easily removable to facilitate ease of cleaning and maintenance. Each connection in the pipe line should be fitted with a gasket.

A pipe branch should be welded into the exhaust line to enable measurements of the exhaust back pressure to be taken.

To prevent the ingress of water, the terminal outlet should be provided with a collar, as shown in fig 1.

The exhaust piping is to be provided with water drains, which are to be kept open constantly for draining the condensation water or possible leak water from waste heat boilers.

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1 Collar
2 Exhaust silencer
3 Fixed supports
4 Expansion bellow
5 Movable supports
6 Connection to breather pipe
7 Breather pipe
8 Branch for measuring exhaust gas back pressure
9 Socket for sensors (Yards supply)
10 Blow off pipe (Yard supply)

Figure 1: Exhaust gas system

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Pressure drop in exhaust gas system

General

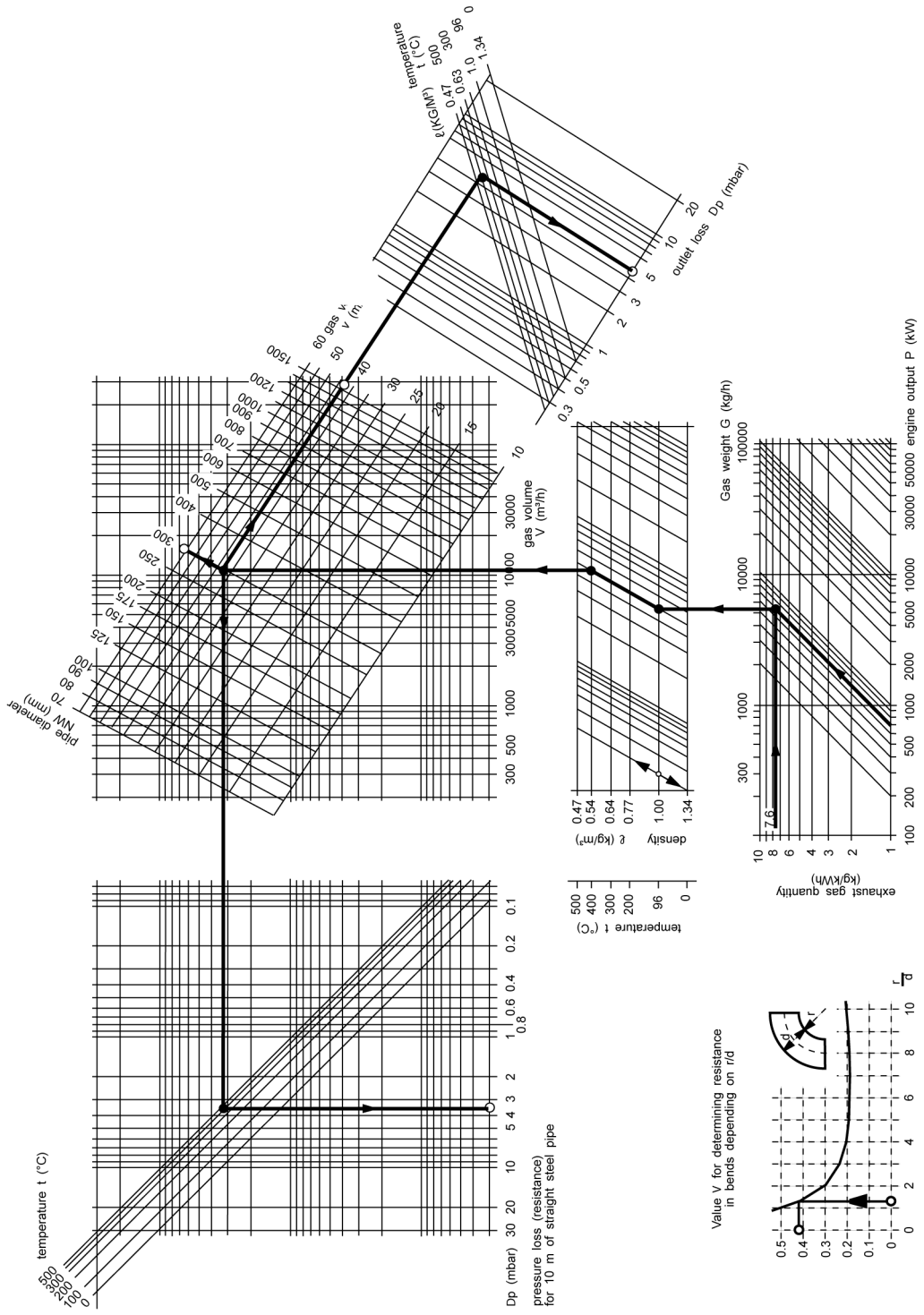


Figure 1: Nomogram for pressure drop in exhaust gas piping system.

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Example

Where:	Engine rating	735 kW
	Exhaust gas quantity	7.6 kg/kWh
	Exhaust gas temperature **t** (under full-load conditions)	400°C
	Ambient air conditions	20°C, 980 mbar
	Density of air ρ_L	1.165 kg/m³
	Exhaust pipe system (pipes laid out without changes in section)	
	Straight runs of pipe horizontal	12 m (L_H)
	vertical	8 m (L_V)
	Three 90° pipe bends (with r/d = 1.3)	
	1 absorbtion silencer (35 dBA damping)	
Required:	Total pressure loss across exhaust gas system (static and dynamic) = flow resistance in pipes and silencer + outlet losses - up-draught	
From the diagram:	Density of exhaust gasses ρ_A	0.54 kg/m³
	Exhaust gas volume	10200 m³/h
	With a pipe diameter of 300 mm this gives:	
	Exhaust gas velocity	42 m/sec
	Resistance per 10 m of straight run of pipe (at 400°C)	3.6 mbar
	Outlet loss (at 400°C)	4.7 mbar ($\rho_A \times \frac{V^2}{2} \times 10^{-2}$)
	ζ value for pipe bend (at r/d = 1.3)	0.41
	Resistance of a 90° pipe bend (0.41 x 4.7)	1.9 mbar ($\zeta \times \rho_A \times \frac{V^2}{2} \times 10^{-2}$)
	Up-draught in vertical pipe	8 (1.165 - 0.54) x 9.81 = 50 Pa = 0.5 bar
Result:	The total pressure loss in the system is	
	Straight runs of pipe (12 + 8 = 20 m) = 2 x 3.6	7.2 mbar
	3 pipe bends of 1.9 mbar each	5.7 mbar
	Silencer (35 dB(A) without spark arrestor) (see product manual page E 16 04 3)	1.7 mbar
	Outlet loss	4.7 mbar
		19.3 mbar
	Lift	- 0.5 mbar
		18.8 mbar

Permissible total resistance:
IMO Tier II: 30 mbar
IMO Tier III (SCR), scrubber and other aftertreatment: 50 mbar

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Density of air

Density of air can be determined by following empiric, formula*:

$$\rho = \frac{348.3}{t + 273} \times P$$

ρ = density kg/m^3
P = air pressure bar
t = temperature °C

* This formula is only valid between -20° to 60°C.

Example

At ambient air conditions 20°C and pressure 0.98 bar, the density is:

$$\rho = \frac{348.3}{20 + 273} = 1.165 \text{ kg/m}^3$$

At 1.0132 bar:

t	-20	0	20	40	60
ρ	1.4	1.29	1.21	1.13	1.06

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Pressure drop in exhaust gas system

Description

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SCR (Selective Catalytic Reduction)

Introduction

SCR technology

Everllence decided to develop it's own SCR technology to be able to optimise the emissions technology and the engine performance in addition with the Everllence own SCR control programme to the utmost customer benefit.

Common SCR systems require constantly high exhaust gas temperatures. The Everllence SCR system however is an integrated system (engine + SCR) that is automatically adjusting the exhaust gas temperature in an optimal way to ensure ideal operation of both engine and SCR. For example, the engine is operating at optimum condition, however the system is registering an increasing backpressure over the SCR reactor. To resolve this, the regeneration feature of the integrated SCR system is activated and the wastegate engaged to increase exhaust gas temperature. After a short time, the SCR system is regenerated and the engine can continue operation in the design point area. Thus the SCR assures ideal engine operation by regenerating the SCR system whenever necessary to achieve minimum fuel oil consumption. Nevertheless, the SCR system complies with the IMO Tier III regulations on NO_X emissions at any time.

Fuels for operation with SCR catalyst

The SCR components were special designed for operation with heavy fuel oil (HFO) in accordance with specification DIN ISO 8217 up to sulphur content of 3.5 %. *See description 010.000.023-05, "Specification of Heavy Fuel Oil (HFO)".*

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Engine overview and SCR system components

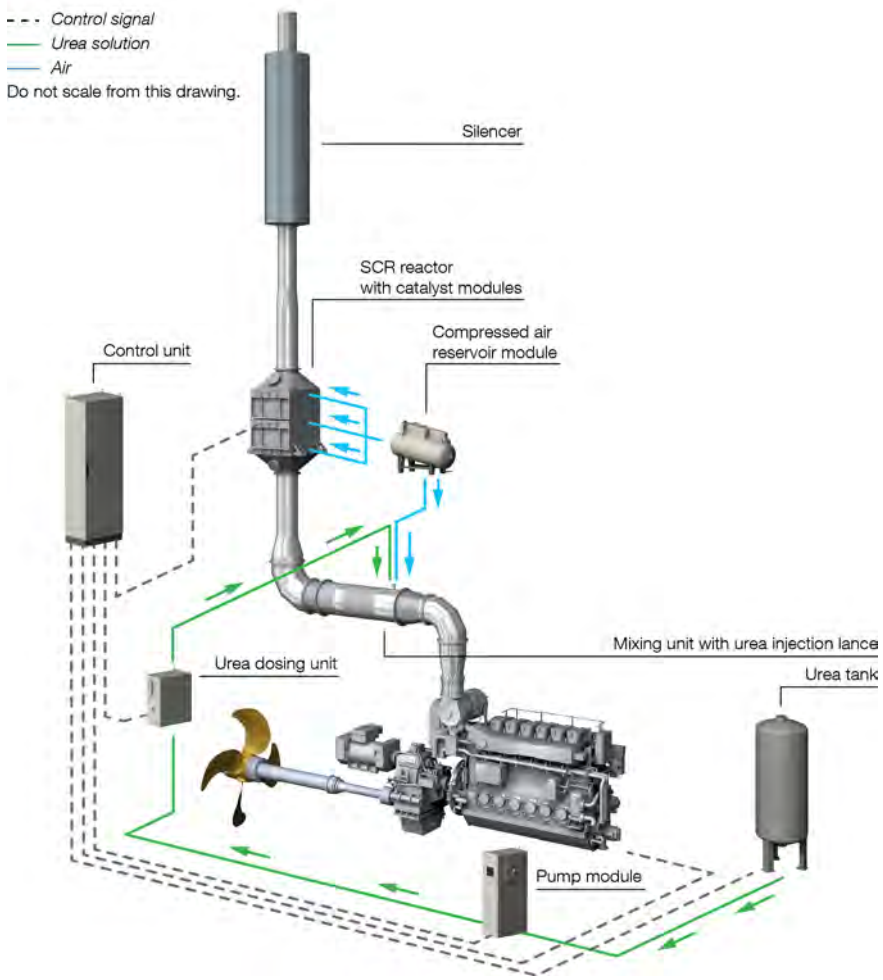


Figure 1: SCR system components overview

Engine and operation

Certification IMO Tier III

The engine's certification for compliance with NO_x limits according to NO_x technical code will be done according scheme B, meaning engine + SCR will be handled as separate parts. Certification has to be in line with IMO Resolution MEPC 198(62), adopted 15 July 2011.

Emission level engine: IMO Tier II

Emission level engine + SCR catalyst: IMO Tier III

Certification of engine

Engine will be tested as specified in section Programme for Factory Acceptance Test (FAT) according to relevant classification rules. It will also certified as member or parent engine according NO_x technical code for emission category IMO Tier II.

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Certification of complete system (engine plus SCR system)

Certification of SCR catalyst and components will be done in accordance to MEPC 198(62) for a scaled, standardised SCR reactor and SCR components based on product features and following scaled parameters:

- Exhaust gas mass flow
- Exhaust gas composition (NO_x, O_2, CO_2, H_2O, SO_2)
- Exhaust gas temperature
- Catalyst modules (AV, SV or LV value)
- Reducing agent
- Desired NO_x conversion rate

The On-board Confirmation Test required for a scheme B certification will be done for the parent engine plus SCR system for a group according to IMO resolution MEPC 198(62).

SCR - Special notes

Principle of SCR technology

The selective catalytic reduction SCR uses ammonia (NH_3) to convert nitrogen oxides in the exhaust gas to harmless nitrogen and water within a catalyst. However, ammonia is a hazardous substance which has to be handled carefully to avoid any dangers for crews, passengers and the environment. Therefore urea as a possible ammonia source is used. Urea is harmless and, solved in water, it is easy to transport and to handle. Today, aqueous urea solutions of 32.5 % or 40 % are the choice for SCR operation in mobile applications on land and at sea.

Using urea, the reaction within the exhaust gas pipe and the catalyst consists of two steps. In the beginning, the urea decomposes in the hot exhaust gas to ammonia and carbon dioxide using the available water in the injected solution and the heat of the exhaust gas:

$(NH_2)_2CO + H_2O \rightarrow 2NH_3 + CO_2$ [1]

The literal NOx-reduction takes place supported by the catalyst, where ammonia reduces nitrogen oxides to nitrogen and water.

$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$ [2]

System overview

The Everllence SCR system is available in different sizes to cover the whole medium speed engine portfolio. The SCR system consists of the reactor, the mixing unit, the urea supply system, the pump module, the dosing unit, the control unit and the soot-blowing system.

After initial start-up of the engine, the SCR system operates continuously in automatic mode. The amount of urea injection into the SCR system depends on the operating conditions of the engine. Since the control unit of the SCR system is connected to the engine control system all engine related informations are continuously and currently available. This is one of the important benefits of the Everllence SCR system.

The urea is sprayed into the mixing unit which is part of the exhaust gas duct. Entering the reactor the reducing agent starts to react with NO_x coming from the combustion. The amount of reducing agent is controlled by the dosing unit, which is supported by a pump connected to an urea tank. It furthermore regulates the compressed air flow for the injector.

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Each reactor is equipped with a soot blowing system to prevent blocking of the SCR catalyst by ashes and soot.

Scope of supply

- Engine in standard configuration according stated emission level (see above).
- Engine attached equipment for control of the temperature after turbine.
- Engine SaCoS software including functions for control of temperature after turbine and for optimising engine + SCR performance.
- IMO Tier III Certificate.
- Everllence will act as "Applicant" within the meaning of the IMO.

Main components of SCR system in the standard scoper supply

- SCR reactor
- Catalyst modules
- Soot blowing system
- Dosing unit
- Mixing unit
- Urea injection lance
- Control unit SCR
- Pump module
- Compressed air reservoir module

Not included in the standard scope of supply, among others

- Urea storage tank
- Urea storage tank minimum level switch
- Piping
- insulation

Operation

Standard operation

Common SCR systems provided by third parties require constantly high exhaust gas temperatures. The Everllence SCR system on the other hand is an integrated engine + SCR system that allows operation on lower exhaust gas temperature levels.

The Everllence SCR system automatically adjusts the engine exhaust gas temperature to ensure both optimum engine + SCR operation. For a maximum on safety the surveillance mode is always activated.

Enhanced operation

The Everllence SCR system assures ideal engine operation, regenerating the SCR system whenever necessary to account for a minimum fuel oil consumption while complying with IMO Tier III emission limits at all times. Dependent on the ambient conditions it may be needed to adapt the engine load during the regeneration phase.

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Boundary conditions for SCR operation

Please consider following boundary conditions for the SCR operation:

- Temperature control of temperature turbine outlet:
  - By adjustable waste gate (attached to engine).
  - Set point 320 °C as minimum temperature for active SCR.
  - Set point 290 °C as minimum temperature for deactivated SCR.
- Fuel:
  - In line with Everllence specification, maximum 3.5 % sulfur content.
- SCR active in following range:
  - 10 °C (arctic) up to 45 °C (tropic) intake air temperature.
  - In the range of 25 % to 100 % engine load.
- IMO requirements for handling of SCR operation disturbances:
  - In case of SCR malfunction IMO regulations allow that the system will be turned off and the ship's journey will be continued to the port of destination. There, the ship needs to be repaired, if the emission limits of the harbor/sea area would be exceeded.

    Accordingly, the vessel may leave a port in case it will only sail in areas requiring IMO II, even if the SCR system is still out of service.
- Differential pressure Δp SCR (normal operation):
  - Max. 20 mbar.

For the design of the complete exhaust gas line, please consider:

- Maximum permissible exhaust gas back pressure (to be calculated from engine turbocharger outlet to end of complete exhaust gas line):
  - Max. 50 mbar (at 100 % engine load).
- Maximum permissible temperature drop of exhaust gas line (to be calculated as difference of exhaust gas temperature turbine outlet and temperature SCR inlet):
  - Max. 5 K in the range of 25 % to 100 % engine load (calculated at 5 °C air temperature in the engine room).
- Recommended for exhaust gas line:
  - Insulation according to SOLAS standard.

NOTICE

The SCR system requires high exhaust gas temperatures for an effective operation. Everllence therefore recommends to arrange the SCR as the first device in the exhaust gas line, followed by other auxiliaries like boiler, silencer etc.

Performance coverage for SCR system

- Performance guarantee for engine plus SCR within defined in section Boundary conditions for SCR operation.
- Guarantee for engine plus SCR for marine applications to meet IMO Tier III level as defined by IMO within defined in section Boundary conditions for SCR operation (details will be handled within the relevant contracts).

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NOTICE

Please be aware

All statements in this document refer to Everllence SCR systems only.

Everllence can only deliver an IMO Tier III certificate and act as "Applicant" (within the meaning of the IMO) if the engine plus SCR system is supplied by Everllence.

If the engine is supplied without Everllence SCR system, only a standard warranty for a single engine will be given. No guarantee regarding minimum exhaust gas temperature after turbine or emissions after third party SCR or suitability of the engine in conjunction with a third party SCR system can be given.

If the engine is supplied without Everllence SCR system, no optimisation function within SaCoS can be applied and as maximum exhaust gas temperature after turbine only will be possible:

- **320 °C (25 % load – 100 % load).**

Main dimensions, weights and views of SCR components

Depending on the individual projects SCR properties may vary. The following dimensions and weights are for guidance only.

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SCR reactor

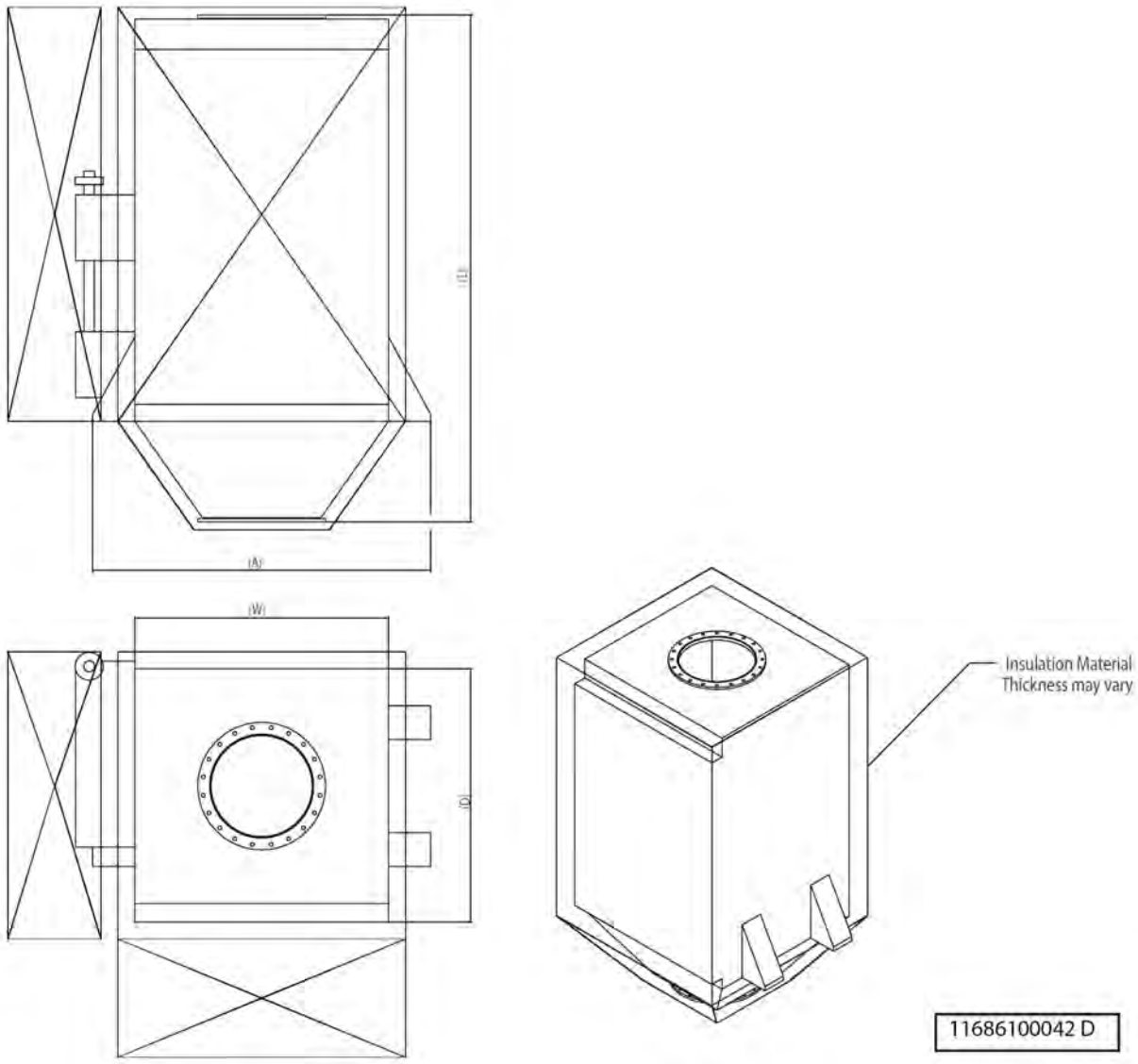


Figure 2: SCR reactor

Control cab.	Engine power approximately	L (Total length)	D (Without insulation)	W (Without insulation)	A (With anchorage)	Maximum weight structurally[1)]	Service space
No.	kW	mm	mm	mm	mm	kg	min. mm
1	0 – 800	2,800	1,000	1,000	1,600	1,350	750
2	801 – 1,400	2,900	1,250	1,250	1,800	2,050	750
3	1,401 – 2,400	3,000	1,500	1,500	2,000	2,950	750
4	2,401 – 3,650	3,100	1,750	1,750	2,300	3,900	750
5	3,651 – 4,900	3,200	2,000	2,000	2,680	5,050	750
6	4,901 – 6,000	3,400	2,350	2,350	2,930	6,550	750
7	6,001 – 7,800	3,600	2,900	2,350	2,930	8,000	750
8	7,801 – 9,000	3,600	2,900	2,900	3,430	9,600	750

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Control cab.	Engine power approximately	L (Total length)	D (Without insulation)	W (Without insulation)	A (With anchorage)	Maximum weight structurally[1)]	Service space
No.	kW	mm	mm	mm	mm	kg	min. mm
9	9,001 – 12,000	3,900	3,400	2,900	3,430	11,450	750
10	12,001 – 13,700	3,900	3,400	3,400	4,030	13,300	750
11	13,701 – 15,000	4,100	3,950	3,400	4,030	15,300	750
12	15,001 – 17,000	4,100	3,950	3,950	4,630	17,450	750
13	17,001 – 20,000	4,300	4,450	3,950	4,630	19,700	750
14	20,001 – 21,600	4,300	4,450	4,450	5,130	21,950	750

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[1)] See section .

Table 1: SCR reactor

NOTICE

In accordance with applicable security policies there must be provided adequate maintenance space, which permits the safe execution of all necessary maintenance work

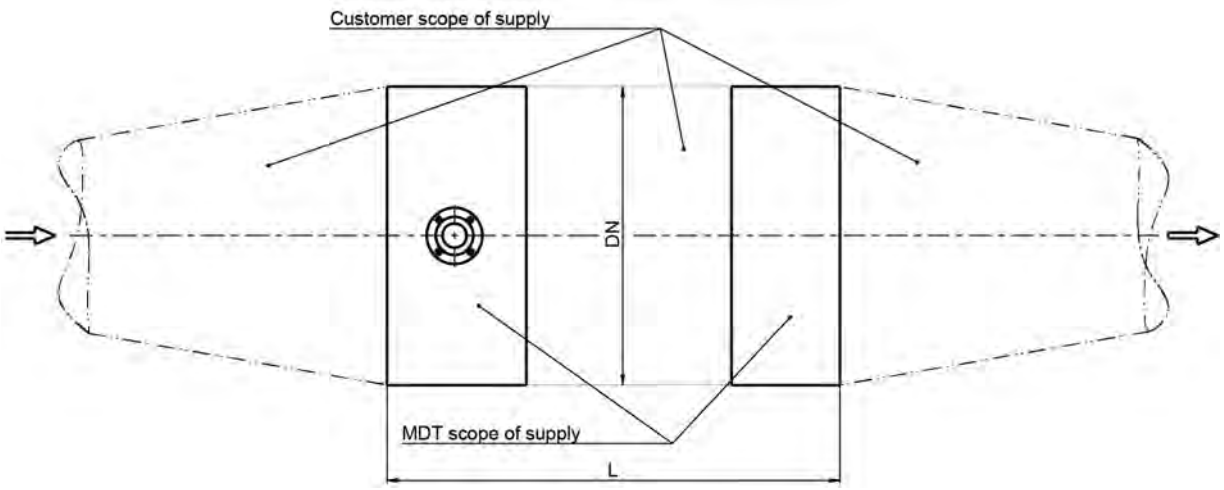


Figure 3: Mixing unit with urea lance

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Mixing unit with urea lance

Mixing unit	Engine power approximately	Mixing pipe[1)]	Length straight mixing pipe (L)
No.	kW	DN	mm
1	0 – 1,000	500	3,400
2	1,001 – 2,000	600	3,400
3	2,001 – 3,000	800	3,550
4	3,001 – 4,200	1,000	3,650
5	4,201 – 5,400	1,100	3,700
6	5,401 – 6,800	1,200	3,800
7	6,801 – 8,500	1,400	3,850
8	8,501 – 10,500	1,500	4,000
9	10,501 – 13,000	1,600	4,400
10	13,001 – 20,000	2,100	4,610
11	20,001 – 21,600	2,300	5,010

[1)] Diameter mixing pipe differs from exhaust pipe diameter.

Table 2: Mixing unit with urea lance

Dosing unit

Dosing unit	Height	Width	Depth	Weight
No.	mm	mm	mm	kg
1	800	800	300	80

Table 3: Dosing unit

SCR control cabinet

Control cabinet	Height	Width	Depth	Weight
No.	mm	mm	mm	kg
1	2,100	800	400	220

Table 4: SCR control cabinet

Pump module

Pump module	Height	Width	Depth	Weight
No.	mm	mm	mm	kg
1	1,300	700	300	120

Table 5: Pump module

Compressed air reservoir module

Air module	Height	Width	Depth	Weight
No.	mm	mm	mm	kg
1	1,050	1,500	500	250

Table 6: Compressed air reservoir module

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Waste gate

Temperature after turbine control by continuously adjustable waste gate (see flap 7 in figure 4)

The waste gate is used to by-pass the turbine of the turbocharger with a part of the exhaust gas. This leads to a charge air pressure reduction and the temperature after turbine is increased.

For plants with an SCR catalyst, waste gate is necessary in order to ensure proper performance of SCR.

In case the temperature before SCR falls below the set minimum exhaust gas temperature value, the waste gate is opened gradually in order to blow-off exhaust gas before the turbine until the exhaust gas temperature before the SCR catalyst has reached the required level.

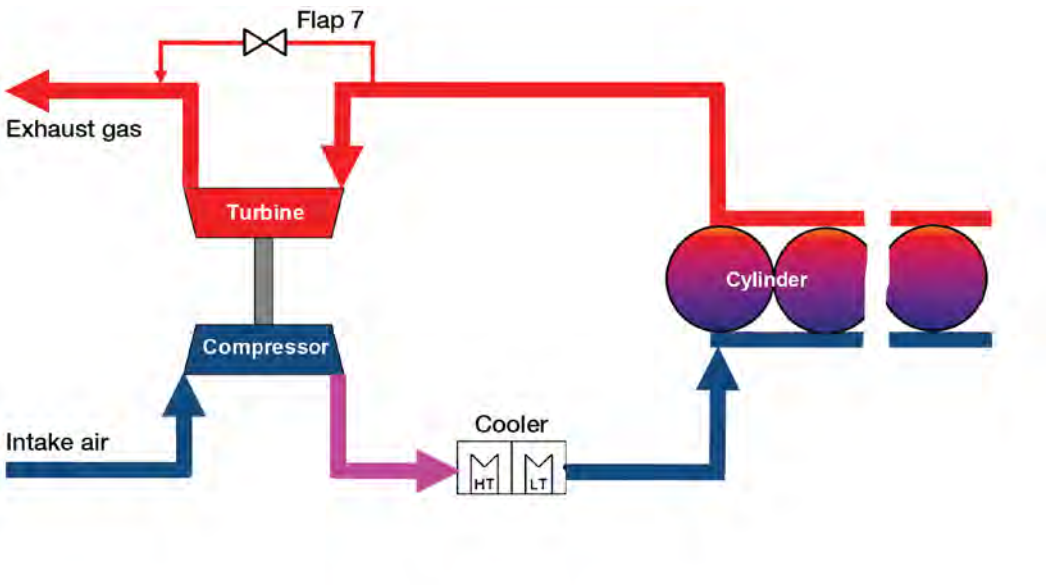


Figure 4: Overview flaps

Specification for engine supplies

Specification of urea solution

Use of good quality urea solution is essential for the operation of a SCR catalyst. Using urea solution not complying with the specification below e.g. agricultural urea, can either cause direct operational problems or long-term problems like deactivation of the catalyst.

NOTICE

The overall SCR system is designed for one of the two possible urea solution qualities (32.5 % AdBlue® or 40 % concentration) as listed in the tables below. This must be taken into account when ordering. The mixture of the both different solutions is not permissible!

	Urea solution concentration [%] 39 - 41	ISO 22241-2 Annex C
Density at 20 °C [g/cm^3]	1.105-1.115	DIN EN ISO 12185
Refractive index at 20 °C	1.3930-1.3962	ISO 22241-2 Annex C
Biuret [%]	max. 0.5	ISO 22241-2 Annex E
Alkality as NH_3 [%]	max. 0.5	ISO 22241-2 Annex D
Aldehyde [mg/kg]	max. 10	ISO 22241-2 Annex F
Insolubles [mg/kg]	max. 20	ISO 22241-2 Annex G
Phosphorus (as PO_4) [mg/kg]	max. 0.5	ISO 22241-2 Annex H
Calcium [mg/kg]	max. 0.5	ISO 22241-2 Annex I
Iron [mg/kg]	max. 0.5	ISO 22241-2 Annex I
Magnesium [mg/kg]	max. 0.5	ISO 22241-2 Annex I
Sodium [mg/kg]	max. 0.5	ISO 22241-2 Annex I
Potassium [mg/kg]	max. 0.5	ISO 22241-2 Annex I
Copper [mg/kg]	max. 0.2	ISO 22241-2 Annex I
Zinc [mg/kg]	max. 0.2	ISO 22241-2 Annex I
Chromium [mg/kg]	max. 0.2	ISO 22241-2 Annex I

Table 7: Urea 40 % solution specification

	Urea solution concentration [%] 31.8 - 33.2	ISO 22241-2 Annex C
Density at 20 °C [g/cm^3]	1.087-1.093	DIN EN ISO 12185
Refractive index at 20 °C	1.3814-1.3843	ISO 22241-2 Annex C
Biuret [%]	max. 0.3	ISO 22241-2 Annex E

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	Urea solution concentration [%] 31.8 - 33.2	ISO 22241-2 Annex C
Alkality as NH_3 [%]	max. 0.2	ISO 22241-2 Annex D
Aldehyde [mg/kg]	max. 5	ISO 22241-2 Annex F
Insolubles [mg/kg]	max. 20	ISO 22241-2 Annex G
Phosphorus (as PO_4) [mg/kg]	max. 0.5	ISO 22241-2 Annex H
Calcium [mg/kg]	max. 0.5	ISO 22241-2 Annex I
Iron [mg/kg]	max. 0.5	ISO 22241-2 Annex I
Magnesium [mg/kg]	max. 0.5	ISO 22241-2 Annex I
Sodium [mg/kg]	max. 0.5	ISO 22241-2 Annex I
Potassium [mg/kg]	max. 0.5	ISO 22241-2 Annex I
Copper [mg/kg]	max. 0.2	ISO 22241-2 Annex I
Zinc [mg/kg]	max. 0.2	ISO 22241-2 Annex I
Chromium [mg/kg]	max. 0.2	ISO 22241-2 Annex I

Table 8: Urea 32.5 % solution specification

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Engine supply systems

SCR system

General

The SCR system uses aqueous urea solution and a catalyst material to transform the pollutant nitrogen oxides into harmless nitrogen and water vapor. The main components of the SCR system are described in the following section.

For further information read section "SCR - Special notes".

As-delivered conditions and packaging

All components will be delivered and packaged in a seaworthy way (with dry agent, wooden boxing, shrink wrapped). Black carbon steel components will be coated with an anti-corrosive painting. Stainless steel components will not be coated.

The original packaging should not be removed until the date of installation.

The physical integrity of the packaging must be checked at the date of delivery.

Transportation and handling

Compressed air reservoir module (MOD-085)

Transport of the compressed air reservoir module can be organised by crane, via installed metal eyelets on the top side or fork-lifter.

Urea pump module (MOD-084)

Transport of the urea pump module can be organised by crane, via installed metal eyelets on the top side.

Dosing unit (MOD-082)

Transport of the dosing unit can be organised by crane, via installed metal eyelets on the top side.

Urea injection lance and mixing unit (MOD-087)

Transport of the mixing unit can be organised by crane, via two installed metal eyelets. For horizontal lifting it is sufficient using one of the metal eyelets.

Using a vertical way, the two cables each fixed on one metal eyelet have to be stabilised by a transversal bar.

NOTICE

The metal eyelets are designed to carry only the segments of the mixing unit, further weights are not allowed (e.g. complete welded mixing pipe).

SCR reactor (R-001)

Transport of the reactor can be organised by crane, via installed metal eyelets on the top side.

SCR control unit

Transport of the reactor can be organised by crane, via installed metal eyelets on the top side.

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Storage

Compressed air reservoir module (MOD-085), urea pump module (MOD-084), dosing unit (MOD-082), SCR control unit and sensor elements have to be stored in dry and weather-resistant conditions.

Catalyst elements shall be handled free from shocks and vibrations. Furthermore, catalyst elements have to be stored in dry and weather-resistant conditions. Keep oils or chemicals away from catalyst elements. Seaworthy packaging is only a temporary protection.

Components and assemblies of the SCR system

Catalyst elements

The catalyst elements are placed in metallic frames, so called modules. Due to the honeycomb structure of the catalyst elements, the catalytic surface is increased. The active component Vanadium pentoxide (V2O5) in the surface supports the reduction of NOx to harmless nitrogen.

The effectivity of the catalytic material decreases over time because of poisoning via fuel oil components or thermal impact. The durability depends on the fuel type and conditions of operation.

The status of catalyst deactivation is monitored continuously and the amount of urea injected is adapted according to the current status of the catalyst.

Compressed air reservoir module (MOD-085) and soot blowing system (MOD-086)

The compressed air required for the operation of the SCR system is provided by the compressed air module. It receives its compressed air via the ship´s compressed air grid. For the quality requirements read section Specification of compressed air. The main supply line feeds the compressed air reservoir module, where a compressed air tank is installed. This high-pressure tank is a reservoir with enough capacity to ensure the supply of the dosing unit and the air consumption for the periodically cleaning of the catalysts´ surface, by avoiding fluctuations in the soot blowing system. In case of black out the volume of the tank will be used for flushing the urea line and nozzle.

The module has to be positioned close to the reactor and the dosing unit. The maximum length of the compressed air line to the soot blowing system is 10 m.

The soot blower valves are positioned upstream each catalyst layer in order to clean the complete surface of the catalyst elements by periodical air flushing. The soot blowing always has to be in operation while engine running.

Urea pump modul (MOD-084)

The urea pump module boosts urea to the dosing unit and maintains an adequate pressure in the urea lines. The complete module is mounted in a standard cabinet for wall fastening. Upstream of the supply pump, a filter is installed for protection of solid pollutants. Downstream, the module is equipped with a return line to the urea storage tank with a pressure relief valve to ensure the required urea flow.

The urea pump module has to be positioned on a level below the minimum urea level of the urea storage tank. The pump accepts a maximum pressure loss of 2 bar. One urea pump module can supply up to four SCR systems.

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NOTICE

Urea quality according section Specification of urea solution is required. For urea consumption calculation for Tier III read section Urea consumption for emission standard IMO Tier III.

Dosing unit (MOD-082)

The dosing unit controls the flow of urea to the injection nozzle based on the operation of the engine. Furthermore it regulates the compressed air flow to the injector.

In order to avoid clogging due to the evaporation of urea in the urea pipe and in the nozzle, a line between compressed air line and urea line is installed. An installed solenoid valve will open to flush and cool the urea line and nozzle with compressed air before and after injecting urea into the exhaust gas.

The dosing unit has to be installed close to the urea injection lance and mixing unit (maximum pipe length 5 m).

Urea injection lance and mixing unit (MOD-087)

The urea solution will be injected into the exhaust gas using a two-phase nozzle. The urea will be atomised with compressed air. The evaporation of the urea occurs immediately when the urea solution gets in contact with the hot exhaust gas.

The urea injection and the mixing unit have to be positioned according to Everllence requirements. In general, the mixing section is between 3.0 – 4.5 m long and of DN 500 to DN 2,300. The mixing duct is a straight pipe upstream of the reactor. The exact length has to be calculated. Additional, it has to be considered that an inlet zone upstream the reactor of 0.5 x diameter of the exhaust gas pipe has to be foreseen.

SCR reactor (R-001)

Each engine is equipped with its own SCR reactor and it is fitted in the exhaust gas piping without a by-pass. The SCR reactor housing is a steel structure with an inlet cone. The reactor configuration is vertical and consists of several layers of catalysts. For horizontal installation, please contact Everllence. The reactor is equipped with differential pressure and temperature monitoring, openings for inspection, a maintenance door for service and the soot blowing system for each layer.

The maximum temperature of the exhaust gas is 450 °C and a minimum exhaust gas temperature is required to ensure a reliable operation. Therefore temperature indicators are installed in the inlet and outlet of the reactor in order to monitor and control the optimum operating range.

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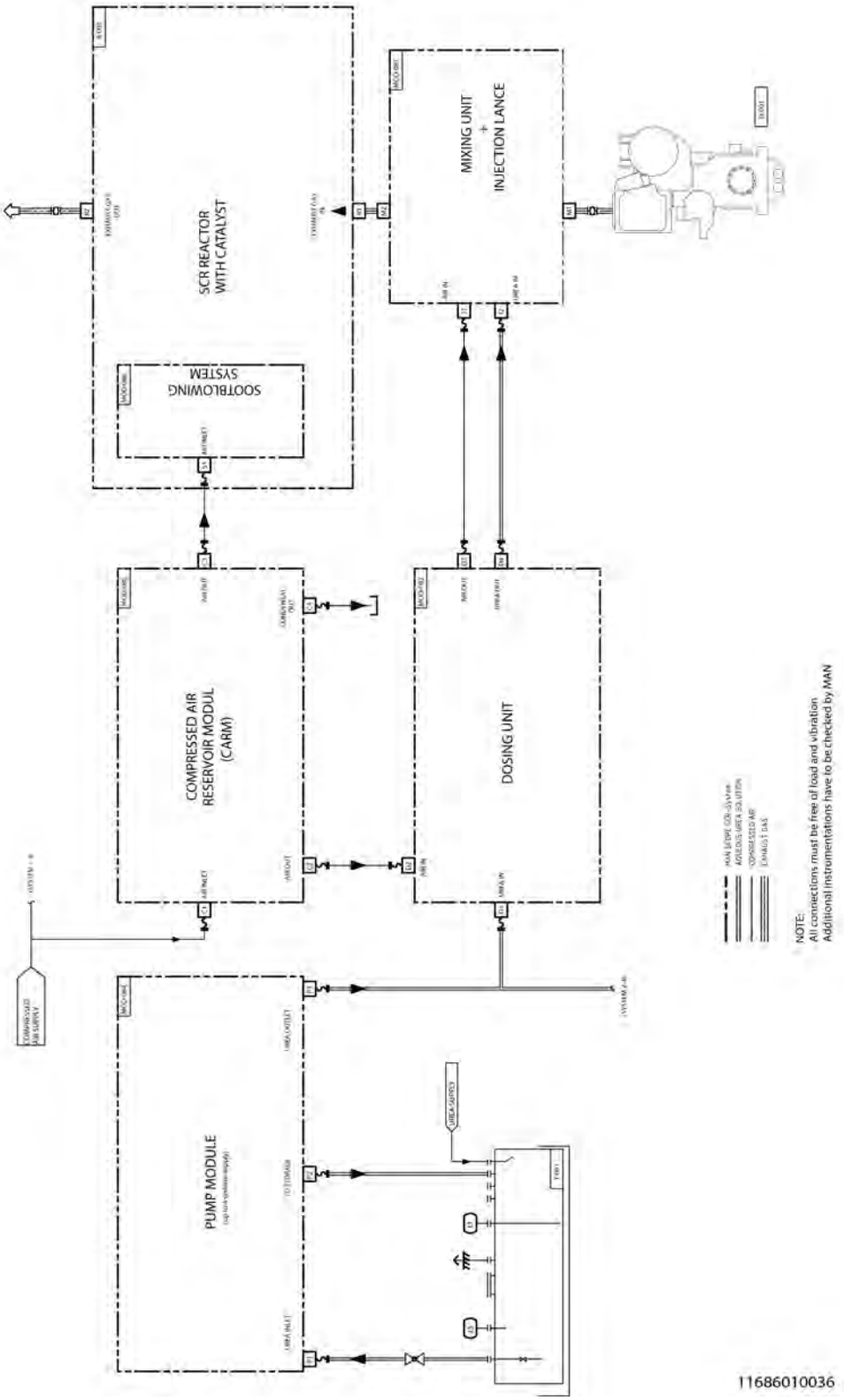


Figure 5: PFD SCR system

Urea pipes (for SCR only)

Galvanised steel pipe, brass and copper components must not be used for the piping of the system.

Proposed material (EN)

X6CrNiMoTi17-12-2

Installation of the SCR system

All modules are check regarding pressure and tightness.

Catalyst elements

For handling the catalyst elements sufficient space and supply tracks have to be foreseen. Depending on the amount of catalyst elements transport devices like carriages, pulleys, fork lifter or elevators are required.

Reactor and soot blowing system

A service space of recommended 800 mm in front of the inspection doors of the reactor for mounting and dismounting the catalyst elements has to be foreseen. Further 750 mm space for service and maintenance of the soot blower equipment and the differential pressure device has to be considered according the installation side of the soot blowing system.

Reactor and piping

In case of a bend before the reactor inlet, a straight inlet duct to the reactor of 0.5 times exhaust gas pipe diameter and a bend radius of 1.5 times exhaust gas pipe diameters has to be considered.

Mixing unit

The mixing unit is designed for vertical or horizontal installation. Bend on the downstream side has to be in accordance to above mentioned “Reactor and Piping”. Upstream of the mixing unit a bend can be installed according the Everllence requirements mentioned on the planning drawing.

Recommendations

All parts mentioned in this paragraph are not Everllence scope of supply.

Piping in general

All piping's have to be in accordance with *descriptions P 69 00 0, 3700402-0, "Pipeline treatment requirements for piping manufacture" and 010.000.001-01, "Operating Fluid Systems, flushing and cleaning"*.
Piping for fluids shall be mounted in an increasing/decreasing way. Siphons should be avoided, drainage system be foreseen.

Exhaust gas piping

The complete inside wall of the exhaust gas piping between engine outlet and SCR reactor inlet should not be coated by any protection material. Poisoning of the catalyst honeycombs could occur.

Preferred materials

All materials used for the construction of tanks and containers including tubes, valves and fittings for storage, transportation and handling must be compatible with urea 40 % solution to avoid any contamination of urea and corrosion of device used. In order to guarantee the urea quality the following materials for tank, pipes and fittings are compatible: Stainless steel (1.4301 or 1.4509) or urea-resistant plastics (e.g. PA12). For gaskets EPDM or HNBR. Piping for compressed air see section Specification of materials for piping.

Unsuitable materials

Unsuitable materials for tank, pipes and fittings are among others: Aluminum, unalloyed steel, galvanised steel, copper and brass.

In case incompatible material is used, clogging of urea filter inside the pump module may occur, or even worse, the catalyst elements may be damaged by catalyst poisons derived from this material. In this case, exchanging the catalyst modules may be necessary.

Urea tank

Store this material in cool, dry, well-ventilated areas. Do not store at temperatures below 10 °C and above 55 °C. The storage capacity of the urea tank should be designed depending on ship load profile and bunker cycle.

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The urea supply line should be provided with a strainer and a non-return valve in order to assure a correct performance for the suction of the urea pump, which is installed downstream the tank. A level switch with the possibility to read out the signal will protect the pump of a dry run. A return line from the urea pump module over a pressure relief valve is entering the tank.

Urea solution quality

Use of good quality urea is essential for the operation of an SCR catalyst. Using urea not complying with the specification below e.g. agricultural urea, can either cause direct operational problems or long term problems like deactivation of the catalyst. For quality requirements, see section Specification of urea solution.

Insulation

The quality of the insulation has to be in accordance with the safety requirements. All insulations for service and maintenance spaces have to be dismountable. The delivered modules have no fixations, if fixations are necessary take care about the permissible material combination. Regarding max. permissible thermal loss see section Boundary conditions for SCR operation.

Water trap

Water entry into the reactor housing must be avoided, as this can cause damage and clogging of the catalyst. Therefore a water trap has to be installed, if the exhaust pipe downstream of the SCR reactor is facing upwards.

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Engine room planning

Exhaust gas ducting

Example: Ducting arrangement

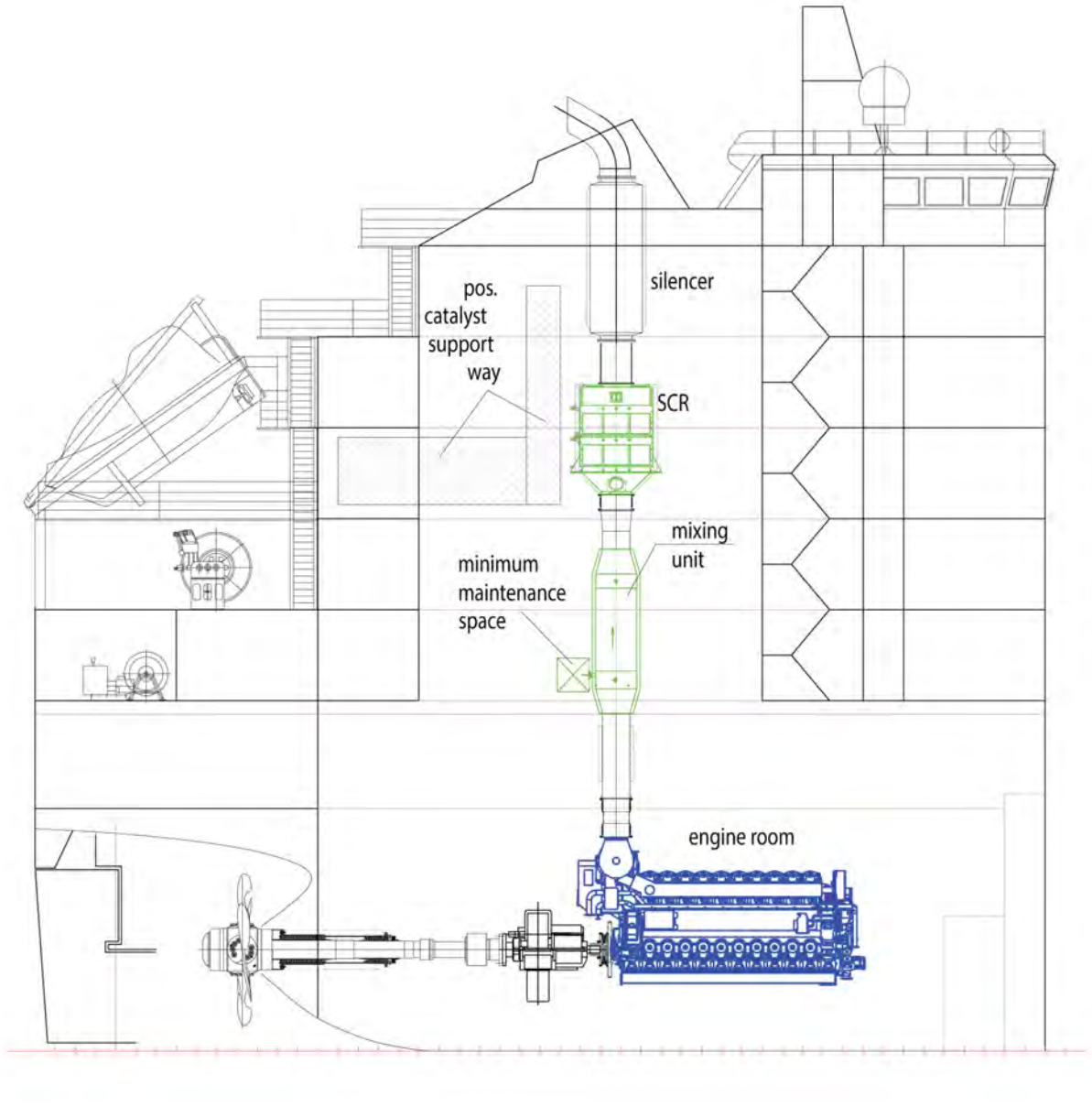


Figure 6: Example: Exhaust gas ducting arrangement

General details for Tier III SCR system duct arrangement

Everllence recommends that the SCR reactor housing should be mounted before all other components (e.g. boiler, silencer) in the exhaust duct, coming from the engine side. A painting on the inside wall of the exhaust duct in front of the the SCR system is not allowed.

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All of the spaces/openings for cleaning and maintenance on the entire unit, including air reservoir module, dosing unit and reactor housing with soot-blowers must be accessible.

We strongly recommend that in front of the reactor housing sufficient space for the maintenance personal and/or for the temporary storage of the catalyst honeycombs has to be foreseen (see section SCR System).

Catalyst elements could reach a weight of 25 kg, the reactor openings could reach a total weight of about 70 kg, Everllence strongly recommends a lifting capability above the reactors.

A very important point is the transportation way and storage space of the catalyst honeycombs within the funnel for supply of the SCR reactor during maintenance or catalyst refreshment, one reactor could contain more than 100 elements.

To avoid time-consuming or implementation of a scaffolding, Everllence strongly recommends at minimum a lifting device in the funnel or any kind of material elevator. A porthole from outside rooms on level with the reactor housing is also a possibility, as far as those rooms could be supplied with the catalyst honeycombs.

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Exhaust gas system

Position of gas outlet on turbocharger

The turbocharger outlet is fitted with a round flange, adapted for direct installation of an expansion bellow.

Figure1 shows alternative positions for the exhaust gas outlet and if requested the outlet can be turned to a desired position prior to dispatch.

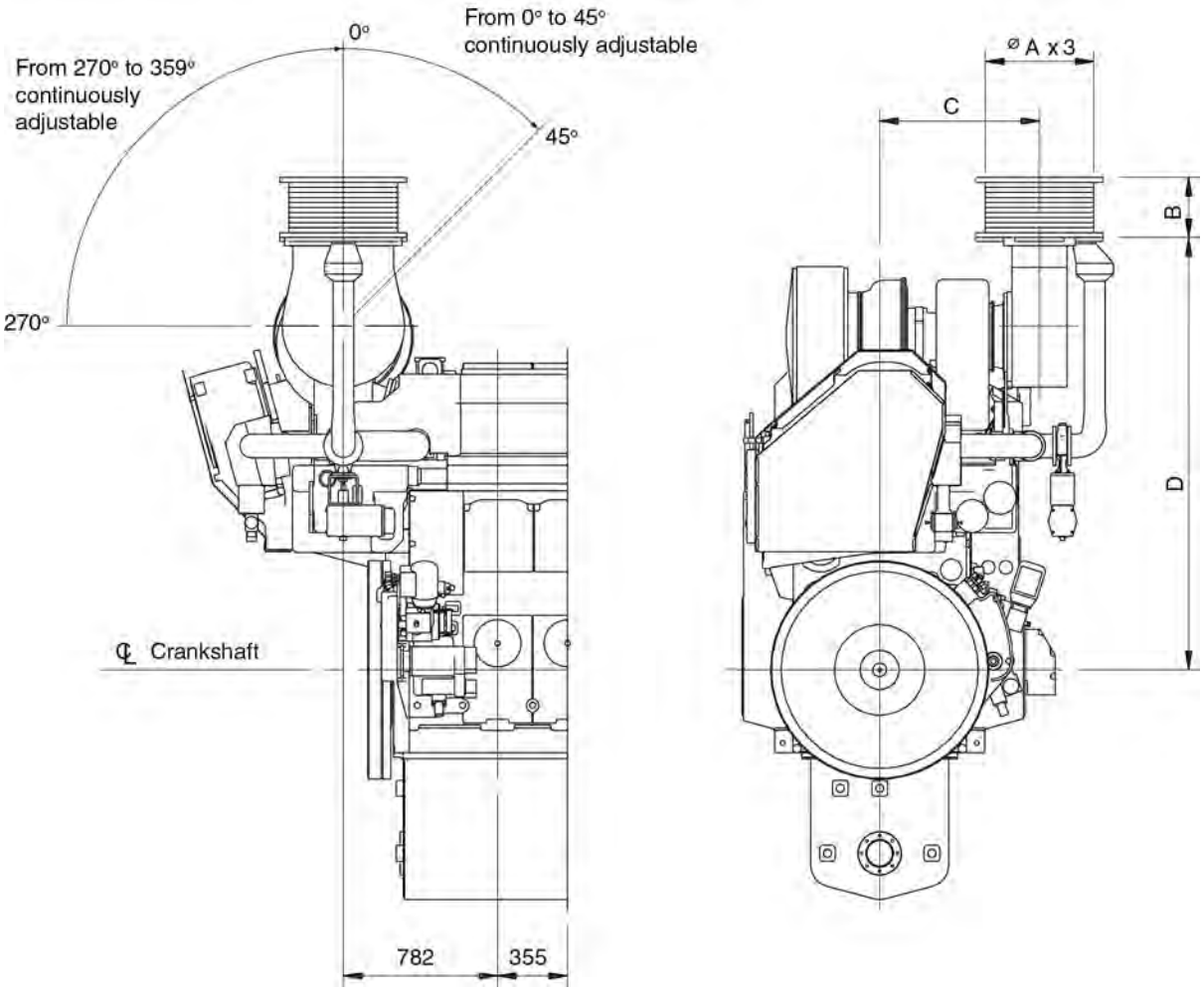


Figure 1: .

Engine	ø A *) mm	B mm	C mm	D mm
6L21/31 (TCR 16)	450	305	721	2029
7L21/31 (TCR 18)	500	305	808	2121
8L21/31 (TCR 18)	500	305	808	2121
9L21/31 (TCR 18)	550	315	808	2121
*) Exhaust pipe dimensions				

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Exhaust gas system - exhaust gas compensator

Exhaust gas compensator

The exhaust gas compensator is required after the gas outlet of the turbocharger *(see description Exhaust gas system, B16020_3700197-0)* in order to prevent transmission of forces of the turbocharger. These forces result from the weight, thermal expansion, later displacement of the exhaust gas piping as well as vibrations caused by the engine. As the vibrations depend on the mounting of engine, figure 1 shows exemplary compensators for rigid (left) and resilient (right) mounting.

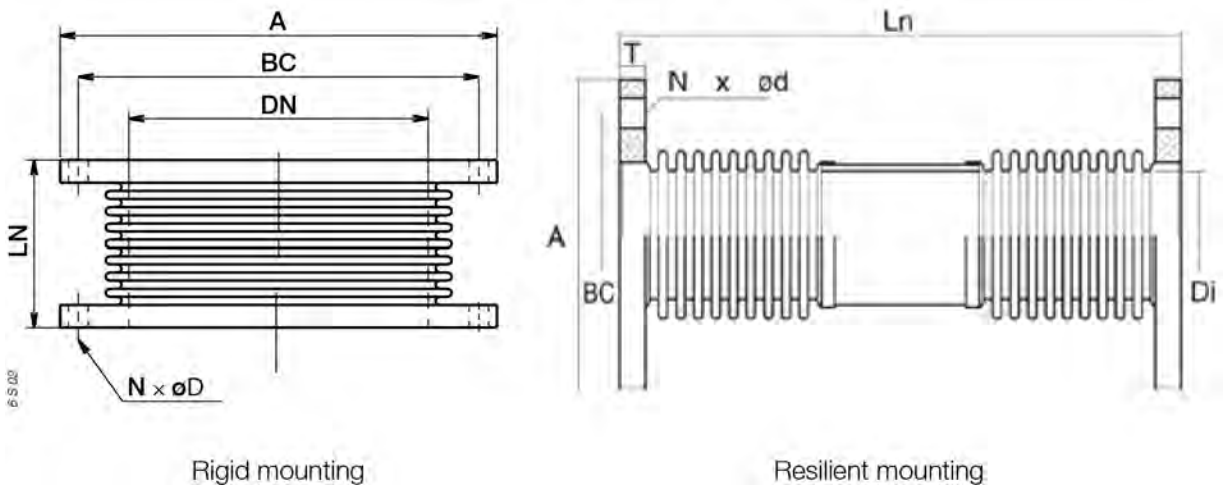


Figure 1: Exhaust gas compensators

As the length of the exhaust gas compensators may vary due to project specific requirements, the measures in table are for guidance only.

Exhaust pipe dimension (mm)		ø450	ø500	ø550
Number of cylinder		6	7 / 8	9
Outer flange diameter	A	595	645	703
Pitch circle diameter	BC	550	600	650
Exhaust pipe dimension	DN	450	500	550
Free length for rigid mounting	LN	305	305	315
Free length for resilient mounting	LN	864	894	890
Number of holes	N x øD	20 x ø22	20 x ø22	20 x ø22

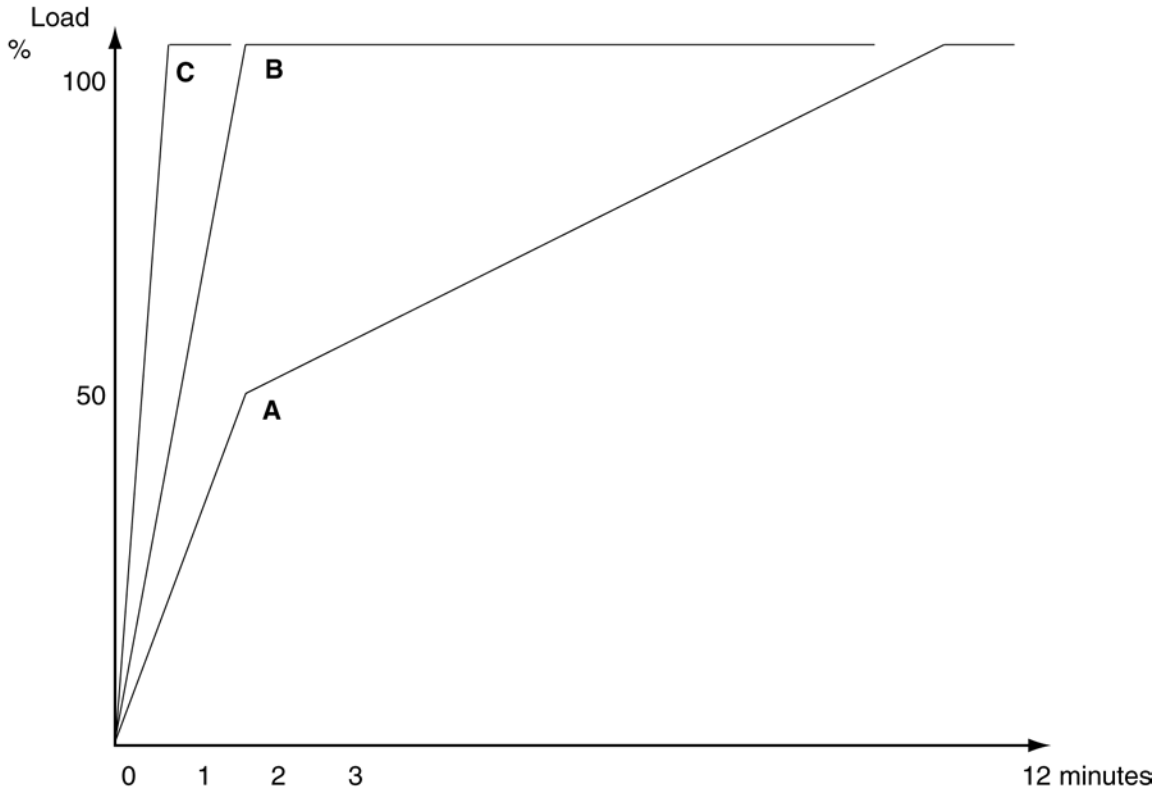
Table 1: Measure of exhaust gas compensators

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Starting of engine

General



The engine can be loaded according to the following procedure:

A) Normal start without pre-heated cooling water. Only on MDO/MGO. Continuous pre-lubrication.

B) Normal start with pre-heated cooling water. On MDO/MGO or HFO. Continuous pre-lubrication.

C) Stand-by engine. Emergency start, with pre-heated cooling water. On MDO/MGO or HFO. Continuous pre-lubrication.

The curves indicate the absolute shortest load-up time and we advise that loading up to 100% take some more minutes.

Starting on HFO

During shorter stops or if the engine is in a standby position on HFO, the engine must be pre-heated, and HFO viscosity must be in the range 12–18 cSt.

During, pre-heating the jacket cooling water temperature must be kept as high as possible at least 60°C (± 5°C) either by cooling water from engines which are running or with a built-in pre-heater.

If the engine normally runs on HFO, pre-heated fuel must be circulated through the injection pumps while pre-heating the engine, although the engine just has run or has been flushed on MDO/MGO for a short period.

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Starting on MDO/MGO

For starting on MDO/MGO, there are no restrictions except for the lubricating oil viscosity, which may not be higher than 1500 cSt (10°C for SAE 40).

Initial ignition may be difficult if the engine and the ambient temperature are lower than 5°C and the cooling water temperature is lower than 15°C.

Prelubricating

Continuous pre-lubrication is standard.

Pre-lubrication at intervals is not allowed for stand-by engines.

If the pre-lubrication, has been switch-off for more than 20 minutes the start valve will be blocked.

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Control and safety systems

General information

SaCoSone PROPULSION is the safety and control system for smaller type L21/31 and L27/38 diesel engines from Everllence.

All sensors and actuators installed in the engine are connected to the system and are controlled by the SaCoSone PROPULSION, which is linked to the engine.

SaCoSone PROPULSION controls and monitors all engine functions, including the coupling control system and the visualisation of engine-related pre-warnings, system alarm messages, safety measures, operating values and conditions.

In this context, the term ‘safety measures’ refers to shutting down the engine as well as requesting a load reduction and automatically shutting down the engine if needed.

Optionally, the system can also monitor and control the gearbox and analyse an oil mist detector installed directly on the engine. Another available option is to monitor the propeller sensors, e.g. for the shaft bearing temperature.

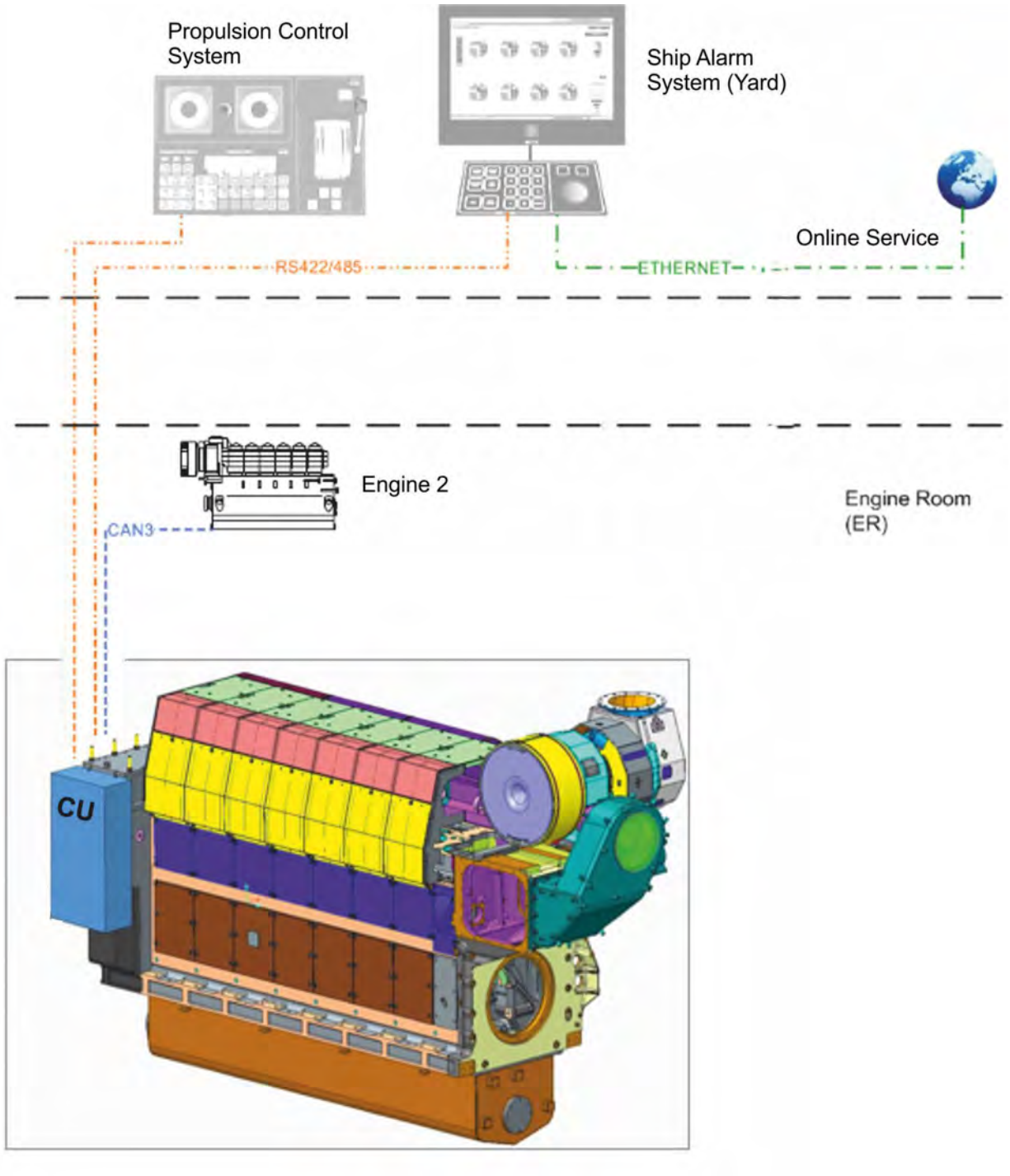
Areas of application

Due to the system architecture and control modules used, the product line can only be used for the following engines and applications:

- Engines in series with a maximum of 9 cylinders, types L21/31 and L27/38
- Engines with Pt1000 temperature sensors

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Layout


Propulsion Control System
Ship Alarm System (Yard)
Online Service
RS422/485
ETHERNET
Engine 2
Engine Room (ER)
CAN3
CU

System Architecture

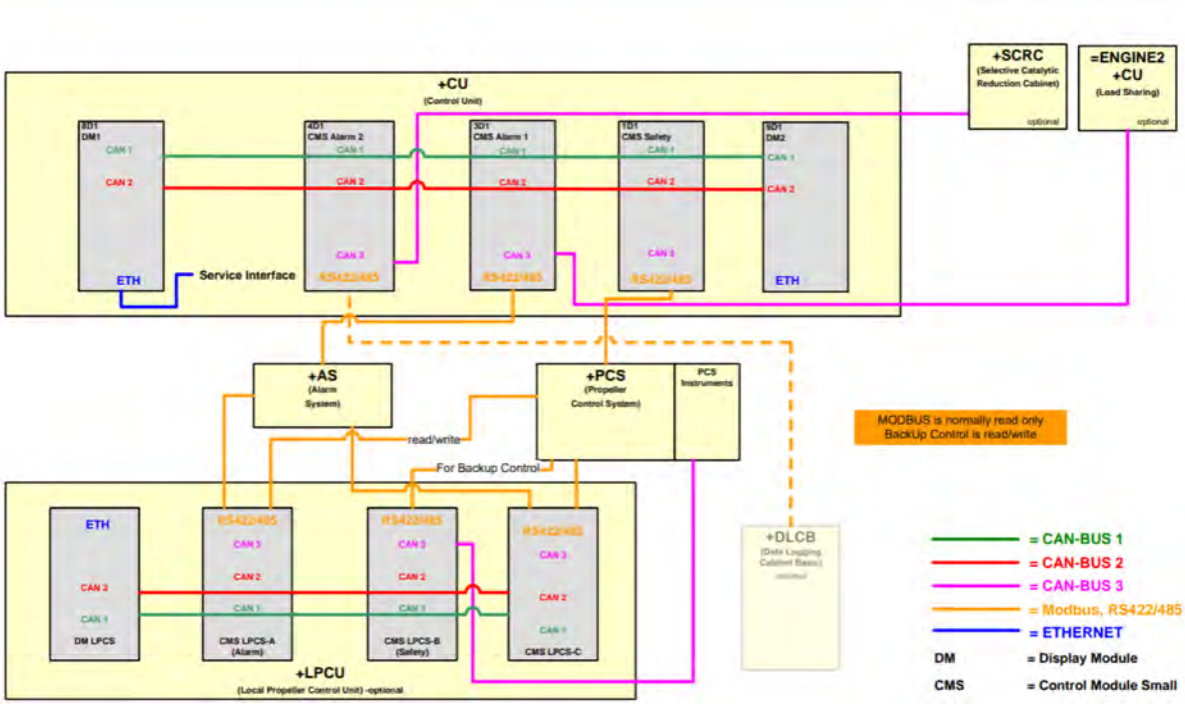


Figure 1: System bus (example)

Components

Control Unit

The Control Unit contains three Control Modules S. One Control Module S functions as a safety system (automatic shut-downs and emergency stops, backup, speed control, etc.). The second and third Control Modules S function as engine control, alarm (monitoring of alarm limit values etc.) and speed control systems.



Figure 2: Control Unit

The Control Unit (CU) contains two Display Modules. These touchscreens are used to control the engine and display all operating values of the engine.

Both displays are always active, fully redundant and have identical operative functions. The only difference is that only LOP1 has an interface for SaCoS_one EXPERT.

Local Gear and Propeller Control (option)

The Local Propulsion Control System (LPCS) consists of two Control Modules Small (A/B). The functions pitch control, wind milling detection, engine running detection and gear/shaft readiness are controlled via the corresponding output signals. Pitch control is designed as a redundant system. Each module can generate operational alarms, reductions and shutdowns.

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Functions

Engine control

Carrying out the engine control is an integral task of the Control Module S, fully controlling the engine in all possible operating states:

- It controls and monitors the entire starting process of the engine.
- It carries out full load-dependent control of the engine speed throughout the entire engine operation.
- It carries out the control and monitoring off all auxiliary units and engine parameters throughout the entire engine operation.
- It ensures the combustion process of the engine is optimised to minimise pollutant emissions and consumption, thus ensuring efficient and load-optimised operation of the engine.
- It manages the controlled stopping process of the engine

Monitoring / Control

- Start/stop function
- Jet assist
- Engine speed
- Turbocharger speed
- Fuel oil
- HT cooling water
- LT cooling water
- Charge air
- Compressed air system
- Exhaust gas
- Crankcase
- Gear lube oil

Functions

- Governor
- Main state machine
- Pre-turning
- Engine running hours
- Standby
- IMO identifier
- Operating station management

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Engine stop

Engine stops can be initiated locally at the LOP and remotely via a hardware channel or the bus interface.

Speed control system

Single-propulsion engines

Single-propulsion engines are equipped with a pressure-compensated, hydraulic governor designed to accept a standard 4-20mA electrical current signal to set the position of the governor. This input signal is set to correspond to

the required engine speed range. The driver actuates a stepper motor that moves the fuel admission control linkage. The position of the fuel control lever determines the compression of a spring and therefore determines the provided fuel quantity to reach the desired engine speed. A minor alarm contact on the driver box can be used to limit the maximum speed setting.

Multi-propulsion engines

For multi-propulsion engines, the electronic speed control is realised by the Control Module S (CMS). The engine is equipped with an electro-hydraulic actuator. Engine speed detection is carried out by means of redundant sen-sors at the camshaft.

The electronic speed governor is a part of the software in the CMS/Alarm module and controls the electro-hydraulic actuator installed at the engine. A stepper motor is installed in the governor to adjust the fuel admission control linkage. A contactless position transducer, attached to the shaft of the speed governor, returns a feedback signal to the Control Module. The Control Module will actuate the speed governor until the feedback signal matches the 4-20mA command input.

The minimum and maximum limits for the speed adjustment range can be parameterized in the Control Module S.

Speed adjustment

Remote speed setting is possible via an analogue 4-20 mA signal.

Clutch, gearbox and propeller control

SaCoSone PROPULSION monitors the relevant temperatures and pressure conditions of the gearbox and propeller. The system also offers hard-wired interfaces for controlling the coupling. Details on the relevant signals can be found in the interface description of the respective gearbox control unit.

Alarm/monitoring system

Alarming

The alarm function of SaCoSone PROPULSION checks all important parameters and issues alarm messages if any discrepancies are detected. The alarms are transmitted to the ship alarm system via a Modbus data communication.

Self-monitoring

SaCoSone PROPULSION features independent self-monitoring functions. For example, the connected sensors are continuously checked for function and wire breaks. In the event of an fault, SaCoSone PROPULSION reports the faults that have occurred in individual system components via system alarms.

Control

SaCoSone PROPULSION controls all internal engine functions and external components, for example:

Start/stop sequences:

- Start/stop sequence triggered locally or remotely

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- Activation of the starting device. Control (auto start / stop signal) for the pre-lubrication pump
- Monitoring and control of the acceleration phase

Jet system:

- To control the air-fuel ratio, compressed air is fed into the turbocharger at start-up and during the load stages.

Control signals for external functions:

- HT cooling water pre-heating unit
- Pre-lubrication oil pump control unit

Redundant shut-down functions:

- Engine overspeed
- Lubricating oil pressure at engine intake low
- HT cooling water temperature at the outlet too high

Safety

The SaCoSone safety system is an electronic system to protect the engine from serious damage. If critical parameters exceed the permissible limit values, one or more of the following safety mechanisms are activated: The engine load is reduced to a lower value or the engine is stopped automatically.

These measures were designed in accordance with the requirements of the classification societies. The automatic reduction of the engine load is controlled by SaCoSone. The load reduction is only part of the system. The main element is the control unit, which has an interface to the additional devices. These devices can be divided into three categories: control panels, sensors/ actuators and external systems. The control unit consists of modules for various applications. The safety system works independently of the remote control and the alarm system. Faults in this system are therefore irrelevant to the safety system. SaCoSone was developed to adapt to the requirements of our four-stroke engines and to offer a user-friendly system.

The safety system monitors all operating values of the engine and takes necessary measures if limit values are exceeded, for example shutting down the engine. The safety system is integrated in the CMS/safety system. The safety system directly controls the emergency shut-down device and the stop mechanism of the speed control system.

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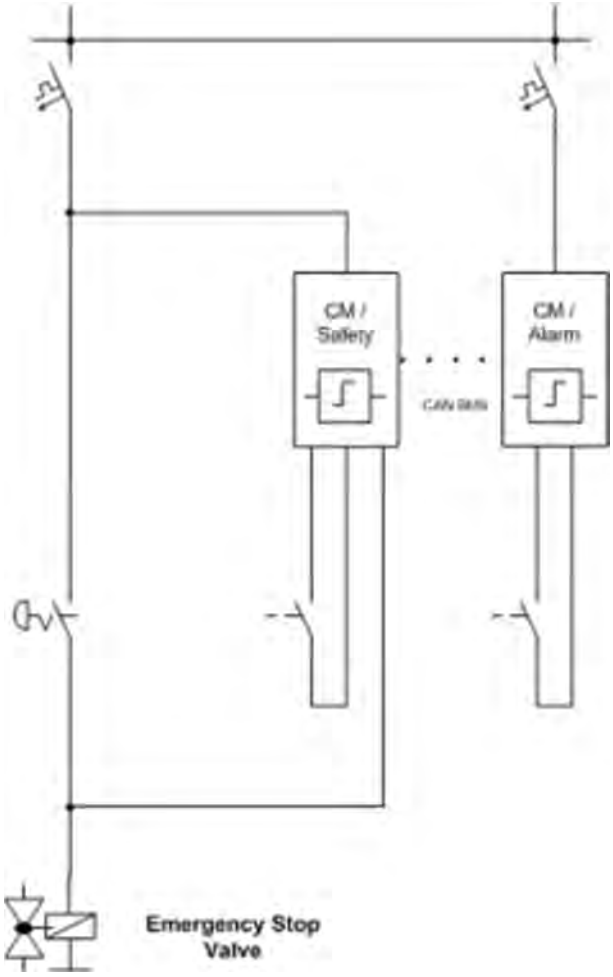


Figure 3: Functional principle of the safety function

Safety architecture

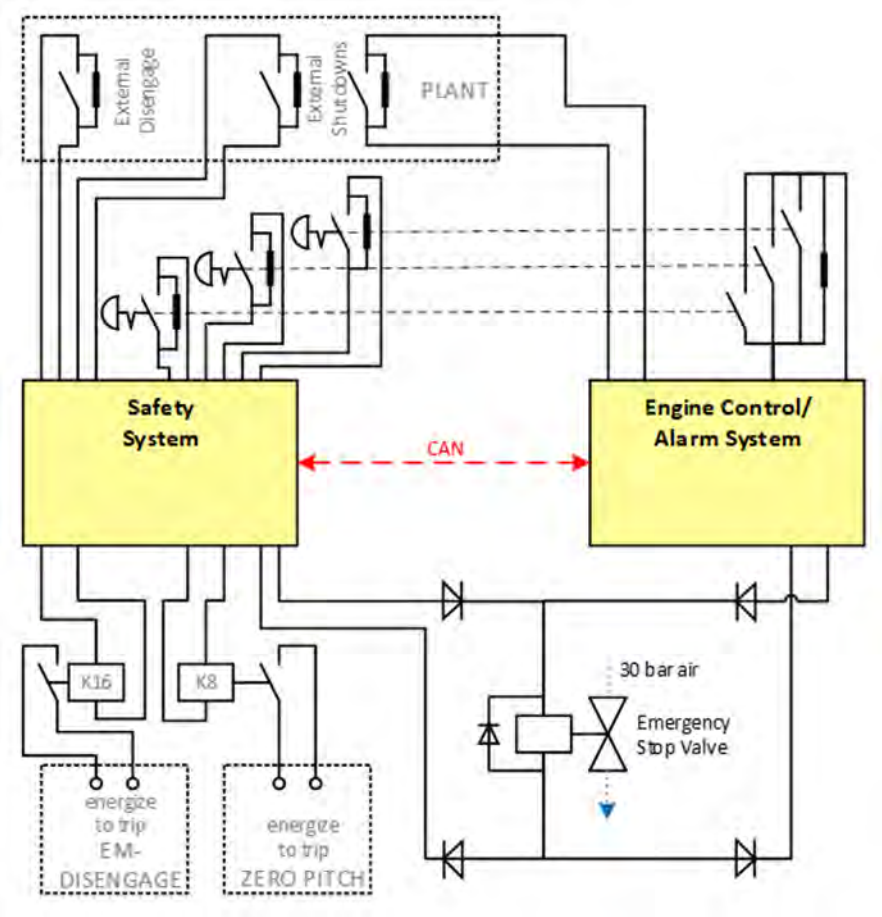


Figure 4: Safety architecture

Emergency stop

An emergency stop is an engine shutdown initiated by a specific action by an operator, such as pressing an emergency stop button. An emergency stop button is located on the LOP of the engine. There is an input channel on the control unit for connection of an external emergency stop button.

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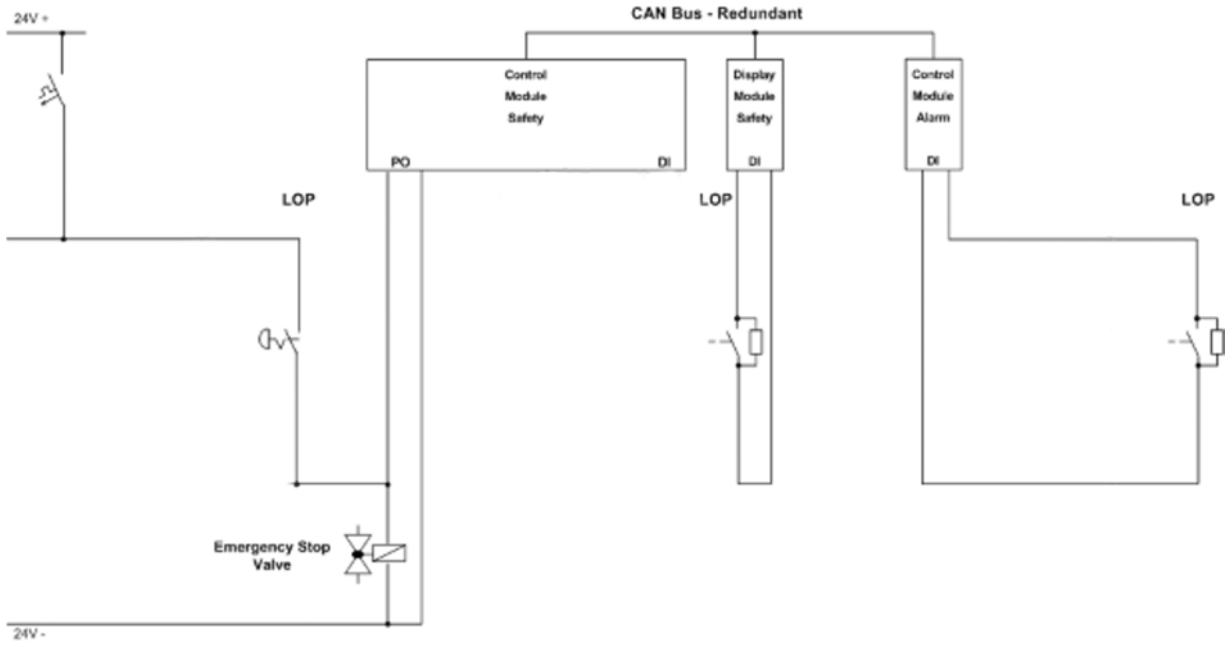


Figure 5: Emergency stop functional principle

Automatic safety functions

SaCoSone PROPULSION monitors all operating values of the engine and initiates necessary measures if limit values are exceeded, e.g. load reduction or engine shutdown. SaCoSone Safety is integrated into the control unit and is divided into the CMS/Alarm and CMS/Safety systems. The safety system initiates automatic shutdown or load reductions.

Automatic shutdown

Automatic shutdown is an engine shutdown that can be triggered as a result of automatic monitoring of internal engine parameters. If the safety system triggers an engine shutdown, the emergency stop signal has a direct effect on the emergency shutdown device and the speed control. At the same time as triggering the emergency stop function, the SaCoSone sends a signal that causes a decoupling. The following list sets out the criteria that lead to automatic shutdown. For more details, see the “List of measuring and control units”.

- Engine overspeed (redundant with the alarm system)
- HT cooling water pressure at the inlet too low
- HT cooling water temperature at the outlet too high (redundant with the alarm system)
- Lubricating oil pressure at engine inlet low (redundant with the alarm system)
- Gear unit lubricating oil pressure too low
- Gear unit bearing temperature too high
- Spray oil temperature at the front bearing too high (optional)
- Main bearing temperature too high (optional)
- High oil mist concentration in crankcase (optional).
- Controller – significant error active (configurable)
- Additional shutdown (e.g. via the gear unit)

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Load reductions

If certain parameters are exceeded, the load must be reduced to 60%. The safety system monitors these parameters and requests load reduction if necessary. The load reduction must be carried out from an external system (PCS, PMS). SaCoSone PROPULSION does not reduce the load itself. The following list sets out the criteria that lead to the requirement for load reduction. For more details, see the “List of measuring and control units”.

- High turbocharger speed
- Exhaust gas temperature at the cylinder too low/high
- Exhaust gas temperature at turbocharger inlet too high
- HTCW pressure too low:
- HTCW temperature on the cylinder output too high
- Charge air temperature too high
- Differential pressure of the lubricating oil filter too high
- Lube oil pressure too low
- Lube oil temperature too high
- Additional load reduction (e.g. via the gear unit)

Automatic disengagement

When SaCoSone PROPULSION is used to monitor the coupling, it performs automatic disengagement to protect the gear unit, propeller and engine from destruction. In this case, the coupling is opened as quickly as possible.

The following list sets out the criteria that lead to automatic disengagement. For more details, see “System messages”.

- Automatic stopping of the engine
- Manual emergency stop of the engine
- Overspeed
- Low coupling oil pressure
- External signal

Override

In critical situations (e.g. entering the harbour, difficult passages, etc.), the override mode prevents safety functions of SaCoSone PROPULSION from being triggered. The override mode can override the following safety functions:

- Automatic shut-down
- Automatic request for load reduction
- Automatic disengagement

While override mode is active, the safety system only generates an alarm instead of triggering the safety function. Override operation cannot suppress the triggering of the following safety functions:

- Manual emergency stop
- Shut-down in case of engine overspeed

The LOP touchscreen indicates if override mode is active. Alarms related to automatic shut-down or load reduction are also displayed on the LOP touchscreen. The following message is displayed every 3 seconds as long as override mode is active:

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Operation

Local Operating Panel

The Local Operating Panel (LOP) consists of two Display Modules. It is integrated in the Control Unit. This display can be used independently for operating and monitoring.

In case of using a gearbox (AT3000 only) all functions will be provided on LOP2.

In case of a malfunction of one display, the engine can be operated with the other display (backup function).

In case of a malfunction of one display (gearbox configuration), all the functions (engine and gear) are controlled with the backup display.

All operating values available in the system as well as alarms, shutdowns, system alarms and the engine operating status are displayed on the LOP. Furthermore, some basic operator actions are handled from the LOP:

- Engine start
- Engine stop
- Acknowledgment and reset of alarms, shutdowns, etc.
- Manual emergency stop
- Engine speed increase/decrease
- Clutch engagement/disengagement (optional)
- Pitch setting (optional)

Interfaces to External Systems

These interfaces are used for data exchange with the ship alarm system or with integrated automation systems (IAS).

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Status messages, alarms and safety measures generated in the system can be transmitted. All measured values and alarms recorded by SaCoSone can be transmitted.

SaCoSone uses the Modbus RTU protocol.

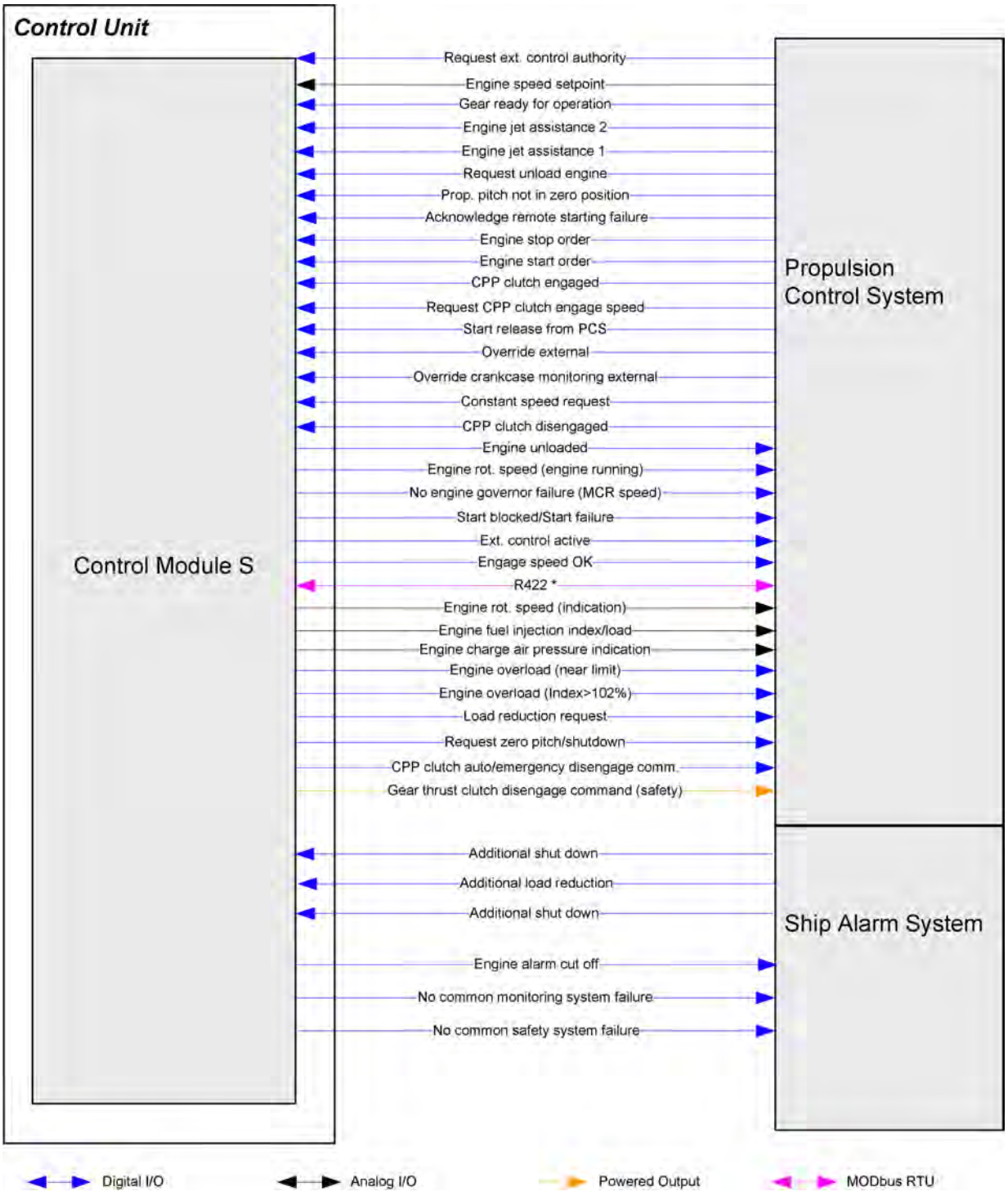
The transmitted data includes measured values and engine alarm or status information.

Measured values are digitised analogue sensor values that are stored in a fixed register of the control module (Small, CMS). Measured values include mean values (pressure, temperature) if monitoring must be carried out the machine alarm system according to the classification rules. A signed integer data type of 16 bit is used. The measured values are scaled with a constant factor to give decimal numbers.

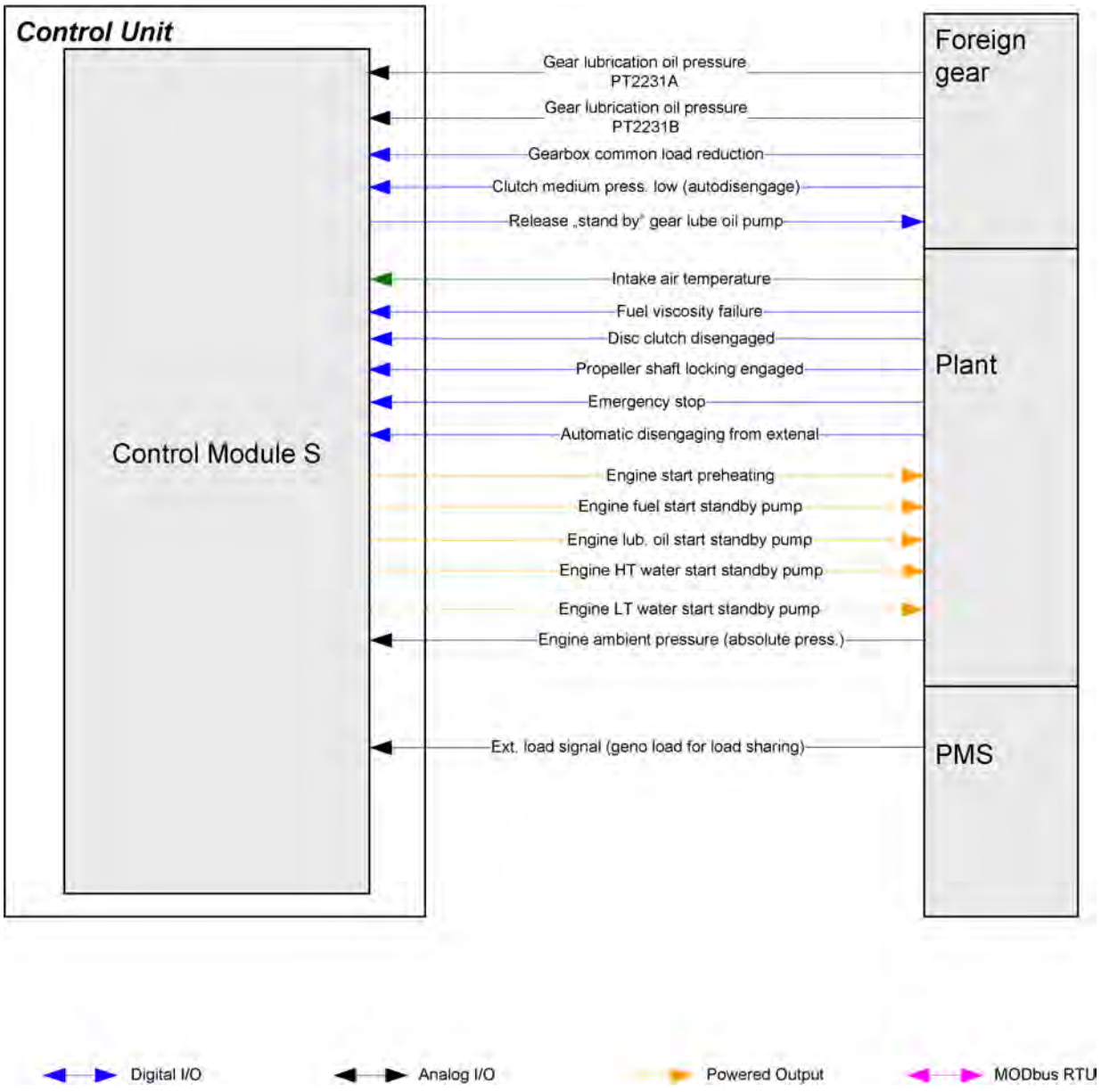
Information on pre-alarms, shut-downs and the SaCoSone system status are available as individual bits in defined registers. An unsigned integer data type with 16 bit is used. The relevant bits for alarm or status information are set to the binary value “1” if the event is active.

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Interface



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Readings and alarm information of the oil mist detector

In compliance with the classification regulations, all readings and the alarm information from the oil mist detector, which are transmitted over Modbus, shall be capable of being read from a safe location away from the engine.

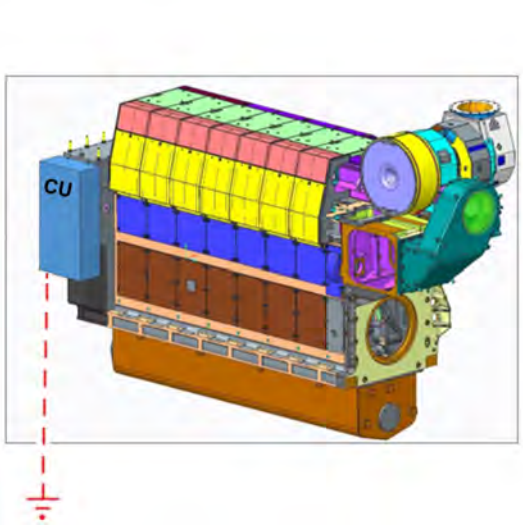
System Requirements

Equipotential bonding and EMC

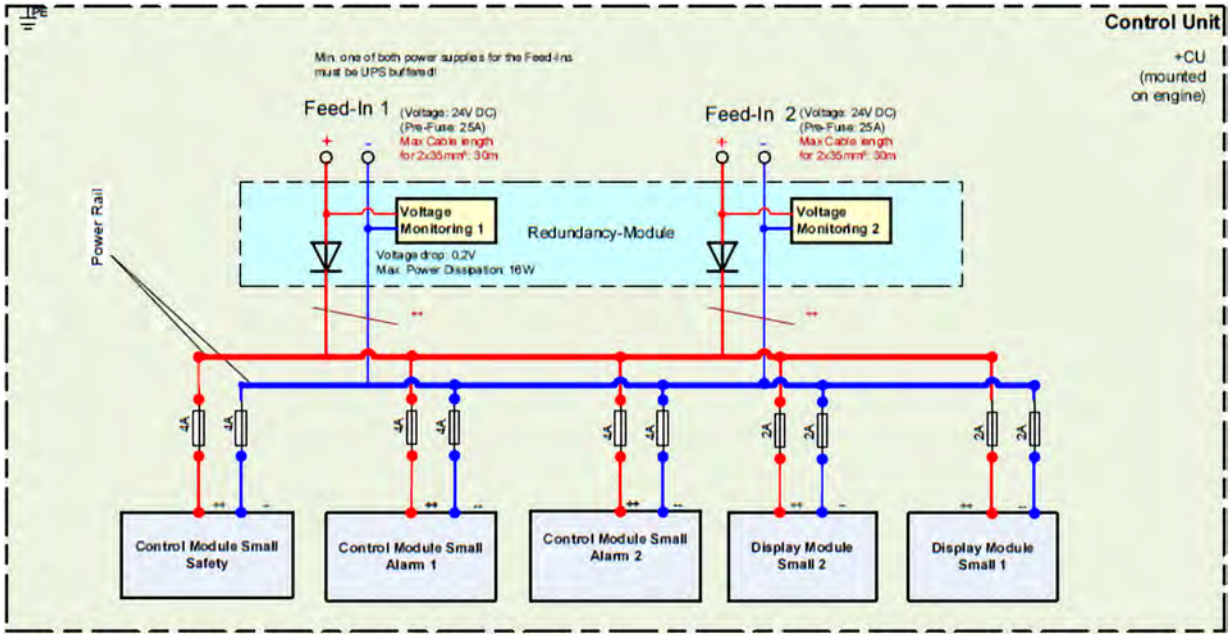
The control unit manufacturer and the operator must take measurements in accordance with the EMC Directive and ensure the plant's electromagnetic compatibility (control unit + machines).

For more information on the installation requirements, see the document "Customer installation requirements".

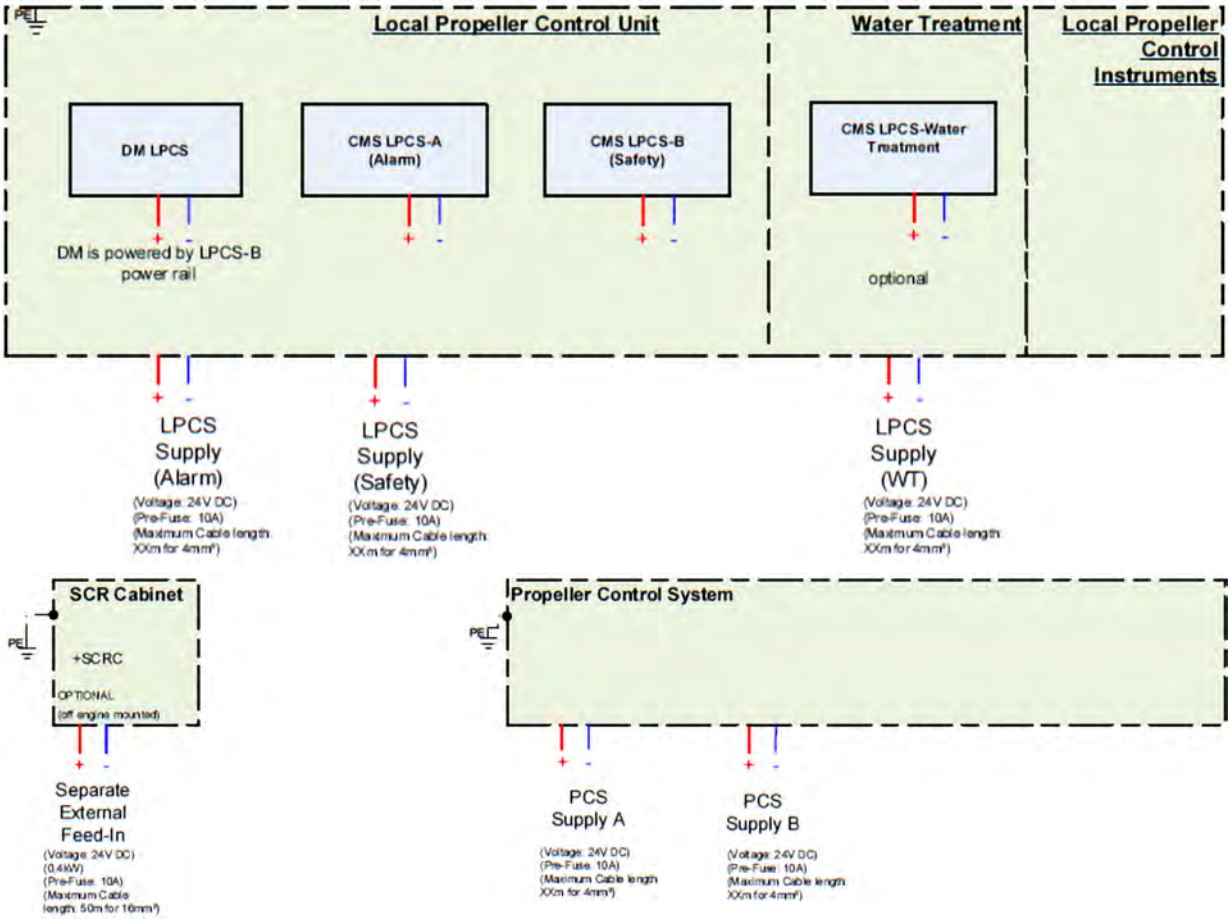
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Power supply



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The system must provide electricity for the automation and monitoring system. As a rule, a redundant, uninterruptible 24 V DC power supply (+20 % -30 % and max. residual ripple 10%).

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Technical data

Control Unit

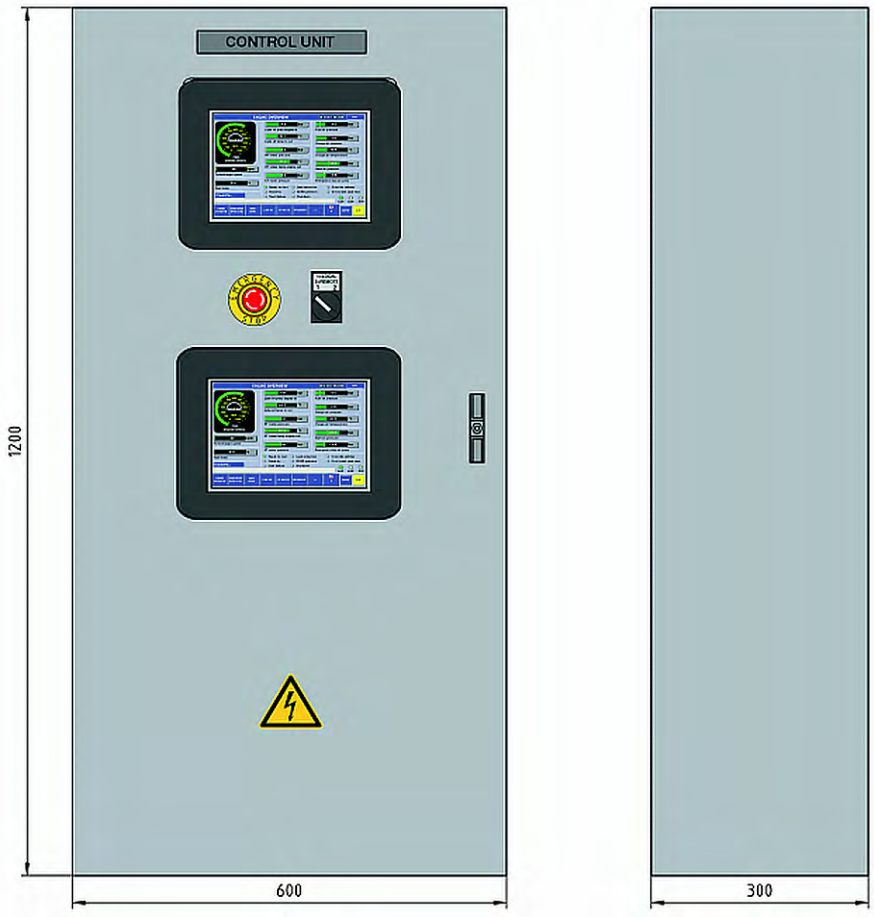


Figure 6: Control unit dimensions

L21/31 dimensions and weight

Width	300 mm
Height	1200 mm
Length	600 mm
Weight	approx. 64 kg

L27/38 dimensions and weight

Width	300 mm
Height	1200 mm
Length	600 mm
Weight	approx. 50 kg

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Additional Information

SaCoSone EXPERT

SaCoSone EXPERT is a parameter tool for configuring and parameterising two-stroke and four-stroke diesel engines for the propulsion of ships and stationary power plants equipped with the SaCoSone control system.

The Ethernet interface on the display module can be used to connect SaCoSone EXPERT.

Abbreviations

Abbreviation	Meaning
CMS	Control Module Small
CU	Control unit
DM	Display module
LPCU	Local propulsion control unit
LPCS	Local propulsion control system
LOP	Local operating panel (integrated into control unit)

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Operation data and set point

Engine load @ MCR

		Normal value at full load at ISO conditions		Alarm set point 100 % load		Delay sec.	Reduced load of engine	Shutdown of engine
				Low	High			
Lubricating oil system								
Temperature after cooler (inlet engine)	°C	TI 21	68-73		80	2	85	
Pressure before filter	bar	PI 21	4.2-5.0			4		
Pressure after filter (inlet engine) < 800 rpm > 800 rpm	bar	PI 22	4.0-4.8	 2.0 2.8		 4 4	 1.9 2.6	 1.8 2.5
Pressure drop across filter	bar	PDAH 21-22	0.1-0.3		0.8	15	1.3	
Pressure inlet turbocharger	bar	PI 23	1.3-2.2 (C)	1.0		4		
Lubrication oil level		LAL 28		low level		4		
Temperature main bearing	°C	TI 29	80-95		103	4	105	108
Fuel oil system								
Pressure after filter - MDO	bar	PI 40	5-8	1		4		
Pressure after filter - HFO	bar	PI 40	8-10 (A)	4-6 (E)		4		
Leaking oil					high leakage level			
Temperature inlet engine - MDO	°C	TI 40	20-40		45	2		
Temperature inlet engine - HFO	°C	TI 40	80-140					
Cooling water system								
Pressure LT system, inlet engine < 850 rpm > 850 rpm	bar	PI 01	2.0-3.0	 1.1 (B) 1.7 (B)		4		
Pressure HT system, inlet engine < 850 rpm > 850 rpm	bar	PI 10	2.0-3.0	 1.1 (B) 1.7 (B)		4	 1.0 1.6	 0.9 1.5
Temperature HT system, outlet engine	°C	TI 12	75-85		92	2	95	97
Temperature HT system, inlet engine	°C	TI 10	65-70	45	80	2		
Temperature LT system, inlet engine	°C	TI 01	25-40		65	2		

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		Normal value at full load at ISO conditions		Alarm set point 100 % load		Delay sec.	Reduced load of engine	Shutdown of engine
				Low	High			
Temperature LT system, outlet engine	°C		35-45					
Exhaust gas and charge air								
Exhaust gas temperature inlet TC	°C	TI 62	480-530		570 (N)	30	590	
Exhaust gas temperature outlet cyl	°C	TI 60	370-450	average (K) ±100	510 (N) average (K) ±50	30	530 average (K) ±70	
Exhaust gas temperature outlet TC	°C	TI 61	300-350		450 (N)	30		
Charge air pressure after cooler	bar	PI 31	3.0-3.2					
Charge air temperature after cooler	°C	TI 31	40-55	25	55	2	58	
Starting air system								
Press. inlet engine TDI Gali	bar	PI 1312	 7-8 (max 10) < 30	 6.5 15		4		
Speed control system								
Engine speed	rpm	SI 90	1000		1100	0		1150
Turbocharger speed	rpm		(L)		97%		100%	
Safety control air pressure	bar	PI 1322	7-8	6		4		

Remarks to individual parameters

A. Fuel oil pressure, HFO operation

When operating on HFO, the system pressure must be sufficient to depress any tendency to gasification of the hot fuel.

The system pressure has to be adjusted according to the fuel oil preheating temperature.

B. Cooling water pressure, alarm set points

As the system pressure in case of pump failure will depend on the height of the expansion tank above the engine, the alarm set point has to be adjusted to 0.4 bar plus the static pressure. The static pressure set point can be adjusted in the display module.

C. Lubricating oil pressure, offset adjustment

At charge air pressure below 1.0 bar the lub. oil pressure to turbocharger is normal at 0.6 ±0.1 bar.

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The read outs of lubricating oil pressure has an offset adjustment because of the transmitter placement. This has to be taken into account in case of test and calibration of the transmitter.

E. Set points depending on fuel temperature

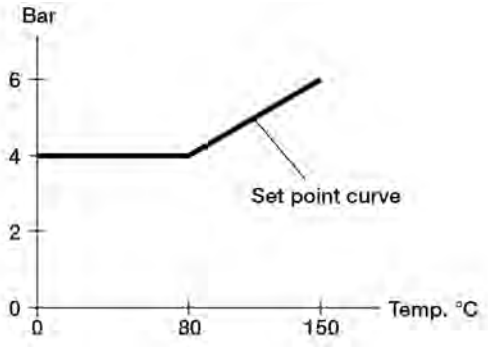


Figure 1: Set point curve

F. Start interlock

The following signals are used for start interlock/blocking:

1. Turning must not be engaged
2. Engine must not be running
3. "Remote" must be activated
4. No shutdowns must be activated.
5. The prelub. oil pressure must be OK, 20 min. after stop.
6. "Stop" signal must not be activated

G. Start failure

If remote start is activated and the engine is in blocking or local mode or turning is engaged the alarm time delay is 2 sec.

Start failure will be activated if revolutions are below 50 rpm within 5 sec. from start or revolutions are below 210 rpm 10 sec. from start.

Start failure alarm will automatically be released after 30 sec. of activation.

H. Alarm hysterese

On all alarm points (except prelub. oil pressure) a hysterese of 0.5% of full scale are present. On prelub. oil pressure alarm the hysterese is 0.2%.

I. Engine run signal

The engine run signal is activated when engine rpm >950 or lube oil pressure >3.0 bar or TC rpm >5000 rpm.

If engine rpm is above 210 rpm but below 950 rpm within 30 sec. the engine run signal will be activated.

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K. Exhaust gas temperatures

The exhaust gas temperature deviation alarm is normally ±50° C with a delay of 1 min., but at start-up the delay is 5 min. Furthermore the deviation limit is ±100° C if the average temperature is below 200° C.

L. Turbocharger speed

Normal value at full load of the turbocharger is dependent on engine type (cyl. no) and engine rpm. The value given is just a guide line. Actual values can be found in the acceptance test protocol or name plate on turbocharger.

N. Alarm at 110% load

During shop test of 110% load it can occur that there is exhaust gas temperature alarm, this can be caused to high air temperature before compressor combined with low ambient air pressure.

10° C change in ambient temperature correspond to approx. 15° C exhaust gas temperature change.

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Modbus interface - SaCoS

Data Bus Interface (Machinery Alarm System)

This interface serves for data exchange to ship alarm systems or integrated automation systems (IAS). The status messages, alarms and safety actions, which are generated in the system, can be transferred. All measuring values and alarms acquired by SaCoSone PROPULSION are available for transfer. The Modbus RTU protocol is the standard protocol used for the communication with ship alarm system.

Modbus RTU protocol

The bus interface provides a serial connection. The protocol is implemented according to the following definitions:

- Modbus application protocol specification, Modbus over serial line specification and implementation guide,

Available interface:

- RS422 – Standard, 4 + 2 wire (cable length <= 100m), cable type as specified by the circuit diagram, line termination: 120 Ohms

Settings

The communication parameters are set as follows:

Modbus Slave	SaCoS
Modbus Master	Machinery alarm system
Slave ID (default)	1
Data rate (default)	57600 baud
Data rate (optionally available)	4800 baud 9600 baud 19200 baud 38400 baud 115200 baud
Data bits	8
Stop bits	1
Parity	None
Transmission mode	Modbus RTU

Function Codes

The following function codes are available to gather data from the SaCoSone controllers:

Function Code	Function Code (hexadecimal)	Description
1	0x01	read coils
3	0x03	read holding registers
5	0x05	write coil
6	0x06	write single register
15	0x0F	write multiple coils
16	0x10	write multiple registers

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22	0x16	mask write register
23	0x17	read write multiple registers

Message Frame Separation

Message frames shall be separated by a silent interval of at least 4 character times.

Provided Data

Provided data includes measured values and alarm or state information of the engine.

Measured values are digitized analogue values of sensors, which are stored in a fixed register of the Control Module Small. Measured values include media values (pressures, temperatures) where, according to the rules of classification, monitoring has to be done by the machinery alarm system. The data type used is signed integer of size 16 bit. Measured values are scaled by a constant factor in order to provide decimals of the measured.

Pre-alarms, shutdowns and state information from the SaCoSone system are available as single bits in fixed registers. The data type used is unsigned of size 16 bit. The corresponding bits of alarm or state information are set to the binary value „1“, if the event is active.

Contents of List of Signals

For detailed information about the transferred data, please refer to the ”list of signals“ of the engine’s documentation set. This list contains the following information:

Field	Description
Address	The address (e.g.: MW15488) is the software address used in the Control Module Small.
HEX	The hexadecimal value (e.g.: 3C80) of the software address that has to be used by the Modbus master when collecting the specific data.
Bit	Information of alarms, reduce load, shutdown, etc. are available as single bits. Bits in each register are counted 0 to 15.
Meas. Point	The dedicated denomination of the measuring point or limit value as listed in the „list of measuring and control devices“.
Description	A short description of the measuring point or limit value.
Unit	Information about how the value of the data has to be evaluated by the Modbus master (e.g. „°C/100“ means: reading a data value of „4156“ corresponds to 41,56 °C).
Origin	Name of the system where the specific sensor is connected to, or the alarm is generated.
Signal range	The range of measured value.

Life Bit

In order to enable the alarm system to check whether the communication with SaCoS is working, a life bit is provided in the list of signals (MW15861; Bit2). This Bit is alternated every 10 seconds by SaCoS. Thus, if it remains unchanged for more than 10 seconds, the communication is down.

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Shaftline earthing device installation

Scope and field of application

A difference in the electrical potential between the hull and the propeller shaft will be generated due to the difference in materials and to the propeller being immersed in sea water.

In some cases, the difference in the electrical potential has caused spark erosion on the thrust, main bearings and journals of the crankshaft of the engine.

In order to reduce the electrical potential between the crankshaft and the hull and thus prevent spark erosion, a highly efficient shaftline earthing device must be installed.

The shaftline earthing device should be able to keep the electrical potential difference below 50 mV DC. A shaft-to-hull monitoring equipment with a mV-meter and with an output signal to the alarm system must be installed so that the potential and thus the correct function of the shaftline earthing device can be monitored.

Note that only one shaftline earthing device is needed in the propeller shaft system.

Design description

The shaftline earthing device consists of two silver slip rings, two arrangements for holding brushes including connecting cables and monitoring equipment with a mV-meter and an output signal for alarm.

The slip rings should be made of solid silver or back-up rings of cobber with a silver layer all over. The expected life span of the silver layer on the slip rings should be minimum 5 years.

The brushes should be made of minimum 80% silver and 20% graphite to ensure a sufficient electrical conducting capability.

Resistivity of the silver should be less than 0.1µ Ohm x m. The total resistance from the shaft to the hull must not exceed 0.001 Ohm.

Cabling of the shaftline earthing device to the hull must be with a cable with a cross section not less than 45 mm^2. The length of the cable to the hull should be as short as possible.

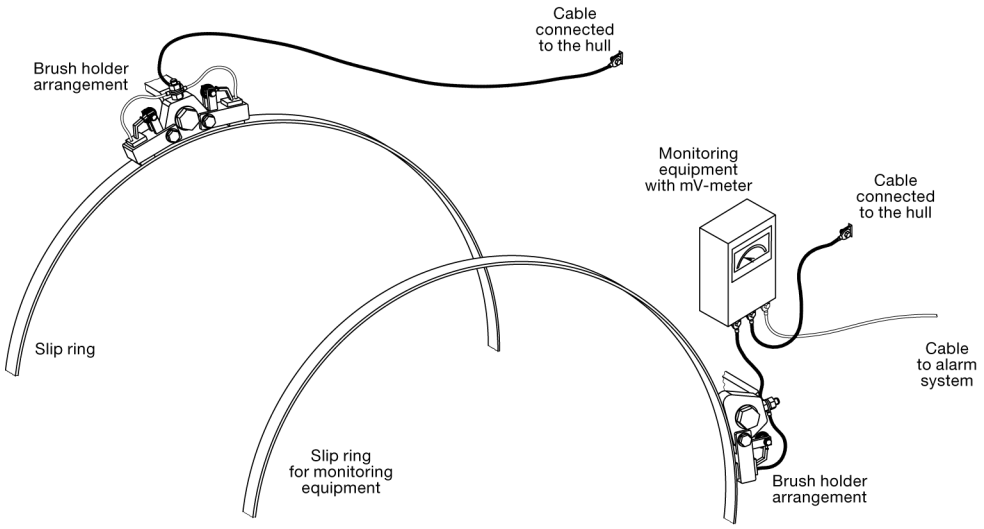
Monitoring equipment should have a 4-20 mA signal for alarm and a mV-meter with a switch for changing range. Primary range from 0 to 50 mV DC and secondary range from 0 to 300 mV DC.

When the shaftline earthing device is working correctly, the electrical potential will normally be within the range of 10-50 mV DC depending of propeller size and revolutions.

The alarm set-point should be 80 mV for a high alarm. The alarm signals with an alarm delay of 30 seconds and an alarm cut-off, when the engine is stopped, must be connected to the alarm system.

Connection of cables is shown in the sketch, see Fig. 5.17.01.

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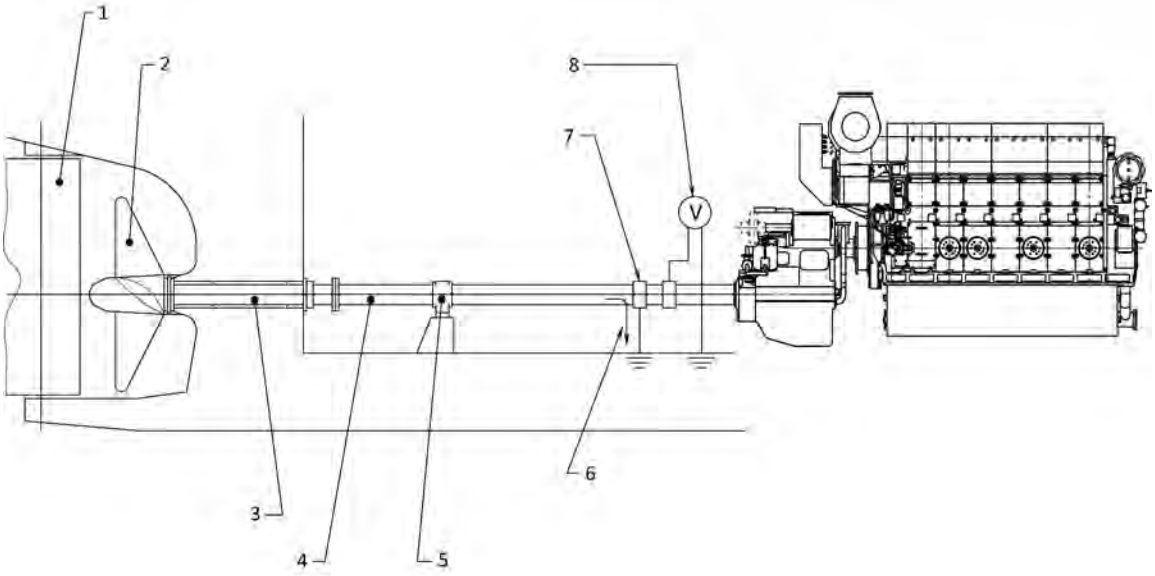


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Figure 1: Connection of cables for the shaftline earthing device

Shaftline earthing device installation

The shaftline earthing device slip rings must be mounted on the foremost intermediate shaft as close to the engine as possible, see Figure 2.



1 Rudder
2 Propeller
3 Propeller shaft
4 Intermediate shaft
5 Intermediate shaft bearing
6 Current
7 Shaftline earthing device
8 Voltage monitoring for shaft-hull potential difference

Figure 2: Installation of shaftline earthing device.

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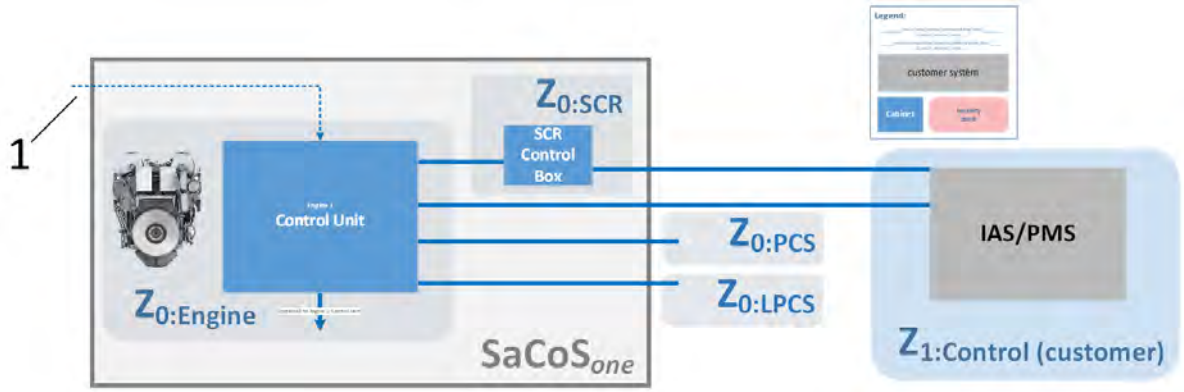
Cybersecurity guidelines

Cybersecurity guidelines

Definitions and abbreviations

Definition or abbreviation	Definition
CM-S	Control Module Small
CU	Control unit
DM	Display module
ECR	Engine control room
ER	Engine room
eToken	SaCoSone Security Token (Thales Group eToken 5110+)
EXPERT	Everllence tool for SaCoS parameterisation
IAS	Integrated alarm system (see also “customer network”)
M	Injection module
LOP	Local operating panel
LPCS	Local propulsion control system
PCS	Propeller control system
PMS	Power management system
SaCoSone	Safety and control system on engine
SCR	Selective catalytic reduction
SDI	SaCoSone device image

System overview



1 Everllence (licensee service device

Figure 1: SaCoSone propulsion: Zones and connections (simplified)

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System overview shows a simplified overview of the SaCoSone system (propulsion variant), and the zones and connections relevant for cybersecurity analysis

The system is divided into the following main security zones (see Figure 1):

- $Z_{0:Engine}$: Devices in this zone implement the main functionality of the engine control system.
- $Z_{0:SCR}$: Devices in this zone implement the SCR functionality and enable local monitoring and control of the SCR system.
- $Z_{0:PCS}$: The propeller control system (PCS) is in this zone.
- $Z_{0:LPCS}$: The local propulsion control system (LPCS) is in this zone.
- $Z_{1:Control\ (customer)}$: This zone contains the ship's integrated alarm and/or power management system (IAS/PMS).

Most of the devices making up the control system are installed in locked control cabinets or units. Install in restricted areas such as engine rooms (ER) or engine control rooms (ECR). Devices or systems that are not part of the system under consideration but are connected to it via hardwiring are the responsibility of the integrator and must meet the relevant requirements such as IACS UR E27. In addition, the PCS and LPCS systems must also meet the same requirements.

Physical security of SaCoS

The control system's devices and communication links must be physically protected against unauthorized access at all times (for example, including during commissioning), for example by installing them in restricted access areas such as engine rooms (ER). Access to the control system must be logged. The operator/integrator is responsible for assessing the security level of these protective measures; the system context, system purpose, system location, assumptions about actual and future threats to the operator's business operations, and applicable regulations must be considered.

Secure access and storage of SaCoS data

It is necessary to keep the data created by or for SaCoS secure and protected against access by third parties.

Securing $Z_{1:Control(Customer)}$

$Z_{1:Control(Customer)}$ must be a trusted network in the sense of IACS UR E27.

A compromised SaCoS can also pose a threat to customer networks and devices by infecting/compromising the customer systems within them. The operator/integrator can implement extra measures such as installing more network security devices to protect against this threat.

Maintaining network segmentation

Network segmentation is one of SaCoS's key protection measures. Therefore, the network structure set up by Everllence must not be changed.

Specifically, the following guidelines must be adhered to:

- Do not bridge Individual network segments.
- Do not connect additional devices to the SaCoS network segments. This does not apply to temporary connections for proper commissioning or service purposes (for example, loading new control unit software) using suitable tools. The tools used must meet general cybersecurity require-

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ments and, in particular, the applicable requirements of the relevant standards (for example, IACS UR E27). The user is responsible for proper use. Only devices managed by the user's respective IT organization (operator, integrator, service, manufacturer, ...) may be used.

Preparation for security incidents

Residual risks may remain even if the present guidelines are followed. The operator must prepare for possible security incidents to be able to react to them promptly. This includes the creation of an incident response plan, which must address the following points, among others:

- Obtain spare parts to replace SaCoSone modules that have failed or been compromised due to an attack.
- If changes are made to the system (for example, parameterization of the system), these changes must be saved accordingly.
- Report the security incident to the engine manufacturer's first-level support via a secure channel and follow the instructions.
- Save all data relevant to the cause (may require assistance from the engine manufacturer's first-level support). This includes, but is not limited to, the access logs and general audit logs generated by the customer devices and the plant.
- Analyze the data and take steps to address the vulnerability that led to the incident.

The operator is also instructed to monitor the system for indications of a possible security incident as far as possible.

Safe disposal

The operator is responsible for the security of potentially sensitive data when disposing of the devices.

User account management

The operator and service personnel are responsible for managing the access data for SaCoS devices.

Security incident report

Security incidents affecting SaCoS must be reported to the engine manufacturer's first-level support.

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Guidelines for cables and wiring

General specification

All electronic control systems are provided or accepted by Everllence. Electrical equipment must be selected and located so that it is unaffected by water, steam, oil, or oil fumes to which it is likely to be exposed. Instrumentation must be as specified according to the drawings for the actual plant concerned.

All boxes for electronic equipment must be closed when work inside the boxes is not in progress. Measures for preventing electrostatic discharge (ESD) must be taken when handling and working with electronics.

Electrostatic discharge can damage equipment and impair electrical circuitry. It occurs when electronic components are improperly handled and can result in complete or intermittent failures. Cables can be grouped in different interference classes to Electro Magnetic Interference (EMC) and sensitivity.

Cables in different classes are to be laid separately and the distance between the different classes is to be maximized. Redundant cable systems are to be mounted in such a way that the two systems are separated.

Cables often act as large effective antennas, carrying common mode currents to the apparatus. These currents may cause interference not only at the input and output circuits directly connected to the leads, but also at circuits deeper inside the apparatus.

Use of ferrules

Area of application for ferrules

In case of bolted connections (e.g. terminal strip, five pin connector), corresponding ferrules must be used on the wire end.In case of bolted connections (e.g. terminal strip, five pin connector), corresponding ferrules must be used on the wire end.

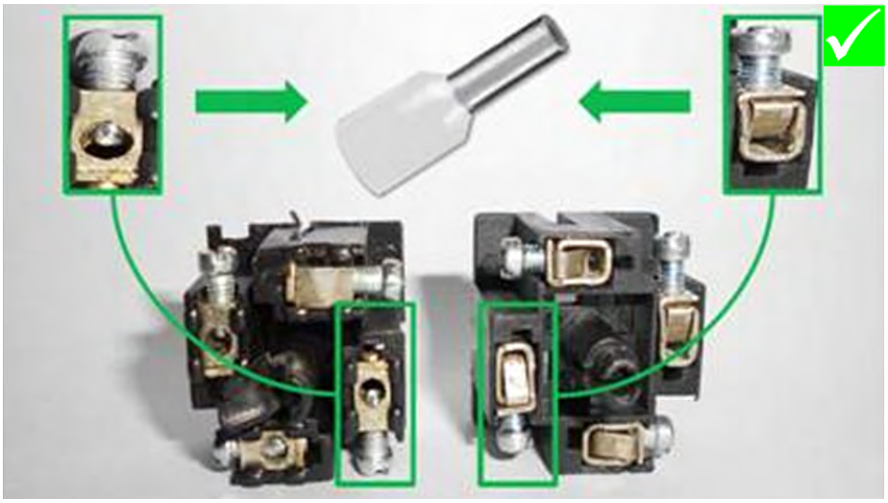


Figure 1: Using ferrules

Area of application for stripped wires without ferrules

For spring terminals, the individual wires must be clamped without ferrules.

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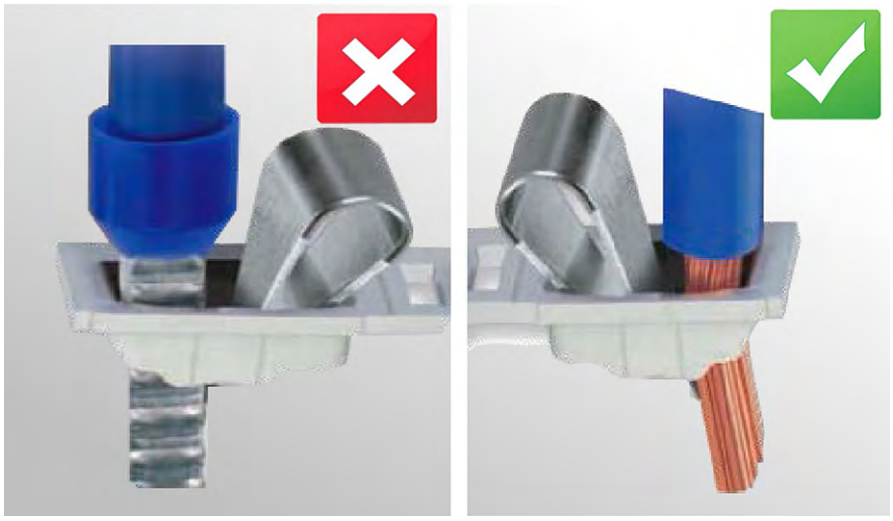


Figure 2: Using ferrules

Cable and wire marking

Internal wires and equipment

Terminals, wires, and electrical equipment inside a cabinet or junction box must be marked in accordance with the electrical documentation. The electrical documentation provides the needed information for markings and tags.

Terminals for circuits with different system voltages must be clearly separated and clearly marked with the voltage.

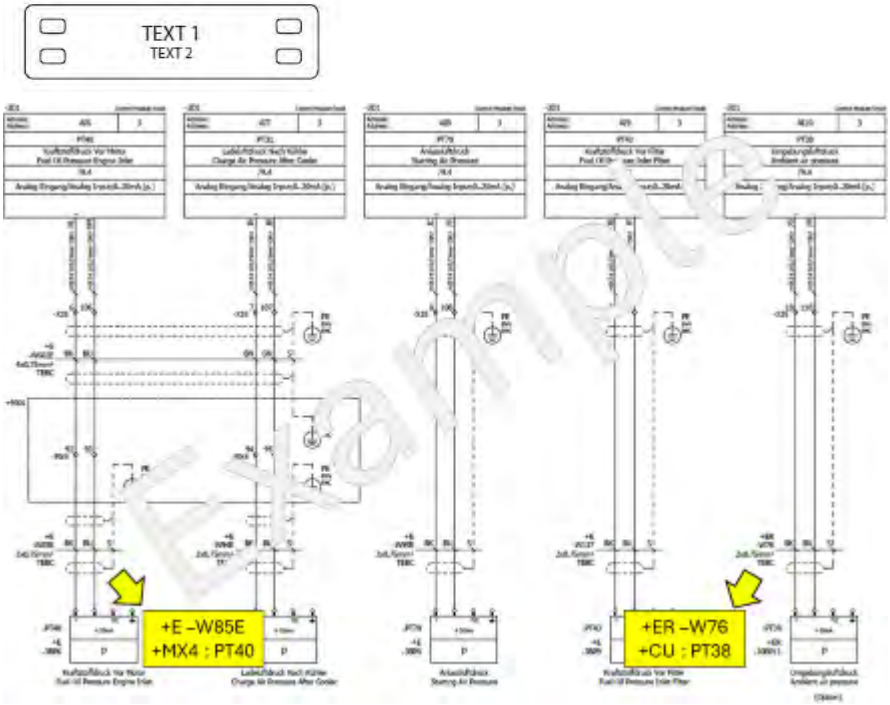
In local-end connection labelling, each core end shall be labelled with the designation of the terminal to which it is connected. This permits the core to be removed and reconnected to the terminal without having to refer to a connection table or connection diagram.



Figure 3: Correct implementation with single wire numbering

Cables

A cable must be tagged the same at both ends. The first line on the label must contain the cable name and the second line must contain the tag of cable origin and termination. The electrical documentation provides the needed information for markings and tags.



Marking of Intrinsically Safe Cabling

Special markings and identification are required when operating with intrinsically safe circuits. Cables containing intrinsically safe circuits must be marked with a light blue shrink tubing in both ends. Alternatively the cable itself can be colored light blue.

If the intrinsically safe cable has a correct termination in EMC-glands (shielded cable), it may be laid together with other none intrinsically safe cables.

If cable is not shielded, a respect distance of at least 50mm to other cables (not intrinsically safe) must be kept.

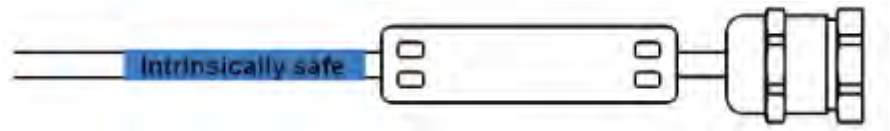


Figure 4: Light blue tube on intrinsically safe circuit's identifications.

Mounting guidelines

A technically flawless installation of the engine or the plant is a basic requirement for a failure-free and trouble-free operation.

Cable trays, guards, band steel, supports and cable ties are to be made of the quality according to the drawings for the actual plant concerned and general Everllence specifications.

Cable runs should be as straight and accessible as possible.

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The correct laying and fixing of cables, cable harnesses and wires is very important. Chafing might occur due to vibrations, which might then be responsible for earth faults.

By routing cables correctly, it has to be ensured that there will be no damage during operation considering the prevailing operating conditions.

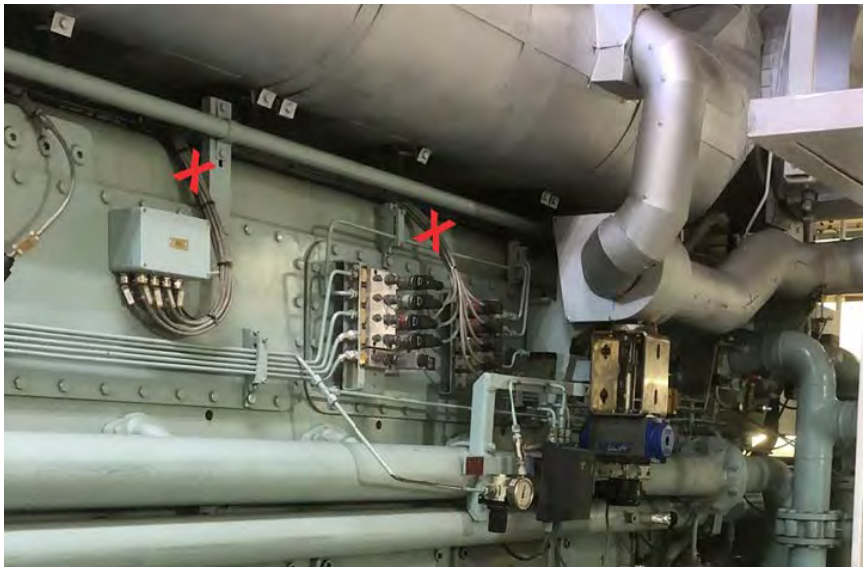


Figure 5: Incorrect routing of control cables. The cables will be exposed to high temperatures from the

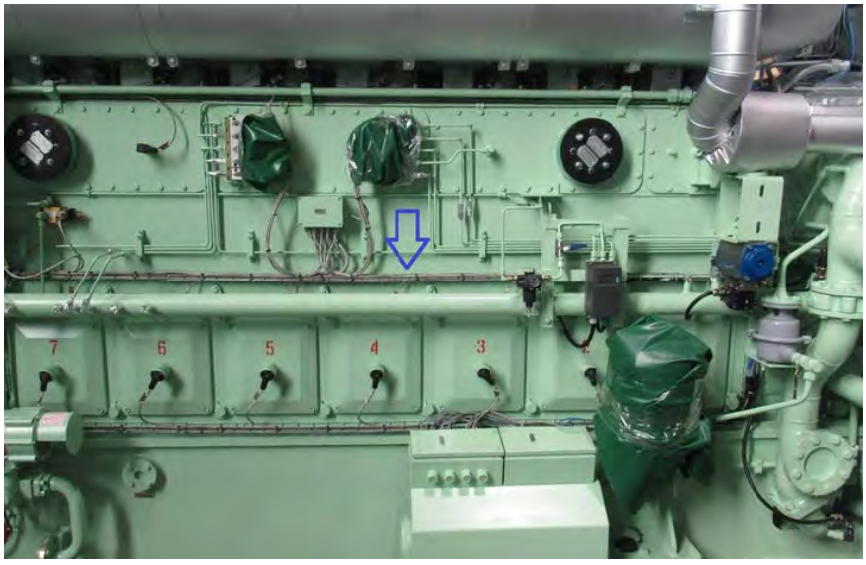


Figure 6: Correct routing of control cables in safe distance from exhaust receiver.

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Figure 7: Exhaust gas temperature sensor cables must be routed in a cable tray distanced as far as possible

Cable ends from cable tray to sensor should be laid in suitable length allowing connector disconnection/ sensor removal.
When selecting cable ties, the following has to be observed:

- Suitable for the temperature range of the mounting position.
- Appropriate length and width (tensile strength).
- Non-inflammability.
- High resistance against environmental factors at the mounting position.

Cable ties must not be moveable after being tightened. After tightening the cable ties, cut off the excessive ends of the cable ties completely so that they are flush with any surface, in order to reduce the risk of injury.

There must not be burrs or sharp edges at the cable outlets so that the cables are not damaged.



Figure 8: Nice and smooth - Acceptable.

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Figure 9: Sharp edges and lead wrapping - Not acceptable.

When routing cables, ensure that cables are not bent, crushed or pulled over sharp edges.



Figure 10: Edge protection as protection against sharp edges.

The cables must be bundled neatly.



Figure 11: The left illustration shows incorrect bundling of lines; the illustration on the right is correct

Cable glands and connector sockets should not be mounted pointing upwards in order to avoid the risk of liquid penetration.

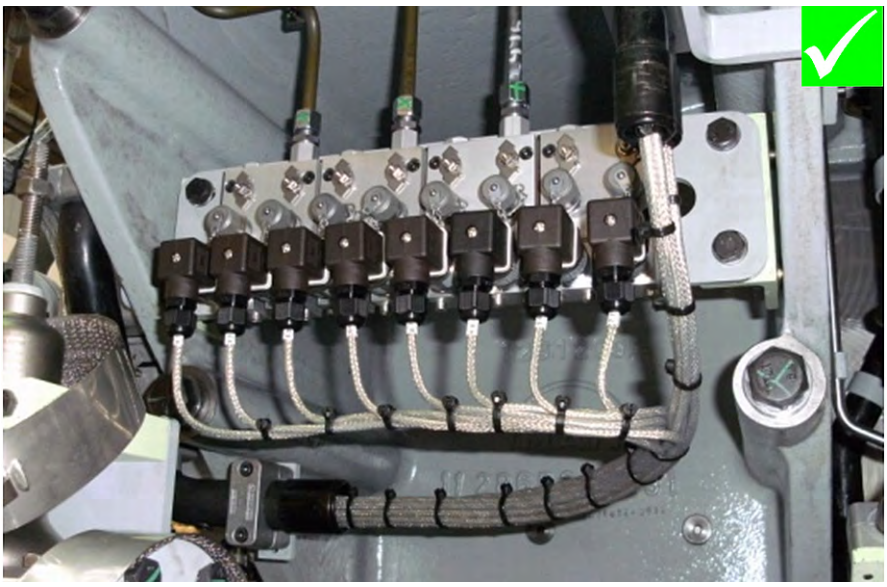


Figure 12: Cable glands for sensors should point downward to avoid fluid insertion.

Cables which might be exposed to higher temperatures must be routed so that they are protected against the influence of excessive temperature.

Loose cable loops must not occur at the engine. It is only admissible as an exceptional measure if it is not possible otherwise to avoid cable loops due to constructional reasons.

If it is not possible to shorten the cable to the appropriate length, the excess length has to be combined.

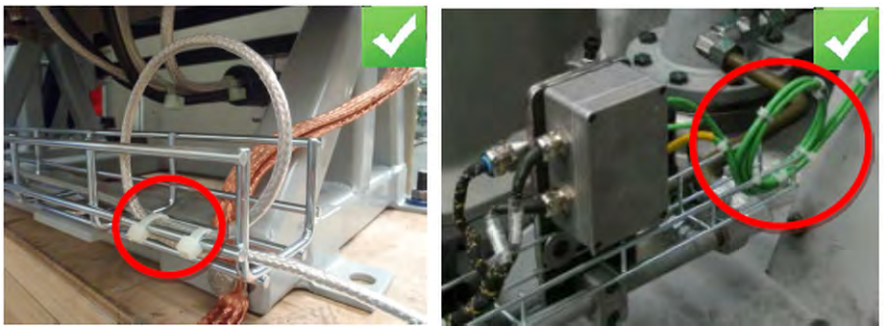


Figure 13: The loop has to be fixed, distributed evenly, to the cable routing either with at least two cable ties or with four cable ties for a double loop. Observe the appropriate bending radius.

The cables for the alternator auxiliaries (automatic voltage regulator, winding temperature sensors, potentiometer etc.) must also be with shielded cables and grounded accordingly.

All cables from the diesel junction box must be shielded including d.c. power supply cables. The shield must be grounded correctly in the EMC cable glands which are installed in the junction box.

Junction boxes are to be fitted with an EMC type cable gland and lock nut at the cables entry. It is vital that the cable screen is fitted correctly.

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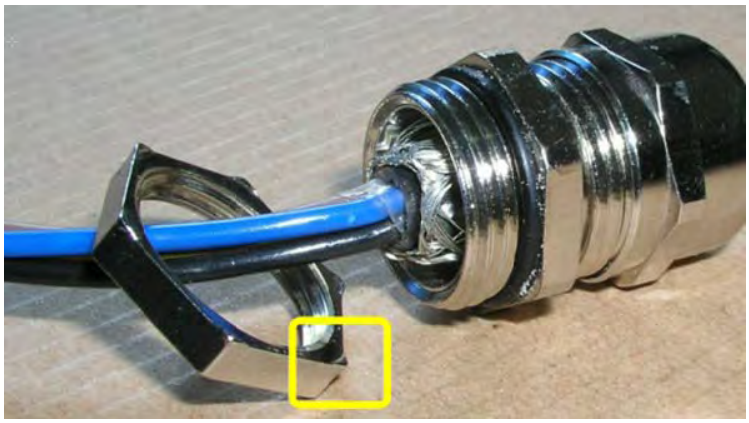


Figure 14: Correct installation of EMC type cables.

To avoid electromagnetic interference the shield has to be connected at both ends.

Any conductor in a cable, which is spare or not used, must always be grounded (chassis, cable trough, cabinet etc.) at both ends.

The safety system must have its own power supply. According to the classification societies it is not allowed to feet both safety system and monitoring system with the same cable.

Electrical equipment must be placed in such a way that, as far as practicable, it is not exposed to the risk of mechanical damage.

Bolts and nuts securing current-carrying parts must be effectively locked so that they cannot work loose by vibration.

Electrical equipment must be installed away from locations where flammable gases or vapours are liable to accumulate, except where the installation of equipment for explosive gas atmosphere is provided.

Cable trays are to be fixed to the engine or to ship structure.

Sharp edges are unacceptable where cables enter a cable-tray.



Figure 15: Welded-on brackets



Figure 16: Cable tray clamped to engine.



Figure 17: Cable ends from cable conduit to sensor laid in suitable length allowing connector disconnection/

When mounted near hot/warm surfaces, distance pieces must be added between the hot/warm surface and the cable tray, so as to avoid heating up and damaging of the cables.

To avoid damaging the cable, the minimum bending radius for each type of cable is determined. The minimum bending radius depends on whether the cable is armoured or not. Armoured cables must not be bent to a radius less than eight times the overall cable diameter. Unarmoured cables must not be bent to a radius less than six times the overall cable diameter. Makers specifications takes priority.

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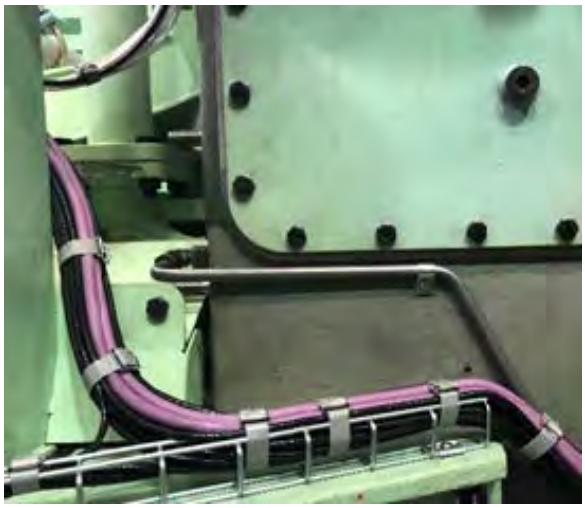


Figure 18: Acceptable bending radius and fastening.

General guidelines for cabling and wiring work in junction boxes and cabinets. Conductors must be supported internally in the cabinets and the junction boxes; they must be tied together and arranged in a way that prevents abrasive wear on the conductor insulation.

Shorten and route the wires so that they do not chafe on the interior of the intermediate terminal box.

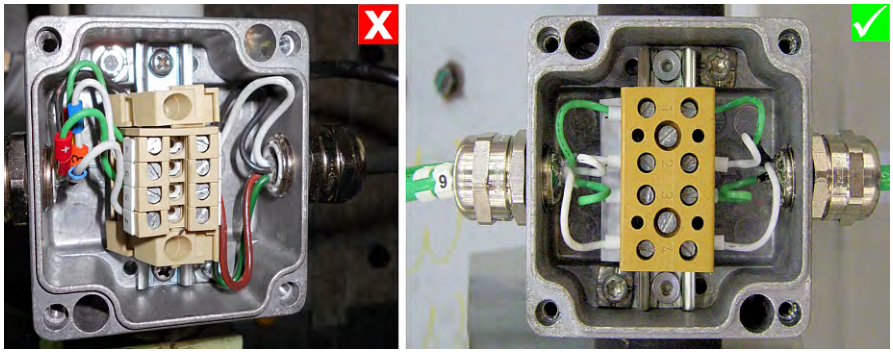


Figure 19: (Left) Wires chafing on the housing; (Right) Wires are not chafing.

In cabinets and in junction boxes with support bars, the conductors must be tied to the support bar every 30 mm. Rubber coated support bars are recommended.

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Figure 20: Junction box with correct installed and supported wires.

If support bars are omitted, the conductors must be bundled and tied together with cable ties to form a solid body that will not cause abrasive wear between the conductors.

Unused conductors must be tied to the support bar in the same way as used conductors. They must also be separately insulated or terminated according to the diagram. Conductors with live signals must not be grounded. Individual conductors must be cut to the correct length; excessive conductor length is not accepted.

To ensure that the applied cable ties will not break prematurely due to the environment, cable ties material should be “Heat Stabilized Nylon 6.6” or similar.

Unused holes and cable glands in all junction boxes and gland plates must be plugged to maintain the IP protection class.



Figure 21: Unused holes and cable glands plugged.

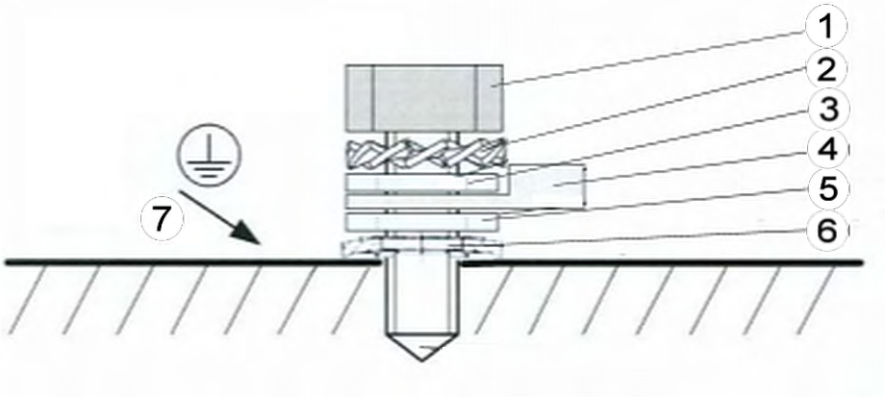
General cleanliness is to be maintained at all times. After finishing cabling in a cabinet or junction box it is important that the interior of the cabinet or junction box is cleaned for small pieces of metal and cable residue to avoid short circuits in the electronics.

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Figure 22: Cables coming out of cable glands/routings must first run straight before the bending radius begins.

When installing earthing straps use only galvanised or stainless-steel materials. The earthing strap is made of copper or coated with copper. Lock washer and flat washers must be used as below.



1 Bolt
2 Serrated lock washer (DIN 6798 A, external serration)
3 Washer (DIN 125)
4 Cable lug or earthing strip
5 Washer (DIN 125)
6 Contact washer
7 Attach a PE symbol

Figure 23: Earthing straps mounting



Figure 24: Incorrect attachment of earthing strap (left) and correct one on the right.

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The wires at the motor terminal board (internal and external wires and the protective conductor terminal) have to be routed so that they do not chafe on the inside of the terminal block.

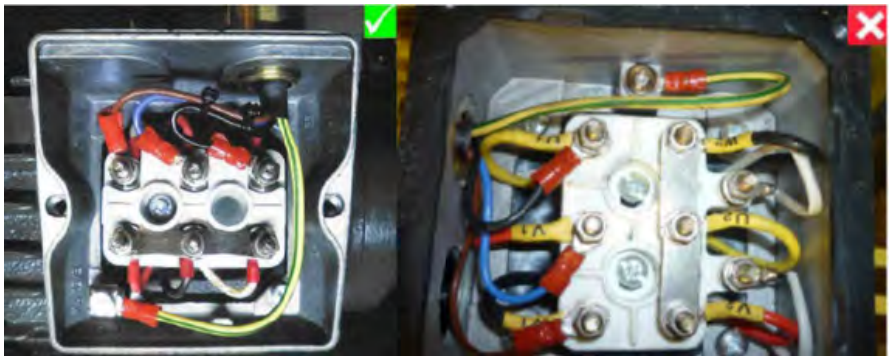
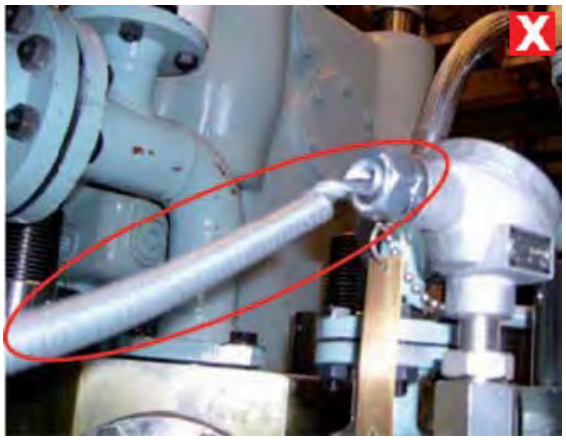
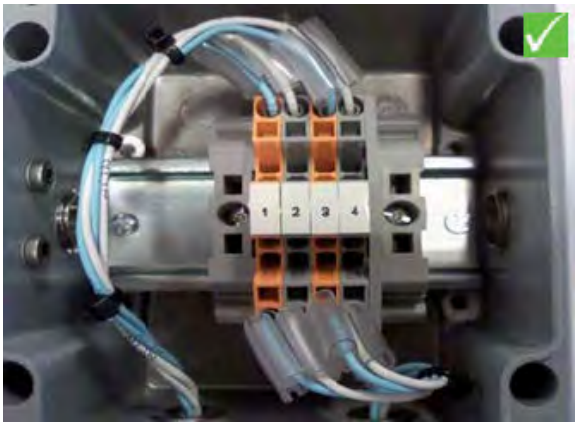


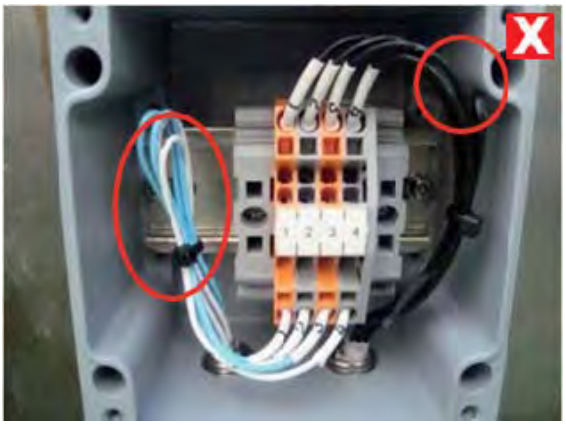
Figure 25: Incorrect chafing of wires (right) and correct one on the left.

Acceptable and not acceptable installations

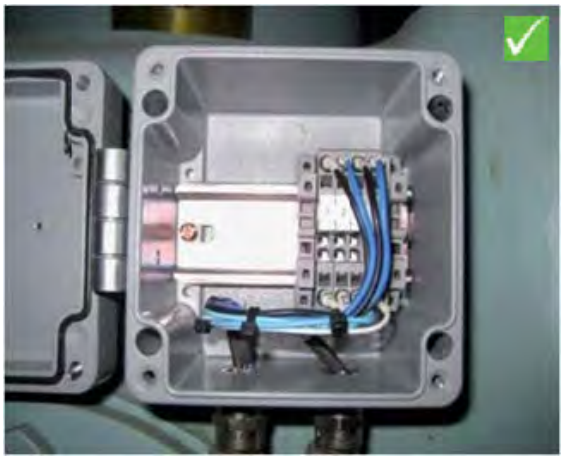
	
Nice and smooth - Acceptable.	Cables bend over sharp edge - Not acceptable.
	
Acceptable protection - Cable easy to inspect.	Do not use this protection - Cable difficult to inspect and sharp edges inside.



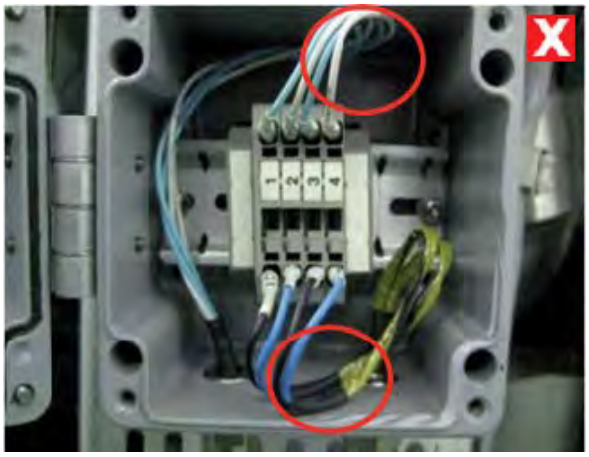
Tailbox short wires, bundled with cable ties and arranged with no contact with box - Acceptable



Tailbox excessive wire length - No cable ties - Wires touching box - Not acceptable



Tailbox short wires, bundled with cable ties and arranged with no contact with box - Acceptable.



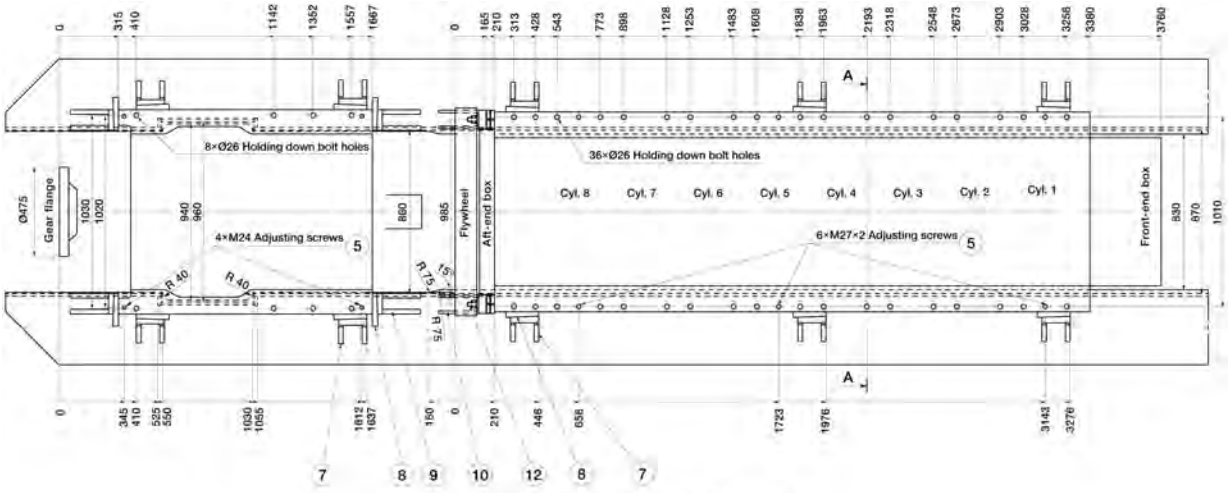
Tailbox excessive wire length - No cable ties - Wires touching box - Not acceptable.



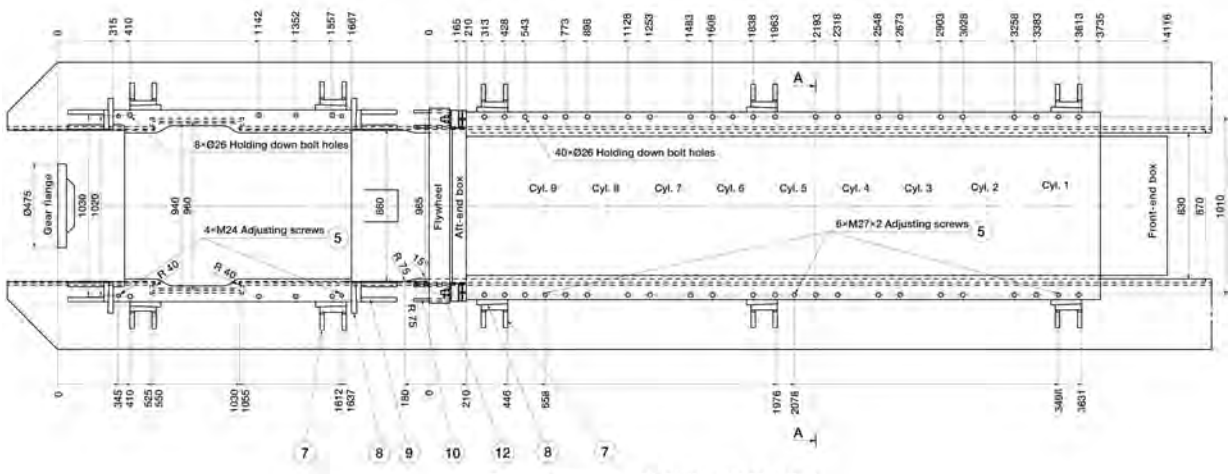
Tailbox excessive wire length - No cable ties - Wires touching box - Not acceptable.

Foundation for engine

Dimensions



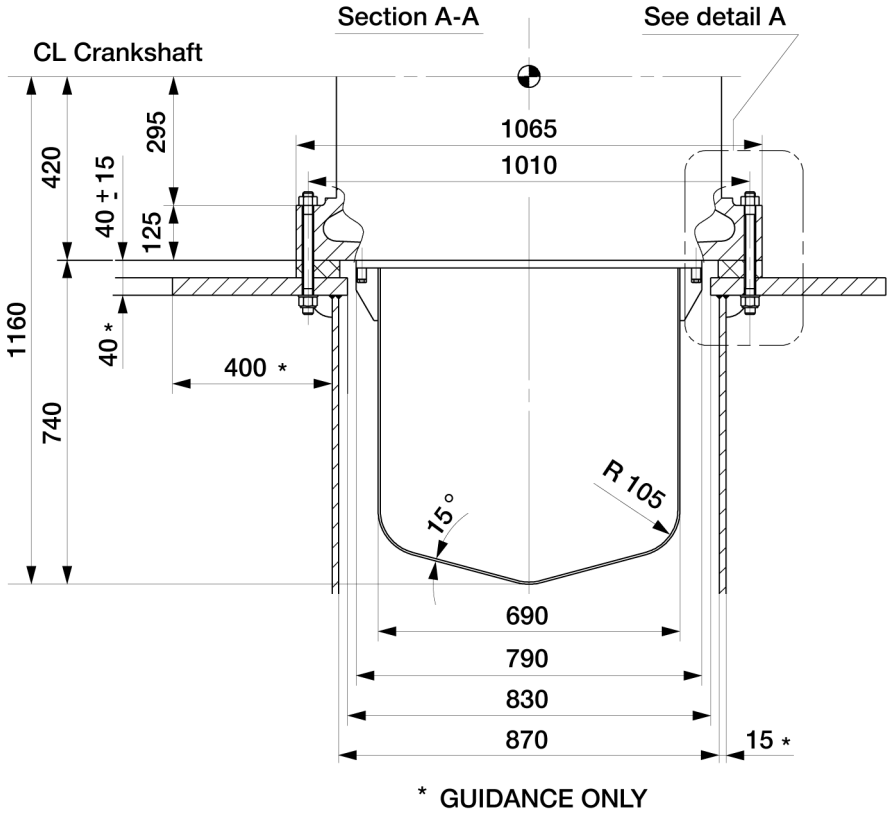
Engine seating - 8L21/31, AMG16EV



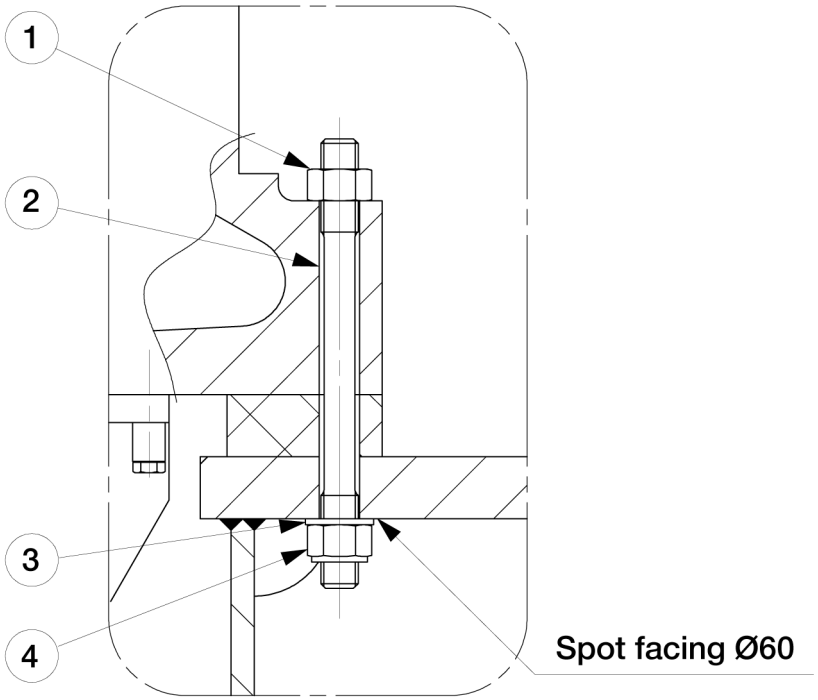
Engine seating - 9L21/31, AMG16EV

The wedges item 8 are to be very lightly driven into position during the alignment in cold condition. After sea trial at service temperature the positions of the wedges are re-checked to ensure that there is just contact. To lock the wedges they are to be tack-welded to the bracket.

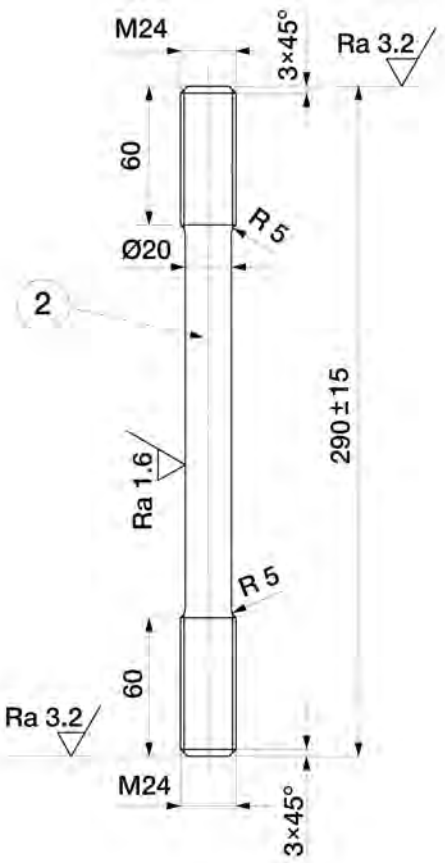
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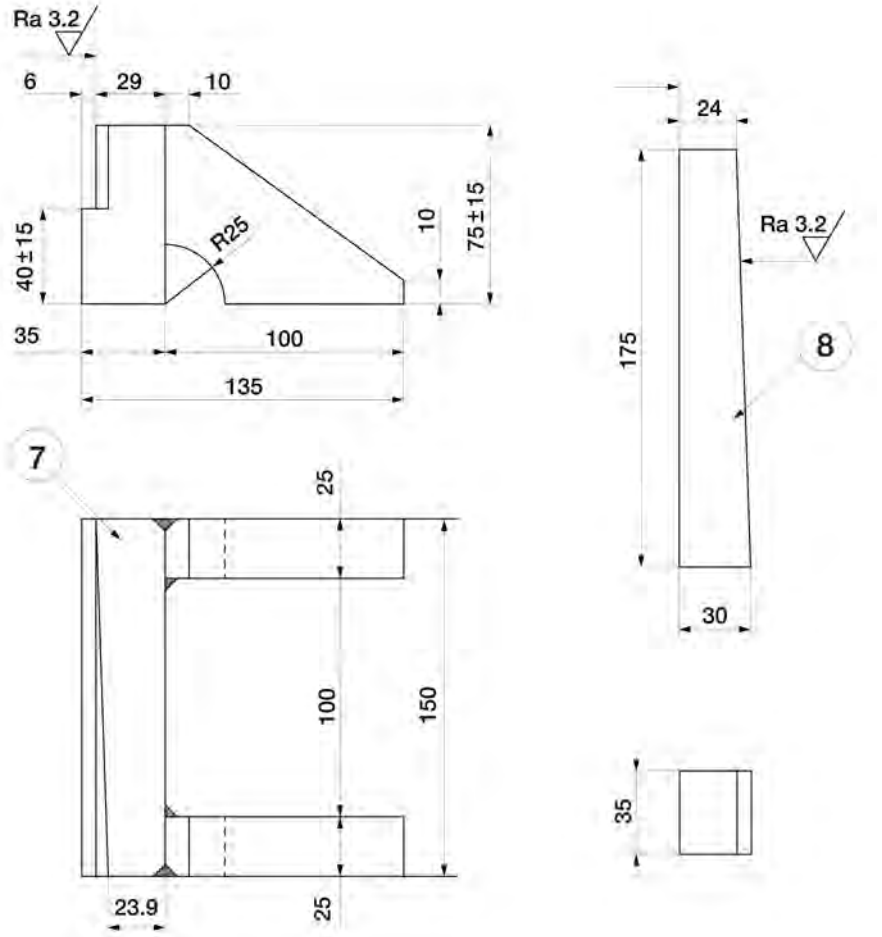
DETAIL A, ENGINE



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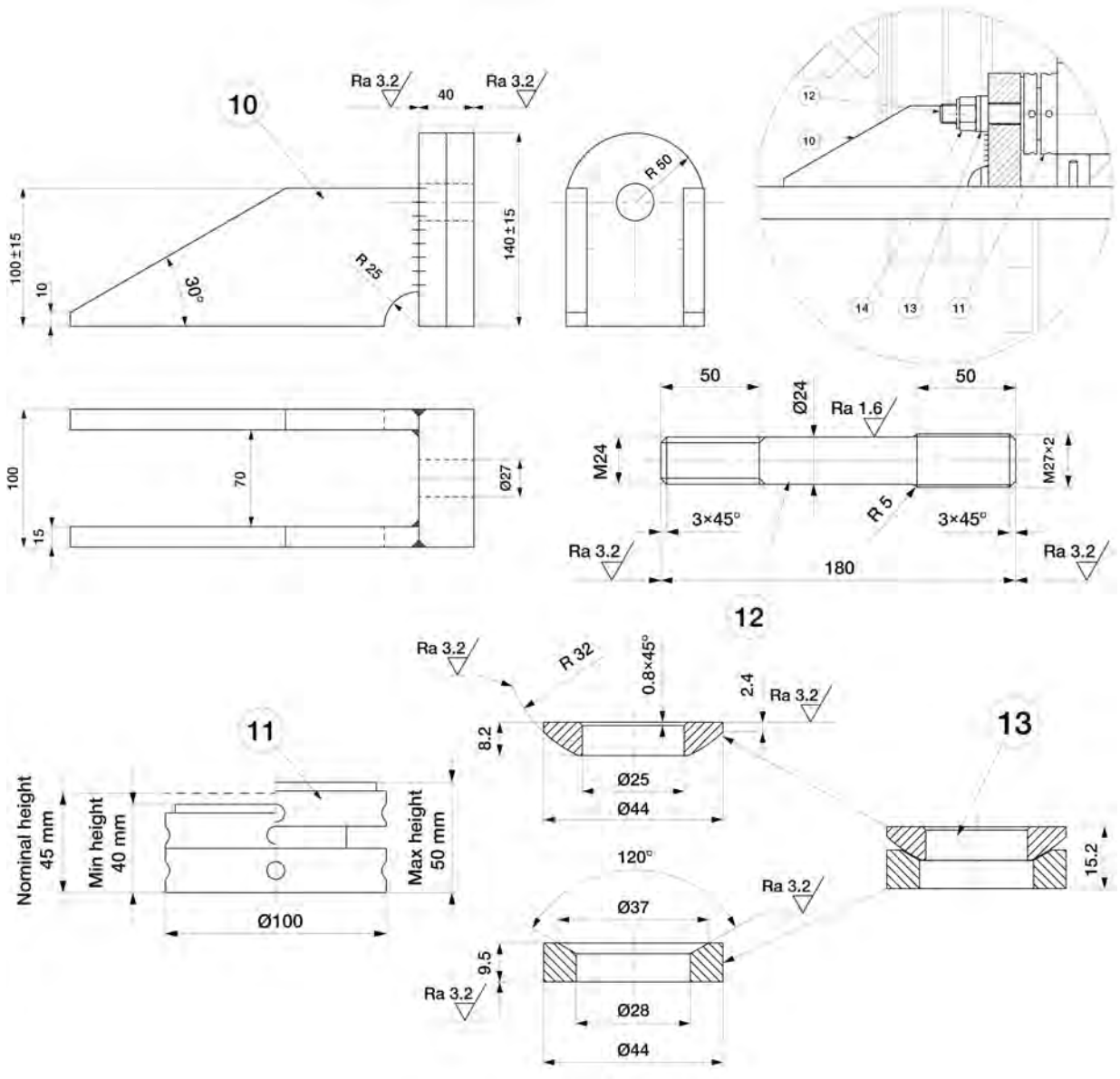
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Material specification :

1) Holding-down bolts item 2 and 6, nuts item 1 and 4 and endchock bolts item 12 :
   Tensile strength min 700 N/mm².
   Yield point min 640 N/mm².
   ISO property class 8.8 or similar.
2) Epoxy chocks :
   Epoxy plan, see guiding " calculation for epoxy chocks "
   Height of chocks for engine and gear : 40 ± 15 mm
3) Tightening torque for holding-down bolt item 2 and 6, oil lubricated :
   Tightening torque according to epoxy chock calculation
   Tightening torque for end chock bolts, item 12 : 530 Nm

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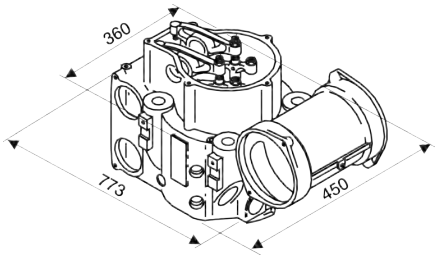
The end chock brackets, item 10, must be adapted to the foundation top plate, and full welded both inside and outside.

2026-05-28 - en

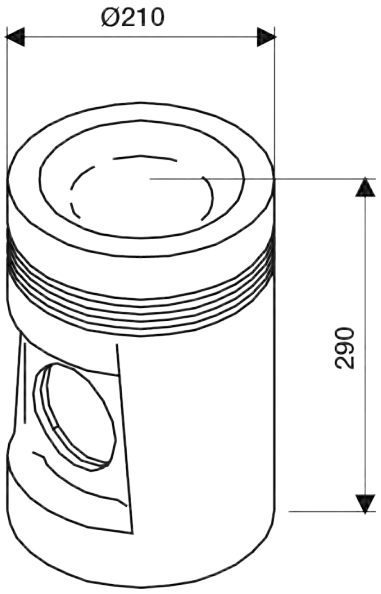
ITEM	DESCRIPTION
1	M24 nut
2	M24 holding-down bolt for engine
3	Plain washer. min hardness 200HB
4	M24 nut with locking device
5	Adjusting screw
6	M24 holding-down bolt for gear
7	Side chocks
8	Wedge
9	Gear box end chocks
10	Engine end chocks
11	Adjustable spherical washer
12	M24/M27 bolt for engine end chocks
13	Spherical washer
14	M24 nut with locking device

2026-05-28 - en

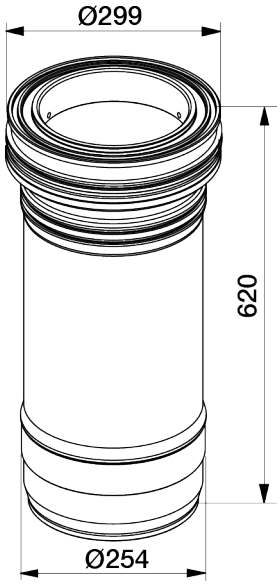
Weight and dimensions of principal parts



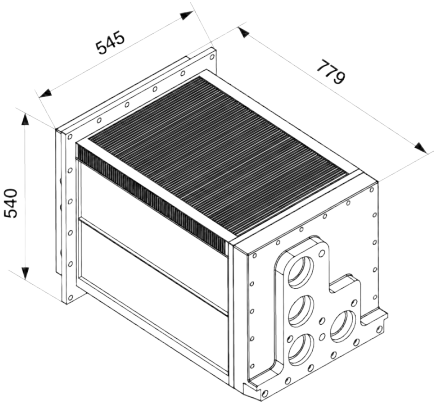
Cylinder head incl. rocker arms approx. 225 kg



Piston approx. 30 kg



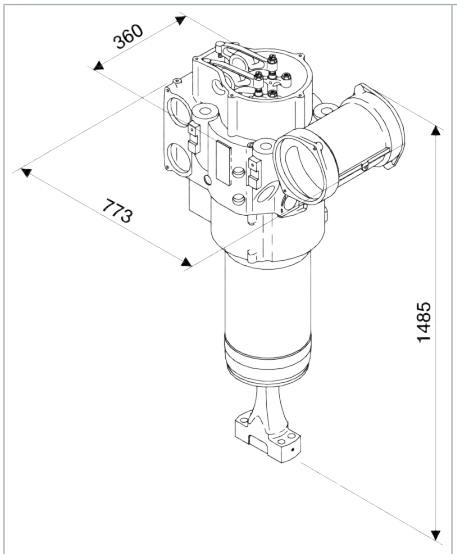
Cylinder liner approx. 80 kg



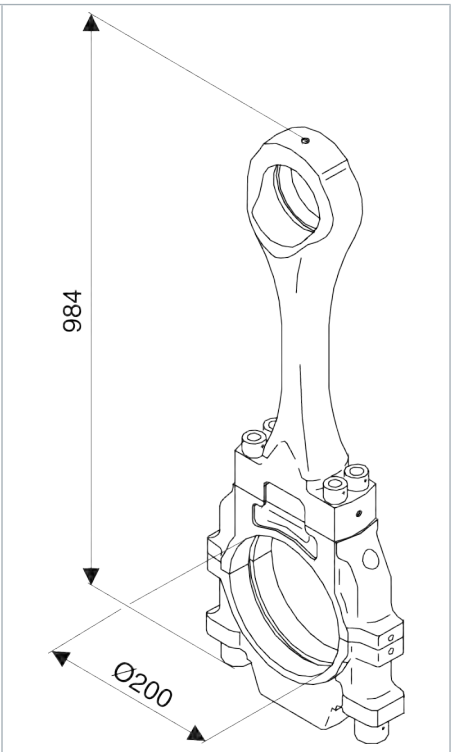
Charge air cooler approx. 295 kg

Please note: 5 cyl. only for GenSet

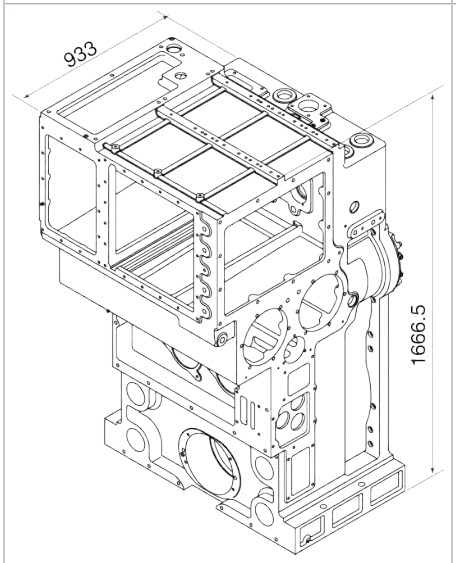
2023-09-12 - en



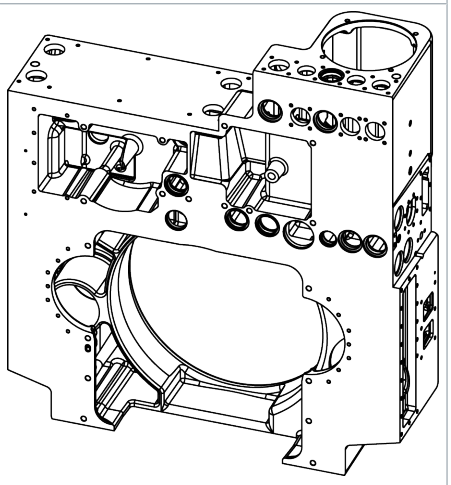
Cylinder unit approx. 485 kg



Connecting rod approx. 64 kg



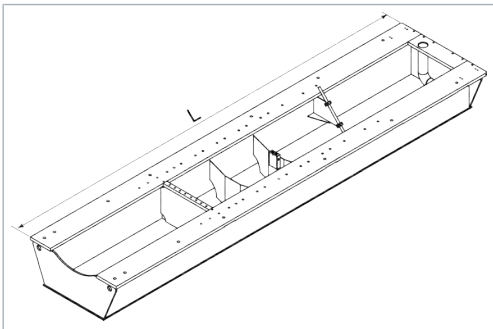
Front end box for GenSet approx 1465 kg



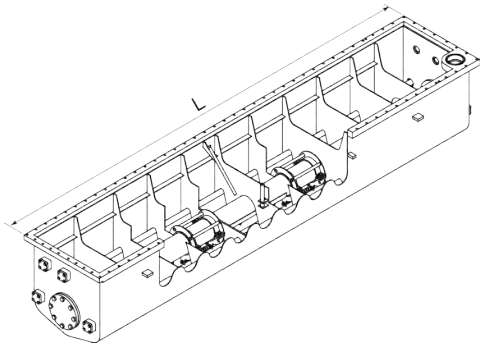
Front end box for propulsion

Please note: 5 cyl. only for GenSet

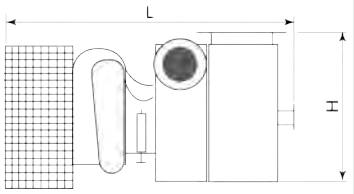
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Base frame for GenSet	Length (L)* [mm]	Weight [kg]
5 cyl.	4529	2978
6 cyl.	5015.5	3063
7 cyl.	5423	3147
8 cyl.	6700	3300
9 cyl.	7000	3500
Width: 1400 mm ** Depending on alternator type*		



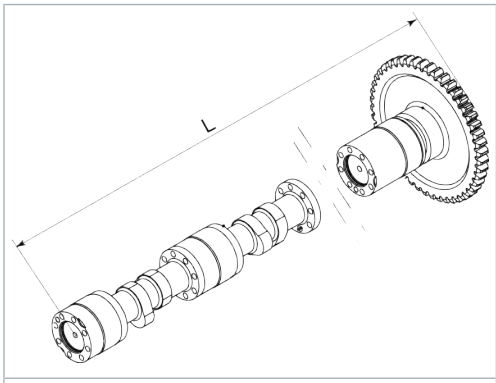
Oil pan for propul-sion	Length (L)* [mm]	Weight [kg]
6 cyl.	2920.5	660
7 cyl.	3275.5	720
8 cyl.	3630.5	780
9 cyl.	3985.5	850
Width: 1065 mm		



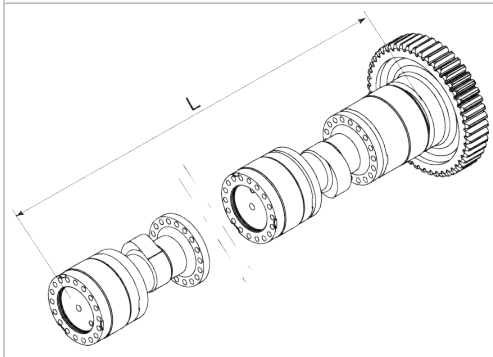
Turbochar-ger	Length (L) [mm]	Height (H) [mm]	Weight (kg)
TCR16	1110	615	290
TCR18	1328	772	460

Please note: 5 cyl. only for GenSet

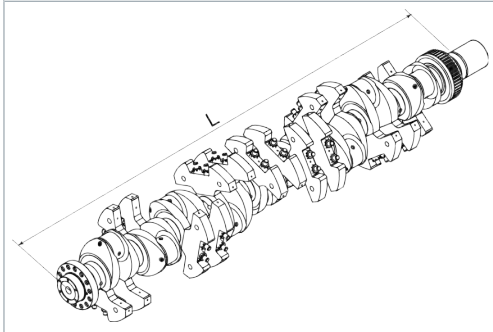
2023-09-12 - en



Valve cam-shaft	Length (L) [mm]	Weight [kg]
5 cyl.	1994.5	130
6 cyl.	2349.5	150
7 cyl.	2704.5	170
8 cyl.	3059.5	190
9 cyl.	3414.5	209



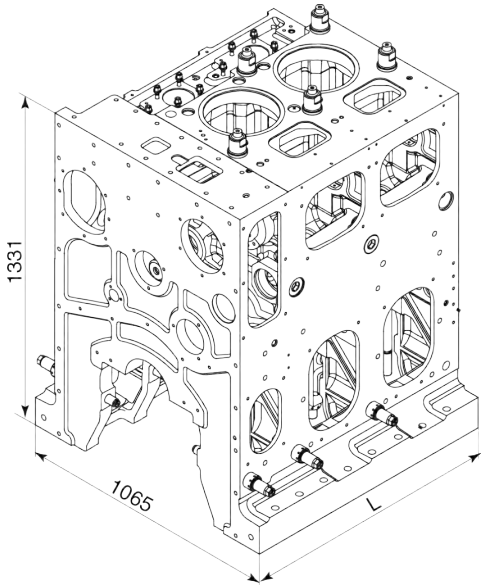
Injection camshaft	Length (L) [mm]	Weight [kg]
5 cyl.	1980.5	275
6 cyl.	2335.5	321
7 cyl.	2690.5	367
8 cyl.	3045.5	413
9 cyl.	3400.5	459



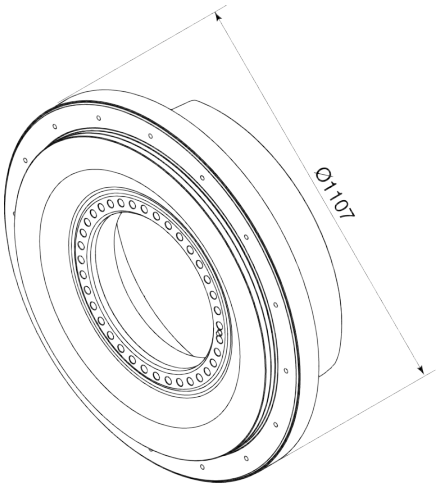
Crankshaft with counter weights	Length (L) [mm]	Weight (kg)
5 cyl.	2470	1350
6 cyl.	2825	1580
7 cyl.	3180	1813
8 cyl.	3535	2053
9 cyl.	3890	2260

Please note: 5 cyl. only for GenSet

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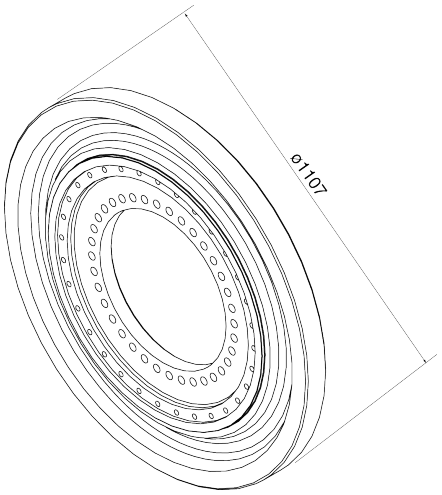


Frame	Length (L) [mm]	Weight (kg)
5 cyl.	2105.5	3435
6 cyl.	2460.5	3981
7 cyl.	2815.5	4527
8 cyl.	3170.5	5073
9 cyl.	3525.5	5619



Flywheel with gear rim
only for GenSet

Small: 890 kg
Medium: 1051 kg
Large: 1213 kg



Flywheel with gear rim
only for propulsion

Please note: 5 cyl. only for GenSet

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Spare parts for unrestricted service

General

Spare parts for unrestricted service, according to the Classification Societies requirements/recommendations.
For multi-engine installations spares are only necessary for one engine.

Cylinder head

Description	Plates	Item	Qty.
Valve seat ring, inlet	P50501	123	2
O-ring		172	6
Valve seat ring, exhaust		184	4
O-ring		196	2
Circlip	P50502	095	2
Conical ring in 2/2		178	6
Rotocap, complete		191	6
Spring		201	6
O-ring		237	1
O-ring		250	1
Valve spindles, inlet and exhaust		274	6
O-ring		536	4
Gasket	P50507	043	1
O-ring		055	2
O-ring		080	2
O-ring		092	1
Gasket, top cover	P50510	014	1

Piston, connecting rod and cylinder liner

Description	Plates	Item	Qty.
Piston pin	P50602	026	1
Retaining ring		038	2
Bush for connecting rod	P50603	008	1
Screw for connecting rod		021	4
Nut		057	2
Screw for connecting rod		069	4
Nut		094	2
Connecting rod bearing 2/2	P50604	003	1
Piston ring	P50605	009/093	1
Piston ring		010/103	1
Oil scraper ring		022/127	1

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Description	Plates	Item	Qty.
Seal ring	P50610	031/003	1
O-ring		055	1
O-ring		209	1
O-ring		210	1

Engine frame and base frame

Description	Plates	Item	Qty.
Tie rod	P51101	062	2
O-ring	P51101	074	4
Nut	P51101	086	2
Tie rod	P51101	182	2
Crown nut	P51101	194	2
Cylindrical pin	P51101	204	1
Nut	P51101	228	2
O-ring	P51101	265	2
Protecting cap	P51101	312	4
Tie rod	P51101	456	2
Ring	P51101	527	2
Main bearing shell 2/2	P51104	021	1
Thrust bearing ring		033	2

Turbocharger system

Description	Plates	Item	Qty.
O-ring	P51229	015	4

Fuel oil system and injection equipment

Description	Plates	Item	Qty.
Seal ring	P51401	002	1
Fuel injection pump		565	1
Fuel injection valve	P51402	116	1/C
Fuel oil high-pressure pipe	P51404	117	1

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Cooling water system

Description	Plates	Item	Qty.
Seal ring	P51630	033	12
Intermediate piece		070	2
Intermediate piece		190	4
Intermediate piece		356	2
V-profile clamp		368	4

Notice

Scope of this list are subject to change and therefore the latest version of this document should always be used, please see Everllence homepage or Extranet.
Spare parts listed may also vary if optional components are selected.

NOTICE

Please notice that the content of spare parts for specific projects may vary from the list of standard spare parts.

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Spare parts for restricted service

General

Spare parts for restricted service, according to the Classification Societies requirements/recommendations.

Description	Plates[1]	Item[1]	Qty.[2]
Valve spindles and valve gear accessories			
Valve rotation device	50502	191	4
Valve spindle, inlet and exhaust	50502	274	4
Pressure spring	50502	291	4
Cylinder head accessories			
Valve seat ring, inlet	50501	123	2
Valve seat ring, exhaust	50501	184	2
Fuel injection valve			
Fuel injection valve, complete	51402	116	3
Kit for cylinder unit			
Kit for cylinder unit	51704	021	1

1. Plate and Item No. refer to the spare part plates in the instruction manual.
2. Quantity is in force per engine type per plant.

Notice:

Scope of this list are subject to change and therefore the latest version of this document should always be used, please see MAN Diesel & Turbo homepage or Extranet. Spare parts listed may also vary if optional components are selected.
Please notice that the content of spare parts for specific projects may vary from the list of standard spare parts.

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Introduction to spare part plates for tools

Description

For our engines the following three tool packages are available:

Standard tool for normal maintenance
This package is delivered as standard, this tool package do consist of a mix of special designed tools as well as ordinary available tools needed in connection with the operation of the engine and to perform daily engine maintenance. The tool do as well consists of tools to perform emergency repair as required by the various classification societies.

Additional tools
This tool package can only be ordered as single parts from the list in addition to the standard tool package. The tool package consists of special tools needed in addition to the standard tool in case a major overhaul or a part of this is to be carried out.

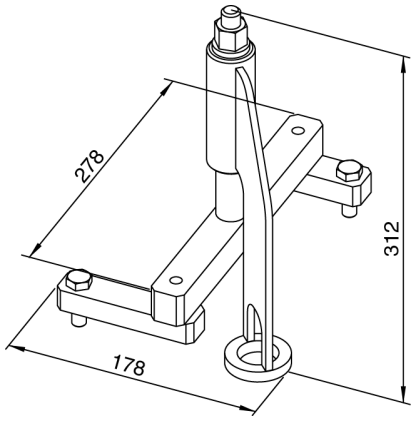
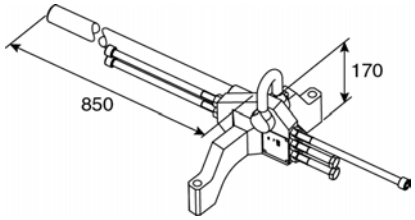
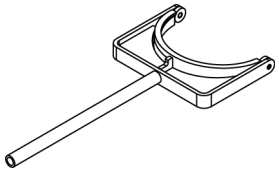
Hand Tools
This tool package can be ordered as a whole or partly in addition to the standard tool package. The tool package consists of ordinary hand tools needed in addition to the delivered standard tool for normal maintenance, in connection with the daily maintenance as well as major overhauls.

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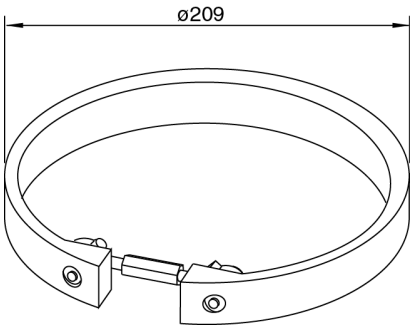
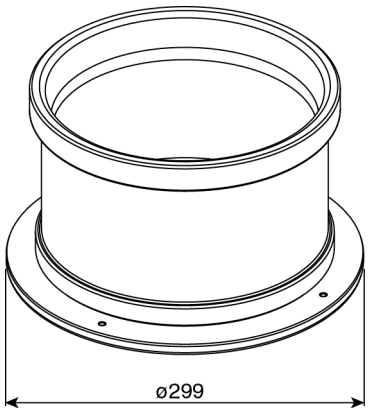
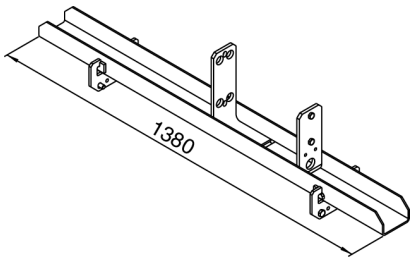
Standard tools for normal maintenance

Cylinder head

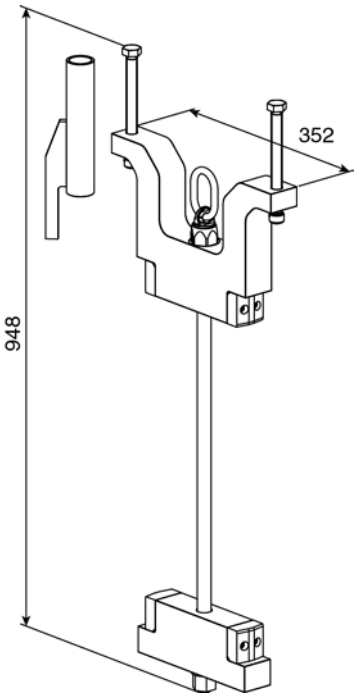
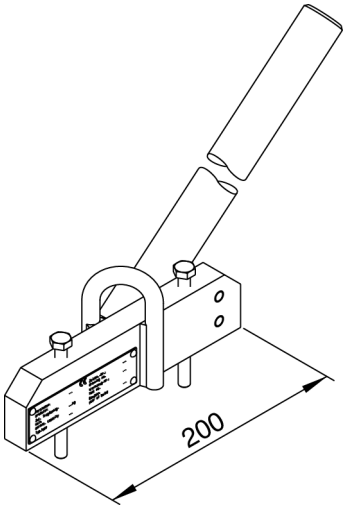
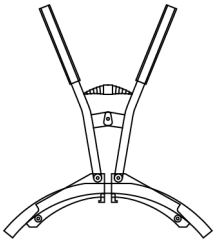
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Valve spring tightening device			1	014	
Lifting tool for cylinder unit and cylinder head			1	038	
Broad chissel			1	473	

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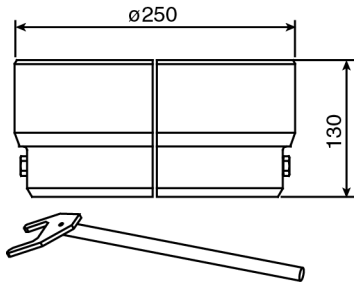
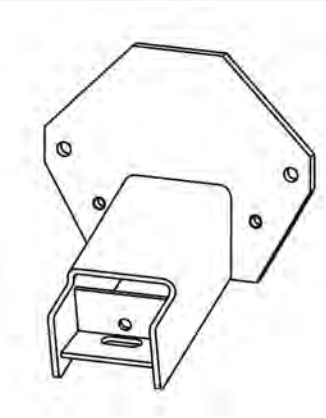
Piston, connecting rod and cylinder liner

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Removing device for flame ring			1	021	
Guide bush for piston			1	045	
Fit and removal device for connecting rod bearing, incl eye screws (2 pcs)			1	069	

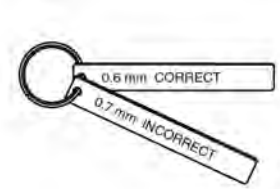
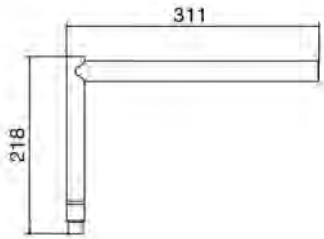
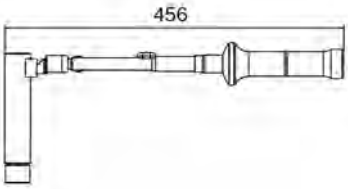
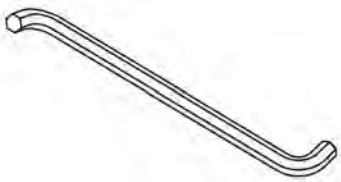
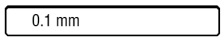
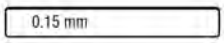
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Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Lifting device for cylinder liner			1	082	
Lifting device for piston and connecting rod			1	104	
Piston ring opener			1	190	

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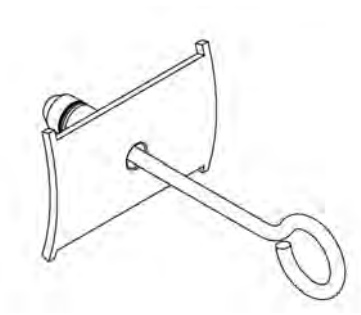
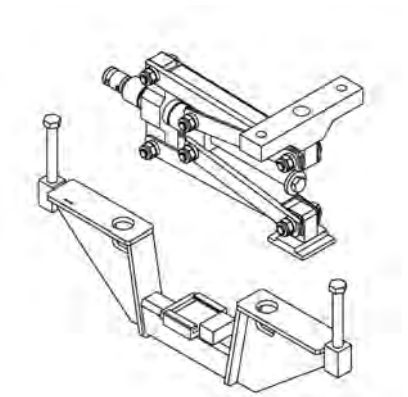
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Supporting device for connecting rod and piston in the cylinder liner, incl. fork			1	212	
Dismantling tool for bearing shell			1	818	
Dismantling tool for connecting rod bearing shell			1	831	

Operating gear for inlet and exhaust valves

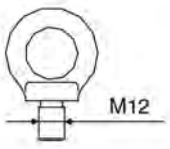
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Feeler gauge, 0.6-0.7 mm			1	010	
Socket wrench			1	652	
Socket wrench and torque spanner			1 1	664 676	
Socket screw key			1	832	
Feeler gauge for adjustment of roller guide			2	640a	
Feeler gauge for adjustment of roller guide			2	640b	

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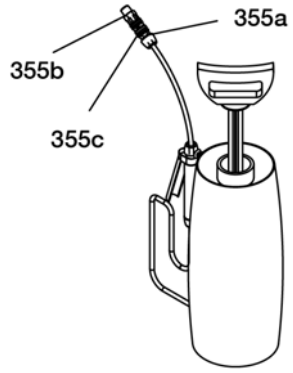
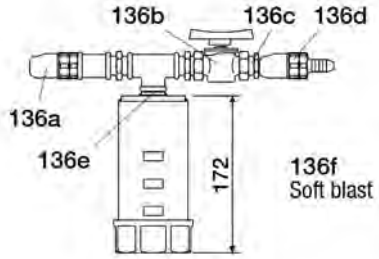
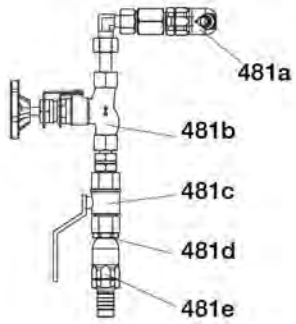
Crankshaft and main bearings

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Dismantling tool for main bearing upper shell			1	035	
Fit and removing device for main bearing cap			1	047	

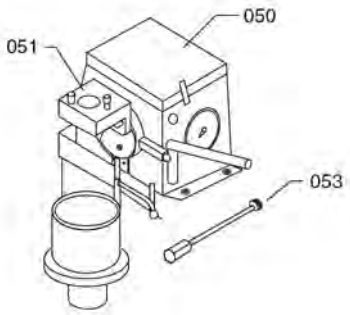
Turbocharger system

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Eye screw for lifting of charge air cooler/lubricating oil cooler			2	036	

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Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Container complete for water washing of compressor side Reducing piece Fitting Fitting			1	355 355a 355b 355c	
Blowgun for dry cleaning of turbocharger Snap coupling Ball valve Snap coupling Snap coupling Packing rings Soft blast (granulate)			1	136 136a 136b 136c 136d 136e 136f	
Water washing of turbine side, complete Snap coupling Regulating valve Ball valve Snap coupling Snap coupling			1	481 481a 481b 481c 481d 481e	

Fuel oil system

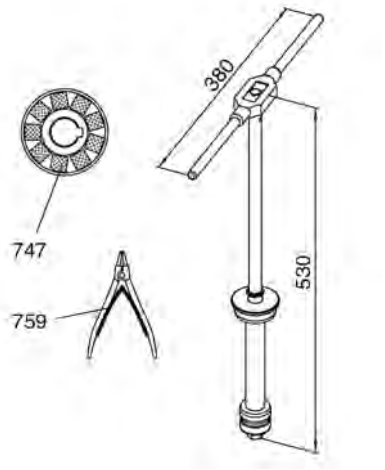
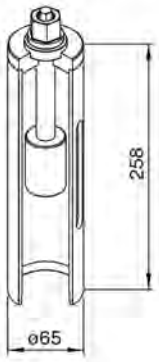
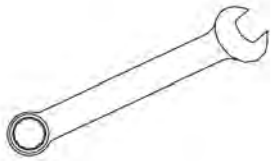
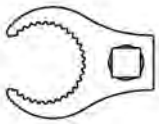
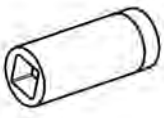
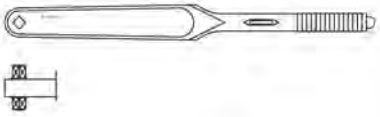
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Pressure testing tool Clamping bracket for fuel injector Fuel pipe			1 1 1	050 051 053	

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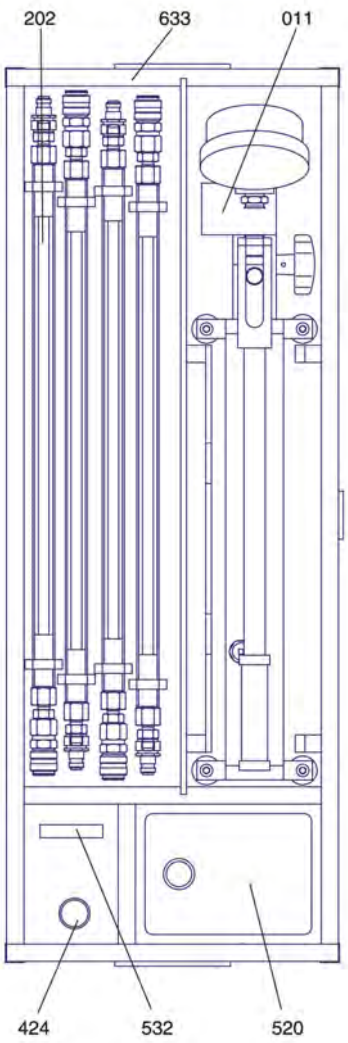
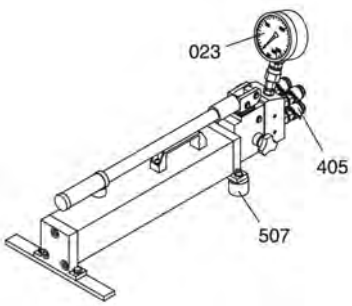
Standard tools for normal maintenance

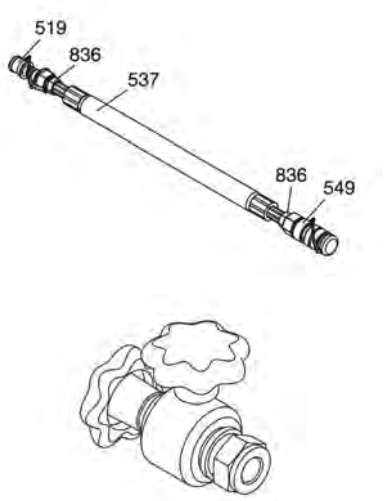
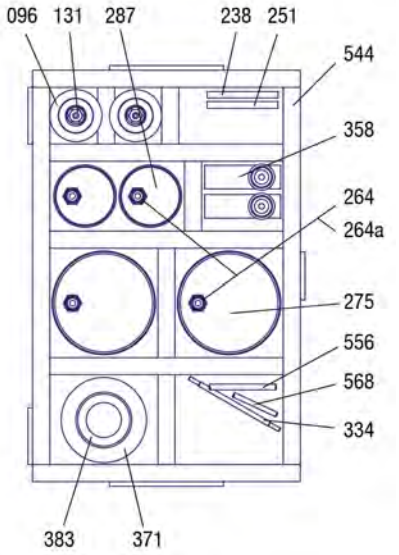
Description

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Grinding device for nozzle seat, incl item 747, 759 Grinding paper Plier			1 1 1	074 747 759	
Extractor device for injector valve			1	407	
Combination spanner, 36 mm			1	772	
Crow foot, 36 mm			1	784	
Long socket spanner 1/2" 36 mm			1	879	
Torque spanner 1/2" 50-300 Nm			1	902	

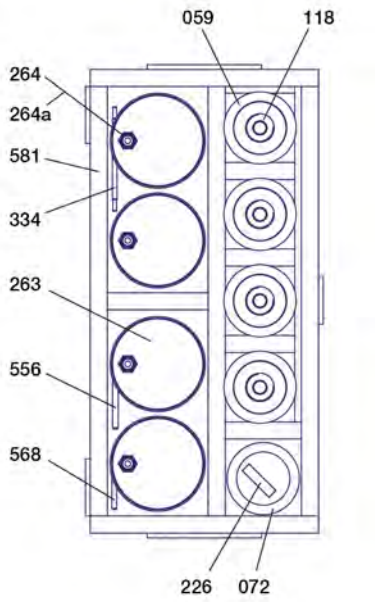
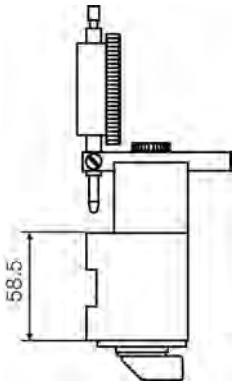
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Hydraulic tools

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Hydraulic tools complete consisting of the following 3 boxes:				806	
Pressure pump box 1, consisting of:				633	
Pressure pump, complete			1	011	
Manometer				023	
Quick coupling				405	
Rubber buffers				507	
Set of spare parts			1	532	
Hose with unions			4	202	
Hose, 4000 mm				537	

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Quick coupling				549	
Adapter				836	
Nipple				519	
Storage tank			1	520	
Force-off device			1	424	
Hydraulic tools box 2 consisting of:			1	544	
Hydraulic tightening cylinder M33 x 2			2	275	
Pressure part, M33 x 2			2	371	
Set of spare parts			1	238	
Hydraulic tightening cylinder M22 x 2			2	287	
Pressure part, short M22 x 2			2	383	
Pressure part, long M22 x 2			2	096	
Tension screw M22 x 2			2	131	
Set of spare parts			1	251	
Turn pin ø6			1	556	
Turn pin ø5			1	568	
Turn pin ø4/ø5			1	334	
Angle piece			2	358	
Nipple			1	264	
Seal ring			1	264a	

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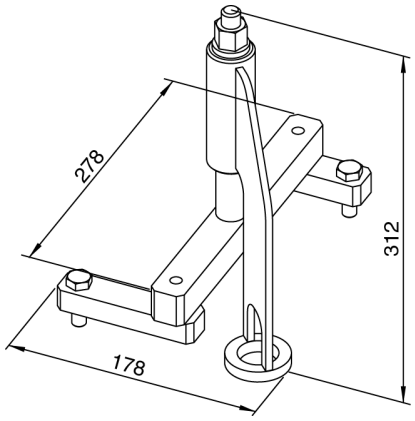
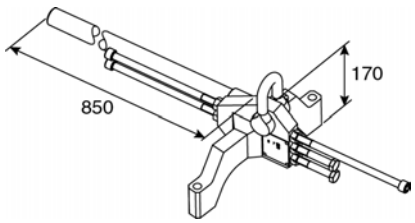
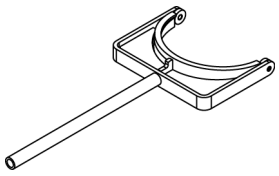
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Hydraulic tools box 3 consisting of:			1	581	
Hydraulic tightening cylinder M30 x 2			4	263	
Pressure part, short M30 x 2			2	072	
Pressure part, long M30 x 2			4	059	
Tension screw			4	118	
Set of spare part			1	226	
Turn pin ø6			1	556	
Turn pin ø5			1	568	
Turn pin ø4/ø5			1	334	
Nipple			1	264	
Seal ring			1	264a	
Measuring device (not a part of Hydraulic tools complete, to be ordered separately)			2	533	

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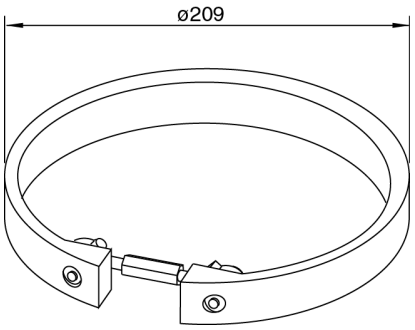
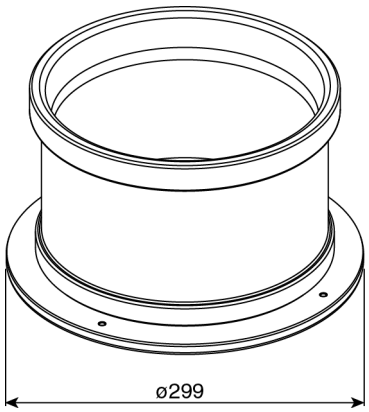
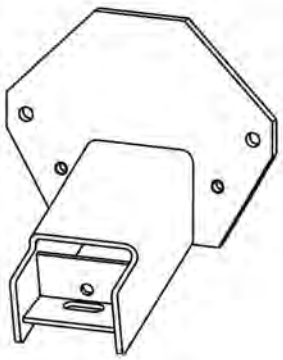
Standard tools (restricted service)

Cylinder head

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Valve spring tightening device			1	014	
Lifting tool for cylinder unit and cylinder head			1	038	
Broad chissel			1	473	

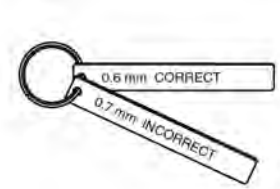
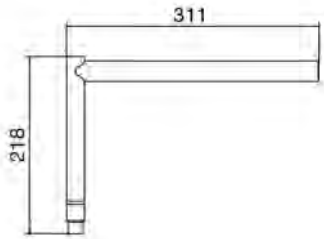
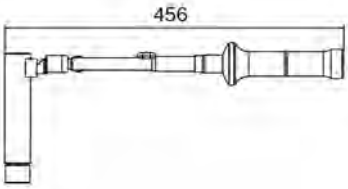
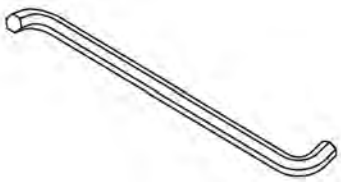
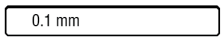
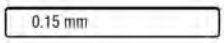
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Piston, connecting rod and cylinder liner

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Removing device for flame ring			1	021	
Guide bush for piston			1	045	
Dismantling tool for bearing shell			1	818	
Dismantling tool for connecting rod bearing shell			1	831	

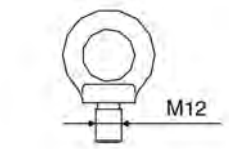
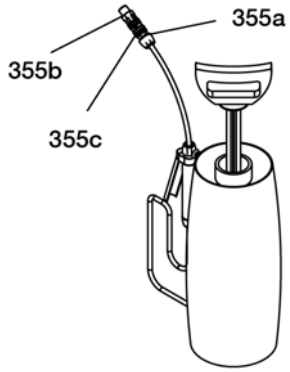
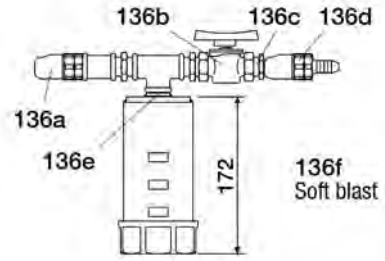
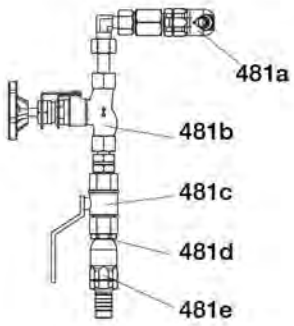
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Operating gear for inlet and exhaust valves

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Feeler gauge, 0.6-0.7 mm			1	010	
Socket wrench			1	652	
Socket wrench and torque spanner			1 1	664 676	
Socket screw key			1	832	
Feeler gauge for adjustment of roller guide			2	640a	
Feeler gauge for adjustment of roller guide			2	640b	

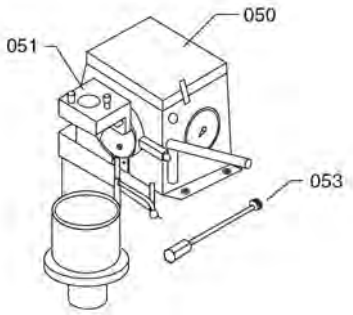
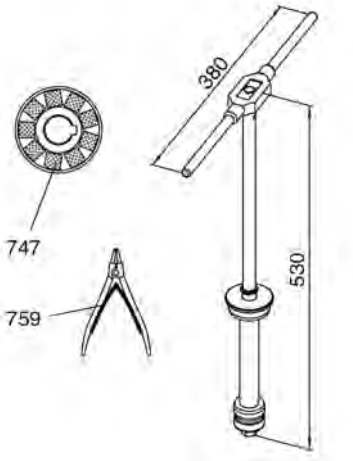
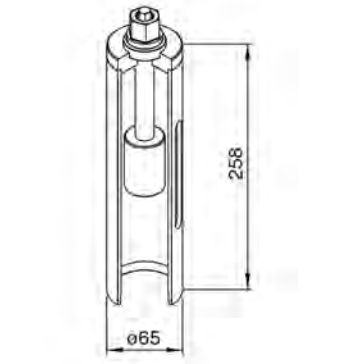
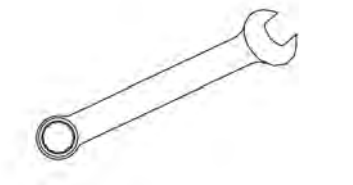
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Turbocharger system

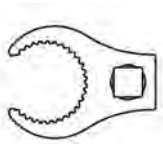
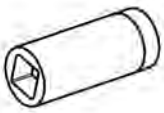
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Eye screw for lifting of charge air cooler/lubricating oil cooler			2	036	
Container complete for water washing of compressor side Reducing piece Fitting Fitting			1	355 355a 355b 355c	
Blowgun for dry cleaning of turbocharger Snap coupling Ball valve Snap coupling Snap coupling Packing rings Soft blast (granulate)			1	136 136a 136b 136c 136d 136e 136f	
Water washing of turbine side, complete Snap coupling Regulating valve Ball valve Snap coupling Snap coupling			1	481 481a 481b 481c 481d 481e	

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Fuel oil system

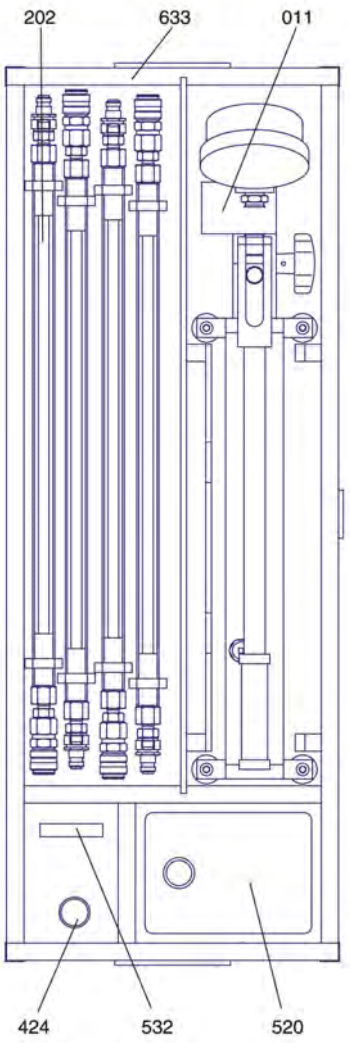
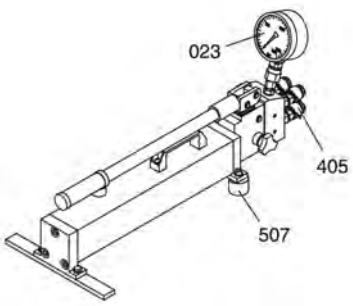
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Pressure testing tool			1	050	
Clamping bracket for fuel injector			1	051	
Fuel pipe			1	053	
Grinding device for nozzle seat, incl item 747, 759			1	074	
Grinding paper			1	747	
Plier			1	759	
Extractor device for injector valve			1	407	
Combination spanner, 36 mm			1	772	

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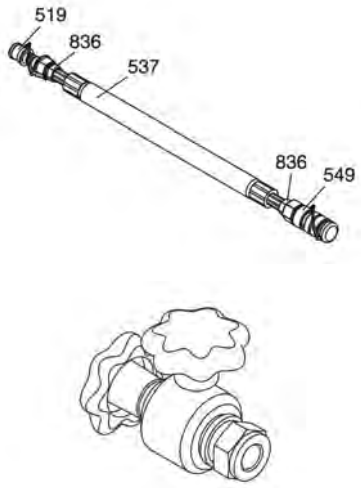
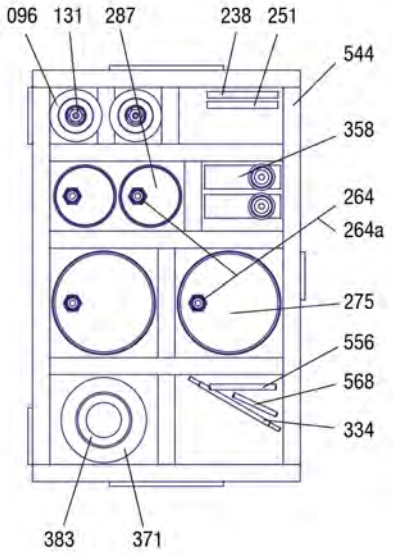
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Crow foot, 36 mm			1	784	
Long socket spanner 1/2" 36 mm			1	879	
Torque spanner 1/2" 50-300 Nm			1	902	

Hydraulic tools

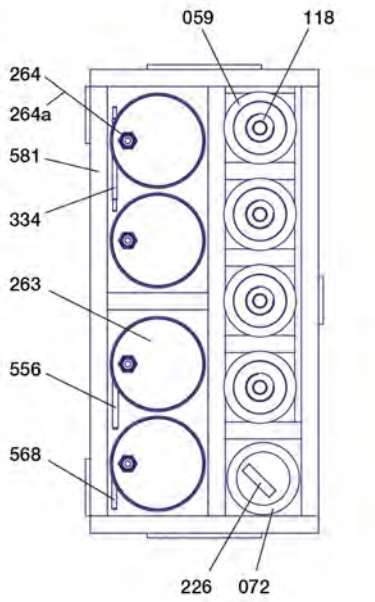
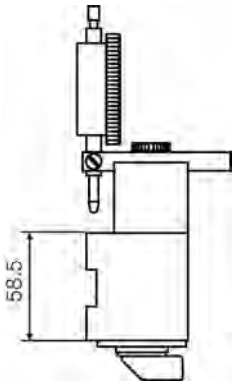
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Hydraulic tools complete consisting of the following 3 boxes:				806	

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Pressure pump box 1, consisting of:				633	
Pressure pump, complete			1	011	
Manometer				023	
Quick coupling				405	
Rubber buffers				507	
Set of spare parts			1	532	
Hose with unions			4	202	
Hose, 4000 mm				537	
Quick coupling				549	
Adapter				836	
Nipple				519	
Storage tank			1	520	

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Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Force-off device			1	424	
Hydraulic tools box 2 consisting of:			1	544	
Hydraulic tightening cylinder M33 x 2			2	275	
Pressure part, M33 x 2			2	371	
Set of spare parts			1	238	
Hydraulic tightening cylinder M22 x 2			2	287	
Pressure part, short M22 x 2			2	383	
Pressure part, long M22 x 2			2	096	
Tension screw M22 x 2			2	131	
Set of spare parts			1	251	
Turn pin ø6			1	556	
Turn pin ø5			1	568	
Turn pin ø4/ø5			1	334	
Angle piece			2	358	
Nipple			1	264	
Seal ring			1	264a	

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Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Hydraulic tools box 3 consisting of:			1	581	
Hydraulic tightening cylinder M30 x 2			4	263	
Pressure part, short M30 x 2			2	072	
Pressure part, long M30 x 2			4	059	
Tension screw			4	118	
Set of spare part			1	226	
Turn pin ø6			1	556	
Turn pin ø5			1	568	
Turn pin ø4/ø5			1	334	
Nipple			1	264	
Seal ring			1	264a	
Measuring device (not a part of Hydraulic tools complete, to be ordered separately)			2	533	

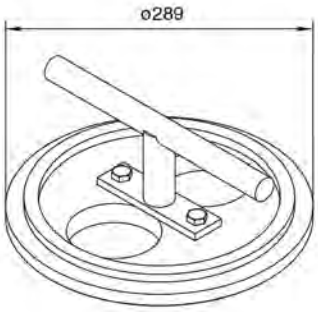
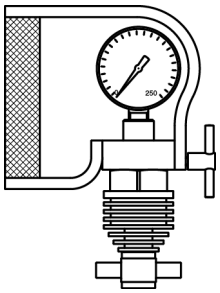
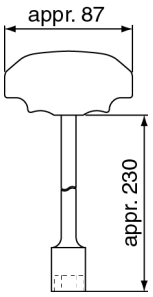
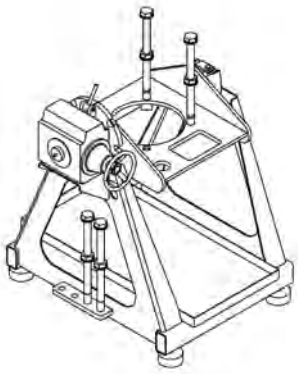
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Additional tools

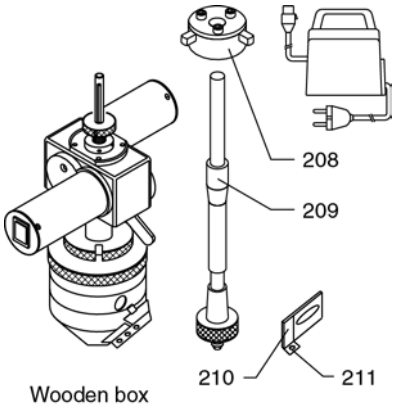
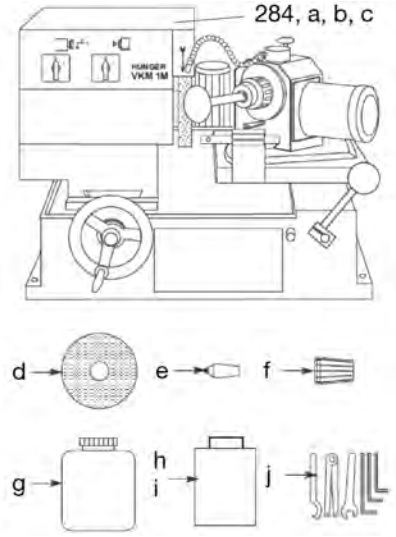
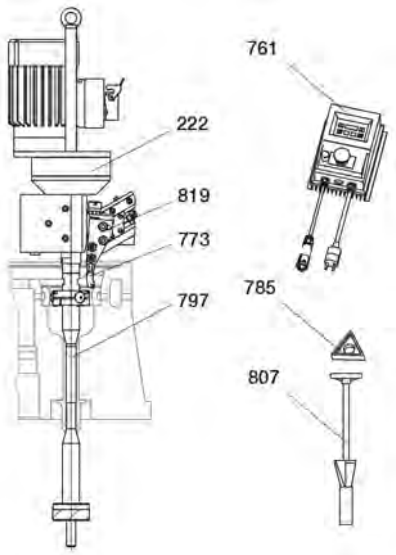
Cylinder head

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Grinding tool for cylinder head/liner			1	126	
Max. pressure indicator, 0-250 bar			1	138	
Handle for indicator valve			1	498	
Turning device for cylinder unit			1	114	

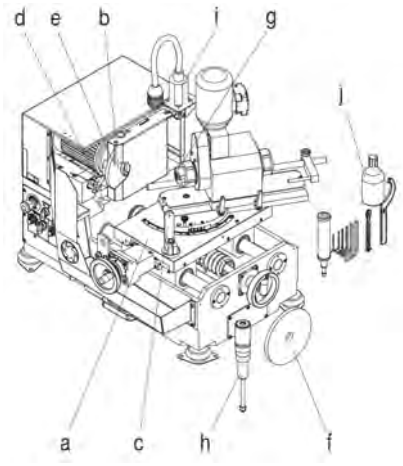
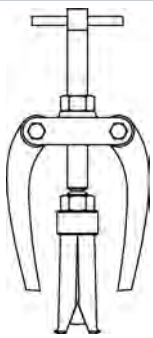
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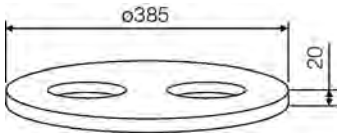
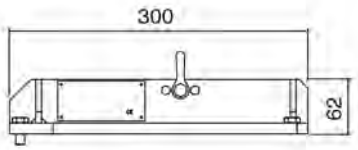
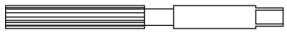
Additional tools
Description

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Grinding machine for valve seat ring			1	199	
Supporting spider			1	208	
Mandrel			1	209	
Cutting tool			1	210	
Carbide cutting insert			1	211	
Grinding tool for valves					
230V 3P			1	284	
400V 3P			1	284a	
480V 3P			1	284b	
690V 3P			1	284c	
Grinding wheel			1	284d	
Diamond dresser			1	284e	
Collet R14			1	284f	
Concentrated coolant			1	284g	
Transformer					
480/400V			1	284h	
690/400V			1	284i	
Servicing tools			1	284j	
Grinding machine for valve seat rings			1	222	
Frequence converter			1	761	
Tool holder			1	773	
Turning bit			1	785	
Pilot spindle incl. stabilizer			1	797	
Cleaning tool			1	807	
Tool holder bracket			1	819	

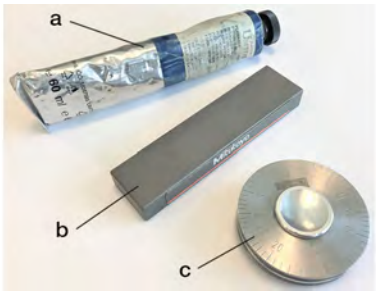
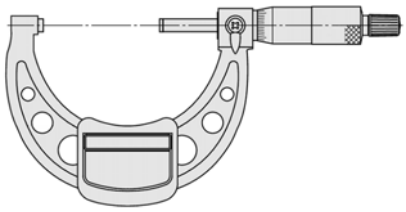
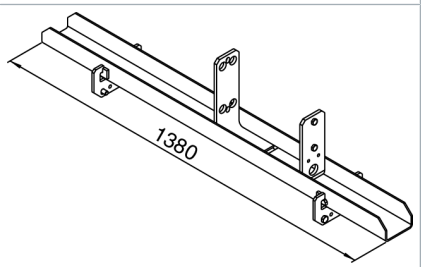
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Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Grinding machine for valve spindle, complete			1	285	
Basic machine			1	285a	
Grinding wheel hub			2	285b	
Balancing apparatus			1	285c	
Grinding wheel dresser			1	285d	
Grinding wheel, blue			1	285e	
Grinding wheel, white			2	285f	
Collet			1	285g	
Clamp			1	285h	
Working light			1	285i	
Tool			1	285j	
Fit and removing device for valve guides			1	258	
Fitting device for valve seat rings			1	295	
Extractor for valve seat rings			1	329	
Plate (used with item 329)			1	317	

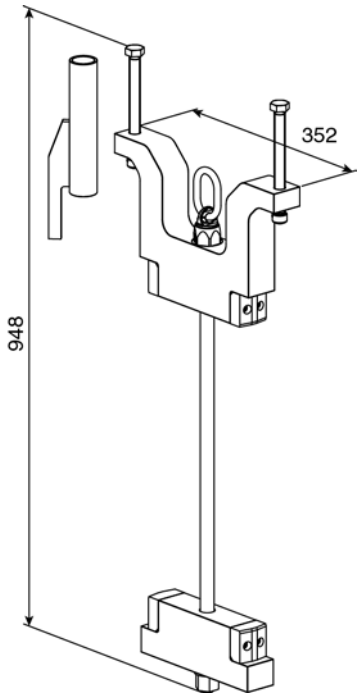
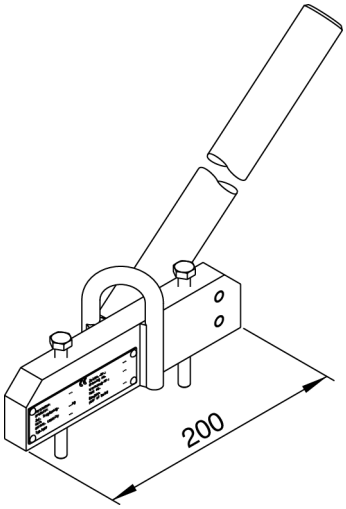
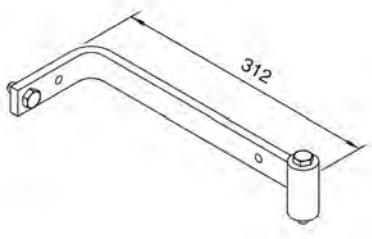
2024-07-09 - en

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
					
Lifting tool for cylinder unit (low dismantling height)			1	474	
Reamer for valve guide			1	748	
Electronic Pmax indicator, Kistler			1	903	

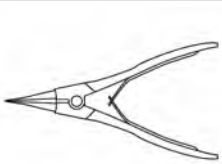
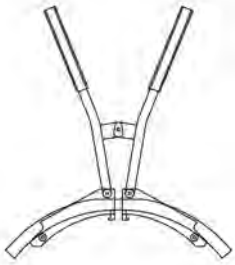
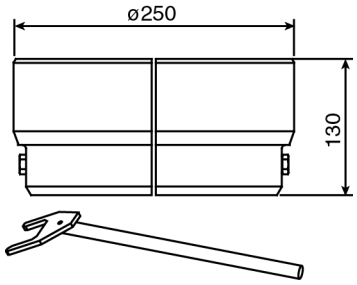
Piston, connecting rod and cylinder liner

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Ridge wear kit, complete Engineering blue Black stone Layer thickness gauge			1 1 1 1	018 018a 018b 018c	
Outside micrometer			1	019	
Fit and removal device for connecting rod bearing, incl eye screws (2 pcs)			1	069	

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Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Lifting device for cylinder liner			1	082	
Lifting device for piston and connecting rod			1	104	
Tool for fixing of marine head for counterweight			1	187	

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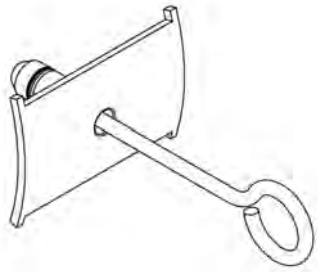
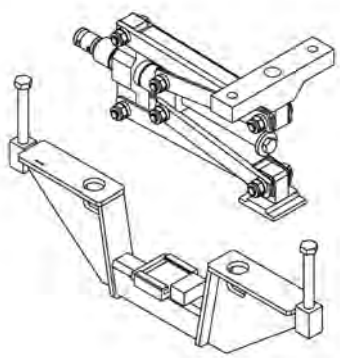
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Plier for piston pin lock ring			1	759	
Piston ring opener			1	190	
Supporting device for connecting rod and piston in the cylinder liner incl. fork			1	212	
Testing mandrel for piston ring grooves, 6.43 mm			1	151	
Testing mandrel for piston ring grooves, 5.43 mm			1	163	
Micrometer screw			1	425	

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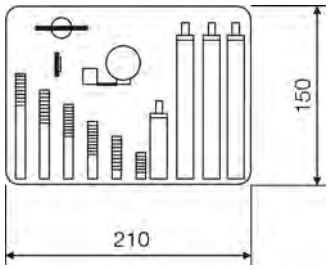
Control and safety systems - automatics and instruments

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Infrared thermometer			1	727
Calibration tool			1	728

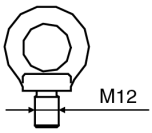
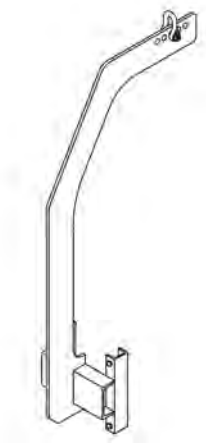
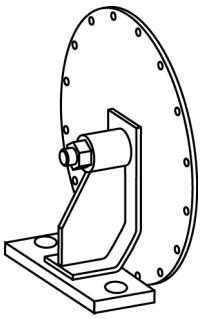
Crankshaft and main bearings

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Dismantling tool for main bearing upper shell			1	035	
Fit and removing device for main bearing cap			1	047	

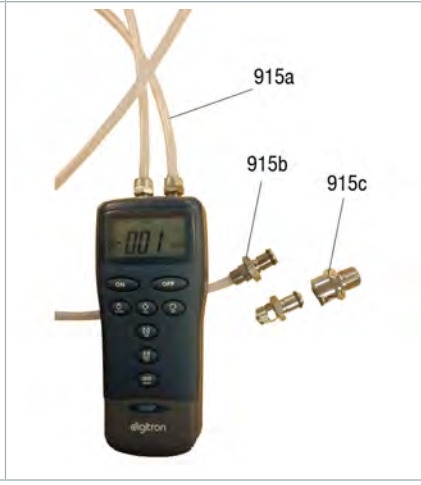
2024-07-09 - en

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Crankshaft alignment gauge (autolog)			1	067	

Turbocharger system

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Eye crew for lifting of charge air cooler/ lubricating oil cooler			2	036	
Fit and removing device for cooler insert			1	401	
Closing cover, TCR16 Closing cover, TCR18 (standard with only one propulsion engine)			1 1	449 450	

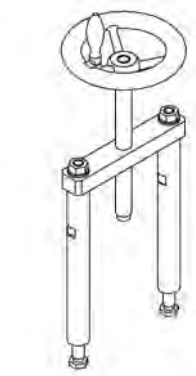
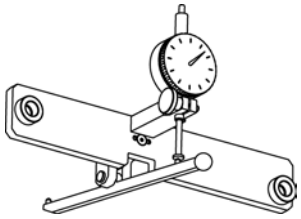
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Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Differential pressure tools complete Hose Nipple Nipple			1 1 2 2	915 915a 915b 915c	

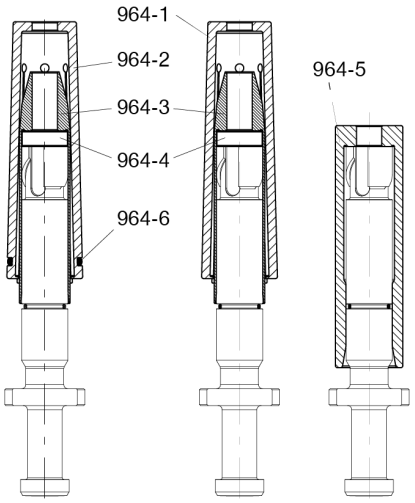
Compressed air system

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Set of tools, TDI air starter T50			1	928

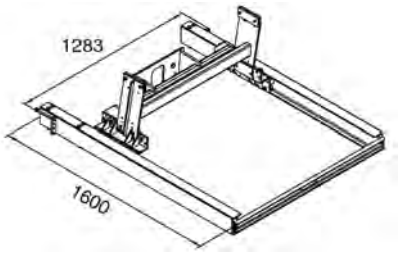
Fuel oil system

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Fit and removing device for fuel injection pump			1	342	
Setting device for fuel injection pump			1	366	

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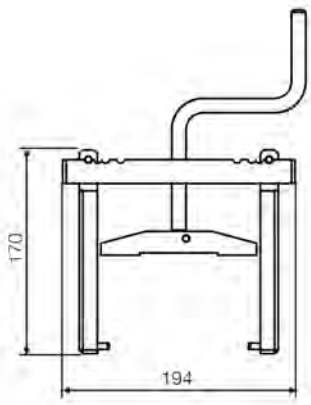
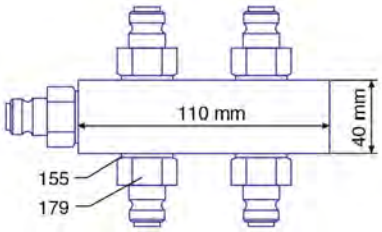
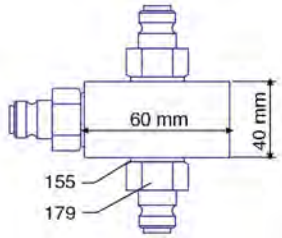
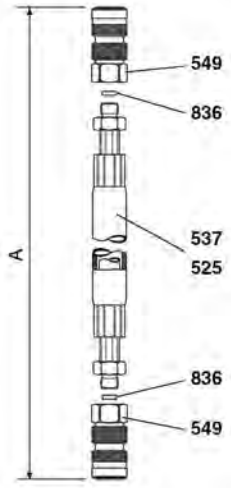
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Mounting tool for seals, plunger complete (only sealed plunger/barrel) Mounting tool Mounting tool Mounting tool Mounting tool Mounting tool O-ring			1	964 964-1 964-2 964-3 964-4 964-5 964-6	

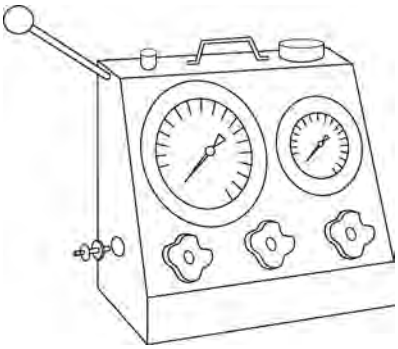
Lubricating oil system

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Fitting device for lubricating oil cooler / thermostat housing			1	521	
Gun for 2-component glue			1	990	

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Hydraulic tools

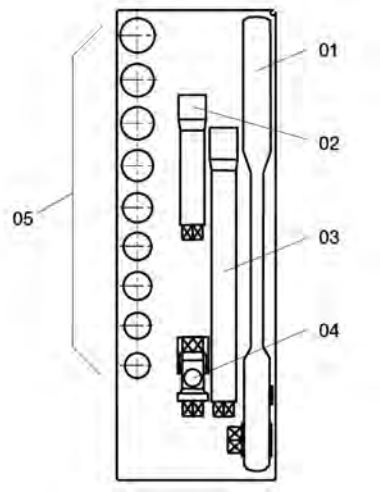
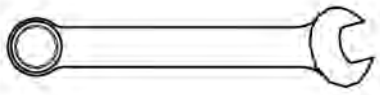
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Resetting device for hydraulic cylinder			1	092	
Distributing piece for cylinder head, complete Gasket Quick coupling			1	143 155 179	
Distributing piece for main bearing, complete Gasket Quick coupling			1	167 155 179	
Hose with unions for cylinder head complete, 1000 mm Hose with unions for connection of oil pump and distributing block complete, 3000 mm Hose, 3000 mm Quick coupling with protecting cap Hose, 1000 mm Disc			4 1	180 202 537 549 525 836	

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Air driven high pressure pump for hydraulic valve			1	653	
Remote controlled unit for hydraulic bolt tensioning			1	939	

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Hand tools

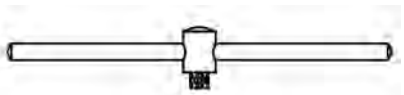
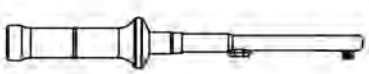
Hand tools

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Set of tools, consists of: Item 01 Ratchet Item 02 Extension, 125 mm Item 03 Extension, 250 mm Item 04 Universal Item 05, Sockets double hexagon, 10 mm double hexagon, 13 mm double hexagon, 17 mm double hexagon, 19 mm double hexagon, 22 mm internal hexagon, 5 mm internal hexagon, 6 mm internal hexagon, 7 mm internal hexagon, 8 mm internal hexagon, 10 mm internal hexagon, 12 mm screw driver, 1.6x10 mm cross head screw, 2 mm cross head screw, 3 mm cross head screw, 4 mm			1	019	
Combination spanner, 10 mm			1	032	
Combination spanner, 12 mm			1	044	
Combination spanner, 13 mm			1	056	
Combination spanner, 14 mm			1	068	
Combination spanner, 17 mm			1	081	
Combination spanner, 19 mm			1	093	
Combination spanner, 22 mm			1	103	
Combination spanner, 24 mm			1	115	
Combination spanner, 30 mm			1	127	
Combination spanner, 16 mm			1	223	

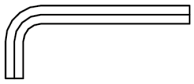
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Hand tools
Description

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Combination spanner, 18 mm			1	235	
Tee handle 1/2" square drive			1	139	
Ratchet, 20 mm			1	140	
Extension bar			1	152	
Socket spanner, square drive, size 24			1	164	
Socket spanner, square drive, size 30			1	176	
Socket spanner, square drive, size 36			1	188	
Bit, hexagon socket screw, square drive, size 8			1	247	
Bit, hexagon socket screw, square drive, size 10			1	259	
Bit, hexagon socket screw, square drive, size 12			1	260	
Torque spanner, 20-120 Nm - 1/2" Torque spanner, 40-200 Nm - 1/2" Torque spanner, 30-320 Nm - 1/2"			1 1 1	272 284 296	

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Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Hexagon key 7 mm			1	331	
Hexagon key 8 mm			1	343	
Hexagon key 10 mm			1	355	
Hexagon key 12 mm			1	367	
Hexagon key 14 mm			1	379	
Hexagon key 17 mm			1	380	
Hexagon key 19 mm			1	392	

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Project planning data

Standard propeller plants

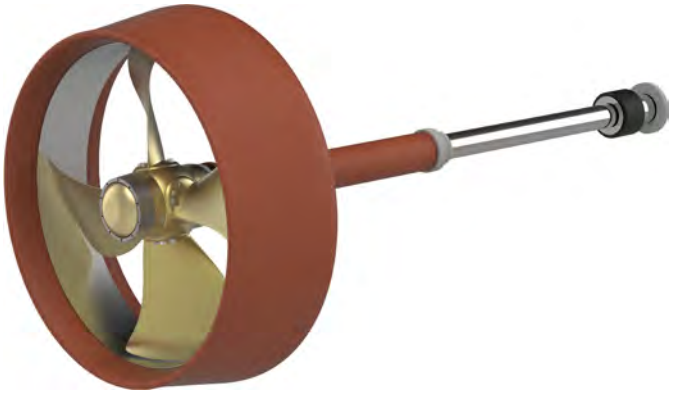
A complete range of propulsion systems has been developed to enable the selection of an optimum solution.

The range is particularly suitable for selecting the right combination of engine, gearbox and propeller equipment in the project stage. The condition chosen for optimisation is characterised by:

	Dim.	Open propeller	Ducted propeller
Engine power	%	90	90
Engine revolutions	%	98	98
Ship speed	knots	13	4

The dimensioning of the equipment is carried out at 100% MCR according to the rules of classification societies without ice class notation.

In case the optimisation criteria deviate considerably from the table above or the vessel has an ice class notation, please do contact us for a detailed calculation.



Optimizing the propeller equipment

We have the facilities and expertise to design and supply a propulsion package, optimized to a customer's specific requirements provided adequate data is available.

The design of the propeller, giving regard to the main variables which include diameter, rpm, area ratio etc, is determined by the requirements for maximum efficiency and minimum vibrations and noise levels.

The chosen diameter should be as large as the hull can accommodate, allowing the propeller revolutions to be selected according to optimum efficiency. The optimum propeller revolutions corresponding to the chosen diameter can be found from fig 1 for a given reference condition.

For a specific plant please fill in the page "Project layout data".

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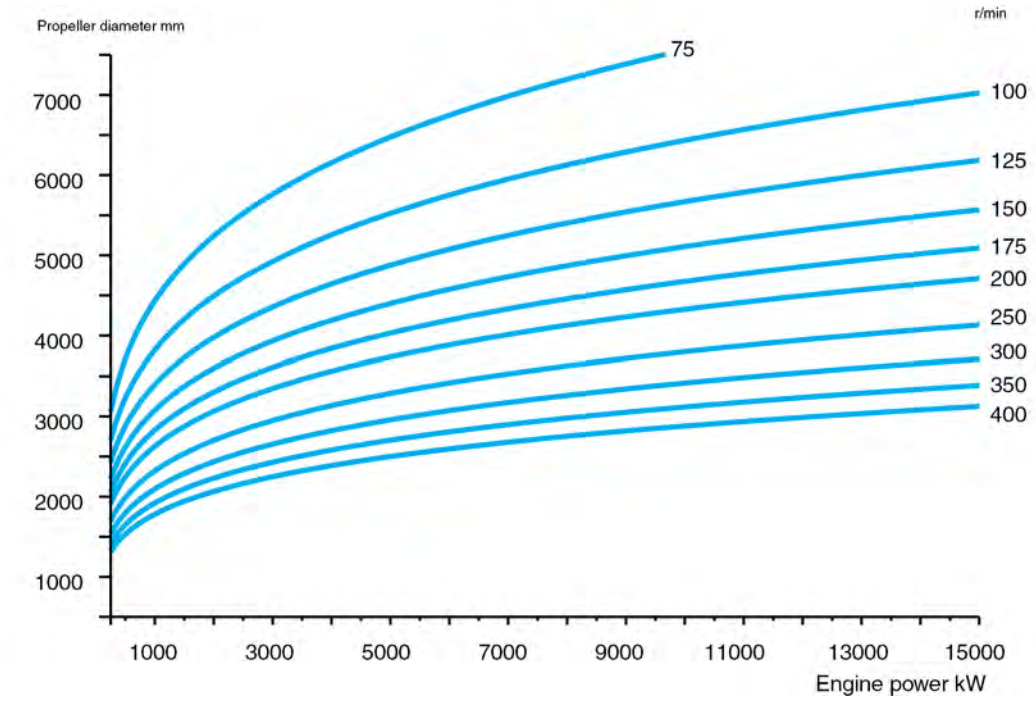


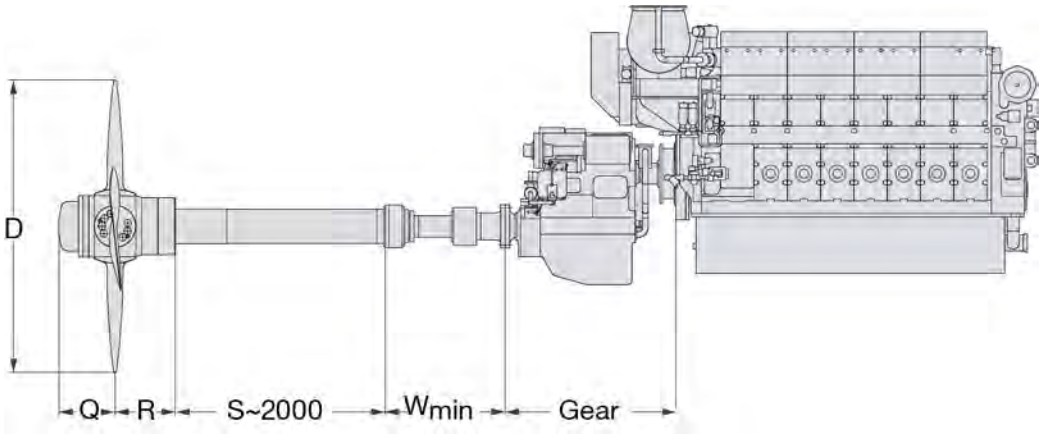
Figure 1: Optimum propeller diameter - open propeller 14 knots

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Standard programme L21/31 propeller

Engine type	MCR Power(kW)	Propeller speed at MCR (RPM)	Propeller hub type	Propeller diameter (mm) D	Q (mm)	R (mm)	Wmin (mm)	ODG size
6L21/31	1290	274	VBS600	2350	456	566	1,320	ODG200
6L21/31	1290	232	VBS600	2600	456	566	1,320	ODG225
6L21/31	1290	205	VBS660	2800	501	631	1,320	ODG225
6L21/31	1290	181	VBS660	3000	501	631	1,320	ODG225
7L21/31	1505	260	VBS600	2500	456	566	1,320	ODG225
7L21/31	1505	223	VBS660	2750	501	631	1,320	ODG225
7L21/31	1505	198	VBS660	2950	501	631	1,320	ODG225
7L21/31	1505	176	VBS720	3150	547	650	1,320	ODG225
8L21/31	1720	261	VBS600	2550	456	581	1,320	ODG250
8L21/31	1720	219	VBS660	2850	501	631	1,320	ODG250
8L21/31	1720	196	VBS720	3050	547	650	1,320	ODG225
8L21/31	1720	176	VBS720	3250	547	650	1,350	ODG225
9L21/31	1935	262	VBS660	2600	501	631	1,320	ODG250
9L21/31	1935	221	VBS720	2900	547	650	1,320	ODG250
9L21/31	1935	199	VBS720	3100	547	650	1,350	ODG250
9L21/31	1935	188	VBS720	3200	547	650	1,350	ODG225

Table 1: Standard package examples



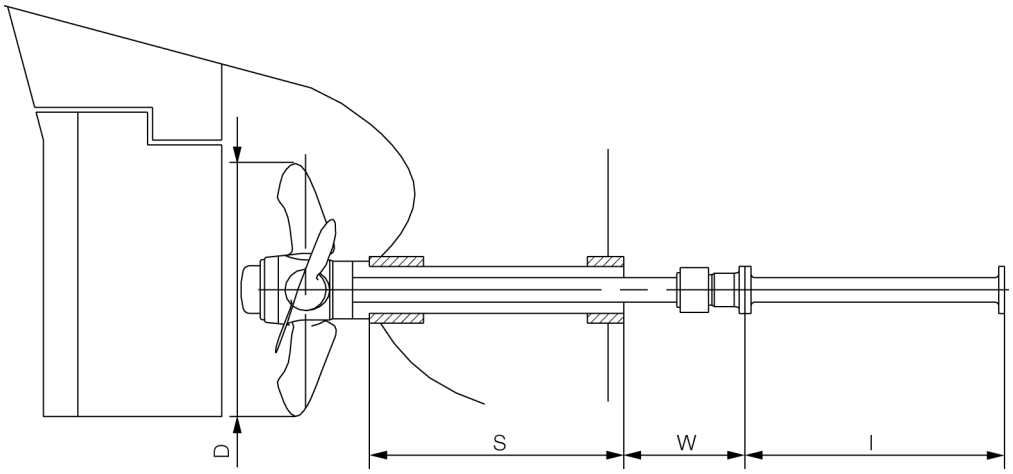
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Propeller layout data

Project :_____

Type of vessel :_____



For propeller layout please provide the following information:

1. S :_____ mm W :_____ mm I :_____ mm (as shown above)
   D : _____ mm
2. Stern tube and shafting arrangement layout
3. Stern tube mountings: Epoxy mounted _____ or interference fitted _____
4. Propeller aperture drawing
5. Copies of complete set of reports from model tank test (resistance test, self-propulsion test and wake measurement).
   In case model test is not available section 10 must be filled in.
6. Drawing of lines plan
7. Classification society :_____ Notation :_____
   Ice class notation :_____
8. Maximum rated power of shaft generator :_____ kW
9. To obtain the highest propeller efficiency please identify the most common service condition for the vessel:

Ship speed	:_____ kn.	Engine service load	:_____ %
Service/sea margin	:_____ %	Shaft gen. service load	:_____ kW
Draft	:_____ m		

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10. Vessel Main Dimensions (*Please fill-in if model test is not available*)

	Symbol	Unit	Ballast	Loaded
Length between perpendiculars	L_{PP}	m		
Length of load water line	L_{WL}	m		
Breadth	B	m		
Draft at forward perpendicular	T_F	m		
Draft at aft perpendicular	T_A	m		
Displacement	s	m^3		
Block coefficient (L_{PP})	C_B	-		
Midship coefficient	C_M	-		
Waterplane area coefficient	C_{WL}	-		
Wetted surface with appendages	S	m^2		
Centre of buoyancy forward of $L_{PP}/2$	LCB	m		
Propeller centre height above baseline	H	m		
Bulb section area at forward perpendicular	A_B	m^2		

11. Comments: _____

_____

_____

_____

Date: _____ Signature: _____

2025-02-19 - en

Layout of Fix-Pitch-Propeller

Propeller curve

The relation between power and propeller speed for a fixed pitch propeller is described by means of the propeller law, i.e. the third power curve:

$P = c \times n^3$, in which:

P = engine power for propulsion

n = propeller speed

c = constant

The exponent i=3 is valid for frictional resistance. For vessels having sufficient engine power to sail fast enough to experience significant wave-making resistance, the exponent may be higher in the high load range.

Propeller design

Normally, estimates of the necessary propeller power and speed are based on theoretical calculations for loaded ship, and often experimental tank tests, both assuming optimum operating conditions, i.e. a clean hull and good weather.

The combination of speed and power obtained may be called the ship's propeller design point.

Fouled hull

When the ship has sailed for some time, the hull and propeller become fouled and the hull's resistance will increase. Consequently, the ship's speed will be reduced unless the engine delivers more power to the propeller, i.e. the propeller will be further loaded and will be heavy running (HR).

Sea margin and heavy weather

If the weather is bad with headwind, the ship's resistance may increase compared to operating in calm weather conditions. When determining the necessary engine power, it is normal practice to add an extra power margin, the so-called sea margin, so that the design speed can be maintained in average conditions at sea. The sea margin is traditionally about 15% of the power required to achieve design speed with a clean hull in calm weather.

Engine layout (heavy propeller)

When determining the necessary engine layout speed that considers the influence of a heavy running propeller for operating at high extra ship resistance, it is recommended to choose a heavier propeller line. The propeller curve for clean hull and calm weather may then be said to represent a 'light running' (LR) propeller.

We recommend using a light running margin (LRM) of normally 4.0-7.0%, however for special cases up to 10%, that is, for a given engine power, the light running propeller RPM is 4.0 to 10.0% higher than the RPM on the engine layout curve.

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The recommendation is applicable to all draughts at which the ship is intended to operate, whether ballast, design or scantling draught. The recommendation is applicable to engine loads from 50 to 100%. If an average of the measured (and possibly corrected) values between 50 and 100% load is used for verification this will smoothen out the effect of measurement uncertainty and other variations.

The high end of the range, 7 to 10%, is primarily intended for vessels where it is important to be able to develop as much of the full engine power as possible in adverse conditions with a heavy running propeller. For example for vessels that are operating in ice.

Vessels with shaft generators may in some cases also benefit from a light running margin in the high range. It is then possible to keep the shaft generator in operation for a larger proportion of the time spent at sea.

Engine margin

Besides the sea margin, a so-called 'engine margin' of some 10% or 15% is frequently added. The corresponding point is called the 'specified MCR for propulsion'.

With engine margin, the engine will operate at less than 100% power when sailing at design speed with a vessel resistance corresponding to the selected sea margin, for example 90% engine load if the engine margin is 10%.

If a main engine driven shaft generator is installed. The extra power demand of the shaft generator must also be considered.

Four-stroke engines with gearbox need to consider loss in gearbox (approx 5%).

Note:

Light/heavy running, fouling and sea margin are overlapping terms. Light/heavy running of the propeller refers to hull and propeller deterioration and heavy weather, whereas sea margin i.e. extra power to the propeller, refers to the influence of the wind and the sea. However, the degree of light running must be decided upon experience from the actual trade and hull design of the vessel.

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Propeller operation

Operating range for controllable-pitch propeller

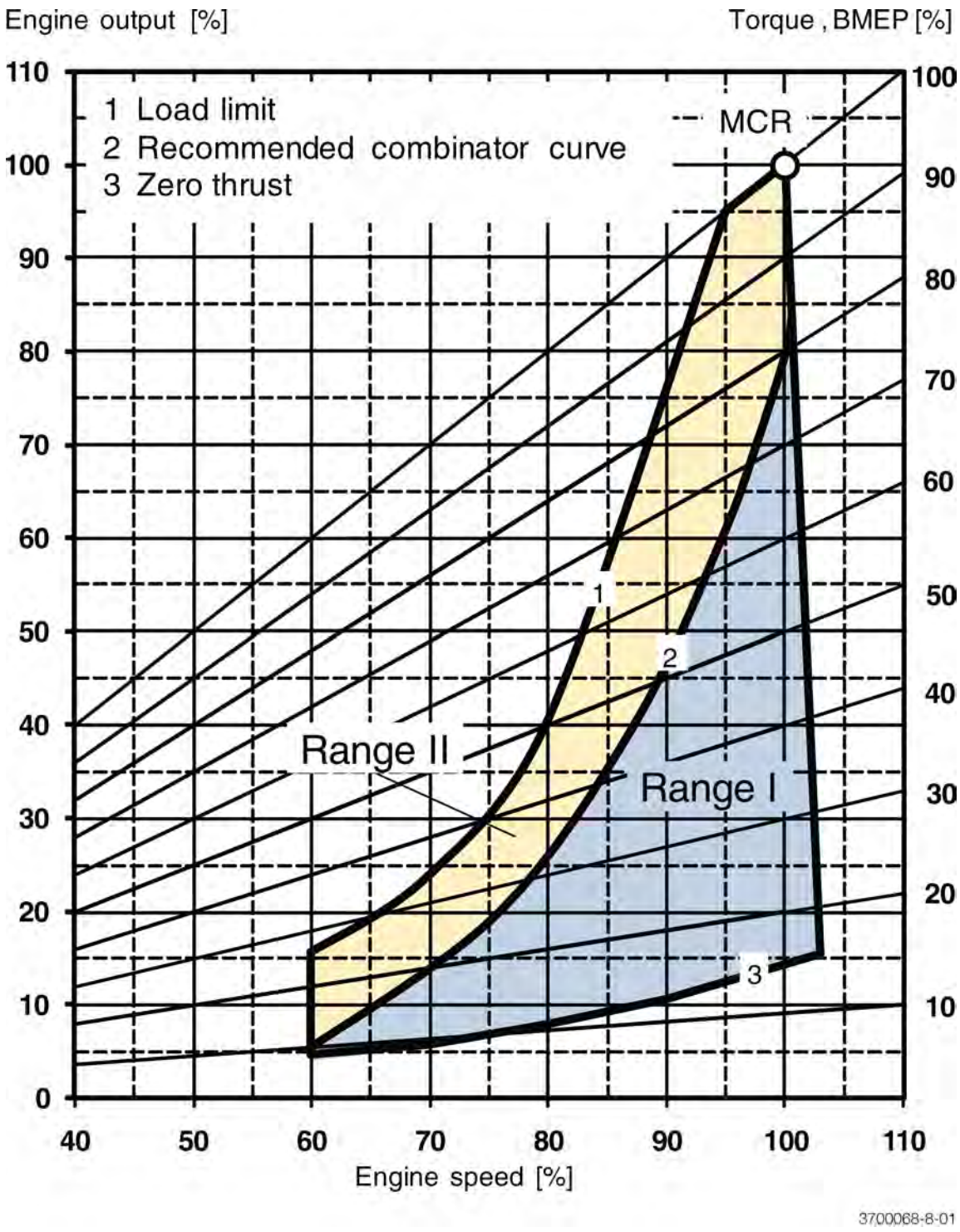


Fig 1 Operating range for controllable-pitch propeller

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Rated output/operating range

Maximum continuous rating (MCR)

Range I: Operating range for continuous operation.

Range II: Operating range which is temporarily admissible e.g. during acceleration and manoeuvring.

The combinator curve must keep a sufficient distance to the load limit curve. For overload protection, a load control has to be provided.

Transmission losses (e.g. by gearboxes and shaft power) and additional power requirements (e.g. by PTO) must be taken into account.

General requirements for propeller pitch control

Pitch control of the propeller plant

For mechanical speed governors

As a load indication a 4–20 mA signal from the engines admission teletransmitter is supplied to the propeller control system.

For electronic speed governors

As a load indication a 4–20 mA signal from the engines electronic governor is supplied to the propeller control system.

General

A distinction between constant-speed operation and combinator-curve operation has to be ensured.

Combinator-curve operation:
The 4–20 mA signal has to be used for the assignment of the propeller pitch to the respective engine speed. The operation curve of engine speed and propeller pitch (for power range, *see Fig 1, Operating range for controllable-pitch propeller*) has to be observed also during acceleration/load increase and unloading.

Acceleration/load increase

The engine speed has to be increased before increasing the propeller pitch (*see Fig 2, Example to illustrate the change from one load step to another*).

Or if increasing both synchronic the speed has to be increased faster than the propeller pitch. The area above the combinator curve should not be reached.

Deceleration/unloading the engine

The engine speed has to be reduced later than the propeller pitch (*see Fig 2, Example to illustrate the change from one load step to another*).

Or if decreasing both synchronic the propeller pitch has to be decreased faster than the speed. The area above the combinator curve should not be reached.

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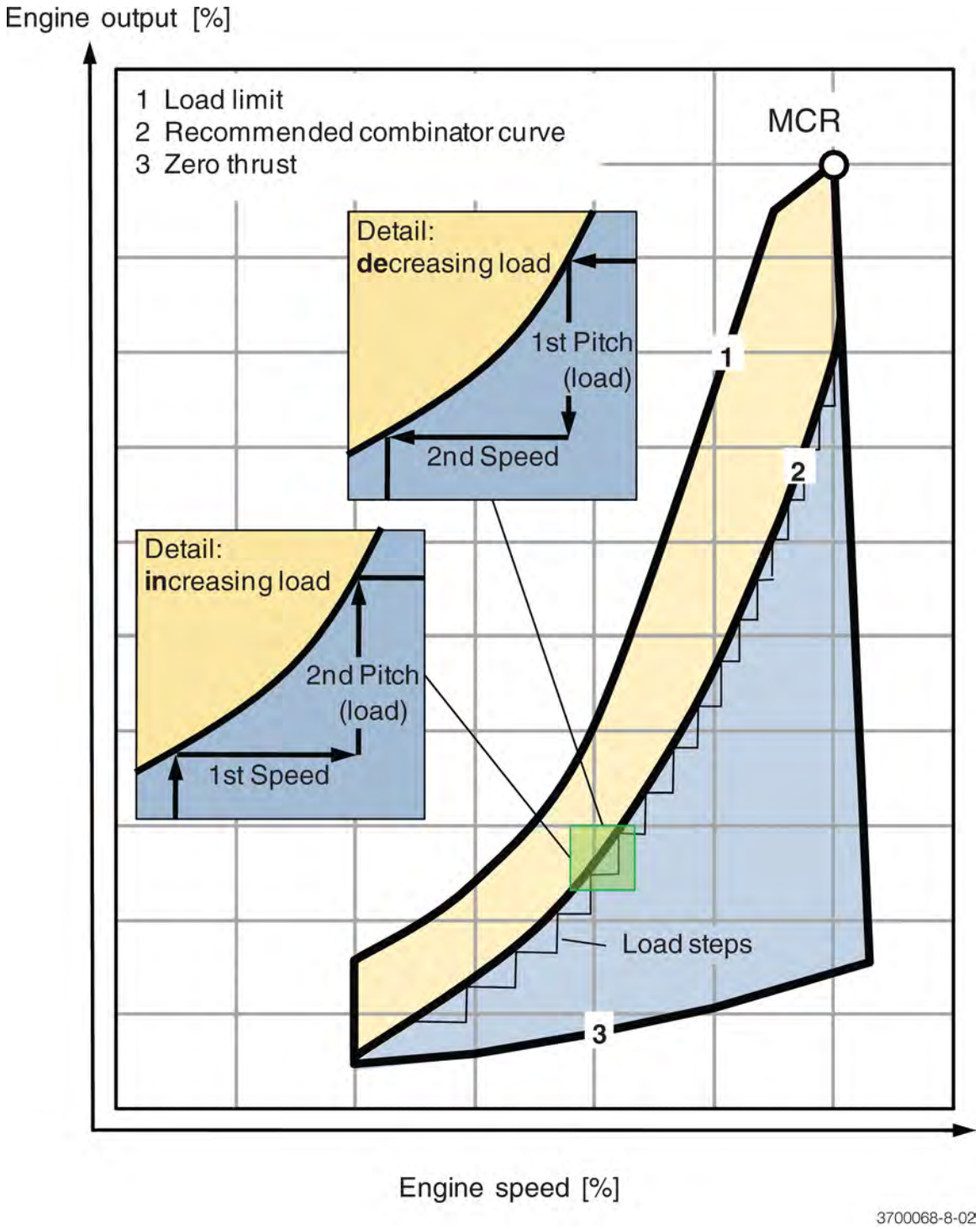


Fig 2 Example to illustrate the change from one load step to another

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Windmilling protection

If a stopped engine (fuel admission at zero) is being turned by the propeller, this is called "windmilling". The permissible period for windmilling is short, because windmilling can cause, due to poor lubrication at low propeller speed, excessive wear of the engines bearings.

Single-screw ship

The propeller control has to ensure that the windmilling time is less than 40 sec.

Multiple-screw ship

The propeller control has to ensure that the windmilling time is less than 40 sec. In case of plants without shifting clutch, it has to be ensured that a stopped engine won't be turned by the propeller.

(Regarding maintenance work a shaft interlock has to be provided for each propeller shaft.)

Binary signals from engine control

Overload contact

The overload contact will be activated when the engines fuel admission reaches the maximum position. At this position, the control system has to stop the increase of the propeller pitch. If this signal remains longer than the predetermined time limit, the propeller pitch has to bo decreased.

Operation close to the limit curves (only for electronic speed governors)

This contact is activated when the engine is ope-rated close to a limit curve (torque limiter, charge air pressure limiter ....). When the contact is activated, the propeller control system has to keep from increasing the propeller pitch. In case the signal remains longer than the predetermined time limit, the propeller pitch has to be decreased.

Propeller pitch reduction contact

This contact is activated when disturbances in engine operation occur, for example too high exhaust-gas mean-value deviation. When the contact is activated, the propeller control system has to reduce the propeller pitch to 60% of the rated engine output, without change in engine speed.

Distinction between normal manoeuvre and emergency manoeuvre

The propeller control system has to be able to distinguish between normal manoeuvre and emergency manoeuvre (i.e., two different acceleration curves are necessary).

Everllence's guidelines concerning acceleration times and power range, *see page 5 and page 1*.

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Acceleration times

Acceleration times for controllable pitch-propeller plants

Notes on design

For remote controlled propeller drives for ships with unmanned or centrally monitored engine room operation, a load programme has to be provided for the engines. Within the scope of the remote control system (for the pitch adjustment of the controllable pitch propeller or reversing and load application of the engine).

This programme serves to protect the preheated engine(s) (lube oil temperature ≥ 40°C and fresh water temperature ≥ 60°C) against excessive thermal stresses, increased wear and exhaust gas turbidity, when the engines are loaded for the first time – possibly up to the rated output.

In case of a manned engine room, the engine room personnel is responsible for the soft loading sequence, before control is handed over to the bridge.

The lower time limits for normal and emergency manoeuvres are given in our diagrams for application and shedding of load. *We strongly recommend that the limits for normal manoeuvring will be observed* during normal operation, to achieve trouble-free engine operation on a long-term basis. An automatic change-over to a shortened load programme is required for emergency manoeuvres.

The final design of the programme should be jointly determined by all the involved parties, considering the demands for manoeuvring and the actual service capacity.

Please note that the time constants for the dynamic behaviour of the prime mover and the vessel are in the ratio of about 1:100. It can be seen from this that an extremely short load application time generally don't lead to an improvement in ships manoeuvring behaviour (except tugs and small, fast vessels).

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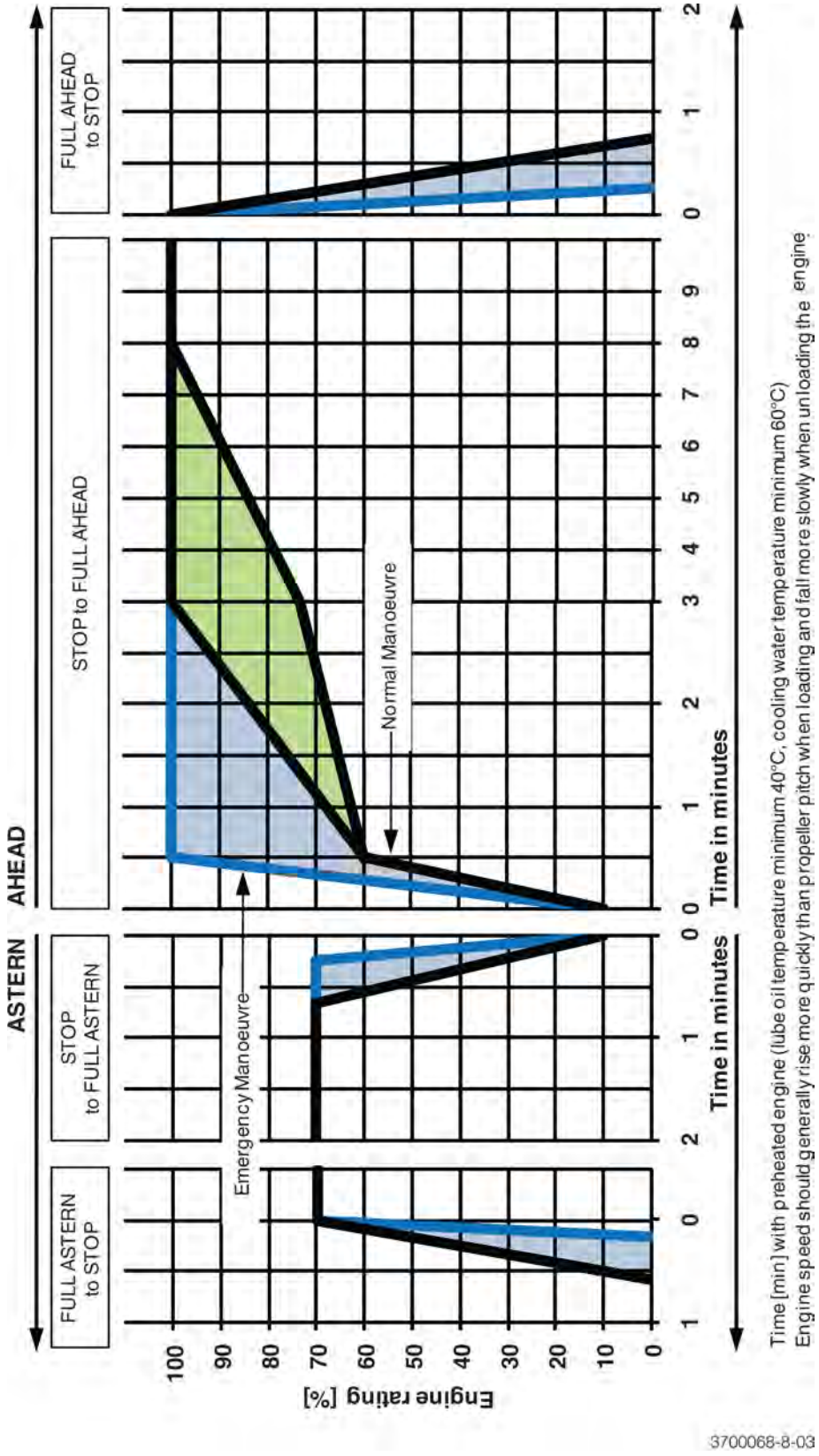


Fig 3 Control lever setting / propeller pitch

Operating range for fixed-pitch propeller

Single shaft vessel

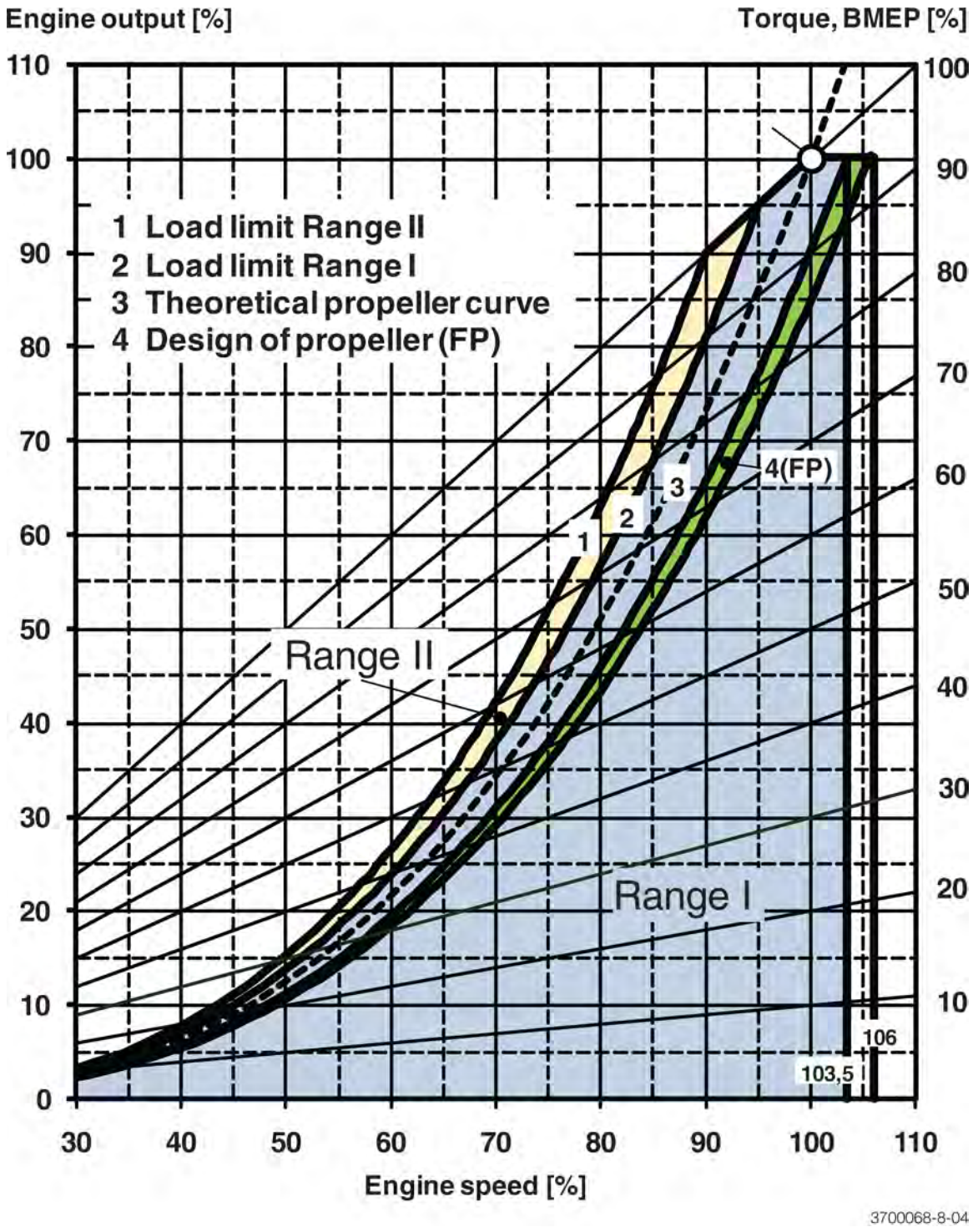


Fig 4 Operating range for fixed-pitch propeller

- Maximum continuous rating (MCR), fuel stop power
- Range I

  Operating range for continuous service subject to a propeller light-running of 4–7% and in special cases up to 10%, see B 53 00 0 'Layout of fix-pitch propeller'.
- Range II (torque limit)

  Operating range which is temporarily admissible e.g. during acceleration, manoeuvring.
- Theoretical propeller curve

  Applies to a fully loaded vesel after a fairly long operating time and to a possible works trial run with zero-thrust propeller.
- FP

  Design range for fixed-pitch propeller. A new propeller must be designed to operate in this range.

NOTICE

Engine operation in a speed range between 103% and 106% is permissible for maximum 1 hour!

The propeller design depends on type and application of the vessel. Therefore the determination of the installed propulsive power in the ship is always the exclusive responsiblity of the yard.

Determining the engine power: The energy demand or the energy losses from all at the engine additionally attached aggregates has to be considered (e.g. shaft alternators, gearboxes). That means, after deduction of their energy demand from the engine power the remaining engine power must be sufficient for the required propulsion power.

NOTICE

Type testing of the engines is carried out at 110% rated output and 103% rated engine speed.

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Stern tube

Net cutter and net pick-up

To avoid fishing lines and nets being wound−up by the rotating propeller and causing damage to the AFT stern tube seal, two precautions can be taken.

By installing net cutters, a first barrier which will try to cut the net and line into smaller pieces is established.

The net cutters consist of 4 to 10 knives (depending on the AFT seal size) which are bolted on the rope guard. The net cutters are overlapping the rotating part of the propeller.

A second barrier may be applied by installing a line guard which will wind-up the net before it reaches the AFT stern tube seal, in case the lines are able to pass the net cutters. The Line Guard is placed under the protection cover at the fore-end of the propeller hub.

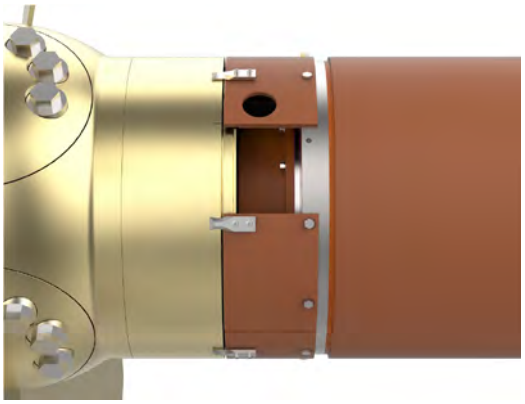




Figure 1: Line guard



Figure 2: Net cutter

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Installation

Installation of propeller equipment into the ship's hull shows many different solutions depending on installation requirements from the ship yard and the ship owners operational demands.

We have the expertise and knowledge of all the different possible stern tube installations to meet specific wishes and requirements.

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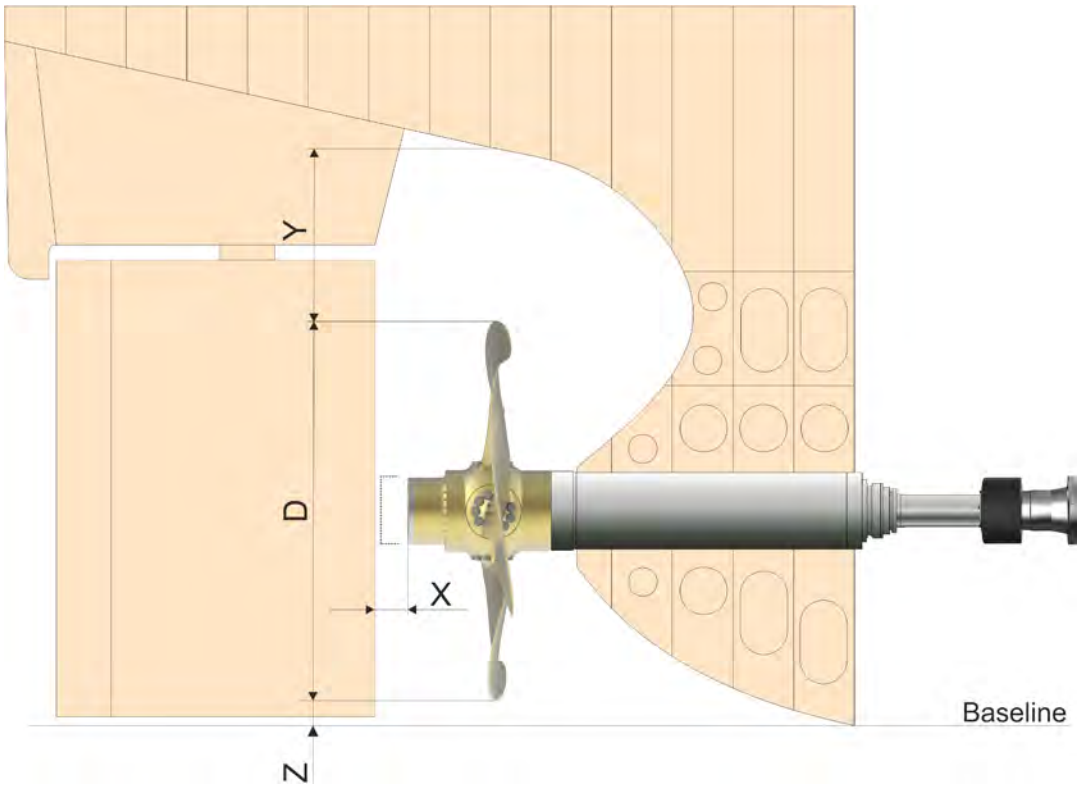
Propeller clearance

Description

To reduce emitted pressure impulses and vibrations from the propeller to the hull, MAN Energy Solutions recommend a minimum tip clearance as shown in fig 1.

For ships with slender aft body and favourable inflow conditions the lower values can be used whereas full aft body and large variations in wake field causes the upper values to be used.

In twin-screw ships the blade tip may protrude below the base line.



Hub	Dismantling of cap X mm	High skew propeller Y mm	Non-skew propeller Y mm	Baseline clearance Z mm
VBS 600	95	15-20 % of D.	20-25 % of D.	Minimum 50-100
VBS 660	115			
VBS 720	120			

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Direction of rotation

Definitions

The direction of rotation is defined seen from aft. The normal direction is anti-clockwise for the propeller. Opposite rotating direction can also be supplied by changing direction of the engine.

Twin-screw propulsion plants

The direction of rotation of the propellers for twin-screw propulsion plants can be chosen in two ways, *as shown in figure 1 and figure 2*.

Usually, we recommend the propellers to turn towards each other at the top.

This solution will normally give the propellers the highest efficiency, because the flow around the stern of most vessels will favour this direction of rotation.

However, it is not possible to give an opinion concerning this, unless model tests are carried out for the specific vessel.

The configuration in *figure 2* is recommended for icebreakers, river craft or the lake, which operate in areas prone to damage, trees, ice etc. floating in the water.

Outward turning propellers will tend to throw out foreign matter rather than wedging it in.

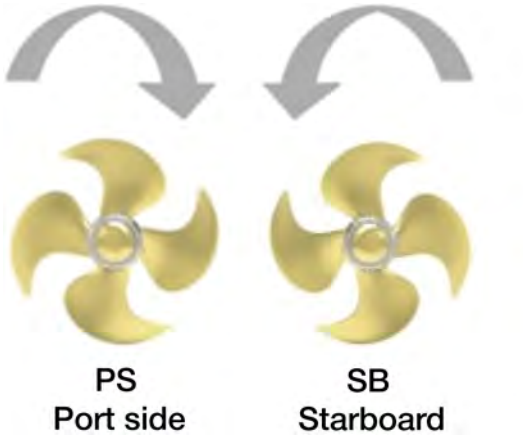


Figure 1: Inward turning propellers

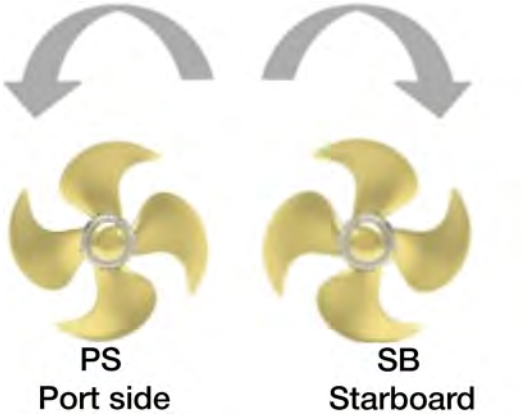


Figure 2: Outward turning propellers

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Propulsion control system

We offer single source solutions

Our state-of-the-art medium-speed propulsion package:

Everllence Alpha controllable pitch propellers with tailored stem tubes, seals, tail shafts, intermediate shafts, couplings and the Alphatronic 3000 control system => optimized and fine-tuned for the wide range for small-bore Everllence L21/31 or L27/38 engines.

Benefits at a glance

- High efficiency and low noise
- Low operational costs
- Low installation costs
- Superior package value

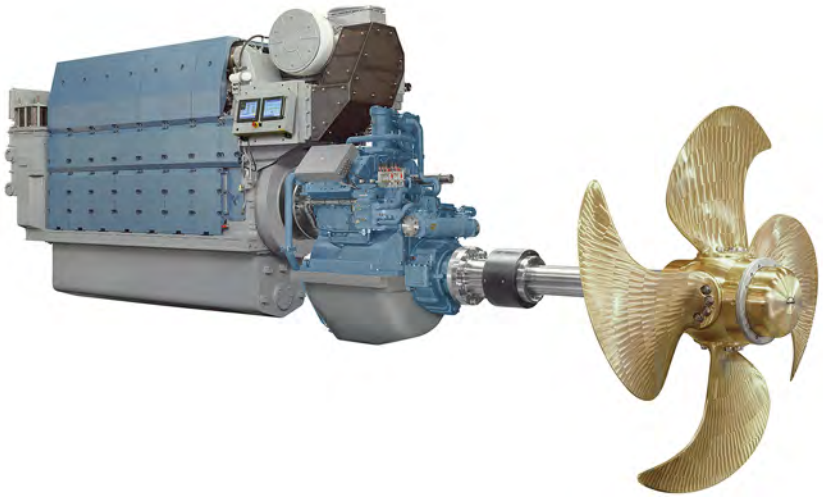


Figure 1: Propulsion package – Everllence L27/38 with controllable pitch propeller (CPP)

Our state-of-the-art propulsion control system



Figure 2: Alphatronic 3000 control station for geared propulsion systems – twin screw CPP example

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Propulsion control system – Propeller

System overview

Alphatronic 3000 (AT3000) is the propulsion remote control system developed by Everllence for the Everllence diesel and gas engine range.

The basic features of the Alphatronic 3000 system design are:

- Main engine start/stop
- Main engine setpoint (combinator, constant rpm and separate)
- Main engine load control (load control limitations)
- Main engine load reduction (rpm and/ or load reduction)
- Main engine speed measurement (and indication)
- Combinator control from single lever in ECR and on the bridge
- Controllable pitch propeller (CPP) setpoint system (combinator curves)
- Control transfer (bridge/ECR setpoint selection)
- Propulsion mode selection (combinator, constant rpm and separate)
- Bridge wing control with wing panels and electric shaft on setpoint levers
- Serial interface to Alphacomm units on the main engine (if mounted)
- Alarm announcement and indication

The Alphatronic 3000 can be extended with the following options:

- Clutch control (ME, PTO and PTI (engage/ disengage))
- Propeller shaft speed measurement and indication
- Interface to PTO connected shaft generator (SG waiting station)
- Alternative propulsion (PTI mode)
- Power boost (ME + PTI simultaneously)
- Reverse power from winches
- Speed Pilot integrated in the system
- Maneuvering order printer integrated in the system
- Wind assisted ship propulsion systems

Modularity

Depending on the propulsion engines' application, plant scope and functionality, additional display and control functions can be added in order to meet the requirements of the classification societies and customers. As central element, the PCU (propulsion control unit) communicates between the control stations as well as with engines and plant equipment. Due to its modularity, the complete control system can be customized up to a high degree in order to fulfill the customer's individual needs.

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System configuration

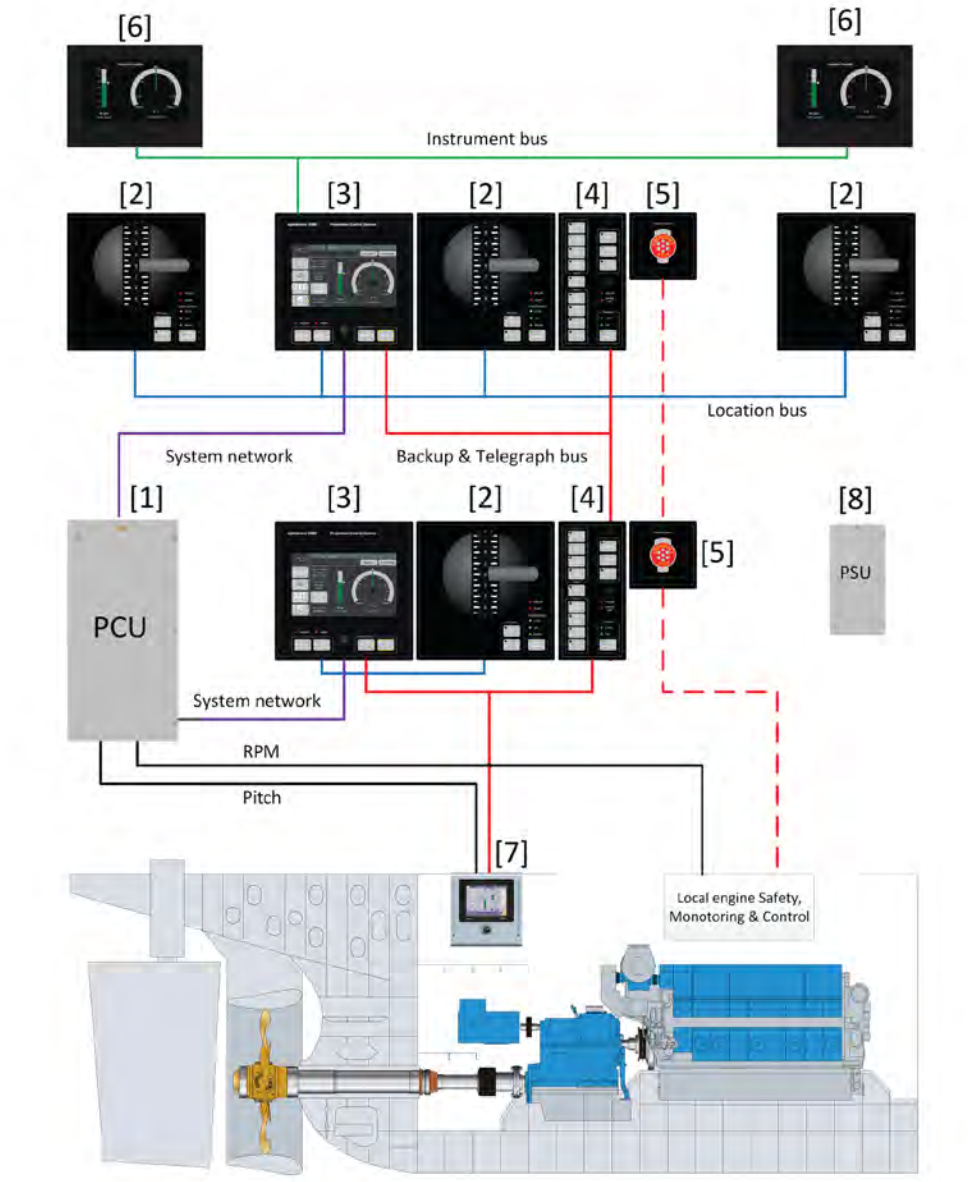


Figure 3: Alphatronic 3000 system configuration – propulsion plant with CPP

[1] Propulsion control unit (PCU)

The propulsion control unit (PCU) is delivered in a cabinet intended for bulkhead installation in the machinery space. The control unit comprises I/O modules for interfaces to the machinery and to the external systems. The included digital processor unit is handling the system software related to normal control level, which incorporates the following main control functions:

- Automatic load control with engine overload protection and engine running- up load program
- Automatic load reduction and slowdown control
- Electric shaft control of all included levers ensuring bumpless transfer of responsibility

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- Engine start/stop and gear clutch control
- Self-monitoring and system failure alarm handling

[2] Manoeuvre handle panel (MHP)

The manoeuvre handle panel (MHP) is the primary control device for the main propeller. The panel is always located on the ship's bridge, normally also in the ECR and optionally on the bridge wings. A control station will comprise one MHP in a suitable version for the actual propulsion plant.



Figure 4: Single-handle version MHP for CPP

The double-handle version is for independency of the two shaft lines divided into two separate electric circuits. All handles comprise a stepper motor for alignment (electric shaft system) of the levers according to the commands from the lever in command.



Figure 5: MHP in a simple control station console – with PCP and TOP

[3] Propulsion control panel (PCP) 7" display module

The propulsion control panel (PCP) with 7" display module comprises a touch screen with soft keys for handling transfer of control responsibility and setup of propulsion power. In addition to propulsion setup the display is handling the general monitoring and alarm for the propulsion control system as well.

The control functions related to "shutdown" and "load reduction" from the engine safety system are also available in the display panel.

The PCP is optional for bridge wing positions.

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Figure 6: Propulsion control panel – PCP – For CPP

[3A] Information display 15"

Like for the 7" touch screen in the PCP, a separate 15" information display can be tailor-made to the specific engine and propulsion system applications.



Figure 7: PCP information display

[4] Telegraph order panel (TOP)

The telegraph order panel (TOP) is operating totally independently of the propulsion remote control system. According to SOLAS requirements, at least one telegraph panel per propeller shaft must be available on the bridge control location and in the engine room for safety and redundancy reasons. However, the telegraph panel can be placed on any bridge control station where the telegraph order communication is expected to be relevant.

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Figure 8: Telegraph order panel – TOP

The telegraph can be used for independent order communication from the bridge to the engine room.

[5] Emergency stop panel (ESP)

The propulsion power emergency stop panel (ESP) is operating totally independently of the propulsion remote control system. According to regulatory, at least one emergency stop panel per propeller shaft must be available on the bridge control location and in the ECR. For safety reasons, it is recommended to incorporate an emergency stop panel on all control stations.



Figure 9: Emergency stop panel – ESP

[6] Propeller indicator panel

Standard indoor panel (Panama instrument) showing propeller speed and pitch.

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Figure 10: Propeller indicator panel – PIP

[7] – Local Propulsion Control system LPCS and Local Operator Panel-Propeller LOP-P

The LPCS is the propeller closed loop control system and take care of pitch control, gearbox clutch control, and BACKUP and Telegraph functionality.



Figure 11: LOP

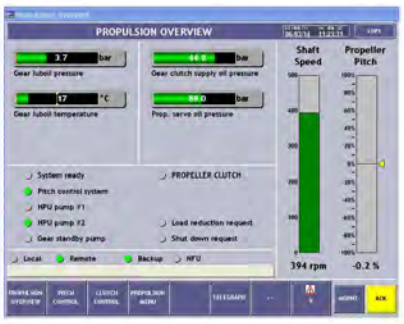


Figure 12: Propulsion overview

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Alphatronic 3000 requirements

The following item is part of the Alphatronic 3000 system configuration, see figure Alphatronic 3000 system configuration. There the power supply is numbered with [8].

[8] Power supply with battery backup

Being an essential consumer, the power to the propulsion control system is divided into two different distribution lines. The main supply for the two power supplies must be from independent sections of the main power system on board the vessel. In the installation documentation, the two supplies are described as Power A and Power B. Power A must be supplied by an AC/DC converter to ensure galvanic isolation, and Power B must be a 24 V DC no-break power supply with at least 30 minutes battery backup. The power from the two power supplies are distributed in three groups each:

- Propulsion control system: Nominal load 80 W, peak load 150 W
- Bridge propulsion control panels: Nominal load 100 W, peak load 200 W
- Local propulsion control system: Nominal load 150 W, peak load 200 W

The power supply is normally a standard required yard supply. On request, a power supply unit with duplicated power input, battery backup and fuses for power distribution to the propulsion control systems can be incorporated in the Alphatronic 3000 scope of delivery.

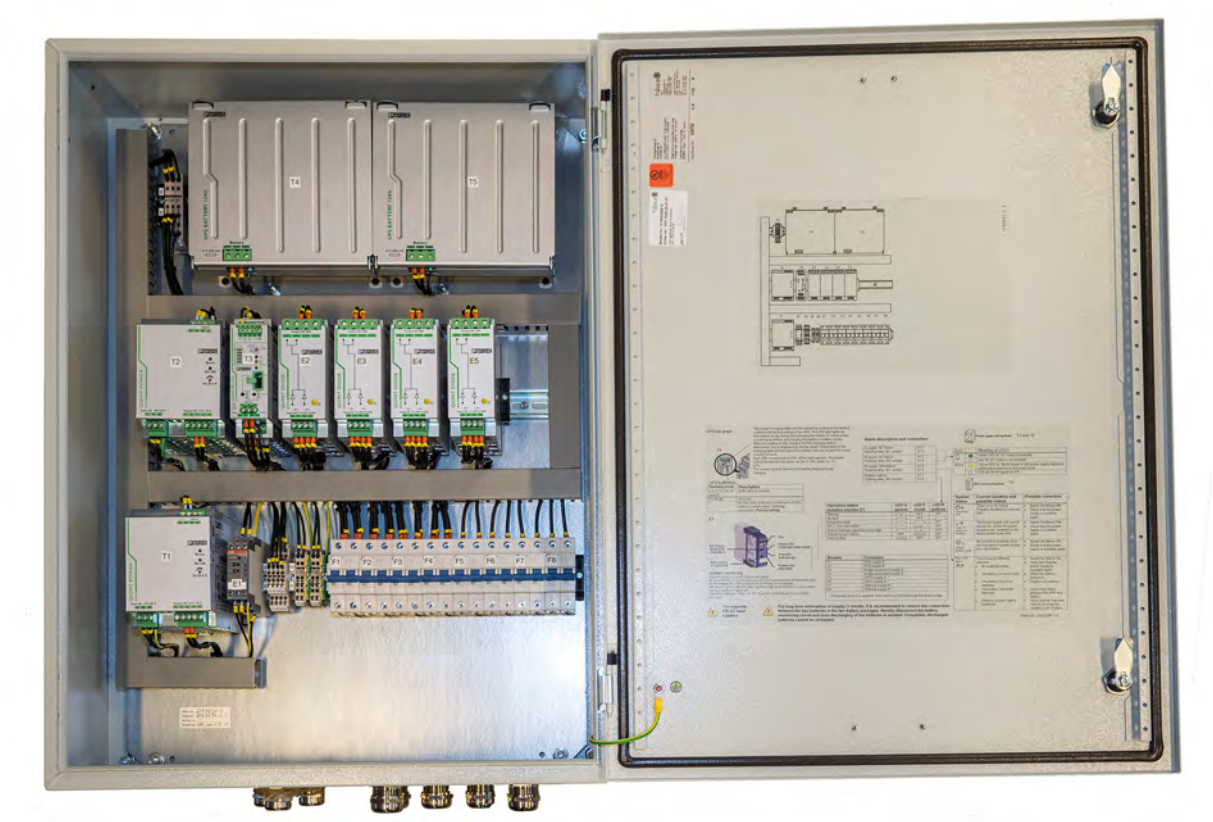


Figure 13: Power supply unit

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Alphatronic 3000 functionality

Speed pilot – Optional

A speed pilot feature is available with connection to the ship‘s GPS system for "Speed over ground" (SOG) input. The speed pilot optimizes the voyage planning and operational speeds e.g. for pulling, steaming and convoy sailing – with fuel saving potentials of up to 4 %.

Alphatronic 3000 interfaces

Standard engine interface for engine

The interface comprises hardwired interface for engine safety system, control transfer and engine speed and load control. Optionally remote start and stop of engines can be included.

Optional interface for shaft brake control

A propeller shaft brake can be controlled by Alphatronic 3000. Some gearbox designs feature the possibility of automatically activating a hydraulic shaft brake when clutching out. Please contact the gearbox supplier in every case.

The Alphatronic 3000 propeller/gear interface features shaft brake control via hardwired interfaces to the gearbox control and enables independent functionality in normal and backup control level. The interfaces comprise functionality for oil pump control, remote clutch control and shaft brake control. Interfaces to external control and monitoring systems

Optional interface to ship alarm system

Alarm and monitoring parameters provided by the Alphatronic 3000 propulsion control system for monitoring and announcement in the ship’s alarm system are specified in a plant-specific summary of alarms. The data transmitted on the modbus to the ship’s alarm system comprises a combination of alarm parameters requiring the attention from an engineer, propulsion status and monitoring parameters available for general information in the ship’s alarm and control system. Refer to our standard reference drawing: 2173577-0 Summary of Alarms (A 7-page document not inserted in this Project Guide – will be forwarded upon request).

Optional interface to voyage data recorder (VDR)

The status in the normal control system is transmitted to the voyage data recorder system via a NMEA serial line according to IEC/EN 61996 and IEC/EN 61162-1. The status in the telegraph system is independent of the normal control status and is also transmitted to the voyage data recorder system via an NMEA serial line according to IEC/EN 61996 and IEC/EN 61162-1. Refer to our standard reference drawing: 2171083-3 VDR interface for normal control level (A 5-page document not inserted in this Project Guide – will be forwarded upon request). And refer to our standard reference drawing: 2171084-5 VDR interface for telegraph orders and backup control level (A 4-page document not inserted in this Project Guide – will be forwarded upon request).

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Optional interface to GPS for Alphatronic 3000 speed pilot and master clock

An interface from the GPS is required if the optional Alphatronic 3000 speed pilot is included in the supply. The interface is made according to the NMEA 0183 standard for interfacing marine electric devices.

A GPRMC sentence comprising "Speed over ground" information is expected to be received from the GPS. The interface for the GPS can as well comprise the master clock functionality with control of UTC and local time via a ZDA sentence from the GPS to Alphatronic 3000. Refer to:

- our standard reference drawing: 2172660-2 Interface for Speed Pilot and
- our standard reference drawing: 2188788-6 Interface to Master Clock.

Further, the Alphatronic 3000 can include interface to the ship's navigation system if the ship speed and course are intended to be automatically controlled by a high level route planning system.

Optional interface to DP and joystick control system

It's possible to transfer the control of the main propeller to an external control system such as a dynamic positioning system or a joystick control system. Control can be transferred to an external system when the manoeuvring responsibility is on the bridge, the engine is running and the propeller is engaged. During joystick control, the engine is still fully protected against overload.

With independent interfaces to a dynamic positioning system and a joystick control system the Alphatronic 3000 system fulfils the IMO requirements for dynamic position class 2 (DP2).

Refer to our standard reference drawing: 2176193-8 Interface to DP system and/or joystick control system (A 3-page document not inserted in this Project Guide – will be forwarded upon request).

Alphatronic 3000 installation

Cable plans and cabling

Cable plans and connection lists showing each cable connection to control system terminals are supplied by Everllence – when a purchase contract has been signed and upon receipt of all necessary shipyard information. In order to ensure the optimum function, reliability and safety of the control system, without compromise, the following installation requirements must be taken into consideration:

- Power supply cables must be at least of size 2.5 mm^2
- If the supply cable length between the bridge and the engine room is in excess of 60 metres, the voltage drop should be considered
- The signal cables should have wires with cross sectional area of min. 0.75 and max. 1.5 mm^2
- All cables should be shielded and the screen must be connected to earth (terminal boxes) at both ends
- Signal cables are not to be located alongside any other power cables conducting high voltage (i.e. large motors) or radio communication cables. The remote control signals can be disturbed by current induced into the cables from their immediate environment. Induced current may disturb or even damage the electronic control system if the cables are not installed according to our guidance

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Installation guidance

Purpose

The purpose of this document is to describe the general requirements for installation of an Alphatronic 3000 propulsion control system on board a ship.

Installation documentation

For mechanical installation of delivered equipment refer to the dimension drawings of the individual units to be installed. For each workstation our recommended layout for the workstation is forwarded. The types of cables specified in this document are referring to the plant specific cable installation documents forwarded to the yard. For interfaces to external systems, descriptions of expected signals exchanged with the external systems are forwarded.

Mechanical installation

The delivered control cabinet is intended for installation on the bulkhead, allowing 30 to 100 centimetres of free space between the bottom of the cabinet and the deck. This provides space for cables coming in through the cable flanges in the bottom of the cabinet. The cable flanges may be removed for drilling of holes for cable glands suitable for the cables delivered by the installation yard. Components delivered in terminal boxes or cabinets must not be removed from their casing. For electrical noise protection, an electric ground connection must be made from the cabinet to the ship's hull. The cabinets must be installed on a place suitable for service inspection. Do not install the cabinets close to devices generating heat. The enclosure protection of cabinets intended for indoor installation on bridge or in machinery space is IP54. The enclosure protection of units intended for open deck or bridge wings is IP56.

The delivered control panels are fixed in the consoles by 4 M6 nuts from the rear after insertion of the panel from the front. For arrangement of propulsion control stations, refer to the layout drawings delivered for the vessel in question.

NOTICE

As standard the control panels are delivered for indoor installation. Panels intended for open deck or open bridge wings will be delivered with special gaskets for enclosure protection IP56 according to required protection for equipment on ship's deck.

Power supply

As an essential consumer the power to the propulsion control system must be divided in two different distribution systems. The main supply for the two power supplies must be from independent sections of the main power system on board the vessel. In the installation documentation the two supplies are described as Power A and Power B.

Power A must be supplied by an AC/DC converter to ensure galvanic isolation, and Power B must be a 24 V DC no break power supply with at least 30 minutes battery backup.

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Voltage	24 V DC + 30 % – 25 % incl. voltage ripple
Voltage ripple	10 % AC rms over steady DC voltage

The power from the two power supplies are distributed in three groups each:

Propulsion control system	Nominal load 80 W, peak load 150 W
Bridge propulsion control panels	Nominal load 100 W, peak load 200 W
Local propulsion control system	Nominal load 150 W, peak load 200 W
Max. current each	10 Amp, fused

Type of cables used for the Alphatronic 3000 system

Type 1

Cables used for power supplies and hardwired input/output: Shielded cables with stranded wires must be used. The size of the power supply cables is specified in the cable plan, but must always have sufficient capacity to ensure that the voltage drop does not exceed 1 volt from power supply to last consumer in the system.

Type 2

Communication cable for serial input/outputs: Shielded cables with stranded wires twisted in pairs must be used.

Type 3

Network communication cables:

The network cables between the propulsion control unit and the control panels.

Wires	Four twisted pairs, stranded wires (4 x 2 x 0.5 or 4 x 2 x 0.75)
Impedance	Approximately 100 ohm
Shielding	Copper braid shield with drain wire on the cable
Examples of cables	BELDEN AWG 24, type No. 8102 LOCAP, type AWG 20, Digital No. 17-0130-01 NK Cables, type LJST-HF 2 x 2 x 0.5 FMGCG 2 x 2 x 0.75

Type 4

Industrial ethernet Cat 5e ES cable:

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TCP/IP communication	Electrical data at 20 °C Loop resistance ≤ 120 ohm/km Signal run time ≤ 5.3 ns/m Insulation resistance ≤ 500 mohm*km Characteristic impedance 1 – 100 MHz (100 ±15) ohm Surface transfer impedance of screen 10 MHz ≤ 10 mohm/m Test voltage (wire/wire/screen rms 50 Hz 1 min) = 700 V

Examples of cables:

Supplier	LEONI Special Cables GmbH
Type	L-9YH(ST)CH 2 X 2 X 0.34/1.5-100 GN VZ
Supplier part number	202280 L45467-J16-B26

Type 5

CAN bus communication cables:

SaCoSone CAN bus communication and propeller indication panels.

Type	Databus 120 ohm, 2 x 0.5 + 0.5
Impedance	120 ohm

Example of cables:

Supplier	HUBER+SUHNER

Type 6

Not used.

Type 7

Data cable 4 x 2 x 0.5 Cat 5e SFTP marine approved cable.

Type 8

Data cable 4 x 2 x 0.5 Cat 5e SFTP marine approved cable with RJ45 connectors.

From the C-Rail with ethernet terminals on bridge and in ECR to the display panels the yard must deliver patch cables type Cat 5e SFTP with RJ45 male connectors.

Type 9

LEONI fiber breakout cable AT-V(ZN)H(ZN)H4 fiber type G 62,5 126 OM1 STB900 H with cable color (1-red, 2-green, 3-blue, 4-yellow) DNV-GL approved or similar.

NB Fiber cable to be connected with SC connector type on all 4 fibers in both ends. SC connector type HUBER+SUHNER SC Plug G50-125;G62,5/125 or similar.

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NOTICE

Only stranded Cu wires are accepted for installations on ships.

Cable installation

For layout of cables and specific terminal connections, refer to the cable plan and connection lists delivered for the vessel in question.

NOTICE

The individual cables shown on the cable plan must not be put together as one.

Laying-up of cables

When placing the cables in the vessel, the following must be taken into consideration:

- Paralleling with mains voltage or radio cables (both radio supply and antenna) for more than 5 m, must be at a minimum distance of 500 mm. Crossing of mains voltage or radio cables in right angles must be at a minimum distance of 200 mm
- All screens must be connected to the cabinets and made as short and broad as possible

Cable specification

Example: W051A 4 x 2 x 0.75 (3)

W Reference for a cable to be delivered by the yard 051A Identification number for a specific cable, where the extension A indicates that the cable is a connection between units located on a common control station

4 x 2	Number of wires in the cable (here 8 wires arranged in 4 sets of twisted pairs)
x 0.75	Wire size (cross-sectional area in mm^2)
(3)	Cable type according to cable specifications in this document

Marking of cables and wires

All cables must be marked so they are easily recognisable, according to the Everllence forwarded cable plan. All wires must be marked with the marking of the plug and terminal they are inserted in

Cable screens

Only shielded cables must be used for the Alphatronic 3000 system. The cable screen must be connected in both ends of the cable. Three types of screen connections are used in the Alphatronic 3000 system.

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Terminal boxes in engine room

Cables connected to units located in the engine room will enter the terminal box through a special EMC cable gland designed for connection of the cable screen inside the cable gland. To fulfil the requirements of the enclosure protection IP54 all cable glands not used must be sealed before the ship goes into service.

Control cabinet intended for location in ECR

Cables connected to control cabinets located in the engine control room or on the bridge have a ground (GND) rail for connection of the cable screens inside the cabinet close to the entrance of the cable.

Consoles mounted control panels

Cables connected to control panels in engine control room and on the bridge consoles must be fitted to the panel protection cover with the cable screen connected to the cover close to the terminal plugs.

Checking wires

We recommend portable digital multimeter for measuring ohm values, when checking the installation by the "ringing through" method.

NOTICE

The wires must not be tested for short circuits by high voltage equipment, i.e. meggers.

Label

Label placed inside propulsion control cabinet – Valid for the complete installation



Figure 14: Label placed inside propulsion control cabinet – Valid for the complete installation

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Layout measures

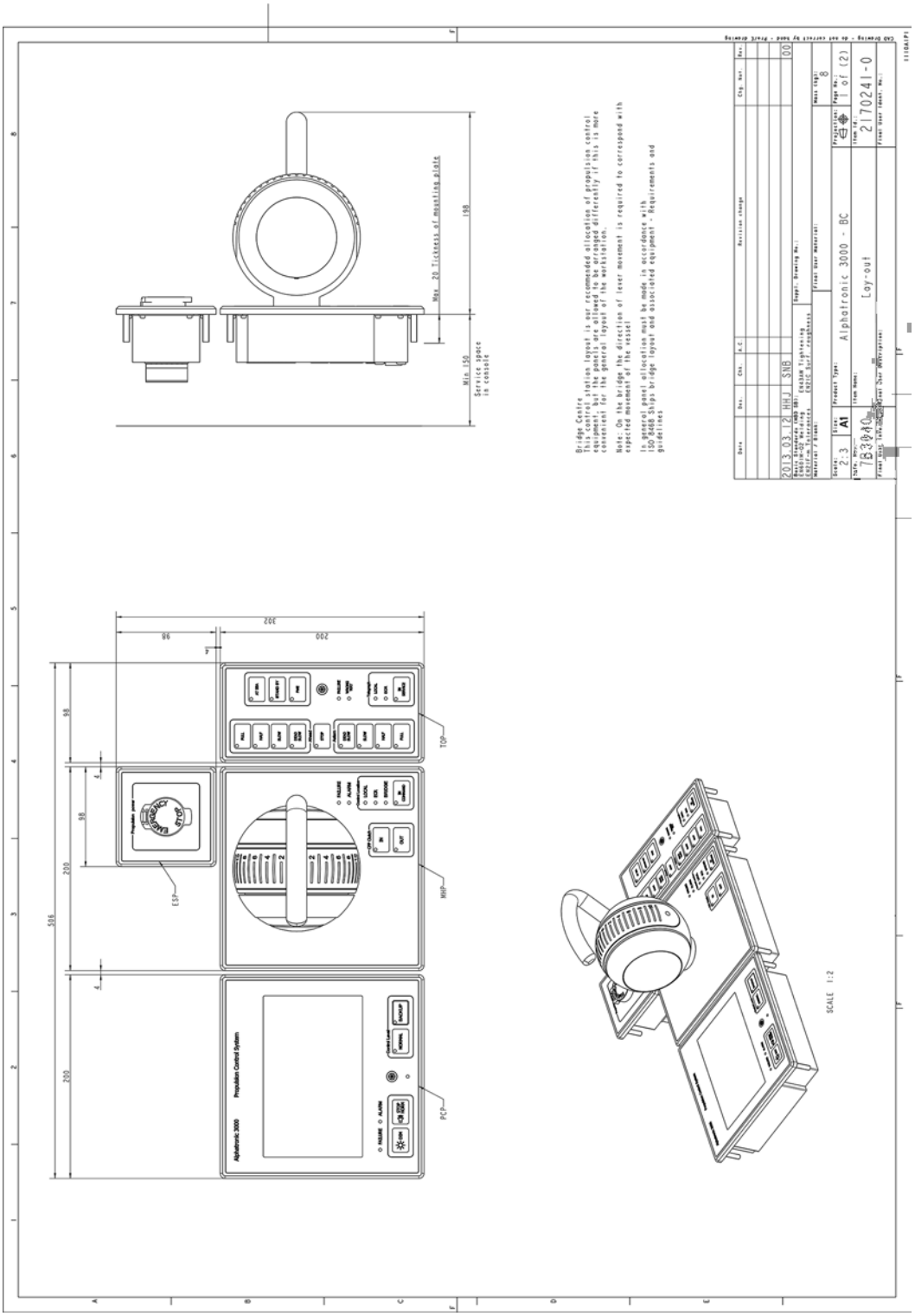


Figure 15: Layout measures for control station modules – Standard single screw example

Layout measures for standard cabinets

Propulsion control unit – PCU – H x W x D cabinet dimensions: 600 x 600 x 300 mm

Power supply unit – PSU – H x W x D cabinet dimensions: 800 x 600 x 200 mm

Cut-out measures

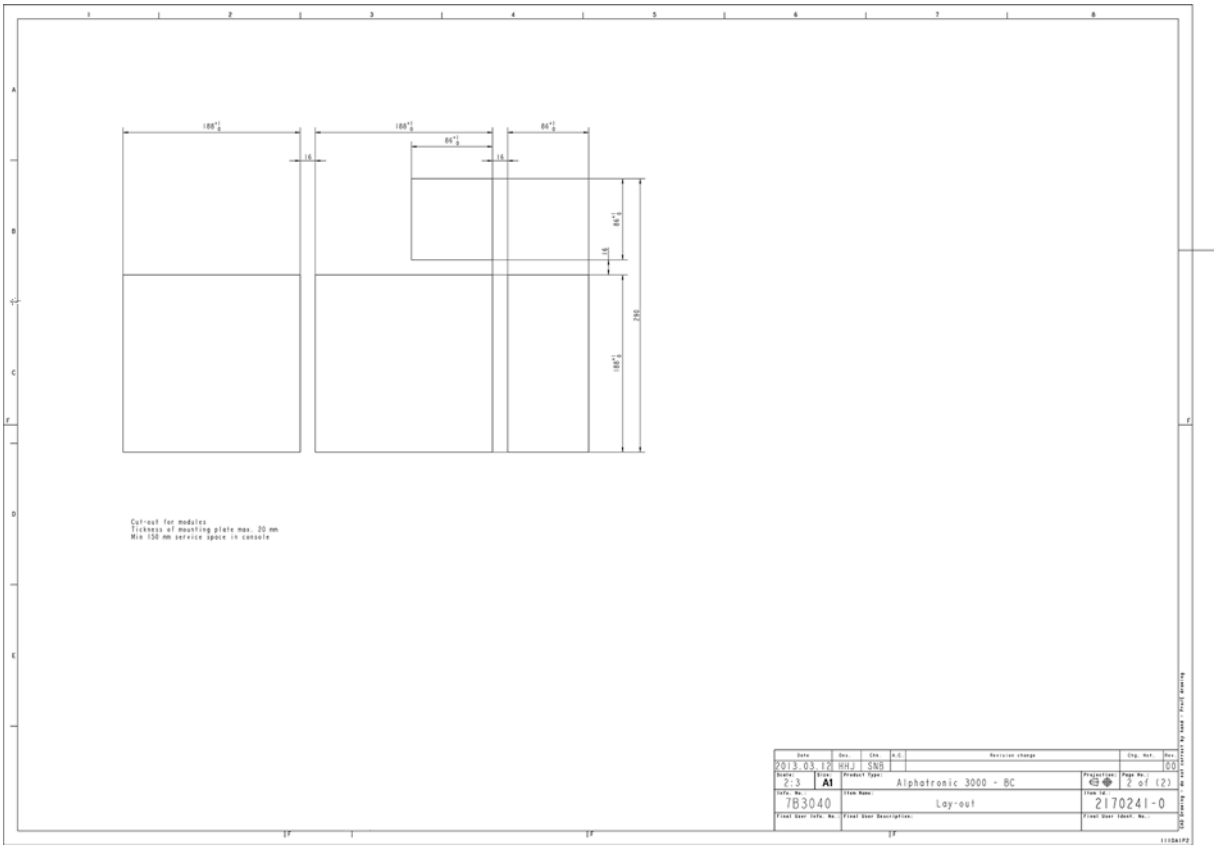


Figure 16: Cut-out measures for control station modules – standard single screw example

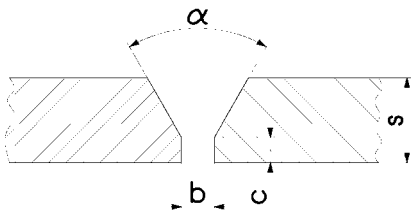
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Pipeline treatment requirements for piping manufacture

Pipeline welding

Area of Application

Air pipes, fuel pipes, oil pipes, water pipes, steam pipes.



α Angle 60°

Figure 1: Weld preparation

s- material thickness	1-2.0	2.5-3.0	3.2-5	5-8
b dimension	1	2	3	4
c dimension	0	1	1.5	2

Table 1: All dimensions in mm

General

MAN Diesel & Turbo requires using the TIG welding method (Tungsten – Inert – Gas) for all welding seams in contact with fluid.

If pipes are made of stainless steel, make sure that the flanges used are made of the same material.

In addition, make sure that proper welding material is used.

Cleaning and treatment after welding operation

If pipes of stainless steel are used, cleaning may be refused, providing the welded seams are of high quality. Otherwise, the following steps must be performed.

All pipes attached to the engine shall be cleaned mechanically or mechanically/chemically after manufacture. In case of a longer period between cleaning and fitting, the pipes must be preserved and sealed at the ends. For this purpose, blind plugs or caps in conspicuous colours are optimal to ensure that they are not overlooked during installation.

Piping of cooling water, exhaust gas and intake air systems shall be cleaned mechanically.

Mechanical and chemical cleaning is performed on lubricating oil, fuel, compressed air, steam and water condensate system piping.

Isolating and regulating units, as well as other devices may only be fitted after the cleaning process.

The entire lube oil, fuel and water system must be thoroughly flushed before commissioning the engine installation.

The compressed air system must be blown out.

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Mechanical Cleaning

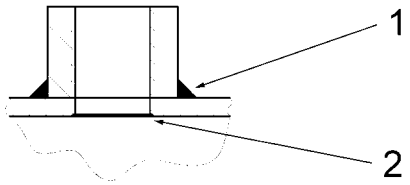
Scale and weld splatter shall be removed carefully from the welded joints, using a chisel, file or grinding wheel. If pipes of stainless steel are grinded out, make sure that suitable tools are used, which could not cause any workpiece corrosion.

The complete pipe section shall be knocked with a hammer and blown through with compressed air at the same time, to remove the smallest particles.

All pipe connections are to be blocked off until assembly.

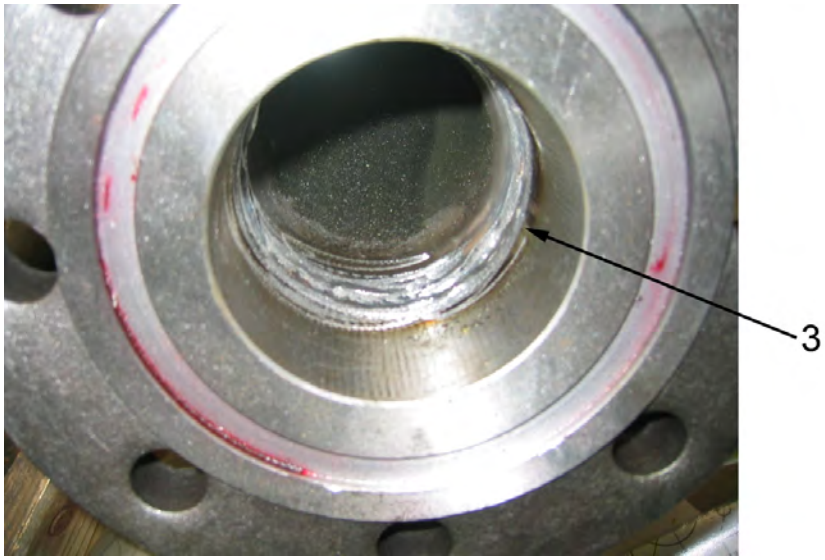
Provide unobstructed access to welding joints in contact with fluid.

This means: Fitting flange connections at places that are inaccessible.



1 Welding joint
2 After welding: drilled and deburred

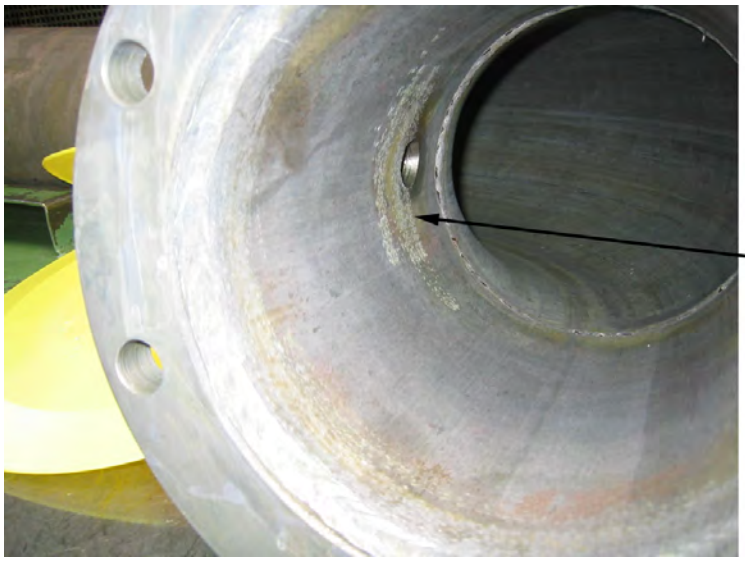
Figure 2: Threaded sleeves for fitting the measurement sensors must be installed as follows



3 Welding seam after proper mechanical rework

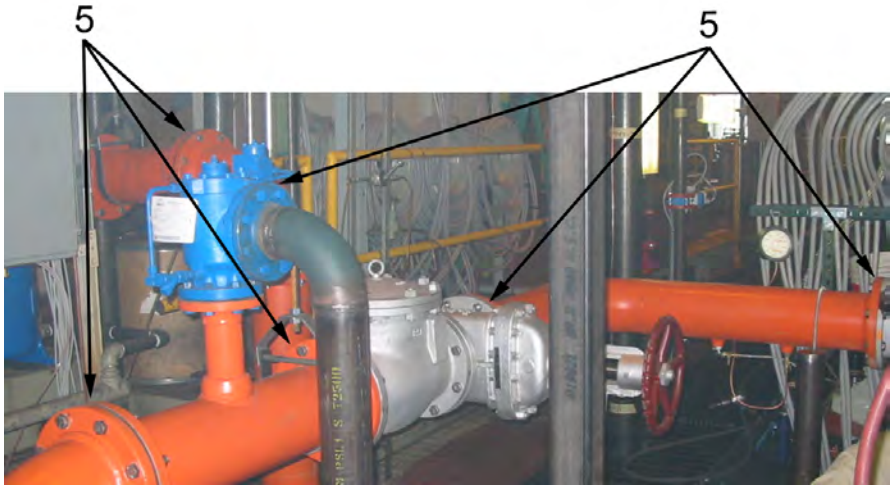
Figure 3: Proper installation

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4 Pipe opening for sleeve connection made using a twist drill and deburred after sleeve welding.

Figure 4: Proper installation

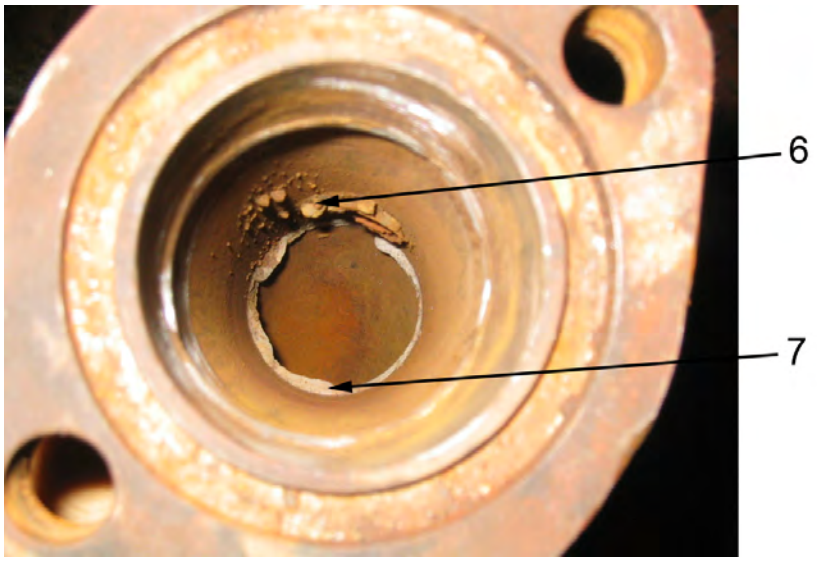


5 Fitting the flanges to avoid any inaccessible welding seams

Figure 5: Proper installation

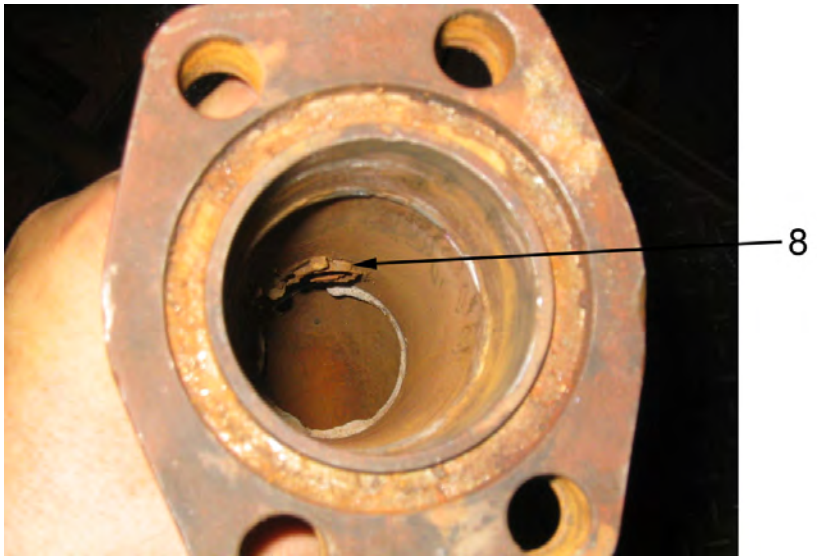
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Example: Insufficient rework



6 Scale and welding pearls have not been removed
7 Insufficient or no rework of the welding joints

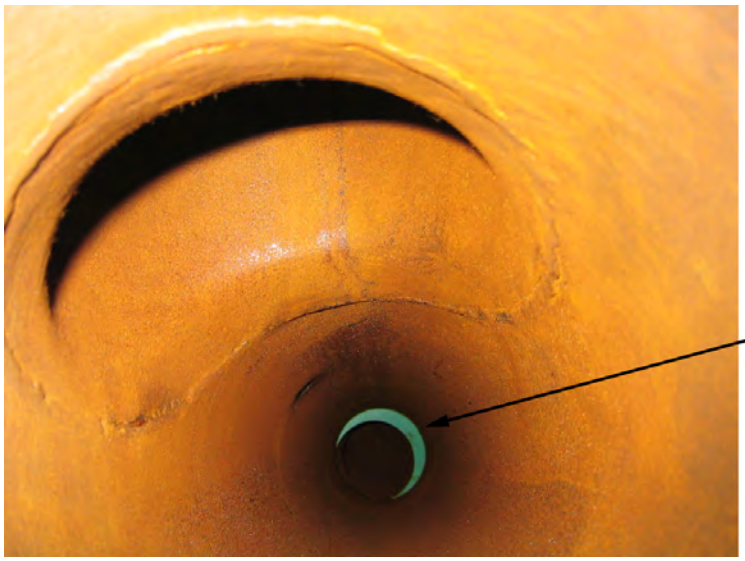
Figure 6: Insufficient rework



8 Pipe opening for sleeve fitting using welding torch. – unacceptably fitted

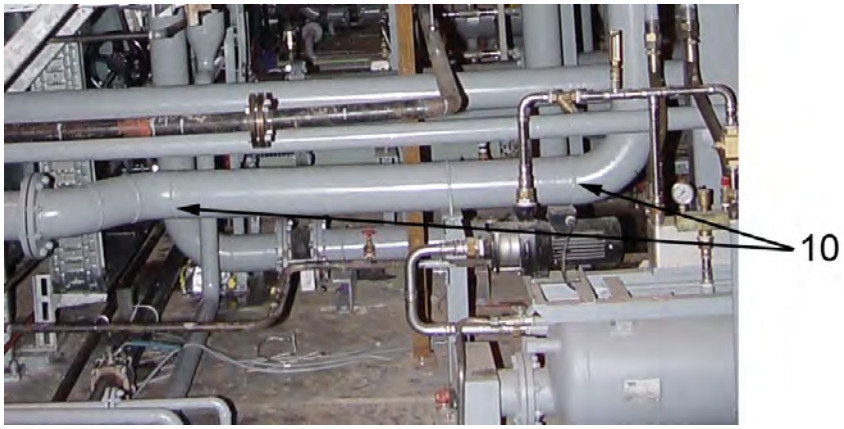
Figure 7: Insufficient rework

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9 Seal projects into the pipe

Figure 8: Insufficient rework



10 Welding seams are inaccessible from the inside

Figure 9: Insufficient rework

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Stainless steel pipes



Stainless steel pipe with steel flange

Figure 10: Stainless steel pipes



Figure 11: Stainless steel pipes

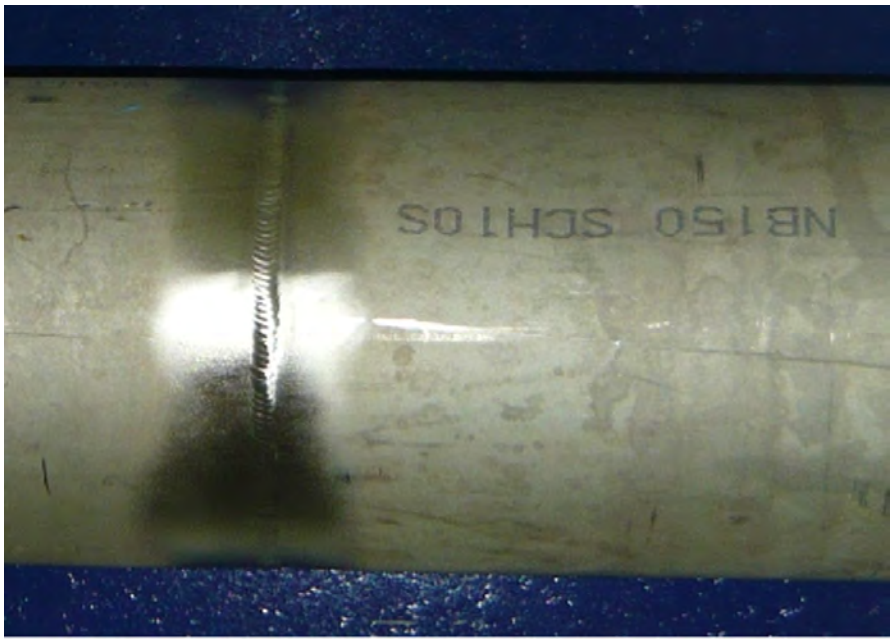
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11 This welding joint must be reworked!

Welding joint with slag on a stainless steel pipe resulted from improper welding process

Figure 12: Stainless steel pipes



TIG welding joint on a stainless steel pipe of a good quality

Figure 13: Stainless steel pipes

Chemical cleaning

For pipes cleaned mechanically and chemically, an acid bath is required.

The acid bath device essentially consists of:

- an acid bath
- a water bath for washing the acid off
- an alkaline bath for neutralising and phosphatising

The regional protection regulations must also be observed.

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Treatment of steel pipes

1. Pickling in acid bath
   Hydrochloric acid (HCl) is available commercially in concentrations of 31-33% and with arsenic content less then 1%.
   Mixing ratio for the bath:
   HCl : H2O = 3 : 2 (parts by weight)

⚠ CAUTION

Handling acid

When using, observe the following items.

- Pour the acid into water, not the other way around
- The treatment shall not be performed at a temperature below 20℃
- The duration is determined by visual inspection
- With pipes with threads, acid corrosion on the crest of the thread must be monitored. It determines the duration of treatment in this case

2. After completion of the pickling procedure, the acid solution adhering to the pipes must be washed off in the water bath.
3. Neutralisation of the acid solution still remaining in grooves and pores of the surface structure using a tri-sodium phosphate bath.
   In addition, the pipes are simultaneously coated with a phosphate layer for short-term protection against corrosion.
   Mixing ratio for the bath:
   Na3PO4 : H2O = 1 : 8 (parts by weight)
   Treatment temperature: 80℃

Pressure Testing of Pipes

During the system flushing, the pipes must be tested for tightness.

Preservation of Pipes

When stored for a short period indoors in a dry environment, phosphatisation and an oil film are sufficient for corrosion protection (inside and outside). Also during long-term storage, phosphating before the actual preservation with slushing oil or lacquer (only outside) offers a good basic preservation.

Open pipe ends, connection points and threaded sleeves are to be sealed with coloured plastic caps. They must always be removed before fitting.

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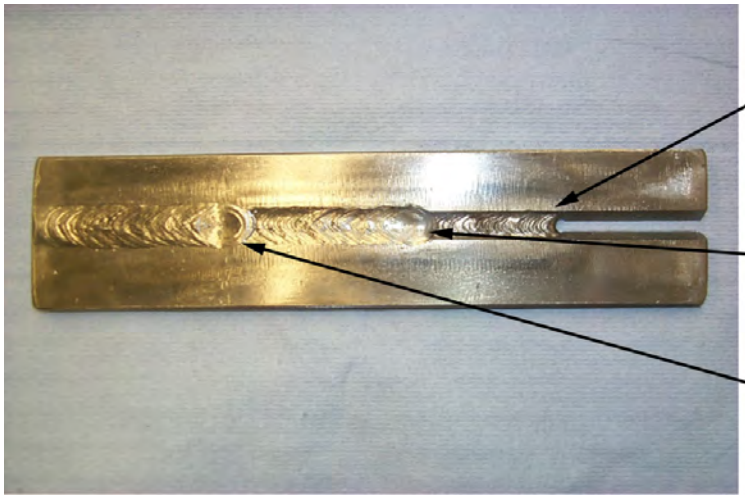
Pipe processing – step by step

Pipe bend



12 Pipe preparation, tacking

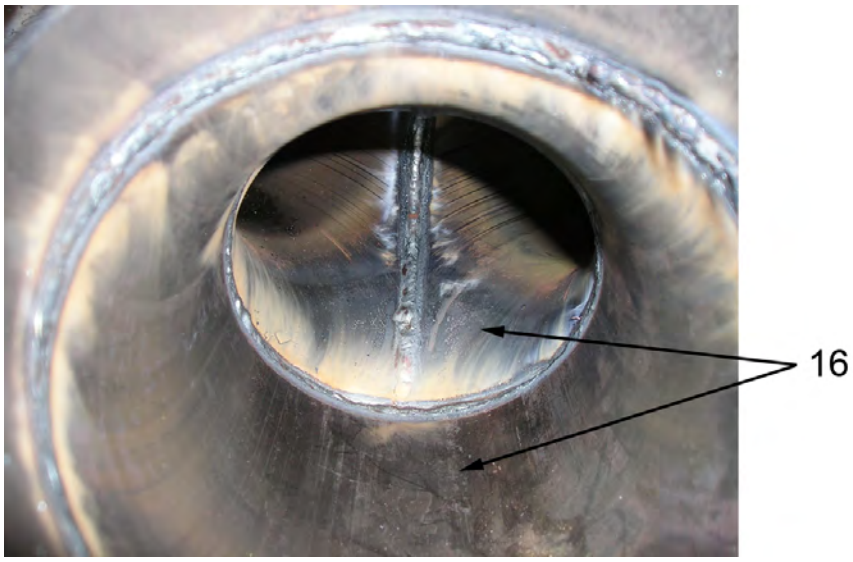
Figure 14: Pipe bend



13 Root pass: TIG welding
14 Interpass: TIG/MAG/E welding
15 Final pass: TIG/MAG/E welding

Figure 15: Pipe bend

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16 TIG pipe welding joint, not mechanically machined

Figure 16: Pipe bend



Y-pipe inside after mechanical machining of the welding joints, subsequently neutralised and preserved

Figure 17: Pipe bend

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Flange connection



17 Flange preparation, tacking

Figure 18: Flange connection



Flange fitting, tacking

Figure 19: Flange connection

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18 Flange – pipe welding inside

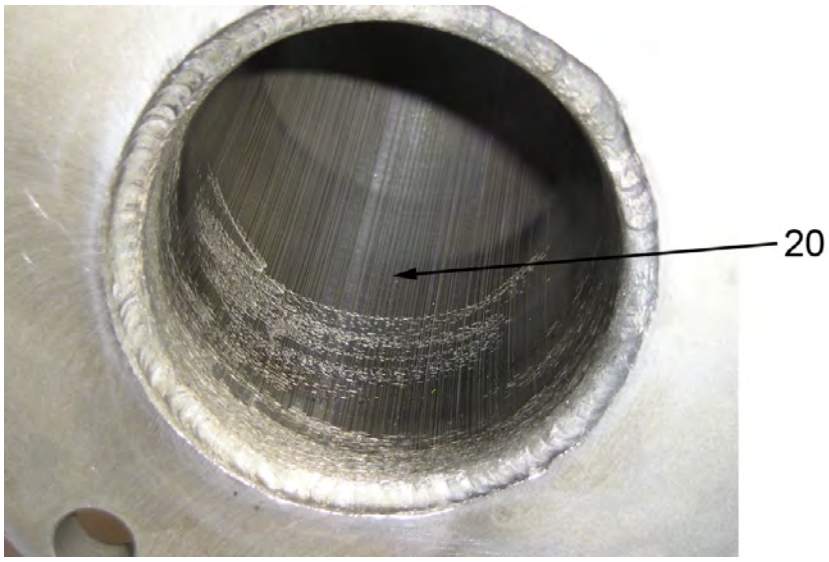
Figure 20: Flange connection



19 Flange welding joint, mechanically machined

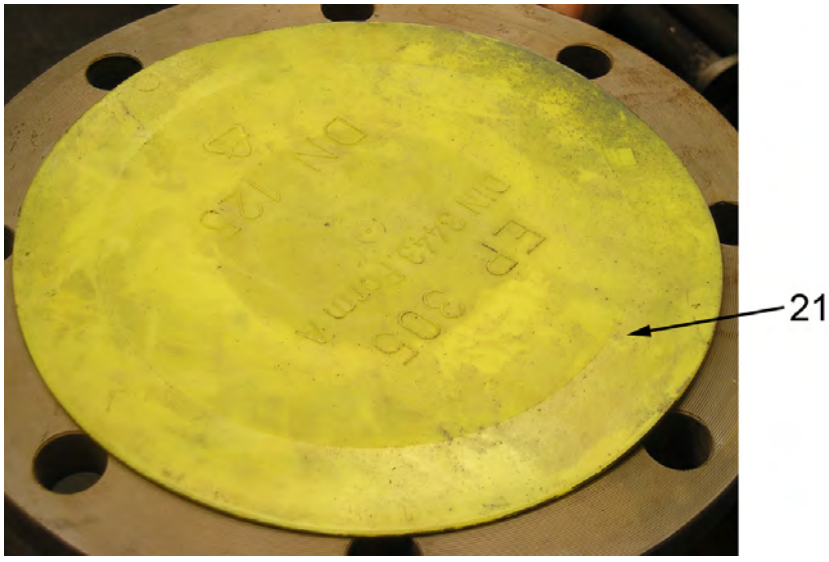
Figure 21: Flange connection

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20 Pipes chemically, mechanically cleaned and preserved

Figure 22: Flange connection

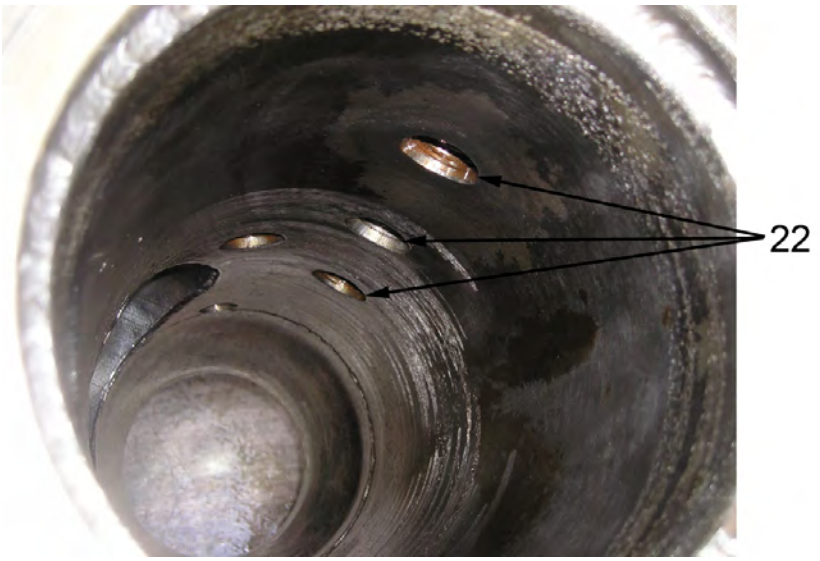


21 Pipe sealed with cover

Figure 23: Flange connection

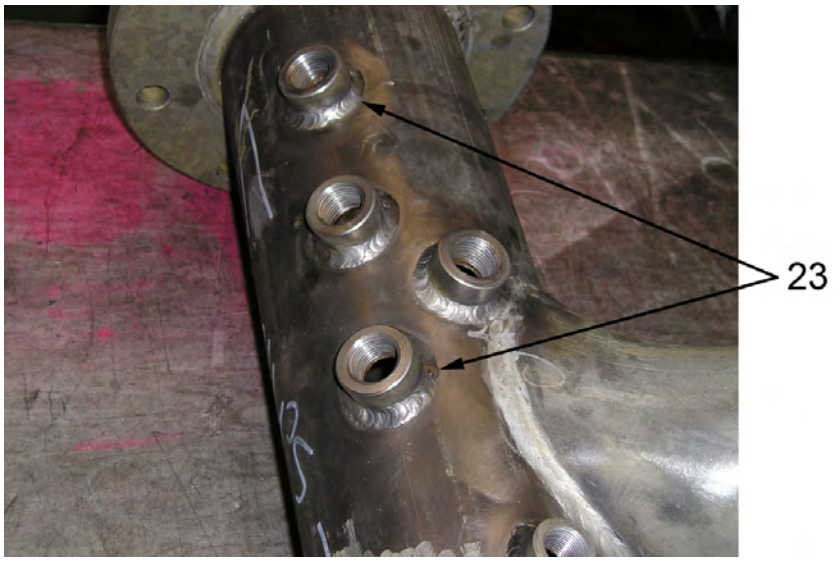
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Pipe with weld-on sleeves



22 Pipe section with a bore for threaded sleeves, mechanically machined inside

Figure 24: Pipe with weld-on sleeves

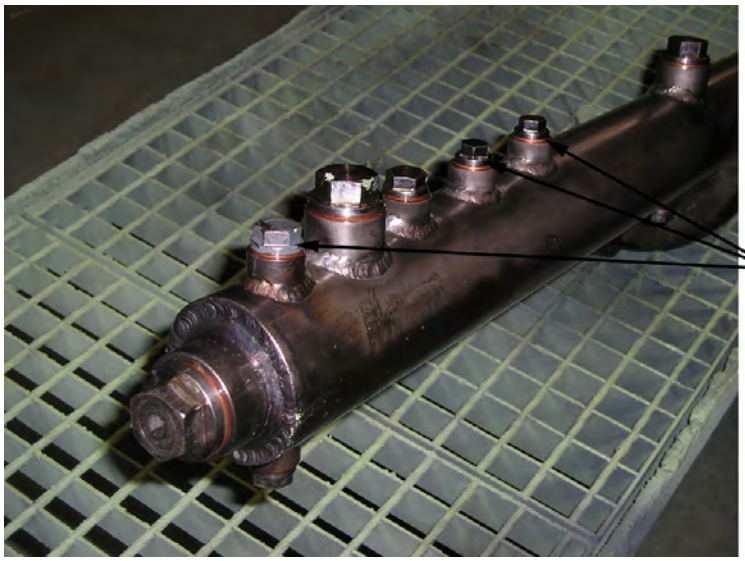


23 Pipe section with weld-on threaded sleeves. TIG welding;

It may happen that threads have to be regrinded after acidification and neutralisation.

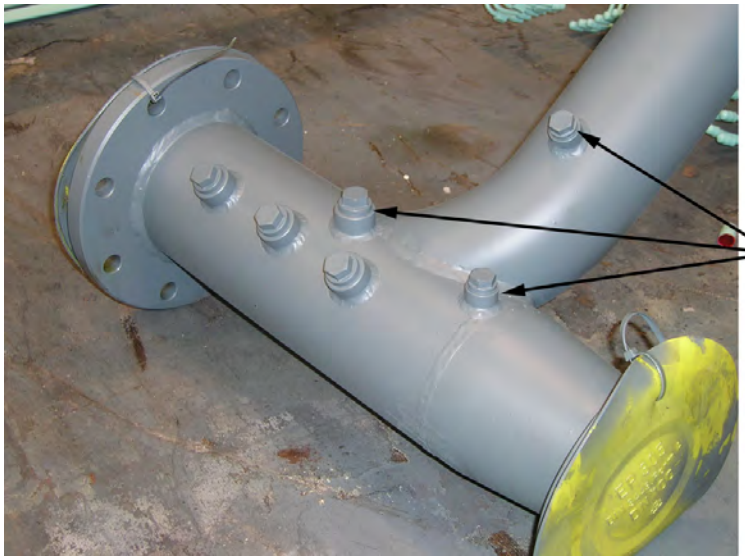
Figure 25: Pipe with weld-on sleeves

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24 Seal sleeves with blind plugs

Figure 26: Pipe with weld-on sleeves

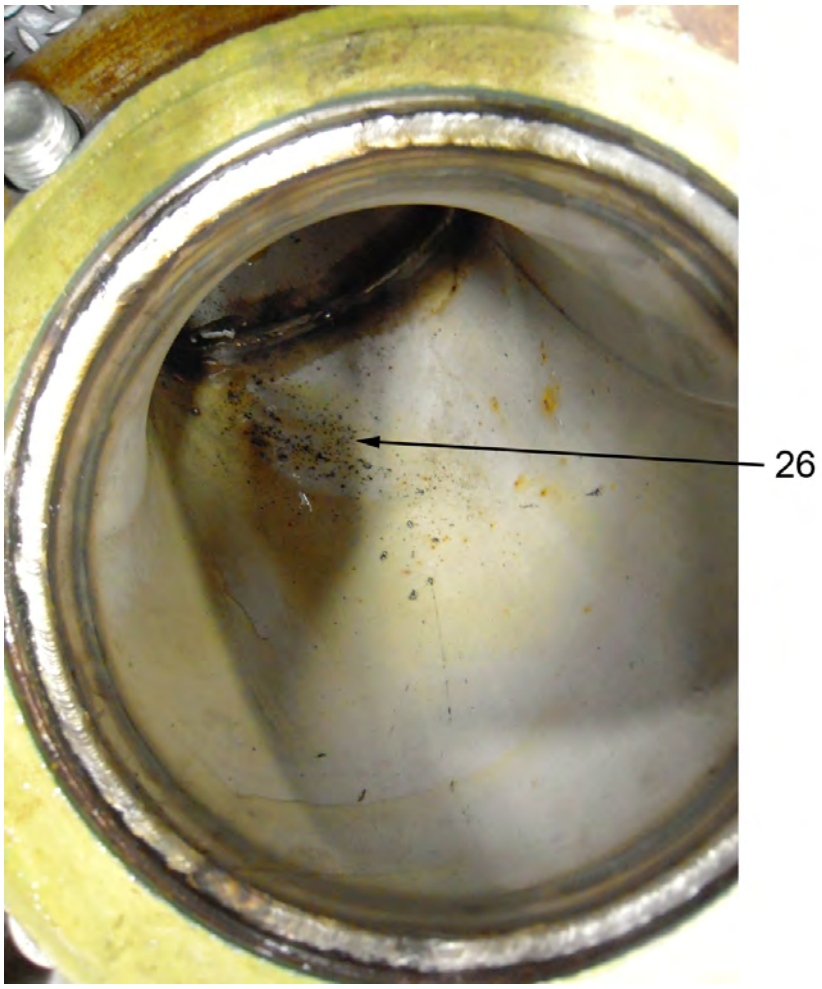


25 Blind plugs

Pipe preserved with lacquer outside, pipe ready-to-fit

Figure 27: Pipe with weld-on sleeves

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26 During installation, pay attention to cleanliness.

Particles and system-foreign fluid must be removed out of the pipes

Figure 28: Pipe with weld-on sleeves

Pipe and hose installation

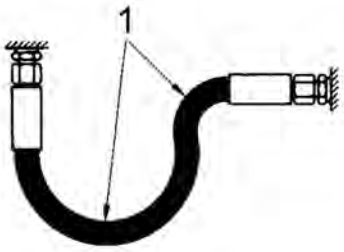
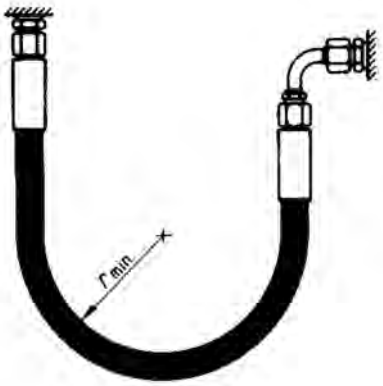
Hose lines

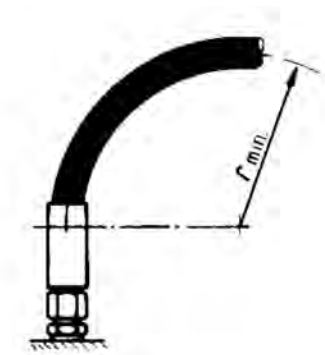
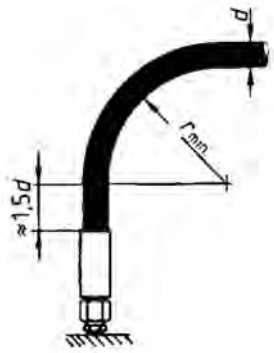
When using and installing hose lines, make sure that they are fitted properly and observe permissible tolerances.

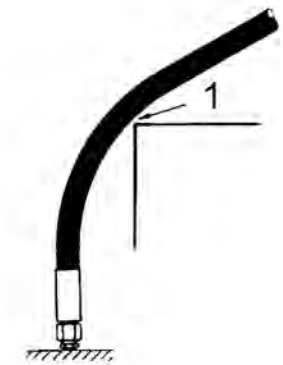
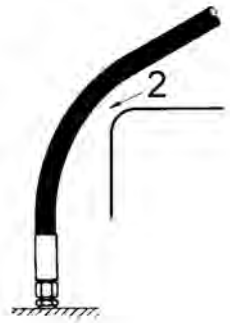
incorrect	**incorrect**
Hose pipes must be fitted so as to avoid their tensile strains under all operating conditions, except for their dead weight; the same applies to hose load in case of short lengths.	
	
Hose load	Tensile strain

incorrect	**correct**
Hose lines must be fitted following their normal position, as far as possible, while the bend radii shall not be below the minimum permissible values.	

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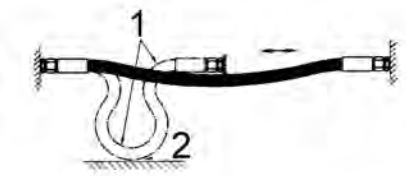
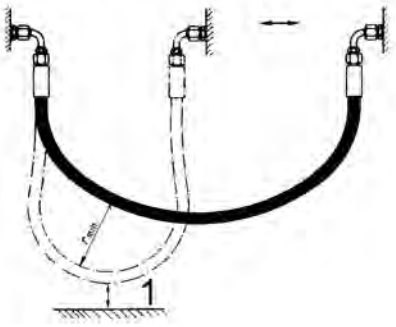
incorrect	correct
	
1 to small bend radii	

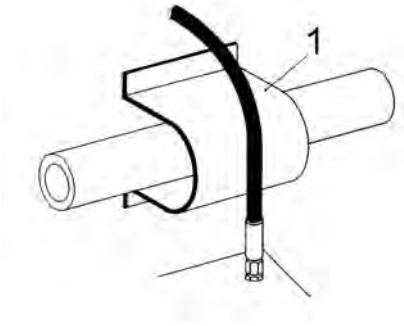
incorrect	correct
For bent fitting, the hose line length must be selected so that the constructive designed hose bending begins only after a length of ≈ 1.5d; bend protection must be provided if necessary.	
	

incorrect	correct
Outer mechanical effects on the hose lines, including the hose scuffing at components or among each other, must be avoided by suitable arrangement and fixing. If necessary, the hoses must be protected with protective coating. Sharp-edged components must be covered.	
	

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incorrect	correct
1 abrasion	

incorrect	correct
When connecting a hose line to moving components, the hose length must be sized so that the minimum permissible bending radius is observed and/or the pipe line is not additionally tensioned within the whole movement range.	
	
1 to small bend radii	1 observe sufficient distance!
2 abrasion	

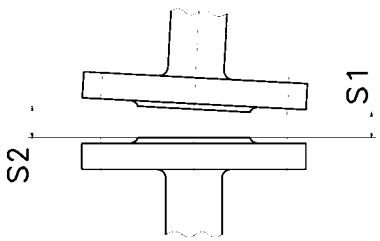


1 Heat protection

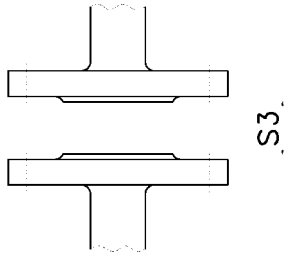
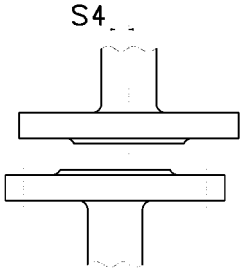
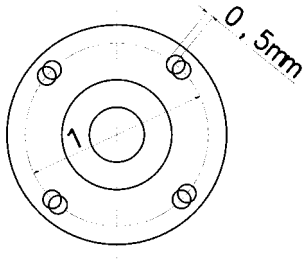
Figure 29: In case of high external temperatures, the hose lines must be either fitted at a sufficient distance to heat radiating components or protected by suitable appliances (screen).

Pipe connections

When installing steel pipes make sure that they are fitted properly and observe permissible tolerances. High loads on flange connections in the system and on the engine are not permissible.

Illustrations	Installation tolerances
	max. tolerance (S2-S1) -0.3 mm for DN<150 -0.4 mm for DN 200 to 300 -0.5 mm for DN >300
S1 tolerance	

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Illustrations	Installation tolerances
S2 tolerance	
	S3 distance between the flanges. -Seal thickness +1.0 mm
S3 distance	
	Maximum permissible lateral movement S4 ≤ 0.5 mm
S4 lateral movement	
	The screw holes are positioned on the pitch circle diameter <0.5 mm at a permissible turning offset in accordance with DIN 2501-1
1 pitch circle diameter	

Flushing of the lube oil system

When working on the system, absolute cleanliness must be maintained. During any work on opened systems, welding and grinding must be prohibited to prevent dirt ingress. Opened pipe flanges on the engine and in the system must be closed immediately.

When flushing the lube oil system, the lube oil inlet pipe must be disconnected from the engine and connected to the lube oil return of the engine.

If there is no indicator filter, the automatic filter must be used for flushing.

In this case, a temporary filter (<50µm) for flushing must be installed in the backflushing line of the main paper lub. oil filter.

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(Precautions for flushing are marked red in the diagram below).

If an indicator filter is installed downstream of the automatic filter, the main paper lub. oil filter is excluded from the flushing, and flushing is performed only through the indicator filter.

The flushing is performed through the free standing lube oil pump. If the engine has an attached lube oil pump and a priming pump of a low capacity, an external pump with sufficient capacity must be used for flushing.

The flushing procedure and the filter evaluation is attended and correspondingly released by MAN personnel.

Lubricating oil pipe from separator "D8" is connected to lubricating oil pipe to separator "D7".

Flushing conditions for the lube oil system

-External lube oil pump capacity if necessary (min ≥ 70% m³/h of the required flow rate)

-Lube oil separator is in operation during flushing

-Lube oil temperature > 50°C

-Cooling water system filled and preheated up to 60°C. To prevent condensation in the drive chamber

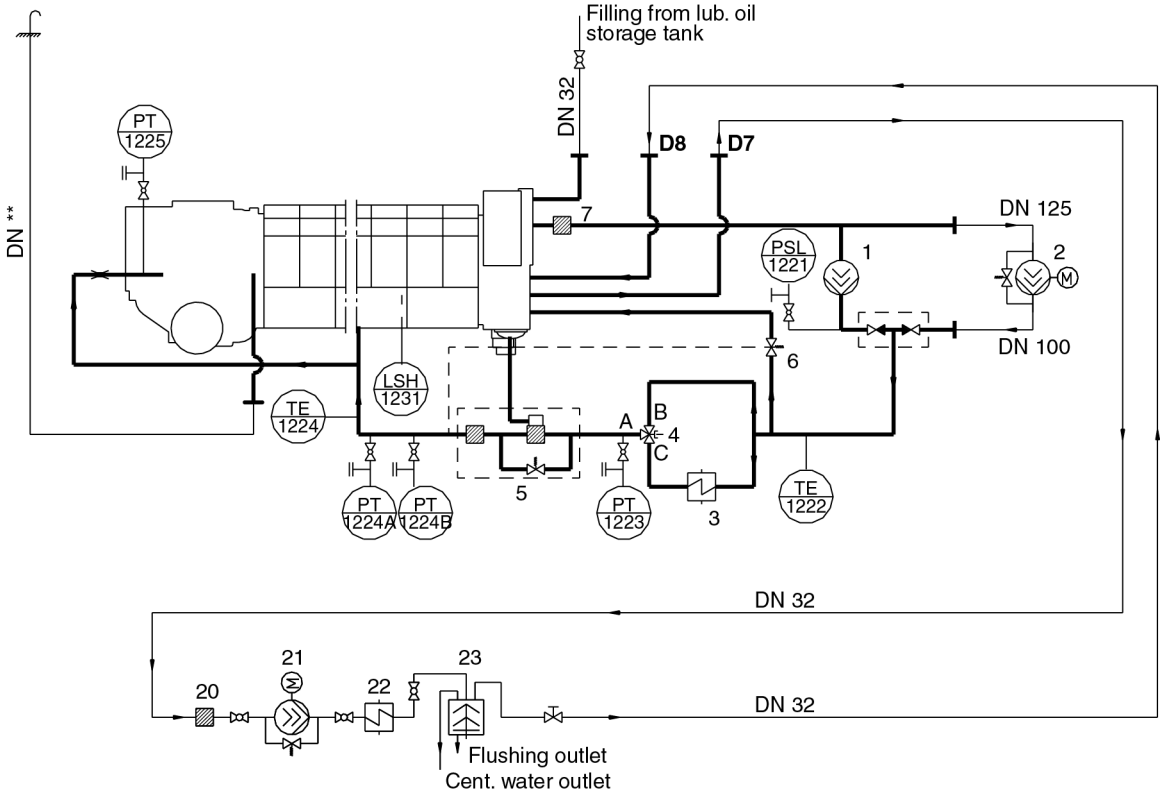


Figure 30: Lubricating oil system

Fuel system flushing

When working on the system, absolute cleanliness must be maintained. During any work on opened systems, welding and grinding must be prohibited to prevent dirt ingress. Opened pipe flanges on the engine and in the system must be closed immediately.

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For flushing the fuel system, the fuel-injection inlet pipe "B1/B3" is connected with the fuel return pipe "B7A" before the engine.

In booster module (if available), sensible instruments must be removed for their protection if necessary (viscosimeter etc.)

When flushing using the supply and booster pumps, a sufficient fluid flow must be ensured.

Dry running and cavitation of the pumps must be avoided.

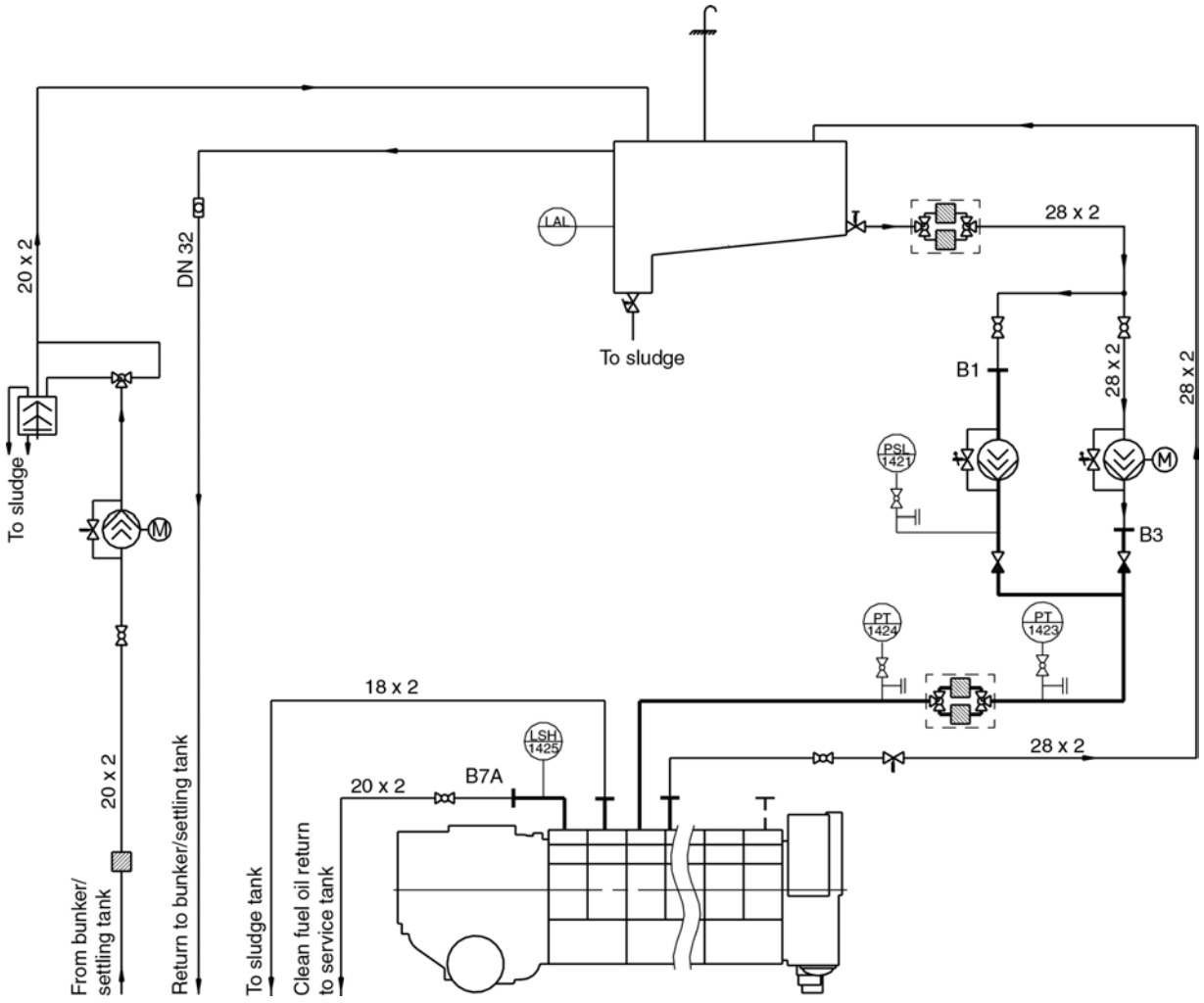


Figure 31: Fuel oil system

Flushing the starting air system

The starting air system is “flushed” by blowing out the system using the starting air cylinder. For this purpose the flange connection of the starting air pipe on the main starting valve is temporary dismantled and laid free to the atmosphere.

If the system is blown out using compressed air at the pressure of 30 bar, a sufficient pipe fixing must be provided to prevent damages to other components.

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When blowing out, the shut-off valves must be opened as far as possible, and the system must be blown out minimum with 2 to 3 cylinder fillings.

If the result is not satisfactory, the process must be repeated and other suitable measures must be taken if necessary.

The pilot air line cleaning is performed in the same sequence as the blow-out of the main starter air pipe described above.

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Flushing of the starting air system

Description

The starting air pipes are cleaned by blowing them through with compressed air. For this purpose, detach the flexible hose at starting air supply pipe to the engine connection, and bolt it securely to the flange in such a way that air can flow freely from the hose. The air supply at the main starting air bottle are then opened fully, following are the starting air valve before the engine opened, open and close the valve 3-4 times during the process, continue to blow the pipe until all debris are removed from the staring air pipes, the procedure must be continued until the pipes are free from dirt, the procedure are followed at all engines. After the cleaning process, connect the staring air pipe to the engine again.

The starting air system can now be considered ready for the first function test of the engine starting system.

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Flushing of the external lube oil system

Description

The engines are delivered from the engine builder with a preserved and sealed lube oil system.

In order to avoid operating problems the lubrication oil system must be kept free from contamination and residues, therefore it is necessary to ensure that dirt and particles from external oil tanks, pipe lines etc. are removed before the engine are connected to an external lubrication oil system.

The yard or the contractor that establish the pipeline is responsible for flushing and the cleanliness of the oil tanks and the pipe system.

In order to ensure that dirt from lubrication oil tank and external lubrication oil pipelines is removed and not passed to the engine, it is recommended to perform flushing and cleaning in the following steps:

- Thorough cleaning of lubrication oil tank before filling up.
- Flushing and cleaning of external pipes, during this process must the engine not be connected to the system.

The external pipes connections in front of the engine must be connected to each other in order to perform a loop that can be flushed by means of the separator and/ or an external flushing rig with pump and filter. The pipe sections can be connected by hoses.

As flushing media a low viscosity flushing oil of 55-70 cSt/40°C (e.g. SAE20) can be used, due to low viscosity no preheating will be required.
If the flushing is carried out with the oil intended for the subsequent engine operation SAE30 / SAE40 the oil is to be preheated to 60-65°C in order to obtain a proper viscosity for the flushing process. The separator preheating facilities are to be used for this purpose.

At the inlet of the separator a provisional filter with a mesh width of 6-10 µm has to be installed.
The filter has to be equipped with a differential pressure gauge. A duplex filter is preferable.

When the separator is started and the feed pump is in operation and circulating the oil, the separator must operate during the entire flushing process.

The flushing period has to continue until the required cleanliness are achieved, depending at the condition of the external system the flushing may require flushing of 24 hours or more.

In order to check that the cleanliness of the system is satisfactory at the final stage of the flushing process, it is recommended to carry out a visual inspection of the content and volume of dirt on the surface of the filter cartridge, e.g. by means of a microscope.

Verification of the external lubrication oil system´s cleanliness can also be done by particle counting. When using particle counting, flushing should not

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be accepted as completed until the cleanliness is found to be within the range of ISO 4406:1999 code 20/18/15.

When a satisfactory cleanliness level of the external lubrication oil system is obtained, the pipe system can be connected to the engine.

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Flushing of second fuel supply pipes

Description

Remove dirt and particles from the second fuel supply pipes and N_2 pipes before operation to ensure system cleanliness and prevent damage.

Safety

- Keep clear of outlets; pigs and air can eject at high speed.
- Always wear PPE: safety glasses, ear protection, gloves.
- Maintain a safety distance behind screens and monitor pressure indicators.
- Two operators required, with constant communication.

Flushing options

1. Water/Oil flushing
   - Use tap water (chlorine ≤ 30 ppm) or clean hydraulic oil.
   - Flushing rig and pipe vibrators are recommended.
   - Continue until ISO 4406 xx/19/15 cleanliness is achieved.
   - Dry pipes thoroughly with nitrogen or compressed air (ISO 8573.1:2010), 5 bar pressure.
   - Close and seal the pipes after drying
2. Compressed air and cleaning pigs
   - Blow compressed air through pipes (ISO 8573.1:2010).
   - Insert pigs repeatedly until no particles remain.
   - Attach filter bag at outlet to collect pigs.
   - Recommended pig specs: size ≈ 1.3 × pipe diameter, density >15 kg/m^3, color white.

Acceptance criteria

- The process is completed when three consecutive pigs show no contamination.
- If in doubt, perform a water/oil flush and verify cleanliness per ISO 4406 xx/19/15.

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Flushing of the external fuel oil system

Description

The engines are delivered from the engine builder with a preserved and sealed fuel oil system.

In order to avoid operating problems the fuel oil system must be kept free from contamination and residues, therefore it is necessary to ensure that dirt and particles from external oil tanks, pipe lines etc. are removed before the engine are connected to an external fuel supply system.

The yard or the contractor that establish the pipeline is responsible for flushing and the cleanliness of the oil tanks and the pipe system.

In order to ensure that dirt from fuel oil tanks and external fuel oil pipelines is removed and not passed to the engine, it is recommended to perform flushing and cleaning in the following steps:

- Thorough cleaning of the fuel oil tanks before filling up.
- Flushing and cleaning of external pipes, during this process must the engine not be connected to the system.
- Flushing of the entire fuel system including the internal engine fuel system.

Flushing of the external fuel supply system.

During this process, the external fuel supply system is flushed via the existing filter in the fuel oil supply system.

The fuel supply and return pipe in front of the engine must be connected to each other by means of a temporary bypass pipe. The fuel oil system is to be switched so that the entire pipe system will be flushed, and fuel oil will return into the service tank. The bypass pipes existing in the system (e.g. for viscosity control units, heat ex-changers, etc.) must be opened.

Flush the system with the opened return line to the service tank, if installed put the heat ex-changers in the fuel oil return line into operation.

The flushing is performed by means of the fuel oil supply and booster pump. The flushing process must be performed until the filters are free of contaminants and impurities. To determine the cleanness of the fuel supply system the main filter in the system must be cleaned with certain intervals during the flushing process depending on the dirt amount in the system.
When satisfactory cleanness is reached during the flushing process the valves at the bypass pipes, of the automatic filter, viscosity control units, mixing pipe etc. must be closed.

Experience shows that the minimum flushing duration is 24 hours.

After closing the above mentioned bypass pipes in the supply and return lines the new connected components must be flushed within an additional period of about 6 h.

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After completing the flushing process, all temporary modifications on the fuel oil system are to be cancelled. All filter elements including the strainer before the feed pump must be cleaned.

Flushing of fuel oil supply system including the engine.

The fuel supply and return pipe must now be connected to the engine in order to include this in the flushing loop.

The flushing process is continued until the main filter are free of impurities.

To determine the cleanness of the fuel supply system the main filter in the system must be cleaned with regular intervals during the flushing process, the time between the filter cleaning depend on the dirt amount in the system.

Experience shows that the minimum flushing duration is 6 hours.

Draining the system components.

In order to remove possible built up of dirt all fuel system components such as preheater, filter chambers, mixing tank must be drained completely through their available drain valves. In order to drain out water and sludge from the service tank, this must be drained regularly, minimum at each 24 hours settling time.

After correct flushing the system must be adjusted according to Document D010.000.023-25 Setting the heavy fuel oil system.

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Flushing of cooling water system

Warnings and key information

⚠ CAUTION

The products recommended in this document may be harmful to the health and the environment. Always read the manufacturers safety and health advice carefully before use.

- The chemical products described in this document can be a risk to the health and the environment. Always take proper precautions if they are not taken.
- Precautions should include proper ventilation and personal protection in accordance with local safety and health regulations.
- Handling and disposal of chemicals must comply with local environmental regulations.
- This instruction refers to specific chemical products. If other chemical products are used, different process parameters and guidelines may apply.

NOTICE

Engine cooling water must be carefully selected, treated, maintained, and monitored. Specifications, procedures, requirements, and permissible additives can be found in the following link: here

Description

Ensure that the surfaces exposed to cooling water are free from corrosion and any other residue before commissioning the engine.

If rust is detected, the system needs to be cleaned following the approved procedures, *see work card M5160195-01, M6160195-01H.*

Flush the cooling water system prior to commissioning the engine. Add a detergent to the water to remove any residues of the preservative used. Suitable agents are listed alphabetically in Table 1. Detergents from other manufacturers may also be used, provided that they have the same properties.

After flushing, rinse with untreated fresh water.

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Manufacturer	Product	Concentration	Cleaning time / temperature
Drew	HDE-777	4 - 5%	4 h at 50 - 60 °C
Nalfleet	MaxiClean 2	2 - 5%	4 h at 60 °C
Unitor	Aquabreak	0.05 - 0.5%	4 h at ambient temperature
Vecom	Ultrasonic Multi Cleaner	4%	12 h at 50 - 60 °C

Table 1: Detergents for removing oily residues

Mud traps must be temporarily installed to filter out coarser impurities. The mesh must be 1 mm for both LT and HT systems. Install two gate valves in each case to avoid water leakages when cleaning or removing the mud traps.

After flushing, treat the cooling water in accordance with the quality requirements for cooling water.

Inspect the cooling water regularly according to the procedures and clean according to instructions, *see work card M5160195-01, M6160195-01H.*

NOTICE **For engines already in service, we recommend removing the thermostatic valves before flushing for a better result. Please see the corresponding work cards:**

- L16/24, L21/31, L23/30, L27/38: M5160400
- L28/32H, V28/32H: M6160400-01H

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Lifting instructions

Lifting of engine

The engine should only be lifted in the two wire straps. Normally, the lifting tools and the wire straps are mounted by the factory. If not, it must be observed that the fixing points for the lifting tools are placed differently depending on the number of cylinders.

The lifting tools are to be removed after the installation and the protective caps should be fitted.

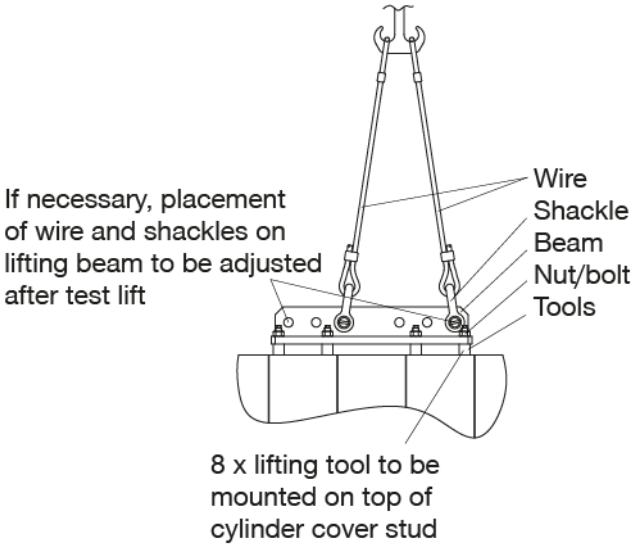


Fig 1: Lifting tools

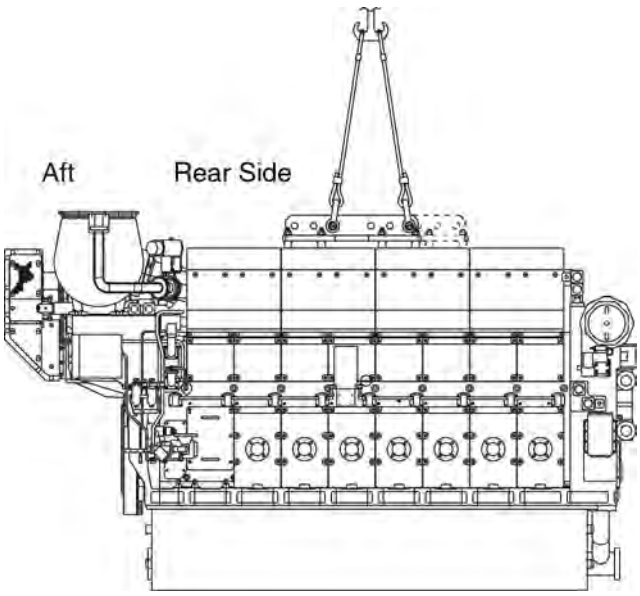


Fig. 2: Lifting tools and wires placing on engine

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Engine Type	Aprox. dry weight	Lifting beam fastened to extension studs from cylinder no	Lifting wires fastened with shackles to hole no.
6L21/31	16.0 ton	2 and 4	1 and 8
7L21/31	17.5 ton	3 and 5	1 and 8
8L21/31	19.0 ton	4 and 6	1 and 8
9L21/31	20.5 ton	4 and 6	1 and 8
6L27/38	31.0 ton	3 and 5	1 and 6
7L27/38	34.0 ton	3 and 5	2 and 7
8L27/38	37.0 ton	4 and 6	1 and 5
9L27/38	40.5 ton	4 and 6	2 and 7
6L27/38 Mk2	30.5 ton	3 and 5	1 and 6
7L27/38 Mk2	33.7 ton	3 and 5	2 and 7
8L27/38 Mk2	36.6 ton	4 and 6	1 and 5
9L27/38 Mk2	40.0 ton	4 and 6	2 and 7

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