L21/31

Technical Documentation

Project Guide

Design Specification: .... **IMO Tier III**
Plant No.. **L21/31**
Date **2024-09-16**

2024-09-16

Original instructions

L21/31

MAN Energy Solutions
H. Christoffersensvej 6
4960 Holeby
Denmark

Phone +45 54 69 31 00
Fax +45 54 69 30 30
info-hol@man-es.com
www.man-es.com

2024-09-16

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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 MAN Energy Solutions 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. MAN Energy Solutions 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.

MAN Energy Solutions 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.

MAN four-stroke small bore engines – all emission requirements

Besides focus on power density and fuel economy, MAN Energy Solutions 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, MAN Energy Solutions 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), MAN Energy Solutions has developed a comprehensive range of selective catalytic reduction (SCR) systems that tremendously reduce NO_X levels surpassing IMO Tier III requirements.

MAN Energy Solutions 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, MAN Energy Solutions was awarded the first IMO Tier III EIAPP certificate together with the classification society DNV-GL.

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

MAN ES 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. MAN SCR systems work with 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).

All data provided in this document is non-binding and serves informational purposes only. 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.

Code numbers

Identification No. X XX XX X

Code letter

Function/system

Sub-function

Choice number

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 remaining residual risks. They contain important information on how the affected users must protect themselves from the remaining residual risks. The basic safety instructions provide information on the safety concept and the minimum requirements for the safety use of the 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 MAN ES engines is to be carried out exclusively by qualified professional personnel.

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

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.

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 cocks, 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 turbochargers 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.

⚠ 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

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

Safety precautions at running engine

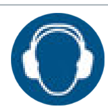
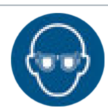
●	Stay clear of any rotating parts
●	Do not work on any pressurized systems

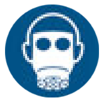
Safety precautions for overhauling of components in work shop

●	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	

Warning signs		Mandatory action signs	
Electricity		Wear protective gloves	
Overhead load		Wear face shield	
Hot surface		Wear head protection	
Crushing		Wear mask	
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 chip entry 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.

- 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 MAN ES 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.
- 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.
- 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.

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 shutdown 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.

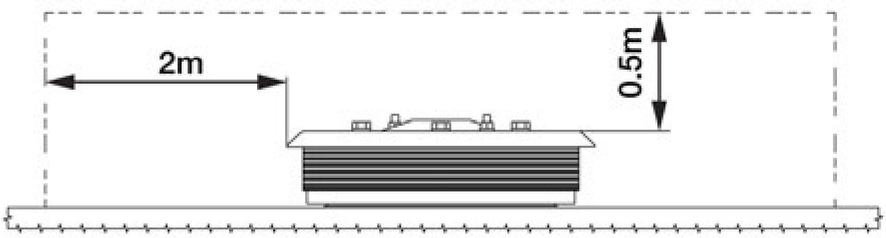


Figure 1: Hazard zone around a relief valve

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 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.

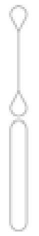
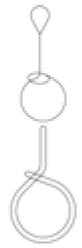
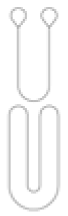
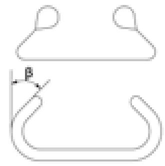
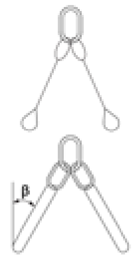
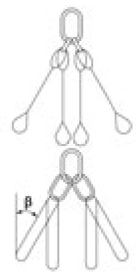
- Before lifting a load, the weight and center of gravity must be uniquely determined.
- Always use all intended and available lifting points when lifting loads.
- For loads without existing anchor points, the anchor points must be determined.
- Secure loads against slipping by fixing with suitable means.
- 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

Reduction of the load capacity by the sling angle

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

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°										

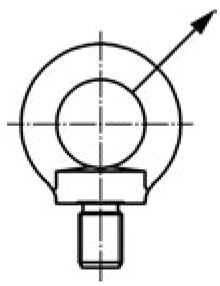
Shackles

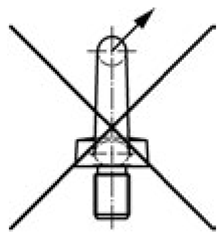
Screw pins to be tightened to full contact.

Eye screw / Eye nut

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

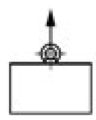
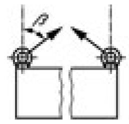
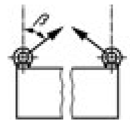
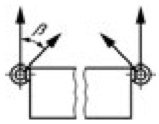
Lateral loading is prohibited in all cases!





Prohibited lateral load

Load capacity depending on the load direction

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

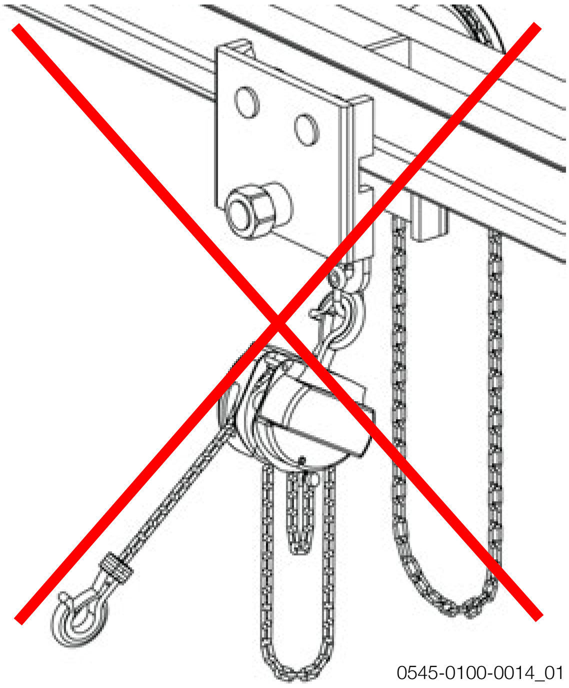
Equipment required for operation, maintenance and servicing must be stored properly after use. For example:

- 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 .

- 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.

Tools

All tools supplied by 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

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Marking of piping systems

The following marking of piping systems is a recommendation of MAN Energy Solutions. 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 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.

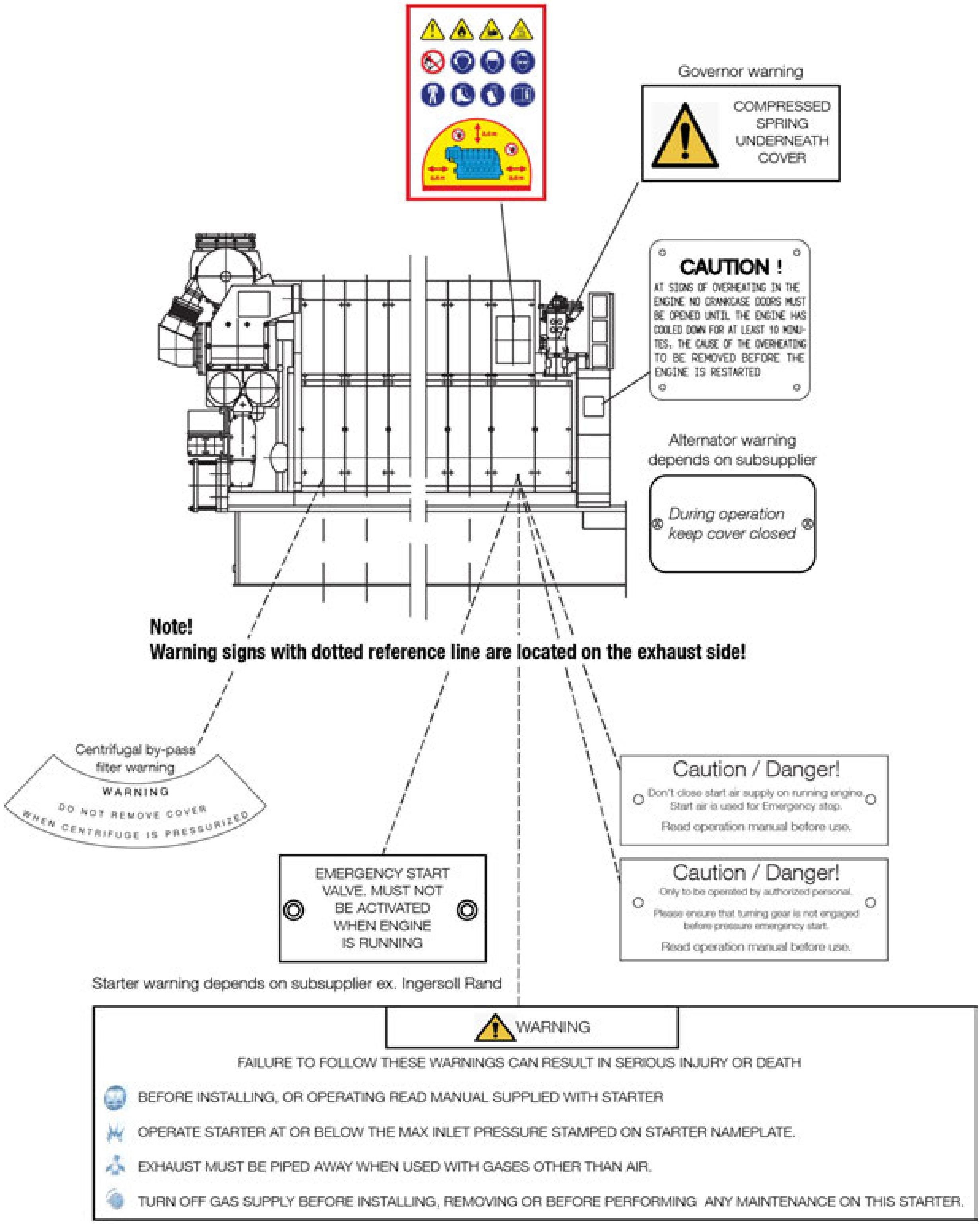
System	Medium	Label	Colour name	Colour	RAL	Note
Starting	Non-flammable gases	Starting air 30 bar	Grey		7001	
Exhaust	Waste media [a]	Exhaust gas	Black		9005	
Lube	Oils other than fuels	Lubricant 6 bar	Orange		2003	Apply actual pressure
Hydraulic	Oils other than fuels	Hydraulic oil 30 bar	Orange		2003	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

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 pres-sure
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	

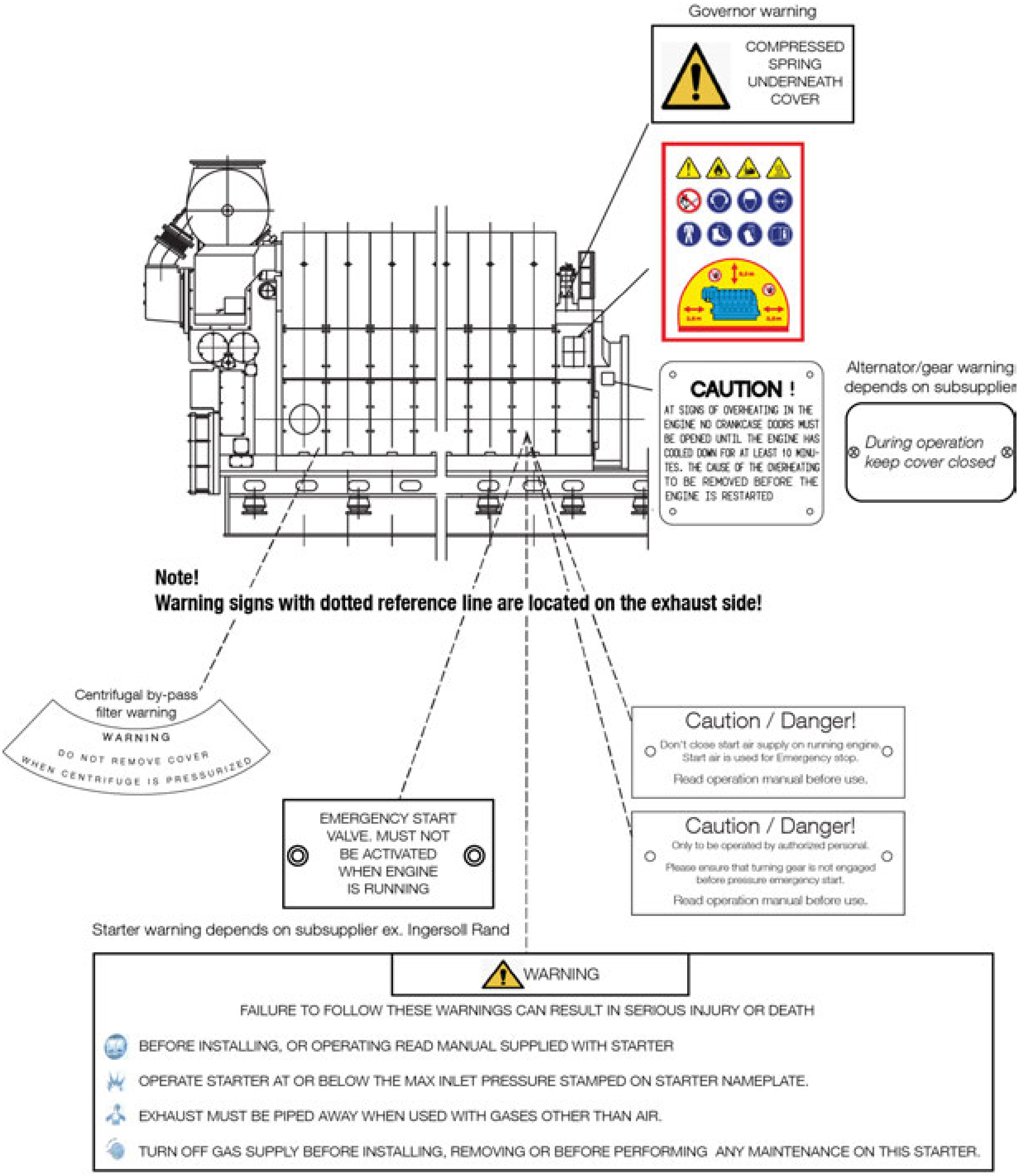
[a] Examples: black water, grey water, waste oil, exhaust gas.
[b] For ships with mixed navigation (sea-river ships): all outside waters..

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

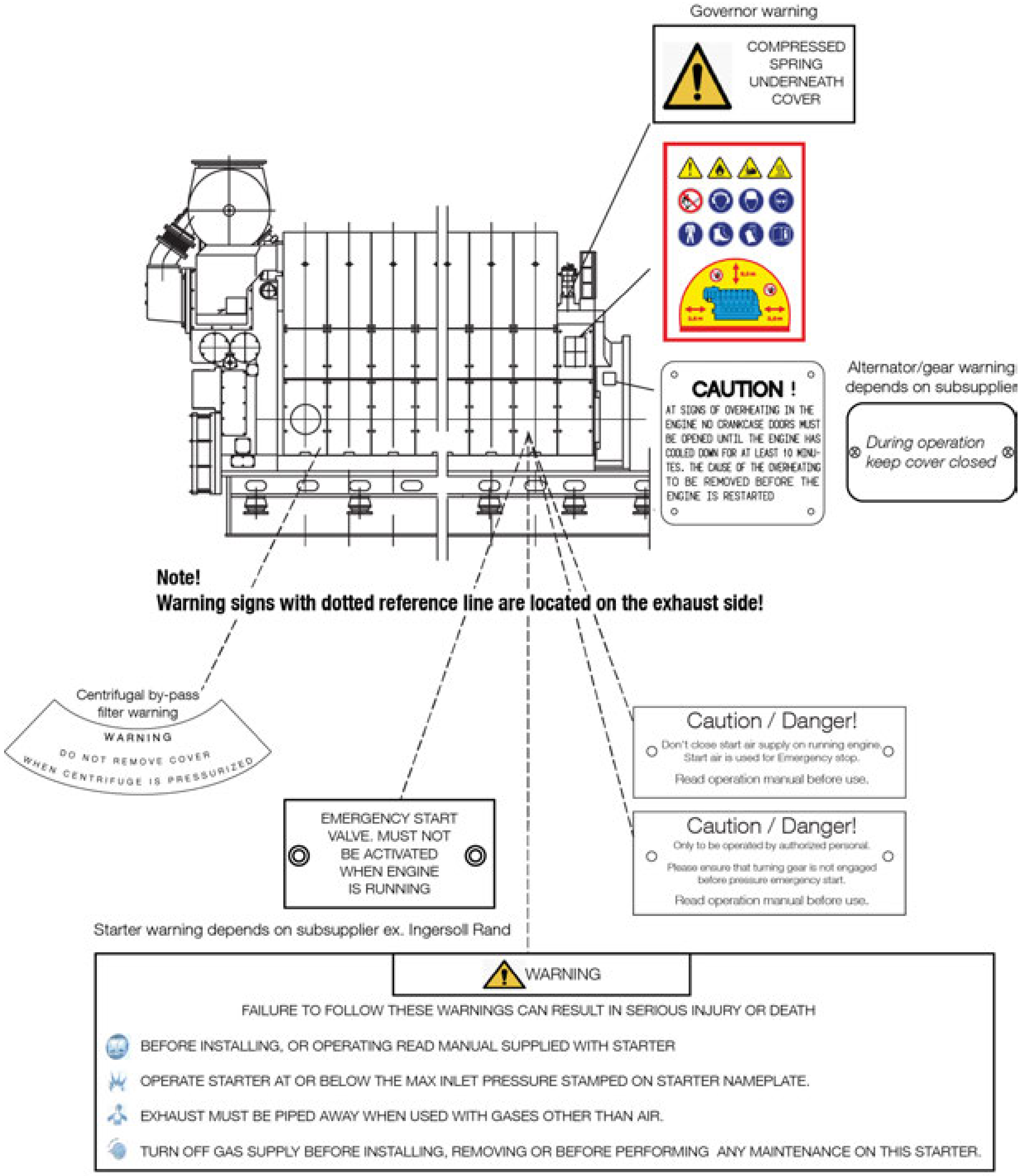
Placement of warning signs
L16/24, L16/24S



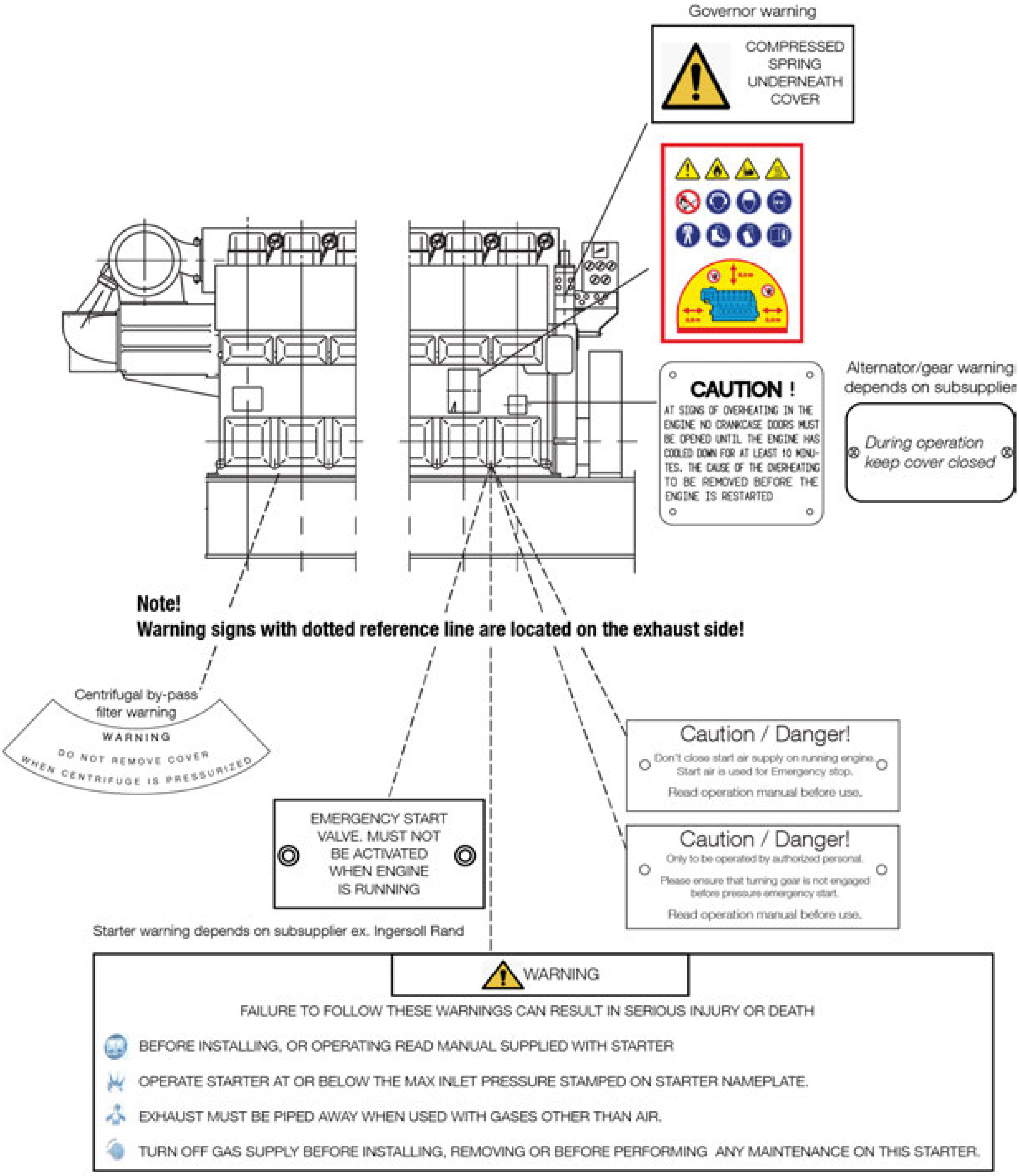
Placement of warning signs
L21/31, L21/31S, L21/31 Mk2, L21/31 Mk1.1, L21/31DF-M



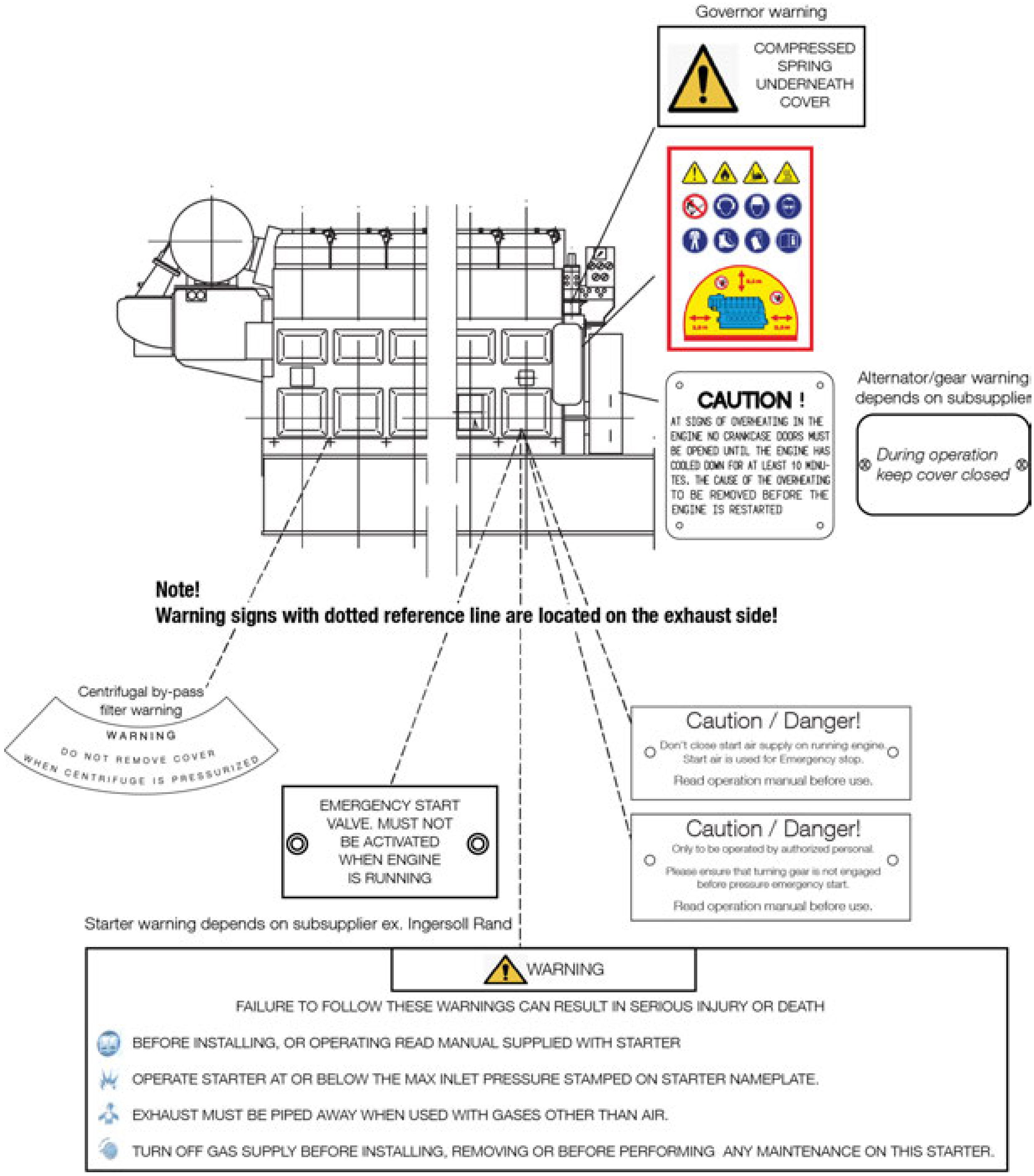
Placement of warning signs
L27/38, L27/38S, L27/38 Mk2



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



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



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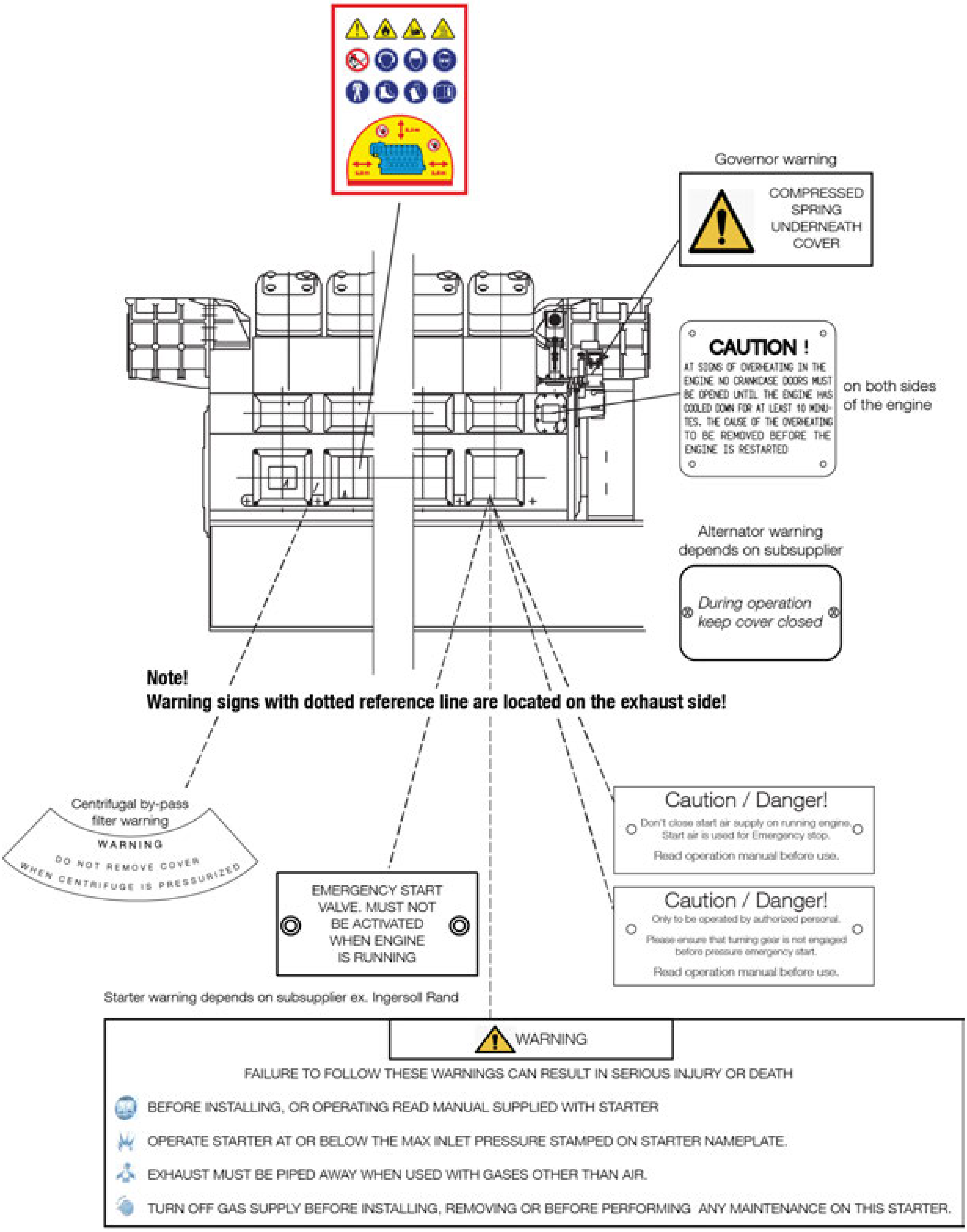
Placement of warning signs
V28/32S



Key for engine designation

Key for engine designation

The engine types of the MAN Energy Solutions programme are identified by the following figures:

6 L 28/32 H

No. of cylinders (6)

5, 6, 7, 8, 9
12, 16, 18

Engine type (L)

L : In-line
V : V-built

Cyl. diam/stroke (28/32)

16/24 : 160/240
21/31 : 210/310
23/30 : 225/300
27/38 : 270/380
28/32 : 280/320

Design variant (H)

A - Propulsion
H - GenSet Marine
S - GenSet Power
CR - Common Rail
DF - Dual Fuel
Mk(x) - Design version

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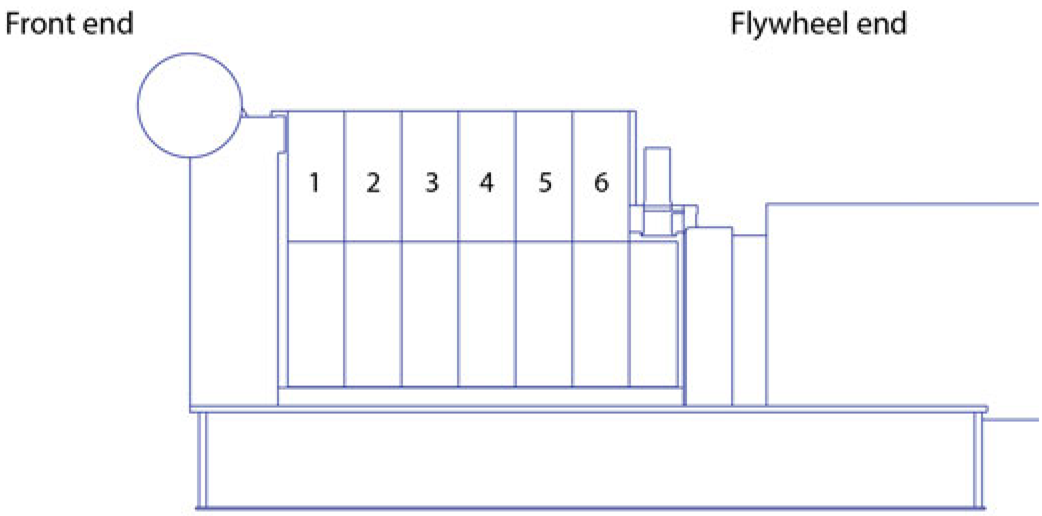
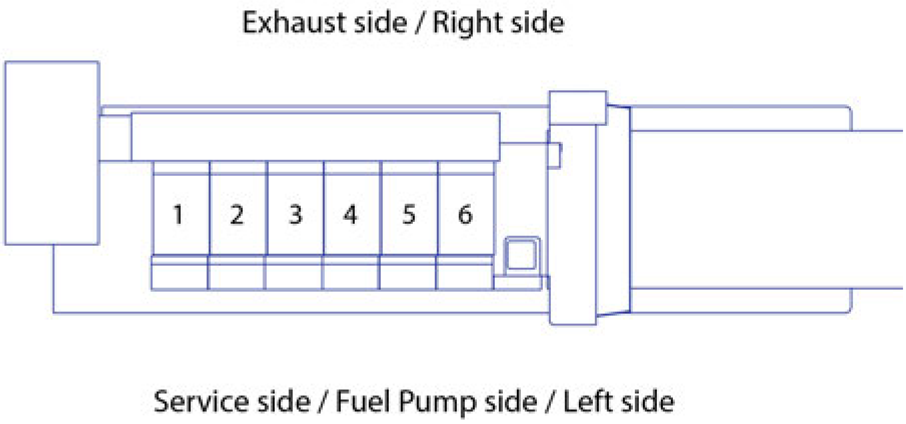
Designation of cylinders

General





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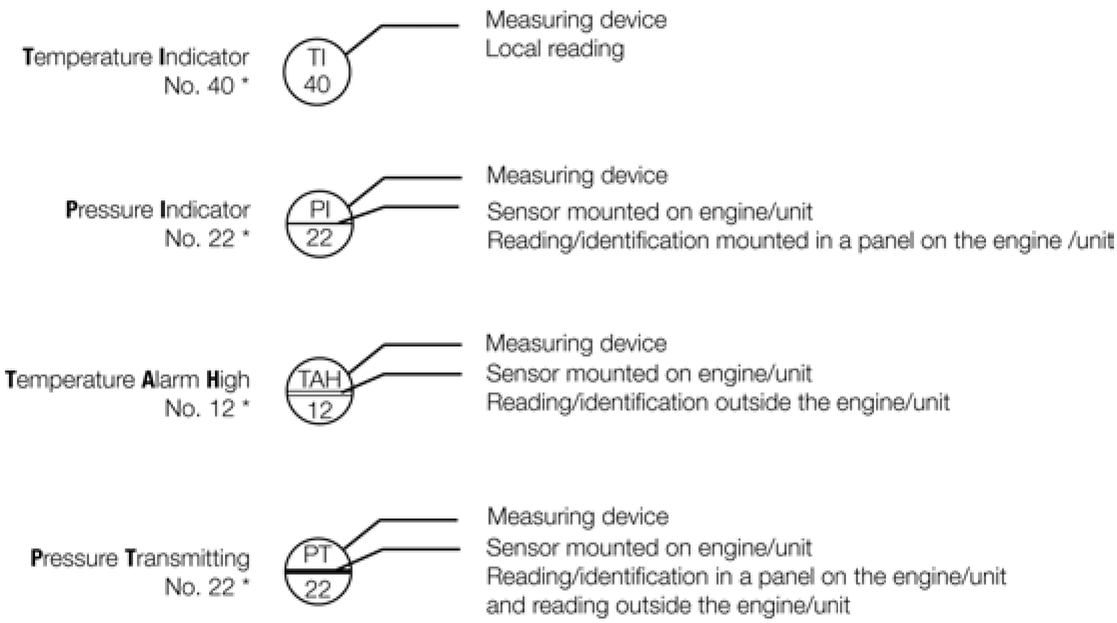
Code identification for instruments

Explanation of symbols



* Refer to standard location and text for instruments on the following pages.

Specification of letter code for measuring devices			
1st letter		**Following letters**	
F	Flow	A	Alarm
L	Level	D	Differential
P	Pressure	E	Element
S	Speed, System	H	High
T	Temperature	I	Indicating
U	Voltage	L	Low
V	Viscosity	S	Switching, Stop
X	Sound	T	Transmitting
Z	Position	X	Failure
		V	Valve, Actuator

Standard text for instruments

Diesel engine/alternator

LT water system

- 01 inlet to air cooler
- 02 outlet from air cooler
- 03 outlet from lub. oil cooler
- 04 inlet to alternator
- 05 outlet from alternator
- 06 outlet from fresh water cooler (SW)
- 07 inlet to lub. oil cooler
- 08 inlet to fresh water cooler
- 09

HT water system

- 10 inlet to engine
- 10A FW inlet to engine
- 11 outlet from each cylinder
- 12 outlet from engine
- 13 inlet to HT pump
- 14 inlet to HT air cooler
- 14A FW inlet to air cooler
- 14B FW outlet from air cooler
- 15 outlet from HT system
- 16 outlet from turbocharger
- 17 outlet from fresh water cooler
- 18 inlet to fresh water cooler
- 19 preheater
- 19A inlet to prechamber
- 19B outlet from prechamber

Lubricating oil system

- 20 inlet to cooler
- 21 outlet from cooler/inlet to filter
- 22 outlet from filter/inlet to engine
- 23 inlet to turbocharger
- 23B outlet from turbocharger
- 24 sealing oil - inlet engine
- 25 prelubricating
- 26 inlet rocker arms and roller guides
- 27 intermediate bearing/alternator bearing
- 28 level in base frame
- 29 main bearings

Charging air system

- 30 inlet to cooler
- 31 outlet from cooler
- 32 jet assist system
- 33 outlet from TC filter/inlet to TC compr.
- 34 charge air conditioning
- 35 surplus air inlet
- 36 inlet to turbocharger
- 37 charge air from mixer
- 38 Ambient temperature
- 39

Fuel oil system

- 40 inlet to engine
- 41 outlet from engine
- 42 leakage
- 43 inlet to filter
- 44 outlet from sealing oil pump
- 45 fuel-rack position
- 46 inlet to prechamber
- 47
- 48
- 49

Nozzle cooling system

- 50 inlet to fuel valves
- 51 outlet from fuel valves
- 52
- 53
- 54
- 55 valve timing
- 56 injection timing
- 57 earth/diff. protection
- 58 oil splash
- 59 alternator load

Exhaust gas system

- 60 outlet from cylinder
- 61 outlet from turbocharger
- 62 inlet to turbocharger
- 63 combustion chamber
- 64
- 65
- 66
- 67
- 68
- 69

Compressed air system

70	inlet to engine	74	inlet to reduction valve	78	inlet to sealing oil system
71	inlet to stop cylinder	75	microswitch for turning gear	79	
72	inlet to balance arm unit	76	inlet to turning gear		
73	control air	77	waste gate pressure		

Load speed

80	overspeed air	84	engine stop	88	index - fuel injection pump
81	overspeed	85	microswitch for overload	89	turbocharger speed
82	emergency stop	86	shutdown	90	engine speed
83	engine start	87	ready to start		

Miscellaneous

91	natural gas - inlet to engine	95	voltage	99	common alarm
92	oil mist detector	96	switch for operating location	100	inlet to MDO cooler
93	knocking sensor	97	remote	101	outlet to MDO cooler
94	cylinder lubricating	98	alternator winding	102	alternator cooling air

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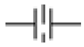
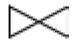
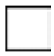
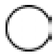
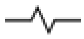
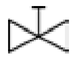
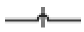
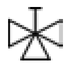
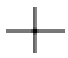
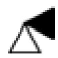
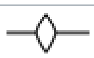
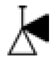
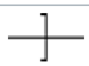
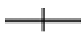
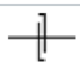
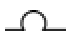
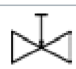
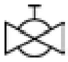
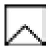
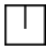
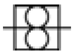
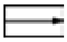
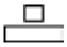
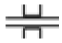
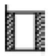
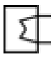
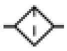
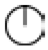
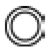
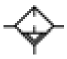
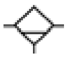
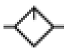
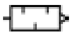
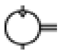
Symbols for piping

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 instru-ments	2.18		Snap coupling
1.6		High-pressure pipe	2.19		Pneumatic flow or exhaust to at-mosphere
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) gen-eral	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

2.12		Cap nut	3.14		Ball valve (cock)

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-return 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 bottom conn.	4.10		Manual (at pneumatic valves)
3.29		Cock, angle, with bottom connection	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

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	

General

Symbol	Designation	Standard
	Pump, general	DIN 2481
	Centrifugal pump	DIN 2481
	Centrifugal pump with electric motor	DIN 2481
	Gear pump	DIN 2481
	Screw pump	DIN 2481
	Screw pump with electric motor	DIN 2481
	Compressor	ISO 1219
	Heat exchanger	DIN 2481
	Electric pre-heater	DIN 2481
	Heating coil	DIN 8972
	Non-return valve	
	Butterfly valve	
	Gate valve	
	Relief valve	
	Quick-closing valve	
	Self-closing valve	
	Back pressure valve	
	Shut off valve	
	Thermostatic valve	
	Pneumatic operated valve	

Symbol	Designation	Standard
	Ballcock	
	Cock, three-way, L-port	
	Double-non-return valve	DIN 74.253
	Spectacle flange	DIN 2481
	Spectacle flange, open	DIN 2481
	Spectacle flange, closed	DIN 2481
	Orifice	
	Flexible pipe	
	Centrifuge	DIN 28.004
	Suction bell	
	Air vent	
	Sight glass	DIN 28.004
	Mudbox	
	Filter	
	Filter with water trap	ISO 1219
	Typhon	DIN 74.253
	Pressure reducing valve (air)	ISO 1219
	Oil trap	DIN 28.004
	Accumulator	
	Pressure reducing valve with pressure gauge	

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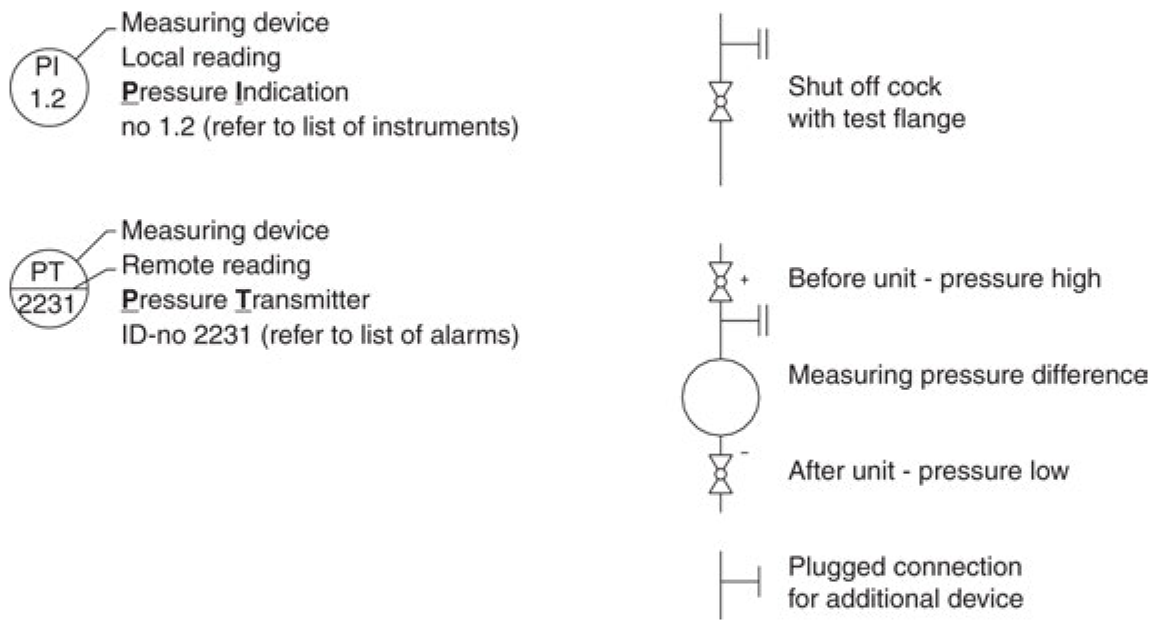
General



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.	

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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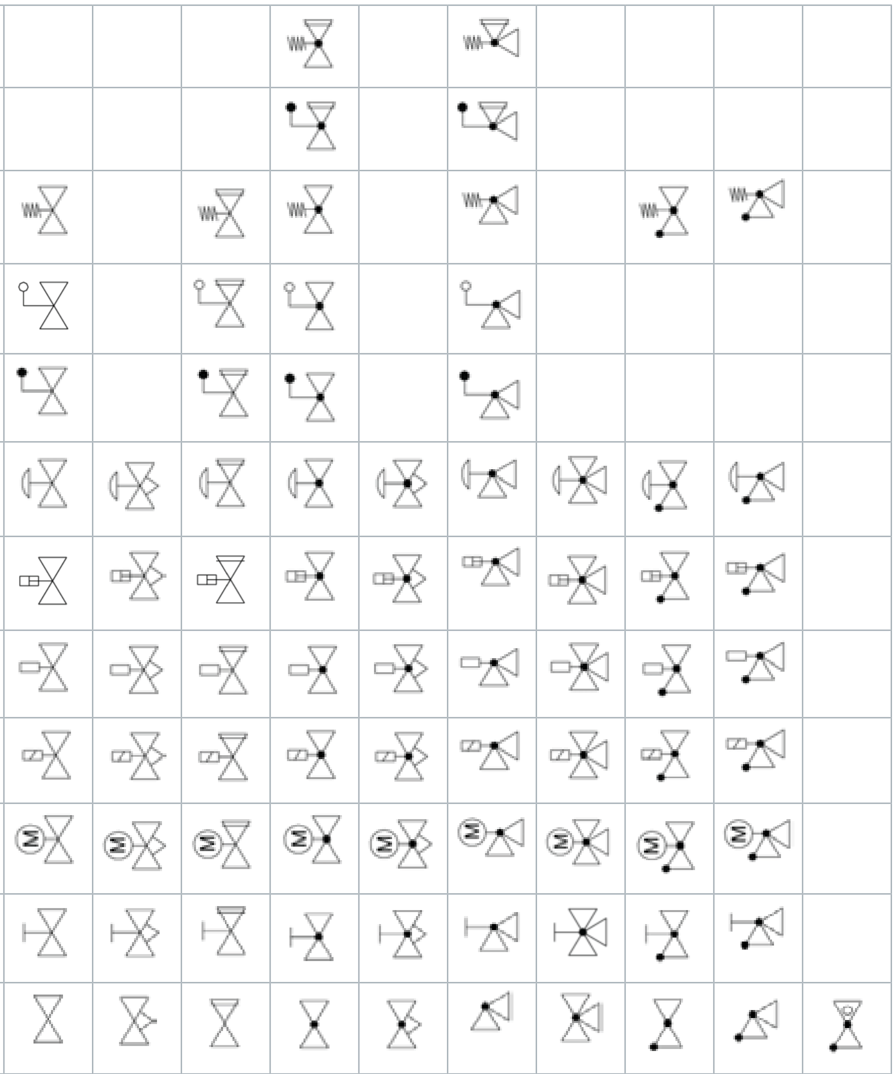
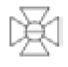
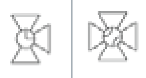
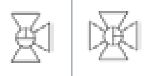
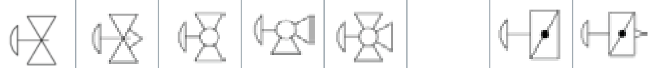
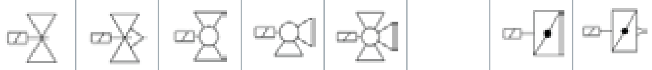
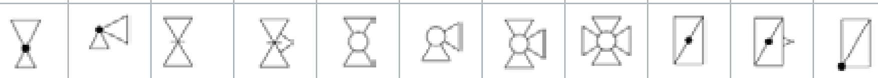
Basic symbols for piping



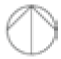
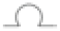
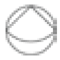
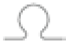
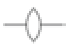
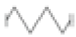
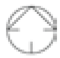
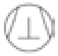
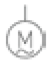
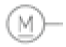
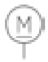
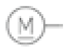
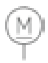
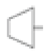
2237	Spring operated safety valve										
2238	Mass operated Safety valve										
2228	Spring actuator										
2284	Float actuator										
2229	Mass										
2231	Membrane actuator										
2230	Piston actuator										
2232	Fluid actuator										
2223	Solenoid actuator										
2234	Electric 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

	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 actu-ator											
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

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

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

List of capacities

Capacities

5L: 200 kW/cyl., 6L-9L: 220kW/cyl. at 900 rpm, 1-String			5	6	7	8	9
Engine output		kW	1000	1320	1540	1760	1980
Speed		rpm	900	900	900	900	900
External (from engine to system)							
1-string cooling water (mix)		°C	52.4	56.4	59.1	61.6	64.2
Heat to be dissipated 3)							
Cooling water cylinder		kW	208	289	347	405	464
Charge air cooler; cooling water HT		kW	346	435	490	542	590
Charge air cooler; cooling water LT		kW	198	244	274	303	332
Lubricating oil cooler		kW	176	238	281	324	368
Heat radiation engine		kW	49	65	76	87	98
Flow rates 4)							
Internal (inside engine)							
HT circuit (cylinder + charge air cooler HT stage)		m^3/h	55	55	55	55	55
LT circuit (lube oil + charge air cooler LT stage)		m^3/h	55	55	55	55	55
Lubrication oil		m^3/hh	31	31	41	41	41
External (from engine to system)							
HT water flow (at 40°C inlet)		m^3/h	11.1	14.1	16.0	17.8	19.5
LT water flow (at 38°C inlet)		m^3/h	55	55	55	55	55
Air data							
Temperature of charge air at charge air cooler outlet		°C	52	56	58	60	62
Air flow rate		m^3/h 5)	6656	8786	10250	11714	13178
		kg/kWh	7.28	7.28	7.28	7.28	7.28
Charge air pressure		bar	4.58	4.61	4.63	4.64	4.66
Air required to dissipate heat radiation (eng.) (t_2-t_1= 10°C)		m^3/h	17980	23800	27600	31500	35300
Exhaust gas data 6)							
Volume flow (temperature turbocharger outlet)		m^3/h 7)	13484	17918	20981	24055	27130
Mass flow		t/h	7.5	9.9	11.5	13.2	14.8
Temperature at turbine outlet		°C	353	357	360	362	363
Heat content (190°C)		kW	366	496	587	679	771
Permissible exhaust back pressure		mbar	< 30	< 30	< 30	< 30	< 30
Permissible exhaust back pressure (SCR)		mbar	< 50	< 50	< 50	< 50	< 50
Pumps							
External pumps 8)							
Diesel oil pump	(5 bar at fuel oil inlet A1)	m^3/h	0.89	1.18	1.37	1.57	1.76
Fuel oil supply pump	(4 bar discharge pressure)	m^3/h	0.30	0.39	0.46	0.52	0.59
Fuel oil circulating pump 9)	(8 bar at fuel oil inlet A1)	m^3/h	0.89	1.18	1.37	1.57	1.76
Starting air data							
Air consumption per start, incl. air for jet assist (TDI)		Nm^3	1.0	1.2	1.4	1.6	1.8
Air consumption per start, incl. air for jet assist (Gali)		Nm^3	1.8	2.1	2.4	2.7	3.0

Conditions

Reference condition : Tropic		
Air temperature LT water temperature inlet engine (from system) Air pressure Relative humidity	°C °C bar %	45 38 1 50
Temperature basis: Set point HT cooling water engine outlet [1)] Set point LT cooling water engine outlet [2)] Set point lubrication oil inlet engine	 °C °C °C	 79°C nominal *(Range of mech. thermostatic element 77-85°C)* 35°C nominal *(Range of mech. thermostatic element 29-41°C)* 66°C nominal *(Range of mech. thermostatic element 63-72°C)*

Remarks to capacities

1) HT cooling water flows first through HT stage charge air cooler, then through water jacket and cylinder head, water temperature outlet engine regulated by mechanical thermostat.
2) LT cooling water flows first through LT stage charge air cooler, then through lube oil cooler, water temperature outlet engine regulated by mechanical thermostat.
3) Tolerance: + 10% for rating coolers, - 15% for heat recovery.
4) Basic values for layout of the coolers.
5) Under above mentioned reference conditions.
6) Tolerance: quantity +/- 5%, temperature +/- 20°C.
7) Under below mentioned temperature at turbine outlet and pressure according above mentioned reference conditions.
8) Tolerance of the pumps' delivery capacities must be considered by the manufactures.
9) In order to ensure sufficient flow through the engine fuel system the capacity of the fuel oil circulation pumps must be minimum 3 times the full load consumption of the installed engines

NOTICE

High temperature alarms can occur for some engine types running 100% MCR with SCR catalyst (50 mbar exhaust back pressure) and tropical condition (ambient air 45°C & LT-water 38°C).

List of capacities

Capacities

5L:200 kW/cyl., 6L-9L: 220 kW/cyl. at 1000 rpm, 1-String			5	6	7	8	9
External (from engine to system)							
1-String coding water (mix)		°C	50.6	54.1	56.4	58.6	60.8
Engine output		kW	1000	1320	1540	1760	1980
Speed		rpm	1000	1000	1000	1000	1000
Heat to be dissipated [3]							
Cooling water cylinder		kW	206	285	342	399	456
Charge air cooler; cooling water HT		kW	321	404	455	503	548
Charge air cooler; cooling water LT		kW	192	238	266	294	321
Lubricating oil cooler		kW	175	236	279	322	365
Heat radiation engine		kW	49	65	76	87	98
Flow rates [4]							
Internal (inside engine)							
HT circuit (cylinder + charge air cooler HT stage)		m^3/h	61	61	61	61	61
LT circuit (lube oil + charge air cooler LT stage)		m^3/h	61	61	61	61	61
Lubrication oil		m^3/h	34	34	46	46	46
External (from engine to system)							
HT water flow (at 40°C inlet)		m^3/h	10.7	13.5	15.4	17.1	18.8
LT water flow (at 38°C inlet)		m^3/h	61	61	61	61	61
Air data							
Temperature of charge air at charge air cooler outlet		°C	51	55	57	59	60
Air flow rate		m^3/h [5]	6647	8774	10237	11699	13161
		kg/kWh	7.27	7.27	7.27	7.27	7.27
Charge air pressure		bar	4.25	4.28	4.29	4.30	4.31
Air required to dissipate heat radiation (eng.) (t_2-t_1= 10°C)		m^3/h	17980	23800	27600	31500	35300
Exhaust gas data [6]							
Volume flow (temperature turbocharger outlet)		m^3/h [7]	13730	18235	21348	24468	27594
Mass flow		t/h	7.5	9.9	11.5	13.2	14.8
Temperature at turbine outlet		°C	365	369	372	373	375
Heat content (190°C)		kW	394	532	628	725	823
Permissible exhaust back pressure		mbar	< 30	< 30	< 30	< 30	< 30
Permissible exhaust back pressure (SCR)		mbar	< 50	< 50	< 50	< 50	< 50
Pumps							
External pumps [8]							
Diesel oil pump	(5 bar at fuel oil inlet A1)	m^3/h	0.89	1.18	1.37	1.57	1.76
Fuel oil supply pump	(4 bar)	m^3/h	0.30	0.39	0.46	0.52	0.59
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8) Tolerance of the pumps' delivery capacities must be considered by the manufactures.
9) In order to ensure sufficient flow through the engine fuel system the capacity of the fuel oil circulation pumps must be minimum 3 times the full load consumption of the installed engines

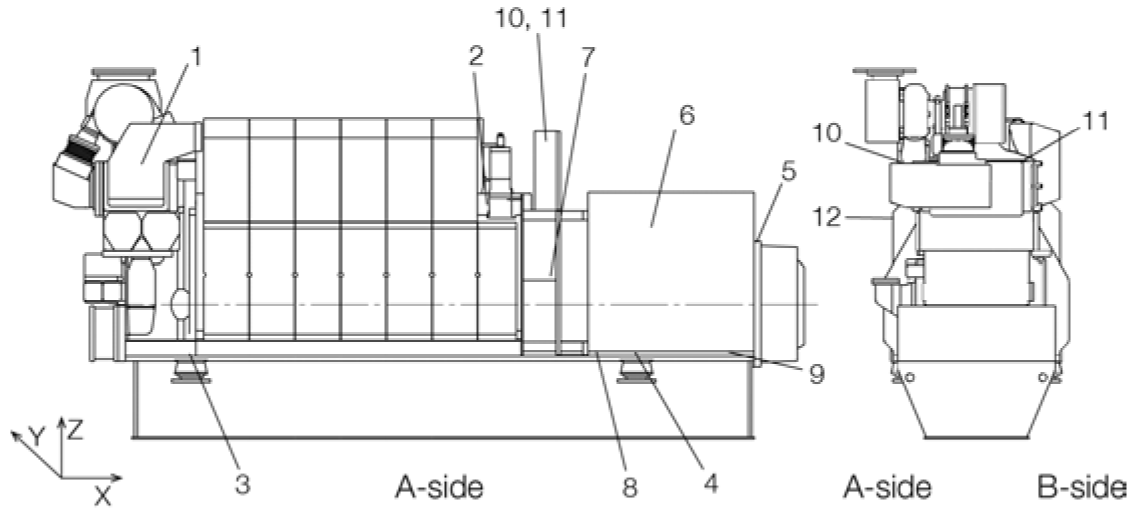
NOTICE

High temperature alarms can occur for some engine types running 100% MCR with SCR catalyst (50 mbar exhaust back pressure) and tropical condition (ambient air 45°C & LT-water 38°C).

2017-03-15 - en

Vibration limits and measurements

GenSet



Measure-ment point	Description	Limit	Measure-ment point	Description	Limit	Measure-ment point	Description	Limit
1	TC fore	18	5	Aft alternator bearing	18	9	Alternator foot	See below *
2	Governor/TC aft	18	6	Alternator cooler	25	10	Automation box A-side	25
3	Front support	18	7	Intermediate bearing	18	11	Automation box B-side	25
4	Aft support	18	8	Alternator foot	See below *	12	T&P panel	25

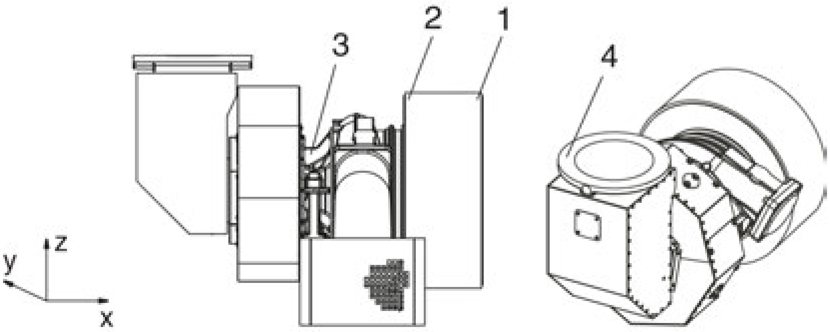
Engine: VDI 2063T
Alternator: ISO 8528-9, DIN 6280-11
Note: All measurements are specified as mm/s r.m.s.

* Alternator	Value 1	Value 2
P ≤ 1250 kVA	20	24
P > 1250 kVA	18	22

Value 1 or 2 are depending on alternator make

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

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			2.9		2.2		2.9		6.4		3.2		5.8
TCR12 NR12			2.6		2.0		2.6		5.8		2.9		5.2
TCR14 NR14, NR15, NR17	3-300	45	2.0	35	1.6	45	2.0	100	4.5	50	2.2	90	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
Shop test		100				
			Crosswise (y) (Turbocharger oriented)			
		100				
			Longitudinal (x) (Turbocharger oriented)			
		100				

Description of sound measurements

General

Purpose

This should be seen as an easily comprehensible sound analysis of MAN 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 x 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 x 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 MAN Energy Solutions' 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:

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

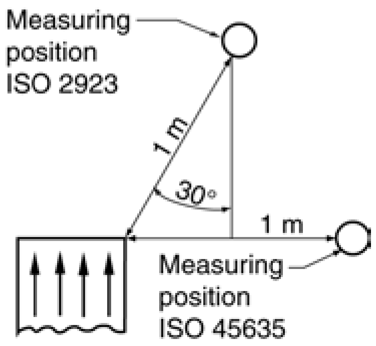


Figure 1: .

Description of structure-borne noise

Introduction

This paper describes typical structure-borne noise levels from standard resiliently mounted MAN-ES 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.

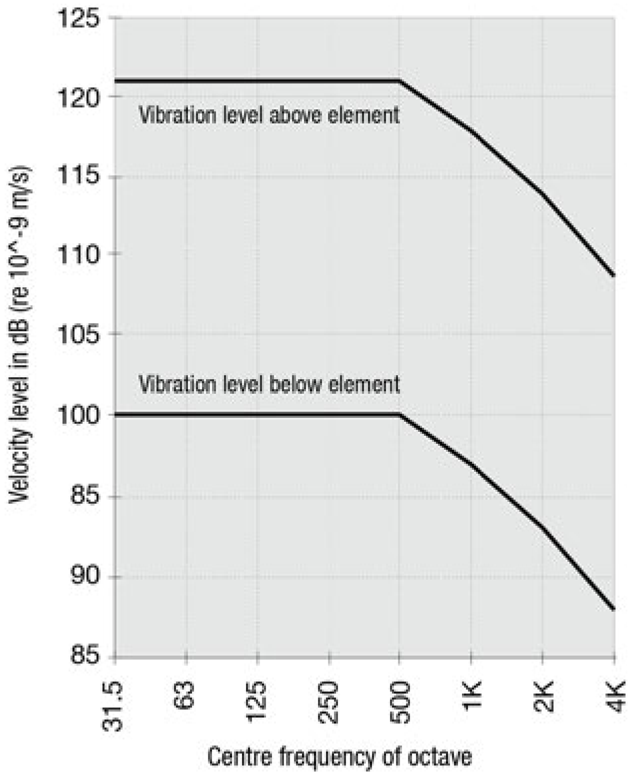


Figure 1: Structure-borne noise on resiliently mounted engine.

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

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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 MAN Energy Solutions 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 MAN Energy Solutions 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 MAN Energy Solutions four-stroke diesel engines is at a very low level.

Particulate matter PM

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

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.

NOx emission

Maximum allowed emission value NOx

Related speed	rpm	720	750	800	900	1000	1200
IMO Tier II cycle D2/E2/E3	g/kWh	9.69	9.60	9.46	9.20	8.98	8.61
IMO Tier III cycle D2/E2/E3	g/kWh	2.41	2.39	2.36	2.31	2.26	2.18

Marine engines are guaranteed to meet the revised International Convention for the Prevention of Pollution from Ships, "Revised MARPOL Annex VI (Regulations for the prevention of air pollution from ships), Regulation 13 as adopted by the International Maritime Organization (IMO).

Cycle values as per ISO 8178-4: 2007, operating on ISO 8217 DM grade fuel (marine distillate fuel: MGO or MDO).

Maximum allowed NO_X emissions for marine diesel engines according to IMO Tier II:
$130 \leq n \leq 2000 \rightarrow 44 \times n^{-0,23}$ g/kWh (n = rated engine speed in rpm)

Maximum allowed NO_X emissions for marine diesel engines according to IMO Tier III:
$130 \leq n \leq 2000 \rightarrow 9 \times n^{-0,2}$ g/kWh (n = rated engine speed in rpm)

Calculated as NO_2:
D2:Test cycle for "Constant-speed auxiliary engine" application
E2: Test cycle for "Constant-speed main propulsion" application including diesel-electric drive and all controllable pitch propeller installations
E3: Test cycle for "Propeller-law-operated main and propeller-law operated auxiliary engine" application

Specified reference charge air temperature corresponds to an average value for all cylinders that will be achieved with 25°C LT cooling water temperature before charge air cooler (as according to ISO).

Dual-fuel engines (L23/30DF and L28/32DF) comply with IMO Tier III emission rules without exhaust gas after treatment.

Liquid fuel engines (HFO, MDO, MGO etc.) can only comply with IMO Tier III emission rules with use of exhaust gas after treatment (example SCR).

NOTICE

The engine´s certification for compliance with the NO_X limits will be carried out during factory acceptance test, FAT as a single or a group certification.

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Moment of inertia

GenSet

Eng. type	Moments of inertia			Flywheel		
Number of cylinders	Continuous rating	Moments required total J_{min}	Engine + damper	Moments of inertia	Mass	Required moment of inertia after flywheel *)
	kW	Kgm^2	Kgm^2	Kgm^2	kg	Kgm^2
n = 900 rpm						
5L21/31	1100	324	95	164	890	65
6L21/31	1320	389	104	164	890	121
7L21/31	1540	454	113	164	890	177
8L21/31	1760	519	145**)	164	890	210
9L21/31	1980	584	154**)	164	890	266
n = 1000 rpm						
5L21/31	1100	263	95	164	890	4
6L21/31	1320	315	104	164	890	47
7L21/31	1540	368	113	164	890	91
8L21/31	1760	420	145**)	164	890	111
9L21/31	1980	473	154**)	164	890	155

*) Required moment of inertia after flywheel is based on 164 Kgm^2 flywheel, and the most common damper. The calucation is based on 42% engine acceleration.

Larger flywheel means lower alternator inertia demand, as total GenSet inertia is the final demand.

Selection of bigger flywheel for having lower alternator inertia demand, have to be approved by a torsional vibration calculation.

The following flywheels are available:

J = 133 kgm^2
J = 164 kgm^2
J = 205 kgm^2
J = 247 kgm^2

**) Incl. flexible coupling for two bearing alternator.

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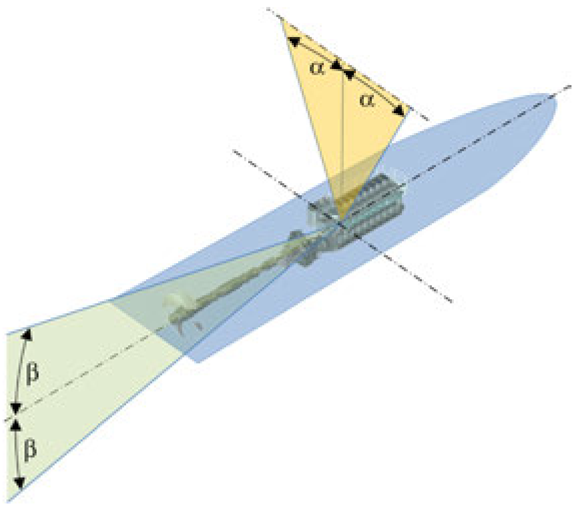
Inclination of engines

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] L < 100 m	Trim (static) [2] L > 100 m	Pitching (dynamic)
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.

2023-08-30 - en

NOTICE

For higher requirements contact MAN Energy Solutions. 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”.

MAN Energy Solutions 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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GenSet extension of TBO (Time Between Overhaul)

Condition based overhaul

The market trend for our engines are that maintenance programmes are changed from programme-based to condition-based overhaul intervals where various inspections and control parametes can be set up as indicators of the present condition. This will enable the operator to judge and predict the schedule for next maintenance operation.

Based on market feedback and experience gained over the years we have worked out a planned maintenance programme for our GenSet which mainly is based on operating hours referred to as recommended Time Between Overhaul (TBO).

As per the service instruction manual the TBO for GenSet is originally recommended at 12,000 to 16,000 hours for the major overhauls.

It is now documented that the GenSet can reach a TBO of 20,000 - 22,000 hours in HFO operation provided that the engine is operated according to the instruction manual, that the following parts are installed and that the below-mentioned guidelines are followed:

1. T/C wet and dry cleaning (More information, see SL2015-597)
   W-W: Weekly Wet cleaning
   D-D: Daily Dry cleaning
2. Installation of backflush filter 6/10µm in the external fuel oil system according to MAN recommendations (More information, see SL2016-615)
3. Mandatory use of on board lubricating oil purifiers (treatment and maintenance of lubricating oil (More information, see SL2013-582)
4. GenSet engine is build according to newest design specification
   - Installation of 25mµ safety filter in the internal fuel oil system (More information, see SL2013-577)
   - Lubricating oil centrifugal filter is installed at engine (standard)
   - Charge air preheating is installed at engine (option)

NOTICE	**It is important to note and remember:** **Availability of tools for both wet and dry cleaning to be observed**

In general, we recommend the operators of our engines to closely monitor the operation parameters and keep records of these in order to follow the trends of the engine performance.

The condition-based maintenance system is based on observations and safe operation.
For evaluation of condition, the below list of service letters, must be considered and followed.

1) Lub. oil treatment (SL2013-582)
2) Fuel injection valve condition (SL2016-628)
3) Cooling water treatment (SL2016-623)
4) Fuel oil cleaning (SL2017-640)
5) Cleaning of condensate drain (SL2017-649)
6) Quality of fuel (SL2010-527)

It is therefore necessary to change the maintenance intervals on the GenSets when changing from programme-based to conditioned-based maintenance.

New maintenance programme is issued in cooperation with MAN Energy Solutions.

2022-01-26 - en

Overhaul recommendation, maintenance and expected life time

Component	Overhaul Recommendations, Maintenance and Expected Life Time	Time between overhauls (TBO) Hours **	Expected life time Hours
Main bearings	Inspection Retightening *	32.000	96.000
Connecting rod	Inspection	32.000	64.000
Big-end bearing	Inspection Retightening *	32.000	64.000
Camshaft	Inspection of cams surface	8.000	64.000
Piston	Overhaul and measuring of ring grooves	32.000	64.000
	Replacement of compression rings and scraper rings	32.000	32.000
Cylinder liner	Inspection, measuring and honing of running surface condition	32.000	64.000
Cylinder head		32.000	96.000
Valve clearance	Checking and adjustment	8.000	
Fuel injection valve	Checking and cleaning 3)	Based on observation	8.000 3)
Inlet and Exhaust valve	Overhaul and regrinding of spindle	32.000	64.000
Valve seat ring	Exchange and grinding	32.000	32.000
Rotorcap	Function check of rotation	2.000	32.000
Valve guide	Measuring of inside diameter	32.000	64.000
Cylinder head nuts	Retightening *		
Fuel pump	Fuel pump barrel/plunger assembly.	Based on observation	32.000
Lub. Oil pump	Overhaul	32.000	64.000
Cooling water pumps	Overhaul	32.000	48.000
Air Cooler	Cleaning and pressure testing	Based on observation	72.000
Compr. air system	Check of compressed air system, air starter	Based on observation	
Autolog reading	Check last crank through	Once a year	
Lub. oil filter cartr.	Replacement based on observations of pressure drop		1.500
Regulating system	Function check of overspeed and shutdown devices. Check that the control rod of each individual fuel pump can easily go to "stop" position	Quarterly	
Flexible mountings	Check anti-vibration mountings	Quarterly	
Vibration damper	Expected lifetime		48.000-54.000
Turbocharger	Water washing of compressor side	Based on observation	
	Water washing of turbine side		
	Dry cleaning of turbine side	Based on observation	
	Air filter cleaning	Based on observation	

* After starting up and before loading engine.

** Time between overhauls:
It is a precondition for the validity of the values stated above, that the engine is operated in accordance with our instructions and recommendations for cleaning of fuel and lub. oil and original spare parts are used.
In the Project Guide for GenSet, see Lub. oil treatment, in section B 12 00 0 and Fuel oil specification in section B 11 00 0 and section 14 000 for Propulsion.
In the Instruction Manual for GenSet and L21/31 Propulsion, see Lub. oil treatment and Fuel oil specification in section 504/604. For Propulsion L27/38, L23/30A, L28/32A see section 1.00.

1. Island mode, max. 75 % average load.
2. Parallel running with public grid, up to 100 % load.
3. See working card for fuel injection valve in the instruction manual, section 514/614 for GenSet and section 1.20.
4. Time can be adjusted acc. to performance observations.

NOTICE Time between overhaul for Crude oil is equal to HFO
Time between overhaul for Biofuel is equal to MDO, except for fuel equipment case by case, depending on TAN number

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Overhaul recommendation, maintenance and expected life time

Component	Overhaul Recommendations, Maintenance and Expected Life Time	Time between overhauls (TBO) Hours **	Expected life time Hours
Main bearings	Inspection Retightening *	16.000	48.000
Connecting rod	Inspection	16.000	64.000
Big-end bearing	Inspection Retightening *	32.000	48.000
Camshaft	Inspection of cams surface	8.000	48.000
Piston	Overhaul and measuring of ring grooves	16.000	48.000
	Replacement of compression rings and scraper rings	16.000	16.000
Cylinder liner	Inspection, measuring and honing of running surface condition	16.000	32.000
Cylinder head		16.000	48.000
Valve clearance	Checking and adjustment	8.000	
Fuel injection valve	Checking and cleaning 3)	Based on observation	8.000 3)
Inlet and Exhaust valve	Overhaul and regrinding of spindle	16.000	32.000
Valve seat ring	Exchange and grinding	16.000	32.000
Rotorcap	Function check of rotation	2.000	32.000
Valve guide	Measuring of inside diameter	16.000	32.000
Cylinder head nuts	Retightening *		
Fuel pump	Fuel pump barrel/plunger assembly.	Based on observation	16.000
Lub. Oil pump	Overhaul	16.000	48.000
Cooling water pumps	Overhaul	16.000	48.000
Air Cooler	Cleaning and pressure testing	Based on observation	72.000
Compr. air system	Check of compressed air system, air starter	Based on observation	
Autolog reading	Check last crank through	Once a year	
Lub. oil filter cartr.	Replacement based on observations of pressure drop		1.000
Regulating system	Function check of overspeed and shutdown devices. Check that the control rod of each individual fuel pump can easily go to "stop" position	Quarterly	
Flexible mountings	Check anti-vibration mountings	Quarterly	
Vibration damper	Expected lifetime		48.000-54.000
Turbocharger	Water washing of compressor side	Based on observation	
	Water washing of turbine side	150 4)	
	Dry cleaning of turbine side	Daily 4)	
	Air filter cleaning	Based on observation	

* After starting up and before loading engine.

** Time between overhauls:
It is a precondition for the validity of the values stated above, that the engine is operated in accordance with our instructions and recommendations for cleaning of fuel and lub. oil and original spare parts are used.
In the Project Guide for GenSet, see Lub. oil treatment, in section B 12 00 0 and Fuel oil specification in section B 11 00 0 and section 14 000 for Propulsion.
In the Instruction Manual for GenSet and L21/31 Propulsion, see Lub. oil treatment and Fuel oil specification in section 504/604. For Propulsion L27/38, L23/30A, L28/32A see section 1.00.

1. Island mode, max. 75 % average load.
2. Parallel running with public grid, up to 100 % load.
3. See working card for fuel injection valve in the instruction manual, section 514/614 for GenSet and section 1.20.
4. Time can be adjusted acc. to performance observations.

NOTICE Time between overhaul for Crude oil is equal to HFO
Time between overhaul for Biofuel is equal to MDO, except for fuel equipment case by case, depending on TAN number

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General description

General

The engine is a turbocharged, single-acting fourstroke diesel engine of the trunk type with a cylinder bore of 210 mm and a stroke of 310 mm. The crankshaft speed is 900 or 1000 rpm.

The engine can be delivered as an in- line engine with 5 to 9 cylinders.

For easy maintenance the cylinder unit consists of: the cylinder head, water jacket, cylinder liner, piston and connecting rod which can be removed as complete assemblies with possibility for maintenance by recycling. This allows shoreside reconditioning work which normally yields a longer time between major overhauls.

The engine is designed for an unrestricted load profile on HFO, low emission, high reliability and simple installation.

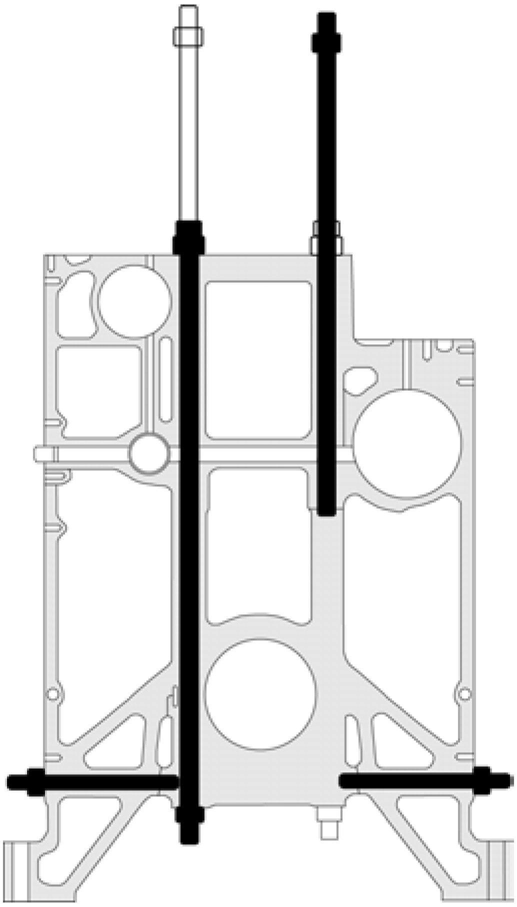

Figure 1: Engine frame.

Engine frame

The monobloc cast iron engine frame is designed to be very rigid. All the components of the engine frame are held under compression stress. The frame is designed for an ideal flow of forces from the cylinder head down to the crankshaft and gives the outer shell low surface vibrations.

Two camshafts are located in the engine frame. The valve camshaft is located on the exhaust side in a very high position and the injection camshaft is located on the service side of the engine.

The main bearings for the underslung crankshaft are carried in heavy supports by tierods from the intermediate frame floor, and are secured with the bearing caps. These are provided with side guides and held in place by means of studs with hydraulically tightened nuts. The main bearing is equipped with replaceable shells which are fitted without scraping.

On the sides of the frame there are covers for access to the camshafts and crankcase. Some covers are fitted with relief valves which will operate if oil vapours in the crankcase are ignited (for instance in the case of a hot bearing).

Base frame

The engine and alternator are mounted on a rigid base frame. The alternator is considered as an integral part during engine design. The base frame, which is flexibly mounted, acts as a lubricating oil reservoir for the engine.

Cylinder liner

Cylinder liner, cooling water jacket, top land ring

The cylinder liners, made of special centrifugal cast iron, are encased by a nodular cast iron cooling water jacket in the upper section. This is centered in the crankcase. The lower section of the cylinder liner is guided in the crankcase. The so-called top land ring fits on the top of the cylinder liner.

The subdivision into 3 components i.e. the cylinder liner, cooling water jacket and top land ring provides the best possible structure with reference to resistance to deformation, with regard to cooling and with regard to ensuring the minimum temperatures on certain component assemblies.

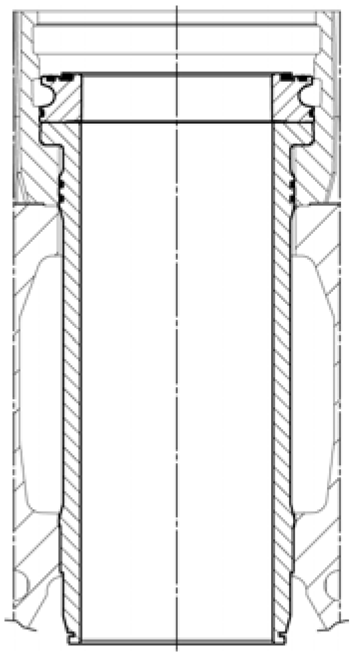

Figure 2: Cylinder liner with top land ring.

Interaction stepped piston/top land ring

The top land ring which projects above the cylinder liner bore works together with the recessed piston crown of the stepped piston to ensure that burnt carbon deposits on the piston crown do not come into contact with the running surface of the cylinder liner. This prevents bore polishing where lube oil would not adhere properly.

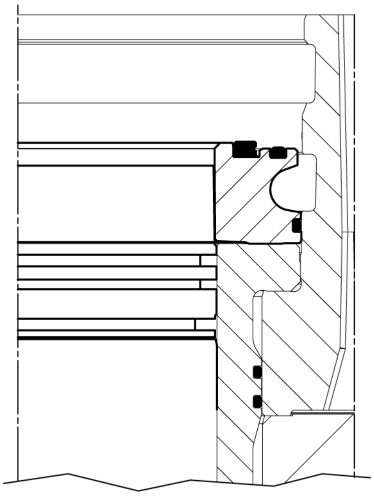

Figure 3: Interaction of top land ring and stepped piston.

Cooling

The coolant reaches the cylinder liner via a line that is connected to the cooling water jacket. The coolant flows through trimmed ducts in the cooling water jacket to the cooling areas in the cylinder liner, and top land ring, and through holes on to the cooling chambers in the cylinder heads. The cylinder head, cooling water jacket and top land ring can be drained together.

The top land ring and cylinder head can be checked by using check holes in the cooling water jacket for gas and coolant leaks.

Cylinder head

The cylinder head is of cast iron with an integrated charge air receiver, made in one piece. It has a bore-cooled thick walled bottom. It has a central bore for the fuel injection valve and 4 valve cross flow design, with high flow coefficient. Intensive water cooling of the nozzle tip area made it possible to omit direct nozzle cooling. The valve pattern is turned about 20° to the axis and achieves a certain intake swirl.

The cylinder head is tightened by means of 4 nuts and 4 studs which are screwed into the engine frame. The nuts are tightened by means of hydraulic jacks.

The cylinder head has a screwed-on top cover. It has two basic functions: oil sealing of the rocker chamber and covering of the complete head top face.

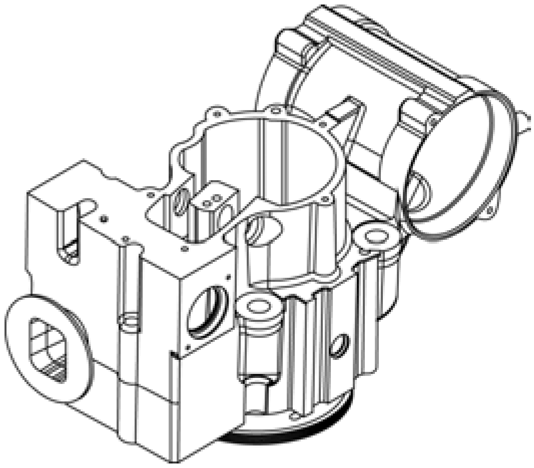

Figure 4: Cylinder head.

Air inlet and exhaust valves

The valve spindles are made of heat-resistant material and the spindle seats are armoured with welded-on hard metal.

All valve spindles are fitted with valve rotators which turn the spindles each time the valves are activated. The turning of the spindles ensures even temperature levels on the valve discs and prevents deposits on the seating surfaces.

The cylinder head is equipped with replaceable valve seat rings. The exhaust valve seat rings are water cooled in order to assure low valve temperatures.

Valve actuating gear

The rocker arms are actuated through rollers, roller guides and push rods. The roller guides for inlet and exhaust valves are mounted in the water jacket part.

Each rocker arm activates two spindles through a valve bridge with thrust screws and adjusting screws for valve clearance.

The valve actuating gear is pressure-feed lubricated from the centralized lubricating system, through the water chamber part and from there into the rocker arm shaft to the rocker bearing.

Fuel injection system

The engine is provided with one fuel injection pump unit, an injection valve, and a high pressure pipe for each cylinder.

The injection pump unit is mounted on the engine frame. The pump unit consists of a pump housing embracing a roller guide, a centrally placed pump barrel and a plunger. The pump is activated by the fuel cam, and the volume injected is controlled by turning the plunger.

The fuel injection valve is located in a valve sleeve in the centre of the cylinder head. The opening of the valve is controlled by the fuel oil pressure, and the valve is closed by a spring.

The high pressure pipe which is led through a bore in the cylinder head is surrounded by a shielding tube.

The shielding tube also acts as a drain channel in order to ensure any leakage from the fuel valve and the high pressure pipe will be drained off.

The complete injection equipment including injection pumps and high pressure pipes is well enclosed behind removable covers.

Piston

The piston, which is oil-cooled and of the composite type, has a body made of nodular cast iron and a crown made of forged deformation resistant steel. It is fitted with 2 compression rings and 1 oil scraper ring in hardened ring grooves.

Figure 5: Piston.

By the use of compression rings with different barrelshaped profiles and chrome-plated running surfaces, the piston ring pack is optimized for maximum sealing effect and minimum wear rate.

The piston has a cooling oil space close to the piston crown and the piston ring zone. The heat transfer, and thus the cooling effect, is based on the shaker effect arising during the piston movement. The cooling medium is oil from the engine's lubricating oil system.

Oil is supplied to the cooling oil space through a bore in the connecting rod. Oil is drained from the cooling oil space through ducts situated diametrically to the inlet channels.

The piston pin is fully floating and kept in position in the axial direction by two circlips.

Connecting rod

The connecting rod is of the marine head type.

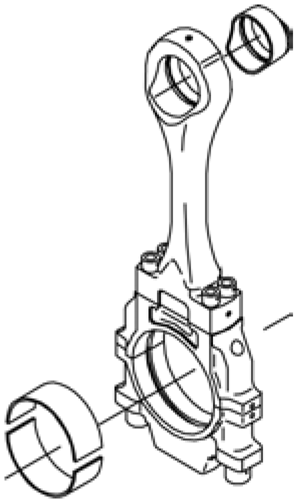

Figure 6: Connecting rod.

The joint is above the connecting rod bearing. This means that the big-end bearing need not to be opened when pulling the piston. This is of advantage for the operational safety (no positional changes/no new adaption), and this solution also reduces the height dimension required for piston assembly / removal.

Connecting rod and bearing body consist of dieforged CrMo steel.

The material of the bearing shells are identical to those of the crankshaft bearing. Thin-walled bearing shells having an AlSn running layer are used.

The bearing shells are of the precision type and are therefore to be fitted without scraping or any other kind of adaption.

The small-end bearing is of the trimetal type and is pressed into the connecting rod. The bush is equipped with an inner circumferential groove, and a pocket for distribution of oil in the bush itself and for the supply of oil to the pin bosses.

Crankshaft and main bearings

The crankshaft, which is a one-piece forging, is suspended in underslung bearings. The main bearings are of the trimetal type, which are coated with a running layer. To attain a suitable bearing pressure and vibration level the crankshaft is provided with counterweights, which are attached to the crankshaft by means of two hydraulic screws.

At the flywheel end the crankshaft is fitted with a gear wheel which, through two intermediate wheels, drives the camshafts.

Also fitted here is a flexible disc for the connection of an alternator. At the opposite end (front end) there is a gear wheel connection for lub. oil and water pumps.

Lubricating oil for the main bearings is supplied through holes drilled in the engine frame. From the main bearings the oil passes through bores in the crankshaft to the big-end bearings and then through channels in the connecting rods to lubricate the piston pins and cool the pistons.

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Camshaft and camshaft drive

The inlet and exhaust valves as well as the fuel pumps of the engine are actuated by two camshafts.

Due to the two-camshaft design an optimal adjustment of the gas exchange is possible without interrupting the fuel injection timing. It is also possible to adjust the fuel injection without interrupting the gas exchange.

The two camshafts are located in the engine frame. On the exhaust side, in a very high position, the valve camshaft is located to allow a short and stiff valve train and to reduce moving masses.

The injection camshaft is located at the service side of the engine.

Both camshafts are designed as cylinder sections and bearing sections in such a way that disassembly of single cylinder sections is possible through the side openings in the crankcase.

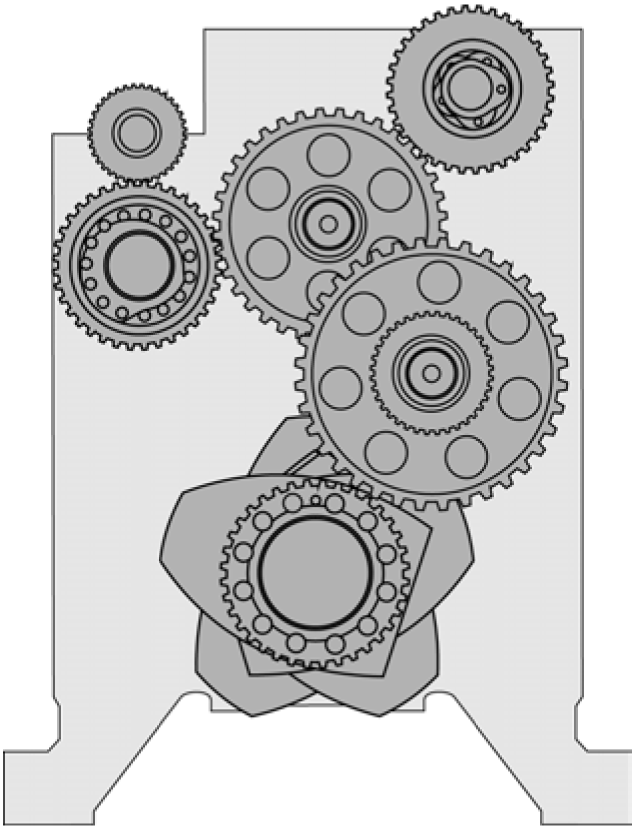


Figure 7: Twin camshafts.

The two camshafts and the governor are driven by the main gear train which is located at the flywheel end of the engine. They rotate with a speed which is half that of the crankshaft.

The camshafts are located in bearing bushes which are fitted in bores in the engine frame; each bearing is replaceable.

Front-end box

The front-end box is fastened to the front end of the engine. It contains all pipes for cooling water and lubricating oil systems and also components such as pumps, filters, coolers and valves.

The components can be exchanged by means of the clip on/clip off concept without removing any pipes. This also means that all connections for the engine, such as cooling water and fuel oil, are to be connected at the front end of the engine to ensure simple installation.

Governor

The engine speed is controlled by an electronic governor with hydraulic actuators. In some cases a hydraulic governor can be used as an alternative.

Monitoring and control system

The engine is equipped with MAN Energy Solutions' own design of safety and control system called $\text{SaCoS}_{\text{one}}$. *See “B 19 00 0 Safety, control and monitoring system” and “B 19 00 0 Communication from the GenSet”.*

Turbocharger system

The turbocharger system of the engine, which is a constant pressure system, consists of an exhaust gas receiver, a turbocharger, a charge air cooler and a charge air receiver.

The turbine wheel of the turbocharger is driven by the engine exhaust gas, and the turbine wheel drives the turbocharger compressor, which is mounted on the common shaft. The compressor draws air from the engine room through the air filters.

The turbocharger forces the air through the charge air cooler to the charge air receiver. From the charge air receiver the air flows to each cylinder through the inlet valves.

The charge air cooler is a compact two-stage tubetype cooler with a large cooling surface. The high temperature water is passed through the first stage of the charging air cooler and the low temperature water is passed through the second stage. At each stage of the cooler the water is passed two times through the cooler, the end covers being designed with partitions which cause the cooling water to turn.

From the exhaust valves, the exhaust gas is led through to the exhaust gas receiver where the pulsatory pressure from the individual cylinders is equalized and passed on to the turbocharger as a constant pressure, and further to the exhaust outlet and silencer arrangement.

The exhaust gas receiver is made of pipe sections, one for each cylinder, connected to each other by means of compensators to prevent excessive stress in the pipes due to heat expansion.

To avoid excessive thermal loss and to ensure a reasonably low surface temperature the exhaust gas receiver is insulated.

Compressed air system

The engine is started by means of a built-on air driven starter.

The compressed air system comprises a dirt strainer, main starting valve and a pilot valve which also acts as an emergency valve, making it possible to start the engine in case of a power failure.

Fuel oil system

The built-on fuel oil system consists of inlet pipes for fuel oil, mechanical fuel pump units, high-pressure pipes as well as return pipes for fuel oil.

Fuel oil leakages are led to a leakage alarm which is heated by means of the inlet fuel oil.

Lubricating oil system

All moving parts of the engine are lubricated with oil circulating under pressure.

The lubricating oil pump is of the helical gear type. A pressure control valve is built into the system. The pressure control valve reduces the pressure before the filter with a signal taken after the filter to ensure constant oil pressure with dirty filters.

The pump draws the oil from the sump in the base frame, and on the pressure side the oil passes through the lubricating oil cooler and the full-flow depth filter with a nominel fineness of 15 microns. Both the oil pump, oil cooler and the oil filter are placed in the front end box. The system can also be equipped with a centrifugal filter.

Cooling is carried out by the low temperature cooling water system and temperature regulation effected by a thermostatic 3-way valve on the oil side.

The engine is as standard equipped with an electrically driven prelubricating pump.

Cooling water system

The cooling water system consists of a low temperature system and a high temperature system.

Both the low and the high temperature systems are cooled by treated fresh water.

Only a one string cooling water system to the engine is required.

The water in the low temperature system passes through the low temperature circulating pump which drives the water through the second stage of the charge air cooler and then through the lubricating oil cooler before it leaves the engine together with the high temperature water.

The high temperature cooling water system passes through the high temperature circulating pump and then through the first stage of the charge air cooler before it enters the cooling water jacket and the cylinder head. Then the water leaves the engine with the low temperature water.

Both the low and high temperature water leaves the engine through separate three-way thermostatic valves which control the water temperature.

The low temperature system (LT) is bleeded to high temperature system (HT) and the HT system is automatically bleeded to expansion tank.

It should be noted that there is no water in the engine frame.

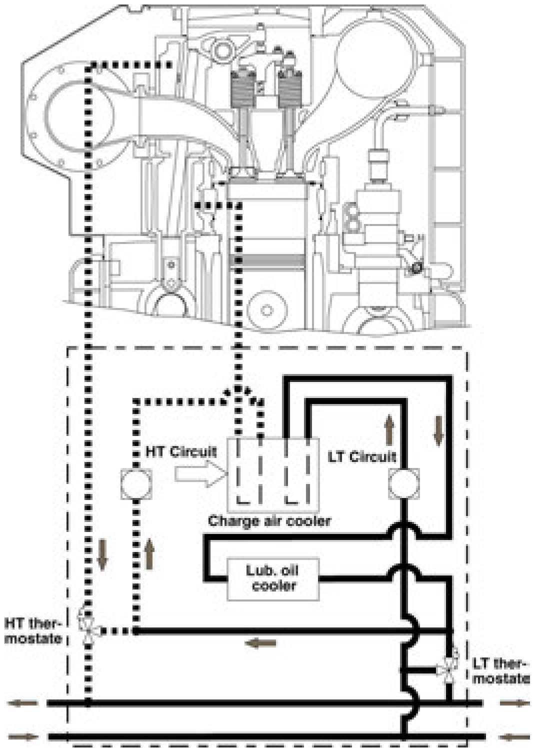


Figure 8: Internal cooling water system.

Tools

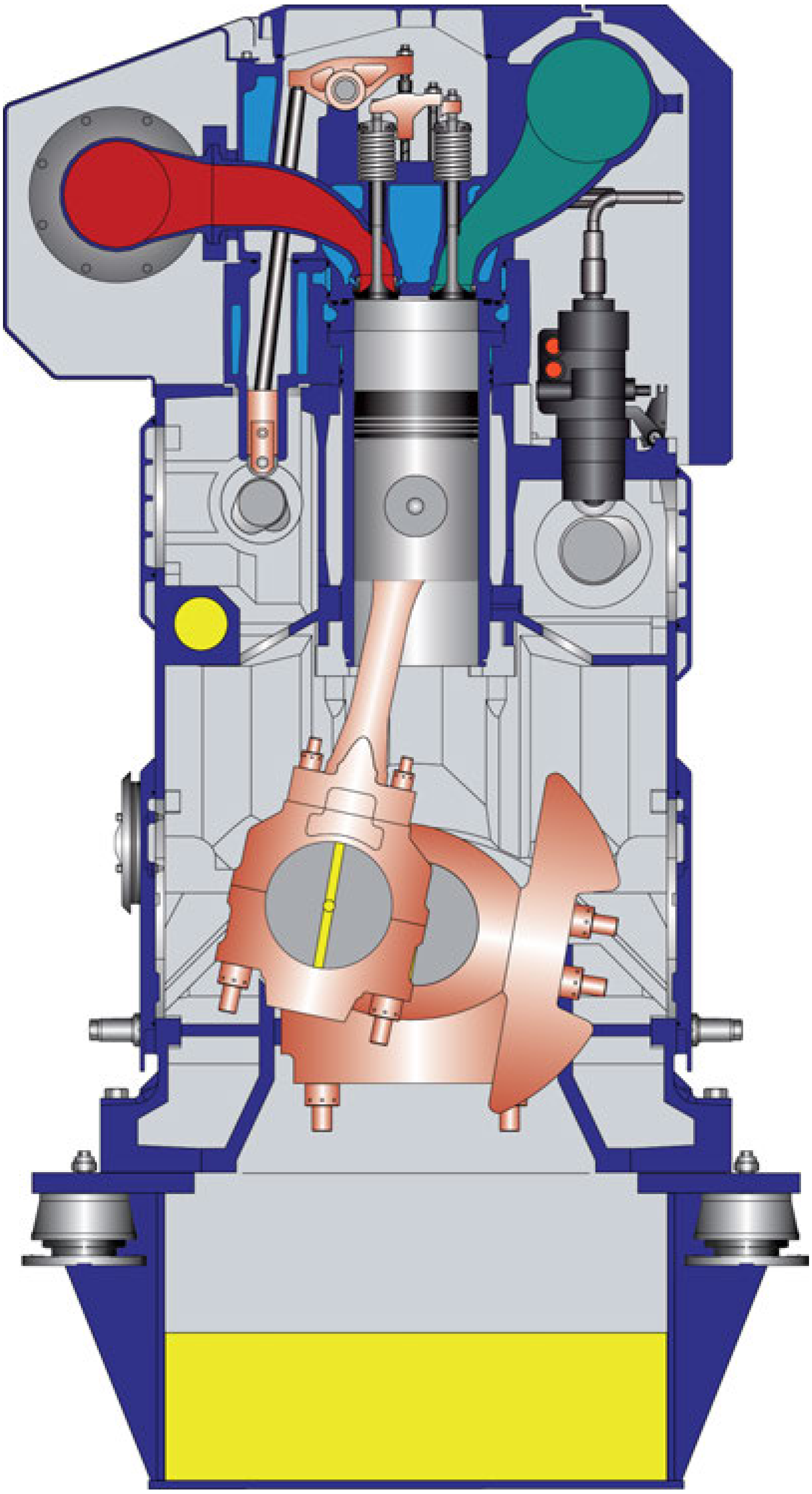
The engine can be delivered with all necessary tools for the overhaul of each specific plant. Most of the tools can be arranged on steel plate panels.

Turning

The engine is equipped with a manual turning device.

Cross section

Cross section



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Power, outputs, speed

Engine ratings

Engine type No of cylinders	900 rpm		1000 rpm	
	900 rpm	Available turning direction	1000 rpm	Available turning direction
	kW	CW [1]	kW	CW [1]
5L21/31	1000	Yes	1000	Yes
6L21/31	1320	Yes	1320	Yes
7L21/31	1540	Yes	1540	Yes
8L21/31	1760	Yes	1760	Yes
9L21/31	1980	Yes	1980	Yes

[1] CW clockwise

Table 1: Engine ratings for emission standard

Definition of engine ratings

General definition of diesel engine rating (acccording to ISO 15550: 2002; ISO 3046-1: 2002)

Reference conditions: ISO 3046-1: 2002; ISO 15550: 2002		
Air temperature T_r	K/°C	298/25
Air pressure p_r	kPa	100
Relative humidity Φr	%	30
Cooling water temperature upstream charge air cooler T_{cr}	K/°C	298/25

Table 2: Standard reference conditions.

Available outputs

	$P_{Application}$ Available output in percentage from ISO-Standard-Output	Fuel stop power (Blocking)	Max. allowed speed reduction at maximum torque [1]	Tropic conditions $t_r/t_{cr}/p_r$=100 kPa	Remarks
Kind of application	**(%)**	**(%)**	**(%)**	**(°C)**	
Electricity generation					
Auxiliary engines in ships	100	110	–	45/38	[2]
Marine main engines (with mechanical or diesel electric drive)					
Main drive generator	100	110	–	45/38	[2]

[1] Maximum torque given by available output and nominal speed.
[2] According to DIN ISO 8528-1 overload > 100% is permissible only for a short time to compensate frequency deviations. This additional engine output must not be used for the supply of electric consumers.

t_r – Air temperature at compressor inlet of turbocharger.
t_{cr} – Cooling water temperature before charge air cooler
p_r – Barometric pressure.

Table 3: Available outputs / related reference conditions.

$P_{Operating}$: Available output under local conditions and dependent on application.

Dependent on local conditions or special application demands, a further load reduction of $P_{Application, ISO}$ might be needed.

De-rating

1) No de-rating due to ambient conditions is needed as long as following conditions are not exceeded:

	No de-rating up to stated reference conditions (Tropic)	Special calculation needed if following values are exceeded
Air temperature before turbocharger T_x	≤ 318 K (45 °C)	333 K (60 °C)
Ambient pressure	≥ 100 kPa (1 bar)	90 kPa
Cooling water temperature inlet charge air cooler (LT-stage)	≤ 311 K (38 °C)	316 K (43 °C)
Intake pressure before compressor	≥ -20 mbar [1]	-40 mbar [1]
Exhaust gas back pressure after turbocharger	≤ 30 mbar [1]	60 mbar [1]

[1] Overpressure

Table 4: De-rating – Limits of ambient conditions.

2) De-rating due to ambient conditions and negative intake pressure before compressor or exhaust gas back pressure after turbocharger.

$$a = \left[\left(\frac{318}{T_x + U + O}\right)^{1.2} \times \left(\frac{311}{T_{cx}}\right) \times 1.09 - 0.09\right]$$

with $a \leq 1$

$P_{Operating} = P_{Application,\ ISO} \times a$

a	Correction factor for ambient conditions
T_x	Air temperature before turbocharger [K] being considered (T_x = 273 + t_x)
U	Increased negative intake pressure before compressor leeds to a de-rating, calculated as increased air temperature before turbocharger
U =	(-20mbar – $p_{Air\ before\ compressor}$ [mbar]) x 0.25K/mbar with U ≥ 0
O	Increased exhaust gas back pressure after turbocharger leads to a de-rating, calculated as increased air temperature before turbocharger:
O =	($P_{Exhaust\ after\ turbine}$ [mbar] – 30mbar) x 0.25K/mbar with O ≥ 0
T_{cx}	Cooling water temperature inlet charge air cooler (LT-stage) [K] being considered (T_{cx} = 273 + t_{cx})
T	Temperature in Kelvin [K]
t	Temperature in degree Celsius [°C]

3) De-rating due to special conditions or demands. Please contact MAN Energy Solutions, if:

- limits of ambient conditions mentioned in "*Table 4 De-rating – Limits of ambient conditions*" are exceeded
- higher requirements for the emission level exist
- special requirements of the plant for heat recovery exist
- special requirements on media temperatures of the engine exist
- any requirements of MAN Energy Solutions mentioned in the Project Guide can not be kept

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Main particulars

Main Particulars

Cycle	:	4-stroke
Configuration	:	In-line
Cyl. nos available	:	5 - 6 - 7 - 8 - 9
Power range	:	1000 - 1980 kW
Speed	:	900 / 1000 rpm
Bore	:	210 mm
Stroke	:	310 mm
Stroke/bore ratio	:	1.48 : 1
Piston area per cyl.	:	346 cm^2
swept volume per cyl.	:	10.7 ltr
Compression ratio	:	16.5 : 1
Max. combustion pressure	:	210 bar (in combustion chamber)
Turbocharging principle	:	Constant pressure system and intercooling
Fuel quality acceptance	:	HFO (up to 700 cSt/50º C, RMK700) MDO (DMB) - MGO (DMA, DMZ) according ISO8217-2010

Power lay-out		**MCR version**	
Speed	rpm	900	1000
Mean piston speed	m/sec.	9.3	10.3
Mean effective pressure			
5 cyl. engine	bar	24.9	22.4
6, 7, 8, 9 cyl. engine	bar	27.3	24.6
Power per cylinder			
5 cyl. engine	kW per cyl.	200	200
6, 7, 8, 9 cyl. engine	kW per cyl.	220	220

Firing order

5 cyl. engine	1	2	4	5	3				
6 cyl. engine	1	2	4	6	5	3			
7 cyl. engine	1	2	4	6	7	5	3		
8 cyl. engine	1	2	4	6	8	7	5	3	
9 cyl. engine	1	2	4	6	8	9	7	5	3

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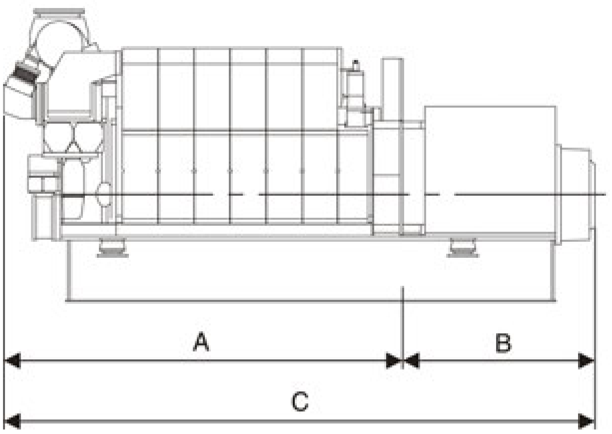
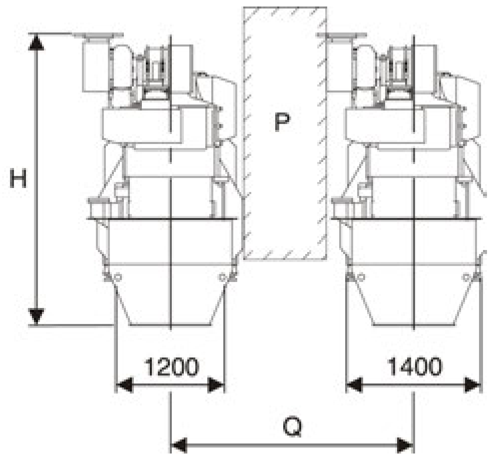
Dimensions and weights

General





1 bearing

Cyl. no	A (mm)	* B (mm)	* C (mm)	H (mm)	** Dry WEight GenSet (t)
5 (900 rpm)	3959	1820	5779	3183	22.5
5 (1000 rpm)	3959	1870	5829	3183	22.5
6 (900 rpm)	4314	1870	6184	3183	26.0
6 (1000 rpm)	4314	2000	6314	3183	26.0
7 (900/1000 rpm)	4669	1970	6639	3289	29.5

2 bearings

Cyl. no	A (mm)	* B (mm)	* C (mm)	H (mm)	** Dry weight GenSet (t)
5 (900/1000 rpm)	4507	2100	6607	3183	22.5
6 (900/1000 rpm)	4862	2100	6962	3183	26.0
7 (900/1000 rpm)	5217	2110	7327	3289	29.5
8 (900/1000 rpm)	5572	2110	7682	3289	33.0
9 (900/1000 rpm)	5927	2135	8062	3289	36.5

P Free passage between the engines, width 600 mm and height 2000 mm.
Q Min. distance between engines: 2400 mm (without gallery) and 2600 mm (with gallery)

* Depending on alternator
** Weight included a standard alternator

All dimensions and masses are approximate, and subject to changes without prior notice.

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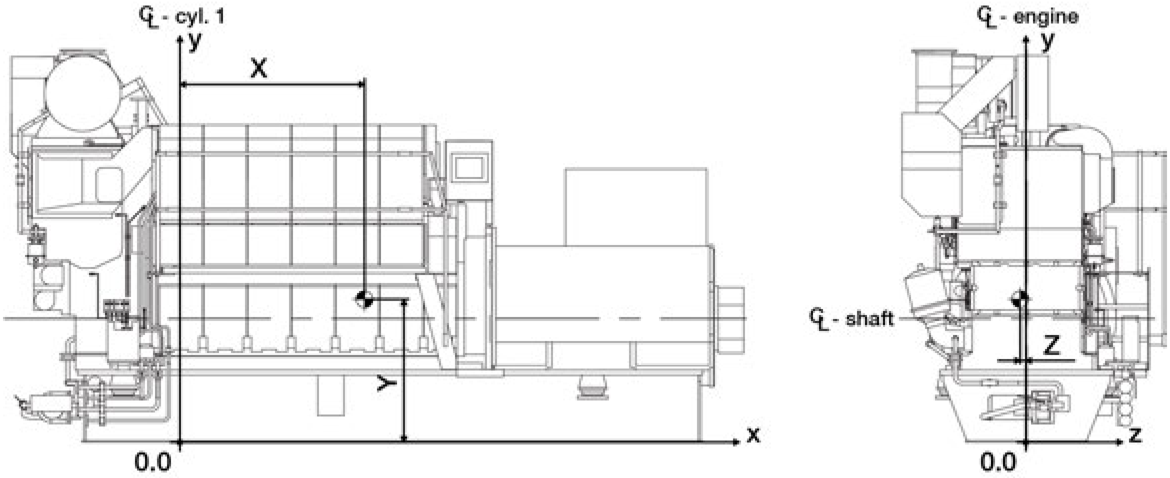
Centre of gravity

Description



	X - mm	Y - mm	Z - mm
5 cyl. engine	1205	1235	0
6 cyl. engine	1470	1235	0
7 cyl. engine	1730	1235	0
8 cyl. engine	1925	1235	0
9 cyl. engine	2315	1235	0

The values are expected values based on alternator, make Uljanik. If another alternator is chosen, the values will change.

Actual values are stated on General Arrangement.

Centre of gravity is stated for dry GenSet.

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Overhaul areas

Dismantling height

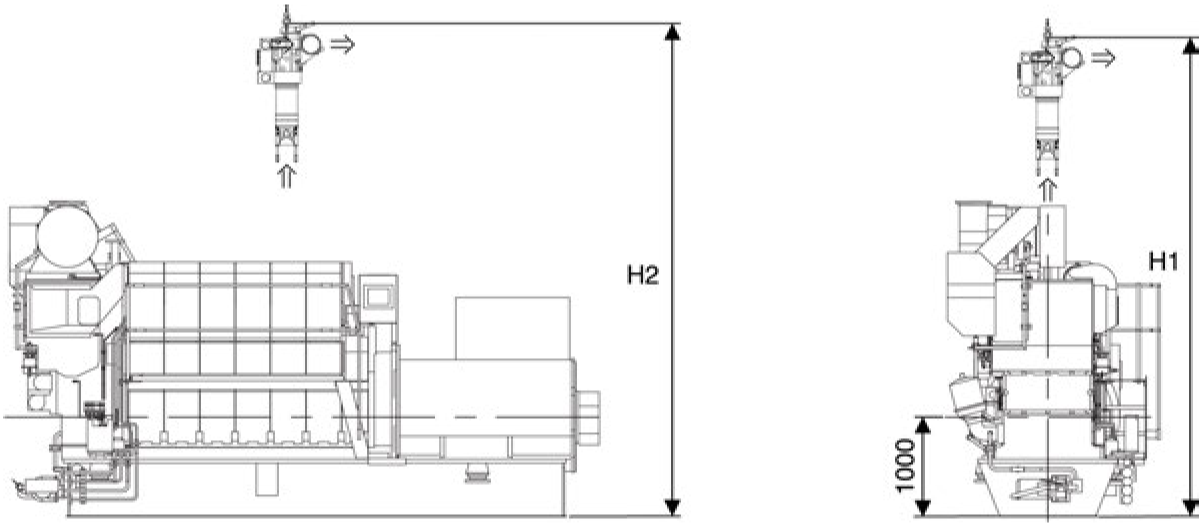


Figure 1: Dismantling height.

Engine type	H1 (mm)	H2 (mm)
Cylinder unit, complete	3705	3950
Cylinder unit, complete - tie rod removed	3493	3950
Unit dismantled - low dismantling height :		
Cylinder liner, water jacket, connecting rod and piston	3100	3275
Cylinder liner, water jacket, connecting rod and piston - tie rod removed	2850 *	3275
* Have to be tilted		

H1 : For dismantling at the service side.

H2 : For dismantling passing the alternator. (Remaining cover not removed.)

Dismantling space

It must be taken into consideration that there is sufficient space for pulling the charge air cooler element, lubricating oil cooler, lubricating oil filter cartridge, lubricating pump and water pumps.

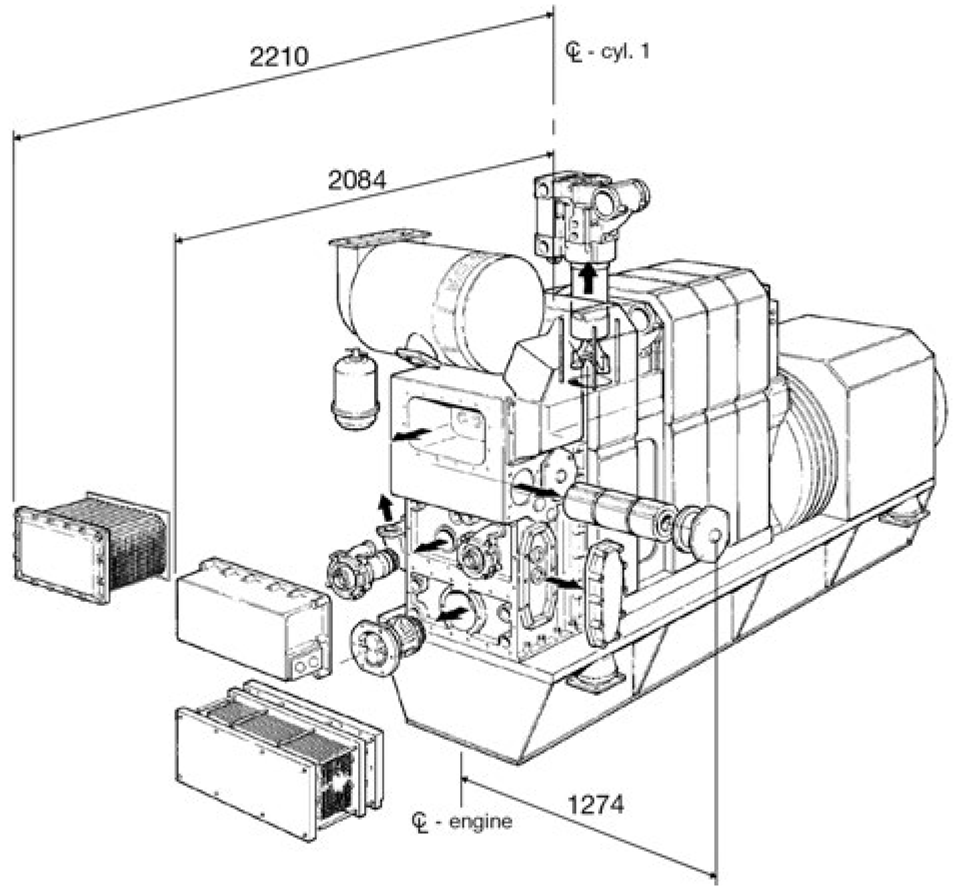


Figure 2: Overhaul areas for charge air cooler element, lub. oil cooler and lub. oil filter cartridge.

Power take-off (PTO)

Description

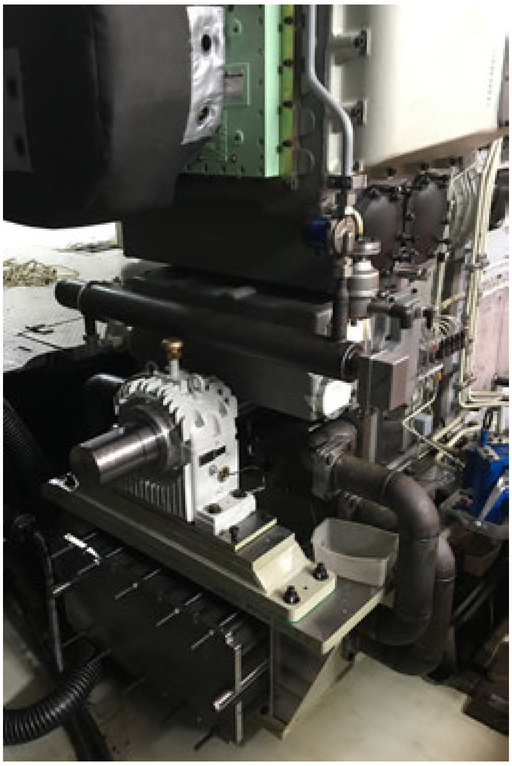
The engine can be supplied with a power take-off (PTO) in several positions, as an adapted extension to the crankshaft or alternator shaft.

The PTO is dimensioned to transmit the full engine power.

Between PTO and driven equipment there need to be selected a highly flexible coupling to transmit full engine power and to accommodate and absorb any vibrations which may be present radially and axially.

The PTO-arrangement for the driven equipment may only cause minimal axial force to the engine crankshaft. Any temperature expansion shall be avoided.

Crankshaft 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.



NOTICE

There need to be performed a full torsional vibration analysis for engine, PTO and driven equipment.

Please contact MAN Energy Solutions for support and assistance.

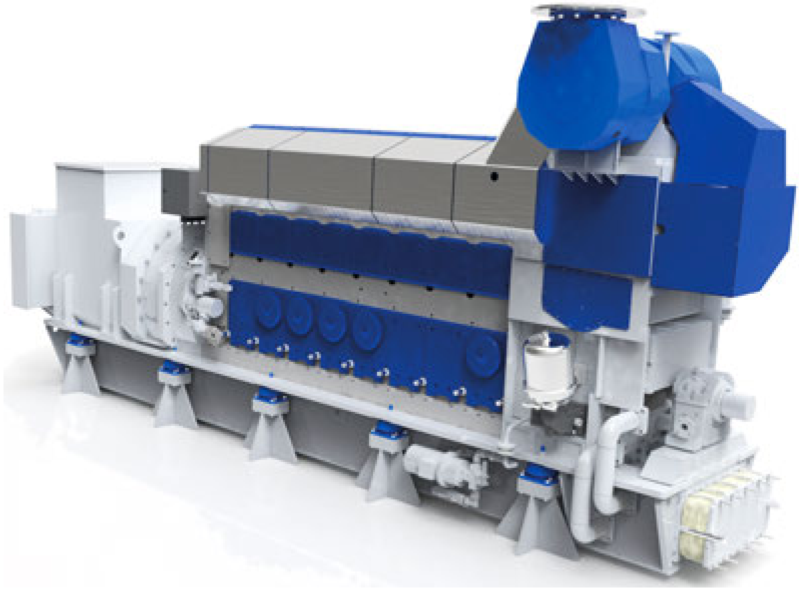


Figure 1: PTO on front end - external pump

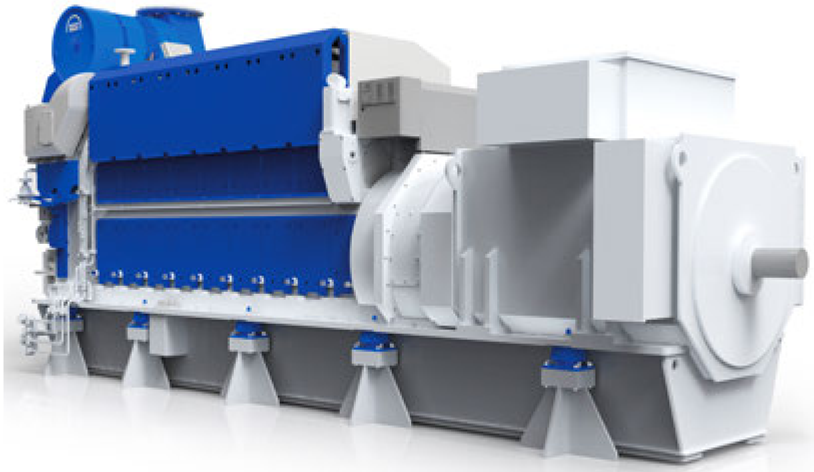


Figure 2: PTO on alternator - external pump

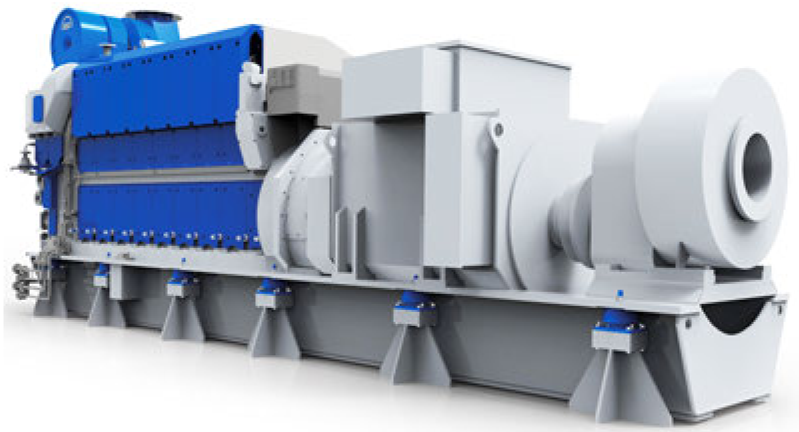


Figure 3: Pump on alternator - common base frame

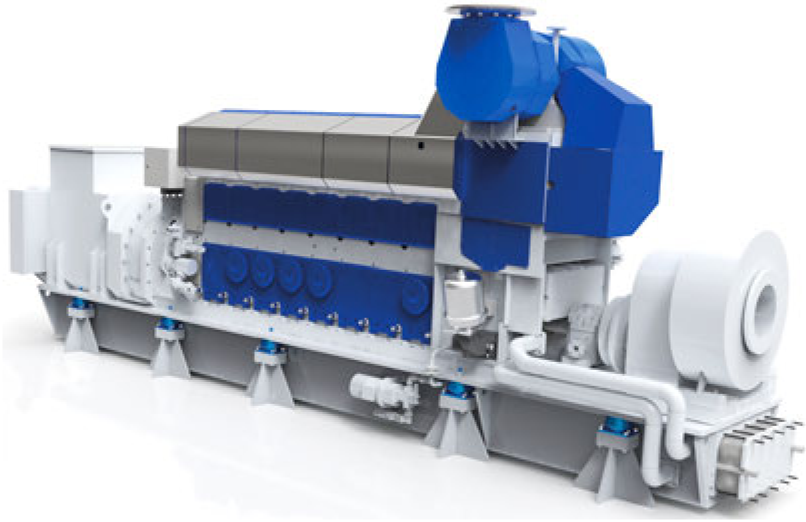


Figure 4: Pump on front end - common base frame

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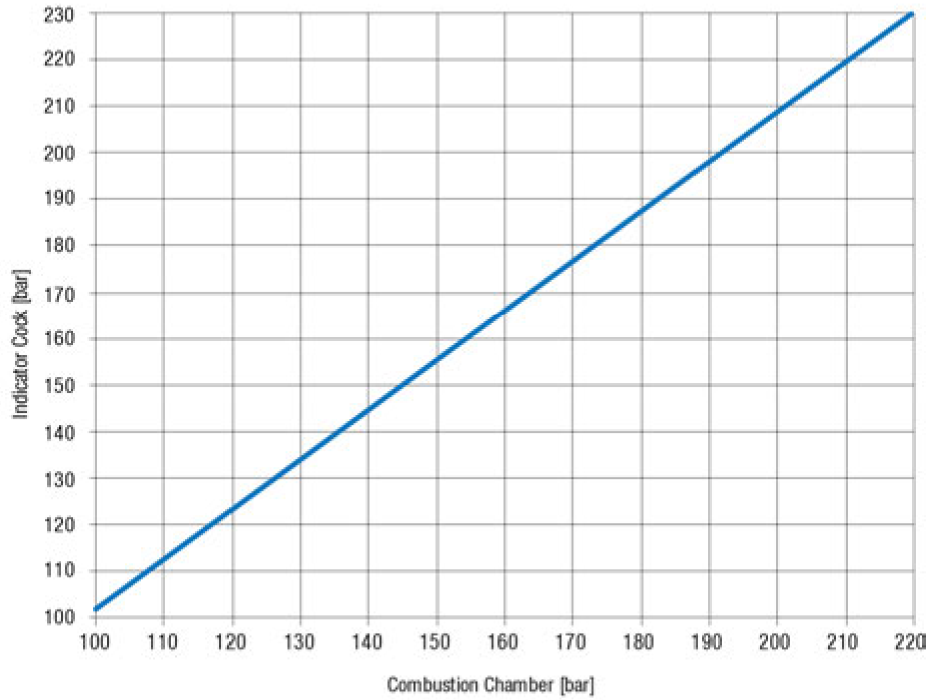
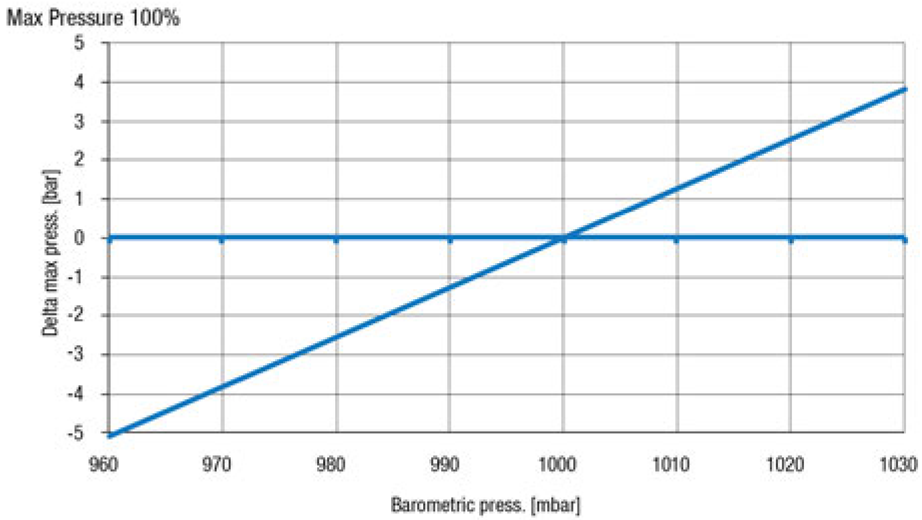
Firing pressure comparison

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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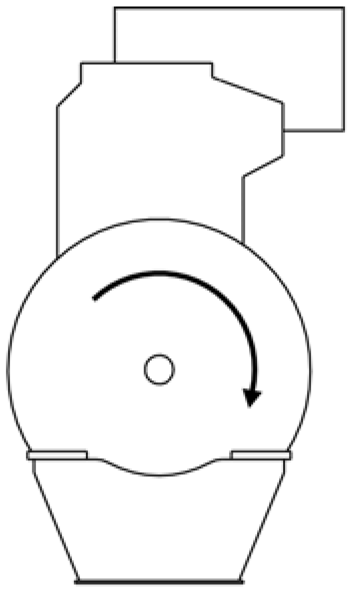
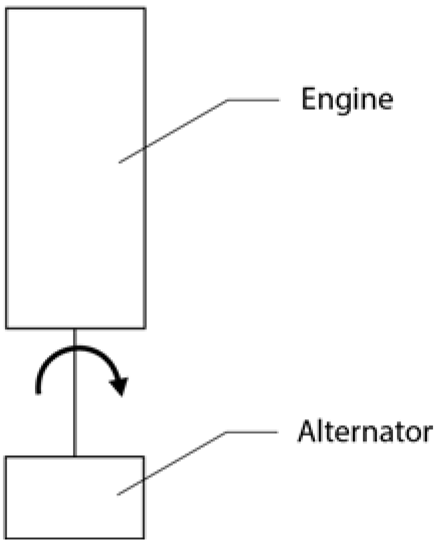
Engine rotation clockwise

Engine rotation clockwise



Direction of rotation seen from flywheel end "Clockwise"



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Internal fuel oil system

Diagram

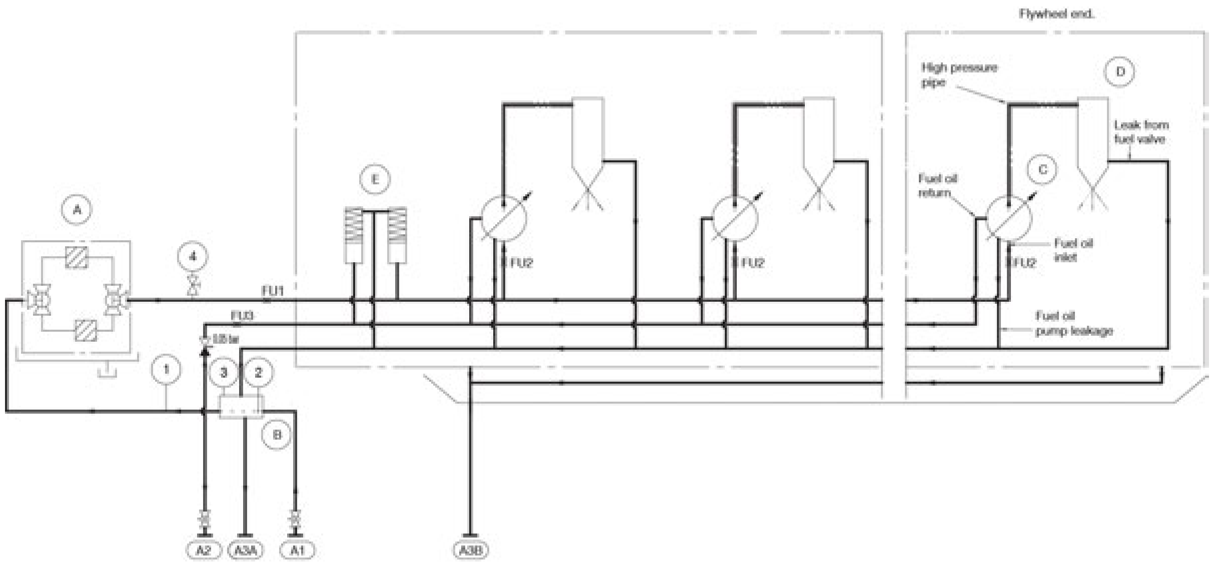

Figure 1: Diagram for fuel oil system (only for guidance, please see the plant specific engine diagram)

Connections			Description	
A1	Fuel oil inlet		A	Fuel oil safety filter duplex 10/25µ Nominel/Absolute
A2	Fuel oil outlet		B	Fuel leakage alarm
A3A	Clean leak oil outlet to service tank		C	Pump, single variable displacement
A3B	Waste oil outlet to drain tank		D	Injection valve
			E	Pulsation damper

Table 1: Flange connections are as standard according to DIN 2501

Tag no			
1	PT 43	1PT5068	Pressure transmitting inlet to duplex filter
2	TE 40	1TE5070	Temperature element inlet to engine
3	LAH 42	1LSAH5080	Level alarm high leakage
4	PT 40	1PT5070	Pressure transmitting inlet to engine

General

The internal built-on fuel oil system as shown in fig. 1 consists of the following parts:

- the running-in filter
- the high-pressure injection equipment
- the waste oil system

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Running-in filter

The running-in filter has a fineness of 50 microns (sphere passing mesh) and is placed in the fuel inlet pipe. Its function is to remove impurities in the fuel pipe between safety filter and the engine in the running-in period.

Note: The filter must be removed before ship delivery or before handling over to the customer.

It is adviced to install the filter every time the extern fuel pipe system has been dismantled, but it is important to remove the filter again when the extern fuel oil system is considered to be clean for any impurities.

Fuel oil filter duplex (Safety filter)

GenSets with conventional fuel injection system or common rail fuel systems are equipped with a fuel oil filter duplex, with a fineness of max. 25 microns (sphere passing mesh) The fuel oil filter duplex 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. 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 injection equipment

Each cylinder unit has its own set of injection equipment comprising injection pump unit, high-pressure pipe and injection valve.

The injection equipment and the distribution supply pipes are housed in a fully enclosed compartment thus minimizing heat losses from the preheated fuel. This arrangement reduces external surface temperatures and the risk of fire caused by fuel leakage.

The injection pump units are with integrated roller guide directly above the camshaft.

The fuel quantity injected into each cylinder unit is adjusted by means of the governor, which maintains the engine speed at the preset value by a continuous positioning of the fuel pump racks, via a common regulating shaft and spring-loaded linkages for each pump.

The injection valve is for "deep" building-in to the centre of the cylinder head.

The injection oil is supplied from the injection pump to the injection valve via a double-walled pressure pipe installed in a bore in the cylinder head.

This bore has an external connection to lead the leak oil from the injection valve and high-pressure pipe to the waste oil system, through the double walled pressure pipe.

A bore in the cylinder head vents the space below the bottom rubber sealing ring on the injection valve, thus preventing any pressure build-up due to gas leakage, but also unveiling any malfunction of the bottom rubber sealing ring due to leak oil.

Waste oil system

Clean leak oil from the fuel injection valves, fuel injection pumps and high-pressure pipes, is led to the fuel leakage alarm unit, from which it is drained into the clean leak fuel oil tank.

The leakage alarm unit consists of a box, with a float switch for level monitoring. In case of a leakage, larger than normal, the float switch will initiate an alarm. The supply fuel oil to the engine is led through the leakage alarm unit in order to keep this heated up, thereby ensuring free drainage passage even for high-viscous waste/leak oil.

Waste and leak oil from the hot box is drained into the sludge tank.

Clean leak fuel tank

Clean leak fuel is drained by gravity from the engine. The fuel should be collected in a separate clean leak fuel tank, from where it can be pumped to the service tank and reused without separation. The pipes from the engine to the clean leak fuel tank should be arranged continuously sloping. The tank and the pipes must be heated and insulated, unless the installation is designed for operation exclusively on MDO/MGO.

The leak fuel piping should be fully closed to prevent dirt from entering the system.

Sludge tank

In normal operation no fuel should leak out from the components of the fuel system. In connection with maintenance, or due to unforeseen leaks, fuel or water may spill in the hot box of the engine. The spilled liquids are collected and drained by gravity from the engine through the dirty fuel connection.

Waste and leak oil from the hot box is drained into the sludge tank.

The tank and the pipes must be heated and insulated, unless the installation is designed for operation exclusively on MDO/MGO.

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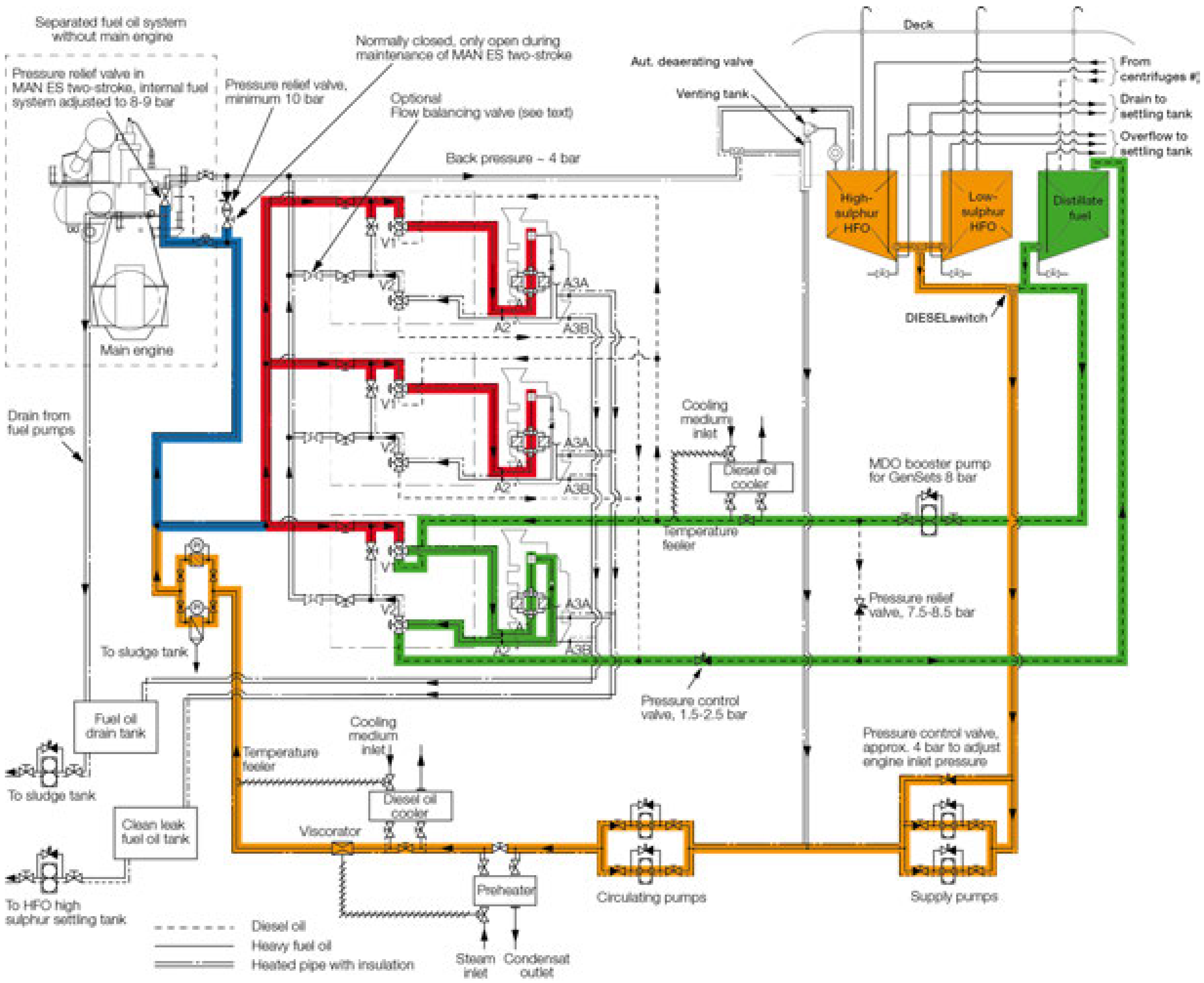
Fuel oil diagram

Fuel oil diagram with drain split



UNI-fuel

The fuel system is designed as a UNI-fuel system indicating that the MAN ES 2-stroke propulsion and the GenSets are running on the same fuel oil and are supplied from a common fuel system.

The UNI-fuel concept is a unique possibility for substantial savings in operating costs. It is also the simplest fuel system, resulting in lower maintenance and easier operation. The diagram is only for guidance. It has to be adapted in each case to the actual engine and pipe layout.

Tank design

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

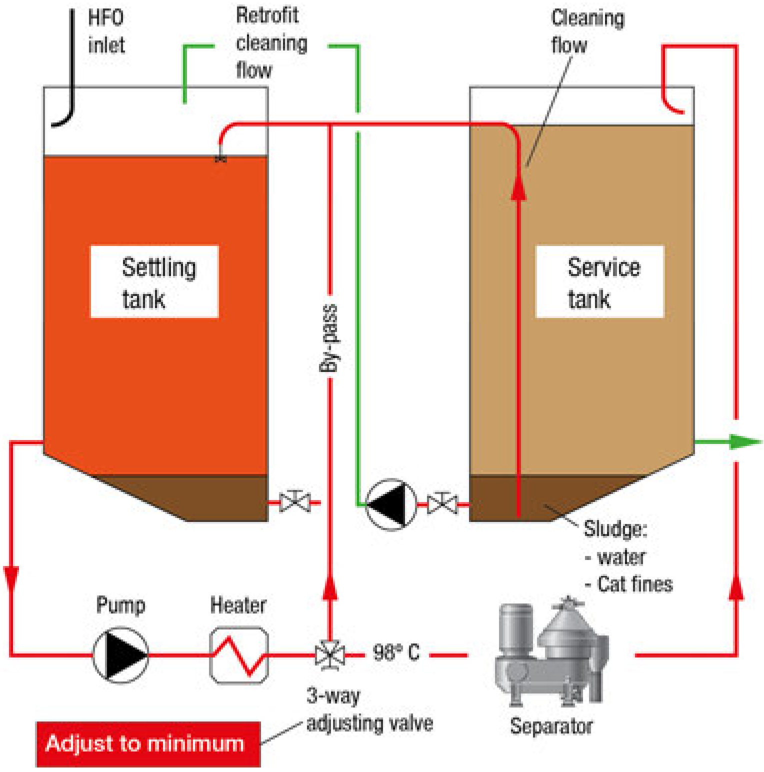
In all fluids a natural settling of particles, takes place. This results in a higher concentration of particles in the bottom of the tanks. Due to this phenomenon it is important that the various fuel tanks are designed and operated correctly.

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.



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 GenSets 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 internally in the MAN ES 2-stroke propulsion fuel oil system.

Fuel circulation pressure has to be 8-9 bar at MAN ES 2-stroke propulsion fuel oil inlet. Back-pressure in the circulation-system is approximately 4 bar (from supply system).

Fuel oil pressure for GenSet 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.

External relieve valve needs to be adjusted minimum 10 bar to avoid interference with internal valve. External relief valve can also be closed during normal operation and only opened when dismantling fuel oil system on MAN ES 2-stroke propulsion.

For UNI-fuel system without MAN ES 2-stroke propulsion it can be needed to use external pressure relief valve for adjusting the surplus amount of fuel.

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* MAN Energy Solutions.

Adjustment of fuel oil system

Please see detailed guideline for adequate adjustment and control of circulating fuel system. See "Setting the heavy fuel oil supply system" 010.000.023-25

In short terms are here the four steps that have to be performed:

1. Flow and pressure head of supply and circulation pumps
2. Flow distribution between main engine and GenSets
3. Flow distribution between GenSets (recommendation)
4. Adjustment of distillate circuit

Ad 3) Recommendation regarding flow balancing valves. In a UNI-fuel system with MAN ES 2-stroke propulsion and with large fuel flow in the system will the internal mounted fuel oil restrictions in GenSet be sufficient for controlling fuel flow over the GenSet.

If fuel system is separated and/or in systems with smaller main engine the above mentioned guideline can reveal insufficient fuel flow over the GenSet or uneven distribution between GenSet. Then it can be necessary to remove internal restrictions and mount external flow balancing valves to insure correct fuel flow for all GenSets.

Fuel filtration and cleaning

Fuel oil bunkers should always be considered as contaminated upon delivery and should therefore be thoroughly cleaned to remove solids as well as liquid contaminants before use. The solid contaminants in the fuel oil are mainly rust, sand, dust and refinery catalysts (cat fines). Liquid contaminants are mainly water, i.e. either fresh water or salt water. Impurities in the fuel can cause damage to the engine.

To protect against impurities in the fuel the most efficient filter setup is experienced to be following:

- Fuel oil separator between settling and service tank.
- Common automatic back-flush filter installed in the circulation line.
- Fuel oil filter duplex (*safety filter*) on each GenSet.

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*).

GenSets 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.

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Former solution to protect both the propulsion engine and the GenSets with an automatic back-flush filter in the feeder circle is still valid.

NOTICE

A filter surface load of 1 l/cm² per hour must not be exceeded !

Operation on distillate

The distillate to the GenSets 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 GenSets can be changed independently of the fuel supply to the propulsion engine. As an option the GenSet 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 GenSet and a fuel changing valve control box common for all GenSets.

A separate fuel changing system for each GenSet gives the advantage of individually choosing distillate or HFO mode. Such a changeover may be necessary if the GenSets 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 GenSets 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 GenSet installation, it is recommended not to change between fuels, but to select some GenSet for HFO and some GenSet for distillate fuels. The change-over procedure will then be starting/stopping GenSet and not changing between fuels.

Distillate pump capacity need to be minimum for one GenSet (see desription D 10 05 0 "List of capacities"). If 2 or more GenSets 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 GenSets 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 GenSet.

Emergency start

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

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 GenSet. With no pumps available, it is possible to start up the GenSet if a gravity tank can be installed minimum 8 metres directly above the GenSet. However, only if the connection to the GenSet is as directly as possible, meaning change-over valve “V1-V2” should be placed as near as possible to the GenSet.

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.

Guidelines regarding MAN Energy Solutions GenSets operating on low sulphur fuel oil

General

Exhaust emissions from marine diesel engines have been the focus of recent legislation. Apart from nitrous oxides (NOx), sulphur oxides (SOx) are considered to be the most important pollution factor. A range of new regulations have been implemented and others will follow (IMO, EU Directive, and CARB). These regulations demand reduction of SOx emissions by restricting the sulphur content of the fuel. That is to say sulphur limits for HFO as well as mandatory use of low sulphur distillate fuels for particular applications. This guideline covers the engine related aspects of the use of such fuels.

Low sulphur HFO

From an engine manufacturer's point of view there is no lower limit for the sulphur content of HFO. We have not experienced any trouble with the currently available low sulphur HFO, that are related to the sulphur content or specific to low sulphur HFO. This may change in the future if new methods are applied for the production of low sulphur HFO (desulphurization, uncommon blending components). MAN Energy Solutions will monitor developments and inform our customers if necessary.

If the engine is not operated permanently on low sulphur HFO, then the lubricating oil should be selected according to the highest sulphur content of the fuels in operation.

Low sulphur distillates

In general our GenSet is developed for continuous operation on HFO as well as on MDO/MGO. Occasionally changes in operation mode between HFO and MDO/MGO are considered to be within normal operation procedures for our engine types and do thus not require special precautions.

Running on low sulphur fuel (< 0.1% S) will not cause problems, but please notice the following restrictions:

In order to avoid seizure of the fuel oil injection pump components the viscosity at engine fuel oil inlet must be > 2 cSt. In order achieve this it may be necessary to install a fuel oil cooler, when the engine is running on MGO. This is both to ensure correct viscosity and avoid heating up the service tank, which is important as the fuel oil injection pumps are cooled by the fuel.

When operating on MDO/MGO a larger leak oil amount from fuel oil injection pumps and fuel oil injection valves can be expected compared to operation on HFO.

In order to carry out a quick change between HFO and MDO/MGO the change over should be carried out by means of the valve V1-V2 installed in front of the engine.

For the selection of the lubricating oil the same applies as for HFO. For temporary operation on distillate fuels including low sulphur distillates nothing has to be considered. A lubricating oil suitable for operation on diesel fuel should only be selected if a distillate fuel is used continuously.

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Fuel injection valve

Fuel injection valve

The fuel valve is uncooled and placed in a sleeve in the centre of the cylinder head.

O-rings around the fuel valve body prevent fuel and lubricating oil from mixing. From the side of the cylinder head, a lance for fuel supply is screwed into the fuel valve (L16/24 is mounted by means of 3 leaf springs). The lance is sealed with a bushing and two o-rings where the lance goes into the cylinder head. A double-walled high pressure pipe connects the fuel pump with the lance.

Leak oil from the fuel valve or from a possible defective high pressure pipe is led to the bore for the lance in the cylinder head. From here a pipe will drain the fuel to the leakage alarm and further to the leak oil connection. From here the HFO can be led to leak oil tank and MDO/MGO to the day tank.

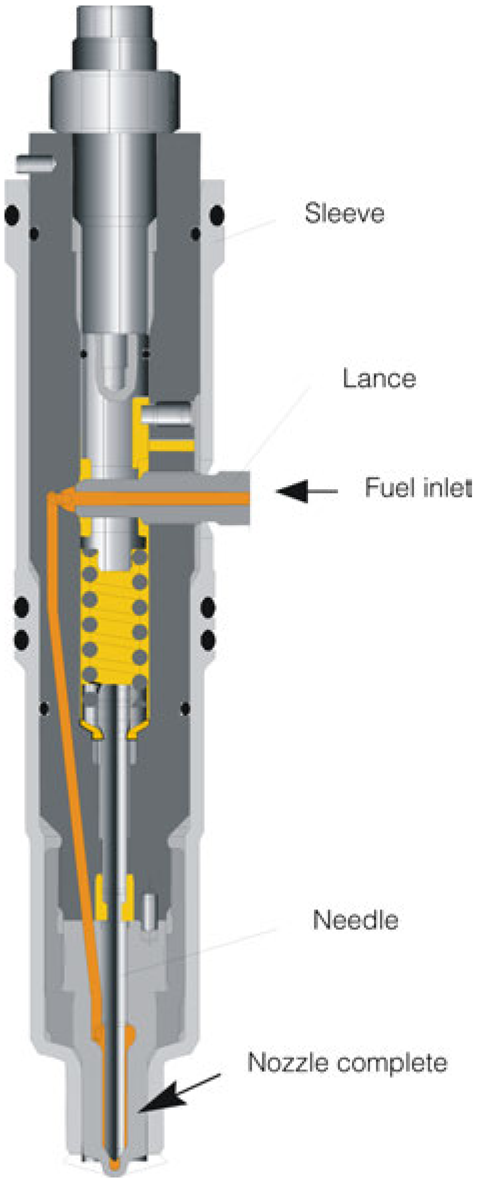

Figure 1: Fuel injection valve.

Part-load optimisation - PLO

Description

MAN Energy Solutions is continuously adapting our engine programme to the changing market conditions.

At the request of various shipowners, we have developed and introduced a new IMO Tier II/III compliant tuning method for GenSets which mostly operate below the normal 75% MCR.

Tuning method – part load optimisation

The new tuning method is referred to as part load optimisation (PLO), and it is recommended for GenSets which mostly run below 75% MCR.

Traditionally, GenSets are fuel oil optimised at 85% MCR, but with PLO tuning, the engine performance is optimised at approx. 60-65% MCR, which ensures optimisation in the low-and part-load areas.

The most obvious benefit of applying PLO is the fuel oil saving of, typically, up to 5 g/kWh, depending on engine type/model and load point.

Furthermore, thanks to the improved combustion process resulting from the optimised nozzle ring in the turbocharger, valuable engine components, such as pistons, fuel equipment, valves and T/C nozzle ring, will be operating under optimal conditions at the given load.

The GenSets are fully compliant with IMO Tier II, even though the fuel oil consumption is reduced in the low and part load area, as a fuel oil penalty is imposed in the high load range.

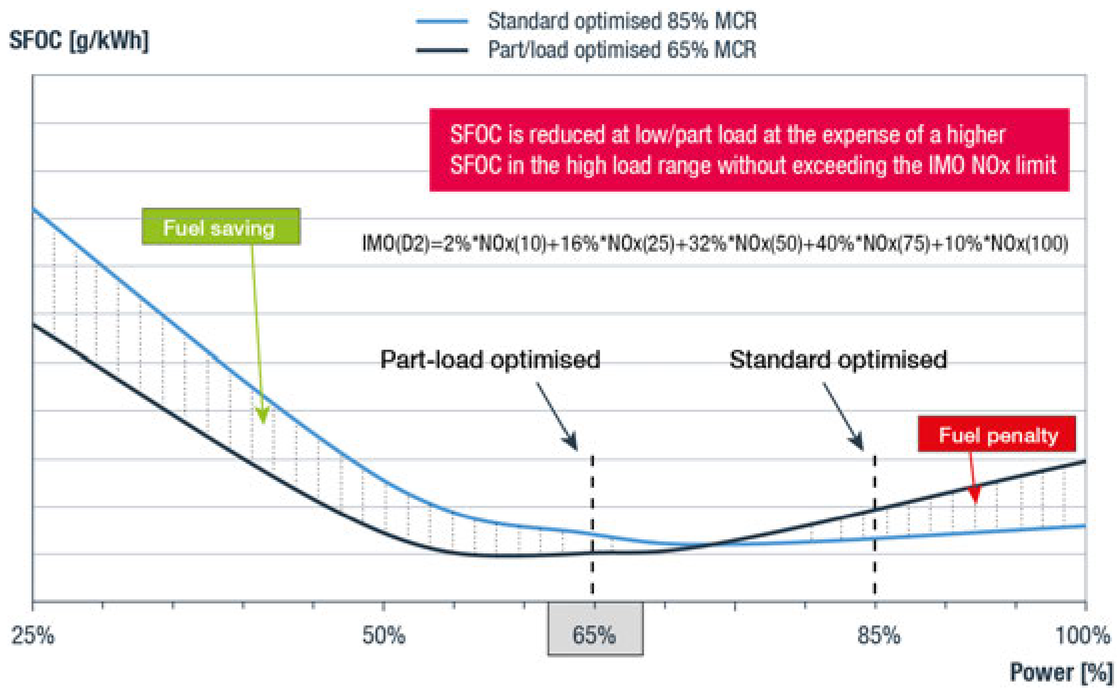

Figure 1: SFOC-curves from first delivery of PLO

However, a fuel oil penalty will rarely occur, since it is unusual that GenSets operate beyond 75% load, because the power management system will engage an additional GenSet when more power is needed.

PLO will give the same relative advantage when applied in combination with SCR-systems for IMO Tier III compliance.

Design changes:

- New turbocharger arrangement for optimised part-load operation
- Blow-off arrangement on charge air receiver to prevent “over-boosting” of engine at MCR operation
- New valve cam for optimised valve overlap for SFOC optimisation
- Change of timing for delayed injection optimisation of SFOC vs. NOx emissions

Fuel application

General

In general our GenSets and Propulsion engines are developed for continuous operation at maximum rating on MDO/MGO and HFO.

In case of low load operation it is recommended to switch the engine to MDO/MGO; as there are no load limitations for operation on MDO/MGO.

The applied fuel must comply with the quality requirements specified in the current edition of ISO 8217.

Marine fuels, which fully meet requirements and purchase specifications of ISO 8217:2017, will still require treatment before they meet the requirements for the engine.

Biofuels / non-standardized fuels

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

Before application of biofuels / non-standard fuels please contact MAN Energy Solutions in order to obtain guidelines for operation with the actual fuel.

Engine operation

Occasional changes in operation mode between the fuel types complying with ISO 8217 are considered to be within normal operation procedures for our engine types, and do thus not require special precautions.

Low viscosity fuels

In order to avoid seizure of the fuel oil injection pump components the viscosity at engine fuel oil inlet must be > 2 cSt. In order achieve this it may be necessary to install a fuel oil cooler, when the engine is running on MGO. This is to ensure correct viscosity and to avoid heating of the service tank, which is important as the fuel oil injection pumps are cooled by the fuel.

When operating on MDO/MGO, a larger leak oil amount must be expected from the fuel oil injection pumps and fuel oil injection valves compared to operation on HFO.

Selection of the lubricating oil is similar to HFO. For temporary operation on distillate fuels including low Sulphur distillates, nothing has to be considered. A lubricating oil suitable for operation on diesel fuel is only to be selected if a distillate fuel is used continuously.

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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.

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

Liquid biofuels used in MAN 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.

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).

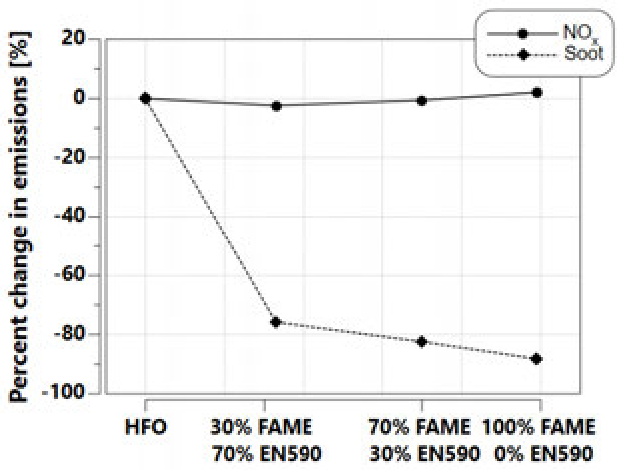

Figure 1: Emission behavior with FAME.

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.

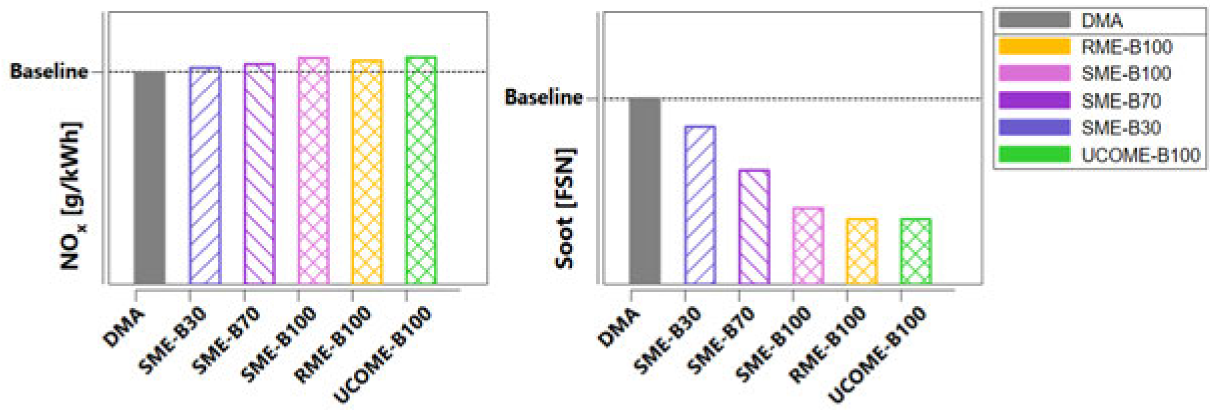

Figure 2: NOx and soot emission trends

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.

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 MAN Energy Solutions 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.

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 MAN ES 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). MAN ES 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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Crude oil specification

Crude oil

Crude oil is a naturally occurring flammable liquid consisting of a complex mixture of hydrocarbons of various molecular weights and other liquid organic compounds, that are found in geologic formations beneath the Earth's surface.

The flash point of crude oil is low, typically below ambient temperature.

Our four-stroke medium-speed engines are well proven in operation on crude oil taken directly from oil wells and conditioned on site.

Exploiting crude oil to feed the large consumers involved in oil and gas exploration and production is both an economical solution and saves the considerable CO_2 emissions involved in the refining of distillate fuels and their transport via pumping stations from and to the oil field.

Properties/Characteristics	Unit	Limit	Test method
Viscosity, before injection pumps, min.	cSt	3	
Viscosity, before injection pumps, max.	cSt	18	
Viscosity @ 50°C, max.	cSt	700	ISO 3104
Density @ 15°C, max.	kg/m^3	1010.0	ISO 3675 or ISO 12185
CCAI, max.	–	870	ISO 8217
Water before engine, max.	% volume	0.2	ISO 3733
Sulphur, max.	% mass	4.5	ISO 8754 or ISO 14596
Ash, max.	% mass	0.15	ISO 6245
Vanadium, max.	mg/kg	600	ISO 14597 or IP 501 or IP 470
Sodium + Potassium before engine, max.	mg/kg	1/3 Vanadium content	ISO 10478
Aluminium + Silicon before engine, max.	mg/kg	15	ISO 10478 or IP 501 or IP 470
Carbon residue, max.	% mass	20	ISO 10370
Asphaltenes, max.	% mass	2/3 of carbon residue (according to Conradson)	ASTM D3279
Reid vapour pressure (RVP), max.	kPa @ 37.8°C	65	ASTM D323
Lubricity (wear scar diameter)	µm	< 520	ISO 12156-1
Pour point, max.	°C	30	ISO 3016
Cold filter plugging point	°C	Minimum 10° C below the lowest temperature in the entire fuel system	IP 309
Total sediment potential, max.	% mass	0.10	ISO 10307-2
Hydrogen sulphide, max.	mg/kg	2	IP 570
AN (acid number), max.	mg KOH/g	2.5	ASTM D664

Table 1: Crude oil - specifications.

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Fuel oil consumption for emissions standard

L21/31 at 900 rpm

5L21/31: 200 kW/cyl., 6-9L21/31: 220 kW/cyl.

% Load	100	85	75	50	25
Spec. fuel consumption (g/kWh) without attached pumps [2) 3)]	192.1	188.9	188.8	192.5	206.2
Spec. fuel consumption (g/kWh) with attached pumps [2) 3)]	197.1	194.6	195.2	201.7	223.0

Table 1: Fuel oil consumption.

L21/31 at 900 rpm (Part Load Optimized)

5L21/31: 200 kW/cyl., 6-9L21/31: 220 kW/cyl.

% Load	100	85	75	50	25
Spec. fuel consumption (g/kWh) without attached pumps [2) 3)]	189.1	185.4	182.6	186.5	202.0
Spec. fuel consumption (g/kWh) with attached pumps [2) 3)]	192.7	189.5	187.1	193.0	214.0

Table 2: Fuel oil consumption.

L21/31 at 1000 rpm

5L21/31: 200 kW/cyl., 6-9L21/31: 220 kW/cyl.

% Load	100	85	75	50	25
Spec. fuel consumption (g/kWh) without attached pumps [2) 3)]	193.1	190.9	191.7	195.5	215.3
Spec. fuel consumption (g/kWh) with attached pumps [2) 3)]	198.1	196.6	198.2	204.8	232.9

Table 3: Fuel oil consumption.

L21/31 at variable speed (EPROX)

% Load		100	85	75	50	25
Speed	rpm	1000	1000	910	820	750
Spec. fuel consumption (g/kWh) with attached pumps[2) 3)]		199.9	197.6	196.7	198.2	214.9

Table 4: Fuel oil consumption.

All data provided in this document is non-binding and serves informational purposes only. 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.

Idle running

No of cylinders	Fuel oil consumption at idle running (kg/h)				
	5L	6L	7L	8L	9L
Speed 900/1000 rpm	24	28	32	36	40

Table 5: Fuel oil consumption at idle running.

[2] Tolerance +5%. Please note that the additions to fuel consumption must be considered before the tolerance is taken into account.
[3] Based on reference conditions, see "Reference conditions"
Running on HFO/MDO (DMB). Attached pumps include lubricating oil pump, LT- and HT cooling water pumps.

IMO Tier II requirements

IMO: International Maritime Organization MARPOL 73/78; Revised Annex VI-2008, Regulation 13.

Tier II: NOx technical code on control of emission of nitrogen oxides from diesel engines.

NOTICE

Operating pressure data without further specification are given below/above atmospheric pressure.

For calculation of fuel consumption, *see "B 11 01 0 Calculation of specific fuel oil consumption (SFOC)".*

For operation with MGO (DMA/DMX) fuel oil consumption will be increased by up to 2 g/kWh

For different net calorific value, the SFOC is to be corrected [in %] by:

Net calorific value NCV	rise	427 kJ/kg	- 1.0 %

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

$U = (-20\ [mbar] - p_{Air\ before\ compressor}\ [mbar]) \times 0.25\ [K/mbar]$ with $U \geq 0$

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

$O = (p_{Exhaust\ after\ turbine}\ [mbar] - 30\ [mbar]) \times 0.25\ [K/mbar]$ with $O \geq 0$

Charge air blow-off for exhaust gas temperature control (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.

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Fuel injection pump

Fuel injection pump

The fuel pump and the roller guide are one unit, placed over the fuel cam. A pipe supplies lubricating oil from the camshaft bearing to the roller guide.

The barrel is installed with seals on the outer circumference at various levels to avoid leakages and to give the possibility to drain fuel from the lower part of the barrel bore.

The injection amount of the pump is regulated by transversal displacement of a toothed rack in the side of the pump housing. By means of a gear ring, the pump plunger with the two helical millings, the cutting-off edges, is turned whereby the length of the pump stroke is reckoned from when the plunger closes the inlet holes until the cutting-off edges again uncover the holes.

A delivery valve is installed on top of the barrel. In the delivery valve housing a second valve is installed. This valve will open for oscillating high pressure waves between the needle in the fuel injection valve and the delivery valve on the pump, causing the needle in the fuel valve to stay closed after the injection is finished. This will reduce formation of carbon around the nozzle tip and save fuel.

The amount of fuel injected into each cylinder unit is adjusted by means of the governor, which maintains the engine speed at the preset value by a continuous positioning of the fuel pump racks, via a common regulating shaft and spring-loaded linkages for each pump.

The rack for fuel control is shaped as a piston at one end. The piston works inside a cylinder. When the cylinder is pressurized, the fuel rack will go to zero and the engine will stop.

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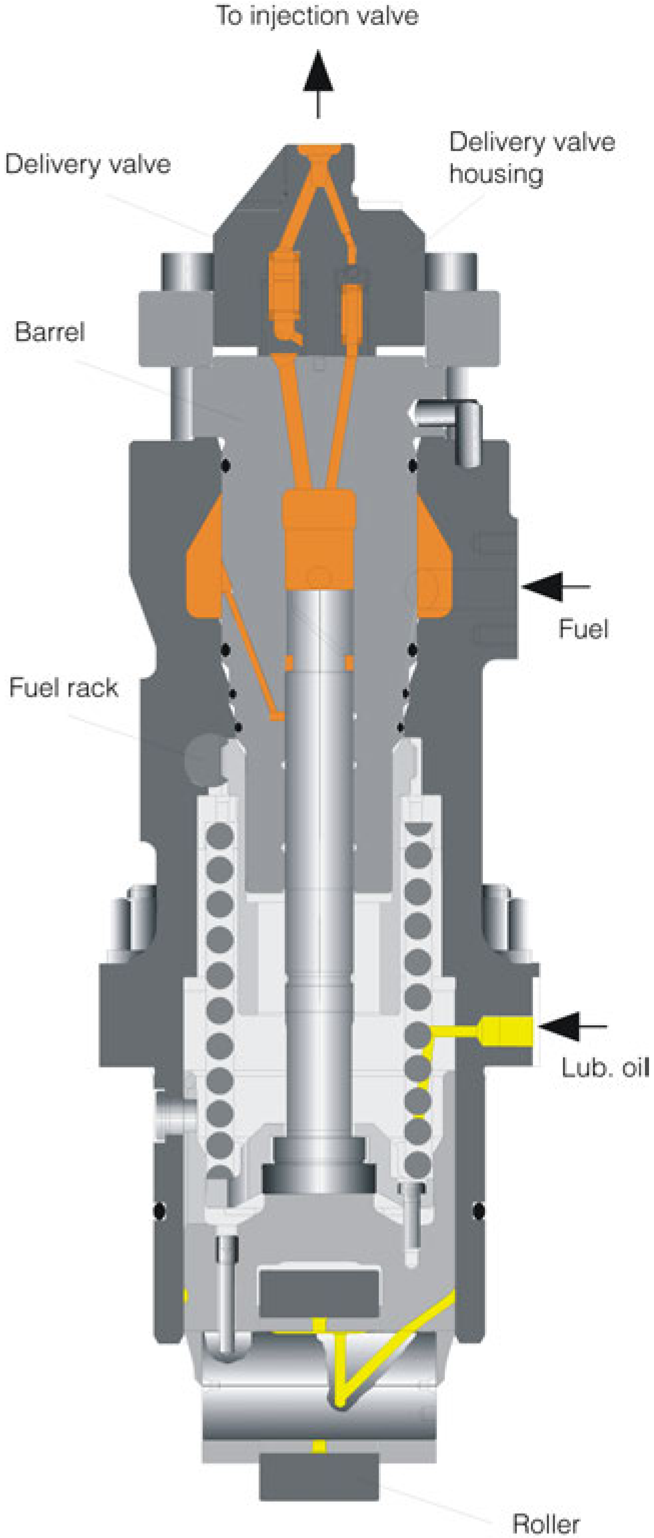

Figure 1: Fuel injection pump.

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 (MGO) and diesel oil. It must not contain any residue from crude oil refining. The fuel may consist of synthetic components (e.g. BtL, CtL, GtL, & HVO).

Selection of suitable diesel 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 is dependent on climatic conditions. All requirements specified in the current edition of ISO 8217 apply.

The following values must be maintained at the engine inlet:

Property	Unit		Threshold value[1]	Standard[2]
Kinematic viscosity at 40 °C[3]	mm^2/s	Max.	6.000	ISO 3104, ASTM D7042, ASTM D445, DIN EN 16896
		Min.	2.000	
Density at 15°C	kg/m^3	Max.	890.0	ISO 3675, ISO 12185
		Min.	820.0	
Cetane index & cetane number		Min.	40	ISO 4264 & ISO 5165
Sulphur content[4]	% (m/m)	Max.	1.0	ISO 8754, ISO 14596, ASTM D 4294, DIN 51400-10
Flash point[5]	°C	Min.	60.0	ISO 2719
Hydrogen sulphide	mg/kg	Max.	2.0	IP 570
Acid number	mg KOH/g	Max.	0.5	ASTM D664
Corrosion on copper	Class	Max.	1	ISO 2160
Oxidation stability[6]	g/m^3	Max.	25	ISO 12205, EN 15751
	h	Min.	20	
Fatty acid methyl ester (FAME) content[7]	% (V/V)	Max.	7.0	ASTM D7963, IP 579, EN 14078
Carbon residue[8]	%(m/m)	Max.	0.30	ISO 10370
Appearance	–	–	Clear & haze free	visually
Water content	% (m/m)	Max.	0.02	DIN 51777, DIN EN 12937, ASTM D6304
Ash content	% (m/m)	Max.	0.010	ISO 6245

Diesel fuel (DMA, DFA) specifications

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Property	Unit		Threshold value[1)]	Standard[2)]
Lubricity[9)]	µm	Max.	520	ISO 12156-1, ASTM D6079

Table 1: Requirements for diesel fuel

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.

[2)] Always in relation 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)] SOLAS specification. A lower flash point is possible for non-SOLAS-regulated applications.

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

[7)] The FAME must either be in accordance with EN 14214 or with ASTM D6751.

[8)] Determined on 10% distillation residue.

[9)] Diameter of the corrected wear scar (WSD).

The following fuels are approved for use:

- Classes ISO F-DMA & DMZ as per ISO 8217 in the current edition.
- Class ISO F-DFA & DFZ as per ISO 8217 in the current edition with additional requirements regarding oxidation stability.
- Diesel fuel as per EN 590 in the current edition with additional requirement regarding flash point >60 °C in SOLAS regulated areas.
- Diesel fuel no. 2-D as per ASTM D975-15 with additional requirement regarding flash point >60 °C in SOLAS regulated areas
- Synthetic diesel fuel as per EN 15940 in the current edition with additional requirement regarding flash point >60 °C in SOLAS regulated areas. To obtain the full power output from engines with conventional injection systems, the minimum density in the table Requirements for the diesel fuel must be strictly adhered to.

Please submit enquiries to for all fuels which do not meet the abovementioned standards.

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 requirements of the fuel upstream of the engine is a maximum of 520 µm WSD in each case.

Military fuel specification

The fuel types F-75 or F-76 as per NATO STANAG 1385 may be used. The following must be observed when doing so:

Diesel fuel (DMA, DFA) specifications

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- According to the specification, the minimum permissible fuel viscosity for F-75 & F-76 is 1.7 mm²/s at 40 °C. This corresponds to a minimum fuel viscosity of 1.5 mm²/s at 45 °C (upstream of the engine).
- Use of a low-viscosity fuel (1.7 cSt at 40 °C) does not immediately cause the injection system to fail.
- A more severe leakage can trigger a variety of alarms!
- Extended operation of the engine with low-viscosity fuel leads to shortened maintenance intervals for the components of the injection system!
- If permanent operation with low-viscosity fuel is intended, a fuel cooling system should be installed. Contact for further information.
- The lubricity requirements of the fuel for the engine are always max. 520 µm WSD as per ISO 12156-1.

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.

Bio-fuel admixture

The DFA fuel may contain up to 7.0% of bio-fuel based on fatty acid methyl ester (FAME). The FAME to be added must comply with either EN14214 or ASTM D 6751. Compared to fuels on mineral oil basis only, fuels containing FAME have an increased tendency to oxidise and age and are more vulnerable to microbiological contamination. Furthermore, the fuel may contain an increased quantity of water. This why it is necessary to check the ageing stability at regular intervals when using this type of fuel. In addition, it is important to regularly check the water content of the fuel.

To minimise microbiological contamination, the tanks must be drained on a regular basis. During standstill periods this is required daily, otherwise weekly.

When first using fuels containing bio-diesel, deposits that have accumulated over a longer period of time may become detached. These deposits can block filters or even cause immediate damage.

Using bio-diesel blends in emergency power generators should be avoided. Bio-diesel fuel should be stored in separate reservoirs. Storing fuel containing bio-diesel for more than 6 months is generally not recommended. is not liable for damage and any possible consequences resulting from the use of fuel containing bio-diesel.

Diesel fuel (DMA, DFA) specifications

Analyses

Analysis of fuel samples is of great importance for safe engine operation. We can analyse fuel for customers at the PrimeServLab laboratory.

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

Diesel fuel (DMA, DFA) specifications

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]	mm²/s	Max.	11.00	ISO 3104, ASTM D7042, ASTM D445, DIN EN 16896
		Min.	2.000	
Density at 15°C	kg/m³	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

Non-standardised fuels

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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):

Properties/features	Properties/unit	Testing method
Density at 15 °C	900–930 kg/m^3	DIN EN ISO 3675, EN ISO 12185

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Properties/features	Properties/unit	Testing method
Flash point	> 60 °C	DIN EN 22719
Lower calorific 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
Coke 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
Monoglyceride content	< 0.70% (m/m)	EN14105
Diglyceride content	< 0.20% (m/m)	EN14105
Triglyceride content	< 0.20% (m/m)	EN14105
Free glycerol content	< 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 number	< 125g/100g	DIN EN 14111
TAN (total acid number)	< 5 mg KOH/g	DIN EN ISO 660
Cold filter plugging point	10 °C below the lowest temperat- ure in the fuel system	EN 116

Table 2: Specifications for non-interesterified bio fuel

⚠ WARNING

Handling of operating fluids

Handling of operating fluids can cause serious injury and damage to the environment.

- Observe safety data sheets of the operating fluid supplier.

Tests

Analysis of samples

To ensure sufficient cleaning of the fuel via the separator, perform regular functional check by sampling up- and downstream of the separator.

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

To ensure the safety of the team and to obtain a representative sample, sampling should be carried out as per Work Card M10.000.002-07.

Non-standardised fuels

Non-standardised fuels

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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. It is also referred to as: Marine diesel oil (MDO) 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 heavy fuel oil in the supply chain. This means that it is possible for the fuel to be blended with high-viscosity heavy fuel oil 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 diesel 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 is dependent on climatic conditions. All requirements specified in the current edition of ISO 8217 apply.

The following values must be maintained at the engine inlet:

Property	Unit		Threshold value[1)]	Standard[2)]
Kinematic viscosity at 40 °C[3)]	mm^2/s	Max.	11.0	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.	35	ISO 4264 & ISO 5165
Sulphur content[4)]	% (m/m)	Max.	1.50	ISO 8754, ISO 14596, ASTM D 4294, DIN 51400-10
Flash point[5)]	°C	Min.	60.0	ISO 2719
Hydrogen sulphide	mg/kg	Max.	2.0	IP 570
Acid number	mg KOH/g	Max.	0.5	ASTM D664
Corrosion on copper	Class	Max.	1	ISO 2160
Oxidation stability[6)]	g/m^3	Max.	25	ISO 12205, EN 15751
	h	Min.	20	
Fatty acid methyl ester (FAME) content[7)]	% (V/V)	Max.	7.0	ASTM D7963, IP 579, EN 14078
Carbon residue	% (m/m)	Max.	0.30	ISO 10370
Appearance[8)]	–	–	Free from contamination	visually

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Marine diesel oil (DMB, DFB) specifications
Marine diesel oil (DMB, DFB) specifications

Property	Unit		Threshold value[1]	Standard[2]
Water content	% (m/m)	Max.	0.02	DIN 51777, DIN EN 12937, ASTM D6304
Ash content	% (m/m)	Max.	0.010	ISO 6245
Lubricity[9]	µm	Max.	520	ISO 12156-1, ASTM D6079

Table 1: Requirements for diesel fuel

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

[6] If there is more than 2% (V/V) FAME, an analysis as per EN15751 must additionally be performed

[7] The FAME must either be in accordance with EN 14214 or with ASTM D6751.

[8] 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.

[9] Diameter of the corrected wear scar (WSD).

The following fuels are approved for use:

- Class ISO F-DMB according to ISO 8217 in the current edition.
- Class ISO F-DFB as per ISO 8217 in the current edition with additional requirements regarding oxidation stability.

Please submit enquiries to for all fuels which do not meet the abovementioned standards.

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 requirements of the fuel upstream of the engine is a maximum of 520 µm WSD in each case.

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

Marine diesel oil (DMB, DFB) specifications

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- 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.

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.

Bio-fuel admixture

The DFB fuel can contain up to 7.0% of bio-fuel based on fatty acid methyl ester (FAME). The FAME to be added must comply with either EN 14214 or ASTM D6751. Compared to fuels on mineral oil basis only, fuels containing FAME have an increased tendency to oxidise and age and are more vulnerable to microbiological contamination. Furthermore, the fuel may contain an increased quantity of water. This why it is necessary to check the ageing stability at regular intervals when using this type of fuel. In addition, it is important to regularly check the water content of the fuel.

To minimise microbiological contamination, the tanks must be drained on a regular basis. During downtimes this is required daily, otherwise weekly.

When first using fuels containing bio-diesel, deposits that have accumulated over a longer period of time may become detached. These deposits can block filters or even cause immediate damage.

Using bio-diesel blends in emergency power generators should be avoided. Bio-diesel fuel should be stored in separate reservoirs. Storing fuel containing bio-diesel for more than 6 months is generally not recommended. is not liable for damage and any possible consequences resulting from the use of fuel containing bio-diesel.

Analyses

Analysis of fuel samples is of great importance for safe engine operation. We can analyse fuel for customers at the PrimeServLab laboratory.

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

Marine diesel oil (DMB, DFB) specifications

Marine diesel oil (DMB, DFB) specifications

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Residual fuel (HFO) specification

Prerequisites

Four-stroke diesel engines from can be powered with any residual fuel recovered from crude oil that fulfils the requirements specified in the table Properties of residual fuel, provided that the engine and the fuel management system are designed accordingly. In order to ensure a favourable ratio between fuel costs, spare parts and also repair and maintenance expenditure, we recommend observing the following points.

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 is usually a blend of residual oil and distillates. The blend components 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 responsibility for selecting suitable residual fuels lies with the engine operator.

Specifications

Fuels that can be used in an engine must satisfy the specifications to ensure adequate quality. The limit values for residual fuels are specified in the table Specifications for residual fuel. The entries in the last column of this table contain important background information and must therefore be observed.

The relevant international specification is ISO 8217 in the respectively applicable version. The fuel may only be used if it fully complies with the standard. All qualities in these specifications up to K700 can be used, provided the fuel management system has been designed for these fuels. To use fuels that do not comply with these specifications (e.g. crude oil), consultation with the technical service from Augsburg is required. Residual fuels with a maximum density of 1,010 kg/m^3 may only be used if up-to-date separators are installed.

Important

Even if they fulfil the aforementioned specifications, the fuel properties specified in the table Heavy fuel oil requirements may possibly not be adequate to determine the ignition and combustion properties and also the stability of the fuel. This means that the operating behaviour of the engine can 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 ducts 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.

Blends

The addition of engine oils (old lubricating oil, ULO – used lubricating oil) and additives that are not manufactured from mineral oils, (coal-tar oil, for example), and residual products of chemical or other processes such as solvents (polymers or chemical waste) is not permitted. Some of the reasons for this are as follows: abrasive and corrosive effects, unfavourable combus-

Residual fuel (HFO) specification

Residual fuel (HFO) specification

tion characteristics, poor compatibility with mineral oils and, last but not least, adverse effects on the environment. The order for the fuel must expressly state what is not permitted as the fuel specifications that generally apply do not include this limitation.

If engine oils (old lubricating oil, ULO – used lubricating oil) are added to fuel, this poses a particular danger as the additives in the lubricating oil act as emulsifiers that cause dirt, water and catfines to be transported as fine suspension. They therefore prevent the necessary cleaning of the fuel. In our experience (and this has also been the experience of other manufacturers), this can severely damage the engine and turbocharger components.

The addition of chemical waste products (solvents, for example) to the fuel is prohibited for environmental protection reasons according to the resolution of the IMO Marine Environment Protection Committee passed on 1st January 1992.

Leak oil collector

Leak oil collectors that act as receptacles for leak oil, and also return and overflow pipes in the lube oil system, must not be connected to the fuel tank. Leak oil lines should be emptied into sludge tanks.

Property	**Unit**	**Threshold value**[1)]	**Standard**[2)]
Viscosity (at 50°C)[3)]	mm^2/s (cSt)	max. 700	ISO 3104, ASTM D7042; ASTM D445, DIN EN 16896
Viscosity (at 100°C)[3)]	mm^2/s (cSt)	max. 55	
Density (at 15°C)	kg/m^3	max. 1010	ISO 3675, ISO 12185, DIN 51757
Flash point[4)]	°C	min. 60	ISO 2719
Pour point[5)]	°C	max. 30	ISO 3016
Acid number	mg KOH/g	max. 2.5	ASTM D664
Aluminium and silicon	mg/kg	Max. 15[6)]	IP 501, IP 470, ISO 10478
Total sediment (aged)	%(m/m)	max. 0.10	ISO 10307-2
Carbon residue (Conradson)	%(m/m)	max. 20	DIN EN ISO 10370
Sulphur	%(m/m)	Max. 5.0[7)]	ISO 8754, ISO 14596
Ash	%(m/m)	max. 0.15	ISO 6245
Vanadium	mg/kg	max. 450	IP 501, IP 470, ISO 14597, DIN 51790-4
Water	% (v/v)	Max. 0.20[8)]	DIN 51777; ASTM D6304
CCAI		870	ISO 8217
Asphalt content	%(m/m)	Max. 2/3 of the carbon residue (Conradson)	factory standard, DIN 51595
Sodium	mg/kg	Max. Na < 1/3 V, Na < 100	IP 501, IP 470, DIN 51399-1
Waste oil[9)]	mg/kg	Max. Ca < 30 and Zn < 15 or Ca < 30 and P < 15	IP 501, IP 470, IP 500, DIN 51399-1
Hydrogen sulphide	mg/kg	max. 2	IP 570

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Property	Unit	Threshold value[1)]	Standard[2)]
[1)] Requirement at engine inlet: additional parameters defined for ISO 8217. The entire document ISO 8217 in its current version 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 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 contributes to further contamination of the air and/or may impair the safety of personnel or the performance of the machine.			
[2)] Always reference to the latest edition.			
[3)] Specific requirements of the injection system must be taken into account.			
[4)] SOLAS provision: A lower flash point is possible for non-SOLAS-regulated applications.			
[5)] The pour point must be selected by the operating company in accordance with the design of the fuel system and based on the requirements at the place of installation.			
[6)] The bunker product (before cleaning) may contain max. 60 mg/kg Al and Si.			
[7)] Independent of the maximum permissible sulphur content, local laws and regulations must be adhered to. NOTICE: For bore size <400 mm, lower sulphur content for World Bank II - see description D 10 28 0, Emission limits World Bank II.			
[8)] The bunker product (before cleaning) may contain max. 0.50% water.			
[9)] The fuel must be generally free of waste oil. If the threshold values are exceeded, the waste oil will be contaminated.			

Table 1: Properties for heavy fuel oil

Please submit enquiries to for all fuels which do not meet the abovementioned standards.

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

Heavy fuel oil 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 (for GenSets, L16/24, L21/31, L23/30H, L27/38, L28/32H: 12–18 cSt) 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 motor can be found in the viscosity temperature diagram.

Heavy fuel oil preparation

Fault-free engine operation depends to a considerable extent on the care with which the heavy fuel oil 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.

Residual fuel (HFO) specification

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 heavy fuel oil 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 heavy fuel oil 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). Heavy fuel oil 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 heavy fuel oil. In most cases, these catalyst particles are aluminium silicates causing a high degree of wear in the injection system and the engine.

Flash point (ASTM D 93)

National and international transportation and storage regulations governing the use of fuels must be complied with in relation to the flash point. In general, a flash point of above 60 °C is prescribed for diesel engine fuels.

Low-temperature behaviour (ASTM D 97)

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

Pump characteristics

If the viscosity of the fuel is higher than 1000 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 paragraph Low-temperature behaviour (ASTM D 97.

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 asphaltene 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 heavy fuel oil, or if incompatible heavy fuel oil 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.

Residual fuel (HFO) specification

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.

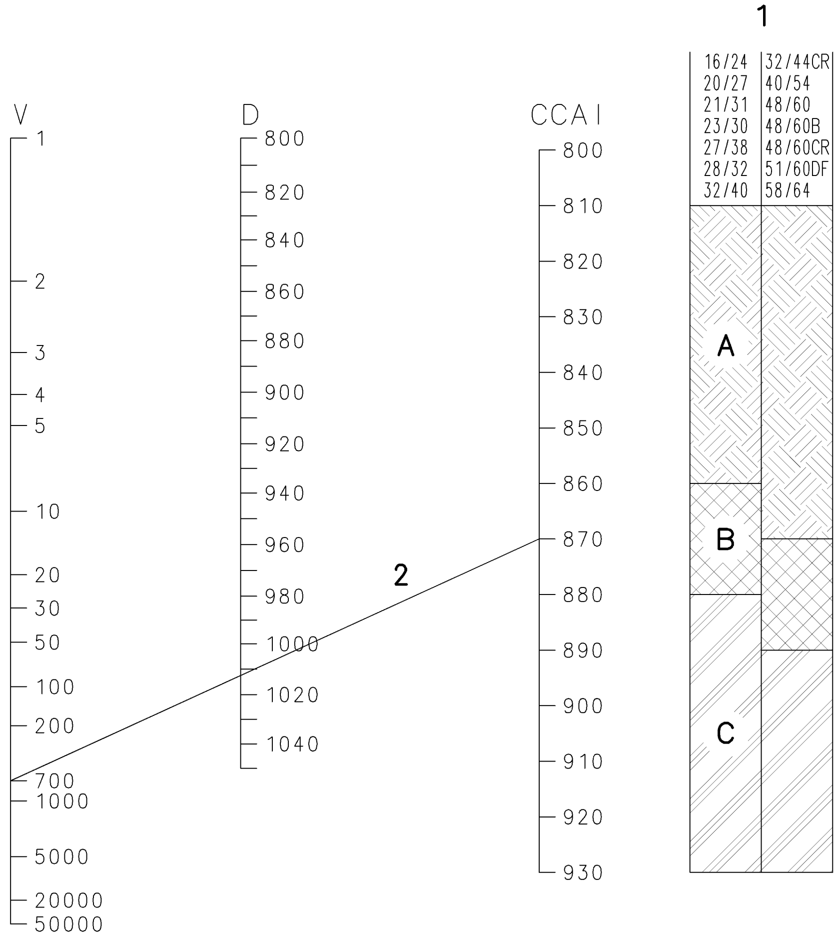
The disadvantages of using fuels with poor ignition characteristics can be limited by pre-heating the charge air in partial load operation and reducing the output for a limited period. However, a more effective solution is a high compression ratio and operational adjustment of the injection system to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

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.

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.

Residual fuel (HFO) specification



V	Viscosity in mm²/s (cSt) at 50°C		A	Normal operating conditions
D	Density [in kg/m³] at 15°C		B	The ignition characteristics can be poor and require an adjustment to the engine or the operating conditions.
CCAI	Calculated Carbon Aromaticity Index		C	Any problems identified can even lead to engine damage after a short operating period.
1	Engine type		2	The CCAI is calculated from the density and viscosity of the heavy fuel oil.

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

Residual fuel (HFO) specification

Sulphuric acid corrosion

The engine should be operated at the coolant temperatures prescribed in the operating handbook for the relevant 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 effectively prevented, even if alkaline lube oil is used.

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 Heavy fuel oil requirements).

Compatibility

The supplier must guarantee that the heavy fuel oil 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.

Blending residual fuels

If residual fuel for the main engine is blended with distillate fuel (e.g. DMA) 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 inhomogeneous fuels are not produced when blending.

Additives for heavy fuel oil

- 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.

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

heavy fuel oil with low sulphur content

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

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

⚠ WARNING

Handling of operating fluids

Handling of operating fluids can cause serious injury and damage to the environment.

- Observe safety data sheets of the operating fluid supplier.

Residual fuel (HFO) specification

Tests

Analysis of samples

To ensure sufficient cleaning of the fuel via the separator, perform regular functional check by sampling up- and downstream of the separator.

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

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

Residual fuel (HFO) specification

Viscosity-temperature diagram (VT diagram)

Explanations of viscosity-temperature diagram

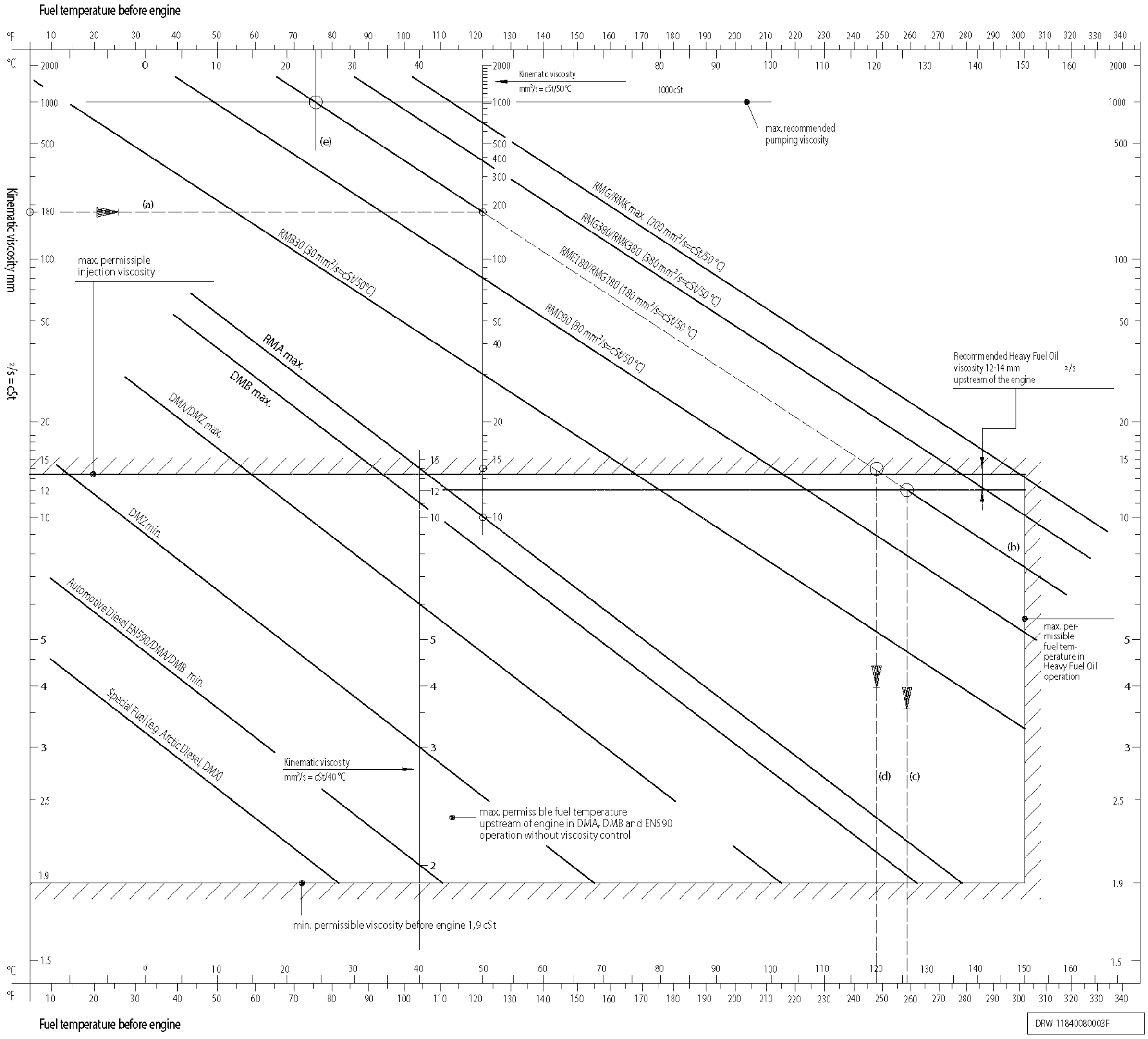


Figure 1: Viscosity-temperature diagram (VT diagram)

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)

Viscosity-temperature diagram (VT diagram)
Viscosity-temperature diagram (VT diagram)

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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

Viscosity-temperature diagram (VT diagram)

Setting the heavy fuel oil supply system

General information

The specified flow rate of fuel oil (FO) through the engines is essential for them to function reliably. If the minimum flow is not reached for each engine, problems such as stuck fuel injection pumps may result. The reason for this is that an inadequate flow rate deteriorates the cooling and lubrication properties of fuel, leading to laquering and seizing during HFO operation, or seizing alone in MDO/MGO operation.

It is important to remember that even if plant-related fuel pumps are correctly designed as per the project guide, this does not guarantee the minimum flow through each engine. The entire fuel oil system must be commissioned carefully, as even a single incorrectly adjusted valve can hinder fuel flow through the engines. The system diagram shown should be regarded as an example of the system setting. The relevant requirements for the engine type are set out in the pertinent project guide.

Based on the MAN Diesel & Turbo uni-fuel system, this guideline explains how the correct setting is performed and how each engine is supplied with its required fuel flow and pressure, as set out in the project specification for reliable operation. This guideline can also be applied to fuel systems for GenSets alone, without MDT two-stroke engines. It applies to MAN Diesel & Turbo marine GenSets with a conventional injection system.

Preliminary work (precondition)

- The main engine is connected to the fuel system (Uni-concept fuel system).
- Check whether the flow rates of the booster and supply pump correspond to the specifications in the planning documentation.
- Attach or install an ultrasonic flowmeter (FM) which is suitable for pipe diameters of DN15 and larger.
- The entire heavy oil supply system (HFO main system and a separate MDO system) must be flushed according to the work instructions “Operating Fluid Systems - flushing and cleaning;” see Volume 010.005 Engine – Work Instructions 010.000.001-01 and 000.03.
- After flushing, be sure to remove the run-in filters.
- Clean all fuel filters for GenSets and the main engine.
- The shut-off valve (1) via the inlet and outlet of the main engine is closed. (It is opened only during maintenance of the main engine. Otherwise, undesired interference can occur with the internal pressure relief valve of the main engine).
- If the main engine cannot be connected to the fuel oil system at this time of commissioning, the shut-off valve (1) is open and the pressure relief valve (2) must be set to at least 10 bar.
- GenSets must be connected to the main HFO fuel oil system (Check all V1 and V2 changeover valves).
- The main engine and all GenSets are in standby mode (i.e. are not running).

Setting the heavy fuel oil supply system

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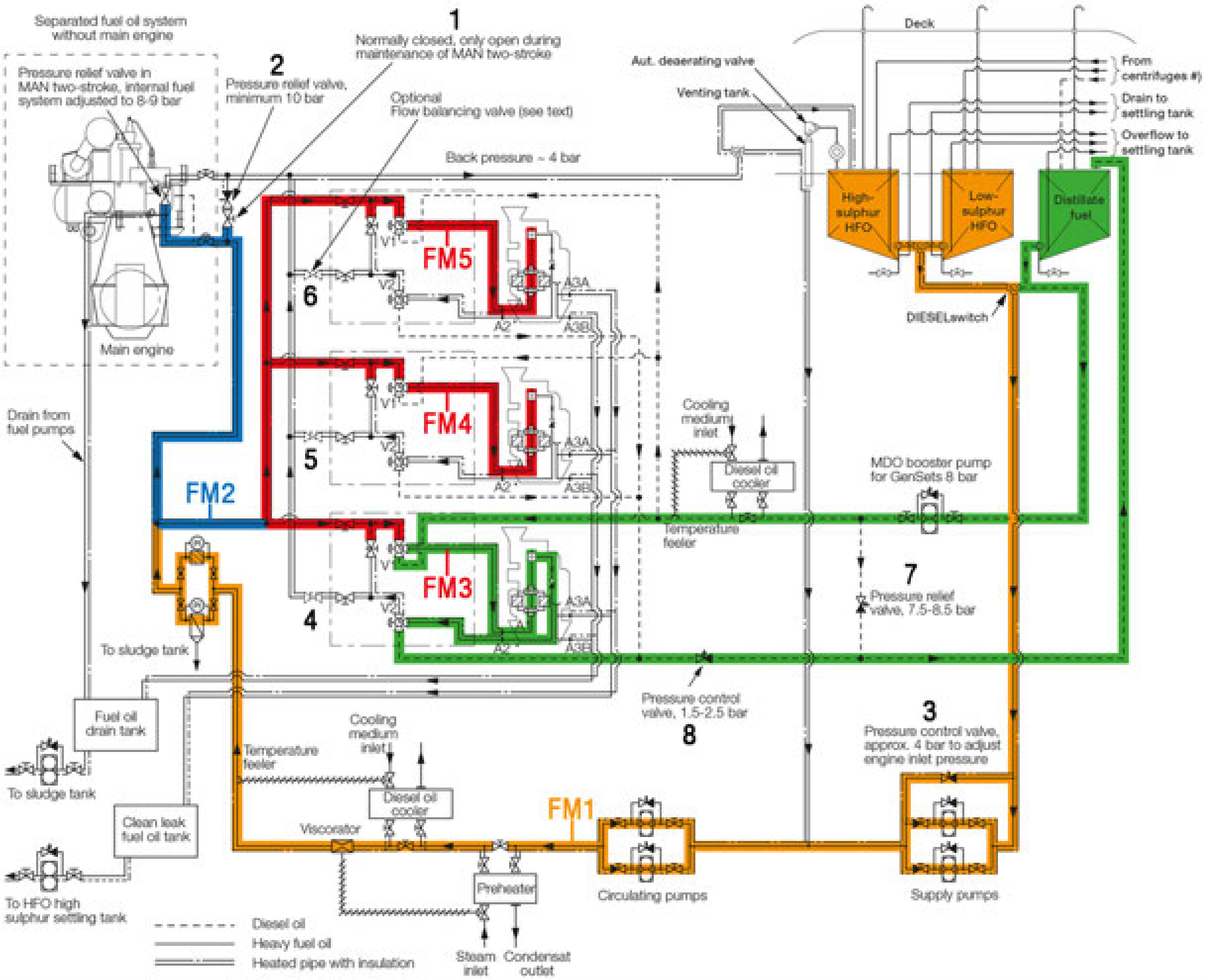
Setting the heavy fuel oil supply system

Setting procedure for the heavy oil system

To supply the main engine and all GenSets with sufficient fuel pressure and flow, four steps have to be executed. The following drawing shows components of the system which are set in the corresponding steps.



FM1 Flow rate of circulation pumps
FM2 Flow distribution between main engine and GenSets
FM3 Flow rate at GenSets in MDO cycle
FM4 Flow distribution between GenSets (recommendation)
FM5 Flow distribution between GenSets (recommendation)

Flow rate and pressure of circulating and supply pumps

Aim: To achieve the required flow rate and pressure at the outlet of circulating and supply pumps

Procedure

- Check whether the opening differential pressure of the safety valves on the circulating and supply pump is adjusted according to the pump manufacturer's specifications and whether the valves remain shut during normal operation.
- Set the correct pressure at fuel oil inlet of the main engine by setting the pressure control valve (3) parallel to the supply pump (set point approx. 4 bars). This results in a counter-pressure also amounting to approx. 4 bar in the main engine fuel outlet.

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- At “FM1,” measure whether the flow rate downstream of the booster pump is in accordance with the planning documentation.

NOTICE

Safety valves

The safety valves of the circulating and supply pump are exclusively intended as safety devices for the pumps in which they are installed. The safety valves of the booster and supply pump must not be used to set the system or pump supply pressure.

Flow distribution between main engine and GenSets

Aim: To reach the required flow distribution between GenSets and main engine

Applies to the Uni concept only.

Procedure

- Check whether the flow rate to “FM2” after splitting the FO pipeline into a branch to the main engine and another to the GenSets reaches the minimum fuel flow rate for all GenSets, as stipulated in the Project Guide.
- An inadequate pressure loss can be caused by insufficient pipe dimensioning, a long pipe length, soiled filters, clogging in the pipeline, an incorrectly adjusted internal overpressure valve of the main engine etc.

NOTICE

FO system without an MDT main engine

When a FO system is to be set without an MDT main engine, a pressure relief valve similar to the valve (2) is installed in the system to divert excess fuel away when an engine is disconnected from the system. Ensure that the valve is set to a differential pressure of at least 10 bar.

Flow distribution between GenSets

Aim: To achieve a sufficient flow for each GenSet

This step is compulsory for 32/40 engines. For the other GenSets, this step is recommended if they still have a non-uniform flow distribution after the above steps have been performed, and if the minimum fuel flow as specified in the project manual cannot be achieved at all GenSets. This can occur if the pipe diameter is too small, pipe lengths between GenSets are too long or the recirculation pumps are too small for the intended purpose.

Preconditions for adjustment

- Installation of flow balancing valves downstream of each engine.

Procedure

- Flow measurement at the fuel inlet of the GenSet (preferably as far as possible from heavy oil pumps, e.g. at “FM3”).
- If the flow rate at “FM3” is too high, gradually close the flow balancing valve (4) until the required flow rate is reached.
- Continue with the next GenSet if the flow rate at “FM3” is too low.
- If the flow rate at “FM4” is too high, close the flow balancing valve (5) until the required flow rate is reached.
- Continue with the next GenSet again if the flow rate at “FM4” is too low.
- If the flow rate at “FM5” is too high, close the flow balancing valve (6) until the required flow rate is reached.

Setting the heavy fuel oil supply system

- Then, start working at “FM3” again and repeat this procedure until each GenSet reaches its respective minimum flow rate.
- If the inlet pressure on a GenSet becomes too high during this procedure, open the pressure control valve (3) until the required pressure is reached again.

Setting procedure for the MDO fuel circuit

Aim: To achieve a sufficient flow rate for each GenSet in the MDO circuit

This circuit is intended for diesel operation.

Preconditions for adjustment

- Check how many GenSets the MDO pump can supply with the required flow rate. Please note that an insufficient supply flow rate in the MDO circuit may result in seizures.
- Switch the switch-over valves “V1” and “V2” to MDO mode for the maximum number of GenSets to be supplied at the same time.
- If available, adjust the flow distribution between GenSets. (See the steps pertaining to Flow Distribution between GenSets.)

Procedure: Pressure adjustment

- If the pressure at the engine inlet is too low, close the pressure relief valve (7) connecting the inlet and outlet of the MDO circuit to one another until the required pressure is reached or the inlet pressure is no longer affected.
- If the required pressure cannot be reached by turning the pressure relief valve (7) towards the closed position, the pressure control valve (8) at the outlet of the MDO circuit must be closed until the required pressure is reached.
- Otherwise, if the pressure at the engine inlet is too high, open the pressure control valve (8) until the required pressure is reached.

Procedure: Flow setting

- Flow measurement at the fuel inlet of the corresponding GenSet (“FM3” to “FM5”).
- If the flow rate through the engine is too low, close the pressure relief valve (7) until the required pressure is reached.
- If the incoming pressure becomes too high, open the pressure control valve (8) until the required pressure is reached again.

Setting the heavy fuel oil supply system

MDO / MGO cooler

General

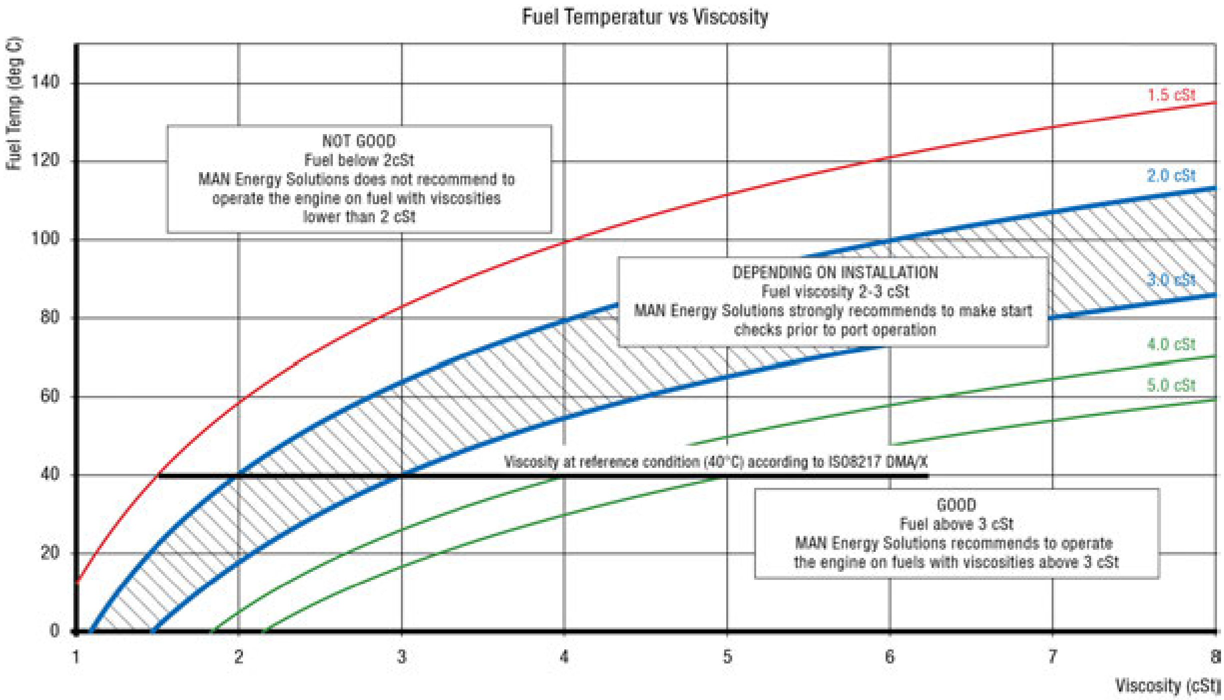

Figure 1: Fuel temperature versus viscosity.

In order to ensure a satisfactory hydrodynamic oil film between fuel injection pump plunger/barrel, thereby avoiding fuel injection pump seizures/sticking, MAN Energy Solutions recommends to keep a fuel oil viscosity at minimum 2.0 cSt measured at the engine inlet. This limit has been used over the years with good results and gives the required safety margin against fuel injection pump seizures.

For some MGO´s viscosities below 2.0 cSt may be reached at temperatures above 35°C. As the fuel temperature increases during operation, it is impossible to maintain this low temperature at the engine inlet without a MDO/ MGO cooler.

In the worst case, a temperature of 60-65°C at the engine inlet can be expected corresponding to a viscosity far below 2.0 cSt. The consequence may be sticking fuel injection pumps or nozzle needles.

Also most pumps in the external system (supply pumps, circulating pumps, transfer pumps and feed pumps for the separator) already installed in existing vessels, need viscosities above 2.0 cSt to function properly.

We recommend that the actual pump maker is contacted for advice.

Installation of MDO/MGO Cooler or MDO/MGO Cooler & Chiller

To be able to maintain the required viscosity at the engine inlet, it is necessary to install a MDO/MGO cooler in the fuel system (MDO/MGO cooler installed just before the engine).

The advantage of installing the MDO/MGO cooler just before the engine is that it is possible to optimise the viscosity regulation at the engine inlet. However, the viscosity may drop below 2.0 cSt at the circulating and other pumps in the fuel system.

The MDO/MGO cooler can also be installed before the circulating pumps. The advantage in this case is that the viscosity regulation may be optimised for both the engine and the circulating pumps.

It is not advisable to install the MDO/MGO cooler just after the engine or after the Diesel oil service tank as this will complicate viscosity control at the engine inlet. In case the MDO/MGO cooler is installed after the service tank, the supply pumps will have to handle the pressure drop across the MDO/MGO cooler which cannot be recommended.

The cooling medium used for the MDO/MGO cooler is preferably fresh water from the central cooling water system.

Seawater can be used as an alternative to fresh water, but the possible risk of MDO/MGO leaking into the sea water and the related pollution of the ocean, must be supervised.

The horizontal axis shows the bunkered fuel viscosity in cSt at 40°C, which should be informed in the bunker analysis report.

If the temperature of the MGO is below the upper blue curve at engine inlet, the viscosity is above 2.0 cSt. The black thick line shows the viscosity at reference condition (40°C) according to ISO8217, marine distillates.

Example: MGO with viscosity of 4.0 cSt at 40°C must have a temperature below 55°C at engine inlet to ensure a viscosity above 3.0 cSt.

Example: MGO with a viscosity of 5.0 cSt at 40°C is entering the engine at 50°C. The green curves show that the fuel enters the engine at approximately 4.0 cSt.

Example: MGO with a viscosity of 2.0 cSt at 40°C needs cooling to 18°C to reach 3.0 cSt.

The following items should be considered before specifying the MDO/MGO cooler :

- The flow on the fuel oil side should be the same as the capacity of the fuel oil circulating pump (see D 10 05 0, List of Capacities)
- The fuel temperature to the MDO/MGO cooler depends on the temperature of the fuel in the service tank and the temperature of return oil from the engine(s)
- The temperature of the cooling medium inlet to the MDO/MGO cooler depends on the desired fuel temperature to keep a minimum viscosity of 2.0 cSt
- The flow of the cooling medium inlet to the MDO/MGO cooler depends on the flow on the fuel oil side and how much the fuel has to be cooled

The frictional heat from the fuel injection pumps, which has to be removed, appears from the table below.

Engine type	**kW/cyl.**
L16/24, L16/24S	0.5
L21/31, L21/31 Mk1-1, L21/31S L21/31 Mk 2, L21/31DF-M	1.0
L27/38, L27/38S	1.5

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Engine type	kW/cyl.
L23/30H, L23/30H Mk 2, L23/30H Mk 3, L23/30S	0.75
L23/30DF	0.75
L28/32H	1.0
L28/32DF	1.0
V28/32S	1.0

Based on the fuel oils available in the market as of June 2009, with a viscosity ≥ 2.0 cSt at 40°C, a fuel inlet temperature ≤ 40°C is expected to be sufficient to achieve 2.0 cSt at engine inlet *(see fig 1).*

In such case, the central cooling water / LT cooling water (36°C) can be used as coolant.

For the lowest viscosity MGO´s and MDO´s, a water cooled MGO/MGO cooler may not be enough to sufficiently cool the fuel as the cooling water available onboard is typically LT cooling water (36°C).

In such cases, it is recommended to install a so-called “Chiller” that removes heat through vapourcompression or an absorption refrigeration cycle *(see fig 2).*

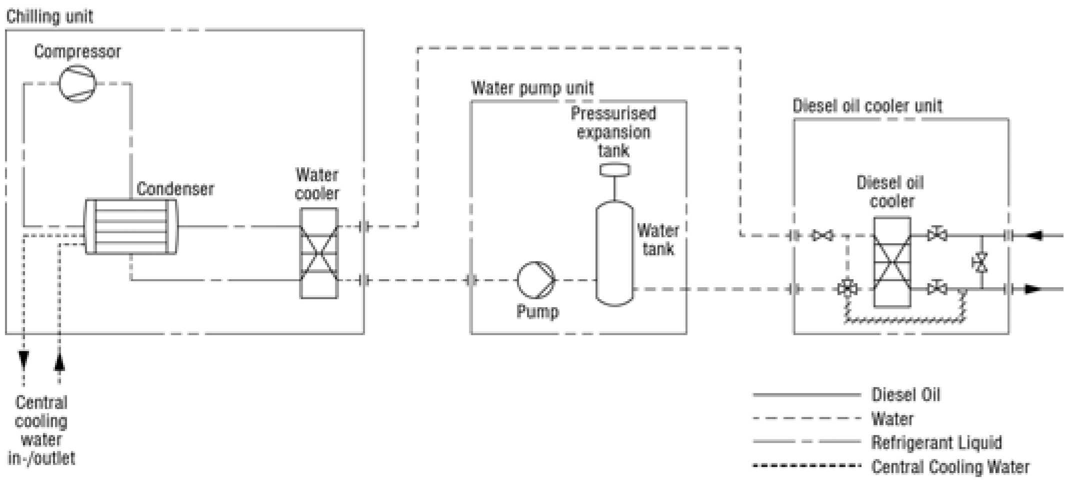

Figure 2: Chiller.

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Fuel oil filter duplex

Fuel oil filter duplex

	Fuel oil filter duplex - Star-pleated element		
	25 microns (400/40) (sphere passing mesh)		
	HFO 12-18 cSt	MDO 2.5-14 cSt	MGO 1.5-6 cSt
	litres/h	litres/h	litres/h
DN25	1000	1000	1000
DN32	1500	1500	1500
DN40	2800	2800	2800
DN50	3500	3500	3500
DN65	5800	5800	5800
	Filter area (cm^2)		
DN25	652	652	652
DN32	1000	1000	1000
DN40	1844	1844	1844
DN50	2337	2337	2337
DN65	3885	3885	3885
	Pressure drop (bar)		
DN25	0.018	0.016	0.013
DN32	0.016	0.015	0.012
DN40	0.019	0.018	0.015
DN50	0.016	0.014	0.012
DN65	0.015	0.013	0.011

Table 1: Fuel oil filter duplex

To safeguard the injection system components on the GenSets, is it recommended to install a fuel oil filter duplex, as close as possible to each GenSet.

The fuel oil filter duplex is with star-pleated filter elements. The fuel oil filter duplex is supplied loose and it is recommended to install it, as close as possible to each GenSet, in the external fuel oil supply line.

GenSets with conventional fuel injection system or common rail fuel system must have fuel oil filter duplex with a fineness of max. 25 microns (sphere passing mesh) installed as close as possible to each GenSet.

The filter surface load of the 25 microns filters must not exceed 1.5 l/cm^2 per hour !

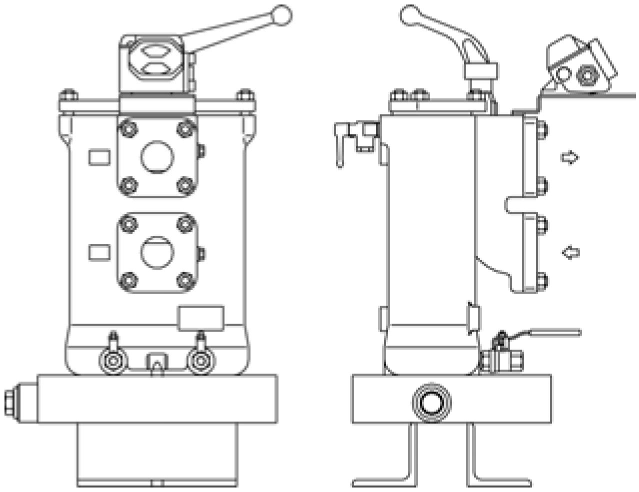

Figure 1: Fuel oil filter duplex.

HFO/MDO changing valves (V1 and V2)

Description

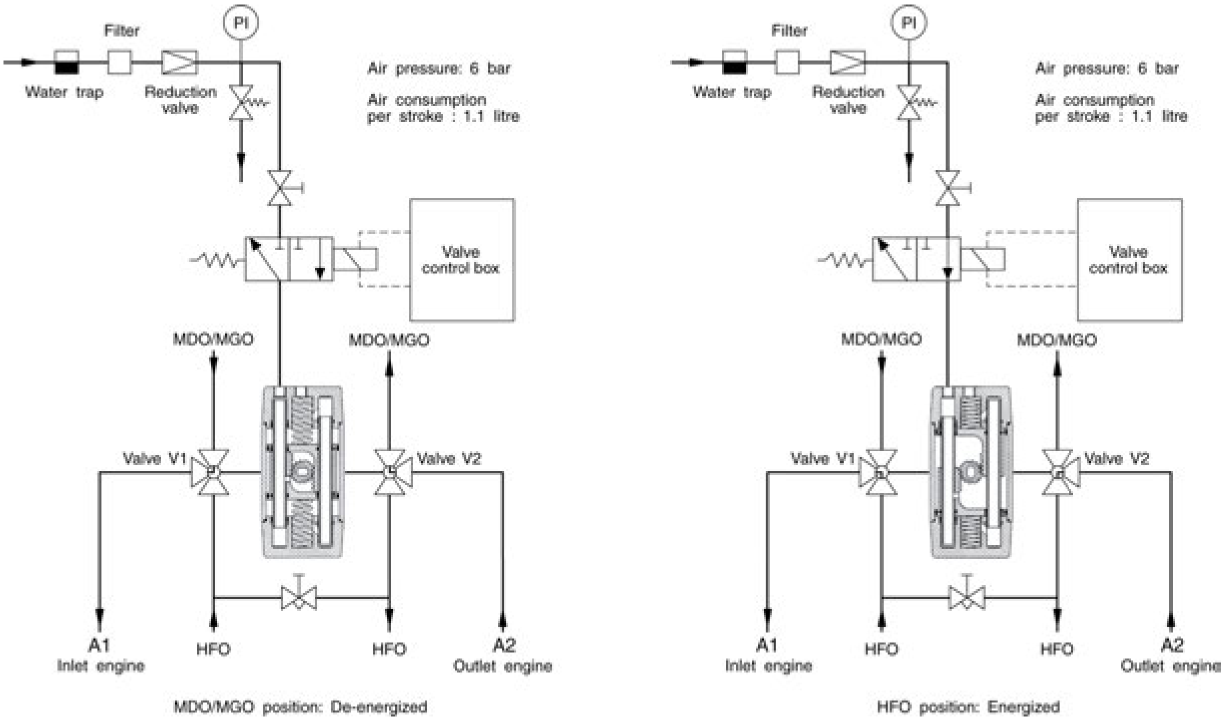

Figure 1: Pneumatic diagram for 3-way changing valves V1 & V2.

The fuel change-over system consists of two remote controlled and interconnected 3-way valves, which are installed immediately before each GenSet. The 3-way valves “V1-V2” are operated by an electrica/pneumatic actuator of the simplex type, with spring return and a common valve control box for all GenSets.

The flexibility of the system makes it possible, if necessary, to operate the GenSets on either diesel oil or heavy fuel oil, individually by means of the L-bored 3-way valves “V1-V2”.

The control box can be placed in the engine room or in the engine control room.

To maintain re-circulation in the HFO flow line, when the GenSet is operated on MDO, is a by-pass valve installed between the fuel inlet valve “V1” and the fuel outlet valve “V2” at each GenSet as shown in *fig 1.*

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Valve control box

The electrical power supply to the valve control box is 3 x 400 Volt - 50 Hz, or 3 x 440 Volt - 60 Hz, depending on the plant specification, and is established in form of a single cable connection from the switchboard.

Due to a built-in transformer, the power supply voltage will be converted to a 24 V DC pilot voltage for serving the relays, contactors, and indication lamps.

Furthermore the 24 V DC pilot voltage is used for operating the fuel changing valves with an electrically/pneumatically operated actuator of the simplex type with spring return.

The mode of valve operation is:
HFO-position: Energized
MDO-position: De-energized

In the event of a black-out, or other situations resulting in dead voltage potential, will the remote controlled and interconnected 3-way valves at each GenSet be de-energized and automatically change over to the MDO/MGO-position, due to the built-in return spring. The internal piping on the GenSets will then, within a few seconds, be flushed with MDO/MGO and be ready for start up.

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

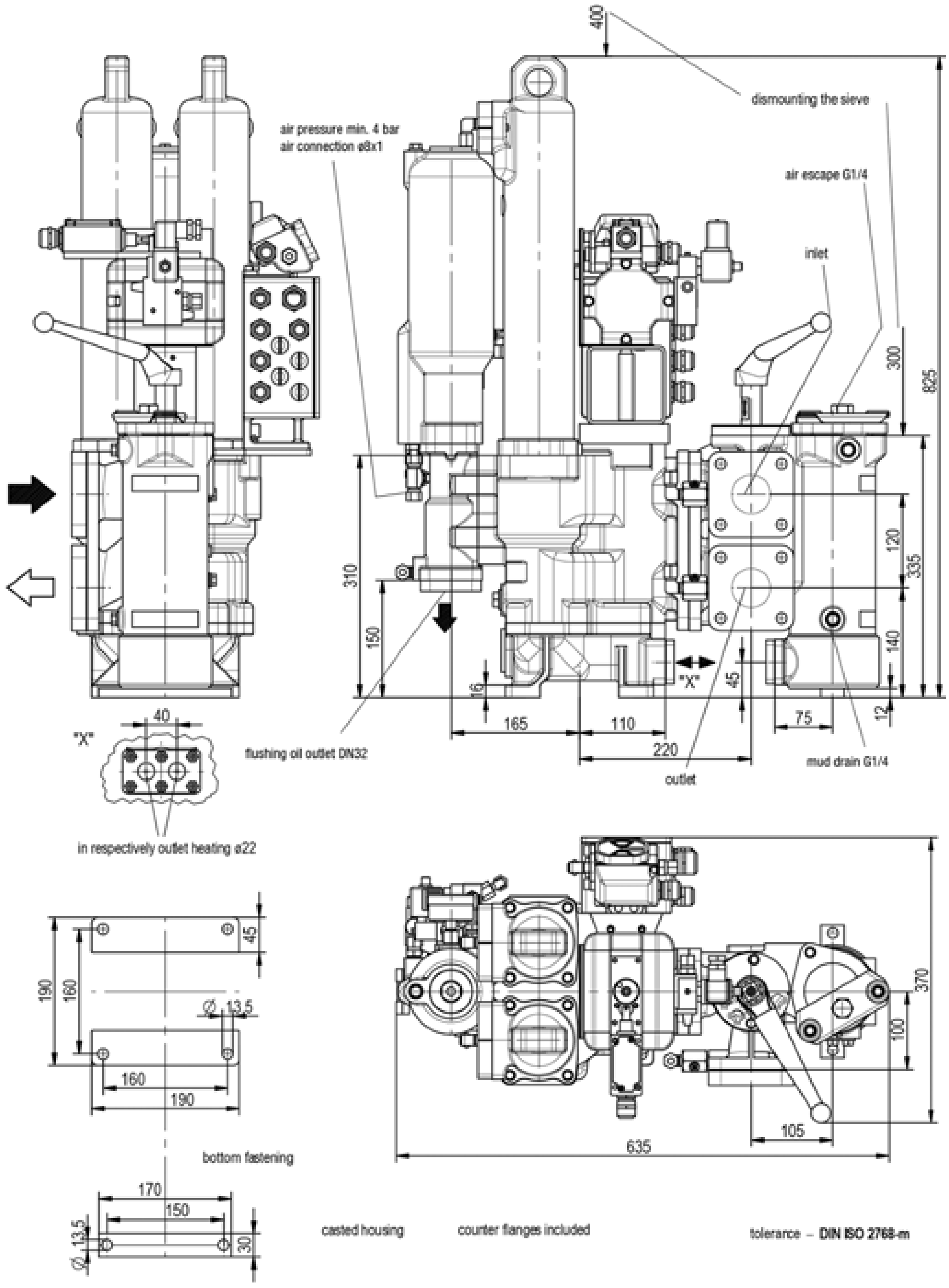
900 rpm	Booster circuit		
Qty. engines	6 cyl. engine	7 cyl. engine	8 cyl. engine
1	DN40	DN40	DN40
2	DN40	DN65	DN65
3	DN65	DN65	DN65
4	DN65	DN65	DN65

Specification L28/32H

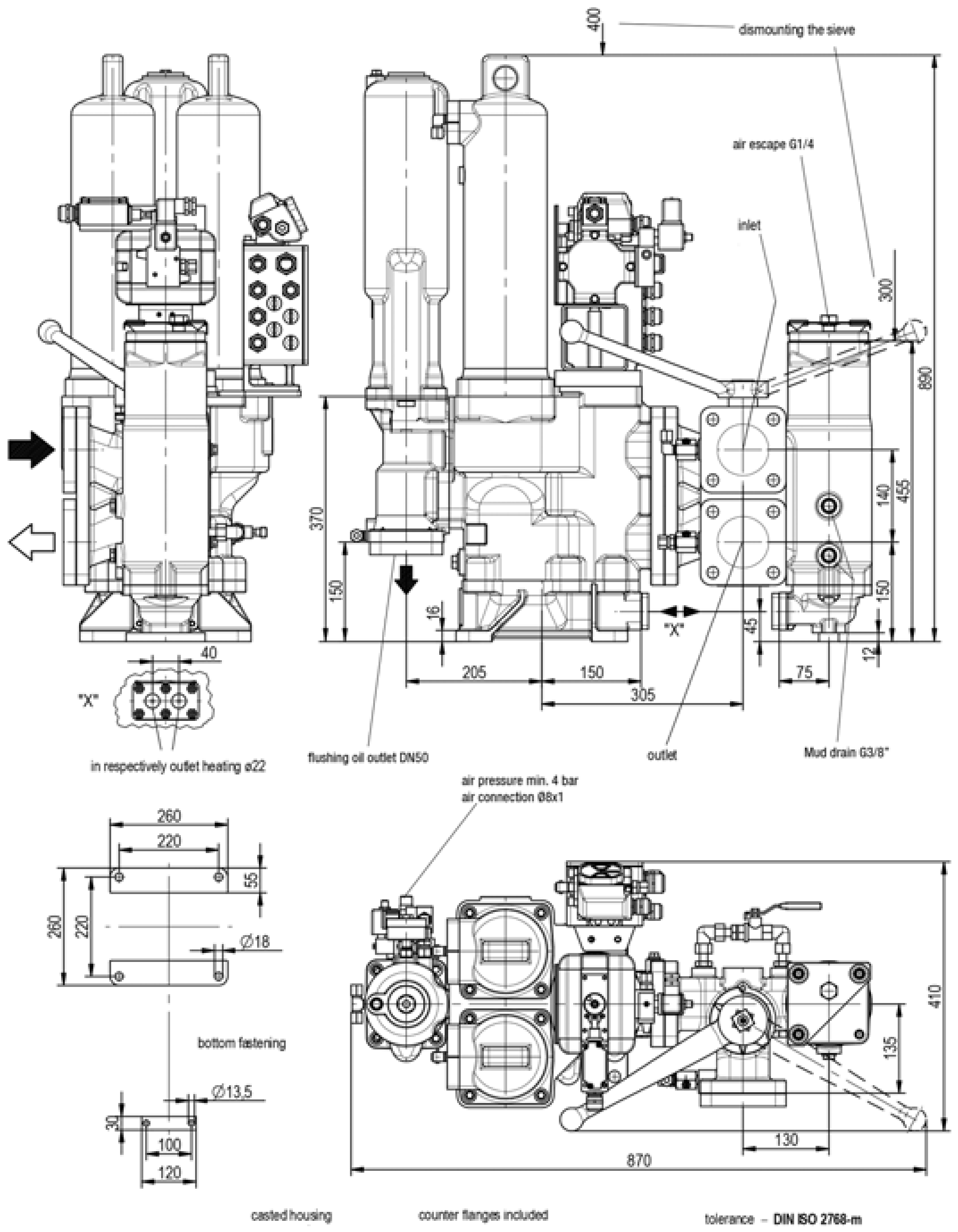
720 rpm	Booster circuit				
Qty. engines	5L28/32H	6L28/32H	7L28/32H	8L28/32H	9L28/32H
1	DN40	DN40	DN40	DN40	DN40
2	DN40	DN65	DN65	DN65	DN65
3	DN65	DN65	DN65	DN65	DN65
4	DN65	DN65	DN65	DN65	DN80

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

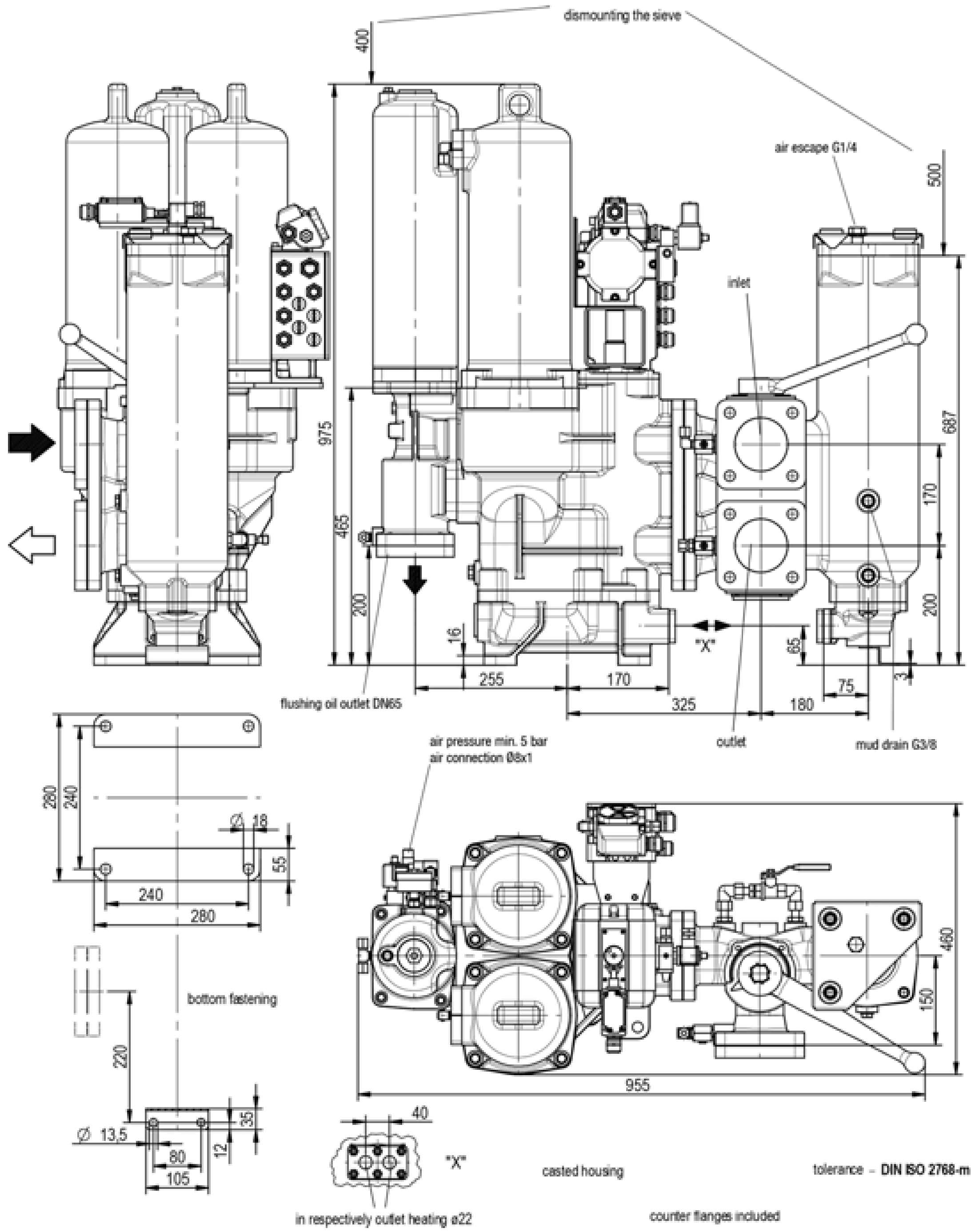
DN40 - Typ 6.72.1



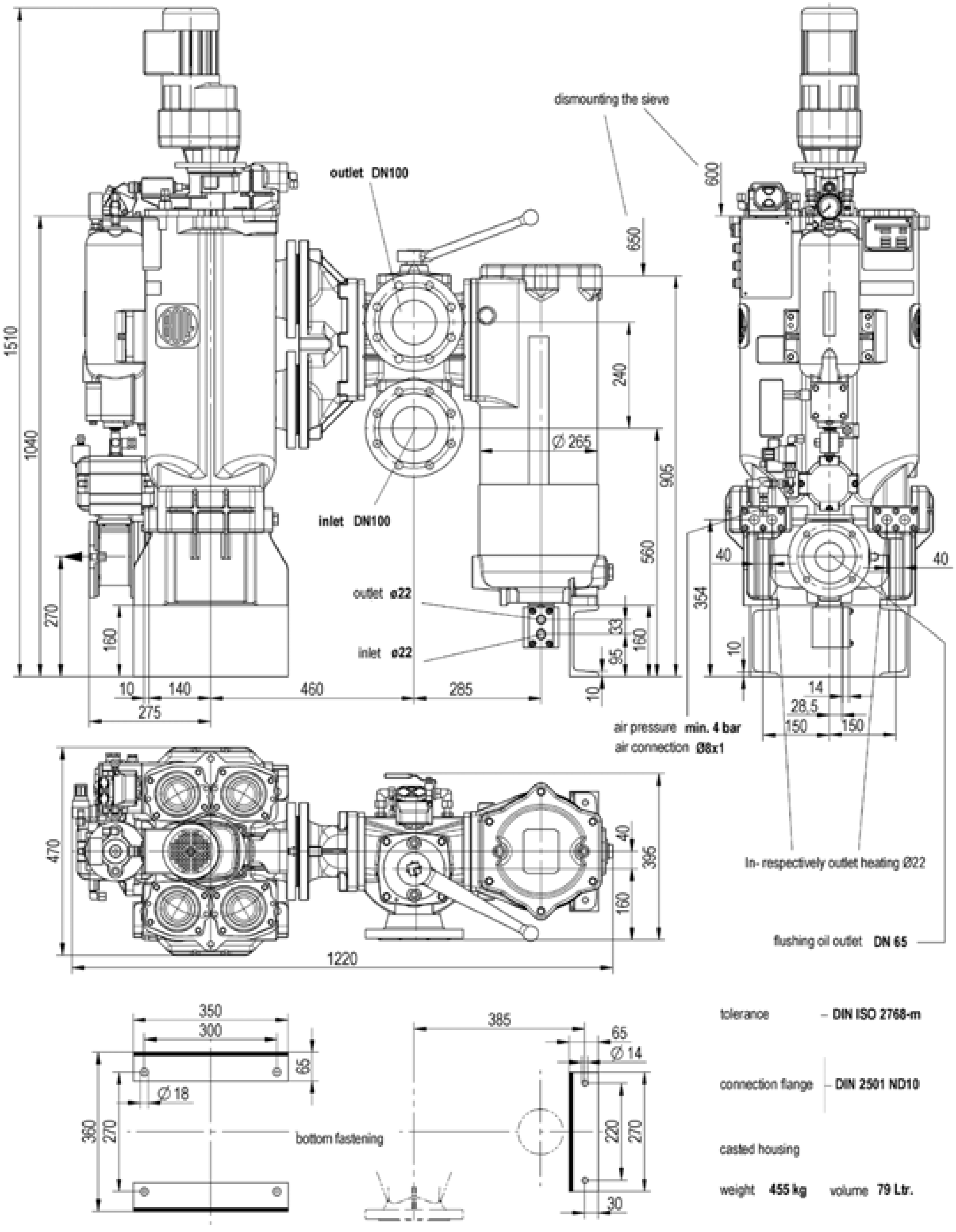
DN65 - Typ 6.72.1



DN80 - Typ 6.72.1



DN100 - Typ 6.64.1



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 and is back-flushed continuously, without any interruptions of flow.

The continuous back-flushing significantly prevents adhesion of retained solids to filter surfaces and no manual cleaning of filter elements is needed.
The constant pressure drop across the filter, combined with the pressure drop indicator, facilitates the detection of a malfunction in the fuel oil system.
The use of filtered oil for the back-flushing process eliminates the need for compressed air.
The diversion chamber acts as an automatic maintenance-free sludge treatment system, collecting particles back-flushed from the full-flow chamber and cleaning itself to concentrate sludge. The solids settle to the bottom of the diversion chamber, where they are periodically discharged through the drain cock.

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Filter specification

Range of application	:	Heavy fuel oil 700 cSt @ 50°C
Max. operating pressure	:	16 bar
Test pressure	:	30 bar
Max. operating temperature	:	160°C
Nominal width of connection flanges	:	DN25, DN40, DN50
Grade of filtration	:	10 microns (absolute/sphere passing mesh)
Cleaning	:	Continuous back flushing driven by the filtered oil
Alarm contact switches at differential pressure	:	0.8 bar
Housing material	:	Nodular cast iron
Filter screen material	:	Stainless steel
Heating method	:	Steam/hot water/thermal oil
Power supply	:	110/220 V, 50/60 Hz, single phase
Consumption	:	0.20 A (110 V), 0.10 A (220 V)
Protection Class F	:	IP55, tropicalized

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Specification L16/24

1000 rpm		Booster circuit				
Qty. engines		5L16/24	6L16/24	7L16/24	8L16/24	9L16/24
1	Outlet flow	0.32	0.4	0.47	0.54	0.6
	Inlet flow	0.57	0.65	0.72	0.79	0.85
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01
2	Outlet flow	0.64	0.8	0.94	1.08	1.2
	Inlet flow	0.89	1.05	1.19	1.33	1.45
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01
3	Outlet flow	0.96	1.2	1.41	1.62	1.8
	Inlet flow	1.21	1.45	1.66	1.91	2.12
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 12/6 A01	FM-152-DE 12/6 A01
4	Outlet flow	1.28	1.6	1.88	2.16	2.4
	Inlet flow	1.53	1.88	2.21	2.54	2.82
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 12/6 A01	FM-152-DE 12/6 A01	FM-152-DE 12/6 A01

1200 rpm		Booster circuit				
Qty. engines		5L16/24	6L16/24	7L16/24	8L16/24	9L16/24
1	Outlet flow	0.35	0.47	0.54	0.62	0.7
	Inlet flow	0.60	0.72	0.79	0.87	0.95
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01
2	Outlet flow	0.7	0.94	1.08	1.24	1.4
	Inlet flow	0.95	1.19	1.33	1.49	1.65
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01
3	Outlet flow	1.05	1.41	1.62	1.86	2.1
	Inlet flow	1.30	1.66	1.91	2.19	2.47
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 12/6 A01	FM-152-DE 12/6 A01	FM-152-DE 12/6 A01
4	Outlet flow	1.4	1.88	2.16	2.48	2.8
	Inlet flow	1.65	2.21	2.54	2.92	3.29
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 12/6 A01	FM-152-DE 12/6 A01	FM-152-DE 16/8 A01	FM-152-DE 16/8 A01

Specification L21/31, L21/31 Mk1.1, L21/31 Mk2, L21/31DF-M

900 rpm		Booster circuit				
Qty. engines		5 cyl. engine	6 cyl. engine	7 cyl. engine	8 cyl. engine	9 cyl. engine
1	Outlet flow	0.89	1.18	1.37	1.57	1.76
	Inlet flow	1.14	1.43	1.62	1.85	2.07
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 12/6 A01
2	Outlet flow	1.78	2.36	2.74	3.14	3.52
	Inlet flow	2.09	2.78	3.22	3.69	4.14
	Recommended filter size	FM-152-DE 12/6 A01	FM-152-DE 12/6 A01	FM-152-DE 16/8 A01	FM-152-DE 16/8 A01	FM-152-DE 24/12 A01
3	Outlet flow	2.67	3.54	4.11	4.71	5.28
	Inlet flow	3.14	4.16	4.84	5.54	6.21
	Recommended filter size	FM-152-DE 16/8 A01	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01	FM-152-DE 30/12 A01
4	Outlet flow	3.56	4.72	5.48	6.28	7.04
	Inlet flow	4.19	5.55	6.45	7.39	8.28
	Recommended filter size	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01	FM-152-DE 30/12 A01	FM-152-DE 60/24 A01	FM-152-DE 60/24 A01

1000 rpm		Booster circuit				
Qty. engines		5 cyl. engine	6 cyl. engine	7 cyl. engine	8 cyl. engine	9 cyl. engine
1	Outlet flow	0.89	1.18	1.37	1.57	1.76
	Inlet flow	1.14	1.43	1.62	1.85	2.07
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 12/6 A01
2	Outlet flow	1.78	2.36	2.74	3.14	3.52
	Inlet flow	2.09	2.78	3.22	3.69	4.14
	Recommended filter size	FM-152-DE 12/6 A01	FM-152-DE 12/6 A01	FM-152-DE 16/8 A01	FM-152-DE 16/8 A01	FM-152-DE 24/12 A01
3	Outlet flow	2.67	3.54	4.11	4.71	5.28
	Inlet flow	3.14	4.16	4.84	5.54	6.21
	Recommended filter size	FM-152-DE 16/8 A01	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01	FM-152-DE 30/12 A01
4	Outlet flow	3.56	4.72	5.48	6.28	7.04
	Inlet flow	4.19	5.55	6.45	7.39	8.28
	Recommended filter size	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01	FM-152-DE 30/12 A01	FM-152-DE 60/24 A01	FM-152-DE 60/24 A01

Specification L23/30H, L23/30H Mk2, L23/30H Mk3

720/750 rpm		Booster circuit			
Qty. engines		5 cyl. engine	6 cyl. engine	7 cyl. engine	8 cyl. engine
1	Outlet flow	0.53	0.63	0.74	0.84
	Inlet flow	0.78	0.88	0.99	1.09
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01
2	Outlet flow	1.06	1.26	1.48	1.68
	Inlet flow	1.31	1.51	1.74	1.98
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 12/6 A01
3	Outlet flow	1.59	1.89	2.22	2.52
	Inlet flow	1.87	2.22	2.61	2.96
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 12/6 A01	FM-152-DE 12/6 A01	FM-152-DE 16/8 A01
4	Outlet flow	2.12	2.52	2.96	3.36
	Inlet flow	2.49	2.96	3.48	3.95
	Recommended filter size	FM-152-DE 12/6 A01	FM-152-DE 16/8 A01	FM-152-DE 16/8 A01	FM-152-DE 24/12 A01

900 rpm		Booster circuit		
Qty. engines		6 cyl. engine	7 cyl. engine	8 cyl. engine
1	Outlet flow	0.75	0.88	1.01
	Inlet flow	1.00	1.13	1.26
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01
2	Outlet flow	1.5	1.76	2.02
	Inlet flow	1.76	2.07	2.38
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 12/6 A01	FM-152-DE 12/6 A01
3	Outlet flow	2.25	2.64	3.03
	Inlet flow	2.65	3.11	3.56
	Recommended filter size	'FM-152-DE 12/6 A01	FM-152-DE 16/8 A01	FM-152-DE 16/8 A01
4	Outlet flow	3	3.52	4.04
	Inlet flow	3.53	4.14	4.75
	Recommended filter size	FM-152-DE 16/8 A01	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01

Specification L27/38

720 rpm		Booster circuit				
Qty. engines		5L27/38	6L27/38	7L27/38	8L27/38	9L27/38
1	Outlet flow	1.06	1.4	1.63	1.87	2.1
	Inlet flow	1.31	1.65	1.92	2.20	2.47
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 12/6 A01	FM-152-DE 12/6 A01	FM-152-DE 12/6 A01
2	Outlet flow	2.12	2.8	3.26	3.74	4.2
	Inlet flow	2.49	3.29	3.84	4.40	4.94
	Recommended filter size	FM-152-DE 12/6 A01	FM-152-DE 16/8 A01	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01
3	Outlet flow	3.18	4.2	4.89	5.61	6.3
	Inlet flow	3.74	4.94	5.75	6.60	7.41
	Recommended filter size	FM-152-DE 16/8 A01	FM-152-DE 24/12 A01	FM-152-DE 30/12 A01	FM-152-DE 30/12 A01	FM-152-DE 60/24 A01
4	Outlet flow	4.24	5.6	6.52	7.48	8.4
	Inlet flow	4.99	6.59	7.67	8.80	9.88
	Recommended filter size	FM-152-DE 24/12 A01	FM-152-DE 30/12 A01	FM-152-DE 60/24 A01	FM-152-DE 60/24 A01	FM-152-DE 60/24 A01

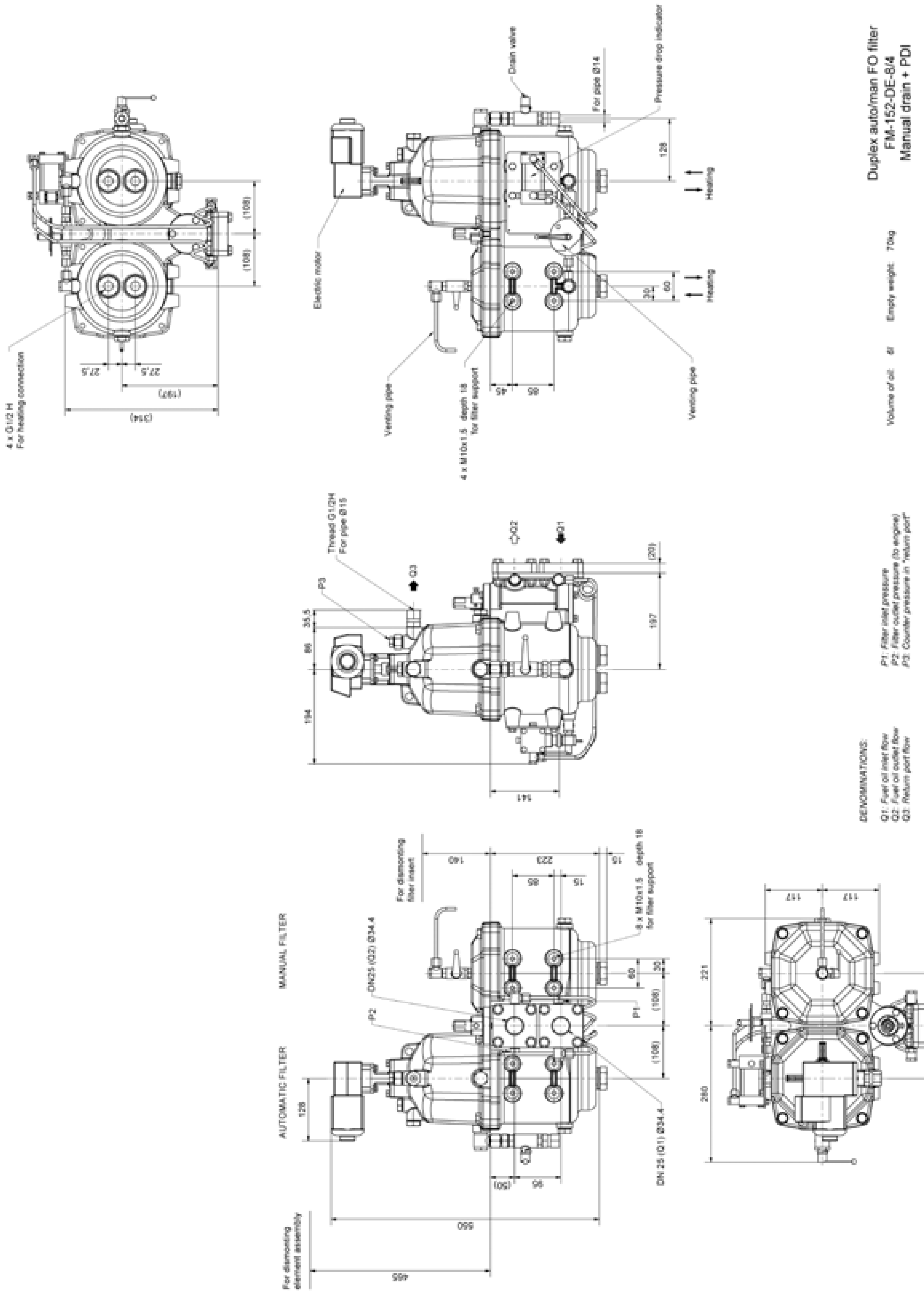
750 rpm		Booster circuit				
Qty. engines		5L27/38	6L27/38	7L27/38	8L27/38	9L27/38
1	Outlet flow	1.13	1.4	1.63	1.87	2.1
	Inlet flow	1.38	1.65	1.92	2.20	2.47
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 12/6 A01	FM-152-DE 12/6 A01	FM-152-DE 12/6 A01
2	Outlet flow	2.26	2.8	3.26	3.74	4.2
	Inlet flow	2.66	3.29	3.84	4.40	4.94
	Recommended filter size	FM-152-DE 12/6 A01	FM-152-DE 16/8 A01	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01
3	Outlet flow	3.39	4.2	4.89	5.61	6.3
	Inlet flow	3.99	4.94	5.75	6.60	7.41
	Recommended filter size	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01	FM-152-DE 30/12 A01	FM-152-DE 30/12 A01	FM-152-DE 60/24 A01
4	Outlet flow	4.52	5.6	6.52	7.48	8.4
	Inlet flow	5.32	6.59	7.67	8.80	9.88
	Recommended filter size	FM-152-DE 24/12 A01	FM-152-DE 30/12 A01	FM-152-DE 60/24 A01	FM-152-DE 60/24 A01	FM-152-DE 60/24 A01

Specification L28/32H

720 rpm		Booster circuit				
Qty. engines		5L28/32H	6L28/32H	7L28/32H	8L28/32H	9L28/32H
1	Outlet flow	0.74	0.89	1.04	1.19	1.34
	Inlet flow	0.99	1.14	1.29	1.44	1.59
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01
2	Outlet flow	1.48	1.78	2.08	2.38	2.68
	Inlet flow	1.74	2.09	2.45	2.80	3.15
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 12/6 A01	FM-152-DE 12/6 A01	FM-152-DE 12/6 A01	FM-152-DE 16/8 A01
3	Outlet flow	2.22	2.67	3.12	3.57	4.02
	Inlet flow	2.61	3.14	3.67	4.20	4.73
	Recommended filter size	FM-152-DE 12/6 A01	FM-152-DE 16/8 A01	FM-152-DE 16/8 A01	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01
4	Outlet flow	2.96	3.56	4.16	4.76	5.36
	Inlet flow	3.48	4.19	4.89	5.60	6.31
	Recommended filter size	FM-152-DE 16/8 A01	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01	FM-152-DE 30/12 A01

750 rpm		Booster circuit				
Qty. engines		5L28/32H	6L28/32H	7L28/32H	8L28/32H	9L28/32H
1	Outlet flow	0.78	0.93	1.09	1.24	1.4
	Inlet flow	1.03	1.18	1.34	1.49	1.65
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01
2	Outlet flow	1.56	1.86	2.18	2.48	2.8
	Inlet flow	1.84	2.19	2.56	2.92	3.29
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 12/6 A01	FM-152-DE 12/6 A01	FM-152-DE 16/8 A01	FM-152-DE 16/8 A01
3	Outlet flow	2.34	2.79	3.27	3.72	4.2
	Inlet flow	2.75	3.28	3.85	4.38	4.94
	Recommended filter size	FM-152-DE 12/6 A01	FM-152-DE 16/8 A01	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01
4	Outlet flow	3.12	3.72	4.36	4.96	5.6
	Inlet flow	3.67	4.38	5.13	5.84	6.59
	Recommended filter size	FM-152-DE 16/8 A01	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01	FM-152-DE 30/12 A01	FM-152-DE 30/12 A01

FM-152-DE 8/4



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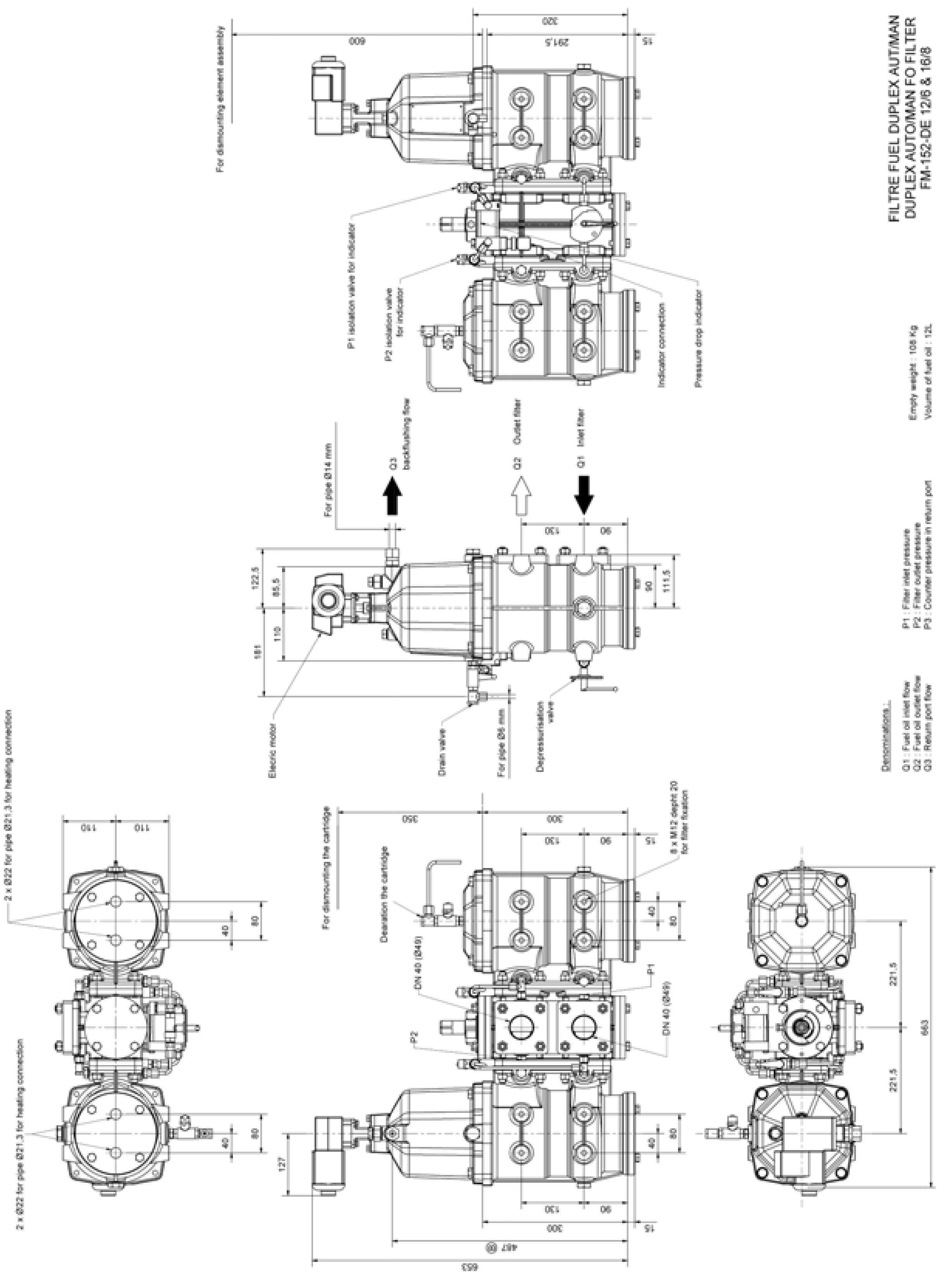
FM-152-DE 12/6 & 16/8



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Automatic back-flush filter

Description

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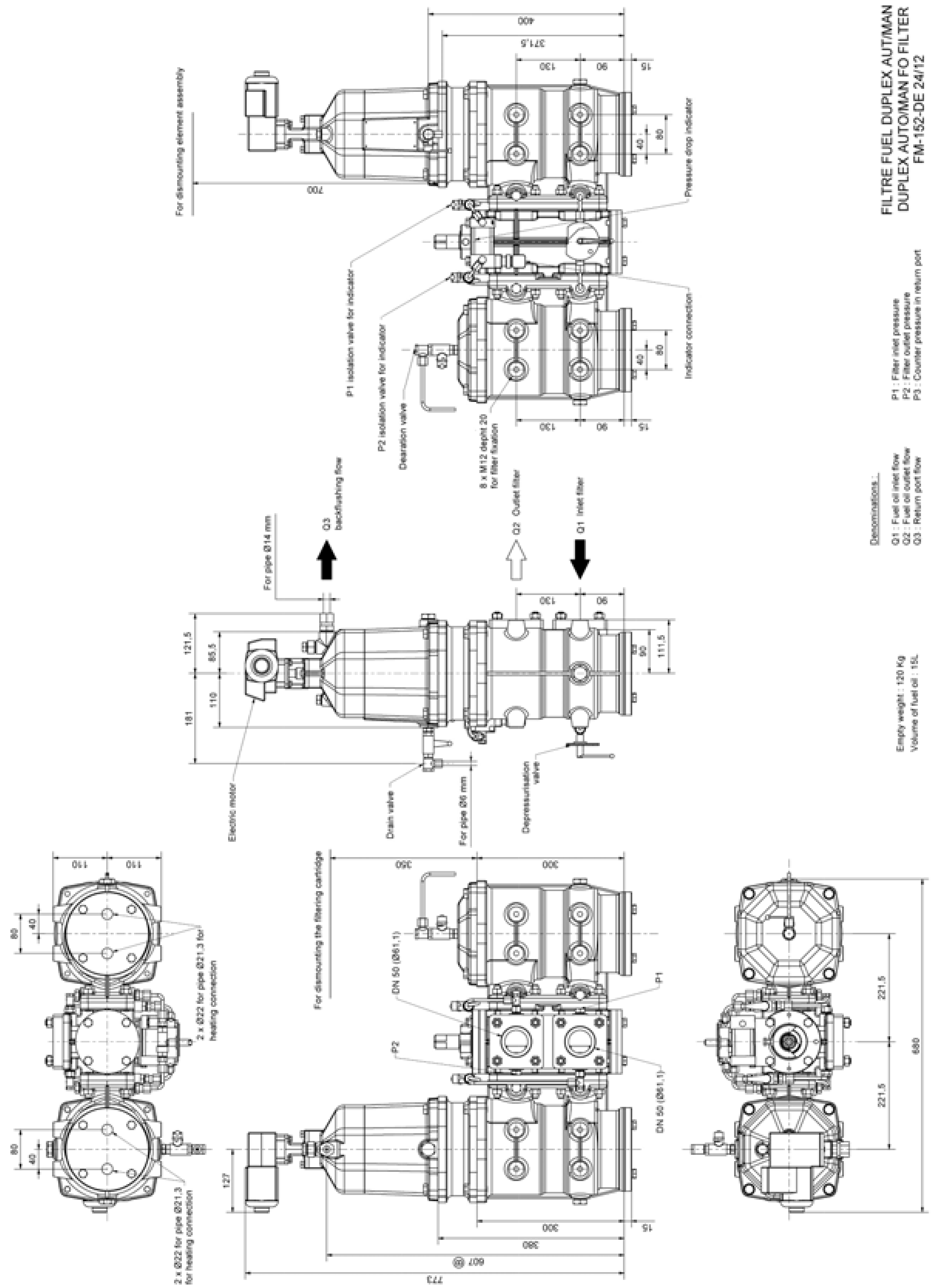

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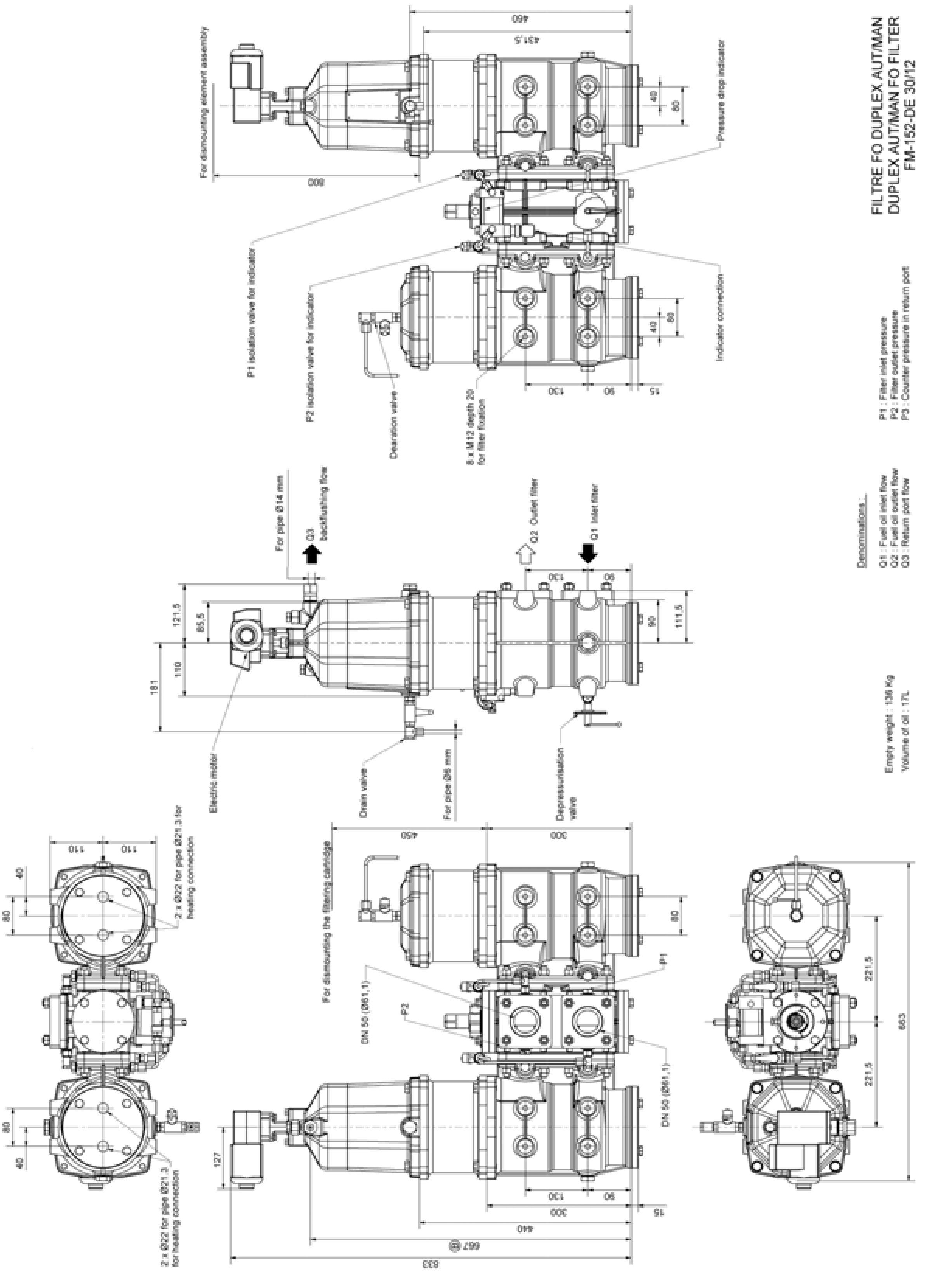
FM-152-DE 30/12



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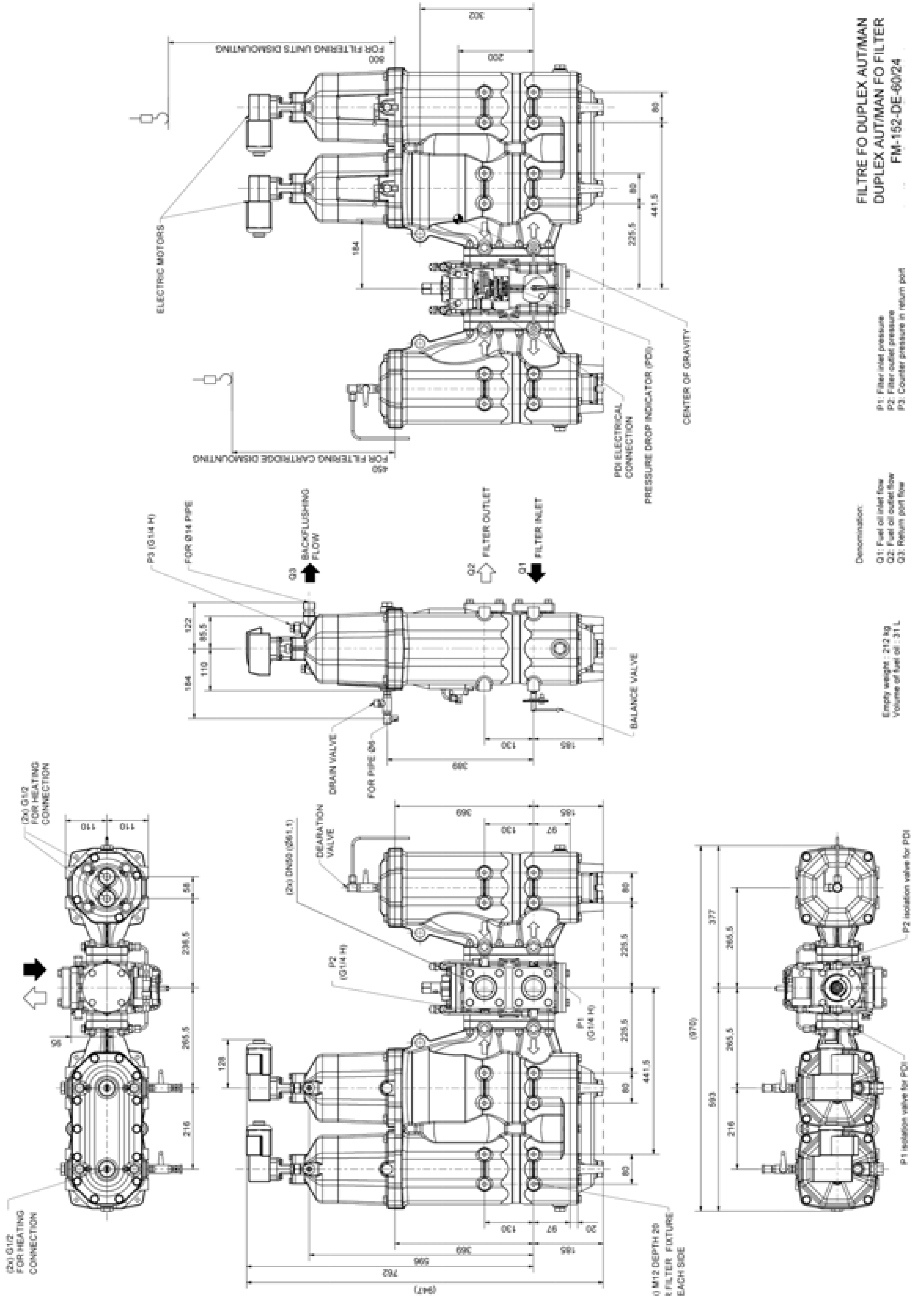

Internal lubricating oil system

Internal lubricating oil system

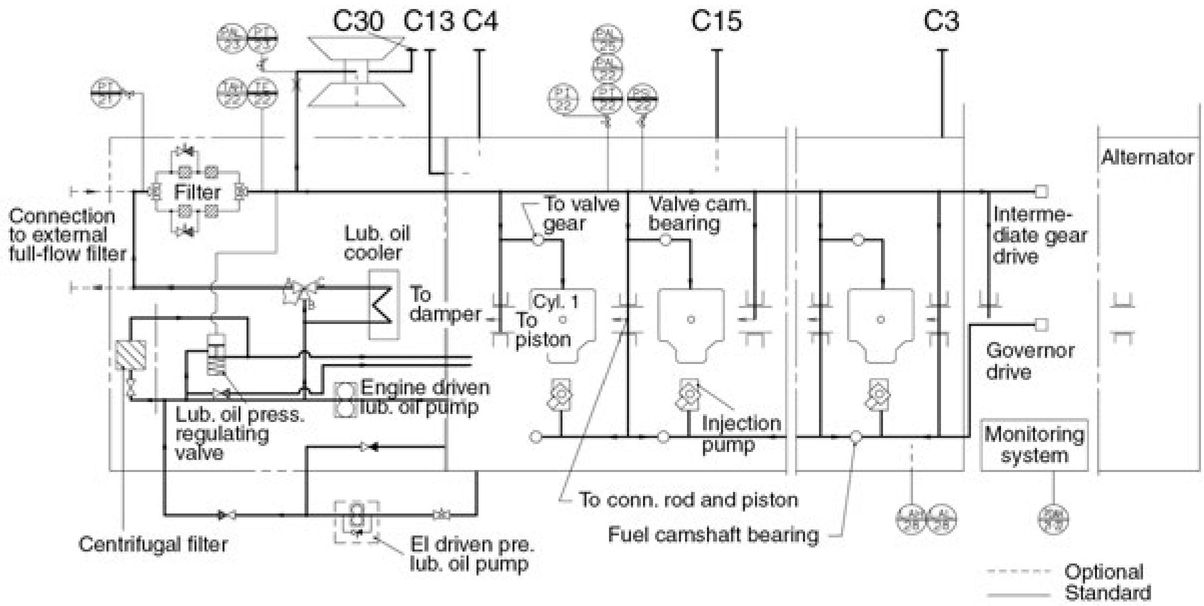

Figure 1: Diagram for internal lubricating oil system

Pipe description		
C3	Lubricating oil from separator	DN25
C4	Lubricating oil to separator	DN25
C13	Oil vapour discharge*	DN65
C15	Lubricating oil overflow	DN50
C30	Venting pipe turbocharger bearings	DN40

Table 1: Flange connections are as standard according to DIN 2501

* For external pipe connection, *please see Crankcase ventilation, B 12 00 0/515.31*.

General

As standard the lubricating oil system is based on wet sump lubrication.

All moving parts of the engine are lubricated with oil circulating under pressure in a closed system.

The lubricating oil is also used for the purpose of cooling the pistons and turbocharger.

The standard engine is equipped with:

- Engine driven lubricating oil pump
- Lubricating oil cooler
- Lubricating oil thermostatic valve
- Duplex full-flow depth filter
- Pre-lubricating oil pump

Oil quantities

The approximate quantities of oil necessary for a new engine, before starting up are given in the table, see "*B 12 01 1 / 504.06 / 604.06 Lubricating Oil in Base Frame*" (max. litre H3)

If there are connected external, full-flow filters etc., the quantity of oil in the external piping must also be taken into account.

Max. velocity recommendations for external lubricating oil pipes:

- Pump suction side	1.0 - 1.5 m/s
- Pump discharge side	1.5 - 2.0 m/s

Lubricating oil consumption

The lubricating oil consumption, see "*Specific lubricating oil consumption - SLOC, B 12 15 0 / 504.07*"

It should, however, be observed that during the running in period the lubricating oil consumption may exceed the values stated.

Quality of oil

Only HD lubricating oil (Detergent Lubricating Oil) should be used, characteristic stated in "*Lubricating Oil Specification, 010.000.023*".

System flow

The lubricating oil pump draws oil from the oil sump and presses the oil through the cooler and filter to the main lubricating oil bore, from where the oil is distributed to the various lubricating points. From the lubricating points the oil returns by gravity to the oil sump. The oil pressure is controlled by an adjustable spring-loaded relief valve built in the system.

The main groups of components to be lubricated are:

1. Turbocharger
2. Main bearings, big-end bearing etc.

3. Camshaft drive
4. Governor drive
5. Rocker arms
6. Camshaft

7. The turbocharger is an integrated part of the lubricating oil system, thus allowing continuous priming and lubrication when engine is running. For priming and during operation the turbocharger is connected to the lubricating oil circuit of the engine. The oil serves for bearing lubrication and also for dissipation of heat.

   The inlet line to the turbocharger is equipped with an orifice in order to adjust the oil flow.
8. Lubricating oil for the main bearings is supplied through holes in the engine frame. From the main bearings it passes through bores in the crankshaft to the connecting rod big-end bearings.

   The connecting rods have bored channels for supply of oil from the big-end bearings to the small-end bearings, which has an inner circumferential groove, and a bore for distribution of oil to the piston.

   From the front main bearings channels are bored in the crankshaft for lubricating of the damper.
9. The lubricating oil pipes for the camshaft drive gear wheels are equipped with nozzles which are adjusted to apply the oil at the points where the gear wheels are in mesh.
10. The lubricating oil pipe for the gear wheels are adjusted to apply the oil at the points where the gear wheels are in mesh.
11. The lubricating oil to the rocker arms is led through bores in the engine frame to each cylinder head. The oil continuous through bores in the cylinder head and rocker arm to the movable parts to be lubricated at the rocker arm and valve bridge.
12. Through a bores in the frame lubricating oil is led to camshafts bearings.

Lubricating oil pump

The lubricating oil pump, which is of the gear wheel type, is mounted on the front-end box of the engine and is driven by the crankshaft.

Lubricating oil cooler

As standard the lubricating oil cooler is of the plate type. The cooler is mounted on the front-end box.

Thermostatic valve

The thermostatic valve is a fully automatic three-way valve with thermostatic elements set of fixed temperature.

Built-on full-flow depth filter

The built-on lubricating oil filter is of the duplex paper cartridge type. It is a depth filter with a nominel fineness of 10-15 microns, and a safety filter with a fineness of 60 microns.

Centrifugal by-pass filter

As standard the engine is equipped with a centrifugal by-pass filter.

This filter removes contaminants through centrifugal force, and is used as an indicator on the correct use of the external separator units.

The cleaning intervals is according to "*Planned maintenance programme, see D 10 36 0 /500.25/500.26*". The sludge amount must be measured either by means of weight or thickness and noted for reference.

If the centrifugal by-pass filter is building up deposits quickly, it is a sign on that the external separator unit is working poorly.

Pre-lubricating

As standard the engine is equipped with an electric-driven pre-lubricating pump mounted parallel to the main pump. The pump is arranged for automatic operation, ensuring stand-still of the pre-lubricating pump when the engine is running, and running during engine stand-still in stand-by position by the engine control system.

Draining of the oil sump

It is recommended to use the separator suction pipe for draining of the lubricating oil sump.

Oil level switches

The oil level is automatically monitored by level switches giving alarm if the level is out of range.

Data

For heat dissipation and pump capacities, see *D 10 05 0* "*List of capacities*".

Operation levels for temperature and pressure are stated in *B 19 00 0* "*Operating Data and Set Points*".

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.

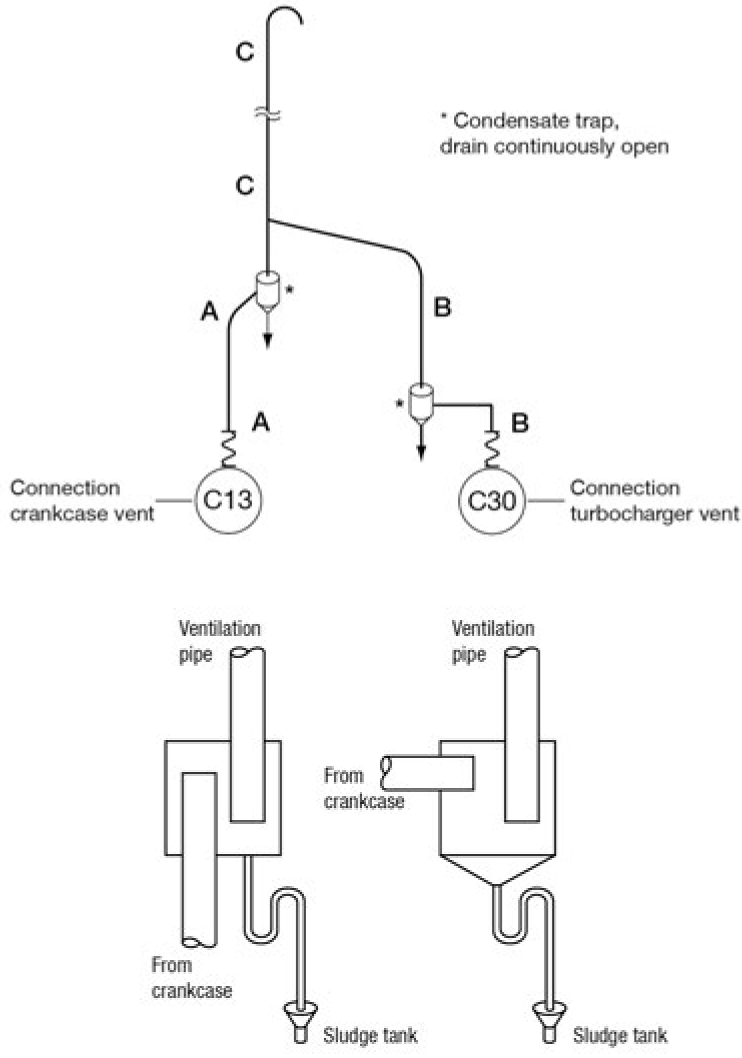

Figure 1: Crankcase ventilation

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.

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	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 [m³/h] at 100 % engine load.

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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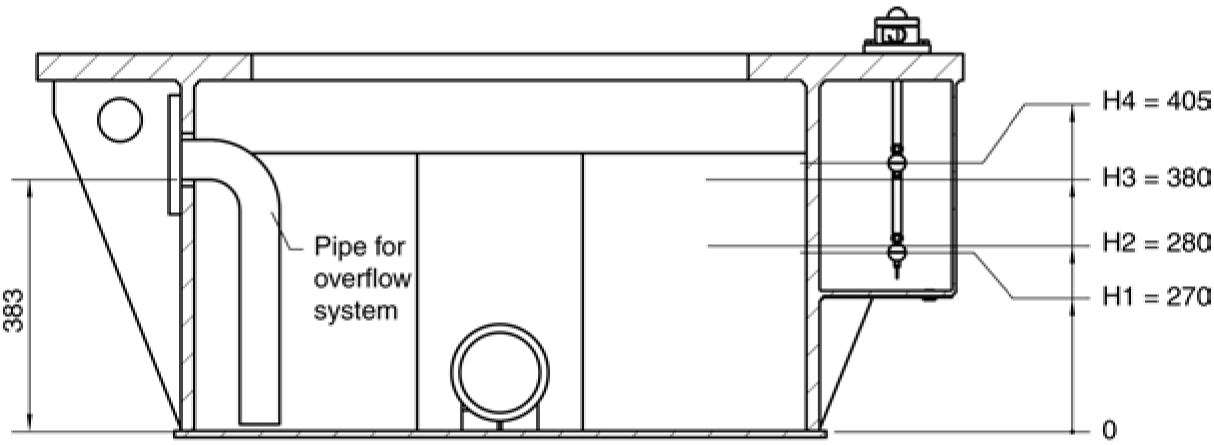
Lubricating oil in base frame

Lubricating oil in base frame



H1 = Min. level alarm point
H2 = Min. level dipstick
H3 = Max. level dipstick
H4 = Max. level alarm point

Type L21/31	5 cyl.	6 cyl.	7 cyl.	8 cyl.	9 cyl.
Min. litre (H2) in base frame	686	778	868	960	1050
Max. litre (H3) in base frame	931	1056	1178	1303	1425

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Prelubricating pump

General

The engine is as standard equipped with an electrically driven pump for prelubricating before starting.

The pump is self-priming.

The engine must always be prelubricated 2 minutes prior to start if the automatic continuous prelubricating has been switched off.

The automatic control of prelubricating must be made by the customer or can be ordered fra MAN Energy Solutions.

The voltage for the automatic control must be supplied from the emergency switchboard in order to secure post- and prelubrication in case of a critical situation. The engines can be restarted within 20 minutes after prelubrication has failed.

Engine type	No. of cyl.	Pump type	m^3/h	rpm	Electric motor 3x380 V, 50 Hz		
					kW	Start current Amp.	Full-load current Amp.
L16/24	5-6-7-8-9	Make: IMO Type: ACD025N6 NVBP	2.15	2755	0.55	6.0	1.3

Engine type	No. of cyl.	Pump type	m^3/h	rpm	Electric motor 230/400 V, 50 Hz		
					kW	Start current Amp.	Full-load current Amp.
L21/31	5-6-7-8-9	Make: Type: R35/40 FL-Z-DB-SO	6.9	2905	3.0	74.2	10.6
L27/38	5-6-7-8-9	Make: Type: R35/40 FL-Z-DB-SO	6.9	2905	3.0	74.2	10.6

Engine type	No. of cyl.	Pump type	m^3/h	rpm	Electric motor 3x440 V, 60 Hz		
					kW	Start current Amp.	Full-load current Amp.
L16/24	5-6-7-8-9	Make: IMO Type: ACD025N6 NVBP	2.57	3321	0.75	7.0	1.4

Engine type	No. of cyl.	Pump type	m^3/h	rpm	Electric motor 230/460 V, 60 Hz		
					kW	Start current Amp.	Full-load current Amp.
L21/31	5-6-7-8-9	Make: Type: R35/40 FL-Z-DB-SO	8.3	3505	3.45	42.7	6.1

Engine type	No. of cyl.	Pump type	m^3/h	rpm	Electric motor 230/460 V, 60 Hz		
					kW	Start current Amp.	Full-load current Amp.
L27/38	5-6-7-8-9	Make: Type: R35/40 FL-Z-DB-SO	8.3	3505	3.45	42.7	6.1

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 (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
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 MAN-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:

$$\text{SLOC [g/kWh]} = \frac{(\text{lubricating oil added - A1 - A2 [dm}^3]) \times \rho_{\text{lub oil}} \text{ [kg/m}^3]}{\text{run.hrs.period} \times P_{MCR} \text{ [kW]}}$$

In order to evaluate the correct engine SLOC, the following circumstances must be noticed and subtracted from the engine SLOC:

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:

$$\rho_{lub\ oil}\ [kg/m^3] = \rho_{lub\ oil\ @\ 15^\circ C}\ [kg/m^3] - 0.64 \times (t_{lub\ oil}\ [^\circ C] - 15)$$

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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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 MAN Energy Solutions 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.

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

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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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.

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.

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 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.

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 MAN Energy Solutions recommendation, on condition that the separator unit is operated according to MAN Energy Solutions 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 MAN Energy Solutions 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.

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.

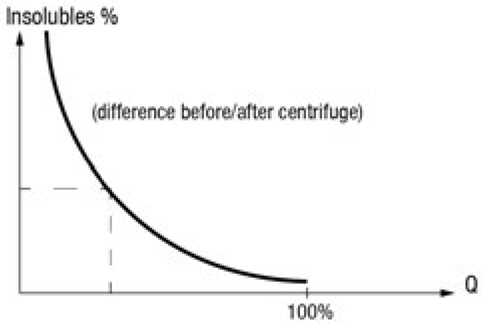

Figure 1: .

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).

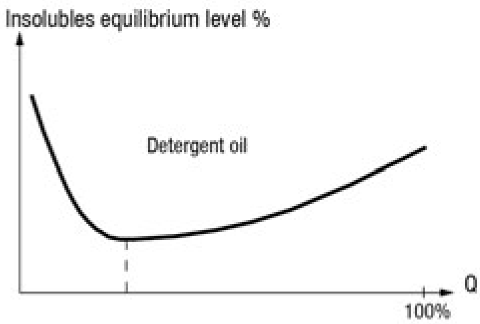

Figure 2: .

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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, MDT 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:

$$Q = \frac{1000 \times 1.36 \times 6}{23.5} = 347 \text{ l/h}$$

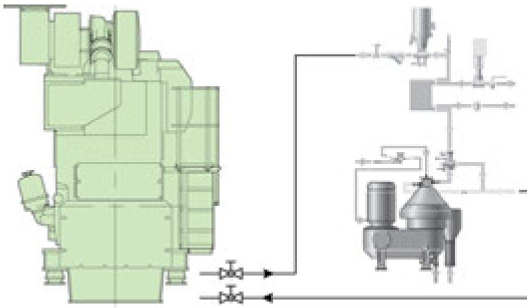


Figure 3: One separator per engine plant

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

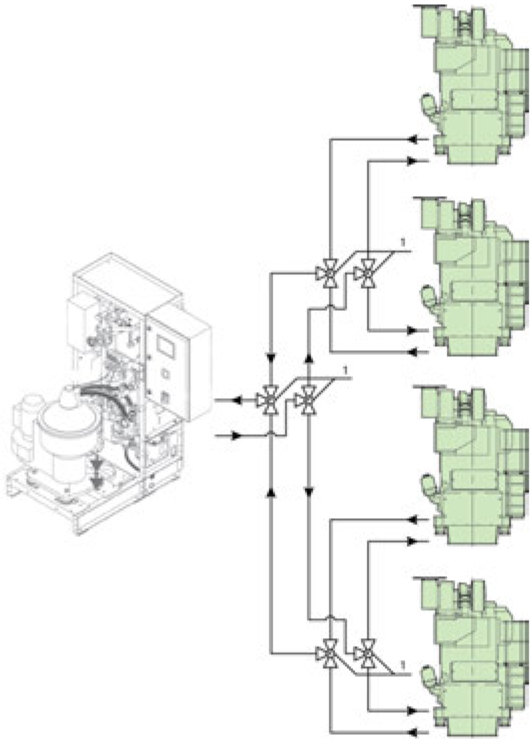
With multi-engine plants, one separator unit per engine in operation is recommended (*see figure 3*), but if only one separator unit is in operation, the following layout can be used:

- 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.



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.

$$V = \frac{d^2 (\rho_p - \rho_l)\, r\omega^2}{18\mu}$$

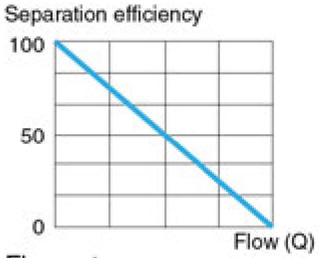
V	=	settling velocity [m/sec]
$r\omega^2$	=	acceleration in centrifugal field [m/sec^2]
d	=	diameter of particle [m]
ρ_p	=	density of particle [kg/m^3]
ρ_l	=	density of medium [kg/m^3]
μ	=	viscosity of medium [kg/m, sec.]

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.

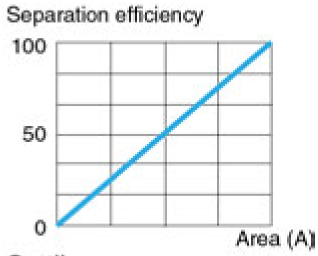
Density and viscosity are important parameters for efficient separation. The greater the difference in density between the particle and the lubricating oil, the higher the separation efficiency. The settling velocity increases in inverse proportion to viscosity. However, since both density and viscosity 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 centrifugal 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:

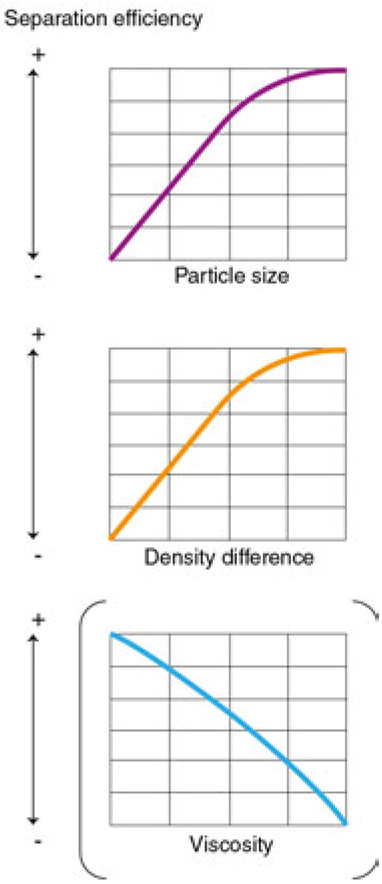


Flow rate



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.

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.

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.

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

General

The specific output achieved by modern diesel engines combined with the use of fuels that satisfy the quality requirements more and more frequently increase the demands on the performance of the lubricating oil which must therefore be carefully selected.

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 may be used.

The list of the currently approved lubricating oils is available at https://corporate.man-es.com/lubrication.

Specifications

Base oil

The base oil (doped lubricating oil = base oil + additives) must have a narrow distillation range and be refined using modern methods. If it contains paraffins, they must not impair the thermal stability or oxidation stability.

The base oil must comply with the limit values in the table below, particularly in terms of its resistance to ageing:

Properties/Characteristics	Unit	Test method	Limit value
Make-up	–	–	Ideally paraffin based
Low-temperature behaviour, still flowable	°C	ASTM D 2500	–15
Flash point (Cleveland)	°C	ASTM D 92	> 200
Ash content (oxidised ash)	Weight %	ASTM D 482	< 0.02
Coke residue (according to Conradson)	Weight %	ASTM D 189	< 0.50
Insoluble n-heptane	Weight %	ASTM D 4055 or DIN 51592	< 0.2
Evaporation loss	Weight %	-	< 2

Table 1: Target values for base oils

Medium alkalinity lubricating oil

The prepared oil (base oil with additives) must have the following properties:

Additives

The additives must be dissolved in oil and their composition must ensure that as little ash as possible is left over after combustion, even if the engine is provisionally operated with distillate fuel.

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

The ash must be soft. If this prerequisite is not met, it is likely the rate of deposition in the combustion chamber will be higher, particularly at the outlet valves and at the turbocharger inlet housing. Hard additive ash promotes pitting of the valve seats, and causes valve burn-out, it also increases mechanical wear of the cylinder liners.

Additives must not increase the rate, at which the filter elements in the active or used condition are blocked.

Washing ability

The washing ability must be high enough to prevent the accumulation of tar and coke residue as a result of fuel combustion. The lubricating oil must not absorb the deposits produced by the fuel.

Dispersion capability

The selected dispersibility must be such that commercially-available lubricating oil cleaning systems can remove harmful contaminants from the oil used, i.e. the oil must possess good filtering properties and separability.

Neutralisation capability

The neutralization capacity (DIN ISO 3771) must be high enough to neutralize the acidic products formed during combustion. The reaction time of the additives must be adapted to the process in the combustion chamber.

For tips on selecting the base number, refer to the table entitled Base number to be used for various operating conditions.

Evaporation tendency

The evaporation tendency must be as low as possible as otherwise the oil consumption will be adversely affected.

Additional requirements

The lubricating oil must not contain viscosity index improver. 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, 32/44, 35/44DF, 40/54, 45/60, 48/60, 58/64, 51/60DF	40

Table 2: 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 (MDO) 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, 32/44K, 40/54, 48/60 as well as 58/64 and 51/60DF operating with 100% HFO 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, 32/44K, 40/54, 48/60 as well as 58/64 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, 32/44K, 40/54, 48/60 and 58/64, 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 3: 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.

Cylinder lubricating oil

In engines with separate cylinder lubrication systems, the pistons and cylinder liners are supplied with lubricating oil via a separate lubricating oil pump. The quantity of lubricating oil is set at the factory according to the quality of the fuel to be used and the anticipated operating conditions.

Use a lubricating oil for the cylinder and lubricating circuit as specified above.

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.

Lube oil additives

It is not permissible to use any other additives in conjunction with the lube 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 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 table Limit values for used lube 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.

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

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

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 manufacturer 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 manufacturer 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 4: 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 PrimeServLab.

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

NOTICE

No liability assumed if these oils are used

does not assume liability for problems that occur when using these oils.

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

General

The specific output achieved by modern diesel engines combined with the use of fuels that satisfy the quality requirements more and more frequently increase the demands on the performance of the lubricating oil which must therefore be carefully selected.

Doped lubricating oils (HD oils) have a proven track record as lubricants for the drive, cylinder, turbocharger and also for cooling the piston. Doped 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 may be used. These are listed under https://corporate.man-es.com/lubrication.

Specifications

Base oil

The base oil (doped lubricating oil = base oil + additives) must have a narrow distillation range and be refined using modern methods. If it contains paraffins, they must not impair the thermal stability or oxidation stability.

The base oil must comply with the limit values below, particularly in terms of its resistance to ageing.

Properties/characteristics	Unit	Test method	Limit value
Structure	–	–	Preferably on paraffin basis
Cold behaviour, still fluid	°C	ASTM D2500	-15
Flash point (Cleveland)	°C	ASTM D92	> 200
Ash content (oxidised ash)	weight %	ASTM D482	< 0.02
Coke residue (according to Conradson)	weight %	ASTM D189	< 0.50
Insoluble n-heptane	weight %	ASTM D4055 or DIN 51592	< 0.2
Evaporation loss	weight %	-	< 2

Table 1: Target value for base oils

Doped lube oils (HD oils)

The base oil which has been mixed with additives (doped lube oil) must have the following properties:

Additives

The additives must be dissolved in the oil, and their composition must ensure that as little ash as possible remains after combustion.

The ash must be soft. If this prerequisite is not met, it is likely the rate of deposition in the combustion chamber will be higher, particularly at the outlet valves and at the turbocharger inlet housing. Hard additive ash promotes pitting of the valve seats, and causes valve burn-out, it also increases mechanical wear of the cylinder liners.

Additives must not increase the rate, at which the filter elements in the active or used condition are blocked.

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

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

Washing ability

The washing ability must be high enough to prevent the accumulation of tar and coke residue as a result of fuel combustion.

Dispersion capability

The selected dispersibility must be such that commercially-available lubricating oil cleaning systems can remove harmful contaminants from the oil used, i.e. the oil must possess good filtering properties and separability.

Neutralisation capability

The neutralization capacity (DIN ISO 3771) must be high enough to neutralize the acidic products formed during combustion. The reaction time of the additives must be adapted to the process in the combustion chamber.

Evaporation tendency

The evaporation tendency must be as low as possible as otherwise the oil consumption will be adversely affected.

Additional requirements

The lubricating oil must not contain viscosity index improver. 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, 32/44, 35/44DF, 40/54, 45/60, 48/60, 58/64, 51/60DF	40

Table 2: Viscosity (SAE class) of lubricating oils

Doped oil quality

Exclusively lube oils approved by must be used. Lube oils according to the military specification O-278 can be used if they are included in the current list of approved lube oils under https://corporate.man-es.com/lubrication.

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 sulfur 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.

Cylinder lubricating oil

In engines with separate cylinder lubrication systems, the pistons and cylinder liners are supplied with lubricating oil via a separate lubricating oil pump. The quantity of lubricating oil is set at the factory according to the quality of the fuel to be used and the anticipated operating conditions.

Use a lubricating oil for the cylinder and lubricating circuit as specified above.

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.

Lube oil additives

It is not permissible to use any other additives in conjunction with the lube 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 lube 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 lube 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 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 table Limit values for used lube 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 PrimeServLab.

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

⚠ WARNING

Handling of operating fluids

Handling of operating fluids can cause serious injury and damage to the environment.

- Observe safety data sheets of the operating fluid supplier.

The list of the currently approved lubricating oils is available at https://corporate.man-es.com/lubrication.

NOTICE

No liability assumed if these oils are used

does not assume liability for 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 the fresh oil	ISO 3771
Flash point (PM)	min. 185 °C	ISO 2719
Water content	max. 0.20 % (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	–

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

	Limit value	Procedure
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
For operation with bio-fuels: proportion of bio-fuel	max. 12 %	FT-IR

Table 3: Limit values for used lubricating oil

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

By-pass depth filter

General

The lube oil in a trunk diesel engine is constantly contaminated by combustion blow-by debris, and metal particles. The smaller combustion particles damage the oil and accelerate oil oxidation, thereby lead to decreased TBN, increased viscosity and finally lube oil change. However, most harmful to the engine parts are the solid 3 - 10 micron particles which cause wear, blockage, fatigue and polishing of cylinder liners, camshafts and journals/bearings. Effective removal of contaminants through an external bypass cleaning system will add further life to both engine and engine lube oil.

Bypass depth filters are easy to install and the depth filter insert has a very large dirt holding capacity. The bypass depth filters have low operational costs and are also almost maintenance free. All fine filter inserts have a 3 µm absolute filtration ratio and will remove particles, water and oil degradation products in one and the same operation.

The external bypass filter consists of a 3/0,8 (absolute/nominal) micron cellulose based depth filter, a filter supply pump and a frequency converter included in the control box The lube oil condition is maintained by filtering the oil through the external bypass depth filter continuously, when the engine is in operation as well as in standby. A certain ratio of lube oil circulation through the filter related to engine output(kW) and oil sump volume is necessary.
When oil temperature is low, a control system will automatically reduce the pump's rotation speed. This gives an approximately constant pressure drop over the filter inserts and thus optimum filter performance. Filter is equipped with patented back pressure system and continuous air by-pass
When filter inserts are nearly clogged a pre-warning will be present in the unit control display. When filter inserts are fully clogged the unit will shut down automatically and inserts needs replacement.

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Filter specification

Range of application	:	Diesel engine lube oils
Max. operating pressure	:	6 bar
Test pressure	:	According to class rule
Max. operating temperature	:	120°C
Nominal width of connection flanges	:	ISO 8434-1 / BSPP Thread
Filter to be replaced at a pressure drop	:	2.1 bar
Grade of filtration	:	3 µm absolute: 98.7% of all solid particles >3 µm 0.8 µm nominal: 50% of all solid particles > 0.8 µm are retained in each pass.

The dirt holding capacity of one A 27/27 insert is 4 litres of evenly distributed solids. Filter units for MAN engines according to these guidelines contain 4, 8, 12, 16 pcs filter inserts.

- Degradation Products
  Oxidation by-products, resin / sludge, and varnish are retained by the cellulose material. The cellulose will retain approx. 4 kg of degradation products.
- Water Removal
  The water absorption potential is up to 50% (i.e. 2000 mL H2O) of the total contaminant holding capacity.

NOTICE Regardless selection of filter solution will condition of lubrication oil in engine still have to be evaluated and need to fulfil requirement in descriptionB *12 15 0 "Criteria for cleaning/exchange of lubrication oil"*.

Figure 1: Clean and dirty filter insert

L16/24 - HFO operation

Cylinder [No.]	Engine power [kW]	Filter unit	Flow [l/h]
5 (1200/1000 rpm)	500/450	HDU 27/108	110
6 (1200/1000 rpm)	660/570	HDU 27/108	110
7 (1200/1000 rpm)	770/665	HDU 27/108	180
8 (1200/1000 rpm)	880/760	HDU 27/108	180
9 (1200/1000 rpm)	990/855	HDU 27/108	180

L16/24 - MDO/MGO operation (Exclusively)

Cylinder [No.]	Engine power [kW]	Filter unit	Flow [l/h]
5 (1200/1000)	500/450	HDU 27/108	110
6 (1200/1000)	660/570	HDU 27/108	110
7 (1200/1000)	770/665	HDU 27/108	110
8 (1200/1000)	880/760	HDU 27/108	110
9 (1200/1000)	990/855	HDU 27/108	110

L21/31 - HFO operation

Cylinder [No.]	Engine power [kW]	Filter unit	Flow [l/h]
5 (900/1000 rpm)	1000 kW	HDU 27/108	240
6 (900/1000 rpm)	1320 kW	HDU 27/108	300
7 (900/1000 rpm)	1540 kW	HDU 27/108	455
8 (900/1000 rpm)	1760 kW	HDU 27/108	455
9 (900/1000 rpm)	1980 kW	HDU 27/108	455

L21/31 - MDO/MGO operation (Exclusively)

Cylinder [No.]	Engine power [kW]	Filter unit	Flow [l/h]
5 (900/1000 rpm)	1000 kW	HDU 27/108	180
6 (900/1000 rpm)	1320 kW	HDU 27/108	180
7 (900/1000 rpm)	1540 kW	HDU 27/108	240
8 (900/1000 rpm)	1760 kW	HDU 27/108	300
9 (900/1000 rpm)	1980 kW	HDU 27/108	300

L27/38 - HFO operation

Cylinder [No.]	Engine power [kW]	Filter unit	Flow [l/h]
5 (720/750 rpm)	1500/1600	HDU 427/54	455
6 (720/750 rpm)	1980	HDU 427/81	455
7 (720/750 rpm)	2310	HDU 427/81	510
8 (720/750 rpm)	2640	HDU 427/108	710
9 (720/750 rpm)	2970	HDU 427/108	710

L27/38 - MDO/MGO operation (Exclusively)

Cylinder [No.]	Engine power [kW]	Filter unit	Flow [l/h]
5 (720/750 rpm)	1500/1600	HDU 27/108	240
6 (720/750 rpm)	1980/2100	HDU 27/108	300
7 (720/750 rpm)	2310/2450	HDU 27/108	455
8 (720/750 rpm)	2640/2800	HDU 27/108	455
9 (720/750 rpm)	2970/3150	HDU 27/108	455

L23/30H - Mk2 - HFO operation

Cylinder [No.]	Engine power [kW]	Filter unit	Flow [l/h]
5 (720/750 rpm)	535/525	HDU 27/108	145
5 (720/750 rpm)	650/675	HDU 27/108	145
5 (720/750 rpm)	710/740	HDU 27/108	145
6 (720/750 rpm)	852/888	HDU 27/108	240
6 (900 rpm)	1050	HDU 27/108	240
7 (720 rpm)	994	HDU 27/108	240
7 (750/900 rpm)	1036/1225	HDU 27/108	240
8 (720/750/900 rpm)	1136/1184/1400	HDU 27/108	300

L23/30H - Mk2 - MDO/MGO operation (Exclusively)

Cylinder [No.]	Engine power [kW]	Filter unit	Flow [l/h]
5 (720/750)	535/525	HDU 27/108	110
5 (720/750)	650/675	HDU 27/108	110
5 (720/750)	710/740	HDU 27/108	145
6 (720/750/900 rpm)	852/888/1050	HDU 27/108	145

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Cylinder [No.]	Engine power [kW]	Filter unit	Flow [l/h]
7 (720/750/900 rpm)	994/1036/1225	HDU 27/108	145
8 (720/750/900 rpm)	1136/1184/1400	HDU 27/108	145

L23/30H - Mk3 - HFO operation

Cylinder [No.]	Engine power [kW]	Filter unit	Flow [l/h]
5 (720 rpm)	500	HDU 27/108	145
5 (720/750 rpm)	850/885	HDU 27/108	240
6 (720/750 rpm)	1020/1062	HDU 27/108	240
7 (720/750 rpm)	1190/1239	HDU 27/108	240
8 (720/750 rpm)	1360/1416	HDU 27/108	300
9 (720/750 rpm)	1530/1593	HDU 27/108	300

L23/30H - Mk3 - MDO/MGO Operation

Cylinder [No.]	Engine power [kW]	Filter unit	Flow [l/h]
5 (720 rpm)	500	HDU 27/108	110
5 (720/750 rpm)	850/885	HDU 27/108	145
6 (720/750 rpm)	1020/1062	HDU 27/108	145
7 (720/750 rpm)	1190/1239	HDU 27/108	145
8 (720/750 rpm)	1360/1416	HDU 27/108	145
9 (720/750 rpm)	1530/1593	HDU 27/108	240

L28/32H - HFO operation

Cylinder [No.]	Engine power [kW]	Filter unit	Flow [l/h]
5 (720/750 rpm)	1050/1100	HDU 27/108	240
6 (720/750 rpm)	1260/1320	HDU 27/108	240
7 (720/750 rpm)	1470/1540	HDU 427/81	455
8 (720/750 rpm)	1680/1760	HDU 427/81	455
9 (720/750 rpm)	1890/1980	HDU 427/81	510

L28/32H - MDO/MGO operation (Exclusively)

Cylinder [No.]	Engine power [kW]	Filter unit	Flow [l/h]
5 (720/750 rpm)	1050/1100	HDU 27/108	180
6 (720/750 rpm)	1260/1320	HDU 27/108	240

Cylinder [No.]	Engine power [kW]	Filter unit	Flow [l/h]
7 (720/750 rpm)	1470/1540	HDU 27/108	240
8 (720/750 rpm)	1680/1760	HDU 27/108	300
9 (720/750 rpm)	1890/1980	HDU 27/108	300

L23/30DF - MDO/MGO operation

Cylinder [No.]	Engine power [kW]	Filter unit	Flow [l/h]
5 (720/750 rpm)	625/625	HDU 27/108	110
6 (720/750/900 rpm)	750/750/900	HDU 27/108	145
7 (720/750/900 rpm)	875/875/1050	HDU 27/108	145
8 (720/750/900 rpm)	1000/1000/1200	HDU 27/108	145

L28/32DF - MDO/MGO operation

Cylinder [No.]	Engine power [kW]	Filter unit	Flow [l/h]
5 (720/750 rpm)	1000	HDU 27/108	180
6 (720/750 rpm)	1200	HDU 27/108	180
7 (720/750 rpm)	1400	HDU 27/108	240
8 (720/750 rpm)	1600	HDU 27/108	240
9 (720/750 rpm)	1800	HDU 27/108	240

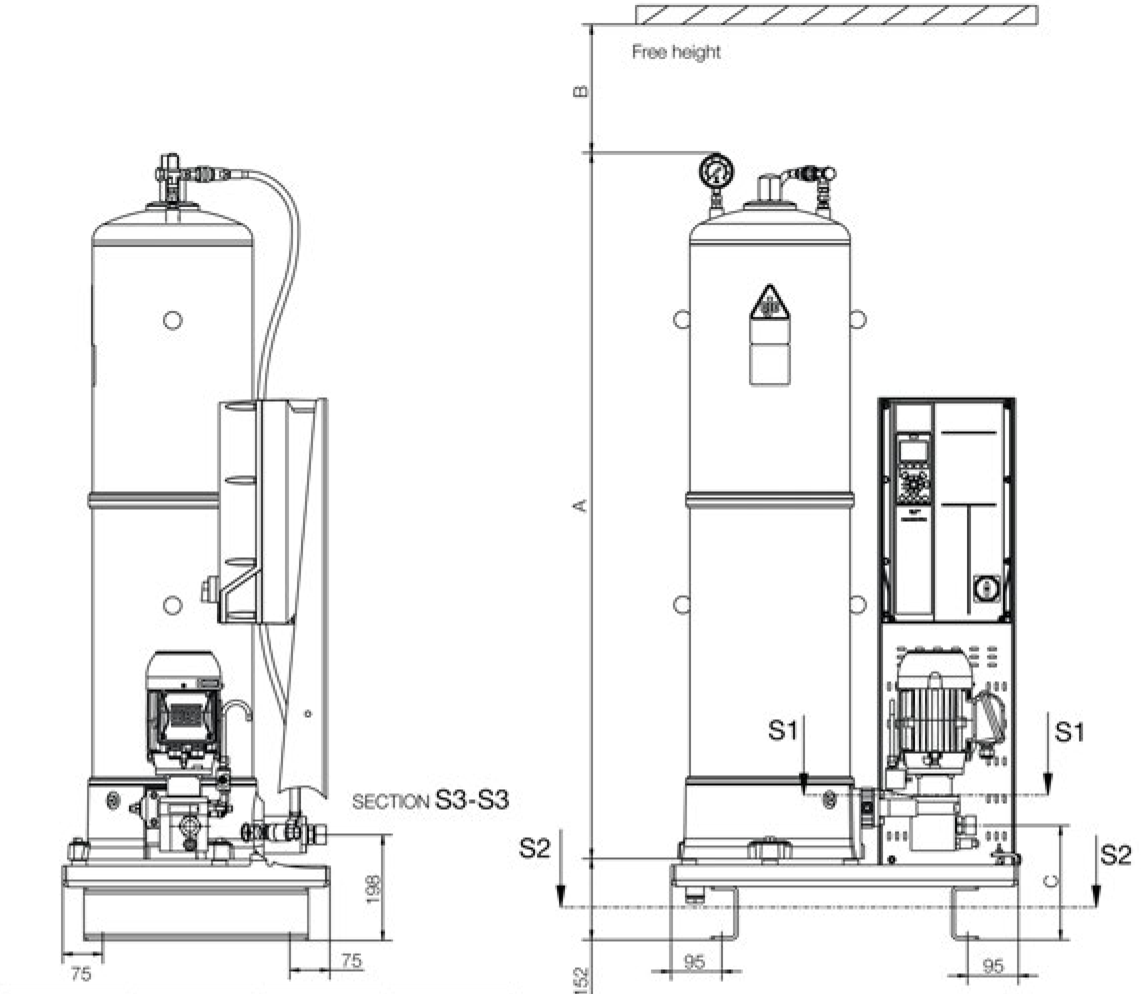
V28/32S - HFO Operation

Cylinder [No.]	Engine power [kW]	Filter unit	Flow [l/h]
16 (720/750 rpm)	3600/3760	HDU 427/108	940
18 (720/750 rpm)	4050/4230	HDU 427/108	940

V28/32S - MDO/MGO Operation (Exclusively)

Cylinder [No.]	Engine power [kW]	Filter unit	Flow [l/h]
16 (720/750 rpm)	3600/3760	HDU 427/108	510
18 (720/750 rpm)	4050/4230	HDU 427/108	510

HDU 27/108



A	B	C	D
1320	600	247	305
1320	600	247	305
1320	600	247	305
1320	600	247	305
1320	600	247	305
1320	600	214	262
1320	600	247	305
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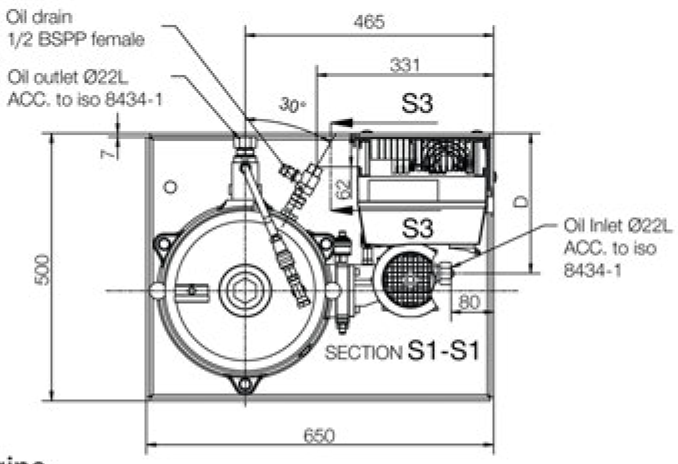
1320	600	247	305



Pipe Installation
Oil inlet: to be connected to C4 on engine.
Oil outlet: to be connected to C3 on engine.
Unit must be installed according to valid solas regulations.

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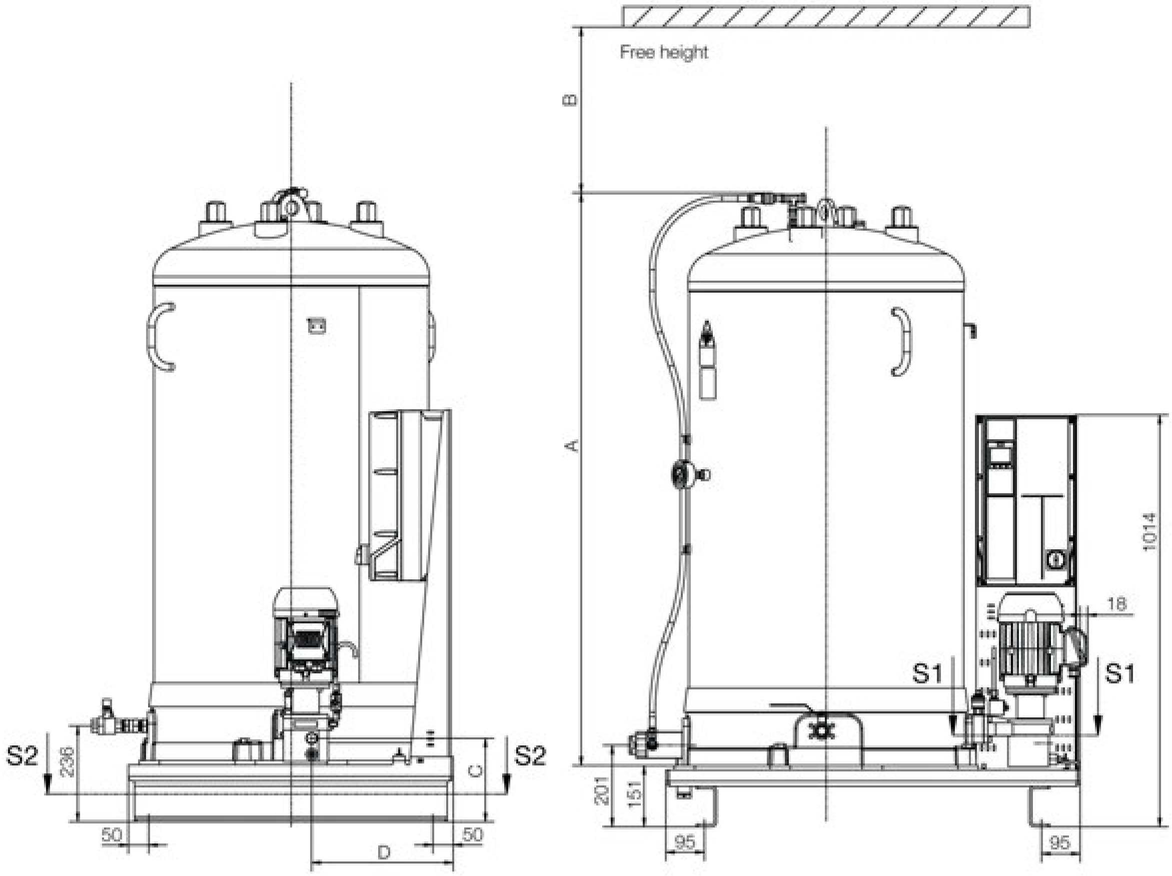
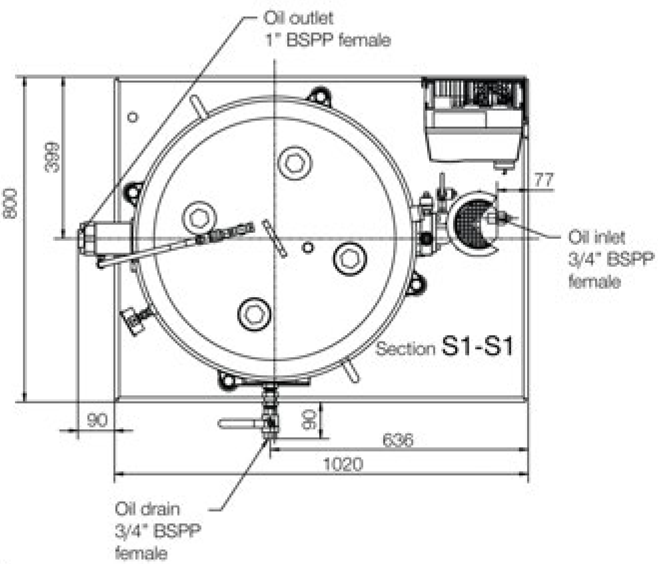
HDU 427/54-81-108





A	B	C	D
870	685	207	352
1140	950	207	352
1140	950	207	352
1410	855	207	352
1410	855	206	349
1410	855	207	352

Pipe Installation
Oil inlet: to be connected to C4 on engine.
Oil outlet: to be connected to C3 on engine.
Unit must be installed according to valid solas regulations.

Internal cooling water system

Internal cooling water system

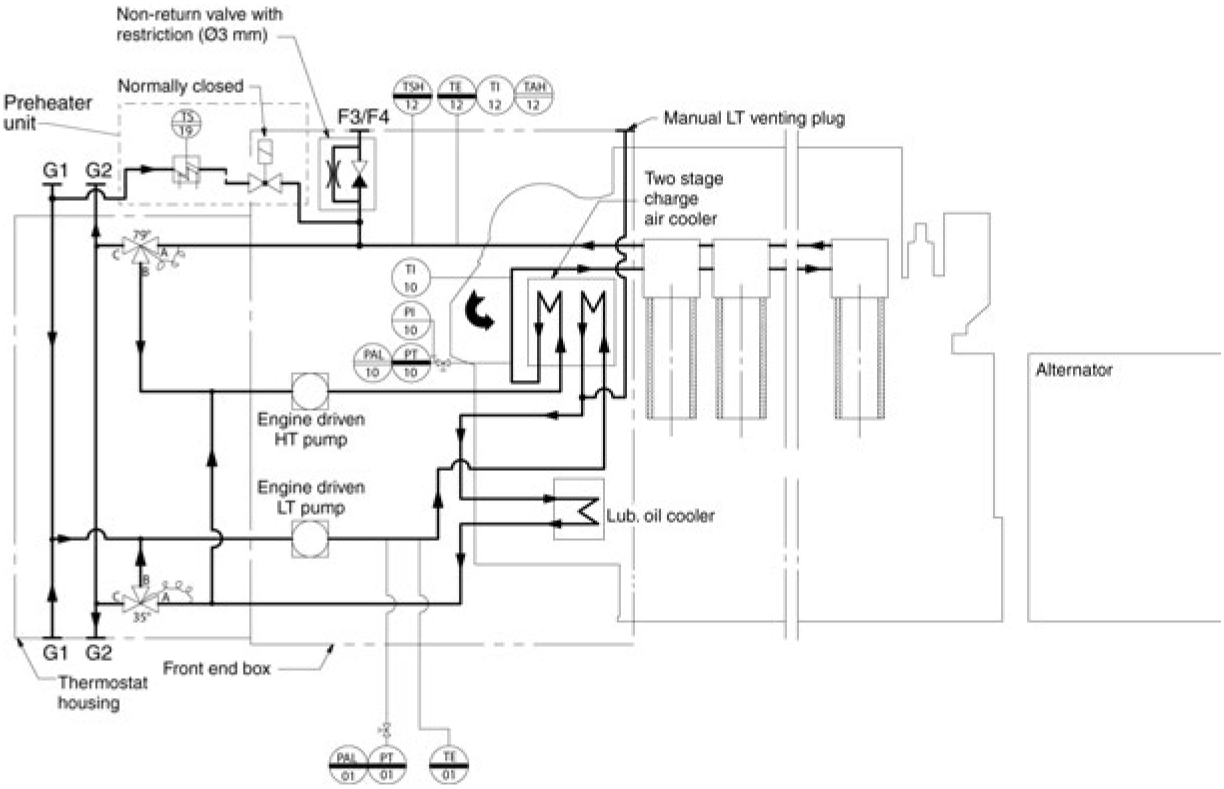


Figure 1: Diagram for internal cooling water system with internal preheater unit (for guidance only, please see the plant specific engine diagram)

Pipe description

F3	Venting to expansion tank	DN 25
F4	HT fresh water from preheater	DN 25
G1	LT fresh water inlet	DN 80
G2	LT fresh water outlet	DN 80

Table 1: Flange connections are standard according to DIN 2501

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Description

The system is designed as a single circuit with only two flange connections to the external centralized cooling water system.

The engine is equipped with a self-controlling temperature water circuit.Thus, the engine on the cooling water side only requires fresh water between 10 and 40°C and so the engine can be integrated in the ship's cooling water system as a stand-alone unit. This is a simple solution with low installation costs, which also can be interesting in case of repowering, where the engine power is increased, and the distance to the other engines is larger.

Low temperature circuit

The components for circulation and temperature regulation are placed in the internal system.

The charge air cooler and the lubricating oil cooler are situated in serial order. After the LT water has passed the lubricating oil cooler, it is let to the thermostatic valve and depending on the water temperature, the water will either be re-circulated or led to the external system.

High temperature circuit

The built-on engine-driven HT circulating pump of the centrifugal type pumps water through the first stage of the charge air cooler and then through the distributing bore to the bottom of the cooling water jacket. The water is led out through bores at the top of the cooling water jacket to the bore in the cylinder head for cooling of this, the exhaust valve seats and the injector valve.

From the cylinder heads the water is led through to the thermostatic valve, and depending on the engine load, a smaller or larger amount of the water will be led to the external system or will be re-circulated.

Data

For heat dissipation and pump capacities, see *D 10 05 0, "List of Capacities".*

Set points and operating levels for temperature and pressure are stated in *B 19 00 0, "Operating Data and Set Points".*

Other design data are stated in *B 13 00 0, "Design Data for the External Cooling Water System".*

Internal cooling water system

Internal cooling water system

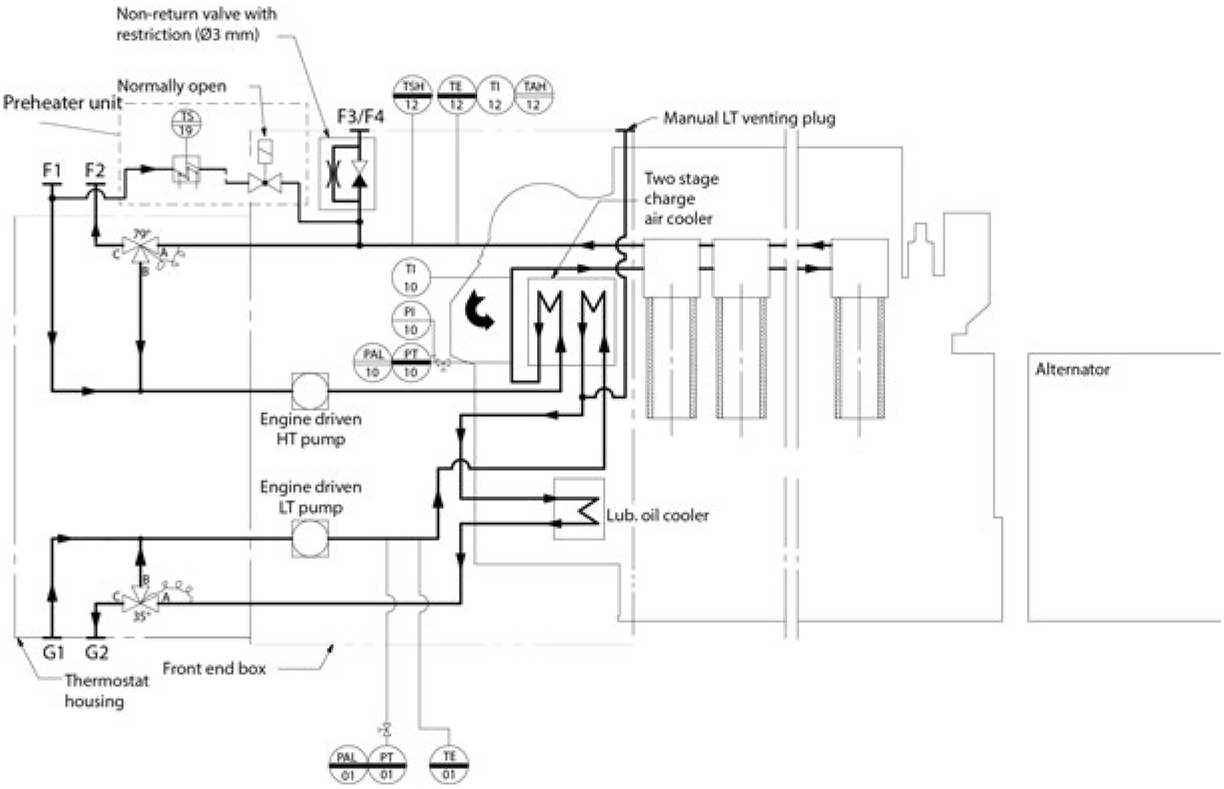

Figure 1: Diagram for internal cooling system with internal preheater unit (for guidance only, please see the plant specific engine diagram)

Pipe description

F1	HT fresh water inlet	DN 80
F2	HT fresh water outlet	DN 80
F3	Venting to expansion tank	DN 25
F4	HT fresh water for preheating	DN 25
G1	LT fresh water inlet	DN 80
G2	LT fresh water outlet	DN 80

Table 1: Flange connections are standard according to DIN 2501

Description

The system is designed as a two string circuit with four flange connections to the external centralized cooling water system.

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The engine is equipped with a self-controlling temperature water circuit. This is a simple solution with low installation costs, which also can be interesting in case of repowering.

Low temperature circuit

The components for circulation and temperature regulation are placed in the internal system.

The charge air cooler and the lubricating oil cooler are situated in serial order. After the LT water has passed the lubricating oil cooler, it is let to the thermostatic valve and depending on the water temperature, the water will either be re-circulated or led to the external system.

The engine on the cooling water side only requires fresh water between 10 and 40°C.

High temperature circuit

The built-on engine-driven HT-circulating pump of the centrifugal type pumps water through the first stage of the charge air cooler and then through the distributing bore to the bottom of the cooling water guide jacket. The water is led out through bores at the top of the cooling water guide jacket to the bore cooled cylinder head for cooling of this, the exhaust valve seats and the injector valve.

From the cylinder heads the water is led through an integrated collector to the thermostatic valve, and depending on the engine load, a smaller or larger amount of the water will be led to the external system or will be re-circulated.

Data

For heat dissipation and pump capacities, see *D 10 05 0, "List of Capacities".*

Set points and operating levels for temperature and pressure are stated in *B 19 00 0, "Operating Data and Set Points".*

Other design data are stated in *B 13 00 0, "Design Data for the External Cooling Water System".*

External cooling water system

Design of external cooling water system

It is not difficult to make a system fulfil the requirements, but to make the system both simple and cheap and still fulfil the requirements of both the engine builder and other parties involved can be very difficult. A simple version cannot be made without involving the engine builder.

The diagrams are principal diagrams, and are MAN ES recommendation for the design of external cooling water systems.

The systems are designed on the basis of the following criteria:

Simplicity.

Cooling water systems have a tendency to be unnecessarily complicated and thus uneconomic in installation and operation. Therefore, we have attached great importance to simple diagram design with optimal cooling of the engines and at the same time installation- and operation-friendly systems resulting in economic advantages.

Preheating with surplus heat.

It has been stressed on the diagrams that the GenSet in stand-by position as well as the propulsion engine in stop position are preheated, optimally and simply, with surplus heat from the running engines.

Preheating in engine top, downwards.

The engines are preheated with reverse cooling water direction, i.e. from the top and downwards, for optimal heat distribution is reached in the engine. This method is at the same time more economic since the need for heating is less and the water flow is reduced.

As few change-over valves as possible.

The systems have been designed in such a way that the change-over from sea operation to harbour operation/stand-by with preheating can be made with a minimum of manual or automatic interference.

Fresh water treatment

The engine cooling water is, like fuel oil and lubricating oil, a medium which must be carefully selected, treated, maintained and monitored.

Otherwise, corrosion, corrosion fatigue and cavitation may occur on the surfaces of the cooling system which are in contact with the water, and deposits may form.

Corrosion and cavitation may reduce the life time and safety factors of parts concerned, and deposits will impair the heat transfer and may result in thermal overload of the components to be cooled.

The treatment process of the cooling water has to be effected before the first commission of the plant, i.e. immediately after installation at the shipyard or at the power plant.

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Design data for the external cooling water system

General

This data sheet contains data regarding the necessary information for dimensioning of auxiliary machinery in the external cooling water system for the L21/31 type engine(s).The stated data are for one engine only and are specified at MCR.

The cooling water inlet pipe line has the function as preheating line during standstill.

Note: make sure that this pipe line always is open for this function.

For heat dissipation and pump capacities *see D 10 05 0 "List of Capacities".* Set points and operating levels for temperature and pressure are stated in *B 19 00 0 "Operating Data and Set Points".*

Cooling water pressure

Max. cooling water inlet pressure before engine is 2.5 bar.

External pipe velocitiy

For external pipe connections we prescribe the following maximum water velocity:

Fresh water : 3.0 m/s

Pressure drop across engine

The engines have an attached centrifugal pump for both LT and HT cooling water. The pressure drop across the engine's system is approximately 0.5 bar. Therefore the internal pressure drops are negligible for the cooling water pumps in the external system. For engines installed in closed cooling water systems, without any external cooling water pumps, the pressure drop in the external system should not exceed 1.0 bar.

Expansion tank

To provide against volume changes in the closed jacket water cooling system caused by changes in temperature or leakage, an expansion tank must be installed.

As the expansion tank also provides a certain suction head for the fresh water pump to prevent cavitation, the lowest water level in the tank should be minimum 8-10 m above the center line of the crankshaft.

The venting pipe must be made with continuous upward slope of minimum 5°, even when the ship heel or trim (static inclination).

The venting pipe must be connected to the expansion tank below the minimum water level; this prevents oxydation of the cooling water caused by "splashing" from the venting pipe. The expansion tank should be equipped with venting pipe and flange for filling of water and inhibitors.

Minimum recommended tank volume: 0.1 m³.
For multi plants the tank volume should be min.:

V = 0.1 + (exp. vol. per extra eng.) [m^3]

On engines equipped with 1-string cooling water system, the LT system is vented via the HT system. This means that both systems are connected to the same expansion tank.

On engines equipped with 2-string cooling water system, separate expansion tanks for the LT system and HT system must be installed. This to accommodate for changes of volume due to varying temperatures and possible leakage in the LT system and/or the HT system. The separated HT system and LT system facilitates trouble shooting.

Data for external preheating system

The capacity of the external preheater should be 2.5-3.0 kW/cyl. The flow through the engine should for each cylinder be approx. 4.0 l/min with flow from top and downwards and 25 l/min with flow from bottom and upwards. See also table 1 below.

Cyl. No	**5**	**6**	**7**	**8**	**9**
Quantity of water in eng: HT and LT system (litre)	110	130	150	170	190
Expansion vol. (litre)	6	7	8	9	10

Table 1: Showing cooling water data which are depending on the number of cylinders.

Expansion tank

General

To provide for changes in volume in the closed jacket water cooling system caused by changes in temperature or leakage, an expansion tank must be installed.

As the expansion tank also should provide a certain suction head for the fresh water pump to prevent cavitation, the lowest water level in the tank should be minimum 8-10 m above the centerline of the crankshaft.

The venting pipe must be connected to the expansion tank below the minimum water level; this prevents oxydation of the cooling water caused by "splashing" from the venting pipe. The expansion tank should be equipped with venting pipe and flange for filling of water and inhibitors.

Volume

Engine type	Cyl. qty.	Expansion volume litre*	Recommended tank volume m^3**
L23/30	5 cyl. engine 6 cyl. engine 7 cyl. engine 8 cyl engine 9 cyl engine	11 13 15 17 -	0.1 0.1 0.1 0.1 -
L28/32	5 cyl. engine 6 cyl. engine 7 cyl. engine 8 cyl engine 9 cyl engine	28 33 39 44 50	0.15 0.15 0.15 0.15 0.15
V28/32	12 cyl. engine 16 cyl. engine 18 cyl. engine	66 88 99	0.3 0.3 0.3
L16/24	5 cyl. engine 6 cyl. engine 7 cyl. engine 8 cyl engine 9 cyl engine	4 5 5 5 6	0.1 0.1 0.1 0.1 0.1
L21/31	5 cyl. engine 6 cyl. engine 7 cyl. engine 8 cyl engine 9 cyl engine	6 7 8 9 10	0.1 0.1 0.1 0.1 0.1
L27/38	5 cyl. engine 6 cyl. engine 7 cyl. engine 8 cyl engine 9 cyl engine	10 12 13 15 20	0.15 0.15 0.15 0.15 0.15

Engine type	Cyl. qty.	Expansion volume litre*	Recommended tank volume m^3**
* Per engine ** Common expansion tank			

Table 1: Expansion volume for cooling water system and recommended volume of expansion tank.

1 string central cooling water system

1 string central cooling water system

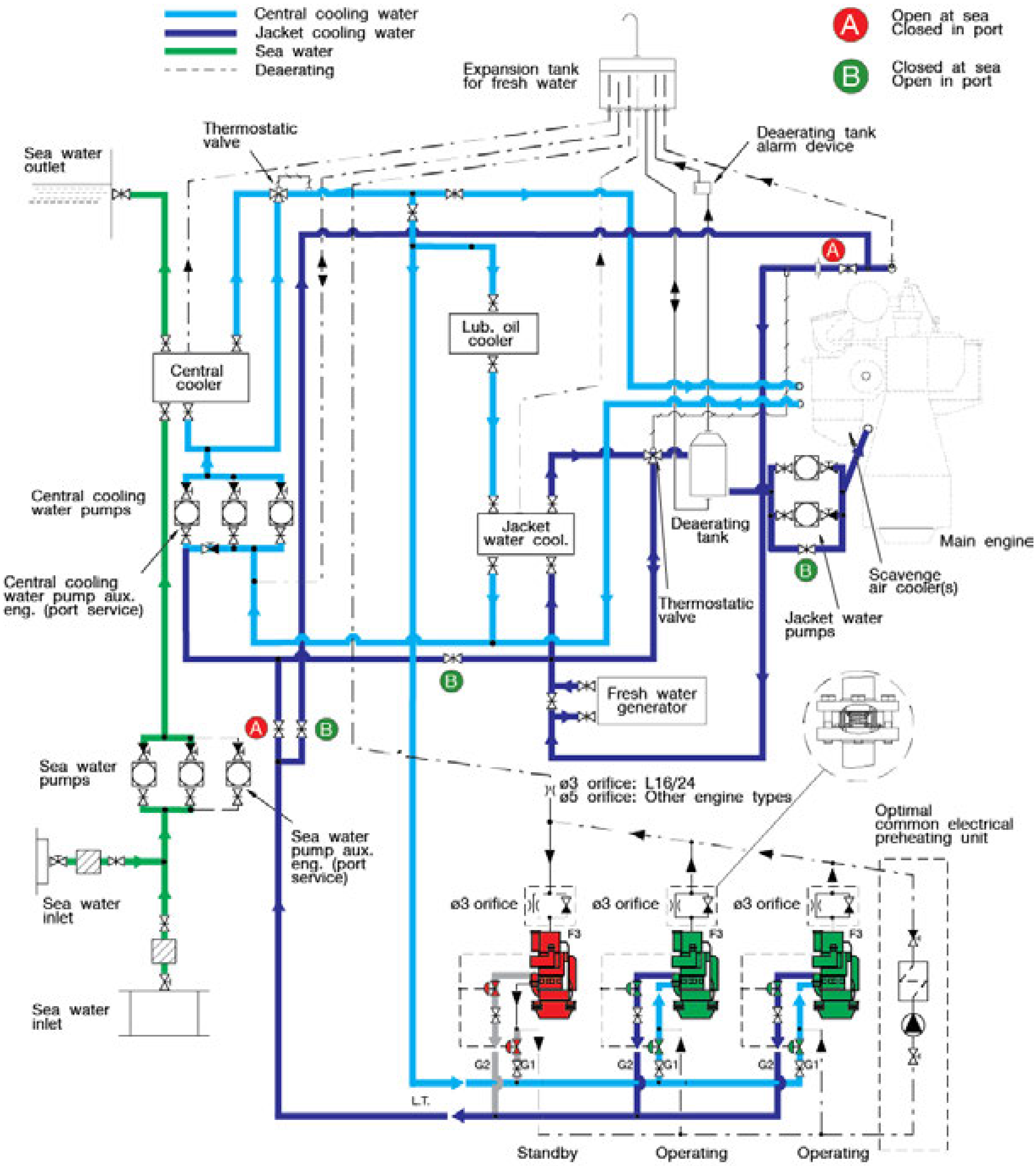

Figure 1: Central cooling system.

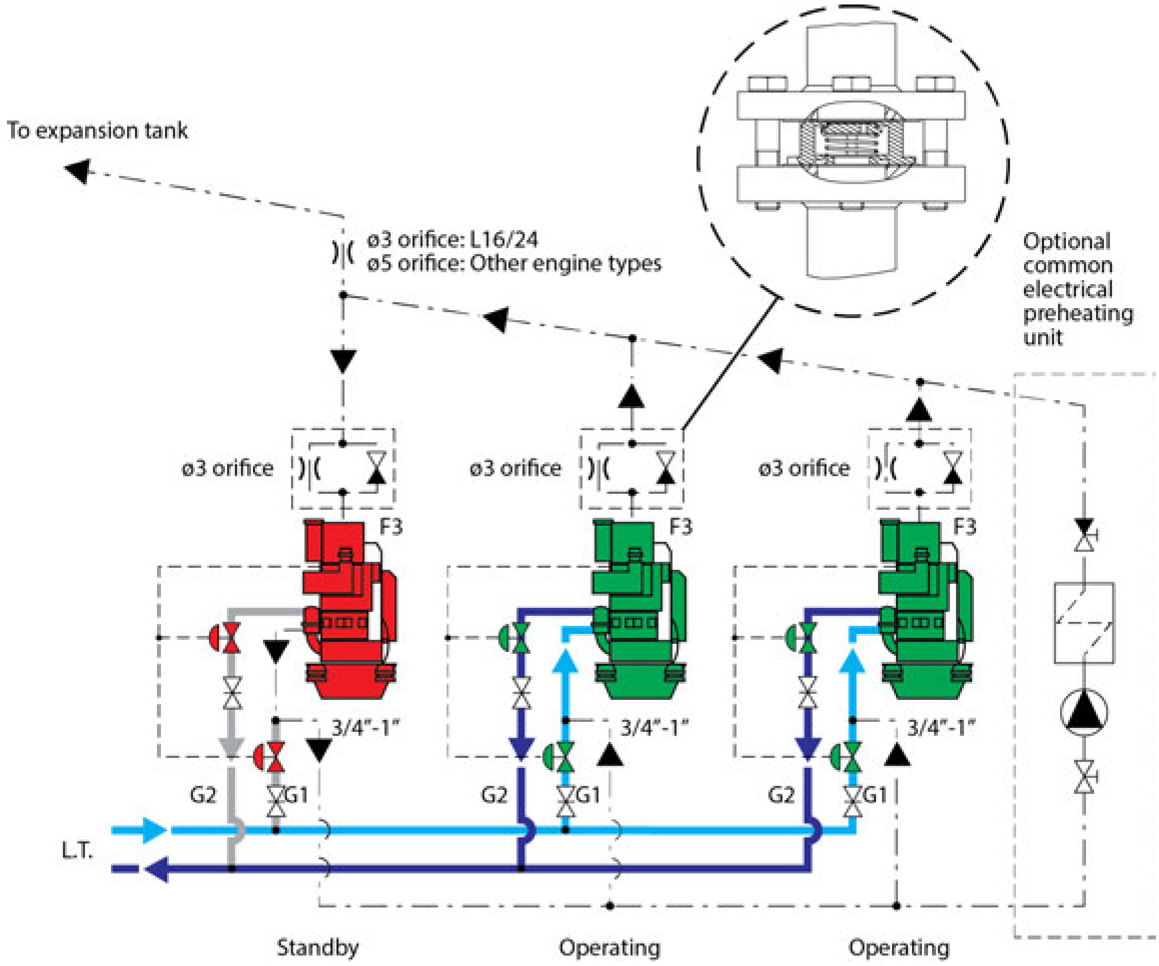

Figure 2: Preheating.

System design

The system is a central cooling water system of simple design with only one central cooler. In order to minimize the power consumption the FW pump installation consists of 3 pumps, two for sea operation and a smaller one for harbour operation.

The GenSets are connected as a one-string plant, with only one inlet and one outlet cooling water connection and with internal HT- and LT-circuit, *see also B 13 00 0 "Internal Cooling Water System 1"*, describing this system.

Preheating

Engines starting on HFO and engines in stand-by position must be preheated. It is also recommended to preheat engines operating on MDO due to the prolonged life time of the engines' wearing parts. Therefore it is recommended that the preheating is arranged for automatic operation, so that the preheating is disconnected when the engine is running, and connected when the engine is in stand-by position. The preheating is adjusted so that the temperature is ≥ 60°C at the top cover (see thermometer TI12), and approximately 25 to 45°C at outlet of the cylinders (see thermometer TI10).

When working out the external cooling water system it must be ensured, that no cold cooling water is pressed through the engine and thus spoiling the preheating during stand-by. The diesel engine has no built-in shut-off valve in the cooling water system. Therefore the designer of the external cooling water system must make sure that the preheating of the GenSets is not disturbed.

Preheating of stand-by auxiliary engines during sea operation

Auxiliary engines in stand-by position are preheated via the venting pipe (F3), leading to the expansion tank, with HT water from the operating auxiliary engines.

During preheating the non-return valve on the preheated auxiliary engine will open due to the pressure difference. The HT pumps on the operating auxiliary engines will force the HT water downwards, through the stand-by auxiliary engine, out of the (F1) HT inlet and back to the operating auxiliary engines, via the bypass manifold which interconnect all the (F1) HT inlet lines.

The on/off valve can be controlled by "engine run" signal or activated by lub. oil pressure. MAN can deliver valves suitable for purpose.

Please note that preheating pipe mounted *before* on/off valve (size 3/4"-1" for guidance) connected to either preheat unit (optional) or directly to expansion tank pipe. This will deliver preheating water to stand-by engine via (F3).

The non-return valve in the venting pipe (F3) is closed when the auxiliary engine is operating, and deaerating to the expansion tank flows through the small ø3 bore in the non-return valve disc.

The small ø3 bore in the non-return valve disc will also enable the auxiliary engine to keep the recommended cooling water temperature in the HT-system during low load operation which is essential for the combustion of HFO.

Preheating of stand-by auxiliary engines and propulsion engines during harbour operation

The propulsion engine is preheated by utilizing hot water from the auxiliary engines.

Depending on the size of propulsion engine and auxiliary engines an extra preheater may be necessary. This preheating is activated by closing valve A and opening valve B.

Activating valves A and B will change the direction of flow, and the water will now be circulated by the auxiliary engine driven pumps. From the auxiliary engines the water flows through valve B directly to the propulsion engine jacket outlet. When the water leaves the propulsion engine, through the jacket inlet, it flows to the thermostatically controlled 3-way valve.

As the temperature sensor for the thermostatically controlled 3-way valve, in this operating mode, is measuring in a non-flow, low temperature piping, the valve will lead most of the cooling water through the common thermostatically controlled 3-way valve, serving the auxiliary engines, and back to their common HT inlet line. The integrated loop in the auxiliary engines will ensure a constant temperature of approximately 80°C at the auxiliary engine outlet. The propulsion engine will be preheated, and the auxiliary engines in stand-by can also be preheated as described in the above mentioned section.

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1.5 string central cooling water system

1.5 string central cooling water system

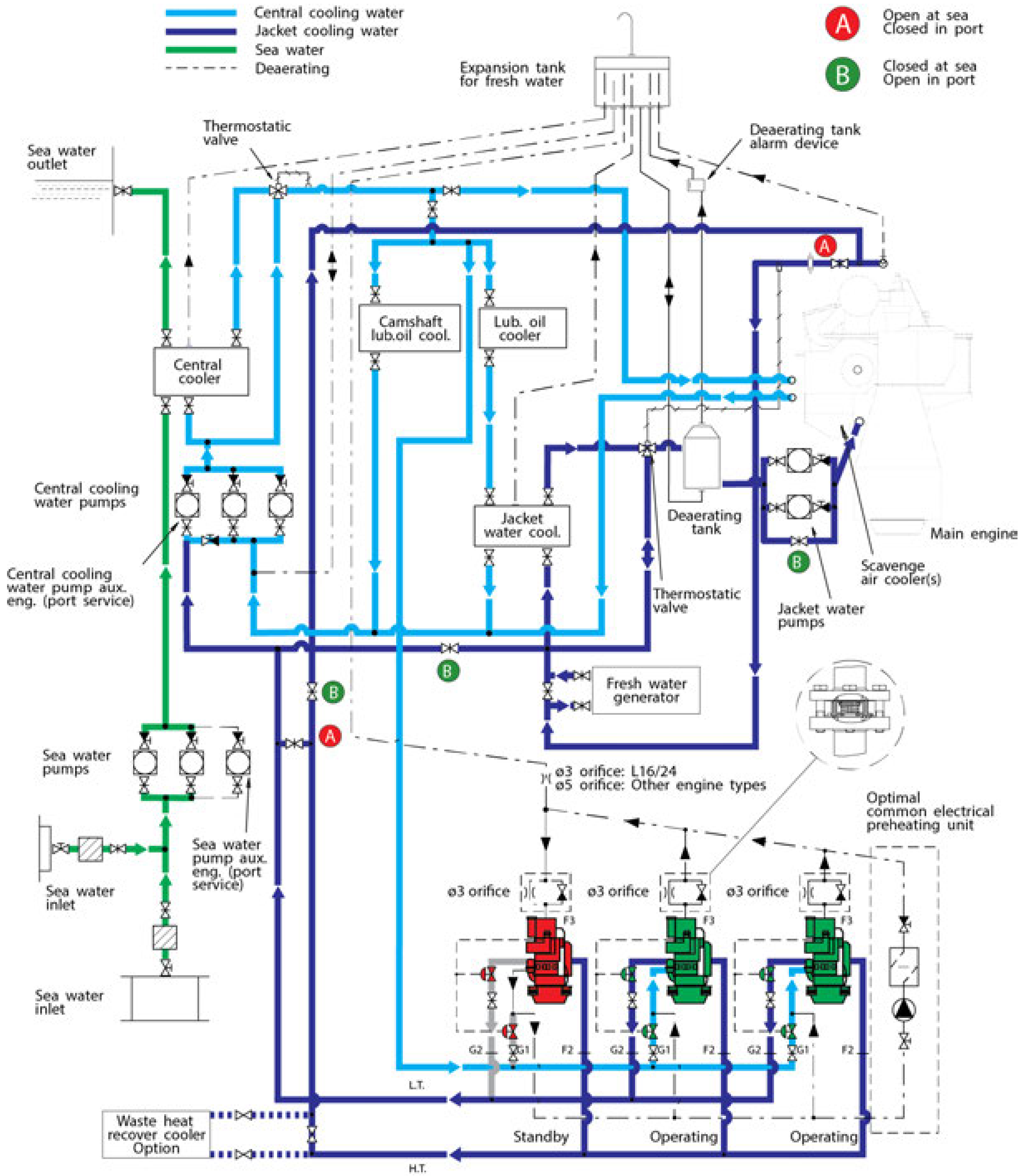

Figure 1: Central cooling system

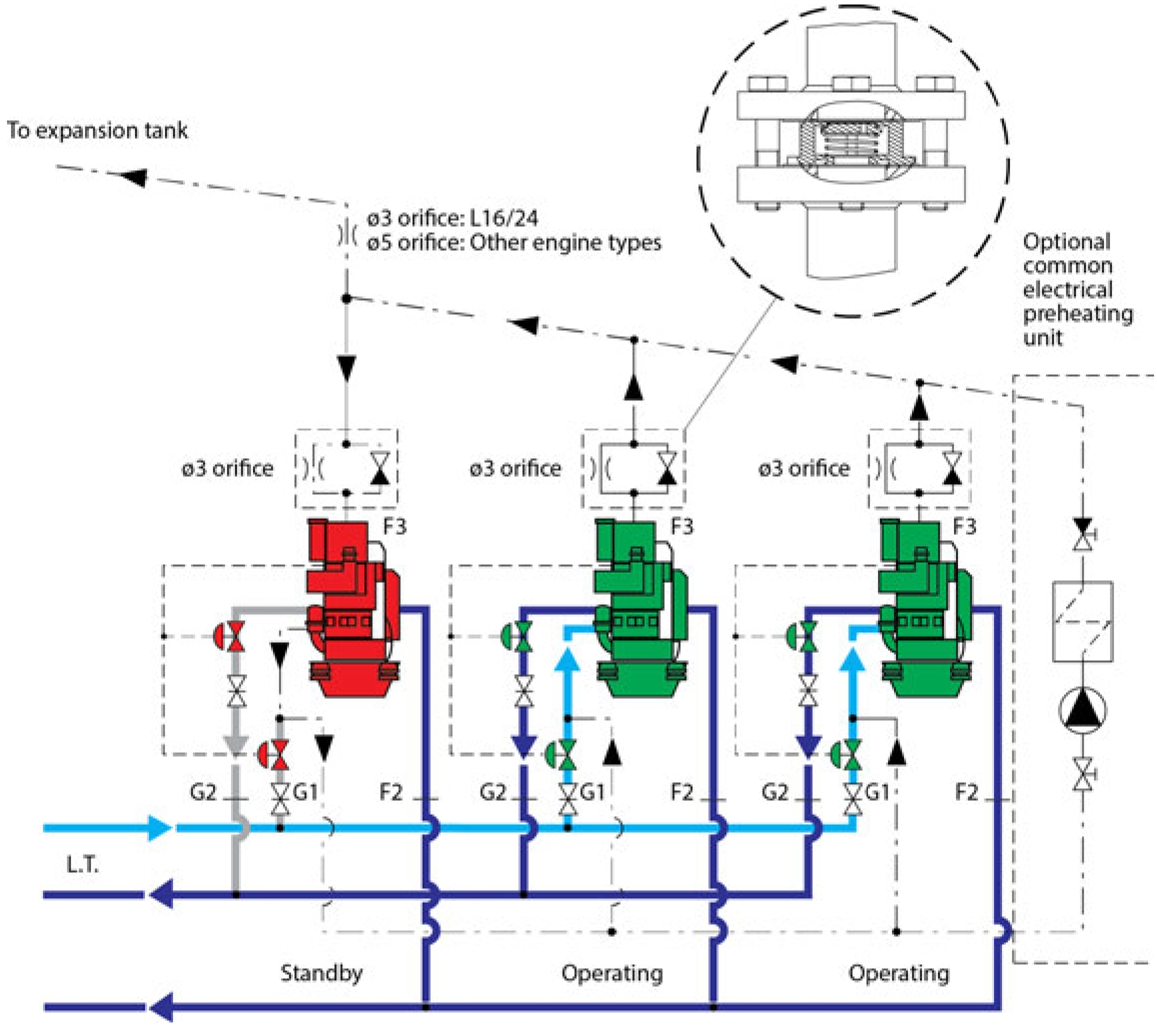

Figure 2: Preheating

System design

The system is a central cooling water system of simple design with only one central cooler. In order to minimize the power consumption the FW pump installation consists of 3 pumps, two for sea operation and a smaller one for harbour operation.

The GenSets are connected as a one-string system, but with an extra connection for the available heating capacity in H.T. system (waste heat recovery) for fresh water production, tank heating etc.

The propulsion engines' HT-circuit temperature is adjusted with LT-water mixing by means of the thermostatic valve.

Preheating

Engines starting on HFO and engines in stand-by position must be preheated. It is also recommended to preheat engines operating on MDO due to the prolonged life time of the engines' wearing parts. Therefore it is recommended that the preheating is arranged for automatic operation, so that the preheating is disconnected when the engine is running, and connected when the engine is in stand-by position. The preheating is adjusted so that the temperature is ≥ 60°C at the top cover (see thermometer TI12), and approximately 25 to 45°C at outlet of the cylinders (see thermometer TI10).

When working out the external cooling water system it must be ensured, that no cold cooling water is pressed through the engine and thus spoiling the preheating during stand-by. The diesel engine has no built-in shut-off valve in the cooling water system. Therefore the designer of the external cooling water system must make sure that the preheating of the GenSets is not disturbed.

Preheating of stand-by auxiliary engines during sea operation

Auxiliary engines in stand-by position are preheated via the venting pipe (F3), leading to the expansion tank, with HT water from the operating auxiliary engines.

During preheating the non-return valve on the preheated auxiliary engine will open due to the pressure difference. The HT pumps on the operating auxiliary engines will force the HT water downwards, through the stand-by auxiliary engine, out of the (F1) HT inlet and back to the operating auxiliary engines, via the bypass manifold which interconnect all the (F1) HT inlet lines.

The on/off valve can be controlled by "engine run" signal or activated by lub. oil pressure. MAN can deliver valves suitable for purpose.

Please note that preheating pipe mounted *before* on/off valve (size 3/4"-1" for guidance) connected to either preheat unit (optional) or directly to expansion tank pipe. This will deliver preheating water to stand-by engine via (F3).

The non-return valve in the venting pipe (F3) is closed when the auxiliary engine is operating, and deaerating to the expansion tank flows through the small ø3 bore in the non-return valve disc.

The small ø3 bore in the non-return valve disc will also enable the auxiliary engine to keep the recommended cooling water temperature in the HT-system during low load operation which is essential for the combustion of HFO.

Preheating of stand-by auxiliary engines and propulsion engines during harbour operation

The propulsion engine is preheated by utilizing hot water from the auxiliary engines.

Depending on the size of propulsion engine and auxiliary engines an extra preheater may be necessary. This preheating is activated by closing valve A and opening valve B.

Activating valves A and B will change the direction of flow, and the water will now be circulated by the auxiliary engine driven pumps. From the auxiliary engines the water flows through valve B directly to the propulsion engine jacket outlet. When the water leaves the propulsion engine, through the jacket inlet, it flows to the thermostatically controlled 3-way valve.

As the temperature sensor for the thermostatically controlled 3-way valve, in this operating mode, is measuring in a non-flow, low temperature piping, the valve will lead most of the cooling water through the common thermostatically controlled 3-way valve, serving the auxiliary engines, and back to their common HT inlet line. The integrated loop in the auxiliary engines will ensure a constant temperature of approximately 80°C at the auxiliary engine outlet. The propulsion engine will be preheated, and the auxiliary engines in stand-by can also be preheated as described in the above mentioned section.

2 string central cooling water system

2 string central cooling water system

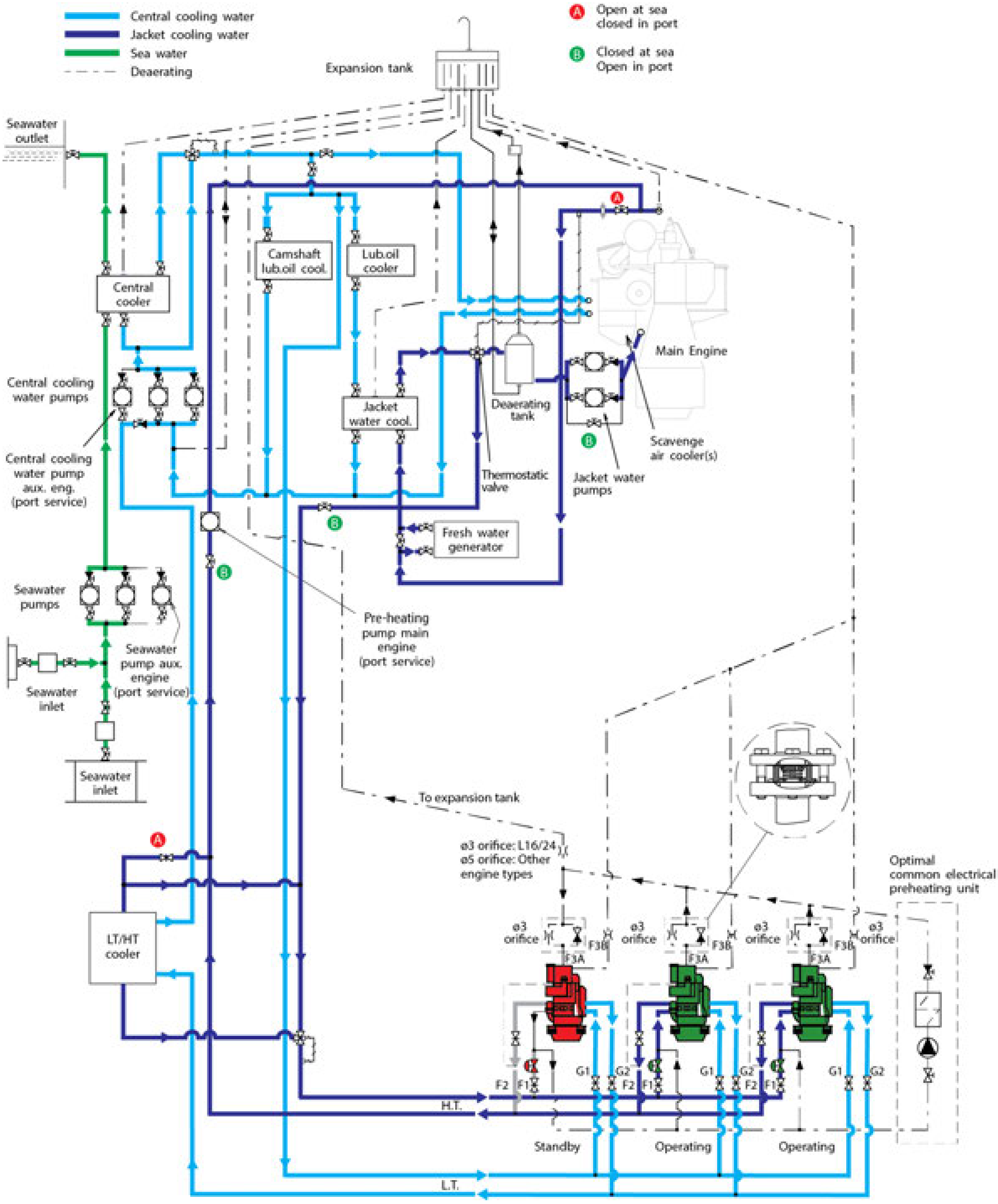

Figure 1: Operating at sea

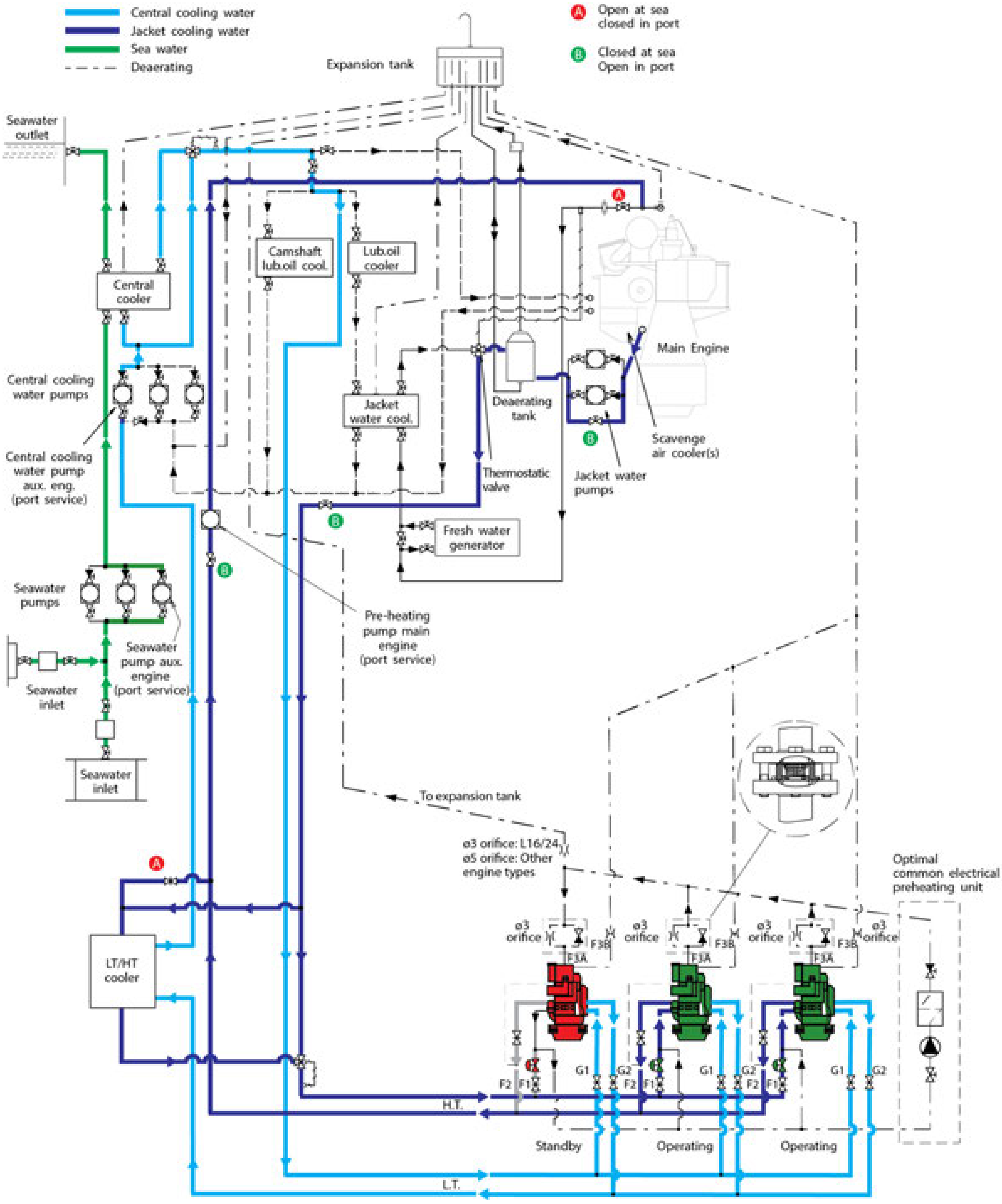

Figure 2: Operating in port

System design

The two string central cooling water system, of simple design, has only one central cooler. Low temperature (LT) and high temperature (HT) cooling water pumps are common for all engines.

To minimize the power consumption the LT fresh water pump installation consists of 3 pumps. Two pumps for sea operation and a smaller one for harbour operation.

The auxiliary engines are connected as a two string unit with separate LT- and HT-circuits. Propulsion and auxiliary engines have separate HT temperature regulation. The HT cooling water temperature is adjusted by mixing with LT cooling water, *see also B 13 00 0 "Internal Cooling Water System 2".*

The system is also remarkable for its preheating of stand-by auxiliary engines and propulsion engine, by utilizing hot water from the operating auxiliary engines.

Preheating

Engines starting on HFO and engines in stand-by position must be preheated. It is also recommended to preheat engines operating on MDO due to the prolonged life time of the engines' wearing parts. Therefore it is recommended that the preheating is arranged for automatic operation, so that the preheating is disconnected when the engine is running, and connected when the engine is in stand-by position. The preheating is adjusted so that the temperature is ≥ 60°C at the top cover (see thermometer TI12), and approximately 25 to 45°C at outlet of the cylinders (see thermometer TI10).

When working out the external cooling water system it must be ensured, that no cold cooling water is pressed through the engine and thus spoiling the preheating during stand-by. The diesel engine has no built-in shut-off valve in the cooling water system. Therefore the designer of the external cooling water system must make sure that the preheating of the GenSets is not disturbed.

Preheating of stand-by auxiliary engines during sea operation

Auxiliary engines in stand-by position are preheated via the venting pipe (F3A), leading to the expansion tank, with HT water from the operating auxiliary engines.

During preheating the non-return valve on the preheated auxiliary engine will open due to the pressure difference. The HT pumps on the operating auxiliary engines will force the HT water downwards, through the stand-by auxiliary engine, out of the (F1) HT inlet and back to the operating auxiliary engines, via the bypass manifold which interconnect all the (F1) HT inlet lines.

The on/off valve can be controlled by "engine run" signal or activated by lub. oil pressure. MAN can deliver valves suitable for purpose.

Please note that preheating pipe mounted *before* on/off valve (size 3/4"-1" for guidance) connected to either preheat unit (optional) or directly to expansion tank pipe. This will deliver preheating water to stand-by engine via (F3A).

The non-return valve in the venting pipe (F3A) is closed when the auxiliary engine is operating, and deaerating to the expansion tank flows through the small ø3 bore in the non-return valve disc.

The small ø3 bore in the non-return valve disc will also enable the auxiliary engine to keep the recommended cooling water temperature in the HT-system during low load operation which is essential for the combustion of HFO.

Preheating of stand-by auxiliary engines and propulsion engines during harbour operation

The propulsion engine is preheated by utilizing hot water from the auxiliary engines.

Depending on the size of propulsion engine and auxiliary engines an extra preheater may be necessary. This preheating is activated by closing valve A and opening valve B.

Activating valves A and B will change the direction of flow, and the water will now be circulated by the auxiliary engine driven pumps. From the auxiliary engines the water flows through valve B directly to the propulsion engine jacket outlet. When the water leaves the propulsion engine, through the jacket inlet, it flows to the thermostatically controlled 3-way valve.

As the temperature sensor for the thermostatically controlled 3-way valve, in this operating mode, is measuring in a non-flow, low temperature piping, the valve will lead most of the cooling water through the common thermostatically controlled 3-way valve, serving the auxiliary engines, and back to their common HT inlet line. The integrated loop in the auxiliary engines will ensure a constant temperature of approximately 80°C at the auxiliary engine outlet. The propulsion engine will be preheated, and the auxiliary engines in stand-by can also be preheated as described in the above mentioned section.

Optional preheating solutions

Optionally engines can be delivered with internal preheating.

Optionally a common electrical preheating unit for the auxiliary engines can be installed.

It is also possible to install an electrical preheating unit for the propulsion engine as an option.

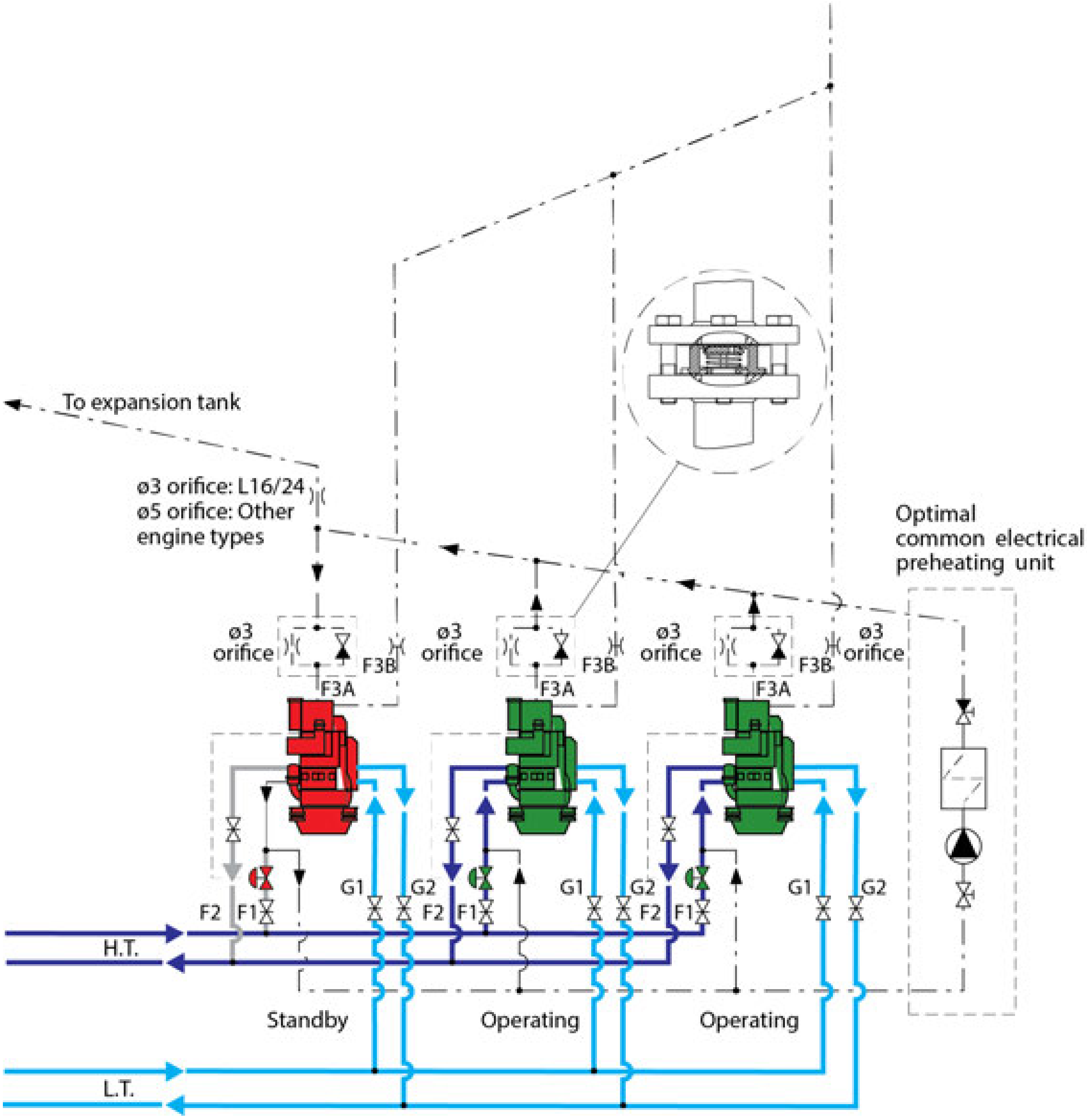

Figure 3: Preheating

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Preheater arrangement in high temperature system

General

The built-on cooling water preheating unit consists of a thermostat-controlled el-preheating element built onto the outlet connection on the thermostat housing on the engine's front end box. The pipe is connected below the non-return valve on the pipe to expansion tank.

Cyl. No.	Preheater 3x400V/3x440V kW
5-6	1 x 12
7-9	1 x 15

The system is based on thermo-syphon cooling and reverse water direction, i.e. from top and downward, and an optimal heat distribution in the engine is thus reached.

When the engine is in standstill, an extern valve must shut off the cooling water inlet.

Operation

Engines starting on HFO and engines in stand-by position must be preheated. It is therefore recommended that the preheater is arranged for automatic operation, so that the preheater is disconnected when the engine is running and connected when the engine is in stand-by position. The thermostat setpoint is adjusted to 70°C, that gives a temperature of app. 50°C at the top cover.

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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

Equipment for checking the fresh water quality

The following equipment can be used:

- The water testing kit, or similar testing kit, with all necessary instruments and chemicals that determine the water hardness, pH value and chloride content (obtainable from or Mar-Tec Marine, Hamburg).

Equipment for testing the concentration of additives

When using chemical additives:

- Testing equipment in accordance with the supplier's recommendations. Testing kits from the supplier also include equipment that can be used to determine the fresh water quality.

Testing the typical values of water

Short specification

Typical value/property	Water for filling and refilling (without additive)	Circulating water (with additive)
Water type	Fresh water, free of foreign matter	Treated coolant
Total 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

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Coolant
Coolant

Testing the concentration of rust inhibitors

Short specification

Anti-corrosion agent	Concentration
Chemical additives	In accordance with quality specification in volume 010.005 Engine – Operating Instructions 010.000.023-14
Antifreeze	In accordance with quality specification in volume 010.005 Engine – Operating Instructions 010.000.023-14

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. Respectively, the concentrations recommended by (quality specifications in volume 010.005 Engine – Operating Instructions 010.000.023-14) must be maintained 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, consult .

Regular water samplings

Small quantities of lube oil in coolant can be found by visual check during regular water sampling from the expansion tank.

Testing

Regular analysis of coolant is very important for safe engine operation. We can analyse fuel for customers at laboratory PrimeServLab.

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

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 from lubricating oil that has entered the cooling system or a high concentration of anticorrosive agents can be removed by flushing the system with fresh water to which some cleaning agent has been added. Suitable cleaning agents are listed alphabetically in the table entitled Cleaning agents for removing oil sludge. Products by other manufacturers can be used providing they have similar properties. The manufacturer's instructions for use must be strictly observed.

Manufacturer	Product	Concentration	Duration of cleaning procedure/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: Cleaning agents for removing oil sludge

Lime and rust deposits

Lime and rust deposits can form if the water is especially hard or if the concentration of the anticorrosive agent is too low. A thin lime scale layer can be left on the surface as experience has shown that this protects against corrosion. However, limescale deposits with a thickness of more than 0.5 mm obstruct the transfer of heat and cause thermal overloading of the components being cooled.

Rust that has been flushed out may have an abrasive effect on other parts of the system, such as the sealing elements of the water pumps. Together with the elements that are responsible for water hardness, this forms what is known as ferrous sludge which tends to gather in areas where the flow velocity is low.

Products that remove limescale deposits are generally suitable for removing rust. Suitable cleaning agents are listed alphabetically in the table entitled Cleaning agents for removing limescale and rust deposits. Products by other manufacturers can be used providing they have similar properties. The manufacturer's instructions for use must be strictly observed. Prior to cleaning, check whether the cleaning agent is suitable for the materials to be cleaned. The products listed in the table entitled Cleaning agents for removing limescale and rust deposits are also suitable for stainless steel.

Manufacturer	Product	Concentration	Duration of cleaning procedure/temperature
Drew	SAF-Acid Descale-IT Ferroclean	5 – 10 % 5 – 10 % 10 %	4 h at 60 – 70 °C 4 h at 60 – 70 °C 4 – 24 h at 60 – 70 °C
Nalfleet	Nalfleet 9 - 068	5 %	4 h at 60 – 75 °C
Unitor	Descalex	5 – 10 %	4 – 6 h at approx. 60 °C
Vecom	Descalant F	3 – 10 %	ca. 4 h at 50 – 60 °C

Table 2: Cleaning agents for removing lime scale and rust deposits

In emergencies only

Hydrochloric acid diluted in water or aminosulphonic acid may only be used in exceptional cases if a special cleaning agent that removes limescale deposits without causing problems is not available. Observe the following during application:

- Stainless steel heat exchangers must never be treated using diluted hydrochloric acid.
- Cooling systems containing non-ferrous metals (aluminium, red bronze, brass, etc.) must be treated with deactivated aminosulphonic acid. This acid should be added to water in a concentration of 3 – 5 %. The temperature of the solution should be 40 – 50 °C.
- Diluted hydrochloric acid may only be used to clean steel pipes. If hydrochloric acid is used as the cleaning agent, there is always a danger that acid will remain in the system, even when the system has been neutralised and flushed. This residual acid promotes pitting. We therefore recommend you have the cleaning carried out by a specialist.

The carbon dioxide bubbles that form when limescale deposits are dissolved can prevent the cleaning agent from reaching boiler scale. It is therefore absolutely necessary to circulate the water with the cleaning agent to flush away the gas bubbles and allow them to escape. The length of the cleaning process depends on the thickness and composition of the deposits. Values are provided for orientation in the table entitled 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.

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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.

⚠ 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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Specification of engine coolant

Preliminary remarks

An engine coolant is composed as follows: water for heat removal and coolant additive for corrosion protection.

Like the fuel and lubricating oil, the engine coolant must be carefully selected, handled and checked. If this is not the case, 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 system must be treated with an anticorrosive 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 untreated coolant must correspond to the following limit values:

Properties/Characteristic	Properties	Unit
Water type	Distillate or fresh water, free of foreign matter.	–
Total hardness	max. 10	dGH[1)]
pH value	6.5 – 8	–
Chloride ion content	max. 50	mg/l[2)]

Table 1: Properties of coolant that must be complied with

1) 1 dGH (German hardness) ≙ 10 mg CaO in 1 litre of water ≙ 17.8 mg $CaCO_3$/l
≙ 0.357 mval/l ≙ 0.178 mmol/l

2) 1 mg/l ≙ 1 ppm

Testing equipment

The water testing equipment incorporates devices that determine the water properties directly related to the above. The manufacturers of anticorrosive agents also supply user-friendly testing equipment.

Notes for cooling water check see 010.005 Engine – Work Instructions 010.000.002-03

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

Specification of engine coolant

Specification of engine coolant

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.

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. Subsequent hardening of extremely soft water is only necessary to prevent foaming if emulsifiable slushing oils are used.

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 Anforderungen.

Protective films can be formed by treating the coolant with anticorrosive chemicals or emulsifiable slushing oil.

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.

Specification of engine coolant

Additives for coolants

Only the additives approved by and listed in the tables under the paragraph entitled Permissible cooling water additives may be used.

In closed circuits only

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 coolant containing additives. For more information, consult the additive supplier.

Chemical additives

Sodium nitrite and sodium borate based additives etc. have a proven track record. Galvanised 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 that may occur due to the coolant temperatures which are usual in engines nowadays. If necessary, the pipes must be deplated.

Slushing oil

For engines, it is not permissible to use corrosion protection oils in the cooling water circuit.

Anti-freeze agents

If temperatures below the freezing point of water in the engine cannot be excluded, an antifreeze agent that also prevents corrosion must be added to the cooling system or corresponding parts. Otherwise, the entire system must be heated.

Sufficient corrosion protection can be provided by adding the products listed in the table entitled Antifreeze agent with slushing properties (Military specification: Federal Armed Forces Sy-7025), while observing the prescribed minimum concentration. This concentration prevents freezing at temperatures down to –22 °C and provides sufficient corrosion protection. However, the quantity of antifreeze agent actually required always depends on the lowest temperatures that are to be expected at the place of use.

Antifreeze agents are generally based on ethylene glycol. A suitable chemical anticorrosive agent must be added if the concentration of the antifreeze agent prescribed by the user for a specific application does not provide an appropriate level of corrosion protection, or if the concentration of antifreeze agent used is lower due to less stringent frost protection requirements and does not provide an appropriate level of corrosion protection. Considering that the antifreeze agents listed in the table Antifreeze agents with slushing properties also contain corrosion inhibitors and their compatibility with other anticorrosive agents is generally not given, only pure glycol may be used as antifreeze agent in such cases.

Simultaneous use of anticorrosive agent from the table Nitrite-free chemical additives together with glycol is not permitted, because monitoring the anticorrosive agent concentration in this mixture is no more possible.

Antifreeze agents reduce the capacity of the coolant to absorb heat. In some cases the cooling effect of the coolant may not be sufficient for certain operation conditions. The standard design is not based on using antifreeze agents. In case it is intended to use anti-freeze agent, consult beforehand.

Specification of engine coolant

Before an antifreeze agent is used, the cooling system must be thoroughly cleaned.

If the coolant contains emulsifiable slushing oil, antifreeze agent may not be added as otherwise the emulsion would break up and oil sludge would form in the cooling system.

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.

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 system must therefore be cleaned with the engine switched off using a suitable cleaning agent (see 010.005 Engine – Work Instructions 010.000.001-01 and 010.000.002-04).

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 coolant system

Treated coolant may become contaminated when the engine is in operation, which causes the additive to loose some of its effectiveness. It is therefore advisable to regularly check the cooling system and the coolant condition. To determine leakages in the lube oil system, it is advisable to carry out regular checks of water in the expansion tank. Indications of oil content in water are, e.g. discoloration or a visible oil film on the surface of the water sample.

The additive concentration must be checked at least once a week using the test kits specified by the manufacturer. The results must be documented.

NOTICE

Concentration of chemical additives

The chemical additives must be added in the specified concentration. See section Permitted coolant additives.

Excessively low concentrations lead to corrosion and must be avoided. Concentrations that are somewhat higher do not cause damage. Concentrations that are more than twice as high as recommended should be avoided.

Every 2 to 6 months, a coolant sample must be sent to an independent laboratory or to the engine manufacturer for an integrated analysis.

If chemical additives or antifreeze agents are used, coolant should be replaced after 3 years at the latest.

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

If there is a high concentration of solids (rust) in the system, the water must be completely replaced and entire system carefully cleaned.

Deposits in the cooling system may be caused by fluids that enter the coolant or by emulsion break-up, corrosion in the system, and limescale deposits if the water is very hard. If the concentration of chloride ions has increased, this generally indicates that seawater has entered the system. The maximum specified concentration of 50 mg chloride ions per kg must not be exceeded as otherwise the risk of corrosion is too high. If exhaust gas enters the coolant, this can lead to a sudden drop in the pH value or to an increase in the sulphate content.

Water losses must be compensated by filling with untreated water that meets the quality requirements specified in the paragraph Requirements. The concentration of anticorrosive agent must subsequently be checked and adjusted if necessary.

Subsequent checks of the coolant are especially required if the coolant had to be drained off in order to carry out repairs or maintenance.

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 your 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.

Auxiliary engines

If the coolant system used in a 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.

Specification of engine coolant

Analysis

can analyse antifreeze agent for their customers in the chemical laboratory PrimeServLab. A 0.25 l sample is required for the test.

Permitted coolant additives

A list of currently approved coolant additives and their concentration can be found at https://corporate.man-es.com/lubrication.

Specification of engine coolant

Expansion tank pressurized

Description

Engine type	Cyl. qty.	Expansion volume litre*	Recommended tank volume m³**
L23/30	5 cyl. engine 6 cyl. engine 7 cyl. engine 8 cyl engine 9 cyl engine	11 13 15 17 -	0.1 0.1 0.1 0.1 -
L28/32	5 cyl. engine 6 cyl. engine 7 cyl. engine 8 cyl engine 9 cyl engine	28 33 39 44 50	0.15 0.15 0.15 0.15 0.15
V28/32	12 cyl. engine 16 cyl. engine 18 cyl. engine	66 88 99	0.3 0.3 0.3
L16/24	5 cyl. engine 6 cyl. engine 7 cyl. engine 8 cyl engine 9 cyl engine	4 5 5 5 6	0.1 0.1 0.1 0.1 0.1
L21/31	5 cyl. engine 6 cyl. engine 7 cyl. engine 8 cyl engine 9 cyl engine	6 7 8 9 10	0.1 0.1 0.1 0.1 0.1
L27/38	5 cyl. engine 6 cyl. engine 7 cyl. engine 8 cyl engine 9 cyl engine	10 12 13 15 20	0.15 0.15 0.15 0.15 0.15
* Per engine ** Common expansion tank			

Table 1: Expansion volume for cooling water system and recommended volume of expansion tank.

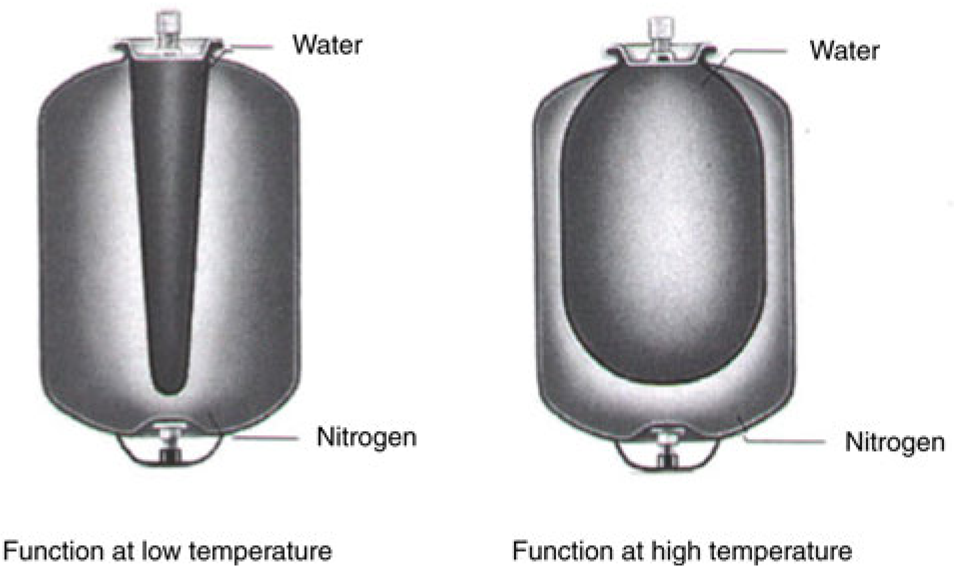


Figure 1: Function of expansion tank.

- Water connection in the top ensures easy and simple installation and control under operation.
- Cooling water is absorbed in a rubber bag which is hanging in the all-welded vessel.
- Corrosion of the all-welded vessel is excluded.
- The rubber bag is replaceable.

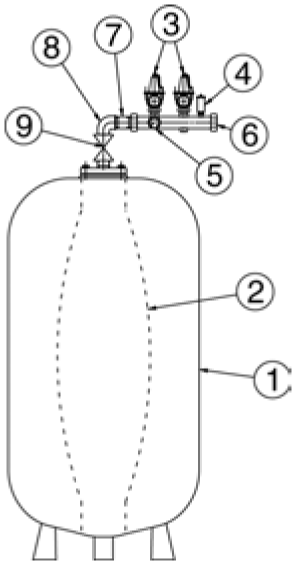
The expansion vessel should be connected to the system at a point close to the cooling water inlet connections (G1 / F1) in order to maintain positive pressures throughout the system and allow expansion of the water.

The safety valves are fitted on the manifold.

The pressure gauge is fitted on the manifold in such a position that it can be easily read from the filling point.

The filling point should be near the pressure expansion vessel. Particularly the pressure gauge in such a position that the pressure gauge can be easily read from the filling point, when filling from the mains water.

Automatic air venting valve should be fitted at the highest point in the cooling water system.



1 Pressure vessel
2 Exchangeable rubber bag
3 Safety valves
4 Automatic air venting valve
5 Pressure gauge
6 Manifold
7 Threaded pipe
8 Elbow
9 Shutt-off valve

Figure 2: Expansion tank

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Compressed air system

Diagram

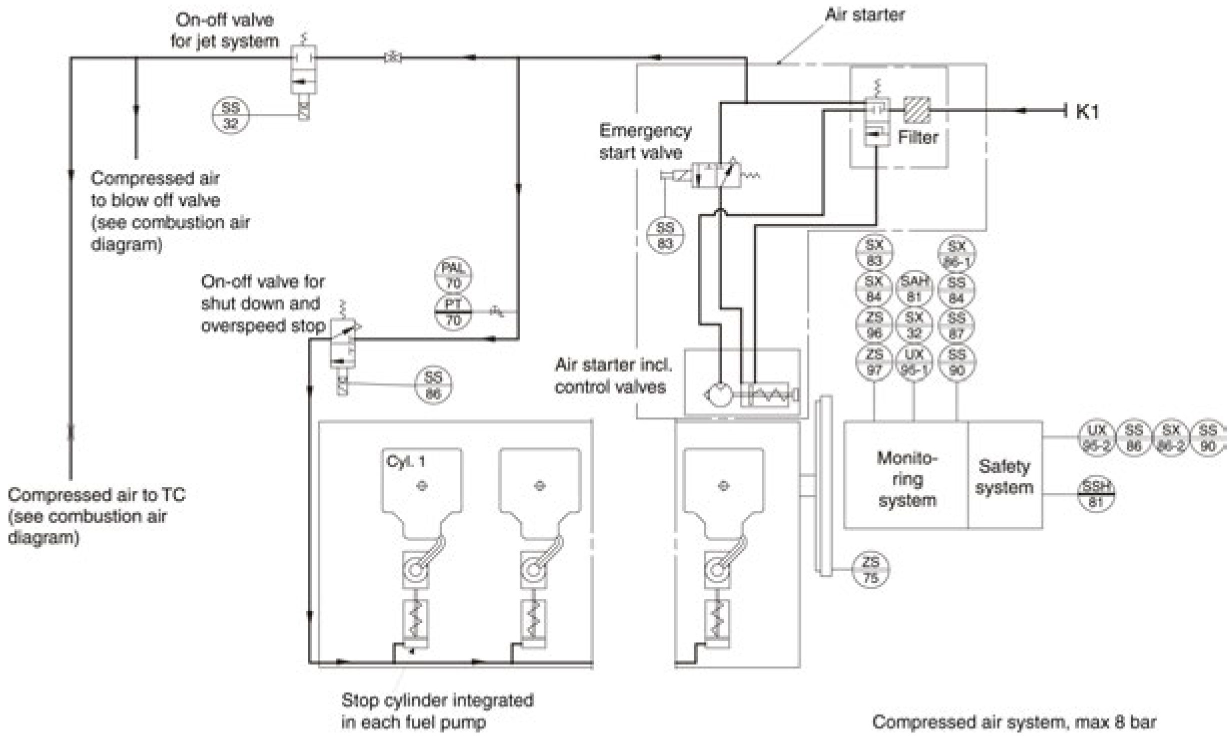

Figure 1: Diagram for compressed air system (for guidance only, please see the plant specific engine diagram)

⚠ CAUTION Air supply must not be interrupted when engine is running

Pipe description

Pipe description		
K1	Compressed air inlet	DN 40

Table 1: Flange connections are standard according to DIN 2501

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. Max. inlet pressure at starter unit is 8 bar to the engine.

To avoid dirt particles in the internal system, a strainer is mounted in the inlet line to the engine.

Starting system

The engine is started by means of a built-on air starter, 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 basemodule 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

Air supply must not be interrupted when the engine is running.

As standard the engine is equipped with a pneumatic/mechanical stop cylinder, which starts to operate if the safety system is activated. The system is activated electrically. One stop cylinder for each cylinder is intergrated in each fuel injection pump.

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.

Optionals

Besides the standard components, the following standard optional can be built-on:

- Main valve, inlet engine.

Compressed air system

Diagram

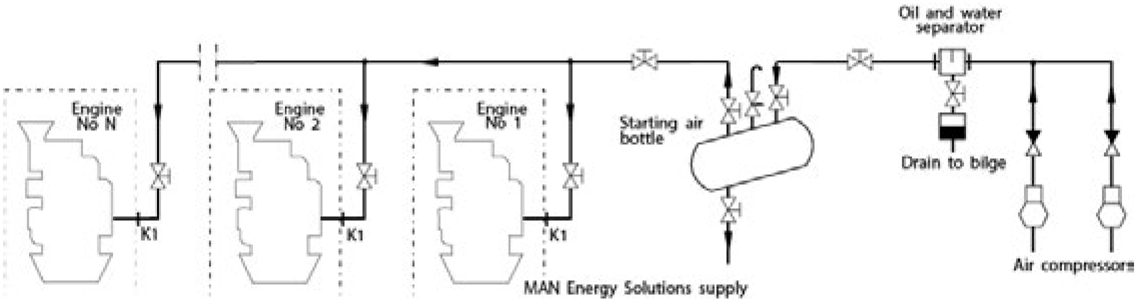

Figure 1: Diagram for compressed air system

Design of external system

The external compressed air system should be common for both propulsion engines and GenSet engines.

Separate tanks shall only be installed in turbine vessels, or if GenSets in engined vessels are installed far away from the propulsion plant.

The design of the air system for the plant in question should be according to the rules of the relevant classification society.

As regards the engine's internal compressed air system, please *see B 14 00 0 "Internal Compressed Air System".*

An oil and water separator should be mounted between the compressor and the air receivers, and the separator should be equipped with automatic drain facilities.

Each engine needs only one connection for compressed air, please *see diagram for the compressed air system.*

Installation

In order to protect the engine's starting and control equipment against condensation water, the following should be observed:

- The air receiver(s) should always be installed with good drainage facilities. Receiver(s) arranged in horizontal position must be installed with a slope downwards of min. 3°-5°.
- Pipes and components should always be treated with rust inhibitors.
- The starting air pipes should be mounted with a slope towards the receivers, preventing possible condensed water from running into the compressors.
- Drain valves should be mounted at the lowest position on the starting air pipes.

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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.

- 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

Engine room ventilation and combustion air

Combustion air requirements

- The combustion air must be free from water spray, dust, oil mist and exhaust gases. See D010.000.023-17.
- The air ventilation fans shoud be designed to maintain a positive air pressure of 50 Pa (5 mmWC) in the auxiliary engine room in all running conditions.

The combustion air is normally taken from the engine room through a filter mat on the turbocharger.

In tropical condition a sufficient volume of air must be supplied to the turbocharger(s) at outside air temperature. For this purpose there must be an air duct installed for each turbocharger, with the outlet of the duct facing the respective intake air silencer. No water of condensation from the air duct must be allowed to be drawn in by the turbocharger.

In arctic condition the air must be heated to at least 5°C or other measures must be taken in engine design specification. See B 15 00 0, "Combustion air system for arctic operation".

Ventilator capacity

The capacity of the air ventilators must be large enough to cover:

- The combustion air requirements of all consumers.
- The air required for carrying off the heat emission.
- Maintain an positive air pressure in engine room.

See "List of capacities" section D 10 05 0 for information about required combustion air quantity and heat emission.

For minimum requirements concerning engine room ventilation see applicable standards such as ISO 8861.

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Combustion air system

General

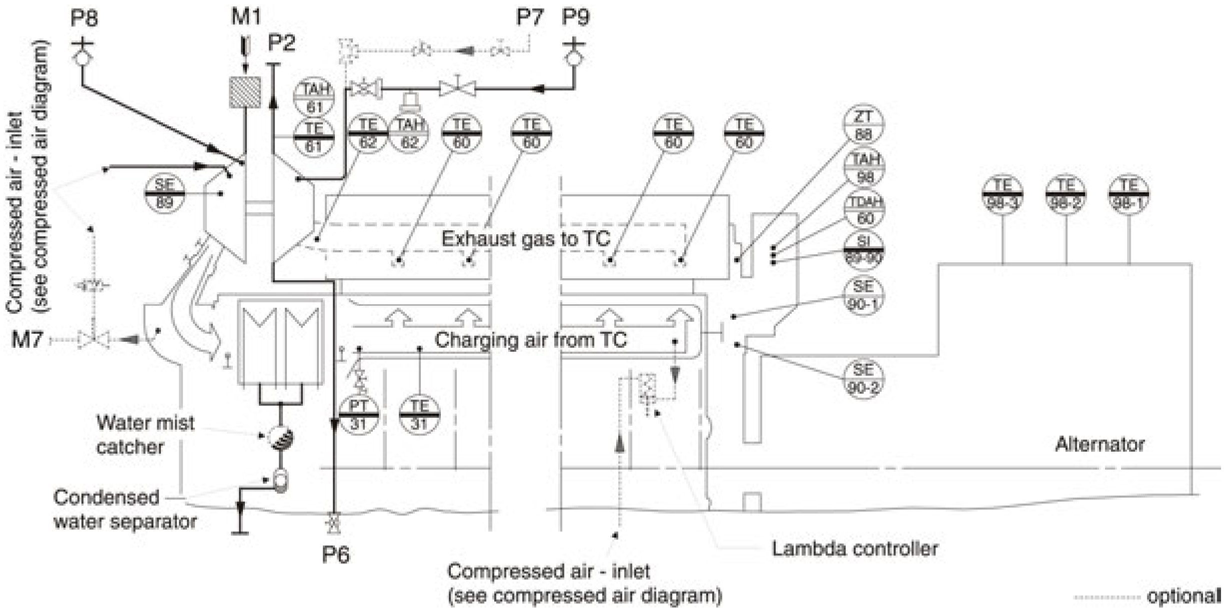


Figure 1: Diagram for combustion air system. (for guidance only, please see the plant specific engine diagram)

Pipe description		
M1	Charge air inlet	
M7	Charge air by-pass or blow off (optional)	
P2	Exhaust gas outlet: 5 cyl. engine 6 cyl. engine 7+8 cyl. engines 9 cyl. engine	 DN 400 DN 450 DN 500 DN 550
P6	Drain from turbocharger - outlet	
P8	Water washing compressor side with quick coupling - inlet	
P9	Working air, dry cleaning turbine side with quick coupling - inlet	

Table 1: P2 flange connections are standard according to DIN 86 044. Other flange connections are standard according to DIN 2501

The air intake to the turbochargers takes place directly from the engine room through the intake silencer on the turbocharger.

From the turbocharger the air is led via the charge air cooler and charge air receiver to the inlet valves of each cylinder.

2023-09-14 - en

The charge air cooler is a compact two-stage tubetype cooler with a large cooling surface.

The charge air cooler is mounted in the engine's front end box.

It is recommended to blow ventilation air in the level of the top of the engine(s) close to the air inlet of the turbocharger, but not so close that sea water or vapour may be drawn-in. It is further required that there always should be a positive air pressure (overpressure) in the engine room.

Turbocharger

The engine is always installed with a high-efficient MAN Energy Solutions TCR turbocharger of the radial type, which is located on the top of the front end box.

Cleaning of Turbocharger

The turbocharger is fitted with an arrangement for both dry and wet cleaning of the turbine side, and water washing of the compressor side.

Lambda controller / Charge air limiter integrated into SaCoS

The purpose of the charge air limiter is to prevent injection of more fuel in the combustion chamber than can be burned during a momentary load in-crease. This is carried out by controlling the relation between the fuel index and the charge air pressure. The lambda controller has the following advantages:

- Reduction of visible smoke in case of sudden momentary load increases.
- Improved load ability.
- Less fouling of the engine's exhaust gas ways.

The above states that the working conditions are improved under difficult circumstances and that the maintenance costs for an engine, working with many and major load changes, will be reduced.

Data

For charge air heat dissipation and exhaust gas data, *see D 10 05 0 "List of Capacities".*

Set points and operating levels for temperature and pressure are stated in *B 19 00 0 "Operating Data and Set Points".*

Combustion air system for arctic operation

General

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).

Engine operation under arctic conditions

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 ≥ t_x > −60 °C

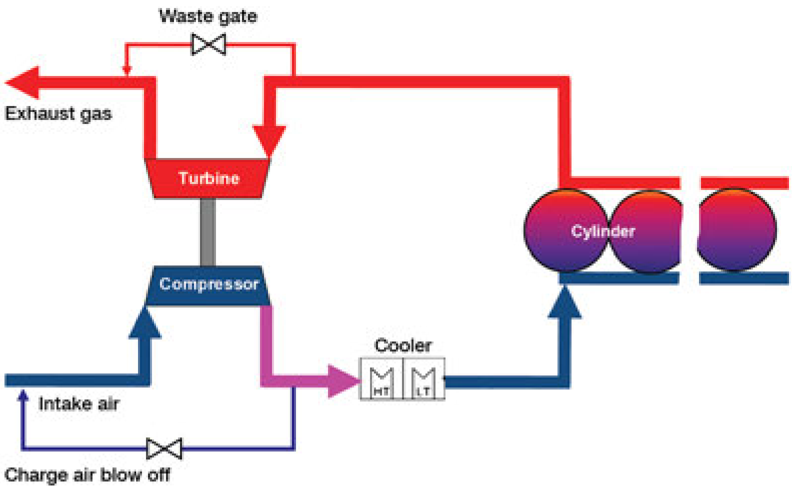


Figure 1: Diagram

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.

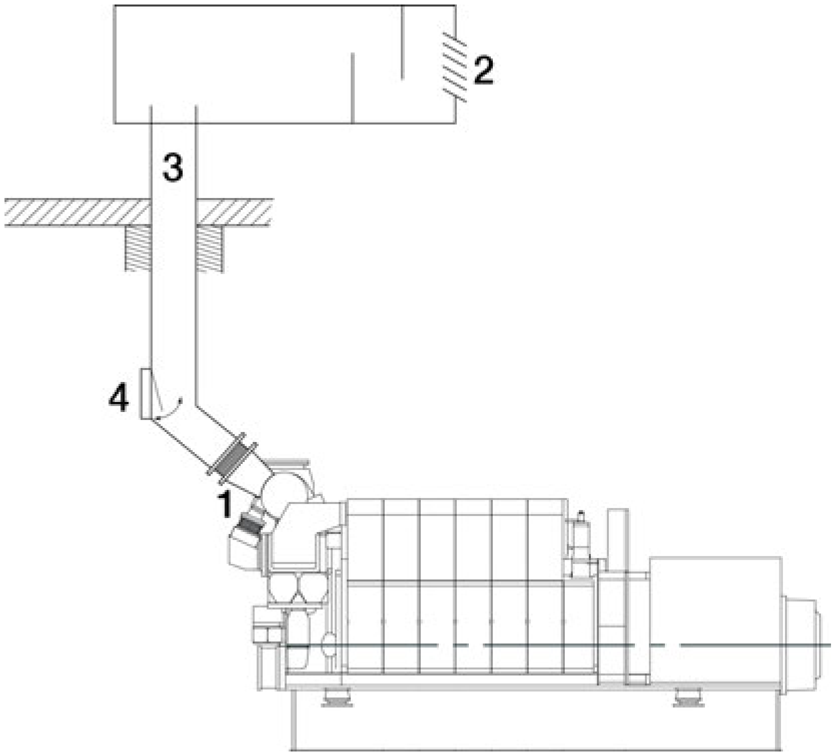
If not compensated for, the low air temperature could cause two problems for the engine performance; (namely) a too high combustion pressure and a too low charge air temperature.

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.

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 MAN 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 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 MAN Diesel & Turbo.

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 MAN Diesel & Turbo for approval.

- 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 MAN Diesel & Turbo.

Turbocharger - make MAN

Description

The engines are as standard equipped with a turbocharger of the radial type MAN 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
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

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

Water washing of turbocharger - compressor

Description

During operation the compressor will gradually be fouled due to the presence of oil mist and dust in the inlet air.

The fouling reduces the efficiency of the turbocharger which will result in reduced engine performance.

Therefore manual cleaning of the compressor components is necessary in connection with overhauls. This situation requires dismantling of the turbocharger.

However, regular cleaning by injecting water into the compressor during normal operation of the engine has proved to reduce the fouling rate to such an extent that good performance can be maintained in the period between major overhauls of the turbocharger.

The cleaning effect of injecting pure fresh water is mainly based upon the mechanical effect arising, when the water droplets impinge the deposit layer on the compressor components.

The water is injected in a measured amount and within a measured period of time by means of the water washing equipment.

The water washing equipment, see fig 1, comprises two major parts. The transportable container (6) including a hand valve with handle (5) and a plug-in coupling (4) at the end of a lance.

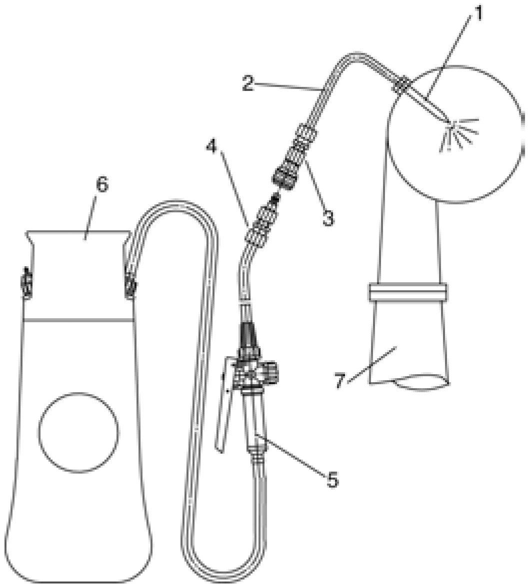
Installed on the engine there is the injection tube (1), connected to a pipe (2) and a snap coupling (3).

The cleaning procedure is:

1) Fill the container (6) with a measured amount of fresh water. Blow air into the container by means of a blow gun, until the prescribed operation pressure is reached.
2) Connect the plug-in coupling of the lance to the snap coupling on the pipe, and depress the handle on the hand valve.
3) The water is then injected into the compressor.

The washing procedure is executed with the engine running at normal operating temperature and with the engine load as high as possible, i.e. at a high compressor speed.

The frequency of water washing should be matched to the degree of fouling in each individual plant.



1 Injection tube
2 Pipe
3 Snap coupling
4 Plug-in coupling
5 Hand valve with handle
6 Container
7 Charge air line

Figure 1: Water washing equipment.

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

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Specifications of intake air (combustion air)

Specifications of intake air (combustion air)

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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Exhaust gas system

Internal exhaust gas system

From the exhaust valves, the gas is led to the exhaust gas receiver where the fluctuating pressure from the individual cylinders is equalized and the total volume of gas led further on to the turbocharger, at a constant pressure. After the turbocharger, the gas is led to the exhaust pipe system.

The exhaust gas receiver is casted sections, one for each cylinder, connected to each other, by means of compensators, to prevent excessive stress due to heat expansion.

After each cylinder a thermosensor for reading the exhaust gas temperature is fitted.

To avoid excessive thermal loss and to ensure a reasonably low surface temperature the exhaust gas receiver is insulated.

External exhaust gas system

The exhaust back-pressure should be kept as low as possible.

It is therefore of the utmost importance that the exhaust piping is made as short as possible and with few and soft bends.

Long, curved, and narrow exhaust pipes result in higher back-pressure which will affect the engine combustion. Exhaust back-pressure is a loss of energy and will cause higher fuel comsumption.

The exhaust back-pressure should not exceed 30 mbar at MCR. An exhaust gas velocity through the pipe of maximum 35 m/sec is often suitable, but depends on the actual piping.

During commissioning and maintenance work, checking of the exhaust gas back pressure by means of a temporarily connected measuring device may become necessary. For this purpose, a measuring socket must be provided approx. 1-2 m after the exhaust gas outlet of the turbocharger at an easily accessible place. Usual pressure measuring devices require a measuring socket size of ½". This measuring socket must be provided to ensure utilisation without any damage to the exhaust gas pipe insulation.

MAN Energy Solutions will be pleased to assist in making a calculation of the exhaust back-pressure.

The gas outlet of turbocharger, the expansion bellows, the exhaust pipe, and silencer, (in case of silencer with spark arrestor care must be taken that the cleaning parts are accessible), must be insulated with a suitable material.

The insulation should be shielded by a thin plating, and should comply with the requirements of the classification society and/or the local authorities.

Exhaust pipe dimensions

It should be noted that concerning the maximum exhaust gas velocity the pipe dimension after the expansion bellows should be increased for some of the engines.

The wall thickness of the external exhaust pipe should be min. 3 mm.

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Exhaust pipe mounting

When the exhaust piping is mounted, the radiation of noise and heat must be taken into consideration.

Because of thermal fluctuations in the exhaust pipe, it is necessary to use flexible as well as rigid suspension points.

In order to compensate for thermal expansion in the longitudinal direction, expansion bellows must be inserted. The expansion bellows should preferably be placed at the rigid suspension points.

Note: The exhaust pipe must not exert any force against the gas outlet on the engine.

One sturdy fixed-point support must be provided for the expansion bellows on the turbocharger. It should be positioned, if possible, immediately above the expansion bellows in order to prevent the transmission of forces, resulting from the weight, thermal expansion or lateral displacement of the exhaust piping, to the turbocharger.

The exhaust piping should be mounted with a slope towards the gas outlet on the engine. It is recommended to have drain facilities in order to be able to remove condensate or rainwater.

Position of gas outlet on turbocharger

B 16 02 0 shows turning alternatives positions of the exhaust gas outlet. Before dispatch of the engine exhaust gas outlet will be turned to the wanted position.

The turbocharger is, as standard, mounted in the front end.

Exhaust gas boiler

To utilize the thermal energy from the exhaust, an exhaust gas boiler producing steam or hot water can be installed.

Each engine should have a separate exhaust gas boiler or, alternatively, a common boiler with separate gas ducts. Concerning exhaust gas quantities and temperature, *see "List of capacities" D 10 05 0,* and *"Engine performance" D 10 10 0.*

The discharge temperature from the exhaust gas boiler should not be lower than 180°C (in order to avoid sulphuric acid formation in the funnel).

The exhaust gas boilers should be installed with by-pass entering in function at low-load operation.

The back-pressure over the boiler must be included in the back-pressure calculation.

Expansion bellows

The expansion bellows, which is supplied separately, must be mounted directly on the exhaust gas outlet, *see also E 16 01 1-2.*

Exhaust silencer

The position of the silencer in the exhaust gas piping is not decisive for the silencing effect. It would be useful, however, to fit the silencer as high as possible to reduce fouling. The necessary silencing depends on the loudness of the exhaust sound and the discharge from the gas outlet to the bridge wing.

The exhaust silencer, *see E 16 04 2-3-5-6,* is supplied loose with counterflange, gaskets and bolts.

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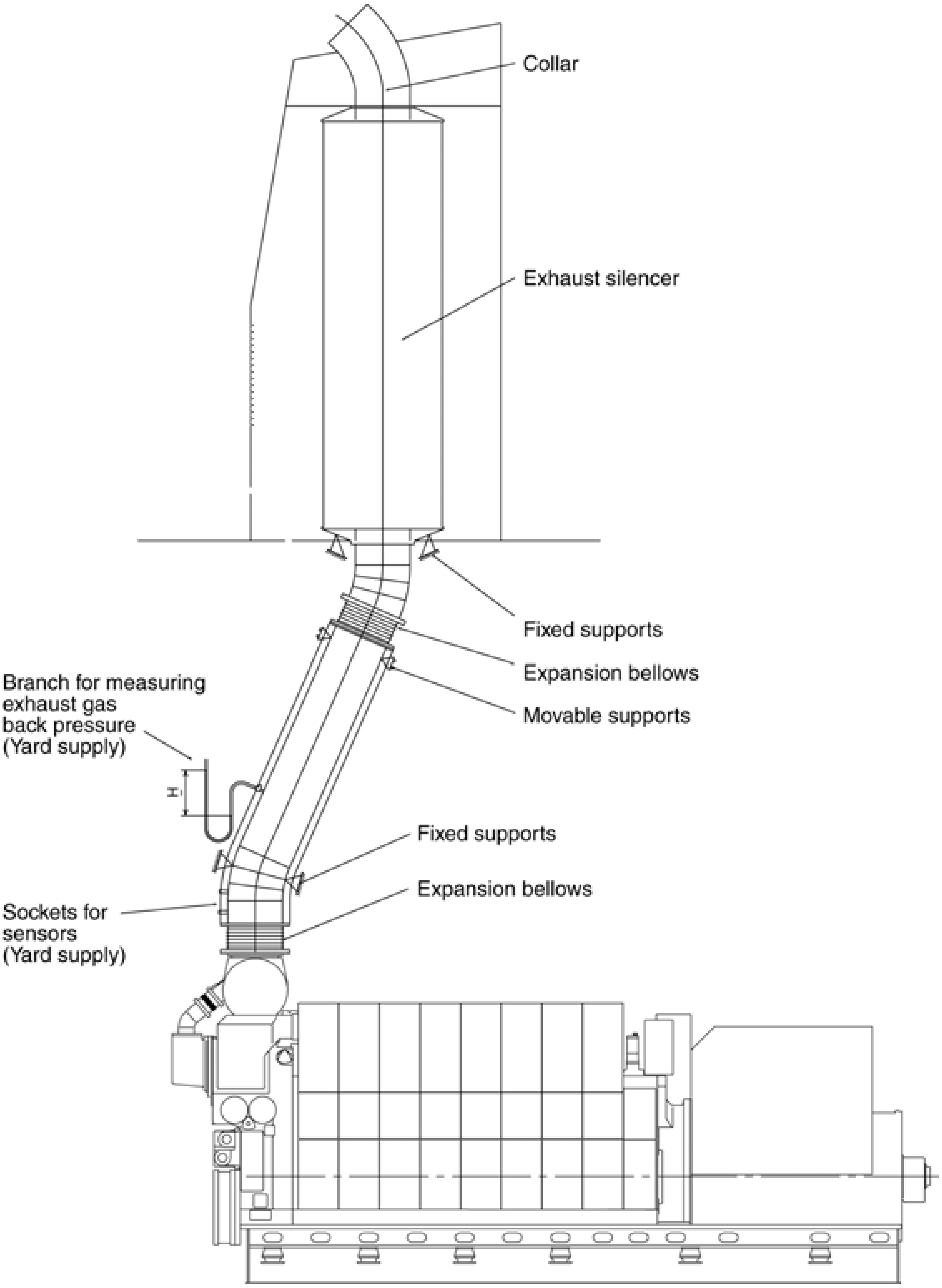
Collar
Exhaust silencer
Fixed supports
Expansion bellows
Movable supports
Branch for measuring exhaust gas back pressure (Yard supply)
H
Fixed supports
Expansion bellows
Sockets for sensors (Yard supply)

Resulting installation demands

If the recommended exhaust gas back pressure cannot be kept due to exhaust gas after treatment installations. Following items need to be considered.

Exhaust gas back pressure after turbocharger	
Operating pressure Δp_{exh}, standard	0 ... 30 mbar
Operating pressure Δp_{exh}, range with increase of fuel consumption	30 ... 60 mbar
Operating pressure Δp_{exh}, where a customized engine matching is needed	> 60 mbar

Table 1: Exhaust gas back pressure after turbocharger

Intake air pressure turbocharger	
Operating pressure Δp_{intake}, standard	0 ... –20 mbar
Operating pressure Δp_{intake}, range with increase of fuel consumption	–20 ... –40 mbar
Operating pressure Δp_{intake}, where a customized engine matching is needed	< –40 mbar

Table 2: Intake air pressure turbocharger

Sum of the exhaust gas back pressure after turbocharger and the absolute value of the intake air pressure before turbocharger	
Operating pressure Δp_{exh} + Abs(Δp_{intake}), standard	0 ... 50 mbar
Operating pressure Δp_{exh} + Abs(Δp_{intake}), range with increase of fuel consumption	50 ... 100 mbar
Operating pressure Δp_{exh} + Abs(Δp_{intake}), where a customized engine matching is needed	> 100 mbar

Table 3: Sum of the exhaust gas back pressure after turbocharger and the absolute value of the intake air pressure before turbocharger

Maximum exhaust gas pressure drop – Layout

- Shipyard and supplier of equipment in exhaust gas line have to ensure that pressure drop Δp_{exh} over entire exhaust gas piping incl. pipe work, scrubber, boiler, silencer, etc. must stay below stated standard operating pressure at all operating conditions.
- It is recommended to consider an additional 10 mbar for consideration of aging and possible fouling/staining of the components over lifetime.
- Possible counter measures could be a proper dimensioning of the entire flow path including all installed components or even the installation of an exhaust gas blower if necessary.
- At the same time the pressure drop Δp_{intake} in the intake air path must be kept below stated standard operating pressure at all operating conditions and including aging over lifetime.

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Pressure drop in exhaust gas system

General

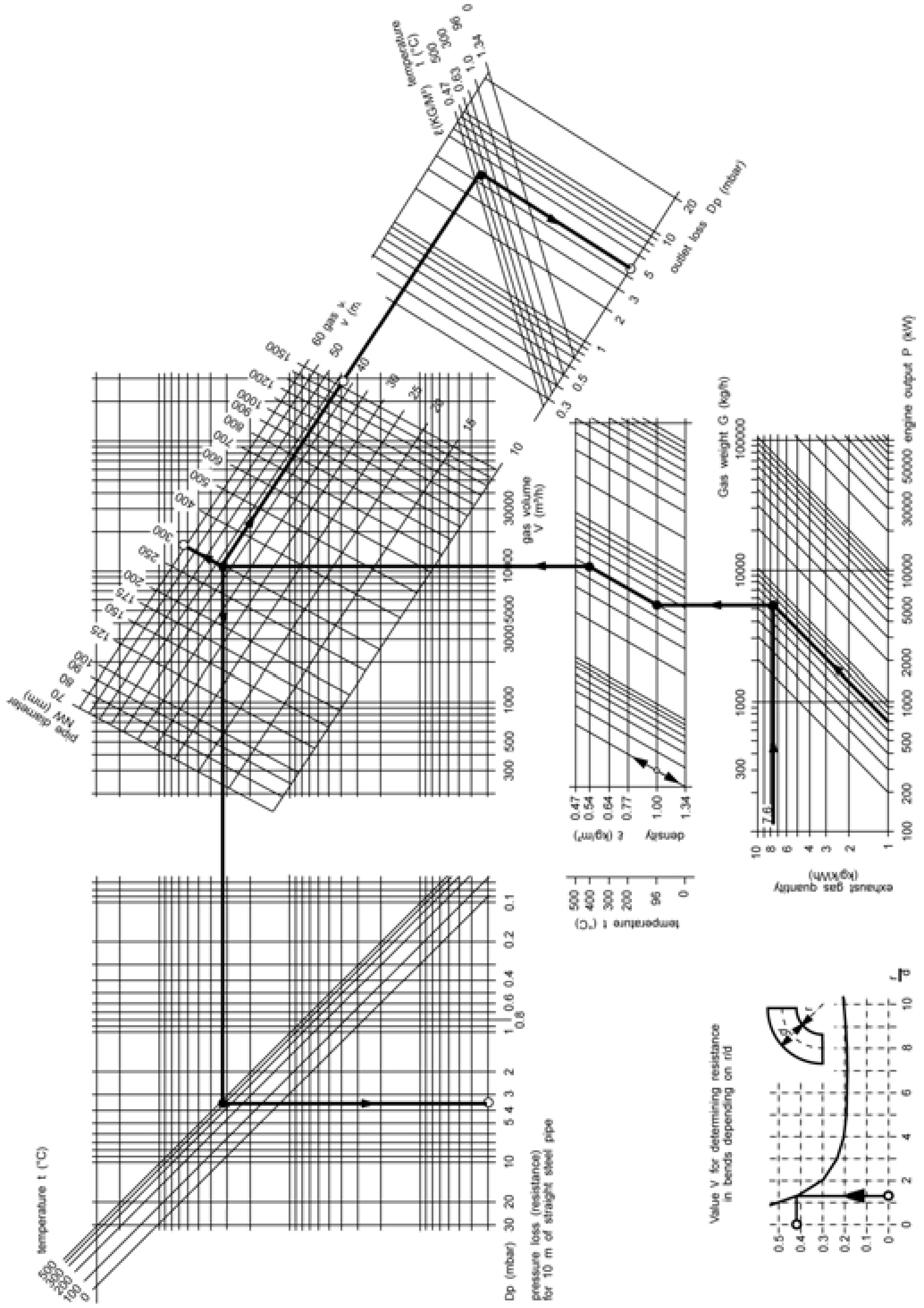

Figure 1: Nomogram for pressure drop in exhaust gas piping system.

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

Density of air

Density of air can be determined by following empiric, formula*:

$$\rho = \frac{348.3}{t + 273} \times P$$

ρ = density kg/m³

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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Equipment to optimize performance

Overview

MAN Energy Solutions four-stroke Diesel engines and turbochargers are designed in accordance with specifications so that optimum results, e.g. fuel consumption and emissions performance, are obtained through the services normally provided. However, it is possible that specific operating situations could be managed more effectively using additional or alternative equipment.

Equipment used to adapt the engine to specific operating conditions or to optimise its performance is listed in Table 1. The ideal areas of application are also stated in this table. The purpose of table is to provide you with an overview of the options available and the circumstances in which they should be used.

Equipment/Measure	Propulsion	GenSet
Blow off charge air	X	X
Bypass charge air	X	X
Charge air preheating – via H.T./L.T. switch-over (2-stage charge air cooler)	X	X
Blow off exhaust gas (Waste gate)	X	X
Accelerate turbocharger (Jet assist)	X	X
Compressor by-pass	X	
X = Availability		

Table 1: Equipment for optimising the operating behaviour

Brief description

Charge air blow off or compressor by-pass

Blow-off charge air pressure used for:

- Reduction of charge air pressure/max. pressure at cold ambient conditions.
- Prevent surging at cold ambient conditions.
- Control of max. pressure at "Part Load Optimised" operation.
- Control of exhaust gas temperature for SCR operation.

When operating engines under full load at a low intake temperature (≤ 5°C) there is a danger, due to the high air density, that the charge pressure, and therefore the ignition pressure, increases excessively. In order to avoid such conditions, excess charge air in front of or after the charge air cooler is removed and released. In the first case, the charge air is blown off into the engine room and in the second case, when charge air released from the charge air cooler is hot, the charge air is blown off into atmosphere to prevent danger to persons and equipment. Alternatively, this hot charge air may be also used for inlet air preheating, called compressor by-pass.

Charge air by-pass

Charge air by-pass used for:

- EPROX GenSet version (variable speed DC)
- For "Fixed Pitch Propeller" operation on part load.

- For CPP (controled pitch propeller) operating in combinator mode on propeller curve.
- Increaseds charge air pressure and airflow.
- Decreases exhaust gas temperatures.
- Decreases smoke emission.

The charge air pipe is connected via a pipe with a smaller diameter and a bypass flap to the exhaust pipe. The flap is closed in normal operation. In the case of propeller operation (diesel-mechanical) at engine loads between 20% and 60% and at rated or reduced speed, the flap is opened to direct a part of the charge air into the exhaust pipe upstream of the turbine. The increased air flow of the turbine results in a higher charge air pressure of the compressor and consequently in improved operating behaviour of the engine. Additionally this flap may be used to prevent turbocharger pumping.

The throttle flap is controlled by a pneumatic actuator cylinder depending on the engine speed and the filling setting of the fuel delivery pumps.

Charge air preheating - 2-stage charge air cooler

Charge air preheating:

- For HFO low load operation (improves ignition delay).
- Increases charge air temperature (compression temperature).
- Decreases smoke emission.

Charge air preheating – via L.T. (low temperature) cut-out is used in the partial load range from 0 % to 40 % of engine load, to achieve the higher charge air temperature. Thereby an improved combustion is ensured and thus - conditionally reduced exhaust smoke.

Device for accelerating the jet assist

This equipment is used where special demands exist for rapid acceleration and/or load application. In such cases, the compressed air from the starting air cylinders is reduced to 4 bars (relative), directed to the compressor casing of the turbocharger and blown to the compressor wheel. In this way, additional air is supplied to the compressor which, in turn, is accelerated, thus increasing the charge air pressure. Operation of the accelerating system is activated by the control system, during start-up and load steps.

Waste gate (WG)

Exhaust gas waste gate used for:

- Control of max. pressure at "Part Load Optimised" operation.
- Control of exhaust gas temperature for SCR operation.

By blowing-off exhaust gas before the turbine, and its return to the exhaust pipe behind the turbine, exhaust gas pressure reduction at the turbocharger takes place and result in lower TC rpm and lower charge air pressure. This measure is necessary when the turbocharger is designed for an optimised partial-load operation. The WG result in higher exhaust temperatures which are used in connection with SCR after treatment of the exhaust gas.

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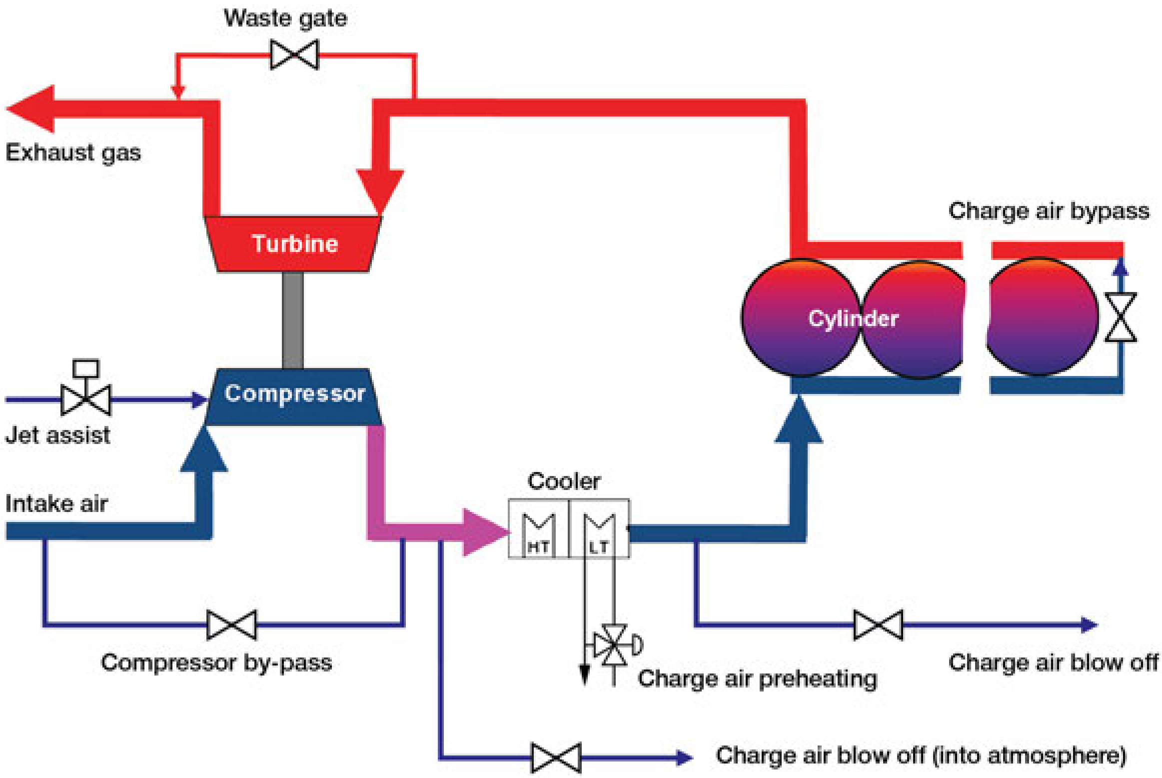

Figure 1: Overview of flaps

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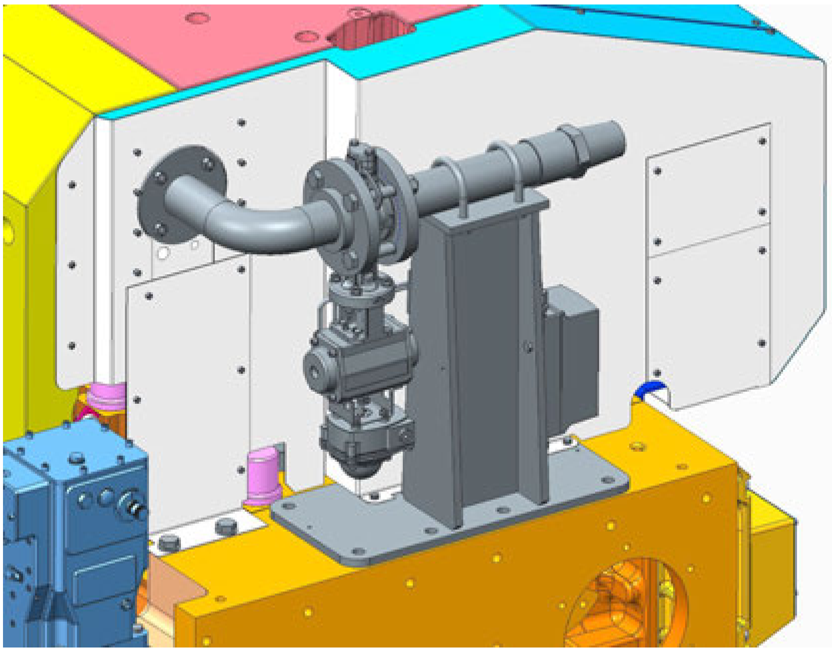
Charge air blow off device

Design of the equipment

The device for blowing off charge air consists of the blow-off pipe on the charge air receiver, the blow-off "butterfly" valve (BOV) with silencer and its electro-pneumatic control system.

Brief description

Depending upon the operation conditions or climatic circumstances, (i.e. if the intake air is cold), the charge air pressure may become too high.
This situation requires a controlled pressure reduction by drawing air from the charge air pipe via the BOV.



Principle of operation

The air supply for pneumatic drive of the valve is controlled by a modulating positioner. The charge air pressure and engine load serves as the criteria for the activation of the BOV. If the charge is less than the threshold value, the BOV remains closed. If the charge pressure is larger than the threshold value, and the engine load higher than the threshold value, the control system triggers the opening of the BOV, blowing part of the charge air off to the engine room, thus reducing the charge air pressure in the engine.

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Cleaning the turbocharger in service - turbine side

Description

High exhaust gas temperatures are often observed and claimed in service. High exhaust gas temperatures are normally caused by fouling on the turbine side of the turbocharger:

➢ Fouling turbine (coke deposit)

⇨ Lower turbocharger performance

⇨ Lower air flow / pressure through the engine

⇨ Increasing exhaust gas temperatures

⇨ Increasing fuel oil consumption

Fouling of the turbine and consequently higher exhaust gas temperature is influenced by: level of maintenance, condition of the fuel injection nozzles / fuel pumps, fuel oil quality and/or long-term low-load operation.

Smaller turbochargers are, due to area-relation in matching parts, more sensitive to coke deposit than larger turbochargers and consequently low power engines as L16/24 or L23/30H will need turbine cleaning more frequent than more powerful engines.

Turbine cleaning intervals must be expected to be following when operating on HFO:
"D-D" Dry-cleaning Daily Cleaning
"W-W" Wet-cleaning Weekly
Cleaning intervals can be shorter/longer based on operational experience. Regular performance observations will show the trend in charge air pressure, exhaust gas temperatures, and define the cleaning intervals for the turbine. However the turbine must be cleaned when exhaust gas temperature before turbine are about 20°C above the normal temperature (ISO corrected) (Sea trial).

Practical service experience have revealed that turbine side of turbocharger only can be sufficient cleaned by combination of nut-shell dry cleaning and water washing.

Dry cleaning of turbine side

This cleaning method employs cleaning agents consisting of dry solid bodies in the form of granules. A certain amount of these granules, depending on the turbocharger size, is, by means of compressed air, blown into the exhaust gas line before the gas inlet casing of the turbocharger.

The injection of granules is done by means of working air with a pressure of 5-7 bar.

On account of their hardness, particularly suited blasting agents such as nutshells, broken or artificially shaped activated charcoal with a grain size of 1.0 mm to max. 1.5 mm should be used as cleaning agents.

The solid bodies have a mechanical cleaning effect which removes any deposits on nozzle vanes and turbine blades.

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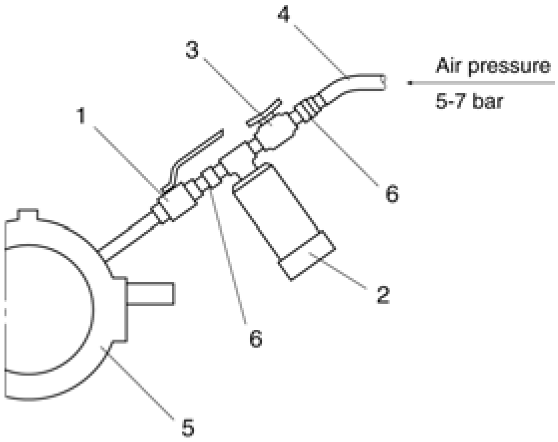
Dry cleaning can be executed at full engine load and does not require any subsequent operating period of the engine in order to dry out the exhaust system.

Cleaning system

The cleaning system consists of a cleaning agent container (2) with a capacity of approx. 0.5 liters and a removable cover. Furthermore the system consists of an air valve (3), a closing valve (1) and two snap on connectors.

The position numbers (2) and (3) indicate the system's "blow-gun". Only one "blow-gun" is used for each engine plant. The blow-gun is working according to the ejector principle with pressure air (working air) at 5-7 bar as driven medium. Injection time approx. 2 min. Air consumption approx. 5 Nm^3/2 min.



1	Closing valve	2	Container
3	Air valve	4	Working air inlet
5	Exhaust pipe	6	Snap coupling

Figure 1: Arrangement of dry cleaning of turbocharger - turbine

Water washing of turbine side

The water flow must be so high that all of the water do not evaporate. Also the waterflow must not be so high that the turbine wheel is drowned and stops rotating. The exhaust gas temperature before turbine and turbine speed must be adjusted in accordance with the below table.

Carry out sequential washing so that exhaust gas temperature after turbine drops below 100°C and in the drying period increases to more than 100°C.

The necessary water flow is depending on exhaust gas flow and temperature. The flow needed depends on the turbocharger size.

For preadjustment of the washing tool, check that the water flow is in accordance with the value in the below table. Open the water supply and adjust the water flow at the valve at the tool. Check in a bucket that the water flow is in the correct range.

Type	Flow rate of washing water l/min
TCR10	3
TCR12	5

Type	Flow rate of washing water l/min
TCR14	7.5
TCR16	7.5
TCR18	10
TCR20	13.5
TCR22	20
The max. permissible cleaning conditions: u_2 = 300 m/s T_{vT} = 320°C anc $P_{water\ max.}$ = approx. 3 bar	
u_2 = peripheral speed of the turbine rotor T_{vT} = exhaust gas temperature upstream of turbine $P_{water\ max.}$ = water pressure	

Table 1: Quantity of washing water for turbine cleaning

Experience has shown, that washing at regular intervals is essential to successful cleaning, as excessive fouling is thus avoided. Washing at intervals of 150 hours is therefore recommended. Depending on the fuel quality these intervals can be shorter or longer. However, the turbine must be washed at the latest when the exhaust gas temperature upstream of the turbine has risen about 20° C above the normal temperature.

Heavily contaminated turbines, which where not cleaned periodically from the very beginning or after an overhaul, cannot be cleaned by this method.

If vibration in the turbocharger occur after waterwashing has been carried out, the washing should be repeated. If unbalance still exists, this is presumably due to heavy fouling, and the engine must be stopped and the turbocharger dismantled and manually cleaned.

The cleaning effect is based on the water solubility of the deposits and on the mechanical action of the impinging water droplets and the water flow rate.

The washing water should be taken from the fresh water system and not from the fresh cooling water system or salt water system. No cleaning agents and solvents need to be added to the water.

To avoid corrosion during standstill, the engine must, upon completing of water washing run for at least 1 hour before stop to insure that all parts are dry.

Water washing arrangement / tool

New engines are as standard delivered with "water washing gun" as a part of standard tools for engines. The tool can be seen in figure 2 and is using the same connecting as the dry cleaning connection.

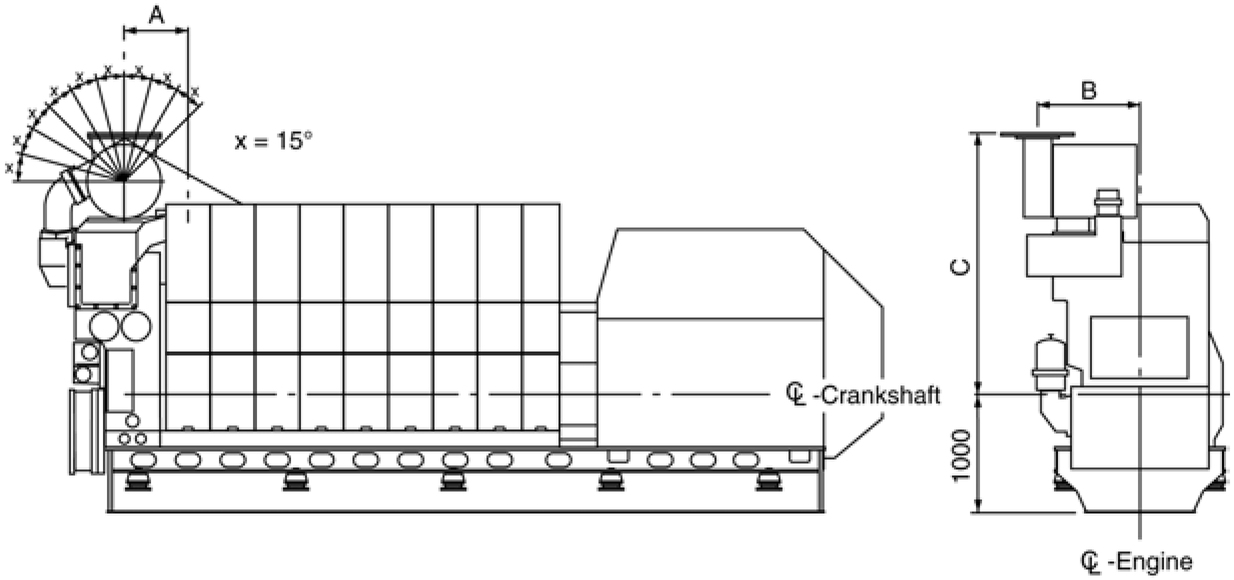
Figure 2: Maneuvering valve

The water for washing the turbine, is supplied from the external fresh water system through a flexible hose with couplings. The flexible hose must be disconnected after water washing.

By activating the maneuvering valve and the regulating valve the water is sprayed into the exhaust gas pipe before the turbine side of the turbocharger. See specific work card for water washing of turbine side. The water that is not evaporated is led out through a drain pipe in the exhaust gas outlet.

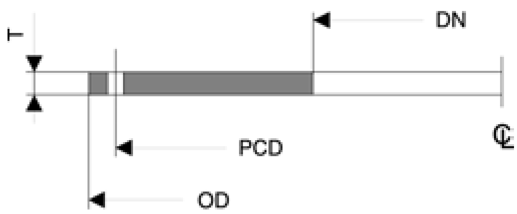
Position of gas outlet on turbocharger

Dimensions



Dimensions			
Engine type	**A**	**B**	**C**
5-7L21/31	792	740	2182.5
8-9L21/31	792	790	2289

Flange



Exhaust flange D. mating dimensions						
Engine type	**DN (mm)**	**OD (mm)**	**T (mm)**	**PCD (mm)**	**Hole size (mm)**	**No of holes**
5L21/31, 900/1000 rpm (TCR16)	400	540	20	495	22	16
6L21/31, 900/1000 rpm (TCR16)	450	595	20	550	22	16
7L21/31, 900/1000 rpm (TCR18) 8L21/31, 900/1000 rpm (TCR18)	500	645	20	600	22	20
9L21/31, 900/1000 rpm (TCR18)	550	703	20	650	22	20

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SCR (Selective Catalytic Reduction)

Introduction

SCR technology

MAN Energy Solutions decided to develop it's own SCR technology to be able to optimise the emissions technology and the engine performance in addition with the MAN Energy Solutions own SCR control programme to the utmost customer benefit.

Common SCR systems require constantly high exhaust gas temperatures. The MAN Energy Solutions 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)".*

Engine overview and SCR system components

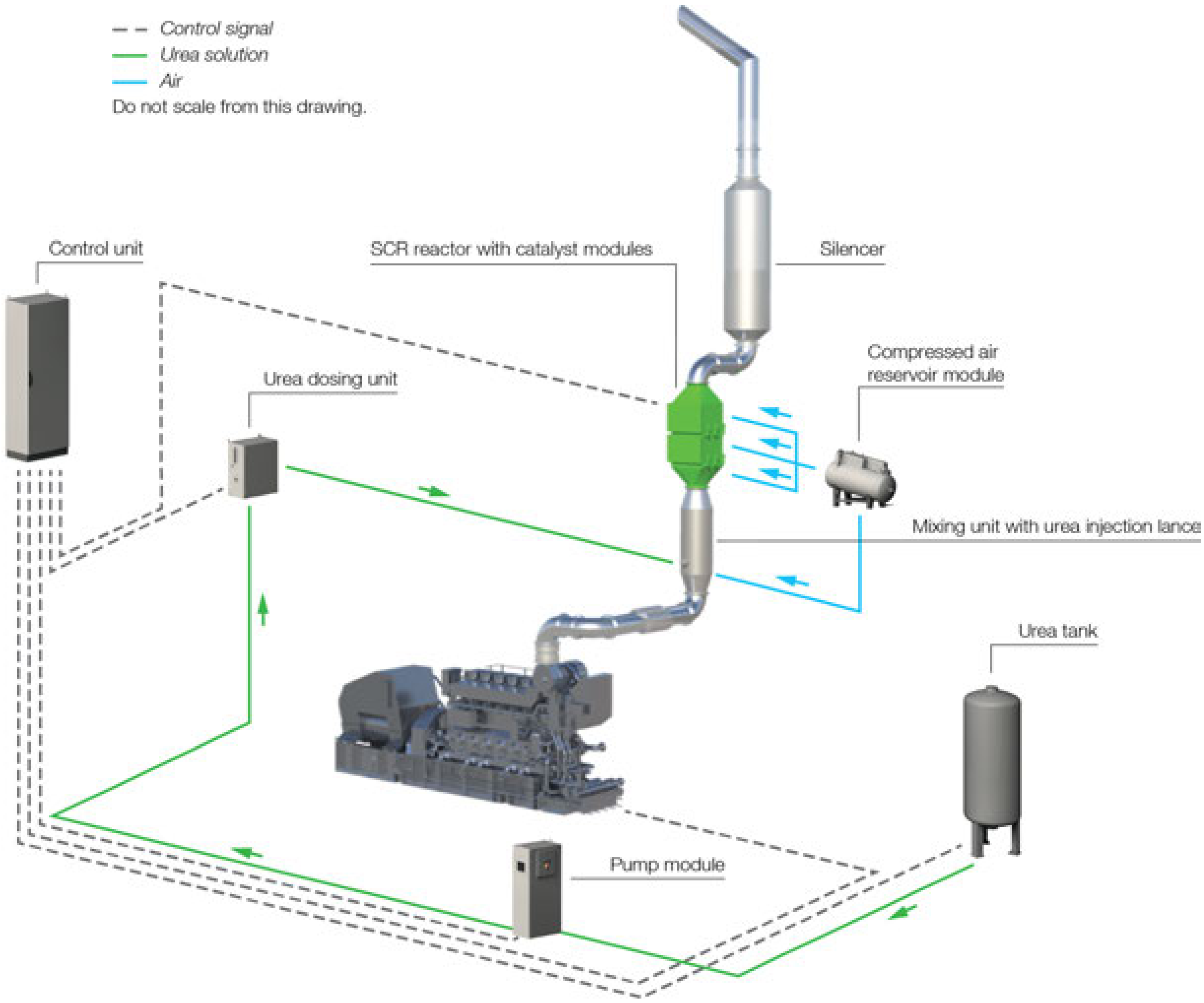

Figure 1: SCR system components overview

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. *See description B 21 01 1, 1356501-5, "Shop test programme for marine GenSet".*

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]

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System overview

The MAN Energy Solutions 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 MAN Energy Solutions 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.

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.
- MAN Energy Solutions 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 MAN Energy Solutions SCR system on the other hand is an integrated engine + SCR system that allows operation on lower exhaust gas temperature levels.

The MAN Energy Solutions 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 MAN Energy Solutions 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.

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 MAN Energy Solutions 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. MAN Energy Solutions therefore recommends to arrange the SCR as the first device in the exhaust gas line, followed by other auxiliaries like boiler, silencer etc.

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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).

NOTICE

Please be aware

All statements in this document refer to MAN Energy Solutions SCR systems only.

MAN Energy Solutions 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 MAN Energy Solutions.

If the engine is supplied without MAN Energy Solutions 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 MAN Energy Solutions 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.

SCR reactor

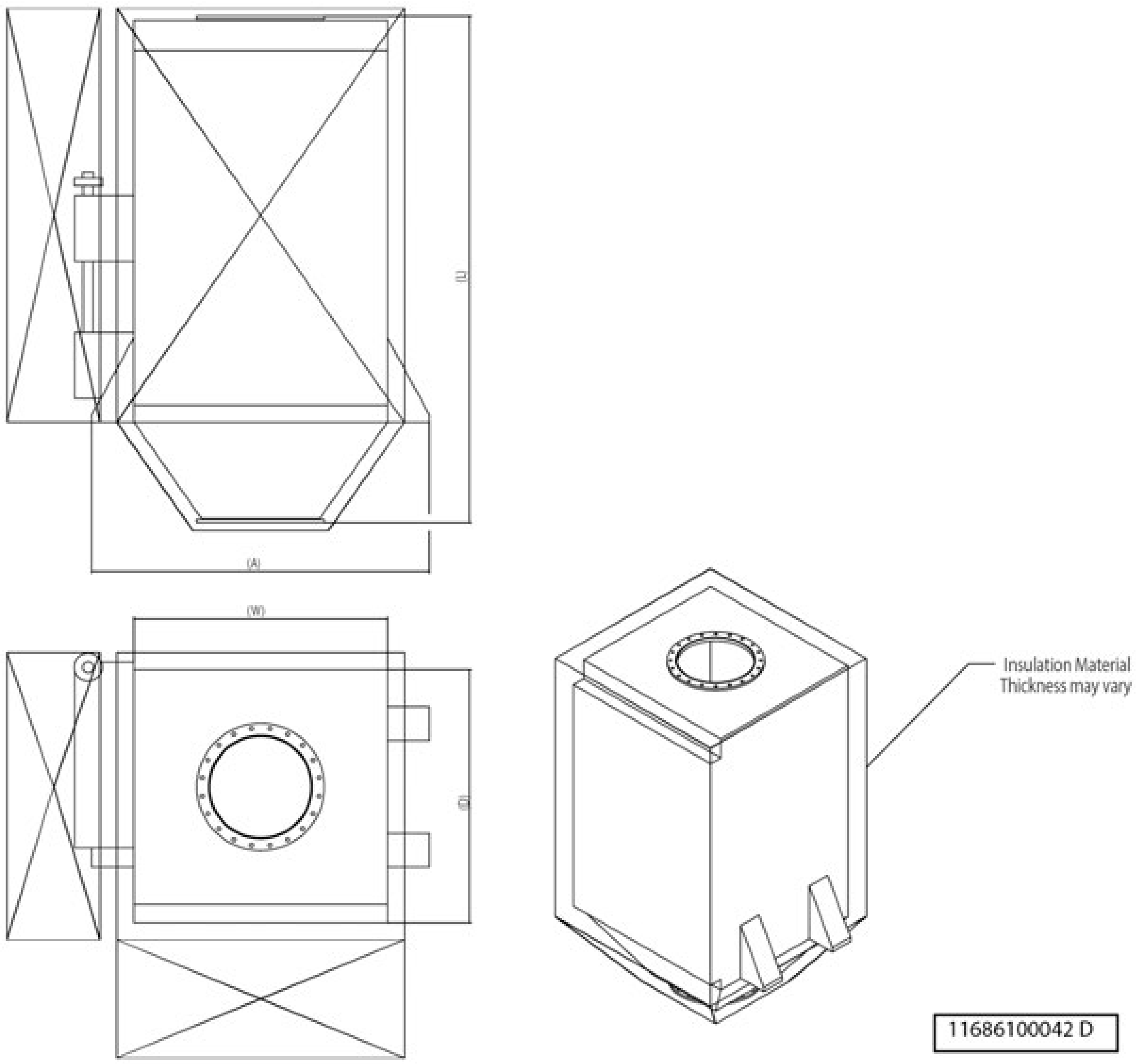

Figure 2: SCR reactor

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

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
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
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

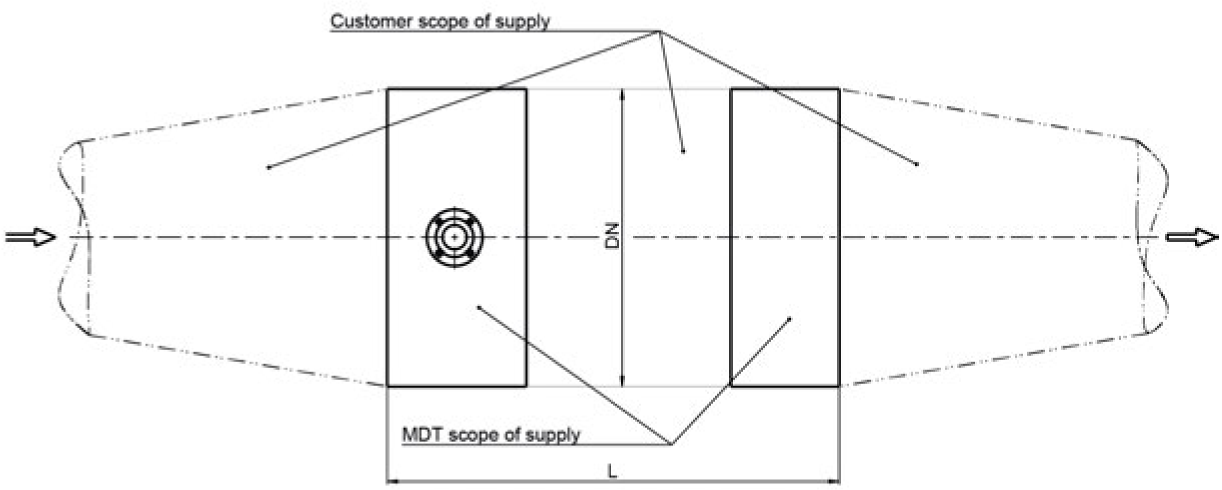


Figure 3: Mixing unit with urea lance

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

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.

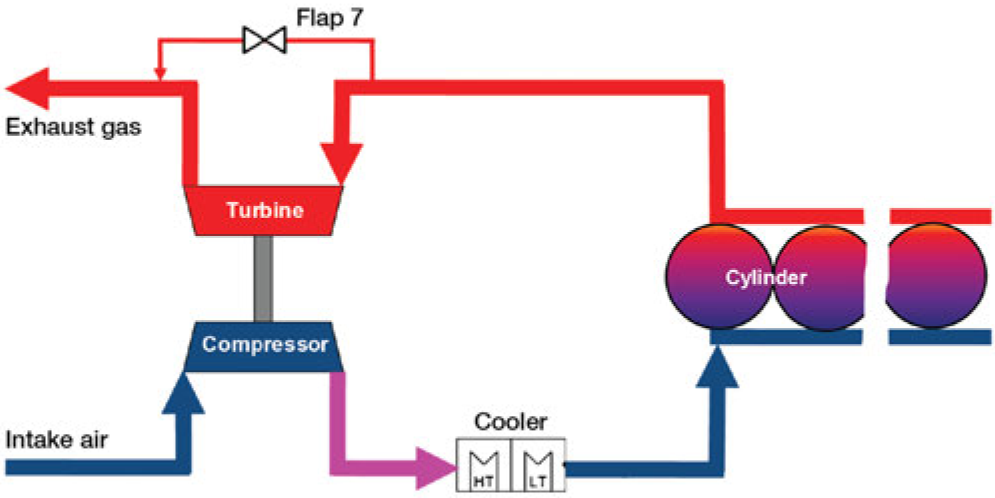


Figure 4: Overview flaps

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

	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

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.

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 (V_2O_5) 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.

2019-01-03 - en

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 MAN Energy Solutions 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 MAN Energy Solutions. 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.

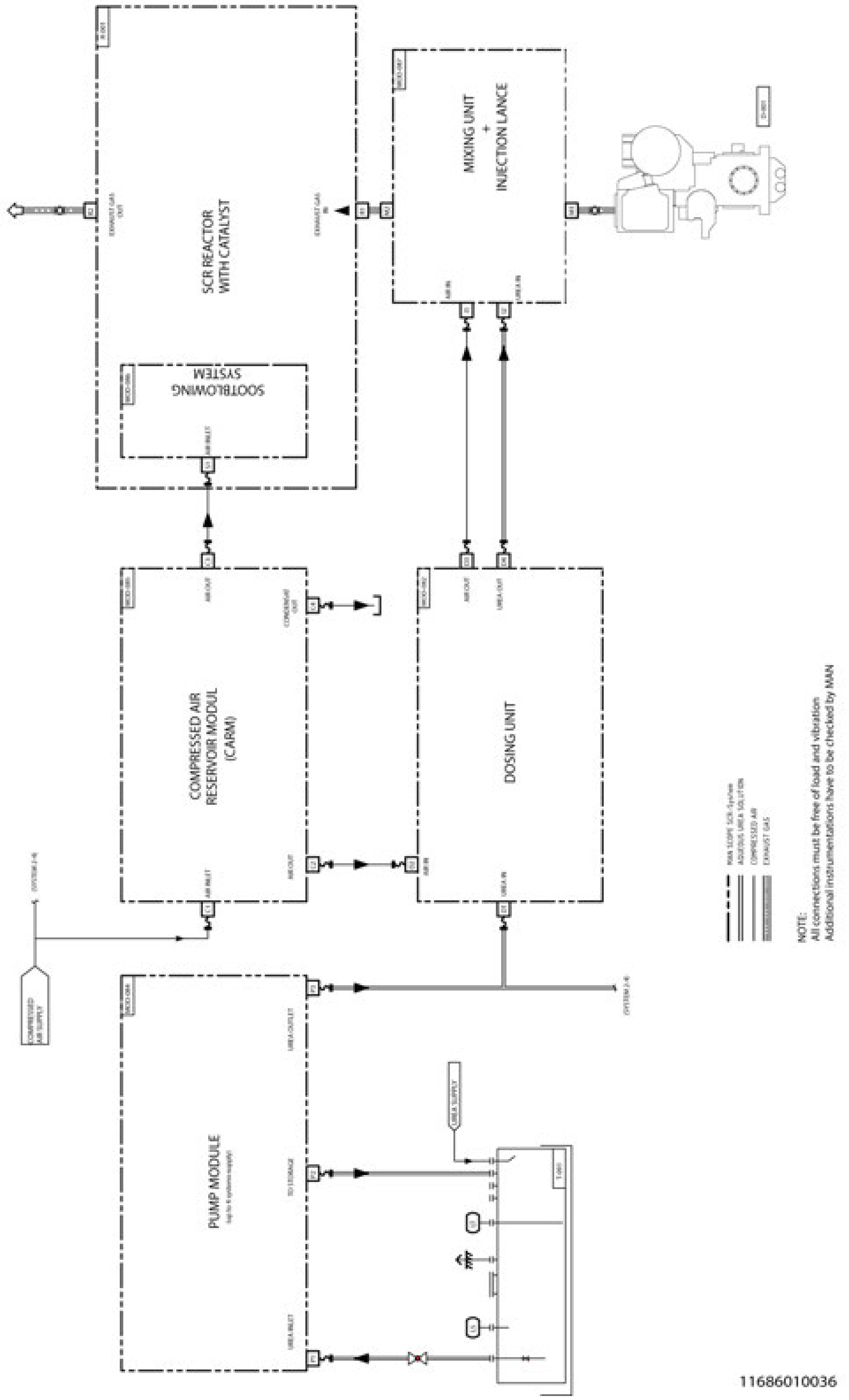


Figure 5: PFD SCR system

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 MAN Energy Solutions requirements mentioned on the planning drawing.

Recommendations

All parts mentioned in this paragraph are not MAN Energy Solutions 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.

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.

Engine room planning

Exhaust gas ducting

Example: Ducting arrangement

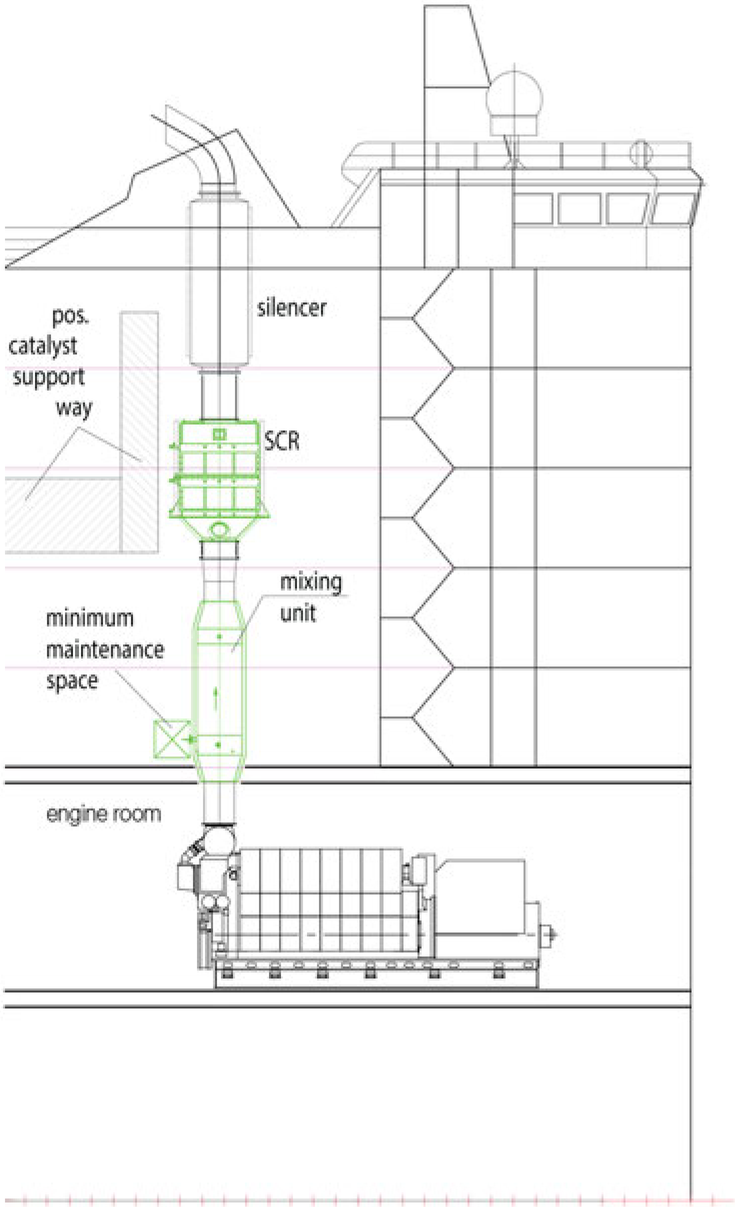


Figure 6: Example: Exhaust gas ducting arrangement

General details for Tier III SCR system duct arrangement

MAN Energy Solutions 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.

All of the spaces/openings for cleaning and maintenance on the entire unit, including air reservoir module, dosing unit and reactor housing with sootblowers 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).

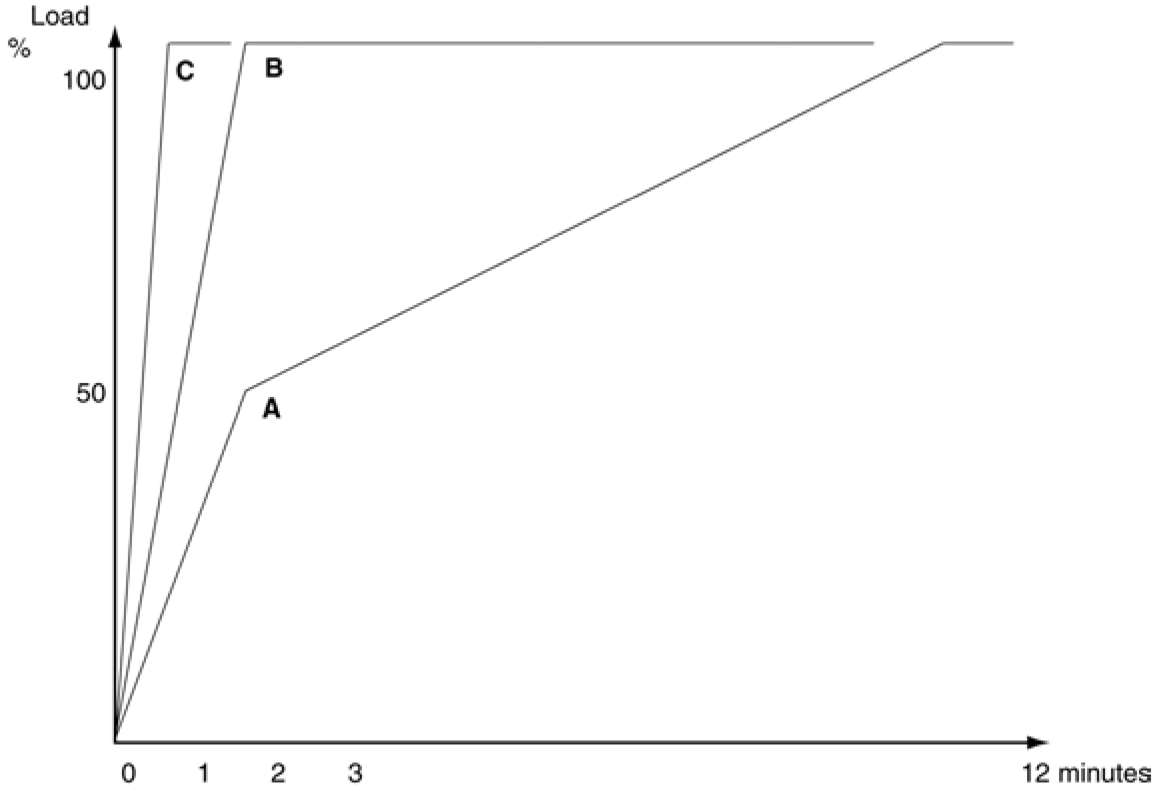
Catalyst elements could reach a weight of 25 kg, the reactor openings could reach a total weight of about 70 kg, MAN Energy Solutions strongly recommends a lifting capability above the reactors.

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, MAN Energy Solutions 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.

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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Load curves for diesel electric propulsion

Running the GenSet as diesel electric propulsion

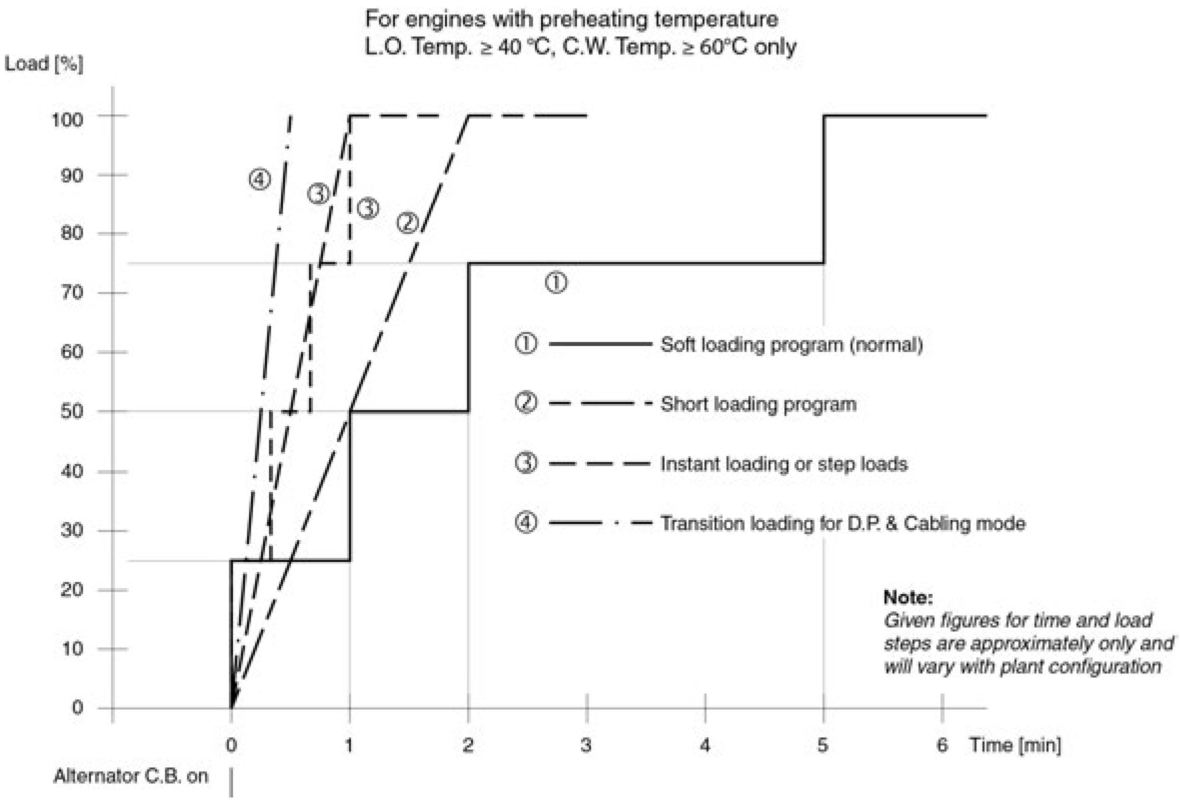

Figure 1: .

When using the GenSet as diesel electric propulsion the curves in fig. 1 is to be followed.

During Diesel Electrical Propulsion normally the Generators are running in isochronous load sharing to improve load sharing during high load transients.

A proper load curve is to be set in the propulsion system to get as smooth load sharing and engine performance as possible.

Isochronous load sharing is done on two possible ways.

1. Using the standard system where the engine control system is working as speed governor. For load sharing a load sharing devise is used for fast and proper load sharing.
2. An external speed governor is used for speed control and proper load control.

Both systems requires additional interface to the power management system and the main switchboard.

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Windmilling protection

If no loaded engines (fuel admission at zero) are being driven by the propeller, this is called "windmilling". The permissible period for windmilling is short, as windmilling may result in opening circuit breaker due to reverse power. The vessels total hotel consumption might very well be lower that the reverse power set point for the connected GenSets.

Please be aware that fuel admission below “0” cannot be controlled by the governors or load sharing device.

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Actuators

Actuator types

As standard, the engines are equipped with an electro-hydraulic actuator, make Regulateurs Europa, type 2800; or make Woodward, type UG25+. Speed Control is carried out via $SaCoS_{one}$ GENSET.

Actuator signal

	Actuator input signal
Regulateurs Europa, type 2800	0-1 A nominal operating range
Woodward, type UG25+	4-20mA nominal operating range

Speed adjustment range

Speed adjustment range is adjustable in $SaCoS_{one}$.

Droop

Droop is adjustable in $SaCoS_{one}$.

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Operation data

Engine load @ MCR

Description		Normal value at full load at ISO conditions		Acceptable value at shop test or after re-pair
Lubricating oil system				
Temperature after cooler, inlet engine	°C	TI 21 TE2165	68-73	<73
Pressure after filter, inlet engine	bar	PI 22 PT2170	4.2-5.0	>4.5
Pressure drop across filter	bar	PDAH 21-22 PDAH2165	0.1-1	<0.5
Prelubricating pressure	bar	(PI 22) PT2170	0.13-1.5	<1.0
Pressure, inlet turbocharger	bar	PI 23 PT2570	1.3-2.2 (C)	>1.3
Pressure before filter	bar	PI 21 PT2165	4.5-5.5	
Temperature main bearing	°C	TI 29 TE	80-95	
Fuel oil system				
Pressure after filter - MDO	bar	PI 40 PT5070	5-8	
Pressure after filter - HFO	bar	PI 40 PT5070	8-10 (A)	
Temperature inlet engine - MDO	°C	TI 40 TE5070	30-40	
Temperature inlet engine - HFO	°C	TI 40 TE5070	110-150	
Cooling water system				
Pressure LT system, inlet engine	bar	PI 01 PT4170	2.4-4.5	>1.8
Pressure HT system, inlet engine	bar	PI 10 PT3170	2.0-5.0	>1.8-<6
Temperature HT system, outlet engine	°C	TI 12 TE3180	75-85	<85
Temperature LT system, inlet engine	°C	TI 01 TE4170	30-40	
Exhaust gas and charge air				

Description		Normal value at full load at ISO conditions		Acceptable value at shop test or after re-pair
Exhaust gas temperature, inlet TC L21/31 L21/31 Mk 2	°C	TI 62 TE6575	 510-560 510-575	
Exhaust gas temperature, outlet cyl	°C	TI 60 TE6570	350-450	
Difference between individual cyl.	°C	TDAH 60 TDAH6570		average ±25
Exhaust gas temperature, outlet TC L21/31 (200 kW/cyl) L21/31 (220 kW/cyl) L21/31 Mk 2 (200 kW/cyl) L21/31 Mk 2 (220 kW/cyl	°C	TI 61 TE6580	 250-350 300-380 TBD 300-390	
Charge air pressure, after cooler L21/31 L21/31 Mk 2	bar	PI 31 PT6180	 3.2-3.5 3.2	
Charge air temperature, after cooler	°C	TI 31 TE6180	40-55	<55
Compressed air system				
Pressure inlet engine TDI Gali	bar	PI 70 PT7170	 7-8 (max 10) < 30	 >7-<8 16-30
Alternator				
Winding temperature	°C	TI 98 TE1095	100	
Bearing temperature	°C	TI 27 TE1094	40-60	

Alarm set points

All alarm set points have to be found in "List of measuring and control devices" (LMC-list). This is included in documentation to SaCoS.

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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.

C. Lubricating oil pressure, offset adjustment

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.

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ENGINE AUTOMATION

MAN Diesel &Turbo SE

SaCoS*one* GENSET
System description

Revision 1.5

Revision History

Revision	Date	Name	Comments
0.1	03.08.2009	Karger	First issue
0.2	04.08.2009	Karger	Interface overview added
0.3	07.08.2009	Brendle	Formal modifications
0.4	11.08.2009	Karger	Interface overview and description corrected
0.5	14.08.2009	Karger	Modbus list added, measurements of the units added, interface overview modified and corrected, power supply scheme added
0.6	23.09.2009	Brendle	Speed governing signals modified
0.7	04.11.2009	Karger	Interface overview modified, detailed interface description added, Modbus ASCII description added
0.8	12.11.2009	Karger	Interface overview modified, GenSet picture corrected
0.9	13.01.2010	Karger	Updated due to comments from Mr. Bojtas
0.10	11.02.2010	Karger	Interface description outsourced to independent document
1.0	18.02.2010	Karger	Measurements, weight and serial interface added
1.1	20.02.2010	Karger	Updated due to comments from H. Cevik
1.2	09.03.2010	Karger	Interface description for Crankcase Monitoring Unit added
1.3	28.05.2010	Karger	Chapter “2.3 Speed control system” modified
1.4	14.06.2010	Karger	Chapter “2.3 Speed control system” and power supply modified
1.5	16.08.2010	Karger	Chapter 3.8.: corrected power supply for safety system

SaCoSone.GENSET_System description_m_en_V1.5.docx

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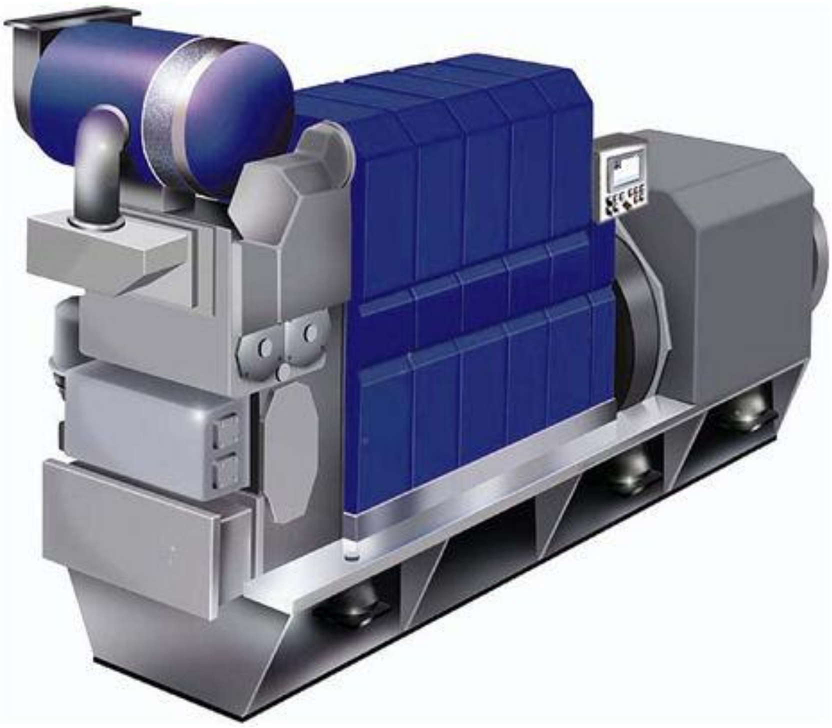
1 General information

This document is valid for the following engine types:

- L16/24
- L21/31
- L27/38

The monitoring and safety system SaCoS$_{one}$ GENSET serves for complete engine operation, control, monitoring and safety of GenSets. All sensors and operating devices are wired to the engine-attached units.
The SaCoS$_{one}$ design is based on high reliable and approved components as well as modules specially designed for installation on medium speed engines. The used components are harmonised to a homogenously system. The whole system is attached to the engine cushioned against vibration.



SaCoS$_{one}$ GENSET mounted on a L16/24 GenSet (Probable Layout)

1.1 Control Unit

The Control Unit includes a highly integrated Control Module for engine control, monitoring and alarm system (alarm limits and delay). The module collects engines measuring data and transfers most measurements and data to the ship alarm system via Modbus.
Furthermore, the Control Unit is equipped with a Display Module. This module consists of a touchscreen and an integrated PLC for the safety system. The Display Module also acts as safety system for over speed, low lubrication oil pressure and high cooling water temperature.

The Display Module provides the following functions:

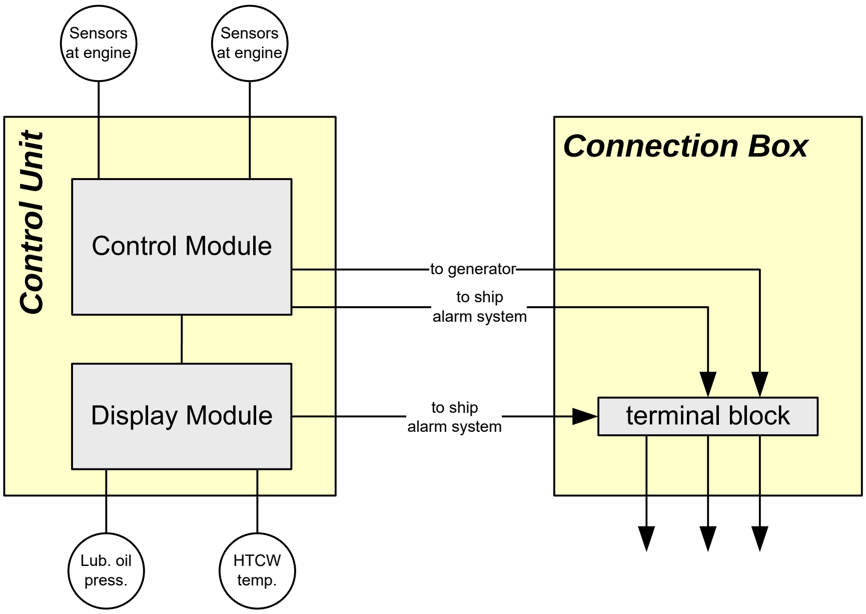
- safety system
- visualisation of measured values and operating values on a touchscreen
- engine operation via touchscreen

The safety system is electrically separated from the control system due to requirements of the classification societies.
For engine operation, additional hardwired switches are available for relevant functions.
The system configuration can be edited via an Ethernet interface at the Display Module.

Prototype of the SaCoS$_{one}$ GENSET

1.2 Connection Box

The Connection Box is the central connecting and distribution point for the 24 VDC power supply of the whole system.
Furthermore it connects the Control Unit with the GenSet, the ship alarm system and the optional crankcase monitoring.

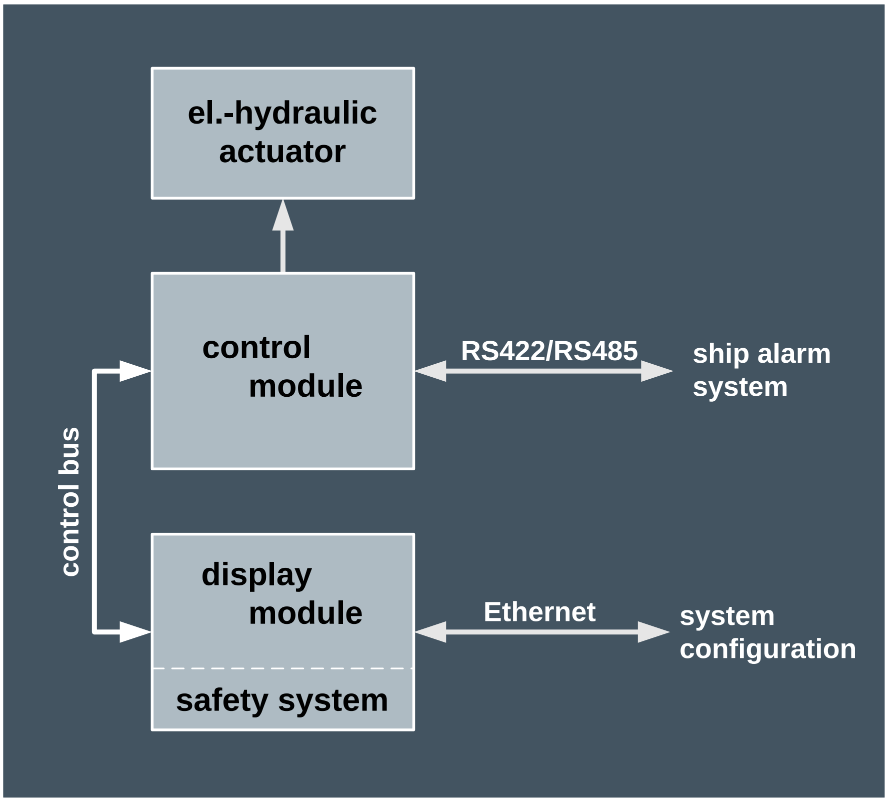


1.3 System bus

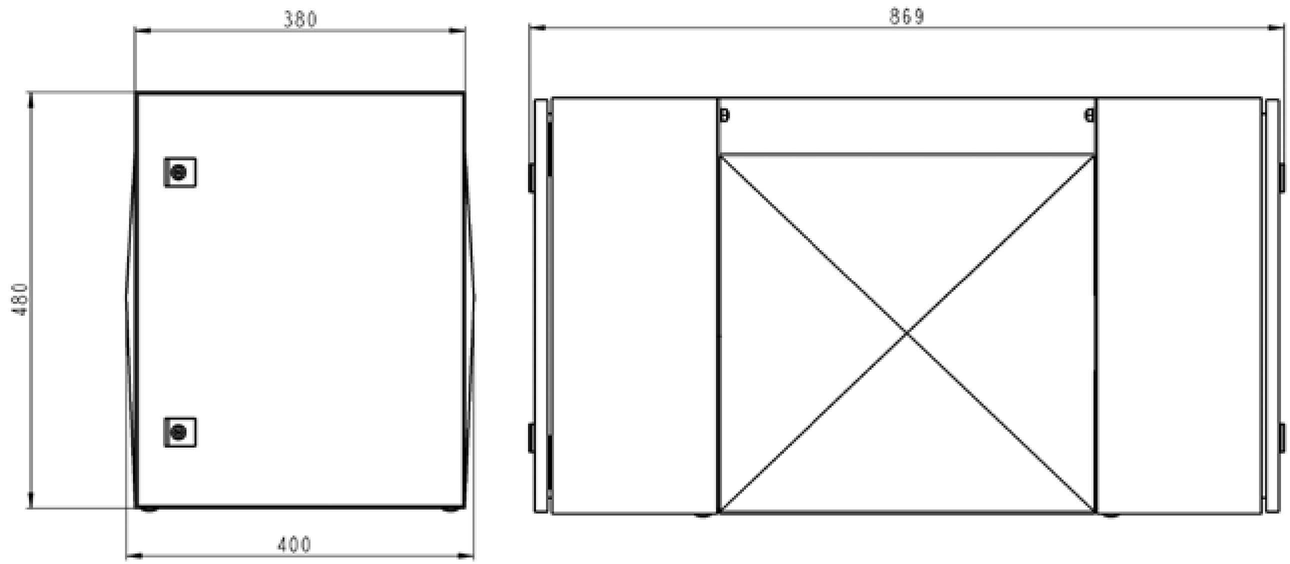
The $SaCoS_{one}$ system is equipped with a redundant bus based on CAN. The bus connects all system modules. This redundant bus system provides the basis data exchange between the modules. The control module operates directly with electro-hydraulic actuator.

- **engine control**
- **speed control**
- **alarm system**

- **display**
- **operation**
- **safety system**



1.4 Technical data



Example shows the dimensions of L16/24

	L16/24	L21/31	L27/38
Width	400 mm	400 mm	400 mm
Height	480 mm	565 mm	480 mm
Length	869 mm	1168 mm	1323 mm
Length overall	902 mm	1201 mm	1356 mm
Weight	60 kg	60 kg	65 kg

2 System description

2.1 Safety system

Safety functions

The safety system monitors all operating data of the engine and initiates the required actions, i.e. engine shut-down, in case the limit values are exceeded. The safety system is integrated the Display Module.
The safety system directly actuates the emergency shut-down device and the stop facility of the speed governor.

Auto shutdown

Auto shutdown is an engine shutdown initiated by any automatic supervision of engine internal parameters.

Emergency stop

Emergency stop is an engine shutdown initiated by an operator manual action like pressing an emergency stop button. An emergency stop button is placed at the Control Unit on engine. For connection of an external emergency stop button there is one input channel at the Connection Box.

Engine shutdown

If an engine shutdown is triggered by the safety system, the emergency stop signal has an immediate effect on the emergency shut-down device and the speed control. At the same time the emergency stop is triggered, SaCoS$_{one}$ issues a signal resulting in the generator switch to be opened.

Shutdown criteria

- Engine overspeed
- Failure of both engine speed sensors
- Lube oil pressure at engine inlet low
- HT cooling water temperature outlet too high
- High bearing temperature/deviation from Crankcase Monitoring System. (optional)
- High oilmist concentration in crankcase. (optional)
- Remote Shutdown. (optional)
    - Differential protection (optional)
    - Earth connector closed (optional)
    - Gas leakage (optional)

2.2 Alarm/monitoring system

Alarming

The alarm function of SaCoS$_{one}$ supervises all necessary parameters and generates alarms to indicate discrepancies when required. The alarms will be transferred to ship alarm system via Modbus data communication.

Self-monitoring

SaCoS$_{one}$ carries out independent self-monitoring functions. Thus, for example the connected sensors are checked constantly for function and wire break. In case of a fault SaCoS$_{one}$ reports the occurred malfunctions in single system components via system alarms.

Control

SaCoS$_{one}$ controls all engine-internal functions as well as external components, for example:

- Start/stop sequences:
  - Local and remote start/stop sequence for the GenSet.
  - Activation of start device. Control (auto start/stop signal) regarding prelubrication oil pump.
  - Monitoring and control of the acceleration period.

- Jet system:
  - For air fuel ratio control purposes, compressed air is lead to the turbocharger at start and at load steps.

- Control signals for external functions:
  - Nozzle cooling water pump (only engine type 32/40)
  - HT cooling water preheating unit
  - Prelubrication oil pump control
- Redundant shutdown functions:
  - Engine overspeed
  - Low lub. oil pressure inlet engine
  - High cooling water temperature outlet engine

2.3 Speed Control System

Governor

The engine electronic speed control is realized by the Control Module. As standard, the engine is equipped with an electro-hydraulic actuator.

Speed adjustment

Local, manual speed setting is possible at the Control Unit with a turn switch.

Remote speed setting is either possible via 4-20mA signal or by using hardwired lower/raise commands.

Speed adjustment range

Between -5% and +10% of the nominal speed at idle running.

Droop

Adjustable by parameterisation tool from 0-5% droop.

Load distribution

By droop setting.

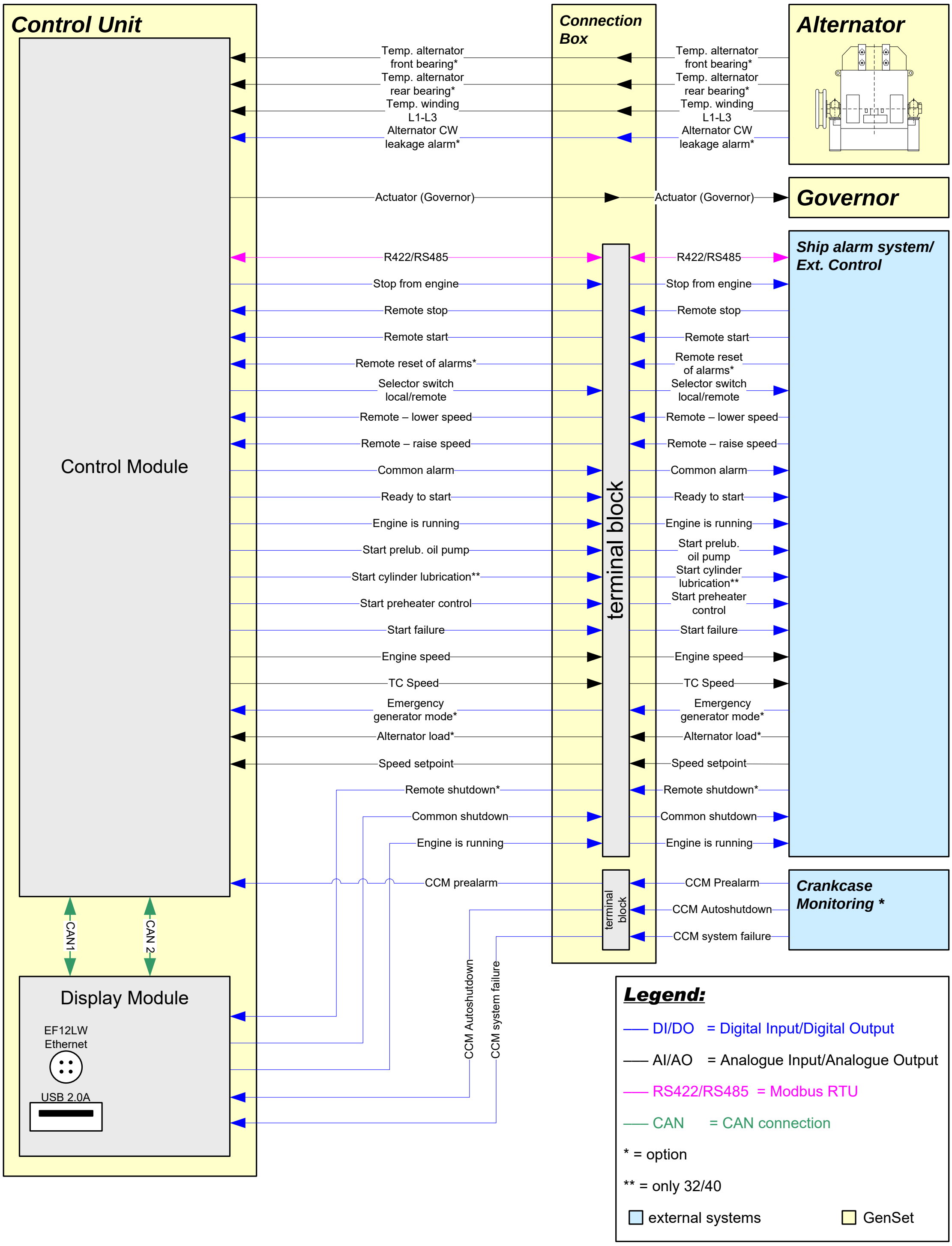
Engine stop

Engine stop can be initiated local at the display module and remote via a hardware channel or the bus interface.

3 Interfaces to external systems

3.1 Overview

A detailed signal description is available on the GS Product page in the document "*SaCoSone.GenSet.Interface_description_Vx.x.docx*". (Available as PDF)



3.2 Data Machinery Interface

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 SaCoS$_{one}$ GENSET are available for transfer.

The following MODBUS protocols are available:

- MODBUS RTU (Standard)
- MODBUS ASCII (for retrofits)

For a detailed description of these protocols see the document "SaCoS$_{one}$ GENSET, Communication from the GenSet".

3.3 Generator Control

SaCoS$_{one}$ provides inputs for all temperature signals for the temperatures of the generator bearings and generator windings.

3.4 Power Management

Hardwired interface for remote start/stop, speed setting, alternator circuit breaker trip etc.

3.5 Remote control

For remote control several digital inputs are available.

3.6 Ethernet interface

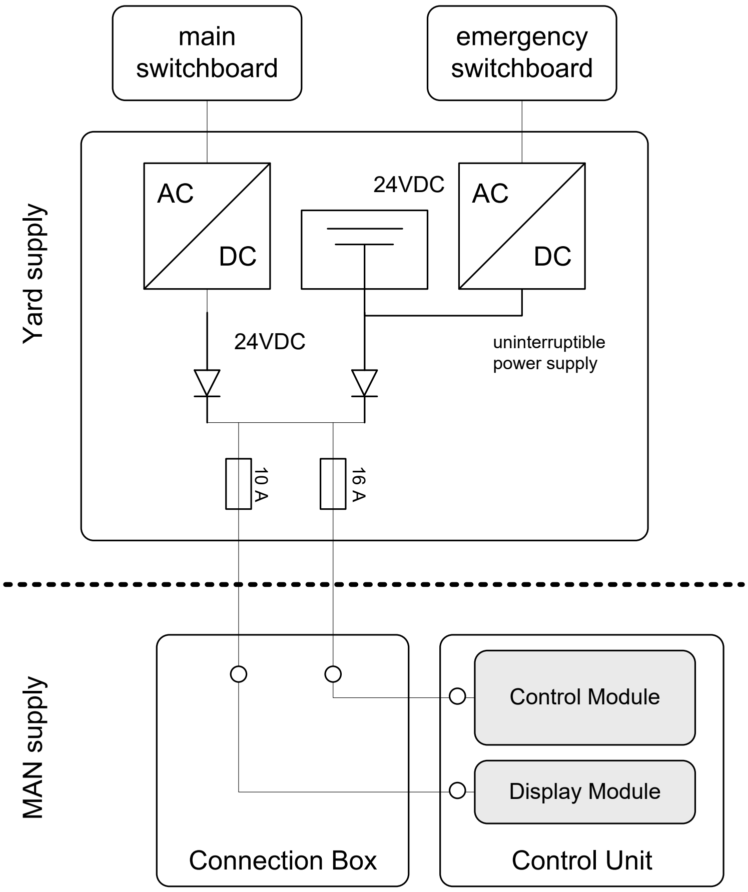
The Ethernet interface at the Display Module can be used for the connection of SaCoS$_{one}$ EXPERT.

3.7 Serial interface

CoCoS-EDS can be connected to a serial RS485 interface.

3.8 Power supply

The plant has to provide electric power for the automation and monitoring system. In general a redundant, uninterrupted 24V DC (+20% -30% and max ripple 10%) power supply is required for SaCoS$_{one}$.
The alarm system requires a 24V DC, 12,5 A uninterrupted power supply with a 16 A pre-fuse.
The safety system requires a 24V DC, 8,5 A uninterrupted power supply with a 10 A pre-fuse.



3.9 Crankcase Monitoring Unit (optional)

SaCoS$_{one}$ GENSET provides an interface to an optional Crankcase Monitoring Unit. This unit is not part of SaCoS$_{one}$ GENSET and is not scope of supply. If applied, it is delivered as stand-alone system in an extra control cabinet.

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SaCoS*one* GENSET
Communication from GenSet

Revision **1.7**

Revision history

Rev.	Description	Date	Department
0.1	First issue	11.01.2010	ESPP
0.2	Block 4 of Modbus ASCII removed, class information removed	02.03.2010	ESPP
1.0	Modbus TCP list updated	16.03.2010	ESPP
1.1	Modbus list updated	27.05.2010	ESPP
1.2	Modbus ASCII is available for all engines	10.06.2010	ESPP
1.3	Modbus ASCII block addresses deleted, Modbus list is now a separate document	02.08.2010	ESPP
1.4	Chapter 1: possibility of Modbus TCP for CoCoS-EDS communication added Chapter 2: Added notice about which module allows the use which Modbus protocol Chapter 2.4.2: Live Bit: live bit alternates every 4 seconds.	17.05.2011	ESPP
1.5	Chapter 2.4.2: Live Bit: Modbus address removed from description. For details see Modbus List	09.08.2011	ESPP
1.6	Chapter 3.3: Data format description corrected Document layout changed	16.12.2011	ESPP
1.7	Chapter 4: Information added about extended operation hour counter	23.11.2012	EESPD

MAN Diesel & Turbo
86224 Augsburg, Germany
Phone +49 821 322-0
Fax +49 821 322-3382
info-de@mandieselturbo.com
www.mandieselturbo.com

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1 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 $SaCoS_{one}$ GENSET are available for transfer.

The following Modbus protocols are available:

- Modbus RTU (Standard)
- Modbus ASCII
- Modbus TCP (only for CoCoS-EDS)

The Modbus RTU protocol is the standard protocol used for the communication from the GenSet. For the integration in older automation system, Modbus ASCII is also available. Modbus TCP is only available for the connection of CoCoS-EDS via Gateway Module.

2 Modbus RTU protocol

The Modbus RTU protocol is the standard protocol used for the communication from the GenSet.

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,

NOTICE

Important

For serial Modbus communication the following hardware requirements must be observed:

- Control Module S: Modbus RTU and Modbus ASCII possible
- Gateway Module: only Modbus RTU available

There are two serial interface standards available:

- RS422 – Standard, 4 + 2 wire (cable length <= 100m), cable type as specified by the circuit diagram, line termination: 120 Ohms
- RS485 – Standard, 2 + 2 wire (cable length <= 100m), cable type as specified by the circuit diagram, line termination: 120 Ohms

2.1 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

2.2 Function Codes

The following function codes are available to gather data from the SaCoS_{one} 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

Function Code	Function Code (hexadecimal)	Description
22	0x16	mask write register
23	0x17	read write multiple registers

2.3 Message Frame Separation

Message frames shall be separated by a silent interval of at least 4 character times.

2.4 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 SaCoS$_{one}$ 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.

2.4.1 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.

2.4.2 Live Bit

In order to enable the alarm system to check whether the communication with SaCoS is working, a live bit is provided in the list of signals. This Bit is alternated every 4 seconds by SaCoS. Thus, if it remains unchanged for more than 4 seconds, the communication is down.

3 Modbus ASCII protocol

3.1 General

The communication setup is: 9600 baud, 8 databits, 1 stopbit, no parity.

The Modbus protocol accepts one command (Function Code 03) for reading analogue and digital input values one at a time, or as a block of up to 32 inputs.

The following chapter describes the commands in the Modbus protocol, which are implemented, and how they work.

3.2 Protocol Description

The ASCII and RTU version of the Modbus protocol is used, where the CMS/DM works as Modbus slave.

All data bytes will be converted to 2-ASCII characters (hex-values). Thus, when below is referred to “bytes“ or “words“, these will fill out 2 or 4 characters, respectively in the protocol. The general “message frame format“ has the following outlook:

[:] [SLAVE] [FCT] [DATA] [CHECKSUM] [CR] [LF]

– [:]	1 char. Begin of frame
– [SLAVE]	2 char. Modbus slave address (Selected on DIP-switch at Display Module)
– [FCT]	2 char. Function code
– [DATA]	n X 2 chars data.
– [CHECKSUM]	2 char checksum (LRC)
– [CR]	1 char CR
– [LF]	1 char LF (end of frame)

The following function codes (FCT) is accepted:

- – 03H: Read n words at specific address.
- – 10H: Write n words at specific address.

In response to the message frame, the slave (CMS) must answer with appropriate data. If this is not possible, a package with the most important bit in FCT set to 1 will be returned, followed by an exception code, where the following is supported:

– 01: Illegal function

– 02: Illegal data address

– 03: Illegal data value

– 06: BUSY. Message rejected

FCT = 03H: Read n words

The master transmits an inquiry to the slave (CMS) to read a number (n) of datawords from a given address. The slave (CMS) replies with the required number (n) of datawords. To read a single register (n) must be set to 1. To read block type register (n)

must be in the range 1...32.

Request (master):

[DATA] = [ADR][n]

[ADR]=Word stating the address in HEX.

[n]=Word stating the number of words to be read.

Answer (slave-CMS):

[DATA] = [bb][1. word][2. word]....[n. word]

[bb]=Byte, stating number of subsequent bytes.

[1. word]=1. dataword

[2. word]=2. dataword

[n. word]=No n. dataword

FCT = 10H: Write n words

The master sends data to the slave (CMS/DM) starting from a particular address. The slave (CMS/DM) returns the written number of bytes, plus echoes the address.

Write data (master):

[DATA] = [ADR][n] [bb][1. word][2. word]....[n word]

[ADR] = Word that gives the address in HEX.

[n] = Word indicating number of words to be written.

[bb] = Byte that gives the number of bytes to follow (2*n)

Please note that 8bb9 is byte size!

[1. word]=1. dataword

[2. word]=2. dataword

[n. word]=No n. dataword

Answer (slave-CMS/DM):

[DATA] = [ADR][bb*2]

[ADR]= Word HEX that gives the address in HEX

[bb*2]=Number of words written.

[1. word]=1. dataword

[2. word]=2. dataword

[n. word]=No n. dataword

Modbus ASCII protocol

3.3 Data Format

Example for Modbus ASCII Data Format:

Extract from Modbus ASCII list

MW 113	71	0	F	Signal fault ZS82 : Emergency stop (pushbutton)	SF=1	CMS	binary
		1	F	Signal fault ZS75 : Turning gear disengaged	SF=1	CMS	binary
		2	F	Signal fault SS84 : Remote stop	SF=1	CMS	binary
		3	F	Signal fault SS83 : Remote start	SF=1	CMS	binary
		4	F	Signal fault LAH28 : Lube oil level high	SF=1	CMS	binary
		5	F	Signal fault LAL28 : Lube oil level low	SF=1	CMS	binary
		6	F	Signal fault LAH42 : Fuel oil leakage high	SF=1	CMS	binary
		7	F	Signal fault ZS97 : Remote switch	SF=1	CMS	binary
		8	F	Signal fault LAH92 : OMD alarm	SF=1	CMS	binary
		9	F	Signal fault TAH 29-27 : CCMON alarm	SF=1	CMS	binary
		10	F	Signal fault : Remote reset	SF=1	CMS	binary
		11	F	Signal fault LAH98 : Alternator cooling water leakage alarm	SF=1	CMS	binary
		12	F	Signal fault : Emergency generator mode	SF=1	CMS	binary
		13	F	Signal fault : Speed raise	SF=1	CMS	binary
		14	F	Signal fault : Speed lower	SF=1	CMS	binary
		15	F	Signal fault : Switch isochronous / droop mode	SF=1	CMS	binary

For this example we assume that the following alarms have been triggered:

Signal fault SS83 : Remote start,
Signal fault LAL28 : Lube oil level low,
Signal fault ZS97 : Remote switch,
Signal fault LAH92 : OMD alarm,
Signal fault TAH 29-27 : CCMON alarm,
Signal fault : Emergency generator mode,
Signal fault : Switch isochronous / droop mode

The Bit-sample of MW 113:

Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Value	0	0	0	1	0	1	0	1	1	1	0	0	1	0	0	1

In Modbus ASCII these 16 Bits are grouped in 4 groups each containing 4 Bits and then translated from binary format to hexadecimal format (0-9, A-F)

	Binary	Hex
Bit 0-3	0001	1
Bit 4-7	0101	5
Bit 8-11	1100	C
Bit 12-15	1001	9

In the next step these Hexadecimal values are interpreted as ASCII-signs (extract from ASCII table):

Hexadecimal	ASCII
30	0
31	1
32	2
33	3
34	4
35	5
36	6
37	7
38	8
39	9
41	A
42	B
43	C
44	D
45	E
45	F

In this example the letter (ASCII letter) 1 will be translated hexadecimal value 31 and so on:

1 --> 31

5 --> 35

C --> 43

9 --> 39

When the ship alarm system recalls MW113, it receives the following data embedded in the Modbus message: 31 35 43 39

4 Extended operating hour counters via MODBUS

The operating hour counter and the overload hour counter are available via the Modbus Interface. The maximum range was extended to 1,193,046 hours in CM-Software version 1.2.1.

At the Modbus register addresses MW124 and MW125 the existing operating hour counters are still available to ensure compatibility. These operating hour counters are showing up to 65,535 hours.

Register addresses

The new register addresses for the extended operating hour counter:

- Low word: MW 130
- High word: MW 131

The new register addresses for the extended overload hour counter:

- Low word: MW 132
- High word: MW 133

Data type

The data type used at these registers is **unsigned integer** of size **16 bit**.

To use the extended operating hour counter, connected systems must concatenate two Modbus register addresses in the following way:

MW 130 LW

MW 131 HW

OpHour [h] = ((HW x 65536) + LW) / 3600

This procedure is also applicable for the overload hour counter:

MW 132 LW

MW 133 HW

OverloadHour [h] = ((HW x 65536) + LW) / 3600

5 Modbus list

The Modbus list is valid for Modbus ASCII and Modbus RTU. The list can be found in the document “SaCoS-one.GENSET_SignListMan_MP_EN_xx.xx.pdf” where “xx.xx” means the actual revision.

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Modbus list

The Modbus list is valid for Modbus ASCII and Modbus RTU

Adress	Hex	Bit	Meas. Point	Description	Unit	Origin	Signal range
MW 0	0		TE60-1	Exhaust gas temperature cylinder A1	°C	CMS	0 - 700
MW 1	1		TE60-2	Exhaust gas temperature cylinder A2	°C	CMS	0 - 700
MW 2	2		TE60-3	Exhaust gas temperature cylinder A3	°C	CMS	0 - 700
MW 3	3		TE60-4	Exhaust gas temperature cylinder A4	°C	CMS	0 - 700
MW 4	4		TE60-5	Exhaust gas temperature cylinder A5	°C	CMS	0 - 700
MW 5	5		TE60-6	Exhaust gas temperature cylinder A6	°C	CMS	0 - 700
MW 6	6		TE60-7	Exhaust gas temperature cylinder A7	°C	CMS	0 - 700
MW 7	7		TE60-8	Exhaust gas temperature cylinder A8	°C	CMS	0 - 700
MW8	8		TE60-9	Exhaust gas temperature cylinder A9	°C	CMS	0 - 700
MW9	9		TE60-10	Exhaust gas temperature cylinder A10	°C	CMS	0 - 700
MW10	A		TE62	Exhaust gas temp. before turbocharger A	°C	CMS	0 - 700
MW11	B		TE61	Exhaust gas temp. after turbocharger A	°C	CMS	0 - 700
MW15	F			Exhaust gas temperature mean value	°C	CMS	0 - 700
MW 16	10	0		Sensor fault TE60-1: Exh. gas temp. cylinder A1	SF=1	CMS	binary
		1		Sensor fault TE60-2: Exh. gas temp. cylinder A2	SF=1	CMS	binary
		2		Sensor fault TE60-3: Exh. gas temp. cylinder A3	SF=1	CMS	binary
		3		Sensor fault TE60-4: Exh. gas temp. cylinder A4	SF=1	CMS	binary
		4		Sensor fault TE60-5: Exh. gas temp. cylinder A5	SF=1	CMS	binary
		5		Sensor fault TE60-6: Exh. gas temp. cylinder A6	SF=1	CMS	binary
		6		Sensor fault TE60-7: Exh. gas temp. cylinder A7	SF=1	CMS	binary
		7		Sensor fault TE60-8: Exh. gas temp. cylinder A8	SF=1	CMS	binary
		8		Sensor fault TE60-9: Exh. gas temp. cylinder A9	SF=1	CMS	binary
		9		Sensor fault TE60-10: Exh. gas temp. cylinder A10	SF=1	CMS	binary
		10		Sensor fault TE62: Exhaust gas temp. before TC A	SF=1	CMS	binary
		11		Sensor fault TE61: Exhaust gas temp. after TC A	SF=1	CMS	binary
MW 17	11	0	TAH60-1	Alarm: High exhaust gas temperature cylinder A1	active=1	CMS	binary
		1	TAH60-2	Alarm: High exhaust gas temperature cylinder A2	active=1	CMS	binary
		2	TAH60-3	Alarm: High exhaust gas temperature cylinder A3	active=1	CMS	binary
		3	TAH60-4	Alarm: High exhaust gas temperature cylinder A4	active=1	CMS	binary
		4	TAH60-5	Alarm: High exhaust gas temperature cylinder A5	active=1	CMS	binary
		5	TAH60-6	Alarm: High exhaust gas temperature cylinder A6	active=1	CMS	binary
		6	TAH60-7	Alarm: High exhaust gas temperature cylinder A7	active=1	CMS	binary
		7	TAH60-8	Alarm: High exhaust gas temperature cylinder A8	active=1	CMS	binary
		8	TAH60-9	Alarm: High exhaust gas temperature cylinder A9	active=1	CMS	binary
		9	TAH60-10	Alarm: High exhaust gas temperature cylinder A10	active=1	CMS	binary
		10	TAH62	Alarm: High exh. gas temp. before turbocharger A	active=1	CMS	binary
		11	TAH61	Alarm: High exhaust gas temp. after turbocharger A	active=1	CMS	binary

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Adress	Hex	Bit	Meas. Point	Description	Unit	Origin	Signal range
MW 18	12	0	TAD60-1	Alarm: Mean value deviation exh. gas temp. cyl. A1		CMS	binary
		1	TAD60-2	Alarm: Mean value deviation exh. gas temp. cyl. A2		CMS	binary
		2	TAD60-3	Alarm: Mean value deviation exh. gas temp. cyl. A3		CMS	binary
		3	TAD60-4	Alarm: Mean value deviation exh. gas temp. cyl. A4		CMS	binary
		4	TAD60-5	Alarm: Mean value deviation exh. gas temp. cyl. A5		CMS	binary
		5	TAD60-6	Alarm: Mean value deviation exh. gas temp. cyl. A6		CMS	binary
		6	TAD60-7	Alarm: Mean value deviation exh. gas temp. cyl. A7		CMS	binary
		7	TAD60-8	Alarm: Mean value deviation exh. gas temp. cyl. A8		CMS	binary
		8	TAD60-9	Alarm: Mean value deviation exh. gas temp. cyl. A9		CMS	binary
		9	TAD60-10	Alarm: Mean value deviation exh. gas temp. cyl. A10		CMS	binary
MW 32	20		TE12	HT cooling water temperature engine outlet		CMS	0 - 200
MW 33	21		TE01	LT cooling water temperature air cooler inlet		CMS	0 - 200
MW 34	22		TE21	Lube oil temperature filter inlet		CMS	0 - 200
MW 35	23		TE40	Fuel oil temperature engine inlet		CMS	0 - 200
MW 36	24		TE31	Charge air temperature cooler outlet		CMS	0 - 200
MW 37	25		TE98-1	Alternator windwing temperature L1		CMS	0 - 200
MW 38	26		TE98-2	Alternator windwing temperature L2		CMS	0 - 200
MW 39	27		TE98-3	Alternator windwing temperature L3		CMS	0 - 200
MW 40	28		TE38	Ambient air temperature		CMS	0 - 200
MW 41	29		TE10	HT cooling water temperature engine inlet		CMS	0 - 200
MW 42	2A		TE27-1	Alternator front bearing temperature		CMS	0 - 200
MW 43	2B		TE27-2	Alternator rear bearing temperature		CMS	0 - 200
MW 48	30	0		Sensor fault TE12 : HT cool water temp. engine outlet		CMS	binary
		1		Sensor fault TE01 : LT cool water temp. air cooler inlet		CMS	binary
		2		Sensor fault TE21 : Lube oil temperature filter inlet		CMS	binary
		3		Sensor fault TE40 : Fuel oil temperature engine in-let		CMS	binary
		4		Sensor fault TE31 : Charge air temp. cooler outlet		CMS	binary
		5		Sensor fault TE98-1 : Alternator windwing temp. L1		CMS	binary
		6		Sensor fault TE98-2 : Alternator windwing temp. L2		CMS	binary
		7		Sensor fault TE98-3 : Alternator windwing temp. L3		CMS	binary
		8		Sensor fault TE38 : Ambient air temperature		CMS	binary
		9		Sensor fault TE10 : HT cool. water temp. engine inlet		CMS	binary
		10		Sensor fault TE27-1 : Alternator front bearing temp.		CMS	binary
		11		Sensor fault TE27-2 : Alternator rear bearing temp.		CMS	binary

Adress	Hex	Bit	Meas. Point	Description	Unit	Origin	Signal range
MW 64	40		PT10	HT cooling water pressure		CMS	
MW 65	41		PT01	LT cooling water pressure		CMS	
MW 66	42		PT21	Lube oil pressure filter inlet		CMS	
MW 67	43		PT22	Lube oil pressure filter outlet		CMS	
MW 68	44		PT23	Lube oil pressure TC		CMS	
MW 69	45		PT40	Fuel oil pressure engine inlet		CMS	
MW 70	46		PT31	Charge air pressure cooler outlet		CMS	
MW 71	47		PT70	Start air pressure		CMS	
MW 72	48		PT43	Fuel oil pressure filter inlet		CMS	
MW 73	49		ZT59	Alternator load		CMS	
MW 74	4A		ZT45	Fuel rack position		CMS	
MW 75	4B		PT38	Ambient air pressure		CMS	
MW 76	4C			Analog speed setpoint		CMS	
MW 80	50	0		Sensor fault PT10 : HT cooling water pressure		CMS	binary
		1		Sensor fault PT01 : LT cooling water pressure		CMS	binary
		2		Sensor fault PT21 : Lube oil pressure filter inlet		CMS	binary
		3		Sensor fault PT22 : Lube oil pressure filter outlet		CMS	binary
		4		Sensor fault PT23 : Lube oil pressure TC		CMS	binary
		5		Sensor fault PT40 : Fuel oil pressure engine inlet		CMS	binary
		6		Sensor fault PT31 : Charge air press. cooler outlet		CMS	binary
		7		Sensor fault PT70 : Start air pressure		CMS	binary
		8		Sensor fault PT43 : Fuel oil pressure filter inlet		CMS	binary
		9		Sensor fault ZT59 : Alternator load		CMS	binary
		10		Sensor fault ZT45 : Fuel rack position		CMS	binary
		11		Sensor fault PT38 : Ambient air pressure		CMS	binary
		12		Sensor fault : Analog speed setpoint		CMS	binary
MW 96	60		SE90	Engine speed		CMS	0..2000
MW 97	61		SE89	TC speed		CMS	0..7000 0
MW 112	70	0	SE90-1	Sensor fault engine speed pick up 1		CMS	binary
		1	SE90-2	Sensor fault engine speed pick up 2		CMS	binary
		2	SE90-1	Sensor fault engine speed pick up 1		DM	binary
		3	SE90-2	Sensor fault engine speed pick up 2		DM	binary
		4	SE89	Sensor fault TC speed pick up		CMS	binary
MW 113	71	0		Signal fault ZS82 : Emergency stop (pushbutton)		CMS	binary
		1		Signal fault ZS75 : Turning gear disengaged		CMS	binary
		2		Signal fault SS84 : Remote stop		CMS	binary
		3		Signal fault SS83 : Remote start		CMS	binary
		4		Signal fault LAH28 : Lube oil level high		CMS	binary
		5		Signal fault LAL28 : Lube oil level low		CMS	binary
		6		Signal fault LAH42 : Fuel oil leakage high		CMS	binary
		7		Signal fault ZS97 : Remote switch		CMS	binary
		8		Signal fault LAH92 : OMD alarm		CMS	binary
		9		Signal fault TAH 29-27 : CCMON alarm		CMS	binary
		10		Signal fault : Remote reset		CMS	binary
		11		Signal fault LAH98 : Altern. cool w. leakage alarm		CMS	binary
		12		Signal fault : Emergency generator mode		CMS	binary
		13		Signal fault : Speed raise		CMS	binary
		14		Signal fault : Speed lower		CMS	binary
		15		Signal fault : Switch droop / isochronous mode		CMS	binary

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Adress	Hex	Bit	Meas. Point	Description	Unit	Origin	Signal range
MW 114	72	0 4 13 15		Spare Signal fault : Actuator signal Signal fault SS83 : Start solenoid valve Signal fault SS32 : Jet system valve		CMS CMS CMS CMS	binary binary binary binary
MW 115	73	0 2 3 4		Spare Signal fault ZS34-1 : Charge air blow off valve 1 Signal fault ZS34-2 : Charge air blow off valve 2 Signal fault: VIT feedback position		CMS CMS CMS CMS	binary binary binary binary
MW 116	74	0 1 2 3 4 5 6 7 9 10 11 12		Sensor fault TSH12 : HT cool water engine outlet termostate Sensor fault PSL22 : Lube oil eng. inlet pressostate Sensor fault ZS82 : Emergency stop (pushbutton) Sensor fault LSH92 : OMD shutdown Sensor fault TSH27-29 : CCMON shutdown Sensor fault ZX92 : OMD system failure Sensor fault ZX27-29 : CCMON system failure Sensor fault : Remote shutdown Sensor fault ZS30-2 : Charge air press. relief valve Sensor fault ZS30-1 : Charge air shut off flap Sensor fault SS86-1 : Emergency stop valve Signal fault ZS82 : Emergency stop (pushbutton)		DM DM DM DM DM DM DM DM DM DM DM DM	binary binary binary binary binary binary binary binary binary binary binary binary
MW 117	75	0 1 2 3 4 5		CAN-1 error CAN-2 error Communication error to CMS Backlight error Ethernet communication error Wirebrake supervision of remote signals disabled		DM DM DM DM DM DM	binary binary binary binary binary binary
MW 118	76	0 1 2 3 10 11 12 15		CAN-1 error CAN-2 error CAN-3 error Communication error to DM Emergency generator mode MDO used HFO used Live-Bit (status changes at least every 5 seconds)		CMS CMS CMS CMS CMS CMS CMS CMS	binary binary binary binary binary binary binary binary
MW 119	77	0 1 2 3 4 5 6 7		Shutdown : HT cool. water temp. engine outlet high Shutdown overridden : HT cool. water temp. engine outlet high Shutdown : Lube oil pressure filter outlet low Shutdown overridden : Lube oil press. filter outl. low Shutdown : Engine overspeed Shutdown : Actuator Error Shutdown : Double Pick-Up Error Shutdown : Stop failure		CMS CMS CMS CMS CMS CMS CMS CMS	binary binary binary binary binary binary binary binary

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Adress	Hex	Bit	Meas. Point	Description	Unit	Origin	Signal range
MW 120	78	0 1 2 3 4 5 6 7 8 9 10		Shutdown : HT cool. water temp. engine outlet high Shutdown overridden : HT cool. water temp. eng. outlet high Shutdown : Lube oil pressure filter outlet low Shutdown overridden : Lube oil press. filter outl. low Shutdown : Engine overspeed Shutdown : OMD Shutdown overridden : OMD Shutdown : CCMON Shutdown overridden : CCMON Shutdown : Emergency stop active Shutdown : Remote Shutdown		DM DM DM DM DM DM DM DM DM DM/ CMS DM	binary binary binary binary binary binary binary binary binary binary binary
MW 121	79	0 1 2 3 4 5 6 7 8 9 11 12 13 14 15		Alarm : HT cooling water temp. engine outlet high Alarm : Lube oil pressure filter outlet low Alarm : Engine overspeed Alarm LAH28 : Lube oil level high Alarm LAL28 : Lube oil level low Alarm LAH42 : Fuel oil leakage Alarm FE94 : Cylinder lubrication no flow Alarm LAL98 : Alternator cooling water leakage Alarm : Start failure Alarm PAL25: Prelub. Oil pressure low Alarm : Startpreparation failure Alarm : Engine running error Alarm PAL01 : L.T. cooling water pressure low Alarm PAL10 : H.T. cooling water pressure low Alarm PDAH21-22 : Diff. pressure lube oil filter high		CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS	binary binary binary binary binary binary binary binary binary binary binary binary binary binary binary
MW 122	7A	0 1 2 3 4 5 6 7 8 9 10 11 12 14 15		Alarm TAH21 : Lube oil temperature filter inlet high Alarm PAL23 : Lube oil pressure TC low Alarm PDAH40-43 : Diff. pressure fuel oil filter high Alarm PAL40 : Fuel oil pressure engine inlet low Alarm PAL70 : Start air pressure low Alarm TAH98-1 : Alternator winding temp. L1 high Alarm TAH98-2 : Alternator winding temp. L2 high Alarm TAH98-3 : Alternator winding temp. L3 high Alarm TAH29-1 : Alternator front bearing temp. high Alarm TAH29-2 : Alternator rear bearing temp. high Alarm : OMD Alarm : CCMON Alarm : TC Overspeed Alarm: Cylinder Lubrication Error Alarm: Prelube pressure low		CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS	binary binary binary binary binary binary binary binary binary binary binary binary binary binary binary

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Adress	Hex	Bit	Meas. Point	Description	Unit	Origin	Signal range
MW 123	7B	0 1 2 3 5		Alarm ZX92 : OMD system failure Alarm ZX27-29 : CCMON system failure Alarm: VIT positioning Error Alarm: CAN 3 Error - VIT communication Error Alarm: Jet System Error		DM DM DM DM DM	binary binary binary binary binary
MW 124	7C			Operating hour counter		CMS	0..65535
MW 125	7D			Overload hour counter	h	CMS	0..65535
MW 126	7E	0 1		Load reduction request: VIT emergency mode error Load reduction request overridden : VIT emerg. mode error	active=1 active=1	DM DM	binary binary
MW 127	7F			Start of spare			
MW 1799	707			End of spare			

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Control and safety systems

General information

This document is valid for the following engine types:

- L16/24
- L21/31
- L23/30
- L27/38
- L28/32

The monitoring and safety system SaCoSone GENSET serves for complete engine operation, control, monitoring and safety of GenSets. All sensors and operating devices are wired to the engine-attached units.

The SaCoSone design is based on high reliable and approved components as well as modules specially designed for installation on medium speed engines. The used components are harmonised to a homogenously system. The whole system is attached to the engine cushioned against vibration.

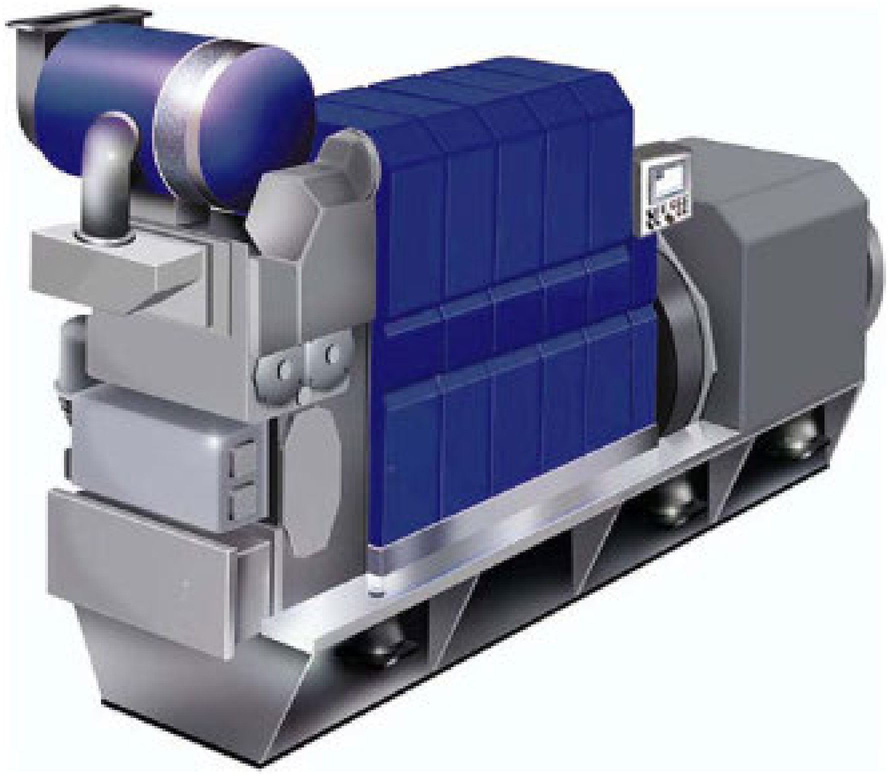

Figure 1: SaCoSone GENSET mounted on a L16/24 GenSet (Probable Lay-out)

Control Unit and Connection Box

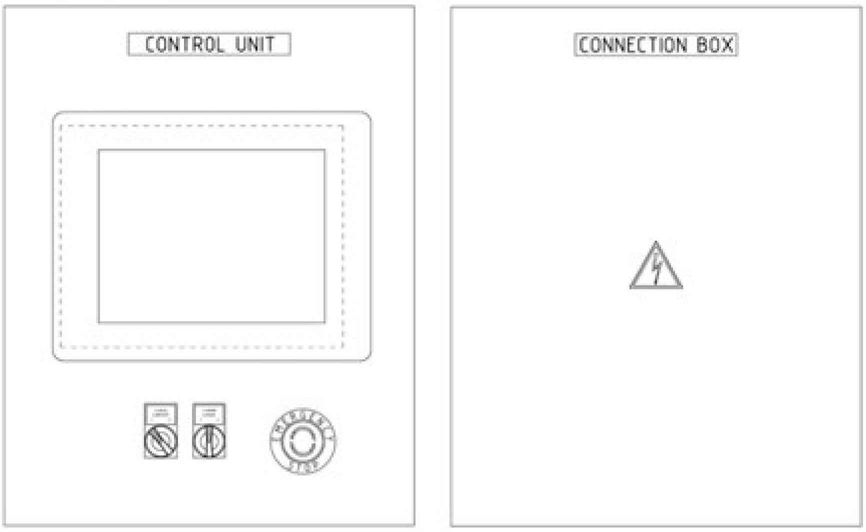

Figure 2: Example of Control Unit and Connection Box of 16/24, 21/31 and 27/38

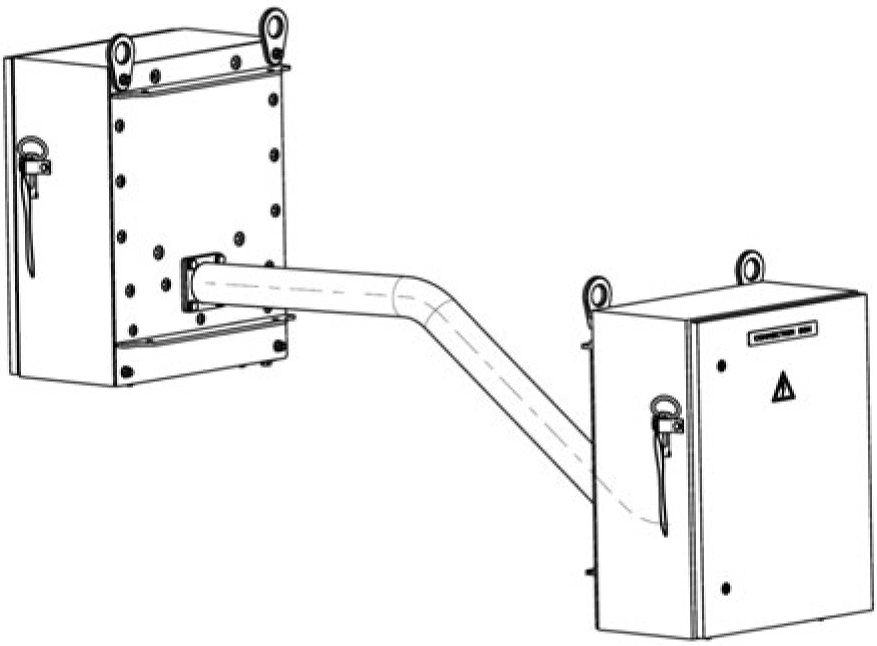

Figure 3: Example of Control Unit and Connection Box of 23/30

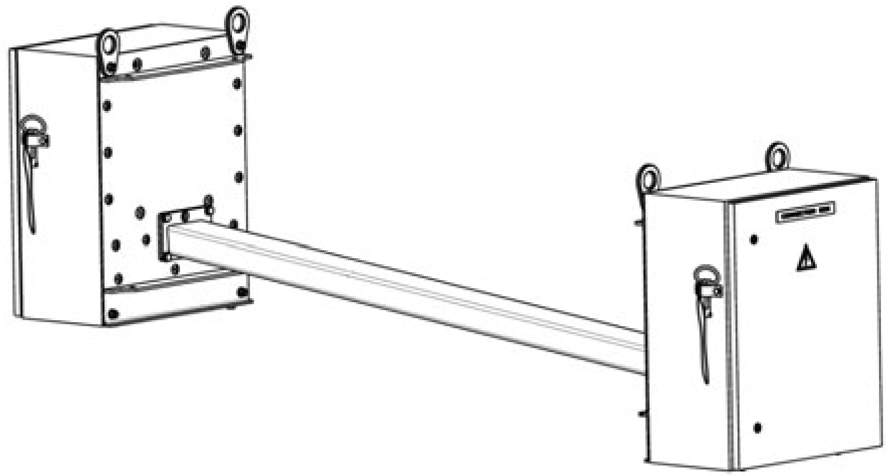

Figure 4: Example of Control Unit and Connection Box of 28/32

Control Unit

The Control Unit includes a highly integrated Control Module for engine control, monitoring and alarm system (alarm limits and delay). The module collects engines measuring data and transfers most measurements and data to the ship alarm system via Modbus.

Furthermore, the Control Unit is equipped with a Display Module. This module consists of a touchscreen and an integrated PLC for the safety system. The Display Module also acts as safety system for over speed, low lubrication oil pressure and high cooling water temperature.

The Display Module provides the following functions:

- safety system
- visualisation of measured values and operating values on a touchscreen
- engine operation via touchscreen

The safety system is electrically separated from the control system due to requirements of the classification societies.

For engine operation, additional hardwired switches are available for relevant functions.

The system configuration can be edited via an Ethernet interface at the Display Module.

Connection Box

The Connection Box is the central connecting and distribution point for the 24 VDC power supply of the whole system.

Furthermore it connects the Control Unit with the GenSet and the ship alarm system.

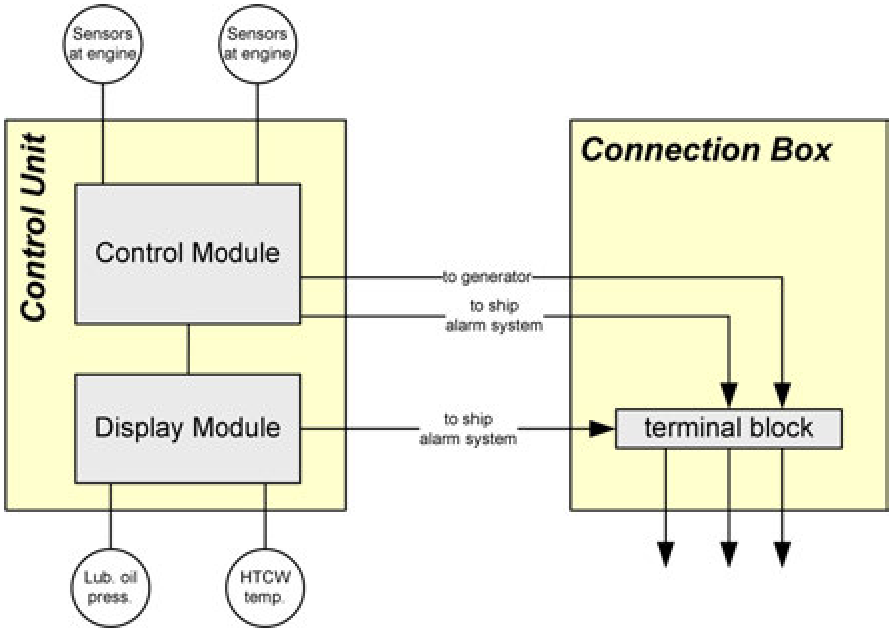

Figure 5: Schematic view of Control Unit and Connection Box

Multifunction Monitoring System (MMS)

The multifunction monitoring system (MMS) is part of the alarm and safety system and is connected via the redundant CAN bus to the control module.

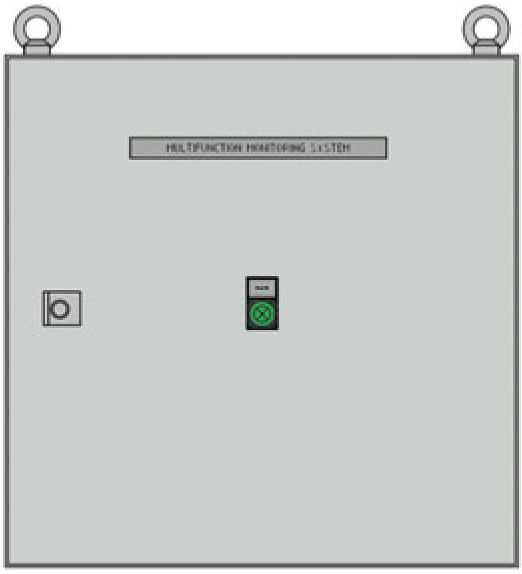

Figure 6: Multifunction Monitoring System

Systembus

The SaCoSone system is equipped with a redundant bus based on CAN. The bus connects all system modules. This redundant bus system provides the basis data exchange between the modules. The control module operates directly with electro-hydraulic actuator.

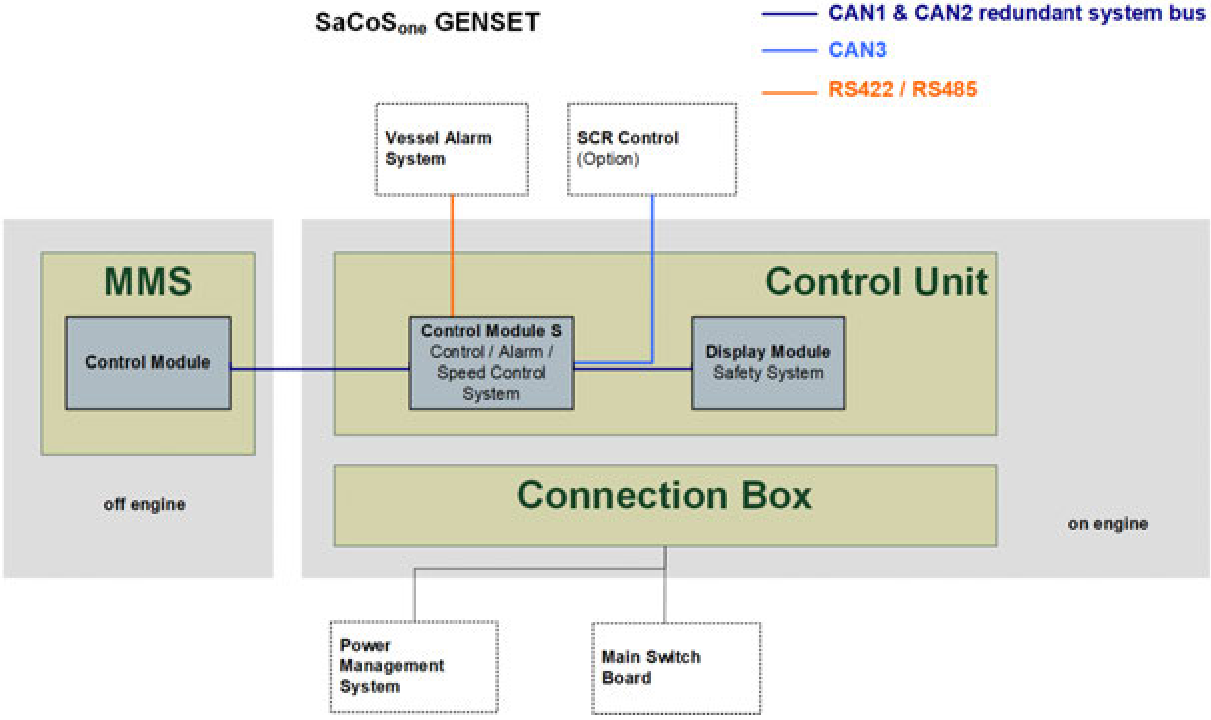

Figure 7: System bus

Technical data of Control Unit and Connection Box

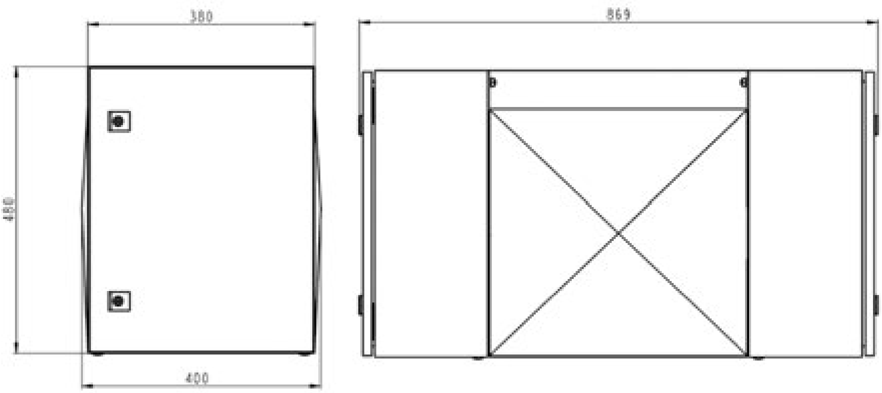

Figure 8: Example shows the dimensions of L16/24

	L16/24	L21/31	L27/38	L23/30	L28/32
Width	400 mm	400 mm	400 mm	532 mm	742 mm
Height	480 mm	565 mm	480 mm	851 mm	742 mm
Length	869 mm	1168 mm	1323 mm	1284 mm	1424 mm
Length overall	902 mm	1201 mm	1356 mm	1317 mm	1456 mm
Weight	60 kg	60 kg	65 kg	58 kg	60 kg

Technical data of MMS

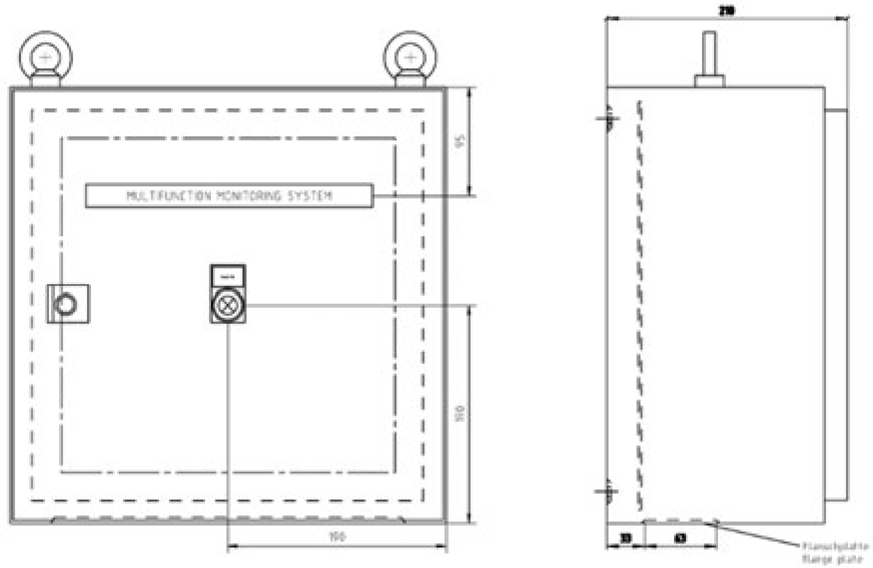

Figure 9: Example shows the dimensions of the MMS. The dimensions are equal for all types of GenSet.

	L16/24	L21/31	L27/38	L23/30	L28/32
Width	380 mm	380 mm	380 mm	380 mm	380 mm
Height	380 mm	380 mm	380 mm	380 mm	380 mm
Length	210 mm	210 mm	210 mm	210 mm	210 mm
Length overall	243 mm	243 mm	243 mm	243 mm	243 mm
Weight	20 kg	20 kg	20 kg	20 kg	20 kg

System description

Safety system

Safety functions

The safety system monitors all operating data of the engine and initiates the required actions, i.e. engine shut-down, in case the limit values are exceeded. The safety system is integrated the Display Module.

The safety system directly actuates the emergency shut-down device and the stop facility of the speed governor.

Auto shutdown

Auto shutdown is an engine shutdown initiated by any automatic supervision of engine internal parameters.

Emergency stop

Emergency stop is an engine shutdown initiated by an operator manual action like pressing an emergency stop button. An emergency stop button is placed at the Control Unit on engine. For connection of an external emergency stop button there is one input channel at the Connection Box.

Engine shutdown

If an engine shutdown is triggered by the safety system, the emergency stop signal has an immediate effect on the emergency shut-down device and the speed control. At the same time the emergency stop is triggered, SaCoSone issues a signal resulting in the generator switch to be opened.

Shutdown criteria

- Engine overspeed
- Failure of both engine speed sensors
- Lube oil pressure at engine inlet low
- HT cooling water temperature outlet too high
- High alternator winding temperature from MMS
- High bearing temperature/deviation from MMS
- High Splash-Oil temperature/deviation from MMS
- High oilmist concentration in crankcase (optional)
- Remote Shutdown (optional)
- Differential protection (optional)
- Earth connector closed (optional)
- Gas leakage (optional)

Alarm/monitoring system

Alarming

The alarm function of SaCoSone supervises all necessary parameters and generates alarms to indicate discrepancies when required. The alarms will be transferred to ship alarm system via Modbus data communication.

Self-monitoring

SaCoSone carries out independent self-monitoring functions. Thus, for example the connected sensors are checked constantly for function and wire break. In case of a fault SaCoSone reports the occurred malfunctions in single system components via system alarms.

Control

SaCoSone controls all engine-internal functions as well as external components, for example

- Start/stop sequences:

  Local and remote start/stop sequence for the GenSet.

  Activation of start device. Control (auto start/stop signal) regarding prelubrication oil pump.

  Monitoring and control of the acceleration period.
- Jet system:

  For air fuel ratio control purposes, compressed air is lead to the turbocharger at start and at load steps.

- Control signals for external functions:
  Nozzle cooling water pump (only engine type 32/40)
  HT cooling water preheating unit
  Prelubrication oil pump control
- Redundant shutdown functions:
  Engine overspeed
  Low lub. oil pressure inlet engine
  High cooling water temperature outlet engine

Speed Control System

Governor

The engine electronic speed control is realized by the Control Module. As standard, the engine is equipped with an electro-hydraulic actuator.

Speed adjustment

Local, manual speed setting is possible at the Control Unit with a turn switch.

Remote speed setting is either possible via 4-20mA signal or by using hard-wired lower/raise commands.

Speed adjustment range

Between -5% and +10% of the nominal speed at idle running.

Droop

Adjustable by parameterisation tool from 0-5% droop.

Load distribution

By droop setting.

Engine stop

Engine stop can be initiated local at the display module and remote via a hardware channel or the bus interface.

Multifunction Monitoring System (MMS)

The Multifunction Monitoring System has the following functions:

- Monitoring of the splash oil temperature
- Monitoring of the main bearing temperature
- Monitoring of the crankcase pressure
- Monitoring of the camshaft sprocket bearing temperature
- Monitoring of the alternator bearing and winding temperature
- Monitoring of the exhaust gas temperature
- Connection for an oil mist detector
- Monitoring of the engine speed

Only PT1000 temperature sensors can be monitored!
The MMS can only monitor PT1000 temperature sensors and NiCrNi exhaust gas temperature sensors.

Interfaces to external systems

Overview

A detailed signal description is available on the GS Product page in the document "SaCoSone GENSET for L16/24, L21/31, L23/30, L27/38, L28/32 – Interface Description".

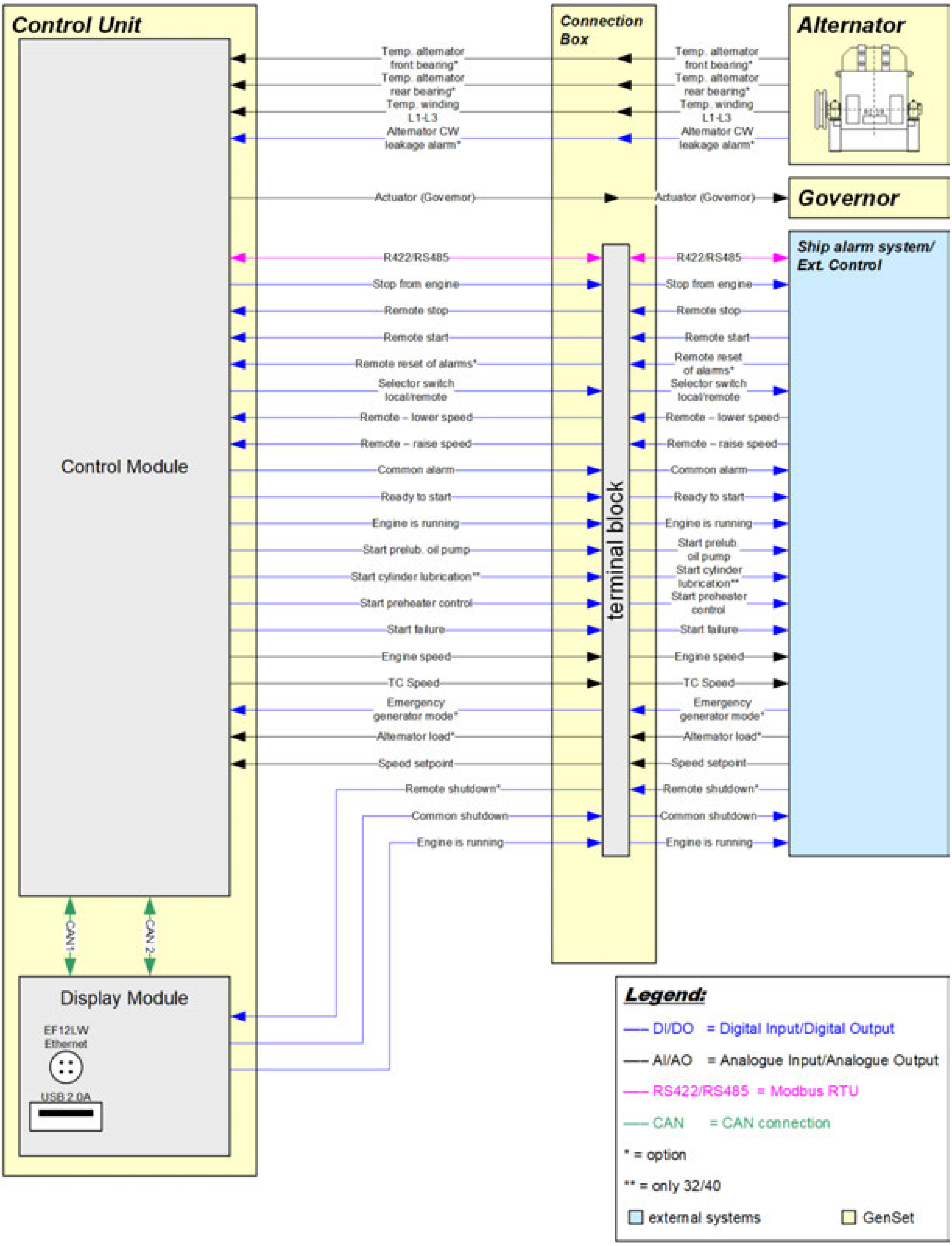

Figure 10: Signal overview

Overview of MMS

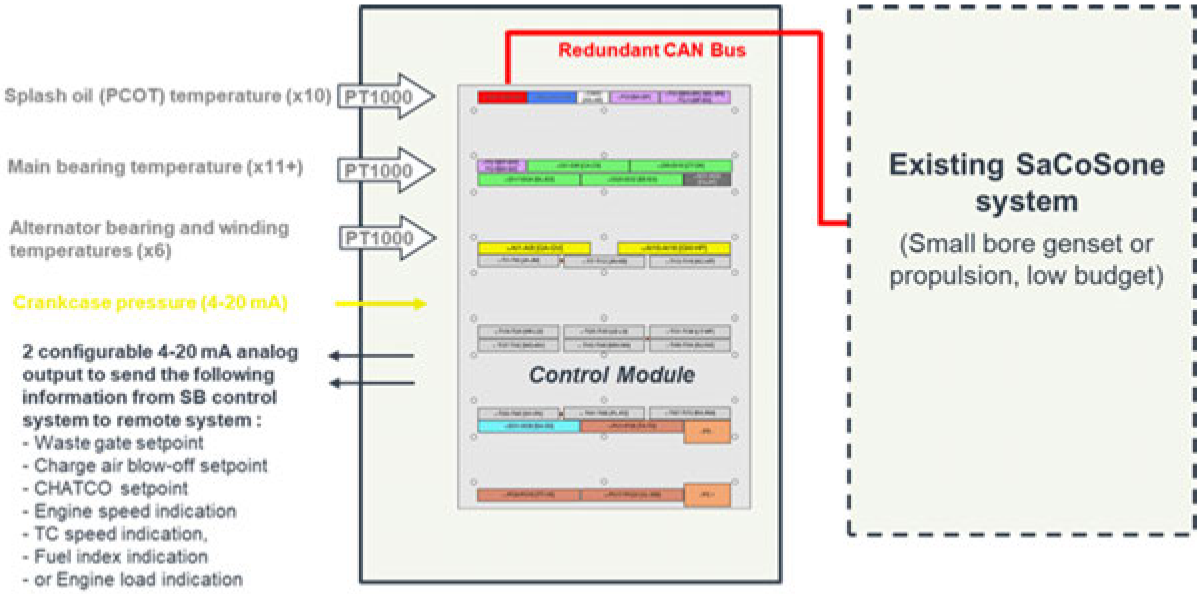

Figure 11: Signal overview MMS

Data Machinery Interface

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 GENSET are available for transfer.

The following MODBUS protocols are available:

- MODBUS RTU (Standard)
- MODBUS ASCII (for retrofits)

For a detailed description of these protocols see the document “SaCoSone GENSET, Communication from the GenSet”.

Generator Control

SaCoSone provides inputs for all temperature signals for the temperatures of the generator bearings and generator windings.

Power Management

Hardwired interface for remote start/stop, speed setting, alternator circuit breaker trip etc.

Remote control

For remote control several digital inputs are available.

Ethernet interface

The Ethernet interface at the Display Module can be used for the connection of SaCoSone EXPERT.

Serial interface

CoCoS-EDS can be connected to a serial RS485 interface.

Power supply

The plant has to provide electric power for the automation and monitoring system. In general a redundant, uninterrupted 24V DC (+20% -30% and max ripple 10%) power supply is required for SaCoSone.

SaCoSone GENSET requires a 24V DC, 10 A power supply with a 10 A pre-fuse and a 24V DC, 10 A uninterrupted power supply with a 10 A pre-fuse.

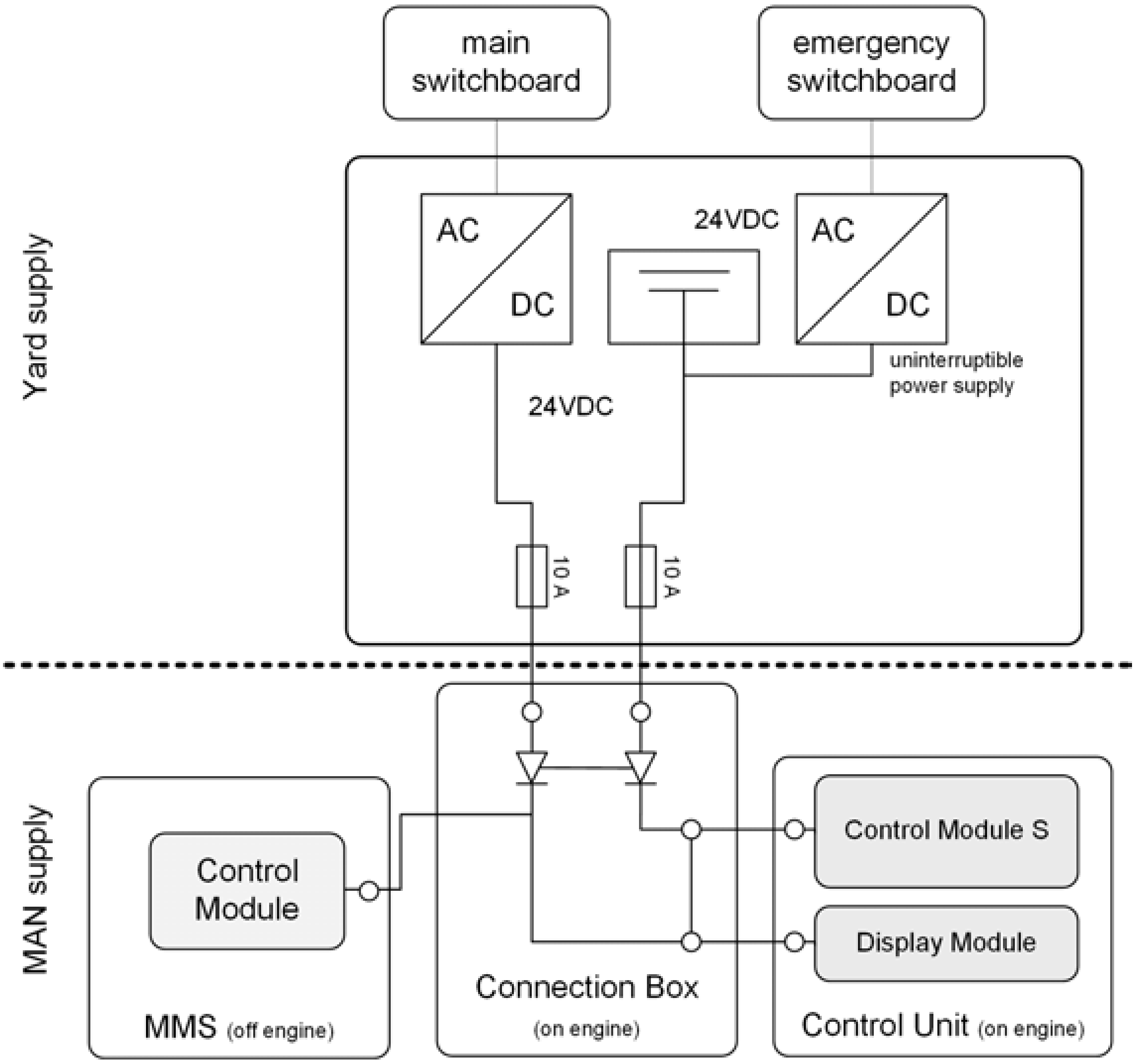

Figure 12: Power supply diagram

Cybersecurity guidelines

Cybersecurity guidelines

Terms, abbreviations and definitions

Term, abbreviation	Definition
CM-S	Control module small (Note: A CM-E1 can also be used instead of the CM-S in some architectures. In this document, the designation CM-S is used to represent both modules)
CU	Control Unit
DM	Display module
ECR	Engine control room
ECU	Electronic control unit
ER	Engine room
eToken	SaCoSone Security Token (Thales Group eToken 5110+)
EXPERT	tool for SaCoS parameterization
IAS	Integrated alarm system (see also “customer network”)
IM	Injection module
LOP	Local operating panel
PMS	Power management system
SaCoSone	Safety and Control System on engine
SCR	Selective catalytic reduction
SDI	SaCoSone device image

Table 1: Terms, abbreviations, and definitions

System Overview

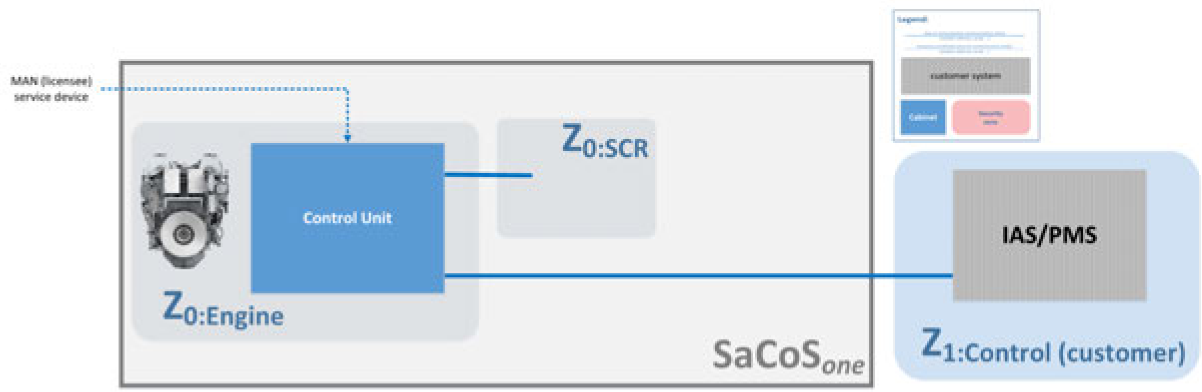

Figure 1: SaCoSone small-bore genset: Zones and connections (simplified)

Figure *SaCoSone small-bore genset: Zones and connections (simplified)*:
Shows a simplified overview of the SaCoSone system (small-bore genset variant), as well as all zones and connections relevant for the cyber security analysis

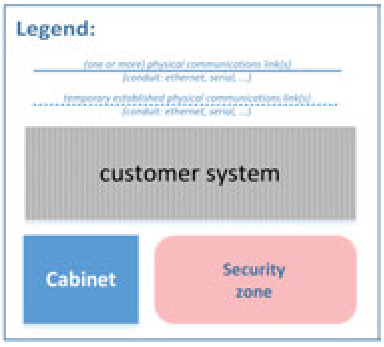

Figure 2: SaCoSone small-bore genset: Zones and connections (simplified) – Key

Figure *SaCoSone small-bore genset: Zones and connections (simplified) – Key*:
Shows the key for the simplified overview of the SaCoSone system (small-bore genset variant).

The system is divided into the following main security zones:

- $Z_{0:Engine}$: 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.
- $Z_{1:Control\ (customer)}$: This zone contains the ship's integrated alarm and/or power management system(s) (IAS/PMS)

The majority of SaCoS devices are installed in locked cabinets or units such as the control unit (CU). These must be installed in restricted areas such as engine rooms (ER).

Communication within and between zones is via ethernet, CAN, serial and/or hard-wired connections. Each connection in the figure *SaCoSone small-bore genset: Zones and connections (simplified)* is implemented as one or more such lines.

Physical security of SaCoS

Some devices and communication links must be physically protected against unauthorised access at all times (i.e., including during commissioning). Some module interfaces do not enforce user or device authentication or authorisation. Only authorised and authenticated personnel may have access to these devices and connections. These accesses must be logged. The resulting logs must also be stored securely for future audits. Further physical protection measures (walls, lockable doors, laying cables to protect against unauthorised access ...) must be implemented to prevent unauthorised access (personal and technical) and manipulations of SaCoSone hardware, software, cables, and data as well as to prevent any changes to the network topology.

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 shall be taken into account.

Such measures are necessary above all to protect the SaCoS components and communication connections, as these perform safety-critical functions; depending on the SaCoS variant, this may include the following components and connections:

- All system devices, including display modules (DM), Gateway Modules (GM), control modules (CM-S/CM-E1), injection modules (IM), as well as WAGO modules
- CAN bus (including between CM-S and SCR) and any CAN repeaters.
- sensors and actuators
- Serial and network connections connecting devices in the system to each other or connecting the system to external zones (e.g. $Z_{1:Control(Customer)}$)

Failure to comply with these guidelines can have the following consequences, among others:

- The safety of the engine, the plant and its surroundings is impaired
- The engine can no longer be controlled by the operator and/or can be controlled by the attacker
- The operator loses access to (authentic) information about the status of the engine and the automation system (incl. alarm data), and/or an attacker gains access to this information
- Notes on possible impacts (here and further down in the document):
  - Depending on the means and resources available to the attacker, a *targeted* attack on may have serious consequences, up to and including the complete compromise of SaCoS and the systems connected to it
  - The list of possible effects is not exhaustive

Safety of the communication link with Z1:Control(Customer) and Z0:SCR

can be monitored remotely from $Z_{1:Control(Customer)}$ via a serial connection and also communicates with $Z_{0:SCR}$ via a CAN connection. For this purpose, the CM-S provides interfaces that can be used by devices in $Z_{1:Control(Customer)}$ and $Z_{0:SCR}$.

The integrator/operator must therefore ensure the following:

- Physical access to lines connecting with devices in $Z_{1:Control(Customer)}$ and $Z_{0:SCR}$ must be impossible for unauthorised persons
- Communication between and devices in $Z_{1:Control(Customer)}$ and $Z_{0:SCR}$ must not be accessible to potential aggressors (possibly infected, compromised, or otherwise untrustworthy devices).
- $Z_{1:Control(Customer)}$ must be a trusted network in the sense of IACS UR E27

Failure to comply with these guidelines can have the following consequences, among others:

- Operator loses access to (authentic) information about the status of the engine and the automation system (incl. alarm data), and/or an attacker gains access to this information
- Attacker influences the engine control unit or the SCR system by intercepting and then manipulating the communication between the two systems

Secure access and storage of SaCoS data

It is necessary to keep the data created by or for SaCoS (such as SDIs, parameter sets, or log data) secure and protected against access by third parties.

Secure access and retention of such data can be implemented, for example, by adhering to the following guidelines:

- Use different data carriers and devices (e.g. dedicated ‘ Service Stick’ ...) for different purposes (e.g. storage of SDIs, parameterisation of ...)
- Never use such media and devices for other purposes and never connect them to other devices or networks
- Only connect data carriers and devices to trustworthy devices or networks
- Encrypt and/or authenticate SaCoS data held outside of SaCoS
- SaCoS devices in a physically protected, restricted-access location
- Never pass on SaCoS-relevant access data, passwords, cryptographic keys as well as other sensitive or secret data to third parties. This includes the password of the Security Tokens (“eToken”), DM touchscreen passwords, or access data for additional devices managed by the operator and integrated into the SaCoSone system
- Data that is uploaded to the system (e.g. SDIs, parameter sets) shall be checked for authenticity

Failure to comply with these guidelines may have the following consequences, among others:

- Third parties learn details about the use, properties and condition of the system.
- Third parties are able to alter the engine condition, which may pose a risk to the engine's safety

Securing Z1:Control(Customer)

CM-S can be accessed via its serial interface without prior authentication, which enables the engine to be monitored. GM (SCR) can be accessed by the customer via their Eth2 network interface without prior authentication via a network service that enables the SCR system to be monitored and controlled. The zone from which this interface can be accessed is referred to below as $Z_{1:Control(Customer)}$ and must be secured by the operator/integrator so as not to lose access to information about the engine, among other things.

Securing this network is the responsibility of the operator/integrator

Therefore, the operator/integrator shall implement safeguards to secure this network, which may include, but are not limited to, the following:

- Connecting devices in $Z_{1:Control(Customer)}$ to SaCoS exclusively via the network interface of the CM-S or the GM
- Protecting and restricting physical and communicative access to the devices and their connections located in the customer network
- No wireless technologies
- In addition to the CM-S and GM, only IAS/PMS devices may be in $Z_{1:Control(Customer)}$
- Separating the$Z_{1:Control(Customer)}$ zone from other networks, as well as internal segmentation of the network so that different engine and SCR systems connected to the network cannot influence each other
- Do not connect potential aggressor devices to $Z_{1:Control(Customer)}$ that are or may be potentially infected or compromised. Only then can this network be considered “trusted” by SaCoS in the sense of IACS E26/E27

- Establishing security measures and implement processes to ensure that devices and connections within $Z_{1:Control(Customer)}$ are never reconnected to other networks
- Securing all devices and connections within $Z_{1:Control(Customer)}$ according to a risk management plan established for that plant. Protective measures may include the use of anti-virus software, hardening measures, regular security updates, disabling USB ports, and maintaining an “air gap” (where possible)
- Avoiding the operation of other Modbus services within $Z_{1:Control(Customer)}$ in order to prevent erroneously established Modbus client connections to such services.

If these guidelines are not observed, the following effects may occur, among others:

- Attackers in the customer network can read the display on the operating panels and the devices in $Z_{1:Control(Customer)}$
- Attackers in $Z_{1:Control(Customer)}$ are able to control the SCR system and read out its operating values
- Attackers in $Z_{1:Control(Customer)}$ may be able to deactivate the SCR GM, which can cause the SCR sootblowers to fail
- Attackers in $Z_{1:Control(Customer)}$ may be able to deactivate the CM-S, which leads to an engine stop

In addition, a compromised SaCoS can pose a threat to customer networks and devices, by infecting/compromising the customer systems within. Although the corresponding risk is assessed as low by in the context of a risk analysis (in the context of Security Level 1 according to IEC 62443), the operator/integrator can implement additional measures to protect themselves against this risk. Such protective measures may include, but are not limited to:

- Installing additional network security devices (e.g. firewall, intrusion protection system) to protect the connections between SaCoS and the customer networks. This allows, for example, any communication between SaCoS and the customer networks to be monitored for suspicious or unusual activity
- Implementing hardening measures for devices in $Z_{1:Control(Customer)}$ under the assumption that SaCoS can act as aggressor
- Not making sensitive data or services available in $Z_{1:Control(Customer)}$, e.g. those that enable the control of other plants

Securing the operating panels

The operating panels are not “hardened”, are not regularly provided with security updates, and their communication with the rest of the system is not secured against attackers.

The operator/integrator is therefore advised to adhere to the following guidelines:

- Physical access to the operating panels must be strictly controlled and only allowed to authorised personnel
- Physical access to the communication connections and interfaces of the operating panels (incl. USB and network interfaces) must be restricted to authorised service employees only. The operator/integrator may neither change the connections set up by nor connect their own devices to the operating panels

- When entering the password on the DM, care must be taken to ensure that unauthorised persons cannot read the entered password from the display

The service personnel authorised to configure the password-protected engine parameterisation functions are also required to check the default values of the relevant security parameters (such as the time until the user is automatically logged out) and/or to change them in accordance with the security policy applicable to the system.

If these guidelines are not adhered to, the following effects may occur, among others (for further possible effects, see also Section Securing Z1:Control(Customer)):

- Operational safety of the engine is impaired
- The operator loses control of the engine and/or the attacker takes control of the engine
- Data manipulated by the attacker is displayed on operating panels and/or transmitted to devices in the customer network.
- Operating panels are not functional

Maintaining network segmentation

Network segmentation is one of 's key protection measures. Therefore, the network structure set up by must not be changed.

Specifically, the following guidelines shall be adhered to:

- Individual network segments must not be bridged
- No additional devices may be connected to the network segments of SaCoS

If these guidelines are not followed, SaCoS can be compromised by an attacker and the operational safety of the engine can be compromised.

Preparation for security incidents

Residual risks may remain even if the present guidelines are followed. The operator shall prepare for possible security incidents in order to be able to react to them promptly. This includes the creation of an incident response plan, which shall address the following points, among others:

- Obtain spare parts to replace modules that have failed or been compromised due to an attack.
- If changes are made to the system (e.g. parameterisation of the system), these changes must be saved accordingly.
- Report the security incident to the engine manufacturer’s 1st level support via a secure channel and follow the instructions.
- Save all relevant data for all causes. This includes, but is not limited to, the access logs and general audit logs generated by the customer devices and the plant.
- Analyse 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. Any of the following indicators can point to a possible security incident:

- The data displayed on the operating panels and/or reported by SaCoS to devices in $Z_{1:Control(Customer)}$ is inconsistent, unrealistic, or unexpected.

- The system and/or the engine behave abnormally, which can be attributed to engine control commands that do not originate from the operator
- The system can no longer be controlled
- The engine stops unexpectedly
- IAS/PMS report the loss of the network connection with the GM
- The system alerts the operator to the failure of a DM or CM-S
- The system alerts the operator to a network flood attack on the GM/DM

In order to address such incidents in the short term, the operator can consider the following countermeasures after the corresponding operational safety assessment:

- Putting the engine in a safe state appropriate to the situation (e.g.shut down the engine, switch off the system ...), informing service of the incident and not resuming normal operation until the problem has been rectified
- If continued operation of engine is intended, the system can be set to island mode by physically disconnecting the connections at the DM network interfaces as well as connections to SCR and IAS/PMS
- If the above measures do not achieve the desired effect, the affected modules (e.g. the CM-S) can be restarted or replaced.
- One of the security mechanisms is to switch off the network interface of a GM/DM in the event of a network flood. As a result, the GM/DM must be restarted to reopen the ports

By violating these guidelines, potentially emerging security incidents can remain undetected for longer or, in the worst case, go completely undetected. therefore recommends complying with/fulfilling the aforementioned guidelines as far as possible.

Secure disposal

When disposing of devices, it shall be noted that they store sensitive information such as engine parameters, log data, and cryptographic keys, which could be extracted. The operator is responsible for the security of this data when disposing of the devices.

User account management

Most devices do not allow interactive access by the user, with the following exceptions:

- GM/DM service access with an EXPERT eToken (only for authorised service personnel with an eToken)
- Privileged access to DM via touchscreen for engine parameterisation

The management of DM touchscreen passwords is the responsibility of the operator and service personnel. Passwords shall be long and randomly generated, stored in a secure, access-protected location, and not reused on other accounts or devices. The passwords shall be set when the module is integrated by authorised service personnel, and communicated via a secure channel to the operator who is authorised for engine parameterization.

If there is any suspicion of unlawful use, the password must be changed immediately.

Security Incident Report

Security incidents affecting shall be reported to the engine manufacturer's 1st level support.

Oil mist detector

Description

The oil mist detector type Tufmon from company Dr. Horn is option for all engine types. Standard on 7, 8 and 9L27/38.

The oil mist detector is based on direct measurement of the oil mist concentration in the natural flow from the crankcase to the atmosphere.

The detector is developed in close cooperation between the manufacturer Dr. Horn and us and it has been tested under realistic conditions at our testbed.

The oil mist sensor is mounted on the venting pipe together with the electronic board. At first the sensor will activate an alarm, and secondly the engine will be stopped, in case of critical oil mist concentration. Furthermore there is an alarm in case of sensor failure. To avoid false alarms direct heating of the optical sensor is implemented.

The installation is integrated on the engine. No extra piping/cabling is required.

Technical data

Power supply	: 24 V DC +30% / -25%
Power consumption	: 1 A
Operating temperature	: 0°C....+70°C

Enclosure according to DIN 40050:

Analyzer	: IP54
Speed fuel rack and optical sensors	: IP67
Supply box and connectors	: IP65

Figure 1: Oil mist detector.

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Combined box with prelubricating oil pump, preheater and el turning device

Description

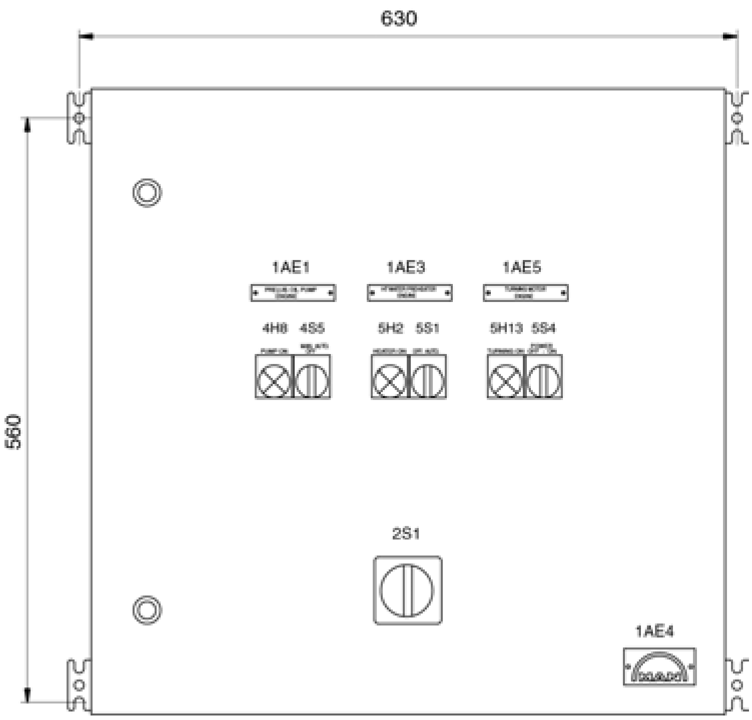

Figure 1: Dimensions

The box is a combined box with starters for prelubricating oil pump, preheater and el turning device.

The starter for prelubricating oil pump is for automatic controlling start/stop of the prelubricating oil pump built onto the engine.

Common for both pump starters in the cabinet is overload protection and automatic control system. On the front of the cabinet there is a lamp for "pump on", a change-over switch for manual start and automatic start of the pump; furthermore there is a common main cut-off switch.

The pump starter can be arranged for continuous or intermittent running. (For engine types L16/24, L21/31 & L27/38 only continuous running is accepted). *See also B 12 07 0, Prelubricating Pump.*

The preheater control is for controlling the electric heater built onto the engine for preheating of the engines jacket cooling water during stand-still.

On the front of the cabinet there is a lamp for "heater on" and a off/auto switch. Furthermore there is overload protection for the heater element.

The temperature is controlled by means of an on/off thermostat mounted in the common HT-outlet pipe. Furthermore the control system secures that the heater is activated only when the engine is in stand-still.

The box also include the control of el turning device. There is a "running" indication lamp and a on/off power switch on the front. The control for the turning gear is prepared with to contactors for forward and reverse control. The turning gear control has also overload protection.

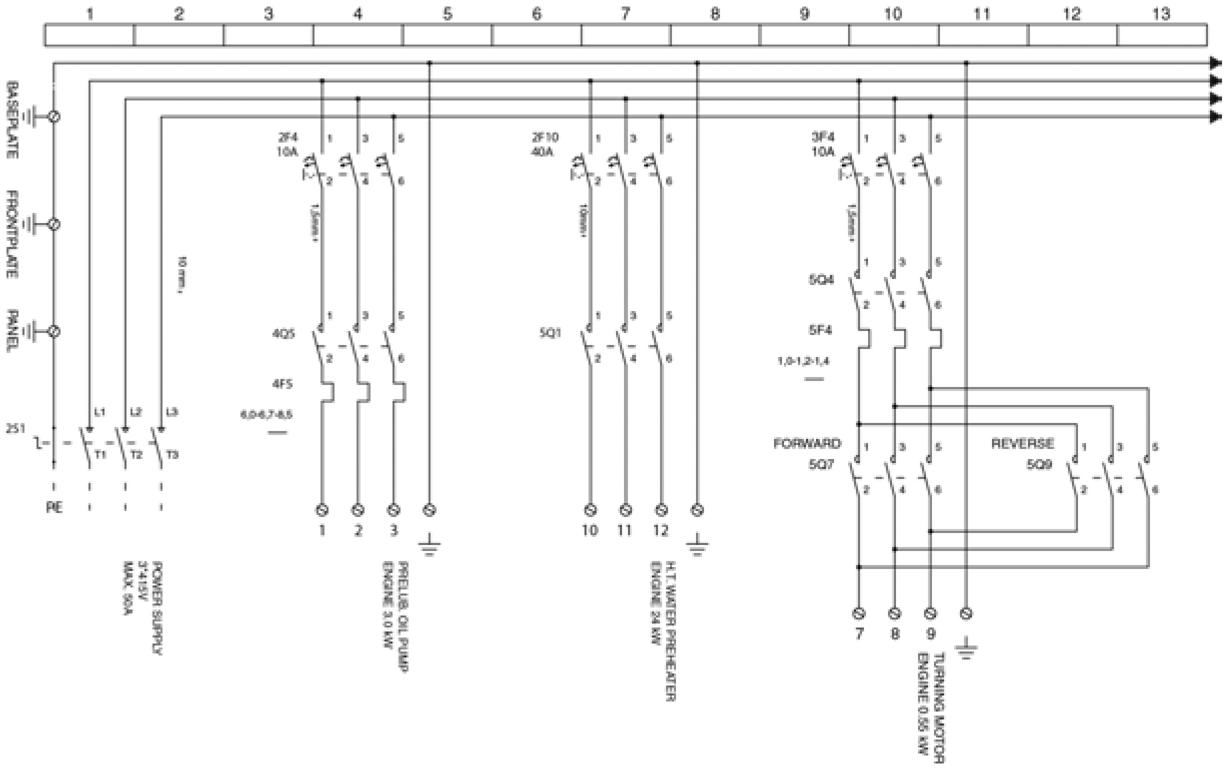

Figure 2: Wiring diagram

Prelubricating oil pump starting box

Description

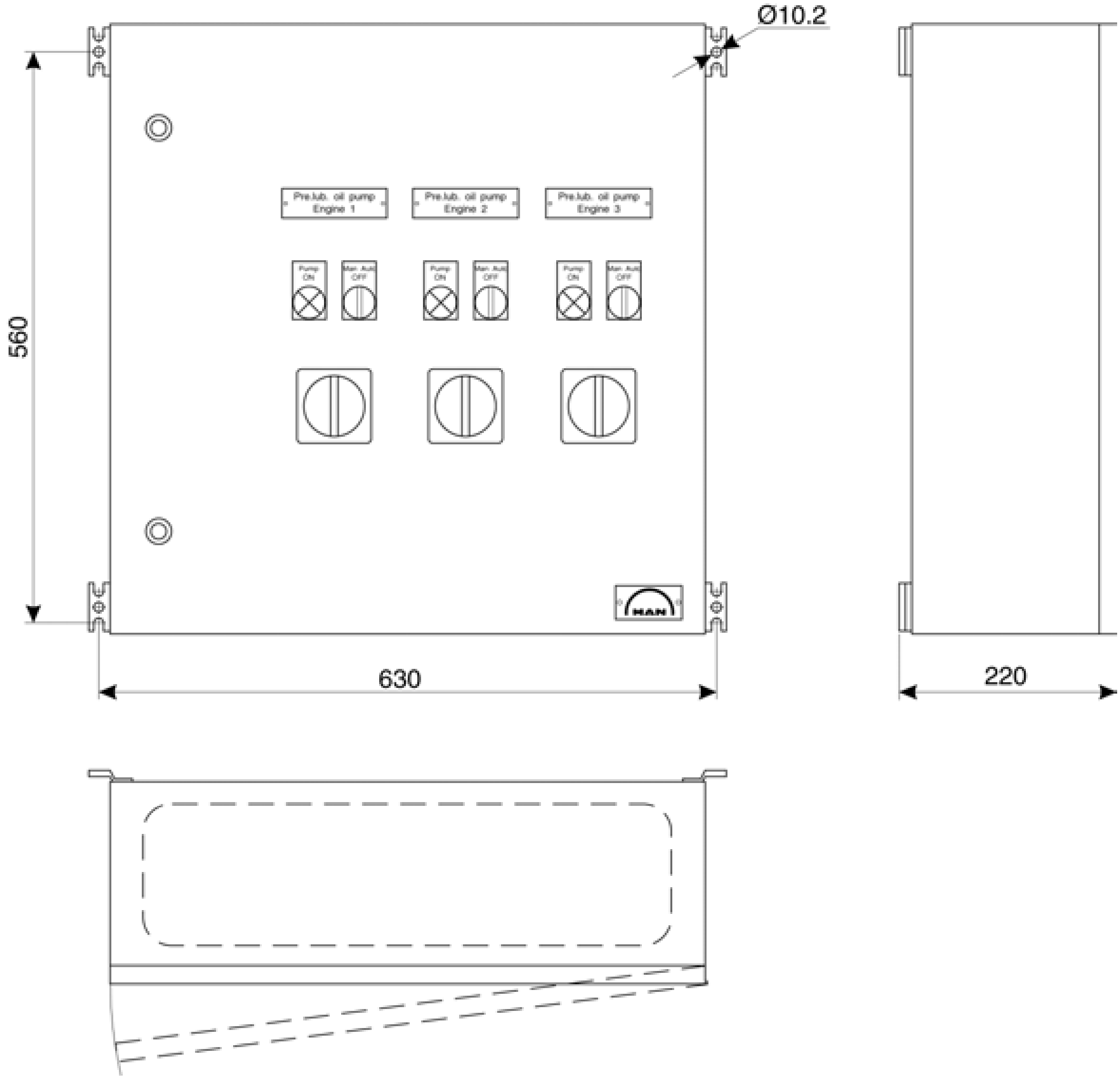

Figure 1: Dimensions.

The prelubricating oil pump box is for controlling the prelubricating oil pump built onto the engine.

The control box consists of a cabinet with starter, overload protection and control system. On the front of the cabinet there is a lamp for "pump on", a change-over switch for manual start and automatic start of the pump, furthermore there is a main switch.

The pump can be arranged for continuous or intermittent running. (For L16/24, L21/31 and L27/38 only continuous running is accepted).

Depending on the number of engines in the plant, the control box can be for one or several engines.

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The prelubricating oil pump starting box can be combined with the high temperature preheater control box. *See also B 12 07 0, Prelubricating Pump.*

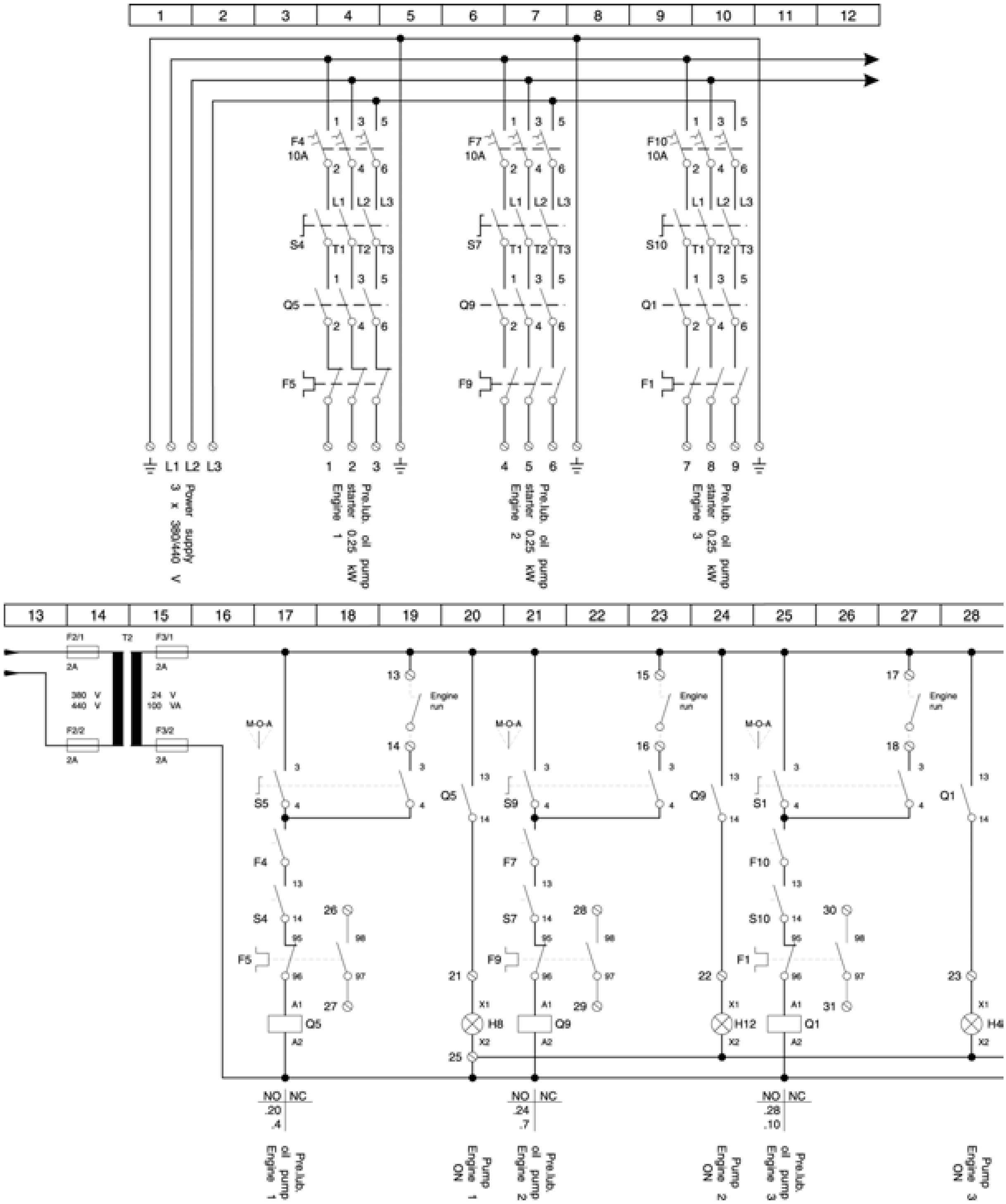

Figure 2: Wiring diagram.

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Recommendations concerning steel foundations for resilient mounted GenSets

Foundation recommendations

When the generating sets are installed on a transverse stiffened deck structure, it is generally recommended to strengthen the deck by a longitudinal stiffener in line with the resilient supports, *see fig 1.*

For longitudinal stiffened decks it is recommended to add transverse stiffening below the resilient supports.

It is a general recommendation that the steel foundations are in line with both the supporting transverse and longitudinal deck structure, *fig 2,* in order to obtain sufficient stiffness in the support of the resilient mounted generating sets.

The strength and the stiffness of the deck structure has to be based on the actual deck load, i.e. weight of machinery, tanks etc. and furthermore, resonance with the free forces and moments from especially the propulsion system have to be avoided.

Stiffness for foundation has to be minimum the following:

- Z-direction, stiffness for foundation has to be minimum 20 times the conical stiffness.
- Y-direction, stiffness for foundation has to be minimum 10 times the conical stiffness.
  (see fig 3)

Example for conical stiffness:

- RD314-45 Shore A to 65 Shore A - stiffness 4.865 kN/m to12.660 kN/m (Preload 30 kN - 20 deg. C)

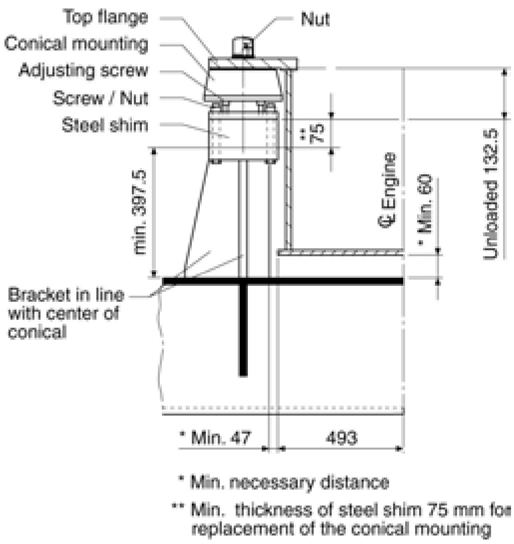

Figure 1: Transverse stiff deck structure.

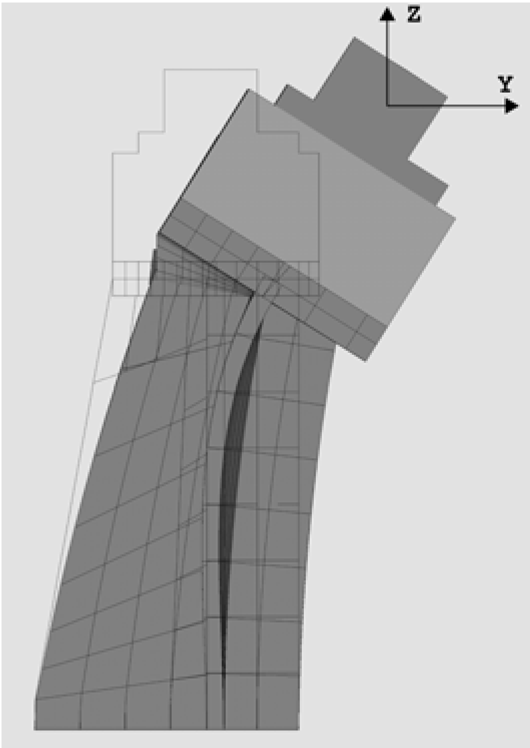

Figure 2: Stiffness for foundation

Resilient mounting of generating sets

Resilient Mounting of Generating Sets

On resiliently mounted generating sets, the diesel engine and the alternator are placed on a common rigid base frame mounted on the ship's/machine house's foundation by means of resilient supports, Conical type.

All connections from the generating set to the external systems should be equipped with flexible connections and pipes. Gangway etc. must not be welded to the external part of the installation.

Resilient Support

A resilient mounting of the generating set is made with a number of conical mountings. The number and the distance between them depend on the size of the plant. These conical mountings are bolted to the top flange of the base frame (*see fig 1*).

The setting from unloaded to loaded condition is normally between 5-11 mm for the conical mounting.

The support of the individual conical mounting can be made in one of the following three ways:

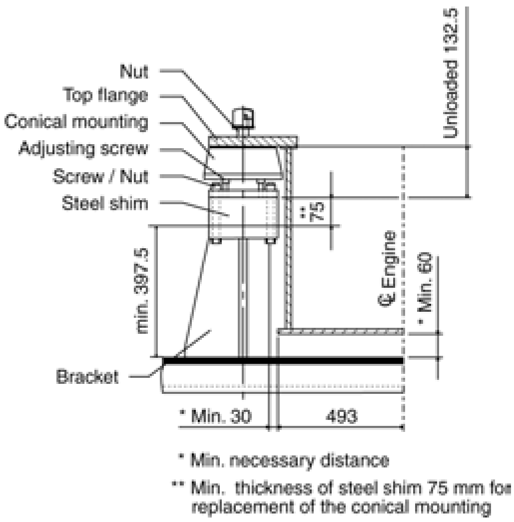

Figure 1: Resilient mounting of generating sets

1) The support between the bottom flange of the conical mounting and the foundation is made with a loose steel shim. This steel shim is adjusted to an exact measurement (min. 75 mm) for each conical mounting.
2) The support can also be made by means of two steel shims, at the top a loose steel shim of at least 75 mm and below a steel shim of at least 10 mm which are adjusted for each conical mounting and then welded to the foundation.

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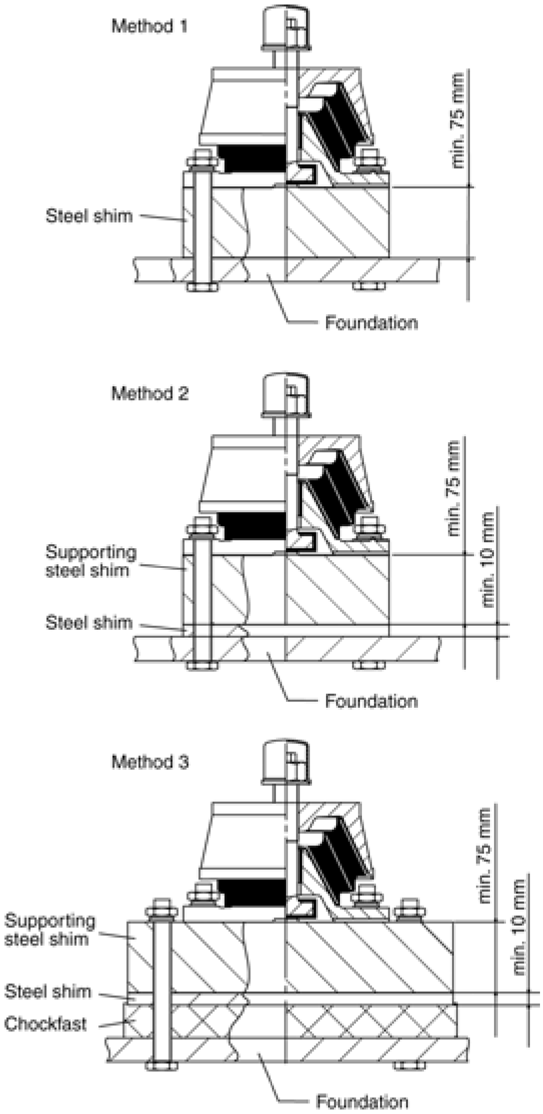

Figure 2: Support of conicals

3) Finally, the support can be made by means of chockfast. It is necessary to use two steel shims, the top steel shim should be loose and have a minimum thickness of 75 mm and the bottom steel shim should be cast in chockfast with a thickness of at least 10 mm.

Irrespective of the method of support, the 75 mm steel shim is necessary to facilitate a possible future replacement of the conical mountings, which are always replaced in pairs.

Check of Crankshaft Deflection

The resiliently mounted generating set is normally delivered from the factory with engine and alternator mounted on the common base frame. Eventhough engine and alternator have been adjusted by the engine builder, with the alternator rotor placed correctly in the stator and the crankshaft deflection of the engine (autolog) within the prescribed tolerances, it is recommended to check the crankshaft deflection (autolog) before starting up the GenSet.

Shop test programme for marine GenSets

Requirement of the classification societies

Requirement of the classification societies	ABS	BV	DNV	LR	RINA	NK	IACS	MAN ES pro-gramme
1) Starting attempts	X	X	-	X	X	X	X	X
2) Governor test (see page 2)	X	X	X	X	X	X	X	X
3) Test of safety and monitoring system	X	X	-	X	X	X	X	X
4) Load acceptance test (value in minutes)								

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Engines driving alternators	Continuous rating (MCR)	Constant speed								
	100% [1*]	60	60	M	60	60	60	120 [2*]	60	60
	110%	30	45	M	45	45	45	45 [3*]	30	45
	75%	M	M	M	M	M	M	30	M	30
	50%	M	M	M	M	M	M	30	M	30
	25%	M	M	-	M	M	M	-	M	30
	Idling = 0%	M	M	-	M	M	M	-	M	30
Engines driving alternators for electric propulsion	Continuous rating (MCR)	Constant speed								
	100% [1*]	60	60	M	60	60	60	120 [2*]	60	60
	110%	30	45	M	45	45	45	45 [3*]	30	45
	90%	-	-	M	-	-	-	-	-	30
	75%	M	M	M	M	M	M	30	M	30
	50%	M	M	M	M	M	M	30	M	30
	25%	M	M	-	M	M	M	-	M	30
	Idling = 0%	M	M	-	M	M	M	-	M	30
5)	Verification of GenSet parallel running, if possible (cos Φ = 1, unless otherwise stated)									
6a)	Crankshaft deflection measurement of engines with rigid coupling in both cold and warm condition									
6b)	Crankshaft deflection measurement of engines with flexible coupling only in cold condition									
7)	Inspection of lubricating oil filter cartridges of each engine									
8)	General inspection									

1*	Two service recordings at an interval of 30 minutes.
2*	According to agreement with NK the running time can be reduced to 60 minutes.
3*	According to agreement with NK the running time can be reduced to 30 minutes.
M	Measurement at steady state condition of all engine parameters.
IACS	International Association of Classification Societies.

The operating values to be measured and recorded during the acceptance test have been specified in accordance with ISO 3046-1:2002 and with the rules of the classification societies.

The operation values are to be confirmed by the customer or his representative and the person responsible for the acceptance test by their signature on the test report. After the acceptance test components will be checked so far it is possible without dismantling. Dismantling of components is carried out on the customer's or his representative's request.

GenSet load responce

Load application for ship electrical systems

In the age of highly turbocharged diesel engines, building rules of classification societies regarding load application (e.g. 0 % => 50 % => 100 %) cannot be complied with, in all cases. However the requirements of the International Association of Classification Societies (IACS) and ISO 8528-5 are realistic. In the case of ship´s engines the application of IACS requirements has to be clarified with the respective classification society as well as with the shipyard and the owner. Therefore the IACS requirements has been established as generel rule.

For applications from 0 % to 100 % continuous rating, according to IACS and ISO 8528-5, the following diagram is applied:

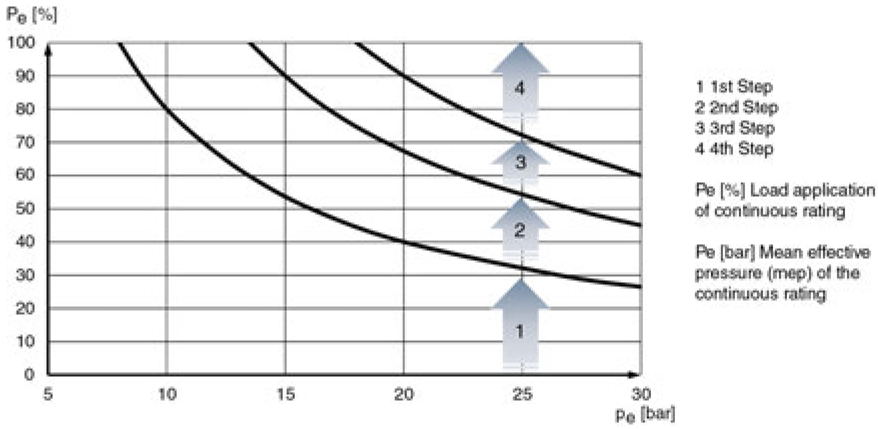

Fig. 1 Load application in steps as per IACS and ISO 8528-5.

According to the diagram in Fig. 1 the maximum allowable load application steps are defined in the table below. (24.4 bar mean effective pressure has been determined as a mean value for the listed engine types.)

Note: Our small bore GenSets has normally a better load responce than required by IACS and therefore a standard load responce test where three load steps (3 x 33%) is applied will be demostrated at factory acceptance test.

Minimum requirements concerning dynamic speed drop, remaining speed variation and recovery time during load application are listed below.

In case of a load drop of 100 % nominal engine power, the dynamical speed variation must not exceed 10 % of the nominal speed and the remaining speed variation must not surpass 5 % of the nominal speed.

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<table>
<tr><th>Engine</th><th>bmep (bar) *</th><th>1 st step</th><th>2nd step</th><th>3th step</th><th>4th step</th></tr>
<tr><td>L16/24</td><td>22.4/23.6
-20.7/22.8</td><td rowspan="7">IACS 33%
MDT 34%</td><td rowspan="7">IACS 23%
MDT 33%</td><td rowspan="7">IACS 18%
MDT 33%</td><td rowspan="7">IACS 26%</td></tr>
<tr><td>L23/30H Mk1</td><td>18.2 - 18.1 - 17.9</td></tr>
<tr><td>L23/30H Mk2</td><td>19.9/19.8/19.6</td></tr>
<tr><td>L23/30H Mk3</td><td>23.8/23.7/22.4</td></tr>
<tr><td>L21/31</td><td>24.9/27.3
-22.4/24.6</td></tr>
<tr><td>L27/38</td><td>23/25.3
-23.5/24.3</td></tr>
<tr><td>L28/32H</td><td>17.8 -17.9</td></tr>
<tr><td colspan="6">* see project guide B 10 01 1 'main particulars', for actual bmep at nominel rpm.</td></tr>
</table>

Fig. 2. maximum allowable load application steps (higher load steps than listed are not possible as a standard)

Regulating test and load responce performance

Load step on MAN Energy Solutions GenSets is to be tested according to following procedure.

<table>
<tr><th>Classification society</th><th>Dynamic speed drop in % of the nominal speed</th><th>Remaining speed variation in % of the nominal speed</th><th>Recovery time until reaching the tolerance band ±1 % of nominal speed</th></tr>
<tr><td>RINA</td><td rowspan="6">≤ 10 %</td><td rowspan="6">≤ 5 %</td><td rowspan="6">≤ 5 sec.</td></tr>
<tr><td>Lloyd´s Register</td></tr>
<tr><td>American Bureau of Shipping</td></tr>
<tr><td>Bureau Veritas</td></tr>
<tr><td>Det Norske Veritas</td></tr>
<tr><td>ISO 8528-5</td></tr>
</table>

Fig. 3 Minimum requirements of the classification societies plus ISO rule.

Momentum speed variation (m) must not vary more than 10% max. deviation from steady speed 1 %. Permanent speed variation (p) must not be higher than 5%.

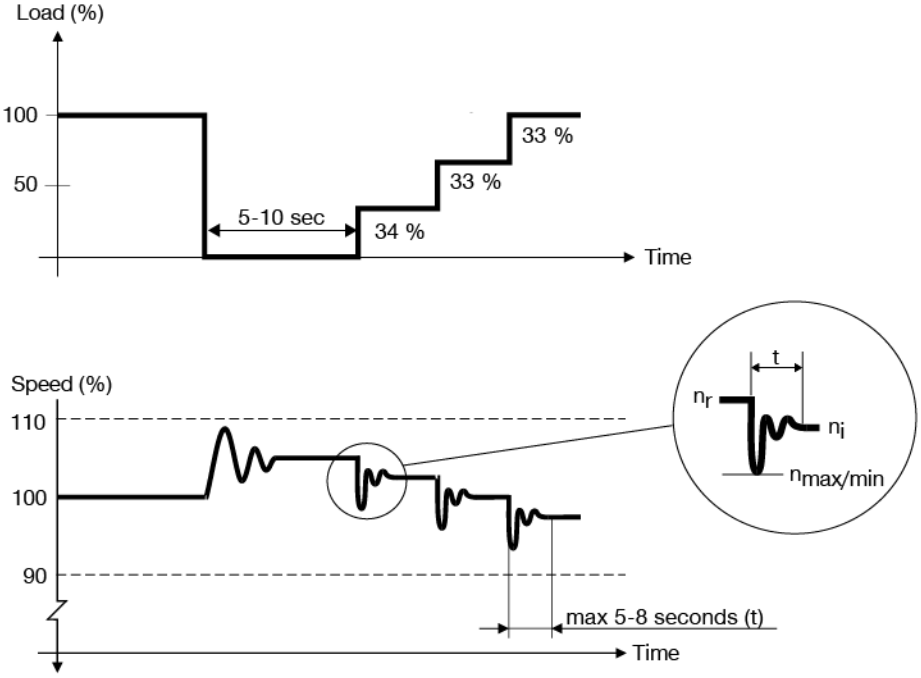

Fig. 4 Minimum requirements of the classification societies plus ISO rule.

bmep: Must be found in product guide. For most classification sociaties 3 x 33% load application will be accepted. *Actual classification society rules must be observed.*

Speed droop: _____, Needle valve open: ______°

$$m = \frac{n_{max/min} - n_r}{n_r} \times 100 \qquad p = \frac{n_i - n_r}{n_r} \times 100$$

Load (%)	(n_r) Rated speed [Hz]	($n_{max/min}$) Momentum speed [Hz]	(n_i) Permanent speed [Hz]	(m) Momentum speed variation [%]	(p) Permanent speed variation [%]	(t) Time to steady speed [sec]
0 - 34						
34 - 67						
67 - 100						

According to IACS requirements and ISO 8528-5.

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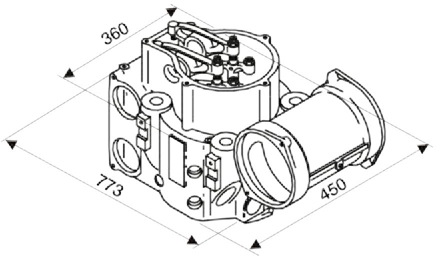
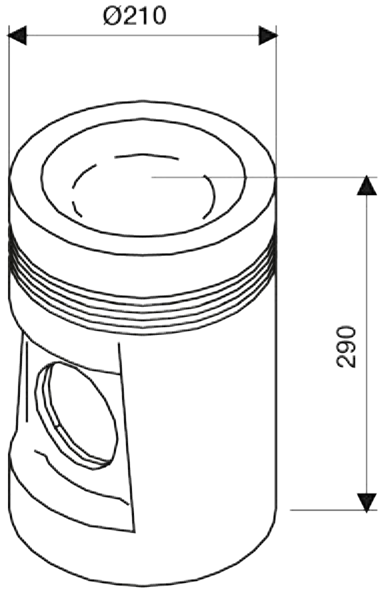
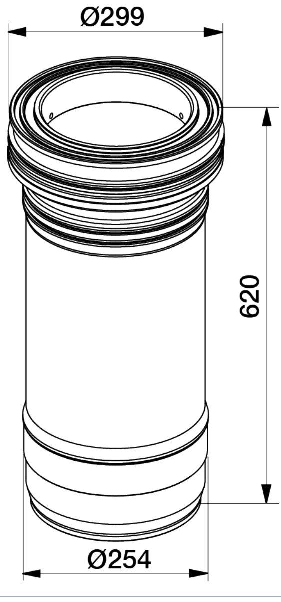
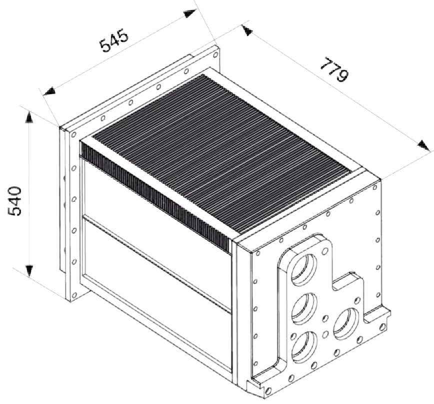
Weight and dimensions of principal parts

	
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

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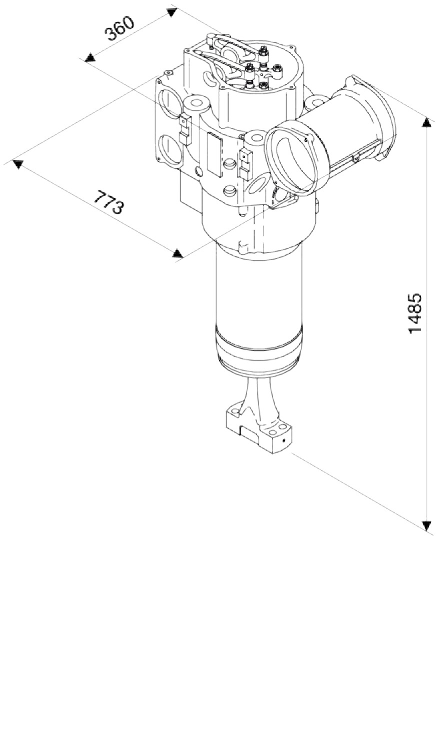
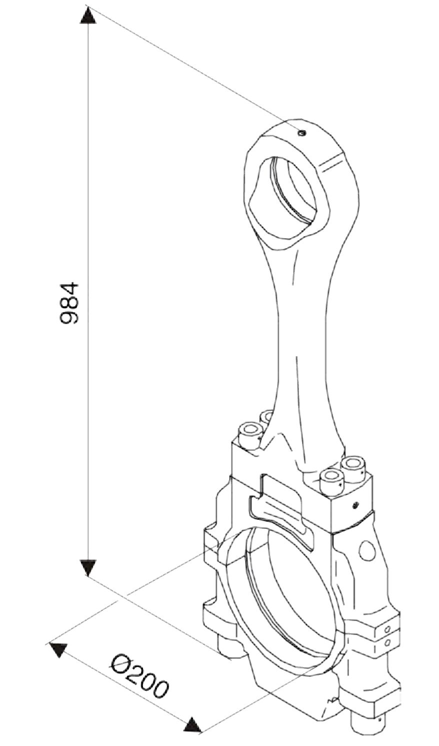
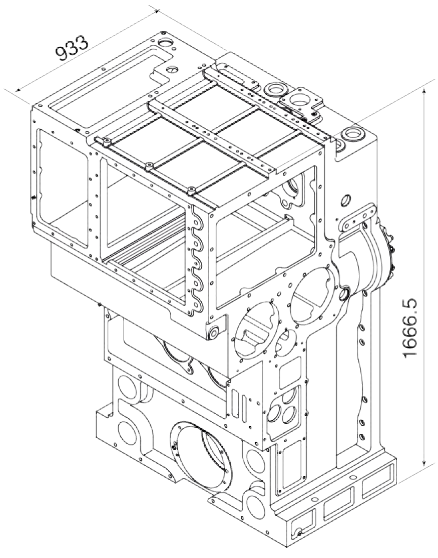
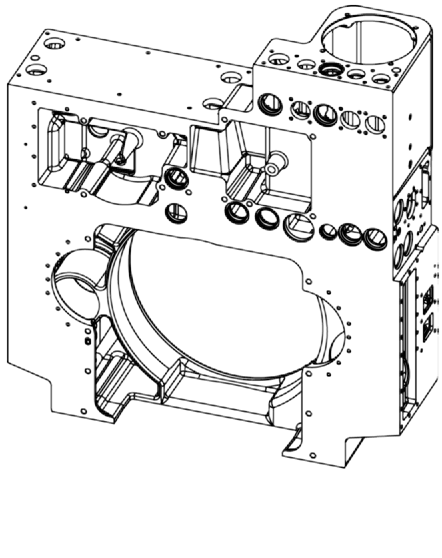
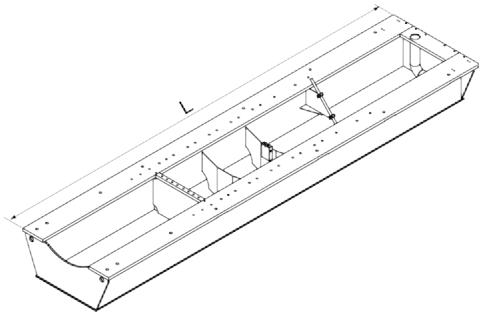
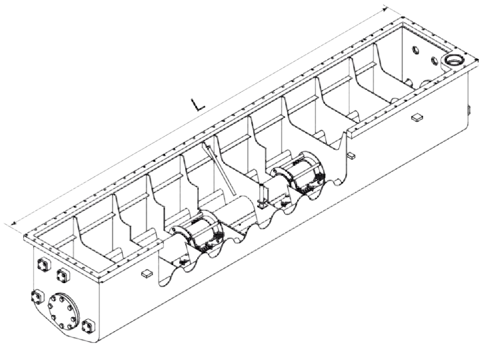
	
Cylinder unit approx. 485 kg	Connecting rod approx. 64 kg
	
Front end box for GenSet approx 1465 kg	Front end box for propulsion

Please note: 5 cyl. only for GenSet



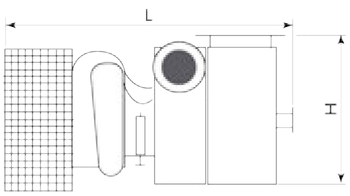
Base frame for GenSet	Length (L)* [mm]	Weight [kg]
5 cyl.	4529	2978
6 cyl.	5015.5	3063
7 cyl.	5423	3147
8 cyl.	6700	3300
9 cyl.	7000	3500

Width: 1400 mm
** Depending on alternator type*



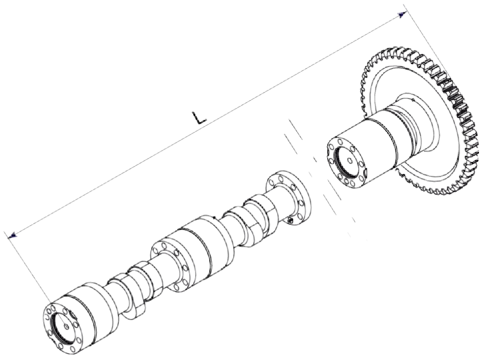
Oil pan for propulsion	Length (L)* [mm]	Weight [kg]
6 cyl.	2920.5	660
7 cyl.	3275.5	720
8 cyl.	3630.5	780
9 cyl.	3985.5	850

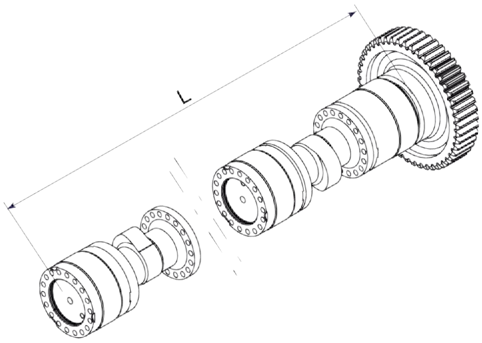
Width: 1065 mm

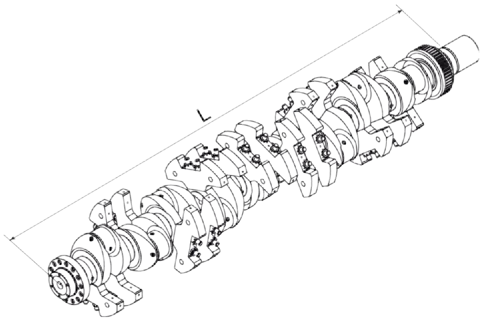


Turbocharger	Length (L) [mm]	Height (H) [mm]	Weight (kg)
TCR16	1110	615	290
TCR18	1328	772	460

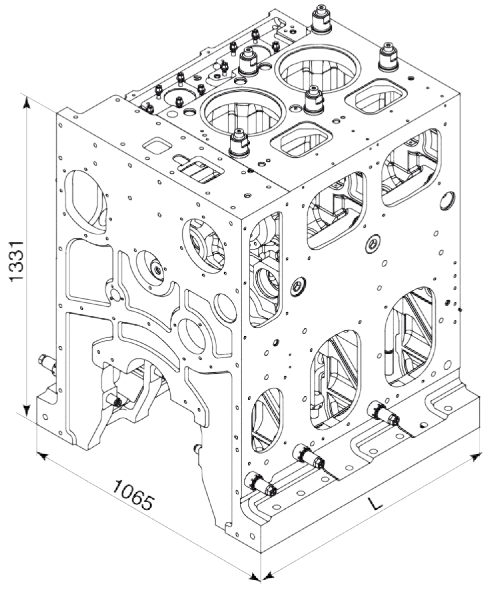
Please note: 5 cyl. only for GenSet

	Valve camshaft	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

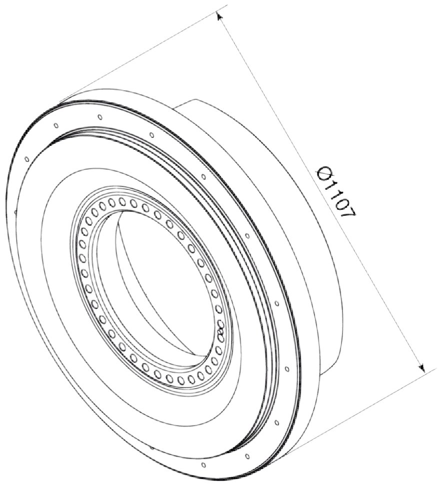
	Injection camshaft	Length (L) [mm]	Weight [kg]
	5 cyl.	1980.5	275
	6 cyl.	2335.5	321
	7 cyl.	2690.5	367
	8 cyl.	3045.5	413
	9 cyl.	3400.5	459

	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

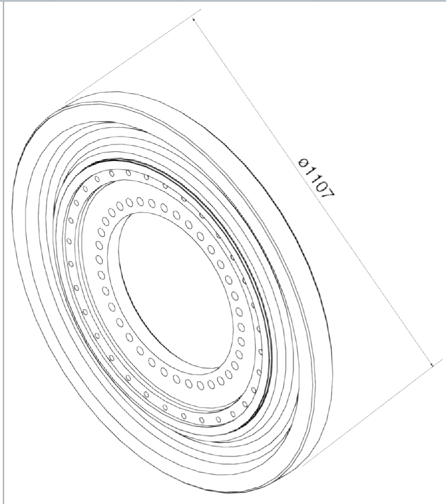


Frame	Length (L) [mm]	Weight (kg)
5 cyl.	2105.5	3435
6 cyl.	2460.5	3981
7 cyl.	2815.5	4527
8 cyl.	3170.5	5073
9 cyl.	3525.5	5619



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 and/or MAN Energy Solutions standard.

Cylinder head

Description	Plates	Item	Qty.
Valve seat ring, inlet O-ring Valve seat ring, exhaust O-ring	P50501	123 172 184 196	2 6 4 2
Circlip Conical ring in 2/2 Rotocap, complete Spring O-ring O-ring Valve spindles, inlet and exhaust O-ring	P50502	095 178 191 201 237 250 274 536	2 6 6 6 1 1 6 4
Gasket O-ring O-ring O-ring	P50507	043 055 080 092	1 2 2 1
Gasket, top cover	P50510	014	1

Piston, connecting rod and cylinder liner

Description	Plates	Item	Qty.
Piston pin Retaining ring	P50602	026 038	1 2
Bush for connecting rod Screw for connecting rod Nut Screw for connecting rod Nut	P50603	008 021 057 069 094	1 4 2 4 2
Connecting rod bearing 2/2	P50604	003	1
Piston ring Piston ring Oil scraper ring	P50605	009/093 010/103 022/127	1 1 1
Seal ring O-ring O-ring O-ring	P50610	031 055 209 210	1 1 1 1

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Engine frame and base frame

Description	Plates	Item	Qty.
Main bearing shell 2/2 Thrust bearing ring	P51104	021 033	1 2

Turbocharger system

Description	Plates	Item	Qty.
O-ring	P51229	015	4

Fuel oil system and injection equipment

Description	Plates	Item	Qty.
Seal ring O-ring Fuel injection pump	P51401	002 457 565	1 1 1
O-ring O-ring Fuel injection valve O-ring	P51402	033 104 116 236	5 5 5 5
O-ring O-ring Fuel oil high-pressure pipe Connection pipe	P51404	010 022 117 129	1 2 1 1

Cooling water system

Description	Plates	Item	Qty.
O-ring V-profile clamp	P51630	003 014	8 1

Notice

Scope of this list are subject to change and therefore the latest version of this document should always be used, please see MAN Energy Solutions 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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Introduction to spare part plates for tools

Description

For our GenSets 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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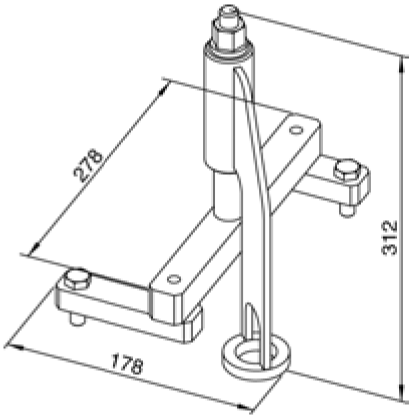
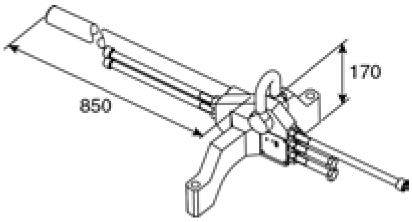
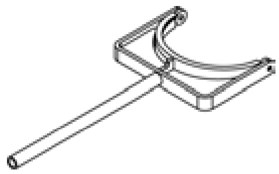
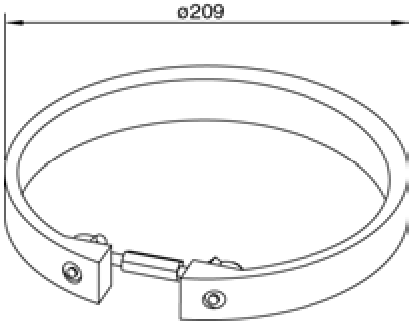
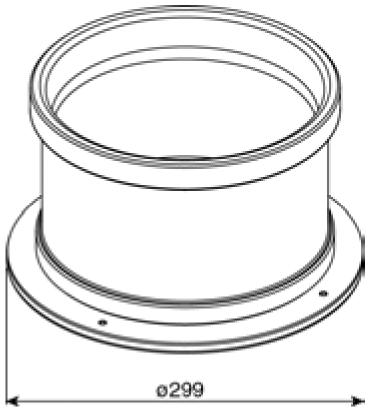
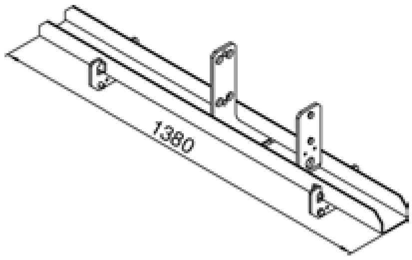
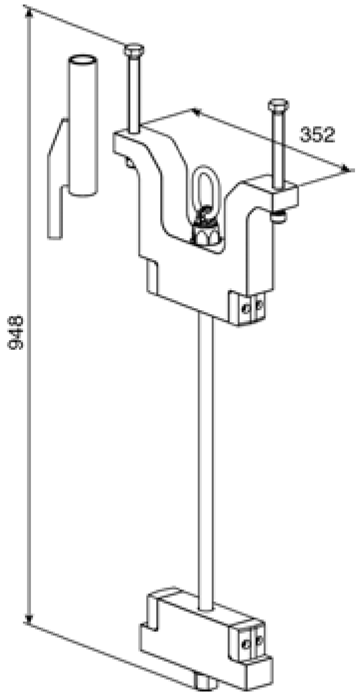
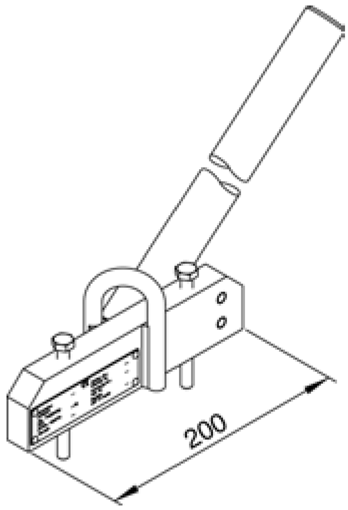
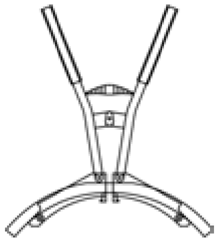
Standard tools for normal maintenance

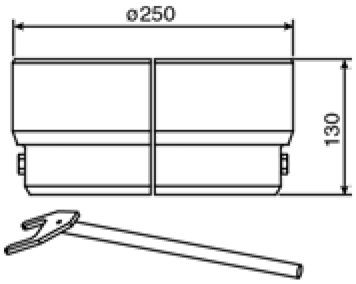
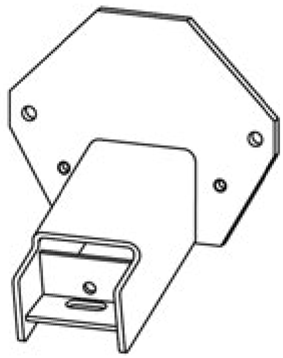
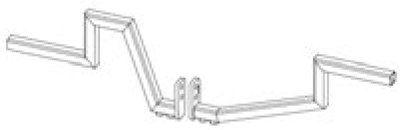
Cylinder head

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	

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	

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	

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	

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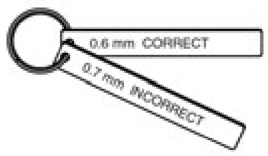
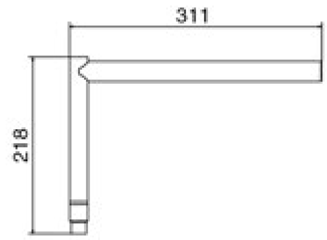
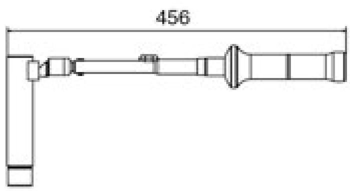
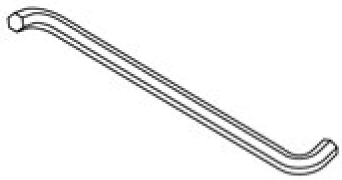
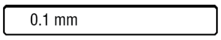
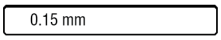
Operating gear for inlet and exhaust valves

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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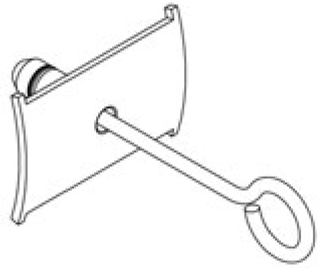
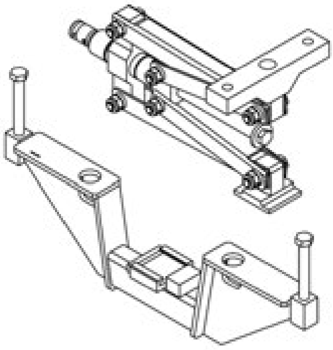
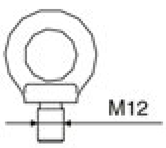
Standard tools for normal maintenance

Description

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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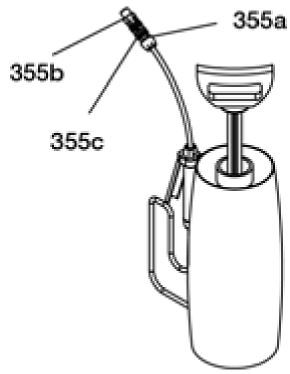
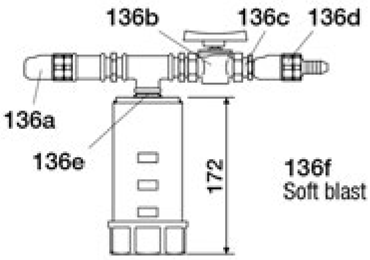
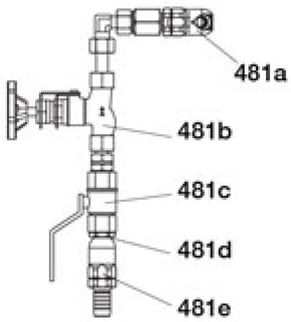
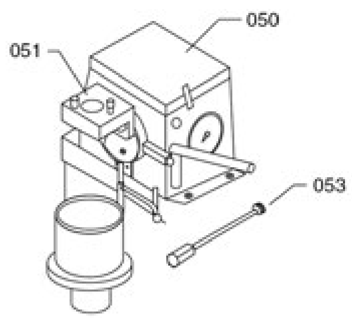
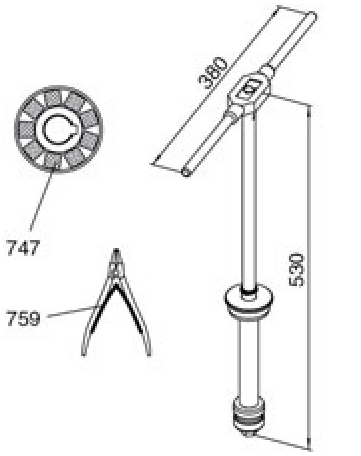
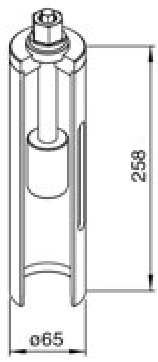
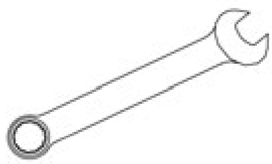
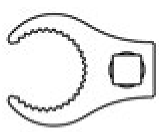
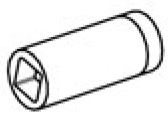
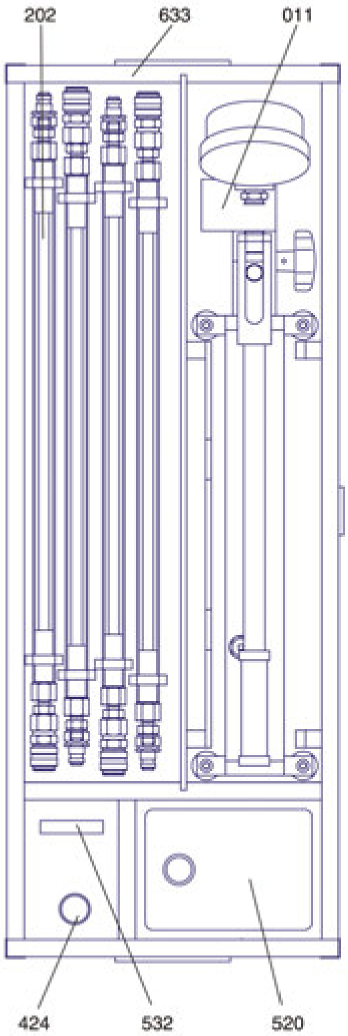
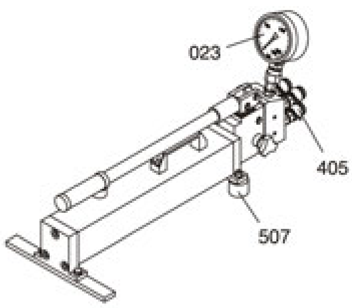
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Container complete for water washing of compressor side Reducing piece Fitting Fitting			1	355 355a 355b 355c	
Blowgun for dry cleaning of turbocharger Snap coupling Ball valve Snap coupling Snap coupling Packing rings Soft blast (granulate)			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	

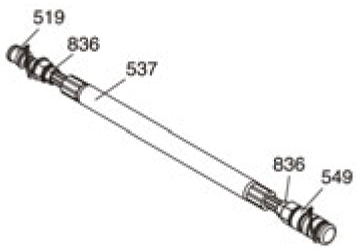
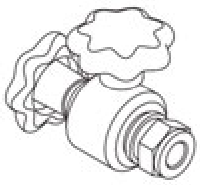
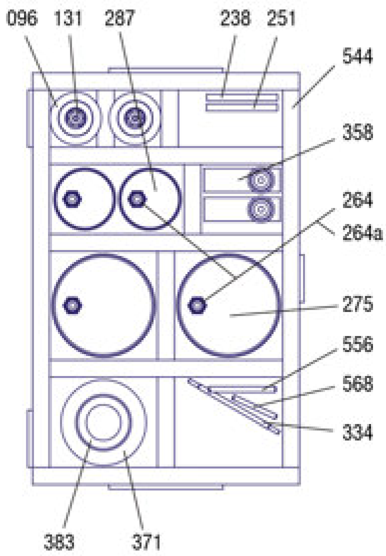
Fuel oil system

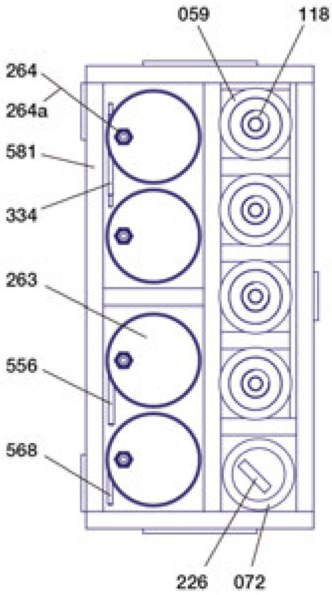
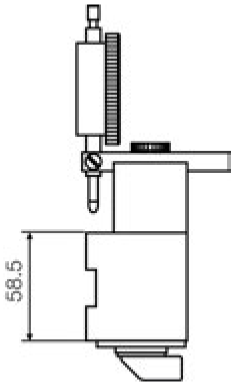
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Pressure testing tool Clamping bracket for fuel injector Fuel pipe			1 1 1	050 051 053	

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	

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	

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 for normal maintenance

Description

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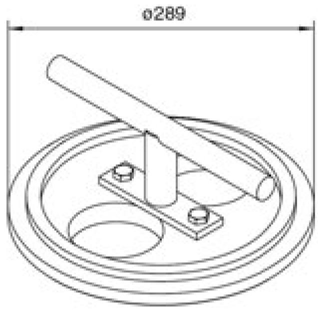
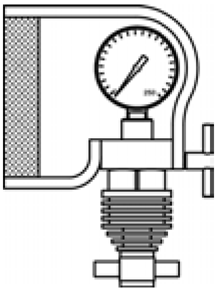
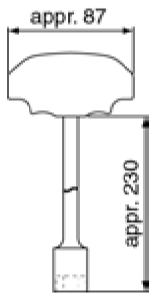
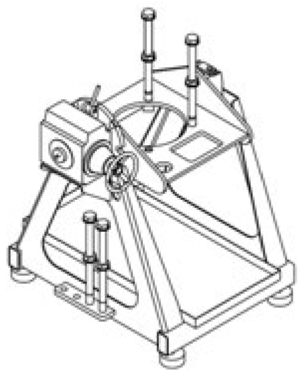
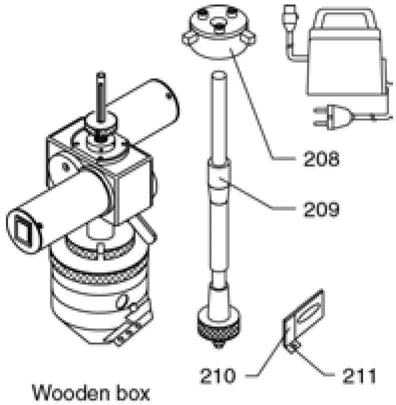
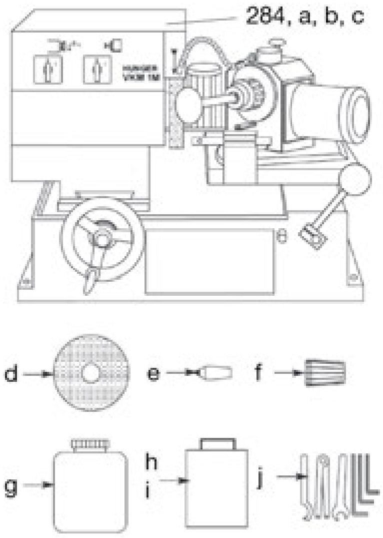
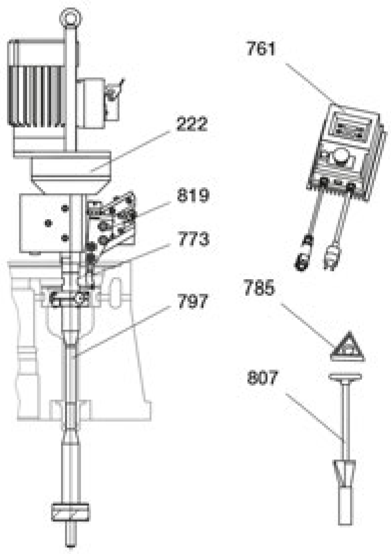
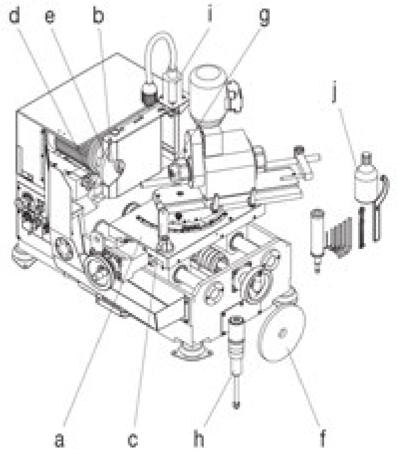
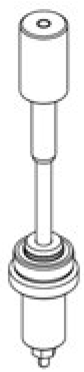
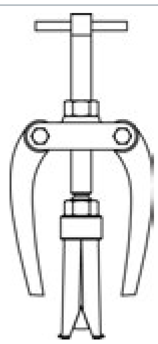
Additional tools

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	

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	Wooden box L x B x H = 450 x 380 x 190 mm		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	

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	

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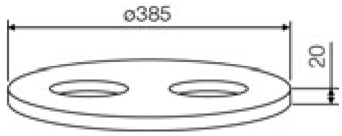
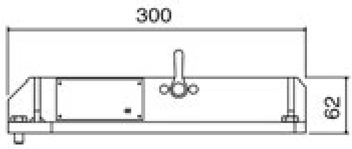
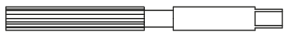
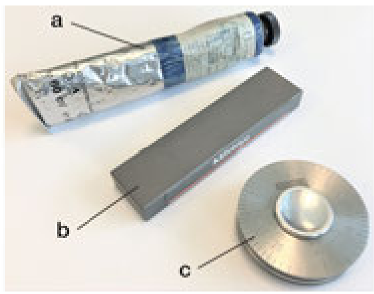
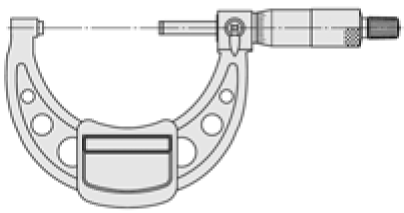
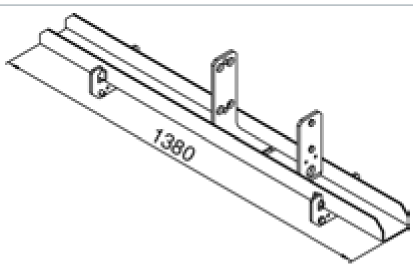
Additional tools

Description

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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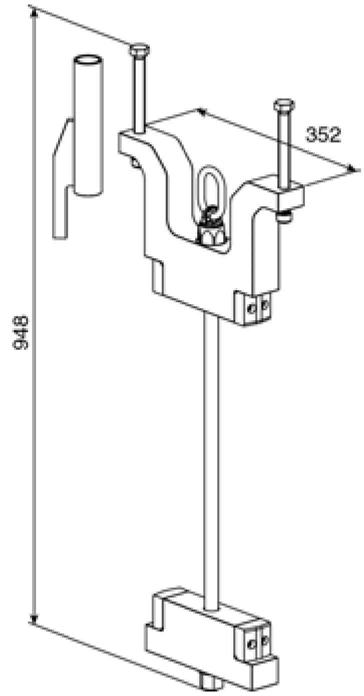
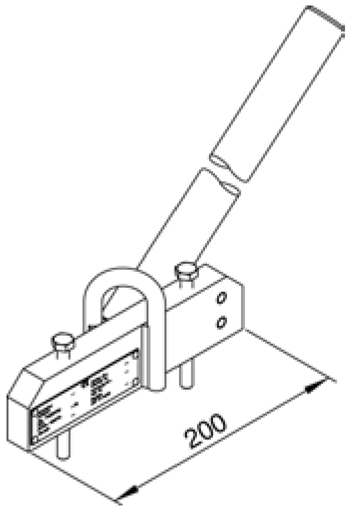
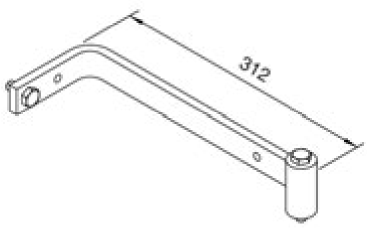
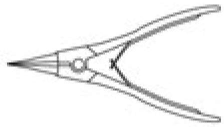
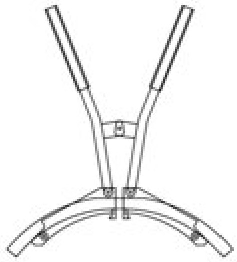
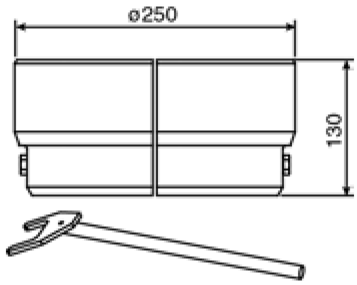
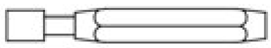
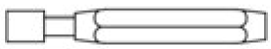
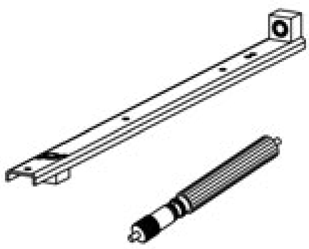
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Lifting device for cylinder liner			1	082	
Lifting device for piston and connecting rod			1	104	
Tool for fixing of marine head for counterweight			1	187	

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 con-necting 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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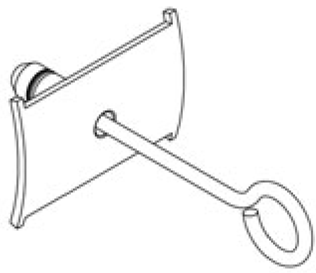
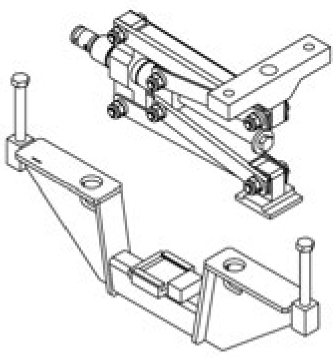
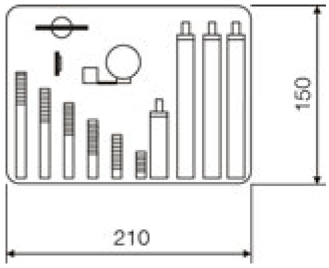
Control and safety systems - automatics and instruments

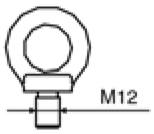
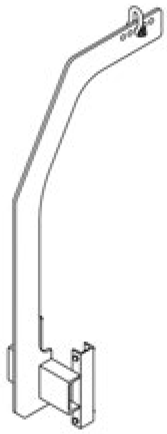
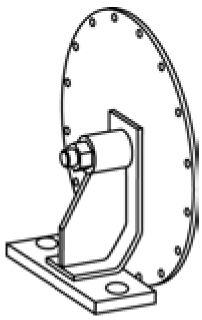
Name	Sketch	Supply per ship		Item no
		Working	Spare	
Infrared thermometer			1	727
Calibration tool			1	728

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	

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Crankshaft alignment gauge (autolog)			1	067	

Turbocharger system

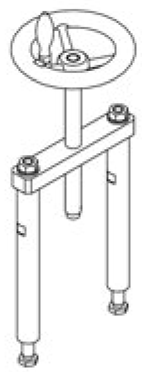
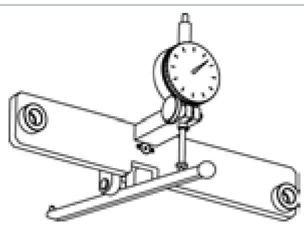
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Eye crew for lifting of charge air cooler/ lubricat-ing oil cooler			2	036	
Fit and removing device for cooler insert			1	401	
Closing cover, TCR16 Closing cover, TCR18 (standard with only one propulsion engine)			1 1	449 450	

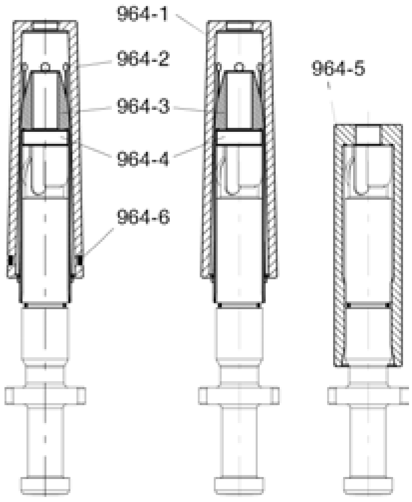
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Differential pressure tools complete Hose Nipple Nipple			1 1 2 2	915 915a 915b 915c	

Compressed air system

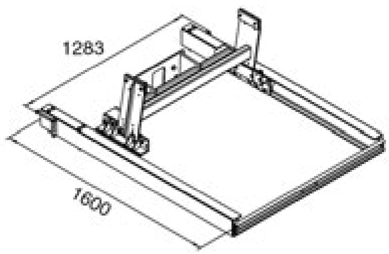
Name	Sketch	Supply per ship		Item no
		Working	Spare	
Set of tools, TDI air starter T50			1	928

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 injec-tion pump			1	366	

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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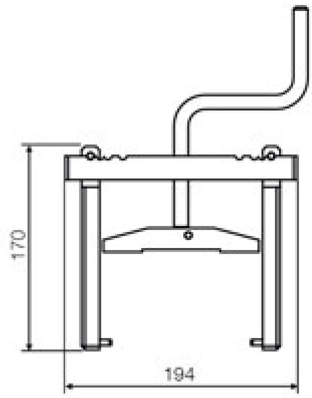
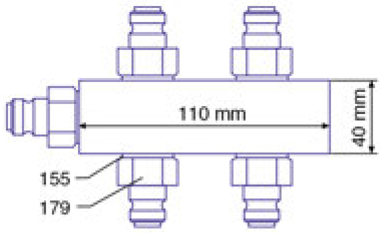
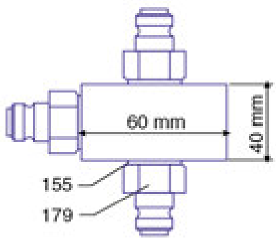
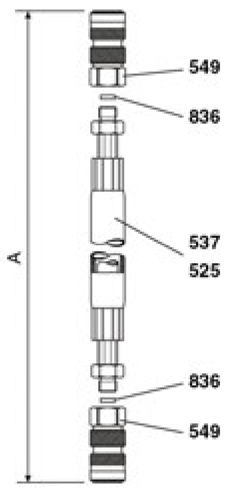
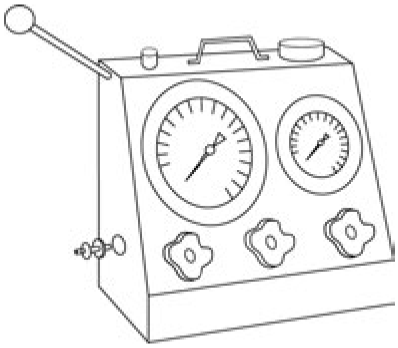
Additional tools
Description

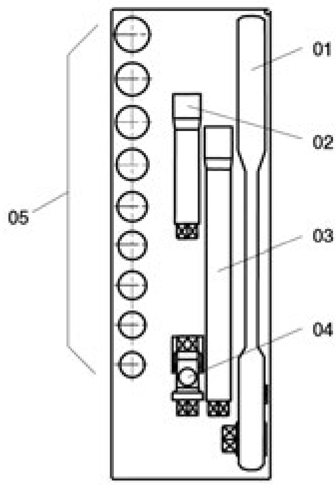
Hydraulic tools

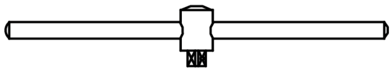
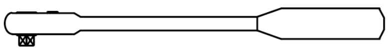
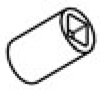
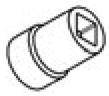
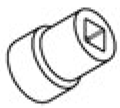
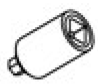
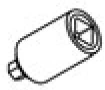
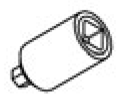
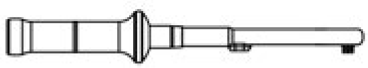
Name	Sketch	Supply per ship Working	Spare	Drawing Item no	Remarks
Resetting device for hy-draulic cylinder			1	092	
Distributing piece for cylinder head, complete			1	143	
Gasket				155	
Quick coupling				179	
Distributing piece for main bearing, complete			1	167	
Gasket				155	
Quick coupling				179	
Hose with unions for cylinder head complete, 1000 mm			4	180	
Hose with unions for connection of oil pump and distributing block complete, 3000 mm			1	202	
Hose, 3000 mm				537	
Quick coupling with protecting cap				549	
Hose, 1000 mm				525	
Disc				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	

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	

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	

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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Alternators for GenSets

GenSet

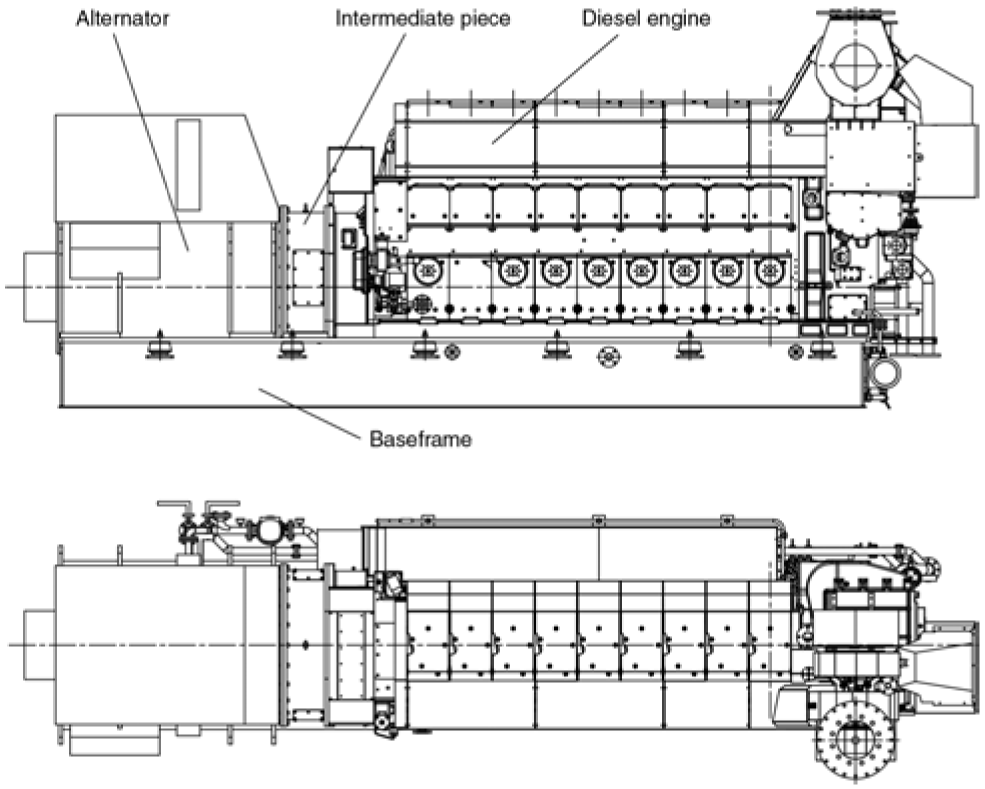

Figure 1: GenSet

A GenSet is a joined unit with a diesel engine, an alternator and a common base frame. The alternator has a stator housing with a front flange which is connected to the diesel engine with bolts. Similar to this the alternator has foot flanges with bolt connection to the base frame. The base frame is anchored to the foundation with a variable number of rubber dampers.

Mechanical alternator design

The rotor in the alternator is installed with either one or two bearings. On one-bearing alternators the rotor is connected to the flywheel of the diesel engine with a flex disc. The one-bearing alternator does not have a front bearing and in this case the rotor is carried by the crankshaft of the engine. On two-bearing alternators the connection is a flexible rubber coupling, and the rotor front is seated in the stator housing of the alternator.

In both cases the alternator stator housing is connected to the diesel engine with bolts, however, with two-bearing alternators an intermediate piece with bolt flanges is used which at the same time is shielding the flexible rubber coupling.

The bearing type can be ball bearing, roller bearing or sleeve bearing.

NOTICE The engine types 8L21/31, 9L21/31, 8L27/38 and 9L27/38 only use two-bearing alternators to keep the load on the engine's rear crankshaft bearing on a low level.

The alternator can be delivered air-cooled with insulation class IP23 or water-cooled with insulation class IP44.

The air-cooled alternator takes air in through filters; leads the air through the alternator by means of a built-in ventilator and out of the alternator again.

The water-cooled alternator circulates air internally in the alternator by means of the ventilator. The airflow passes through a built-in water cooler, removing the heat from the alternator through the connected cooling water system.

The entrance to the electrical main cables can be placed on the right or left side of the alternator with a horizontal or vertical inlet.

Electrical alternator design

The alternator is a three-phase AC synchronous alternator – brushless with built-in exciter and automatic, electronic voltage regulator (AVR) with potentiometer for remote control. (The potentiometer for final adjustment of the voltage is included in the standard delivery and normally part of the control panel).

The alternator is intended for parallel running.

The insulation class for the windings can be H/H or lower. H/H corresponds to 180° C on the windings and 180° C operating temperature.

According to the GL classification rules the alternator must as maximum be used up to 155° C operating temperature – corresponding to insulation class F. It may also be a customer requirement to keep the efficiency below class H.

The windings have tropical resistance against high humidity.

The alternator is equipped with anti-condensate standstill heater.

For temperature surveillance in the windings, the alternator is equipped with PT 1000 Sensors.

For surveillance of the bearing temperature and for water cooled alternators for surveillance of cooling air temperature. Alternators may also be equipped with visual thermometers on bearings.

Alternators car be delivered for the voltage 380 VAC to 13.8 KVAC, Frequencies 50 HZ or 60HZ Special application with DC and variable frequency can be installed in at EPROX application

The alternator fulfils the requirements for electromagnetic compatibility protection EMC, is designed and tested according to IEC34 and fulfils the DIN EN 60034 / VDE0530 requirements.

Alternator cable installation

Description

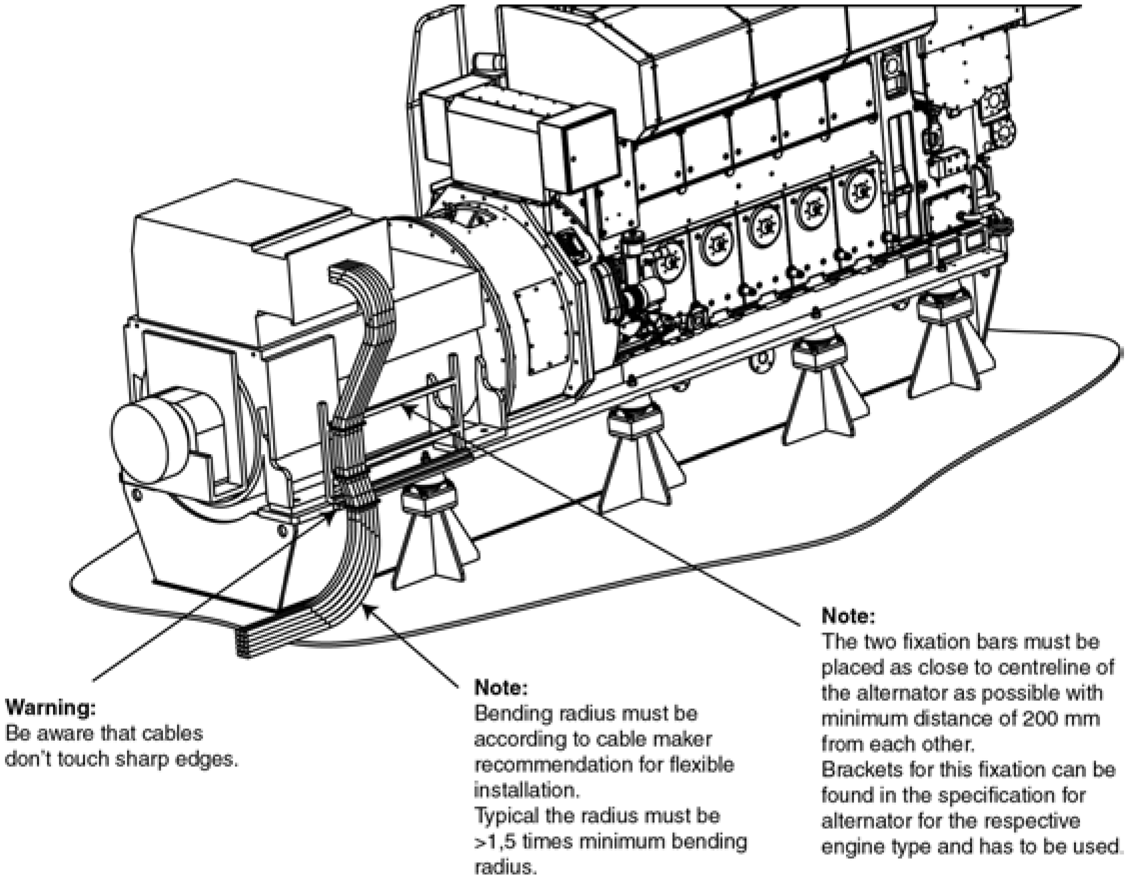

Figure 1: Connection of cables (example)

Main cables

The resilient installation of the GenSet must be considered when fixing the alternator cables.

The cables must be installed so that no forces have any effect on the terminal box of the alternator.

A support bracket can be welded on the engine base frame. If this solution is chosen, the flexibility in the cables must be between the cable tray and the support bracket.

The free cable length from the cable tray to the attachment on the alternator must be appropriate to compensate for the relative movements between the GenSet and the foundation.

The following can be used as a guideline:
The fix point of the alternator cables must be as close as possible to the centre line of the rotor.

Bending of the cables must follow the recommendations of the cable supplier regarding minimum bending radius for movable cables.

If questions arise concerning the above, please do not hesitate to contact MAN Energy Solutions.

Note: The responsibility for alternator cable installation lies with the Installation Contractor. The Installation Contractor has to define the dimension of the cables with due respect to heat conditions at site, cable routing (nearby cables), number of single wires per phase, cable material and cable type.

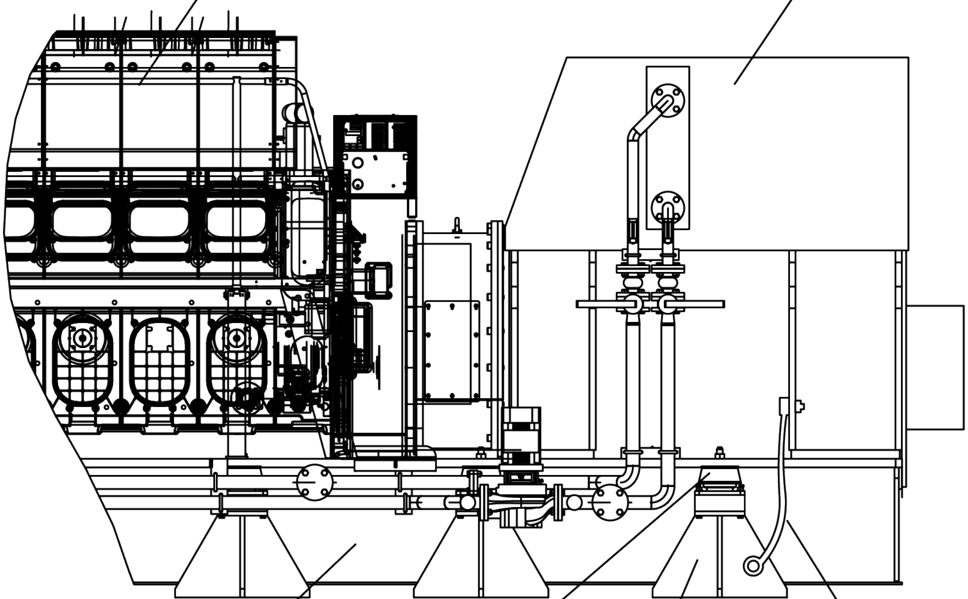

Figure 2: Marine operation (example)

Binding radius has to be observed, and furthermore binding radius for cables used for resilient installed engines must be observed.

Earth cable connection

It is important to establish an electrical connecting across the rubber dampers. The earth cable must be installed as a connection between alternator and ship hull for marine operation, and as a connection between alternator and foundation for stationary operation.

For stationary operation, the Contractor must ensure that the foundation is grounded according to local legislation.

Engine, base frame and alternator have internal metallic contact to ensure earth connection. The size of the earth cable is to be calculated on the basis of output and safety conditions in each specific case; or must as a minimum have the same size as the main cables.

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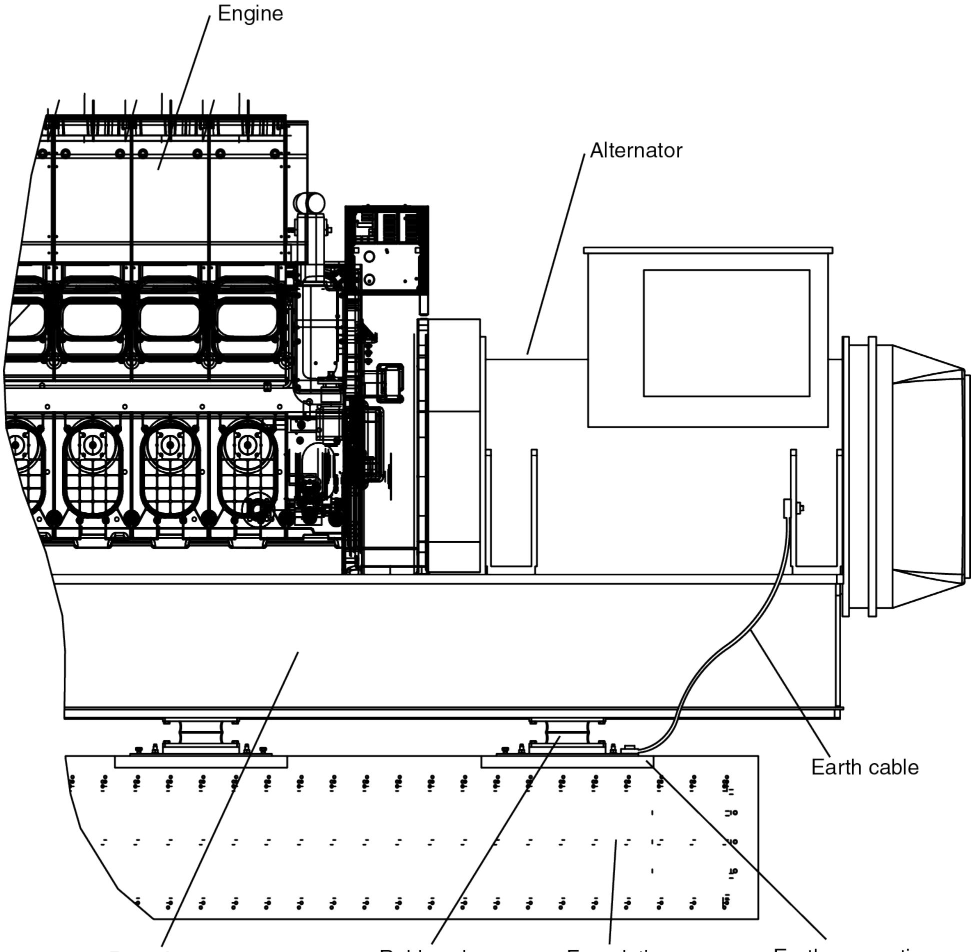

Figure 3: Stationary operation (example)

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Combinations of engine- and alternator layout

L23/30H Mk1 L23/30S Mk 1 L23/30H Mk1, Monocoque	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 720 RPM	• 2)	1)	2)	1)
5 Cyl. 750 RPM	• 2)	1)	2)	1)
6 Cyl. 720 RPM	•	#	#	#
6 Cyl. 750 RPM	•	#	#	#
6 Cyl. 900 RPM	•	#	#	#
7 Cyl. 720 RPM	•	#	#	#
7 Cyl. 750 RPM	•	#	#	#
7 Cyl. 900 RPM	•	#	#	#
8 Cyl. 720 RPM	•	#	#	#
8 Cyl. 750 RPM	•	#	#	#
8 Cyl. 900 RPM	•	#	#	#

L23/30H Mk 2 L23/30S Mk 2	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 720 RPM	• 2)	1)	2)	1)
5 Cyl. 750 RPM	• 2)	1)	2)	1)
6 Cyl. 720 RPM	•	#	#	#
6 Cyl. 750 RPM	•	#	#	#
6 Cyl. 900 RPM	•	#	#	#
7 Cyl. 720 RPM	•	#	#	#
7 Cyl. 750 RPM	•	#	#	#
7 Cyl. 900 RPM	X	X	•	#
8 Cyl. 720 RPM	•	#	#	#
8 Cyl. 750 RPM	•	#	#	#
8 Cyl. 900 RPM	•	#	#	#

L28/32H L28/32DF L28/32S	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 720 RPM	•	#	#	#
5 Cyl. 750 RPM	•	#	#	#
6 Cyl. 720 RPM	•	#	#	#
6 Cyl. 750 RPM	•	#	#	#
7 Cyl. 720 RPM	X	X	•	#
7 Cyl. 750 RPM	X	X	•	#
8 Cyl. 720 RPM	X	X	•	#
8 Cyl. 750 RPM	X	X	•	#
9 Cyl. 720 RPM	•	#	#	#
9 Cyl. 750 RPM	•	#	#	#

Monocoque: L23/30H Mk 2 L23/30DF	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 720 RPM	•	#	#	#
5 Cyl. 750 RPM	•	#	#	#
6 Cyl. 720 RPM	•	#	#	#
6 Cyl. 750 RPM	•	#	#	#
6 Cyl. 900 RPM	•	#	#	#
7 Cyl. 720 RPM	•	#	#	#
7 Cyl. 750 RPM	•	#	#	#
7 Cyl. 900 RPM	X	X	•	#
8 Cyl. 720 RPM	•	#	#	#
8 Cyl. 750 RPM	•	#	#	#
8 Cyl. 900 RPM	•	#	#	#

For a GenSet the engine and alternator are fixed on a common base frame, which is flexibly installed. This is to isolate the GenSet vibration-wise from the environment. As part of the GenSet design a full FEM calculation has been done and due to this and our experience some combinations of engine type and alternator type concerning one - or two bearings must be avoided. In the below list all combinations can be found.

Comments to possible combinations:

• : Standard
: Option
X : Not recommended
1) : Only in combination with "top bracing" between engine crankcase and alternator frame
2) : Need for 'topbracing' to be evaluated case by case

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Combinations of engine- and alternator layout

Description

Monocoque: L23/30H Mk 3	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 720 RPM	•	#	#	#
5 Cyl. 750 RPM	•	#	#	#
6 Cyl. 720 RPM	•	#	#	#
6 Cyl. 750 RPM	•	#	#	#
6 Cyl. 900 RPM	•	#	#	#
7 Cyl. 720 RPM	•	#	#	#
7 Cyl. 750 RPM	•	#	#	#
7 Cyl. 900 RPM	•	#	#	#
8 Cyl. 720 RPM	•	#	#	#
8 Cyl. 750 RPM	•	#	#	#
8 Cyl. 900 RPM	•	#	#	#
9 Cyl. 720 RPM	•	#	#	#
9 Cyl. 750 RPM	•	#	#	#
9 Cyl. 900 RPM	•	#	#	#

L16/24 L16/24S	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 1000 RPM	•	#	#	#
5 Cyl. 1200 RPM	•	#	#	#
6 Cyl. 1000 RPM	•	#	#	#
6 Cyl. 1200 RPM	•	#	#	#
7 Cyl. 1000 RPM	•	#	#	#
7 Cyl. 1200 RPM	•	#	#	#
8 Cyl. 1000 RPM	•	#	#	#
8 Cyl. 1200 RPM	•	#	#	#
9 Cyl. 1000 RPM	•	#	#	#
9 Cyl. 1200 RPM	•	#	#	#

L21/31 L21/31S L21/31 Mk2	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 900 RPM	•	#	#	#
5 Cyl. 1000 RPM	•	#	#	#
6 Cyl. 900 RPM	•	#	#	#
6 Cyl. 1000 RPM	•	#	#	#
7 Cyl. 900 RPM	•	#	#	#
7 Cyl. 1000 RPM	•	#	#	#
8 Cyl. 900 RPM	X	X	•	#
8 Cyl. 1000 RPM	X	X	•	#
9 Cyl. 900 RPM	X	X	•	#
9 Cyl. 1000 RPM	X	X	•	#

L27/38 L27/38S	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 720 RPM	•	#	#	#
5 Cyl. 750 RPM	•	#	#	#
6 Cyl. 720 RPM	•	#	#	#
6 Cyl. 750 RPM	•	#	#	#
7 Cyl. 720 RPM	•	#	#	#
7 Cyl. 750 RPM	•	#	#	#
8 Cyl. 720 RPM	X	X	•	#
8 Cyl. 750 RPM	X	X	•	#
9 Cyl. 720 RPM	X	X	•	#
9 Cyl. 750 RPM	X	X	•	#

V28/32S	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
12 Cyl. 720 RPM	X	X	•	1)
12 Cyl. 750 RPM	X	X	•	1)
16 Cyl. 720 RPM	X	X	•	1)
16 Cyl. 750 RPM	X	X	•	1)
18 Cyl. 720 RPM	X	X	•	1)
18 Cyl. 750 RPM	X	X	•	1)

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Diesel-electric propulsion plants

1.1 Advantages of diesel-electric propulsion

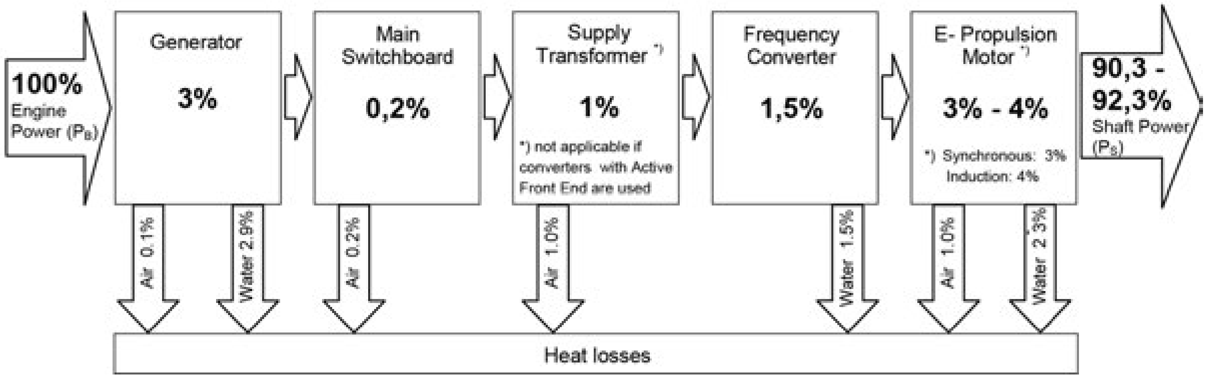
Due to different and individual types, purposes and operational profiles of diesel-electric driven vessels the design of a diesel-electric propulsion plant differs a lot and has to be evaluated case by case. All the following is for information purpose only and without obligation.

In general the advantages of diesel-electric propulsion can be summarized as follows:

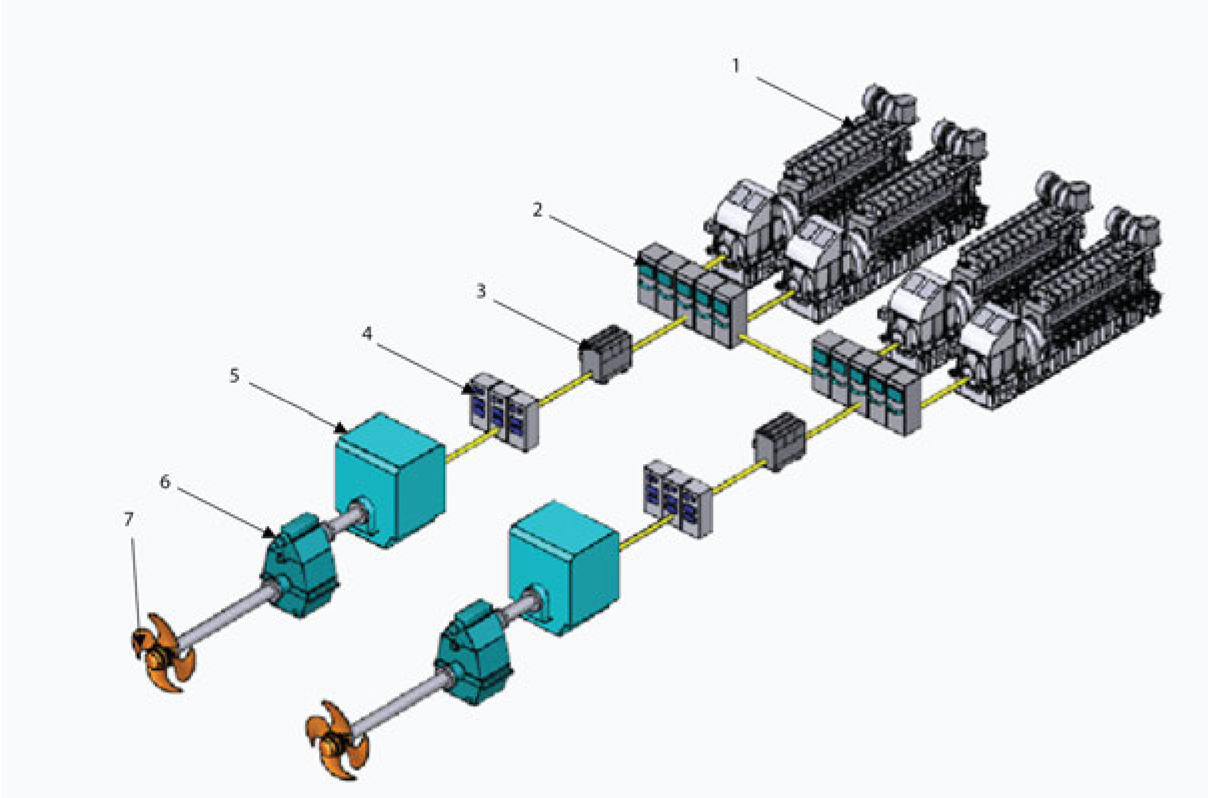
- Lower fuel consumption and emissions due to the possibility to optimize the loading of diesel engines / gensets. The gensets in operation can run on high loads with high efficiency. This applies especially to vessels which have a large variation in load demand, for example for an offshore supply vessel, which divides its time between transit and station-keeping (DP) operation.
- High reliability, due to multiple engine redundancy. Even if an engine / genset malfunctions, there will be sufficient power to operate the vessel safely. Reduced vulnerability to single point of failure providing the basis to fulfill high redundancy re-quirements.
- Reduced life cycle cost, resulting form lower operational and maintenance costs.
- Improved manoeuvrabilty and station-keeping ability, by deploying special propulsors such as azimuth thrusters or pods. Precise control of the electrical propulsion motors controlled by frequency converters.
- Increased payload, as diesel-electric propulsion plants take less space.
- More flexibility in location of diesel engine / gensets and propulsors. The propulsors are supplied with electric power through cables. They do not need to be adjacent to the diesel engines / gensets.
- Low propulsion noise and reduced vibrations. For example a slow speed E-motors allows to avoid gearboxes and propulsors like pods keep most of the structure bore noise outside of the hull.
- Efficient performance and high motor torques, as the system can provide maximum torque also at slow speeds, which gives advantages for example in icy conditions.

1.2 Efficiencies in diesel-electric plants

A diesel-electric propulsion plant consists of standard electrical components. The following efficiencies are typical:



1.3 Components of a diesel-electric propulsion plant



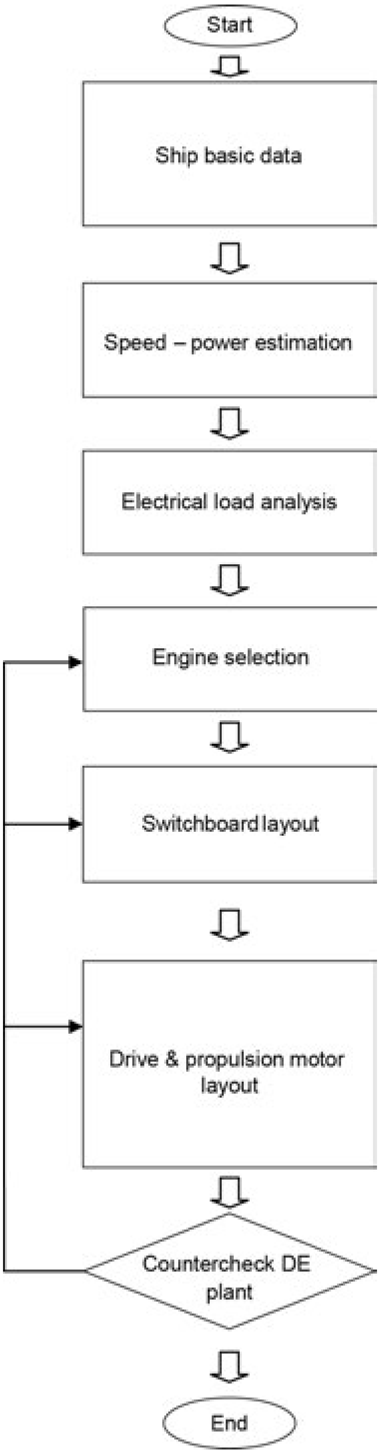
Example: Diesel-electric propulsion plant

Legend

1	GenSets: Diesel engines + alternators
2	Main switchboards
3	Supply transformers (optional): Dependent on the type of the converter. Not needed in case of the use of frequency converters with an Active Front End / Sinusoidal Drive
4	Frequency converters / drives
5	Electric propulsion motors
6	Gearboxes (optional): Dependent on the speed of the E-propulsion motor
7	Propellers / propulsors

1.4 Diesel electric plant design

Generic workflow how to design a diesel-electric propulsion plant:



- Type of vessel
- Propulsion type: Shaft line, thruster, pod, ...
- Propeller type: FPP, CPP
- Operational profile
- Class notation: Propulsion redundancy, ice class, ...

- Ship design points
- Propulsion power: At sea, maneuvering, at port, ...
- Sea margin

- Electrical power: At sea, maneuvering, at port, ...
- Efficiency of DE plant: Typically = 91%
- Efficiency of alternators: Typically = 96% - 97%

- Number and type of engines / gensets: Installed power
- Max. allowed loading of engines: % of MCR
- Maintenance of engines: At sea operation, at port, ...

- Frequency choice: 50 / 60 Hz
- Voltage choice: Low voltage, medium voltage
- Number of switchboard sections
- Alternator parameters: cos ϕ, xd"

- Selection of converter type: PWM, LCI, Sinusoidal, ...
- Selection of pulse number: 6p, 12p, 24p
- Selection of supply transformer: Investigate transformer less configuration (Active Front End)
- Selection of E-propulsion motor type and no. of windings
- THD mitigation method

- Check I_{sc}" : Increase voltage, optimize xd", ...
- Check availability of reactive power: Change number/type of alternators, cos ϕ, ...
- Check THD limits: Increase pulse number, add filters, ...

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The requirements of a project will be considered in an application specific design, taking into account the technical and economical feasibility and later operation of the vessel. In order to provide you with appropriate data, please fill the form *Questionnaire* in the appendix.

1.5 Engine selection

The engines for a diesel-electric propulsion plant have do be selected accordingly to the maximum power demand at the design point. For a concept evaluation the rating, the capability and the loading of engines can be calculated like this:

Example: Offshore Construction Vessel (at design point)

- Propulsion power demand (at E-motor shaft) — 7200 kW (incl. sea margin)
- Max. electrical consumer load — 1800 kW

No	Item	Unit	
1.1	Shaft power on propulsion motors	P_S [kW]	
	Electrical transmission efficiency		7200
			0,91
1.2	Engine power for propulsion	P_{B1} [kW]	7912
2.1	Electric power for ship (E-Load)	[kW]	1800
	Alternator efficiency		0,96
2.2	Engine power for electric consumers	P_{B2} [kW]	1875
2.3	Total engine power demand (= 1.2 + 2.2)	[kW]	9787
3.1	Diesel engine selection	type	9L27/38
3.2	Rated power (MCR)	[kW]	2970
3.3	Number of engines		4
3.4	Total engine power installed	P_B [kW]	11880
4.1	Loading of engines (= 2.3 / 3.4)	% of MCR	82,4%
5.1	Check: Max. allowed loading of engines		90,0%

For the detailed selection of the type and number of engines furthermore the operational profile of the vessel, the maintenance strategy of the engines and the boundary conditions given by the general arrangement have to be considered. For the optimal cylinder configuration of the engines often the power conditions in port is decisive.

1.6 E-plant, switchboard and alternator design

The configuration and layout of an electrical propulsion plant, the main switchboard and the alternators follows some basic design principles. For a concept evaluation the following items should be considered:

- A main switchboard which is divided in symmetrical sections is reliable and redundancy requirements are easy to be met
- An even number of gensets / alternators ensures the symmetrical loading of the bus bar sections
- Electrical consumers should be arranged symmetrically on the bus bar sections
- The switchboard design is mainly determined by the level of the short circuit currents which have to be withstand and by the breaking capacity of the circuit breakers (CB)
- The voltage choice for the main switchboard depends on several factors. On board of a vessel it is usually handier to use low voltage. As a rule of thumb the following table can be used:

Total installed alternator power [MWe]	Voltage [V]	Breaking capacity of CB [kA]
< 10 - 12 (and: Single propulsion motor < 3,5 MW)	440	100
< 13 - 15 (and: Single propulsion motor < 4,5 MW)	690	100
< 48	6600	30
< 130	11000	50

- The design of the alternators and the electric plant always has to be balanced between voltage choice, availability of reactive power, short circuit level and allowed total harmonic distortion (THD)
- On the one hand side a small xd" of the alternators increases the short circuit current Isc", which also increase the forces the switchboard has to withstand (F ~ Isc" ^ 2). This may lead to the need of a higher voltage. On the other side a small xd" gives a lower THD. As a rule of thumb a xd"=16% is a good figure for low voltage applications and a xd"=14% is good for medium voltage applications.
- For a rough estimation of the short circuit currents the following formulas can be used:

	Short circuit level [kA] (rough)	Legend
Alternators	$n * P_r / (\sqrt{3} * U_r * xd" * \cos \phi_{Grid})$	n: No. of alternators connected P_r: Power of alternator [kWe] U_r: Rated voltage [V] xd”: Subtransient reactance [%] cos ϕ: Power factor of the network (typically = 0.9)
Motors	$n * 6 * P_r / (\sqrt{3} * U_r * xd" * \cos \phi_{Motor})$	N : No. of motors (directly) connected P_r: Power of motor [kWe] U_r: Rated voltage [V] xd”: Subtransient reactance [%] cos ϕ: Power factor of the motor (typically = 0.85 ... 0.90 for an induction motor)
Converters	Frequency converters do not contribute to the I_{sc}”	

- The dimensioning of the panels in the main switchboard is usually done accordingly to the rated current for each incoming and outgoing panel. For a concept evaluation the following formulas can be used:

Type of switchboard panel	Rated current [kA]	Legend
Alternator incoming	$P_r / (\sqrt{3} * U_r * \cos \phi_{Grid})$	P_r: Power of alternator [kWe] U_r: Rated voltage [V] cos ϕ: Power factor of the network (typically = 0.9)
Transformer outgoing	$Sr / (\sqrt{3} * U_r)$	S_r: Apparent power of transformer [kVA] U_r: Rated voltage [V]
Motor outgoing (Induction motor controlled by a PWM-converter)	$P_r / (\sqrt{3} * U_r * \cos \phi$ Converter $* \eta_{Motor} * \eta_{Converter})$	P_r: Power of motor [kWe] U_r: Rated voltage [V] cos ϕ: Power factor converter (typically = 0.95) η_{Motor}: typically = 0.96 $\eta_{Converter}$: typically = 0.97
Motor outgoing (Induction motor started: DoL, Y/Δ, Soft-Starter)	$P_r / (\sqrt{3} * Ur * \cos \phi_{Motor} * \eta_{Motor})$	P_r: Power of motor [kWe] U_r: Rated voltage [V] cos ϕ: Power factor motor (typically = 0.85 ... 0.90) η_{Motor}: typically = 0.96

- The choice of the type of the E-motor depends on the application. Usually induction motors are used up to a power of 7 MW (η_{Motor}: typically = 0.96). If it comes to power applications above 7 MW per E-motor often synchronous machines are used. Also in applications with slow speed E-motors (without a reduction gearbox), for ice going or pod-driven vessels often synchronous E- motors (η_{Motor}: typically = 0.97) are used.

- In plants with frequency converters based on VSI-technology (PWM type) the converter themselves can deliver reactive power to the E-motor. So often a power factor cos ϕ = 0.9 is a good figure to design the alternator rating. Nevertheless there has to be sufficient reactive power for the ship consumers, so that a lack in reactive power does not lead to unnecessary starts of (standby) alternators.

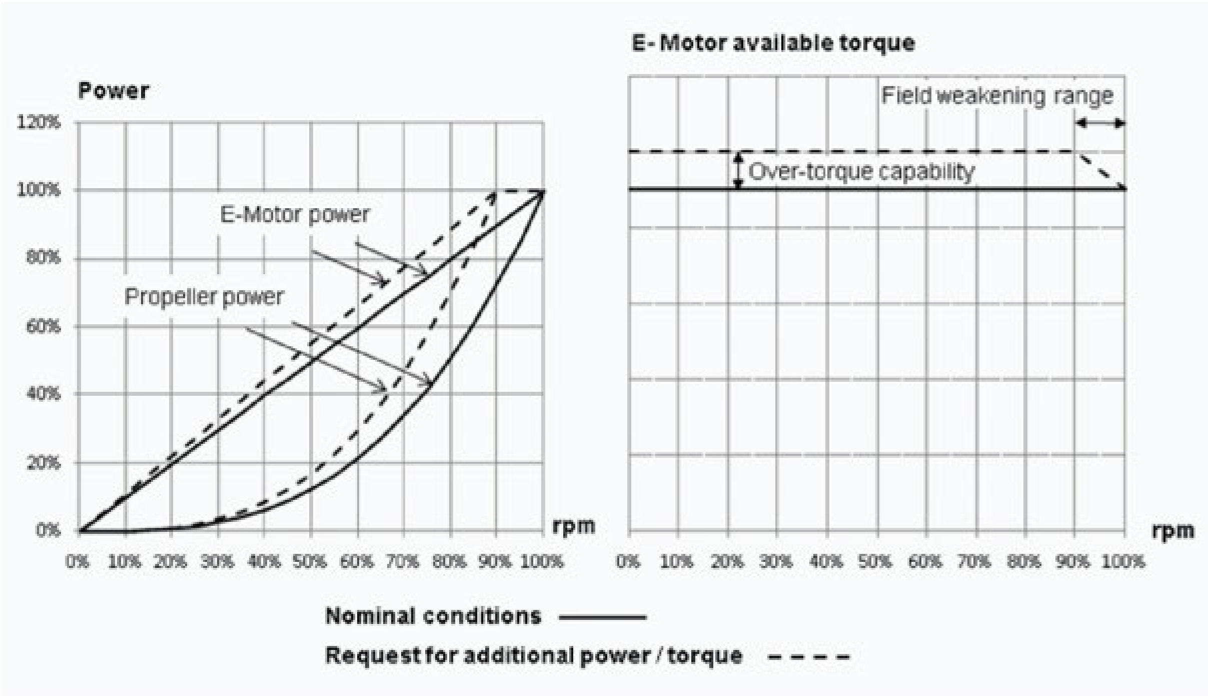
- The harmonics can be improved (if necessary) by using supply transformers for the frequency converters with a 30° phase shift between the two secondary windings, which cancel the dominant 5^{th} and 7^{th} harmonic currents. Also an increase in the pulse number leads to lower THD. Using a 12-pulse configuration with a PWM type of converter the resulting harmonic distortion will normally be below the limits defined by the classification societies. When using a transformer less solution with a converter with an Active Front End (Sinusoidal input rectifier) or in a 6-pulse configuration usually THD-filters are necessary to mitigate the THD on the sub-distributions.

The final layout of the electrical plant and the components has always to be based on a detailed analysis and a calculations of the short circuit levels, the load flows and the THD levels as well as on an economical evaluation.

1.7 Over-torque capability

In diesel-electric propulsion plants, which are running with a fix pitch propeller, the dimensioning of the electric propulsion motor has to be done accurately, in order to have sufficient propulsion power available. As an electric motor produces torque, which directly defines the cost (amount of copper), weight and space of the motor, it has to be investigated what amount of over-torque is required to operate the vessel with sufficient power also in situations, where additional power is needed (for example because of heavy weather or icy conditions).

Usually a constant power range of 5-10% is applied on the propulsion (Field weakening range), where constant E-motor power is available.



Example: Over-torque capability of a E-propulsiontrain for a FPP-driven vessel.

1.8 Protection of the electric plant

In an electric propulsion plant protection devices and relays are used to protect human life from injury from faults in the electric system and to avoid / reduce damage of the electric equipment. The protection system and its parameters always depend on the plant configuration and the operational requirements. During the detailed engineering phase calculations like a short circuit and an earth fault calculation and a selectivity and protection device coordination study have to be made, in order to get the correct parameter settings and to decide, which event / fault should alarm only or trip the circuit breaker.

A typical protection scheme may include the following functions (Example):

Main switchboard:

- Over– and under-voltage
- Earth fault

Alternator:

- Short circuit
- Over-current
- Stator earth fault
- Reverse power
- Phase unbalance, Negative phase sequence
- Differential protection
- Over- and under-frequency
- Over- and under-voltage
- Alternator windings and bearings over-temperature
- Alternator cooling air/water temperature
- Synchronizing check
- Over- and under-excitation (Loss of excitation)

Bus tie feeder:

- Short circuit
- Earth fault
- Synchronizing check
- Differential protection (in ring networks)

Transformer feeder:

- Short circuit
- Over-current
- Earth fault
- Thermal overload/image
- Under-voltage
- Differential protection (for large transformers)

Motor feeder:

- Short circuit
- Over-current
- Earth fault
- Under-voltage
- Thermal overload/image
- Motor start: Stalling I2t, number of starts
- Motor windings and bearings over-temperature
- Motor cooling air/water temperature

1.9 Drive control

The drive control system is a computer controlled system for the speed converters / drives, providing network stability in case of sudden / dynamical load changes. It ensures safe operation of the converters with constant and stable power supply to the E-propulsion motors and avoids the loss of power under all operational conditions. Usually the propulsion is speed controlled. So the system keeps the reference speed constant as far as possible within the speed and torque limitations and dynamic capability.

The drive control system normally interfaces with the propulsion control system, the power management system, the dynamic position system and several other ship control and automation systems. The functionality of the drive control system depends on the plant configuration and the operational requirements.

The main tasks of the drive control system can be summarized as follows:

- Control of the converters / drives, including the speed reference calculation
- Control of drive / propeller speed according to the alternator capability, including anti-overload prevention
- Control of power and torque. It takes care of the limits
- Control of the converter cooling

For some applications (e.g. for ice going vessels, for rough sea conditions, etc, where load torque varies much and fast) often a power control mode is applied, which reduces the disturbances on the network and smoothens the load application on the diesel engines.

1.10 Power management

Power reservation

The main function of a power management system is to start and stop gensets / alternators according to the current network load and the online alternator capacity. The power management system takes care that the next alternator will be started, if the available power (= Installed power of all connected alternators – current load) becomes lower than a preset limit. This triggers a timer and if the available power stays bellow the limit for a certain time period the next genset / alternator in sequence is started. It also blocks heavy consumers to be started or sheds (unnecessary) consumers, if there is not enough power is available, in order to avoid unstable situations.

Class rules require from gensets / alternators 45 seconds for starting, synchronizing and beginning of sharing load. So it is always a challenge for the power management system to anticipate the situation in advance and to start gensets / alternators before consumers draw the network and overload the engines. Overloading an engine will soon decrease the speed / frequency with the danger of motoring the engine, as the flow of power will be altered from network to alternator (Reverse power). The electric protection system must disconnect such alternator from the network. An overload situation is always a critical situation for the vessel and a blackout has to be avoided.

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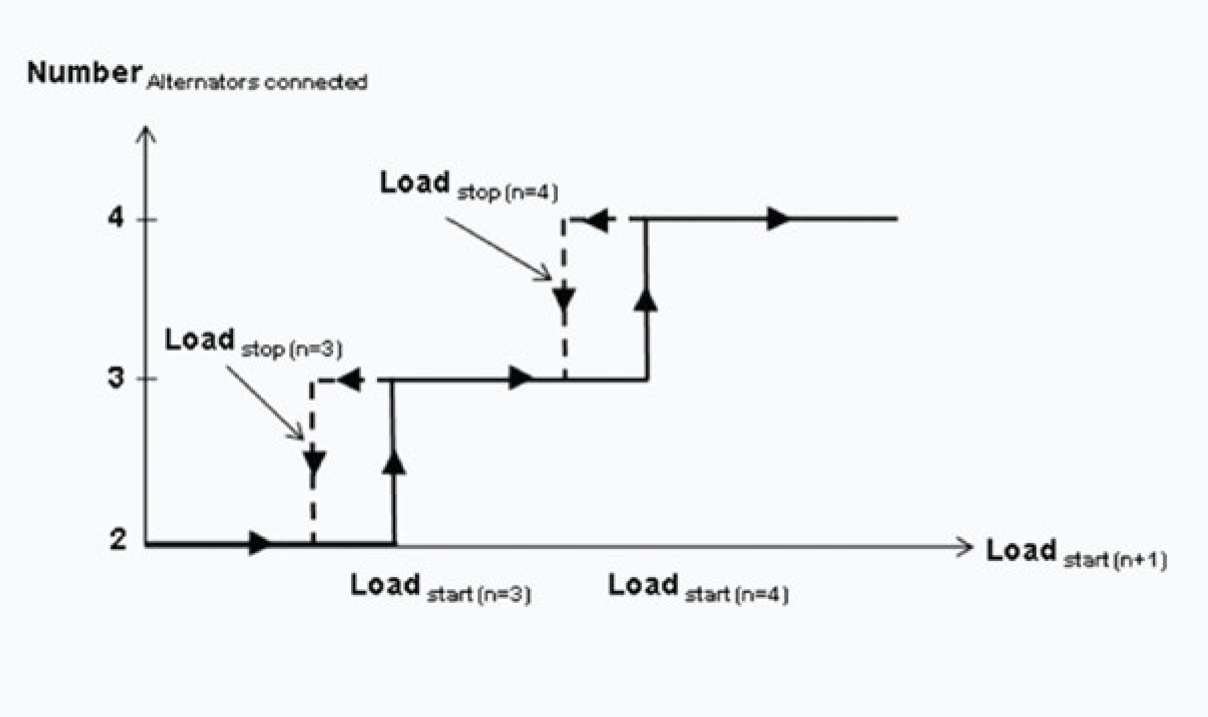
The detailed power management functionality always depends on the plant configuration, the operational requirements but also on general philosophy and preferred solution of the owner. The parameters when to stat or to stop a genset / alternator have always to be evaluated individually. The following figure shows that in principle:

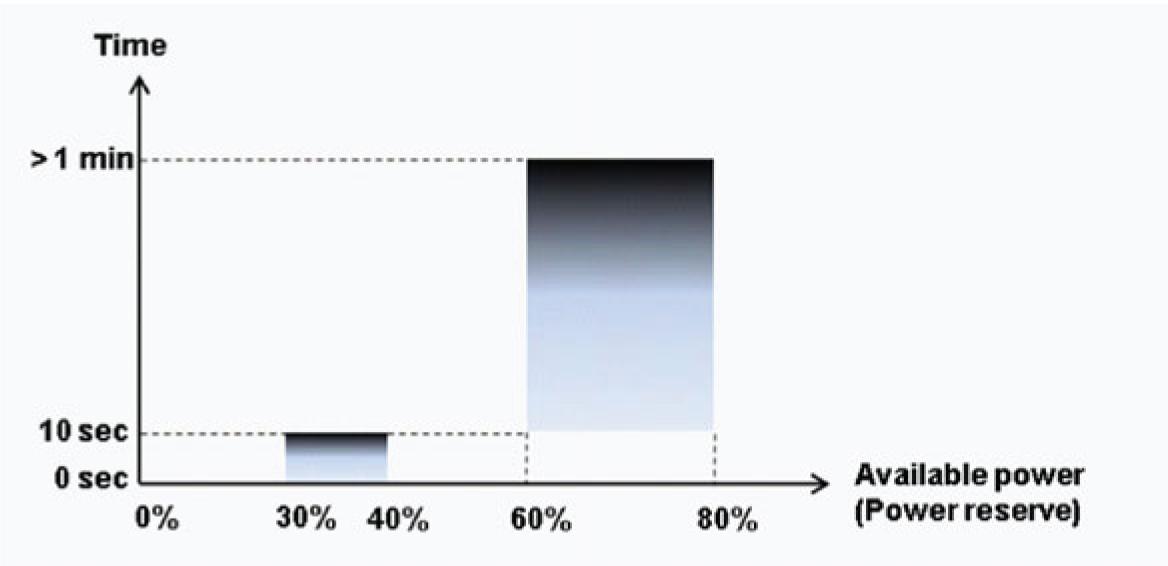


For example the load depending start / stop of gensets / alternators is shown in the next table. It can be seen that the available power depends on the status of the gensets / alternators when they get their starting command. As an example a plant with 4 gensets / alternators is shown:

No of alternators connected	Alternator load	Available power (Power reserve) via load pick-up by the running GenSets	Time to accept load
2	85%	2 x 15% = 30%	0....10 sec
3	87%	3 x 13% = 39%	0....10 sec
4	90%	4 x 10% = 40%	0....10 sec

No of alternators connected	Alternator load	Available power (Power reserve) by starting a standby*) GenSets	Time to accept load
2	70	2 x 30% = 60%	< 1 min
3	75	3 x 25% = 75%	< 1 min
4	80	4 x 20% = 80%	< 1 min
*) preheated, prelubricated, etc. starting conditions see belonging MAN Energy Solutions *Engine Project Guide.*			

The available power for this example could look like this:



Power management system

Derived from the above mentioned main tasks of a power management system the following functions are typical:

- Automatic load dependent start / stop of gensets / alternators
- Manual starting / stopping of gensets / alternators
- Fault dependent start /stop of standby gensets / alternators in cases of under-frequency and/or under-voltage.
- Start of gensets / alternators in case of a blackout (Black-start capability)
- Determining and selection of the starting / stopping sequence of gensets / alternators
- Start and supervise the automatic synchronization of alternators and bus tie breakers
- Balanced and unbalanced load application and sharing between gensets / alternators. Often an emergency program for quickest possible load acceptance is necessary.
- Regulation of the network frequency (with static droop or constant frequency)
- Distribution of active load between alternators
- Distribution of reactive load between alternators
- Handling and blocking of heavy consumers
- Automatic load shedding
- Tripping of non-essential consumers
- Bus tie and breaker monitoring and control

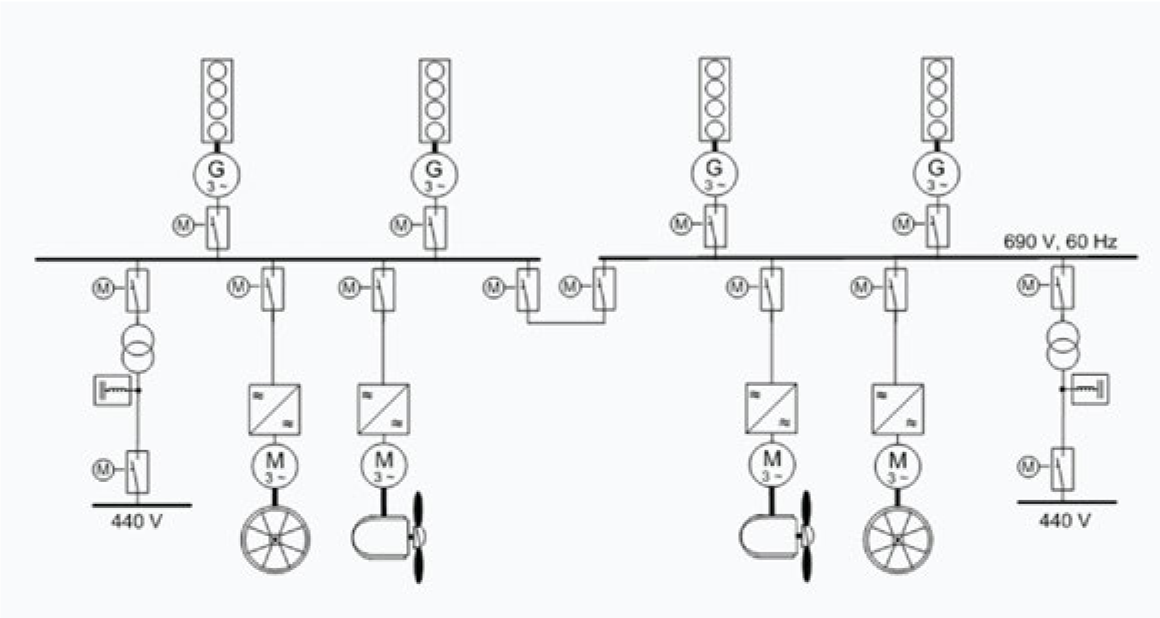
All questions regarding the functionality of the power management system have to be clarified with MAN Energy Solutions at an early project stage.

1.11 Example configurations of diesel-electric propulsion plants

Offshore Support Vessels

The term “Offshore Service & Supply Vessel” includes a large class of vessel types, such as Platform Supply Vessels (PSV), Anchor Handling/Tug/Supply (AHTS), Offshore Construction Vessel (OCV), Diving Support Vessel (DSV), Multipurpose Vessel, etc.

Electric propulsion is the norm in ships which frequently require dynamic positioning and station keeping capability. Initially these vessels mainly used variable speed motor drives and fixed pitch propellers. Now they mostly deploy variable speed thrusters and they are increasingly being equipped with hybrid diesel-mechanical and diesel-electric propulsion.



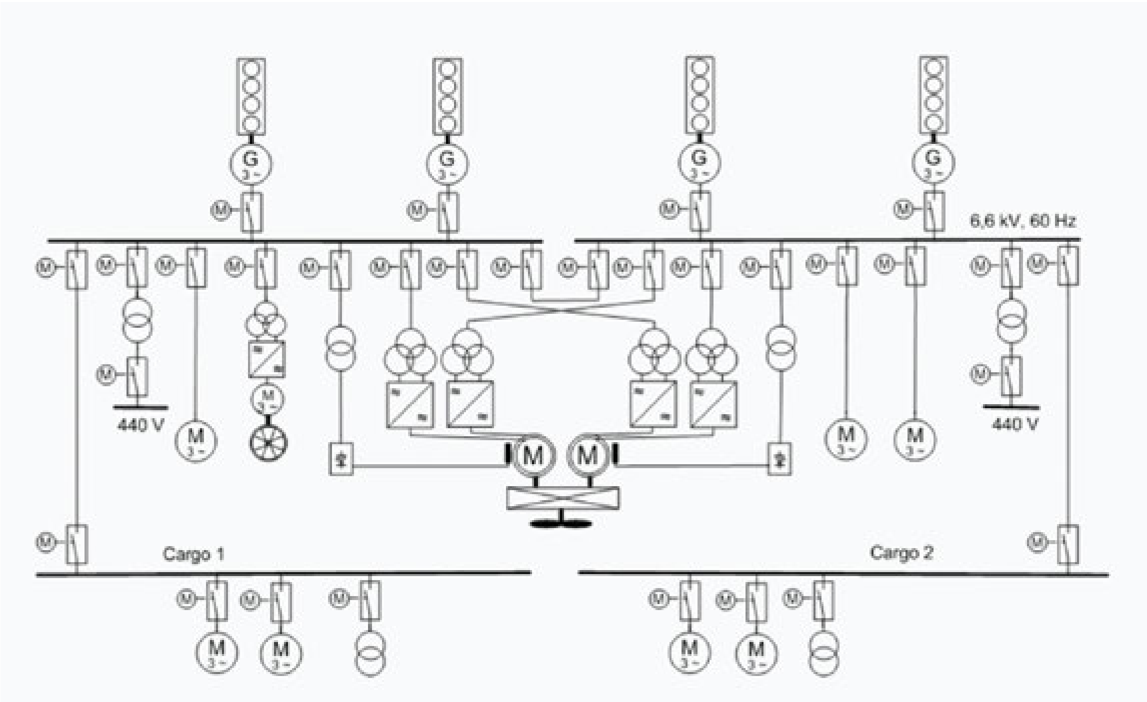
Example: DE-configuration of a PSV.

In modern applications often frequency converters with an Active Front End are used, which give specific benefits in the space consumption of the electric plant, as it is possible to get rid of the heavy and bulky supply transformers.

Type of conveter / drive	Supply transformer	Type of E-motor	Pros & cons
Active Front End	-	Induction	+ Transformer less solution + Less space and weight - THD filter required

LNG Carriers

A propulsion configuration with two high speed E-motors (e.g. 600 RPM or 720 RPM) and a reduction gearbox (Twin-in-single-out) is a typical configuration, which is used at LNG carriers where the installed alternator power is in the range of about 40 MW. The electrical plant fulfils high redundancy requirements. Due to the high propulsion power which is required and higher efficiencies synchronous E-motors are used.



Example: DE-configuration (redundant) of a LNG carrier with geared transmission, single screw and FP propeller

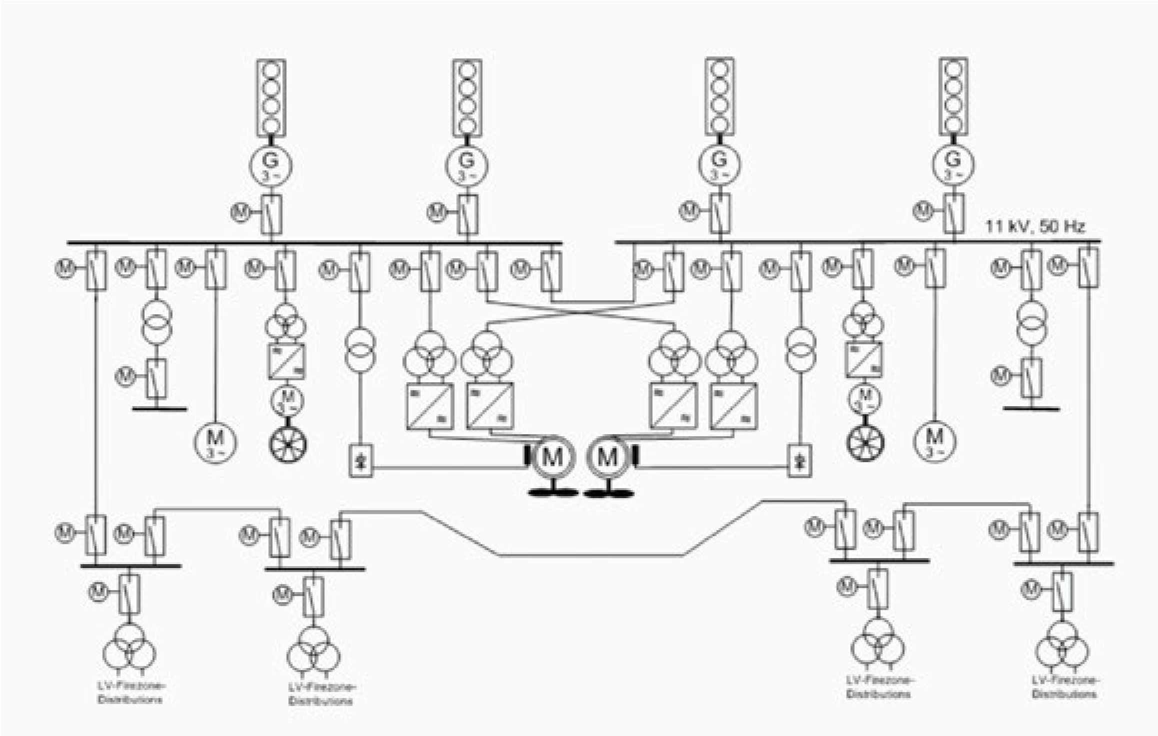
Type of conveter / drive	Supply transformer	Type of E-motor	Pros & cons
VSI with PWM	24pulse	Synchronous	+ High propulsion power + High drive & motor efficiency + Low harmonics - Heavy E-plant configuration

For ice going carriers and tankers also podded propulsion is a robust solution, which has been applied in several vessels.

Cruise and ferries

Passenger vessels – cruise ships and ferries – are an important application field for diesel-electric propulsion. Safety and comfort are paramount. New regulations, as “Safe Return to Port”, require a high reliable and redundant electric propulsion plant and also onboard comfort is a high priority, allowing only low levels of noise and vibration from the ship´s machinery.

A typical electric propulsion plant is shown in the example below.



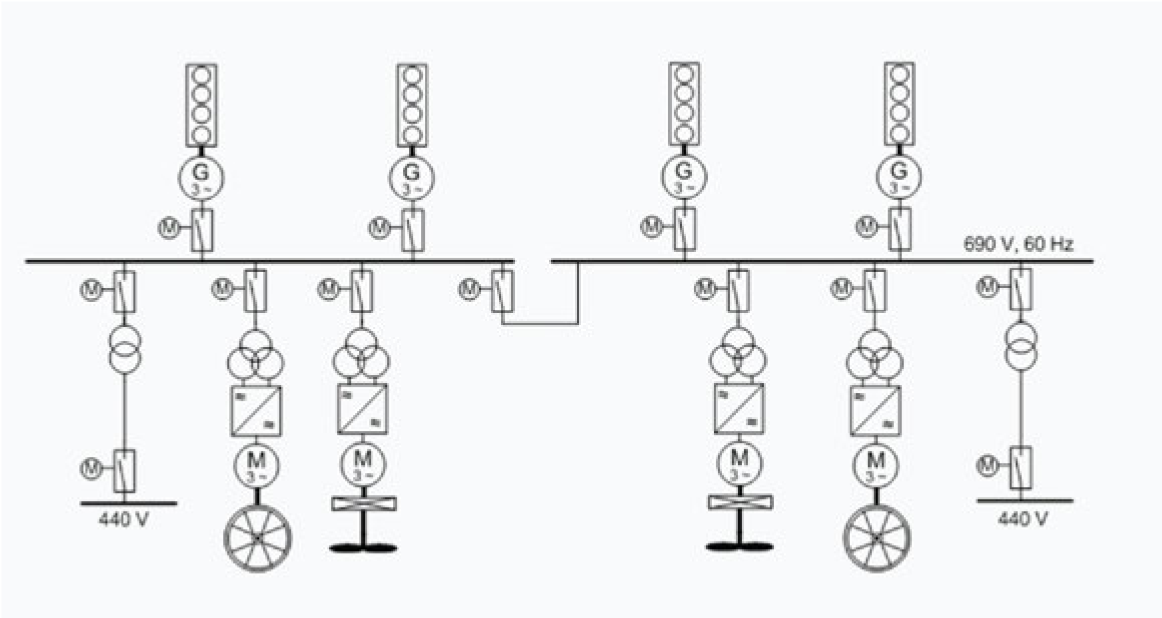
Example: DE-configuration (redundant) of a cruise liner, twin screw, gear less.

Type of conveter / drive	Supply transformer	Type of E-motor	Pros & cons
VSI with PWM	24pulse	Synchronous (slow speed 150 rpm)	+ Highly redundant & reliable + High drive & motor efficiency + Low noise & vibration - Complex E-plant configuration

For cruise liners often also geared transmission is applied as well as pods.

For a RoPax ferry almost the same requirements are valid as for a cruise liner.

The figure below shows an electric propulsion plant with a “classical” configuration, consisting of high speed E-motors (900 RPM or 1200 RPM), geared transmission, frequency converters and supply transformers.



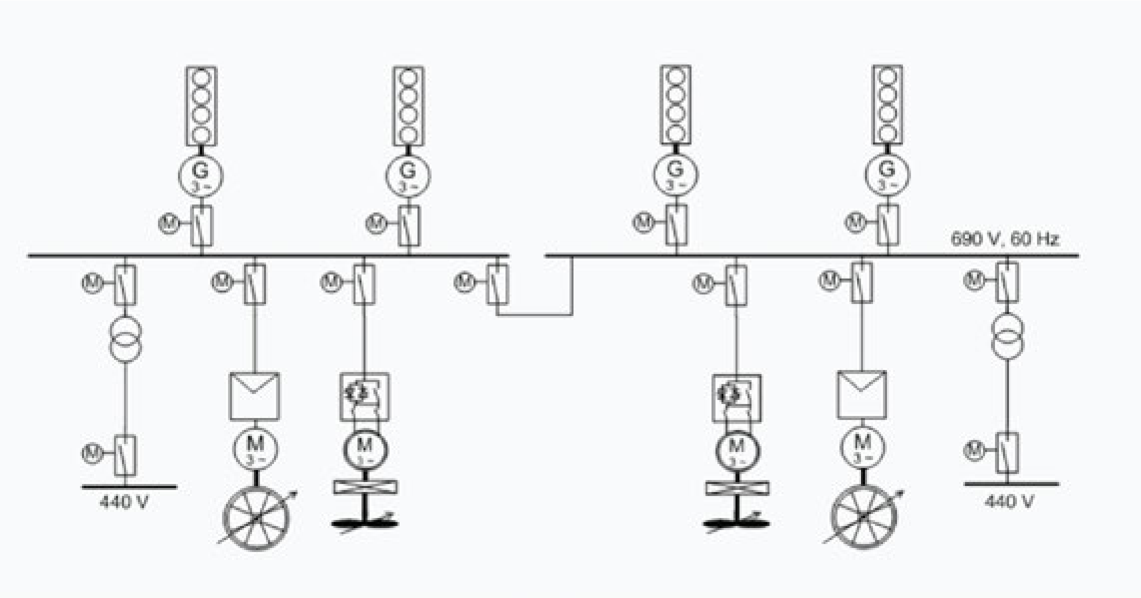
Example: DE-configuration (redundant) of a RoPax ferry, twin screw, geared transmission.

Type of conveter / drive	Supply transformer	Type of E-motor	Pros & cons
VSI-type (with PWM technology)	12 pulse, two secondary windings, 30° phase shift	Induction	+ Robust & reliable technology + No THD filters - More space & weight (compared to transfprmer less solution)

Advanced applications

As MAN Energy Solutions works together with different suppliers for diesel-electric propulsion plants an optimal matched solution can be designed for each application, using the most applicable components from the market (Freedom of choice). The following example shows a smart solution, patented by STADT AS (Norway).

In many cases a combination of an E-propulsion motor, running on two constants speeds (Medium, high) and a pitch controllable propeller (CPP) gives a high reliable and compact solution with low electrical plant losses.



Example: DE-configuration (redundant) of a RoRo, twin screw, geared transmission.

Type of conveter / drive	Supply transformer	Type of E-motor	Pros & cons
Sinusoidal drive (Patended by STADT AS)	-	Induction	+ Highly reliable & compact + Low losses + Transformer less solution + Low THD (No THD filters needed) - Only applicable with a CP propeller

Questionnaire: Diesel-electric propulsion plants

In order to provide you with appropriate project material and to carry out proposals promptly and accurately, we would kindly request you to fill in as many of the following details as possible and return it with a complete set of arrangement drawings to your sales representative.

General data

Name ____________________

Address ____________________

Phone ____________________

E-mail ____________________

Project ____________________

Type of vessel ____________________

Propulsion principle:

☐ Diesel-electric ☐ CODLAD ☐ CODLAG

Main particulars:

Length, overall [m] ____________________

Length, pp [m] ____________________

Breadth, moulded [m] ____________________

Depth, moulded [m] ____________________

Draught, design [m] ____________________

Draught, scantling [m] ____________________

DWT, at sct draught [t] ____________________

Gross tonnage [GRT] ____________________

Crew + Passengers ________+____________

Classification society ____________________ Class notation ________________________________

Additional class notification Redundancy ________________________________

Ice class ________________________________

Ambient conditions:

Max. machinery room temperature [°C] ____

Max. sea water temperature [°C] ____

Max. fresh water temperature [°C] ____

Speed and margins

Speed:

Ship design speed [kn] ______________________________ (at maximum propusionshaft power)

Sea margin [%] ____

Max. allowed load of engines [%] _________________________________ % MCR

Propulsion system and power demand

Main Propulsion:

☐ Shaft propulsion

- ☐ Single screw
  - ☐ Single in - single out
  - ☐ Tandem
  - ☐ Twin in - single out
- ☐ Twin screw
  - ☐ Two shaft lines
  - ☐ 2xTwin in - single out

☐ Steerable rudder propellers (=Azimuth thrusters)

☐ Pods

☐ ____

Data for main propulsion:

☐ FPP

Number ____________

Max. shaft power on propulsion E-motor (per propeller; including sea margin) [kW] ____________

Propeller revolution [RPM] ____________

Input speed (= E-motor RPM) ____________

Reduction gearbox ☐ yes ☐ no

☐ CPP

Number ____________

Max. shaft power on propulsion E-motor (per propeller; including sea margin) [kW] ____________

Propeller revolution [RPM] ____________

Input speed (= E-motor RPM) ____________

Reduction gearbox ☐ yes ☐ no

☐ Azi. thruster

Number ____________

Max. shaft power on propulsion E-motor (per propeller; including sea margin) [kW] ____________

Input speed (= E-motor RPM) ____________

Propeller type ☐ FPP ☐ CPP

☐ Pod

Number ____________

Max. shaft power on propulsion E-motor (per pod; including sea margin) [kW] ____________

E-motor speed [RPM] ____________

☐ ________

Number ____________

Max. shaft power on propulsion E-motor (each; including sea margin) [kW] ____________

Propeller revolution [RPM] ____________

Input speed (= E-motor RPM) ____________

Reduction gearbox ☐ yes ☐ no

Data for manoeuvering propulsors:

☐ Bow thruster Number ___________

Max. shaft power on propulsion E-motor (each; including sea margin) [kW] ___________

Input speed (= E-motor RPM) ___________

Propeller type ☐ FPP ☐ CPP

☐ Stern thruster Number ___________

Max. shaft power on propulsion E-motor (each; including sea margin) [kW] ___________

Input speed (= E-motor RPM) ___________

Propeller type ☐ FPP ☐ CPP

☐ __________ Number ___________

Max. shaft power on propulsion E-motor (each; including sea margin) [kW] ___________

Input speed (= E-motor RPM) ___________

Propeller revolution [RPM] ___________

Propeller type ☐ FPP ☐ CPP

Electrical load balance

Max. total electrical power demand at sea

For main propulsion [kW_{el}] ___________

for vessel's consumers [kW_{el}] ___________

Max. total electrical power demand at manoeuvering

for main propulsion [kW_{el}] ___________

for manoeuvering propulsors [kW_{el}] ___________

for vessel's consumers [kW_{el}] ___________

Max. total electrical power demand at port
for vessel's consumers [kW_{el}] ______________________________

The five biggest electrical consumers of the vessel
(apart from main propulsion and manoeuvering propulsors)

Name ____________________ ;kW_{el}: ____________________

Name ____________________ ;kW_{el}: ____________________

Name ____________________ ;kW_{el}: ____________________

Name ____________________ ;kW_{el}: ____________________

Name ____________________ ;kW_{el}: ____________________

Please provide us with a complete E-Load-Balance of the vessel.

Electrical system and motors

Numbers of generators ______________________________

Power per generator [kW_{el}] ______________________________

Power factor ______________________________

Revolution of generators [RPM] ______________________________

Frequenzy [Hz] ______________________________

Voltage level of generator and MSB [V] ______________________________

Voltage levels of sub-switchboards [V] ______________________________

System grounding of MSB
- ☐ 3-phase, 3-wire, isolated from hull
- ☐ 3-phase, 3-wire, isolated via high-resistive resistor
- ☐ ______________________________

Main propulsion E-motors

Number of winding systems ☐ 1 ☐ 2

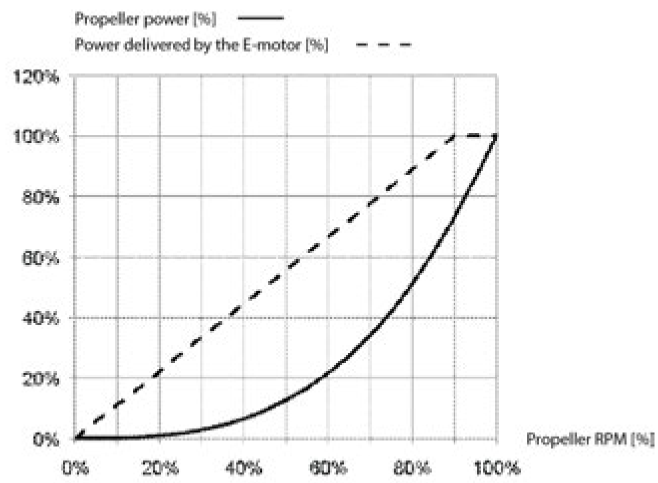
Speed control
- ☐ variable speed via frequency converter
- ☐ ______________________________

Manoeuvering E-motors (i.e. bow thrusters)

- ☐ variable speed via frequency converter
- ☐ constant speed (Start via Y/Δ-unit)
- ☐ constant speed (Start via Softstarter)
- ☐ ____

Dimensioning of frequency converter and propulsion E-motor

The design of the frequency converters and the torque capability of the propulsion E-motors is usually rated in between a constant power range of 90% ... 100% of the propeller revolution (for a FPP-driven vessel).



Torque capability

- ☐ Constant power form _______ % to 100% of propeller RPM
- ☐ Max. over-torque capability of the E-motor ___________ %

Single line diagram

Please provide us with a complete single line diagram of the vessel, if available.

Cooling water system, 1-string

Cooling water system (DE-propulsion)

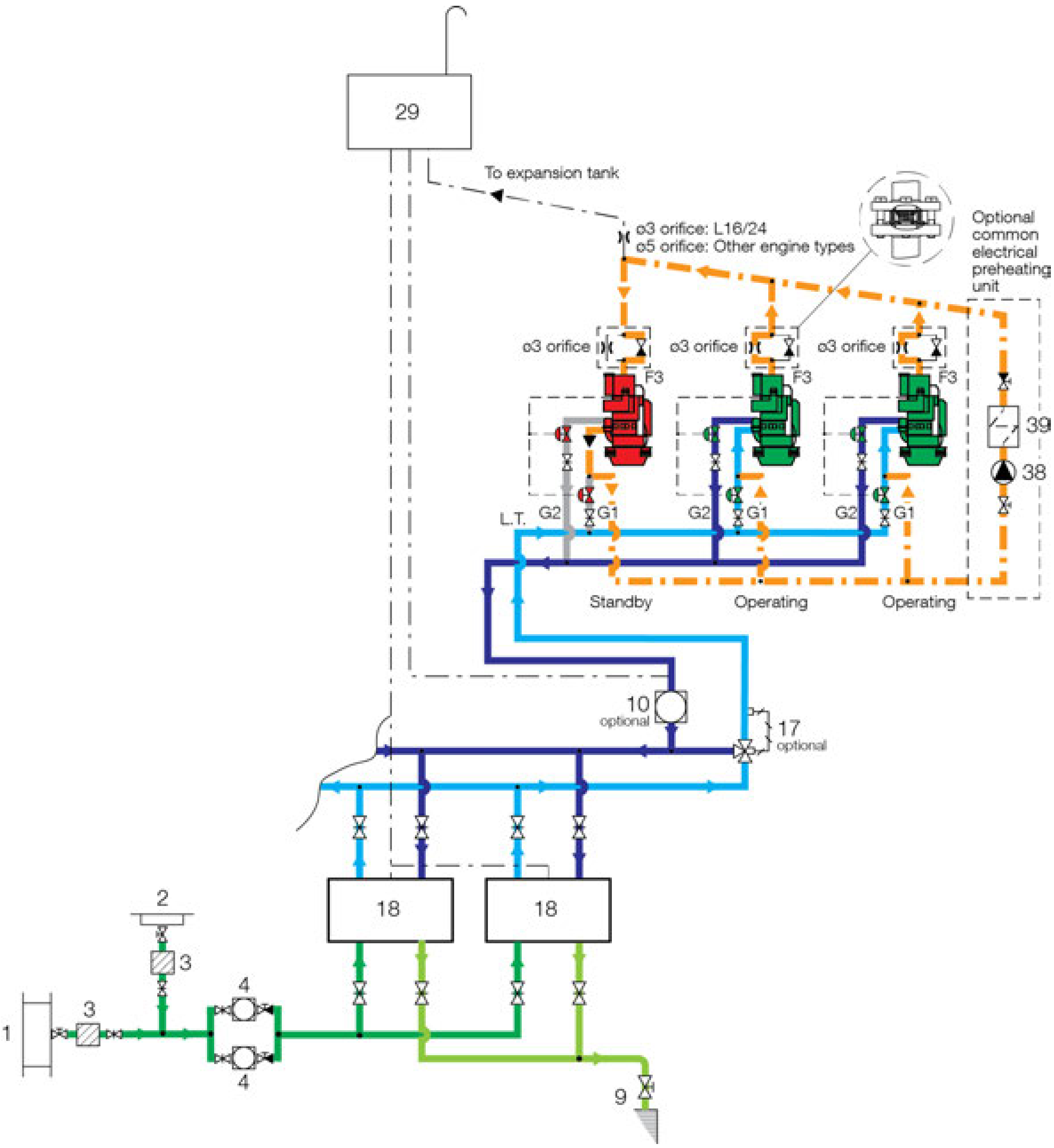


Figure 1: .

Cooling water system

Layout of 1-string cooling water system is the simplest system for cooling the engine.

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.

As alternative the build-on freshwater pumps and thermostatic valve element can be replaced by "dummies" inside the front-end box. Then these functions can be arranged in the external systems according to the customized demands.

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.

Velocity recommendations for freshwater and sea water pipes:

Freshwater	Suction pipe:	1.0 - 2.0 m/s
	Delivery pipe:	2.0 - 3.5 m/s
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

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Pressure drop across dirty filter:	Max 0.1 bar
Mesh size:	ø3 - ø5 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.

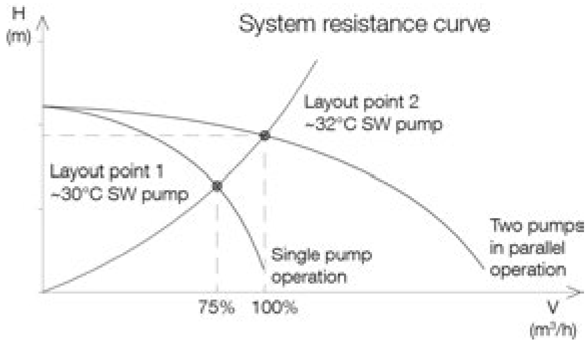

Figure 2: Pump characteristic

The pumps in parallel, layout point 2 (see fig 2), are as standard designed to fulfill:

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 fig 3.

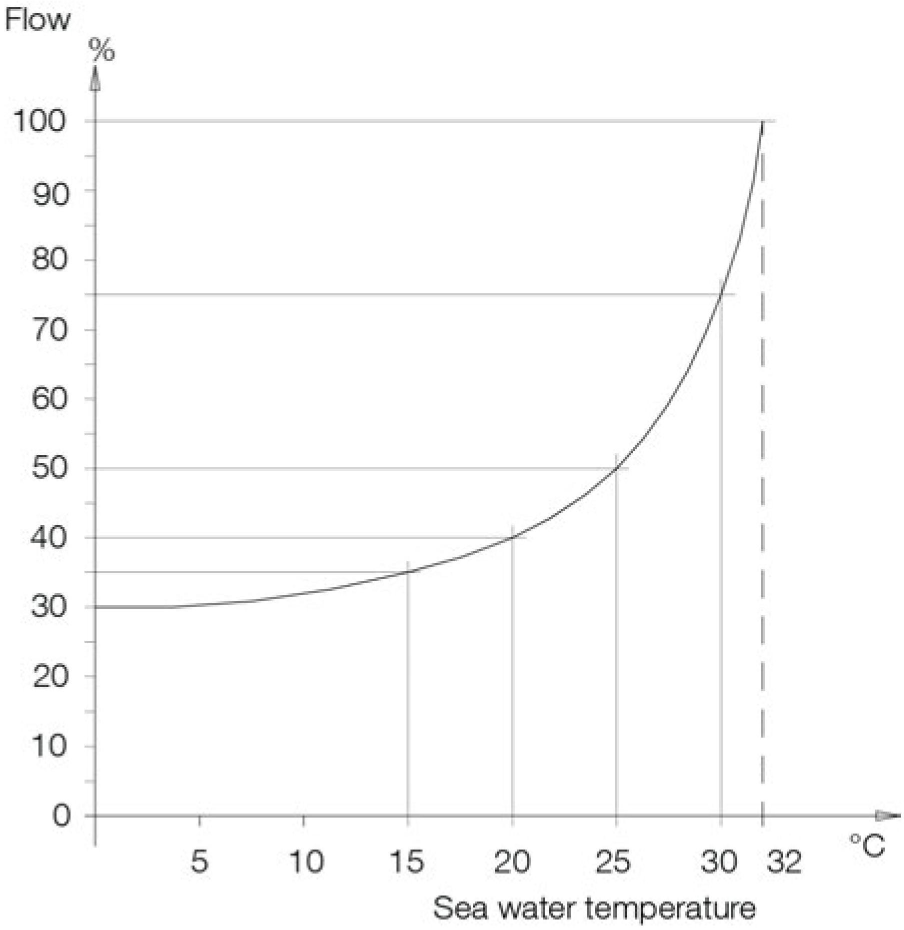

Figure 3: Necessary water flow

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:	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

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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.

Expansion tanks, items 29

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 approximately 8 m above the centre line of the crankshaft. This will ensure sufficient suction head to the fresh water 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 15% of water volume, however, min 100 litres.

Preheating

Engines starting on HFO and engines in stand-by position must be preheated. It is also recommended to preheat engines operating on MDO due to the prolonged life time of the engines' wearing parts. Therefore it is recommended that the preheating is arranged for automatic operation, so that the preheating is disconnected when the engine is running, and connected when the engine is in stand-by position. The preheating is adjusted so that the temperature is ≥ 60°C at the top cover (see thermometer TI12), and approximately 25 to 45°C at outlet of the cylinders (see thermometer TI10).

When working out the external cooling water system it must be ensured, that no cold cooling water is pressed through the engine and thus spoiling the preheating during stand-by. The diesel engine has no built-in shut-off valve in the cooling water system. Therefore the designer of the external cooling water system must make sure that the preheating of the GenSets is not disturbed.

Preheating of stand-by auxiliary engines during sea operation

Auxiliary engines in stand-by position are preheated via the venting pipe (F3), leading to the expansion tank, with HT water from the operating auxiliary engines.

During preheating the non-return valve on the preheated auxiliary engine will open due to the pressure difference. The HT pumps on the operating auxiliary engines will force the HT water downwards, through the stand-by auxiliary engine, out of the (F1) HT inlet and back to the operating auxiliary engines, via the bypass manifold which interconnect all the (F1) HT inlet lines.

The on/off valve can be controlled by "engine run" signal or activated by lub. oil pressure. MAN can deliver valves suitable for purpose.

Please note that preheating pipe mounted before on/off valve (size 3/4"-1" for guidance) connected to either preheat unit (optional) or directly to expansion tank pipe. This will deliver preheating water to stand-by engine via (F3).

The non-return valve in the venting pipe (F3) is closed when the auxiliary engine is operating, and deaerating to the expansion tank flows through the small ø3 bore in the non-return valve disc.

The small ø3 bore in the non-return valve disc will also enable the auxiliary engine to keep the recommended cooling water temperature in the HT-system during low load operation which is essential for the combustion of HFO.

Preheating element, build-in

The preheating power required for electrical preheating is stated below:

Engine type	Heating power
5L21/31, 5L21/31 Mk2	12 kW
6L21/31, 5L21/31 Mk2	12 kW
7L21/31, 5L21/31 Mk2	15 kW
8L21/31, 5L21/31 Mk2	15 kW
9L21/31, 5L21/31 Mk2	15 kW
5L27/38	15 kW
6L27/38	15 kW
7L27/38	24 kW
8L27/38	24 kW
9L27/38	24 kW

The figures are based on raising and maintain the engine temperature to 50°C (L21/31) / 40°C (L27/38) (20 - 60°C) for a period of at least 10 hours including the cooling water contained within the engine.

We will be pleased to make calculations for other conditions on request.

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.

Cyl. No.	5	6	7	8	9
Quantity of water in eng: HT and LT system (litre)	150	180	210	240	270
Expansion vol. (litre)	10	12	13	15	20

Table 1: Showing cooling water data which are depending on the number of cylinders.

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Circulating pump for preheater, item 38

For preheating the engine a pump should be installed to circulate high temperature cooling water through the preheater.

Data for external preheating system, item 39

High pressure from external cooling water pumps may disturb the preheating of the engine. In order to avoid this, it is in most cases necessary to install automatic shut off valve at cooling water inlet, which close when the engine is stopped.

The capacity of the external preheater should be 3.0-3.5 kW/cyl. The flow through the engine should for each cylinder be approx. 4 l/min with flow from top and downwards and 25 l/min with flow from bottom and upwards.

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 (eg 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.

The L21/31 and L27/38 engine are 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 shipowner. We reserve the right not to accept proposed coolers, which seems to be insufficient for its purpose.

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, ie 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 planning data
Pressure drop through all coolers:	Max 0.5 bar
Min vessel speed at MCR:	Normally more than 3 knots

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 the L21/31 and L27/38 engines. 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 large 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.

Cooling water system, 1.5-string

Cooling water system (DE-propulsion)

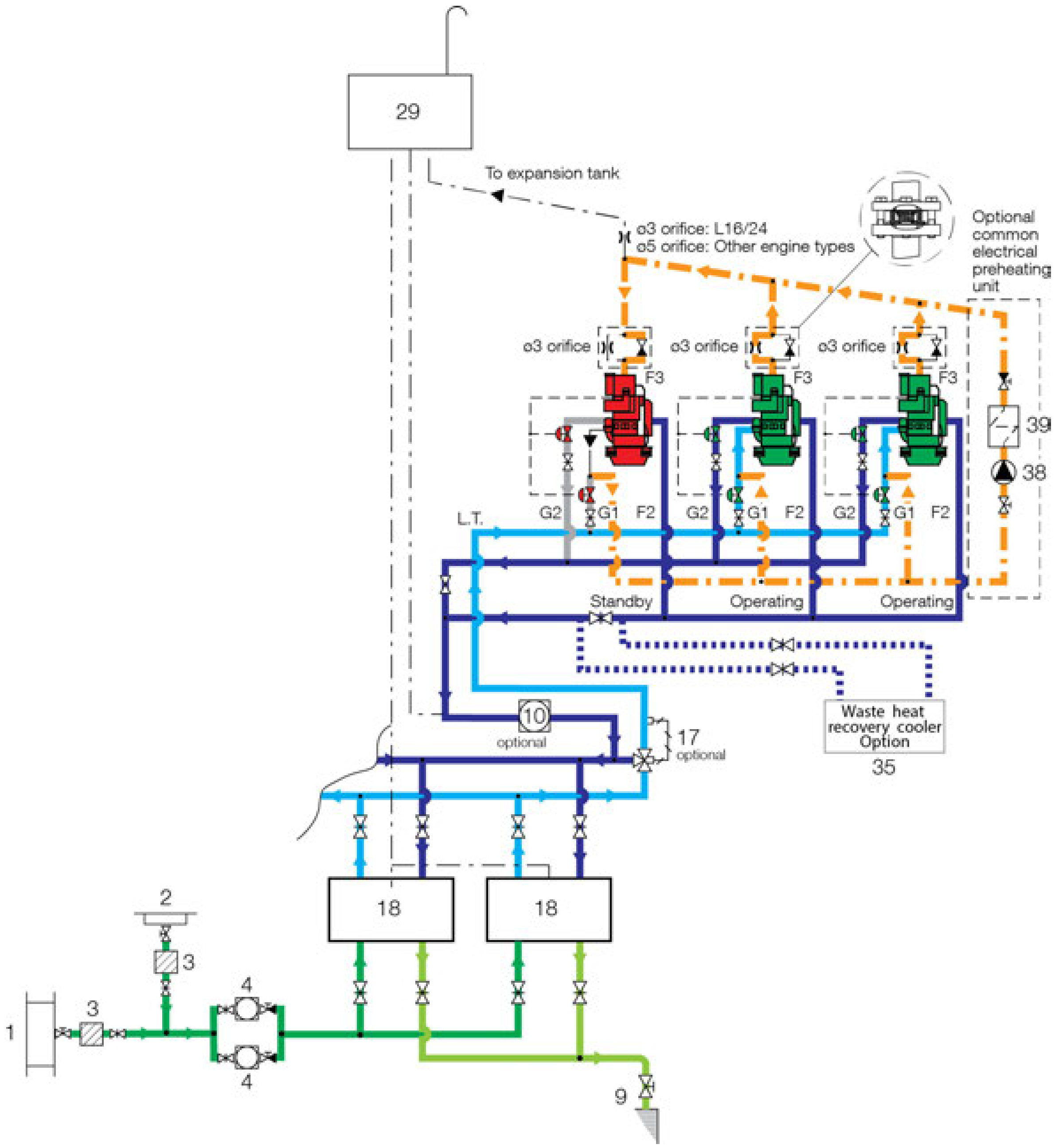

Figure 1: .

Cooling water system

Layout of 1.5-string cooling water system is much similar to 1-string. An additional high temperature outlet connection for e.g. waste heat recovery is added.

Only part of the high temperature water energy can be used by 1.5 string. Full recovery of energy in high temperature water can be obtained by 2-string layout.

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.

As alternative the build-on freshwater pumps and thermostatic valve element can be replaced by "dummies" inside the front-end box. Then these functions can be arranged in the external systems according to the customized demands.

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.

Velocity recommendations for freshwater and sea water pipes:

Freshwater	Suction pipe:	1.0 - 2.0 m/s
	Delivery pipe:	2.0 - 3.5 m/s
Sea water	Suction pipe:	1.0 - 1.5 m/s
	Delivery pipe:	1.5 - 2.5 m/s

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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:	ø3 - ø5 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.

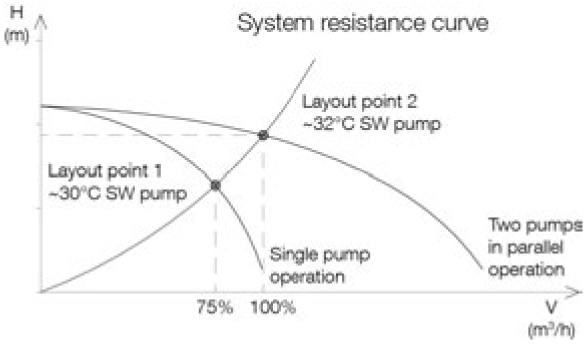

Figure 2: Pump characteristic

The pumps in parallel, layout point 2 (see fig 2), are as standard designed to fulfill:

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 32ºC

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 fig 3.

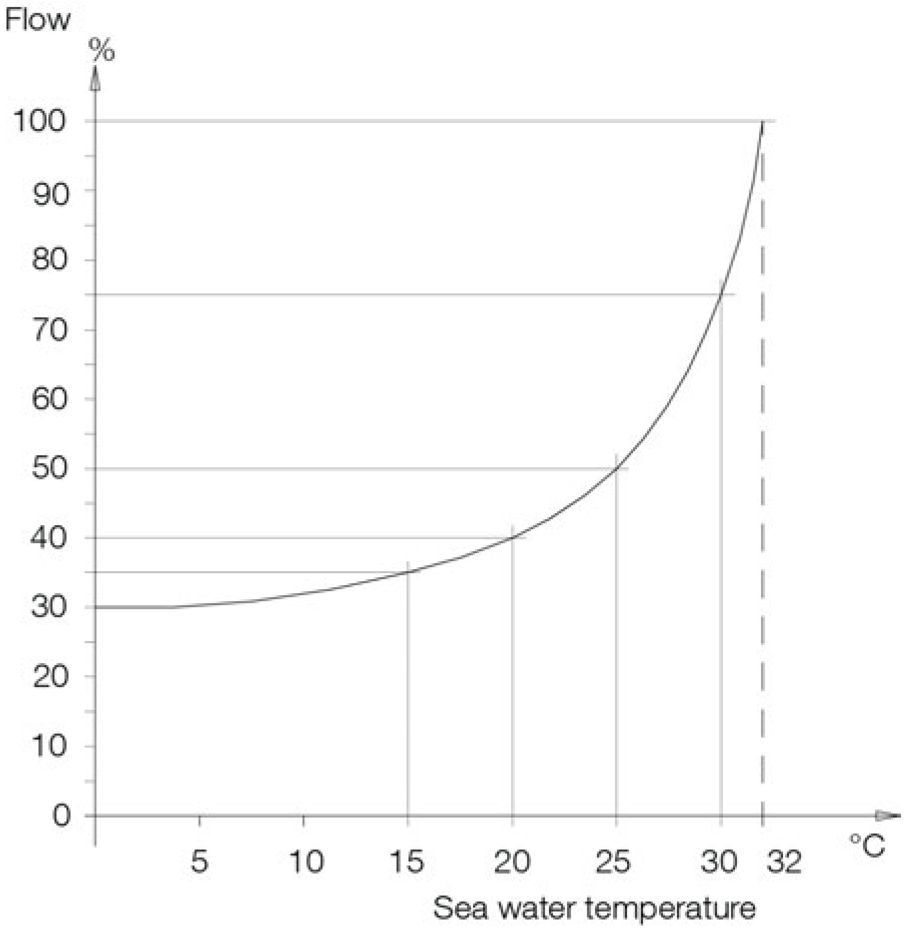

Figure 3: Necessary water flow

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:	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

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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.

Expansion tanks, items 29

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 approximately 8 m above the centre line of the crankshaft. This will ensure sufficient suction head to the fresh water 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 15% of water volume, however, min 100 litres.

Preheating

Engines starting on HFO and engines in stand-by position must be preheated. It is also recommended to preheat engines operating on MDO due to the prolonged life time of the engines' wearing parts. Therefore it is recommended that the preheating is arranged for automatic operation, so that the preheating is disconnected when the engine is running, and connected when the engine is in stand-by position. The preheating is adjusted so that the temperature is ≥ 60°C at the top cover (see thermometer TI12), and approximately 25 to 45°C at outlet of the cylinders (see thermometer TI10).

When working out the external cooling water system it must be ensured, that no cold cooling water is pressed through the engine and thus spoiling the preheating during stand-by. The diesel engine has no built-in shut-off valve in the cooling water system. Therefore the designer of the external cooling water system must make sure that the preheating of the GenSets is not disturbed.

Preheating of stand-by auxiliary engines during sea operation

Auxiliary engines in stand-by position are preheated via the venting pipe (F3), leading to the expansion tank, with HT water from the operating auxiliary engines.

During preheating the non-return valve on the preheated auxiliary engine will open due to the pressure difference. The HT pumps on the operating auxiliary engines will force the HT water downwards, through the stand-by auxiliary engine, out of the (F1) HT inlet and back to the operating auxiliary engines, via the bypass manifold which interconnect all the (F1) HT inlet lines.

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The small ø3 bore in the non-return valve disc will also enable the auxiliary engine to keep the recommended cooling water temperature in the HT-system during low load operation which is essential for the combustion of HFO.

Preheating element, build-in

The preheating power required for electrical preheating is stated below:

Engine type	Heating power
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8L21/31, 5L21/31 Mk2	15 kW
9L21/31, 5L21/31 Mk2	15 kW
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Such systems are advantageous in the following conditions:

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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.

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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 shipowner. We reserve the right not to accept proposed coolers, which seems to be insufficient for its purpose.

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, ie 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 planning data
Pressure drop through all coolers:	Max 0.5 bar
Min vessel speed at MCR:	Normally more than 3 knots

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 the L21/31 and L27/38 engines. 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 large 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.

Cooling water system, 2-string

Cooling water system (DE-propulsion)

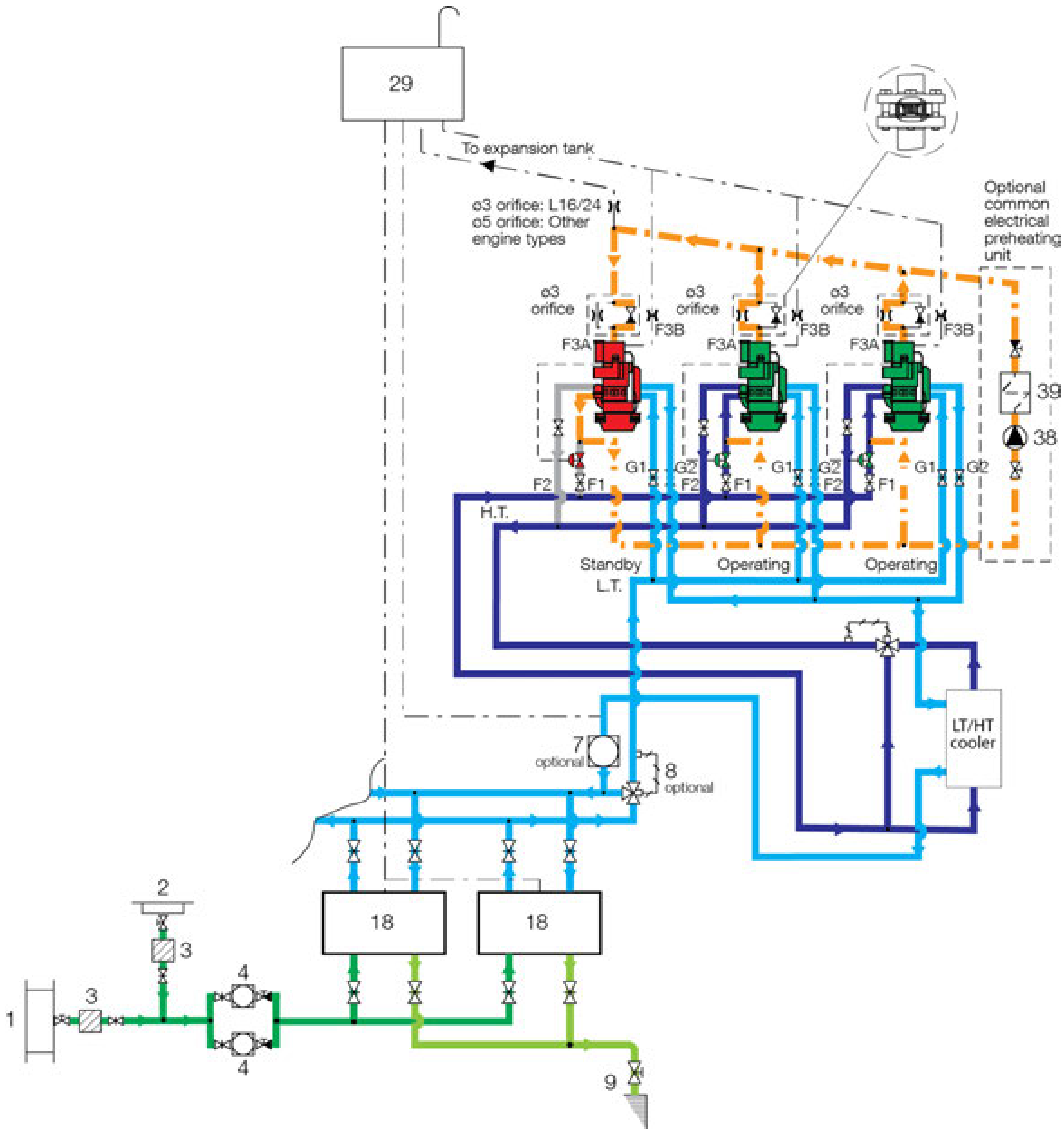

Figure 1: .

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Cooling water system

Layout of 2-string cooling water system is total separation of low temperature water and high temperature water. Normally high temperature water is used for waste heat recovery.

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.

As alternative the build-on freshwater pumps and thermostatic valve element can be replaced by "dummies" inside the front-end box. Then these functions can be arranged in the external systems according to the customized demands.

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.

Velocity recommendations for freshwater and sea water pipes:

Freshwater	Suction pipe:	1.0 - 2.0 m/s
	Delivery pipe:	2.0 - 3.5 m/s
Sea water	Suction pipe:	1.0 - 1.5 m/s
	Delivery pipe:	1.5 - 2.5 m/s

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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:	ø3 - ø5 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.

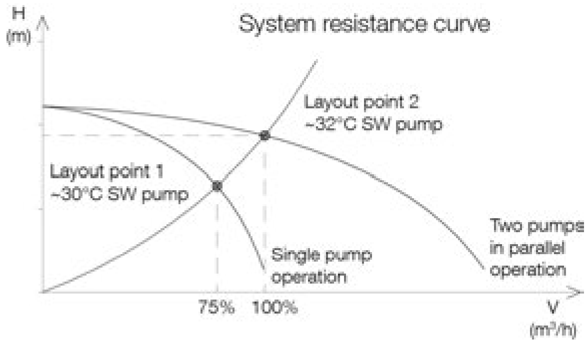

Figure 2: Pump characteristic

The pumps in parallel, layout point 2 (see fig 2), are as standard designed to fulfill:

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 fig 3.

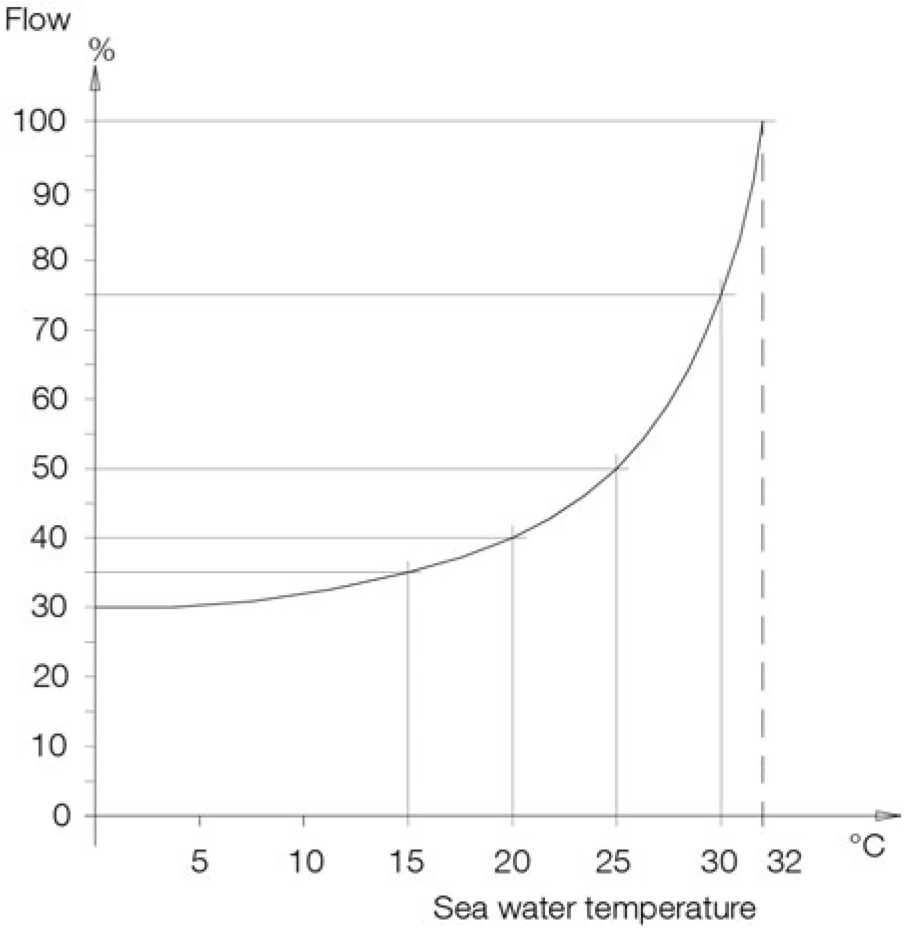

Figure 3: Necessary water flow

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:	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.

Expansion tanks, items 29

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 approximately 8 m above the centre line of the crankshaft. This will ensure sufficient suction head to the fresh water 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 15% of water volume, however, min 100 litres.

Preheating

Engines starting on HFO and engines in stand-by position must be preheated. It is also recommended to preheat engines operating on MDO due to the prolonged life time of the engines' wearing parts. Therefore it is recommended that the preheating is arranged for automatic operation, so that the preheating is disconnected when the engine is running, and connected when the engine is in stand-by position. The preheating is adjusted so that the temperature is ≥ 60°C at the top cover (see thermometer TI12), and approximately 25 to 45°C at outlet of the cylinders (see thermometer TI10).

When working out the external cooling water system it must be ensured, that no cold cooling water is pressed through the engine and thus spoiling the preheating during stand-by. The diesel engine has no built-in shut-off valve in the cooling water system. Therefore the designer of the external cooling water system must make sure that the preheating of the GenSets is not disturbed.

Preheating of stand-by auxiliary engines during sea operation

Auxiliary engines in stand-by position are preheated via the venting pipe (F3), leading to the expansion tank, with HT water from the operating auxiliary engines.

During preheating the non-return valve on the preheated auxiliary engine will open due to the pressure difference. The HT pumps on the operating auxiliary engines will force the HT water downwards, through the stand-by auxiliary engine, out of the (F1) HT inlet and back to the operating auxiliary engines, via the bypass manifold which interconnect all the (F1) HT inlet lines.

The on/off valve can be controlled by "engine run" signal or activated by lub. oil pressure. MAN can deliver valves suitable for purpose.

Please note that preheating pipe mounted before on/off valve (size 3/4"-1" for guidance) connected to either preheat unit (optional) or directly to expansion tank pipe. This will deliver preheating water to stand-by engine via (F3).

The non-return valve in the venting pipe (F3) is closed when the auxiliary engine is operating, and deaerating to the expansion tank flows through the small ø3 bore in the non-return valve disc.

The small ø3 bore in the non-return valve disc will also enable the auxiliary engine to keep the recommended cooling water temperature in the HT-system during low load operation which is essential for the combustion of HFO.

Preheating element, build-in

The preheating power required for electrical preheating is stated below:

Engine type	Heating power
5L21/31, 5L21/31 Mk2	12 kW
6L21/31, 5L21/31 Mk2	12 kW
7L21/31, 5L21/31 Mk2	15 kW
8L21/31, 5L21/31 Mk2	15 kW
9L21/31, 5L21/31 Mk2	15 kW
5L27/38	15 kW
6L27/38	15 kW
7L27/38	24 kW
8L27/38	24 kW
9L27/38	24 kW

The figures are based on raising and maintain the engine temperature to 50°C (L21/31) / 40°C (L27/38) (20 - 60°C) for a period of at least 10 hours including the cooling water contained within the engine.

We will be pleased to make calculations for other conditions on request.

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.

Cyl. No.	5	6	7	8	9
Quantity of water in eng: HT and LT system (litre)	150	180	210	240	270
Expansion vol. (litre)	10	12	13	15	20

Table 1: Showing cooling water data which are depending on the number of cylinders.

Circulating pump for preheater, item 38

For preheating the engine a pump should be installed to circulate high temperature cooling water through the preheater.

Data for external preheating system, item 39

High pressure from external cooling water pumps may disturb the preheating of the engine. In order to avoid this, it is in most cases necessary to install automatic shut off valve at cooling water inlet, which close when the engine is stopped.

The capacity of the external preheater should be 3.0-3.5 kW/cyl. The flow through the engine should for each cylinder be approx. 4 l/min with flow from top and downwards and 25 l/min with flow from bottom and upwards.

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 (eg 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.

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Lifting instruction

Lifting of Complete Generating Sets.

The generating sets 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.

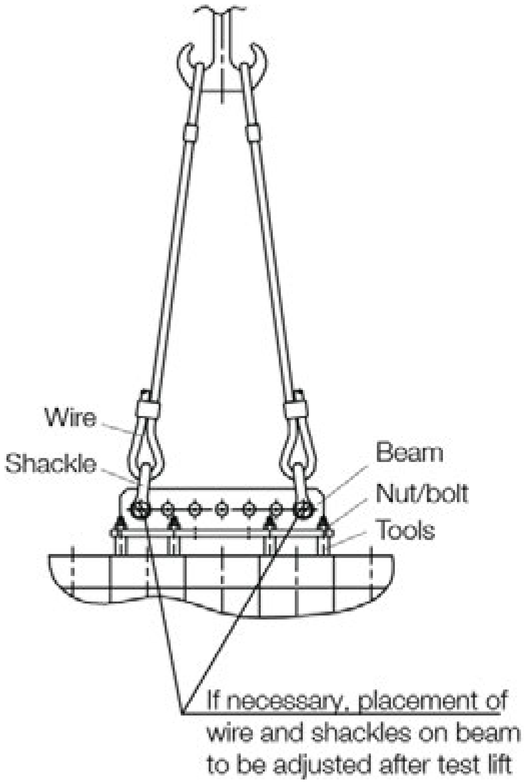

Figure 1: Lifting tools

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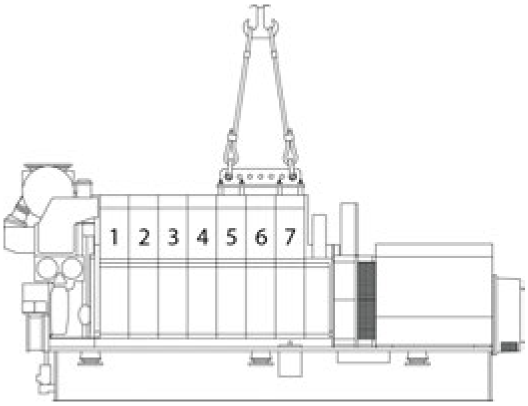

Figure 2: Lifting tools and wires placing on engine.

Engine Type	2 X 4 bolt to be mounted over cover of cyl. no.	
5L16/24, 5L21/31	3 cyl.	5 cyl.
6L16/24, 6L21/31	4 cyl.	6 cyl.
7L16/24, 7L21/31	5 cyl.	7 cyl.
8L16/24, 8L21/31	5 cyl.	7 cyl.
9L16/24, 9L21/31	6 cyl.	8 cyl.

Note: Based on MAN Energy Solutions standard alternator