Operation and Maintenance Manual

(Original Operation and Maintenance Manual)

Diesel engine

KD103V20

From serial number 2025750467

rehlko

EN_US
33521030901_6_1
10-2025

For United States only

⚠ WARNING

This product can expose you to chemicals including carbon monoxide and benzene, which are known to the State of California to cause cancer.
For more information go to
www.P65Warnings.ca.gov

⚠ WARNING

This product can expose you to chemicals including carbon monoxide and benzene, which are known to the State of California to cause birth defects or other reproductive harm.
For more information go to
www.P65Warnings.ca.gov

⚠ WARNING

Breathing diesel engine exhaust exposes you to chemicals known to the State of California to cause cancer and birth defects or other reproductive harm.

- Always start and operate the engine in a well-ventilated area.
- If in an enclosed area, vent the exhaust to the outside.
- Do not modify or tamper with exhaust system.
- Do not idle the engine except as necessary.

For more information go to
www.P65warnings.ca.gov/diesel

EMISSION CONTROL WARRANTY STATEMENT

EMISSION WARRANTY

Discovery Energy, LLC (hereafter known as the “Manufacturer”) warrants to the initial and subsequent owners of a stationary equipment certified diesel engine that such engine is:

- Designed, manufactured and equipped to conform at the time of sale with all applicable emission regulations adopted by the United States Environmental Protection Agency (“EPA”) under Section 213 of the Clean Air Act.
- Free from defects in materials and workmanship with respect to the warranted emission control system and components for a period of five (5) years or 3000 hours of total operation by all persons, whichever event occurs first, after date of delivery to the initial owner.

If any warranted part that is scheduled for replacement as required maintenance fails prior to the first scheduled replacement point for that part, that part will be repaired or replaced by the Manufacturer. If a component of the emission control system fails during the warranty period, it will be repaired or replaced under warranty and warranted for the remainder of the warranty period. A repair or replacement of any component warranted to the stationary equipment engine owner will be provided. The warranty period begins on the date the engine (in service) or machine (in production) is delivered to the initial owner, and upon any sale of the engine by such initial owner to a subsequent owner, the warranty period does not restart, but rather the remaining balance of the warranty period transfers to the subsequent owner.

WARRANTED PARTS

The following parts (as equipped) are warranted under this warranty:

- Fuel Injection System
- Air Induction System
- Turbocharger System
- Charge Air Cooling System
- Exhaust Gas Recirculation (EGR) System
- EGR Control System
- Exhaust Manifold
- Ignition System
- Diesel Particulate Filter System
- Diesel Oxidation Catalyst
- Fuel Additive Devices or Exhaust Aftertreatment Devices
- Selective Catalyst Reduction
- Reductant Containers
- Electronic Control Unit, Sensors, Solenoids, and Wiring Harnesses
- Emission Control Information Label
- Crankcase Ventilation Valves

RESPONSIBILITIES & LIMITATIONS

This warranty is subject to the following conditions.

Manufacturer’s Responsibilities:

In case an emission-related defect is found in a warranted component during the warranty period, the Manufacturer will provide:

- New, remanufactured, or properly repaired components, approved pursuant to applicable regulations, required to correct the defect.
- Labor deemed reasonable and customary, during normal working hours, required to make the warranted repairs, including labor to remove and install the engine, if so required.
- Parts replaced under this warranty become the property of the Manufacturer.

Owner’s Responsibilities:

During the warranty period, the owner of the stationary equipment engine is responsible for:

- Premium or overtime labor costs.
- Costs to investigate engine problems which are not caused by a defect in material or workmanship.
- Warranty coverage may be denied if the stationary engine or a part thereof has failed due to abuse, neglect, improper maintenance, or unapproved modifications.
- Providing timely notice of a warranted failure to an authorized Dealer, and to promptly make the equipment or engine available to the Dealer for repair.
- Proper scheduled and preventive maintenance as outlined in the Operation and Maintenance Manual supplied with the equipment. This includes, but is not limited to, valve adjustment, fuel and oil filter changes, and any other maintenance procedure related to emission control.
- Using only the proper fuel in the engine, as specified in the Operation and Maintenance Manual. Engines other than Tier 4 diesel engines shall only be operated on commercially available diesel fuel. The Tier 4 diesel engines shall only be operated on ultra-low sulfur diesel fuel. Use of any fuel in any engine other than the permitted fuel specified

above and in the Operation and Maintenance Manual would harm the engine's emission control system and may result in the engine no longer operating in compliance with EPA emission requirements. Therefore, use of any fuel in any engine other than the permitted fuel specified above and in the Operation and Maintenance Manual is prohibited and will invalidate this warranty.

- The owner is responsible for initiating the warranty process. Owners are advised to contact their local authorized Dealer to perform warranty service as soon as a problem arises. The warranty repairs should be completed by the authorized Dealer as expeditiously as possible.

EXCLUSIONS

This warranty does not cover:

- **This warranty shall only apply** to Discovery Energy, LLC engines.
- Malfunctions in any part caused by abuse, misuse, alterations, tampering, disconnection, or improper or inadequate maintenance, including, without limitation, any malfunctions caused by using any fuel that is not permitted in such engine as specified the Owner's Responsibilities paragraph above and the Operation and Maintenance Manual.
- Attachments, accessories or components not supplied or approved by the Manufacturer.
- Damage resulting from fire, accident, negligence, act of God or other events beyond the control of the Manufacturer.
- Consequential damages such as loss of use of the engine or equipment powered by the engine, towing, machine transportation, loss of time, downtime, inconvenience, telephone, travel, lodging, or any other indirect or direct damages.
- Loss or damage to personal property, loss of revenue, commercial loss or any other matters not specifically included in this warranty statement.
- Any warranted part that was required to be previously replaced as part of required scheduled maintenance.
- Owner's unreasonable delay in making the equipment available after being notified of a potential product problem.
- Engines installed outside United States of America.
- Any engines in which any fuel that is not permitted in such engine as specified in the Owner's Responsibilities paragraph above and the Operation and Maintenance Manual has been used.

This warranty is in addition to the Standard Warranty and any extended warranty (if applicable) for the equipment and engine involved. Remedies under this warranty are limited to the provisions as specified in this warranty statement.

IN NO EVENT SHALL THE MANUFACTURER, ITS COMPONENT SUPPLIERS NOR THE SELLING DEALER BE LIABLE FOR ANY DELAY, WORK STOPPAGE, LOSS OF USE OF EQUIPMENT, LOSS OF TIME, INCONVENIENCE, LOSS OF PROFITS, OR ANY INDIRECT, INCIDENTAL, SPECIAL, OR CONSEQUENTIAL DAMAGES RESULTING FROM OR ATTRIBUTABLE TO, DEFECTS IN PRODUCTS OR SERVICE, WHETHER RESULTING FROM NEGLIGENCE (INCLUDING GROSS NEGLIGENCE) OR OTHER TORT WARRANTY, CONTRACT, INDEMNITY, BREACH OF THE PROMISE TO REPAIR OR REPLACE CONTAINED HEREIN, STRICT LIABILITY OR OTHERWISE.

IN ADDITION, THE MANUFACTURER, ITS COMPONENT SUPPLIERS AND THE SELLING DEALER SHALL NOT BE LIABLE IN TORT OR STRICT LIABILITY FOR ANY ECONOMIC LOSS RESULTING, IN WHOLE OR IN PART, FROM THE MANUFACTURE OR SUPPLY OF THE PRODUCT, PARTS, COMPONENTS AND/OR LABOR.

NOTWITHSTANDING ANYTHING IN THIS WARRANTY TO THE CONTRARY, THE MAXIMUM LIABILITY, IF ANY, OF THE MANUFACTURER, ITS COMPONENT SUPPLIERS AND THE SELLING DEALER FOR ALL DIRECT DAMAGES SHALL NOT EXCEED THE PRICE OF THE PARTICULAR DEFECTIVE PRODUCT, PART OR SERVICE, AS APPLICABLE.

THE STANDARD WARRANTY, THE EMISSION CONTROL WARRANTIES, AND THE EXTENDED LIMITED MACHINE AND POWERTRAIN WARRANTIES, IF APPLICABLE, ARE THE ONLY WARRANTIES APPLICABLE TO PRODUCTS AND COMPONENTS USED IN THE MANUFACTURER'S PRODUCTS AND ARE EXPRESSLY IN LIEU OF ANY WARRANTIES OR CONDITIONS OTHERWISE IMPLIED BY LAW (INCLUDING ANY WARRANTY OTHERWISE IMPLIED BY LAW FOR THE PRODUCT BY THE MANUFACTURER OR ITS COMPONENT SUPPLIERS), INCLUDING, BUT NOT LIMITED TO, IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE AND IS NOT A WARRANTY OF FUTURE PERFORMANCE.

THE REMEDIES UNDER THIS WARRANTY SHALL BE THE ONLY REMEDIES AVAILABLE TO THE OWNER OF THE MANUFACTURER'S PRODUCTS OR ANY OTHER PERSON, AND NEITHER THE MANUFACTURER, NOR THE SELLING DEALER ASSUMES ANY OTHER OBLIGATION OR RESPONSIBILITY WITH RESPECT TO THE CONDITION OF THE MANUFACTURER'S PRODUCTS, AND AUTHORIZES NO OTHER PERSON TO ASSUME FOR ANY OF THEM, ANY OTHER OBLIGATION OR LIABILITY.

The Manufacturer reserves the right to make changes in design or add any improvements on its products at any time without incurring any obligation to install same on units previously delivered.

If the original owner sells the engine and machine, the remaining period of this warranty shall be transferred to the new owner.

It is requested that each owner of the engine and machine complete and provide the following information, sign in the space indicated, retain a completed and signed copy of this statement for the owner's records, and return a completed and signed copy of this statement to the Manufacturer. Failure to complete, sign, or return this form will not affect any owner's rights or the Manufacturer's obligations under this warranty statement and will not result in denial of warranty coverage.

MODEL: _____ PIN (Prod. Id. No.): _____ - _____

NAME OF DEALER	NAME OF OWNER
SIGNATURE OF AUTHORIZED REPRESENTATIVE OF DEALER	SIGNATURE OF AUTHORIZED REPRESENTATIVE OF OWNER
CITY / STATE / ZIP CODE OF DEALER	CITY / STATE / ZIP CODE OF OWNER

DATE MACHINE PLACED INTO SERVICE

Change history

Version	Author	Modification	Date
002	TB12 - Technical documentation	HVO introduction According to development and improvement	2022-09
003	TB12 - Technical documentation	According to development and improvement	2023-12
004	TB12 - Technical documentation	Maintenance schedule correction	2024-02
005	Rehlko	Rehlko rebranding	2024-12
006	TB12 - Technical documentation	Update for Model Year 2025	2025-10

Preface

Disclaimer

Modifications, conditions, copyright

Discovery Energy, LLC and its affiliates dba Rehlko reserves the right to make modifications in the course of technical development, without issuing prior notification.

The aforementioned provisions do not extend the warranty and liability conditions in the general terms and conditions of business of Discovery Energy, LLC and its affiliates dba Rehlko.

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About this document

This manual has been written for the engine **operator** and **maintenance personnel**.

This manual provides information regarding:
- **Safety Regulations**
- **Handling and operation**
- **Maintenance**

Anyone involved in working with or on the engine must read and follow the instructions in the manual carefully before operating and servicing the engine and at regular intervals.

Work with the engine includes:
- **Handling** and storage of the components.
- **Servicing**, including inspections and preventive maintenance.

This manual facilitates the operator's familiarization with the engine and prevents faults caused by improper operation.

The generator set owner is responsible for supplementing the operating instructions of the engine with its generator set and with instructions based on existing national regulations on accident prevention and environmental protection.

In addition to this manual and the regulations on accident prevention applicable in the user's country and at the place of use, it is also necessary to comply with the recognized technical rules on safety and technically proficient working.

Note

For any information concerning the generator set in which the engine is mounted, refer to the instructions of the generator set.

For additional explanation or information, the Customer Service and Customer Service training center departments of Rehlko are available anytime to answer any queries.

Rehlko engines are subject to continuous development and improvement. This may result in modifications to your engine that may not be referred to in this manual.

Some sections of this manual do not apply to all engines.

Some illustrations in this manual may show details and implements that are different from your engine.

In some illustrations, protective devices and covers have been removed to provide a clearer representation.

Should you have any queries, please contact your authorized Discovery Energy, LLC and its affiliates dba Rehlko service representative.

Task layout

Note

Before any intervention, read the complete task procedure.

Each task in this manual has the following structure:

1. **5.6.4 Collecting and analyzing oil sample — SL1-2021**

2. **Previous tasks**

Make sure that the following preconditions are met:
❑ Preparatory maintenance activities are fulfilled. (For more information see: 5.4 Preparatory maintenance activities, page 91.)

3. **Specific safety instructions**

DANGER
Fire - Ignition of flammable operating fluids: fuel, lubricating oil, or coolant!
Risk of death or injury by burn, scald, or asphyxiation.

- ▶ Make sure that no operating fluid comes into contact with a hot surface or an ignition source.
- ▶ Before servicing the engine, let it cool down until surface temperature allows you to touch it with bare hand.
- ▶ Before servicing the engine, make sure that the operating fluid pressures are relieved.

4. **Consumables and equipment**

Not applicable.

5. **Sample collection**

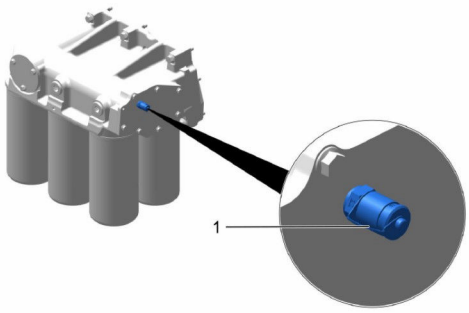


Fig. 73: oil sampling point on engine left side

1 Sampling point

- ▶ Take oil sample from the sampling point.
- ▶ Analyze oil sample.
- ▶ Take recommended action according to analysis results. (For more information see: 5.11.3 Approved lubricating oils and lubricating oil additives, page 153.)

Task layout description

1. Heading introducing the task covered in the chapter
2. List of tasks to be completed before starting the procedure with relevant references
3. Specific safety instructions, which complete the general safety instructions
4. List of consumables and equipment needed to fulfill the task
5. Visual and written instructions needed to fulfill the task

Additional identifications

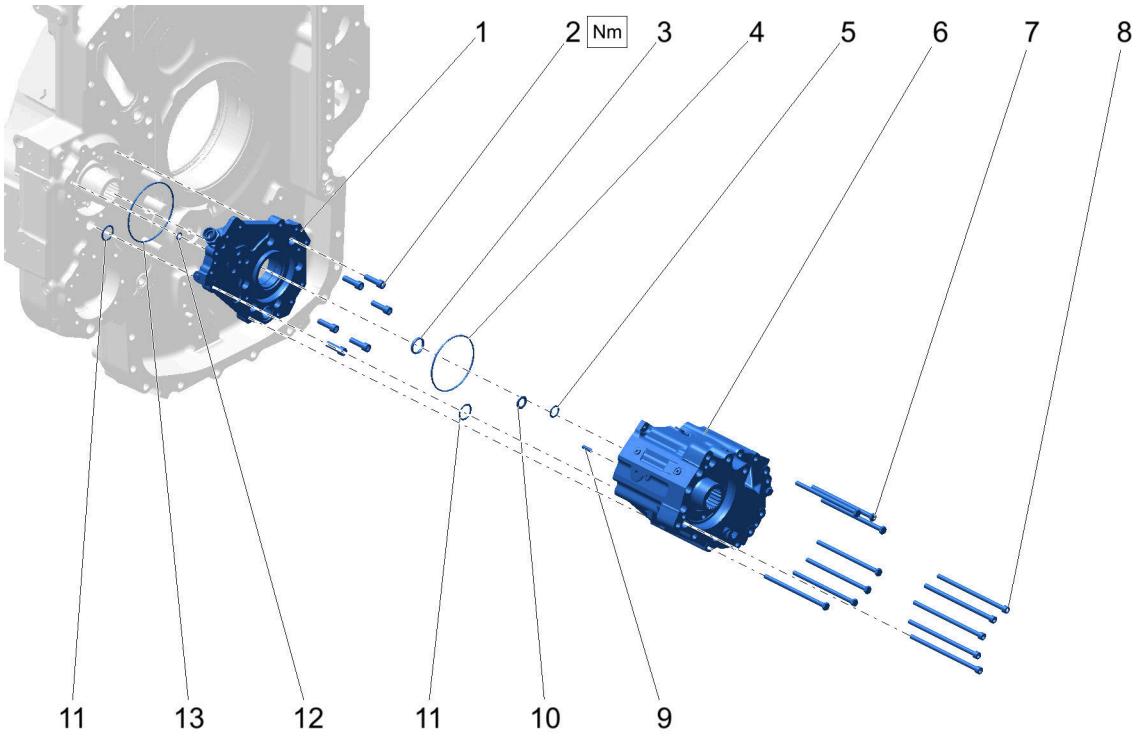
ⓘ	**Note**	Indicates helpful advice and tips.
☐	**Precondition**	Identifies a condition that must be fulfilled to be able to carry out the actions subsequently described.
▶	**Action**	Identifies an action, which has to be carried out.
▷	**Result**	Identifies the result of an action.
—	**Listing**	Identifies a listing.
Nm	**Torque value**	Identifies special tightening torque or specification.

Additional symbols

Tightening specifications

Note

For special tightening torques, the admitted tolerance is 5%.



Marking of special tightening torques

Assemblies requiring special tightening torque, multistep tightening procedure, special tightening sequence, or application of products (lubricants or glues) are marked with the symbol “Nm” (for example: hotspot **2**).

Refer to the table at the end of the task for information about special tightening torques, multistep tightening procedure, special tightening sequences, or application of products (lubricants/glues).

Otherwise, refer to standard tightening torques that are mentioned in the “Appendix” of this manual (for example: hotspots **7, 8, 9**).

Norms and standards

The respective national laws and ordinances or regulations of the respective site of operation must be observed during the installation and operation of Rehlko engines and their components.

In this respect, the regulations for the serial product are the responsibility of the manufacturer of the application.

This documentation was written in compliance with the standards mentioned below.

European guidelines

- Machinery Directive 2006/42/EC

Other standards

- EN 82079-1 - Preparation of instructions for use – Structuring, content and presentation
- ISO 12100 - Safety of machinery
- ISO 1204- Reciprocating internal combustion engines - Designation of the direction of rotation and of cylinders and valves in cylinder heads, and definition of right-hand and left-hand in-line engines and locations on an engine
- ANSI Z535.6 - Product Safety Information in Product Manuals, Instructions, and Other Collateral Materials

Emission compliance (for certified diesel engines only)

European Union

No certificate available.

United States of America

This Operation and Maintenance Manual contains the legally required information for end users according to “US Regulation 40 CFR Parts 1039 and 1068”.

Tier 2 certification as per CFR 1039

This diesel engine is certified Tier 2 according to “USA EPA 40 CFR 1039”.

Diesel engine owner is responsible to comply with this requirement: “Engines only to be installed in emergency stationary standby power applications”.

Operation of diesel engine on other application shall be expressly prohibited and Discovery Energy, LLC and its affiliates dba Rehlko excludes any liability, including but not limited to warranty, to the extent the diesel engine is operated outside of the conditions to which it is type approved.

Notwithstanding anything to the contrary set forth above, in no event shall Discovery Energy, LLC and its affiliates dba Rehlko be liable for any misuse, abuse or any other improper use of the diesel engine (including any parts thereof) or for any modification of the diesel engine (including parts thereof) that has not received Discovery Energy, LLC and its affiliates dba Rehlko’s explicit prior written approval.

Compliance

In accordance with US Regulation 40 CFR Part 1039 and 1068 (§1039.125 and §1068.110), the owner has the option to select any qualified repair shop for proper maintenance, replacement or repair of emission-related components with original parts or equivalent replacement parts. The owner is required to have warranty and recall services paid for by Discovery Energy, LLC and its affiliates dba Rehlko performed by an authorized Discovery Energy, LLC and its affiliates dba Rehlko dealer/service center.

Warranty

Spare parts

Only original Rehlko spare parts, or spare parts purchased by Discovery Energy, LLC and its affiliates dba Rehlko should be used for repairing Rehlko engines.

Discovery Energy, LLC and its affiliates dba Rehlko will declare all possible undertakings carried out by Rehlko and/or their dealers, such as guarantees, service orders, etc. null and void without advance notice, if spare parts other than original Rehlko spare parts or spare parts purchased by Discovery Energy, LLC and its affiliates dba Rehlko are used for maintenance or repair.

Fuels, lubricants, and coolants

Only fuels, lubricants, and coolants approved by Discovery Energy, LLC and its affiliates dba Rehlko may be used for the operation of Rehlko engines.

Discovery Energy, LLC and its affiliates dba Rehlko will declare all possible undertakings carried out by Rehlko and/or their dealers, such as guarantees, service orders, etc. null and void without advance notice, if fuels, lubricants, and coolants other than fuels, lubricants, and coolants approved by Discovery Energy, LLC and its affiliates dba Rehlko are used for maintenance or repair.

Liability and warranty

Due to the wide variety of products offered by other manufacturers (e.g. service products, lubricants, tool attachments, and spare parts), Discovery Energy, LLC and its affiliates dba Rehlko cannot examine the general suitability and absence of defects in third-party products, which are used in or on Rehlko products. The same applies to possible interactions between third-party products and products approved by Discovery Energy, LLC and its affiliates dba Rehlko.

Third-party products are used in or on Rehlko engines at the user's own discretion. Discovery Energy, LLC and its affiliates dba Rehlko does not offer any warranty or accept any liability for losses of any kind caused by failures of or damage to Rehlko engines attributable to the use of third-party products.

Furthermore, Discovery Energy, LLC and its affiliates dba Rehlko will not recognize any warranty claims attributable to incorrect operation, inadequate or insufficient maintenance or use of unapproved operating fluids or non-compliance with safety regulations.

Discovery Energy, LLC and its affiliates dba Rehlko will cancel any obligations entered into by Rehlko and/or its dealers, such as guarantees, service contracts, etc., without advance notice if any parts other than original Rehlko parts or spare parts purchased from Discovery Energy, LLC and its affiliates dba Rehlko are used for maintenance and repair.

The aforementioned provisions do not extend the warranty and liability conditions in the general terms and conditions of business of Discovery Energy, LLC and its affiliates dba Rehlko.

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1.1.1 Design overview

1.1.1.1 Engine equipment

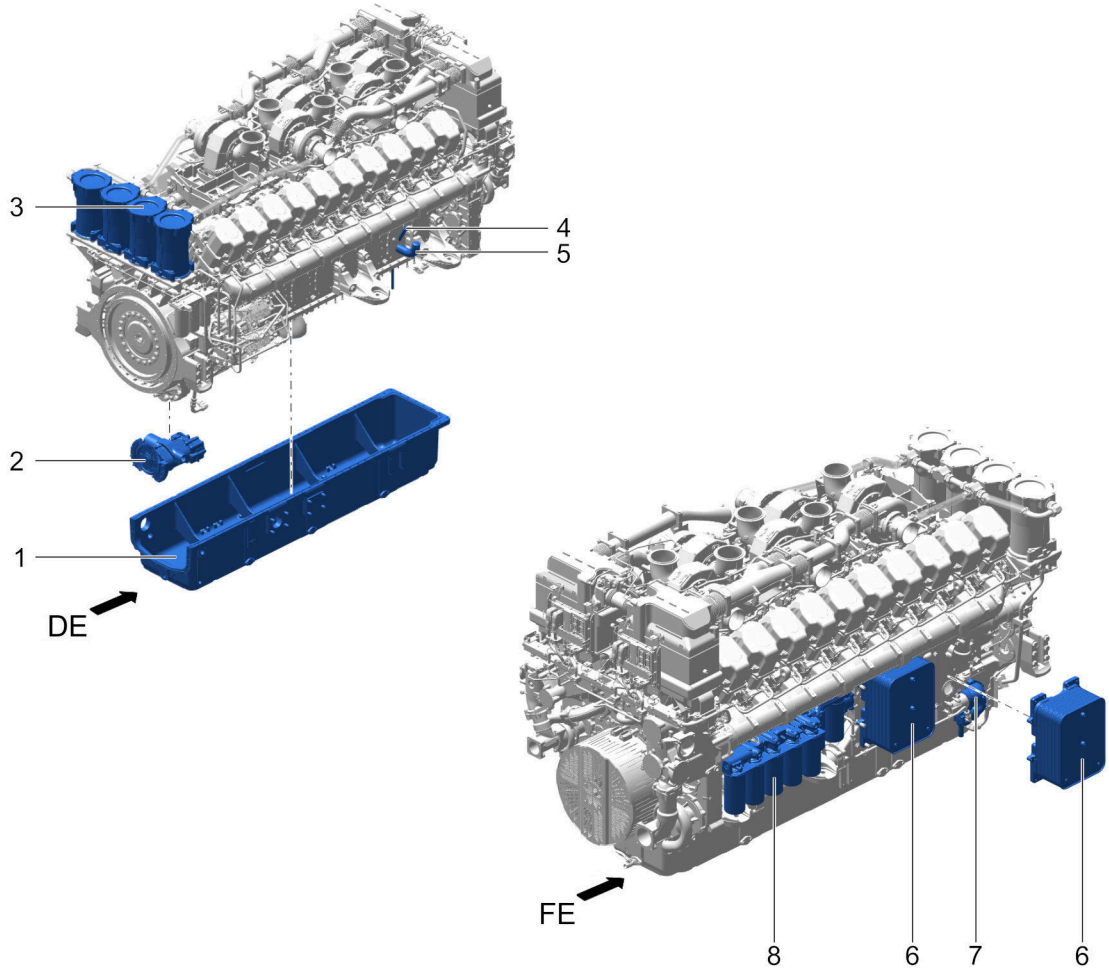


Fig. 1: Engine oil system

DE Driving end

1 Oil pan
2 Oil pump
3 Crankcase breather oil separator
4 Oil dipstick

FE Free end

5 Oil filler neck
6 Oil cooler
7 Oil pressure main valve
8 Spin-on oil filter

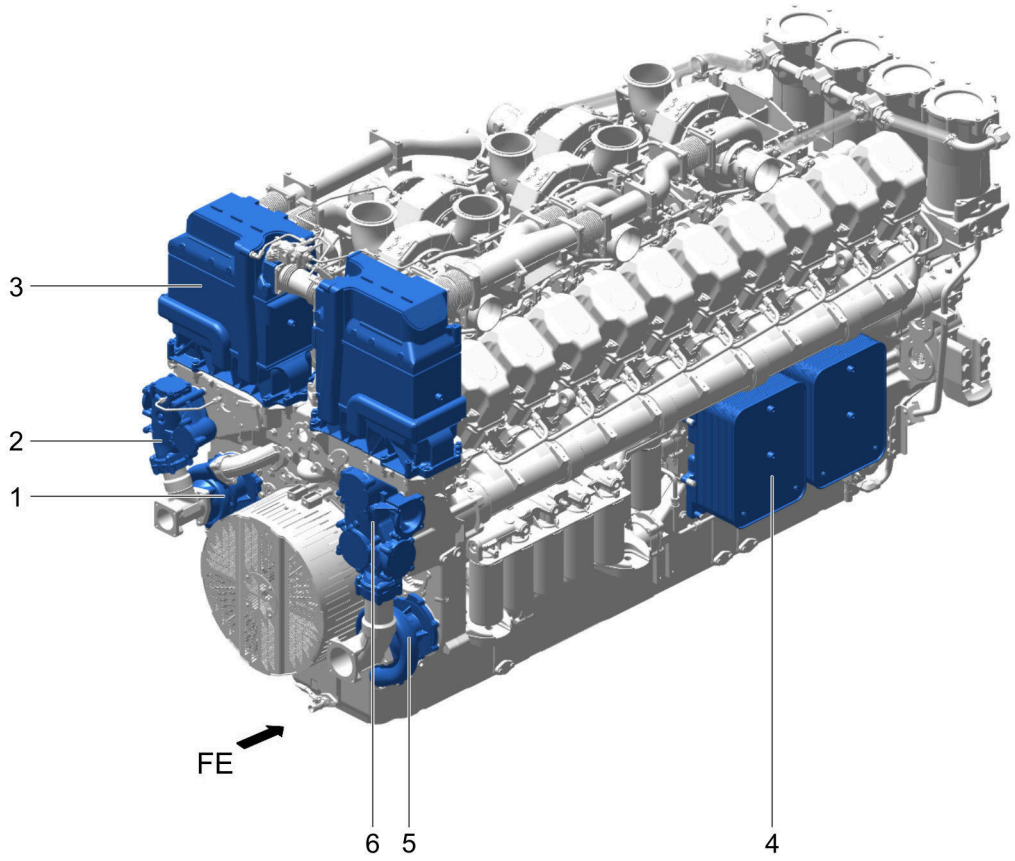


Fig. 2: Cooling system

FE Free end

1 Low-Temperature (LT) coolant pump
2 Low-Temperature (LT) thermostat housing
3 Charge air cooler
4 Oil cooler
5 High-Temperature (HT) thermostat housing
6 High-Temperature (HT) coolant pump

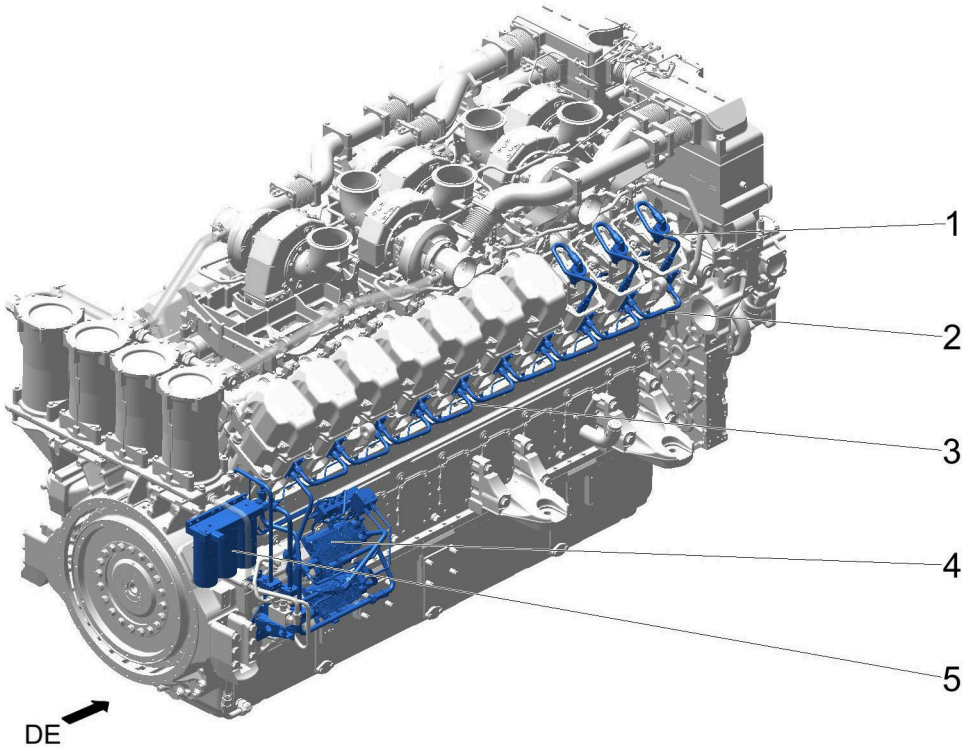


Fig. 3: Fuel system

DE Driving end

1 Injector

2 Double-walled piping (high-pressure fuel line)

3 Single-walled piping (fuel return line)

4 High-Pressure/Low-Pressure (HP/LP) fuel pump

5 Fuel filter

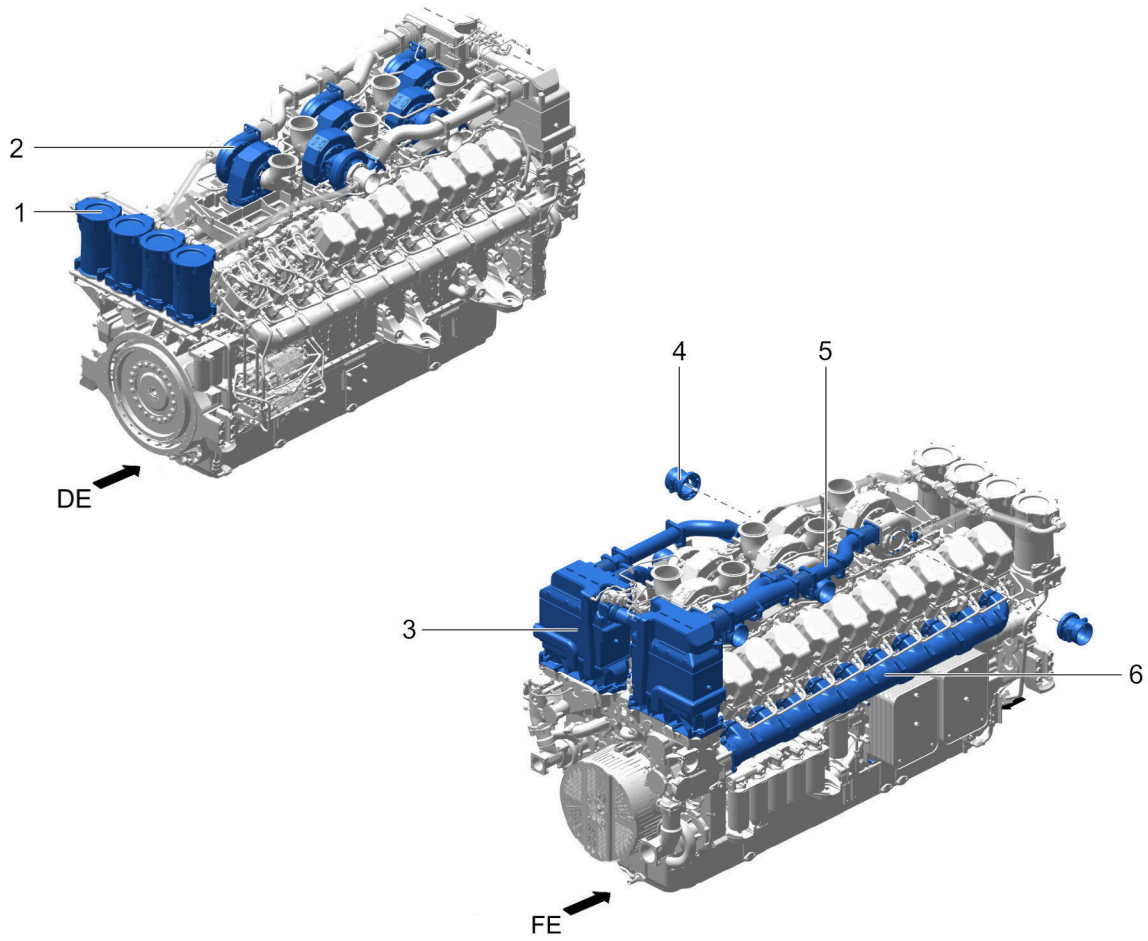


Fig. 4: Air intake system

DE Driving end

1 Crankcase breather oil separator
2 Exhaust gas turbocharger
3 Charge air cooler

FE Free end

4 Straight air intake
5 Hot charge air line
6 Cold charge air line

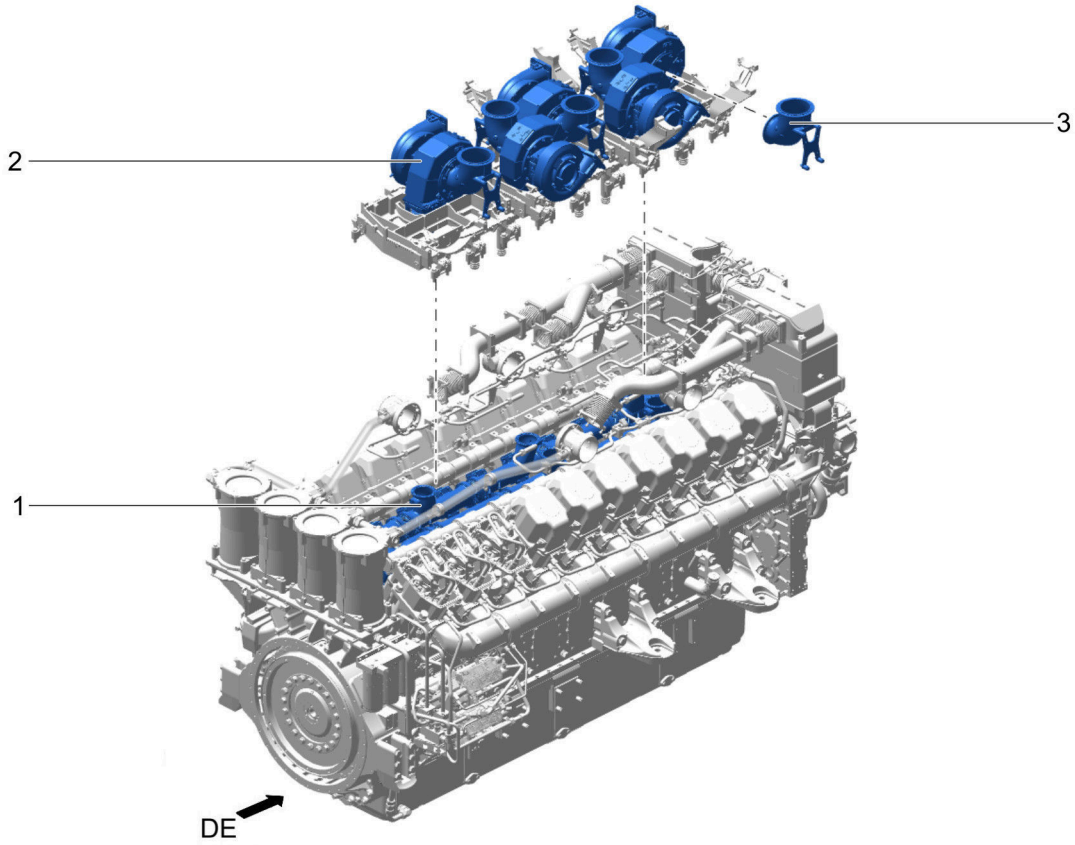


Fig. 5: Exhaust gas system

DE Driving end

1 Exhaust manifold

2 Exhaust gas turbocharger

3 Exhaust elbow from exhaust gas turbocharger

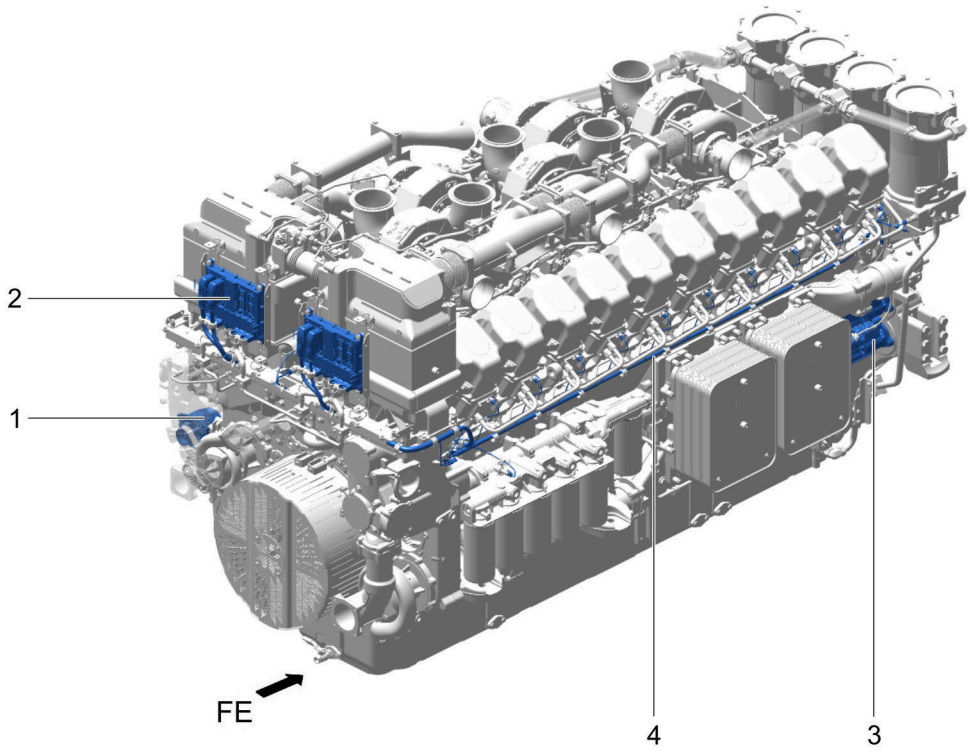


Fig. 6: Electrical system

FE Free end

1 Battery charging alternator
2 Engine Control Unit (ECU)
3 Starter
4 Wiring harness

Optional equipment

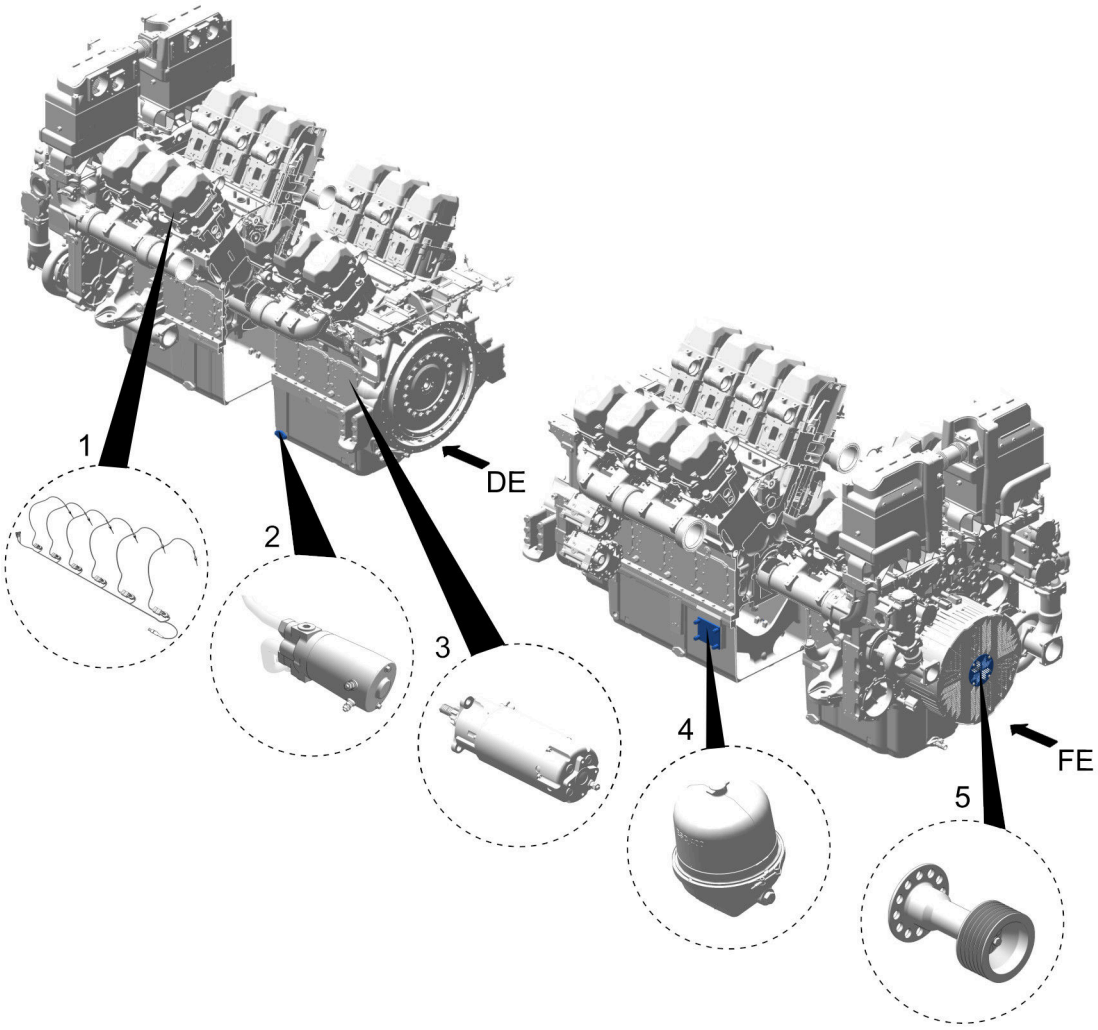


Fig. 7: Optional equipment

DE Driving end

FE Free end

1 Location of exhaust temperature sensors
2 Connections for prelubricating pump
3 Connection for additional starters
4 Connection for centrifugal oil filter
5 Connection for fan drive

1.1.2 Conventions

1.1.2.1 Cylinder designation, direction of rotation, firing sequence

In this manual, all locations and directions shown on the diesel engine are compliant with ISO 1204 in its English version.

Cylinder A1 and cylinder B1 are located on the driving end of the diesel engine. Direction of rotation is counterclockwise, as seen from the driving end of the diesel engine.

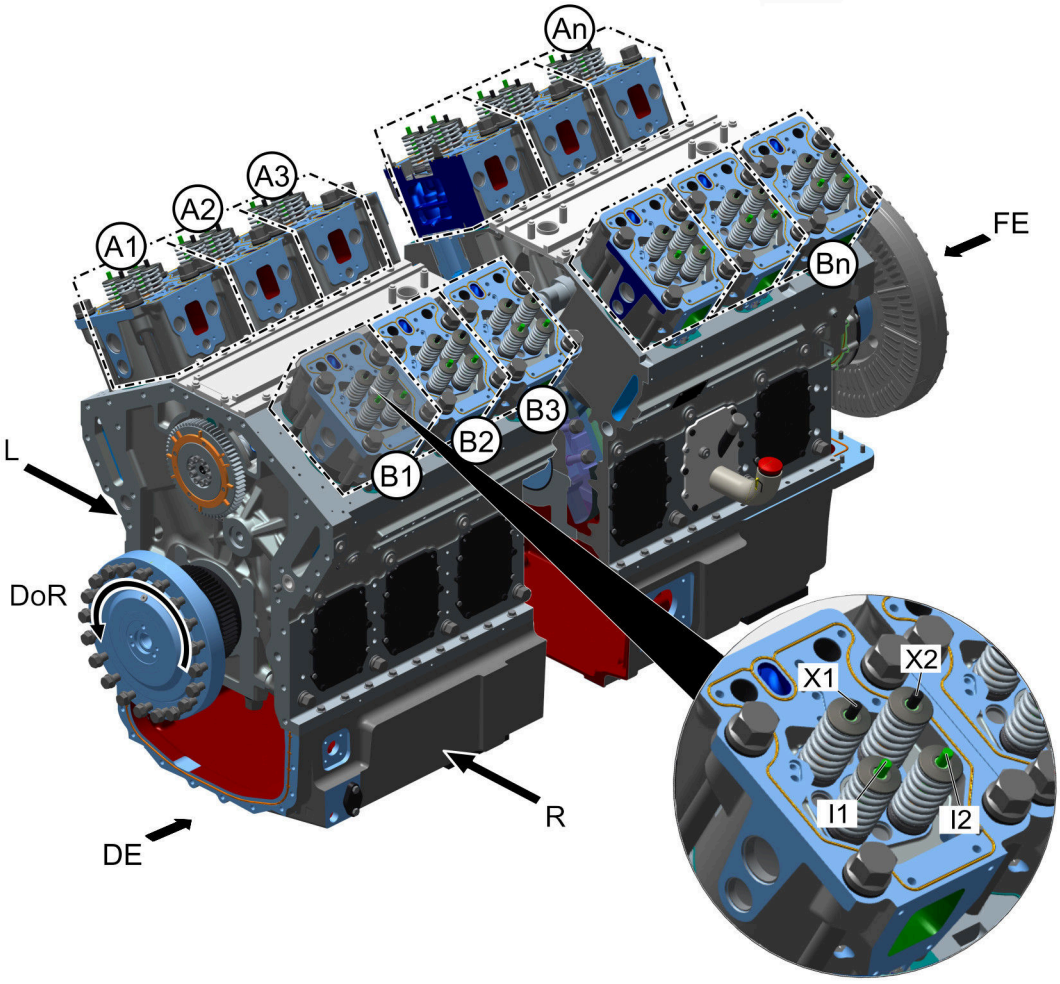


Fig. 8: Cylinder designation - direction of rotation according to ISO 1204

A1-An	Series of cylinders – Bank A	**X**	Exhaust valves
B1-Bn	Series of cylinders – Bank B	**I**	Intake valves
DE	Driving end	**L**	Left engine side
FE	Free end	**R**	Right engine side
DoR	Direction of rotation		

Firing sequence: A1-A6-B2-B10-A2-A10-B7-B9-A7-A9-B8-B4-A8-A4-B5-B3-A5-A3-B1-B6

1.1.3 Engine or component identification

1.1.3.1 Type designation

Designation										**Description**
K	**D**	**103**	**V**	**20**	**-**	**5**	**A**	**F**	**C**	**Engine type description**
K										Engine manufacturer
	D									Fuel type (D=Diesel)
		103								Total displacement in liter
			V							Cylinder configuration
				20						Number of cylinders
						5				Frequency. 5=50Hz; 6=60Hz

Designation										Description
K	D	103	V	20	-	5	A	F	C	Engine type description
							A			Power level. A=power level designation, where A= the lowest power level, B=next higher power level, C=next higher power level...
								F		Emissions or fuel optimization. F=Fuel Optimized, E=Emissions Optimized
									C	Application. C=COP; P=Prime; S=Stand by; D=Data center

Tab. 1: Engine type description

1.1.3.2 Diesel engine signage

The following overview shows the arrangement of signs on the engine.

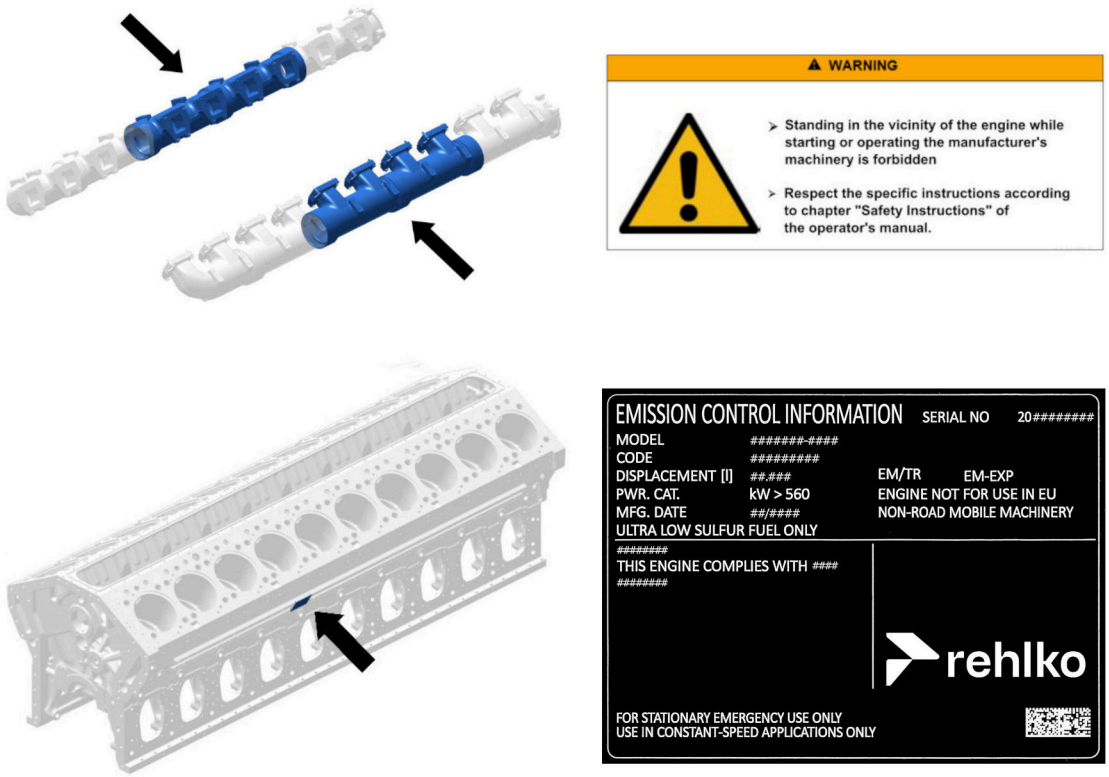


Fig. 9: Arrangement of signs on the engine

Engine serial number

The engine serial number is recorded onto the emission control information label of the engine.

Designation			Description
20##	**73**	**0001**	**Engine serial number**
20##			Year of manufacture

Designation			Description
	73		Engine type code (73=V12) (74=V16) (75=V20)
		0001	Incremental production number

Tab. 2: Engine serial number



Fig. 10: Serial number on label

1 Serial number

Emission control information label

The emission control information label is glued on the crankcase.

Note

The emission control information label carries important and legal information regarding the engine.

Make sure that it remains clean and legible at any time.

Should you need a new emission control information label, please contact your authorized Discovery Energy, LLC and its affiliates dba Rehlko service representative.

In case you need to replace an emission control information label, make sure to undertake the following actions:
- Completely remove the former label before sticking the new one;
- If you are replacing a metallic plate, completely remove the plate and apply spray-paint to prevent rust before sticking the new label (→ 5.6.2 Spray painting, p. 109).

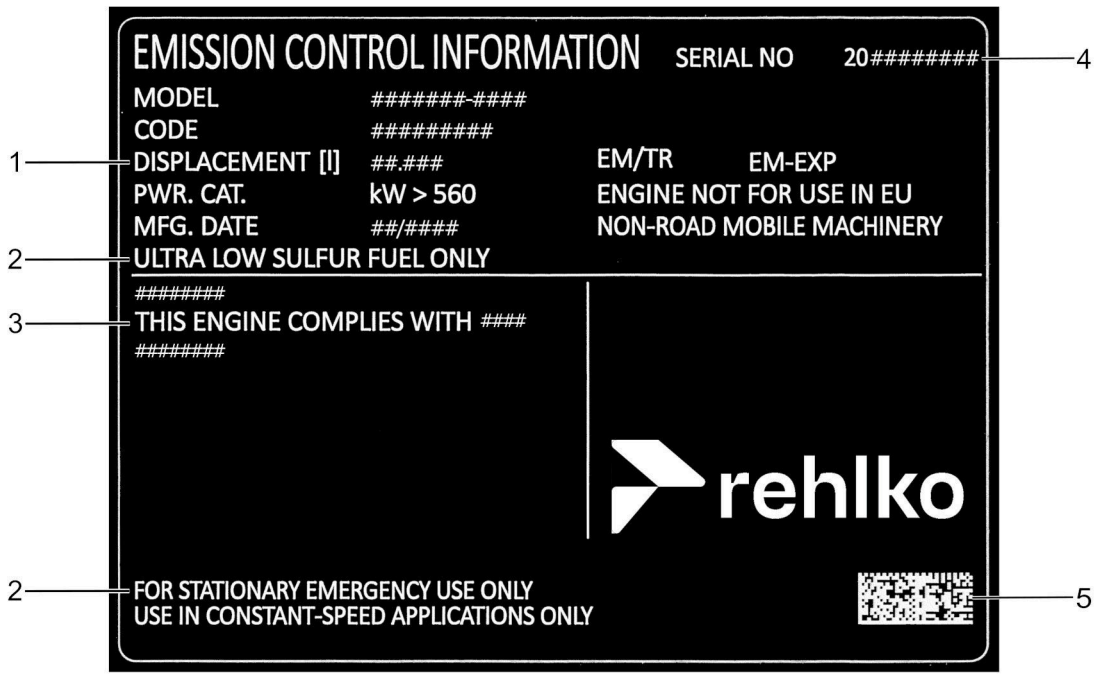


Fig. 11: Emission control information label - serial engine

1 Engine main characteristics
2 Notes regarding potential emissions exemptions, fuels, and application types
3 Local regulations references
4 Engine serial number
5 QR code area

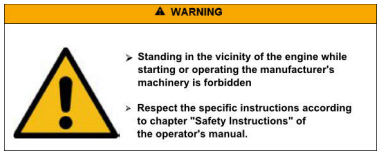
Safety stickers

WARNING
Missing, illegible, or unobserved safety stickers!
Risk of death or injury.

- ▶ Replace missing or illegible safety stickers immediately.
- ▶ Check conditions of safety stickers regularly.
- ▶ Follow the safety stickers instructions.

The safety stickers provide warnings related to risks of accidents.

Some safety stickers are not implemented on every engine depending on implemented options or engine usage.

Sticker	Description
	Indicates additional safety precautions, which have to be taken.

Tab. 3: Safety stickers on the engine

1.1.3.3 Type plate of Engine Control Unit (ECU)

Note

- The information on the ECU type plate corresponds to the delivery status. Depending on software updates in the field, it may be the case that this information is no longer up to date.
- The real information can be viewed in the device display or read out with the diagnosis and service tool KODIA.

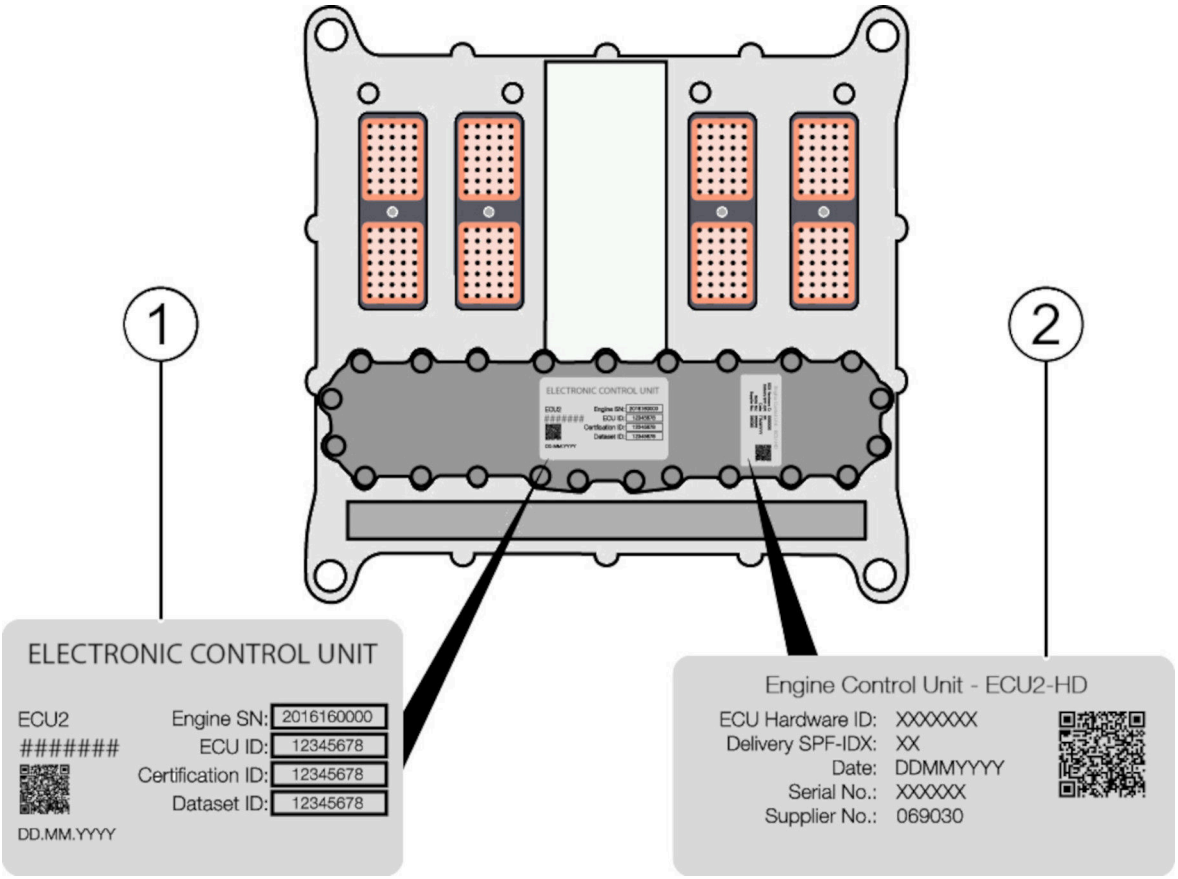


Fig. 13: ECU type plate location

1 Software type plate

2 Hardware type plate

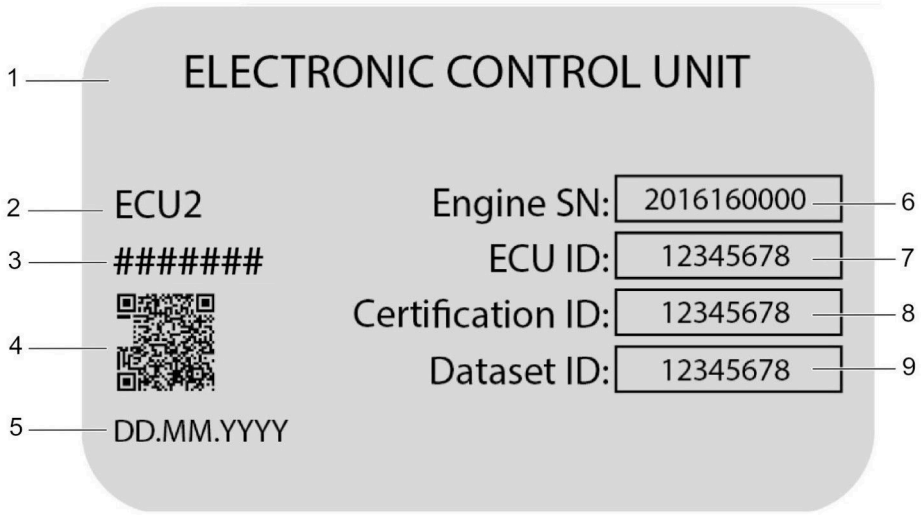


Fig. 14: Software type plate

1 Product designation
2 Product type
3 Engine designation
4 QR Code
5 Delivery date
6 Engine serial number
7 Engine control unit (ECU) ID number
8 Certification ID number
9 Data set ID number

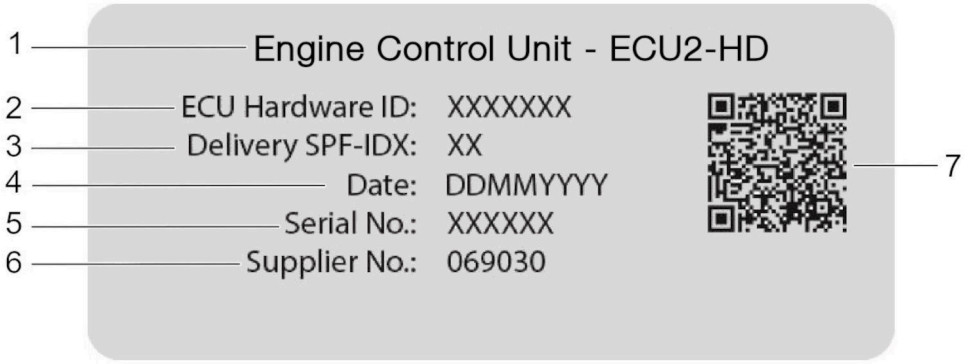


Fig. 15: Hardware type plate

1 Product designation
2 Engine control unit (ECU) ID number
3 Hardware version
4 Delivery date
5 Serial number
6 Supplier number
7 QR Code

1.2 Technical data

1.2.1 Diesel engine

Designation	Value
Cylinder configuration	V-Diesel Engine
Number of cylinders	20
Bore	175 mm (6.89 in)
Stroke	215 mm (8.46 in)
Displacement	103 l (27.21 US gal)
Compression ratio	16
Direction of rotation of the diesel engine (seen from flywheel)	Counterclockwise
Power specification as per	ISO 3046-1
Rated power	See company nameplate
Rated speed	See company nameplate
Emission control information	See company nameplate
Flywheel housing connection	SAE 00

Tab. 4: Technical data table – diesel engine

1.2.2 Cylinder head

Designation	Value
Inlet valve clearance, cold	0.5 mm (0.02 in)
Exhaust valve clearance, cold	1 mm (0.04 in)

Tab. 5: Technical data table – cylinder head

1.2.3 Coolant thermostat

Designation		Value
Low Temperature (LT) Thermostat	Opening start	45 °C (113 °F)
	Completely open	57 °C (135 °F)
High Temperature (HT) Thermostat	Opening start	71 °C (160 °F)
	Completely open	81 °C (178 °F)

Tab. 6: Technical data table – coolant thermostat

1.2.4 Starter

Designation	Value
Voltage	24 V

Designation	Value
Power per starter	9 kW

Tab. 7: Technical data table – starter

Note

In standard configuration, two starters are installed.

1.2.5 Battery charging alternator

Designation	Value
Voltage	28 V
Current	140 A

Tab. 8: Technical data table – battery charging alternator

2 Safety

2.1 Introduction

Follow these instructions and observe any additional or local rules and directives.

Note the following points:
- Safety regulations applicable on site
- Guidelines provided by professional associations

2.1.1 Warnings

	This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injuries or death.

Tab. 9: Example of warning

The safety alert symbol always appears in connection with one of the signal words:
- **DANGER**
- **WARNING**
- **CAUTION**

	**DANGER**	Indicates a hazardous situation that, if not avoided, will result in death or serious injury.
	**WARNING**	Indicates a hazardous situation that, if not avoided, could result in death or serious injury.
	**CAUTION**	Indicates a hazardous situation that, if not avoided, could result in minor or moderate injury.

Tab. 10: Warning signs

The **NOTICE** signal word indicates a risk not related to personal injury.

The risks of engine failure are classified according to ISO 2710-2:
- Critical failure: that may cause engine scrap or breaking the laws or regulations
- Major failure: that causes remarkable degradation of engine performance or operating fault of main components, and cannot be repaired by replacing the part with spare with common tools in a short time
- Minor failure: that affects the performance of the engine, but does not cause operating fault of main components, and can be repaired by replacing the part with spare with common tools, usually in a short time

The short time is generally 30 minutes.

2.2 Target audience

2.2.1 Responsibility of application set owner

Note
The application set owner is responsible for:

- Checking the knowledge and skills of the personnel
- Establishing the required additional, refresher, and further training
- Establishing the responsibilities and authorizations
- Applying the ILO – “C138 - Minimum Age Convention, 1973” with a minimum age for admission to employment of 14 years
- Supplying the required tools and spare parts

Note

The Customer Service training center departments Rehlko provides several training programs.

Please contact your nearest authorized Discovery Energy, LLC and its affiliates dba Rehlko service representative for queries.

2.2.2 Recommended occupations according to International standards

The international standard classification of occupations (ISCO-08) of the International Labor Office (ILO) determines occupational unit groups. The following groups are listed as references to define the target groups, occupations, and joint tasks.

The listed occupation unit groups perform the following work in accordance with the “General safety instructions” chapter (→ 2.4.1 General safety instructions, p. 45):
- Main tasks described in this manual or these instructions
- Tasks identified as requirements to prepare the main tasks

2.2.2.1 ILO - Occupations unit groups

For operation and SLO maintenance: Power Production Plant Operators – unit group 3131 / ISCED-11 level ≥ 2

Power production plant operators operate, monitor, and maintain switchboards and related equipment in electrical control centers, which control the production and distribution of electrical power-generating stations.

Tasks include:
- Operating, monitoring, and inspecting power plants;
- Operating and controlling power-generating systems and equipment;
- Controlling start-up and shut-down of power plant equipment;
- Controlling switching operations, regulating coolant levels;
- Communicating with systems operators to regulate and coordinate transmission loads, frequency, and line voltages;
- Taking readings from charts, meters, and gauges at established intervals, troubleshooting and performing corrective action as necessary;
- Completing and maintaining station records, logs, and reports, and communicating with other plant personnel to assess equipment operating status;

– Cleaning and maintaining equipment such as generators, pumps, and compressors in order to prevent equipment failure or deterioration.

For SL1 maintenance: Agricultural and Industrial Machinery Mechanics and Repairers – Unit group 7233 / ISCED-11 level ≥ 2

Agricultural and industrial machinery mechanics and repairers fit, install, examine, service, and repair engines, agricultural and industrial machinery and mechanical equipment, except motor vehicle, aircraft, and electric motors.

Tasks include:
– Fitting, installing, examining, servicing, and repairing engines, machinery, and mechanical equipment;
– Oiling and greasing stationary engines and machinery;
– Inspecting and testing new machinery and mechanical equipment for conformity with standards and specifications;
– Disassembling machinery and equipment to remove parts and make repairs;
– Examining parts for defects such as breakage and excessive wear;
– Operating newly repaired machinery and equipment to verify the adequacy of repairs;
– Recording repairs and maintenance performed.

For SL2 maintenance: Agricultural and Industrial Machinery Mechanics and Repairers – Unit group 7233 / ISCED-11 level ≥ 4

Agricultural and industrial machinery mechanics and repairers fit, install, examine, service, and repair engines, agricultural and industrial machinery and mechanical equipment, except motor vehicle, aircraft, and electric motors.

Tasks include:
– Fitting, installing, examining, servicing, and repairing engines, machinery, and mechanical equipment;
– Oiling and greasing stationary engines and machinery;
– Inspecting and testing new machinery and mechanical equipment for conformity with standards and specifications;
– Disassembling machinery and equipment to remove parts and make repairs;
– Examining parts for defects such as breakage and excessive wear;
– Operating newly repaired machinery and equipment to verify the adequacy of repairs;
– Recording repairs and maintenance performed.

2.2.3 Unauthorized personnel

All other persons, including operators, supervisors and trainees, are classified as “unauthorized personnel”.

They are not allowed to access the engine, its compartment or covers.

2.3 Use limits

2.3.1 Intended use

The engines produced by Rehlko are partly completed machinery according to Machinery Directive 2006/42/EC Article 2 g (only for European Union).

The Rehlko product described in these instructions is intended for use under the following conditions:

- The engines are intended to supply power to equipment (hydraulic pumps, electric generator) and to equipment auxiliaries as specified by customer.
- The engines are intended for installation in machineries.
- The engines must be fixed to the machinery in order to be operated correctly. Engines that are used within generators as emergency power generator must be firmly connected to the ground of the operation site.
- Appropriate mounting must be used to reduce the generated vibrations. This mounting must be approved by Rehlko.
- Optionally, air conditioning compressors and compressed air production can be operated as auxiliary units.
- The intended operation of the auxiliary units is only possible if indicated and approved by Rehlko before the engine manufacturing.
- The engines may only be operated in faultless condition.
- The engines may be operated in the speed range set by Rehlko.
- The engines must be fixed to the machine or the corresponding operation site using the already mounted engine brackets and by applying the corresponding tightening specifications. Non-original mounts and bearing arrangements must be approved by Rehlko to ensure proper operation.
- The operation of the engines is only permissible in areas inaccessible to the public and protected by an enclosure or compartment cover.
- Engines used as emergency generator must be protected by covers to reduce hazards due to rotating and moving parts.
- The engines may be operated in closed rooms only along with adequate ventilation, an exhaust extraction system, or with a flue gas discharge into the atmosphere.
- The conditions prescribed by the manufacturer of the machinery in which the engines have been installed are also part of intended use.
- The engines must only be installed by personnel who have been trained and familiarized herewith and are aware of the dangers.
- Unauthorized changes on the engines or their components void all warranties and liability of Rehlko for resulting property damage or personal injury.
- Interference with the injection and control system may influence the power and exhaust gas parameters of the engines, meaning that compliance with statutory environmental requirements is no longer assured. Any resulting damage, injuries, or environmental impacts are placed solely on the user.

Any other use above and beyond this is considered to be improper use. In this case, Rehlko is not liable for any damage. The risk is borne solely by the user.

2.3.2 Foreseeable misuse

The use of an engine under conditions or for purposes not intended by Rehlko, but, which can happen, induced by the engine in combination with, or as a result of, common human behavior, is considered as reasonably foreseeable misuse. It includes, but is not limited to the following:

- Drive of not specified machinery.
- Overload of the engine.
- Use of different applications and conditions rather than those specified.
- Improper use of fuels, lubricants, starting aids and coolants.
- Use of the engine manipulated overspeeds controls.

- Modifications of the engine mounting and suspensions.
- Lifting of the engine using unforeseen lifting points.
- Continued use of the engine in emergency mode.
- Operation of the engine with open engine cover.
- Attachment of external cables and wires on engine cables and pipes.
- Drawing of power from the free end except if mechanical fan drive is mounted as original equipment.
- Unauthorized modifications to the engine.

In this case, Rehlko is not liable for any damage. The risk is borne solely by the user.

NOTICE
Risk of engine failure.
Non-compliant installation according to installation plan and torque tightening values will lead to engine main failure (leaks in the charge air circuit, parts ejection, and others).
Mount any component according to:

- ▶ The “Assembly Instructions” for the Discovery Energy, LLC and its affiliates dba Rehlko engine and its components
- ▶ The “Instructions” from the manufacturer's machinery for the machinery incorporating the Discovery Energy, LLC and its affiliates dba Rehlko engine
- ▶ The “Instructions” or “Assembly Instructions” from the supplier for non Discovery Energy, LLC and its affiliates dba Rehlko components

2.4 Safety instructions

2.4.1 General safety instructions



DANGER
Failure to observe safety notes!
Risk of death or injury.

- ▶ Observe local regulations, site rules, and safety notes.
- ▶ In doubt, immediately seek advice from a competent person (for example, safety officer, supervisor).



DANGER
Improper electrical fitting!
Risk of death or injury by asphyxiation, electrocution, or burn by electrical fire.

- ▶ Observe electrical diagram specifications.
- ▶ Observe the tightening torques.



DANGER
Improper pipe fitting - Release of flammable fluids!
Risk of death or injury by burn, asphyxiation, or direct fluid injection.

- ▶ Observe the tightening torques.
- ▶ Observe the clamp installation specifications.

NOTICE
Improper electrical fitting!
Property damage - Risk of destruction of the engine or the machine by electrical fire, signal loss, or control system error.

- ▶ Respect electrical diagram specifications.
- ▶ Respect the tightening torques.

NOTICE
Contact failure at the control connections!
Property damage - Risk of control system error or signal loss.

- ▶ Respect the connector specifications.
- ▶ Respect the tightening torques.



The application owner must apply the following requirements:
- Before receiving the engine, the responsibilities and the definition of the safe conditions have to be established by the application owner.
- Only trained and instructed operators expressly authorized to do so must install, operate, maintain, or repair the engine and the application.
- Only allow operators who have been trained, instructed, or are present for training purposes, to work on the engine or the application under constant supervision of an experienced supervisor.

Organization commitments for the application owner:
- The Operation and Maintenance Manual of the engine has to be at the operator's disposal until the commissioning of the application. Afterwards the Operation and Maintenance Manual has to be a part of operator's manual of the manufacturer of the application.
- Familiarize yourself with the Operation and Maintenance Manual of the application before commissioning the machine.
- Develop, document, implement, and enforce a safety and health program, adapted to the application and its environment, and comply with the local regulations or at least with the International Labour Organization Standards.
- Make sure that operators are conscious of safety and hazards involved in their work and that they regularly check the Operation and Maintenance Manual of the application. This is especially to be repeated for the operators which occasionally operate the application.

NOTICE
Use of non-compliant operating fluids!
Property damage - Risk of critical engine failure.

▶ Use only operating fluids tested and approved by Rehlko.

NOTICE
Use of non-original spare parts!
Property damage - Risk of critical engine failure.

▶ Use only original spare parts approved by Rehlko.

▶ The use of original spare parts guarantees the compliance with the technical requirements established by the engine manufacturer Rehlko.

2.4.1.1 Lockout/tagout (LOTO)

Lockout/tagout (LOTO) is an isolation process that protects workers from exposure to the unintentional or inadvertent release of hazardous energy (electrical energy, mechanical potential energy, etc.).

The LOTO process helps prevent:
- Contact with a hazard while performing tasks that require the removal, bypassing, or deactivation of safe guarding devices.
- Unintended release of hazardous energy (stored energy).
- Unintended start-up or motion of application, equipment, or processes.

Lockout/tagout (LOTO) procedure

The **lockout** process involves the installation of a lockout device (for example, a padlock) on an isolation device (for example, a circuit breaker or a line valve) to isolate energy by engaging a position that prevents system energization.

Tagout is a labeling process that is always used when lockout is required. The tagout process involves the use of informative labels (usually a standardized label).

Generally, the LOTO procedure includes:
1. Identifying which energy sources are present and must be controlled.
2. Informing all affected employees of the LOTO process.
3. Proceeding to shut down the system, ensuring that all moving parts have completely stopped (→ 4.3.1 Shutting down the engine, p. 82).
4. Isolating the system from hazardous energy using lockout devices.
5. Dissipating any residual or stored energy.
6. Making sure that the lockout device cannot be removed and that the system cannot be operated inadvertently.
7. Tagging out the system by attaching or using an information tag or indicator.

8. Verifying isolation by visually inspecting the system and engaging or activating system controls (push buttons, switches, etc.).
9. Completing the activity that required the LOTO process to be started.
10. Making sure that all tools and items have been removed before removing LOTO devices.

DANGER
Failure to observe safety notes!
Risk of death or injury.

- ▶ Observe local regulations, site rules, and safety notes.
- ▶ In doubt, immediately seek advice from a competent person (for example, safety officer, supervisor).

2.4.2 Safety when starting

DANGER
Hazards by entanglement, trapping, ejection of parts or impact.
On starting and while operation, hazards by entanglement, trapping, impact by ejection of parts will result in death or serious injury.

- ▶ The engine shall not be started until the drive train has been connected to the flywheel.
- ▶ Ensure the integrity of the machine and the engine before starting.
- ▶ All openings must be closed and the safe conditions established by the manufacturer of the machinery must be fulfilled.
- ▶ Standing in the vicinity of the engine while starting or operating the manufacturer's machinery is forbidden.

DANGER
Crushing, ejection of parts or high-pressure fluid ejection hazards.
Fatal or serious injuries.

- ▶ Standing in the vicinity of the engine while starting or operating the machinery of the manufacturer is forbidden.
- ▶ Wear proper personal protective equipment.

NOTICE
Engine failure by starting the engine over an altitude of 2000 m (6,561.68 ft).
Risk of property damage.

- ▶ Before starting the engine, call Rehlko – customer service.

WARNING
Hazards generated by exposure to environments temperatures.
Exposure to radiant heat sources in the engine compartment could result in death or serious injuries.

- ▶ The manufacturer of the machinery shall define the appropriate ventilation of the engine compartment.
- ▶ The manufacturer of the machinery shall define the appropriate insulation of the exhaust pipe and the engine compartment.
- ▶ Wear proper personal protective equipment.
- ▶ Wait until the environment of the engine and the engine itself have cooled down.



WARNING
Hazards due to high sound level.
Exposure to high sound level could result in death or serious injuries by hearing loss or other physiological disorders (e.g. loss of balance, loss of awareness).

- ▶ Wear proper personal protective equipment in the vicinity of the engine.
- ▶ Noise reduction systems adapted to the machinery should be designed by the manufacturer, to comply with the local regulations.



WARNING
Hazards generated by excessive vibrations.
Vibrations generated by the engine could result in death or serious injuries.

- ▶ Standing in the vicinity of the engine while starting or operating the equipment is forbidden.



WARNING
Hazards generated by materials and substances processed, used or exhausted by machinery for example.
Materials and substances processed, used or exhausted could result in death or serious injuries by intoxication or poisoning.

- ▶ The manufacturer of the machinery shall design and implement an adapted extraction system.
- ▶ Wear proper personal protective equipment.



DANGER
Ejection of parts due to moving parts.
Fatal or serious injuries.

- ▶ Standing in the vicinity of the engine while starting or operating the manufacturer's machinery is forbidden.
- ▶ Starter activation for service without engine start, e.g. for fuel injection system, must not operate longer than a maximum of 3 cycles lasting 30 seconds each, and with a minimum of 30 seconds between each starter activation.
- ▶ Wear proper personal protective equipment.

NOTICE
Engine failure by non-compliant starting procedure.

- ▶ Unless otherwise instructed, start the engine according to the instructions in the instructions manual of the machinery.
- ▶ Ensure that the engine is started after all display units and control devices have been checked.
- ▶ Ensure that the engine is only running in an enclosed space and sufficient ventilation is available.
- ▶ Ensure that all devices used to ensure evacuation of stagnant air and ensure air supply are functional.



WARNING
Ejection of parts and impact hazards by missing guards on rotating or drive sytem.
On starting and while operation, accessing to the engine could cause serious injury or death by ejection of parts and impact on human body.

- The manufacturer of the machinery shall observe and enforce the country-specific regulations regarding prevention of injuries and risks.
- The manufacturer of the machinery shall define the appropriate guards according to the country-specific regulations regarding ergonomics-related hazards, for the entire life-cycle of the machinery.
- Standing in the vicinity of the engine while starting or operating the machinery is forbidden.
- Wear proper personal protective equipment.

2.5 Preventing injuries

2.5.1 Preventing bruising



WARNING
Hazards by moving parts.
Impacts by ejected objects coming into contact with moving parts could result in death or serious injuries and property damage.

- ▶ When the engine is running, avoid any contact with moving parts.
- ▶ It is forbidden to throw any object into the engine while running.

2.5.2 Preventing burns



WARNING
Contact with hot parts!
Risk of injury by burn.
The Engine Control Unit (ECU) is hot while operating the engine.

- ▶ Observe local regulations, site rules, and safety notes.
- ▶ When the engine is in operation, avoid any contact with the ECU.
- ▶ Before servicing the engine, let it cool down until the surface temperature allows you to touch it with bare hands.
- ▶ Wear proper personal protective equipment.



DANGER
Contact with high temperature released operating fluids: fuel, engine oil, or coolant!
Risk of death or injury by scald.

- ▶ Before servicing the engine, let it cool down until surface temperature allows you to touch it with bare hand.
- ▶ Wear proper personal protective equipment.

2.5.3 Preventing fires and explosion hazards



DANGER
Fire or explosion by flammable and explosive lubricants and fuels.
Burns or explosion release will result in death or serious injury.

- ▶ Keep all caps and valves closed near the operating temperature.
- ▶ Avoid any contact of flammable and explosive operating fluids, gases or combustible materials with any hot surface or ignition source.
- ▶ Keep the engine clean and free from accumulation of dust and flammable liquids.
- ▶ Keep the insulation free of operating fluids contamination.
- ▶ Never release operating fluids while operating the engine.
- ▶ Check the electrical system. Immediately rectify all errors, such as loose connections and frayed cables.
- ▶ During refueling, switch off any additionally installed heater (optional).
- ▶ Lock out and tag out the engine prior to accessing to engine.
- ▶ Ensure a good ventilation while refueling or prior to accessing to the engine.
- ▶ Regularly check all lines, hoses and screw connections for leaks and damage. Immediately rectify the leaks and replace the damaged parts.
- ▶ Smoking and open flames are forbidden in the vicinity of the engine.
- ▶ Always start the engine according to the instructions in the instructions manual of the machinery.



DANGER
Fire or explosion by ignition of the air/gas mixture in the air intake, initiated by electrostatic charging from insulated mounting.
Burns or explosion release will result in death or serious injury.

- ▶ Ground every component potentially electrically insulated from the engine, especially the turbocharger.



Note

According to local regulations, the manufacturer of the specific application is responsible for designing adapted fire protection system.



Note

Engines provided by Rehlko are not intended to be used in potentially explosive atmospheres according to Directive 2014/34/EC.

2.5.4 Preventing intoxication and poisoning hazards

WARNING
Hazards by operating fluids and exhaust gases emissions.
Exhaust gases emissions increase the likelihood of cancers and could result in death or serious injury.
Operating fluids generate toxic gases and emanations and could result in death or serious injury.

- ▶ Ensure a good ventilation while running or refueling the engine.
- ▶ In case of doubt, apply any means to ensure evacuation of personnel and stale air, ensure air supply and ventilation.
- ▶ Respect the local health and safety regulations, the material safety data sheets (MSDS) and the instructions manual of the manufacturer's machinery.
- ▶ Avoid any contact with additives, operating fluids, gases, battery acid and fumes and acid condensate in charge air or exhaust system, especially by inhalation.
- ▶ Regularly check the exhaust gas circuit and turbochargers.
- ▶ Immediately rectify the errors and replace the damaged parts. Safety instructions of the fluids have to be considered.

2.5.5 Preventing electrical hazards

WARNING
Hazards by electrical shocks.
Contact with live conductor could result in death or serious injury.

- ▶ Access to live parts shall only be possible with voluntary action.
- ▶ Proceed to lock out and tag out prior to accessing to the engine.
- ▶ Respect the voltage indication of the engine technical data sheet.
- ▶ Check the grounding connection to avoid any risk of electrical arc.
- ▶ Observe the local safety regulations that apply to the machinery.

2.5.6 Preventing noise hazards

CAUTION
Increased hazards by drowned out warning sounds and high sound pressure level.
Exposure to drowned out warning sounds and high sound pressure level could result in minor or moderate injuries by hearing loss or other physiological disorders.

- ▶ Wear proper personal protective equipment where applicable.
- ▶ Noise reduction systems adapted to the machinery must be designed by the manufacturer, to comply with the local regulations.
- ▶ In case of abnormal noises, rectify it immediately.

2.5.7 Preventing vibrations hazards

CAUTION
Hazards by exposure to vibrations.
Vibrations, by their acceleration, intensity, frequency and duration of exposure, could affect the health of personnel through vascular, neuro-sensory or musculoskeletal disorders, could result in minor or moderate injuries and cause property damage.

- The manufacturer of the machinery must design adapted dampering to comply with the local legislation.
- In case of abnormal vibration noises, identifiy and rectify immediately.

2.5.8 Preventing electro-magnetic hazards

WARNING
Harzards by electromagnetic field and pulse generated by the engine starting and speed variations.
Exposure to electromagnetic fields could result in death or serious injury.

- The manufacturer must ensure the conformity of its machinery to the current Electromagnetic Compatibility (EMC) Directive.
- Observe the safety regulations that apply to the machinery.
- Avoid any electromagnetic sensitive devices in the vicinity of the engine, especially artificial health assist devices.

2.5.9 Preventing falling risks

CAUTION
Hazards by slipping and falling.
Climbing on the engine or leaks could result in minor or moderate injuries by slip and fall.

- Climbing on the engine is prohibited.
- Perform visual inspections for leaks or damage.
- In case of leak, correct deficiencies discovered immediately, clean and dry the operating fluids contaminated area.
- The manufacturer of the machinery must provide adapted stairs and gangways to work in safe conditions.

2.5.10 Safety instructions for the fuel system

DANGER
Hazards due to flammable fluids under high pressure.
When the engine is running, the fuel lines are under a constant pressure of up to 2000 bar (29,007.40 psi).
Fuel escaping under pressure can penetrate the skin or vaporize and explode when an ignition source is present, which will result in death or serious injury.

- Never release the screws on the fuel circuit, especially between the high-pressure pump and the injector when the engine is running.
- Before starting any task on the fuel system, ensure the build-up pressure in the circuit has been released, and the temperature of the engine has cooled down.
- Keep the engine away from heat, sparks, open flame, or any other ignition source.

2.6 Personal Protective Equipment (PPE)

WARNING
Risk of injuries by not wearing of personal protective equipment.
Missing, non-adapted, altered or misuse of personal protected equipment may accentuate the severity of injuries and could result in death or serious injuries.

- ▶ The manufacturer of the machinery shall define the safe conditions, including the personal protective equipment to wear before starting to work on the engine.
- ▶ The manufacturer of the machinery shall forbid any accessories and loose clothing.

The following personal protective equipment is necessary:

Sign (ISO 7010)	Description
	**Protective work wear** Protection against objects and chemical splashes Must be worn in the direct vicinity of the engine
	**Safety helmet** Protection against falling/flying objects and against head injuries Must be worn in the direct vicinity of the engine
	**Safety shoes** Protect feet against falling objects and from entanglement. Additional protection against slipping Must be worn in the direct vicinity of the engine
	**Safety gloves** Protection against hot elements and chemicals Must be worn when handling hot parts, chemicals, operating fluids
	**Hearing protection** Protection against noise Must be worn in the direct vicinity of the engine
	**Safety goggles** Protection against flying objects and chemical splashes Must be worn when handling operating materials and during mechanical operations

Tab. 11: Personal protective equipment

2.7 Accessible areas

2.7.1 Engine ready for use or in operation

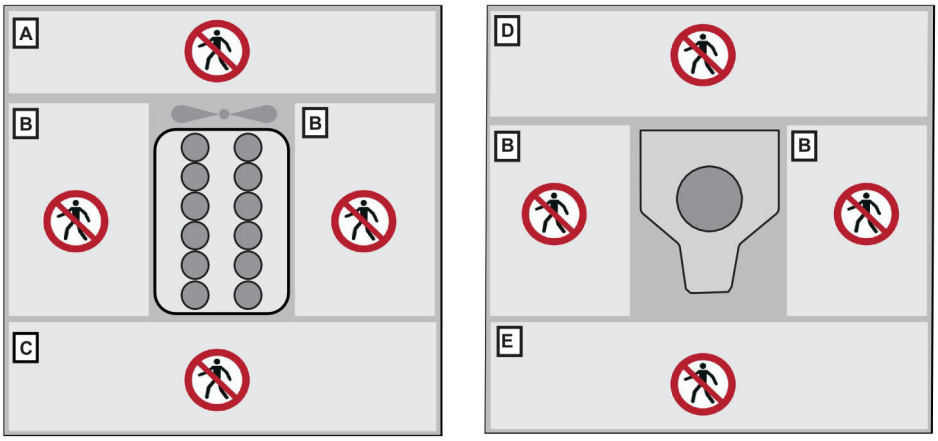


Fig. 27: Areas in operation – view from above and driving end

Access to the following areas is forbidden:

A Engine free end
B Engine sides
C Engine driving end
D Above the engine
E Below the engine

2.7.2 Engine in lockout/tagout or in low idle speed

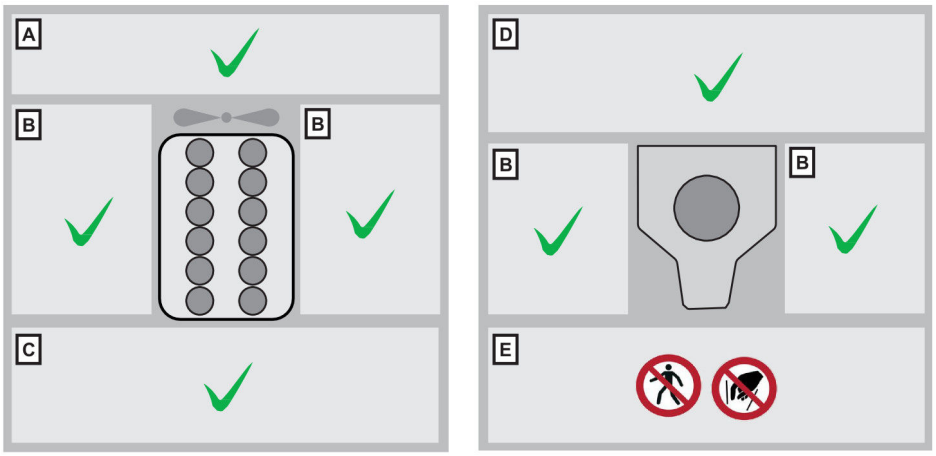


Fig. 28: Engine areas in lockout/tagout or in low idle speed – view from above and driving end

Access to the following areas for commissioning and test run tasks is permitted:

A Engine free end
B Engine sides
C Engine driving end
D Above the engine

Access to the following areas is forbidden:

E Below the engine

2.7.3 Low idle conditions

For commissioning and test run tasks only!

DANGER
Hazards by entanglement, trapping, ejection of parts or impact.
On starting and while operation, hazards by entanglement, trapping, impact by ejection of parts will result in death or serious injury.

▶ Standing in the vicinity of the engine while starting or operating the manufacturer's machinery is forbidden.

Only proceed with commissioning and test run tasks under the following conditions:
- Constant low idle speed
- Constant supervision of an experienced supervisor
- Constant visual contact of a mechanical engineering technician
- Immediate vicinity of an emergency stop

Note

Accessing or standing in the vicinity of the running engine is considered as foreseeable misuse. In this case, Rehlko is not liable for any damage or injuries. The risk is borne solely by the user.

Note

The low idle condition is defined by:

Engine speed < 800 min^{-1}

Engine load < 10%

Only personnel authorized by the manufacturer of the machinery may access the engine room or compartment.

The following rules and conditions shall be established by the manufacturer of the machinery according to the application:
- The "General Safety Instructions" are fulfilled. (→ 2.4.1 General safety instructions, p. 45)
- All local safety conditions are defined and fulfilled.
- The low idle speed is engaged.

2.7.4 Emergency stop

Note

The manufacturer of the application is responsible for defining the risks and danger sources, and the solutions to reduce them.

Emergency stops must withstand the operating conditions and remain visible and legible throughout the lifecycle of the engine.

Additional emergency stops and measures according to project standards and local regulations and standards are possible.

The emergency stop button and signals, as well as the acknowledge buttons, are described in the generator set manual.

NOTICE
Misuse of emergency stop!
Property damage - Risk of engine damage.

▶ Use the emergency stop only in emergency situations (emergency stop is not a normal stop).

Initiating an emergency stop:

▶ Press the emergency stop button.

After an emergency stop:

▶ Remedy to the emergency situation.

▶ Acknowledge the emergency stop button and signals.

2.7.5 Signage recommendations

Note

The machinery owner is responsible for marking the hazardous areas and the fail-safe devices.

The signs must withstand the ambient conditions, and be kept visible and legible during the entire life cycle.

Additional signs and measures according to project standards and local regulations and standards are possible. For example: the signs for the United States market shall comply with ANSI Z535.4.

The following warning signs must be clearly visible and mounted in the accessible areas:

Sign (ISO 7010)	Description
	ISO 7010/W012 – Warning sign - Electricity Death or serious injury due to electrical shocks!
	ISO 7010/W017 – Warning sign - Hot surface Severe injuries due to hot surfaces!
	ISO 7010/W025 – Warning sign - Counterrotating rollers Severe injuries due to drawing-in movement!
	ISO 7010/M002 – Mandatory action sign - Refer to instruction manual/booklet In order to ensure that all residual risks are known by the personnel, the system documentation must be read and understood. Make sure that all residual risks according to the risk assessment are reflected in the system documentation. Provide documentation to the personnel according to the “Target audience”.

Tab. 12: Engine area signs requirement

2.8 Prevent property damage

2.8.1 Safety instructions for engine control unit (ECU)

Note

If necessary, please contact Rehlko after sales service.

Note

The integrator of the specific application is responsible for designing adapted eletrical system keeping the supply voltage higher than 12 V, even with voltage dip.

NOTICE
Improper installation or misuse of the engine leads to ECU damage.
Property damage due to non-compliant installation or operation.

- ▶ Ensure the connection to power supply before starting the engine.
- ▶ It is prohibited to disconnect the electrical power supply during operation.
- ▶ Ensure the connection of the ECU before starting the engine.
- ▶ Using a rapid charging device to start the engine is prohibited. Only jump start with separate batteries is allowed.
- ▶ Electrical welding in the vicinity of the engine is forbidden, especially near the ECU.
- ▶ Switch off the electrical system before connecting or disconnecting the ECU. Apply to the prescribed tightening torque to tighten the fixing screws of the interface plugs. The manufacturer of the machinery has to provide an electrical disconnect.
- ▶ Reversing the polarity of supply voltage results in the ECU destruction.
- ▶ Apply to the prescribed torque to tighten the connections to the injection system.
- ▶ Extreme engine compartment temperatures will damage the ECU. Please refer to the technical data sheet for temperatures values.
- ▶ Use suitable test cables to ensure the measures at plug connectors.
- ▶ Connecting the sensors or actuators individually to or between external voltage sources for testing purposes is prohibited. Risk of destruction or malfunction of the engine. Connect the sensors or actuators to the ECU.
- ▶ Mount and fix the mating connectors to protect the ECU against dust and moisture. When the mating connectors are dismounted, ensure protection of the ECU against dust and moisture by protective covers.
- ▶ Using mobile phones and wireless devices in the vicinity of the engine is prohibited. Risk of malfunction of the ECU and the engine.

2.8.2 Alarm conditions

CAUTION
Neglect of error codes!
Neglecting error codes may lead to engine failure and could result in injuries.

The engine is equipped with an Engine Control Unit (ECU) which monitors both the engine and itself (self-diagnosis). When detecting a fault, the ECU initiates the following actions: generation of an error code; in combination with the application diagnosis system, display of a fault message; if required, activation of automatic protection mode of the engine.

▶ Take immediate recommended actions.

▶ Make sure that authorized service personnel correct the defect.

Note

The application owner is responsible for implementing and enforcing emergency procedures to be followed in the event of accident or operating fault, according to the messages and codes displayed (recommended actions).

The ECU generates the signals and error codes for the engine.

The messages and codes are displayed on the generator set display.

See the application manual for more details.

2.8.3 Cleanliness standards and safety

NOTICE
Property damage due to neglect of cleanliness standards!
Modern components, especially the injection system, consist of high precision parts that are subject to extreme loading.
Dirt particles of 20 µm (0.79 thou) or greater can result in component outages. Due to this high precision engineering, maintain a high standard of cleanliness for all tasks.
Before and while performing any task, observe the following precautions:

- ▶ Ensure a clean area, free of stirred up dust by air movements.
- ▶ Perform visual inspections for leaks or damage.
- ▶ Before starting any task on the closed fuel system, clean the engine and its compartment with lint free tissue.
- ▶ Ensure that waterproof covers are on the electrical components.
- ▶ Do not direct steam jet at electrical components or their covers.
- ▶ Clean and dry the area around the still closed fuel system with compressed air.
- ▶ Remove loose dirt particles such as paint chips and insulation material with suitable equipment.
- ▶ Cover the areas of the engine compartment which could produce dirt particles with a new and clean covering film.
- ▶ Before beginning the dismantling work, wash hands and put on fresh personal protective equipment.
- ▶ Clean tools and working materials.
- ▶ Perform work on components at a suitably equipped workplace.
- ▶ Use only undamaged tools.
- ▶ After opening the fuel system, the use of compressed air for cleaning is prohibited.
- ▶ Remove any loose dirt during installation work with suitable equipment.
- ▶ Remove any paint chips before loosening or tightening any connections.
- ▶ Use only lint-free cloths.
- ▶ Use particle and fiber-free materials.
- ▶ Immediately seal the opened connection with sealing caps.
- ▶ Keep the sealing material in dust-free packaging until use and dispose of it after single use.
- ▶ Place the components into a clean, sealed container.
- ▶ Never use contaminated cleaning or testing fluids.
- ▶ Remove new components from the original packaging immediately before use.
- ▶ Use the original packaging of the new parts to ship removed parts.

2.9 Disposal and environment protection

2.9.1 Engine disposal

The dismantling must be carried out or supervised by a trained and qualified staff.

Prepare the dismantling as follows:

- ▶ Clarify the means and quality of the dismantling procedure according to local regulations.
- ▶ Disconnect the electrical power supply.
- ▶ Remove any electronic control or electrical connections.
- ▶ Drain all fluids.
- ▶ Remove any coolant, lubricants, and fuel connections.
- ▶ Collect and dispose of waste, coolant, lubricants, and fuel.
- ▶ Disassemble the component or engine according to general mechanics procedures.

2.9.2 Components disposal



CAUTION
Environmental and health hazards by incorrect disposal.
Incorrect waste disposal leads to environment and water supply pollution and could result in minor or moderate injuries by hazards from related actions.

- ▶ Observe the country-specific regulations regarding environmental protection when disposing of scrap materials.
- ▶ Before disposing or recycling waste products, ask for the correct method at the responsible environmental or recycling center.
- ▶ When handling waste, lubricants and fuel make sure that none is disposed into the environment.
- ▶ Collect and dispose waste, lubricants and fuel in separate, suitable, properly designated containers.
- ▶ Use adapted leak-proof containers to drain lubricants and fuel. Use of food or drink containers is prohibited.
- ▶ Dispose all scrap materials only at official locations in an environment-friendly manner.

Dispose of the components for recycling according to the categories as follows:
- Steel and iron
- Aluminum
- Non-ferrous metal
- Insulating material
- Cables and wires
- Electrical waste
- Plastics
- Lubricants and greases
- Fuels
- Coolant
- Paint residue
- Cleaning agents
- Lint-free cloths

2.9.3 Packaging material disposal

Note

Use the original packaging of the new parts to ship removed parts.

Recover packaging material as follows:
- Wood, impregnated wood
- Packaging foils
- Board
- Tinplate
- Adhesive tape
- Contaminated packaging materials

3 Handling - Transportation - Storage

Note

The manufacturer of the application is responsible for lifting, handling, and storing the engine.

The storage concrete foundation shall have a sufficient load capacity.

3.1 Safe handling

DANGER
Fall or swing of heavy load from crane or lifting device!
Risk of death or injury by crush or impact.

- ▶ Observe local regulations, site rules, and safety notes regarding lifting.
- ▶ Make sure that the people stay away from the lifting operation.
- ▶ Make sure that only trained and authorized riggers rig, lift, move, and land loads.
- ▶ Make sure that all the people involved in the lifting operation (riggers, crane operators, watchmen, etc.) set up the right means of communication before starting the lifting.
- ▶ Make sure that the whole equipment (slings, lifting eyes, chains, or lifting ropes, cranes, etc.) used for the lifting operation is in good condition and appropriate regarding the load characteristics.

DANGER
Slip of heavy load from transported level!
Risk of death or injury by crush or impact.

- ▶ Make sure that any loose part of the load is fixed or removed.
- ▶ Make sure that the transportation vehicle is appropriate.
- ▶ Make sure that people stay away from the transportation vehicle.
- ▶ Make sure that the rigger knows the location of the center of gravity and the total weight of the load.
- ▶ Make sure that the load is properly secured against slipping and toppling.

NOTICE
Fall or swing of heavy load from crane or lifting device!
Risk of property or engine damage.

- ▶ Observe local regulations, site rules, and safety notes regarding lifting.
- ▶ Make sure that only trained and authorized riggers rig, lift, move, and land loads.
- ▶ Make sure that all the people involved in the lifting operation (riggers, crane operators, watchmen, etc.) set up the right means of communication before starting the lifting.
- ▶ Make sure that the whole equipment (slings, lifting eyes, chains or lifting ropes, cranes, etc.) used for the lifting operation is in good condition and appropriate regarding the load characteristics.

NOTICE
Slip of heavy load from transported level!
Risk of property or engine damage.

- ▶ Make sure that any loose part of the load is fixed or removed.
- ▶ Make sure that the transportation vehicle is appropriate.
- ▶ Make sure that the rigger knows the location of the center of gravity and the total weight of the load.
- ▶ Make sure that the load is properly secured against slipping or toppling.

NOTICE
Shock or bump against the engine!
Property damage - Risk of engine damage.

- ▶ Make sure that the transportation or lifting devices are appropriate.
- ▶ Avoid any abrupt movement during transportation or lifting.
- ▶ After unhooking the engine, move away the transportation or lifting devices and chains.

Note

Several suitable lifting devices are available.

Follow the instructions manual of the hoisting beam, handling devices, and local safety regulations.

Should you have any queries, please contact your nearest authorized Discovery Energy, LLC and its affiliates dba Rehlko service representative.

3.2 Dimensions and weight

Note

The manufacturer of the application is responsible for the lifting, handling, and storage of the engine.

For the latest engine dimensions and weights, refer to the “Installation Drawing” (→ 8 Appendix, p. 230).

WARNING
Crushing, impact, shearing, part ejection hazards by load movement or lifting devices failure.
Guiding the moving load by hand could cause serious injury or death by crushing or shearing.
Lifting the entire machinery could cause serious injury or death by crushing, impact, or parts ejection.
Falling load could cause serious injury or death by crushing, impact, or parts ejection.
Failure of lifting devices could cause serious injury or death by ejection of parts, crushing, and impact.

- ▶ It is forbidden to guide the load by hand.
- ▶ Use the lifting hooks to lift the engine only.
- ▶ Use only adapted lifting devices in good shape.
- ▶ Check and replace the lifting devices according to local regulations.
- ▶ Respect a safe distance while lifting and moving the load.
- ▶ It is forbidden to pass under the load.

NOTICE
Falling/hanging lifting devices on the engine.
Falling/hanging lifting devices could result in property damage by impacts or tearing.

- ▶ Check and replace the lifting devices according to local regulations.
- ▶ Move the lifting devices near the engine cautiously.

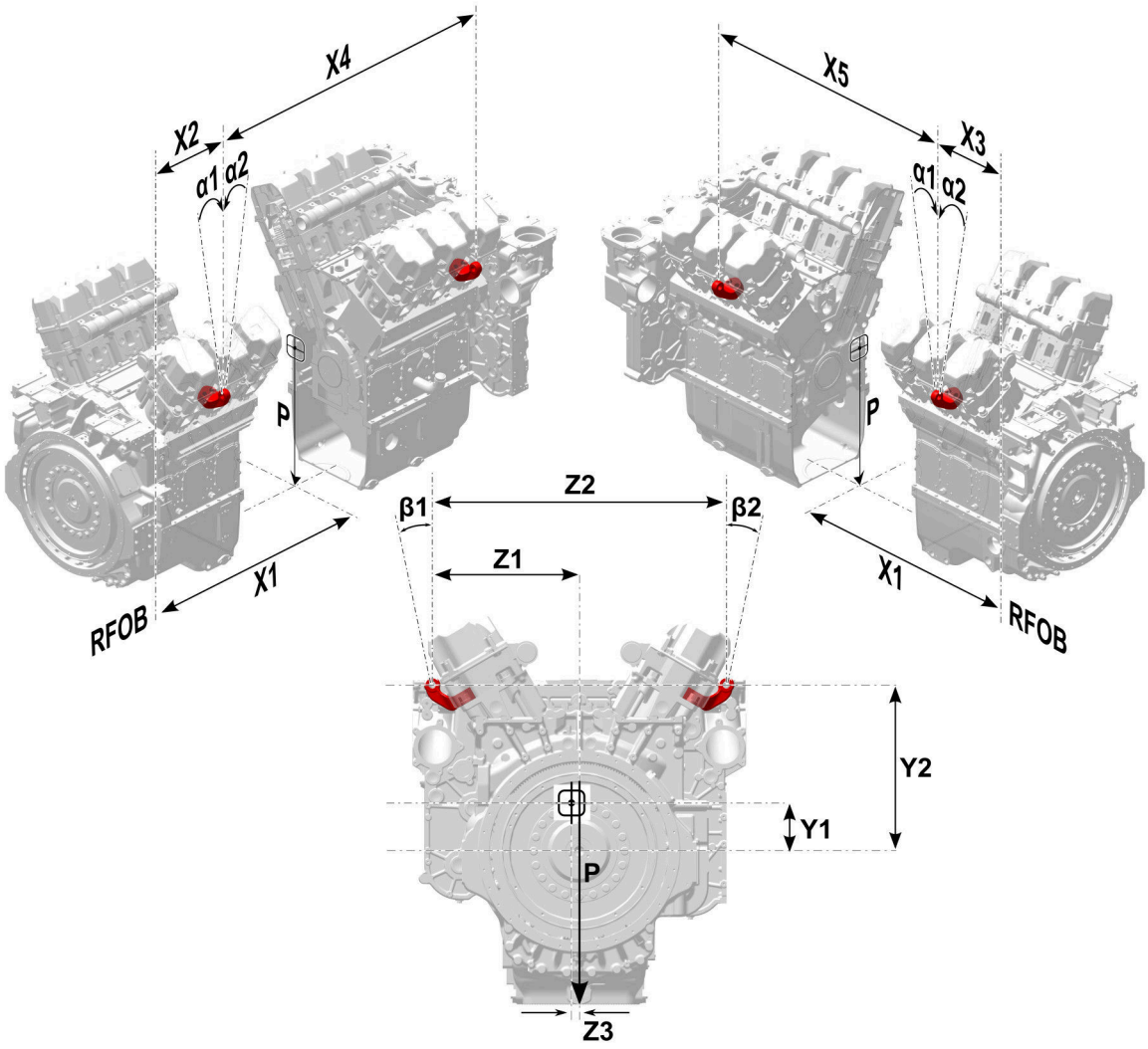


Fig. 33: Dimensions and weight of engine

Note

▶ RFOB stands for “Rear Face of Block”.

Designation	Ref.	Dimensions
Overall length		3637 mm (11.93 ft)
Overall width		1743 mm (5.72 ft)
Overall height		2174 mm (7.13 ft)
From RFOB to center of gravity	X1	1442.9 mm (4.73 ft)
From RFOB to lifting point - right side	X2	594 mm (1.95 ft)
From RFOB to lifting point - left side	X3	545 mm (1.79 ft)
Distance between engine lifting points - right side	X4	1820 mm (5.97 ft)
Distance between engine lifting points - left side	X5	1560 mm (5.12 ft)

Designation	Ref.	Dimensions
Axis to center of gravity	Y1	323.5 mm (1.06 ft)
Axis to lifting point	Y2	729 mm (2.39 ft)
From axis to lifting point	Z1	645 mm (2.12 ft)
Distance between engine lifting points	Z2	1290 mm (4.23 ft)
Axis to center of gravity	Z3	14.3 mm (0.56 in)
Maximum weight	P	13500 kg (29,762 lb)
Maximum angles of lifting devices – side view	α1–α2	15°
Maximum angles of lifting devices – front view	β1–β2	15°

Tab. 13: Dimensions and weight of engine - values

3.3 Lifting device

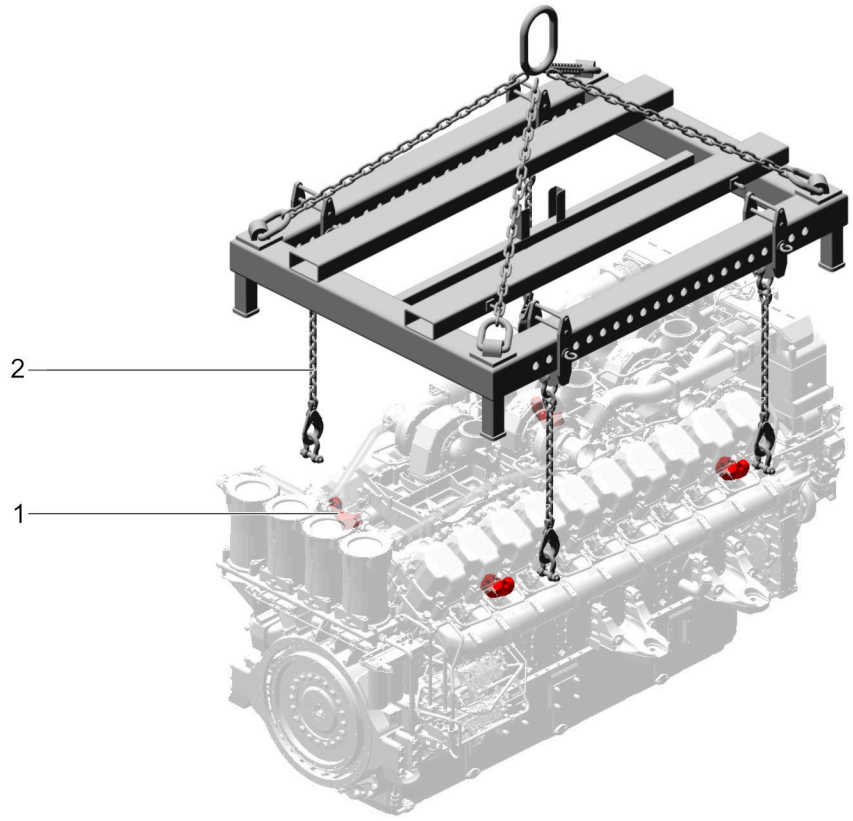




Fig. 34: Example of fixing the lifting device on the engine

1 Lifting hook

2 Lifting beam

3.4 Diesel engine storage

3.4.1 Storage, transportation, and duration definitions

We define four severity categories for transportation and storage:
- A: Light-duty
- B: Medium-duty
- C: Heavy-duty
- D: Very-heavy-duty

We define three categories for storage duration:
- Short-term
- Midterm
- Long-term

3.4.1.1 Storage

Note

D category storage (open air or under cover storage) is prohibited.

We consider the following categories for storage conditions:

Atmosphere	Storage site	Storage category in climatic region			
		Temperate	Cold	Tropical	
				Dry	Humid
Rural, Forest, Mountain	Closed-unheated[A)] storehouse	B	B	A	C
	Air-conditioned storehouse[B)]	A	A	A	A
Industrial	Closed-unheated[A)] storehouse	B	C	B	C
	Air-conditioned storehouse[B)]	A	A	A	A
Coastal	Closed-unheated[A)] storehouse	C	C	-	C
	Air-conditioned storehouse[B)]	A	A	-	A

Tab. 14: Storage categories

A) The storehouse should be frost-free.
B) The relative humidity in an air-conditioned storehouse should not exceed 70%.

3.4.1.2 Transportation

Note

D category transportation (ship deck at sea) is prohibited.

We consider the following categories for transportation conditions:

Transport	Transportation condition	Category
Land	On platform car or in open truck	C
	In rail wagon or in closed truck	B
River	In the hold or on deck with measures to prevent penetration of water	B
Sea	On ship deck with measures to prevent penetration of water	D
	In ship hold	C
Air	-	B

Tab. 15: Transportation categories

3.4.1.3 Duration

We consider the following categories for storage durations:

Duration designation	Period
Short-term	1 month < T < 3 months
Midterm	3 months < T < 12 months
Long-term	12 months < T < 24 months

Tab. 16: Storage durations

3.4.2 Initial packaging

Discovery Energy, LLC and its affiliates dba Rehlko diesel engines are usually delivered in one of these three packagings:
- Standard freight packaging suitable for B transportation, B storage, and midterm duration
- Marine freight packaging suitable for C transportation, B storage, and long-term duration
- Multimodal freight packaging suitable for C transportation, B storage, and long-term duration

Note

We recommend keeping the diesel engine in its original packaging as long as possible.

We recommend unpacking the diesel engine only when everything is ready for its integration in the application or its represervation.

3.4.2.1 Standard freight packaging

This packaging allows diesel engine transportation by road or train (B category transportation).

We prepare the drained diesel engine by adding anti-corrosive products in the coolant and lubricating oil systems. We spray protective products on unpainted surfaces and place some desiccant bags at the required spots. We then lay the diesel engine on a wooden pallet and wrap it in foils impregnated with volatil corrosion inhibitor (VCI) then protective stretchable film.

This packaging allows storage up to 12 months in an air-conditioned storehouse (B category storage).

3.4.2.2 Marine freight packaging

This packaging allows diesel engine transportation by road, train, or boat (C category transportation).

We prepare the drained diesel engine by adding anti-corrosive product in the coolant and lubricating oil systems. We spray protective products on unpainted surfaces and place some desiccant bags at the required spots. We then lay the diesel engine on a wooden pallet and wrap it with protective foam (to prevent perforations) then heat-sealable aluminum foil. We vacuum the formed cover then seal it air-tight.

We protect the whole in a wooden crate, suitable for marine transportation. This crate can be handled from the bottom with adequate forklift trucks.

This packaging allows storage up to 24 months in an air-conditioned storehouse (B category storage).

3.4.2.3 Multimodal freight packaging

This packaging allows diesel engine transportation by road, train, or boat (C category transportation).

We prepare the diesel engine the same way as for the marine freight packaging.

However, the crate is designed and reinforced to allow its handling either with adequate forklift trucks or by lifting it with slings.

This packaging allows storage up to 24 months in an air-conditioned storehouse (B category storage).

3.4.3 Preservation

▶ After dismantling of the machinery and dismounting of the engine, preserve, pack, and store the engine according to the following standards:
– ISO 6749 - Earth-moving machinery - Preservation and storage
– EN ISO 780 - Packaging - Pictorial marking for the handling of goods

3.5 Unpacking and depreservation

3.5.1 Unpacking

CAUTION
Environmental and health hazards by incorrect disposal.
Incorrect waste disposal leads to environment and water supply pollution and could result in minor or moderate injuries by hazards from related actions.

- ▶ Observe the country-specific regulations regarding environmental protection when disposing of scrap materials.
- ▶ Before disposing or recycling waste products, ask for the correct method at the responsible environmental or recycling center.
- ▶ When handling waste, lubricants and fuel make sure that none is disposed into the environment.
- ▶ Collect and dispose waste, lubricants and fuel in separate, suitable, properly designated containers.
- ▶ Use adapted leak-proof containers to drain lubricants and fuel. Use of food or drink containers is prohibited.
- ▶ Dispose all scrap materials only at official locations in an environment-friendly manner.

CAUTION
Cutting or scratches hazards by contact with sharpen surfaces, tools or materials.
Contact with sharpen surfaces, tools or materials could result in minor or moderate injuries by cuts or scratches.

- ▶ Wear proper personal protective equipment.

Make sure that the following preconditions are met:
- ❑ Engine is stored close to the installation site.

Note

Unpack and depreserve the engine or delivered components shortly before the use or the installation.

- ▶ Cut and remove the packing tape.
- ▶ Open the packaging film and release the engine or component.
- ▶ Inspect visually and check for damage or deformations.
- ▶ Check for corrosions which impair function and strength.
- ▶ Check for abrasions, breaks, or dislocation of components, connections, and systems.
- ▶ Inspect lines and hoses and check for damage (chafe marks, cuts, tears), embrittlement of the outer layer (crack formation in the material), any deformations (swelling, crushing), non-compliant bends, delamination, blister formation.
- ▶ Check for damage or deformations to the fittings.
- ▶ Check for dislocation from the fittings.
- ▶ Leave all opening seals in place until connection.

In case of damage, observe the following steps:

- ▶ Register the date of unpacking.
- ▶ Contact your nearest authorized Discovery Energy, LLC and its affiliates dba Rehlko service representative.

3.5.2 Depreservation

After an extended storage period, observe the following procedures to bring the engine out of preservation status before putting it into service:

Engine oil system

- ▶ Drain the long-term storage engine oil (→ 5.8.2 Changing engine oil – SL1-2020, p. 148).
- ▶ Fill the engine oil system with factory approved engine oil (→ 5.8.2 Changing engine oil – SL1-2020, p. 148).
- ▶ Replace all engine oil filters (→ 5.8.4 Replacing spin-on oil filter – SL1-2110, p. 153), (→ 5.8.5 Inspecting and cleaning liner of centrifugal oil filter – SL1-2231, SL1-2232, p. 155).
  - ▷ The engine oil system is ready for operation.

Cooling system:

- ▶ Check coolant levels (→ 5.9.1 Inspecting cooling system overall condition – SL0-3011, p. 166).
- ▶ Replace coolant if necessary.
  - ▷ The engine cooling system is ready for operation.

Fuel system

- ▶ The corrosion inhibitor B0 fuel mixture can be run through the engine upon initial startup.
- ▶ Replace the mixture with an approved diesel engine fuel.
- ▶ Replace all fuel filters (→ 5.10.3 Replacing fuel main filter – SL1-4120, p. 176).
  - ▷ The engine fuel system is ready for operation.

Air system

- ▶ Check all air filters for damage and replace if necessary (→ 5.11 5000 - Combustion air and exhaust gas system, p. 180).

or

- ▶ Remove all air system covers, check that there is no debris in the intake system, and install new air filters (→ 5.11 5000 - Combustion air and exhaust gas system, p. 180).
- ▶ Remove all covers on exhaust mufflers, and check that there is no debris in the exhaust system.

or

- ▶ Remove all exhaust system covers, check that there is no debris in the exhaust system, and install the muffler/exhaust handling system.
  - ▷ The engine air system is ready for operation.

Combustion chambers

- ▶ No special instructions required.

External surfaces

- ▶ Remove the VCI film from the engine.
- ▶ Remove corrosion inhibitors from the engine with mineral spirits or according to the instructions.
- ▶ Check all belts and replace if necessary.

Note

If the engine has been in storage for longer than 3 years, all belts must be replaced.

▶ Check all belt pulleys for rust or pitting and clean or replace if necessary.
▷ Engine belts and pulleys are ready for operation.

Initial run after depreservation

Note

Engine components, particularly exhaust components, should be monitored closely during initial run after depreservation.

Smoke emissions are likely to happen, due to inhibitor remnants and mineral spirits burning off.

Once all engine fluids are checked or replaced with acceptable engine running fluids, observe the following start-up procedure:
- Connect all batteries and other electric connections that were disconnected before preservation.
- Perform engine over crank procedure.
  This procedure is critical as it will circulate oil throughout the engine and provide a prelubricating effect for the engine rotating components as well as pistons and overhead.
- Prime the fuel system.
- Run the engine at idle speed for 5 minutes.
- Check for leaks during operation.
- Shut down the engine.
- Check the engine for leaks in oil, fuel, and cooling systems.
- Run the engine at idle speed for 5 more minutes.
- Allow the engine to ramp up to rated speed after the idle timer finishes.
- After 15 minutes at rated speed, begin adding load to the engine.
- Add load in 20% increments until 100% load is reached. Maintain each interval for 15 minutes.
- Monitor the engine operation for issues.

3.6 Suspension of activity

The measures set herein are used for protection against engine corrosion damage when engine is installed and activity is suspended for up to 12 months.

Divergent measures must be coordinated with Rehlko.

▶ Fill with operating fluids. Respect the filling volumes. (→ 5.13.1 Filling volume, p. 198)

Note

▶ The delivered engine and components are ready for immediate use and do not require depreservation.

▶ In an environmentally friendly manner, reuse the packaging to send back the engine or other components.

▶ Clean the engine and remove any rust.

▶ Spray or apply corrosion inhibitor on unprotected parts. Recommended corrosion inhibitor is Rustilio DWX 30.

Note

▶ Do not spray the corrosion inhibitor on electrical connections.

▶ Follow the procedure for the suspension of activity in the Instructions of the application set.

To start engine after 12 months of suspension of activity:

▶ Follow the starting procedure according to the Instructions of the application set.

4 Control and operation

4.1 Starting the engine

DANGER
Contact with moving part!
Risk of death or injury by entanglement or impact of ejected part.

- ▶ Make sure that the drive train is connected to the flywheel before starting the engine.
- ▶ Start or operate the engine with covers and guards secured in place.
- ▶ Remove all tools or loose parts from the vicinity of the engine after a service activity.
- ▶ Keep tools away from the starting or running engine.
- ▶ When the engine is in operation, stay away from the engine.

DANGER
Fire or hotspot - Overheating of starter or prelube pump due to excessive run-time!
Risk of death or injury by asphyxiation or burn.

- ▶ Observe specified maximal consecutive start attempts.
- ▶ Stay away from starter or prelube pump after start attempt.

NOTICE
Fire - Overheating of starter or prelube pump due to excessive run-time!
Property damage - Risk of destruction of the machine or the engine.

- ▶ Observe specified maximal consecutive start attempts.

NOTICE
Use of non-approved lubricating oil!
Property damage - Risk of engine critical failure.

- ▶ Use an approved lubricating oil.(→ 5.13.3 Approved engine oils and engine oil additives, p. 203)

Make sure that the following preconditions are met:
❑ Operating fluids levels are correct.

4.1.1 Final check

Make sure that the following special tools are available:
– KODIA kit

Before starting the engine, carry out the following checks and top off with operating materials if necessary:

- ▶ Check the oil level.
- ▶ Check the coolant level.

Once the engine has started, carry out the following checks:

- ▶ Perform a visual check for any leaks in the lines.

- ▶ Check for KODIA error messages.
- ▶ Check for error messages on the generator set.

4.1.2 Starting in cold temperatures

WARNING
Hazards by use of starting aids containing ether.
Using starting aids containing ether could cause serious injury or death by inhalation of toxic gases.

- ▶ Using starting aids containing ether is forbidden.

Note

The additional retrofitting preheating devices are scope of the manufacturer of the machinery. For the connections dimensions provided, refer to the “Assembly Instructions" of your engine.

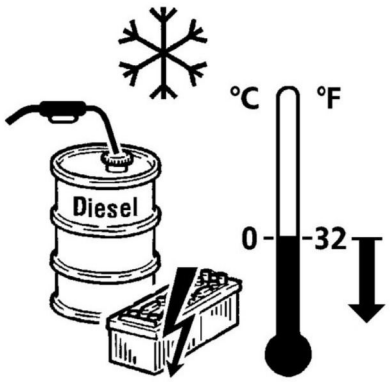


Fig. 35: Precautions at cold temperatures

The following precautions improve the starting performance at low temperatures.

- ▶ Check battery charging.
- ▶ Recharge battery if required.
- ▶ Use diesel fuel with sufficient flow properties.

4.2 Monitoring

4.2.1 Monitoring the running engine

DANGER
Contact with moving part!
Risk of death or injury by entanglement or impact of ejected part.

- ▶ Make sure that the drive train is connected to the flywheel before starting the engine.
- ▶ Start or operate the engine with covers and guards secured in place.
- ▶ Remove all tools or loose parts from the vicinity of the engine after a service activity.
- ▶ Keep tools away from the starting or running engine.
- ▶ When the engine is in operation, stay away from the engine.

WARNING
Toxic exhaust gas inhalation!
Risk of lung disease or injury by irritation.

- ▶ Make sure that there is a proper evacuation of exhaust gas.
- ▶ Ensure a good ventilation while running the engine.

Note

It is forbidden to continuously operate the diesel engine when an alarm is displayed.

Investigate any alarm according to operating conditions, and make sure that authorized personnel correct the defect at first opportunity.

Make sure that the following preconditions are met:
❑ Engine is operated under usual customer conditions.

Note

Rehlko diesel engines have been approved for running at low loads. Operating the engine at low loads for extended periods of time can increase deposits/carbon buildup (intensified at low ambient temperature). This can be detrimental to the longevity and compliance of the engine. If your operating profile has a prolonged low load duration, it is necessary to contact your genset supplier to take the necessary precautions.

To ensure engine performance and endurance, perform the following tasks when operating the application set:

- ▶ Check for unusual noises and vibrations.
- ▶ Record and report any anomaly found on generator set display (for example: faulty parameter).
- ▶ Make sure that authorized service personnel correct the defect.

4.2.2 Exhaust

(→ 6.2 Faults - Cause - Remedy, p. 215)

- ▶ Check exhaust gas color.

▶ Record and report any defect.

If defect is detected:
▶ Make sure that authorized service personnel correct the defect.

4.2.3 Drainage

(→ 6.2 Faults - Cause - Remedy, p. 215)

▶ Check drain holes on cold charge air lines.

Note

It is normal to find condensation; however, traces of coolant, engine oil, or fuel must be investigated.

▶ Record and report any defect.

If defect is detected:
▶ Make sure that authorized service personnel correct the defect.

4.3 Stopping the engine

4.3.1 Shutting down the engine

NOTICE
Misuse of emergency stop!
Property damage - Risk of engine damage.

▶ Use the emergency stop only in emergency situations (emergency stop is not a normal stop).

To stop the engine in normal conditions, observe the following instructions:

▶ Make sure the load is reduced to zero.

▶ Let the engine run at idle speed for 3 minutes.

▶ Shut down the engine.

4.3.2 Emergency stop

The emergency stop button and signals, as the acknowledge buttons are described in the the application set manual.

NOTICE
Misuse of emergency stop!
Property damage - Risk of engine damage.

▶ Use the emergency stop only in emergency situations (emergency stop is not a normal stop).

Initiating an emergency stop:

▶ Press the emergency stop button.

After an emergency stop:

▶ Remedy to the emergency situation.

▶ Acknowledge the emergency stop button and signals.

4.4 Initial starting after out-of-service period

4.4.1 Preparation of initial starting

For initial starting or after a suspension of activity, perform the following tasks:

- Inspect visually the engine (→ 5.7.1 Inspecting engine overall condition – SL0-1011, p. 114).
- Replace engine oil (→ 5.8.2 Changing engine oil – SL1-2020, p. 148).
- Replace spin-on oil filters (→ 5.8.4 Replacing spin-on oil filter – SL1-2110, p. 153).
- Check coolant quality (→ 5.9.3 Collecting and analyzing coolant sample – SL1-3021, p. 172).
- Check coolant level (→ 5.9.1 Inspecting cooling system overall condition – SL0-3011, p. 166).
- Drain off water and sediment from fuel tank (→ 5.10.1 Inspecting fuel system overall condition – SL0-4011, SL1-4022, SL0-5311, p. 174).
- Check water separator of fuel pre-filter and bleed water if necessary (→ 5.6.3 Post-maintenance filling and bleeding, p. 110).
- Replace fuel main filters (→ 5.10.3 Replacing fuel main filter – SL1-4120, p. 176).
- Bleed the fuel system (→ 5.6.3 Post-maintenance filling and bleeding, p. 110).
- Inspect starters (→ 5.12.1 Inspecting starter – SL1-6211, p. 186).
- Inspect battery charging alternator (→ 5.12.2 Inspecting battery charging alternator – SL1-6221, p. 187).
- Check belt of battery charging alternator and replace if necessary (→ 5.12.4 Replacing belt of battery charging alternator – SL1-6232, p. 190).

5 Maintenance

5.1 Maintenance information

5.1.1 Maintenance intervals

Two limits are applicable to the period that a component can remain in service:
- **Operating hours** is the maximum duration in hours of service.
- **Calendar interval** is the maximum duration in years.

A maintenance task is carried out as soon as the first deadline is reached, hourly or calendar.

5.1.2 Time Between Overhaul (TBO)

When your engine reaches its Time Between Overhaul (TBO), you can either replace the engine with a new one or have the existing engine refurbished. The second solution reduces our environmental footprint by preserving the natural resources and saves on costs.

The overhaul consists of a complete disassembly of the engine, where identified parts will be systematically replaced (seals, gaskets, piping, etc.) and others will be assessed to be either reused, sent for remanufacturing, or replaced by new ones (cylinder heads, power units, etc.).

For more information regarding our refurbishment program, please contact your authorized Rehlko service representative.

5.1.3 Service level definition

Type of maintenance	Service level / Scope of activity	Scope and location of work	Example of task	Target audience	Manual
Preventive (according to maintenance schedule)	**SL0 - Daily checks (or checks before start-up)**	Task performed in the application without any disassembly	General visual inspection, top-up of operating fluid	Trained operator / driver (end-customer)	Operation and Maintenance Manual
	SL1 - Basic maintenance	Task performed in the application with limited disassembly	Filter replacement, operating fluid replacement	Qualified and trained technician (end-customer or Discovery Energy, LLC and its affiliates dba Rehlko affiliates)	
	SL2 - Advanced maintenance	Task performed in the application with component[A)] replacement or use of service kit	Replacement of charge air cooler, coolant pump replacement	Qualified, trained, and authorized technician (Discovery Energy, LLC and its affiliates dba Rehlko affiliates)	Service and Repair Manual

Type of maintenance	Service level / Scope of activity	Scope and location of work	Example of task	Target audience	Manual
Corrective (fix as fail)	**SL3 - Repair**	Task performed in the application or in an authorized workshop with part or component[A)] replacement or use of service kit	Power unit replacement, oil cooler replacement	Qualified, trained, and authorized technician (Discovery Energy, LLC and its affiliates dba Rehlko affiliates)	
Preventive (according to maintenance schedule)	**SL4 - Overhaul**	Task performed in an authorized workshop with part or component[A)] assessment and replacement	Engine complete disassembly, assessment, reassembly, and test	Qualified, trained, and authorized technician working in Discovery Energy, LLC and its affiliates dba Rehlko authorized workshops	Specific documentation available only in authorized workshops

Tab. 17: Service level definition

A) Component may be new or remanufactured (as new)

5.1.4 Task identification

SL2	-	4	2	1	3	Task identification
SL2	-					Service level
		4				System (base engine, engine oil system, fuel system, etc.)
			2			Group (power unit, cylinder head, etc.)
				1		Sub-group (injector assembly, fuel filter assembly, etc.)
					3	Part (piston rings, o-rings, etc.)

Tab. 18: Task identification for maintenance schedules

5.1.4.1 List of systems

Designation	Description
1000	Base engine
2000	Engine oil system
3000	Cooling system
4000	Fuel system
5000	Air intake and exhaust gas system
6000	Electrical system
7000	Accessories

Tab. 19: System description

5.2 Generator set ratings

The following generator set ratings are defined by the standard ISO 8528-1.

The classifications according to ISO 8528-1 are intended to help to improve the understanding between manufacturer and customer.

The power of the generator set is the power output available for consumer loads at the generator set terminals, excluding the electrical power absorbed by the essential independent auxiliaries.

5.2.1 Continuous operating power (COP)

Continuous power is defined as being the maximum power, which the generator set is capable of delivering continuously whilst supplying a constant electrical load when operated for an unlimited number of hours per year under the agreed operating conditions with the maintenance intervals and procedures being carried out as prescribed by the manufacturer.

5.2.2 Prime power (PRP)

Prime power is defined as being the maximum power, which a generator set is capable of delivering continuously whilst supplying a variable electrical load when operated for an unlimited number of hours per year under the agreed operating conditions with the maintenance intervals and procedures being carried out as prescribed by the manufacturer.

5.2.3 Emergency standby power (ESP)

Emergency standby power is defined as being the maximum power, which a generator set is capable of delivering during a variable electrical power sequence, in case of a utility power outage, or under test conditions. Emergency standby power can be operated for up to 200 hours per year under the agreed operating conditions.

Always observe the maintenance intervals and procedures prescribed by the manufacturer.

5.3 Maintenance information

5.3.1 General information

Shorten the maintenance intervals according to the operating conditions, for example:
- Dusty environment
- Oil quality
- Fuel quality

Always make sure that lubricants, fuel, other liquids, and replaced parts are disposed of in a safe and environmentally acceptable manner. The environmental regulations applicable in the country of use must be adhered to.

5.3.2 Service level 0 – Monthly maintenance activities, TBO 4000 hours for ESP – Engine Operation – Version: MS2025/04-09

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL0-1011	Engine (stopped)	-	1M	X	-	Task is performed when engine is stopped. Inspect engine overall condition. Record and report any defect (leak, damage, loose part, etc.). (→ 5.7.1 Inspecting engine overall condition – SL0-1011, p. 114)
SL0-1021	Engine (idle speed)	-	1M	X	-	Task is performed when engine is running at idle speed. Inspect engine overall condition. Record and report any defect (leak, faulty parameter, unusual noise, unusual vibration, unusual exhaust gas color). (→ 5.7.2 Inspecting engine running at idle speed – SL0-1021, p. 132)
SL0-1022	Engine in operation	-	1M	X	-	Perform test run at more than a 1/3 load (if parameters are within range) and at least until steady-state temperature is reached. Record and report any anomaly. For example: leak, faulty parameter, unusual noise, unusual vibration, unusual exhaust gas color, etc. (→ 5.7.3 Testing engine in operation (ESP application only) – SL0-1022, p. 133)

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL0-2011	Oil system	-	1M	X	-	Task is performed when engine is stopped. Check engine oil level. Top up if needed. Check prelubricating oil pump operation at engine start (displayed pressure). Take corrective action if defect is present. (→ 5.8.1 Inspecting oil system overall condition – SL0-2011, p. 146)
SL0-3011	Cooling system	-	1M	X	-	Task is performed when engine is stopped. Check coolant level. Top up if needed. (→ 5.9.1 Inspecting cooling system overall condition – SL0-3011, p. 166)
SL0-4011	Fuel system	-	1M	X	-	Task is performed when engine is stopped. Check fuel level. Top up if needed. (→ 5.10.1 Inspecting fuel system overall condition – SL0-4011, SL1-4022, SL0-5311, p. 174)
SL0-5011	Air intake system	-	1M	X	-	Task is performed when engine is stopped. Inspect air filter. Replace air filter if needed. Inspect air ducting and exhaust gas turbocharger when filter is found clogged, damaged, or improperly fitted. (→ 5.11.1 Inspecting air intake system overall condition – SL0-5011, p. 180)

Tab. 20: Service level 0 – ESP – Monthly maintenance activities

5.3.3 Service level 1 – Engine Service, TBO 4000 hours for ESP – Engine Operation – Version: MS2025/04-09

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL1-1122	Valves	1000	4Y	X	-	Check valve clearance and adjust if needed. (→ 5.7.5 Checking valve clearance – SL1-1122, p. 135) Note: first check at first 500 operating hours.
SL1-1661	Crankcase breather oil separator filter	-	3Y	-	X	Replace oil separator filter(s) of crankcase breather system. (→ 5.7.6 Replacing oil separator filter – SL1-1661, p. 143)
Engine oil system **without** centrifugal oil filter						
SL1-2020	Engine oil	250	2Y	-	X	At first 250 operating hours, change engine oil and spin-on oil filters. Change engine oil with engine oil “category 2”. For engine oil “category 3”, the interval is multiplied by 2 (see specification). (→ 5.8.2 Changing engine oil – SL1-2020, p. 148)
SL1-2021	Oil sample	250	1Y	X	-	Collect and send oil sample for analysis. Take recommended action according to analysis results. (→ 5.8.3 Collecting and analyzing oil sample – SL1-2021, p. 152)
SL1-2110	Spin-on oil filter	250	2Y	-	X	At first 250 operating hours, change engine oil and spin-on oil filters. Replace spin-on oil filters. Clean engine side sealing area before and after filter removal. (→ 5.8.4 Replacing spin-on oil filter – SL1-2110, p. 153)
Engine oil system **with** centrifugal oil filter						
SL1-2020	Engine oil	250	2Y	-	X	At first 250 operating hours, change engine oil and spin-on oil filters. Change engine oil with engine oil “category 2”. For engine oil “category 3”, the interval is multiplied by 2 (see specification). (→ 5.8.2 Changing engine oil – SL1-2020, p. 148)

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL1-2021	Oil sample	250	1Y	X	-	Collect and send oil sample for analysis. Take recommended action according to analysis results. (→ 5.8.3 Collecting and analyzing oil sample – SL1-2021, p. 152)
SL1-2110	Spin-on oil filter	250	2Y	-	X	At first 250 operating hours, change engine oil and spin-on oil filters. Replace spin-on oil filters. Clean engine side sealing area before and after filter removal. (→ 5.8.4 Replacing spin-on oil filter – SL1-2110, p. 153)
SL1-2231	Liner of centrifugal oil filter	1000	2Y	-	X	Clean or replace liner [1]. Record sludge accumulation. (→ 5.8.5 Inspecting and cleaning liner of centrifugal oil filter – SL1-2231, SL1-2232, p. 155)
-						
SL1-2411	Oil cooler	-	4Y	X	-	Inspect oil cooler. Take corrective action if defect is present. (→ 5.8.6 Inspecting oil cooler – SL1-2411, p. 164)
SL1-3020	Coolant	-	4Y	-	X	Change coolant. (→ 5.9.2 Changing coolant – SL1-3020, p. 167)
SL1-3021	Coolant sample	-	1Y	X	-	Collect and send coolant sample for analysis. Take recommended action according to analysis results. (→ 5.9.3 Collecting and analyzing coolant sample – SL1-3021, p. 172)
SL1-4110	Fuel pre-filter (off engine)	500	1Y	-	X	Replace fuel pre-filter(s). (→ 5.10.2 Replacing fuel pre-filter – SL1-4110, p. 175)
SL1- 4120	Fuel main filter	500	1Y	-	X	Replace fuel main filter(s). (→ 5.10.3 Replacing fuel main filter – SL1-4120, p. 176)

[1] If centrifugal oil filter is equipped with a paper insert, replace paper insert (→ 8.2.1 Centrifugal oil filter with paper insert, p. 242).

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL1-4221 SL1-4311	HP/LP fuel pump	500	2Y	X	-	Check overall condition of HP/LP fuel pump. Record and report any anomaly. Take corrective action if defect is present. (→ 5.10.4 Inspecting HP/LP fuel pump – SL1-4221, SL1-4311, p. 178)
SL1-5021	Air filter	-	2Y	X	-	Clean air filter. (→ 5.11.2 Cleaning air filter – SL1-5021, p. 181)
SL1-5121	Charge air cooler (CAC)	-	4Y	X	-	Inspect CAC overall condition including coolant and air passages (leaks, contamination, damage, mounting, etc.). Make sure CAC is flushed if needed. (→ 5.11.3 Inspecting charge air cooler – SL1-5121, p. 181)
SL1-5201	Exhaust gas system	-	4Y	X	-	Check overall condition of exhaust gas system (leaks, cracks, mountings). Take corrective action if defect is present. (→ 5.11.4 Inspecting exhaust gas system – SL1-5201, p. 183)
SL1-5411	Exhaust gas turbocharger	-	4Y	X	-	Check overall condition (compressor and turbine blades, shaft play, connections, housings). Record and report any anomaly. Take corrective action if defect is present. (→ 5.11.5 Inspecting exhaust gas turbocharger – SL1-5411, p. 184)
SL1-6211	Starter	-	4Y	X	-	Check overall condition of starters. Replace if defect is present. (→ 5.12.1 Inspecting starter – SL1-6211, p. 186)
SL1-6221	Battery charging alternator	-	4Y	X	-	Clean from body to fan. Replace if defect is present. (→ 5.12.2 Inspecting battery charging alternator – SL1-6221, p. 187)
SL1-6231	Belt drive system of battery charging alternator	250	1Y	X	-	Check overall condition of belt, belt tension, idler pulley. Replace if defect is present. (→ 5.12.3 Inspecting system of alternator belt drive – SL1-6231, p. 189)
SL1-6232	Drive belt of battery charging alternator	500	2Y	-	X	Replace drive belt of battery charging alternator. (→ 5.12.4 Replacing belt of battery charging alternator – SL1-6232, p. 190)

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL1-6233	Tensioner of battery charging alternator	2000	18Y	-	X	Replace tensioner of battery charging alternator. (→ 5.12.5 Replacing belt tensioner of battery charging alternator – SL1-6233, p. 193)

Tab. 21: Service level 1 – ESP – Basic maintenance

5.3.4 Service level 2 / 4 – Engine Service, TBO 4000 hours for ESP – Advanced maintenance / Overhaul – Version: MS2025/04-09

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL2-1121	Cylinder head	-	18 Y	X	-	Inspect cylinder head. Replace cylinder head if needed.
SL2-1211	Combustion chambers	-	9 Y	X	-	Inspect combustion chambers (including cylinder head fire deck) with borescope when injector is replaced. Record and report any anomaly. Take corrective action if defect is present.
SL2-1345	Silicon oil of torsional vibration damper	1000	-	X	-	Collect and send silicon oil sample for analysis. Take recommended action according to analysis results.
SL2-3210	LT coolant pump	-	18 Y	-	X	Replace low-temperature coolant pump.
SL2-3230	HT coolant pump	-	18 Y	-	X	Replace high-temperature coolant pump.
SL2-3310	HT and LT coolant thermostats	-	18 Y	-	X	Replace high-temperature and low-temperature coolant thermostats.
SL2-4210	Fuel injectors	-	9 Y	-	X	Replace fuel injectors.
SL2-4220 SL2-4310	HP/LP fuel pump	-	18 Y	-	X	Replace high-pressure and low-pressure fuel pump.
SL2-5120	Charge air cooler	-	18 Y	-	X	Replace charge air coolers.
SL2-7410	Rubber hoses	-	18 Y	-	X	Replace all rubber hoses connections.

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL4-1030	Engine overhaul	4000	18 Y	X	X	Engine complete disassembly, assessment, reassembly, and test (→ 5.1 Maintenance information, p. 84).

Tab. 22: Service level 2 / 4 – ESP – Advanced maintenance / Overhaul

5.3.5 Service level 0 – Daily maintenance activities, TBO 15000 hours for PRP – Engine Operation – Version: MS2025/04-10

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL0-1011	Engine (stopped)	-	1D	X	-	Task is performed when engine is stopped. Inspect engine overall condition. Record and report any defect (leak, damage, loose part, etc.). (→ 5.7.1 Inspecting engine overall condition – SL0-1011, p. 114)
SL0-1021	Engine (idle speed)	-	1D	X	-	Task is performed when engine is running at idle speed. Inspect engine overall condition. Record and report any defect (leak, faulty parameter, unusual noise, unusual vibration, unusual exhaust gas color). (→ 5.7.2 Inspecting engine running at idle speed – SL0-1021, p. 132)
SL0-2011	Oil system	-	1D	X	-	Task is performed when engine is stopped. Check engine oil level. Top up if needed. Check prelubricating oil pump operation at engine start (displayed pressure). Take corrective action if defect is present. (→ 5.8.1 Inspecting oil system overall condition – SL0-2011, p. 146)

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL0-3011	Cooling system	-	1D	X	-	Task is performed when engine is stopped. Check coolant level. Top up if needed. (→ 5.9.1 Inspecting cooling system overall condition – SL0-3011, p. 166)
SL0-4011	Fuel system	-	1D	X	-	Task is performed when engine is stopped. Check fuel level. Top up if needed. (→ 5.10.1 Inspecting fuel system overall condition – SL0-4011, SL1-4022, SL0-5311, p. 174)
SL0-5011	Air intake system	-	1D	X	-	Task is performed when engine is stopped. Inspect air filter. Replace air filter if needed. Inspect air ducting and exhaust gas turbo-charger when filter is found clogged, damaged, or improperly fitted. (→ 5.11.1 Inspecting air intake system overall condition – SL0-5011, p. 180)

Tab. 23: Service level 0 – PRP – Daily maintenance activities

5.3.6 Service level 1 – Engine Service, TBO 15000 hours for PRP – Engine Operation – Version: MS2025/04-10

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL1-1122	Valves	3000	4Y	X	-	Check valve clearance and adjust if needed. (→ 5.7.5 Checking valve clearance – SL1-1122, p. 135) Note: first check at first 500 operating hours.
SL1-1661	Crankcase breather oil separator filter	7500	3Y	-	X	Replace oil separator filter(s) of crankcase breather system. (→ 5.7.6 Replacing oil separator filter – SL1-1661, p. 143)
Engine oil system **without** centrifugal oil filter						

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL1-2020	Engine oil	250	2Y	-	X	At first 250 operating hours, change engine oil and spin-on oil filters. Change engine oil with engine oil “category 2”. For engine oil “category 3”, the interval is multiplied by 2 (see specification). (→ 5.8.2 Changing engine oil – SL1-2020, p. 148)
SL1-2021	Oil sample	250	1Y	X	-	Collect and send oil sample for analysis. Take recommended action according to analysis results. (→ 5.8.3 Collecting and analyzing oil sample – SL1-2021, p. 152)
SL1-2110	Spin-on oil filter	250	2Y	-	X	At first 250 operating hours, change engine oil and spin-on oil filters. Replace spin-on oil filters. Clean engine side sealing area before and after filter removal. (→ 5.8.4 Replacing spin-on oil filter – SL1-2110, p. 153)
Engine oil system **with** centrifugal oil filter						
SL1-2020	Engine oil	500	2Y	-	X	At first 250 operating hours, change engine oil and spin-on oil filters. Change engine oil with engine oil “category 2”. For engine oil “category 3”, the interval is multiplied by 2 (see specification). (→ 5.8.2 Changing engine oil – SL1-2020, p. 148)
SL1-2021	Oil sample	500	1Y	X	-	Collect and send oil sample for analysis. Take recommended action according to analysis results. (→ 5.8.3 Collecting and analyzing oil sample – SL1-2021, p. 152)
SL1-2110	Spin-on oil filter	500	2Y	-	X	At first 250 operating hours, change engine oil and spin-on oil filters. Replace spin-on oil filters. Clean engine side sealing area before and after filter removal. (→ 5.8.4 Replacing spin-on oil filter – SL1-2110, p. 153)

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL1-2231	Liner of centrifugal oil filter	1000	2Y	-	X	Clean or replace liner [2] . Record sludge accumulation. (→ 5.8.5 Inspecting and cleaning liner of centrifugal oil filter – SL1-2231, SL1-2232, p. 155)
-						
SL1-2411	Oil cooler	7500	4Y	X	-	Inspect oil cooler. Take corrective action if defect is present. (→ 5.8.6 Inspecting oil cooler – SL1-2411, p. 164)
SL1-3020	Coolant	5000	4Y	-	X	Change coolant. (→ 5.9.2 Changing coolant – SL1-3020, p. 167)
SL1-3021	Coolant sample	-	1Y	X	-	Collect and send coolant sample for analysis. Take recommended action according to analysis results. (→ 5.9.3 Collecting and analyzing coolant sample – SL1-3021, p. 172)
SL1-4110	Fuel pre-filter (off engine)	1000	1Y	-	X	Replace fuel pre-filter(s). (→ 5.10.2 Replacing fuel pre-filter – SL1-4110, p. 175)
SL1- 4120	Fuel main filter	1000	1Y	-	X	Replace fuel main filter(s). (→ 5.10.3 Replacing fuel main filter – SL1-4120, p. 176)
SL1-4221 SL1-4311	HP/LP fuel pump	2500	2Y	X	-	Check overall condition of HP/LP fuel pump. Record and report any anomaly. Take corrective action if defect is present. (→ 5.10.4 Inspecting HP/LP fuel pump – SL1-4221, SL1-4311, p. 178)
SL1-5021	Air filter	3000	2Y	X	-	Clean air filter. (→ 5.11.2 Cleaning air filter – SL1-5021, p. 181)
SL1-5121	Charge air cooler (CAC)	5000	4Y	X	-	Inspect CAC overall condition including coolant and air passages (leaks, contamination, damage, mounting, etc.). Make sure CAC is flushed if needed. (→ 5.11.3 Inspecting charge air cooler – SL1-5121, p. 181)

2) If centrifugal oil filter is equipped with a paper insert, replace paper insert (→ 8.2.1 Centrifugal oil filter with paper insert, p. 242).

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL1-5201	Exhaust gas system	7500	4Y	X	-	Check overall condition of exhaust gas system (leaks, cracks, mountings). Take corrective action if defect is present. (→ 5.11.4 Inspecting exhaust gas system – SL1-5201, p. 183)
SL1-5411	Exhaust gas turbo-charger	5000	4Y	X	-	Check overall condition (compressor and turbine blades, shaft play, connections, housings). Record and report any anomaly. Take corrective action if defect is present. (→ 5.11.5 Inspecting exhaust gas turbo-charger – SL1-5411, p. 184)
SL1-6211	Starter	5000	4Y	X	-	Check overall condition of starters. Replace if defect is present. (→ 5.12.1 Inspecting starter – SL1-6211, p. 186)
SL1-6221	Battery charging alternator	5000	4Y	X	-	Clean from body to fan. Replace if defect is present. (→ 5.12.2 Inspecting battery charging alter-nator – SL1-6221, p. 187)
SL1-6231	Belt drive system of battery charging alternator	1000	1Y	X	-	Check overall condition of belt, belt tension, idler pulley. Replace if defect is present. (→ 5.12.3 Inspecting system of alternator belt drive – SL1-6231, p. 189)
SL1-6232	Drive belt of battery charging alternator	5000	2Y	-	X	Replace drive belt of battery charging alter-nator. (→ 5.12.4 Replacing belt of battery charging alternator – SL1-6232, p. 190)
SL1-6233	Tensioner of battery charging alternator	7500	18Y	-	X	Replace tensioner of battery charging alter-nator. (→ 5.12.5 Replacing belt tensioner of battery charging alternator – SL1-6233, p. 193)

Tab. 24: Service level 1 – PRP – Basic maintenance

5.3.7 Service level 2 / 4 – Engine Service, TBO 15000 hours for PRP – Advanced maintenance / Overhaul – Version: MS2025/04-10

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL2-1121	Cylinder head	7500	18 Y	X	-	Inspect cylinder head. Replace cylinder head if needed.
SL2-1211	Combustion chambers	7500	9 Y	X	-	Inspect combustion chambers (including cylinder head fire deck) with borescope when injector is replaced. Record and report any anomaly. Take corrective action if defect is present.
SL2-1345	Silicon oil of torsional vibration damper	5000	-	X	-	Collect and send silicon oil sample for analysis. Take recommended action according to analysis results.
SL2-3210	LT coolant pump	7500	18 Y	-	X	Replace low-temperature coolant pump.
SL2-3230	HT coolant pump	7500	18 Y	-	X	Replace high-temperature coolant pump.
SL2-3310	HT and LT coolant thermostats	7500	18 Y	-	X	Replace high-temperature and low-temperature coolant thermostats.
SL2-4210	Fuel injectors	7500	9 Y	-	X	Replace fuel injectors.
SL2-4220 SL2-4310	HP/LP fuel pump	-	18 Y	-	X	Replace high-pressure and low-pressure fuel pump.
SL2-5120	Charge air cooler	-	18 Y	-	X	Replace charge air coolers.
SL2-5410	Exhaust gas turbochargers	7500	18 Y	-	X	Replace exhaust gas turbochargers.
SL2-7410	Rubber hoses	7500	18 Y	-	X	Replace all rubber hoses connections.
SL4-1030	Engine overhaul	15000	18 Y	X	X	Engine complete disassembly, assessment, reassembly, and test (→ 5.1 Maintenance information, p. 84).

Tab. 25: Service level 2 / 4 – PRP – Advanced maintenance / Overhaul

5.3.8 Service level 0 – Daily maintenance activities, TBO 24000 hours for COP – Engine Operation – Version: MS2025/04-11

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL0-1011	Engine (stopped)	-	1D	X	-	Task is performed when engine is stopped. Inspect engine overall condition. Record and report any defect (leak, damage, loose part, etc.). (→ 5.7.1 Inspecting engine overall condition – SL0-1011, p. 114)
SL0-1021	Engine (idle speed)	-	1D	X	-	Task is performed when engine is running at idle speed. Inspect engine overall condition. Record and report any defect (leak, faulty parameter, unusual noise, unusual vibration, unusual exhaust gas color). (→ 5.7.2 Inspecting engine running at idle speed – SL0-1021, p. 132)
SL0-2011	Oil system	-	1D	X	-	Task is performed when engine is stopped. Check engine oil level. Top up if needed. Check prelubricating oil pump operation at engine start (displayed pressure). Take corrective action if defect is present. (→ 5.8.1 Inspecting oil system overall condition – SL0-2011, p. 146)
SL0-3011	Cooling system	-	1D	X	-	Task is performed when engine is stopped. Check coolant level. Top up if needed. (→ 5.9.1 Inspecting cooling system overall condition – SL0-3011, p. 166)
SL0-4011	Fuel system	-	1D	X	-	Task is performed when engine is stopped. Check fuel level. Top up if needed. (→ 5.10.1 Inspecting fuel system overall condition – SL0-4011, SL1-4022, SL0-5311, p. 174)

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL0-5011	Air intake system	-	1D	X	-	Task is performed when engine is stopped. Inspect air filter. Replace air filter if needed. Inspect air ducting and exhaust gas turbo-charger when filter is found clogged, damaged, or improperly fitted. (→ 5.11.1 Inspecting air intake system overall condition – SL0-5011, p. 180)

Tab. 26: Service level 0 – COP – Daily maintenance activities

5.3.9 Service level 1 – Engine Service, TBO 24000 hours for COP – Engine Operation – Version: MS2025/04-11

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL1-1122	Valves	3000	4Y	X	-	Check valve clearance and adjust if needed. (→ 5.7.5 Checking valve clearance – SL1-1122, p. 135) Note: first check at first 500 operating hours.
SL1-1661	Crankcase breather oil separator filter	8000	3Y	-	X	Replace oil separator filter(s) of crankcase breather system. (→ 5.7.6 Replacing oil separator filter – SL1-1661, p. 143)
Engine oil system **without** centrifugal oil filter						
SL1-2020	Engine oil	250	2Y	-	X	At first 250 operating hours, change engine oil and spin-on oil filters. Change engine oil with engine oil “category 2”. For engine oil “category 3”, the interval is multiplied by 2 (see specification). (→ 5.8.2 Changing engine oil – SL1-2020, p. 148)

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL1-2021	Oil sample	250	1Y	X	-	Collect and send oil sample for analysis. Take recommended action according to analysis results. (→ 5.8.3 Collecting and analyzing oil sample – SL1-2021, p. 152)
SL1-2110	Spin-on oil filter	250	2Y	-	X	At first 250 operating hours, change engine oil and spin-on oil filters. Replace spin-on oil filters. Clean engine side sealing area before and after filter removal. (→ 5.8.4 Replacing spin-on oil filter – SL1-2110, p. 153)
Engine oil system **with** centrifugal oil filter						
SL1-2020	Engine oil	500	2Y	-	X	At first 250 operating hours, change engine oil and spin-on oil filters. Change engine oil with engine oil “category 2”. For engine oil “category 3”, the interval is multiplied by 2 (see specification). (→ 5.8.2 Changing engine oil – SL1-2020, p. 148)
SL1-2021	Oil sample	500	1Y	X	-	Collect and send oil sample for analysis. Take recommended action according to analysis results. (→ 5.8.3 Collecting and analyzing oil sample – SL1-2021, p. 152)
SL1-2110	Spin-on oil filter	500	2Y	-	X	At first 250 operating hours, change engine oil and spin-on oil filters. Replace spin-on oil filters. Clean engine side sealing area before and after filter removal. (→ 5.8.4 Replacing spin-on oil filter – SL1-2110, p. 153)
SL1-2231	Liner of centrifugal oil filter	1000	2Y	-	X	Clean or replace liner [3]. Record sludge accumulation. (→ 5.8.5 Inspecting and cleaning liner of centrifugal oil filter – SL1-2231, SL1-2232, p. 155)
-						

[3] If centrifugal oil filter is equipped with a paper insert, replace paper insert (→ 8.2.1 Centrifugal oil filter with paper insert, p. 242).

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL1-2411	Oil cooler	12000	4Y	X	-	Inspect oil cooler. Take corrective action if defect is present. (→ 5.8.6 Inspecting oil cooler – SL1-2411, p. 164)
SL1-3020	Coolant	6000	4Y	-	X	Change coolant. (→ 5.9.2 Changing coolant – SL1-3020, p. 167)
SL1-3021	Coolant sample	-	1Y	X	-	Collect and send coolant sample for analysis. Take recommended action according to analysis results. (→ 5.9.3 Collecting and analyzing coolant sample – SL1-3021, p. 172)
SL1-4110	Fuel pre-filter (off engine)	1000	1Y	-	X	Replace fuel pre-filter(s). (→ 5.10.2 Replacing fuel pre-filter – SL1-4110, p. 175)
SL1- 4120	Fuel main filter	1000	1Y	-	X	Replace fuel main filter(s). (→ 5.10.3 Replacing fuel main filter – SL1-4120, p. 176)
SL1-4221 SL1-4311	HP/LP fuel pump	4000	2Y	X	-	Check overall condition of HP/LP fuel pump. Record and report any anomaly. Take corrective action if defect is present. (→ 5.10.4 Inspecting HP/LP fuel pump – SL1-4221, SL1-4311, p. 178)
SL1-5021	Air filter	3000	2Y	X	-	Clean air filter. (→ 5.11.2 Cleaning air filter – SL1-5021, p. 181)
SL1-5121	Charge air cooler (CAC)	6000	4Y	X	-	Inspect CAC overall condition including coolant and air passages (leaks, contamination, damage, mounting, etc.). Make sure CAC is flushed if needed. (→ 5.11.3 Inspecting charge air cooler – SL1-5121, p. 181)
SL1-5201	Exhaust gas system	12000	4Y	X	-	Check overall condition of exhaust gas system (leaks, cracks, mountings). Take corrective action if defect is present. (→ 5.11.4 Inspecting exhaust gas system – SL1-5201, p. 183)

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL1-5411	Exhaust gas turbo-charger	6000	4Y	X	-	Check overall condition (compressor and turbine blades, shaft play, connections, housings) Record and report any anomaly. Take corrective action if defect is present. (→ 5.11.5 Inspecting exhaust gas turbo-charger – SL1-5411, p. 184)
SL1-6211	Starter	6000	4Y	X	-	Check overall condition of starter. Replace if defect is present. (→ 5.12.1 Inspecting starter – SL1-6211, p. 186)
SL1-6221	Battery charging alternator	6000	4Y	X	-	Clean from body to fan. Replace if defect is present. (→ 5.12.2 Inspecting battery charging alter-nator – SL1-6221, p. 187)
SL1-6231	Belt drive system of battery charging alternator	1000	1Y	X	-	Check overall condition of belt, belt tension, idler pulley. Replace if defect is present. (→ 5.12.3 Inspecting system of alternator belt drive – SL1-6231, p. 189)
SL1-6232	Drive belt of battery charging alternator	6000	2Y	-	X	Replace drive belt of battery charging alter-nator. (→ 5.12.4 Replacing belt of battery charging alternator – SL1-6232, p. 190)
SL1-6233	Tensioner of battery charging alternator	12000	18Y	-	X	Replace tensioner of battery charging alter-nator. (→ 5.12.5 Replacing belt tensioner of battery charging alternator – SL1-6233, p. 193)

Tab. 27: Service level 1 – COP – Basic maintenance

5.3.10 Service level 2 / 4 – Engine Service, TBO 24000 hours for COP – Advanced maintenance / Overhaul – Version: MS2025/04-11

Task identification	Component	Schedule		Service Type		Task description
		Time limit (h)	Calendar limit (Day - Month - Year)	Inspect / Clean	Service / Replace	
SL2-1121	Cylinder head	8000	18 Y	X	-	Inspect cylinder head. Replace cylinder head if needed.
SL2-1211	Combustion chambers	8000	9 Y	X	-	Inspect combustion chambers (including cylinder head fire deck) with borescope when injector is replaced. Record and report any anomaly. Take corrective action if defect is present.
SL2-1345	Silicon oil of torsional vibration damper	6000	-	X	-	Collect and send silicon oil sample for analysis. Take recommended action according to analysis results.
SL2-3210	LT coolant pump	12000	18 Y	-	X	Replace low-temperature coolant pump.
SL2-3230	HT coolant pump	12000	18 Y	-	X	Replace high-temperature coolant pump.
SL2-3310	HT and LT coolant thermostats	12000	18 Y	-	X	Replace high-temperature and low-temperature coolant thermostats.
SL2-4210	Fuel injectors	8000	9 Y	-	X	Replace fuel injectors.
SL2-4220 SL2-4310	HP/LP fuel pump	12000	18 Y	-	X	Replace high-pressure and low-pressure fuel pump.
SL2-5120	Charge air cooler	12000	18 Y	-	X	Replace charge air coolers.
SL2-5410	Exhaust gas turbochargers	12000	18 Y	-	X	Replace exhaust gas turbochargers.
SL2-7410	Rubber hoses	12000	18 Y	-	X	Replace all rubber hoses connections.
SL4-1030	Engine overhaul	24000	18 Y	X	X	Engine complete disassembly, assessment, reassembly, and test (→ 5.1 Maintenance information, p. 84).

Tab. 28: Service level 2 / 4 – COP – Advanced maintenance / Overhaul

5.4 Preparatory maintenance activities

DANGER
Rotation, movement, or ejection of engine parts!
Risk of death or injury by entanglement or impact of ejected part.
Before monitoring or accessing engine covers, housing, or compartment:

- ▶ Switch off the engine (→ 4.3.1 Shutting down the engine, p. 82).
- ▶ Make sure that all parts are stopped.
- ▶ Secure all parts against unexpected movements.

Note

The application owner shall develop, document, implement, and enforce lockout/tagout (LOTO) procedure.

Make sure that the following special tools are available:
– KODIA kit

(→ 7.1.1 Special tools, p. 220)

Ensure the engine maintenance conditions as follows:

- ▶ Position the engine horizontally.
- ▶ With KODIA take a “Snapshot Report” of the engine status. Pay particular attention to the “Trouble Codes”.
- ▶ Turn off battery main switch.
- ▶ If present, remove main switch key.
- ▶ Secure the area according to LOTO procedure.
- ▶ Let the engine cool down to ambient temperature.

5.5 Cleaning the whole engine

5.5.1 Previous tasks

Make sure that the following preconditions are met:

- ❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).
- ❑ Sensitive parts are protected (Engine Control Unit (ECU), electrical connections, electrical junction box, wiring harness, battery charging alternator, sensors, starters, engine bypass flap, oil filler neck, and air filter) (→ fig. 36, p. 108).
- ❑ Openings are closed and sealed.

5.5.2 Specific safety instructions

WARNING
Improper use of high-pressure water jet!
Risk of death or injury by ejection of debris, slipping and falling, exposure to loud noises, hose whiplash, and contact with sharp objects.

- ▶ Fasten high-pressure water jet hose securely.
- ▶ Make sure that work area is free of debris and sharp edges.
- ▶ Wear appropriate personal protective equipment.

WARNING
Improper use of compressed air!
Risk of death or injury by ejection of debris, exposure to loud noises, hose whiplash, and contact with sharp objects.

- ▶ Fasten air compressor hose securely.
- ▶ Make sure that work area is free of debris and sharp edges.
- ▶ Wear appropriate personal protective equipment.

WARNING
Usage of toxic chemical products!
Risk of injury by inhalation or contact.

- ▶ Observe local regulations, site rules, and safety notes.
- ▶ Refer to material safety datasheet (MSDS) for storage, handling, and usage.
- ▶ Ensure good ventilation of the working area.
- ▶ Wear proper personal protective equipment.

NOTICE
Use of unsuitable chemical products!
Risk of damage to property, engine, or parts.

- ▶ Make sure to use suitable chemical products.

NOTICE
Failure to dry cleaned engine and engine parts thoroughly!
Risk of property damage due to rust.

- ▶ Make sure to dry cleaned engine and engine parts thoroughly.

NOTICE
Improper preservation of cleaned engine and engine parts!
Risk of property damage.

- ▶ Make sure to dry cleaned engine and engine parts thoroughly.
- ▶ Store cleaned engine and engine parts according to storage instructions.

5.5.3 Special tools

Not applicable.

5.5.4 Consumables and equipment

Make sure that the following consumables and equipment are available:
- High-pressure cleaner
- Compressed air blower
- Lint-free cloths
- Preserving agent

5.5.5 Engine cleaning

NOTICE
Improper protection of Engine Control Unit (ECU) and electrical connections!
Risk of critical engine failure.

- ▶ Protect the ECU and electrical connections with appropriate means when cleaning the engine.

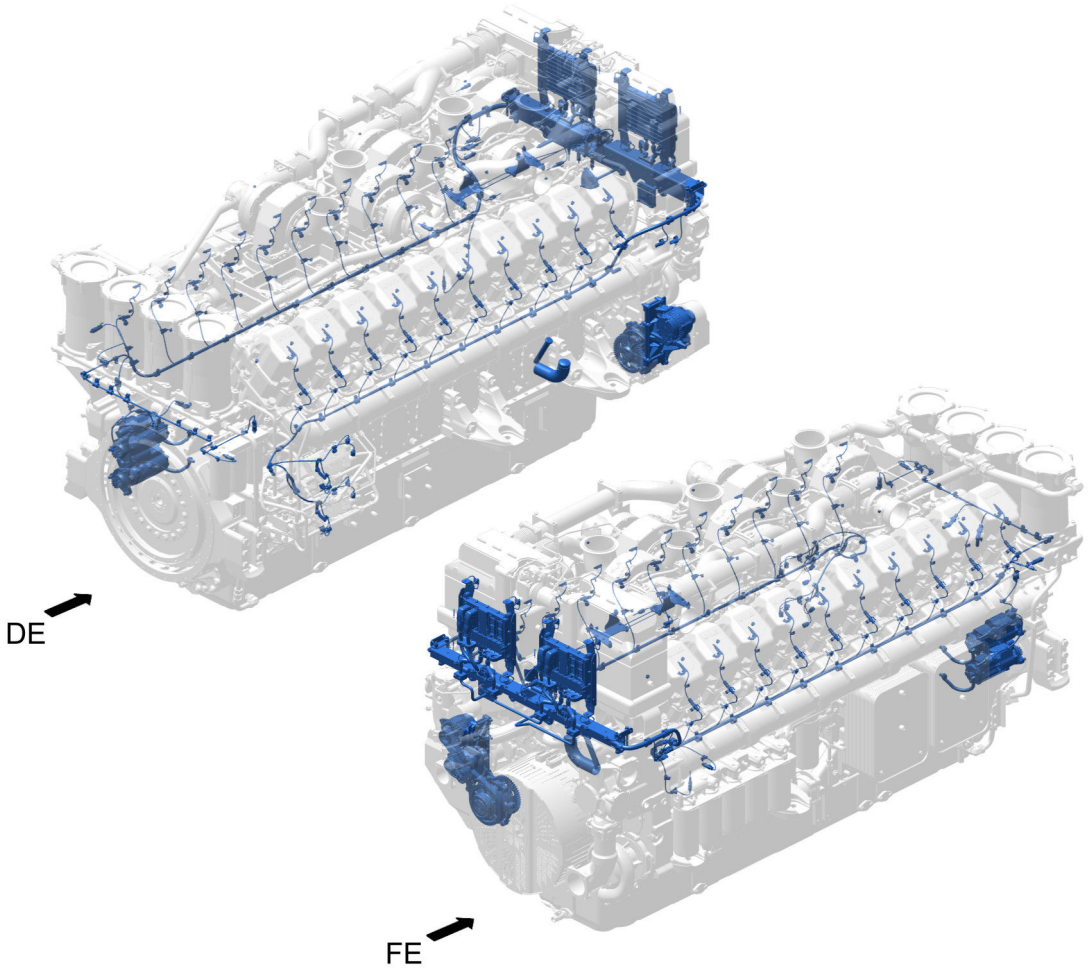


Fig. 36: Protecting ECU, electrical connections and sensitive parts

▶ Clean the engine using the high-pressure cleaner.

Note

Make sure to clean the screws and bolts, the filters, the connections and fittings, the pipes, the valves, and the connecting plates thoroughly.

Note

Make sure to leave at least 50 cm (1.64 ft) between the engine and the high-pressure cleaner.

▶ Remove any remaining debris.

▶ Using the compressed air blower, dry the engine.

Note

Make sure that the engine is free from water residues.

5.6 Post maintenance activities

5.6.1 Part reinstallation

5.6.1.1 Previous tasks

Make sure that the following preconditions are met:
❑ Maintenance activities are completed.

5.6.1.2 Specific safety instructions

Not applicable.

5.6.1.3 Consumables and equipment

Not applicable.

5.6.1.4 Inspection

- ▶ Make sure that all removed components or parts are reinstalled.
- ▶ Make sure that torques were applied according to tightening specifications (→ 8.4 Standard tightening torques, p. 249).
- ▶ Make sure that all tools, special tools, lint-free cloths, and other consumables are removed from the engine.

5.6.2 Spray painting

5.6.2.1 Specific safety instructions



DANGER
Fire or explosion by flammable and explosive chemical products.
Burns or explosion release will result in death or serious injury.

- ▶ Avoid any contact of flammable and explosive chemical products with any hot surface or ignition source.
- ▶ Lock out and tag out the engine prior to carrying out paint works on it.
- ▶ Ensure a good ventilation while carrying out paint works on the engine.
- ▶ Smoking and open flames are forbidden in the vicinity of the engine.



WARNING
Risk of injuries by contact with or inhalation of chemical products.
Contact with or inhalation of chemical products could result in death or serious injuries by intoxication or poisoning.

- ▶ Wear proper personal protective equipment.
- ▶ Refer to the local regulations and the product associated data to safely handle, store, and use these products.

WARNING
Risk of injuries by explosion of pressurized container.
Explosion of pressurized container could result in death or serious injuries.

- ▶ Do not pierce or burn the pressurized container, even after use.
- ▶ Protect the pressurized container from sunlight.
- ▶ Make sure the pressurized contained is not exposed to temperatures over 50 °C (122 °F).

5.6.2.2 Scope

Spray painting may be necessary in the following cases:
- Touch-ups following damage to the original paint
- Painting of spare parts delivered unpainted

5.6.2.3 Previous tasks

Make sure that the following preconditions are met:
- ❑ The surface to be painted is clean and free of grease, dust, and debris.
- ❑ The spray paint can is at ambient temperature.
- ❑ All areas not to be painted are masked.

5.6.2.4 Consumables and equipment

Make sure that the following consumables and equipment are available:
- Spray paint can - black color (230613056)
- Lint-free cloths
- Cleaner

5.6.2.5 Painting

- ▶ Shake the spray paint can for 3 minutes.
- ▶ Spray the paint at a distance of 25 cm (9.84 in) to 30 cm (11.81 in), making a criss-cross pattern.
- ▶ Spray enough layers to cover the whole unpainted area.
- ▶ Turn the spray can upside down and bleed the valve after finishing the paint work.

Note

In optimal conditions (20 °C (68 °F), 65% of humidity), the paint is completely dry after 24 hours.

5.6.3 Post-maintenance filling and bleeding

5.6.3.1 Previous tasks

Make sure that the following preconditions are met:
- ❑ Maintenance activities are completed.
- ❑ Covers and guards are reinstalled.
- ❑ Lockout/tagout (LOTO) procedure is completed (→ 2.4.1.1 Lockout/tagout (LOTO), p. 46).

5.6.3.2 Specific safety advice

Not applicable.

5.6.3.3 Consumables and equipment

Make sure that the following consumables and equipment are available:
- Containers
- Lint-free cloths

5.6.3.4 Filling the systems

▶ Top up all fluids. (For more information, see: Operation and Maintenance Manual.)

5.6.3.5 Bleeding the systems

Servicing an operating fluid system (engine oil, coolant, or fuel) may lead to air entrapment into the system. Trapped air may lead to failed start or poor running conditions.

Bleeding the engine oil system

NOTICE
Prelubricating pump overload!
Property damage - Risk of minor engine failure.

▶ Observe the prelubricating pump limitations: 5 minutes ON / 30 minutes OFF.

If the engine is equipped with a prelubricating pump:
▶ Operate prelubricating pump until pressure build-up.

If the engine is not equipped with a prelubricating oil pump:
▶ Crank the engine without ignition until the engine oil pressure builds up.

Note

Make sure that the engine does not start.

Note

For more information, see: Operation and Maintenance Manual.

Bleeding the cooling system

▶ Open bleeding connections and the cap on the expansion tank.

▶ Bleed the system until it is bubble-free.

▶ Close bleeding connections and the cap on the expansion tank.

Note

Depending on the quantity of coolant removed, bleeding the cooling system may require to start and operate the engine until the coolant temperature is above 60 °C (140 °F).

Note

For more information, see: Operation and Maintenance Manual.

Bleeding the fuel system

If the engine fails to start on the first attempt:
▶ Crank the engine without ignition to complete the automated bleeding through the fuel return line.

▶ Start the engine (→ 5.6.4 Post-maintenance engine starting, p. 112).
▷ After an initial start, we consider that the fuel line has been bled.

Note

For more information, see: Operation and Maintenance Manual.

Final check

▶ Make sure that all caps and open connections are closed.

▶ Check visually for leaks in lubrication, fuel, or cooling systems.

5.6.4 Post-maintenance engine starting

5.6.4.1 Previous tasks

Make sure that the following preconditions are met:
❑ Maintenance activities are completed.
❑ The lockout/tagout (LOTO) procedure is completed (→ 2.4.1.1 Lockout/tagout (LOTO), p. 46).

5.6.4.2 Specific safety instructions

WARNING
Toxic exhaust gas inhalation!
Risk of lung disease or injury by irritation.

▶ Make sure that there is a proper evacuation of exhaust gas.

▶ Ensure a good ventilation while running the engine.

5.6.4.3 Special tools

Make sure that the following special tools are available:
– KODIA kit

(→ 7.1.1 Special tools, p. 220)

5.6.4.4 Consumables and equipment

Not applicable.

5.6.4.5 Starting engine

▶ Start the engine.

Note

If air migrated into the fuel system, the first start attempt may require a longer time than a usual start.

▶ Run the engine at low idle speed (→ 2.7.2 Engine in lockout/tagout or in low idle speed, p. 55).

▶ Observe the engine running at idle speed.

▶ Record and report any defect found on the engine (for example: leak, unusual noise, unusual vibration, unusual exhaust gas color).

- ▶ Record and report any anomaly found on the generator set display (for example: faulty parameter).
- ▶ Shut the engine down.
- ▶ Check visually for leaks in engine oil, fuel, and cooling systems.
- ▶ If required, run functional tests.
- ▶ With KODIA take a “Snapshot Report” of the engine status. Pay particular attention to the “Trouble Codes”.
- ▶ Record and report the intervention.

Note

In the report of the intervention, include at least operating hours, replaced parts, additional interventions required if necessary.

If necessary, place an order to restock the parts used during maintenance activities.

5.7 1000 - Base engine

5.7.1 Inspecting engine overall condition – SLO-1011

5.7.1.1 Previous tasks

Make sure that the following preconditions are met:
❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

5.7.1.2 Specific safety instructions

DANGER
Contact with hot parts!
Death or serious injury from burns.

▶ Stay away from the engine when it is in operation.

▶ Wait for the engine to cool down until the surface temperature allows contact with a bare hand before servicing.

▶ Wear appropriate Personal Protective Equipment (PPE).

5.7.1.3 Consumables and equipment

Not applicable.

5.7.1.4 Visual inspection

To prevent engine damage, visually inspect the engine by performing the following tasks:
– Search for possible leaks.
– Search for loose components.

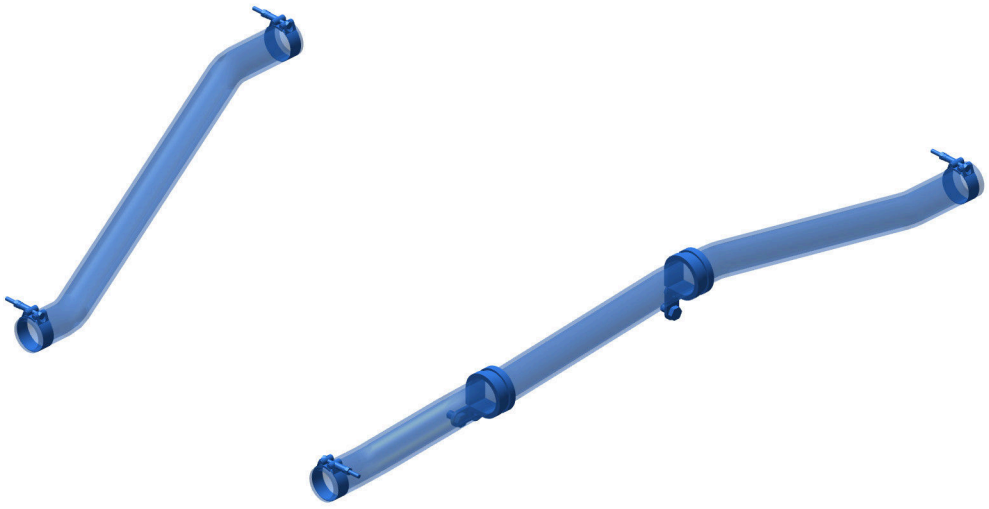


Fig. 37: Hoses

The lines and hoses must be free of the following defects:
– Damage to the outer layer (for example: scratches, cuts, and tears)
– Embrittlement of the outer layer (for example: crack formation in the material)

- Deformation of the hose or line, taking into account depressurized and pressurized conditions of the hose or line, as well as bends (for example: delamination, blister formation)
- Leaks
- Clogs
- Damage or deformation to fittings
- Dislocation of hoses from fittings
- Corrosion on fittings

5.7.1.5 Overview - driving end and right side of the engine

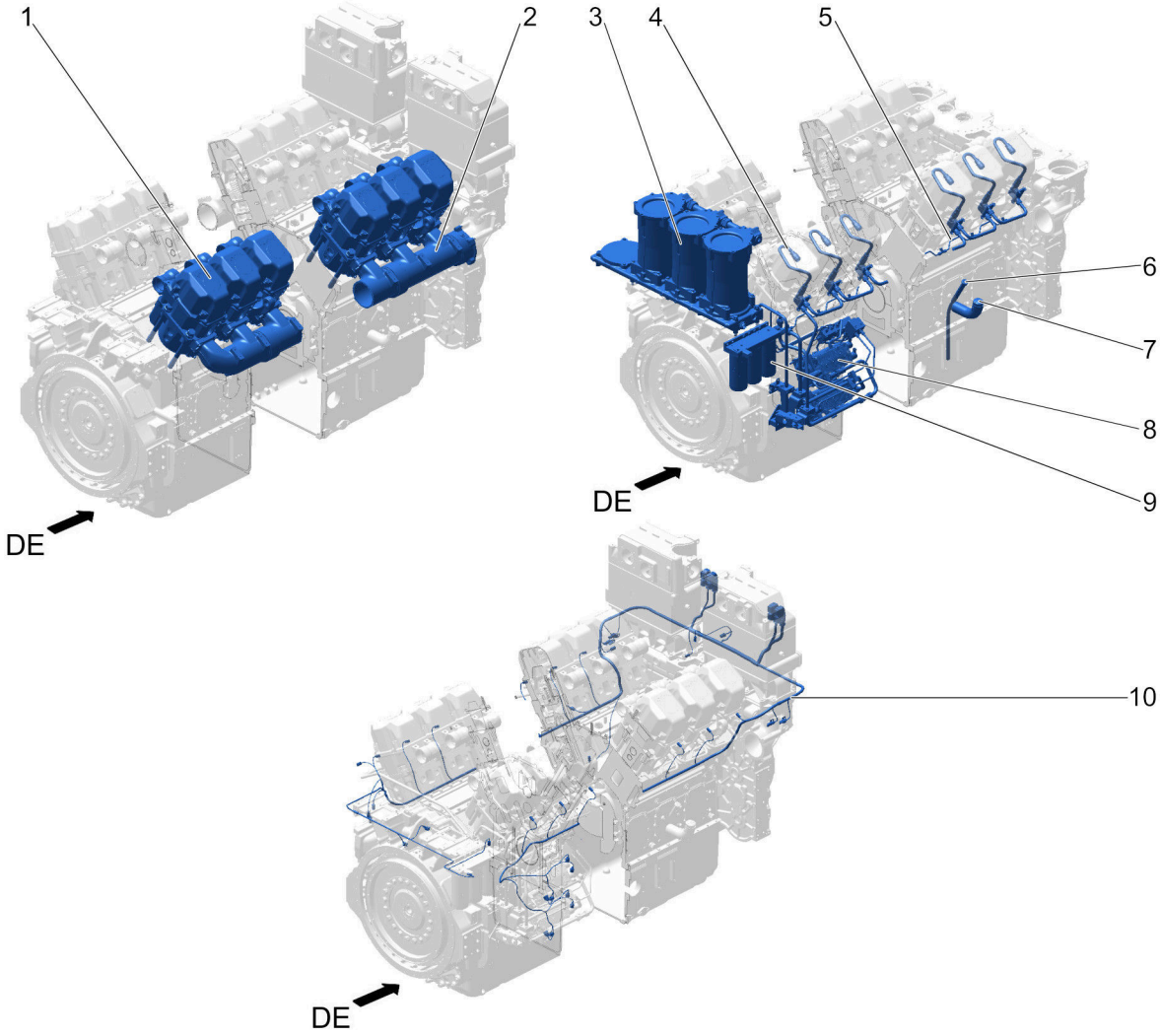


Fig. 38: Visual inspection - view from driving end

DE Driving End

1 Cylinder head
2 Cold charge air line
3 Crankcase breather oil separator
4 Double-walled piping (high-pressure fuel line)
5 Single fuel piping (fuel return line)
6 Oil filler neck
7 Oil dipstick
8 Fuel pump
9 Fuel filter
10 Wiring harness

Cylinder head

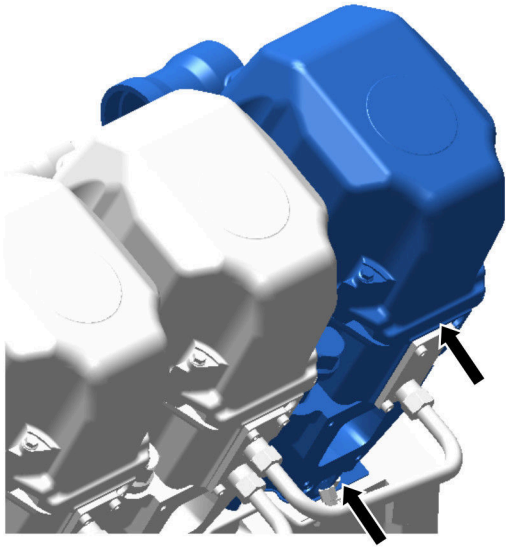


Fig. 39: Cylinder head

- ▶ Inspect the cylinder head.
- ▶ Search for possible leaks between the cylinder head cover and the cylinder head.
- ▶ Search for possible leaks between the cylinder head and the crankcase.
- ▶ Record and report any defect.

If defect is detected:
- ▶ Make sure that authorized service personnel correct the defect.

Cold charge air line

- ▶ Inspect the cold charge air line.
- ▶ Search for possible leaks at connections.
- ▶ Record and report any defect.

If defect is detected:
- ▶ Make sure that authorized service personnel correct the defect.

Dewatering bores of cold charge air line

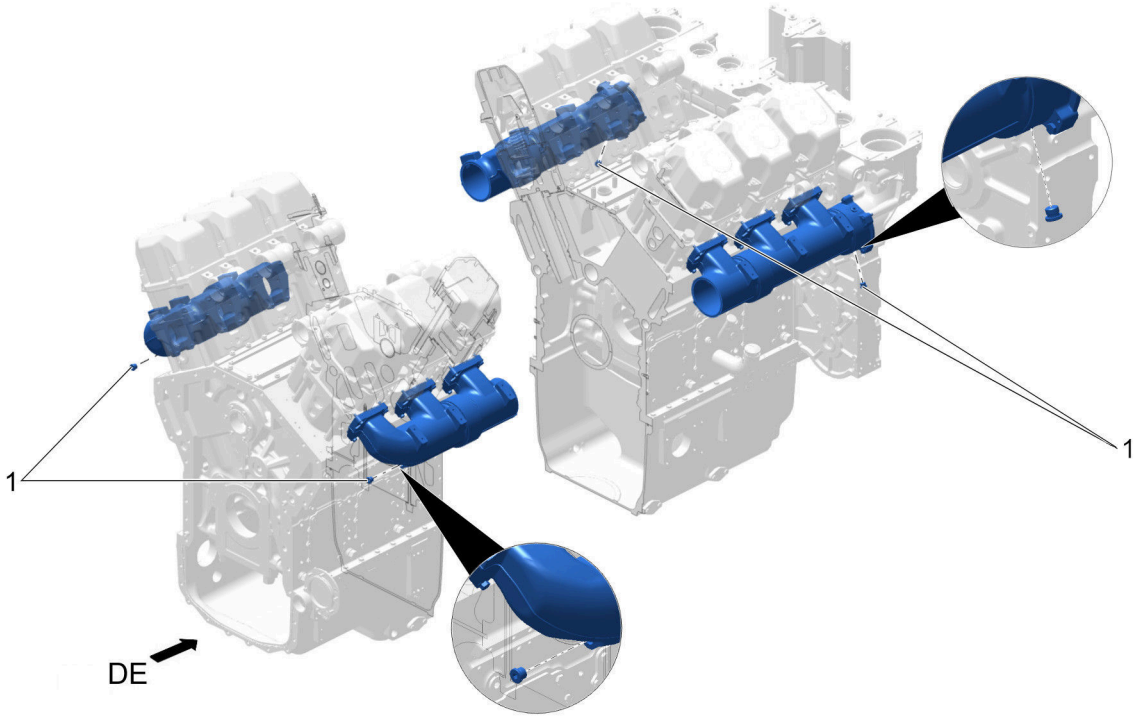


Fig. 40: Dewatering bores of cold charge air line

- ▶ Check for obstruction, dewatering bores must be free of dirt.
- ▶ Check for fluid traces.

In case of traces of water (condensation):
- ▶ Condensation water is normal.

In case of traces of coolant:
- ▶ Request an inspection of the charge air coolers.

In case of traces of oil:
- ▶ Request an inspection of the exhaust gas turbochargers.
- ▶ Record and report any defect.

If defect is detected:
- ▶ Make sure that authorized service personnel correct the defect.

Crankcase breather oil separator

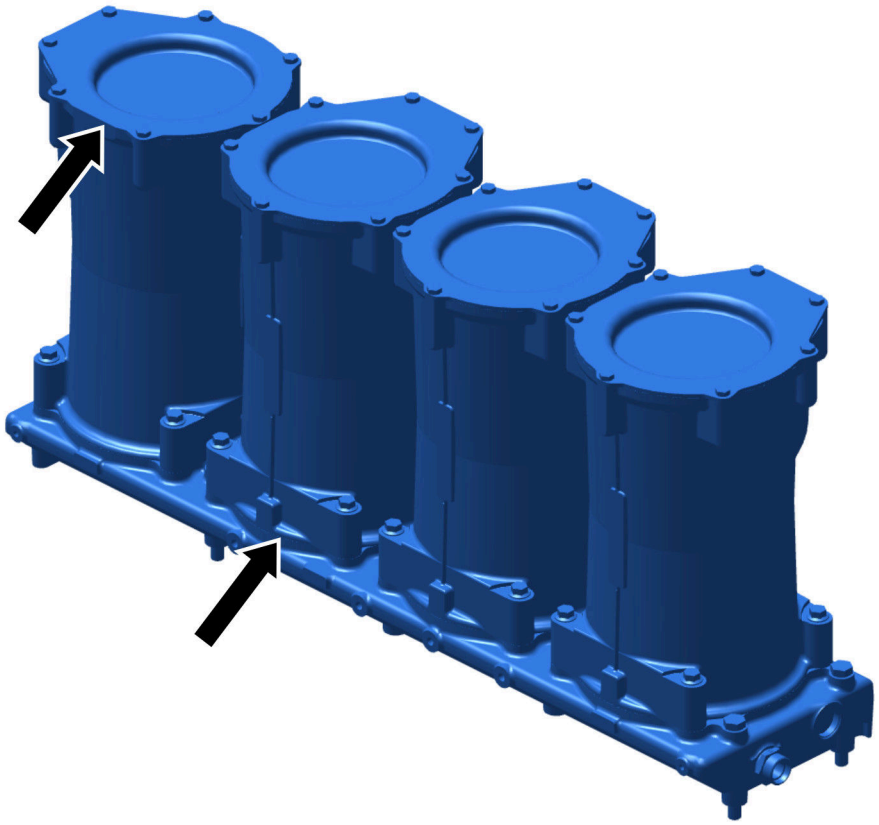


Fig. 41: Crankcase oil breather separator

- ▶ Inspect the crankcase breather oil separator.
- ▶ Search for possible leaks between the cover of the crankcase breather oil separator and the housing.
- ▶ Search for possible leaks between the housing of the crankcase breather oil separator and the support.
- ▶ Inspect the pipes between the crankcase breather oil separator and the air intake of the exhaust gas turbocharger. Search for possible cracks or cuts.
- ▶ Record and report any defect.

If defect is detected:
- ▶ Make sure that authorized service personnel correct the defect.

Double-walled piping (high-pressure fuel line)

- ▶ Inspect the double-walled piping (high-pressure fuel line).
- ▶ Search for possible leaks at connections.
- ▶ Record and report any defect.

If defect is detected:
- ▶ Make sure that authorized service personnel correct the defect.

Single-walled piping

- ▶ Inspect the single-walled piping (fuel return line and fuel feed line).

- ▶ Search for possible leaks at connections.
- ▶ Record and report any defect.

If defect is detected:

- ▶ Make sure that authorized service personnel correct the defect.

Fuel pumps

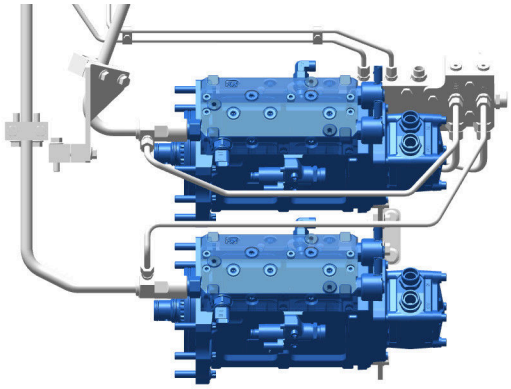


Fig. 42: Fuel pumps

- ▶ Inspect the fuel pumps.
- ▶ Search for possible leaks at connections.
- ▶ Record and report any defect.

If defect is detected:

- ▶ Make sure that authorized service personnel correct the defect.

Fuel filters

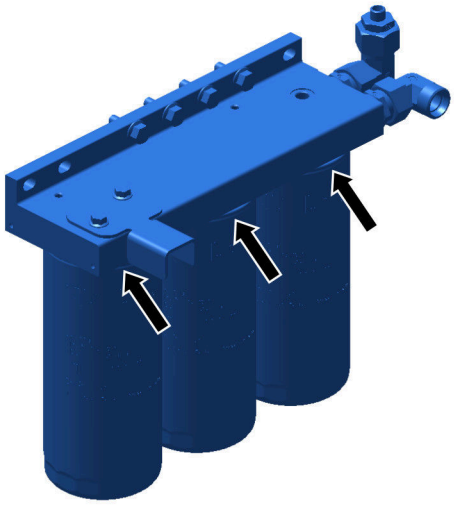


Fig. 43: Fuel filters

- ▶ Inspect the fuel filters.
- ▶ Search for possible leaks between the fuel filter head and the filter.
- ▶ Search for possible leaks at connections.

▶ Record and report any defect.

If defect is detected:
▶ Make sure that authorized service personnel correct the defect.

Oil filler neck

▶ Inspect the oil filler neck.

▶ Make sure that the oil filling cap is in place and tightly closed.

▶ Record and report any defect.

If defect is detected:
▶ Make sure that authorized service personnel correct the defect.

Oil dipstick

▶ Make sure that the oil dipstick is in place.

▶ Record and report any defect.

If defect is detected:
▶ Make sure that authorized service personnel correct the defect.

Wiring harness

▶ Inspect overall condition of the wiring harness.

▶ Inspect connections.

▶ Search for unplugged connectors.

▶ Search for uninsulated conductors.

▶ Record and report any defect.

If defect is detected:
▶ Make sure that authorized service personnel correct the defect.

5.7.1.6 Overview - free end and left side of the engine

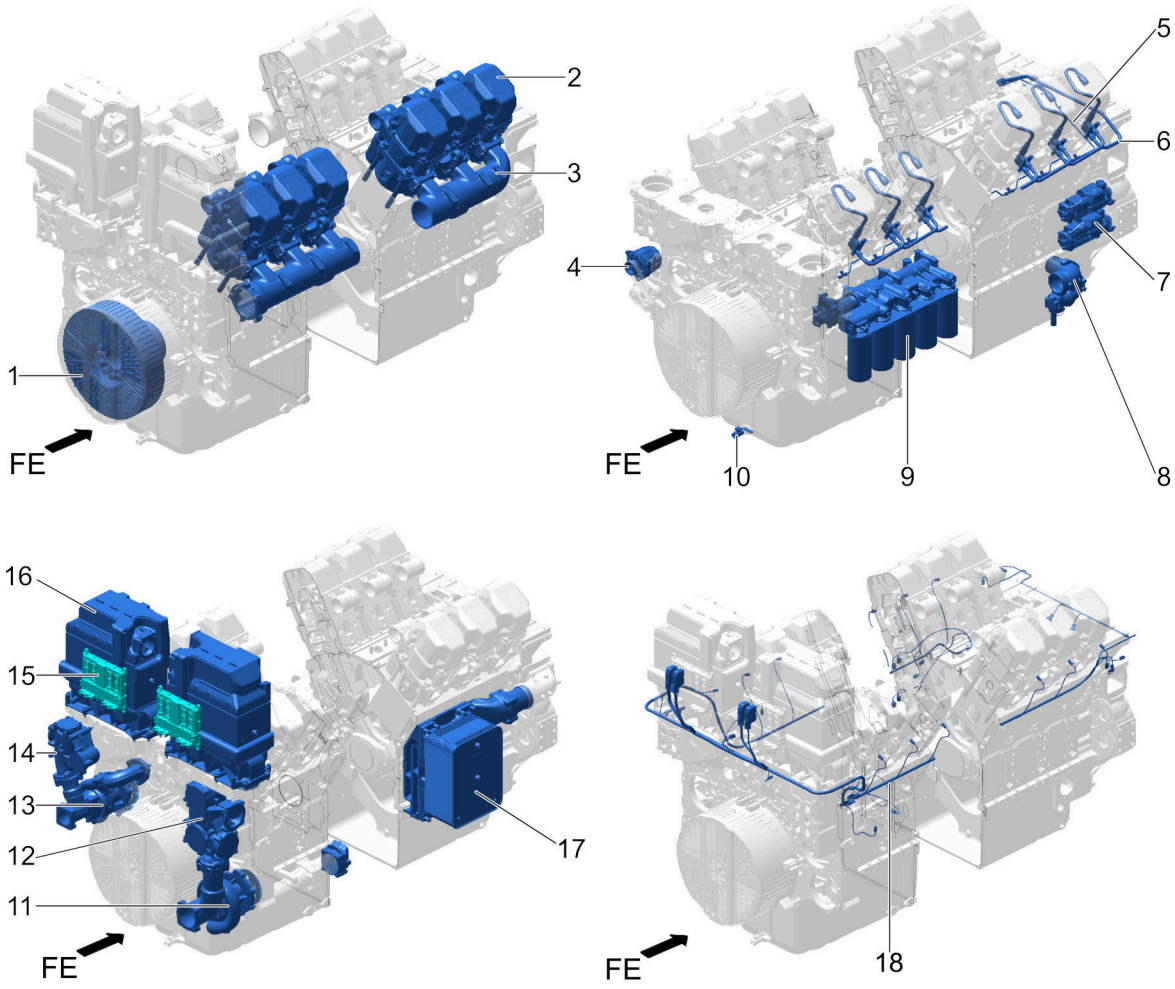


Fig. 44: Visual inspection - view from free end

FE Free End

1 Torsional vibration damper
2 Cylinder head
3 Cold charge air line
4 Battery charging alternator
5 Single-walled piping (fuel return line)
6 Double-walled piping (high-pressure fuel line)
7 Starter
8 Oil pressure regulator
9 Spin-on oil filter
10 Oil drain valve
11 High Temperature (HT) coolant pump
12 High Temperature (HT) thermostat housing)
13 Low Temperature (LT) coolant pump
14 Low Temperature (LT) thermostat housing
15 Charge air cooler
16 Oil cooler
17 Engine Control Unit (ECU)
18 Wiring harness

Torsional vibration damper cover

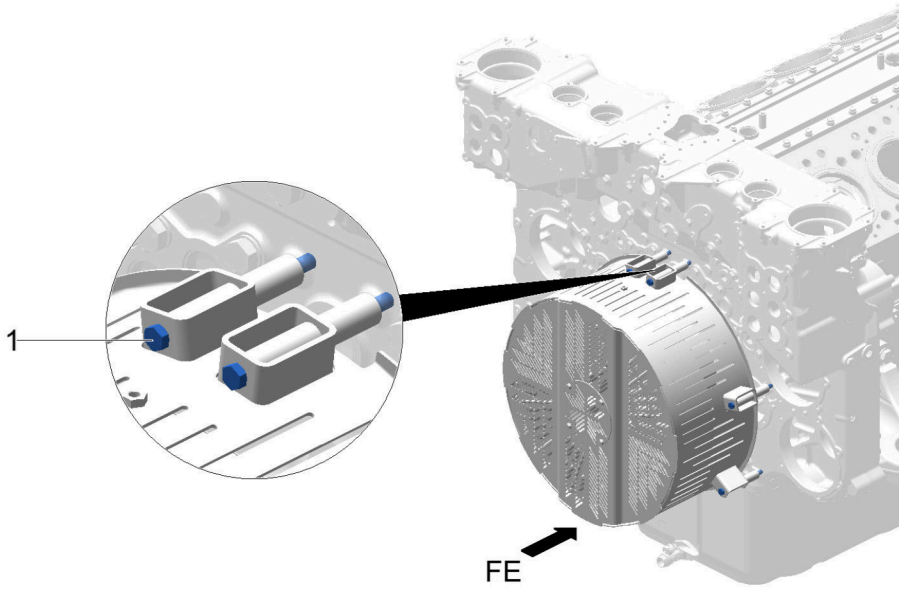


Fig. 45: Torsional vibration damper cover

1 Screw

▶ Inspect the cover of the torsional vibration damper.

▶ Make sure that screws **1** are properly tightened.

▶ Record and report any defect.

If defect is detected:

▶ Make sure that authorized service personnel correct the defect.

Pulley of crankshaft power take-off (depending on configuration)

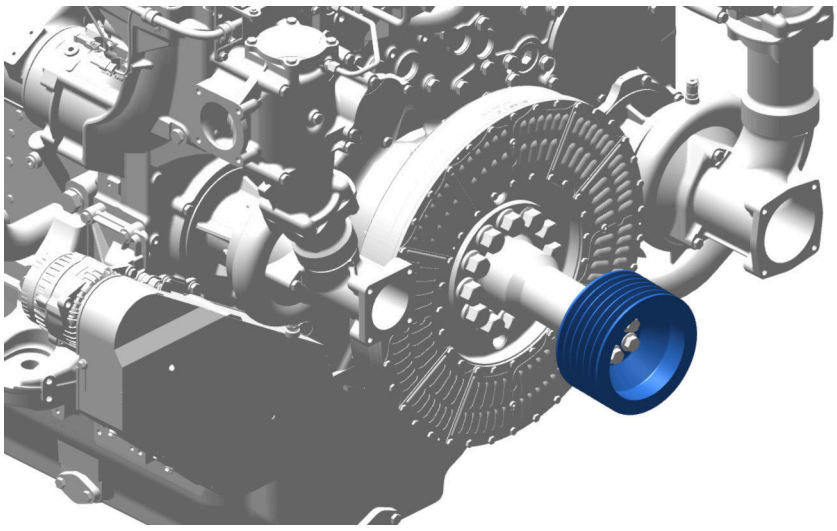


Fig. 46: Crankshaft power take-off

▶ Inspect the pulley for external damage.

▶ Search for potential embrittlements of the pulley (for example: crack formation in the material).

▶ Record and report any defect.

If defect is detected:
▶ Make sure that authorized service personnel correct the defect.

Battery charging alternator

▶ Inspect overall condition of the battery charging alternator.

▶ Check for loose cable connections.

▶ Record and report any defect.

If defect is detected:
▶ Make sure that authorized service personnel correct the defect.

Starters

▶ Inspect overall condition of the starters.

▶ Check for loose cable connections.

▶ Record and report any defect.

If defect is detected:
▶ Make sure that authorized service personnel correct the defect.

Spin-on oil filters

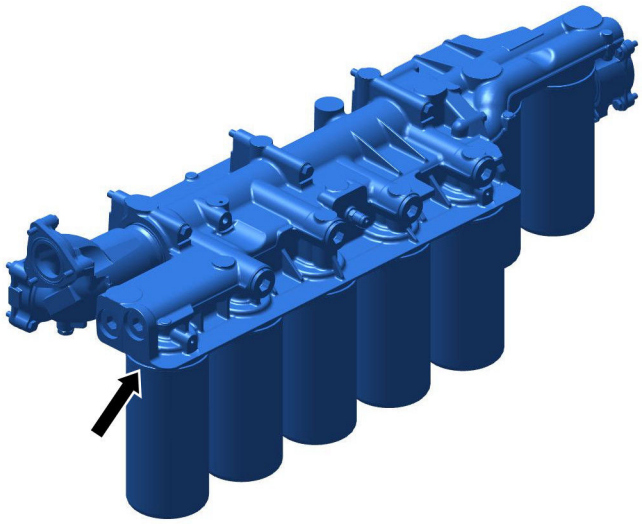


Fig. 47: Spin-on oil filters

▶ Inspect the spin-on oil filters.

▶ Search for possible leaks between the spin-on oil filter head and the spin-on oil filter.

▶ Record and report any defect.

If defect is detected:
▶ Make sure that authorized service personnel correct the defect.

Oil pressure regulator

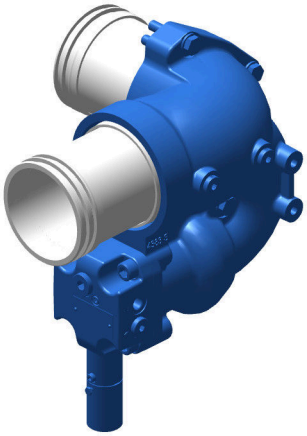


Fig. 48: Oil pressure regulator

- ▶ Inspect the oil pressure regulator.
- ▶ Search for possible leaks at connections.
- ▶ Record and report any defect.

If defect is detected:

- ▶ Make sure that authorized service personnel correct the defect.

Oil drain valve

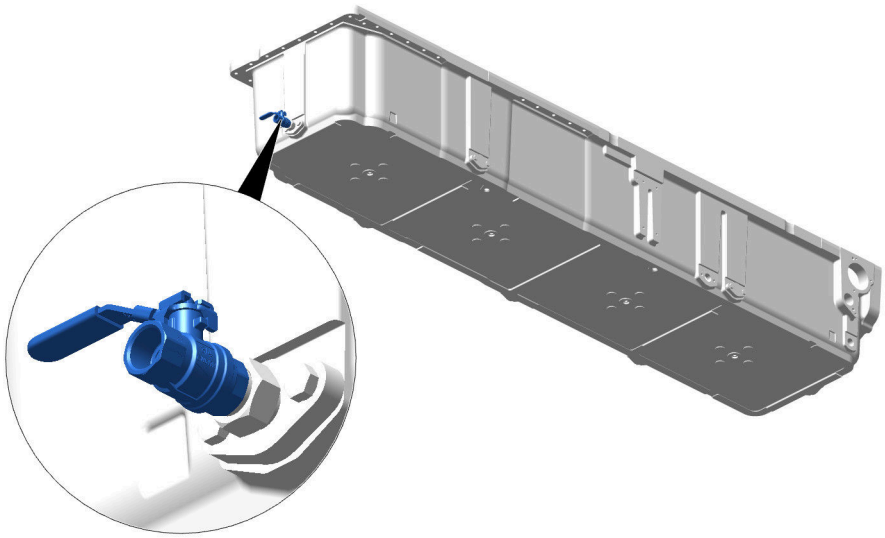


Fig. 49: Oil drain valve

- ▶ Inspect the oil drain valve.
- ▶ Search for possible leaks.
- ▶ Record and report any defect.

If defect is detected:

- ▶ Make sure that authorized service personnel correct the defect.

High Temperature (HT) and Low Temperature (LT) coolant pumps

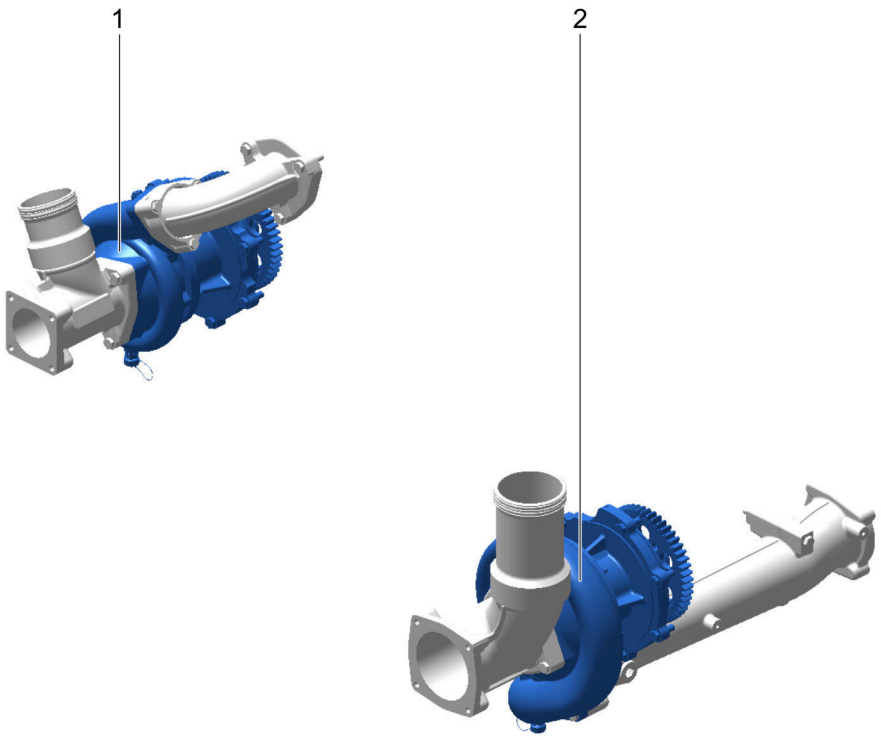


Fig. 50: HT and LT coolant pumps

1 Low Temperature (LT) coolant pump

2 High Temperature (HT) coolant pump

▶ Inspect the HT and LT coolant pumps.

▶ Search for possible leaks at connections.

▶ Record and report any defect.

If defect is detected:

▶ Make sure that authorized service personnel correct the defect.

Relief bores of High Temperature (HT) and Low Temperature (LT) coolant pumps

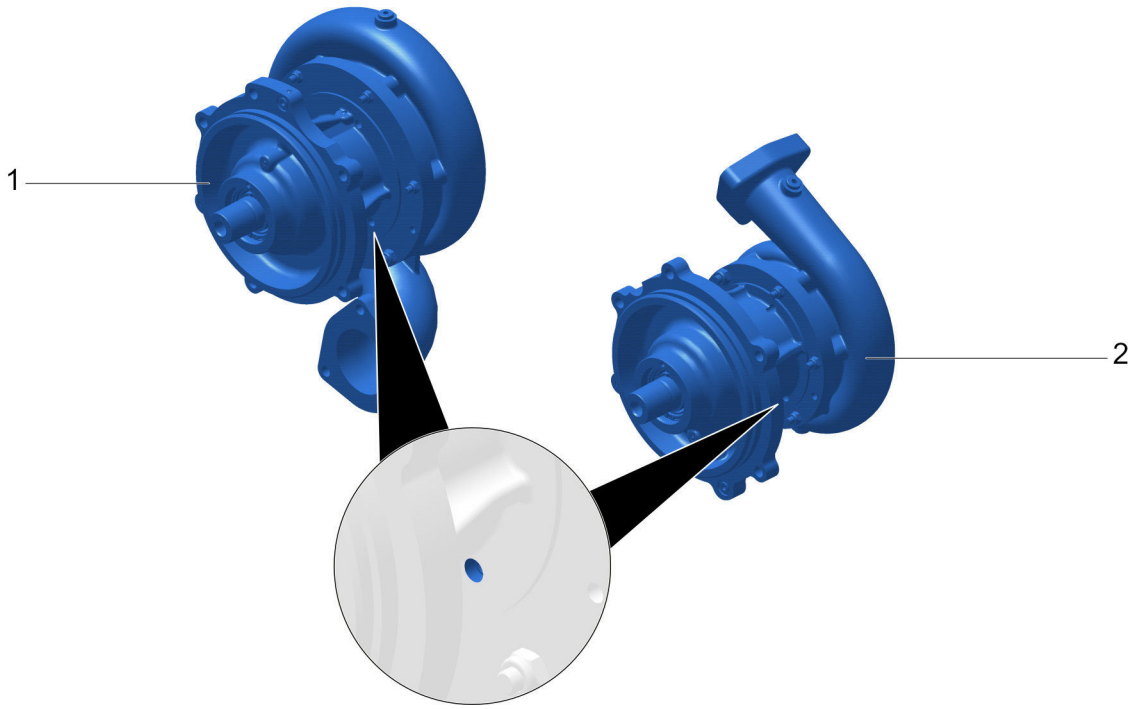


Fig. 51: Relief bores of HT and LT coolant pumps

1 High Temperature (HT) coolant pump **2** Low Temperature (LT) coolant pump

▶ Check for obstruction, relief bores must be free of dirt.

▶ Check for potential leaks.

In case of traces of coolant:
▶ Slight drops are not critical.

In case of traces of oil:
▶ Request an inspection of the coolant pumps.

▶ Record and report any defect.

If defect is detected:
▶ Make sure that authorized service personnel correct the defect.

High Temperature (HT) and Low Temperature (LT) thermostats housings

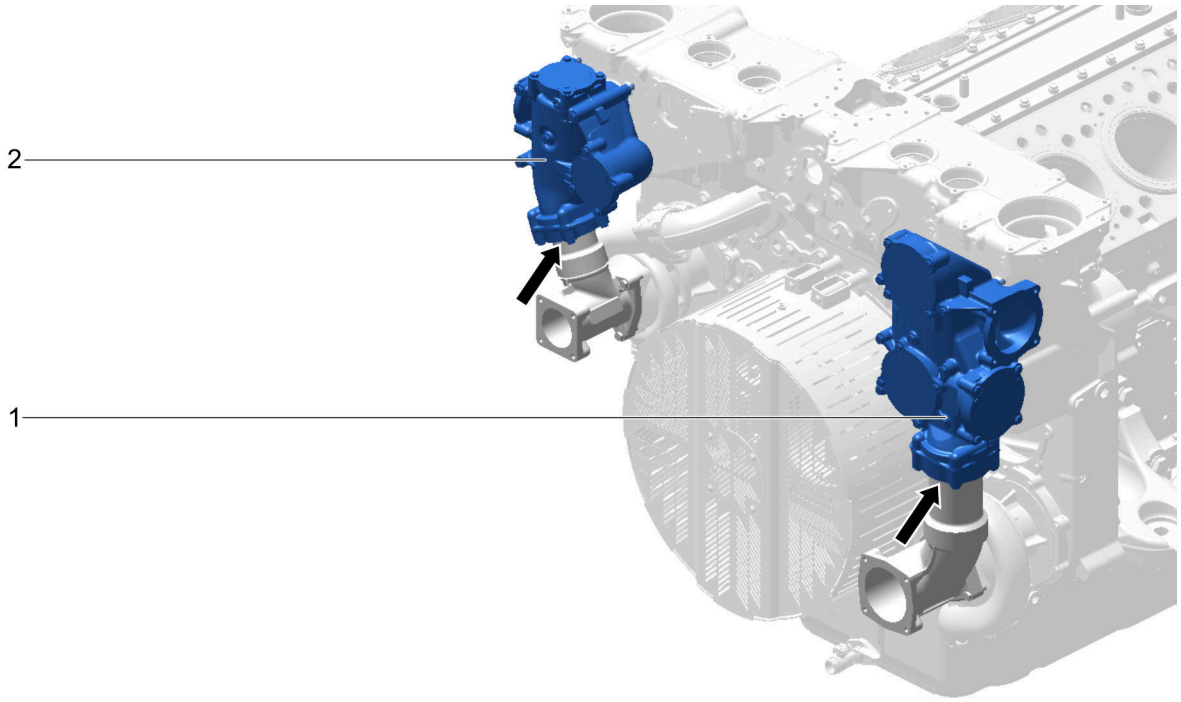


Fig. 52: HT and LT thermostats housings

1 High Temperature (HT) thermostat housing

2 Low Temperature (LT) thermostat housing

▶ Inspect the HT and LT thermostats housings.

▶ Search for possible leaks at connections.

▶ Record and report any defect.

If defect is detected:

▶ Make sure that authorized service personnel correct the defect.

Charge air coolers

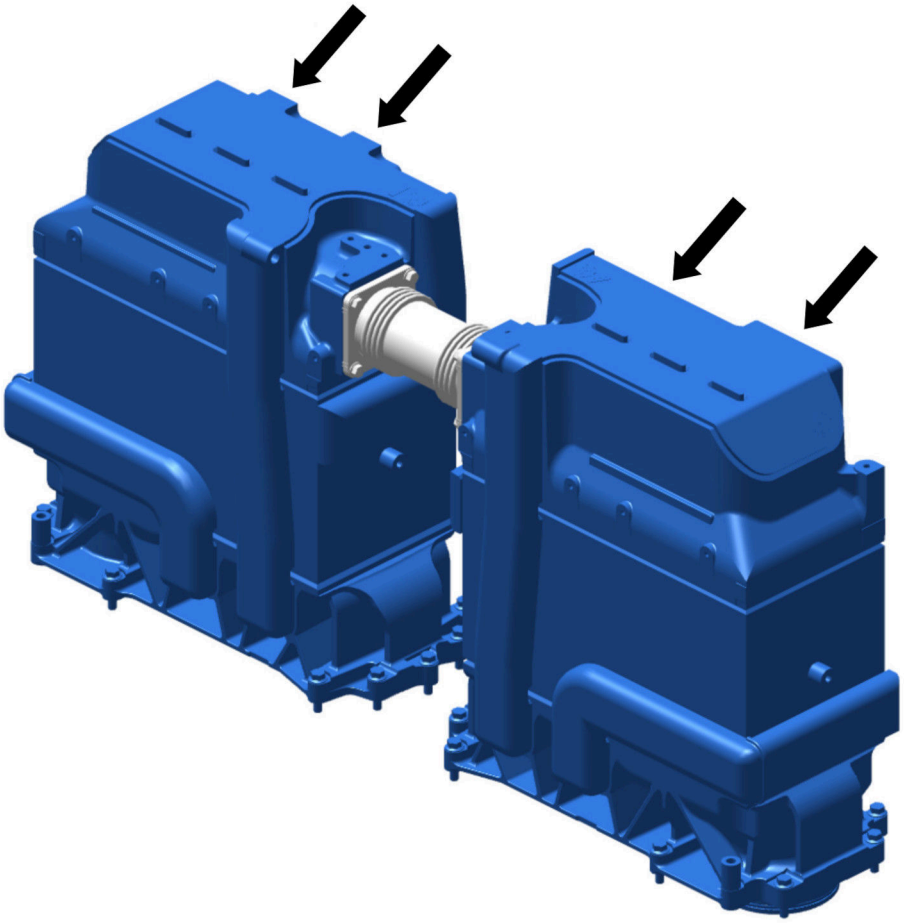


Fig. 53: Charge air coolers

- ▶ Inspect the charge air coolers.
- ▶ Search for possible leaks at connections.
- ▶ Record and report any defect.

If defect is detected:

- ▶ Make sure that authorized service personnel correct the defect.

Oil coolers

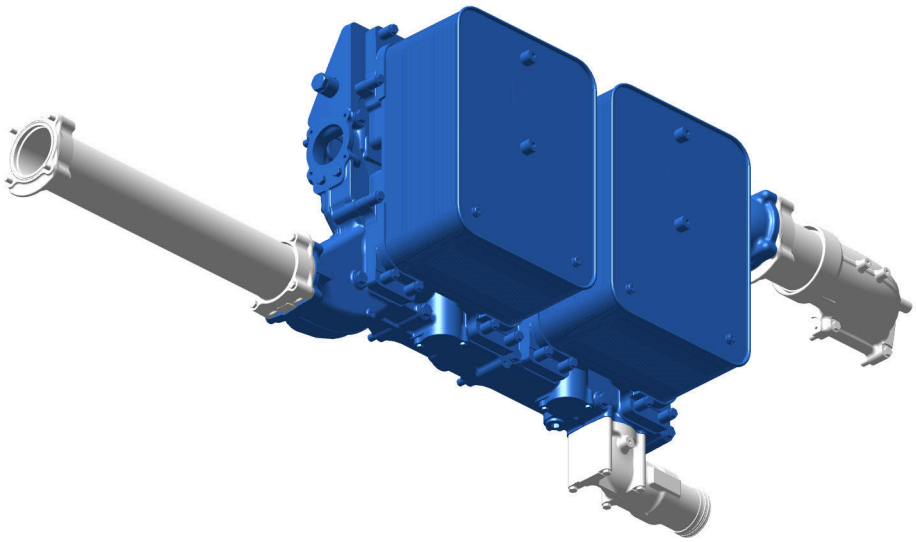


Fig. 54: Oil coolers

- ▶ Inspect the oil coolers (→ 5.8.6 Inspecting oil cooler – SL1-2411, p. 164).
- ▶ Search for possible leaks at connections.
- ▶ Record and report any defect.

If defect is detected:

- ▶ Make sure that authorized service personnel correct the defect.

Engine Control Unit (ECU)

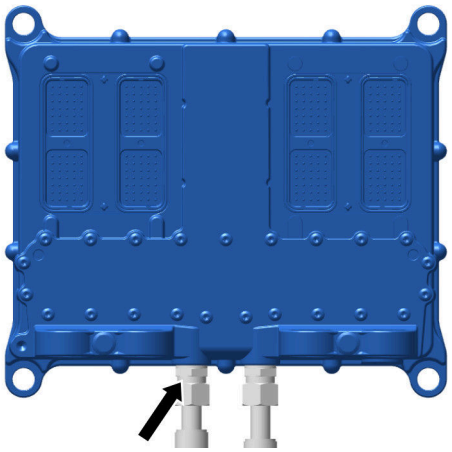


Fig. 55: ECU

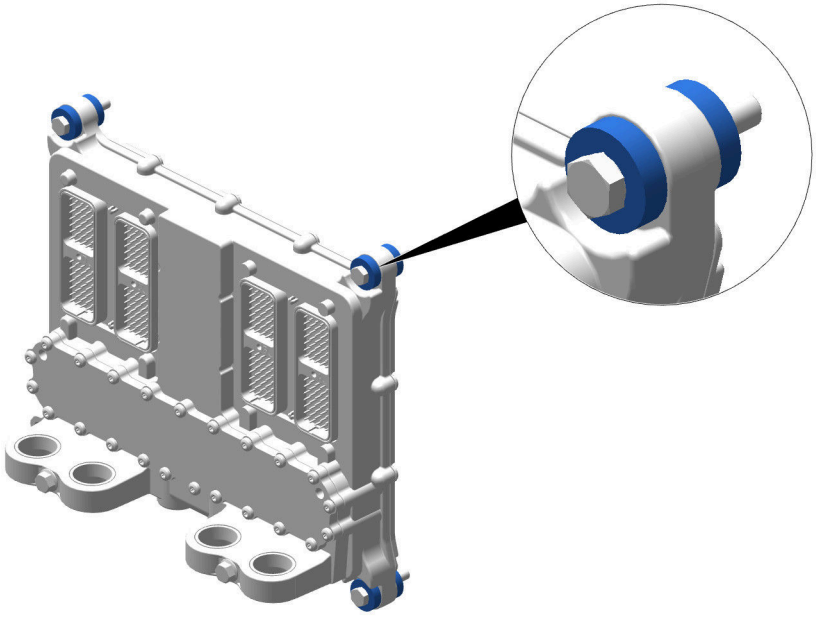


Fig. 56: ECU - Rubber sleeves

- ▶ Inspect the ECU.
- ▶ Inspect the rubber sleeves of the ECU.
- ▶ Search for possible leaks at connections.
- ▶ Make sure that connections are properly tightened.
- ▶ Record and report any defect.

If defect is detected:

- ▶ Make sure that authorized service personnel correct the defect.

5.7.1.7 Overview - top of the engine

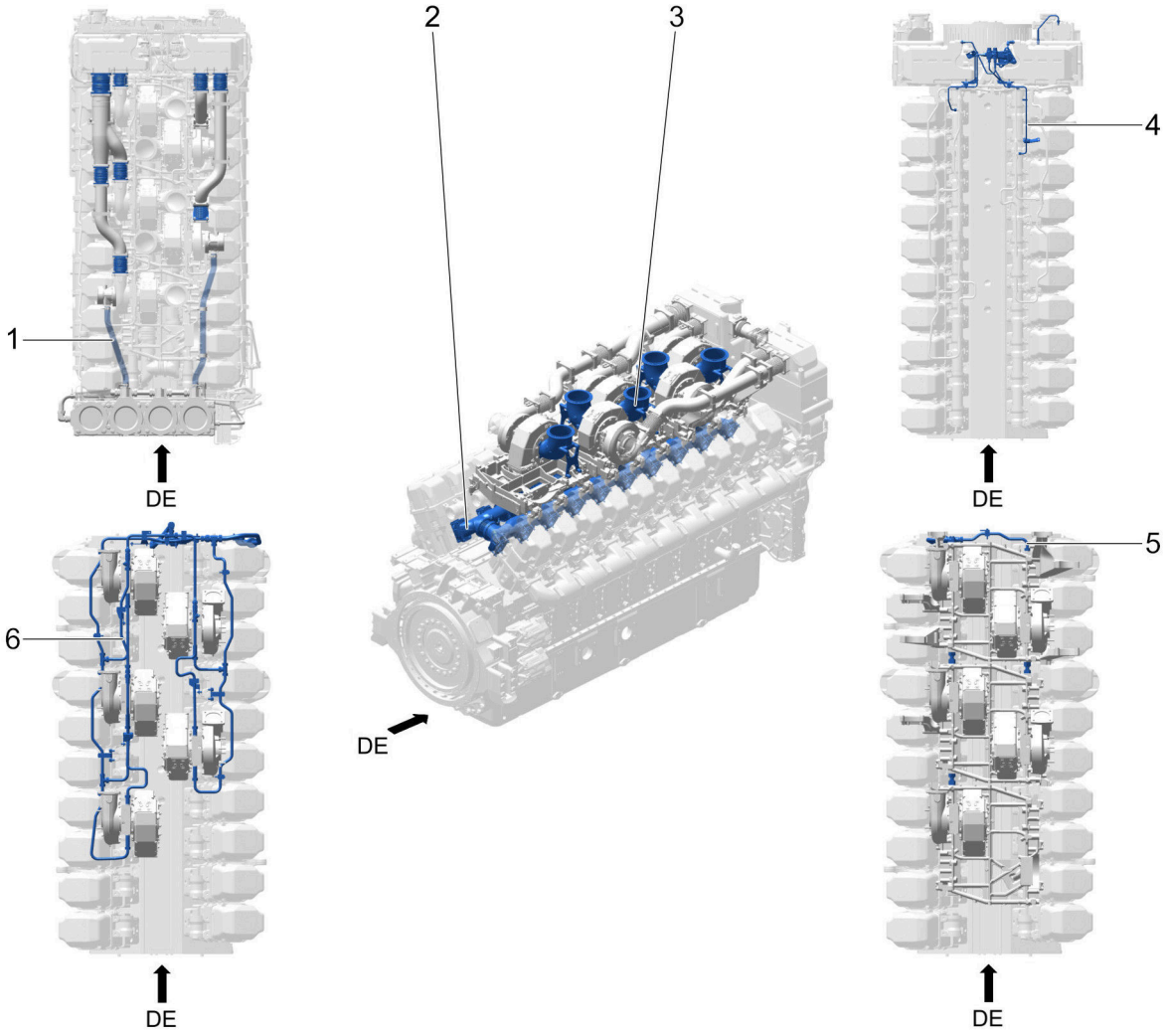


Fig. 57: Visual inspection - view from top

DE Driving End

1 Hose (from crankcase breather system)
2 Exhaust manifold
3 Exhaust elbow from exhaust gas turbocharger
4 Coolant venting line
5 Oil feed line of exhaust gas turbocharger
6 Exhaust gas turbocharger coolant line

Charge air compensator

- ▶ Inspect overall condition of the charge air compensator.
- ▶ Search for leaks, cracks, and inspect mounting.
- ▶ Record and report any defect.

If defect is detected:

- ▶ Make sure that authorized service personnel correct the defect.

Exhaust system

- ▶ Inspect overall condition of the exhaust gas system, including compensators.
- ▶ Search for leaks, cracks, and inspect mounting.

▶ Record and report any defect.

If defect is detected:
▶ Make sure that authorized service personnel correct the defect.

Coolant venting line

▶ Inspect the coolant venting line.

▶ Search for possible leaks at connections.

▶ Record and report any defect.

If defect is detected:
▶ Make sure that authorized service personnel correct the defect.

Coolant line of exhaust gas turbocharger

▶ Inspect the coolant line of the exhaust gas turbocharger.

▶ Search for possible leaks at connections.

▶ Record and report any defect.

If defect is detected:
▶ Make sure that authorized service personnel correct the defect.

Oil feed line of exhaust gas turbocharger

▶ Inspect the oil feed line of exhaust gas turbocharger.

▶ Search for possible leaks at connections.

▶ Record and report any defect.

If defect is detected:
▶ Make sure that authorized service personnel correct the defect.

5.7.2 Inspecting engine running at idle speed – SL0-1021

5.7.2.1 Previous tasks

Make sure that the following preconditions are met:
❑ Engine is running at idle speed.
❑ Engine is secured in the idle speed operating mode.

5.7.2.2 Specific safety instructions

Not applicable.

5.7.2.3 Consumables and equipment

Not applicable.

5.7.2.4 Inspection

▶ Observe the engine running at idle speed.

▶ Record and report any defect found on the engine (for example: leak, unusual noise, unusual vibration, unusual exhaust gas color).

▶ Record and report any anomaly found on generator set display (for example: faulty parameter).

If defect is detected:
▶ Make sure that authorized service personnel correct the defect.

5.7.3 Testing engine in operation (ESP application only) – SL0-1022

5.7.3.1 Previous tasks

Make sure that the following preconditions are met:
❑ Operating test is planned and agreed with the responsible person for the electrical network.
❑ Electrical load is available for the test.
❑ Generator set is ready for operation.

5.7.3.2 Specific safety instructions

Not applicable.

5.7.3.3 Consumables and equipment

Not applicable.

5.7.3.4 Test

▶ Run engine at a higher load than 1/3 of its nominal power until temperature reaches steady state. All parameters must remain within expected range (no alarm).

▶ Monitor the running engine and the generator set display.

▶ Record and report any defect found on the engine (for example: leak, unusual noise, unusual vibration, unusual exhaust gas color).

▶ Record and report any anomaly found on generator set display (for example: faulty parameter).

▶ Make sure that authorized service personnel correct the defect.

5.7.4 Removing and installing cylinder head cover – SL1-1110

5.7.4.1 Previous tasks

Make sure that the following preconditions are met:
❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

5.7.4.2 Specific safety instructions



DANGER
Contacts with hot parts!
Risk of death or injury by burn.

▶ When the engine is in operation, stay away from the engine.

▶ Before servicing the engine, let it cool down until surface temperature allows you to touch it with bare hand.

▶ Wear proper personal protective equipment.

NOTICE
Leaks by reuse of seals!
Property damage - Risk of critical engine failure.

▶ Use new seals after any dismantling.

5.7.4.3 Special tools

Not applicable.

5.7.4.4 Consumables and equipment

Make sure that the following consumables and equipment are available:
– Seal

5.7.4.5 Overview

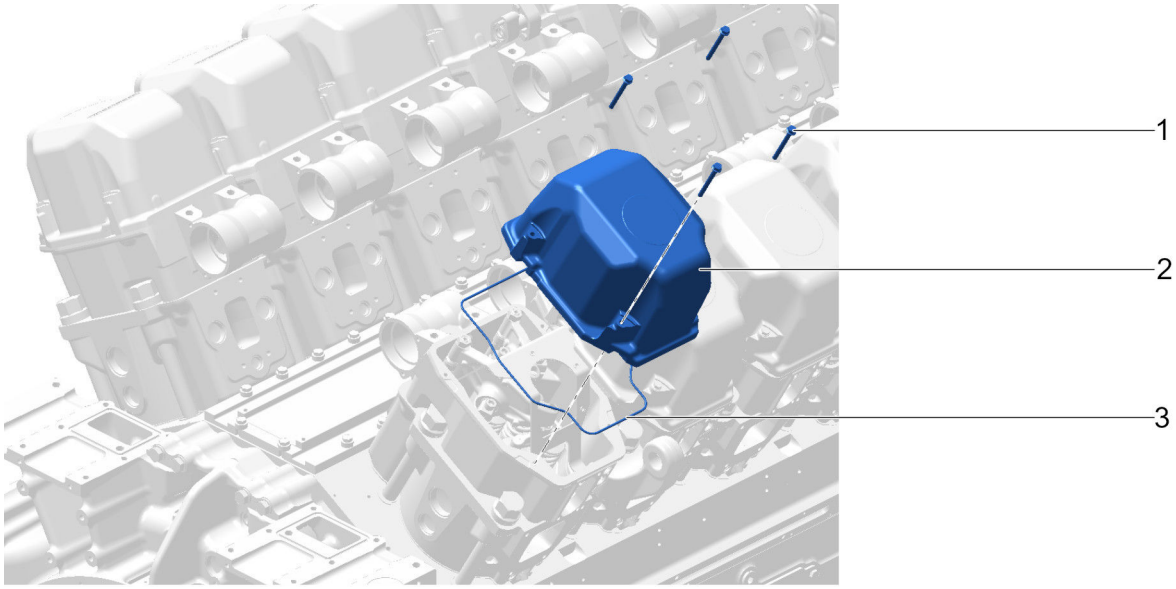


Fig. 58: Task overview

1 Screw (M8)
2 Cylinder head cover
3 Seal

5.7.4.6 Removal

▶ Remove screws **1**.

▶ Remove cylinder head cover **2** and seal **3**.

5.7.4.7 Installation

▶ Install new seal **3** on cylinder head cover **2**.

▶ Install screws **1** into the bores of cylinder head cover **2**.

▶ Install cylinder head cover **2** on rocker arm housing.

▶ Tighten screws **1**.

5.7.4.8 Specific values

Not applicable.

5.7.4.9 Tightening specifications

Refer to standard tightening torques (→ 8.4 Standard tightening torques, p. 249).

5.7.5 Checking valve clearance – SL1-1122

5.7.5.1 Previous tasks

Make sure that the following preconditions are met:
- ❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).
- ❑ Cylinder head cover is removed (→ 5.7.4 Removing and installing cylinder head cover – SL1-1110, p. 133).
- ❑ Turning device is installed (→ 7.1.2 Turning device, p. 227).

5.7.5.2 Specific safety instruction

DANGER
Contact with hot parts!
Death or serious injury from burns.

- ▶ Stay away from the engine when it is in operation.
- ▶ Wait for the engine to cool down until the surface temperature allows contact with a bare hand before servicing.
- ▶ Wear appropriate Personal Protective Equipment (PPE).

Note

Check valve clearance only when the matching cylinder is in the correct position.

5.7.5.3 Special tools

Make sure that the following special tools are available:
- Turning device

(→ 7.1.1 Special tools, p. 220)

5.7.5.4 Consumables and equipment

Make sure that the following consumables and equipment are available:
- Feeler gauges

5.7.5.5 Overview

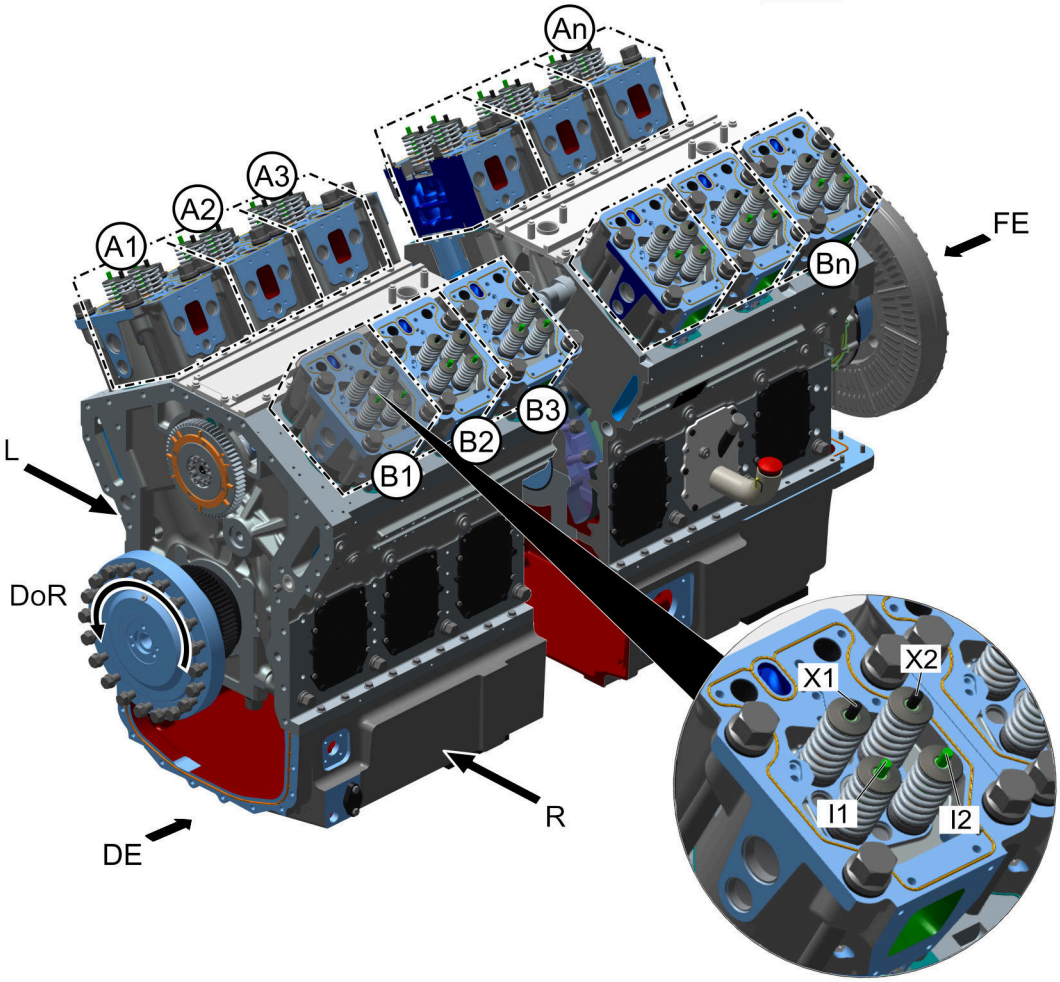


Fig. 59: Cylinder designation / direction of rotation according to ISO 1204

A1-An	Series of cylinders – Bank A	**X**	Exhaust valves
B1-Bn	Series of cylinders – Bank B	**I**	Intake valves
DE	Driving end	**L**	Left engine side
FE	Free end	**R**	Right engine side
DoR	Direction of rotation		

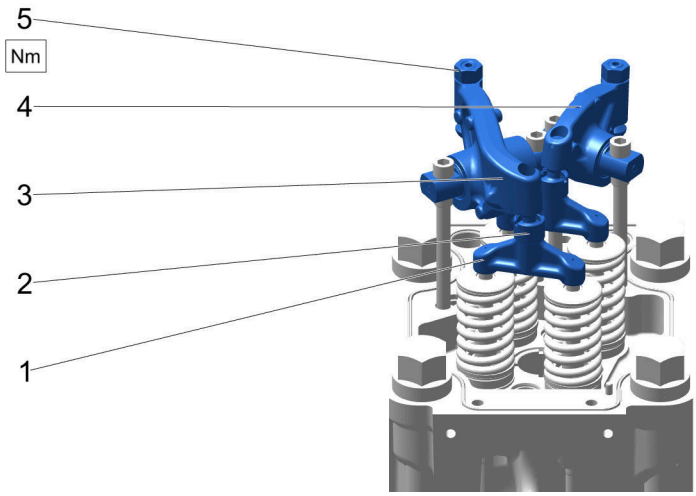


Fig. 60: Task overview

1 Valve bridge
2 Rocker ball cap
3 Inlet rocker arm
4 Exhaust rocker arm
5 Locknut (M14)

5.7.5.6 Setting valve order

Note

There is a marking on the flywheel to set the valve order for checking clearance.

The flywheel grooves 1 to 6 are identified in the following figure.

The valve clearance must be checked in the correct position for the matching cylinder.

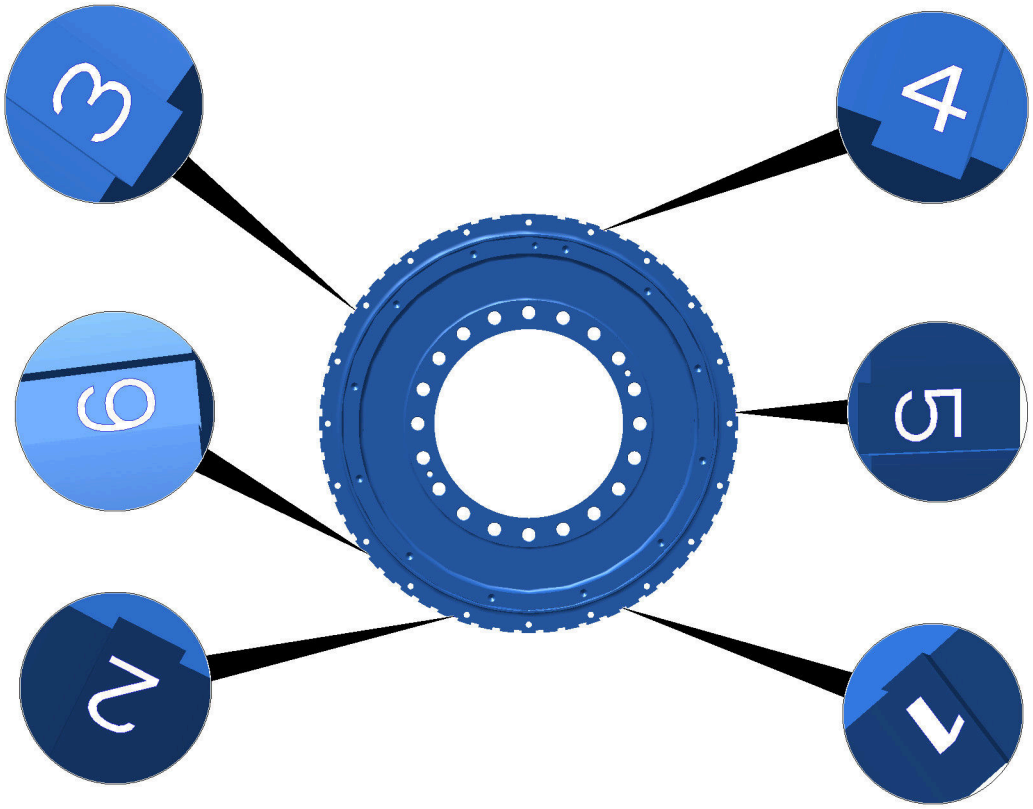


Fig. 61: Flywheel marking

Step	Start point	Groove N°	Sequence	V20	
				Bank A	Bank B
1	TDC overlap - A1	1	1st turn	**A8, A9**	**B4, B8**
2	-	2		No action	No action
3	-	6		No action	No action
4	-	3		**A4, A5**	**B3, B5**
5	-	4		No action	No action
6	-	5		**A1, A3**	**B1, B6**
7	TDC injection - A1	1	2nd turn	No action	No action
8	-	2		No action	No action
9	-	6		**A2, A6**	**B2, B10**
10	-	3		No action	No action
11	-	4		**A7, A10**	**B7, B9**

Tab. 29: Reference table for the flywheel positioning

A) Top Dead Center

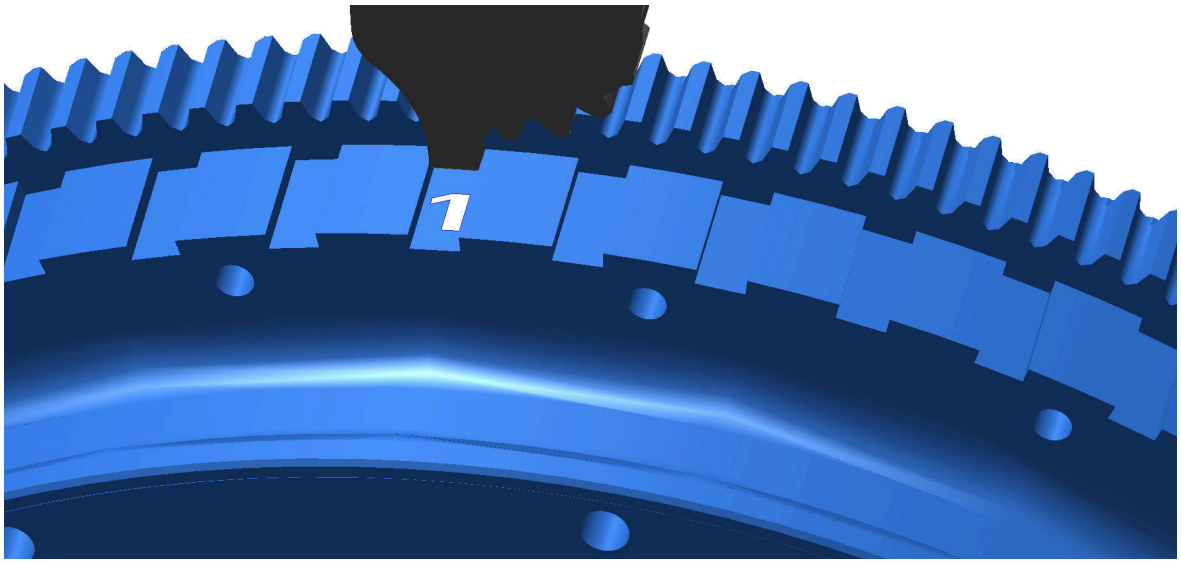


Fig. 62: Position of flywheel and turning device

Step 1

- ▶ Rotate the crankshaft in the direction of rotation until the turning device faces flywheel marking 1.
- ▶ Make sure that cylinder A1 is in overlap position.
- ▶ If cylinder A1 is not in overlap position, rotate the crankshaft another 360°.

After rotation of the crankshaft:

- ▶ Make sure that cylinder A1 is in overlap position.
- ▶ Check the valve clearance for cylinders A8, A9, B4, and B8 (→ tab. 30, p. 142), (→ 5.7.5.7 Checking valve clearance, p. 140).

Step 2

- ▶ Rotate the crankshaft in direction of rotation past flywheel marking 2.

Step 3

- ▶ Rotate the crankshaft in direction of rotation past flywheel marking 6.

Step 4

- ▶ Rotate the crankshaft in direction of rotation until the turning device faces flywheel marking 3.
- ▶ Check the valve clearance for cylinders A4, A5, B3, and B5 (→ tab. 30, p. 142), (→ 5.7.5.7 Checking valve clearance, p. 140).

Step 5

- ▶ Rotate the crankshaft in direction of rotation past flywheel marking 4.

Step 6

- ▶ Rotate the crankshaft in direction of rotation until the turning device faces flywheel marking 5.
- ▶ Check the valve clearance for cylinders A1, A3, B1, and B6 (→ tab. 30, p. 142), (→ 5.7.5.7 Checking valve clearance, p. 140).

Step 7

- ▶ Rotate the crankshaft in direction of rotation past flywheel marking 1.

Step 8

▶ Rotate the crankshaft in direction of rotation past flywheel marking 2.

Step 9

▶ Rotate the crankshaft in direction of rotation until the turning device faces flywheel marking 6.

▶ Check the valve clearance for cylinders A2, A6, B2, and B10 (→ tab. 30, p. 142), (→ 5.7.5.7 Checking valve clearance, p. 140).

Step 10

▶ Rotate the crankshaft in direction of rotation past flywheel marking 3.

Step 11

▶ Rotate the crankshaft in direction of rotation until the turning device faces flywheel marking 4.

▶ Check the valve clearance for cylinders A7, A10, B7, and B9 (→ tab. 30, p. 142), (→ 5.7.5.7 Checking valve clearance, p. 140).

5.7.5.7 Checking valve clearance

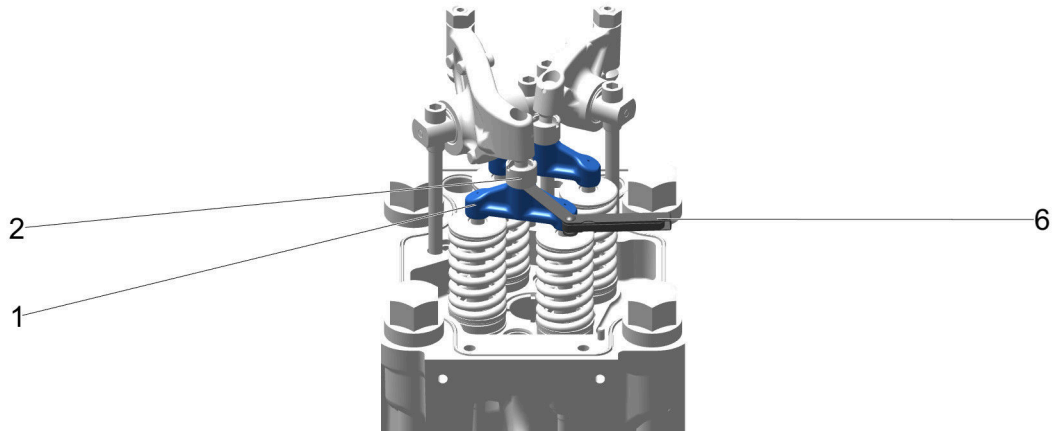


Fig. 63: Checking valva clearance

1 Valve bridge
2 Rocker ball cap
6 Feeler gauge

▶ Insert feeler gauge **6** with the right thickness between rocker ball cap **2** and valve bridge **1** (→ tab. 30, p. 142).

▶ Move feeler gauge **6** back and forth to confirm that there is a slight resistance.

Note

Adjust the valve clearance if it is not correct (→ 5.7.5.8 Adjusting valve clearance, p. 141).

5.7.5.8 Adjusting valve clearance

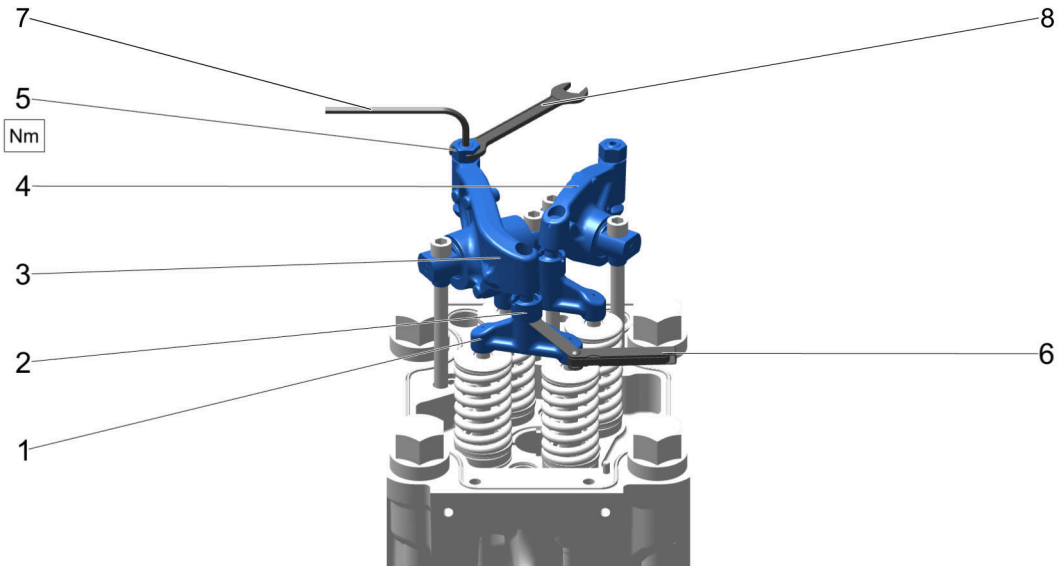


Fig. 64: Adjusting valve clearance

1	Valve bridge	**5**	Locknut (M14)
2	Rocker ball cap	**6**	Feeler gauge
3	Inlet rocker arm	**7**	Spanner
4	Exhaust rocker arm	**8**	Allen key

- ▶ Loosen locknut **5** of inlet rocker arm **3**.
- ▶ Insert feeler gauge **6** with the right thickness between rocker ball cap **2** and valve bridge **1** (→ tab. 30, p. 142).
- ▶ Turn the adjusting screw with Allen key **8** until feeler gauge **6** moves with a slight resistance between rocker ball cap **2** and valve bridge **1**.
- ▶ Hold the adjusting screw in position with Allen key **8** and tighten locknut **5** to torque (→ 5.7.5.10 Tightening specifications, p. 143).
- ▶ Confirm valve clearance with feeler gauge **6**.
- ▶ Repeat entire procedure for exhaust rocker arm **4**.
- ▶ Mark the cylinder when clearance is correct on both inlet and exhaust sides.
- ▶ Repeat procedure for each valve.

5.7.5.9 Specific values

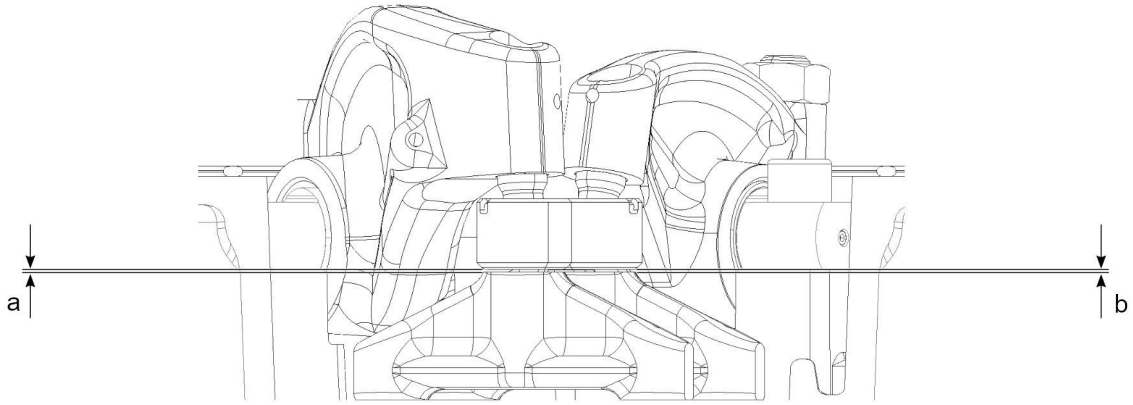


Fig. 65: Valve clearance

Reference	Denomination	Nominal value
a	Intake valve clearance	500 *+100/ -0* µm (19.69 *+3.94/ -0.00* thou)
b	Exhaust valve clearance	1000 *+100/ -0* µm (39.37 *+3.94/ -0.00* thou)

Tab. 30: Valve clearance values

5.7.5.10 Tightening specifications

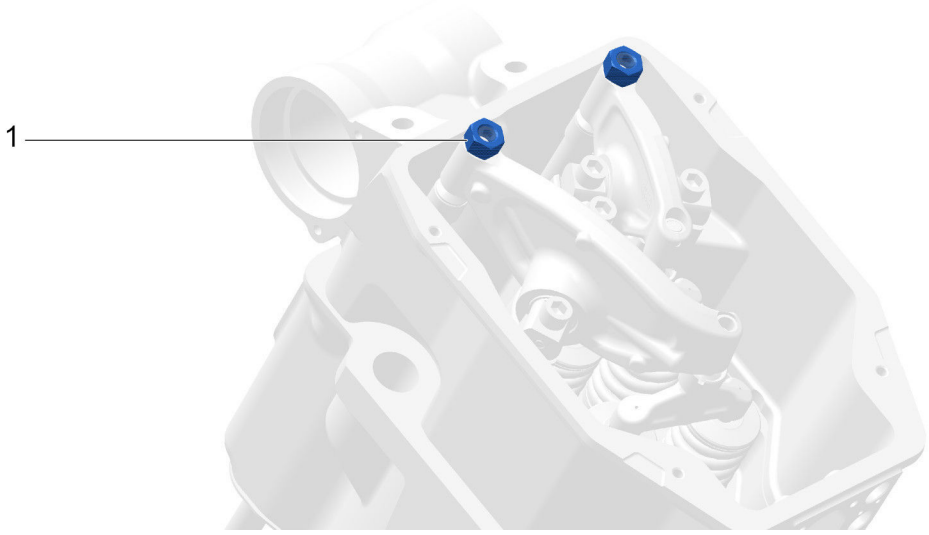


Fig. 66: Rocker arms locknuts

Reference	Key	Screw specifications	Lubricant *	Reuse**	Torque		Angle (°)	
					Step	± 5%	Step	± 5°
1	081AA	Locknut M14	O	Yes	1	40 Nm (30 ft-lb)	-	-

Tab. 31: Tightening specifications table

*Lubricants:
MG = Molykote G-n-plus
MW = Optimol paste white T
MH = Molykote HSC
O = Engine oil
XX = Loctite 243
YY = Loctite 577

**Refer to screws reuse rules (→ 8.4.2 Screws pretightening, reuse, and marking, p. 249).

Otherwise, refer to standard tightening torques (→ 8.4 Standard tightening torques, p. 249).

5.7.6 Replacing oil separator filter – SL1-1661

5.7.6.1 Previous tasks

Make sure that the following preconditions are met:
- ❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

5.7.6.2 Specific safety instructions

NOTICE
Contamination or leaks by reuse of filter!
Property damage - Risk of critical engine failure.

▶ Always use new filters and new seals.

NOTICE
Dusty or dirty environment!
Property damage - Risk of engine damage or ingress of contaminants or impurities.

▶ Ensure a clean area, free of stirred up dust by air movements, especially while performing servicing tasks.

▶ Keep the engine clean and free of dust accumulation.

▶ When removing engine parts, close all openings immediately using suitable means.

5.7.6.3 Special tools

Not applicable.

5.7.6.4 Consumables and equipment

Make sure that the following consumables and equipment are available:
- Original Rehlko oil separator filters with sealing parts
- Seal

5.7.6.5 Removal

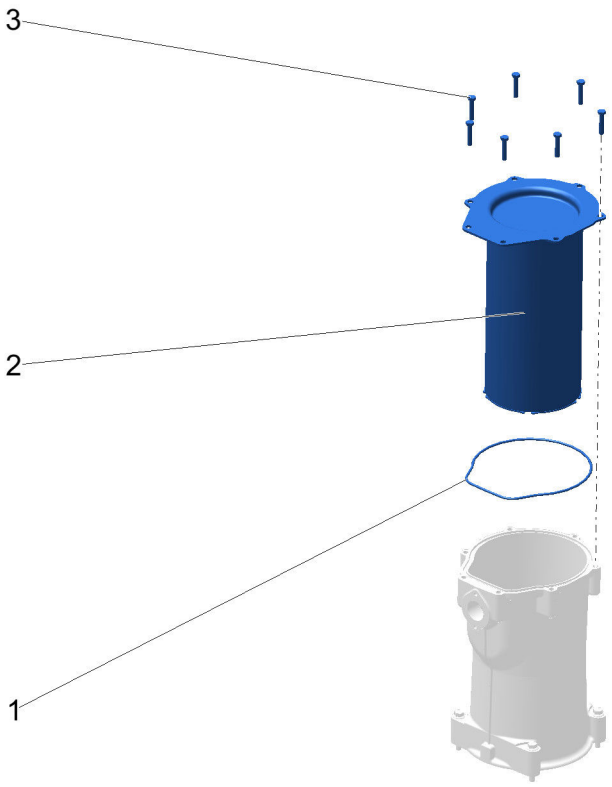


Fig. 67: Oil separator filter of crankcase breather system

1 Seal
2 Filter element
3 Screw (M10)

Note

Actual number and location of oil separator filters depend on configuration.

- ▶ Remove screws **3**.
- ▶ Remove filter element **2**.
- ▶ Remove seal **1**.
- ▶ Check and clean the housing inside.

5.7.6.6 Installation

- ▶ Install new seal **1**.
- ▶ Install filter element **2** with screws **3**.

5.7.6.7 Specific values

Not applicable.

5.7.6.8 Tightening specifications

Refer to standard tightening torques (→ 8.4 Standard tightening torques, p. 249).

5.8 2000 - Lubrication system

5.8.1 Inspecting oil system overall condition – SLO-2011

5.8.1.1 Checking engine oil level

Previous tasks

Make sure that the following preconditions are met:
- ❑ Engine stopped since at least 30 minutes.
- ❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

Specific safety instructions

DANGER
Fire - Ignition of flammable materials and operating fluids: fuel, engine oil, or coolant!
Risk of death or injury by burn, scald, or asphyxiation.

- ▶ Make sure that no operating fluid comes into contact with a hot surface or an ignition source.
- ▶ Before servicing the engine, let it cool down until surface temperature allows you to touch it with bare hand.
- ▶ Before servicing the engine, make sure that the operating fluid pressures are relieved.

DANGER
Contact with high temperature released operating fluids: fuel, engine oil, or coolant!
Risk of death or injury by scald.

- ▶ Before servicing the engine, let it cool down until surface temperature allows you to touch it with bare hand.
- ▶ Wear proper personal protective equipment.

Consumables and equipment

Not applicable.

Oil level check

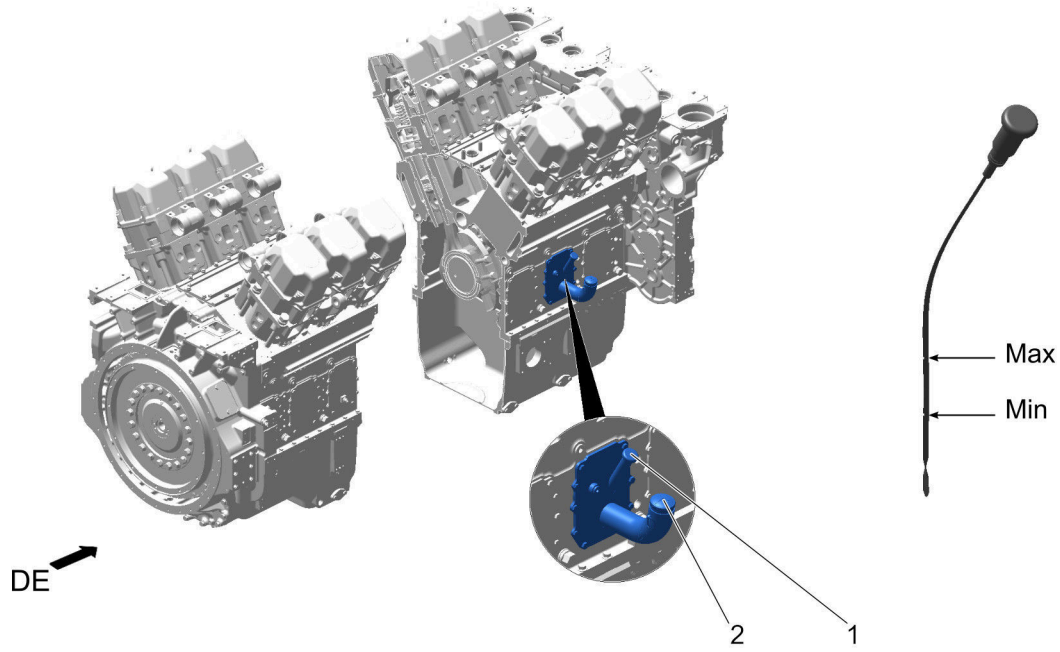


Fig. 68: Oil dipstick – oil filler neck

1 Oil dipstick **2** Oil filler neck

▶ Pull out oil dipstick **1**, wipe with a clean cloth, and reinsert as far as it goes.

▶ Pull out oil dipstick **1** again and check the oil level.
▷ The oil level must be between the “min.” and “max.” marks on the dipstick.

If the oil level is too low:

▶ Remove the oil filler neck cap.

▶ Fill up with oil through oil filler neck **2**.
▷ Make sure that the oil level is between the “min.” and “max.” marks on the dipstick.

▶ Clean the oil filler neck cap and close oil filler neck **2**.

5.8.1.2 Checking prelubricating pump (optional)

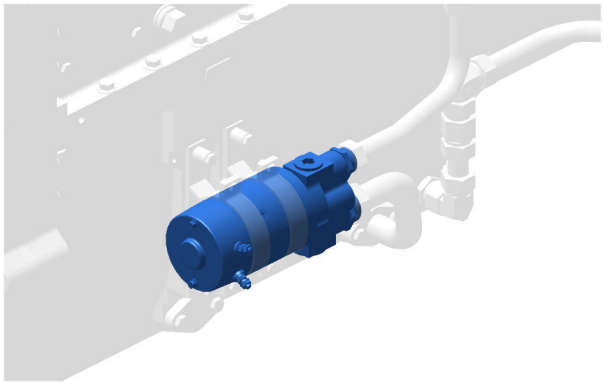


Fig. 69: Prelubricating pump

▶ Check for abnormal noise when operating.

▶ Check pump for leaks.

▶ Check pump functions.

▶ Record and report any defect.

If defect is detected:
▶ Make sure that authorized service personnel correct the defect.

5.8.2 Changing engine oil – SL1-2020

5.8.2.1 Previous tasks

Make sure that the following preconditions are met:
❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

5.8.2.2 Specific safety instructions

DANGER
Fire - Ignition of flammable materials and operating fluids: fuel, engine oil, or coolant!
Risk of death or injury by burn, scald, or asphyxiation.

▶ Make sure that no operating fluid comes into contact with a hot surface or an ignition source.

▶ Before servicing the engine, let it cool down until surface temperature allows you to touch it with bare hand.

▶ Before servicing the engine, make sure that the operating fluid pressures are relieved.

DANGER
Contact with high temperature released operating fluids: fuel, engine oil, or coolant!
Risk of death or injury by scald.

▶ Before servicing the engine, let it cool down until surface temperature allows you to touch it with bare hand.

▶ Wear proper personal protective equipment.

WARNING
Contact with toxic operating fluids: fuel, engine oil, or coolant!
Risk of lung or skin disease, or injury by irritation.

▶ Observe local regulations, site rules, and safety notes.

▶ Refer to the safety datasheet of operating fluids.

▶ Avoid contact with operating fluids.

▶ Wear proper personal protective equipment.

NOTICE
Damage by reuse of screw plugs!
Property damage - Risk of critical engine failure.

▶ Use new screw plugs after any dismantling.

5.8.2.3 Special tools

Not applicable.

5.8.2.4 Consumables and equipment

Make sure that the following consumables and equipment are available:
- The required volume of fresh approved engine oil (→ 5.13.1 Filling volume, p. 198)
- A suitable drainage container
- Screw plugs

5.8.2.5 Draining off engine oil from each drain-off point (complete draining)

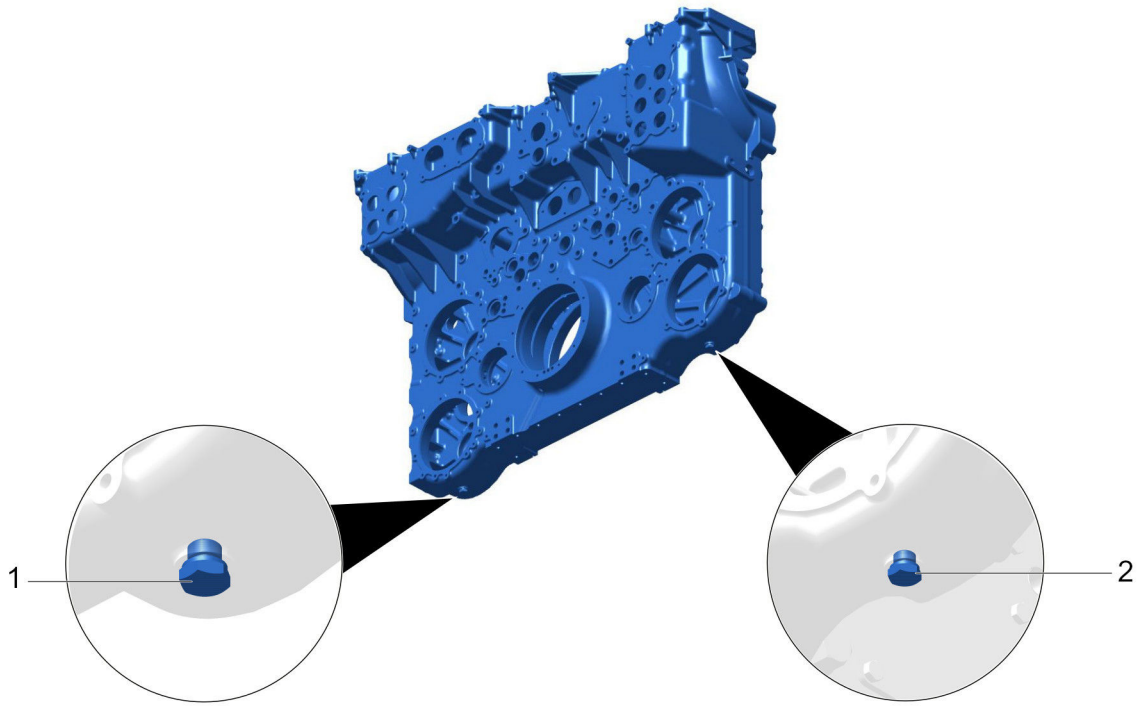


Fig. 70: Main oil drain points - free end of engine

1 Screw plug (M18X1,5) (oil drain on aggregate support - Engine right side)

2 Screw plug (M18X1,5) (oil drain on aggregate support - Engine left side)

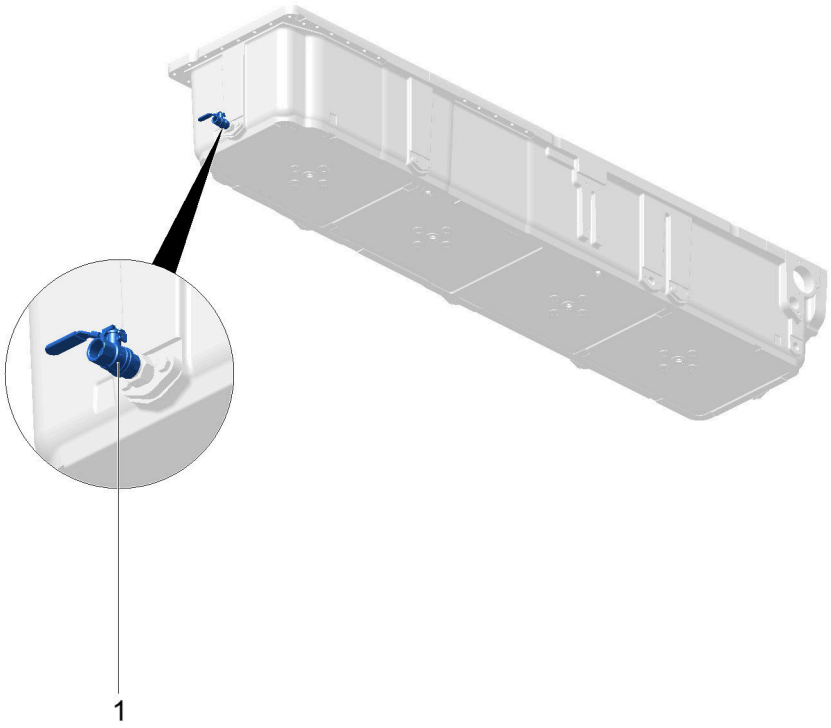


Fig. 71: Main oil drain point - free end of engine

1 Ball valve (oil drain on oil pan)

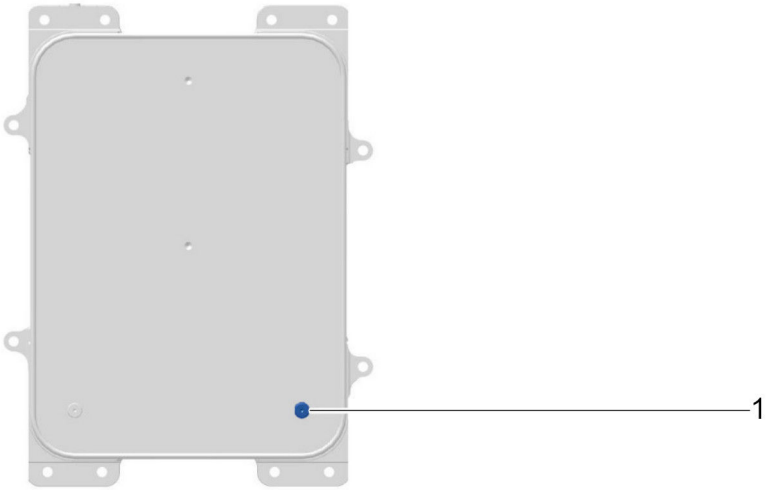


Fig. 72: Oil drain - engine left side

1 Screw plug (oil drain on oil cooler)

On each drain-off point:

Note

Drain the oil from each drain-off point if parts have to be removed or if oil is contaminated.

- ▶ Place a container to collect the used oil.
- ▶ Unscrew and remove the screw plug or open the valve.
- ▶ Let the oil flow into the container.

- ▶ Wait until no more oil drips.
- ▶ Clean the drain holes, valve, and the surrounding area with a clean rag.
- ▶ Install new screw plugs or close the valve.
- ▶ Tighten the screw plugs according to standard torque (→ 8.4 Standard tightening torques, p. 249).
- ▶ Remove the container and dispose of the used oil according to local regulations.

5.8.2.6 Filling engine oil

Make sure that the following preconditions are met:
- ❑ Engine oil is drained.
- ❑ Spin-on oil filters are replaced.
- ❑ Draining plugs and valves are closed.

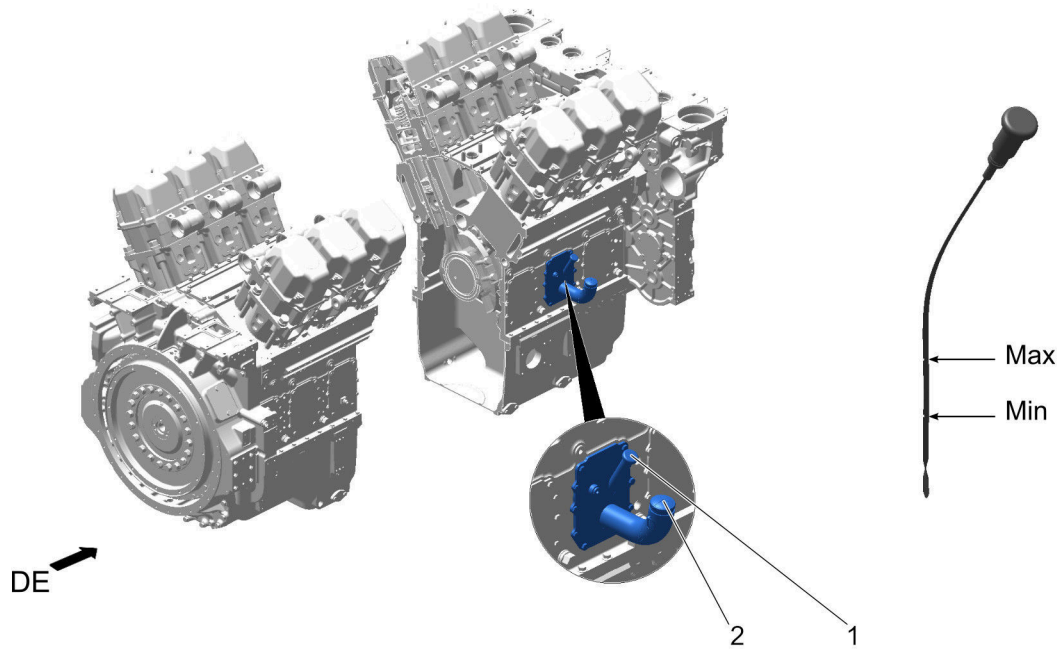


Fig. 73: Filling engine oil - right side

1 Oil dipstick **2** Oil filler neck

- ▶ Make sure that oil pan is free from coolant and debris.
- ▶ Remove the oil filler neck cap.
- ▶ Fill with the following oil quantity through oil filler neck **2**: 709.1 l (187.32 US gal).
  ▷ The oil level must be between the “min.” and “max.” marks on oil dipstick **1**.
- ▶ Clean oil filler neck cap.
- ▶ Install oil filler neck cap on oil filler neck **2** and tighten by hand.
- ▶ If possible, start the engine to check the oil pressure.
- ▶ Stop the engine.
- ▶ After three minutes, check the oil level on oil dipstick **1** (→ 5.8.1 Inspecting oil system overall condition – SLO-2011, p. 146).
- ▶ Top up with oil if necessary.
  ▷ Make sure that the oil level is between the “min.” and “max.” marks on the dipstick.

5.8.2.7 Specific values

Not applicable.

5.8.2.8 Tightening specifications

Refer to standard tightening torques (→ 8.4 Standard tightening torques, p. 249).

5.8.3 Collecting and analyzing oil sample – SL1-2021

5.8.3.1 Previous tasks

Make sure that the following preconditions are met:
- ❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

5.8.3.2 Specific safety instructions

DANGER
Fire - Ignition of flammable materials and operating fluids: fuel, engine oil, or coolant!
Risk of death or injury by burn, scald, or asphyxiation.

- ▶ Make sure that no operating fluid comes into contact with a hot surface or an ignition source.
- ▶ Before servicing the engine, let it cool down until surface temperature allows you to touch it with bare hand.
- ▶ Before servicing the engine, make sure that the operating fluid pressures are relieved.

WARNING
Contact with toxic operating fluids: fuel, engine oil, or coolant!
Risk of lung or skin disease, or injury by irritation.

- ▶ Observe local regulations, site rules, and safety notes.
- ▶ Refer to the safety datasheet of operating fluids.
- ▶ Avoid contact with operating fluids.
- ▶ Wear proper personal protective equipment.

5.8.3.3 Consumables and equipment

Not applicable.

5.8.3.4 Sample collection

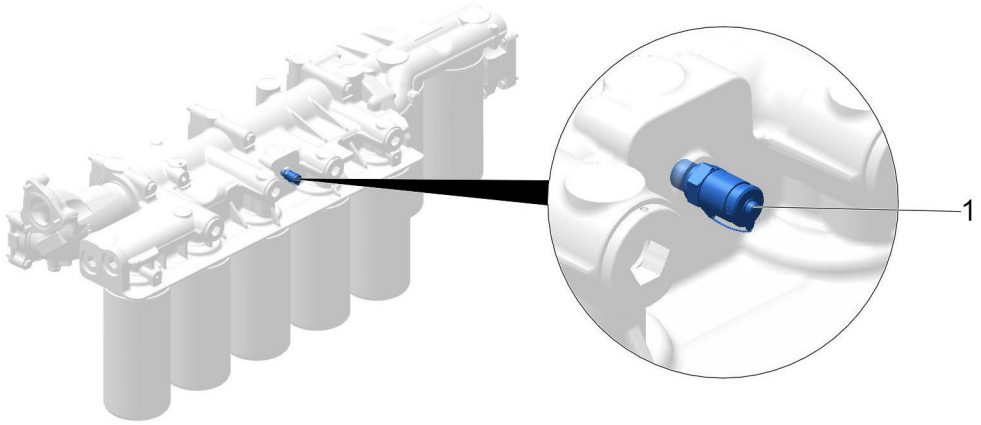


Fig. 74: Oil sampling point on engine left side

1 Sampling point

- ▶ Take an oil sample from sampling point **1**.
- ▶ Analyze the oil sample.
- ▶ Take recommended action according to analysis results (→ 5.13.3 Approved engine oils and engine oil additives, p. 203).

Note

The oil quality is to be ensured by regular analyses.

5.8.4 Replacing spin-on oil filter – SL1-2110

5.8.4.1 Previous tasks

Make sure that the following preconditions are met:

- ❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

5.8.4.2 Specific safety instructions

DANGER

Fire - Ignition of flammable materials and operating fluids: fuel, engine oil, or coolant!
Risk of death or injury by burn, scald, or asphyxiation.

- ▶ Make sure that no operating fluid comes into contact with a hot surface or an ignition source.
- ▶ Before servicing the engine, let it cool down until surface temperature allows you to touch it with bare hand.
- ▶ Before servicing the engine, make sure that the operating fluid pressures are relieved.

WARNING
Contact with toxic operating fluids: fuel, engine oil, or coolant!
Risk of lung or skin disease, or injury by irritation.

- ▶ Observe local regulations, site rules, and safety notes.
- ▶ Refer to the safety datasheet of operating fluids.
- ▶ Avoid contact with operating fluids.
- ▶ Wear proper personal protective equipment.

NOTICE
Contamination or leaks by reuse of filter!
Property damage - Risk of critical engine failure.

- ▶ Always use new filters and new seals.

5.8.4.3 Special tools

Not applicable.

5.8.4.4 Consumables and equipment

Make sure that the following consumables and equipment are available:
- Filter wrench
- Original Rehlko spin-on oil filters

5.8.4.5 Removal

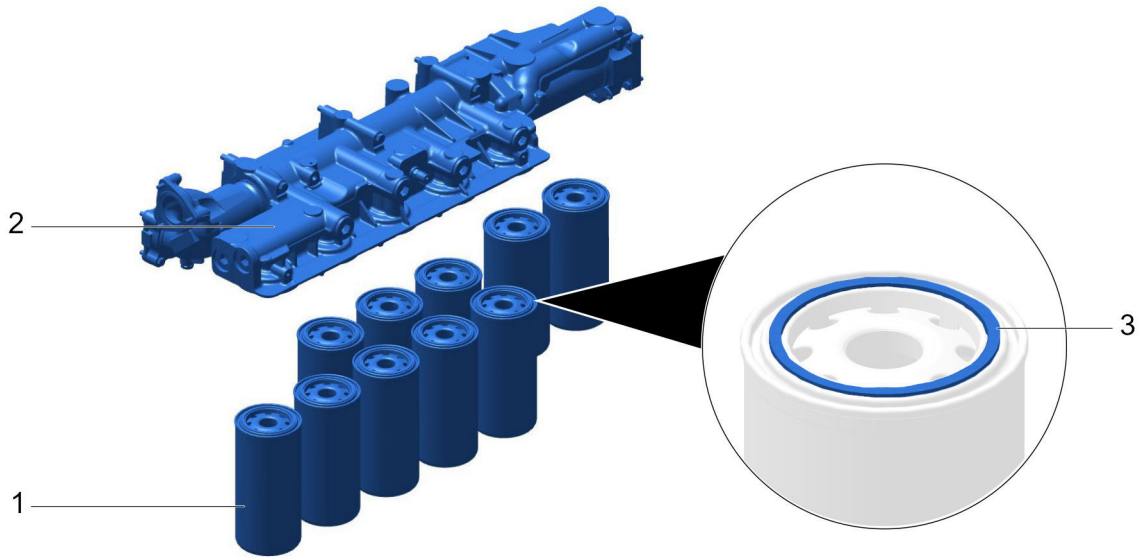


Fig. 75: Spin-on oil filters

1 Spin-on oil filter
2 Filter head
3 Seal

- ▶ Clean the sealing area.
- ▶ Open spin-on oil filter **1** with the filter wrench.
- ▶ Remove spin-on oil filter **1**.
- ▶ Repeat procedure for all filters.

5.8.4.6 Installation

- ▶ Clean the sealing area.
- ▶ Apply clean engine oil to new seal **3**.
- ▶ Tighten spin-on oil filter **1** until contact with filter head **2**.
- ▶ Tighten the filter by hand by ½ turn.
- ▶ Repeat procedure for all filters.
- ▶ Operate prelubricating pump to vent the filters. In the absence of prelubricating pump, disconnect the Top Dead Center (TDC) sensor (on Integrated Front End) and crank the engine until the oil pressure builds up.

Note

Make sure that the engine does not start.

- ▶ Reconnect the TDC sensor.
- ▶ Check for leaks or damage.
- ▶ Retighten by hand only if necessary.

Note

On next engine start-up, a longer starting time is normal.

5.8.4.7 Specific values

Not applicable.

5.8.4.8 Tightening specifications

Refer to standard tightening torques (→ 8.4 Standard tightening torques, p. 249).

5.8.5 Inspecting and cleaning liner of centrifugal oil filter – SL1-2231, SL1-2232

If the centrifugal oil filter is equipped with a paper insert, replace the paper insert (→ 8.2.1 Centrifugal oil filter with paper insert, p. 242).

5.8.5.1 Previous tasks

Make sure that the following preconditions are met:

- ❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

5.8.5.2 Specific safety instructions

DANGER
Fire - Ignition of flammable materials and operating fluids: fuel, engine oil, or coolant!
Risk of death or injury by burn, scald, or asphyxiation.

- ▶ Make sure that no operating fluid comes into contact with a hot surface or an ignition source.
- ▶ Before servicing the engine, let it cool down until surface temperature allows you to touch it with bare hand.
- ▶ Before servicing the engine, make sure that the operating fluid pressures are relieved.

WARNING
Contact with toxic operating fluids: fuel, engine oil, or coolant!
Risk of death or serious injury from poisoning, lung or skin disease, or irritation.

- ▶ Observe local regulations, site rules, and safety instructions.
- ▶ Refer to the Safety Data Sheets (SDS) of operating fluids.
- ▶ Avoid contact with operating fluids.
- ▶ Wear appropriate Personal Protective Equipment (PPE).

NOTICE
Leaks by reuse of seals!
Property damage - Risk of critical engine failure.

- ▶ Use new seals after any disassembly.

5.8.5.3 Special tools

Not applicable.

5.8.5.4 Consumables and equipment

Make sure that the following consumables and equipment are available:
- Lint-free cloths
- Cleaner (suitable for FKM/FPM fluoroelastomers and silicon rubber)
- Spare liner (in case of damage to original liner)
- O-rings

5.8.5.5 Overview

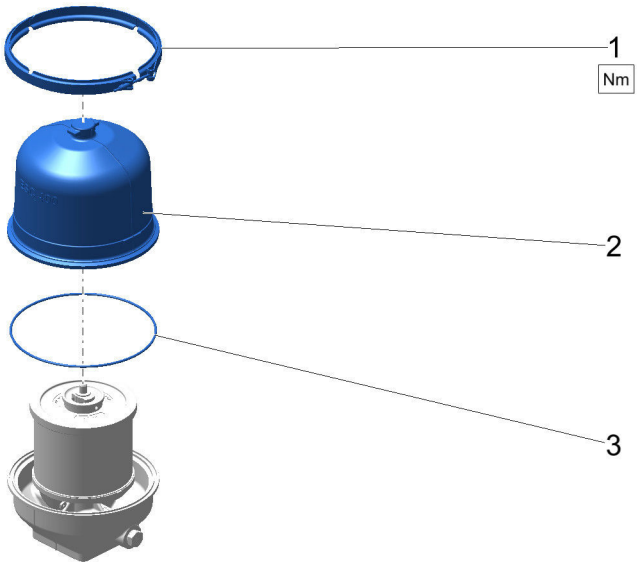


Fig. 76: Task overview

1 V-clamp
2 Cover
3 O-ring

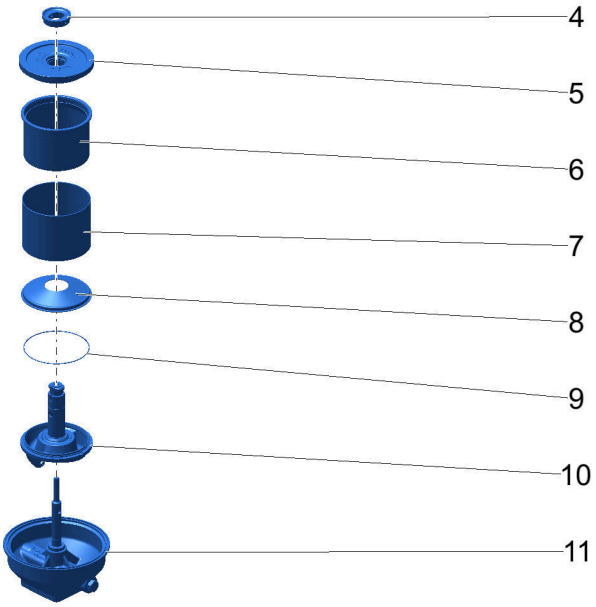


Fig. 77: Task overview

4 Bayonet ring
5 Rotor cover
6 Liner
7 Rotor cylinder
8 Deflector disk
9 O-ring
10 Rotor
11 Rotor base

5.8.5.6 Removal

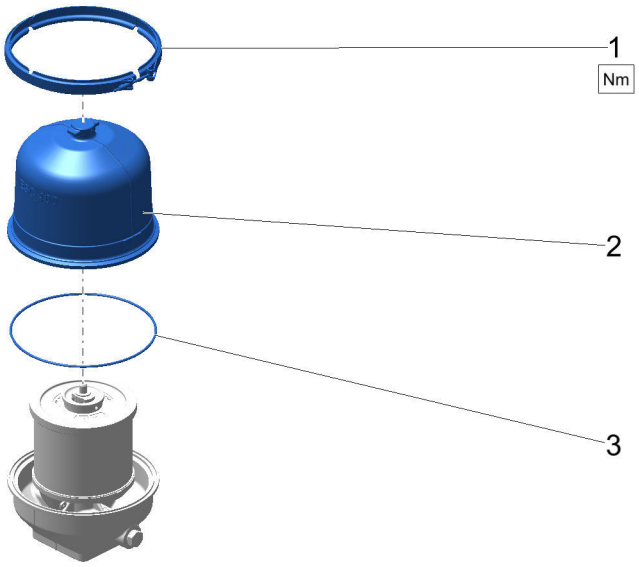


Fig. 78: Removing cover of centrifugal oil filter

- ▶ Loosen the nut of V-clamp **1**.
- ▶ Remove V-clamp **1**.
- ▶ Remove cover **2**.



Fig. 79: Lifting rotor assembly

- ▶ Lift the whole rotor as an assembly from its base.

Note

Engine oil can leak during the lifting of the rotor assembly.

Make sure to place a suitable container under the centrifugal oil filter to collect engine oil.

- ▶ Place the rotor assembly on a suitable work surface.

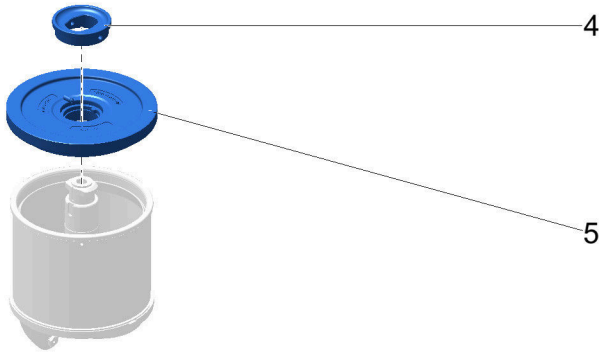


Fig. 80: Removing rotor cover

- ▶ Loosen bayonet ring **4** by rotating it 90° anti-clockwise.
- ▶ Remove bayonet ring **4**.
- ▶ Remove rotor cover **5**.

Note

If necessary, lightly tap on the sides of rotor cover **5** with a mallet to ease removal.

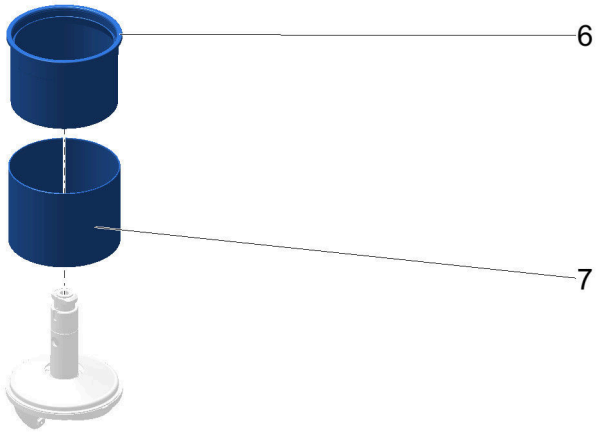


Fig. 81: Removing rotor cylinder and liner

- ▶ Remove rotor cylinder **7** and liner **6** as an assembly.
- ▶ Remove liner **6** from rotor cylinder **7**.

Note

Make sure to avoid any damage to liner **6**.

In particular, it is forbidden to use any sharp object when removing liner **6**.

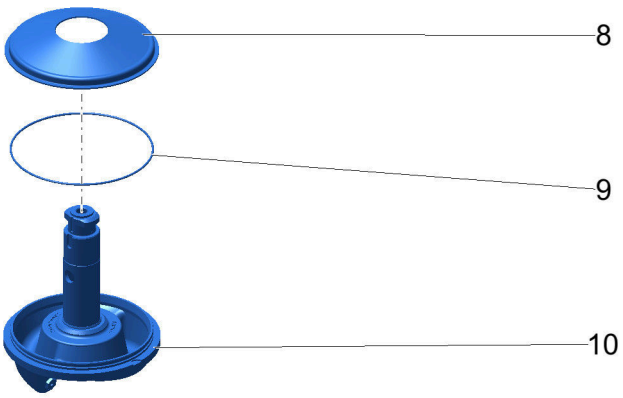


Fig. 82: Removing deflector disk

▶ Lift deflector disk **8** from rotor **10**.

Note

If necessary, use a screwdriver to pry deflector disk **8** away from rotor **10**.

5.8.5.7 Inspection and service

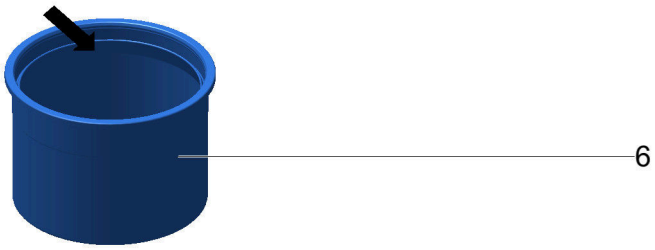


Fig. 83: Measuring sludge thickness of liner

▶ Measure the thickness of sludge accumulated on the sides of liner **6** (→ 5.8.5.9 Specific values, p. 163).

If sludge thickness is outside of specifications:

▶ Make sure to inform authorized service personnel and to adjust service intervals.

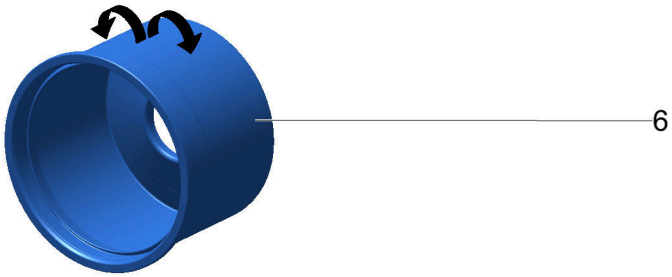


Fig. 84: Cleaning liner

▶ Place liner **6** on its side on a clean suitable surface.

▶ Roll liner **6** back and forth while pressing lightly on it so that accumulated sludge falls from the inner sides.

Note

Make sure to avoid any damage to liner **6**.

In particular, it is forbidden to use any sharp object when cleaning liner **6**.

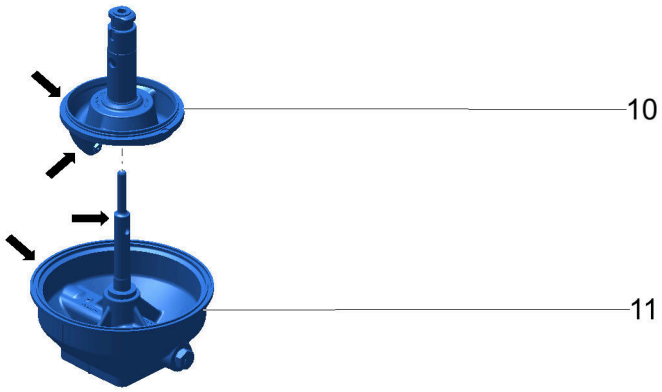


Fig. 85: Cleaning rotor

- ▶ Clean O-ring seat and underside of rotor **10**.
- ▶ Clean O-ring seat and shaft of rotor base **11**.

5.8.5.8 Installation

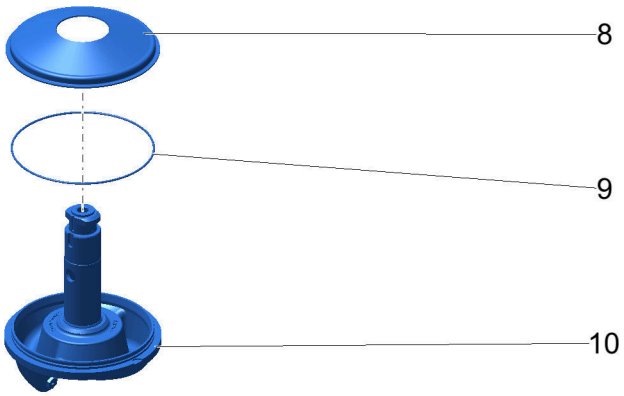


Fig. 86: Installing deflector disk

- ▶ Install deflector disk **8** and new O-ring **9** on rotor **10**.

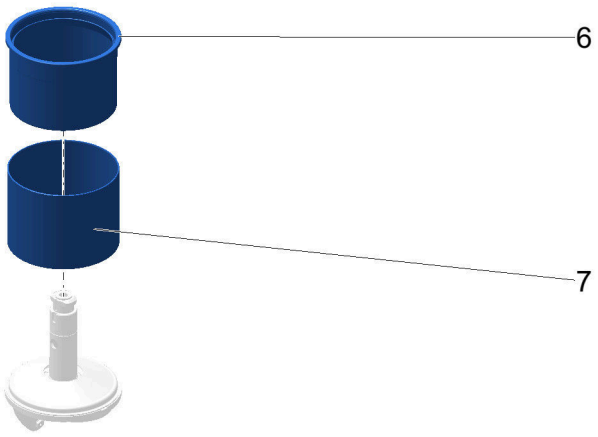


Fig. 87: Installing rotor cylinder and liner

- ▶ Install clean liner **6** in rotor cylinder **7**.
- ▶ Install liner **6** and rotor cylinder **7** as an assembly on rotor assembly.

Note

Make sure to align liner **6** with rotor cylinder **7** and rotor shaft.

Make sure that liner **6** snaps into place.

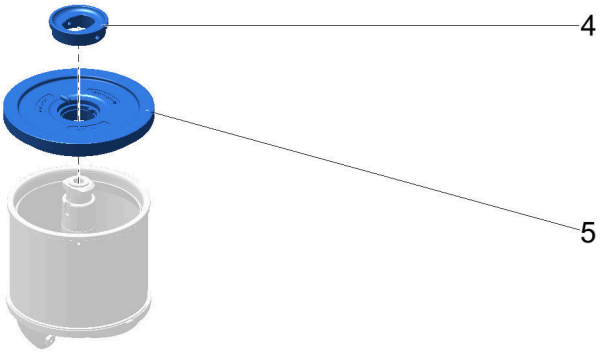


Fig. 88: Installing rotor cover

- ▶ Install rotor cover **5**.

Note

Make sure to align rotor cover **5** with rotor shaft.

- ▶ Install bayonet ring **4**.
- ▶ Tighten bayonet ring **4** by rotating it 90° clockwise.

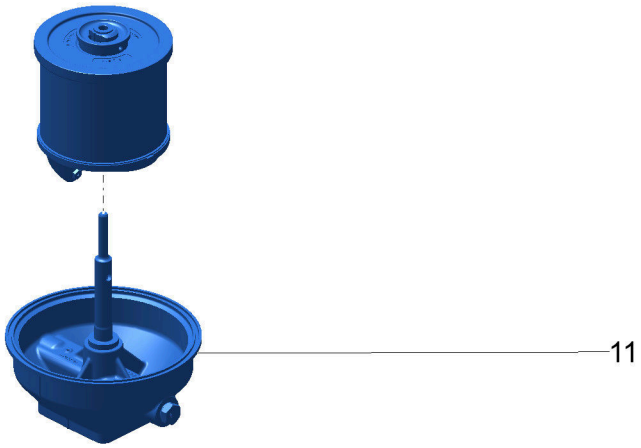


Fig. 89: Installing rotor assembly

▶ Install rotor assembly on rotor base **11**.

Note

Rotate the rotor assembly back and forth within rotor base **11** to make sure that it is in place.

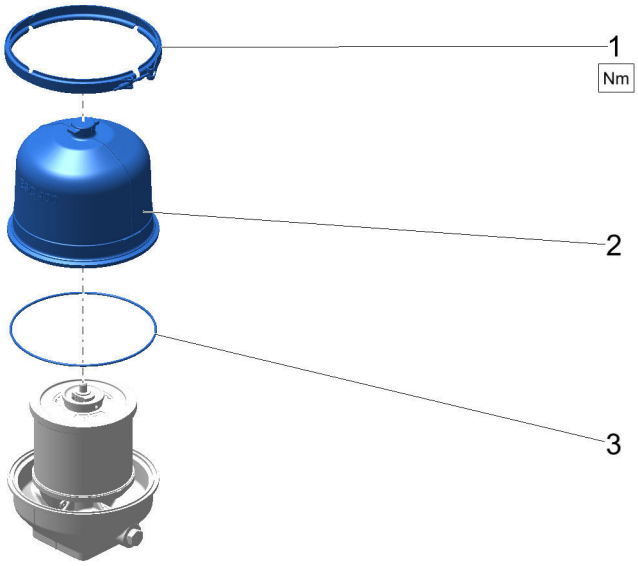


Fig. 90: Installing cover of centrifugal oil filter

▶ Install cover **2** with V-clamp **1** and new O-ring **3**.

▶ Tighten the nut of V-clamp **1** to 8 ±1 Nm (6 ±1 ft-lb).

5.8.5.9 Specific values

Maximum allowed value of sludge thickness: 40 mm (1.57 in)

5.8.5.10 Tightening specifications

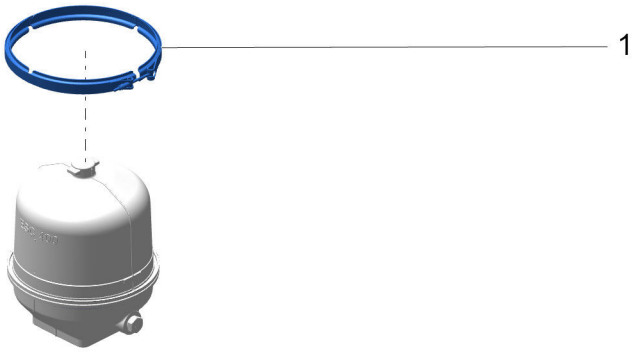


Fig. 91: V-clamp of centrifugal oil filter cover

Reference	Key	Screw specifications	Lubricant *	Reuse**	Torque		Angle (°)	
					Step	± 5%	Step	± 5°
1	-	-	-	Yes	1	8 ±1 Nm (6 ±1 ft-lb)	-	-

Tab. 32: Tightening specifications table

*Lubricants:
MG = Molykote G-n-plus
MW = Optimol paste white T
MH = Molykote HSC
O = Engine oil
XX = Loctite 243
YY = Loctite 577

**Refer to screws reuse rules (→ 8.4.2 Screws pretightening, reuse, and marking, p. 249).

Otherwise, refer to standard tightening torques (→ 8.4 Standard tightening torques, p. 249).

5.8.6 Inspecting oil cooler – SL1-2411

5.8.6.1 Previous tasks

Make sure that the following preconditions are met:
❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

5.8.6.2 Specific safety instructions

Not applicable.

5.8.6.3 Special tools

Not applicable.

5.8.6.4 Consumables and equipment

Not applicable.

5.8.6.5 Inspection

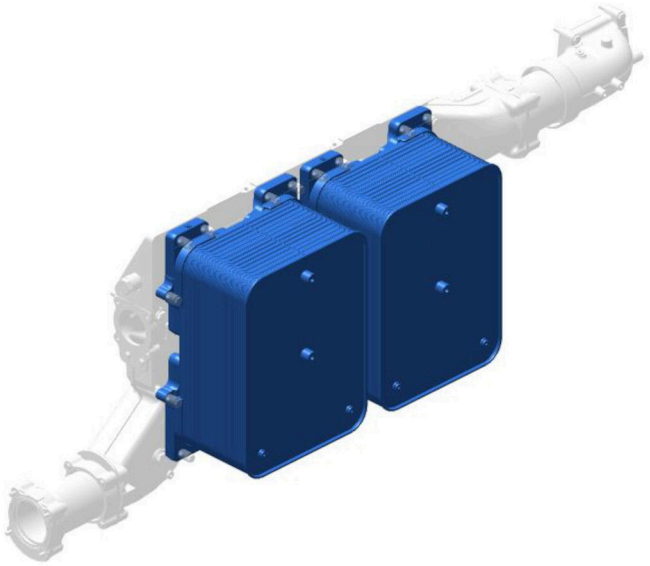


Fig. 92: Oil cooler

- ▶ Inspect oil cooler for external leaks (engine oil or coolant).
- ▶ Record and report any defect.

If defect is detected:

- ▶ Make sure that authorized service personnel correct the defect.

5.8.6.6 Specific values

Not applicable.

5.8.6.7 Tightening specifications

Refer to standard tightening torques (→ 8.4 Standard tightening torques, p. 249).

5.9 3000 - Cooling system

5.9.1 Inspecting cooling system overall condition – SLO-3011

5.9.1.1 Specific safety instructions

DANGER
Fire - Ignition of flammable materials and operating fluids: fuel, engine oil, or coolant!
Risk of death or injury by burn, scald, or asphyxiation.

- ▶ Make sure that no operating fluid comes into contact with a hot surface or an ignition source.
- ▶ Before servicing the engine, let it cool down until surface temperature allows you to touch it with bare hand.
- ▶ Before servicing the engine, make sure that the operating fluid pressures are relieved.

DANGER
Contact with high temperature released operating fluids: fuel, engine oil, or coolant!
Risk of death or injury by scald.

- ▶ Before servicing the engine, let it cool down until surface temperature allows you to touch it with bare hand.
- ▶ Wear proper personal protective equipment.

WARNING
Contact with toxic operating fluids: fuel, engine oil, or coolant!
Risk of lung or skin disease, or injury by irritation.

- ▶ Observe local regulations, site rules, and safety notes.
- ▶ Refer to the safety datasheet of operating fluids.
- ▶ Avoid contact with operating fluids.
- ▶ Wear proper personal protective equipment.

NOTICE
Fire - Ignition of flammable materials and operating fluids: fuel, engine oil, or coolant!
Property damage - Risk of destruction of the machine or the engine.

- ▶ Make sure that no operating fluid comes into contact with a hot surface or an ignition source.

NOTICE
Use of non-approved coolant!
Property damage - Risk of engine critical failure.

- ▶ Use an approved coolant. (→ 5.13.4 Approved coolants, p. 210)

5.9.1.2 Inspecting the engine visually

Make sure that the following preconditions are met:
- ❑ Preparatory maintenance activities are fulfilled. (→ 5.4 Preparatory maintenance activities, p. 105)

▶ Visually inspect the engine according to task SL0-1011. (→ 5.7.1 Inspecting engine overall condition – SL0-1011, p. 114)

5.9.1.3 Checking coolant level

Previous tasks

Make sure that the following preconditions are met:
- ❑ Preparatory maintenance activities are fulfilled. (→ 5.4 Preparatory maintenance activities, p. 105)

Specific safety instructions

See general instructions above.

Consumables and equipment

Make sure that the following consumables and equipment are available:
- Required volume of fresh approved coolant (→ 5.13.1 Filling volume, p. 198)

Topping up coolant level

▶ Refer to the generator set documentation to check the coolant level.

▶ Top up the cooling system with Rehlko approved engine coolant. (→ 5.13.4 Approved coolants, p. 210)

5.9.2 Changing coolant – SL1-3020

5.9.2.1 Previous tasks

Make sure that the following preconditions are met:
- ❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

5.9.2.2 Specific safety instructions



DANGER
Fire - Ignition of flammable materials and operating fluids: fuel, engine oil, or coolant!
Risk of death or injury by burn, scald, or asphyxiation.

▶ Make sure that no operating fluid comes into contact with a hot surface or an ignition source.

▶ Before servicing the engine, let it cool down until surface temperature allows you to touch it with bare hand.

▶ Before servicing the engine, make sure that the operating fluid pressures are relieved.



DANGER
Contact with high temperature released operating fluids: fuel, engine oil, or coolant!
Risk of death or injury by scald.

- ▶ Before servicing the engine, let it cool down until surface temperature allows you to touch it with bare hand.
- ▶ Wear proper personal protective equipment.

5.9.2.3 Special tools

Not applicable.

5.9.2.4 Consumables and equipment

Make sure that the following consumables and equipment are available:
- The required volume of fresh approved coolant (→ 5.13.1 Filling volume, p. 198)
- A suitable drainage container

5.9.2.5 Draining off engine coolant

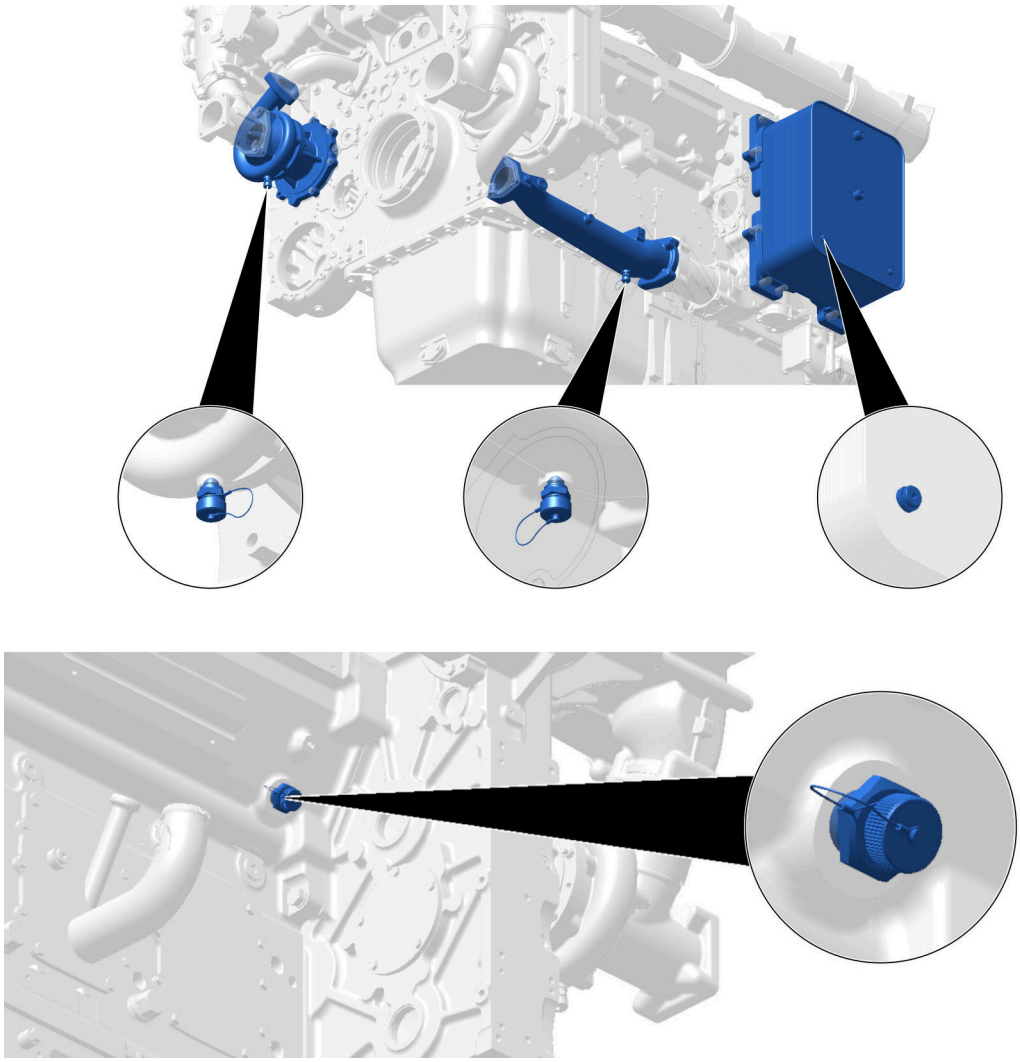


Fig. 93: Coolant drain points

▶ Drain cooling system at the deepest point. Refer to the instructions of the application for more details.

5.9.2.6 Filling

Note

Observe the instructions manual of the manufacturer's application set to fill and check the cooling system.

Fill the cooling system with an approved coolant.

Usually, a level indicator is present and coolant level must be between the "min." and "max." marks.

5.9.2.7 Bleeding

WARNING
Pollution during scrap and waste disposal!
Risk of soil, water, or air pollution.

- ▶ Respect the country-specific regulations regarding environmental protection.
- ▶ Before disposing of or recycling any waste, ask the responsible environmental or recycling center for the correct method.
- ▶ When handling waste, lubricants, coolant, and fuel, make sure that none is released into the environment.
- ▶ Collect and dispose of waste, lubricants, coolant, and fuel in separate, suitable, properly designated containers.
- ▶ Use adapted leakproof containers to drain lubricants, coolant, and fuel. Use of food or drink containers is prohibited.
- ▶ Dispose of all scrap materials only at official locations in an environment-friendly manner.

Note

Bleeding the cooling system depends on the design of the cooling system of the application, which is the responsibility of the application manufacturer.

Make sure to adapt the following procedure to the application cooling system.

Note

Proper operation of the engine requires a bubble-free cooling system.

- ▶ Make sure that the cooling system is filled and functional.

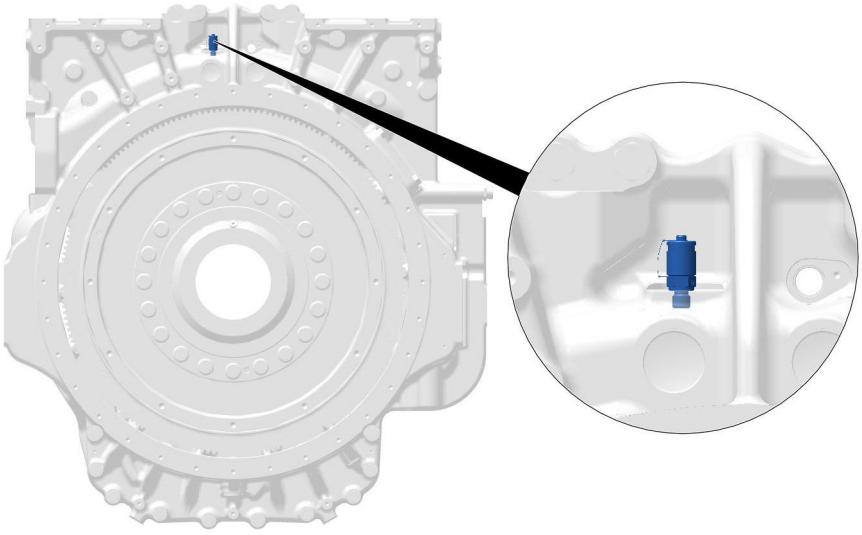


Fig. 94: Bleeding point on flywheel housing

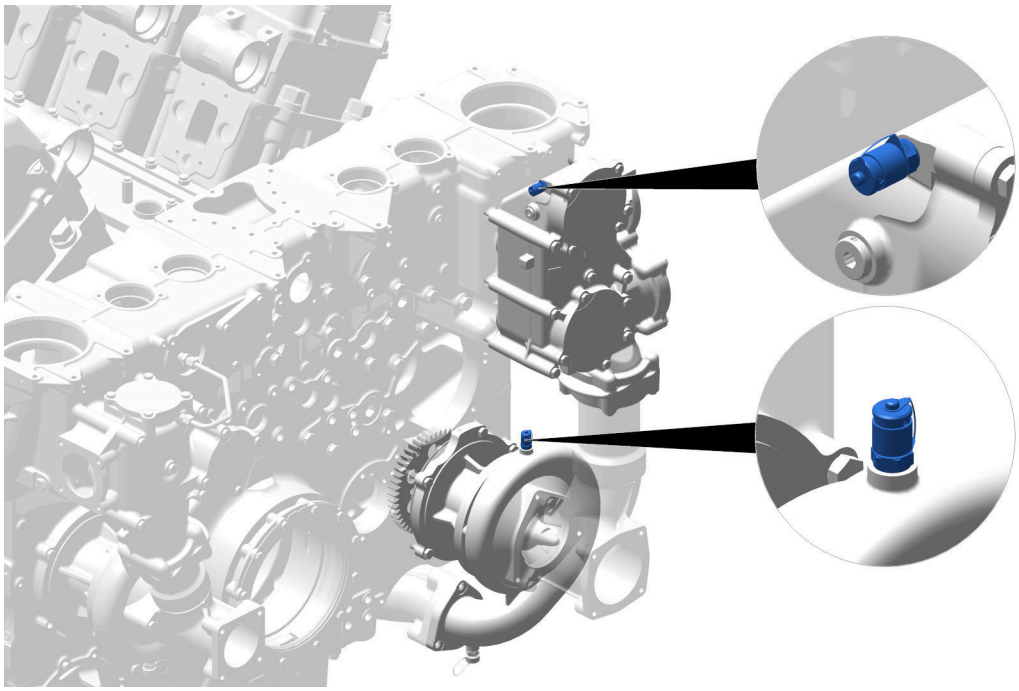


Fig. 95: Bleeding points on high-temperature coolant pump and thermostat housing

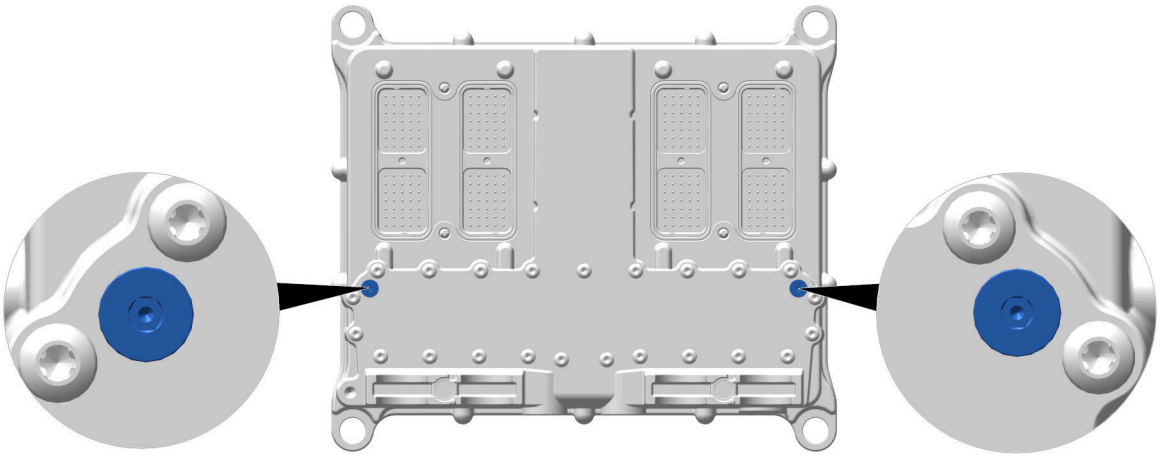


Fig. 96: Bleeding points on engine control unit

- ▶ Open the cap on the expansion tank.
- ▶ Make sure that the expansion tank is filled between the “min.” and “max.” marks.
- ▶ Open the test point fitting on the flywheel housing.
- ▶ Open the test point fitting on the high-temperature coolant pump.
- ▶ Open the test point fitting on the high-temperature thermostat housing.
- ▶ Remove the plugs on the engine control unit.
- ▶ Bleed the circuit until it is bubble free.
- ▶ Close the test point fitting on the flywheel housing.
- ▶ Close the test point fitting on the high-temperature coolant pump.
- ▶ Close the test point fitting on the high-temperature thermostat housing.

- ▶ Reinstall the plugs on the engine control unit.
- ▶ Tighten the plugs on the engine control unit to 7.5 Nm (6 ft-lb).
- ▶ Close the cap on the expansion tank.
- ▶ Operate the engine until the coolant temperature is above 60 °C (140 °F).
- ▶ Check coolant level on the expansion tank.
- ▶ If necessary, top up coolant.

5.9.2.8 Specific values

Not applicable.

5.9.2.9 Tightening specifications

Refer to standard tightening torques (→ 8.4 Standard tightening torques, p. 249).

5.9.3 Collecting and analyzing coolant sample – SL1-3021

5.9.3.1 Previous tasks

Make sure that the following preconditions are met:
- ❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

5.9.3.2 Specific safety instructions

DANGER
Fire - Ignition of flammable materials and operating fluids: fuel, engine oil, or coolant!
Risk of death or injury by burn, scald, or asphyxiation.

- ▶ Make sure that no operating fluid comes into contact with a hot surface or an ignition source.
- ▶ Before servicing the engine, let it cool down until surface temperature allows you to touch it with bare hand.
- ▶ Before servicing the engine, make sure that the operating fluid pressures are relieved.

DANGER
Contact with high temperature released operating fluids: fuel, engine oil, or coolant!
Risk of death or injury by scald.

- ▶ Before servicing the engine, let it cool down until surface temperature allows you to touch it with bare hand.
- ▶ Wear proper personal protective equipment.

WARNING
Contact with toxic operating fluids: fuel, engine oil, or coolant!
Risk of lung or skin disease, or injury by irritation.

- ▶ Observe local regulations, site rules, and safety notes.
- ▶ Refer to the safety datasheet of operating fluids.
- ▶ Avoid contact with operating fluids.
- ▶ Wear proper personal protective equipment.

5.9.3.3 Special tools

Not applicable.

5.9.3.4 Consumables and equipment

Not applicable.

5.9.3.5 Sample collection

▶ Take a coolant sample from the sampling point.

Note

Refer to the instructions of the generator set for more details.

▶ Analyze the coolant sample.

▶ Take recommended action according to analysis results (→ 5.13.4 Approved coolants, p. 210).

Note

The coolant quality is to be ensured by regular analyses.

5.10 4000 - Fuel system

5.10.1 Inspecting fuel system overall condition – SL0-4011, SL1-4022, SL0-5311

5.10.1.1 Specific safety instructions

DANGER
Fire - Ignition of flammable materials and operating fluids: fuel, engine oil, or coolant!
Risk of death or injury by burn, scald, or asphyxiation.

- ▶ Make sure that no operating fluid comes into contact with a hot surface or an ignition source.
- ▶ Before servicing the engine, let it cool down until surface temperature allows you to touch it with bare hand.
- ▶ Before servicing the engine, make sure that the operating fluid pressures are relieved.

DANGER
Contact with High-Temperature (HT) released operating fluids: fuel, engine oil, or coolant!
Death or serious injury from scalding.

- ▶ Wait for the engine to cool down until the surface temperature allows contact with a bare hand before servicing.
- ▶ Wear appropriate Personal Protective Equipment (PPE).

WARNING
Contact with toxic operating fluids: fuel, engine oil, or coolant!
Risk of death or serious injury from poisoning, lung or skin disease, or irritation.

- ▶ Observe local regulations, site rules, and safety instructions.
- ▶ Refer to the Safety Data Sheets (SDS) of operating fluids.
- ▶ Avoid contact with operating fluids.
- ▶ Wear appropriate Personal Protective Equipment (PPE).

NOTICE
Fire - Ignition of flammable materials and operating fluids: fuel, engine oil, or coolant!
Property damage - Risk of destruction of the machine or the engine.

- ▶ Make sure that no operating fluid comes into contact with a hot surface or an ignition source.

NOTICE
Contaminated fuel!
Property damage - Risk of major engine failure.

- ▶ Use an approved diesel fuel.
- ▶ Make sure that the fuel supply system guarantees fuel specification at the inlet of the engine.

5.10.1.2 Inspecting the engine visually

Make sure that the following preconditions are met:
- ❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

▶ Visually inspect the engine according to task SL0-1011 (→ 5.7.1 Inspecting engine overall condition – SL0-1011, p. 114).

5.10.1.3 Checking fuel level

Previous tasks

Make sure that the following preconditions are met:
- ❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

Specific safety instructions

See general instructions above.

Consumables and equipment

Make sure that the following consumables and equipment are available:
- Required volume of approved diesel fuel.
- Depending on configuration, required volume of approved diesel exhaust fluid (DEF).

Topping up fuel level

▶ Refer to the generator set documentation to check the fuel level.

▶ Top up the fuel tank with Rehlko approved diesel fuel (→ 5.13.2 Approved diesel fuels and fuel additives, p. 198).

Draining water and sediments from fuel system

▶ Every week, drain the fuel pre-filters (depending on configuration) and the fuel tank (customer scope) to remove water and sediments from fuel system.

▶ Refer to the generator set documentation for more details.

▶ Dispose of residues according to the current legislation.

Topping up diesel exhaust fluid (DEF)

▶ Depending on configuration, refer to the generator set documentation to check the diesel exhaust fluid (DEF) level.

▶ Depending on configuration, top up the diesel exhaust fluid (DEF) tank with Rehlko approved diesel exhaust fluid (DEF) (→ 5.13.2 Approved diesel fuels and fuel additives, p. 198).

5.10.2 Replacing fuel pre-filter – SL1-4110

Refer to the generator set documentation for more details.

5.10.3 Replacing fuel main filter – SL1-4120

5.10.3.1 Previous tasks

Make sure that the following preconditions are met:
- ❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).
- ❑ Fuel feed is interrupted.

5.10.3.2 Specific safety instructions

DANGER
Fire - Ignition of flammable materials and operating fluids: fuel, engine oil, or coolant!
Risk of death or injury by burn, scald, or asphyxiation.

- ▶ Make sure that no operating fluid comes into contact with a hot surface or an ignition source.
- ▶ Before servicing the engine, let it cool down until surface temperature allows you to touch it with bare hand.
- ▶ Before servicing the engine, make sure that the operating fluid pressures are relieved.

NOTICE
Contamination or leaks by reuse of filter!
Property damage - Risk of critical engine failure.

- ▶ Always use new filters and new seals.

NOTICE
Dusty or dirty environment!
Property damage - Risk of engine damage or ingress of contaminants or impurities.

- ▶ Ensure a clean area, free of stirred up dust by air movements, especially while performing servicing tasks.
- ▶ Keep the engine clean and free of dust accumulation.
- ▶ When removing engine parts, close all openings immediately using suitable means.

5.10.3.3 Special tools

Not applicable.

5.10.3.4 Consumables and equipment

Make sure that the following consumables and equipment are available:
- Filter wrench
- Original Rehlko fuel main filter

5.10.3.5 Removal

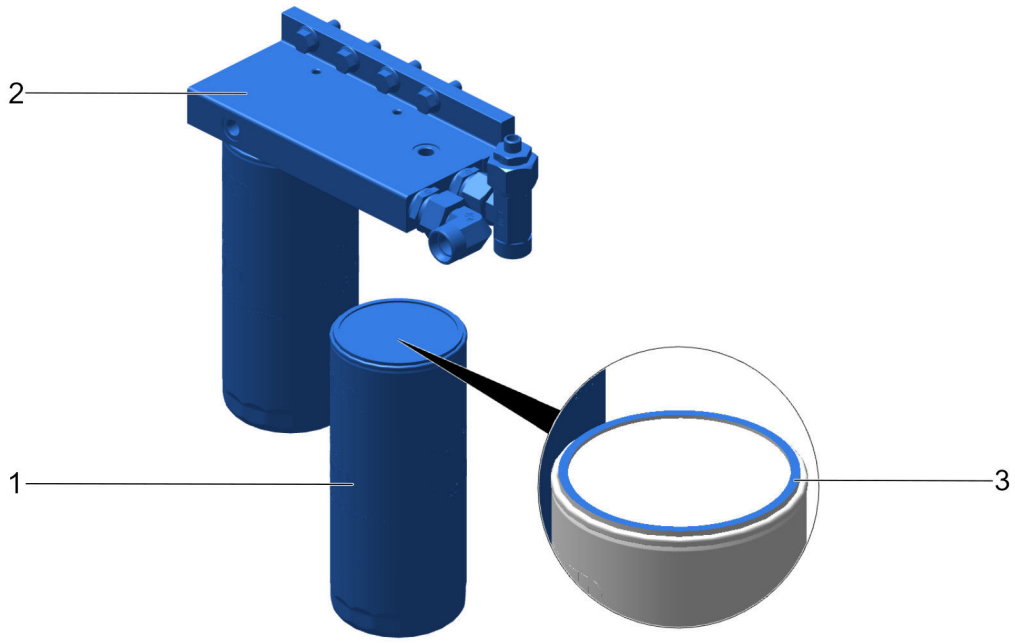


Fig. 97: Removing fuel filters

1 Fuel filter
2 Filter head
3 Filter seal

Note

Actual number of fuel filters depends on engine configuration.

- ▶ Clean the sealing area.
- ▶ Open fuel filter **1** with the filter wrench.
- ▶ Remove fuel filter **1**.
- ▶ Repeat procedure for all filters.
- ▶ Dispose of the old fuel filters.

5.10.3.6 Installation

- ▶ Clean the sealing area.
- ▶ Apply clean and fresh engine oil to filter seal **3**.
- ▶ Tighten fuel filter **2** until contact with filter head **1**.
- ▶ Tighten filter by hand by ¾ to 1 turn.
- ▶ Repeat procedure for all filters.
- ▶ Check for leaks and damage.
- ▶ Retighten if necessary.

5.10.3.7 Bleeding fuel system

High-pressure build-up in the injection system is necessary to start and run the engine. The fuel system uses an automatic bleed line that allows fuel and air to flow back to the tank. Trapped air in the fuel system prevents the high-pressure build-up and may lead to failed starts or poor running conditions.

Note

If air migrated into the fuel system, the first start attempt may require a longer time than a usual start.

If the engine fails to start on the first attempt:

- ▶ Crank the engine without ignition to complete the automated bleeding through the fuel return line.
- ▶ Start the engine.
  - ▷ After an initial start, we consider that the fuel line has been bled.

Refer to generator set documentation for more details.

5.10.3.8 Specific values

Not applicable.

5.10.3.9 Tightening specifications

Refer to standard tightening torques (→ 8.4 Standard tightening torques, p. 249).

5.10.4 Inspecting HP/LP fuel pump – SL1-4221, SL1-4311

5.10.4.1 Previous tasks

Make sure that the following preconditions are met:

- ❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

5.10.4.2 Specific safety instructions

DANGER
Fire - Ignition of flammable materials and operating fluids: fuel, engine oil, or coolant!
Risk of death or injury by burn, scald, or asphyxiation.

- ▶ Make sure that no operating fluid comes into contact with a hot surface or an ignition source.
- ▶ Before servicing the engine, let it cool down until surface temperature allows you to touch it with bare hand.
- ▶ Before servicing the engine, make sure that the operating fluid pressures are relieved.

5.10.4.3 Special tools

Not applicable.

5.10.4.4 Consumables and equipment

Not applicable.

5.10.4.5 Inspection

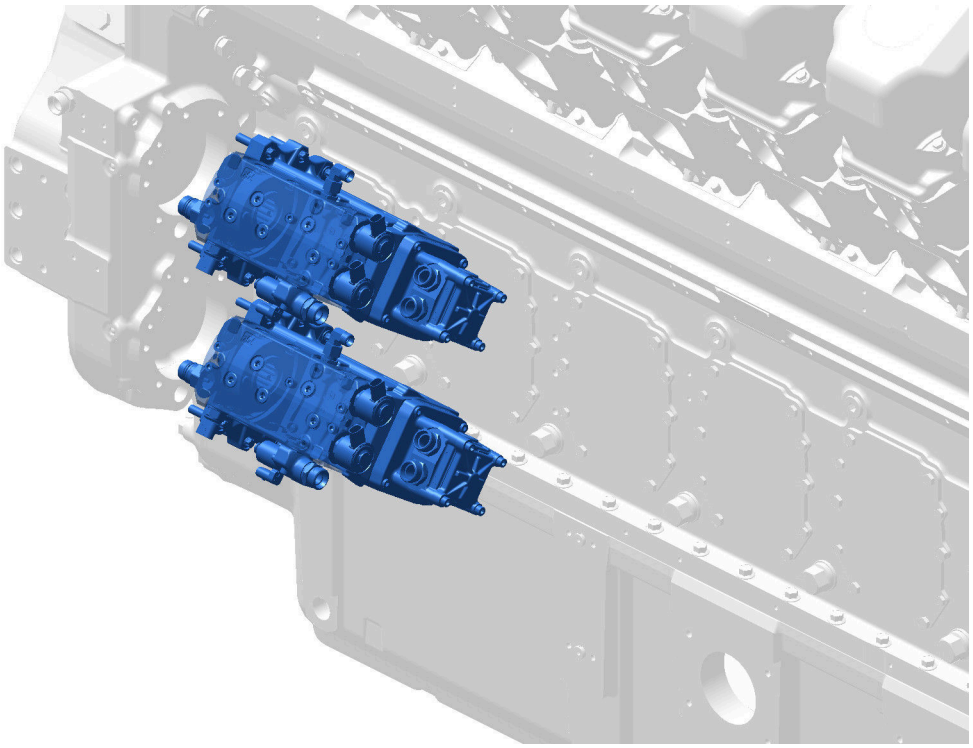


Fig. 98: Fuel pumps

- ▶ Inspect overall condition of the fuel pumps.
- ▶ Search for potential leaks at connections.
- ▶ Record and report any defect.

If defect is detected:

- ▶ Make sure that authorized service personnel correct the defect.

5.10.4.6 Specific values

Not applicable.

5.10.4.7 Tightening specifications

Refer to standard tightening torques (→ 8.4 Standard tightening torques, p. 249).

5.11 5000 - Combustion air and exhaust gas system

5.11.1 Inspecting air intake system overall condition – SLO-5011

5.11.1.1 Specific safety instructions

NOTICE
Leak at the air intake connections!
Property damage - Risk of increase of soot emission, engine stall, or degradation of engine performances.

- ▶ The manufacturer of the machinery must integrate adapted air intake system to comply with the technical requirements.
- ▶ Observe the tightening torques.
- ▶ Observe clamp installation specifications.

NOTICE
High air intake temperature!
Risk of degradation of engine performances.

- ▶ Make sure that you operate the engine in the specified ambient conditions.
- ▶ Make sure that the air intake system of the application fulfills engine specified intake requirements.

NOTICE
Contaminated air!
Property damage - Risk of damage to the exhaust gas turbocharger or the intake system.

- ▶ Manufacturer of the machinery must integrate air filtering system to comply with technical requirements.

5.11.1.2 Inspecting the engine visually

Make sure that the following preconditions are met:
- ❑ Preparatory maintenance activities are fulfilled. (→ 5.4 Preparatory maintenance activities, p. 105)
- ▶ Visually inspect the engine according to task SLO-1011. (→ 5.7.1 Inspecting engine overall condition – SLO-1011, p. 114)

5.11.1.3 Checking air filter and air intake upstream the engine

Previous tasks

Make sure that the following preconditions are met:
- ❑ Preparatory maintenance activities are fulfilled. (→ 5.4 Preparatory maintenance activities, p. 105)

Specific safety instructions

See general instructions above.

Checking air filter and air intake

Refer to generator set documentation for details on tasks to perform:

- ▶ Make sure that the air filters are in place and the connections are tight.
- ▶ Make sure that the air filters are clean and free of any clogging indication or alarm.
- ▶ Make sure that the air intake lines upstream of the engine are clean and sealed.

If the air filters are found clogged, damaged, or improperly fitted:

- ▶ Inspect the air intake lines.
- ▶ Inspect the air inlet of the exhaust gas turbochargers.
- ▶ Replace the air filters.

5.11.2 Cleaning air filter – SL1-5021

Refer to the generator set documentation for more details.

5.11.3 Inspecting charge air cooler – SL1-5121

5.11.3.1 Previous tasks

Make sure that the following preconditions are met:

- ❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

5.11.3.2 Specific safety instructions

Not applicable.

5.11.3.3 Special tools

Not applicable.

5.11.3.4 Consumables and equipment

Not applicable.

5.11.3.5 Inspection

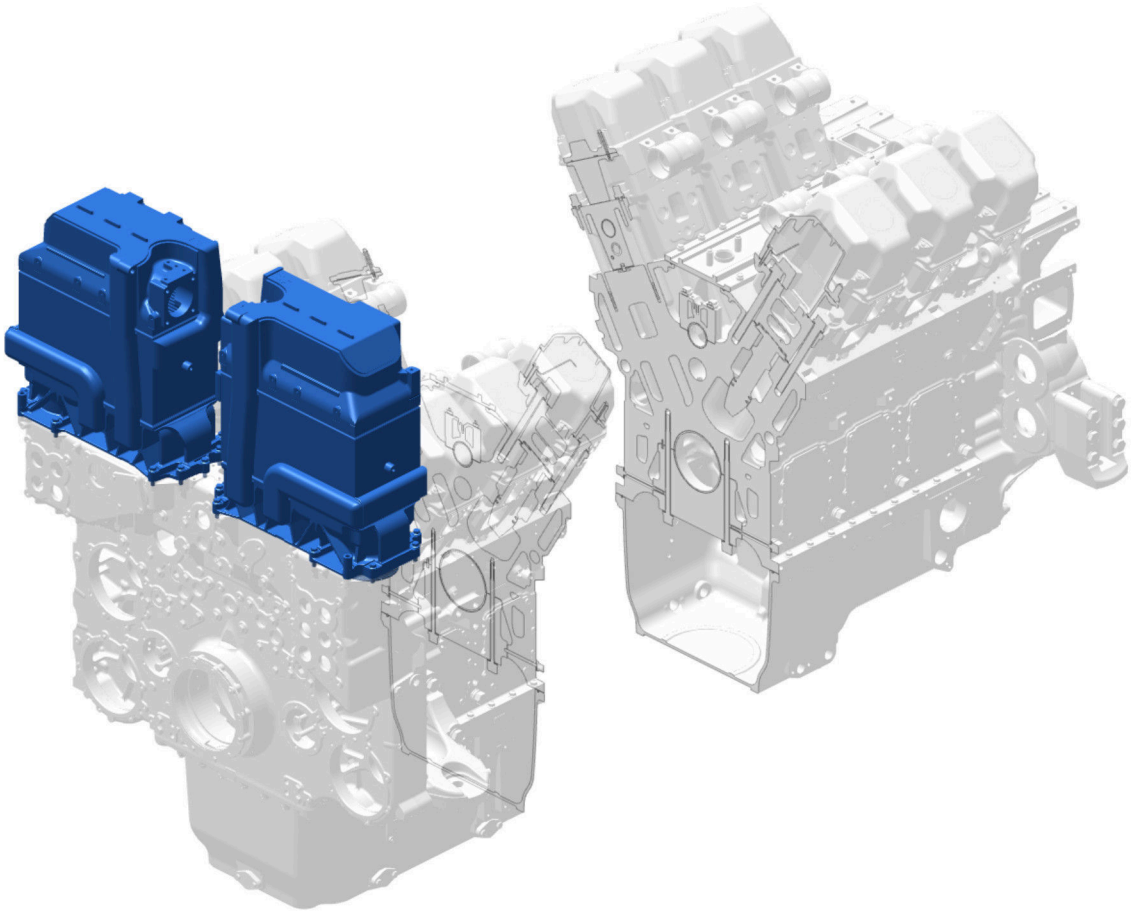


Fig. 99: Charge air coolers

- ▶ Inspect overall condition of the charge air coolers.
- ▶ Search for coolant leaks.
- ▶ Search for external damage and loose mountings.
- ▶ Search for traces of coolant leaks at dewatering bores (→ 5.7.1 Inspecting engine overall condition – SLO-1011, p. 114).
- ▶ Record and report any defect.

If defect is detected:

- ▶ Make sure that authorized service personnel correct the defect.

5.11.3.6 Specific values

Not applicable.

5.11.3.7 Tightening specifications

Refer to standard tightening torques (→ 8.4 Standard tightening torques, p. 249).

5.11.4 Inspecting exhaust gas system – SL1-5201

5.11.4.1 Previous tasks

Make sure that the following preconditions are met:

❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

5.11.4.2 Specific safety instructions

Not applicable.

5.11.4.3 Special tools

Not applicable.

5.11.4.4 Consumables and equipment

Not applicable.

5.11.4.5 Inspection

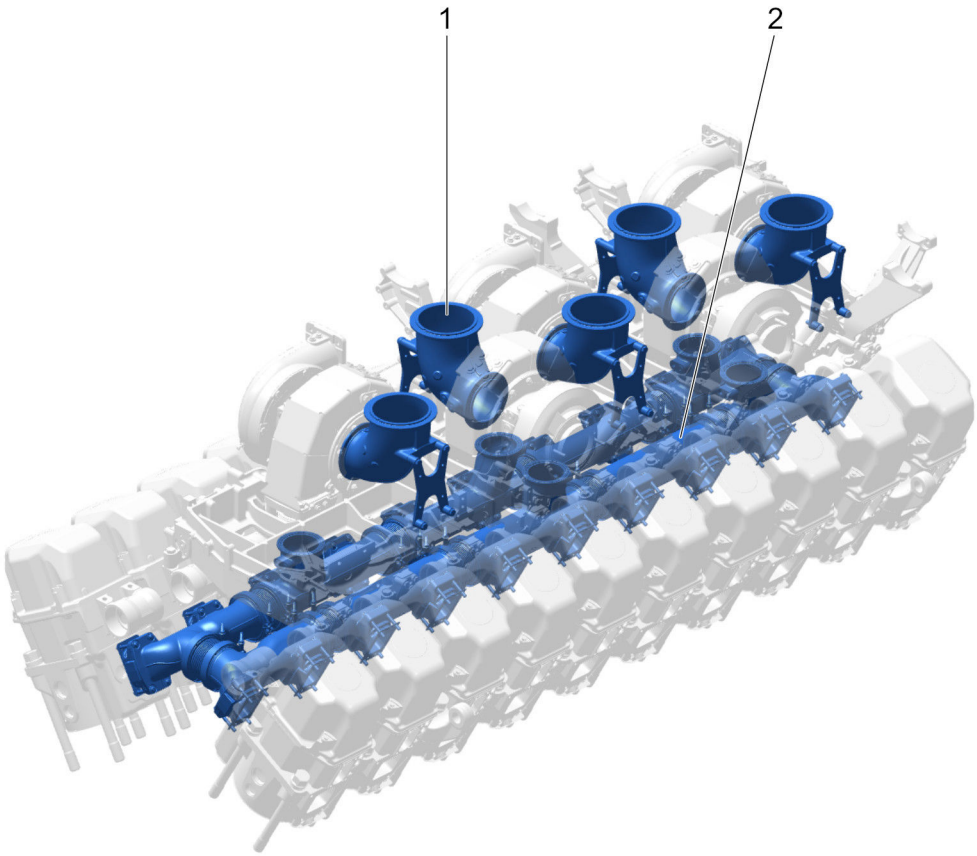


Fig. 100: Exhaust gas system

1 Exhaust elbow from exhaust gas turbocharger

2 Exhaust manifold

▶ Inspect overall condition of the exhaust gas system.

▶ Search for leaks, cracks, and inspect mounting.

▶ Record and report any defect.

If defect is detected:
▶ Make sure that authorized service personnel correct the defect.

5.11.4.6 Specific values

Not applicable.

5.11.4.7 Tightening specifications

Refer to standard tightening torques (→ 8.4 Standard tightening torques, p. 249).

5.11.5 Inspecting exhaust gas turbocharger – SL1-5411

5.11.5.1 Previous tasks

Make sure that the following preconditions are met:
❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

5.11.5.2 Specific safety instructions



WARNING
Contact with hot parts!
Risk of injury by burn.
The Engine Control Unit (ECU) is hot while operating the engine.

▶ Observe local regulations, site rules, and safety notes.

▶ When the engine is in operation, avoid any contact with the ECU.

▶ Before servicing the engine, let it cool down until the surface temperature allows you to touch it with bare hands.

▶ Wear proper personal protective equipment.

5.11.5.3 Special tools

Not applicable.

5.11.5.4 Consumables and equipment

Not applicable.

5.11.5.5 Inspection

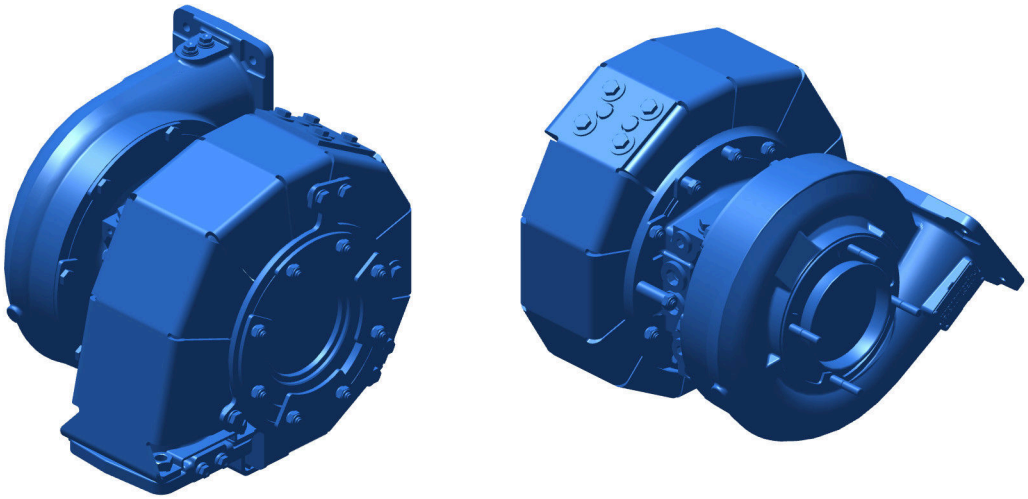


Fig. 101: Exhaust gas turbochargers

Note

The turbocharger design depends on which side of the engine it is installed.

- ▶ Inspect overall condition of the exhaust gas turbochargers.
- ▶ Search for traces of leaks (exhaust gases, coolant, engine oil).
- ▶ If accessible, inspect compressor and turbine blades.
- ▶ Search for external damage.
- ▶ Record and report any defect.

If defect is detected:

- ▶ Make sure that authorized service personnel correct the defect.

5.11.5.6 Specific values

Not applicable.

5.11.5.7 Tightening specifications

Refer to standard tightening torques (→ 8.4 Standard tightening torques, p. 249).

5.12 6000 - Electrical system

5.12.1 Inspecting starter – SL1-6211

5.12.1.1 Previous tasks

Make sure that the following preconditions are met:
❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

5.12.1.2 Specific safety instructions



CAUTION
Contact with live electrical parts!
Risk of injury by electric shock.

- ▶ Observe local regulations, site rules, and safety notes.
- ▶ Before servicing the engine, perform a lockout/tagout (LOTO) procedure.
- ▶ Access to live parts shall only be possible with voluntary action.
- ▶ When the engine is in operation, stay away from the engine.

5.12.1.3 Special tools

Not applicable.

5.12.1.4 Consumables and equipment

Not applicable.

5.12.1.5 Inspection

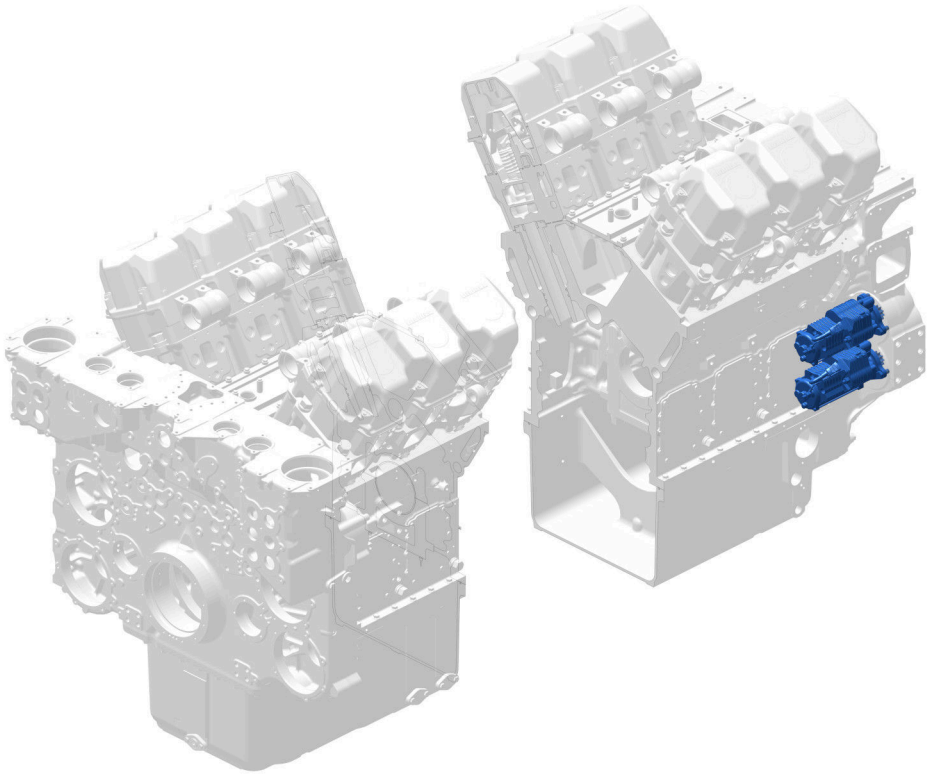


Fig. 102: Starters

- ▶ Inspect overall condition of the starters.
- ▶ Check for loose cable connections.
- ▶ Record and report any defect.

If defect is detected:

- ▶ Make sure that authorized service personnel correct the defect.

5.12.1.6 Specific values

Not applicable.

5.12.1.7 Tightening specifications

Refer to standard tightening torques (→ 8.4 Standard tightening torques, p. 249).

5.12.2 Inspecting battery charging alternator – SL1-6221

5.12.2.1 Previous tasks

Make sure that the following preconditions are met:

- ❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

5.12.2.2 Specific safety instructions

CAUTION
Contact with live electrical parts!
Risk of injury by electric shock.

- ▶ Observe local regulations, site rules, and safety notes.
- ▶ Before servicing the engine, perform a lockout/tagout (LOTO) procedure.
- ▶ Access to live parts shall only be possible with voluntary action.
- ▶ When the engine is in operation, stay away from the engine.

5.12.2.3 Special tools

Not applicable.

5.12.2.4 Consumables and equipment

Make sure that the following consumables and equipment are available:
– Compressed air blower

5.12.2.5 Inspection

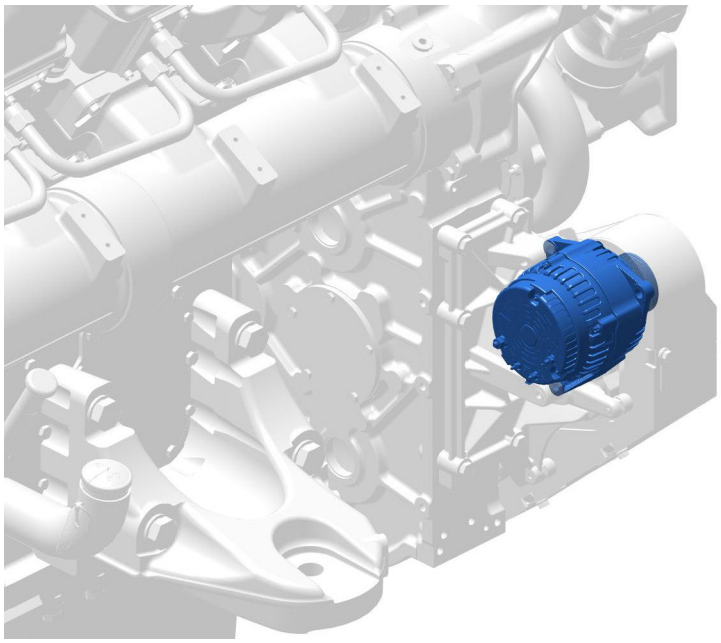


Fig. 103: Battery charging alternator

Clean the battery charging alternator:

- ▶ Using compressed air blower, push all debris towards the alternator fan.
- ▶ Using compressed air blower, clean the alternator fan.

Note

It is forbidden to use any liquid to clean the alternator.

- ▶ Inspect overall condition of the battery charging alternator.
- ▶ Check for loose cable connections.

▶ Record and report any defect.

If defect is detected:
▶ Make sure that authorized service personnel correct the defect.

5.12.2.6 Specific values

Not applicable.

5.12.2.7 Tightening specifications

Refer to standard tightening torques (→ 8.4 Standard tightening torques, p. 249).

5.12.3 Inspecting system of alternator belt drive – SL1-6231

5.12.3.1 Previous tasks

Make sure that the following preconditions are met:
❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).
❑ Cover of battery charging alternator is removed (→ 5.12.6 Removing and installing cover of battery charging alternator – SL1-6235, p. 195).

5.12.3.2 Specific safety instructions



WARNING
Entanglement of fingers between the belt and a pulley!
Risk of injury by crush.

▶ Observe local regulations, site rules, and safety notes.

▶ Stay away from belt, especially moving belt.

▶ Wear proper personal protective equipment.



CAUTION
Contact with live electrical parts!
Risk of injury by electric shock.

▶ Observe local regulations, site rules, and safety notes.

▶ Before servicing the engine, perform a lockout/tagout (LOTO) procedure.

▶ Access to live parts shall only be possible with voluntary action.

▶ When the engine is in operation, stay away from the engine.

5.12.3.3 Special tools

Not applicable.

5.12.3.4 Consumables and equipment

Make sure that the following consumables and equipment are available:
– Frequency meter for belt tension

5.12.3.5 Inspection

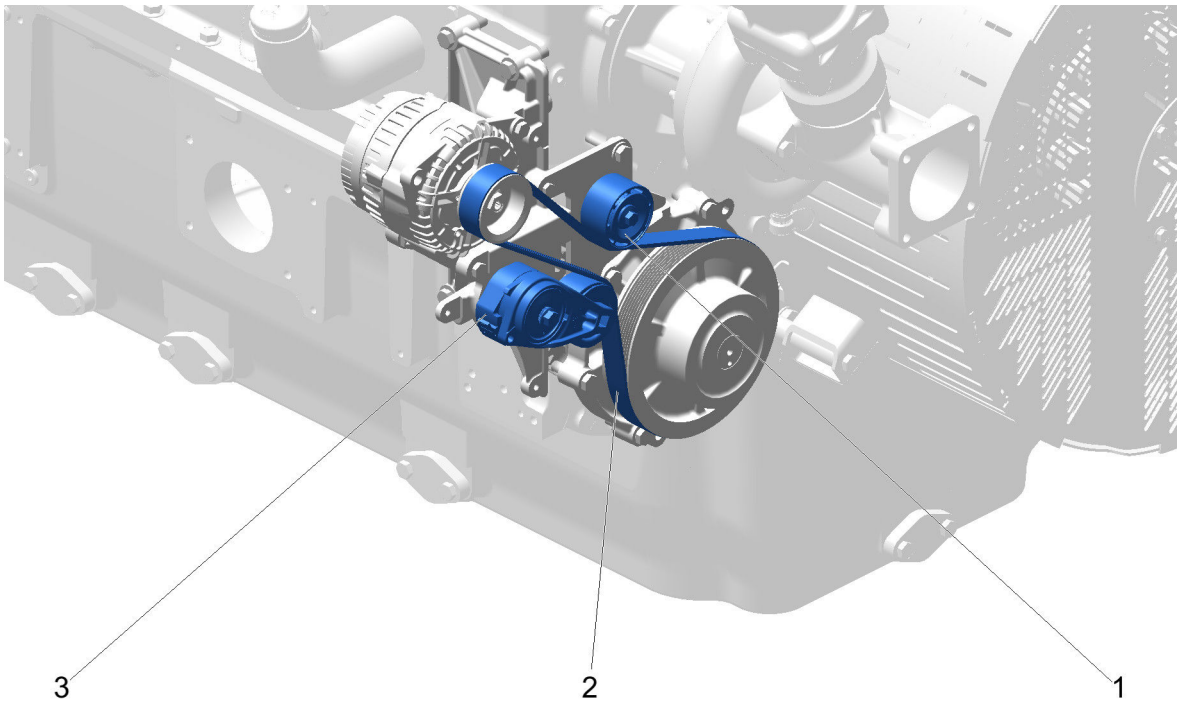


Fig. 104: Inspecting system of alternator belt drive

1 Roller
2 Belt
3 Belt tensioner

▶ Inspect overall condition of the system.

▶ Check tension of belt **2** with a frequency meter (→ 5.12.3.6 Specific values, p. 190).

▶ Record and report any defect.

If defect is detected:
▶ Make sure that authorized service personnel correct the defect.

5.12.3.6 Specific values

Belt tension: 165 $^{\pm 16}$ Hz

5.12.3.7 Tightening specifications

Refer to standard tightening torques (→ 8.4 Standard tightening torques, p. 249).

5.12.4 Replacing belt of battery charging alternator – SL1-6232

5.12.4.1 Previous tasks

Make sure that the following preconditions are met:
❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).
❑ Cover of battery charging alternator is removed (→ 5.12.6 Removing and installing cover of battery charging alternator – SL1-6235, p. 195).

5.12.4.2 Specific safety instructions



WARNING
Entanglement of fingers between the belt and a pulley!
Risk of injury by crush.

- ▶ Observe local regulations, site rules, and safety notes.
- ▶ Stay away from belt, especially moving belt.
- ▶ Wear proper personal protective equipment.



CAUTION
Contact with live electrical parts!
Risk of injury by electric shock.

- ▶ Observe local regulations, site rules, and safety notes.
- ▶ Before servicing the engine, perform a lockout/tagout (LOTO) procedure.
- ▶ Access to live parts shall only be possible with voluntary action.
- ▶ When the engine is in operation, stay away from the engine.

5.12.4.3 Special tools

Make sure that the following special tools are available:
– Pin punch for belt tensioner

(→ 7.1.1 Special tools, p. 220)

5.12.4.4 Consumables and equipment

Make sure that the following consumables and equipment are available:
– Belt tension frequency meter
– Ratchet wrench

5.12.4.5 Removal

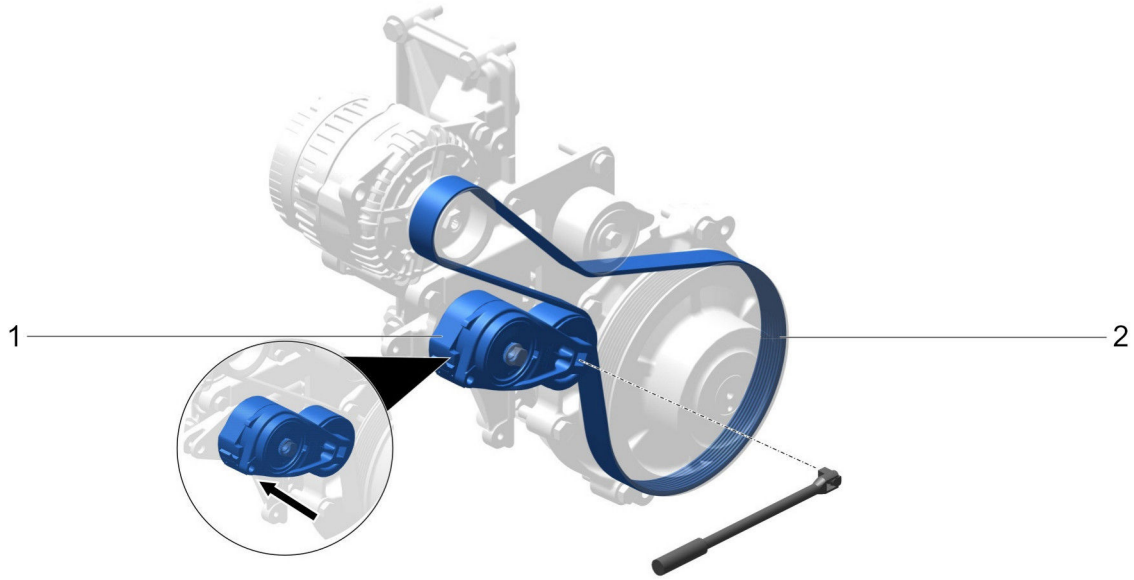


Fig. 105: Removing belt of battery charging alternator

1 Belt tensioner **2** Belt

- ▶ Install the ratchet wrench in belt tensioner **1**.
- ▶ Pivot back belt tensioner **1** against the spring force to the limit stop.
- ▶ Use a pin punch in the specified location to lock belt tensioner **1**.
- ▶ Remove belt **2**.
- ▶ Using the ratchet wrench, hold belt tensioner **1** while removing the pin punch.

5.12.4.6 Installation

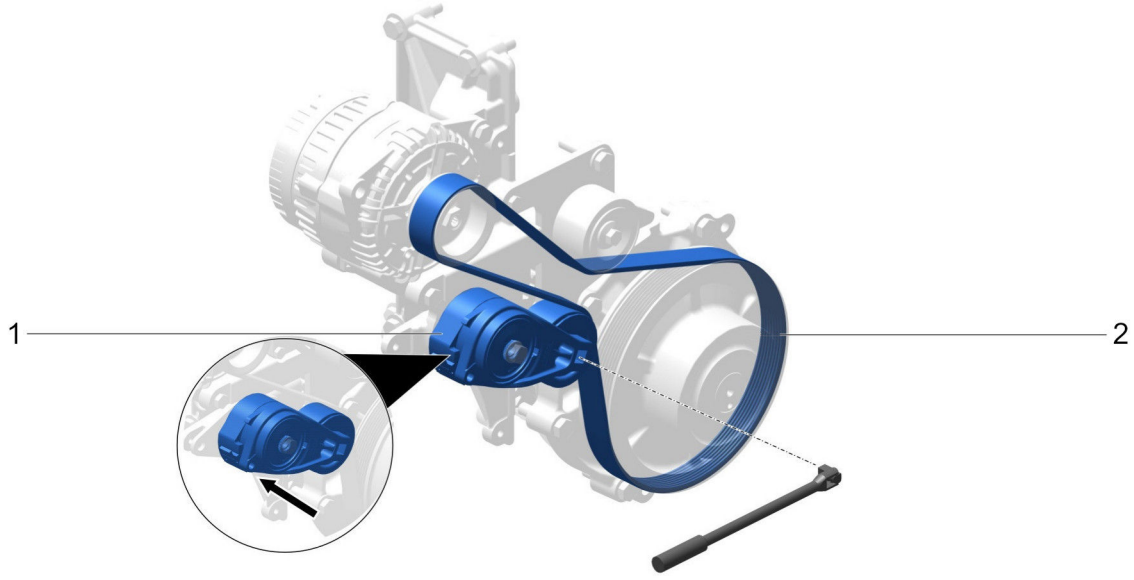


Fig. 106: Installing belt of battery charging alternator

- ▶ Install the ratchet wrench in belt tensioner **1**.

- ▶ Pivot back belt tensioner **1** against the spring force to the limit stop.
- ▶ Use the pin punch in the specified location to lock the belt tensioner **1**.
- ▶ Install belt **2** on the alternator and the Power Take-Off (PTO) pulley.
- ▶ Using the ratchet wrench, hold belt tensioner **1** while removing the pin punch.
- ▶ Check the tension of belt **2** using a frequency meter (→ 5.12.4.7 Specific values, p. 193).

5.12.4.7 Specific values

Belt tension: 165 $^{\pm 16}$ Hz

5.12.4.8 Tightening specifications

Refer to standard tightening torques (→ 8.4 Standard tightening torques, p. 249).

5.12.5 Replacing belt tensioner of battery charging alternator – SL1-6233

5.12.5.1 Previous tasks

Make sure that the following preconditions are met:
- ❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).
- ❑ Belt of battery charging alternator is removed (→ 5.12.4 Replacing belt of battery charging alternator – SL1-6232, p. 190).

5.12.5.2 Specific safety instructions



DANGER
Contact with moving part!
Risk of death or injury by entanglement or impact of ejected part.

- ▶ Make sure that the drive train is connected to the flywheel before starting the engine.
- ▶ Start or operate the engine with covers and guards secured in place.
- ▶ Remove all tools or loose parts from the vicinity of the engine after a service activity.
- ▶ Keep tools away from the starting or running engine.
- ▶ When the engine is in operation, stay away from the engine.

5.12.5.3 Special tools

Not applicable.

5.12.5.4 Consumables and equipment

Not applicable.

5.12.5.5 Removal

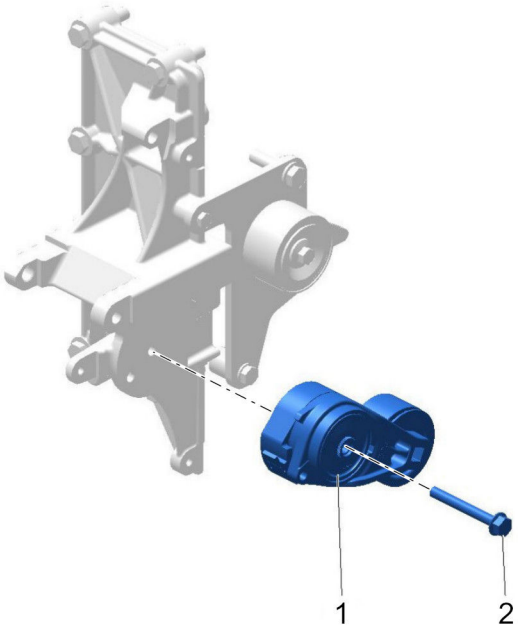


Fig. 107: Removing tensioner

1 Tensioner **2** Screw (M10)

▶ Remove screw **2**.

▶ Remove tensioner **1**.

5.12.5.6 Installation

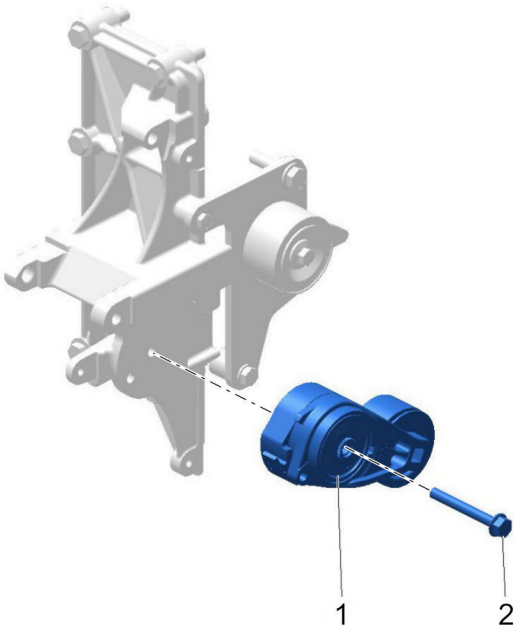


Fig. 108: Installing tensioner

▶ Install tensioner **1** on the bracket with screw **2**.

5.12.5.7 Specific values

Not applicable.

5.12.5.8 Tightening specifications

Refer to standard tightening torques (→ 8.4 Standard tightening torques, p. 249).

5.12.6 Removing and installing cover of battery charging alternator – SL1-6235

5.12.6.1 Previous tasks

Make sure that the following preconditions are met:
- ❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

5.12.6.2 Specific safety instructions



DANGER
Contact with moving part!
Risk of death or injury by entanglement or impact of ejected part.

- ▶ Make sure that the drive train is connected to the flywheel before starting the engine.
- ▶ Start or operate the engine with covers and guards secured in place.
- ▶ Remove all tools or loose parts from the vicinity of the engine after a service activity.
- ▶ Keep tools away from the starting or running engine.
- ▶ When the engine is in operation, stay away from the engine.



CAUTION
Contact with live electrical parts!
Risk of injury by electric shock.

- ▶ Observe local regulations, site rules, and safety notes.
- ▶ Before servicing the engine, perform a lockout/tagout (LOTO) procedure.
- ▶ Access to live parts shall only be possible with voluntary action.
- ▶ When the engine is in operation, stay away from the engine.

5.12.6.3 Special tools

Not applicable.

5.12.6.4 Consumables and equipment

Make sure that the following consumables and equipment are available:
- Rags
- Cleaner

5.12.6.5 Overview

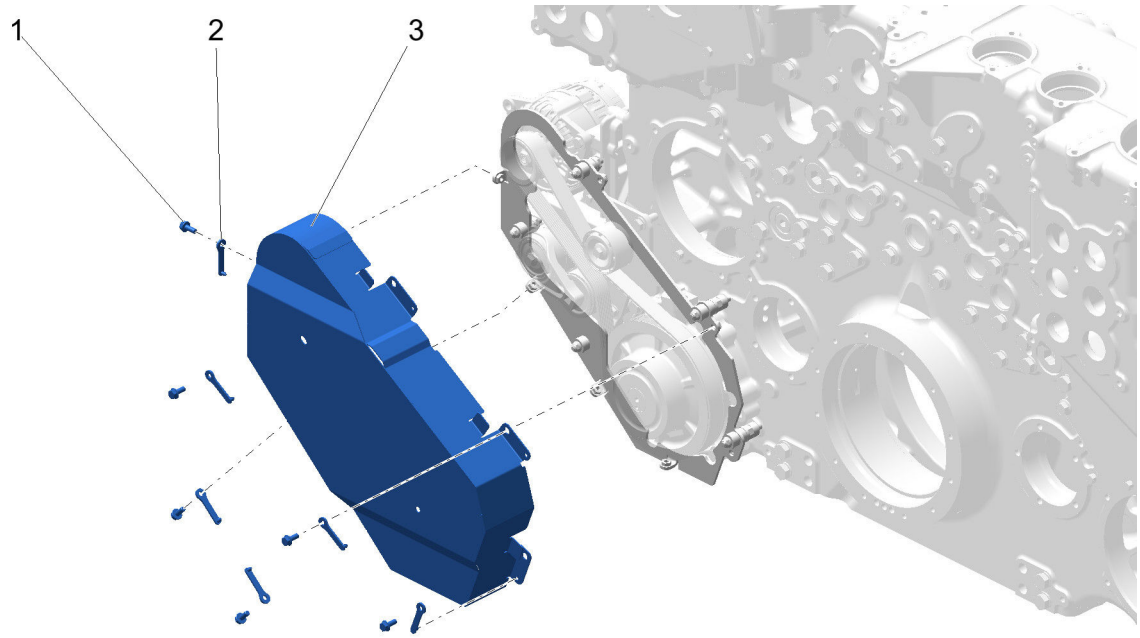


Fig. 109: Task overview

1 Screw (M8)
2 Lock washer
3 Cover

5.12.6.6 Removal

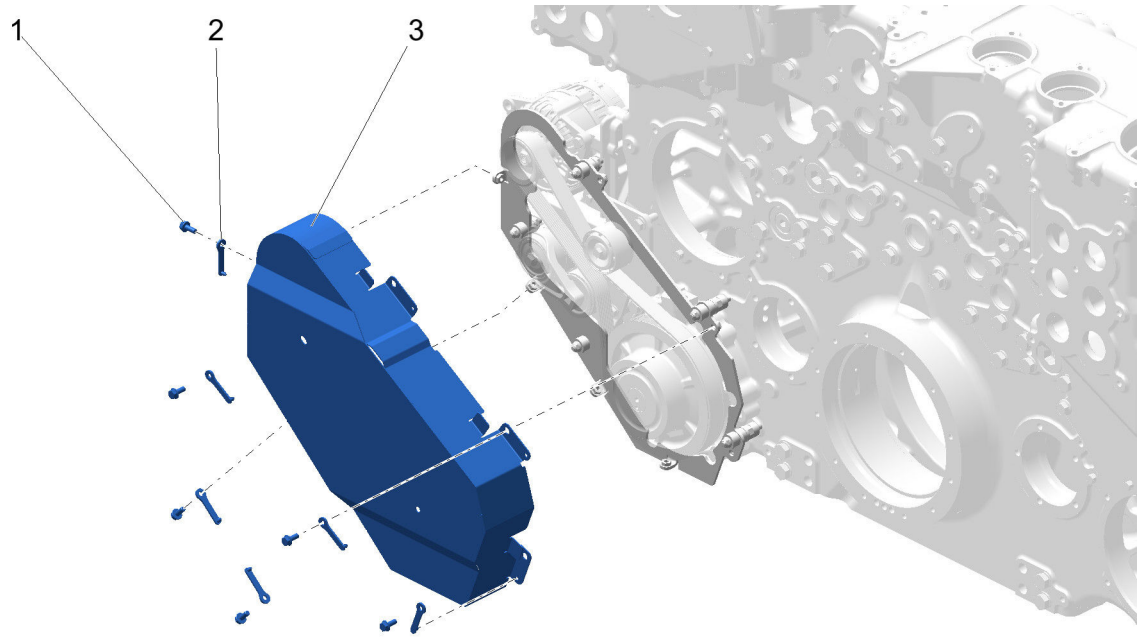


Fig. 110: Removing cover

▶ Remove cover **3** with lock washers **2** and screws **1**.

5.12.6.7 Installation

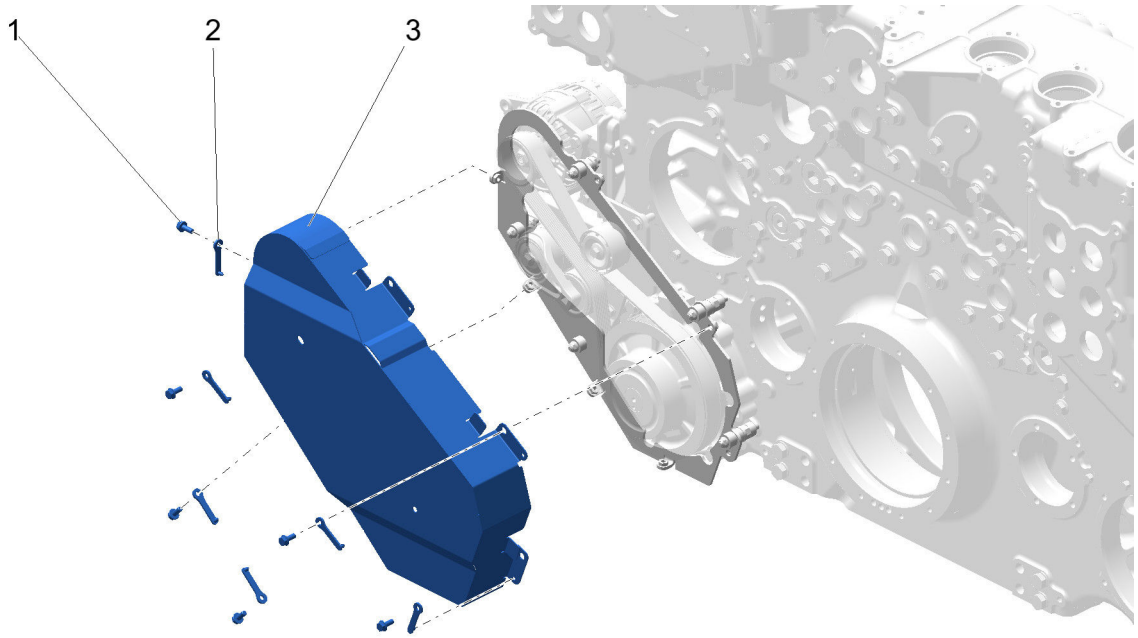


Fig. 111: Installing cover

▶ Install cover **3** with lock washers **2** and screws **1**.

5.12.6.8 Specific values

Not applicable.

5.12.6.9 Tightening specifications

Refer to standard tightening torques (→ 8.4 Standard tightening torques, p. 249).

5.13 Lubricants and operating fluids

5.13.1 Filling volume

Note

The following values are indicative. Refer to the technical data sheet of your diesel engine for the latest values. (→ 8 Appendix, p. 230)

Description	Quantity max.
Engine oil	Engine oil quantity after draining 709.1 l (187.32 US gal)
Coolant (engine only)	High temperature circuit 295 l (77.93 US gal)
	Low temperature circuit 105 l (27.74 US gal)

Tab. 33: Filling volume in the engine (indicative value)

5.13.2 Approved diesel fuels and fuel additives

All performance data provided by Discovery Energy, LLC and its affiliates dba Rehlko are guaranteed only for an EN 590 compliant fuel, with a Lower Heating Value (LHV) of 42.8 MJ/kg. Please apply correction factors when using a fuel with a different LHV.

5.13.2.1 Diesel fuels

Sulfur content and biodiesel content:

Only diesel fuels with a sulfur content lower than 1.5% (15000 ppm) are allowed in Rehlko KD diesel engines.

Note

For emission-certified engines (Tier 2, USA EPA CARB Tier 4 final, 97/68/EC Stage IIIA), only ultra low sulfur diesel fuels (ULSD) with a sulfur content lower than 0.0015% (15 ppm) are allowed in Rehlko KD diesel engines.

Only diesel fuels with a biodiesel content lower than 10% are recommended in Rehlko KD diesel engines.

Winter operation (cold operation):

Most diesel fuels produce paraffin crystals at low ambient temperatures. These crystals increase the flow resistance in the fuel filters and deteriorate the fuel feed to the diesel engine.

To prevent property damage, use only diesel fuels adequate to your ambient conditions. Pay a particular attention in countries changing standard according to season. Filling the tank with “summer fuel” may endanger your operability during winter.

The following fuels are approved for use in Rehlko KD diesel engines. On request, other fuels may be evaluated. Please contact your Discovery Energy, LLC and its affiliates dba Rehlko representative before any use.

On-road diesel

Fuel standard (norm)	Fuel quality (norm complement)	Required lubri-cating capacity (max. HFRR)	Required max. biodiesel ratio (%)	Additional required criteria	Compat-ible with EATS	Perform-ance alter-ation / Reduced mainte-nance interval
EN 590	CSR 4.0.10	-	10%	-	OK	No
ASTM D975	1D-S15	460 µm (18.11 thou)	-	-	OK	No
ASTM D975	1D-S500	460 µm (18.11 thou)	-	-	No	No
ASTM D975	1D-S5000	460 µm (18.11 thou)	-	-	No	No
ASTM D975	2D-S15	460 µm (18.11 thou)	-	-	OK	No
ASTM D975	2D-S500	460 µm (18.11 thou)	-	-	No	No
ASTM D975	2D-S5000	460 µm (18.11 thou)	-	-	No	No
ASTM D975	4D	460 µm (18.11 thou)	-	-	No	No

Tab. 34: KD approved on-road diesel fuels

Non-road diesel

Fuel standard (norm)	Fuel quality (norm complement)	Required lubri-cating capacity (max. HFRR)	Required max. biodiesel ratio (%)	Additional required criteria	Compat-ible with EATS	Perform-ance alter-ation / Reduced mainte-nance interval
EN 590	CSR 4.1.09	-	10%	-	OK	No
BS 2869	A2	-	10%	-	OK	No

Tab. 35: KD approved non-road diesel fuels

Heating-oil

Fuel standard (norm)	Fuel quality (norm complement)	Required lubri-cating capacity (max. HFRR)	Required max. biodiesel ratio (%)	Additional required criteria	Compat-ible with EATS	Perform-ance alter-ation / Reduced mainte-nance interval
DIN 51603	CSR 4.4.09	-	-	Fuel filtration	No	Yes[4)]

Tab. 36: KD approved heating-oil fuels

Military fuels

Fuel standard (norm)	Fuel quality (norm complement)	Required lubri-cating capacity (max. HFRR)	Required max. biodiesel ratio (%)	Additional required criteria	Compat-ible with EATS	Perform-ance alter-ation / Reduced mainte-nance interval
F-34	Equivalent to Jet A-1	460 µm (18.11 thou)	-	With additive S-1750 Not suitable for ESP	No	Yes[5)]
F-35	Equivalent to Jet A-1	460 µm (18.11 thou)	-	With additive S-1750	No	Yes[5)]
F-54 (Road diesel)	Equivalent to EN 590 CSR 4.0.10	460 µm (18.11 thou)	-	-	OK	Yes[5)]
F-63	-	460 µm (18.11 thou)	-	With additive S-1750	No	Yes[5)]
XF-10 (Heating-oil)	Equivalent to heating-oil CSR 4.4.09	460 µm (18.11 thou)	-	-	No	Yes[5)]
XF-51 (Non-road diesel)	Equivalent to EN 590 CSR 4.1.09	460 µm (18.11 thou)	10%	-	OK	Yes[5)]
XF-63	-	460 µm (18.11 thou)	-	With additive S-1750	No	Yes[5)]

Tab. 37: KD approved military fuels

4) Reinforced fuel primary filtration system, including water separator between main storage and daily tank, is mandatory.
5) Exchange interval of fuel filters is reduced (1/2), lifespan of fuel line components may be reduced, fuel consumption is not guaranteed anymore.

Aviation kerosene

Fuel standard (norm)	Fuel quality (norm complement)	Required lubricating capacity (max. HFRR)	Required max. biodiesel ratio (%)	Additional required criteria	Compatible with EATS	Performance alteration / Reduced maintenance interval
Jet A-1	-	460 µm (18.11 thou)	-	With additive S-1750	No	Yes[5]

Tab. 38: KD approved aviation kerosene fuels

Biofuels

Due to the wide range of fuels available on the market, please contact your Discovery Energy, LLC and its affiliates dba Rehlko representative before any use of synthetic fuels not included in the following list.

Biodiesels

Only diesel fuels with a biodiesel content lower than 10% are allowed in Rehlko KD diesel engines.

Note

Diesel fuels with a biodiesel content between 10% and 20% may be used, but Discovery Energy, LLC and its affiliates dba Rehlko do not recommend it as the operating costs linked to maintenance will drastically increase.

Fuel standard (norm)	Fuel quality (norm complement)	Required lubricating capacity (max. HFRR)	Required max. biodiesel ratio (%)	Additional required criteria	Compatible with EATS	Performance alteration / Reduced maintenance interval
EN 14214	-	-	10%	Fuel storage Fuel filtration	No	Yes[5] [6] [7] [8] [9]
EN 14214	-	-	20%	Fuel storage Fuel filtration	No	Yes[5] [6] [7] [8] [9]
ASTM D6751	-	-	10%	Fuel storage Fuel filtration	No	Yes[5] [6] [7] [8] [9]

5) Exchange interval of fuel filters is reduced (1/2), lifespan of fuel line components may be reduced, fuel consumption is not guaranteed anymore.
6) Biodiesels are not recommended for ESP (Emergency Standby Power) generator set applications because of the risk of bacteria development.
7) Specific improved storage condition is mandatory.
8) Reinforced fuel primary filtration system, including water separator between main storage and daily tank, is mandatory.
9) Polishing primary fuel filtration is mandatory.

Fuel standard (norm)	Fuel quality (norm complement)	Required lubricating capacity (max. HFRR)	Required max. biodiesel ratio (%)	Additional required criteria	Compatible with EATS	Performance alteration / Reduced maintenance interval
ASTM D6751	-	-	20%	Fuel storage Fuel filtration	No	Yes[5) 6) 7) 8) 9)]

Tab. 39: KD approved biodiesel fuels

Paraffinic fuels (according to EN 15940)

Paraffinic fuels (“synthetic diesel”) have a high cetane number and a low density compared to diesel fuels. Hydrotreated Vegetable Oils (HVOs) are renewable. Gas-To-Liquids (GTLs) are fossil paraffinic fuels. The use of paraffinic fuels results in lower emissions, but also slightly higher fuel consumption and lower performance.

When using paraffinic diesel, a reduced filter change interval may be necessary due to the cleaning effect.

Rubber and elastomers in the fuel system can be affected when changing from diesel fuel to paraffinic fuel. Check daily whether fuel is leaking, and contact customer service for assistance if necessary.

Note

EN 15940 fits into specification ASTM D975 1D-15 and ASTM D975 2D-15.

Hydrotreated Vegetable Oil (HVO)

Fuel standard (norm)	Fuel quality (norm complement)	Required lubricating capacity (max. HFRR)	-	Additional required criteria	Compatible with EATS	Performance alteration / Reduced maintenance interval
EN 15940	-	-	-	-	No	Yes[10) 11) 12)]

Tab. 40: KD approved HVO fuels

5) Exchange interval of fuel filters is reduced (1/2), lifespan of fuel line components may be reduced, fuel consumption is not guaranteed anymore.
6) Biodiesels are not recommended for ESP (Emergency Standby Power) generator set applications because of the risk of bacteria development.
7) Specific improved storage condition is mandatory.
8) Reinforced fuel primary filtration system, including water separator between main storage and daily tank, is mandatory.
9) Polishing primary fuel filtration is mandatory.
10) Exchange interval of fuel filters may be reduced.
11) Rubber and elastomer parts must be monitored daily.
12) Exchange interval of lubricating oil and lubricating oil filters is reduced (monitor soot in oil).

Gas To Liquid (GTL)

Fuel standard (norm)	Fuel quality (norm complement)	Required lubricating capacity (max. HFRR)	Required max. biodiesel ratio (%)	Additional required criteria	Compatible with EATS	Performance alteration / Reduced maintenance interval
EN 15940	-	-	-	-	OK	Yes[5) 11) 12)]

Tab. 41: KD approved GTL fuels

5.13.2.2 Fuel additives

Rehlko KD diesel engines are designed in such a way that the use of general additives is not necessary nor recommended. However, under specific circumstances, biocide additives may be used according to the supplier recommendations.

Biocides

Should the diesel engine be stopped for a long period or infested with micro-organisms, or should the tank be polluted with sludge, the fuel system must be cleaned and the fuel treated with biocides.

The following biocides are approved for use in Rehlko KD diesel engines:

Commercial designation	Maker	Compatible with EATS
Grotamar 71	Schülke & Mayr GmbH.	OK
Grotamar 82	Schülke & Mayr GmbH.	OK

Tab. 42: KD approved biocides

Starting fluids

The use of starting fluids (ether based or any other low flash point product) is strictly forbidden in KD diesel engines.

5.13.3 Approved engine oils and engine oil additives

5.13.3.1 Engine oils essential characteristics and maintenance

SAPS and engine oil quality

Discovery Energy, LLC and its affiliates dba Rehlko classifies synthetic engine oils among two main categories for SAPS level and three subcategories for quality level.

SAPS stands for Sulfated Ash, Phosphorus, and Sulfur. Phosphorus and sulfur are often incorporated as part of additives to increase engine oil performances (for example: anti-wear, anti-oxidization, cleanliness); sulfated ashes are the result of the combustion of the additives in a

5) Exchange interval of fuel filters is reduced (1/2), lifespan of fuel line components may be reduced, fuel consumption is not guaranteed anymore.
11) Rubber and elastomer parts must be monitored daily.
12) Exchange interval of lubricating oil and lubricating oil filters is reduced (monitor soot in oil).

running diesel engine. SAPS can quickly damage exhaust gas aftertreatment systems (EATS) if not mastered properly. This is why the use of “low SAPS” engine oils is mandatory in diesel engines equipped with exhaust gas aftertreatment systems.

Discovery Energy, LLC and its affiliates dba Rehlko classifies synthetic engine oils in three categories for quality and two subcategories for SAPS content:
- **Engine oil category 1:** mineral and semi-synthetic engine oils
- **Engine oil category 2:** standard quality / synthetic multigrade engine oils
- **Engine oil category 2.1:** standard quality / synthetic multigrade engine oils dedicated for engines with EATS (low SAPS engine oils)
- **Engine oil category 3:** high quality / synthetic multigrade engine oils
- **Engine oil category 3.1:** high quality / synthetic multigrade engine oils dedicated for engines with EATS (low SAPS engine oils)

Note

Engine oil categories 2.1 and 3.1 must be used only with USLD fuels (with a sulfur content lower than 15 ppm).

These quality levels help to determine the exchange interval for engine oil. They indicate the engine oil category factor to be used in relationship to the change interval mentioned in the technical documentation accompanying your diesel engine.

Category	Oil category factor	Comment
Engine oil category 1	1/4	The change interval is divided by four.
Engine oil category 2	1	The change interval is conserved.
Engine oil category 2.1	1	The change interval is conserved.
Engine oil category 3	2	The change interval can be extended by two times.
Engine oil category 3.1	2	The change interval can be extended by two times.

Tab. 43: KD engine oil category factors

Note

Note that it is highly recommended to change engine oil, spin-on oil filters, and liner of centrifugal oil filter (paper or silicon) simultaneously.

Engine oil requirements

Generally speaking, engine oils fulfilling the following criteria can be used in Rehlko KD diesel engines. However, a careful check of the characteristics must be undertaken. This measure ensures that the criteria mentioned in the following sections are explicitly fulfilled before considering the engine oil as approved for use in KD diesel engines.

Parameter	Unit	Expected value		Methods
		Without EATS	With EATS	
Visual appearance	-	Clear	Clear	Visual
Viscosity @ minimum temperature	mm^2 / s	3500	3500	DIN 51562
Viscosity @ operation temperature	mm^2 / s	10.0 - 16.0	10.0 - 16.0	DIN 51562
VI-index	-	> 145	> 155	ISO 2909

Parameter	Unit	Expected value		Methods
		Without EATS	With EATS	
High temperature - High shear	cP	3.5 - 4.3	3.5 - 4.3	CEC L36-A-90
Ignition point	°C	> 220	> 220	ISO 2592
Total base number	mg KOH / g	> 12	> 9	ISO 3771
Shear stability	%	10	10	ASTM D6278
NOAK (1 hour @ 250 °C (482 °F))	%	< 10	< 10	CEC L-040-93
Ash (sulfur) maximum	g / 100 g	1.9	0.95	DIN 51575

Tab. 44: KD engine oil minimum requirements

Engine oil viscosity grade

The viscosity grade is measured against SAE standards. The first number indicates engine oil viscosity at start-up, on cold conditions (W stands for Winter); the second number indicates engine oil viscosity at operating conditions (usually considered at 100 °C (212 °F)).

The engine oils presenting these viscosity grades are approved for use in Rehlko KD diesel engines:

SAE grade	Viscosity (Cranking) mPA.s @ °C	Viscosity (Pumping ability) mPA.s @ °C	Viscosity (Operating) $mm^2.s^{-1}$ @ °C
As per:	ASTM D5293	ASTM D4684	ISO 3104
5W40	6600 @ -30	60000 @ -35	12.5 < μ < 16.3 @ 100
10W40	7000 @ -25	60000 @ -30	
15W40[A)]	7000 @ -20	60000 @ -25	

Tab. 45: KD engine oil viscosity grade requirements

A) Use of 15W40 engine oil presents some restrictions in cold environments.

Rehlko KD diesel engines are designed to start with an ambient temperature above -10 °C (14 °F) with 5W40 or 10W40 engine oils. Specific additional devices should be considered for application intended to start at a temperature below -10 °C (14 °F) or when using a 15W40 engine oil. Please contact your Discovery Energy, LLC and its affiliates dba Rehlko representative for additional information.

Fuel sulfur content and engine oil soot

Fuel sulfurs impact diesel engine hardware by developing sulfuric acids during combustion, thus creating corrosion. Engine oil embeds basic compounds (detergents) to neutralize these acids. The TBN (Total Base Number) measures the detergent content by providing an index of basicity for the engine oil.

With generalization of low sulfur content fuels and the associated evolution of engine oils, the TBN is no more sufficient to monitor operating engine oil status. The TAN (Total Acid Number) is also needed to get an accurate picture of the engine oil condition.

Engine oil soot is a by-product of the combustion comprised of roughly 98% of carbon in mass. It forms on the coolest part of the combustion chamber. Then soot is dragged into the engine oil by the piston rings or migrates to the crankcase through the crankcase breather system.

TBN ratio

The following TBN engine oils are approved for use in Rehlko KD diesel engines.

- When diesel engine is operated with low sulfur content fuels (sulfur content lower than 0.5%):
  - TBN must be higher than 8 mgKOH/g and the soot (S_iO) must be lower than 3%.
- When diesel engine is operated with sulfur content fuels between 0.5% and 1%:
  - TBN must be higher than 10 mgKOH/g and the soot (S_iO) must be lower than 3%.
  - Engine oil change interval must be reduced according to the following table.
  - Engine oil change intervals must be confirmed through analysis process.
- When diesel engine is operated with sulfur content fuels between 1.0% and 1.5%:
  - TBN must be higher than 12 mgKOH/g and the soot (S_iO) must be lower than 3%.
  - Engine oil change interval must be reduced according to the following table.
  - Engine oil change intervals must be confirmed through analysis process.

As a reminder, Rehlko KD diesel engines must not be operated with fuels having a sulfur content higher than 1.5% (15000 ppm).

Emission-certified engines must not be operated with fuel having a sulfur content higher than 0.0015% (15 ppm).

Category	Sulfur content factor	Comment
0.0% < S < 0.5%	1	The change interval is conserved.
0.5% < S < 1.0%	1/2	The change interval is divided by two.
1.0% < S < 1.5%	1/4	The change interval is divided by four.

Tab. 46: KD fuel sulfur content factors

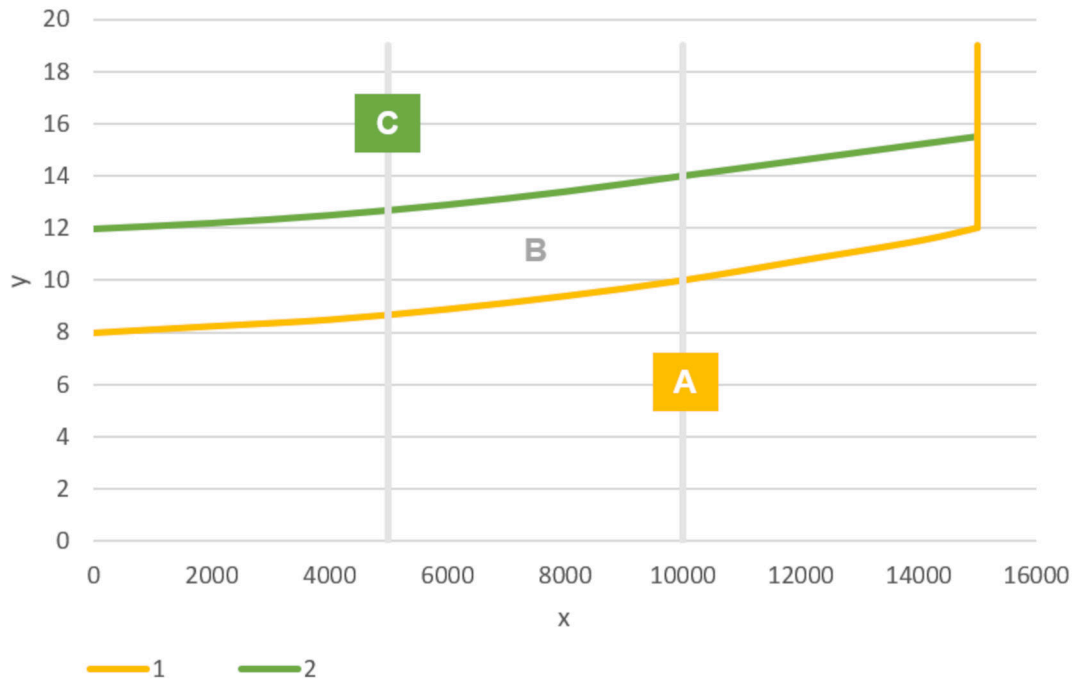


Fig. 112: KD recommended TBN according to fuel sulfur content

A Operation forbidden zone
B Engine oil change to be initiated
C Safe operating zone

x Fuel sulfur content (ppm)
y Total Base Number (TBN)
1 Minimum TBN
2 Recommended TBN

TAN ratio

Discovery Energy, LLC and its affiliates dba Rehlko does not recommend any specific TAN for the engine oil to be used in KD diesel engines.

However, the user must pay a particular attention to the TAN and ensures that the following criteria are always true: TAN < TBN - 2mgKOH / g.

The following graph represents the influence of the TAN and the TBN on engine wear, represented by the quantity of iron found in engine oil.

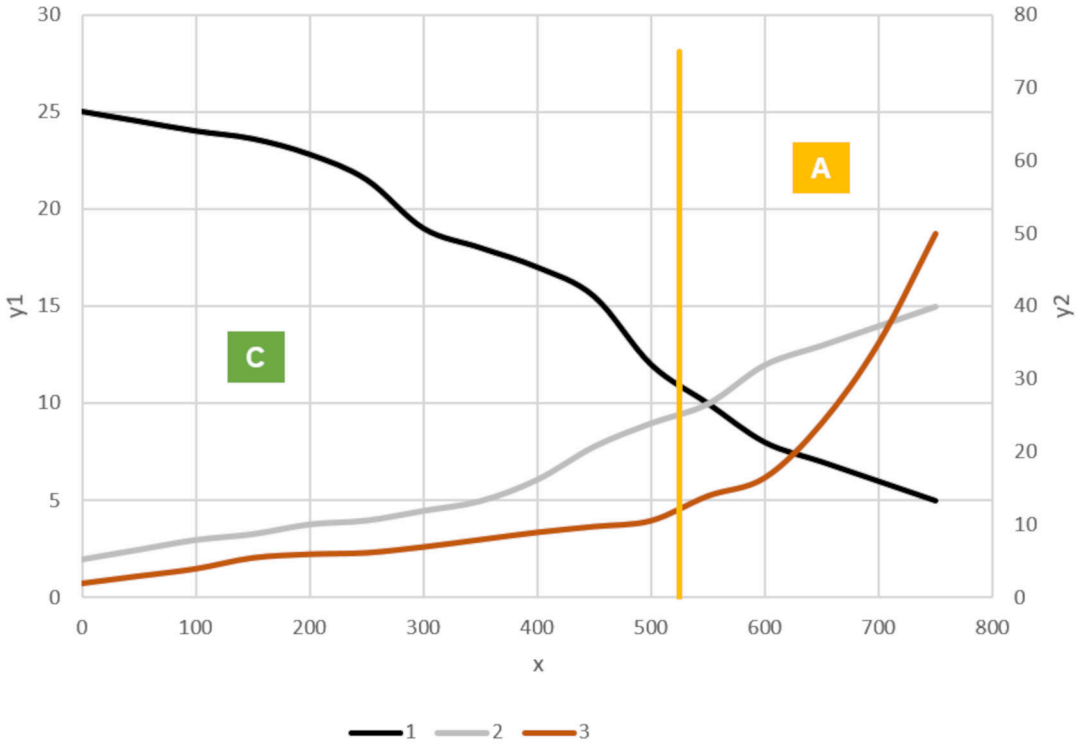


Fig. 113: KD recommended TAN / TBN evolution

A Operation forbidden zone
C Safe operating zone
x Operating hours
y1 TAN-TBN (mgKOH / g)
y2 Iron (ppm)
1 TBN
2 TAN
3 Iron

Engine oil change intervals and monitoring

Engine oil change intervals

Standard change interval for the engine oil is mentioned in the technical documentation accompanying the diesel engine (see “maintenance schedule” section). Additionally, the change interval is also influenced by the engine oil initial quality and the severity of the operation.

The following types of operation are considered as “severe”:
- Frequent cold starts
- Extended non operated period (standstill)

- Severe ambient conditions:
  - Extreme operating temperatures (cold or hot)
  - High humidity
  - Dust

Always refer to the technical documentation of the diesel engine to determine the engine oil change interval. In most of the case, the following definition applies: Change interval = Basic engine oil change interval * Engine oil category factor * Sulfur content factor

Where:
- Standard engine oil change interval is indicated in the technical documentation of the diesel engine.
- Engine oil category factor is defined in the table on KD engine oil category factors (→ tab. 49, p. 209).
- Sulfur content factor is defined in the table on KD fuel sulfur content factors (→ tab. 46, p. 206).

As an example:
- Standard engine oil change interval is 500 operating hours.
- Engine oil category is 3, so engine oil category factor is 2.
- Sulfur content is 1.3%, so sulfur content factor is ¼.
- Change interval = 500 * 2 * 1/4 = 250 hours

Engine oil monitoring

Close monitoring of engine oil quality brings benefits in several areas:
- Optimization of engine oil-change intervals
  - Improves your economics
  - Reduces environmental footprint
- Optimization of diesel engine availability
- Early detection of potential damage

When one of these **warning** values is reached in operating engine oil:
- Immediately collect a new engine oil sample.
- Make sure that the new sample is analyzed quickly.
- Investigate on source of deviation.
- Reduce monitoring interval if necessary.

When one of these **maximum** values is reached in operating engine oil:
- Change engine oil immediately.
- Investigate on source of deviation.

Criteria group	Criteria	Warning values	Maximum values	Methods
Contaminants	Aluminum	< 10 ppm	< 15 ppm	-
	Iron	< 30 ppm	< 40 ppm	-
	Chromium	-	< 10 ppm	-
	Copper	< 20 ppm	< 20 ppm	-
	Lead	< 15 ppm	< 25 ppm	-
	Silicon	-	< 15 ppm	-
	Sodium	< 15 ppm	< 20 ppm	-
	Potassium[A)]	-	< 25 ppm [A)]	-
Other contaminants	Water	< 0.10%	< 0.2%	-
	Carbon	< 2%	< 3%	-
	Fuel	< 2%	< 3%	-

Criteria group	Criteria	Warning values	Maximum values	Methods
Viscosity	@ 40 °C (104 °F)	-	0.9 V_0 < V < 1.1 V_0 (V_0 = fresh engine oil viscosity	ASTM D 7279 DIN 51562
	@ 100 °C (212 °F)	-	0.9 V_0 < V < 1.1 V_0 (V_0 = fresh engine oil viscosity	ASTM D 7279 DIN 51562
	Viscosity index	-	0.88 Vi_0 < Vi < 1.12 Vi_0 (Vi_0 = fresh engine oil viscosity	ISO 2909
Acid / Basic	TAN & TBN	-	TAN < TBN - 2 mgKOH/g	ASTM D 664 (acid) ASTM D 2896 (base)
Oxidation	-	<20 abs.cm^{-1}	< 25 abs.cm^{-1}	-

Tab. 47: KD engine oil monitoring criteria

A) Potassium is now incorporated in new-generation engine oils; conclusion must be drawn only by having initial composition and evolution available.

5.13.3.2 Mineral engine oils

Engine oil category	Engine oil standard	Type of engine oil	Engine oil category factor	Compatible with EATS
Engine oil category 1	ACEA E5-02 API CH-4 DHD-1	Mineral-based (Group 1 and 2 base oils)	1/4	No

Tab. 48: KD engine oil categories

5.13.3.3 Synthetic engine oils

Engine oil category	Engine oil standard	Type of engine oil	Engine oil category factor	Compatible with EATS
Engine oil category 2	ACEA E4 ACEA E7 API CI-4 Plus DHD-1 JASO DH-1	Synthetic (Group 2 and/or 3 base engine oils)	1	No
Engine oil category 2.1	ACEA E6 ACEA E9 API CJ-4 JASO DH-2	Synthetic (Group 2 and/or 3 base engine oils)	1	OK

Engine oil category	Engine oil standard	Type of engine oil	Engine oil category factor	Compatible with EATS
Engine oil category 3	ACEA E4-16 Both ACEA E4 and ACEA E7	Synthetic (Group 3 and/or 4 base engine oils) VI > 155 Long live additive	2	No
Engine oil category 3.1	ACEA E6-12 Both ACEA E6 and ACEA E9 API CK-4	Synthetic (Group 3 and/or 4 base engine oils) VI > 155 Long live additive	2	OK

Tab. 49: KD engine oil categories

5.13.3.4 Engine oil additives

Discovery Energy, LLC and its affiliates dba Rehlko prohibit the use of engine oil additives in the KD diesel engines.

5.13.4 Approved coolants

5.13.4.1 Coolant function

Diesel engine coolant fulfills three functions:
- Heat transfer from the diesel engine and its components to the radiators, without fluid cavitation
- Corrosion protection and deposit prevention in the cooling system
- Antifreeze protection in the cooling system

Note

Corrosion inhibitors present no cavitation protection. Use of water and corrosion inhibitor only in the cooling system is not recommended.

5.13.4.2 Coolant specification

Rehlko KD diesel engines are designed to operate only with confirmed reblending of “BASF Glysantin G40” coolant, which is SI-OAT technology based on ethylene glycol.

Note

The use of other coolant technologies, including those based on “BASF Glysantin G48”, is prohibited.

The user can choose a ready-to-use preparation or prepare their own blend of water with antifreeze and corrosion-protection agents. Discovery Energy, LLC and its affiliates dba Rehlko recommends the use of ready-to-use mixture as it reduces the risk of error in concentration and pollution of the system.

Water specification

When the user wants to blend their own mixture, Discovery Energy, LLC and its affiliates dba Rehlko recommends the use of fully deionized water. If the user wants to use tap water, this

water must fulfill the requirements for drinking water according to 2006 WHO (World Health Organization) guideline.

Criteria	Value
Water hardness	< 2.14 mmol/l (214 ppm) < 10°dH
pH-value	7.2 < pH < 9
Chloride (ions)	< 25 mg/l (25 ppm)
Sulfate	< 25 mg/l (25 ppm)
Bacteria and toxic constituent	Without
Impurities	Clear and free
Conductivity	4 < mS

Tab. 50: KD water requirements

Note

The use of sea water, brackish water, salt water, and industrial waste water is prohibited.

Coolant concentration

Discovery Energy, LLC and its affiliates dba Rehlko recommends a concentration of antifreeze and corrosion-protection agents of 40% all year round in power supply applications.

Only coolants with a glycol content lower than 55% are allowed in Rehlko KD diesel engines. Higher concentrations prevent proper heat transfer and are thus forbidden. Should your application need additional antifreeze protection (arctic conditions), please contact your Discovery Energy, LLC and its affiliates dba Rehlko representative for additional information.

5.13.4.3 Coolant monitoring

Discovery Energy, LLC and its affiliates dba Rehlko recommends the following list of parameters to be checked by coolant analysis at least once a year. However, the user should always check with their coolant provider what the recommendations for analysis and monitoring of their coolant are, according to engine operating conditions.

Discovery Energy, LLC and its affiliates dba Rehlko recommends a close monitoring of the coolant to prevent diesel engine damage by cavitation, corrosion, overheating, or freezing. Monitoring of the coolant can extend the exchange period of the fluid for up to 6000 operating hours or 4 years (what comes first).

Note

Topping up the cooling system with inadequate water or non-compatible coolant mixtures can lead to precipitation in the fluid and malfunction of the engine.

Criteria group	Criteria	Units	Recommended values (if any)	Methods
Physical characteristics	Visual appearance / color	-	-	Visual

Criteria group	Criteria	Units	Recommended values (if any)	Methods
	Water hardness	mmol/l (ppm)	-	EN/ISO 11885
	Glycol concentration	%	-	DIN 51375
	pH	-	-	EN/ISO 10523 ASTM D1287
	Pour point	°C (°F)	-	ISO 3016 ASTM D5985
	Freezing point	°C (°F)	-	ISO 3013 ASTM D1177
Water contaminants	Bromure / Bromide	mg/kg (ppm)	<50	-
	Chlorure / Chloride	mg/kg (ppm)	<50	-
	Fluorure / Fluoride	mg/kg (ppm)	<10	-
	Sulfate	mg/kg (ppm)	<50	-
Biological colonization	Bacteria	count	-	-
Glycol decomposition products	Glycolate	mg/kg (ppm)	<300	-
	Formate	mg/kg (ppm)	<300	-
	Oxalate	mg/kg (ppm)	<300	-
	Lactate	mg/kg (ppm)	<300	-
	Acétate	mg/kg (ppm)	<300	-
Additive elements	B, Ba, Ca, K, Mg, Na, P, S, Si	mg/kg (ppm)	-	DIN 51399
Wear elements	Al, Cr, Cu, Fe, Mg, Mo, Ni, Pb, Sn, Ti, V	mg/kg (ppm)	-	DIN 51399
Corrosion copper	Copper	-	-	EN/ISO 2160
	Steel	-	-	ISO 7120

Tab. 51: KD coolant analysis parameters

5.13.4.4 Keeping the cooling system clean

Usually, cleaning the cooling system is not necessary.

In case of contamination with bacteria, fungi or yeast, a mixture of fresh coolant added with biocides is suitable. The following products are approved:

Manufacturer	Product-name	Concentration
Schülke & Mayr Gmbh	Grotan WS Plus	0.15% by volume
	Grotanol SR1	1% by volume

Manufacturer	Product-name	Concentration
Troy chemical company	Troyshield SC1	1% by volume

Tab. 52: KD cooling system cleaners

If there is need for a full cleaning of the system, flush the entire system with adequate water, then:
- Use the approved products to clean the system (→ tab. 53, p. 213).
- Use the approved products to clean the components (→ tab. 54, p. 213).

Manufacturer	Product-name	Concentration
Kluthe	Hakutex 111	2% by volume
	Hakupur 50-706-3	2% by volume
Nalco	Maxi-Clean 2	2% by volume

Tab. 53: KD cooling system flushing chemicals

Manufacturer	Product-name	Concentration
Henkel	P3-FD	3 to 5% by weight
	Porodox	5 to 10% by weight
Kluthe	Hakutex 60	100% by volume

Tab. 54: KD cooling system components cleaners

6 Operating faults

6.1 Diagnosis principles

For some engine problems with possible causes and corrective measures, see the table Faults - Causes - Remedy.

Note

Engine faults are displayed by means of a fault code on the device display for diagnostic purposes.

The explanations and remedies are explained in the KODIA manual.

Basic logical steps for diagnosis are as following:

- ▶ Know the engine and the associated systems.
- ▶ Thoroughly analyze the problem.
- ▶ Relate symptoms to current knowledge about the engine and the systems.
- ▶ Diagnose problem, starting from the most obvious assumptions.
- ▶ Examine closely before starting to take the engine apart.
- ▶ Identify the causes and thoroughly perform any repair work.

After correction:

- ▶ Check for rectification of the causes.
- ▶ Close the incident.
- ▶ Run the engine according to Operation and Maintenance Manual.

6.2 Faults - Cause - Remedy

Malfunction / error	Cause	Remedy
Starter does not turn.	Main fuse burnt through.	Replace fuse.
	Battery connections loose or corroded.	Clean and tighten loose connections.
	Battery voltage too low.	Recharge or replace battery.
	Starter circuit broken or contacts corroded.	Contact your authorized Rehlko service representative.
	Starter defective.	Contact your authorized Rehlko service representative.
Starter turns over slowly.	Battery voltage too low.	Recharge or replace battery.
	Battery connections loose or corroded.	Clean and tighten loose connections.
	Exterior temperature too low.	Implement measures for winter operation.
Diesel engine does not start and/or stops immediately.	Fuel tank empty.	Refuel the diesel engine.
	Fuel filter blocked.	Replace fuel filter.
	Fuel line, precleaner, or sieve in fuel tank blocked.	Clean and bleed fuel system.
	Fuel system or filter leaking.	Seal and bleed.
	Air in the fuel system.	Bleed fuel system.
	Fuel not cold-resistant.	Clean fuel pre-filter, replace fuel filter; use winter fuel.
	Exterior temperature too low.	Implement measures for winter operation.
Diesel engine starts badly.	Leaks or pressure too low in fuel low-pressure circuit.	Visually control there is no leak; Contact your authorized Rehlko service representative to check diesel engine.
	Diesel engine compression too low.	Contact your authorized Rehlko service representative.
	Fault in electronics.	Read out fault memory of engine control unit. Contact your authorized Rehlko service representative.
Diesel engine shuts down when not desired.	Voltage supply interrupted.	Contact your authorized Rehlko service representative.
	Leaks or pressure too low in fuel low-pressure circuit.	Leak test (visual inspection); Contact your authorized Rehlko service representative to check diesel engine.
	Fault in electronics.	Read out fault memory of engine control unit. Contact your authorized Rehlko service representative.

Malfunction / error	Cause	Remedy
Low diesel engine power (lack of power).	Defect in fuel system (blocked, leaking).	Visual inspection for leaks, replace filter, contact your authorized Rehlko service representative.
	Charging pressure too low.	Loose clips, defective seals, and hoses, air filter contaminated, turbocharger has no power.
	Charging air temperature too high.	Charge air cooler contaminated, low fan power, ambient temperature too high, contact your authorized Rehlko service representative.
	Coolant temperature too high.	Check cooler for contamination, check fan and thermostat, check coolant level, contact your authorized Rehlko service representative.
	Fuel temperature too high.	Contact your authorized Rehlko service representative.
	Use at elevation over 1800 m above sea level.	No remedy. Diesel engine power is automatically reduced.
	Injection nozzles stuck or do not vaporize.	Contact your authorized Rehlko service representative.
	Diesel engine compression too low.	Contact your authorized Rehlko service representative.
	Fault in electronic system.	Read out fault logs of engine control unit, contact your authorized Rehlko service representative.
Diesel engine too hot (according to coolant temperature display).	Coolant quantity low.	Check the level.
	Cooler contaminated or scaled.	Clean or descale.
	Thermostat failure.	Check, replace if necessary, contact your authorized Rehlko service representative.
	Failure of coolant temperature thermocouple.	Check, replace if necessary, contact your authorized Rehlko service representative.
Black smoke from diesel engine.	Injection nozzles stuck or inefficient.	Contact your authorized Rehlko service representative.
	Turbocharger failure (charge pressure too low).	Contact your authorized Rehlko service representative.
	Diesel engine overloaded.	Contact your authorized Rehlko service representative.

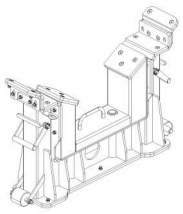
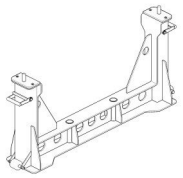
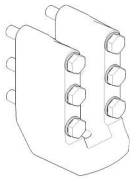
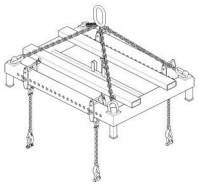
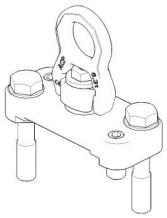
Malfunction / error	Cause	Remedy
Exhaust gases blue.	Oil level in the diesel engine too high.	Adjust oil level.
	Engine oil reaches the combustion chamber and is burned.	Contact your authorized Rehlko service representative.
	Compressor-side seal on the exhaust gas turbocharger defective.	Contact your authorized Rehlko service representative.
	Crankcase breather system defective.	Check, if necessary replace.
Exhaust gases white.	Injection starts too late.	Contact your authorized Rehlko service representative.
	Operating temperature not reached.	Warm up the diesel engine until operating temperature is reached.
	Water in fuel system.	Check fuel system and drain fuel pre-filter.
	Charge air cooler leaking.	Contact your authorized Rehlko service representative.
Diesel engine rattles.	Combustion faults.	Contact your authorized Rehlko service representative.
Diesel engine knocks.	Wrong valve clearance.	Set valve clearance.
	Injection nozzles damaged or carbonized.	Contact your authorized Rehlko service representative.
	Bearing damage.	Contact your authorized Rehlko service representative.
	Piston rings worn or broken, pistons eroded.	Contact your authorized Rehlko service representative.
Abnormal noises.	Leaks in the intake and exhaust lines cause whistling noise.	Seal leaks, replace seal if necessary.
	Turbine or compressor wheel rubbing against the housing; foreign bodies in the compressor or turbine; seized up bearings of rotating parts.	Contact your authorized Rehlko service representative.
Engine oil pressure too low.	Oil level in the oil pan too low.	Fill engine oil to prescribed mark.
	Bad viscosity (engine oil diluted by diesel).	Drain off engine oil, fill with prescribed engine oil.
	Pressure sensor failure.	Check engine oil pressure and replace damaged oil pressure sensor; contact your authorized Rehlko service representative.
	Oil pressure regulation valve does not work properly or dirt in the oil pressure regulation valve.	Contact your authorized Rehlko service representative.
	Bearing play too great due to wear or bearing damage.	Contact your authorized Rehlko service representative.

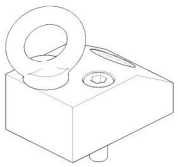
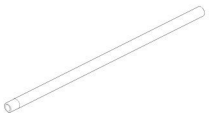
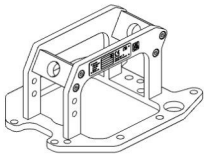
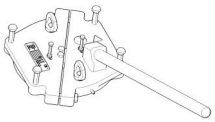
Malfunction / error	Cause	Remedy
Engine oil in the cooling system.	Oil cooler or oil cooler plate leaking.	Contact your authorized Rehlko service representative.
Coolant in the engine oil.	Cylinder liner seals leaking.	Contact your authorized Rehlko service representative.
	Oil cooler or oil cooler plate leaking.	Contact your authorized Rehlko service representative.
Charge air temperature too high.	Coolant concentration incorrect.	Check concentration using test kit.
	Charge air cooler contaminated.	Contact your authorized Rehlko service representative.
	Air intake temperature too high.	Check fans, air supply, and ventilation.
Charge air pressure too low.	Air filter clogged.	Check air-filter service indicator.
	Charge air cooler contaminated.	Contact your authorized Rehlko service representative.
	Turbocharger exhaust defect.	Contact your authorized Rehlko service representative.
Coolant leaks on charge air cooler.	Leaking, breaking.	Contact your authorized Rehlko service representative.

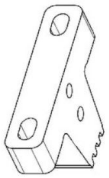
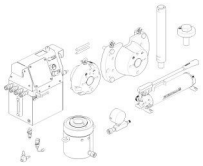
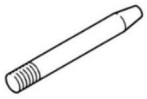
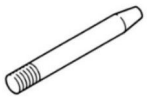
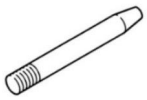
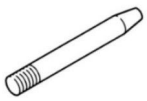
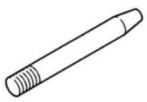
7 Tools and devices

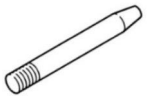
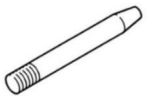
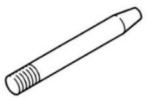
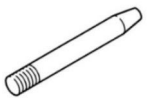
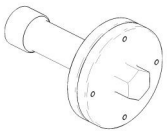
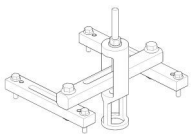
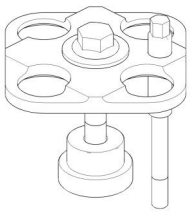
7.1 Tools

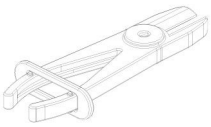
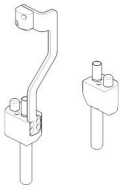
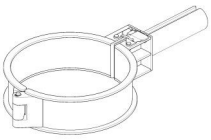
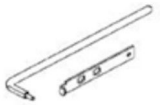
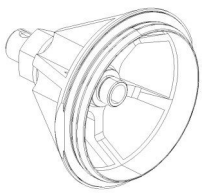
7.1.1 Special tools

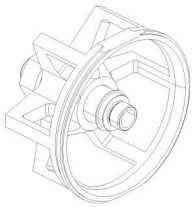
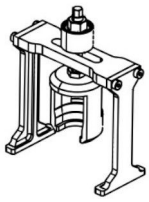
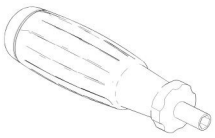
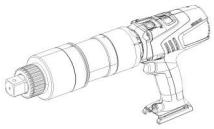
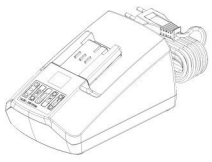
Special tool	Designation	Qty	Ident
Assembly stand			
	Engine stand - small	2	230615853
	Engine stand - large	2	230615776
Adapter			
	Engine bracket Screws Washers	1 6 6	230611347 230611533 230611094
Lifting devices			
	Engine lifting frame	1	230615854
	Lifting device for crankcase	4	230615855

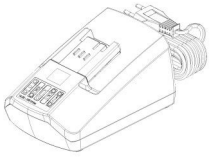
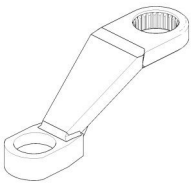
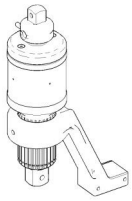
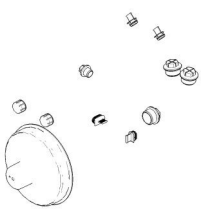
Special tool	Designation	Qty	Ident
	Lifting device for HP fuel pump	1	230614614
	Lifting device for gearbox of HP fuel pump	1	230615410
	Handling bar	1	230612677
	Lifting device for cylinder head	1	230614625
	Power unit extracting and lifting device	1	230612871
Engine turning tools			
	Flywheel turning device	1	230613591
	Crankshaft turning device	1	230615873

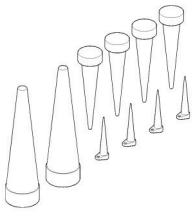
Special tool	Designation	Qty	Ident
	Locking device	1	230612868
Crankshaft hub			
	Hub replacement kit	1	230615223
Guide pins			
	Guide pin M12 - HT/LT thermostat housing L230 mm (9.06 in)	2	230611638
	Guide pin M12 - HT/LT coolant pump L100 mm (3.94 in)	2	230610042
	Guide pin M16 - Oil cooler housing L540 mm (1.77 ft)	2	230610039
	Guide pin M12 - Oil cooler / Oil filter head L400 mm (1.31 ft)	2	230610040
	Guide pin M10 - Exhaust line L80 mm (3.15 in)	2	230610041

Special tool	Designation	Qty	Ident
	Guide pin M30 - Cylinder head L460 mm (1.51 ft)	2	230610035
	Guide pin M28 - Damper L380 mm (1.25 ft)	2	230610036
	Guide pin M22 - Flywheel L380 mm (1.25 ft)	2	230612869
	Guide pin M16 - Flywheel housing / IFE L330 mm (1.08 ft)	2	230615718
Cylinder liner			
	Cylinder liner holding device	1	230615089
Valves			
	Valve spring compressing device	1	230614617
	Valve removal device	1	230614618
Assembly aid			

Special tool	Designation	Qty	Ident
	Hose clamp	1	230613704
	Tool for coolant connector pipe	1	230612686
	Connecting rod guide	1 1	230615417 230615418
Piston			
	Piston ring expander	1	230613065
	Piston ring compressor	1	230613049
Radial oil seal			
	Removal tool for crankshaft seal	1	230614588
	Assembly device for crankshaft seal - without hub	1	230615719

Special tool	Designation	Qty	Ident
	Assembly device for crankshaft seal - with hub (TVD side only)	1	230615720
Fuel injector			
	Injector extraction tool	1	230611925
	Torque screwdriver for injector connector	1	230612675
Fuel system			
	Assembly device for PCV solenoid	1	230613744
Bolt tightening			
	Electric torque multiplier	1	230612678
	Electric torque multiplier - Battery pack	1	230612682
	Electric torque multiplier - 110V charger	1	230612683

Special tool	Designation	Qty	Ident
	Electric torque multiplier - 230V charger	1	230612684
	Electric torque multiplier - Torque reaction arm	1	230612679
	Manual torque multiplier	1	230612680
	Manual torque multiplier - Torque reaction arm	1	230612681
	Torque multiplier - Adapter	1	230612685
Miscellaneous			
	Pin punch for belt tensioner	1	230611639
	Covering caps kit for HP/LP fuel pump	1	230612816

Special tool	Designation	Qty	Ident
	Coned stopper set	1	230611641
	KODIA kit Dongle Adapter cable Licence	- 1 1 1	- 230610368 230613037 Upon request

Tab. 55: Special tools

7.1.2 Turning device

7.1.2.1 Specific safety instructions

The turning device is used to turn a gearwheel that drives the flywheel gear rim.

WARNING
Use of turning device!
Risk of death or injury by crushing, shearing, cutting, or severing.

- ▶ Tag out the application area according to local regulations and site rules.
- ▶ Before using the turning device, warn the personnel in the vicinity of the engine.
- ▶ Use the turning device under the supervision of another authorized technician.
- ▶ Before and during use of the turning device, stay away from the engine.

WARNING
Turning device screwed on the flywheel housing or wrench tool on the turning device during engine operation!
Risk of death or injury by ejected tools or turning device parts.

- ▶ Check spring function of the turning device. If faulty, replace by new turning device.
- ▶ After the rotation of the flywheel, always take away the wrench tool from the turning device.
- ▶ Dismount immediately the turning device and mount the cover on the flywheel housing.

NOTICE
Turning device screwed on the flywheel housing during engine operation!
Property damage - Risk of engine major failure.

- ▶ Dismount immediately the turning device and mount the cover on the flywheel housing.

Note

The wrench tool and the turning device are available for maintenance task only.

Should you have any queries, please contact your authorized Discovery Energy, LLC and its affiliates dba Rehlko service representative.

7.1.2.2 Installation

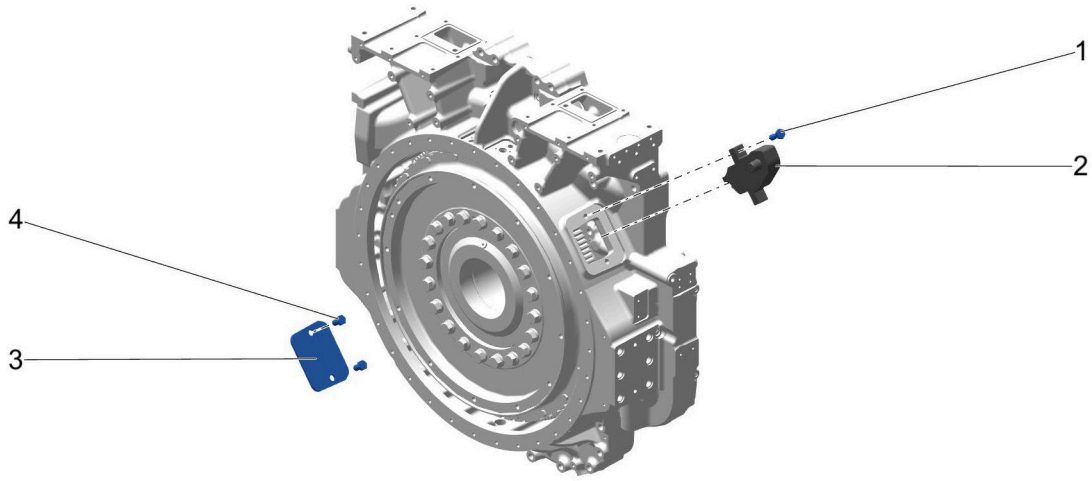


Fig. 162: Mounting the turning device

1 Screws (M16x35 -8.8)
2 Turning device
3 Cover
4 Screws (M16x25 -8.8)

To mount the turning device:

- ▶ Remove screws **4**.
- ▶ Remove cover **3**.
- ▶ Position turning device **2**.
- ▶ Install and tighten screws **1** according to standard torque values.

Note

Should you have any queries, please contact your authorized Discovery Energy, LLC and its affiliates dba Rehlko service representative.

7.1.2.3 Operation

Make sure that the following preconditions are met:
❑ Turning device is mounted on the engine.

Depending on the required setting:

- ▶ Engage a manual wrench tool to turn the wheel from the turning device that drives the flywheel gear rim.
- ▶ Turn the engine flywheel to the required position or as long needed by turning the wrench.
- ▶ Disengage the manual wrench each time you stop to turn.

At the end of the setting:

- ▶ Remove the turning device and install the cover on the flywheel housing.
- ▶ Tighten the turning device cover bolts according to standard torque values.

7.1.2.4 Removal

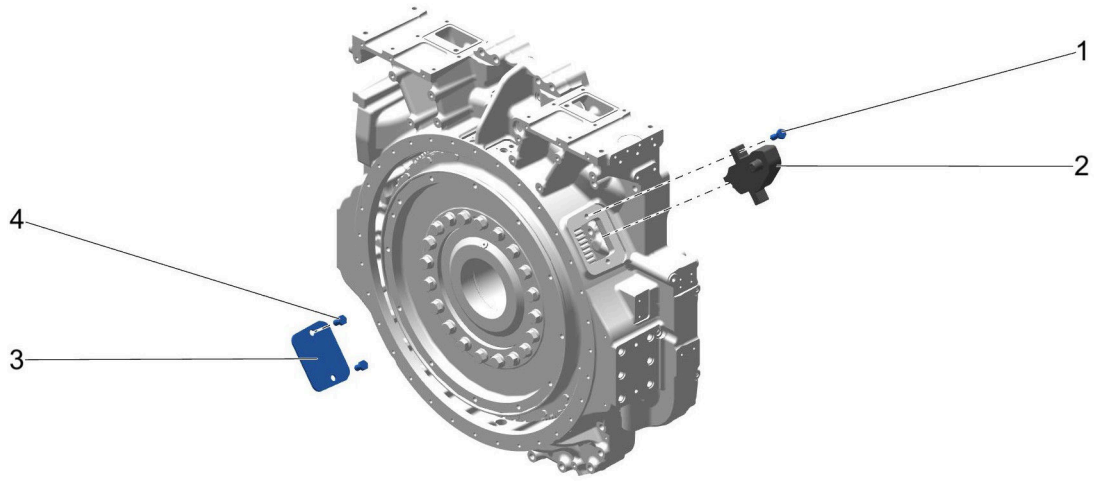


Fig. 163: Mounting the turning device

1 Screws (M16x35 -8.8)
2 Turning device
3 Cover
4 Screws (M16x25 -8.8)

To dismount the turning device:

- ▶ Remove screws **1**.
- ▶ Remove turning device **2**.
- ▶ Position cover **3**.
- ▶ Install and tighten screws **4** according to standard torque values.

Note

Should you have any queries, please contact your authorized Discovery Energy, LLC and its affiliates dba Rehlko service representative.

7.1.3 Diagnostic tools

Discovery Energy, LLC and its affiliates dba Rehlko proposes an advanced diagnosis software (KODIA) for its diesel engines.

KODIA provides the user with a comprehensive set of tools to test the different systems of the engine and to monitor real-time data for advanced diagnosis and analysis. Features such as the oscilloscope function, the engine firmware update, or the error memory check are built into KODIA.

8 Appendix

8.1 Error code

Note

Error code list extracted from engine control unit software version 21.12.23.

The following error code table is indicative. Refer to the technical data sheet of your engine for the latest software version.

For further information, please contact your nearest authorized Discovery Energy, LLC and its affiliates dba Rehlko service representative.

Abbreviations:
- SPN - Suspect Parameter Number
- FMI - Failure Mode Identification

SPN	FMI	Designation
107	11	Air filter - Blocked/clogged
516101	31	Air filter pressure switch - Supply voltage out of range
516428	31	Air pressure sensors - Plausibility error
108	31	Ambient pressure sensor - Supply voltage out of range
171	5	Ambient temperature sensor - Open circuit
171	3	Ambient temperature sensor - Short circuit to battery
171	4	Ambient temperature sensor - Short circuit to ground
171	31	Ambient temperature sensor - Supply voltage out of range
1176	1	Boost pressure - Pressure too high
1176	0	Boost pressure - Pressure too low
636	2	Camshaft position - Plausibility error
636	14	Camshaft position sensor - Ground error
636	5	Camshaft position sensor - Open circuit
636	3	Camshaft position sensor - Short circuit to battery
636	3	Camshaft position sensor - Short circuit to battery or open circuit
636	4	Camshaft position sensor - Short circuit to ground
636	31	Camshaft position sensor - Supply voltage out of range
157	0	Common rail - Critical overpressure
1239	2	Common rail - Leakage
157	15	Common rail - Overpressure warning
516117	11	Common rail - PCV opened due to overpressure
1075	2	Common rail - Plausibility error

SPN	FMI	Designation
516118	11	Common rail - Plausibility error of VCV current
516121	11	Common rail - Pressure remains above the set point
516122	11	Common rail - Pressure remains below the set point
516123	11	Common rail - Start pressure too low
1349	0	Common rail 2 - Critical overpressure
1240	2	Common rail 2 - Leakage
1349	15	Common rail 2 - Overpressure warning
516124	11	Common rail 2 - PCV opened due to overpressure
516125	11	Common rail 2 - Plausibility error of VCV current
516128	11	Common rail 2 - Pressure remains above the set point
516129	11	Common rail 2 - Pressure remains below the set point
516130	11	Common rail 2 - Start pressure too low
1239	0	Common rail leakage 1 - Fuel leak
1239	11	Common rail leakage 1 - Out of range
1239	31	Common rail leakage 1 - Supply voltage out of range
1240	0	Common rail leakage 2 - Fuel leak
1240	11	Common rail leakage 2 - Out of range
1240	31	Common rail leakage 2 - Supply voltage out of range
516131	11	Common rail pressure sensor - No signal variation
157	3	Common rail pressure sensor - Short circuit to battery or open circuit
157	4	Common rail pressure sensor - Short circuit to ground
157	31	Common rail pressure sensor - Supply voltage out of range
516133	11	Common rail pressure sensor 2 - No signal variation
1349	3	Common rail pressure sensor 2 - Short circuit to battery or open circuit
1349	4	Common rail pressure sensor 2 - Short circuit to ground
1349	31	Common rail pressure sensor 2 - Supply voltage out of range
2430	11	Coolant level sensor - Out of range
2430	3	Coolant level sensor - Short circuit to battery
2430	4	Coolant level sensor - Short circuit to ground or open circuit
2430	31	Coolant level sensor - Supply voltage out of range
6303	11	Coolant level sensor 2 - Out of range
6303	3	Coolant level sensor 2 - Short circuit to battery
6303	4	Coolant level sensor 2 - Short circuit to ground or open circuit
6303	31	Coolant level sensor 2 - Supply voltage out of range
6209	0	Coolant temperature at intercooler - Critical overtemperature
6209	15	Coolant temperature at intercooler - Overtemperature warning

SPN	FMI	Designation
110	5	Coolant temperature sensor - Open circuit
110	3	Coolant temperature sensor - Short circuit to battery
110	4	Coolant temperature sensor - Short circuit to ground
110	31	Coolant temperature sensor - Supply voltage out of range
101	0	Crankcase pressure - Critical overpressure
101	15	Crankcase pressure - Overpressure warning
101	31	Crankcase pressure - Supply voltage out of range
101	3	Crankcase pressure sensor - Short circuit to battery
101	4	Crankcase pressure sensor - Short circuit to ground or open circuit
637	2	Crankshaft position - Plausibility error
637	14	Crankshaft position sensor - Ground error
637	5	Crankshaft position sensor - Open circuit
637	3	Crankshaft position sensor - Short circuit to battery
637	3	Crankshaft position sensor - Short circuit to battery or open circuit
637	4	Crankshaft position sensor - Short circuit to ground
637	31	Crankshaft position sensor - Supply voltage out of range
1136	0	Engine control unit - Critical overtemperature
516543	31	Engine control unit - Data recorder was triggered
1136	15	Engine control unit - Overtemperature warning
516495	31	Engine control unit - Runtime reached the maximum time without reset
1136	31	Engine control unit temperature sensor 1 - Supply voltage out of range
516140	31	Engine control unit temperature sensor 2 - Supply voltage out of range
516141	31	Engine control unit temperature sensor 3 - Supply voltage out of range
51644	31	Engine - Starter activated but no engine rotation detected
516356	31	Engine control unit - Communication error to slave injection control unit
639	5	Engine control unit CAN 1 - Open circuit
639	11	Engine control unit CAN 1 - Short circuit
625	5	Engine control unit CAN 2 - Open circuit
625	11	Engine control unit CAN 2 - Short circuit
516148	5	Engine control unit CAN 4 - Open circuit
516148	11	Engine control unit CAN 4 - Short circuit
110	0	Engine coolant - Critical overtemperature
111	17	Engine coolant - Level low

SPN	FMI	Designation
110	15	Engine coolant - Overtemperature warning
4076	14	Engine coolant 2 - Level low
175	0	Engine oil - Critical overtemperature
100	1	Engine oil - Critical underpressure
175	15	Engine oil - Overtemperature warning
100	2	Engine oil - Plausibility error
100	17	Engine oil - Underpressure warning
1180	2	Exhaust boost temperature (CMR sensor) - Communication error
1180	2	Exhaust boost temperature 1 (CMR sensor) - Communication error
1181	2	Exhaust boost temperature 2 (CMR sensor) - Communication error
3245	0	Exhaust temperature before turbocharger 1 - Critical overtemperature
1180	15	Exhaust temperature before turbocharger 1 - Overtemperature warning
3279	0	Exhaust temperature before turbocharger 2 - Critical overtemperature
1181	15	Exhaust temperature before turbocharger 2 - Overtemperature warning
94	0	Fuel supply - Critical overpressure
174	0	Fuel supply - Critical overtemperature
94	1	Fuel supply - Critical underpressure
174	15	Fuel supply - Overtemperature warning
94	3	Fuel supply pressure sensor - Short circuit to battery
94	4	Fuel supply pressure sensor - Short circuit to ground or open circuit
94	31	Fuel supply pressure sensor - Supply voltage out of range
174	5	Fuel temperature sensor - Open circuit
174	3	Fuel temperature sensor - Short circuit to battery
174	4	Fuel temperature sensor - Short circuit to ground
174	31	Fuel temperature sensor - Supply voltage out of range
516195	2	Generator Set Controller - Communication error
190	0	Genset - Engine over speed
729	6	Heating flange 1 - Critical high output current
729	11	Heating flange 1 - Electrical error
729	5	Heating flange 1 - Open circuit
729	3	Heating flange 1 - Short circuit to battery high side
516304	3	Heating flange 1 - Short circuit to battery low side

SPN	FMI	Designation
729	4	Heating flange 1 - Short circuit to ground high side
516305	4	Heating flange 1 - Short circuit to ground low side
730	6	Heating flange 2 - Critical high output current
730	11	Heating flange 2 - Electrical error
730	5	Heating flange 2 - Open circuit
730	3	Heating flange 2 - Short circuit to battery high side
516344	3	Heating flange 2 - Short circuit to battery low side
730	4	Heating flange 2 - Short circuit to ground high side
516345	4	Heating flange 2 - Short circuit to ground low side
516346	5	Heating flange status input 1 - Open circuit
516346	3	Heating flange status input 1 - Short circuit to battery high side
516347	3	Heating flange status input 1 - Short circuit to battery low side
516346	4	Heating flange status input 1 - Short circuit to ground high side
516347	4	Heating flange status input 1 - Short circuit to ground low side
516348	8	Heating flange status input 2 - Open circuit
516348	3	Heating flange status input 2 - Short circuit to battery high side
516349	3	Heating flange status input 2 - Short circuit to battery low side
516348	4	Heating flange status input 2 - Short circuit to ground high side
516349	4	Heating flange status input 2 - Short circuit to ground low side
516187	31	Ignition digital input - Supply voltage out of range
516509	31	Injection data synchronization - Error during measurement of voltage-based small quantity injection correction
651	0	Injector 1 - Current Rise time too long
651	8	Injector 1 - No current rise time measured
651	5	Injector 1 - Open circuit
651	3	Injector 1 - Short circuit to battery
651	4	Injector 1 - Short circuit to ground
660	0	Injector 10 - Current Rise time too long
660	8	Injector 10 - No current rise time measured
660	5	Injector 10 - Open circuit
660	3	Injector 10 - Short circuit to battery
660	4	Injector 10 - Short circuit to ground
661	0	Injector 11 - Current Rise time too long
661	8	Injector 11 - No current rise time measured
661	5	Injector 11 - Open circuit
661	3	Injector 11 - Short circuit to battery
661	4	Injector 11 - Short circuit to ground
662	0	Injector 12 - Current Rise time too long

SPN	FMI	Designation
662	8	Injector 12 - No current rise time measured
662	5	Injector 12 - Open circuit
662	3	Injector 12 - Short circuit to battery
662	4	Injector 12 - Short circuit to ground
663	0	Injector 13 - Current Rise time too long
663	8	Injector 13 - No current rise time measured
663	5	Injector 13 - Open circuit
663	3	Injector 13 - Short circuit to battery
663	4	Injector 13 - Short circuit to ground
664	0	Injector 14 - Current Rise time too long
664	8	Injector 14 - No current rise time measured
664	5	Injector 14 - Open circuit
664	3	Injector 14 - Short circuit to battery
664	4	Injector 14 - Short circuit to ground
665	0	Injector 15 - Current Rise time too long
665	8	Injector 15 - No current rise time measured
665	5	Injector 15 - Open circuit
665	3	Injector 15 - Short circuit to battery
665	4	Injector 15 - Short circuit to ground
666	0	Injector 16 - Current Rise time too long
666	8	Injector 16 - No current rise time measured
666	5	Injector 16 - Open circuit
666	3	Injector 16 - Short circuit to battery
666	4	Injector 16 - Short circuit to ground
667	0	Injector 17 - Current Rise time too long
667	8	Injector 17 - No current rise time measured
667	5	Injector 17 - Open circuit
667	3	Injector 17 - Short circuit to battery
667	4	Injector 17 - Short circuit to ground
668	0	Injector 18 - Current Rise time too long
669	8	Injector 18 - No current rise time measured
669	5	Injector 18 - Open circuit
669	3	Injector 18 - Short circuit to battery
669	4	Injector 18 - Short circuit to ground
652	0	Injector 19 - Current Rise time too long
652	8	Injector 19 - No current rise time measured
652	5	Injector 19 - Open circuit
652	3	Injector 19 - Short circuit to battery

SPN	FMI	Designation
652	4	Injector 19 - Short circuit to ground
652	0	Injector 2 - Current Rise time too long
652	8	Injector 2 - No current rise time measured
652	5	Injector 2 - Open circuit
652	3	Injector 2 - Short circuit to battery
652	4	Injector 2 - Short circuit to ground
670	0	Injector 20 - Current Rise time too long
670	8	Injector 20 - No current rise time measured
670	5	Injector 20 - Open circuit
670	3	Injector 20 - Short circuit to battery
670	4	Injector 20 - Short circuit to ground
653	0	Injector 3 - Current Rise time too long
653	8	Injector 3 - No current rise time measured
653	5	Injector 3 - Open circuit
653	3	Injector 3 - Short circuit to battery
653	4	Injector 3 - Short circuit to ground
654	0	Injector 4 - Current Rise time too long
654	8	Injector 4 - No current rise time measured
654	5	Injector 4 - Open circuit
654	3	Injector 4 - Short circuit to battery
654	4	Injector 4 - Short circuit to ground
655	0	Injector 5 - Current Rise time too long
655	8	Injector 5 - No current rise time measured
655	5	Injector 5 - Open circuit
655	3	Injector 5 - Short circuit to battery
655	4	Injector 5 - Short circuit to ground
656	0	Injector 6 - Current Rise time too long
656	8	Injector 6 - No current rise time measured
656	5	Injector 6 - Open circuit
656	3	Injector 6 - Short circuit to battery
656	4	Injector 6 - Short circuit to ground
657	0	Injector 7 - Current Rise time too long
657	8	Injector 7 - No current rise time measured
657	5	Injector 7 - Open circuit
657	3	Injector 7 - Short circuit to battery
657	4	Injector 7 - Short circuit to ground
658	0	Injector 8 - Current Rise time too long
658	8	Injector 8 - No current rise time measured

SPN	FMI	Designation
658	5	Injector 8 - Open circuit
658	3	Injector 8 - Short circuit to battery
658	4	Injector 8 - Short circuit to ground
659	0	Injector 9 - Current Rise time too long
659	8	Injector 9 - No current rise time measured
659	5	Injector 9 - Open cirscuit
659	3	Injector 9 - Short circuit to battery
659	4	Injector 9 - Short circuit to ground
516191	17	Injector supply boost converter - Undervoltage warning
105	5	Intake air temperature sensor - Open circuit
105	3	Intake air temperature sensor - Short circuit to battery
105	4	Intake air temperature sensor - Short circuit to ground
105	31	Intake air temperature sensor - Supply voltage out of range
102	0	Intake manifold - Critical overpressure
1636	0	Intake manifold - Critical overtemperature
102	1	Intake manifold - Critical underpressure
102	15	Intake manifold - Overpressure warning
1636	15	Intake manifold - Overtemperature warning
102	17	Intake manifold - Underpressure warning
102	3	Intake manifold pressure sensor - Short circuit to battery
102	4	Intake manifold pressure sensor - Short circuit to ground or open circuit
102	31	Intake manifold pressure sensor - Supply voltage out of range
1636	5	Intake manifold temperature sensor - Open circuit
1636	3	Intake manifold temperature sensor - Short circuit to battery
1636	4	Intake manifold temperature sensor - Short circuit to ground
1636	31	Intake manifold temperature sensor - Supply voltage out of range
6209	5	Intercooler coolant temperature sensor - Open circuit
6209	3	Intercooler coolant temperature sensor - Short circuit to battery
6209	4	Intercooler coolant temperature sensor - Short circuit to ground
6209	31	Intercooler coolant temperature sensor - Supply voltage out of range
516197	2	Master slave injection - Communication error
516223	11	Monitoring system - Engine control unit internal safety error
516226	11	Monitoring system - Injector safety error
100	3	Oil pressure sensor - Short circuit to battery

SPN	FMI	Designation
100	4	Oil pressure sensor - Short circuit to ground or open circuit
100	31	Oil pressure sensor - Supply voltage out of range
175	5	Oil temperature sensor - Open circuit
175	3	Oil temperature sensor - Short circuit to battery
175	4	Oil temperature sensor - Short circuit to ground
175	4	Oil temperature sensor - Short circuit to ground or open circuit
175	31	Oil temperature sensor - Supply voltage out of range
4811	0	Piston cooling pressure 1 - Critical overpressure
4811	1	Piston cooling pressure 1 - Critical underpressure
4811	15	Piston cooling pressure 1 - Overpressure warning
4811	17	Piston cooling pressure 1 - Underpressure warning
4811	3	Piston cooling pressure sensor 1 - Short circuit to battery
4811	4	Piston cooling pressure sensor 1 - Short circuit to ground or open circuit
4811	31	Piston cooling pressure sensor 1 - Supply voltage out of range
3597	1	Power supply - Critical undervoltage
3597	15	Power supply - Overvoltage warning
3597	17	Power supply - Undervoltage warning
5571	6	Pressure control valve - Critical high output current
5571	0	Pressure control valve - Critical overcurrent
5571	1	Pressure control valve - Critical undercurrent
516209	15	Pressure control valve - Current remains above the set point
516209	17	Pressure control valve - Current remains below the set point
5571	11	Pressure control valve - Electrical error
5571	5	Pressure control valve - Open circuit
516211	11	Pressure control valve - PWM signal - High limit reached
516212	11	Pressure control valve - PWM signal - Plausibility error
516422	11	Pressure control valve - Short circuit load
5571	3	Pressure control valve - Short circuit to battery high side
516331	3	Pressure control valve - Short circuit to battery low side
5571	4	Pressure control valve - Short circuit to ground high side
516331	4	Pressure control valve - Short circuit to ground low side
516215	6	Pressure control valve 2 - Critical high output current
516215	0	Pressure control valve 2 - Critical overcurrent
516215	1	Pressure control valve 2 - Critical undercurrent
516216	11	Pressure control valve 2 - Current remains above the set point
516217	11	Pressure control valve 2 - Current remains below the set point
516337	11	Pressure control valve 2 - Electrical error

SPN	FMI	Designation
516215	5	Pressure control valve 2 - Open circuit
516220	11	Pressure control valve 2 - PWM signal - High limit reached
516221	11	Pressure control valve 2 - PWM signal - Plausibility error
516215	11	Pressure control valve 2 - Short circuit load
516215	3	Pressure control valve 2 - Short circuit to battery high side
516337	3	Pressure control valve 2 - Short circuit to battery low side
516215	4	Pressure control valve 2 - Short circuit to ground high side
516337	4	Pressure control valve 2 - Short circuit to ground low side
516752	0	SCR system (filter) - Run time critical
516752	16	SCR system (filter) - Run time warning
516493	31	Slave injection control unit - Emission relevant error
3938	2	Speed adjustment - Plausibility error
3938	3	Speed adjustment (current) - Short circuit to battery
3938	4	Speed adjustment (current) - Short circuit to ground or open circuit
3938	31	Speed adjustment (current) - Supply voltage out of range
3938	3	Speed adjustment (voltage) - Short circuit to battery
3938	4	Speed adjustment (voltage) - Short circuit to ground or open circuit
3938	31	Speed adjustment (voltage) - Supply voltage out of range
677	6	Starter - Critical high output current
677	11	Starter - Electrical error
516342	31	Starter - Locked due to overtemperature
677	5	Starter - Open circuit
677	3	Starter - Short circuit to battery high side
516276	3	Starter - Short circuit to battery low side
677	4	Starter - Short circuit to ground high side
516277	4	Starter - Short circuit to ground low side
516369	6	Starter 2 - Critical high output current
516369	11	Starter 2 - Electrical error
516369	31	Starter 2 - Locked due to overtemperature
516369	5	Starter 2 - Open circuit
516369	3	Starter 2 - Short circuit to battery high side
516370	3	Starter 2 - Short circuit to battery low side
516369	4	Starter 2 - Short circuit to ground high side
516371	4	Starter 2 - Short circuit to ground low side
516424	11	Starter digital input - Starter inhibition due to short circuit
516247	31	Starter digital input - Supply voltage out of range

SPN	FMI	Designation
516425	11	Starter digital input 2 - Starter inhibition due to short circuit
516264	31	Starter digital input 2 - Supply voltage out of range
516511	31	Starters - Not connected in the output 1 to engine control unit
516512	31	Starters - Not connected in the output 2 to engine control unit
1076	6	Volume control valve - Critical high output current
1076	0	Volume control valve - Critical overcurrent
1076	1	Volume control valve - Critical undercurrent
516251	11	Volume control valve - Current remains above the set point
516252	11	Volume control valve - Current remains below the set point
516330	11	Volume control valve - Electrical error
1076	5	Volume control valve - Open circuit
516253	11	Volume control valve - PWM signal - High limit reached
516254	11	Volume control valve - PWM signal - Plausibility error
1076	11	Volume control valve - Short circuit load
1076	3	Volume control valve - Short circuit to battery high side
516328	3	Volume control valve - Short circuit to battery low side
1076	4	Volume control valve - Short circuit to ground high side
516329	4	Volume control valve - Short circuit to ground low side
516255	6	Volume control valve 2 - Critical high output current
516255	0	Volume control valve 2 - Critical overcurrent
516255	11	Volume control valve 2 - Critical undercurrent
516256	11	Volume control valve 2 - Current remains above the set point
516257	11	Volume control valve 2 - Current remains below the set point
516336	11	Volume control valve 2 - Electrical error
516255	5	Volume control valve 2 - Open circuit
516258	11	Volume control valve 2 - PWM signal - High limit reached
516259	11	Volume control valve 2 - PWM signal - Plausibility error
516255	11	Volume control valve 2 - Short circuit load
516255	3	Volume control valve 2 - Short circuit to battery high side
516336	3	Volume control valve 2 - Short circuit to battery low side
516255	4	Volume control valve 2 - Short circuit to ground high side
516336	4	Volume control valve 2 - Short circuit to ground low side
5386	6	Wastegate valve - Critical high output current
5386	11	Wastegate valve - Electrical error
5386	5	Wastegate valve - Open circuit
516318	31	Wastegate valve - Short circuit load
5386	3	Wastegate valve - Short circuit to battery high side
516266	3	Wastegate valve - Short circuit to battery low side

SPN	FMI	Designation
5386	4	Wastegate valve - Short circuit to ground high side
516266	4	Wastegate valve - Short circuit to ground low side
97	5	Water in fuel sensor - Open circuit
97	11	Water in fuel sensor - Out of range
97	3	Water in fuel sensor - Short circuit to battery
97	4	Water in fuel sensor - Short circuit to ground
97	31	Water in fuel sensor - Supply voltage out of range
97	0	Water in fuel sensor - Water in fuel detected
6301	5	Water in fuel sensor 2 - Open circuit
6301	11	Water in fuel sensor 2 - Out of range
6301	3	Water in fuel sensor 2 - Short circuit to battery
6301	4	Water in fuel sensor 2 - Short circuit to ground
6301	31	Water in fuel sensor 2 - Supply voltage out of range
6301	0	Water in fuel sensor 2 - Water in fuel detected

Tab. 56: Error code table

8.2 Former configuration

The following sections describe the maintenance of former configurations of assemblies that may be installed on engines.

8.2.1 Centrifugal oil filter with paper insert

8.2.1.1 Removing and installing centrifugal oil filter cover and cover clamp – SL1-2220, SL1-2221

Previous tasks

Make sure that the following preconditions are met:
- ❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

Specific safety instructions

DANGER
Fire - Ignition of flammable materials and operating fluids: fuel, engine oil, or coolant!
Risk of death or injury by burn, scald, or asphyxiation.

- ▶ Make sure that no operating fluid comes into contact with a hot surface or an ignition source.
- ▶ Before servicing the engine, let it cool down until surface temperature allows you to touch it with bare hand.
- ▶ Before servicing the engine, make sure that the operating fluid pressures are relieved.

WARNING
Contact with toxic operating fluids: fuel, engine oil, or coolant!
Risk of lung or skin disease, or injury by irritation.

- ▶ Observe local regulations, site rules, and safety notes.
- ▶ Refer to the safety datasheet of operating fluids.
- ▶ Avoid contact with operating fluids.
- ▶ Wear proper personal protective equipment.

NOTICE
Fire - Ignition of flammable materials and operating fluids: fuel, engine oil, or coolant!
Property damage - Risk of destruction of the machine or the engine.

- ▶ Make sure that no operating fluid comes into contact with a hot surface or an ignition source.

Consumables and equipment

Not applicable.

Removal

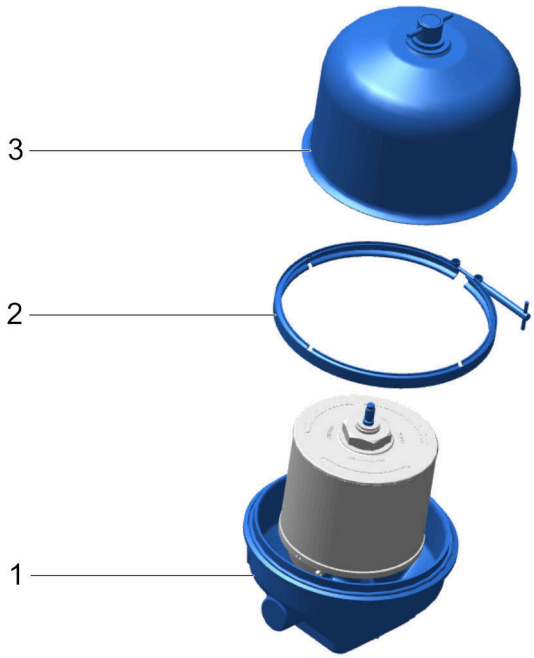


Fig. 164: Removing centrifugal oil filter cover

1 Rotor base
2 V-clamp
3 Cover

▶ Unclamp and remove V-clamp **2**.

▶ Open screw on top of cover **3**.

▶ Remove cover **3**.

Installation

▶ Install cover **3** and tighten nut to 13 Nm (10 ft-lb).

▶ Check seal of V-clamp **2**. Replace if necessary.

▶ Install and tighten V-clamp **2** to 15 $^{\pm 2}$ Nm (11 $^{\pm 1}$ ft-lb).

8.2.1.2 Inspecting and replacing centrifugal oil paper filter – SL1-2232

Previous tasks

Make sure that the following preconditions are met:

❑ Preparatory maintenance activities are fulfilled (→ 5.4 Preparatory maintenance activities, p. 105).

❑ Centrifugal oil filter cover and V-clamp are removed (→ 8.2.1.1 Removing and installing centrifugal oil filter cover and cover clamp – SL1-2220, SL1-2221, p. 242).

Specific safety instructions



DANGER
Fire - Ignition of flammable materials and operating fluids: fuel, engine oil, or coolant!
Risk of death or injury by burn, scald, or asphyxiation.

- ▶ Make sure that no operating fluid comes into contact with a hot surface or an ignition source.
- ▶ Before servicing the engine, let it cool down until surface temperature allows you to touch it with bare hand.
- ▶ Before servicing the engine, make sure that the operating fluid pressures are relieved.



WARNING
Contact with toxic operating fluids: fuel, engine oil, or coolant!
Risk of lung or skin disease, or injury by irritation.

- ▶ Observe local regulations, site rules, and safety notes.
- ▶ Refer to the safety datasheet of operating fluids.
- ▶ Avoid contact with operating fluids.
- ▶ Wear proper personal protective equipment.

NOTICE
Leaks by reuse of seals!
Property damage - Risk of critical engine failure.

- ▶ Use new seals after any dismantling.

Consumables and equipment

Make sure that the following consumables and equipment are available:
- Paper filter
- Seals

Inspection and replacement

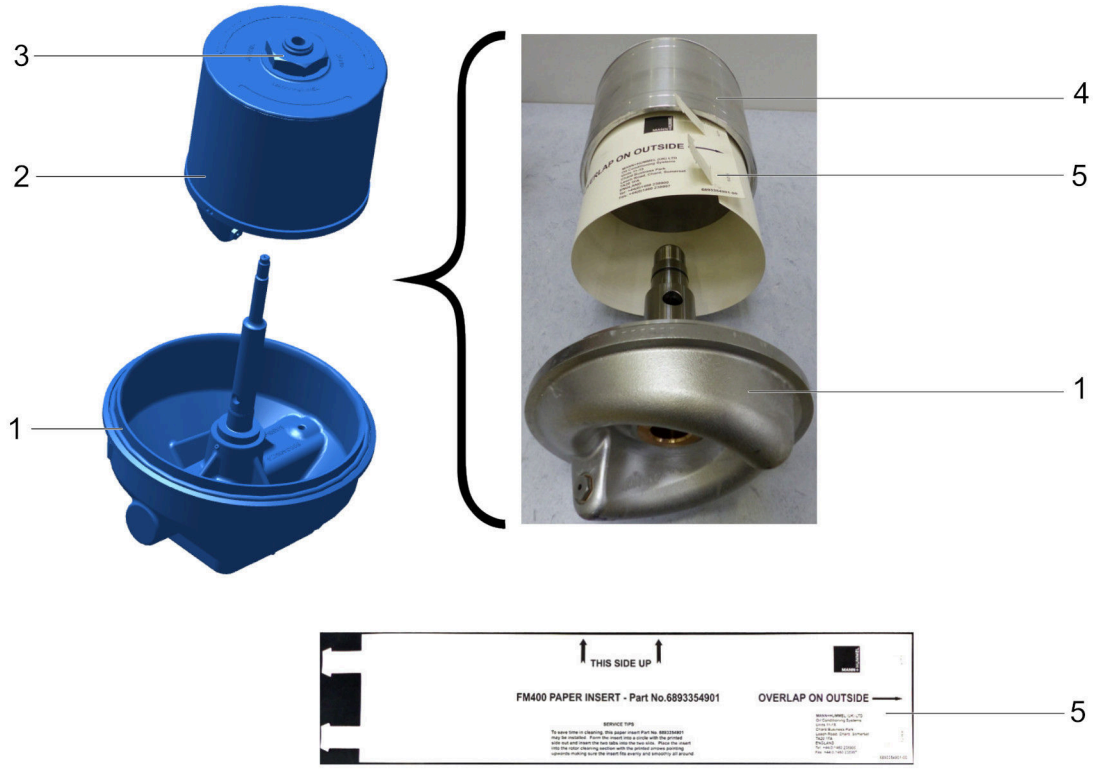


Fig. 165: Centrifugal oil paper filter

1 Rotor base
2 Rotor
3 Rotor cover
4 Rotor cylinder
5 Paper filter



Fig. 166: Opening rotor

- ▶ Unscrew and remove the nut of rotor cover **3**.
- ▶ Lift carefully the rotor cylinder **4** so that the mud remains in the cylinder.
- ▶ Recycle paper filter **5** and mud according to specific national regulations.

Note

The thickness of mud deposit inside the rotor should not be more than 45 mm (1.77 in). Otherwise:

▶ Reduce maintenance intervals and operate oil analysis.

▶ Clean all components of centrifugal oil filter.

▶ Replace rotor cover **3** seals.

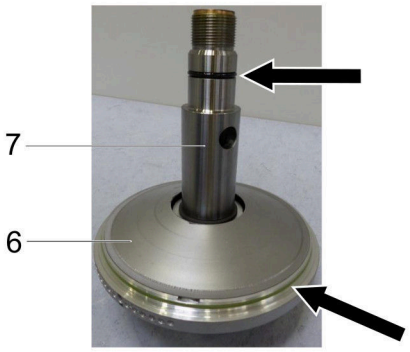


Fig. 167: Deflector disk and seals on rotor base and bearing tube

6 Deflector disk **7** Bearing tube

▶ Lift and clean the deflector disk **6**.

▶ Clean bearing tube **7** and rotor base **1**.

▶ Replace seals of rotor base **1** and bearing tube **7**.

▶ Insert deflector disk **6**.



Fig. 168: Paper filter preparation

▶ Insert paper filter **5** tabs in slot A and slot B.



Fig. 169: Inserting paper filter

▶ Insert paper filter **5** in rotor cylinder **4**.



Fig. 170: Assembling rotor

▶ Assemble rotor cylinder **4** on rotor base **1**.

▶ Mount rotor cover **3** and tighten nut to 40 Nm (30 ft-lb).

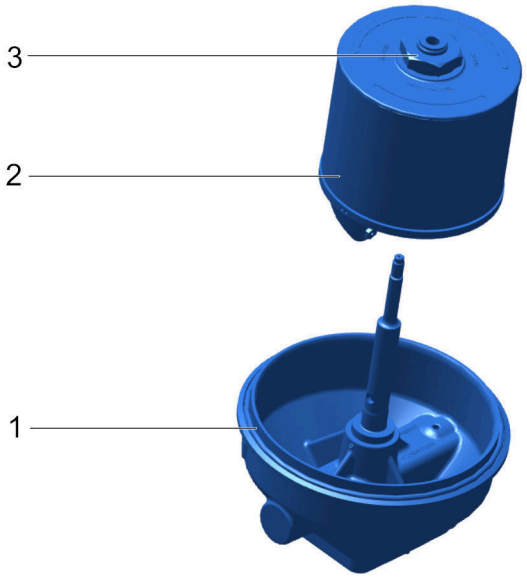


Fig. 171: Installing rotor

▶ Place rotor **2** in rotor base **1**.

8.3 Cleaning agents, thread-locking adhesives and greases

This list includes all thread-locking adhesives and greases required for repair and maintenance tasks on the engine.

The application is described in the respective job specifications.

Note

Should a thread-locking adhesive be required, first clean, degrease, and dry the respective screw thread and threaded bore.

8.3.1 Cleaning agents and thread-locking adhesives

Designation		Designation	Amount (g / fl-oz)	Supplier
Omniclean	or	Loctite 7063	500 / 16.9	Loctite
Loctite 243			250 / 8.4	Loctite
Loctite 270	or	Omnifit 200 M	250 / 8.4	Loctite
Loctite 577			250 / 8.4	Loctite
Loctite 648	or	Omnifit 230 M	250 / 8.4	Loctite

Tab. 57: Cleaning agents and thread-locking adhesives

Designation		Designation	Amount (g / fl-oz)	Supplier
Omnivisc 1050	or	Loctite 601, Reinzo-plast, Hylomar SQ32 / M	90 / 3.0	Loctite
Loctite 480			500 / 16.9	Loctite

Tab. 58: Cleaning agents and thread-locking adhesives

8.3.2 Greases

Designation	Amount (g / fl-oz)	Supplier
Molykote Longterm 2 Plus	1000 / 33.8	Molykote
Staburags NBU 30	1200 / 40.6	Klüber
Copper Paste; Motorex 14	850 / 28.7	Motorex
Optimol White T	100 / 3.4	Castrol

Tab. 59: Greases

8.4 Standard tightening torques

8.4.1 Lubricant and threadlocker application rules

	Application method		Product
Lubricant		Apply lubricant under the screw head and on the first third of the thread.	MG = Molykote G-n-plus MW = Castrol Optimol paste white T MH = Molykote HSC O = Engine oil
Threadlocker		Apply threadlocker on the first third of the thread.	XX = Loctite 243 YY = Loctite 577

Tab. 60: Lubricant and threadlocker application rules

8.4.2 Screws pretightening, reuse, and marking

NOTICE
Improper pretightening, turning angle, or reuse of screws or nuts!
Improper pretightening, turning angle, or reuse of screws or nuts could cause the screw or nut to break and lead to property damage by malfunction, ejection, fall, or tilting of components.

- ▶ Respect the following pretightening, turning angle, reuse, and marking specifications.
- ▶ In case of failure or damage, make sure that authorized service personnel replace the threaded fastener immediately.

Note

The values of the pretightening torque and the turning angle are specified in the maintenance tasks.

Unless otherwise noted, use the standard torque values under the column for screws quality class “8.8” to tighten screws and bolts.

The screws quality classes “10.9” and “12.9” are always indicated with the “Nm” symbol.

8.4.2.1 Pretightening torque and turning angle

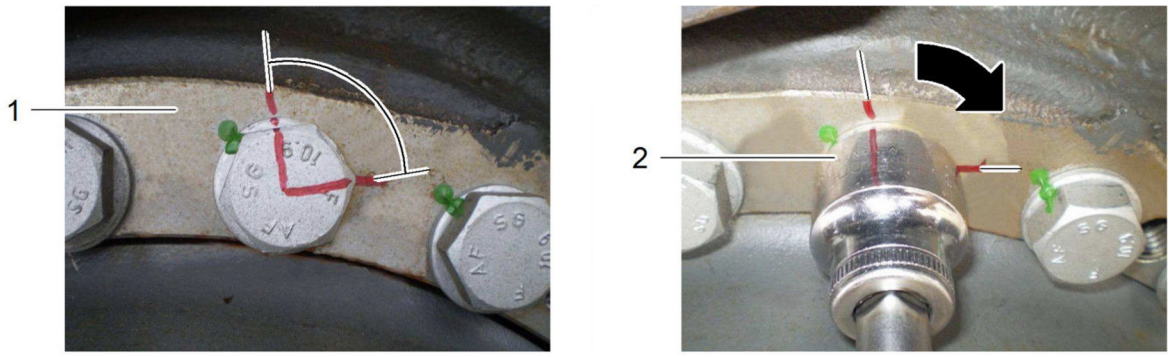


Fig. 174: Pretightening marking and angles

Note

For connections with several screws, place and seat all screws on the connection before proceeding with the tightening steps.

- ▶ Tighten mounting bolt with the specified pretightening torque.
- ▶ Mark the specified turning angle on the screw head and on the component 1.

Note

One edge of hexagonal screw corresponds to 60°.

- ▶ On the socket key of the torque wrench 2, mark the initial position, aligned with the marking on the component.
- ▶ Use the torque wrench to tighten until the marking of the initial position is aligned with the marking on the component.
- ▶ Repeat the procedure for the other screws, according to standard or described sequence.

Note

For every maintenance task, when a sequence is specified, achieve step 1 for all the sequence before starting step 2.

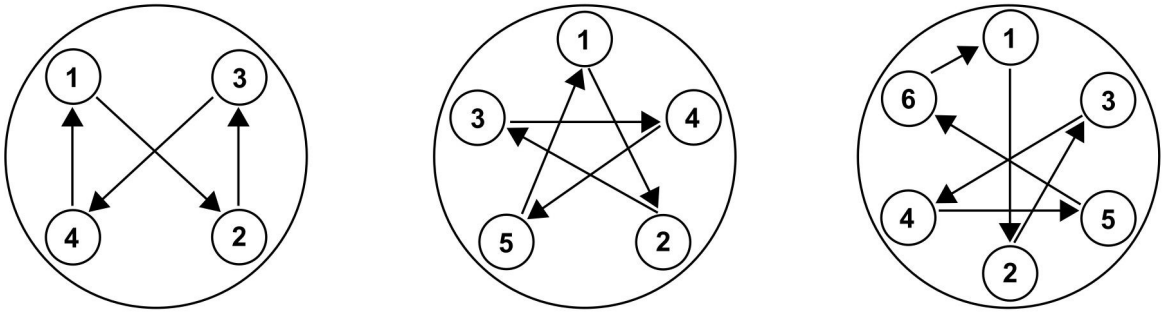


Fig. 175: Standard sequence for four, five, and six screws

8.4.2.2 Screws reuse

Note

Except components listed below, and otherwise noted,
- ▶ Reuse screws as many times as no visible damage appears (thread, coating).
- ▶ Replace screws with the same quality class as soon as damage appears (thread, coating).

For screws on:
- **Main bearing**
- **Connecting rod**
- **Cylinder head**
- **Torsional vibration damper**
- **Flywheel**
- **Camshaft**
- **Trunnion mount**
- **Engine feet DE and FE**
- **Exhaust screws with copper coating**

▶ Replace screws after each dismounting.

Counterweight:

▶ Untightening screws is forbidden.

Screw plugs:

▶ Replace screw plugs after each dismounting.

On fuel and HP injections pipes:

▶ Replace connections after first dismounting.

▶ Change connections after 3 tightenings.

For cutting rings:

▶ Replace connections after first dismounting.

▶ Change connections after 3 tightenings.

8.4.2.3 Screws marking

Note

Except components listed below, and otherwise noted,
- ▶ Marking on screws or nuts to track their reuse is not required.



Fig. 176: Examples of markings on screws and HP pipe nut

Some nuts and screws are marked to track their reuse:
- **Fuel and HP injection pipes**
- **Cutting rings**

If 2 punches appear:
▶ Replace pipe or system after each untightening.

If none or 1 punch appears:
▶ Add one punch after each untightening.

8.4.3 Standard torques for hexagonal / socket / flange screws and hexagonal / flange nuts

Note

Tolerances of the indicated tightening torques: 10%.

Values apply only to screws with coating and without lubricant.

For hexagonal screws in accordance with:

- ISO 4014
- ISO 4017

For socket screws in accordance with:

- ISO 4762

For flange screws in accordance with:

- EN 1665

For hexagonal nuts in accordance with:

- ISO 4032 / ISO 4034 / ISO 4035

For flange nuts in accordance with:

- EN 1664

Thread diameter	Quality class 8.8					Quality class 10.9				
	Hexagonal screw	Socket screw	Hexagonal nut	Flange screw	Flange nut	Hexagonal screw	Socket screw	Hexagonal nut	Flange screw	Flange nut
										
M6	9 Nm (7 ft-lb)					14 Nm (10 ft-lb)				
M8	22 Nm (16 ft-lb)					33 Nm (24 ft-lb)				
M10	43 Nm (32 ft-lb)					63 Nm (46 ft-lb)				
M12	70 Nm (52 ft-lb)			75 Nm (55 ft-lb)		100 Nm (74 ft-lb)			110 Nm (81 ft-lb)	
M16	165 Nm (122 ft-lb)			183 Nm (135 ft-lb)		240 Nm (177 ft-lb)			270 Nm (199 ft-lb)	
M20	320 Nm (236 ft-lb)			358 Nm (264 ft-lb)		470 Nm (347 ft-lb)			525 Nm (387 ft-lb)	

Thread diam-eter	Quality class 8.8		Quality class 10.9	
M24	550 Nm (406 ft-lb)	-	800 Nm (590 ft-lb)	-
M30	1100 Nm (811 ft-lb)	-	1600 Nm (1,180 ft-lb)	-

Tab. 61: Standard torques for hexagonal / socket / flange screws and hexagonal / flange nuts, with coating without lubricant

8.4.4 Standard torques for internal drive pipe plug with conical thread

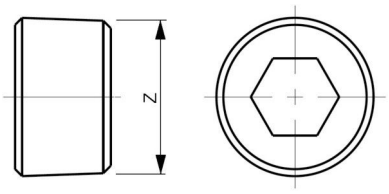


Fig. 187: Internal drive pipe plug with conical thread DIN 906

Note

Tolerances of the indicated tightening torques: 10%.

Always lubricate the thread before tightening these parts (engine oil).

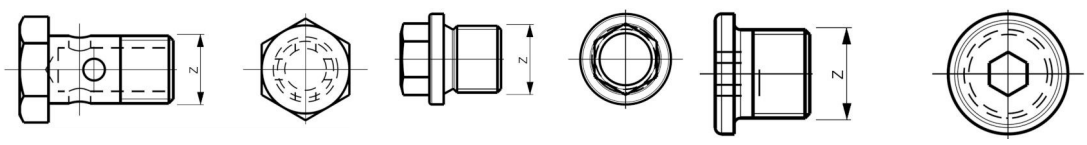
Thread	Tightening torque	Thread	Tightening torque	Thread	Tightening torque
M 6 x 1	5 Nm (4 ft-lb)[1)]	**M 14 x 1.5**	57 Nm (42 ft-lb)	**M 20 x 1.5**	98 Nm (72 ft-lb)
M 8 x 1	12 Nm (9 ft-lb)	**M 16 x 1.5**	68 Nm (50 ft-lb)	**M 36 x 1.5**	280 Nm (207 ft-lb)
M 10 x 1	18 Nm (13 ft-lb)	**M 18 x 1.5**	87 Nm (64 ft-lb)	**M 48 x 1.5**	280 Nm (207 ft-lb)
M 12 x 1.5	30 Nm (22 ft-lb)	-	-	-	-

Tab. 62: Standard torques for internal drive pipe plug with conical thread

[1)] Special tolerance: +0.5 mm (0.02 in)

8.4.5 Standard torques for screws according to DIN 7643, DIN 910, DIN 908

With copper sealing ring according to DIN 7603, for:
- Hollow screw for ring-type banjos according to DIN 7643
- Hexagon head screw plugs with collar - Cylindrical thread according to DIN 910
- Internal drive screw plugs with collar - Cylindrical thread according to DIN 908



Tab. 63: Hollow screw DIN 7643, Hexagon head screw DIN 910, Internal drive screw DIN 908

Note

Tolerances of the indicated tightening torques: 10%.

Always lubricate the thread before tightening these parts (engine oil).

Thread	Tightening torque	Thread	Tightening torque	Thread	Tightening torque
M 6 x 1	7 Nm (5 ft-lb)	**M 24 x 1.5**	68 Nm (50 ft-lb)	**M 42 x 2**	240 Nm (177 ft-lb)
M 8 x 1	7.5 Nm (6 ft-lb)	**M 26 x 1.5**	75 Nm (55 ft-lb)	**M 45 x 1.5**	270 Nm (199 ft-lb)
M 8 x 1.5	7.5 Nm (6 ft-lb)	**M 27 x 2**	87 Nm (64 ft-lb)	**M 45 x 2**	270 Nm (199 ft-lb)
M 10 x 1	15 Nm (11 ft-lb)	**M 30 x 1.5**	115 Nm (85 ft-lb)	**M 48 x 1.5**	300 Nm (221 ft-lb)
M 10 x 1.25	15 Nm (11 ft-lb)	**M 30 x 2**	115 Nm (85 ft-lb)	**M 48 x 2**	300 Nm (221 ft-lb)
M 12 x 1.5	20 Nm (15 ft-lb)	**M 33 x 2**	120 Nm (89 ft-lb)	**M 52 x 1.5**	380 Nm (280 ft-lb)
M 14 x 1.5	30 Nm (22 ft-lb)	**M 36 x 1.5**	155 Nm (114 ft-lb)	**M 52 x 2**	380 Nm (280 ft-lb)
M 16 x 1.5	40 Nm (30 ft-lb)	**M 36 x 2**	155 Nm (114 ft-lb)	**M 56 x 2**	430 Nm (317 ft-lb)
M 18 x 1.5	40 Nm (30 ft-lb)	**M 38 x 1.5**	171 Nm (126 ft-lb)	**M 60 x 2**	510 Nm (376 ft-lb)
M 20 x 1.5	47 Nm (35 ft-lb)	**M 39 x 2**	215 Nm (159 ft-lb)	**M 64 x 2**	570 Nm (420 ft-lb)
M 22 x 1.5	70 Nm (52 ft-lb)	**M 42 x 1.5**	240 Nm (177 ft-lb)	**M 65 x 2**	620 Nm (457 ft-lb)

Tab. 64: Tightening torques for screws according to DIN 7643, DIN 910, DIN 908

8.4.6 Standard torques for metric fittings

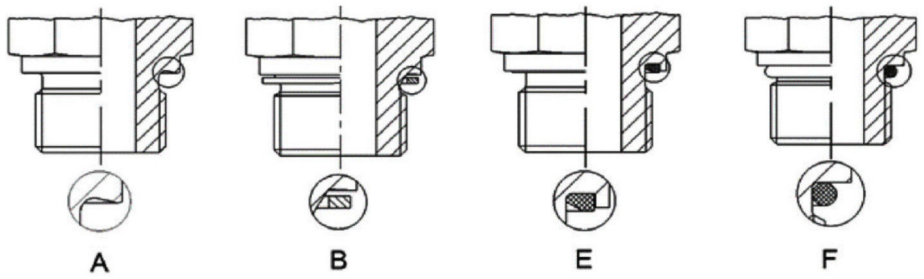


Fig. 191: Fittings overview

8.4.6.1 Standard torques for metric thread unions L series (up to 500 bar/7252 Psi) for steel and iron cast part

According to ISO 9974-2/3 / ISO 6149-2/3 / DIN 3852-1/2, metric threading.

Note

Tolerances of the indicated tightening torques: 10%.

Always lubricate the thread before tightening these parts (engine oil).

Thread Y	Form A with sealing edge	Form B with sealing ring	Form E with flat sealing	Form F with O-ring
M 10 x 1.0	9 Nm (7 ft-lb)	18 Nm (13 ft-lb)	18 Nm (13 ft-lb)	15 Nm (11 ft-lb)
M 12 x 1.5	20 Nm (15 ft-lb)	30 Nm (22 ft-lb)	25 Nm (18 ft-lb)	25 Nm (18 ft-lb)
M 14 x 1.5	35 Nm (26 ft-lb)	45 Nm (33 ft-lb)	45 Nm (33 ft-lb)	35 Nm (26 ft-lb)
M 16 x 1.5	45 Nm (33 ft-lb)	65 Nm (48 ft-lb)	55 Nm (41 ft-lb)	40 Nm (30 ft-lb)
M 18 x 1.5	55 Nm (41 ft-lb)	80 Nm (59 ft-lb)	70 Nm (52 ft-lb)	45 Nm (33 ft-lb)
M 22 x 1.5	65 Nm (48 ft-lb)	140 Nm (103 ft-lb)	125 Nm (92 ft-lb)	60 Nm (44 ft-lb)
M 26 x 1.5	90 Nm (66 ft-lb)	190 Nm (140 ft-lb)	180 Nm (133 ft-lb)	100 Nm (74 ft-lb)
M 33 x 2.0	150 Nm (111 ft-lb)	340 Nm (251 ft-lb)	310 Nm (229 ft-lb)	160 Nm (118 ft-lb)
M 42 x 2.0	240 Nm (177 ft-lb)	500 Nm (369 ft-lb)	450 Nm (332 ft-lb)	210 Nm (155 ft-lb)
M 48 x 2.0	290 Nm (214 ft-lb)	630 Nm (465 ft-lb)	540 Nm (398 ft-lb)	260 Nm (192 ft-lb)

Tab. 65: Standard torques for metric thread unions L series, for steel and iron cast part

8.4.6.2 Standard torques for metric thread unions S series (up to 800 bar/11603 Psi) for steel and iron cast part

According to ISO 9974-2/3 / ISO 6149-2/3 / DIN 3852-1/2, metric threading.

Note

Tolerances of the indicated tightening torques: 10%.

Always lubricate the thread before tightening these parts (engine oil).

Thread Y	Form A with sealing edge	Form B with sealing ring	Form E with flat sealing	Form F with O-ring
M 10 x 1.0	-	-	23 Nm (17 ft-lb)	-
M 12 x 1.5	20 Nm (15 ft-lb)	35 Nm (26 ft-lb)	35 Nm (26 ft-lb)	35 Nm (26 ft-lb)
M 14 x 1.5	35 Nm (26 ft-lb)	55 Nm (41 ft-lb)	55 Nm (41 ft-lb)	45 Nm (33 ft-lb)
M 16 x 1.5	45 Nm (33 ft-lb)	70 Nm (52 ft-lb)	70 Nm (52 ft-lb)	55 Nm (41 ft-lb)
M 18 x 1.5	55 Nm (41 ft-lb)	110 Nm (81 ft-lb)	90 Nm (66 ft-lb)	70 Nm (52 ft-lb)
M 20 x 1.5	55 Nm (41 ft-lb)	150 Nm (111 ft-lb)	125 Nm (92 ft-lb)	80 Nm (59 ft-lb)
M 22 x 1.5	65 Nm (48 ft-lb)	170 Nm (125 ft-lb)	135 Nm (100 ft-lb)	100 Nm (74 ft-lb)
M 27 x 2.0	90 Nm (66 ft-lb)	270 Nm (199 ft-lb)	180 Nm (133 ft-lb)	170 Nm (125 ft-lb)
M 33 x 2.0	150 Nm (111 ft-lb)	410 Nm (302 ft-lb)	310 Nm (229 ft-lb)	310 Nm (229 ft-lb)
M 42 x 2.0	240 Nm (177 ft-lb)	540 Nm (398 ft-lb)	450 Nm (332 ft-lb)	330 Nm (243 ft-lb)
M 48 x 2.0	290 Nm (214 ft-lb)	700 Nm (516 ft-lb)	540 Nm (398 ft-lb)	420 Nm (310 ft-lb)

Tab. 66: Standard torques for metric thread union S series, for steel and iron cast part

8.4.6.3 Standard torques for imperial thread unions L series (up to 500 bar/7252 Psi) for steel and iron cast part

According to ISO 1179-1 / DIN 3852-T2-Form X / DIN 3852-T3-Form X BSP threading.

Note

Tolerances of the indicated tightening torques: 10%.

Always lubricate the thread before tightening these parts (engine oil).

Thread Y	Form A with sealing edge	Form B with sealing ring	Form E with flat sealing
G 1/8A	9 Nm (7 ft-lb)	18 Nm (13 ft-lb)	18 Nm (13 ft-lb)
G 1/4A	35 Nm (26 ft-lb)	35 Nm (26 ft-lb)	35 Nm (26 ft-lb)
G 1/4A	35 Nm (26 ft-lb)	35 Nm (26 ft-lb)	35 Nm (26 ft-lb)
G 3/8A	45 Nm (33 ft-lb)	70 Nm (52 ft-lb)	70 Nm (52 ft-lb)
G 1/2A	65 Nm (48 ft-lb)	140 Nm (103 ft-lb)	90 Nm (66 ft-lb)
G 1/2A	65 Nm (48 ft-lb)	100 Nm (74 ft-lb)	90 Nm (66 ft-lb)
G 3/4A	90 Nm (66 ft-lb)	180 Nm (133 ft-lb)	180 Nm (133 ft-lb)
G 1A	150 Nm (111 ft-lb)	330 Nm (243 ft-lb)	310 Nm (229 ft-lb)
G 1 1/4A	240 Nm (177 ft-lb)	540 Nm (398 ft-lb)	450 Nm (332 ft-lb)
G 1 1/2A	290 Nm (214 ft-lb)	630 Nm (465 ft-lb)	540 Nm (398 ft-lb)

Tab. 67: Standard torques for imperial thread unions L series, for steel and iron cast part

8.4.6.4 Standard torques for imperial thread unions S series (up to 800 bar/11603 Psi) for steel and iron cast part

According to ISO 1179-1 / DIN 3852-T2-Form X / DIN 3852-T3-Form X BSP threading.

Note

Tolerances of the indicated tightening torques: 10%.

Always lubricate the thread before tightening these parts (engine oil).

Thread Y	Form A with sealing edge	Form B with sealing ring	Form E with flat sealing
G 1/4A	35 Nm (26 ft-lb)	55 Nm (41 ft-lb)	40 Nm (30 ft-lb)
G 1/4A	35 Nm (26 ft-lb)	55 Nm (41 ft-lb)	40 Nm (30 ft-lb)
G 3/8A	45 Nm (33 ft-lb)	90 Nm (66 ft-lb)	80 Nm (59 ft-lb)
G 3/8A	45 Nm (33 ft-lb)	90 Nm (66 ft-lb)	80 Nm (59 ft-lb)
G 1/2A	65 Nm (48 ft-lb)	150 Nm (111 ft-lb)	115 Nm (85 ft-lb)
G 1/2A	65 Nm (48 ft-lb)	130 Nm (96 ft-lb)	115 Nm (85 ft-lb)
G 3/4A	90 Nm (66 ft-lb)	270 Nm (199 ft-lb)	180 Nm (133 ft-lb)
G 1A	150 Nm (111 ft-lb)	340 Nm (251 ft-lb)	310 Nm (229 ft-lb)
G 1 1/4A	240 Nm (177 ft-lb)	540 Nm (398 ft-lb)	450 Nm (332 ft-lb)

Thread Y	Form A with sealing edge	Form B with sealing ring	Form E with flat sealing
G 1 1/2A	290 Nm (214 ft-lb)	700 Nm (516 ft-lb)	540 Nm (398 ft-lb)

Tab. 68: Standard torques for imperial thread union S series, for steel and iron cast part

8.4.6.5 Standard torques for metric thread unions L series (up to 500 bar/7252 Psi) for aluminum

According to ISO 9974-2/3 / ISO 6149-2/3 / DIN 3852-1/2, metric threading.

Note

Tolerances of the indicated tightening torques: 10%.

Always lubricate the thread before tightening these parts (engine oil).

Thread Y	Form A with sealing edge	Form B with sealing ring	Form E with flat sealing	Form F with O-ring
M 10 x 1.0	7 Nm (5 ft-lb)	14 Nm (10 ft-lb)	14 Nm (10 ft-lb)	12 Nm (9 ft-lb)
M 12 x 1.5	16 Nm (12 ft-lb)	24 Nm (18 ft-lb)	20 Nm (15 ft-lb)	20 Nm (15 ft-lb)
M 14 x 1.5	28 Nm (21 ft-lb)	36 Nm (27 ft-lb)	36 Nm (27 ft-lb)	28 Nm (21 ft-lb)
M 16 x 1.5	36 Nm (27 ft-lb)	52 Nm (38 ft-lb)	44 Nm (32 ft-lb)	32 Nm (24 ft-lb)
M 18 x 1.5	44 Nm (32 ft-lb)	64 Nm (47 ft-lb)	56 Nm (41 ft-lb)	36 Nm (27 ft-lb)
M 22 x 1.5	52 Nm (38 ft-lb)	112 Nm (83 ft-lb)	100 Nm (74 ft-lb)	48 Nm (35 ft-lb)
M 26 x 1.5	72 Nm (53 ft-lb)	152 Nm (112 ft-lb)	144 Nm (106 ft-lb)	80 Nm (59 ft-lb)
M 33 x 2.0	120 Nm (89 ft-lb)	272 Nm (201 ft-lb)	248 Nm (183 ft-lb)	128 Nm (94 ft-lb)
M 42 x 2.0	192 Nm (142 ft-lb)	400 Nm (295 ft-lb)	360 Nm (266 ft-lb)	168 Nm (124 ft-lb)
M 48 x 2.0	232 Nm (171 ft-lb)	504 Nm (372 ft-lb)	432 Nm (319 ft-lb)	208 Nm (153 ft-lb)

Tab. 69: Standard torques for metric thread unions L series, for aluminum

8.4.6.6 Standard torques for metric thread unions S series (up to 800 bar/11603 Psi) for aluminum

According to ISO 9974-2/3 / ISO 6149-2/3 / DIN 3852-1/2, metric threading.

Note

Tolerances of the indicated tightening torques: 10%.

Always lubricate the thread before tightening these parts (engine oil).

Thread Y	Form A with sealing edge	Form B with sealing ring	Form E with flat sealing	Form F with O-ring
M 10 x 1.0	-	-	19 Nm (14 ft-lb)	-
M 12 x 1.5	16 Nm (12 ft-lb)	28 Nm (21 ft-lb)	32 Nm (24 ft-lb)	28 Nm (21 ft-lb)
M 14 x 1.5	28 Nm (21 ft-lb)	44 Nm (32 ft-lb)	32 Nm (24 ft-lb)	36 Nm (27 ft-lb)
M 16 x 1.5	36 Nm (27 ft-lb)	56 Nm (41 ft-lb)	56 Nm (41 ft-lb)	44 Nm (32 ft-lb)
M 18 x 1.5	44 Nm (32 ft-lb)	88 Nm (65 ft-lb)	72 Nm (53 ft-lb)	56 Nm (41 ft-lb)

Thread Y	Form A with sealing edge	Form B with sealing ring	Form E with flat sealing	Form F with O-ring
M 20 x 1.5	44 Nm (32 ft-lb)	120 Nm (89 ft-lb)	100 Nm (74 ft-lb)	64 Nm (47 ft-lb)
M 22 x 1.5	52 Nm (38 ft-lb)	136 Nm (100 ft-lb)	108 Nm (80 ft-lb)	100 Nm (74 ft-lb)
M 27 x 2.0	72 Nm (53 ft-lb)	216 Nm (159 ft-lb)	144 Nm (106 ft-lb)	136 Nm (100 ft-lb)
M 33 x 2.0	120 Nm (89 ft-lb)	328 Nm (242 ft-lb)	248 Nm (183 ft-lb)	248 Nm (183 ft-lb)
M 42 x 2.0	192 Nm (142 ft-lb)	432 Nm (319 ft-lb)	360 Nm (266 ft-lb)	264 Nm (195 ft-lb)
M 48 x 2.0	232 Nm (171 ft-lb)	560 Nm (413 ft-lb)	432 Nm (319 ft-lb)	336 Nm (248 ft-lb)

Tab. 70: Standard torques for metric thread unions S series, for aluminum

8.4.6.7 Standard torques for imperial thread unions L series (up to 500 bar/7252 Psi) for aluminum

According to ISO 1179-1 / DIN 3852-T2-Form X / DIN 3852-T3-Form X BSP threading.

Note

Tolerances of the indicated tightening torques: 10%.

Always lubricate the thread before tightening these parts (engine oil).

Thread Y	Form A with sealing edge	Form B with sealing ring	Form E with flat sealing
G 1/8A	7 Nm (5 ft-lb)	14 Nm (10 ft-lb)	14 Nm (10 ft-lb)
G 1/4A	28 Nm (21 ft-lb)	28 Nm (21 ft-lb)	28 Nm (21 ft-lb)
G 1/4A	28 Nm (21 ft-lb)	28 Nm (21 ft-lb)	28 Nm (21 ft-lb)
G 3/8A	36 Nm (27 ft-lb)	56 Nm (41 ft-lb)	56 Nm (41 ft-lb)
G 1/2A	52 Nm (38 ft-lb)	112 Nm (83 ft-lb)	72 Nm (53 ft-lb)
G 1/2A	52 Nm (38 ft-lb)	80 Nm (59 ft-lb)	72 Nm (53 ft-lb)
G 3/4A	72 Nm (53 ft-lb)	144 Nm (106 ft-lb)	144 Nm (106 ft-lb)
G 1A	120 Nm (89 ft-lb)	264 Nm (195 ft-lb)	248 Nm (183 ft-lb)
G 1 1/4A	192 Nm (142 ft-lb)	432 Nm (319 ft-lb)	360 Nm (266 ft-lb)
G 1 1/2A	232 Nm (171 ft-lb)	504 Nm (372 ft-lb)	432 Nm (319 ft-lb)

Tab. 71: Standard torques for imperial thread unions L series, for aluminum

8.4.6.8 Standard torques for imperial thread unions S series (up to 800 bar/11603 Psi) for aluminum

According to ISO 1179-1 / DIN 3852-T2-Form X / DIN 3852-T3-Form X BSP threading.

Note

Tolerances of the indicated tightening torques: 10%.

Always lubricate the thread before tightening these parts (engine oil).

Thread Y	Form A with sealing edge	Form B with sealing ring	Form E with flat sealing
G 1/8A	29 Nm (21 ft-lb)	45 Nm (33 ft-lb)	45 Nm (33 ft-lb)

Thread Y	Form A with sealing edge	Form B with sealing ring	Form E with flat sealing
G 1/4A	28 Nm (21 ft-lb)	44 Nm (32 ft-lb)	32 Nm (24 ft-lb)
G 1/4A	28 Nm (21 ft-lb)	44 Nm (32 ft-lb)	32 Nm (24 ft-lb)
G 3/8A	36 Nm (27 ft-lb)	72 Nm (53 ft-lb)	64 Nm (47 ft-lb)
G 1/2A	52 Nm (38 ft-lb)	120 Nm (89 ft-lb)	92 Nm (68 ft-lb)
G 1/2A	52 Nm (38 ft-lb)	104 Nm (77 ft-lb)	92 Nm (68 ft-lb)
G 3/4A	72 Nm (53 ft-lb)	216 Nm (159 ft-lb)	144 Nm (106 ft-lb)
G 1A	120 Nm (89 ft-lb)	272 Nm (201 ft-lb)	248 Nm (183 ft-lb)
G 1 1/4A	192 Nm (142 ft-lb)	432 Nm (319 ft-lb)	360 Nm (266 ft-lb)
G 1 1/2A	232 Nm (171 ft-lb)	560 Nm (413 ft-lb)	432 Nm (319 ft-lb)

Tab. 72: Standard torques for imperial thread union S series, for aluminum

8.4.7 Assembling pipes with cutting rings

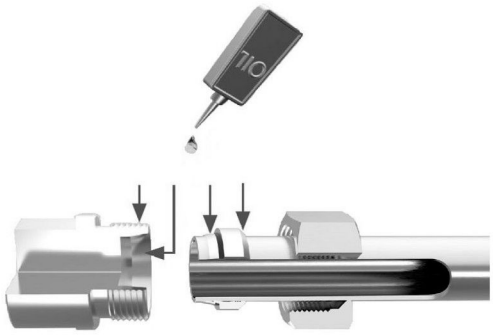


Fig. 192: Cutting ring lubrication

Note

Tolerances of the indicated tightening torques: 10%.

Always lubricate the thread before tightening these parts (engine oil).

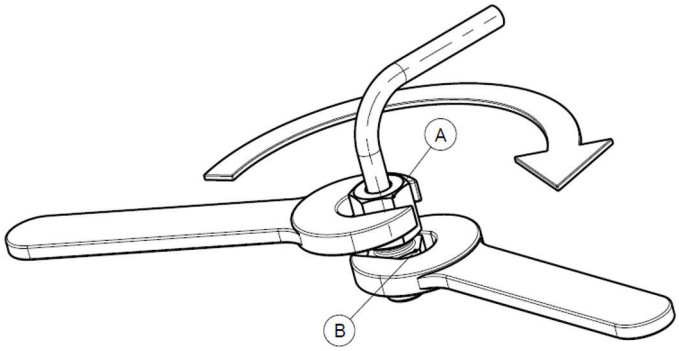


Fig. 193: Cutting ring tightening

Note

To assemble pipes with cutting rings, observe the following steps:

- ▶ Assemble pipe tension free. Mount support clamp after pipe assembling.
- ▶ When tightening nut **A**, make sure that connector **B** does not rotate.
- ▶ Tighten nut **A** by hand until the resisting point.
- ▶ Tighten nut **A** a further 90°.
- ▶ Tighten all pipe support clamps if necessary.

Alternatively, refer to the following table for tightening sequence of nut **A**:

Size	Equivalent specification	Size	Equivalent specification
06L	6 Nm (4 ft-lb) + 90°	06S	20 Nm (15 ft-lb) + 90°
08L	8 Nm (6 ft-lb) + 90°	08S	24 Nm (18 ft-lb) + 90°
10L	12 Nm (9 ft-lb) + 90°	10S	34 Nm (25 ft-lb) + 90°
12L	25 Nm (18 ft-lb) + 90°	12S	36 Nm (27 ft-lb) + 90°
15L	40 Nm (30 ft-lb) + 90°	14S	58 Nm (43 ft-lb) + 90°
18L	50 Nm (37 ft-lb) + 90°	16S	70 Nm (52 ft-lb) + 90°
22L	80 Nm (59 ft-lb) + 90°	20S	130 Nm (96 ft-lb) + 90°
28L	100 Nm (74 ft-lb) + 90°	25S	120 Nm (89 ft-lb) + 90°
32L	120 Nm (89 ft-lb) + 90°	30S	165 Nm (122 ft-lb) + 90°
35L	130 Nm (96 ft-lb) + 90°	38S	325 Nm (240 ft-lb) + 90°
42L	156 Nm (115 ft-lb) + 90°	-	-

Tab. 73: Alternative tightening torques for cutting ring fittings

8.4.8 Standard torques for flare fittings

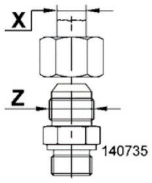


Fig. 194: Flare fittings

Serie	Pipe Ø X		Thread Z	Tightening torque	
	mm	inch	UN/UNF	Steel	Stainless steel
4	**6**	**1/4**	**7/17-20**	15 Nm (11 ft-lb)	30 Nm (22 ft-lb)
5	**8**	**5/16**	**1/2-20**	20 Nm (15 ft-lb)	40 Nm (30 ft-lb)
6	**10**	**3/8**	**9/16-18**	30 Nm (22 ft-lb)	60 Nm (44 ft-lb)

Serie	Pipe Ø X		Thread Z	Tightening torque	
	mm	inch	UN/UNF	Steel	Stainless steel
8	**12**	**1/2**	**3/4-16**	60 Nm (44 ft-lb)	115 Nm (85 ft-lb)
10	**14, 15, 16**	**5/8**	**7/8-14**	75 Nm (55 ft-lb)	145 Nm (107 ft-lb)
12	**18, 20**	**3/4**	**1 1/16-12**	110 Nm (81 ft-lb)	180 Nm (133 ft-lb)
16	**22**	**7/8**	**1 5/16-12**	135 Nm (100 ft-lb)	225 Nm (166 ft-lb)
16	**25**	**1**	**1 5/16-12**	175 Nm (129 ft-lb)	255 Nm (188 ft-lb)
-	**28**	-	**1 5/8-12**	260 Nm (192 ft-lb)	295 Nm (218 ft-lb)
20	**30, 32**	**1 1/4**	**1 5/8-12**	260 Nm (192 ft-lb)	295 Nm (218 ft-lb)
-	**35**	-	**1 7/8-12**	340 Nm (251 ft-lb)	345 Nm (254 ft-lb)
24	**38**	**1 1/2**	**1 7/8-12**	340 Nm (251 ft-lb)	345 Nm (254 ft-lb)
28	**42**	-	**2 1/4-12**	380 Nm (280 ft-lb)	400 Nm (295 ft-lb)
32	-	**2**	**2 1/2-12**	450 Nm (332 ft-lb)	470 Nm (347 ft-lb)

Tab. 74: Standard torques for flare fittings

Note

To tighten the screwed socket:

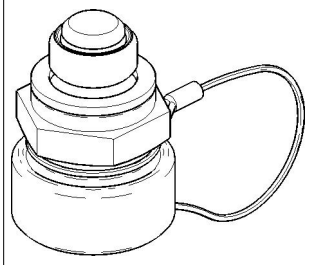
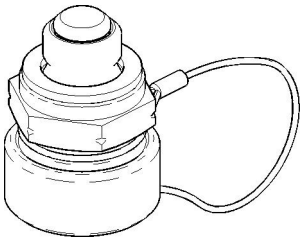
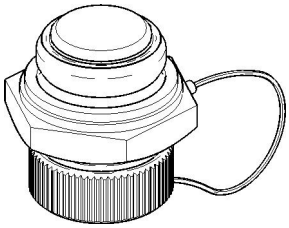
- ▶ Hold screwed socket instead.
- ▶ Unscrew union nut until noticeable resistance (without wrench extension).
- ▶ Tighten union nut according to torque above.

8.4.9 Standard torques for drain valves

Note

Tolerances of the indicated tightening torques: 10%.

Always lubricate the thread before tightening these parts (engine oil).

Drain valve	Size	Tightening torque
	M14x1.5	30 Nm (22 ft-lb)
	G 1/4	30 Nm (22 ft-lb)
	M27x2	150 Nm (111 ft-lb)

Tab. 75: Tightening torques for drain valves

8.4.10 Standard torques for VSTI screw plugs for steel and iron cast part

According to DIN EN ISO 6149-2 / ISO 11926-2, metric threading.

Note

Tolerances of the indicated tightening torques: 10%.

Always lubricate the thread before tightening these parts (engine oil).

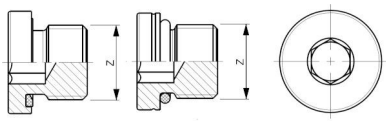


Fig. 198: VSTI screw plugs with ED seal (left), with o-ring (right)

Size	Tightening torque		Size	Tightening torque	
	[1] VSTI ED	VSTI O-ring		[1] VSTI ED	VSTI O-ring
M8x1	10 Nm (7 ft-lb)	10 Nm (7 ft-lb)	G 1/8	13 Nm (10 ft-lb)	-
M10x1	12 Nm (9 ft-lb)	20 Nm (15 ft-lb)	G 1/4	30 Nm (22 ft-lb)	-
M12x1.5	25 Nm (18 ft-lb)	35 Nm (26 ft-lb)	G 3/8	60 Nm (44 ft-lb)	-

Size	Tightening torque		Size	Tightening torque	
	[1] VSTI ED	VSTI O-ring		[1] VSTI ED	VSTI O-ring
M14x1.5	35 Nm (26 ft-lb)	45 Nm (33 ft-lb)	G 1/2	80 Nm (59 ft-lb)	-
M16x1.5	50 Nm (37 ft-lb)	55 Nm (41 ft-lb)	G 3/4	140 Nm (103 ft-lb)	-
M18x1.5	65 Nm (48 ft-lb)	70 Nm (52 ft-lb)	G 1	200 Nm (148 ft-lb)	-
M20x1.5	75 Nm (55 ft-lb)	80 Nm (59 ft-lb)	G 1 1/4	400 Nm (295 ft-lb)	-
M22x1.5	90 Nm (66 ft-lb)	100 Nm (74 ft-lb)	G 1 1/2	450 Nm (332 ft-lb)	-
M24x1.5	90 Nm (66 ft-lb)	-	-	-	-
M26x1.5	125 Nm (92 ft-lb)	-	3/4-16 UNF	70 Nm (52 ft-lb)	-
M30x1.5	240 Nm (177 ft-lb)	-	7/8-1/4 UNF	100 Nm (74 ft-lb)	-
M33x1.5	220 Nm (162 ft-lb)	-	R 3/4"	140 Nm (103 ft-lb)	120 Nm (89 ft-lb)
M27x2	130 Nm (96 ft-lb)	170 Nm (125 ft-lb)	-	-	-
M30x2	-	215 Nm (159 ft-lb)	-	-	-
M33x2	225 Nm (166 ft-lb)	310 Nm (229 ft-lb)	-	-	-
M42x2	360 Nm (266 ft-lb)	330 Nm (243 ft-lb)	-	-	-
M48x2	360 Nm (266 ft-lb)	420 Nm (310 ft-lb)	-	-	-
M60x2	-	500 Nm (369 ft-lb)	-	-	-

Tab. 76: VSTI screw plug tightening torques for steel and iron cast parts

[1] Do not use hydropneumatic screwdriver.

8.4.11 Standard torques for VSTI screw plugs for aluminum

According to DIN EN ISO 6149-2 / ISO 11926-2, metric threading.

Note

Tolerances of the indicated tightening torques: 10%.

Always lubricate the thread before tightening these parts (engine oil).

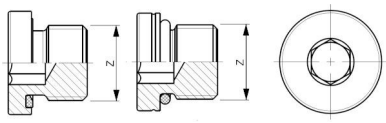


Fig. 199: VSTI screw plugs with ED seal (left), with O-ring (right)

Size	Tightening torque		Size	Tightening torque	
	[1] VSTI ED	VSTI O-ring		[1] VSTI ED	VSTI O-ring
M8x1	8 Nm (6 ft-lb)	8 Nm (6 ft-lb)	G 1/8	10 Nm (7 ft-lb)	-
M10x1	10 Nm (7 ft-lb)	16 Nm (12 ft-lb)	G 1/4	25 Nm (18 ft-lb)	-
M12x1.5	20 Nm (15 ft-lb)	28 Nm (21 ft-lb)	G 3/8	50 Nm (37 ft-lb)	-
M14x1.5	28 Nm (21 ft-lb)	36 Nm (27 ft-lb)	G 1/2	65 Nm (48 ft-lb)	-
M16x1.5	40 Nm (30 ft-lb)	44 Nm (32 ft-lb)	G 3/4	112 Nm (83 ft-lb)	-
M18x1.5	52 Nm (38 ft-lb)	56 Nm (41 ft-lb)	G 1	160 Nm (118 ft-lb)	-
M20x1.5	60 Nm (44 ft-lb)	64 Nm (47 ft-lb)	G 1 1/4	320 Nm (236 ft-lb)	-
M22x1.5	72 Nm (53 ft-lb)	80 Nm (59 ft-lb)	G 1 1/2	360 Nm (266 ft-lb)	-
M24x1.5	72 Nm (53 ft-lb)	-	-	-	-
M26x1.5	100 Nm (74 ft-lb)	-	3/4-16 UNF	56 Nm (41 ft-lb)	-
M30x1.5	192 Nm (142 ft-lb)	-	7/8-1/4 UNF	80 Nm (59 ft-lb)	-
M33x1.5	175 Nm (129 ft-lb)	-	R 3/4"	112 Nm (83 ft-lb)	96 Nm (71 ft-lb)
M27x2	105 Nm (77 ft-lb)	135 Nm (100 ft-lb)	-	-	-
M30x2	-	172 Nm (127 ft-lb)	-	-	-
M33x2	180 Nm (133 ft-lb)	250 Nm (184 ft-lb)	-	-	-
M42x2	290 Nm (214 ft-lb)	265 Nm (195 ft-lb)	-	-	-
M48x2	290 Nm (214 ft-lb)	335 Nm (247 ft-lb)	-	-	-
M60x2	-	400 Nm (295 ft-lb)	-	-	-

Tab. 77: VSTI screw plug tightening torques for aluminum parts

[1] Do not use hydropneumatic screwdriver.

8.4.12 Assembling pipes with DKO connectors (EL, ET, EW, GZ, GZR, RED)

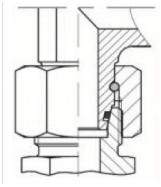


Fig. 200: DKO connector



Fig. 201: DKO connector lubrication

Note

Tolerances of the indicated tightening torques: 10%.

Always lubricate the thread before tightening these parts (engine oil).

Note

To assemble pipes with DKO connectors:

- ▶ When tightening the nut, make sure that the connector does not rotate.
- ▶ Tighten the nut by hand.
- ▶ Hold a wrench as close as possible to the nut.
- ▶ Tighten the nut with the wrench until the resisting point.
- ▶ Tighten the nut a further 90°.

Alternatively, refer to the following table for tightening sequence of the nut:

Size	Equivalent specification	Size	Equivalent specification
06L	20 Nm (15 ft-lb)	06S	25 Nm (18 ft-lb)
08L	30 Nm (22 ft-lb)	08S	40 Nm (30 ft-lb)
10L	40 Nm (30 ft-lb)	10S	50 Nm (37 ft-lb)
12L	50 Nm (37 ft-lb)	12S	60 Nm (44 ft-lb)
15L	70 Nm (52 ft-lb)	14S	75 Nm (55 ft-lb)
18L	90 Nm (66 ft-lb)	16S	85 Nm (63 ft-lb)
22L	120 Nm (89 ft-lb)	20S	140 Nm (103 ft-lb)
28L	160 Nm (118 ft-lb)	25S	190 Nm (140 ft-lb)
35L	250 Nm (184 ft-lb)	30S	270 Nm (199 ft-lb)

Size	Equivalent specification	Size	Equivalent specification
42L	380 Nm (280 ft-lb)	38S	400 Nm (295 ft-lb)

Tab. 78: Alternative tightening torques for DKO connectors

8.4.13 Standard torques for collar clamps



Fig. 202: Collar clamp

Band width	Tightening torque
18 mm (0.71 in)	4 Nm (3 ft-lb)
20 mm (0.79 in)	7 Nm (5 ft-lb)
25 mm (0.98 in)	12 Nm (9 ft-lb)
30 mm (1.18 in)	30 Nm (22 ft-lb)

Tab. 79: Tightening torques for collar clamps according to DIN 3017-3

Note

Tolerances of the indicated tightening torques: 10%.



Fig. 203: Clamp ABA type S20

Band width	Size	Tightening torque
12 mm (0.47 in)	Up to 26 mm (1.02 in) - 38 mm (1.5 in)	4 Nm (3 ft-lb)
	From 32 mm (1.26 in) - 44 mm (1.73 in)	5 Nm (4 ft-lb)

Tab. 80: Tightening torques for clamps ABA type S20 according to NORMA

8.4.14 Standard torques for pipe clamps according to DIN 3015

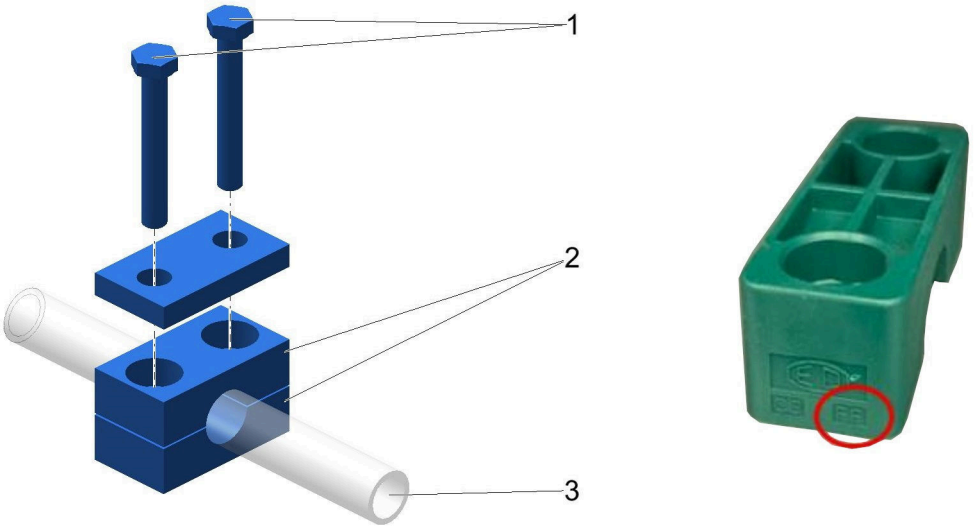


Fig. 204: Pipe clamps

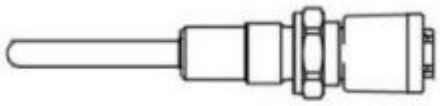
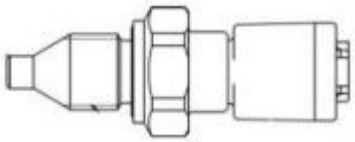
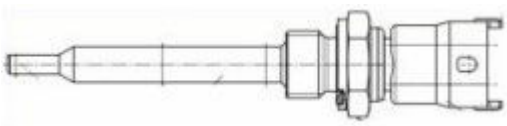
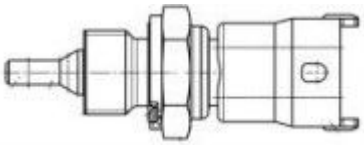
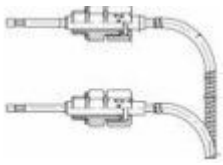
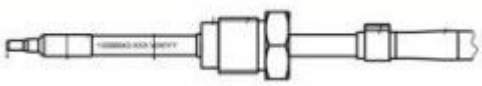
Series	Dimen-sion	Dimension of screw 1	External diameter of pipe 3	Tightening torque according to material marking of clamp 2	
				PP (polypropy-lene)	PA (polyamid)
Light (DIN 3015-1)	All	M6	All	8 Nm (6 ft-lb)	10 Nm (7 ft-lb)
		M8	All	10 Nm (7 ft-lb)	15 Nm (11 ft-lb)
Heavy (DIN 3015-2)	1	M10	6 mm (0.24 in)-18 mm (0.71 in)	12 Nm (9 ft-lb)	20 Nm (15 ft-lb)
	2		19 mm (0.75 in)-30 mm (1.18 in)	12 Nm (9 ft-lb)	20 Nm (15 ft-lb)
	3		30 mm (1.18 in)-42 mm (1.65 in)	15 Nm (11 ft-lb)	25 Nm (18 ft-lb)
	4	M12	38 mm (1.5 in)-66 mm (2.6 in)	30 Nm (22 ft-lb)	40 Nm (30 ft-lb)
	5	M16	70 mm (2.76 in)-90 mm (3.54 in)	45 Nm (33 ft-lb)	55 Nm (41 ft-lb)
	6	M20	90 mm (3.54 in)-127 mm (5 in)	80 Nm (59 ft-lb)	150 Nm (111 ft-lb)
	7	M24	127 mm (5 in)-168 mm (6.61 in)	110 Nm (81 ft-lb)	200 Nm (148 ft-lb)
	8	M30	168 mm (6.61 in)-220 mm (8.66 in)	180 Nm (133 ft-lb)	350 Nm (258 ft-lb)

Tab. 81: Tightening torques for pipe clamps according to DIN 3015

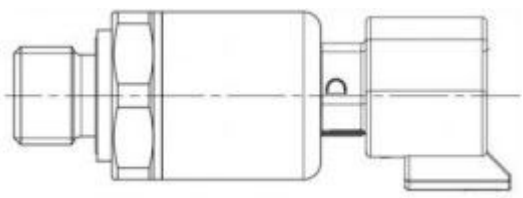
8.4.15 Standard torques for sensors, transmitters and probes

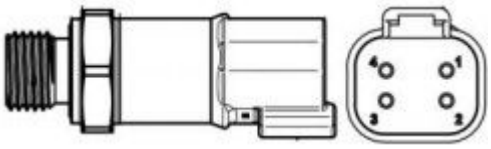
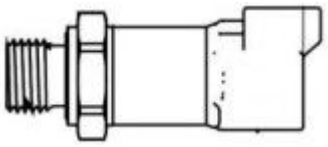
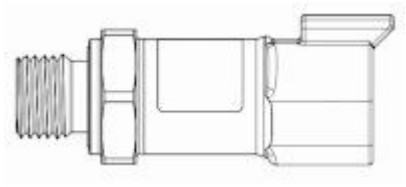
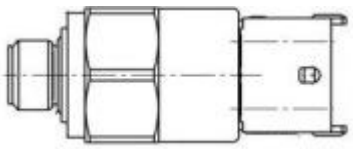
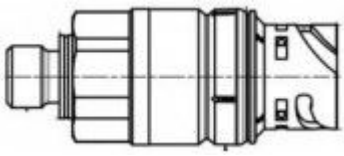
Note

Tolerances of the indicated tightening torques: 10%.

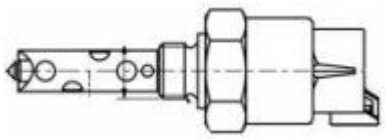
Thread dimension	Temperature sensor	Lubricant	Tightening torque
M14x1,5		-	22 Nm (16 ft-lb)
M14x1,5		-	22 Nm (16 ft-lb)
M14x1,5		-	27 Nm (20 ft-lb)
M14x1,5		-	27 Nm (20 ft-lb)
M14x1,5		MH MH	45 Nm (33 ft-lb) 40 Nm (30 ft-lb) (upper nut)
M14x1,5 (B side) M16x1,5 (A side)		MH MH MH	45 Nm (33 ft-lb) (B side) 50 Nm (37 ft-lb) (A side) 40 Nm (30 ft-lb) (upper nut)
M14x1,5		MH	35 Nm (26 ft-lb)

Tab. 82: Tightening torques for temperature sensors

Thread dimension	Pressure transmitter	Lubricant	Tightening torque
M14x1,5		-	20 Nm (15 ft-lb)

Thread dimension	Pressure transmitter	Lubricant	Tightening torque
M14x1,5		-	32 Nm (24 ft-lb)
M14x1,5		-	32 Nm (24 ft-lb)
M14x1,5		-	32 Nm (24 ft-lb)
M14x1,5		-	40 Nm (30 ft-lb)
M14x1,5		-	22 Nm (16 ft-lb)

Tab. 83: Tightening torques for pressure transmitters

Thread dimension	Level probe	Lubricant	Tightening torque
M14x1,5		-	22 Nm (16 ft-lb)

Tab. 84: Tightening torque for level probes

*Lubricants:
MG = Molykote G-n-plus
MW = Castrol Optimol paste white T
MH = Molykote HSC
O = Engine oil
XX = Loctite 243
YY = Loctite 577

8.5 Abbreviations - Acronyms

To ensure consistency, we kept the abbreviations and acronyms in English in all translated versions of this document. The following tables include their translations in the targeted language of the manual.

Abbr.	Designation	Translation
AC	Alternating Current	Alternating Current
AI	Assembly Instructions	Assembly Instructions
BDC	Bottom Dead Center	Bottom Dead Center
CAN	Controller Area Network	Controller Area Network
CAC	Charge Air Cooler	Charge Air Cooler
CCS	Counter Coupling Side = Damper side	Counter Coupling Side = Damper side
CR	Common Rail	Common Rail
CS	Coupling Side = Flywheel side	Coupling Side = Flywheel side
DC	Direct Current	Direct Current
DE	Driving End	Driving End
EATS	Exhaust Gas Aftertreatment System	Exhaust Gas Aftertreatment System
ECU	Engine Control Unit	Engine Control Unit
EMC	Electromagnetic Compatibility	Electromagnetic Compatibility
EPDM	Ethylene-Propylene-Diene Monomer	Ethylene-Propylene-Diene Monomer
FE	Free End	Free End
HFRR	High Frequency Reciprocating Rig – Measured value for the lubricity of diesel fuels	High Frequency Reciprocating Rig – Measured value for the lubricity of diesel fuels
HP	High Pressure	High Pressure
HT	High Temperature	High Temperature
LOTO	Lockout/tagout	Lockout/tagout
LP	Low Pressure	Low Pressure
LT	Low Temperature	Low Temperature
OM	Operator's Manual	Operator's Manual
OMM	Operation and Maintenance Manual	Operation and Maintenance Manual
PCV	Pressure Control Valve	Pressure Control Valve
PPE	Personal Protective Equipment	Personal Protective Equipment
PTO	Power Take-Off	Power Take-Off
RI	Repair Instructions	Repair Instructions
SAPS	Sulphated Ash, Phosphorus, and Sulfur	Sulphated Ash, Phosphorus, and Sulfur
SCR	Selective Catalytic Reduction	Selective Catalytic Reduction
SRM	Service and Repair Manual	Service and Repair Manual
TBO	Time Between Overhaul	Time Between Overhaul
TDC	Top Dead Center	Top Dead Center

Abbr.	Designation	Translation
VCV	Volume Control Valve	Volume Control Valve

Tab. 85: Abbreviations table

Acronym	Designation	Translation
ANSI	American National Standards Institute	American National Standards Institute
DIN	German standard	German standard
EN	European standard	European Standard
EU	European Union	European Union
ILO	International Labor Organization	International Labor Organization
ISCED	International Standard Classification of Education	International Standard Classification of Education
SAE	Society of Automotive Engineers	Society of Automative Engineers
WHO	World Health Organization	World Health Organization

Tab. 86: Acronyms table

8.6 Unit conversion tables

Use the following tables to convert units used in this guideline. Suitable number of decimals are used for inaccurate conversion factor.

8.6.1 Length conversion factors

Convert from	To	Multiply by
mm	in	0.0394
mm	ft	0.00328
µm	th	0.0394

Tab. 87: Length conversion factors

8.6.2 Mass conversion factors

Convert from	To	Multiply by
kg	lb	2.205
kg	oz	35.274

Tab. 88: Mass conversion factors

8.6.3 Pressure conversion factors

Convert from	To	Multiply by
kPa	psi (lbf/in²)	0.145
kPa	lbf/ft²	20.885
kPa	inch H2O	4.015
kPa	foot H2O	0.335
kPa	mm H2O	101.972

Tab. 89: Pressure conversion factors

8.6.4 Volume conversion factors

Convert from	To	Multiply by
m³	in³	61023.744
m³	ft³	35.315
m³	Imperial gallon	219.969
m³	US gallon	264.172
m³	l (liter)	1000

Tab. 90: Volume conversion factors

8.6.5 Power conversion factors

Convert from	To	Multiply by
kW	hp (metric)	1.360
kW	US hp	1.341

Tab. 91: Power conversion factors

8.6.6 Moment of inertia and torque conversion factors

Convert from	To	Multiply by
kgm^2	$lbft^2$	23.730
kNm	lbf ft	737.562

Tab. 92: Moment of inertia and torque conversion factors

8.6.7 Factors of fuel consumption conversion

Convert from	To	Multiply by
g/kWh	g/hph	0.736
g/kWh	lb/hph	0.00162

Tab. 93: Factors of fuel consumption conversion

8.6.8 Flow conversion factors

Convert from	To	Multiply by
m^3/h (liquid)	US gallon/min	4.403
m^3/h (gas)	ft^3/min	0.586

Tab. 94: Flow conversion factors

8.6.9 Temperature conversion factors

Convert from	To	Multiply by
°C	°F	F = 9/5*C + 32
°C	K	K = C + 273.15

Tab. 95: Temperature conversion factors

8.6.10 Density conversion factors

Convert from	To	Multiply by
Kg/m^3	lb/US gallon	0.00834
Kg/m^3	lb/imperial gallon	0.01002
Kg/m^3	lb/ft^3	0.0624

Tab. 96: Density conversion factors

8.7 Prefix

Name	Symbol	Factor
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
milli	m	10^{-3}
micro	µ	10^{-6}
nano	n	10^{-9}

Tab. 97: Common prefix multipliers table

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