Winterthur Gas & Diesel

WÄRTSILÄ | W-X62DF

# Operation Manual

“Marine”

**Vessel:**

**Type:**

**Engine No.:**

**Document ID:** DBAD220106

**Winterthur Gas & Diesel Ltd.**
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Switzerland

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# Modification Service

Engine Documentation

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# Abbreviations

| Abbreviation | Word(s) in Full |
|---|---|
| AHD | Ahead |
| ALM | Alarm |
| AMS | Alarm and Monitoring System |
| AST | Astern |
| ASTM | American Society for Testing and Materials |
| BDC | Bottom Dead Center |
| BN | Base Number |
| BSEC | Brake Specific Energy Consumption |
| BSFC | Brake Specific Fuel Consumption |
| BSGC | Brake Specific Gas Fuel Consumption |
| BSPC | Brake Specific Pilot Fuel Consumption |
| CAN | Controller Area Network |
| CCAI | Calculated Carbon Aromaticity Index |
| CMCR | Contract Maximum Continuous Rating |
| CCM | Cylinder Control Module |
| COC | Cleveland Open Cup |
| DENIS | Diesel Engine CoNtrol and OptImizing Specification |
| ECA | Emission Control Area |
| ECR | Engine Control Room |
| ECS | Engine Control System |
| ELBA | Electronic Balancer |
| ESS | Engine Safety System |
| EWG | Exhaust Waste Gate |
| FFT | Fast Fourier Transform |
| FQS | Fuel Quality Setting |
| FZG | Gear Research Center |
| GAV | Gas Admission Valve |
| GSS | Gas Safety System |
| GVU | Gas Valve Unit |
| HFO | Heavy Fuel Oil |
| HFR | High Feed Rate |
| HMI | Human Machine Interface |
| ICC | Intelligent Combustion Control |
| IGC | International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk |
| IGF | International Code of Safety for Ships using Gases and other Low Flash-point Fuels |
| IOM | Input Output Module |
| IMO | International Maritime Organisation |
| ISO | International Standard Organisation |

| Abbreviation | Word(s) in Full |
|---|---|
| KOH | Potassium Hydroxide |
| LDU | Local Display Unit |
| LED | Light Emitting Diode |
| LEL | Lower Explosive Limit |
| LFO | Light Fuel Oil |
| LFR | Low Feed Rate |
| LHV | Lower Heat Value |
| LNG | Liquified Natural Gas |
| MARPOL | International Convention for the Prevention of Pollution from Ships |
| MCM | Main Control Module |
| MCR | Maximum Continuous Rating |
| MDO | Marine Diesel Oil |
| ME | Main Engine |
| mep | Mean effective pressure |
| MGO | Marine Gas Oil |
| MIM | Marine Installation Manual |
| MN | Methane Number |
| Modbus | Gould-Modicon Fieldbus |
| NTP | Network Time Protocol |
| OPI | Operator Interface (user interface in the control room) |
| PFI | Pilot Fuel Injection |
| PID | Proportional Integral Derivative (Controller) |
| PMCC | Pensky Martens Closed Cup method |
| RCS | Remote Control System |
| rpm | Revolutions per minute |
| RTD | Resistance Temperature Detector |
| SAC | Scavenge Air Cooler |
| SAE | Society of Automotive Engineers |
| SCS | Speed Control System |
| SHD | Shut Down |
| SLD | Slow Down |
| SOI | Start of Injection |
| SOSP | Servo Oil Service Pump |
| SW | Software |
| TCP/IP | Transmission Control Protocol/Internet Protocol |
| TC | Turbocharger |
| TDC | Top Dead Center |
| UNIC | Unified Controls |
| USB | Universal Serial Bus |
| UTC | Coordinated Universal Time |
| VEC | Variable Exhaust valve Closing |
| VEO | Variable Exhaust valve Opening |
| VIT | Variable Injection Timing |

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# Operating Descriptions　Group 0

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# Preface

## 1. General

This manual is for the operator and is for use only for the related type of diesel engine (the engine described in this manual). The data in this manual is confidential.

Make sure that you read carefully the Operation Manual before you operate the engine.

Make sure that you know the Inspection and Overhaul intervals in the Maintenance Manual before you operate the engine.

Make sure that you read the data in Group 0 in the Maintenance Manual before you do maintenance work on the engine.

The extent of all supplies and services is set exclusively to the related supply contract.

## 2. Data

The specifications and recommendations of the classification societies, which are essential for the design, are included in this manual.

The data, instructions, graphics and illustrations etc. in this manual are related to drawings from Winterthur Gas & Diesel Ltd. These data relate to the date of issue of the manual (the year of the issue is shown on the title page). All instructions, graphics and illustrations etc can change because of continuous new development and modifications.

## 3. Spare Parts

Use only original spare parts and components to make sure that the engine will continue to operate satisfactorily. All equipment and tools for maintenance and operation must be serviceable and in good condition.

## 4. Personnel

Only qualified personnel that have the applicable knowledge and training must do work on the engine, its systems and related auxiliary equipment.

Data related to protection against danger and damage to equipment are specified in this manual as Warnings and Cautions.

## 5. Symbols

**WARNING**

**This symbol shows that the text is safety related. The signal word WARNING is used to show a hazardous condition. If ignored, these conditions could cause serious injury or death to personnel. Warnings come immediately before the related paragraph or procedure.**

**CAUTION**

**This symbol shows that the text is safety related. The signal word CAUTION is used to show a potentially hazardous condition. If ignored, these conditions could cause minor injury to personnel, or damage to engine components. Cautions Warnings come immediately before the related paragraph or procedure.**

**Note: Notes give more data to help you do a task, or give you data about the engine. Notes come immediately before or after the related paragraph.**

# 6. Technical Documentation Set

Because of the continuous development of the engine, the technical documentation changes and is regularly updated. The modification service leaflet on the first page of the manual shows all changes.

Important data and changes are given directly to the customer in the service bulletins.

To order technical documents, the data that follows is necessary:

- Engine type, year of manufacture and engine manufacturer
- Name of vessel or site of installation
- Cylinder or engine number
- Special equipment
- Document type (printed manuals or CD).

The technical documentation set for this duel fuel engine type includes the publications that follow:

## 6.1 Operation Manual

The operation manual contains data about engine operation, the necessary operating media (oil, water and fuel) and descriptions of the components and systems. The manual also gives troubleshooting procedures.

The Operation Manual contains data and indications about:

- The servicing of the engine during operation
- The necessary media (oil, water, air, fuel)
- The functions of components and systems.

The manual is divided into different groups. Each group contains data about components or systems referred to in the design groups.

The manual gives data about the standard engine with all cylinder numbers, alternative designs and special equipment.

The documentation for alternative engine designs are separated into different chapters with the related design name.

In the cross section and longitudinal section illustrations (see 0200−1), important components are shown with their group numbers. These group numbers have hyperlinks to the different groups in the manual, which give more data about the engine.

The cross section and longitudinal section illustrations shown can have small differences because of different engine revisions.

## 6.2 Maintenance Manual

The maintenance manual contains data about disassembly / assembly procedures that are necessary for the engine maintenance and the maintenance schedule. This manual gives more data about the masses (weight) of components, a clearance table, tightening values for important screw connections and a tool list.

## 6.3 Code Book (spare parts catalogue)

In the code book all parts of the engine are marked with a unique code number. The code number is necessary to order spare parts from Wärtsilä Services Switzerland Ltd. or the engine supplier. The spare parts can only be ordered with the code number from the code book.

## 6.4 External Supplier Documentation

The documentation from external suppliers gives data about the parts of the engine that are not supplied by Winterthur Gas & Diesel Ltd. or Wärtsilä Services Switzerland Ltd., such as turbocharger, automatic filter, torsional or vibration damper. Most of this documentation also contains data about spare parts.

## 6.5 Records and Drawings

The setting tables, shop trial documents, schematic diagrams and survey certificates of the related engine are given with the first supply of the documentation.

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# Safety
## Safety Precautions and Warnings (General Data)



## 1. General

A correctly maintained engine gives problem-free and safe operation. Use the data given below as a guide.

For more data about the general maintenance procedures, refer to the Maintenance Manual 0011–1 and 0012–1.

## 2. Warnings

**WARNING**

**Injury Hazard. When you remove valves from the cylinder cover, do not let oil or fuel fall on to the hot piston. This can cause an explosion.**

**WARNING**

**Injury Hazard: If an oil mist detector activates an alarm, keep away from engine. There is a risk of explosion. Do not go into the areas adjacent to the explosion relief valves**

**WARNING**

**Injury Hazard. Be careful when you disassemble the engine without the correct tools and/or the necessary precautions. Compressed springs can suddenly expand and cause injury.**

**WARNING**

**Injury Hazard. When you open valves and shut-off devices, hot fluids or gases can be released. To prevent injury, always open slowly the valves and shut-off devices and look at the direction the medium is released.**

**Note: Refer to 0120–1 Instructions about the Prevention of Crankcase Explosions.**

Make sure that you read the maintenance instructions for the related parts.

## 3. Lighting

There must be good permanent lighting. Also, hand lamps must be available at different locations in the engine room.

## 4. Clean Areas

| CAUTION |
|---|
| **Damage Hazard. Do not use water or cleaning fluids to clean the ECS electronic control boxes on the rail unit. Damage can occur if fluids go into these control boxes.** |

Always keep the engine as clean as possible.

Keep the ECS electronic control boxes on the rail unit clean and dry.

You must repair all leaks as soon as possible.

Dust, sand and chemical vapors must not go into the engine room.

## 5. Fire

| CAUTION |
|---|
| **Injury Hazard. Be careful when you use paints and solvents in the engine room. These materials are flammable.** |

| CAUTION |
|---|
| **Injury Hazard. Insulation material that is soaked with oil or fuel is flammable and must be replaced.** |

Make sure that you know the fire fighting instructions.

Before you do welding work or work that causes sparks, make sure that there are no explosive fluids or gases in the work area.

Make sure that fire fighting equipment is immediately available if you must do work that causes sparks in the engine room.

Some components, e.g. the turbocharger silencer and ECS electronic control boxes, must be protected with an applicable cover.

Keep covers and casings closed until the engine is cool to decrease the risk of fire or explosions.

The engine room and the area below the floor plates must be kept clean. This will help prevent a fire in the engine room and in different areas.

Make sure that no fire extinguisher gases can be automatically released when personnel are in the engine room.

Make sure that the emergency exits are clearly marked.

**Note: When there is a fire alarm in the engine room and the engine operates in gas mode, the engine control system automatically changes to diesel mode (gas trip) and closes the master gas fuel valve (refer to 4002–1 Engine Control System and 8014–1 Gas Fuel System).**

## 6. Tools

Put hand-tools in locations where you can easily get access to them. Put special tools and devices in positions in the engine room near the area where you use them.

All tools must be prevented from unwanted movement and must have protection from corrosion.

## 7. Spare Parts

Keep large spare parts as near as possible to the position where they will be installed and near the engine room crane.

You must prevent the unwanted movement of large spare parts.

All the spare parts must have corrosion protection. The corrosion protection agent must be easy to remove. Examine the corrosion protection agent at regular intervals and replace if necessary.

The spare parts must also have protection from mechanical damage.

Spare parts that are removed from the store must be replaced as soon as possible.

## 8. Crankcase Doors – Open

**WARNING**

**Danger: If you think that parts of the running gear or bearings have become too hot, it is possible that the engine must be shut down. After a minimum time of 20 minutes, the crankcase doors can be opened. This will prevent an explosion.**

**WARNING**

**Injury Hazard. Be careful when you touch hot parts with your hands. This can cause injury.**

## 9. Temperature

**WARNING**

**Danger: If you think that parts of the running gear or bearings have become too hot, it is possible that the engine must be shut down. After a minimum time of 20 minutes, the crankcase doors can be opened. This will prevent an explosion.**

**WARNING**

**Injury Hazard. Be careful when you touch hot parts with your hands. This can cause injury.**

When commissioning an engine after an overhaul of its running gear, do a temperature check to find unusually high temperatures in areas of the engine. Do this temperature check after 10 minutes of engine operation.

Do the temperature check again after approximately one hour of engine operation.

After a short period of operation at full load, do the temperature check again.

## 10. Crankcase, Cylinder, Exhaust Pipes and Scavenge air Receiver

Before you go into the spaces of the crankcase, cylinder, exhaust pipes and scavenge air receiver, make sure that:

- The starting air to the engine is blocked and the ball valves 30−8605_E0_6 and 30−8605_E0_7 are open (refer to 4003−2 Page 1 Engine Control Diagram).
- The turning gear is engaged (see paragraph 13 and the Maintenance Manual 0011−1 Precautionary measures before you start maintenance tasks).

**Note: Other ships in the water cause currents, which will make the propeller and the engine turn. The engine and propeller cannot turn when the turning gear is engaged.**

## 11. Carbon Dioxide Gas

**WARNING**

**Injury Hazard. Where carbon dioxide gas ($CO_2$) is used to extinguish a fire in the engine, there is a risk of suffocation. Make sure that all related spaces have good airflow to remove all $CO_2$ gas before you go into the engine.**

## 12. Crankcase Doors – Close

Make sure that all crankcase doors are closed and locked before you operate the engine. This is also applicable to short periods of engine operation e.g. running-in, after the replacement of bearings etc.

## 13. Turning Gear

**WARNING**

**Injury Hazard: After an air run, the crankshaft can turn suddenly when the pressurized air in the cylinder releases. There is a risk of death, serious injury or damage to components. Before you do maintenance on the engine or engage the turning gear:**

**Make sure that there is no pressurized air in the cylinder and the starting air pipes.**

**Make sure that you open the relief valves on all cylinder covers to release the pressure.**

**WARNING**

**Injury Hazard: Make sure that no personnel and components are in the danger areas (crankcase, piston underside, propeller shaft, etc). The propeller coupling also turns.**

**Note: If the engine is stopped for overhaul, you must engage the turning gear to prevent engine movement.**

The lubricating oil pump must operate if possible, but the oil pressure cannot fully increase when the exhaust valves are open.

If the engine is ready for maneuvering, the turning gear must not be engaged.

Before the you start the engine, make sure that the turning gear is disengaged and the lever is locked. It is possible that the 3/2-way valve 35.31HA can prevent engine start (refer to 4003−2 Page 1 Engine Control Diagram).

## 14. Instruments

Calibrate instruments (and gauges) at regular intervals before you use them.

## 15. Frost Hazard

If the temperature decreases below 0°C and the engine is not in operation, it is possible that water in the engine, pumps, coolers and pipes will freeze. To prevent this, drain the systems or increase the temperature in the engine room.

## 16. Natural Gas

**WARNING**

**Injury Hazard: High concentrations of natural gas can cause dizziness and there is a risk of suffocation. Make sure that all related spaces have good airflow.**

Natural gas in low concentrations is not dangerous to personnel.

Natural gas can be dangerous in a gas engine installation. Gas leakage into the engine room can cause fires and explosions.

An explosion can occur if gas, that is not fully burned, flows into the exhaust system.

It is very important to prevent injury to personnel and damage to equipment if a gas explosion occurs. For more data, refer to 0130–1.

An explosion can be prevented when gas pressure is released / removed from equipment to the ambient air.

When it is necessary to do maintenance work on the engine or the Gas Valve Unit (GVU), the steps that follow must be done:

- The gas fuel system must be depressurized 8014–1 paragraph 2.3.
- The remaining gas fuel in the system must be replaced with inert gas (e.g. nitrogen). For more data, refer to 8014–1 , paragraph 3.4.

The pipes of the engine and the GVU have connections for inert gas. If maintenance is done downstream of the GVU (and it is not necessary to open the GVU enclosure), it is sufficient to remove the gas from the gas pipe between the GVU and the engine.

If maintenance is done on the GVU (and it is necessary to open the enclosure), gas fuel must be removed from the gas pipes upstream of the GVU double block–and–bleed valves. This process prevents gas leakage to the adjacent areas and removes possible risks.

A procedure to remove gas from the pipes during engine operation can become necessary. A connection is installed in the GVU for the removal of gas from the pipes between the GVU and the engine.

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# Safety

## Procedures to Prevent Contamination and Fire in the Scavenge Air Spaces

## 1. General

**Note: The data that follows is applicable only when the engine operates in diesel mode.**

The primary cause of contamination is when combustion materials are blown between the piston and cylinder into the scavenge air spaces (blow-by). The contamination will be more if the fuel is not fully burned, which causes exhaust smoke.

## 2. Causes and Procedures

### 2.1 Unsatisfactory Combustion

The causes of unsatisfactory combustion are as follows:

- The injection valves do not operate correctly (the nozzle tip has trumpets or is worn).
- The fuel is too cold, specially at low load.
- Operation with a temporarily low air supply during large differences in engine load and the scavenge air pressure fuel limiter set too high.
- Too much load
- Low air supply because the airflow in the engine room is not sufficient.
- The silencer and diffuser on the air side of the turbocharger has contamination.
- The wire mesh and nozzle ring upstream of the turbocharger has contamination.
- The exhaust gas boiler, the air cooler and water separator, the air flaps in the scavenge air receiver and the scavenge ports have contamination.

### 2.2 Blow-by

The causes of blow-by are as follows:

- Worn piston rings, broken piston rings or piston rings that cannot move.
- Worn cylinder liner.
- Incorrect operation of a lubricating quill.
- The running surface of the cylinder liners are damaged.

If there are one or more of these conditions, the remaining particles will collect at the areas that follow:

- Between the piston ring and piston ring groove.
- On the piston skirt.
- In the scavenge ports.
- On the bottom of the cylinder block (piston underside).
- In the scavenge air receiver.

### 2.3 Fires

The causes of fires are as follows:

- Combustion gases and sparks that bypass the piston rings between the piston and cylinder liner running surface, go into the piston underside.
- If sealing rings of the piston rod gland leak and drain pipes from the piston underside are blocked, system oil and cylinder lubricating oil will collect. This is a primary fire risk.

You must do periodic checks of the bottom of the cylinder block and scavenge air receiver. If necessary clean the cylinder block and scavenge air receiver.

## 2.4 Indications of a Fire

The indications of a fire as follows:

- You can hear the related temperature alarms.
- A large increase in the exhaust gas temperature of the related cylinder and an increase in piston underside temperature.
- In some conditions the turbocharger can surge.

## 2.5 Fire-fighting Procedures

It is recommended that you do the procedures that follow:

1) Decrease immediately the engine power.
2) Cut out the injection of the related cylinder as given in step a) and step b):
    a) From the MAIN page of the LDU−20 , go to the FUEL INJECTION page (4002−2, paragraph 3.7).
    b) In the Inj. cutoff field for the related cylinder(s), set the parameter to 0.
3) Although there is high temperature in the cylinder(s), increase the feed rate of lubricating oil to maximum as given in step a) and step b):
    a) In the LDU−20, go to the CYL. LUB. page.
    b) In the Manual Lub. To Cyl # field, set the parameter to the related cylinder number.
4) In the Adjustment column, set the parameter to 150%.

**Note: This will make sure that the cylinder(s) is (are) lubricated (refer to 7218−1 Cylinder Lubrication, paragraph 8.4).**

If the plant has a specified fire extinguisher system ($CO_2$ gas), the containers can be attached to the applicable connections on the scavenger air receiver. The related shut-off valve must be fully leak-proof.

5) If you think there is a fire, shut down the engine and fill the scavenge space with $CO_2$ gas.

**Note: Make sure that you read the data in 0100−1 Safety Precautions and Warnings, paragraph 11 Carbon Dioxide Gas and paragraph 16, Natural Gas.**

If steam is used to extinguish a fire, you must do the procedures to prevent corrosion.

It is possible that after approximately 5 minutes to 15 minutes, a fire will be extinguished.

6) To make sure that a fire is extinguished, do a check of:
    - The exhaust gas temperatures
    - The temperatures of the doors to the piston underside space.

After the procedures above, you must stop the engine as soon as possible and find the cause of the fire.

7) Do step a) to step e):
    a) Do a check of the cylinder liner running surface, piston and piston rings.
    b) Do a check of the air flaps in the scavenge air receiver (replace if necessary).
    c) Do a check for possible leakages.
    d) Do a check of the piston rod gland as much as possible.
    e) Do a check of the injection nozzles.

8) After a careful check, or if necessary a repair, do the procedure given in step a) to step c):

   a) Start the engine.

   b) Start the injection and slowly increase the load.

   c) Set the lubricating oil feed rate to the applicable value.

9) If the engine must stay in operation and the fire is extinguished, do the procedure given in step a) and step b):

   a) Cut in the injection and slowly increase the load.

   b) Set the lubricating oil feed rate to the applicable value.

**Note: Do not operate the engine for long periods with a high cylinder lubrication setting.**

## 2.6 Procedures to Prevent Fire

Good engine maintenance will help to prevent a fire in the scavenge air spaces. The data that follow will also help to prevent fire:

1) Make sure that the injection nozzles are serviceable (i.e. the spray from the nozzles must come out correctly).

2) Do regular inspections of the air and gas pipes.

3) Clean regularly the air and gas pipes.

4) Dirty oil from the piston underside must always drain through the dirty oil outlet.

5) Make sure that the oil pipes are clean.

6) Use your hand to feel the drain pipes. If there is a blockage, a drain pipe will have a temperature difference. You must clean the related drain pipe as soon as possible.

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# Safety
## Prevention of Crankcase Explosions

## 1. General

Examples of crankcase explosions in diesel engines have shown that they can only occur in special conditions, and thus do not occur frequently.

The cause of crankcase explosions is oil mist. Oil mist comes from components that have become unusually hot.

Engines have oil mist detectors, which continuously monitor the concentration of oil mist in the crankcase. If there is a high oil mist concentration, the oil mist detector activates an alarm. For more data, refer to 9314−1 Oil Mist Detector.

Correct engine maintenance will help prevent explosions in the crankcase.

## 2. Procedure

**WARNING**

**Danger: If an oil mist alarm is activated, keep away from the engine. There is a risk of explosion.**

**WARNING**

**Danger: Do not open the crankcase doors or the covers for a minimum of 20 minutes. If air goes into the crankcase, an explosion can occur.**

If an oil mist detector activates an alarm, do the procedures given below:

1) Decrease immediately the engine speed (power) .

2) Stop the engine when possible and let the engine temperature decrease for a minimum of 20 minutes.

3) Find the cause (see 0510−1 Problems during Operation ).

The crankcase doors have relief valves. To prevent accidents no person must be in the areas of gases that can come out of these relief valves.

If no fire-extinguishing system is installed or not in use, a portable fire extinguisher must be kept ready when the crankcase doors are opened.

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# Safety
## Prevention of Explosions in the Exhaust System (Gas Mode)

## 1. General

**WARNING**

**Injury Hazard: When you operate the emergency stop button during operation in gas mode, gas can stay in the combustion chamber and exhaust gas system. There is a risk of explosion. Before you start the engine, make sure that there is no gas in the combustion chamber and exhaust gas system.**

For data about safety, refer to 0100−1 Safety Precautions and Warnings and 8014−1 Gas Fuel System.

**Note: The data that follow are applicable only when the engine operates in gas mode.**

Unwanted gas can stay in the exhaust system after the conditions that follow:

- Emergency engine stop (refer to 0600−1 Engine Stop Procedure, paragraph 3.2).
- Shutdown signal cannot be cancelled (refer to 0600−1 Engine Stop Procedure, paragraph 3.1.3).
- Electrical power failure to the engine control system.

The engine control system (ECS) continuously monitors the combustion process. If a misfire occurs during engine operation, the concentration of unburned gas in the exhaust system can increase. To prevent an ignition of unburned gas in the exhaust system (because the concentration is too high), the ECS monitors the combustion. If too many misfires occur, the ECS automatically changes to diesel mode (for more data, refer to 4002−1 Engine Control System, paragraph 3.22).

For the procedure to remove unwanted gas in the exhaust system, refer to the data given in paragraph 2.

**Note: The exhaust system upstream of the turbocharger (with the expansion bellows) is resistant to explosions.**

## 2. Ventilation Procedure

The ECS automatically sends the signal for the ventilation sequence (see Fig. 1). The operator must manually select the applicable function on the LDU-20 and start the ventilation sequence. For more data, refer to 4002–2, Local Control Panel / Local Display Unit (LDU-20) paragraph 3.18 Exhaust Ventilation.

The ventilation procedure has the conditions that follow:

- The operator must make sure that the auxiliary blowers operate.
- The servo oil service pump is set to on.
- The exhaust valves open automatically.

Refer also to the diagram in Fig. 2).

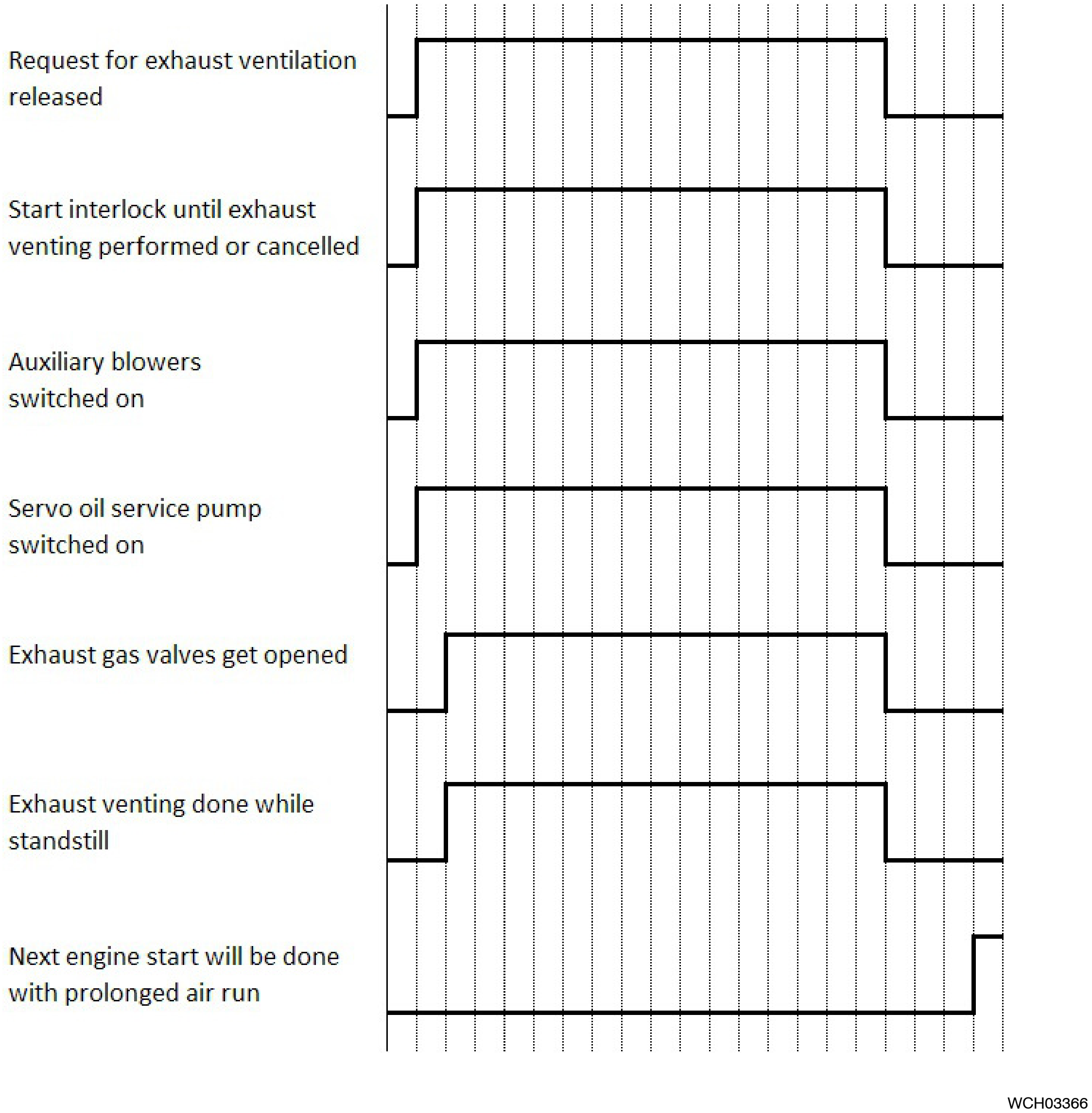


**Fig. 1: Process Diagram – Ventilation Procedure**

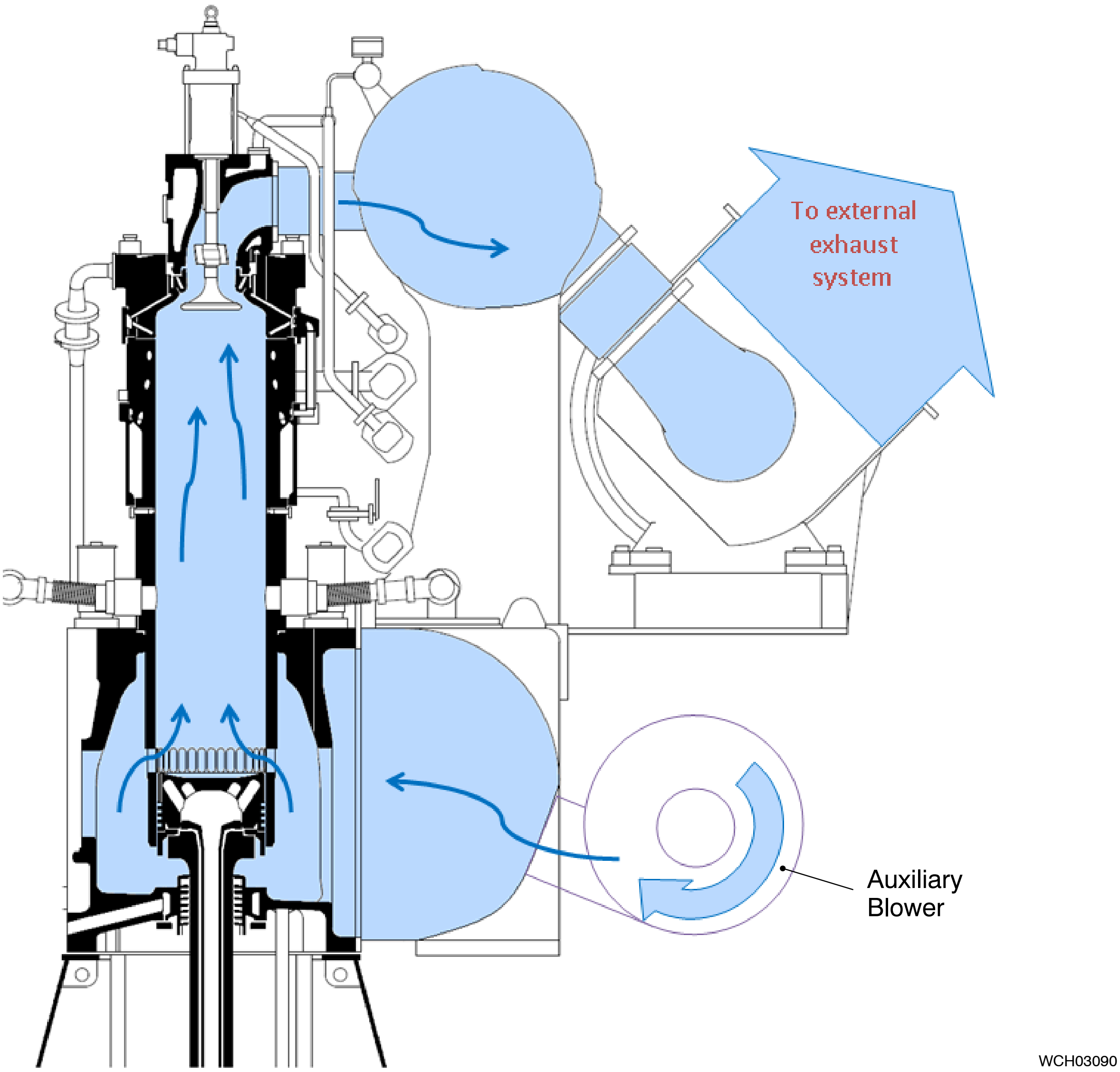


**Fig. 2: Exhaust Ventilation**

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# Engine Data
## Short Description of the Engine



## 1. General

- The W-X Dual Fuel engine is a single acting, two-stroke dual fuel (diesel fuel/gas fuel) engine of crosshead design with exhaust gas turbocharging and uniflow scavenging.
- The W-X62DF obeys the IGC (International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk) and IGF (International Code for Ships using Gas or other Low Flashpoint Fuels) codes.
- The engine can turn in clockwise and counterclockwise directions and is directly connected to the propeller.
- In diesel mode, the engine can use marine gas oil (MGO) and heavy fuel oil (HFO) with different qualities.
- In gas mode, the engine can use low-pressure liquid natural gas (LNG). Engine operation is related to the Otto cycle. The LNG is injected into the cylinder at low pressure (less than 10 bar).
- The pilot fuel is marine diesel oil that is injected into the cylinder to ignite the gas-air mixture during gas mode. The injection timing and pilot fuel quantity is controlled electronically.
- The W-X62DF engine uses the Wärtsilä Common Rail, with full electronic control of the fuel injection system and exhaust valve operation.
- The engine control can have different remote controls, which are related to the Winterthur Gas & Diesel Ltd. specifications from recommended manufacturers.
- If the remote control has a failure, the engine can be controlled with the emergency control from the local control panel.
- Tie rods hold the bedplate, columns and cylinder block together.
- A partition isolates the crankcase from the cylinder block. This partition includes the piston rod glands for the piston rods.
- The thrust bearing and turning gear are installed on the driving end of the engine.
- The  engine control system (ECS) electronically controls all important engine functions (e.g. exhaust waste gate control, speed control, knock detection, overspeed protection and fuel injection).
- The lubricating oil, coolant water, fuel supply, booster pumps (fuel, crosshead lubrication, pilot fuel), air compressors, gas valve unit (GVU) and gas supply system are parts of the engine room installation (auxiliary systems).

## 2. Systems

General data about the systems are given as follows:

- The servo oil system opens the exhaust valves hydraulically. The exhaust valves are closed pneumatically.
- Servo oil pumps installed on the supply unit, supply bearing oil at the applicable pressure through two high pressure (HP) oil pipes to the servo oil rail.
- Bearing oil keeps the pistons cool.
- The fuel pumps in the supply unit, supply high pressure fuel through the HP fuel pipes to the fuel rail. The fuel rail supplies high pressure fuel to all the injection valves.
- The servo oil system operates the exhaust valve control unit, cylinder lubricating pumps and gas admission valves.
- Fresh water keeps cool the cylinder liners and cylinder covers.
- The fresh water cooling system (closed circuit), or the conventional sea-water cooling system (direct) with single-stage coolers are used to keep cool the scavenge air.
- The engine control system (ECS) controls the engine start sequence. Compressed air flows through the starting valve into the cylinders to start the engine.
- The gas fuel system has an internal gas system, the gas valve unit (GVU) and an external gas supply system.
- The primary functions of the GVU are gas pressure control, leak test sequence and inert gas sequence.
- The gas system is continuously monitored. If there is a gas leak, gas detectors (GD) installed in the gas supply pipes will activate an alarm.
- The exhaust gases flow from the cylinders through the exhaust valves into an exhaust gas manifold.
- The turbocharger constantly pressurizes the gas from the manifold.
- The scavenge air from the turbocharger flows through the scavenge air cooler and water separator into the air receiver. This air then flows through air flaps and scavenge ports when the pistons are almost at BDC.
- At low loads, independently operated auxiliary blowers supply air to the scavenge air space.

# 3. Standard Engine Data

**Table 1: General Engine Data**

| | | |
|---|---|---|
| **Engine Type** | | W-X62DF |
| **Bore/Stroke** | | 620 mm / 2658 mm |
| **Number of Cylinders** | | 5 to 8 |
| **Maximum Firing Pressure** 1) | Gas Mode | 200 bar |
| | Diesel Mode | 150 bar |

Note to Table 1:

1) The last firing pressure on an engine can be lower than the guide value given in the table above. This is because of specific engine tunings.

**Table 2: Specific Engine Data Related to the Rating Fields**

| **Rating Field Corners** 1) | **Engine Speed n** | **Engine Power P** | **BSFC** 2), 3) | **BSGC** 2) | **BSPC** 2) | **BSEC** 2), 3), 4) | **Mean Piston Speed** | **Mean Effective Pressure** |
|---|---|---|---|---|---|---|---|---|
| | [rev/min] | [kW/Cyl] | [g/kWh] | [g/kWh] | [g/kWh] | [kJ/kWh] | [m/s] | [bar] |
| | | | Diesel Mode | Gas Mode | Pilot Fuel | | | |
| R1 | 103 | 2385 | 180.0 | 139.2 | 1.6 | 7028 | 9.1 | 17.3 |
| R2 | 103 | 1985 | 180.0 | 140.2 | 1.9 | 7091 | 9.1 | 14.4 |
| R3 | 80 | 1850 | 180.0 | 138.8 | 2.1 | 7030 | 7.1 | 17.3 |
| R4 | 80 | 1540 | 180.0 | 139.7 | 2.5 | 7092 | 7.1 | 14.4 |

Notes to Table 2:

BSFC − Brake Specific Fuel Consumption

BSGC − Brake Specific Gas Fuel Consumption

BSPC − Brake Specific Pilot Fuel Consumption

BSEC − Brake Specific Energy Consumption

1) R1 to R4: Corner points of the field of permitted engine ratings. The power values in kW are the standard figures.

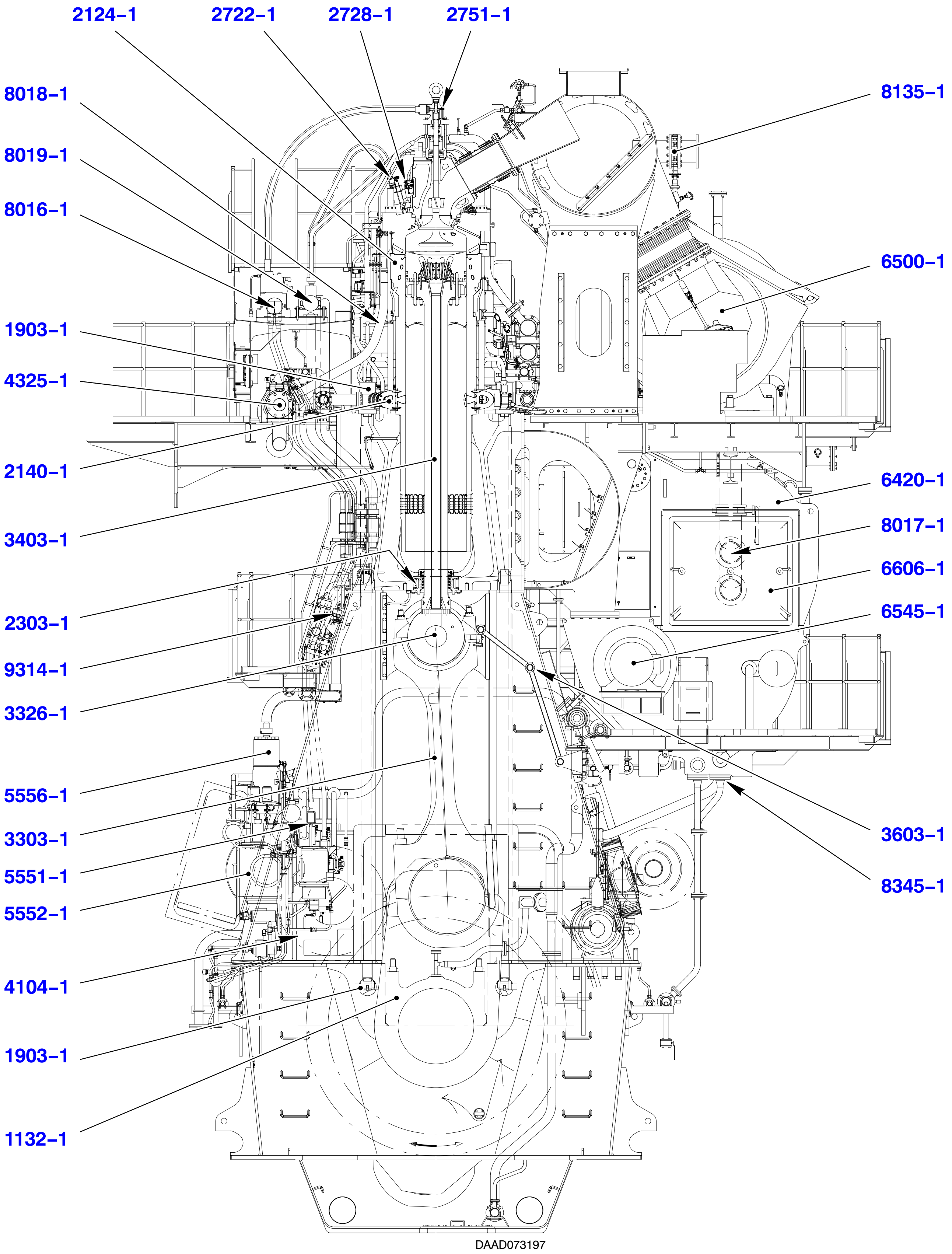
2) Lower Heating Value (LHV): $LHV_{MDO}$ = 42707 kJ/kg, $LHV_{Gas}$ = 50000 kJ/kg
Reference condition (ISO 3046−1:2002):
   - Total barometric pressure: 1.0 bar
   - Suction air temperature: 25° C
   - Water temperature − scavenge air cooling: 25° C

3) +5% tolerance at 100% engine load

4) Total energy consumption (gas mode): BSEC = BSGC x $LHV_{Gas}$ + BSPC x $LHV_{MDO}$

**Note: The data given in paragraph 3 above refer to a Standard engine and a Left engine.**

## 4. Cross Section



# 5. Longitudinal Section

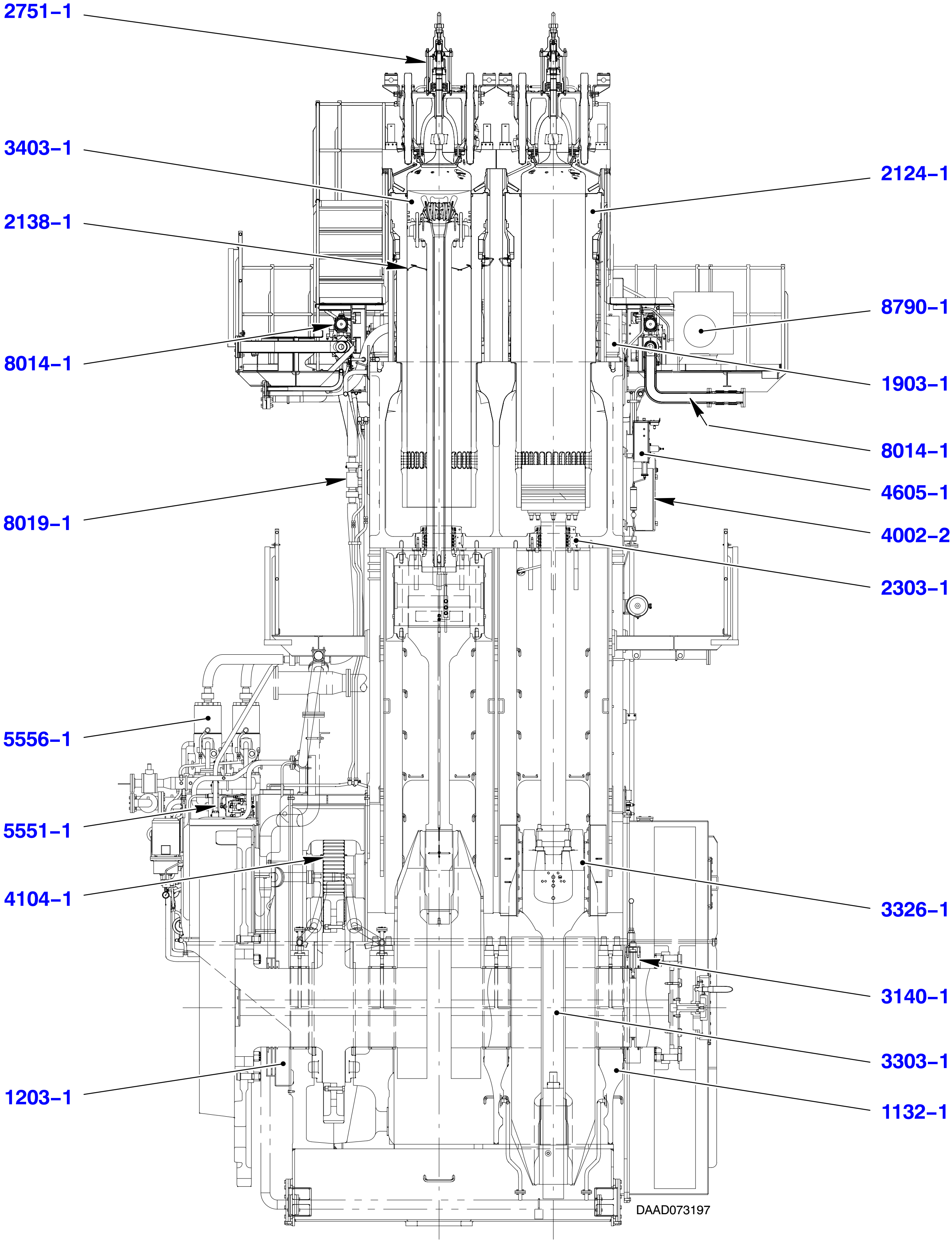



**Fig. 3: Longitudinal Section**

# 6. Engine Numbering and Designations

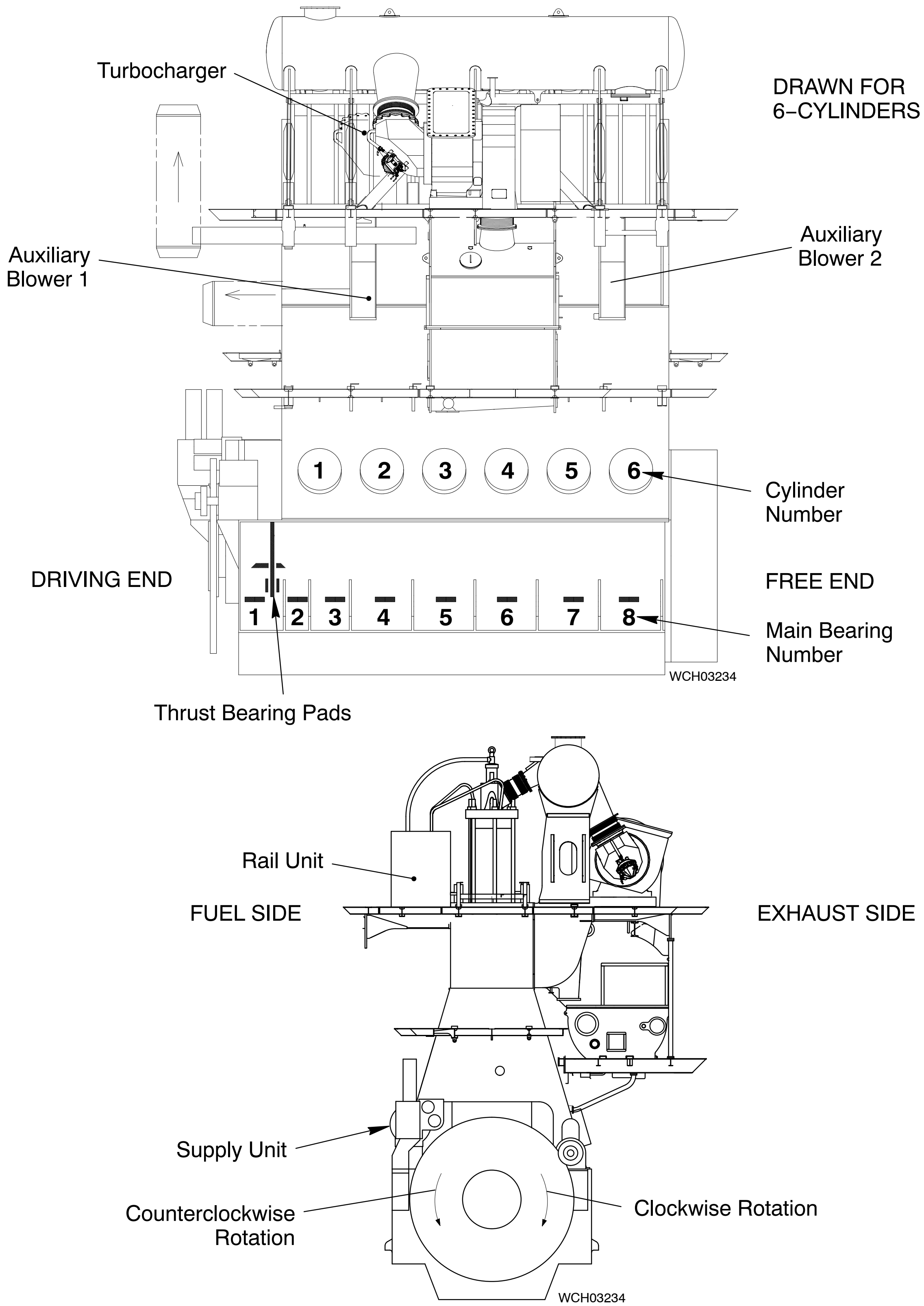
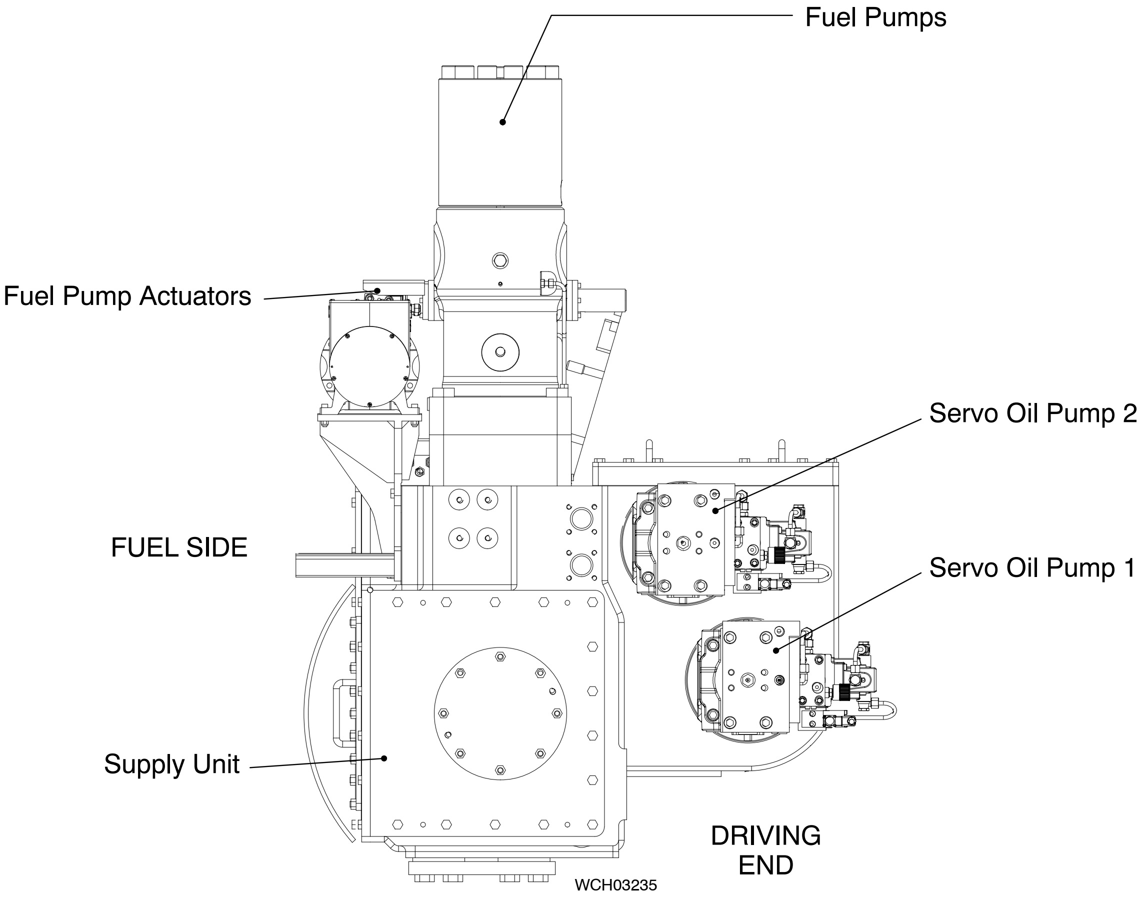



**Fig. 4: Outline View**



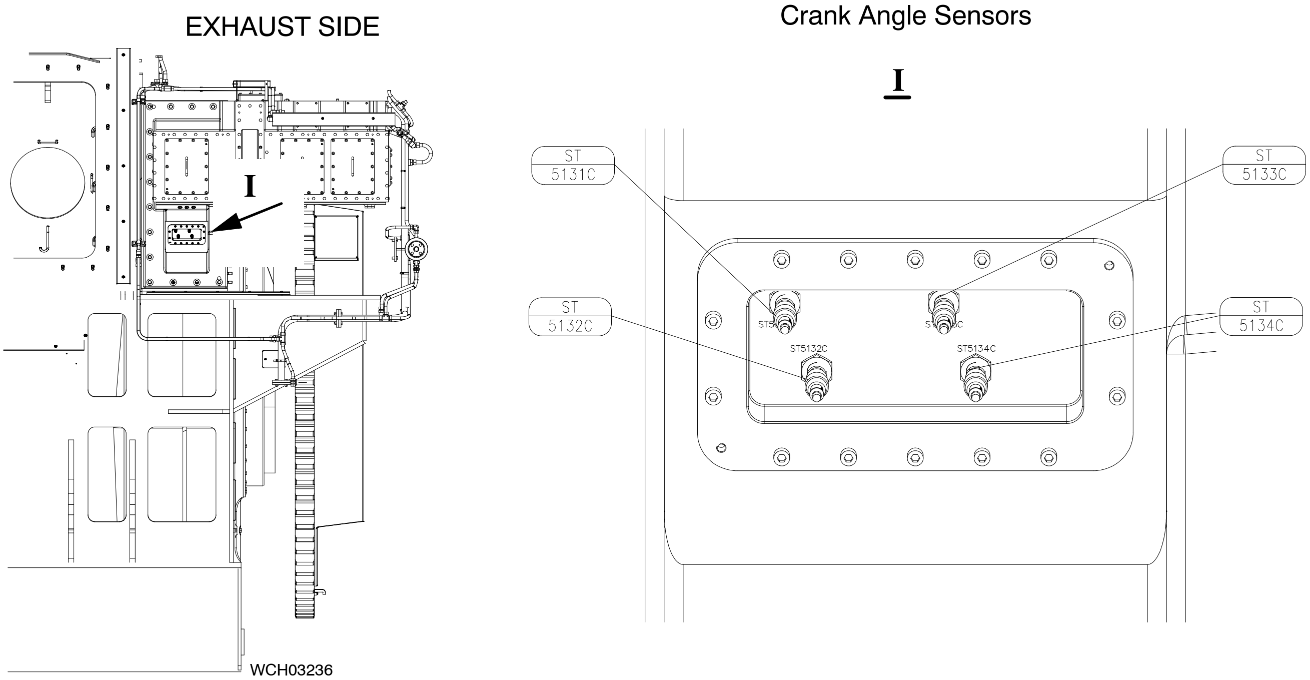




**Fig. 5: Unic Parts**

# 7. Standard and Left Engine Configuration

This Operation Manual is applicable to a ship with one Standard Engine installed in the center position in the hull.

Some ships can have two engines installed as shown in Fig. 7. The engine installed in the port position is a Standard Engine (i.e. clockwise direction). The engine installed in the starboard position is the Left Engine (i.e. counterclockwise direction).

All data applicable to the Standard Engine is also applicable to the Left Engine.

In some chapters of this Operation Manual, some parts and pipe system configurations can look different than those of a Left Engine.

**Note: All parts that are only for a Left Engine have the marks LEFT.**

**All parts for a Standard Engine, and parts that are common to each engine design do not have marks.**

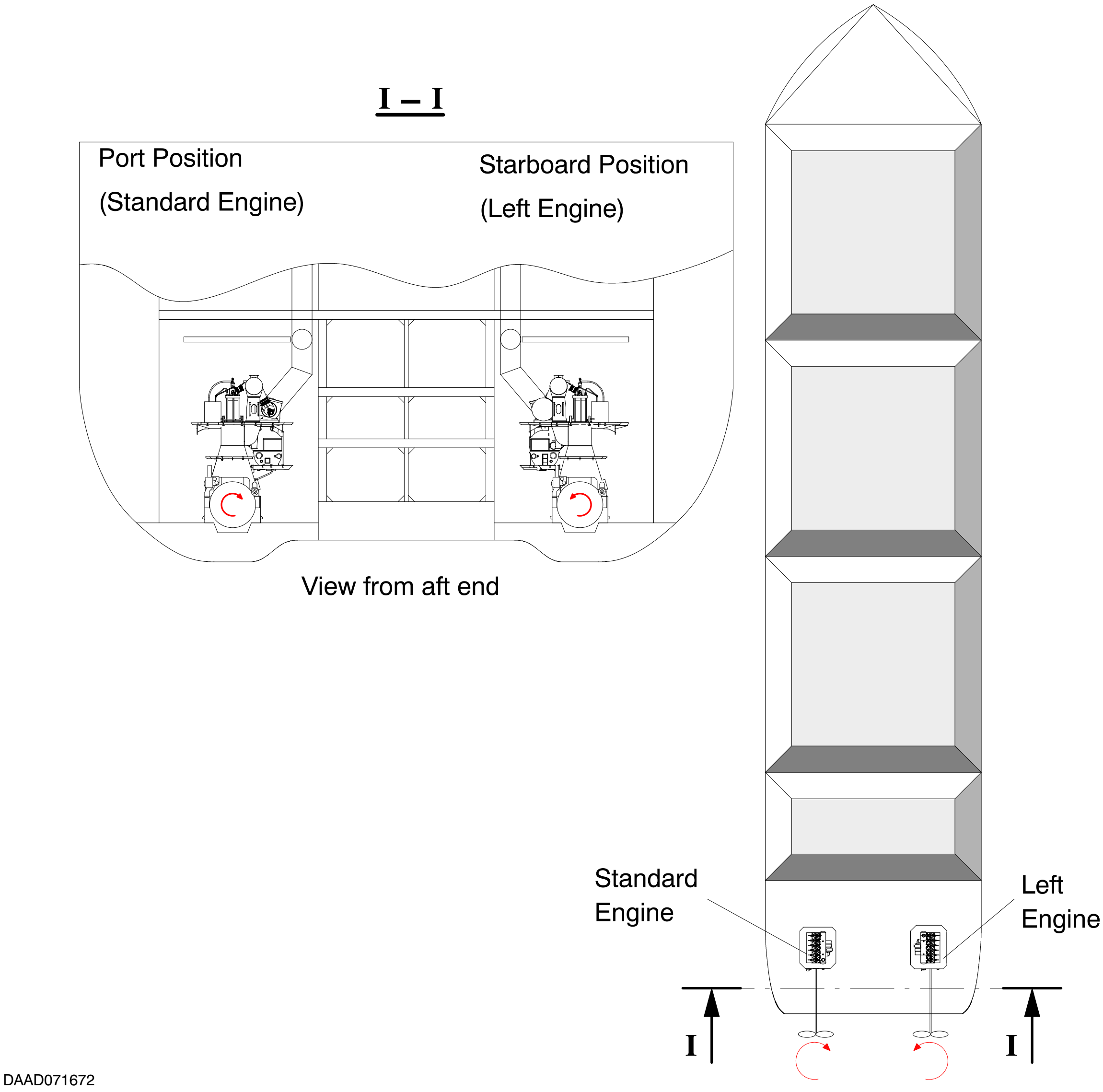



**Fig. 6: Engine Configuration**

# Engine Data
Two-stroke Dual Fuel Engine − Operation

## 1. Piston Movement − Diesel Mode

### 1.1 First Stroke (Compression)

The sequence of piston movements during the compression stroke is as follows:

- The piston is at BDC (Fig. 1).
- The scavenge ports and exhaust valve are open.
- Scavenge air flows into the cylinder and pushes the exhaust gas through the exhaust valve into the exhaust gas manifold and then to the turbocharger.
- The piston moves up.
- At ES, the piston covers the scavenge ports.
- At AS, the exhaust valve closes and compression starts, which increases the temperature of the air / diesel mixture.

### 1.2 Second Stroke (Ignition, Combustion, Expansion, Exhaust and Scavenging)

The sequence of piston movements during the second stroke is as follows:

- When the piston is almost at TDC, fuel is injected into the cylinder.
- The fuel ignites in the compressed, hot air and combustion starts.
- The gases expand and push the piston down.
- At AO, the exhaust valve opens. Exhaust gas flows out of the cylinder into the exhaust gas manifold.
- At EO, the piston continues to move down to let air flow through the scavenge ports.
- Scavenge air flows into the cylinder and pushes the exhaust gas through the exhaust valve into the exhaust gas manifold and then to the turbocharger. Refer also the schematic diagram in 6500−1 Turbocharging.

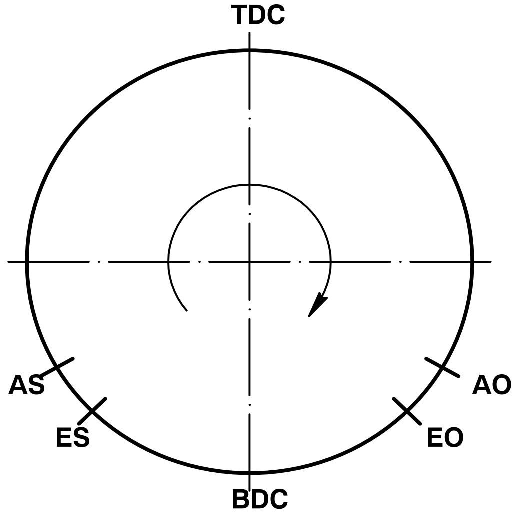



**Fig. 1: Schematic of Engine Operation − Diesel Mode**

# 2. Piston Movement – Gas Mode (Low Pressure)

## 2.1 First Stroke (Compression and Gas Admission)

The sequence of piston movements during the compression stroke is as follows:

- The piston is at BDC (see Fig. 2 and Fig. 3). The scavenge ports and exhaust valve are open.
- Scavenge air flows into the cylinder and pushes the exhaust gas through the exhaust valve into the exhaust gas manifold and then to the turbocharger.
- The piston moves up.
- At position 1, the piston covers the scavenge ports.
- At position 2, the exhaust valve closes, the piston moves up and the compression starts, which increases the temperature of the gas / air mixture.
- At position 3 the gas admission valve operates and gas flows into the combustion chamber (low pressure gas injection at less than 14 bar).
- The piston continues to move up and the compression increases, which increases the temperature of the gas / air mixture.

## 2.2 Second Stroke (Ignition, Combustion, Expansion, Exhaust and Scavenging)

The sequence of piston movements during the second stroke is as follows:

- At position 4, when the piston is almost at TDC, pilot fuel is injected into the cylinder.
- The pilot fuel ignites in the compressed, hot gas / air mixture. The combustion of the gas / air mixture starts. The piston is at TDC.
- The gases expand and push the piston down.
- At position 5, the exhaust valve opens. Exhaust gas flows out of the cylinder into the exhaust gas manifold.
- At position 6, the piston continues to move down to let air in through the scavenge ports.
- Scavenge air flows into the cylinder and pushes the exhaust gas through the exhaust valve into the exhaust gas manifold and then to the turbocharger. The piston is at BDC. Refer also the schematic diagram in 6500–1 Turbocharging.

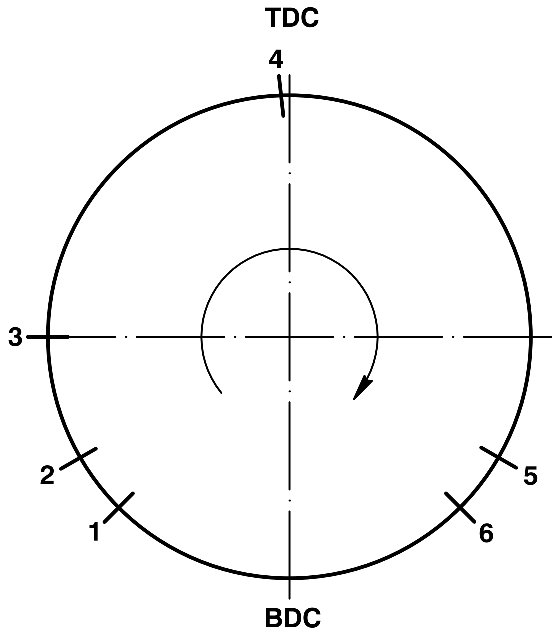



Fig. 2: Schematic Diagram of Engine Operation – Gas Mode

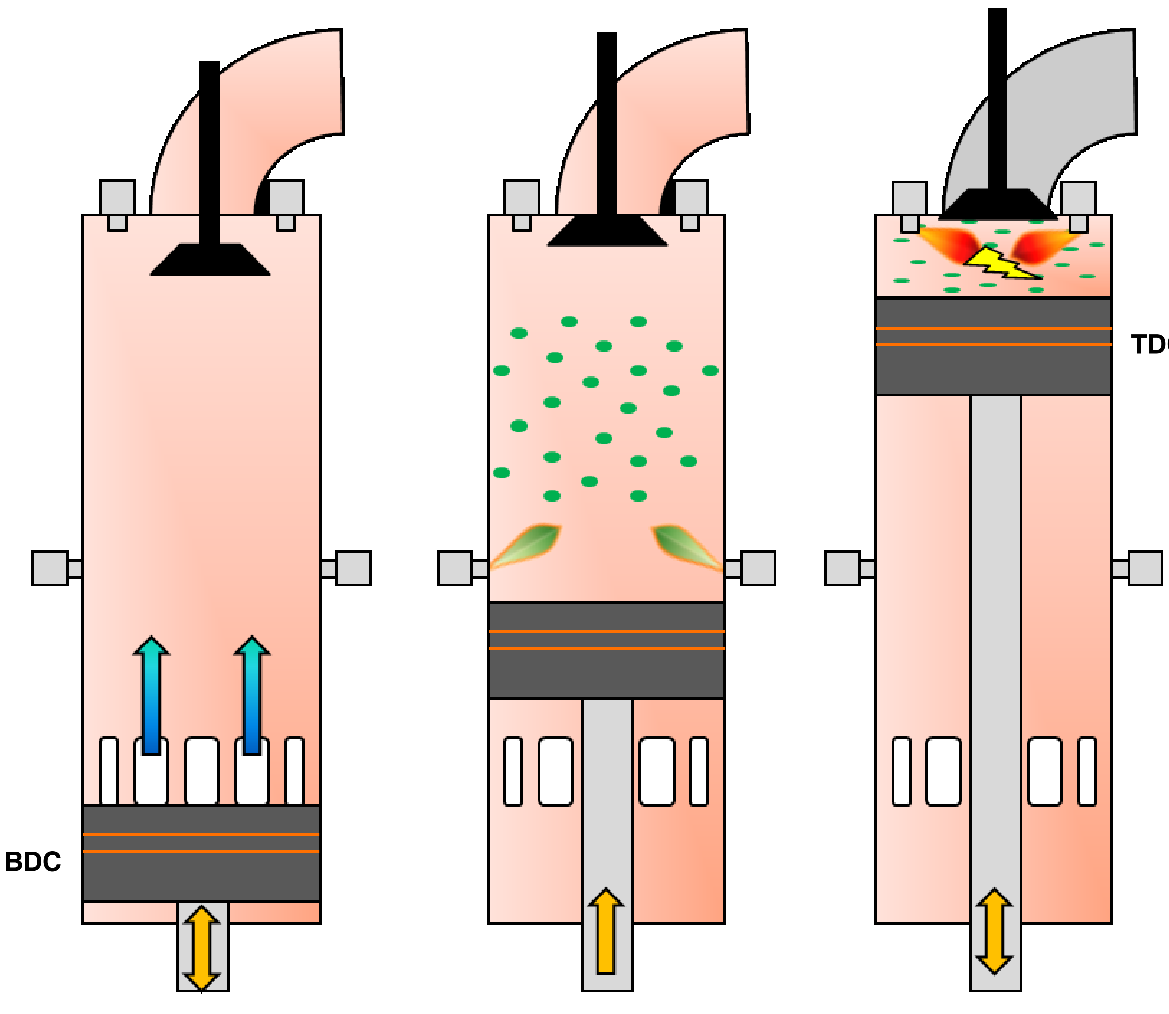



Fig. 3: Gas Mode – 2-stroke Cycle

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# Engine Data
## The Relation between Engine and Propeller



## 1. General

There is a specified relation between the propeller speed and the absorbed power in ships that have fixed pitch propellers. The relation is between the propeller and the speed at which it turns.

The formula that follows (where P = power and n = speed) gives an approximate result, which is sufficient for conventional vessels:

$$\frac{P_1}{P_2} = \left(\frac{n_1}{n_2}\right)^3$$

The graph from this formula is known as the propeller characteristic.

The mean effective pressure (mep) during operation (in accordance with the specified load indication) is related to the approximate mep for this position on the test bed when:

- The engine is in good condition and correctly supplied with fuel and air
- The turbocharger(s) are in good condition and the resistance of the air and exhaust pipes is in the specifications
- The fuel injection quantity is correctly adjusted (see the shop test protocol).

In the diagrams (see paragraph 2), the propeller property line through the CMCR point (100% power at 100% engine speed) is known as the nominal propeller characteristic. Engines which are to be used for the propulsion of vessels with fixed propellers have a load applied on the test bed in accordance with this propeller characteristic. But during the sea trial of a new ship (with a smooth and clean hull), the power specification is lower and the operation point is below the nominal propeller characteristic.

During operation, a higher torque will be necessary for the propeller to keep its speed than at the time of the sea trial (sea margin) because:

- Marine growth on the hull cause changes in wake flow conditions.
- The cargo load has an effect on the depth of the vessel in the water.
- The propeller has a rough surface or has mechanical damage.
- The vessel operates in bad sea and weather conditions.
- The vessel operates in shallow water. The mep of the engine (and thus the fuel injection quantity) will increase. In such a condition, the operating point will then be at the left of the initial propeller curve which was calculated during sea trials.

A hull that was cleaned and painted will help to decrease the resistance as the vessel moves through the water. It is not possible, to get the hull back to its initial condition.

Because the thermal load of the engine is related to the mep, the position of the operating point is also important. The air supply to the engine and the operating conditions will become unsatisfactory if the operation point is far above the propeller curve.

To get the best conditions, the operation point of the engine for service range must be on or below the nominal propeller characteristic.

# 2. Fixed Pitch Propeller (FPP)

## 2.1 Continuous Service Rating (CSR)

Point A (Fig. 1 and Fig. 2) shows the power and speed of a ship that operates at specified speed in calm seas with a new clean hull and propeller. A power / speed combination at point D is necessary for the same ship at the same speed during service conditions with aged hull and average weather. Point D is then the CSR point.

## 2.2 Engine Margin (EM) / Operational Margin (OM)

Most owners specify the loaded service speed of the ship at 85% to 90% of the contract maximum continuous rating (CMCR). The remaining 10% to 15% of power can be used to catch up with changes in schedules or for the timing of dry-dock intervals. This margin is usually subtracted from the CMCR. Thus, to get the 100% power line, you divide the power at point D by between 0.85 to 0.90.

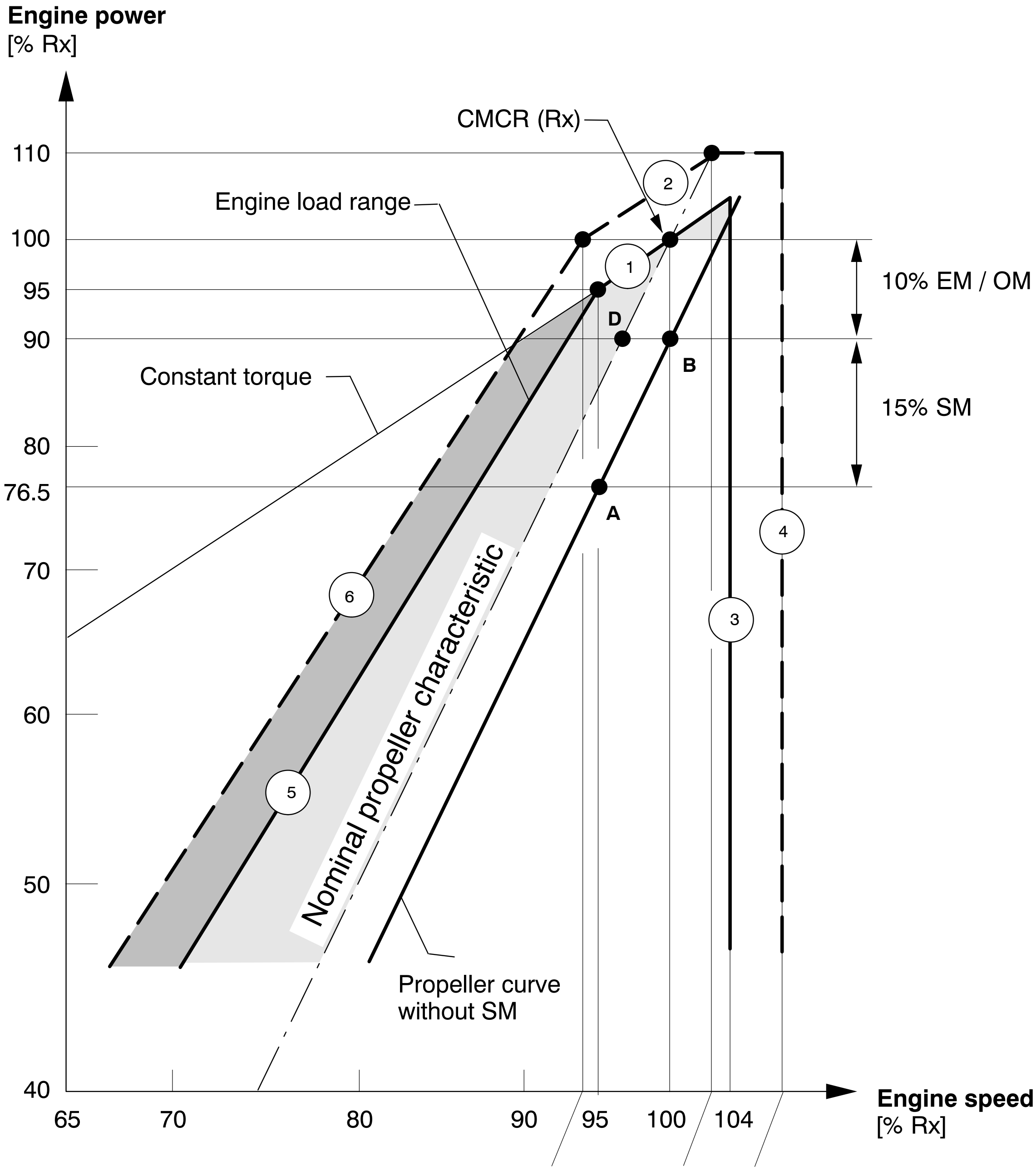
## 2.3 Load Range Limits

When the engine has the best values at CMCR (Rx), the limits that follow give the load range of the engine:

- Line 1 is a constant mep or torque line through CMCR from 100% speed and power down to 95% speed and power.
- Line 2 (applicable only for engine operation in diesel mode) is the overload limit. This is a constant mep line from 100% power and 93.8% speed to 110% power and 103.2% speed. 103.2% speed is the intersection point between the nominal propeller property and 110% power.
- Line 3 is the 104% speed limit where an engine can operate continuously. For Rx with decreased speed ($N_{CMCR} \leq 0.98\ N_{MCR}$) this limit can be extended to 106%, but, the torsional vibration must not be more than the specified limits.
- Line 4 is the overspeed limit. The overspeed range between 104% (106%) and 108% speed is only permitted during sea trials if necessary. This is to demonstrate the speed of the ship at CMCR power with a light running propeller in the presence of authorized representatives of the engine builder. The torsional vibration must not be more than the specified limits.
- Line 5 is the permitted torque limit from 95% power and speed to 45% power and 70% speed. The equation $P_2/P_1 = (N_2/N_1)^{2.45}$ shows a curve. When the engine speed and power is near the data in Line 5 there will be a decrease in scavenge air, which has an effect on the engine. The area between Lines 1, 3 and 5 show the range in which the engine must be operated. The area in the nominal propeller characteristic, 100% power and Line 3 is recommended for continuous operation. The area between the nominal propeller property and Line 5 must be kept for acceleration, shallow water and usual flexibility of operation.

- Line 6 (applicable only for engine operation in diesel mode) gives the equation: $P_2/P_1 = (N_2/N_1)^{2.45}$ through 100% power and 93.8% speed and the maximum torque limit different conditions. The area above Line 1 is the overload range. You must only operate the engine in this range for a maximum of one hour during sea trials in the presence of authorized representatives of the engine builder. The area between Lines 5 and 6 and the constant torque line (shown as a dark area) must only be used for transient conditions, i.e. during fast acceleration. This range is known as the service range with operational time limit.

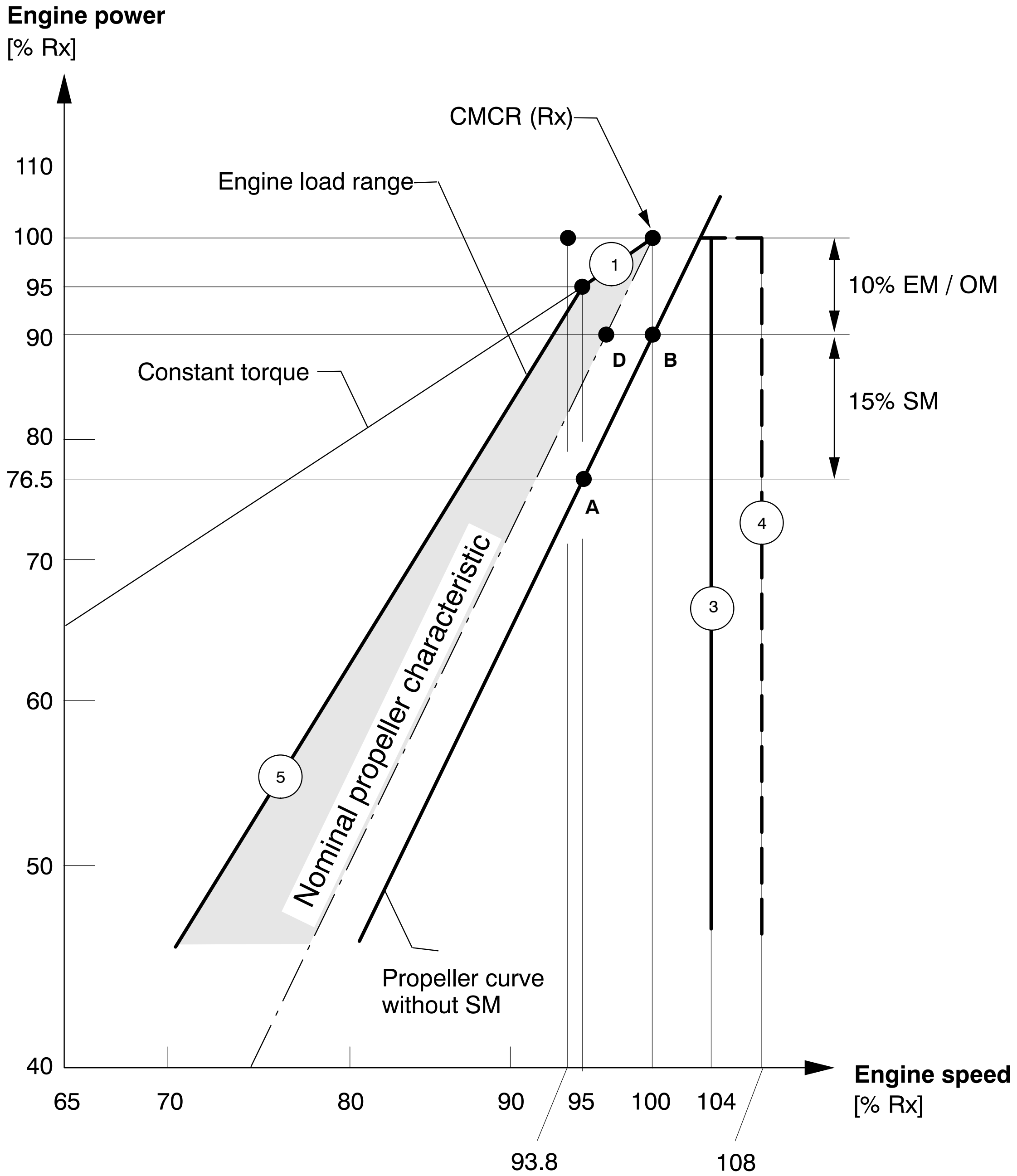
**Load range limits with load diagram of an engine related to a specified rating point Rx**




EM Engine Margin
OM Operational Margin
SM Sea Margin

**Fig. 1: Load Range Limits – Diesel Mode**

**Load range limits with load diagram of an engine related to a specified rating point Rx**




EM Engine Margin
OM Operational Margin
SM Sea Margin

**Fig. 2: Load Range Limits – Gas Mode**

# 3. Controllable Pitch Propeller (CPP)

## 3.1 Load Ranges

After engine start, the engine is operated at an idle speed of up to 70% of the rated engine speed with zero pitch. From idle speed, the propeller pitch must be increased with constant engine speed to the minimum at point E, the intersection with Line 6.

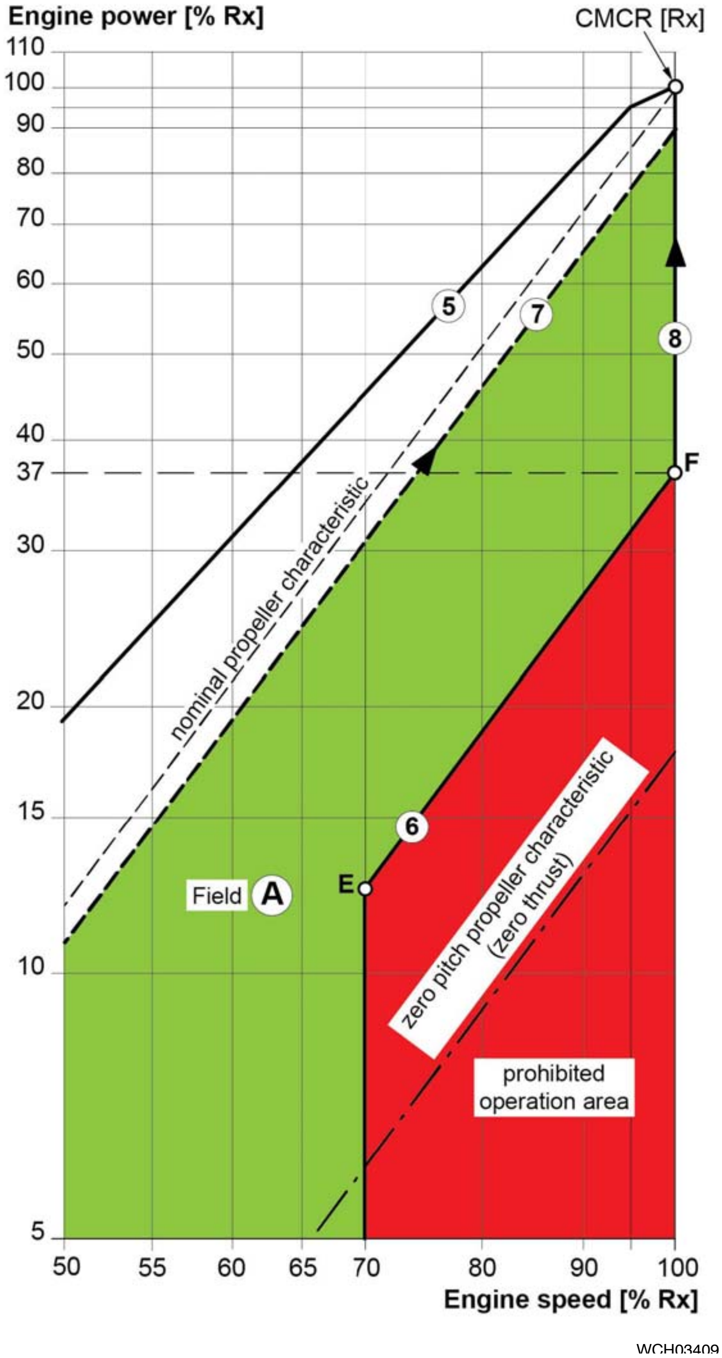



**Fig. 3: Schematic Diagram of Speed / Power Relation (CPP)**

- Line 5 is the top load limit and relates to the permitted torque limit.
- Line 6 shows the zero pitch load that is caused by the resistance of the propeller blades (zero pitch) in the water.
- Line 7 shows a propeller characteristic curve at 90% CMCR [Rx].
- Along Line 8, the power increase from 17% (point F, zero pitch load) to 100% power (CMCR) at 100 % speed. This is the constant speed mode for shaft generator operation (electrical sea load with constant frequency).
- The area A shows the available design range for combinator operation between Line 6, Line 7 and Line 8. You must obey the speed range limits related to the torsional vibrations limits.

Maneuvering at maximum speed with low or zero pitch is not permitted.

Engine operation with zero pitch is only permitted for short periods during maneuvering, e.g. to supply electrical power to the thrusters.

Installations with main engine-driven generators must have a frequency converter when electrical power is to be supplied (e.g. to thrusters) at constant frequency during manoeuvring. As an alternative, power from auxiliary engines can be used for this purpose.

## 3.2 Control System

The CPP control functions are usually part of the engine control system and include the functions in the paragraphs that follow.

### 3.2.1 Combinator Mode 1

Combinator mode for operation without a shaft generator. A combinator curve that includes an applicable light running margin can be set in the permitted operation area, Line 7 (see Fig. 3).

### 3.2.2 Combinator Mode 2

An optional mode used in connection with shaft generators. During maneuvering, the combinator curve follows Line 6. At sea the engine is operated between point F and 100% power (Line 8) at constant speed .

For manual and/or emergency operation, different setpoints for speed and pitch are usually supplied. Obey the data given on the related warning plate.

An alarm is also usually given in the main engine safety system, or the alarm and monitoring system when the engine operates for more than three minutes in the operation area that is not permitted. If the engine operates for more than five minutes in the operation area that is not permitted, the engine speed must be decreased to idle speed (less than 70% ).

# Engine Data

## Operating Data Sheet – Pressure and Temperature Ranges at Continuous Service Power MCR

| Medium | System | Location | Gauge Pressure [bar] | | Temperature [°C] | | |
|---|---|---|---|---|---|---|---|
| | | | Min. | Max. | Min. | Max. | Diff. |
| **Fresh Water** | Cylinder cooling | Inlet | 4.0 | 5.0 | 70 | – | max. 15 |
| | | Outlet each cylinder | – | – | 85 | 95 | |
| | SAC, low temperature circuit LT (single-stage scavenge air cooler) | Inlet | 2.0 | 4.0 | 25 | 36 | Note (3) |
| | | Outlet | – | – | – | 80 | |
| **Lubricating Oil (high pressure)** | Crosshead bearing | Inlet | 12.0 | 14.0 | 40 | 50 | |
| | | Outlet | – | – | – | 65 | |
| **Lubricating Oil (low pressure)** | Servo oil | Pumps inlet | 3.0 | 5.5 | – | – | – |
| | Main bearing oil | Inlet | 4.0 | 5.0 | 40 | 50 | – |
| | Piston cooling oil | Inlet | 4.0 | 5.0 | 40 | 50 | max. 30 |
| | | Outlet | – | – | – | 80 | |
| | Thrust bearing pads | Pads foreside | – | – | – | 80 | – |
| | Torsional vibration damper (if steel spring damper is installed) | Supply | 4.0 | 5.0 | – | – | – |
| | | Housing inlet | 1.5 | – | – | – | – |
| | Integrated axial damper (chamber pressure) | Supply | 4.0 | 5.0 | – | – | – |
| | | Monitoring | 1.7 | – | – | – | – |
| | Turbocharger bearing oil (ABB, A100L type) (with internal oil supply) | Inlet | 1.0 | 2.5 | – | – | – |
| | | Housing outlet | – | – | – | 110 | – |
| | Turbocharger bearing oil (ABB, A100L type) (with external oil supply) | Inlet | 1.3 | 2.5 | – | 85 | – |
| | | Housing outlet | – | – | – | 130 | – |
| **Sealing Oil (Gas admission valve)** | Servo oil | After pressure reducing valve 90–8482_E0_2 | 13 | 25 | – | – | – |
| **Diesel Fuel** | Supply unit | Inlet (fuel pump) | 7.0 Note (1) | 10.0 Note (2) | – | 150 | – |
| | Downstream of pressure retaining valve | Return (fuel pump) | 3.0 | 5.0 | – | – | – |
| **Pilot Fuel** | Pilot fuel unit | Inlet | 5.5 | 7.5 | 30 | 40 | – |
| **Gas Fuel** | Gas fuel | Gas supply at GVU (less than or equal to 15% engine load) Note (5) and (7) | 5.2 | 6.2 | 0 | 60 | – |
| | | Gas supply at GVU in tropical conditions (less than or equal to 15% engine load) Note (5) and (7) | 5.2 | 6.2 | 20 | 60 | – |
| | | Gas supply at GVU (max. engine load) Note (5) and (7) | 15.0 | 16.0 | 0 | 60 | – |
| | | Gas supply at GVU in tropical conditions (max. engine load) Note (5) and (7) | 15.0 | 16.0 | 20 | 60 | – |
| | | Gas supply at GVU (variable supply pressure) Note (8) | see Note (8) | | see Note (8) | | – |

| Medium | System | Location | Gauge Pressure [bar] | | Temperature [°C] | | |
|---|---|---|---|---|---|---|---|
| | | | Min. | Max. | Min. | Max. | Diff. |
| **Scavenge Air** | Scavenge air cooler (SAC) | Downstream of SAC | | | 25 | 80 | − |
| | Intake from engine room (pressure decrease) | Air filter / silencer | max. 10 mbar | | − | − | − |
| | Intake from outboard (pressure decrease) | Ducting and filter | max. 20 mbar | | − | − | − |
| | SAC (pressure decrease) | new SAC | max. 30 mbar | | − | − | − |
| | | fouled SAC | max. 50 mbar | | − | − | − |
| **Air** | Starting air | Engine inlet | 12.0 | 25 / 30 | − | − | − |
| | Control air | Engine inlet | 6.0 | 7.5 | − | − | − |
| | | | Usual 6.5 | | − | − | − |
| | Air spring of exhaust valve | Main distributor | 6.0 | 7.5 | − | − | − |
| | | | Usual 6.5 | | − | − | − |
| **Exhaust Gas** | Receiver | Downstream of each cylinder | − | − | − | 515 | Tolerance ±50 Note (4) |
| | | Turbocharger inlet | − | − | − | 515 | − |
| | Manifold downsteam of turbocharger | new | max. 30 mbar | | − | − | − |
| | | fouled | max. 45 mbar | | − | − | − |

For the limits of the alarm, slow-down and shutdown signals (see 0230−2 Alarms and Safeguards at Continous Service Power).

(1) At 100% engine load.

(2) At stand-by condition; during commissioning of the fuel system, the fuel pressure at the inlet of the fuel pumps is adjusted to 10 bar.

(3) The water flow must be in the specified limits (scavenge air cooler specification).

(4) Maximum temperature difference between the cylinders

(5) Data for R1 engine ratings. For data about lower engine ratings, speak to or send a message to Winterthur Gas & Diesel Ltd.

(6) Nominal value. This value is applicable only for engine operation in gas mode.

(7) Values for constant gas supply pressure.

(8) Values for variable gas supply pressure. For the applicable values see the data given in the Marine Installation Manual (MIM), paragraph 1.3.2 Gas Supply Pressure.

# Engine Data

## Operating Data Sheet – Alarms and Safeguards at Continuous Service Power

| Medium | Unit | Location | Signal No. (1) | Func-tion (2) | Type of signal (3) | Setting value [bar or °C] | Time Interval [sec] |
|---|---|---|---|---|---|---|---|
| **Cylinder Cooling Water** | Pressure | Engine inlet | PT1101A | ALM | L | 4.0 bar | 0 |
| | | | | SLD | L | 3.8 bar | 60 |
| | | | PS1101S | SHD | L | 3.5 bar | 60 |
| | Temperature | Engine inlet | TE1111A | ALM | L | 70°C | 0 |
| | | Outlet each cylinder | TE1121–28A | ALM | H | 95°C | 0 |
| | | | | SLD | H | 97°C | 60 |
| **Scavenge Air Cooling Water** | Pressure | Cooler inlet | PT1361A | ALM | L | 2.0 bar | 0 |
| Single stage SAC, Fresh water see Note (4) | Temperature | Cooler inlet | TE1371A | ALM | L | 25°C | 0 |
| | | Cooler outlet | TE1381A | ALM | H | 80°C | 0 |
| **Lubricating Oil, Bearing and Piston Cooling** | Pressure | Engine inlet | PT2001A | ALM | L | 4.0 bar | 0 |
| | | | | SLD | L | 3.8 bar | 60 |
| | | | PS2002S | SHD | L | 3.3 bar | 10 |
| | Pressure | Before injectors | PT2003A | ALM | L | 2.6 bar | 0 |
| | Temperature | Engine inlet | TE2011A | ALM | H | 50°C | 0 |
| | | | | SLD | H | 55°C | 60 |
| | Temperature | Bearing outlet | TE2101–10A | ALM | H | 65°C | 0 |
| | | | | SLD | H | 70°C | 60 |
| **Servo Oil** Pulse Lubrication | Pressure | Engine free end | PT2041A | ALM | H | 75.0 bar | 3 |
| | | | | ALM | L | 40.0 bar | 3 |
| **Servo Oil** | Flow | Servo oil pump inlet | FS2061–62A see Note (4) | ALM | L | no flow | 0 |
| **Servo Oil Leakage Monitoring** | Level | Servo Oil supply unit see Note (5) | LS2055A | ALM | H | max. | 0 |
| **Thrust Bearing Oil** | Temperature | Thrust bearing Pads (ahead) | TE4521A | ALM | H | 80°C | 0 |
| | | | | SLD | H | 85°C | 60 |
| | | | TS4521S | SHD | H | 90°C | 0 |
| **Crank Bearing Oil** | Temperature | Outlet | TE2201–08A | ALM | H | 65°C | 0 |
| | | | | SLD | H | 70°C | 60 |
| **Crosshead Bearing Oil** | Temperature | Outlet | TE2301–08A | ALM | H | 65°C | 0 |
| | | | | SLD | H | 70°C | 60 |
| | Pressure | Booster Pump Supply | PT2021A Note (11) | ALM | L | 12.0 bar | 0 |
| | | | | SLD | L | 11.0 bar | 60 |
| **Oil Mist** | Concentration | Crankcase | AE2401–08A | ALM | H | – | 0 |
| | | | AS2401A | ALM | H | – | 0 |
| | | | AS2401S | SLD | H | – | 60 |
| | | | AE2421A | ALM | H | – | 0 |
| | | Crankcase gear case | AE2415A | ALM | F | – | 0 |
| | Failure | Detection unit | XS2411A | ALM | F | – | 30 |
| **Piston Cooling Oil** | Temperature | Outlet each cylinder | TE2501–08A | ALM | H | 80°C | 0 |
| | | | | SLD | H | 85°C | 60 |
| | Flow | Inlet each cylinder | FS2521–28S | SHD | H | – | 15 |
| | | | | SHD | L | – | 15 |

Operating Data Sheet – Alarms and Safeguards at Continuous Service Power

| Media | Unit | Location | Signal No. (1) | Func-tion (2) | Type of signal (3) | Setting value [bar or °C] | Time Interval [sec] |
|---|---|---|---|---|---|---|---|
| **Turbocharger Oil – Internal Oil Supply (ABB A100-L / A200-L)** | Pressure | Inlet | PT2611A see Note (6) | ALM | L | 1.0 bar | 5 |
| | | | | SLD | L | 0.8 bar | 60 |
| | | | PS2611S | SHD | L | 0.6 bar | 5 |
| | Temperature | Housing outlet | TE2601A | ALM | H | 110°C | 0 |
| | | | | SLD | H | 120°C | 60 |
| **Turbocharger Oil – External Oil Supply (ABB A100-L / A200–L)** | Pressure | Inlet | PT2611A see Note (6) | ALM | L | 1.3 bar | 5 |
| | | | | SLD | L | 1.1 bar | 60 |
| | | | PS2611S | SHD | L | 0.9 bar | 5 |
| | Temperature | Housing outlet | TE2601A | ALM | H | 130°C | 0 |
| | | | | SLD | H | 140°C | 60 |
| **Turbocharger Oil – External Oil Supply (More Requirements, ABB A100-L / A200–L)** | Temperature | Inlet | TE2621A | ALM | H | 85°C | 0 |
| | | | | SLD | H | 90°C | 60 |
| **Turbocharger Overspeed** | Speed | TC housing | ST5201A | ALM | H | see Note (7) | 0 |
| **GEISLINGER Damper Oil** | Pressure | Casing inlet | PT2711A | ALM | L | 1.5 bar | 0 |
| **Axial Damper Oil** | Pressure | Chamber rear | PT2721A | ALM | L | 1.7 bar | 60 |
| | | Chamber front | PT2722A | ALM | L | 1.7 bar | 60 |
| **Cylinder lubricating oil** | Pressure | Supply | PT3124A | ALM | L | 0.1 bar | 30 |
| **Fuel Oil** | Temperature see Note (8) | Upstream of the supply unit | TE3411A | ALM | H | 50°C to 160°C | 0 |
| | | | | ALM | L | 20°C to 130°C | 0 |
| | Pressure | Supply unit | PT3421A | ALM | L | 7.0 bar | 0 |
| | Viscosity | Upstream of the supply unit | | ALM | H | 17 cSt | 0 |
| | | | | ALM | L | 13 cSt | 0 |
| **Fuel Leakage Monitoring** | Level | Supply unit | LS3426A | ALM | H | max. | 0 |
| | | Rail unit (general) | LS3444A | ALM | H | max. | 0 |
| | | Fuel pipe | LS3446A | ALM | H | max. | 0 |
| **Fuel Heating** | Failure | Heating pipe | XS3463A | ALM | F | – | 0 |
| **Exhaust Gas** | Temperature | Downstream of each cylinder | TE3701–08A | ALM | H | 515°C | 0 |
| | | | | ALM | D | ±50°C | 0 |
| | | | | SLD | H | 530°C | 60 |
| | | | | SLD | D | ±70°C | 60 |
| | | Upstream of each Turbocharger | TE3721A | ALM | H | 515°C | 0 |
| | | | | SLD | H | 530°C | 60 |
| | | Downstream of each Turbocharger | TE3731A | ALM | H | 480°C | 0 |
| | | | | SLD | H | 500°C | 60 |
| **Scavenge Air** | Temperature | Air receiver downstream of cooler | TE4031A see Note (9) | ALM | L | 25°C | 0 |
| | | | | ALM | H | 60°C | 0 |
| | | | | SLD | H | 70°C | 60 |
| | Temperature | each piston underside (fire detection) | TE4081–88A see Note (10) | ALM | H | 80°C | 0 |
| | | | | SLD | H | 120°C | 60 |

| Media | Unit | Location | Signal No. (1) | Function (2) | Type of signal (3) | Setting value [bar or °C] | Time Interval [sec] |
|---|---|---|---|---|---|---|---|
| **Condensation Water – Scavange Air Receiver, see Note (11)** | Level | Water separator | LS4071A | ALM | H | max. | 0 |
| | | | | SLD | H | max. | 60 |
| | | Upstream of the water separator | LS4075A | ALM | H | max. | 0 |
| | | | | SLD | H | max. | 60 |
| **Air Spring Air** | Pressure | Distributor | PT4341A | ALM | H | 7.5 bar | 0 |
| | | | | ALM | L | 5.5 bar | 0 |
| | | | | SLD | L | 5.0 bar | 60 |
| | | | PS4341S | SHD | L | 4.5 bar | 0 |
| **Leakage Oil Of Air Spring Air** | Level | Exhaust valve air spring, driving end | LS4351A | ALM | H | max. | 0 |
| | | Exhaust valve air spring, free end | LS4352A | ALM | H | max. | 0 |
| **Control air** | Pressure | Supply | PT4401A | ALM | L | 6.0 bar | 0 |
| | | | PT4411A | ALM | L | 5.5 bar | 0 |
| | | Engine inlet | PT4421A | ALM | L | 5.0 bar | 0 |
| **Pilot Fuel** | Pressure Difference | Pilot fuel filter inlet | PS3464A | ALM | H | (see Note 12) | – |
| **Starting Air** | Pressure | Engine inlet | PT4301–02C | ALM | L | 12.0 bar | 0 |
| **Actuator Fuel Pump** | Failure | Fuel pump | XS5056A | ALM | F | – | 0 |
| **Cylinder Liner Wall** | Temperature | Cylinder liner (aft side) | TE4801–08C | ALM | H | 220°C | 0 |
| | | | | SLD | H | 240°C | 60 |
| | | Cylinder liner (fore side) | TE4841–48C | ALM | H | 220°C | 0 |
| | | | | SLD | H | 240°C | 60 |
| **Engine Performance Data Overspeed** | Speed | Crankshaft | ST5111–12S | SHD | H | 110% | 0 |
| **Gas Detector** | Concentration | Piston Underside | AE3315S | ALM | H | 20% | 0 |
| | | | | GTrip | H | 30% | 0 |

(1) Signal number shows the interface to the remote control (see 4003–2).

(2) Function:
SLD = Slow down
SHD = Shut down
ALM = Alarm
GTrip = Gas trip (the ECS automatically changes to diesel mode)

(3) Type of signal:
D = Difference in value
F = Failure
H = High
L = Low.

(4) Alarm has an effect only above 30% engine power.

(5) For the location of measurements and signal numbers, see 8016–1, paragraph 4, Servo Oil Leakage and 8019–1, paragraph 4, Fuel Leakage System.

(6) The alarm and slow-down values shown are the minimum settings permitted (from the TC manufacturer). To get a warning in a shorter time, the ALM and SLD values can be increased up to 0.4 bar below the minimum effective pressure (measured in the full operation range). The last ALM/SLD setting is found during commissioning / sea trial of the vessel.

(7) The ALM value is related to the turbocharger type. The SLD signal is optional. For more data, speak to or send a message to Wärtsilä Services Switzerland Ltd.

(8) The ALM value is related to the fuel viscosity of the fuel oil. For more data, see 0300−1 Diesel Engine Fuels.

(9) If the water separator is made of plastic material, you must install the sensor directly downstream the water separator.

(10) The temperature element has the function to detect a fire in the piston underside.

(11) Alarm is effective only above 40 % engine load.

(12) For the applicable setting value, refer to the data from the filter manufacturer.

# Operating Media
## Diesel Engine Fuels



## 1. General

Almost all mineral residual and distillate and some renewable fuels can be burned in a diesel engine if applicable procedures are done. But, the quality of the fuel will have an effect on the frequency of overhauls and the work necessary to prepare the fuel. It is the primary economic considerations that according to the type, size and speed of the engine and its application, gives the fuel quality margins.

Gas oils and diesel oils (distillates) can be used in all Wärtsilä engines with some limits. Wärtsilä 2-stroke diesel engines are designed to operate on up to 700 mm$^2$/s (cSt) at 50°viscosity heavy fuel oil (ISO 8217:2010 RMK 700 grade) if sufficient fuel heating and treatment is done. When fuels with a very low sulphur content are used, operators must be careful when running-in new piston rings and cylinder liners.

Heavy fuel oil must have treatment in an applicable fuel treatment plant.

When bunkering, it is possible that the fuel suppliers will report only some of the values given in the Quality Specifications. Frequently, only the density and maximum viscosity is given. This makes the analysis of a fuel difficult, thus it is important to get a full certificate of analysis with each bunker.

The supplier must guarantee the stability of the fuel, i.e. resistance to the formation of sludge. Also, the fuel must not have a corrosive effect on the injection equipment and must not contain used lubricating oil or chemical waste.

If possible, oils from different bunkers must not be mixed because there is a risk that the fuels will have different compositions (e.g. this can cause fouling of filters or too much sludge, which will overload the fuel preparation equipment). Fresh bunkers must always be put into empty tanks and not on top of old bunkers.

## 2. Heavy Fuel Oil

Diesel engine fuels include many different petroleum products from gas oil to Heavy Fuel Oil (HFO). Gas oil is made from crude oil by distillation and processing. HFO is the remaining material after distillation of the crude oil. To get the necessary viscosity, the material is mixed with lighter, less viscous components. Modern refineries also apply a secondary conversion process, such as viscosity breaking (visbreaking) and catalytic cracking to get a higher yield of lighter products. The remaining products are mixed to get HFO.

Viscosity is usually used to identify diesel engine fuels. The viscosity is shown in $mm^2/s$, referred to as centistokes (cSt) and measured at 50°C. The fuels are classified in accordance with ISO 8217 and the latest revision is the fourth edition dated 15 June 2010.

Viscosity itself is not a quality criterion. To make an analysis of the fuel quality (to make sure that the fuel is applicable for use in a diesel engine), refer to the properties such as those given in Table 1.

To make an estimate of the ignition properties of a distillate diesel fuel, the CETANE number (standardized engine test) or the CETANE index (calculation) were used. The ignition and combustion properties are very important for medium and high-speed engines. For low-speed diesel engines, the ignition properties are not very important.

**Note: Some very poor diesel engine fuels that are not frequently found can have important ignition properties.**

Very good supervision, engine maintenance and fuel treatment equipment is necessary when fuel with properties near the maximum limits are used. Fuel preparation that is not sufficient and poor quality fuels cause overhauls to be more frequent and thus, an increase in the cost of maintenance.

The values in the column Bunker limit (ISO 8217:2010 RMK700) show the minimum quality of heavy fuel as bunkered, i.e. as supplied to the ship/installation. Good operation results come from commercially available fuels that are in the ISO 8217 limits. But the use of fuel with metal, ash and carbon contents and a lower density can have a positive effect on overhaul periods. These effects can improve combustion and exhaust gas composition as well as a decrease in wear.

The fuel as bunkered must be processed before it goes into the engine. It is recommended that you refer to the related specifications of Winterthur Gas & Diesel Ltd. for the design of the fuel treatment plant. The minimum centrifuge capacity is 1.2 x CMCR x BSFC / 1000 (litres/hour), which is has a relation to 0.21 l/kW. The fuel treatment must remove sludge and decrease catalyst fines and water to the recommended engine inlet limits.

In ISO 8217, foreign substances such as used oil or chemical waste must not be added to the fuel. This is because of the hazards to the crew, machines and the environment. Tests that are done for unwanted substances as acids, solvents and monomers with titrimetric, infrared and chromatographic methods, are recommended. This is because of the damage these foreign substances can cause to fuel treatment, fuel injection equipment, pistons, rings, liners, and exhaust valves and seats. Turbocharger, exhaust system and boiler contamination can also occur because of poor fuel quality.

The engine inlet fuel quality uses the latest ISO 8217:2010 specification. Bunkers that comply with ISO 8217:2005 can be used until the latest ISO specification is fully released. In such conditions, the higher values for carbon residue and vanadium can be satisfactory.

It is very important that the fuel is fit for purpose in the related engine application.

**Table 3: Fuel Specifications**

| Parameter | Unit | Bunker Limit | Test Method | Applicable Fuel Quality at Engine Inlet |
|---|---|---|---|---|
| Kinematic viscosity at 50°C | $mm^2/s$ [cSt] | Maximum 700 | ISO 3104 | 13 to 17 [2)] |
| Density at 15°C | $kg/m^3$ | Maximum 1010 [3)] | ISO 3675/12185 | Maximum 1010 |
| CCAI | – | 870 | Calculated | 870 |
| Sulphur [4)] | m/m [%] | Statutory specifications | ISO 8754/14596 | Maximum 3.5 |
| Flash point | °C | Minimum 60.0 | ISO 2719 | Minimum 60.0 |
| Hydrogen sulphide [5)] | mg/kg | Maximum 2.00 | IP 570 | Maximum 2.00 |
| Acid number | mg KOH/g | Maximum 2.5 | ASTM D 664 | Maximum 2.5 |
| Total sediment aged | m/m [%] | Maximum 0.10 | ISO 10307−2 | Maximum 0.10 |
| Carbon residue: micro | m/m [%] | Maximum 20.00 | ISO 10370 | Maximum 20.00 |
| Pour point (upper) [6)] | °C | Maximum 30 | ISO 3016 | Maximum 30 |
| Water | v/v [%] | Maximum 0.50 | ISO 3733 | Maximum 0.20 |
| Ash | m/m [%] | Maximum 0,150 | ISO 6245 | Maximum 0,150 |
| Vanadium | mg/kg [ppm] | Maximum 450 | ISO 14597/ IP501/470 | Maximum 450 |
| Sodium | mg/kg [ppm] | 100 | IP501/IP470 | Maximum 30 |
| Aluminum plus Silicon | mg/kg [ppm] | Maximum 60 | ISO 10478/ IP501/470 | Maximum 15 |
| Used lubricating oils (ULO) may not be present:<br>Calcium and zinc<br>Calcium and phosphorous | mg/kg | ULO shows if:<br>Ca>30 and Zn>15<br>or<br>Ca>30 and P>15 | IP501 or<br>IP470<br>IP500 | Do not use if:<br>Ca>30 and Zn>15<br>or<br>Ca>30 and P>15 |
| **Winterthur Gas & Diesel Ltd fuel specifications and quality limits at the engine inlet related to ISO 8217:2012 [1)]** | | | | |

The notes that follow are related to the data in Table 1:

- $1 mm^2/s = 1 cSt$ (Centistoke)
- 1) You can get ISO standards from the ISO Central Secretariat, Geneva, Switzerland (www.iso.ch).
- 2) For W−X engines the fuel viscosity at the fuel pump inlet can be in the range of between 13 $mm^2/s$ (cSt) and 20 $mm^2/s$ (cSt). When the engine operates on HFO, Winterthur Gas & Diesel Ltd. recommends a fuel viscosity at the fuel pump inlet in the range of between 13 $mm^2/s$ (cSt) and 17 $mm^2/s$ (cSt).
- 3) The maximum limit is 991kg/m3 if the fuel treatment plant cannot remove water from high-density fuel.
- 4) ISO 8217:2010, RMK700. Note that lower sulphur limits can apply and are related to statutory specifications and sulphur limits not given in ISO 8217:2010.
- 5) The hydrogen sulphide limit is applicable from 1 July 2012.
- 6) Purchasers must make sure that the pour point is sufficient for the equipment on board, specially for operation in cold climates.

**Note: For data about the parameters given in the table above, see paragraph 3.1 to paragraph 3.12.**

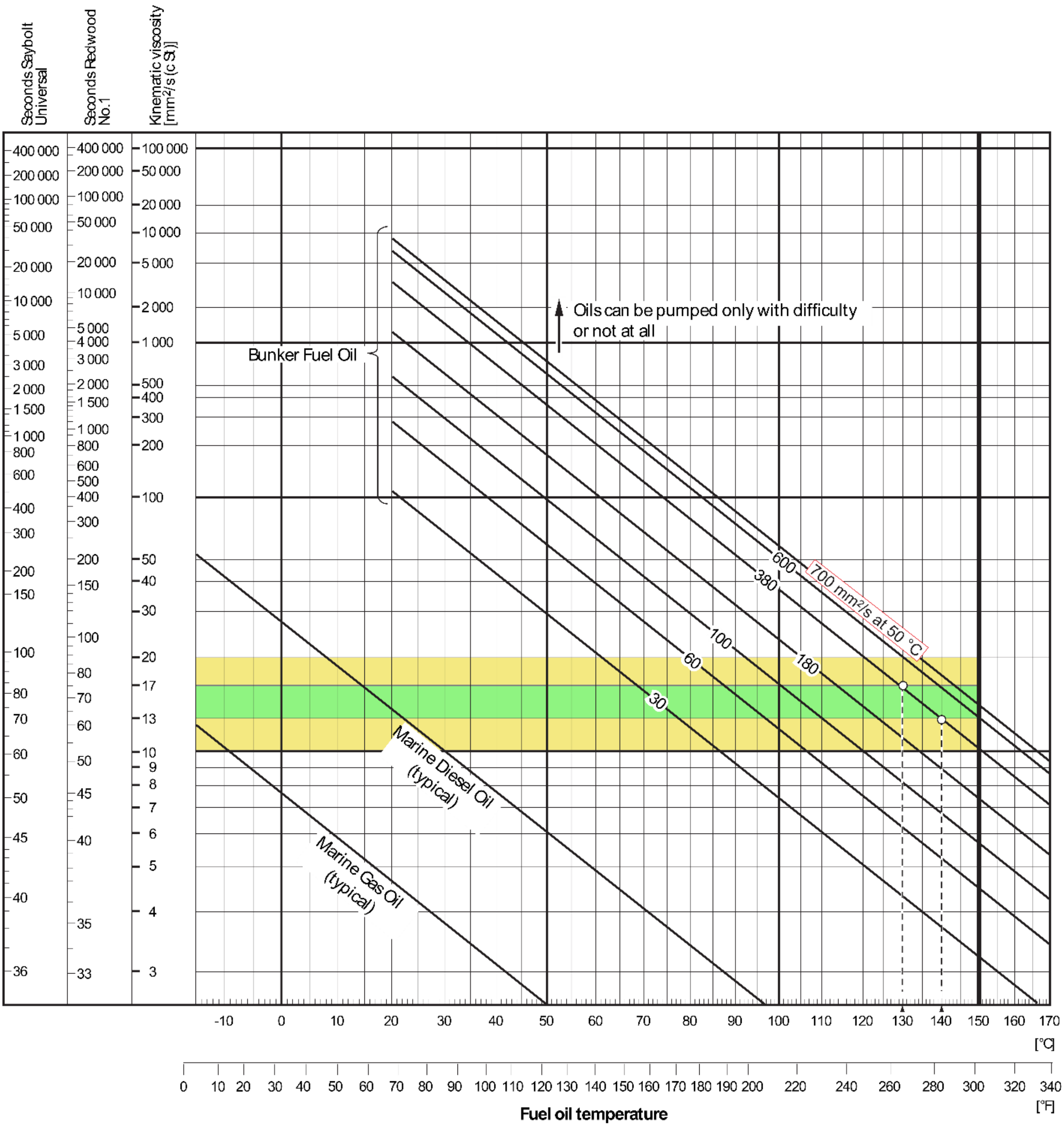
| CAUTION |
|---|
| **Damage Hazard: For Wärtsilä 2-stroke engines, the maximum permitted fuel temperature at the engine inlet is 150°C. Always make sure that you obey this limit. Damage to the engine can occur.** |

**Note: For more data, refer to 0230−1 Operation Data Sheet.**

# 3. Data about Heavy Fuel Oil Specifications

## 3.1 Viscosity

The recommended viscosity range upstream of the engine is between 13 mm$^2$/s (cSt) and 17 mm$^2$/s (cSt). You get the necessary temperature for a given nominal viscosity from the data in Fig. 1 below:




1. Required viscosity range for RTA and older engines
2. Recommended viscosity range for RT-flex and W-X engines

Required viscosity range for RT-flex and W-X engines

Example:

To get the recommended viscosity upstream of the fuel pumps, the fuel of 380 mm$^2$/s [cSt] at 50°C must be heated to between 130°C and 140°C.

WCH03126

**Fig. 1: Viscosity / Temperature Diagram**

The maximum permitted viscosity of the fuel that can be used in an installation is related to the heating and fuel preparation facilities available. The flow rate and the temperature of the fuel that flows through the centrifuges must be adjusted in relation to the viscosity to get good separation. The temperature of the fuel must not be increased to more than 150°C to get the recommended viscosity at the engine inlet. This is because the fuel can start to decompose, get contamination and be dangerous as it is possible that the temperature will be higher than the flash point.

## 3.2 Density

The composition of the fuel gives the density. A high density shows a high aromatic content. It is not always possible to use conventional methods to measure the density at 15°C. Thus, the measurement is made at a higher temperature and then converted and adjusted to the reference temperature. Most bunkers are to the ISO 8217:2010 RMG specification, which has a maximum density of 991.0 kg/m$^3$. Applicable fuel preparation equipment, which can be adjusted for a fuel density greater than 991.0 kg/m$^3$, must be available on board if high density fuels are used.

## 3.3 Calculated Carbon Aromaticity Index (CCAI)

The ignition and combustion properties of the fuel in a diesel engine are related to the specific engine design, load profile and fuel properties.

The CCAI is a calculated quantity of the ignition properties or ignition interval of the fuel related to the viscosity and density. The CCAI has no effect on the combustion properties. The CCAI limit is useful to measure fuels with unusual density-viscosity relations.

More tests are available to find ignition and combustion properties and these can be helpful to examine the performance of fuels.

## 3.4 Sulphur

Sulphur limits are not specified in ISO 8217:2010 because statutory specifications put a limit on this value. The maximum sulphur level that can be used in Wärtsilä 2-stroke engines is 3.5% m/m.

The alkalinity (base number (BN)) of the cylinder lubricating oil must be selected in relation to the sulphur level of the fuel in use. The engine can operate for short periods (some hours) with a cylinder lubricating oil that has an incorrect BN, but a longer operation time must be prevented.

Indications for the selection of the BN of the lubricating oil in relation to the sulphur content of the fuel are found in:

- 0570−1, Running-in of cylinder liners and rings
- 0320−1, Lubricating Oils, paragraph 3.

## 3.5 Flash Point

The flash point is an important safety and fire hazard parameter for diesel fuels. Fuel is always a fire hazard. There can be flammable vapors above the remaining fuel in the tanks. There must be caution on ships when the temperature of the remaining fuel is increased above the flash point to help with the filter process and injection.

## 3.6 Hydrogen Sulphide

**WARNING**

**Danger: Hydrogen Sulphide ($H_2S$) is a very toxic gas and exposure to high concentrations is dangerous and can kill you. Be careful when tanks or fuel lines are opened because there can be $H_2S$ vapor. At low concentrations $H_2S$ smells almost the same as bad eggs. You cannot sense $H_2S$ at moderate concentrations. $H_2S$ will cause nausea and dizziness.**

## 3.7 Acid Number

Fuels with high acid numbers have caused damage to fuel injection systems. Most fuels have a low acid number, which is not dangerous, but an acid number above 2.5 mg KOH/g, can cause problems. Some naphthenic fuels can have an acid number of more than 2.5 mg KOH/g, but still be permitted. Only a full laboratory analysis can find the strong acid number.

## 3.8 Sediment, Carbon and Asphaltenes

High quantities of sediment, carbon and asphaltenes decrease the ignition and combustion quality of the fuel and increase wear and damage to engine components. Asphaltenes also have an effect on the stability of mixed fuels and can cause too much sludge in the separators and filters. If the mixed fuel is not stable, particles can collect on the bottom of the tank.

To keep risks to a minimum, make sure that bunkers from different suppliers and sources are not mixed in the storage tanks on board. Also be careful when HFO is mixed on board to decrease the viscosity. Paraffinic distillate, when added to an HFO of low stability reserve, can cause the asphaltenes to collect, which causes heavy sludge.

HFO can contain up to 14% asphaltenes and will not cause ignition and combustion problems in 2-stroke engines if the fuel preparation equipment is adjusted correctly.

## 3.9 Pour Point

The operation temperature of the fuel must be kept between approximately 5°C and 10°C above the pour point to make sure that the fuel can flow easily.

## 3.10 Water

The separator and the correct configuration of drains in the settling and service tanks is used to decrease the water quantity in the fuel. A complete removal of water is highly recommended to decrease the quantity of hydrophilic cat fines and sodium in the fuel. Sodium is not a natural oil component, but diesel engine fuel often has sea water contamination, which has sodium. 1.0% sea water in the fuel is related to 100 ppm sodium.

To get a good separation effect, the flow rate and temperature of the fuel must be adjusted in relation to the viscosity. For high-viscosity fuels the separation temperature must be increased, although the flow rate must be decreased in relation to the nominal capacity of the separator. For the recommended data to operate the separator, refer to the instruction manual.

## 3.11 Ash and Trace Metals

Fuels with a low content of ash, vanadium, sodium, aluminium, silicon, calcium, phosphorous and zinc are recommended. These materials can increase mechanical wear, high-temperature corrosion and particles in the turbocharger, exhaust system and boilers.

### 3.11.1 Vanadium and Sodium

Sodium compounds decrease the melting point of vanadium oxide and sulphate salts, specially when the vanadium to sodium ratio is 3:1. High sodium quantities (as well as lithium and potassium) at the engine inlet can cause damage to the turbocharger, exhaust system and boilers. Ash modifiers can correct the effect of high-temperature corrosion and particles.

### 3.11.2 Aluminum and Silicon

Aluminum (Al) and silicon (Si) in the fuel are an indication of catalytic fines (cat fines). These are particles of hard oxides (round particles of material almost the same as porcelain) which cause high abrasive wear to pistons, piston rings and cylinder liners. Cat fines are used as a catalyst in some processes in petroleum refining and can be found in diesel engine fuels. The most dangerous cat fines are between 10 microns and 20 microns.

Cat fines are attracted to water droplets and are very difficult to remove from the fuel. With correct treatment in the fuel separator, the aluminium and silicon content of 60 ppm (mg/kg) can be decreased to 15 ppm (mg/kg), which is thought to be satisfactory. For satisfactory separation, a fuel temperature as close as possible to 98°C is recommended. If there are more than 40 ppm cat fines in the bunkered fuel, a decreased flow rate in the separator is recommended. Also, the instructions of the equipment manufacturer must be obeyed.

Cat fines can collect in the sediment of the fuel tank from other bunkers. During bad weather conditions, the movement of the ship mixes the sediment into the fuel. Thus, it is better to think that all fuels contain cat fines, although it is possible that a fuel analysis can show a different result. This makes continuous and satisfactory separation very important.

**Note: The Al+Si limit in the new ISO 8217:2010 specification is decreased to 60 mg/kg for the RMG and RMK grades.**

## 3.12 Used Lubricating Oil and Chemical Waste

Used lubricating oils and chemical waste must not be mixed into the fuel pool. If used lubricating oil is mixed in, fuel is not stable because the base oil is very paraffinic and can cause too much sludge. Most used lubricating oil is from the crankcase, thus sufficiently large quantities of calcium, zinc, phosphorous and other additives and wear metals can cause contamination. The limits in ISO 8217: 2010 and the Winterthur Gas & Diesel Ltd. specification make sure that no used lubricating oil is in the fuel. This is related to the limits of the test methods used to find the levels of these metals, which can occur naturally in the fuel.

Chemical waste must not be added to the fuel. There were some examples of polymers, styrene and other chemical substances found in fuel. These materials can cause the fuel to become too thick, to become almost solid and block filters. They can also cause damage to fuel injection systems and cause fuel pump plungers and injectors to stop.

# 4. Distillate Fuel Specifications

**Note: For data about the parameters given in Table 2, see 5.1 to paragraph 5.12.**

**Table 4: Fuel Specifications**

| Parameter | Unit | Bunker Limit | Test Method | Applicable Fuel Quality at the Engine Inlet |
|---|---|---|---|---|
| Kinematic viscosity at 40°C | $mm^2/s$ [cSt] | Maximum 11.0<br>Minimum 2.0 | ISO 3104 | Minimum 2.0<br>Not related to temperature |
| Density at 15°C | kg/m3 | Maximum 900.0 | ISO 3675/12185 | Maximum 900.0 |
| Cetane index | – | Minimum 35 | ISO 4264 | Minimum 35 |
| Sulphur [1)] | m/m [%] | 2.0 | ISO 8754/14596 | Maximum 2.0 |
| Flash point | °C | Minimum 60.0 | ISO 2719 | Minimum 60.0 |
| Hydrogen sulphide [2)] | mg/kg | Maximum 2.00 | IP 570 | Maximum 2.00 |
| Acid number | mg KOH/g | Maximum 0.50 | ASTM D 664 | Maximum 0.50 |
| Total sediment by hot filtration | m/m [%] | Maximum 0.10 | ISO 10307−1 | Maximum 0.10 |
| Oxidation stability | $g/m^3$ | Maximum 25 | ISO 12205 | Maximum 25 |
| Carbon residue: micro method on 10% volume distillation residue (for grades DMX, DMA and DMZ) | m/m % | Maximum 0.30 | ISO 10370 | – |
| Carbon residue: micro method (grade DMB) | m/m % | Maximum 0.30 | ISO 10370 | Maximum 0.30 |
| Pour point (upper) winter [3)] | °C | Maximum –6 | ISO 3016 | Maximum 0 |
| Pour point (upper) summer | °C | Maximum 6 | ISO 3016 | Maximum 6 |
| Water | v/v [%] | Maximum 0.30 | ISO 3733 | Maximum 0.20 |
| Ash | m/m [%] | Maximum 0,010 | ISO 6245 | Maximum 0.010 |
| Lubricity, corrected wear scar diameter (wsd 1.4) at 60°C | μm | Maximum 520 | – | – |
| **Winterthur Gas & Diesel Ltd. distillate fuel specifications and quality limits at the engine inlet related to ISO 8217:2012** | | | | |

The notes that follow relate to data in Table 2:

- $1 mm^2/s = 1 cSt$
- 1)The purchaser must specify the maximum sulphur content in accordance with the usual statutory specifications.
- 2) The hydrogen sulphide limit is applicable from 1 July 2012.
- 3) Purchasers must make sure that the pour point is sufficient for the equipment on board, specially for operation in cold climates.

Distillate fuels are used more in 2-stroke engines to meet area specified emission standards. They are easier to operate than residual fuel, but caution is necessary for some problems. Refer to Service Bulletin RT−82: Distillate Fuel Use.

ISO 8217: 2010 specifies DMX, DMA, DMZ and DMB categories. The Wärtsilä engine inlet specification is based on the DMB grade which is the highest viscosity grade. The DMX grade must not be bunkered as the viscosity could be below 2.0 $mm^2/s$ and the flash point could be below 60°C.

# 5. Data about Distillate Fuel Specifications

## 5.1 Viscosity

The recommended viscosity range on residual fuel upstream of the engine inlet is 13 $mm^2/_s$ (cSt) to 17 $mm^2/_s$ (cSt). But, because distillate fuel does not have such a high viscosity, a minimum viscosity of 2.0 $mm^2/_s$ (cSt) at the fuel pump inlet is necessary.

Operators must be careful during the change-over procedure from distillate to residual fuel and back to make sure of problem free operation. See the Service document: Engine operation on MDO/MGO, change-over from HFO to MDO/MGO and the Service Bulletin RT−82: Distillate Fuel Use.

In some conditions, it is possible that you cannot get the minimum viscosity of 2.0 $mm^2/_s$ (cSt) at the fuel pump inlet. In such conditions, a fuel cooling system will be necessary to make sure that the inlet to the fuel pumps has the minimum viscosity.

## 5.2 Density

The composition of the fuel gives the distillate density and a high density indicates a high aromatic quantity.

## 5.3 Cetane Index

The ignition and combustion properties of a distillate fuel in a diesel engine is related to the specific engine design, load profile and fuel properties. The Cetane Index is a calculated quantity of the ignition properties or ignition interval of the fuel related to the distillation and density. The density and the temperature when 10%, 50% and 90% of the fuel is distilled, gives the Cetane Index. This has no effect on the fuel combustion properties.

## 5.4 Sulphur

Sulphur limits are specified in ISO 8217:2010 for distillate fuels, but statutory specifications must be obeyed. The alkalinity (BN) of the cylinder lubricating oil must be selected in relation to the sulphur content of the fuel in use.

The engine can operate for short periods (some hours) with a cylinder lubricating oil that has an incorrect BN, but a longer operation time must be prevented.

Indications for the selection of the BN of lubricating oil in relation to the sulphur content of the fuel are found in:

- 0570−1, Running-in of cylinder liners and rings
- 0320−1, Lubricating Oils, paragraph 3.

## 5.5 Flash Point

The flash point is an important safety and fire hazard parameter for diesel fuels. Fuel is always a fire hazard because there can be flammable vapors above the remaining fuel in the tanks.

## 5.6 Hydrogen Sulphide

**WARNING**

**Danger: Hydrogen Sulphide ($H_2S$) is a very toxic gas and exposure to high concentrations is dangerous and can kill you. Be careful when tanks or fuel lines are opened because there can be $H_2S$ vapor. At low concentrations $H_2S$ smells almost the same as bad eggs. You cannot sense $H_2S$ at moderate concentrations. $H_2S$ will cause nausea and dizziness.**

## 5.7 Acid Number

Fuels with high acid numbers have caused damage to fuel injection systems. Most fuels have a low acid number, which is not dangerous, but an acid number above 2.5 mg KOH/g, can cause problems.

## 5.8 Sediment

High quantities of sediment decrease the ignition and combustion quality of the fuel and increase wear and damage to engine components. High sediment quantities can cause filters to block, or frequent discharge from filter systems that have automatic cleaning. For more data about mixtures, see paragraph 3.8 in the HFO section.

## 5.9 Pour Point

The operation temperature of the fuel must be kept between approximately 5°C and 10°C above the pour point to make sure that the fuel flows easily. It is possible that in very cold conditions, there could be problems for distillate fuel.

## 5.10 Water

The quantity of water in distillate fuel can be decreased as follows:

- Let the fuel settle in the service tanks
- Use the centrifuge to remove water from the fuel.

## 5.11 Ash and Trace Metals

Distillates must have low quantities of ash, vanadium, sodium, aluminium, silicon, calcium, phosphorous and zinc related to residual fuels. High quantities of these materials increase mechanical wear, high-temperature corrosion and particles in the turbocharger, exhaust system and the boilers.

## 5.12 Used Lubricating Oil and Other Contamination

Lubricating oils and chemical waste must not be mixed into the distillate fuel pool. Lubricating oil can cause water to stay because of the large quantity of detergent. Additive materials such as calcium, magnesium, zinc and phosphorous could increase the ash content to more than that given in the specification.

Chemical waste must not be added to distillate fuel. There were some examples of chemical waste substances found in fuel. These materials can cause the fuel to become too thick, to become almost solid and block filters. They can also cause damage to fuel injection systems and cause fuel pump plungers and injectors to stop.

## 6. Bio-derived Products and Fatty Acid Methyl Esters

Such components can be found in diesel engine fuels and can cause a decrease of greenhouse gases and SOx emissions. Most bio-fuel components in the diesel pool are Fatty Acid Methyl Esters (FAME), which come from a special chemical treatment of natural plant oils. These components are mandatory in automotive and agricultural diesel in some countries. FAME is specified in ISO 14214 and ASTM D 6751.

FAME has good ignition properties and very good lubrication and environmental properties, but the other properties that follow about FAME are well known:

- Possible oxidation and thus long term storage problems.
- A chemical force that causes fuel and water to combine
- Microbial growth can appear in the fuel
- Unsatisfactory low temperature properties.
- FAME material particles can appear on exposed surfaces and filter elements.

Where FAME is used as a fuel, make sure that the on board storage, handling, treatment, service and machinery systems can be used with such a product.

## 7. Fuel Additives

Usually, fuel additives are not necessary to make sure of the satisfactory operation of fuels that obey the ISO 8217:2010 standard. But some operators can use specified additives to change the effect of some fuel properties. Wärtsilä Services Switzerland Ltd. can make an analysis of such additives and supply a No Objection Letter for specified additives if they are in the limits of internal specifications.

**Note: Winterthur Gas & Diesel Ltd. and Wärtsilä Services Switzerland Ltd. do not accept liability or responsibility for the performance or potential damage caused by the use of such additives.**

# 8. Diesel Fuel Treatment and Fuel Systems

## 8.1 General

Heavy fuel oils (HFO), as they are supplied today for use in diesel engines must have careful treatment, which makes the installation of applicable plant necessary. The best procedure to remove solid particles and water from fuel is to use centrifugal separators.

## 8.2 Treatment of HFO and Treatment Plant

HFO are contaminated with solid particles and water. If HFO, that is dirty or has not had sufficient treatment, goes into the engine, engine components can become worn (e.g. piston rings, cylinder liners, injection pumps, valves etc). Also, too much sediment can collect in the combustion spaces.

Sodium in the fuel (which comes from seawater) causes contamination on the pistons and in the turbocharger. Seawater must be carefully removed from the fuel.

Settling tanks are used for the first steps of treatment, but their effect is only a coarse separation to release water from the HFO. The settling tanks must have the sludge and water, that collects in the bottom of the tank, drained at intervals.

Correctly operated centrifuges that are of the best size and adjustment are used to get good results during the procedure to clean the fuel. Modern designs mean that is not necessary to adapt the gravity discs for fuels of different densities.

Modern machines automatically remove the sludge from the centrifuge. For modern engines designed to burn HFO of the lowest grade, such centrifuges are necessary. This is applicable when HFO with densities of 991 $kg/m^3$ and higher and with viscosities of 700 cSt/50°C are used.

Homogenizers can improve combustion properties, but cannot remove solid particles from the fuel. Homogenizers thus, are only auxiliaries in the treatment plant.

Filters hold solid particles of a specified size and shape, but cannot hold back water. Water will cause the filters to be blocked quickly.

## 8.3 HFO and MDO Fuel Separation

It is recommended that modern centrifuges are used for the treatment of heavy fuels.

The separation effect, i.e. the cleaning effect, is related to the flow rate and viscosity of the HFO. Usually, the smaller the volume ($m^3$/h or ltr/h) and the lower the viscosity of the HFO, the better the separation. Separator efficiency is decreased if the flow rate is too high and/or the separation temperature is too low.

If the HFO separators do not operate satisfactorily, it is possible that impurities (e.g. cat fines) in the bunkers will not be sufficiently removed. This can cause damage to the engine (e.g. increased wear of piston ring, cylinder liner and fuel injection equipment).

The temperature of the HFO must be increased before it goes into the centrifuge to keep the temperature constant to a tolerance of ± 2° C. The separation temperature must be as near as possible to 98° C. The instructions of the centrifuge manufacturer must be obeyed during the separation procedure.

The sludge that comes from the separation process must be removed regularly from the separator drum. For self-cleaning centrifuges, the sequence of the procedure can be controlled automatically. But in such a plant, personnel must keep control of the correct function and frequency of procedures. Regular checks must be done to make sure that the sludge from the separator drum can drain freely. This prevents back pressure, which makes sure that the centrifuge operates correctly to clean the HFO.

## 8.4 Configuration of the HFO and MDO Fuel System

In the recommended standard plant, pressure is kept in the full fuel system to prevent the evaporation of water in the fuel at the temperature necessary for the HFO. Refer to Fig. 2 and Fig. 3.

At the applicable position of the 3-way valve (10), the low pressure pump (19) supplies heavy fuel from the service tank (2) to the mixing unit (21). The booster pump (22) supplies the fuel from the mixing unit (21) through the end heater (23) and fuel filter (24) to the fuel pumps in the supply unit (28). The rated capacity of the booster pump (23) is more than that necessary for the engine. The fuel that the engine does not use flows back to the mixing unit (21).

The pressure retaining valve (27) sets the applicable system pressure. The pressure regulating valve (17) sets the pressure at the inlet to the fuel pumps (for the adjustment value, see 0230–1 Operating Data Sheet).

The pump (8) supplies only as much fuel from the HFO service tank (3) as necessary for the engine. If necessary, the temperature of the fuel in the HFO service tank must be increased.

**Note: The official safety regulations give a maximum temperature limit of the HFO.**

The temperature of the fuel between the mixing unit (21) and the fuel system on the engine must be increased to the applicable injection temperature. The end heater (23) increases the temperature of this fuel. If necessary during the temperature increase, the heating systems of the mixing unit (21) and the return pipe can be set to on.

HFO must not go into the MDO service tank (6).

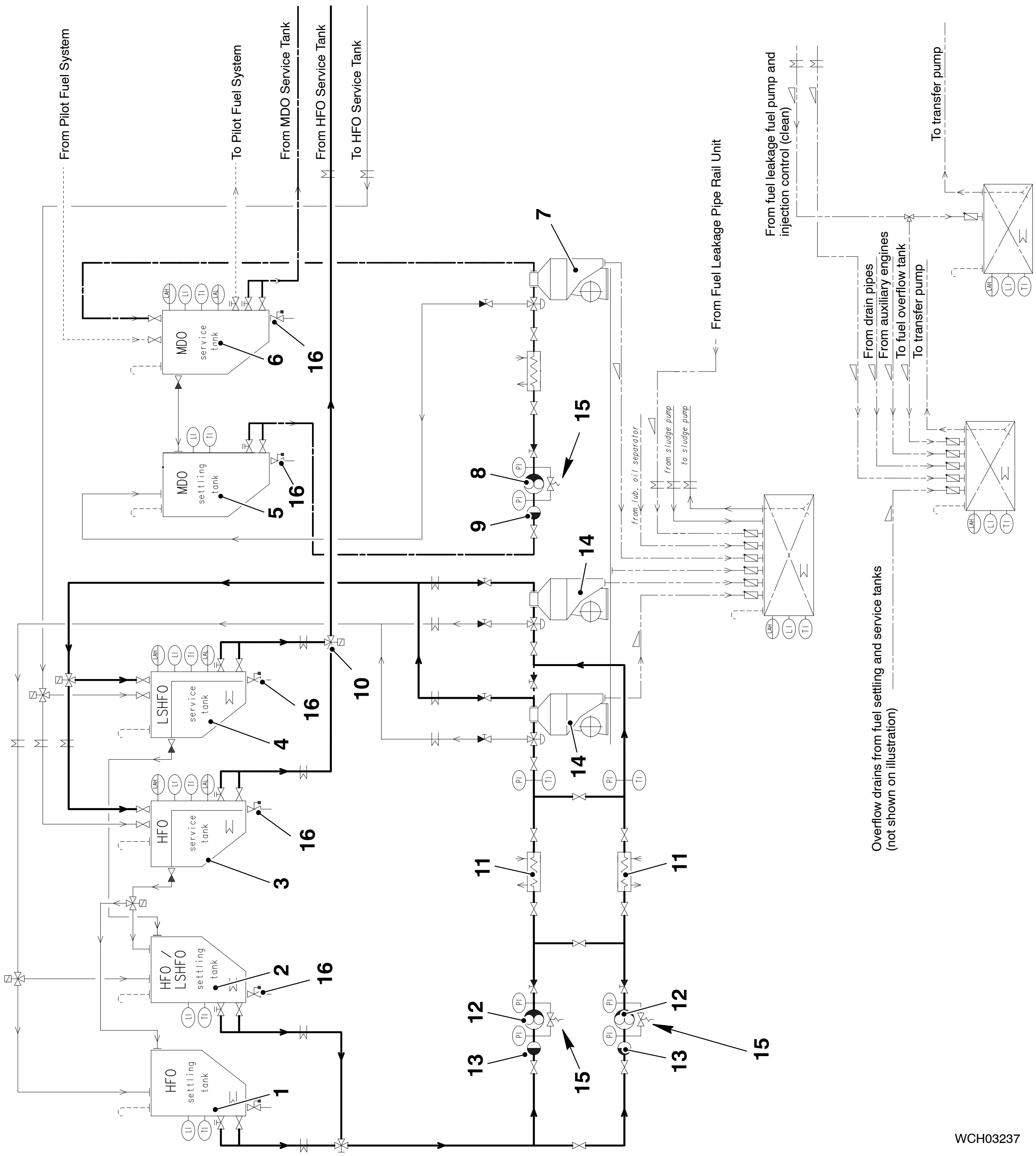



**Fig. 2: HFO and MDO Separation System**

1 HFO settling tank
2 HFO/LSHFO settling tank
3 HFO service tank
4 LSHFO service tank
5 MDO settling tank
6 MDO service tank
7 Self-cleaning MDO separator
8 MDO separator supply pump
9 MDO suction filter
10 Three-way valve
11 HFO/LSHFO preheater
12 HFO/LSHFO separator supply pump
13 Suction filter
14 Self-cleaning HFO/LSHFO separator
15 Pressure regulating valve
16 Drain valve
PI Pressure indicator
TI Temperature indicator
LAH Level alarm, high
LAL Level alarm, low

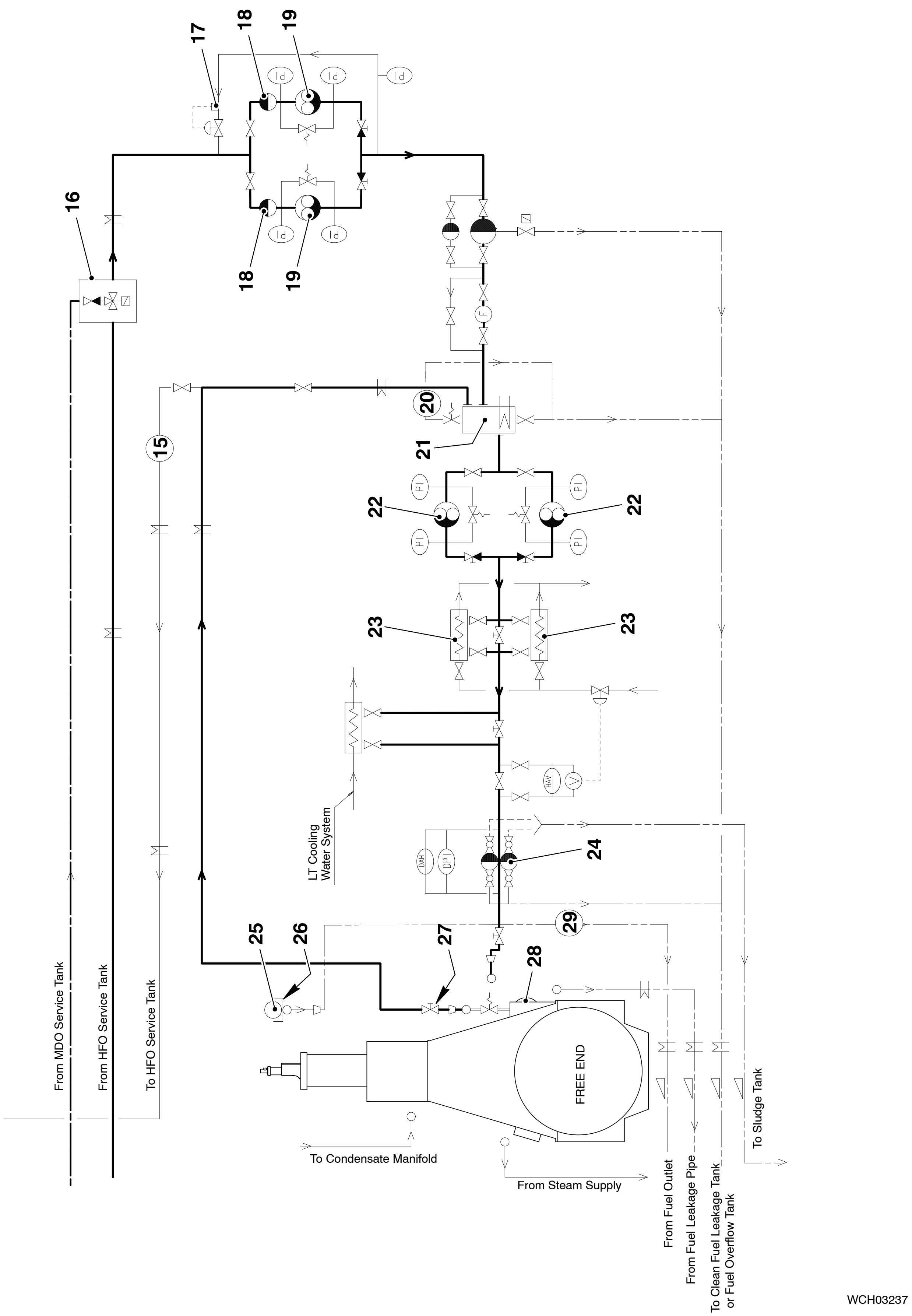



**Fig. 3: Schematic Diagram − Fuel System**

**Key to Fig. 2**

| | | | |
|---|---|---|---|
| 15 | Bypass pipe | 23 | End heater |
| 16 | Automatic fuel change-over unit | 24 | Fuel filter |
| 17 | Pressure regulating valve | 25 | Fuel rail |
| 18 | Suction filter | 26 | Fuel leakage rail unit |
| 19 | Low pressure pump | 27 | Pressure retaining valve |
| 20 | Air overflow pipe | 28 | Supply unit (fuel pump) |
| 21 | Mixing unit, heated and insulated | 29 | Fuel leakage pipe injection valve |
| 22 | Booster pump | | |
| PI | Pressure gauge | TI | Temperature indicator |
| HAV | Viscosity alarm high | DAH | Differential pressure alarm high |
| | Flow indicator | | |
| | Heated & insulated pipes | | |
| | Insulated pipes | | |
| | Pressure regulating valve | | |
| | Sight glass | | |
| | Viscosimeter | | |

## 8.5 Pilot Fuel System

Pilot fuel is diesel fuel (marine diesel oil) that is injected into the cylinder to ignite the gas/air mixture during engine operation in gas mode. The injection timing and pilot fuel quantity is electronically controlled (refer to 4002−1, Engine Control System, paragraph 3.19 Pilot Fuel Pressure Control and paragraph 3.20 Pilot Fuel Injection Control).

**Note: The pilot fuel system also operates with a decreased quantity of fuel injection during engine operation in diesel mode. This prevents contamination on the tips of the pilot injection valves and the pre-combustion chambers.**

The primary components of the pilot fuel system are as follows:

- Pilot fuel supply unit (refer to 8790−1, Pilot Fuel System)
- Pilot injection valves (see 2790−1 Pilot Injection Valve)
- MDO service tank (1, Fig. 4)
- Common rail pipe
- HP pilot fuel pipes.

The pilot fuel pump is installed on the engine. The pilot fuel supply unit has the pilot fuel pump (4), suction filters (3) and pressure regulating/relieve valves.

The pilot fuel supply pump (4) supplies pilot fuel at the applicable operation pressure (for the values see 0230−1 Operation Data Sheet). The pilot fuel supply pump (4) is an electrically operated radial piston pump with a built-in overpressure bypass valve.

The pilot fuel is supplied to the pilot injectors at a constant pressure (see 2790−1 Pilot Injection Valve). For safety, the pipes from the pilot fuel supply pump (4) to the pilot injection valves have double walls. If there is a leak, the leakage collects in the leakage collector pipe and the level switch LS3444A activates an alarm (refer to 4003−2, Page 1 Engine Control Diagram).

The HT cooling water system keeps cool the pre-combustion chamber, (refer to 2124−1, Cylinder Liner, paragraph 2 Cooling). The system oil keeps cool the pilot injection valves, (refer to 2790−1, Pilot Injection Valve, paragraph 3 Cooling).

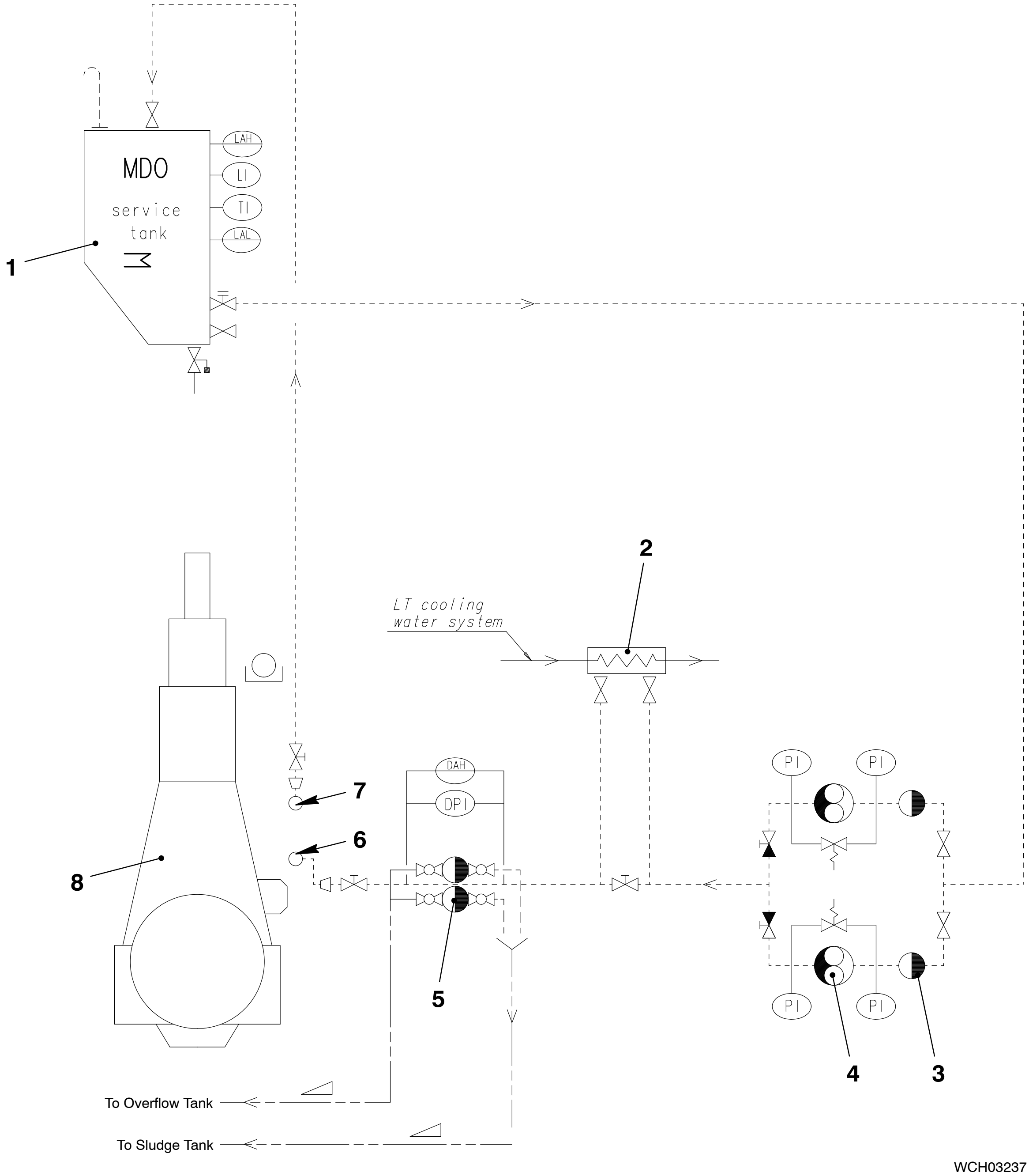



**Fig. 4: Schematic Diagram − Pilot Fuel System**

1 MDO service tank
2 Fuel heat exchanger
3 Duplex filter
4 Pilot fuel pump
5 Fuel filter
6 Pilot fuel inlet
7 Pilot fuel outlet
8 Main engine

# Operating Media
Scavenge Air and Starting Air

## 1. Scavenge Air

The turbocharger compresses the air from the engine room or from outside for the scavenge air and air for the cylinders, (for data about the turbocharger, refer to 6500−1 Turbocharging).

The air must be as clean as possible to make sure that the cylinder liner, piston rings, turbocharger compressor etc do not get worn too much. Silencers are installed to the suction part. The silencers have filter mats in them, which help to keep the air clean.

The filter mats must be serviced and/or cleaned regularly (for more data, refer to the turbocharger manual).

## 2. Starting Air / Control Air

### 2.1 Starting Air

Compressors pressurize the air in the starting air bottles to a maximum of 30 bar. The starting air from the starting air bottles flows directly into starting air shut-off valve, then into starting air valve in the cylinder. This air must be clean and dry. The starting air bottles must be drained regularly to remove condensation (see 8018−1 Starting Air Diagram).

### 2.2 Control Air

The control air and air spring air supplied from the shipboard system must be clean and dry.

If no air comes from the control air board supply, compressed air at decreased pressure is available from the starting air supply (for more data, refer to 4003−2, Page 1 Control Diagram and 4003−9).

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# Operating Media
## Lubricating Oils



## 1. General

The engine has different oils for system oil and cylinder lubrication.

## 2. System Oil

System oil lubricates the bearings, the running parts of the engine and the crosshead assembly. System oil is also used as hydraulic fluid in the servo oil system of the engine and used to keep cool the pistons (see 8016−1 Lubricating Oil / Servo Oil System).

The system oil must have:

- An additive-type crankcase oil of the SAE 30 viscosity grade must be used as system oil.
- A minimum base number (BN) of 5.0 mg KOH/g and detergent properties.
- The load carrying performance from the FZG gear machine test method A/8, 3/90 in accordance with ISO 14635−1, failure load stage 11 as a minimum.
- Good thermal stability, anti-corrosion and anti-foam properties, and good demulsifying performance.

**Note: The applicable system oils for Wärtsilä 2-stroke engines are shown in paragraph 8.2. For different or new lubricating oils, speak to or send a message to Wärtsilä Services, Switzerland Ltd.**

## 2.1 Oil Care

### 2.1.1 System Oil

To keep the lubricating oil in good condition for long periods, good oil treatment is necessary. To do this, a self-cleaning, centrifugal separator is used.

The self-cleaning, centrifugal separator is used as a purifier in by-pass mode. The oil flows from the oil tank through the centrifugal separator. The system oil volume must be put through the centrifugal separator a minimum of three times each day. The manufacturer of the centrifugal separator sets the output. The recommended oil temperature for this treatment is between 96°C and 98°C unless the centrifugal separator supplier recommends differently.

Solid contaminants (dirt) and water must be removed from the oil as completely as possible. There is always a risk that water, specially sea water, can enter the system and cause corrosion on engine parts. Water contamination can also cause bacterial infection of the oil, which gives a decrease in lubrication and heavy corrosion of the system. Good maintenance is the best precaution to keep water out of the oil. The water content of the lubricating oil must not be more than 0.2% by mass during a long period. If higher water contamination is seen, special procedures such as treatment in the centrifugal separator, or in a renovating tank must be done.

The coarse and fine filters of the servo oil system must be serviceable. For more data, see the documentation of the fine filter manufacturer and paragraph 2.3.2.

### 2.1.2 Servo Oil

To increase the lifetime of the sliding parts, fine-filtered oil is used in the servo oil system.

The bypass filter element can be used temporarily to inspect and clean the regular filter elements.

## 2.2 Limits for Selected System Oil Parameters

You make an analysis of the selected parameters to estimate the condition of the lubricating system oil. Regular checks can find deterioration early and procedures can be done to correct the problems.

Make sure that the limits of the system oil are not more than those given in the Table 1 for long periods in service.

**Table 1: Alert Limits of System Oil Parameters**

| Parameter | Limit | Test Method |
|---|---|---|
| Viscosity at 40°C | Maximum 140 mm$^2$/s [cSt] | ASTM D 445 |
| Flash point (PMCC) | Minimum 200°C | ASTM D 92 |
| Total insolubles | Maximum 0.70% m/m 1) | ASTM D 893b |
| Base Number (BN) | Maximum 12 mg KOH/g | ASTM D 2896 |
| Water content | Maximum 0.20% m/m | ASTM D 95 or ASTM D 1744 |
| FZG gear machine test | Minimum failure load stage 9 | ISO 14635-1(test method A/8.3/90) |

1) % m/m means by mass, e.g. a water content of 0.20% m/m means that the water content is 0.20% of the mass of the total solution.

If one of the limits of the system oil is at a value given in the table above, applicable procedures must be done to correct the problem. Such procedures can be purification (decrease of the flow rate, adjustment of temperatures), treatment in a renovating tank (settling tank) or partial exchange of the oil charge. It is recommended that you speak to the oil supplier in such a condition.

The oil condemnation limits are given in Table 2. If the oil condition has so much deterioration that the purifier and filters cannot make the condition better, some of the oil charge must be replaced. The oil charge will then go back to a satisfactory performance level.

**Table 2: Condemnation Limits**

| Parameter | Limit | Test Method |
|---|---|---|
| Viscosity at 40°C | Maximum 150 mm$^2$/s [cSt] | ASTM D 445 |
| Flash point (PMCC) | Minimum 180°C | ASTM D 92 |
| Total insolubles | Maximum 1.0% m/m | ASTM D 893b |
| Base Number (BN) | Maximum 15 mg KOH/g | ASTM D 2896 |
| Water content | Maximum 0.30% m/m | ASTM D 95 |
| Strong Acid Number (SAN) | nil mg KOH/g | ASTM D 664 |
| Calcium | Maximum 6000 mg/kg [ppm] | ICP |
| Zinc | Minimum 100 mg/kg [ppm] | ICP |
| Phosphorous | Minimum 100 mg/kg [ppm] | ICP |
| FZG gear machine test | Minimum failure load stage 8 | ISO 14635-1 (test method A/8.3/90) |

These limits are a guide. The condition of the oil in the system cannot be fully calculated by one parameter. Other oil parameters must be used to find the cause of the problem, and the applicable treatment.

If the Base Number (BN) of the system oil increases suddenly, do a check of the piston rod gland box and piston rod condition.

Some consumption and replenishment of the system oil is necessary to keep the oil in good condition.

If there is an important decrease in the flash point below the recommended value shown above, Wärtsilä Services Switzerland Ltd. recommends a replenishment of the oil charge.

A replacement of the oil charge prevents an increase in the system oil BN. A small increase in BN is often an indication that the system oil consumption is low.

The open cup type of flash point test procedure (e.g. COC) must be used to decide if some of the oil, or a full oil change is necessary. The closed cup type of flash point test procedure (e.g. PMCC) can be used to monitor the system oil condition, but not for oil change.

The FZG performance (to the procedure in ISO 14635−1) of the oil is important if a new gear wheel is installed or was polished. This gives protection against scuffing during the running-in of the gears.

If the system oil is used for more than one year, the FZG performance of the oil must be done to make sure that the performance is sufficient for the new or polished gear(s).

You must do regular on-board checks of the BN and water content to get an early indication of a lower oil quality.

## 2.3 Particle Size and Count

Particle size analysis can give useful data about the wear in an engine. Abrasive particles in the oil can cause wear, thus the procedures must be carefully followed. The hydraulic system operates the exhaust valve and the fuel and cylinder lubricating oil injection systems, (i.e. the servo oil downstream of the fine filter, which is usually 10 μm maximum sphere passing size). Some engines have a 25 μm maximum or other fine filter.

The ISO 4406 particle count and size classes are applicable for the system oil downstream of the filter and given in Table 3.

**Table 3: Particle Count and Size Classes**

| Number of particles per 100 ml | | | |
|---|---|---|---|
| | **More Than** | **Up To and Includes** | **Class** |
| | 250 000 000 | – | Less than 28 |
| | 130 000 000 | 250 000 000 | 28 |
| | 64 000 000 | 130 000 000 | 27 |
| | 32 000 000 | 64 000 000 | 26 |
| | 16 000 000 | 32 000 000 | 25 |
| | 8 000 000 | 16 000 000 | 24 |
| | 4 000 000 | 8 000 000 | 23 |
| | 2 000 000 | 4 000 000 | 22 |
| | 1 000 000 | 2 000 000 | 21 |
| More than 6 μm maximum | 500 000 | 1 000 000 | 20 |
| | 250 000 | 500 000 | 19 |
| | 130 000 | 250 000 | 18 |
| More than 14 μm maximum | 64 000 | 130 000 | 17 |
| | 32 000 | 64 000 | 16 |
| | 16 000 | 32 000 | 15 |
| | 8 000 | 16 000 | 14 |
| | 4 000 | 8 000 | 13 |
| | 2 000 | 4 000 | 12 |
| | 1 000 | 2 000 | 11 |
| | 500 | 1 000 | 10 |
| | 250 | 500 | 9 |
| | 130 | 250 | 8 |
| | 64 | 130 | 7 |
| | 32 | 64 | 6 |
| | 16 | 32 | 5 |
| | 8 | 16 | 4 |
| | 4 | 8 | 3 |
| | 2 | 4 | 2 |
| | 1 | 2 | 1 |
| | 0 | 1 | 0 |

The ISO 4406 particle count system operates with three size classes related to a 100 ml oil sample, which are:

- $R_6$ = number of particles equal to or larger than 6 μm
- $R_{14}$ = number of particles equal to or larger than 14 μm.

### 2.3.1 Recommended Limits for ISO 4406 Particle Count

The specification for a 100 ml oil sample is ISO 4406 --/20/17 maximum in the system oil downstream of the filter, which means:

- It is not necessary to count particles of size equal to or more than 4 μm
- A maximum of 1 000 000 particles of size equal to or less than 6 μm
- A maximum of 130 000 particles of size equal to or more than 14 μm.

This is the same as the specification before for a maximum of NAS Class 8 particle count.

ISO 4406 is only for particles up to 21 μm. For particles larger than 21 μm, the SAE particle count must be obeyed.

The samples that follow are acceptable:

- ISO 4406 19/15/11
- ISO 4406 16/13/12
- ISO 4406 15/12/10.

The samples that follow are not acceptable:

- ISO 4406 20/17/13
- ISO 4406 19/16/15
- ISO 4406 20/18/16.

### 2.3.2 Servo Oil – Particle Counts

If the particle count is more than the limit given, do a check of the coarse and fine filters. This will make sure that all filter elements, gaskets and seals are not damaged. If a high particle count continues and the filters are serviceable, it is possible that an area of wear in the engine causes an unsatisfactory number of particles. Too many particles can also go into the system oil if the piston rod gland boxes do not correctly seal and used cylinder lubricating oil mixes with the system oil.

The purifier removes particles, and you must make sure that the purifier is operated at the correct temperature. Refer to the manufacturers recommendations and make sure that the flow rate is adjusted to get the best operation.

## 2.4 Oil Samples

At regular intervals, (i.e. at approximately each 3000 operating hours), it is recommended to get a sample of the system oil. Send the sample of the system oil to a laboratory to make an analysis. The analysis must include ISO 4406 particle counts for samples taken from downstream of the coarse filter or fine filter.

Take the sample downstream of the filter, before the oil flows into the main oil gallery or the servo oil system. Get a sample of system oil as follows:

1) Make sure that the oil pump operates and the engine oil is at the correct temperature for operation.
2) Put an applicable container below a ball valve in the lubricating system.
3) Open the ball valve to flush out possible dirt.
4) Close the ball valve.
5) Use some oil to clean the container.
6) Put the container below a ball valve.
7) Open the ball valve to get a sample.
8) Close the ball valve.
9) Put the sample in a bottle.
10) Write the data that follows on the bottle:
    - Name of the ship or name of plant
    - Engine type
    - Engine serial number
    - Date of sample
    - Operating hours of oil and of engine
    - Location of the sample point
    - Oil brand and quality.

# 3. Cylinder Lubricating Oil

A high-alkaline cylinder lubricating oil of the SAE 50 viscosity grade that has a minimum kinematic viscosity of 18.5 cSt at 100°C is recommended. But, cylinder lubricating oils of the viscosity grades SAE 40 and SAE 60 can be used in some conditions. The Base Number (BN) measured in mg KOH/g in accordance with the method ASTM D 2896 shows the alkalinity of the oil.

To set the correct alkalinity of the cylinder lubricating oil, use an on-board programme to monitor the piston underside (PU) drain oil. The residual base number (BN) of the piston underside drain oil shows if the setting values for the cylinder lubrication are correct. The BN of the cylinder lubricating oils is not an index for detergency, but a direct measure of alkalinity. The alkalinity of the cylinder lubricating oil must be set in relation to the sulphur content of the fuel, engine operation condition and cylinder lubricating oil feed rate. The higher the sulphur content, the higher the BN of the cylinder lubricating oil must be. For a list of applicable cylinder lubricating oils, see paragraph 8.2 Cylinder Lubricating Oils.

When the analysis of the piston underside drain oil shows that the engine operates in the safe area shown in Fig. 2, you can adjust the feed rate and alkalinity of the cylinder lubricating oil. The permitted maximum feed rate is 1.2 g/kWh (see 7218–1 Cylinder Lubrication and 7218–3 Feed Rate – Adjustment). If the analysis of the piston underside drain oil shows that an adjustment to a higher feed rate than 1.2 g/kWh is necessary, you must change to a higher BN cylinder lubricating oil.

## 3.1 Fuel Sulphur Content and Cylinder Lubricating Oil Base Number

Fig. 1 shows recommendations of applicable cylinder lubricating oils related to the sulphur content of the used fuel. Also shown is the data for fuel with a sulphur content in the range of 1.5% m/m to 3.5% m/m and cylinder lubricating oil with a base number between BN 50 to BN 100.

If you do not use an on-board monitoring programme to monitor the piston underside drain oil, use the data given in Fig. 1 to choose an applicable cylinder lubricating oil. For data about the applicable feed rates, see 7218–1 Cylinder Lubrication and 7218–3 Feed Rate – Adjustment.

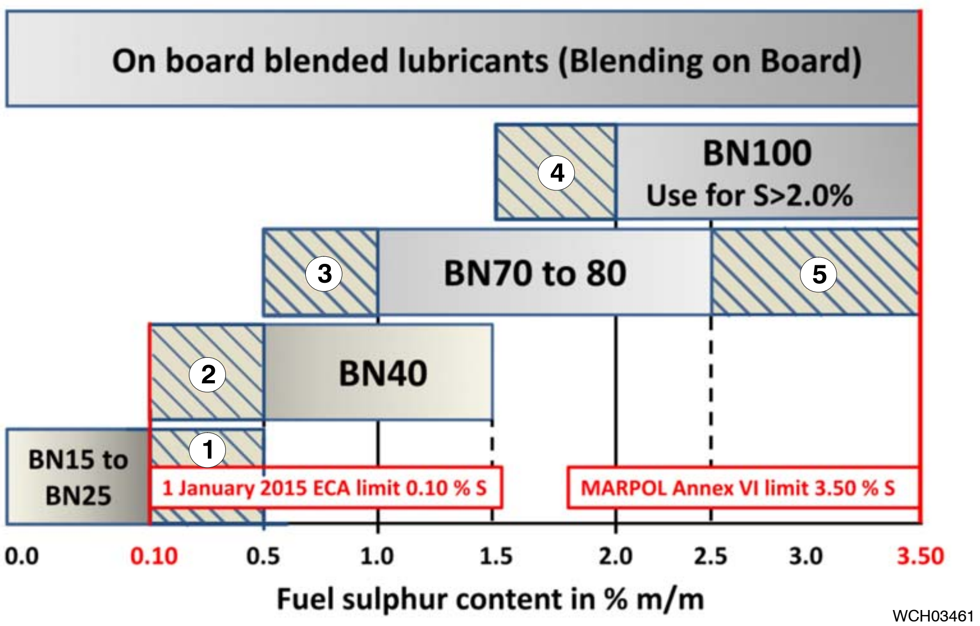


**Fig. 1: Relation between Fuel Sulphur Content and Cylinder Lubricating Oil BN**

- Range 1 (see Fig. 1): When the fuel sulphur content is more than 0.1% m/m and less than 0.5% m/m during operation with BN 15 to BN 25 cylinder lubricating oil, you must do an analysis of the piston underside drain oil from the on-board monitoring system. You must obey the data that follows:
  - The residual base number must not be less than BN10.
  - The iron (Fe) content must be less than 500 ppm.
  - Do regular checks of the piston and piston ring conditions through scavenge port inspections. If necessary, increase the cylinder lubrication oil feed rate to more than 1.2 g/kWh (see 7218−1 Cylinder Lubrication and 7218−3 Feed Rate − Adjustment).
- Range 2 (see Fig. 1): When the fuel sulphur content is more than 0.1% m/m and less than 0.5% m/m during operation with BN 40 cylinder lubricating oil, operation is permitted only, when you do an analysis of the piston underside drain oil from the on-board monitoring system. You must obey the data that follows:
  - Do regular checks of the piston and piston ring conditions through scavenge port inspections.
  - Do regular checks of the cylinder liner condition.
  - You must obey the data given in Fig. 2.
- Range 3 (see Fig. 1): When the fuel sulphur content is more than 0.5% m/m and less than 1.0% m/m during operation with BN 70 to BN 80 cylinder lubricating oil, operation is permitted only, when you do an analysis of the piston underside drain oil from the on-board monitoring system. You must obey the data that follows:
  - Do regular checks of the piston and piston ring conditions through scavenge port inspections.
  - Do regular checks of the cylinder liner condition.
  - You must obey the data given in Fig. 2.
- Range 4 (see Fig. 1): When the fuel sulphur content is more than 1.5% m/m and less than 2.0% m/m during operation with BN 100 cylinder lubricating oil, , operation is permitted only, when you do an analysis of the piston underside drain oil from the on-board monitoring system. You must obey the data that follows:
  - Do regular checks of the piston and piston ring conditions through scavenge port inspections.
  - Do regular checks of the cylinder liner condition.
  - You must obey the data given in Fig. 2.
- Range 5 (see Fig. 1): When the fuel sulphur content is more than 2.5% m/m and less than 3.5% m/m during operation with BN 70 to BN 80 cylinder lubricating oil, operation is permitted only, when you do an analysis of the piston underside drain oil from the on-board monitoring system. You must obey the data that follows:
  - Do regular checks of the piston and piston ring conditions through scavenge port inspections.
  - Do regular checks of the cylinder liner condition.
  - You must obey the data given in Fig. 2.

**Note: From 1st January 2015 only fuel with less than 0.1% m/m sulphur content must be used in Emission Control Areas (ECA). You can use $SO_x$ scrubbers to reduce the effective exhaust sulphur content. For more data, see paragraph 7.**

**Note: Use a BN 100 cylinder lubricating oil, if the fuel sulphur content is more than 2.5% m/m and no piston underside drain oil monitoring system is installed.**

**Note: Monitor the piston underside residual BN of the cylinder lubricating oil and examine the piston rings and cylinder liners. This makes sure that you select the applicable BN oil, set the best oil feed rate, prevent corrosion and excessive piston crown deposits and top land deposits. For more data, see 7218–1 Cylinder Lubrication and 7218–3 Feed Rate – Adjustment.**

Cylinder lubricating oils that have a BN that is too high for the fuel sulphur content can cause excessive deposits on the piston crown. Piston crown deposits must be carefully monitored through scavenge port inspections. The deposits can cause the lubricant film to break down and excessive liner, piston and piston ring wear.

BN 40 cylinder lubricating oils have neutral additives (low BN) to increase the detergency level and thermal stability to the level of a BN 70 cylinder lubricating oil. No significant increase in corrosive cylinder liner and piston ring wear is to be expected when BN 40 cylinder lubricating oils are used (up to 1.5% m/m sulphur) when the cylinder lubricating oil feed rate is kept high. The cylinder lubrication feed rate must be applicable (maximum 1.2 g/kWh) and related to the data from the analysis (residual base number) of the piston underside drain oil.

BN 40 lubrication oils cause less and softer deposits on the piston crown land and in exhaust areas (e.g. on the turbocharger nozzle ring) in relation to the BN 70 and other higher BN products at the same feed rate.

The BN 40 products can also be used safely with HFO that has a sulphur content in the range 0.5% m/m to 1.5% m/m. It is possible that the feed rate must be increased in relation to the remaining BN measured in the piston underside drain oil or scrape-down samples.

There are intermediate (between BN 50 and BN 60) and other BN cylinder lubricating oils available. To use these cylinder lubricating oils, make sure that their performance is monitored regularly. Also, make sure that the cylinder lubricating oil feed rate is adjusted to prevent a piston underside BN that is too low. Incorrectly adjusted piston underside BN can cause high corrosive wear and scuffing (see the limits and recommendations in paragraph 3.2.

**Note: Use only the cylinder lubricating oils given in paragraph 8.2. The oil company assumes all responsibility for the performance of the cylinder lubricating oils in service of all Wärtsilä 2-stroke engines to the exclusion of any liability of any Wärtsilä company belonging to the Wärtsilä group. The oil company and other possible manufacturers and distributors of the products in question shall indemnify, compensate and hold free from liability, Wärtsilä and companies belonging to the Wärtsilä group from and against any claims, damages and losses caused by the cylinder lubricating oils in question.**

To prevent problems with fuel sulphur content, keep sufficient fuel from the bunker you took before. This can be used until an analysis of the sulphur content of the new bunker is received. The results of the bunker analysis and the values given in the Bunker Delivery Note (BDN) can be different. Always use the higher sulphur content value to set the feed rate to make sure that the engine operates safely.

## 3.2 Oil Samples − Piston Underside Drain or Scrape-down

Wärtsilä Services Switzerland Ltd recommends to get piston underside drain oil samples (scrape-down oil) at regular intervals from each cylinder and to make an analysis to monitor the engine condition.

These analyses are used to make an estimate of the cylinder liner and piston ring wear and to set the applicable alkalinity and feed rate of the cylinder lubricating oil. The data given in paragraph 3.1, 7218−1 Cylinder Lubrication and 7218−3 Feed Rate − Adjustment are calculated values. The applicable values for each engine can be different, related to the engine and operating conditions.

You can adjust the cylinder lubricating feed rate related to the analysis of the piston underside drain oil. The permitted maximum feed rate is 1.2 g/kWh. If the analysis of the piston underside drain oil shows that an adjustment to a higher feed rate than 1.2 g/kWh is necessary, you must change to a higher BN cylinder lubricating oil.

The recommended intervals for an analysis of the piston underside drain oil are:

- At each bunker change of the HFO (very important if the sulphur content of the HFO is more than 2.5% m/m).
- At each change of more than 10% CMCR of the average engine (24 hours).
- A minimum of one time each week.

Worn metals, the residual BN, viscosity, fuel components and water are measured. The quantity of system oil additive metals in the sample gives an indication about the piston rod gland box condition. It is important to monitor trends and not full values, and to think about the quantity of drained oil relative to the analysis results.

For data about the procedure to get an oil sample from the piston underside, refer to 8016−1, Lubricating Oil / Servo Oil System, paragraph 2.1 Dirty Oil Samples.

The total iron in the scrape down oil is measured to calculate the corrosion of the liners and steel parts. A large quantity of system oil can be mixed with the used cylinder lubricating oil in the piston underside space. To get an accurate view of the used cylinder lubricating oil, a correction is necessary to remove the effect of the system oil on the results. The iron and residual BN values are corrected in relation to the phosphorus and/or zinc content of the system oil in the used cylinder lubricating oil. This correction analysis must be done carefully because some cylinder lubricating oils also include phosphorus and/or zinc.

The analyses of many piston underside samples from a wide range of engines that operate with a high sulphur content in the range 0.5% m/m to 3.5% m/m and cylinder lubricating oil from BN 40 to Bn 100 has shown:

- The safe corrected piston underside residual BN to prevent piston ring and liner corrosion is more than 25 mg KOH/g but less than 50 mg KOH/g (see Fig. 2).
- The alert corrected limit for piston underside residual BN to prevent excessive corrosion is approximately 15 mg KOH/g.
- The danger corrected limit is less than 10 mg KOH/g piston underside remaining BN. It is possible that there will be too much corrosion, and piston rings and liners can become quickly worn if not corrected. Scuffing can occur. Piston rings can quickly become defective. Corrosion to cylinder liners can occur very quickly.

For each engine it is necessary to find:

- The safe value for continuous operation on fuel oil with a low sulphur content (of between 0.0% m/m and 0.5% m/m).
- A low BN cylinder lubricating oil (between BN 15 and BN 25) .

To find this safe value, you monitor the piston underside samples and do regular checks of the pistons, piston rings and cylinder liners for excessive deposits, corrosion and wear.

Fig. 2 shows the operation ranges for engines with chrome ceramic piston rings and fully honed cylinder liners installed. It shows the relation between the piston underside total oil iron content and the residual BN. If necessary, the cylinder lubricating oil BN and/or feed rate must be adjusted to prevent excessive corrosion or magnetic iron in the piston underside oil.

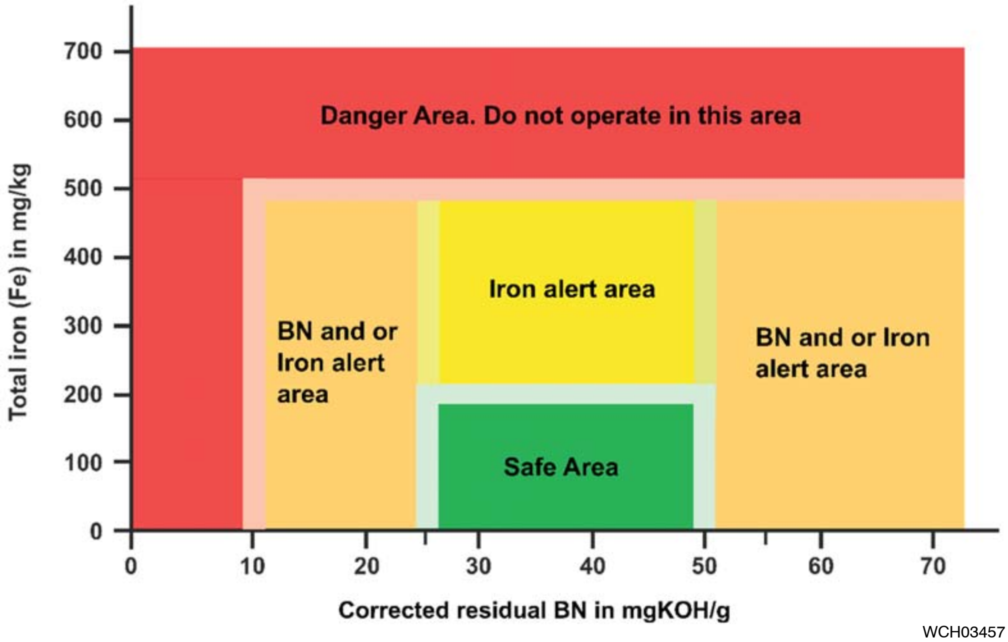


**Fig. 2: Piston Underside, Scrape-down or Drip Oil Analysis Interpretation**

**Note: There are smooth transitions between the different areas shown in Fig. 2.**

For engines with chrome ceramic piston rings installed the chromium content of the piston underside oil shows if there is corrosion or if the engine is worn.

- A chromium content less than 25 mg/kg shows small corrosion, or if the engine is worn.
- A chromium value more than 25 mg/kg shows corrosion or the engine is worn. The service life of the piston rings and the cylinder liners can decrease.
- The chromium value must not be more than 25 mg/kg for a longer period.

**Note: Engines with cast iron (or non-chrome ceramic piston rings) installed, can have a much larger total iron level than engines with chrome ceramic piston rings during usual operation conditions.**

## 3.3 General Recommendations

Service experience has shown that the quantity of corrosion can change very much while the engine operates at less than 60% CMCR (low load).

If the engine is to be operated at continuous low load (i.e. more than 24 hours of operation below 60% CMCR) and the sulphur content of the used HFO is more than 2.5% m/m, Wärtsilä Services Switzerland Ltd. recommends the use of a BN 100 cylinder lubricating oil, as the cylinder oil feed rate cannot be adjusted to sufficiently compensate for the lower alkalinity. If you use a cylinder lubricating oil with a BN less than 100, the permitted maximum feed rate is 1.2 g/kWh (see 7218–1 Cylinder Lubrication and 7218–3 Feed Rate – Adjustment). If the analysis of the piston underside drain oil shows that an adjustment to a higher feed rate than 1.2 g/kWh is necessary, you must change to a cylinder lubricating oil of BN 100.

For data about applicable cylinder lubricating oils, refer to paragraph 8.2.

**Note: You can use the Wärtsilä Blending on Board package to adjust the base number of the cylinder lubricating oil. For more data, speak to or send a message to Wärtsilä Services Switzerland Ltd.**

It is necessary to monitor the residual BN at regular intervals (see paragraph 3.1 and paragraph 3.2). Wärtsilä Services Switzerland Ltd recommends an on-board monitoring programme that, at a minimum, gives you an analysis of the residual BN from the piston underside drain oil. Wärtsilä Services Switzerland Ltd. also recommends the analysis of the total iron and chromium content in the piston underside oil. A sudden increase of the iron or chromium content indicates excessive cold corrosion. For more data, refer to Technical Bulletin RT-161.

## 3.4 Intermediate BN Lubricating Oils

| CAUTION |
| --- |
| **Damage Hazard: For engine operation at less than 60% CMCR (low load) for more than 24 hours. If the sulphur content of the used HFO is in the range of 0.5% m/m to 2.5% m/m, use only intermediate BN lubricating oils (between BN 50 and BN 60) Damage to the engine can occur.** |

If an intermediate BN cylinder lubricating oil (where the BN is more than 40 mg KOH/g and less than 70 mg KOH/g) is used, Wärtsilä Services Switzerland Ltd. recommends the procedures that follow:

1) Use an on-board monitoring programme that, at a minimum, gives you an analysis of the residual BN from the piston underside drain oil. The recommended intervals for an analysis are:

   a) At each bunker change the HFO (very important if the sulphur content of the HFO is more than 2.5% m/m).

   b) At each change of more than 10% CMCR of the average engine (24 hours).

   c) A minimum of one time each week.

# 4. Turbocharger Oil

To select the turbocharger lubricating oil and keep this oil in a satisfactory condition, refer to the recommendations given in the turbocharger instruction manual.

The turbocharger lubricating oil is usually system oil or turbine oil.

# 5. Turning Gear Oil

To select the turning gear oil and keep this oil in a satisfactory condition, refer to the recommendations given in the instruction manual of the turning gear manufacturer.

# 6. Lubricants – Flywheel and Pinion Gear Teeth

To select and apply the lubricants, refer to the specification in the Maintenance Manual 3206-1, and the recommendations from the engine manufacturer.

The lubricant suppliers are given in paragraph 8.4.

# 7. Environmentally Acceptable Lubricants

Environmentally Acceptable Lubricants (EAL) are currently necessary for ships operating in USA waters, and this area may be extended in future.

These lubricants, which are required for all oil-to-sea interfaces (and include stern tubes, thrusters, rudders, stabilizers, variable pitch propellers, underwater ropes, machinery and underwater transmissions) are made with base oils and additives which are different to those used for system and cylinder oil.

Thus, EAL must not be mixed into system or cylinder oils where they are to be used in engine applications. Small quantities of contamination of EAL (related to base oil quality) in system and cylinder oil can cause elastomer compatibility, water emulsification and high temperature deposit formation problems.

# 8. Applicable Lubricating Oils

## 8.1 Lubricating Oil Instruction and Liability

The handling of lubricating oils must be in compliance with the Wärtsilä general lubricating oil requirements and recommendations given in the Operation Manual (this manual) and the Maintenance Manual. Also, refer to the Service Bulletins RT-138, RT-138 Appendix 1, RT-138 Appendix 2 and RT-161.

The supplier oil company takes all responsibility for the performance of the oil in service to the exclusion of any liability of Wärtsilä Services Switzerland Ltd.

## 8.2 Cylinder Lubricating Oils

**Table 4: List of Applicable Lubricating Oils (Last Update: January 2015)**

| Oil Supplier | 15 ≤ BN ≤ 25 6) | BN 40 6) | 50 ≤ BN ≤ 60 6) | 70 ≤ BN ≤ 80 6) | BN 100 6) |
|---|---|---|---|---|---|
| Aegean | Alfacylo 525 DF (BN 25) 5) | – | – | Alfacyclo 570 (BN 70) 5) | Alfacyclo100 HS 5) |
| Bardahl | – | – | – | Naval 50 (BN 70) | – |
| Castrol | AW0053 (BN 16) | Cyltech 40 SX (BN 40) | – | Cyltech 70 (BN 70); Cyltech 80 AW (BN 80) | Cyltech 100 5) |
| Chevron | Taro Special HT LF (BN 25) | Taro Special HT LS 40 | Taro Special HT 55 (BN 55) 3) | Taro Special HT 70 (BN 70); Taro Special 70 (BN 70) 4) | Taro Special HT 100 5) |
| ENI | – | – | – | Punica 570 5) | – |
| ExxonMobil | Mobilgard 525 (BN 25) | Mobilgard L 540 | Mobilgard 560VS (BN 60) 1) | Mobilgard 570 (BN 70) | Mobilgard 5100 |
| FL Selenia | – | – | – | MECO 5070 (BN 70) | – |
| Gdanska | – | – | – | Marinol RG 7050 (BN 70) 4) | – |
| Gulf Oil Marine | GulfSea Cylcare ECA 50 (BN 15) | GulfSea DCA Cylcare 5040H 5) | – | GulfSea Cylcare DCA5070H (BN 70) | GulfSea Cylcare 50100 5) |
| IOC | – | – | – | Servo Marine 7050 (BN 70) | – |
| JX Nippon Oil & Energy | – | Marine C405 (BN 40) Marine C405Z (BN 40) | – | Marine C705 (BN 70) | – |
| LUKOIL | Navigo MCL Ultra (BN 20) 5) | Navigo 40 MCL | – | Navigo 70 MCL (BN 70) | Navigo 100 MCL |
| Mexicana de Lubricantes | – | – | – | Marinelub 7050 (BN 70) 4) | – |
| Pertamina | – | – | – | Medripal 570 (BN 70) | – |
| Petrobras | – | Marbrax CID–54–APN | Marbrax CID–55 (BN 50) 2) | Marbrax CID–57 (BN 70) | – |
| PetroChina | – | – | – | KunLun DCA 5070H (BN 70) | – |
| Shell | Alexia S3 (BN 25) | – | Alexia S4 (BN 60) 1) | Alexia 50 (BN 70); Alexia S5 (BN 80) | Alexia S6 |

**Note: Table 3 continues on the next page.**

Table 3 continued.

| Oil Supplier | 15 ≤ BN ≤ 25 [6)] | BN 40 [6)] | 50 ≤ BN ≤ 60 [6)] | 70 ≤ BN ≤ 80 [6)] | BN 100 [6)] |
|---|---|---|---|---|---|
| SINOPEC | Cylinder Oil 5025 (BN 25) [5)] | Cylinder Oil 5040 [5)] | – | Cylinder Oil 5070 (BN 70) [4)]; Cylinder Oil 5070S (BN 70); Cylinder Oil 5080S (BN 80) | Cylinder Oil 50100 [5)] |
| SK | – | Supermar CYL 40 (BN 40); Supermar CYL 40L (BN 40) | – | Supermar Cyl 70 plus (BN 70) | – |
| Total | Talusia LS 25 (BN 25) | Talusia LS 40 (BN 40) | Talusia Universal (BN 57) [1)] | Talusia HR 70 (BN 70) | Talusia Universal 100 |

Notes to table 3:

1) BN 57 and BN 60 cylinder lubricating oils can be used for the sulphur ranges that follow:

- Between 0.5% m/m and 3.5% m/m if an on-board monitoring programme is used.
- Between 0.5% m/m and 2.5% m/m if:
  - No on-board monitoring programme is used
  - The engine was built before the year 2011
  - The engine load is less than 60% CMCR for more than 24 hours. You must obey the data given in paragraph 3.3.

If there is a sulphur dependency application, the lubricating oils must be thought of as BN 57 and BN 60 as applicable. The BN 60 break-point and feed rate adjustment must be applied, refer to 7218-1 paragraph 8.4 Lubricating Oil Feed Rate – Adjustment.

2) For engines built before the year 2000, BN 50 cylinder lubricating oils can be used with HFO with a sulphur content up to 2.5% m/m.

3) For engines built before the year 2011, BN 55 cylinder lubricating oils can be used for the sulphur ranges between:

- Between 1.5% m/m and 2.5% m/m for continuous operation, and
- Between 0.5% m/m and 1.5% m/m for intermittent operation up to 10 days.

4) Applicable only for engines built before the year 1995.

5) These cylinder lubricating oils are not applicable at this time.

6) The Base Number (BN) measured in mg KOH/g in accordance with method ASTM D 2896 shows the alkalinity of the oil.

**Note: Intermediate cylinder lubricating oils (where the BN is more than 40 mg KOH/g and less than 70 mg KOH/g) can be used, but their performance must be regularly monitored. The lubricating oil feed rate must be adjusted to prevent a piston underside BN which is too low and can cause excessive corrosive wear and scuffing. Refer to the data given in paragraph 3.4. You must be very careful, if you use intermediate BN lubricants and HFO with a sulphur content more than 2.5% m/m.**

**Note: If HFO with a sulphur content of between 1.5% m/m to 3.5% m/m is used, see the data given in paragraph 3.2.**

## 8.3 System Oils

**Table 5: List of Applicable System Oils (Last Update: January 2015)**

| Oil Supplier | Brand |
|---|---|
| Aegean | Alfasys 305 2) |
| BP | Energol OE−HT 30 |
| Castrol | CDX 30 |
| Chevron | Veritas 800 Marine 30 |
| ENI | Cladium 50 |
| ExxonMobil | Mobilgard 300<br>Mobilgard 300 HD 1) |
| FL Selenia | MESYS 3006 |
| Gulf Oil Marine | GulfSea Superbear 3008<br>GulfSea Superbear 3006 |
| IOC | Servo Marine 0530 |
| JX Nippon Oil & Energy | Marine S30 |
| LUKOIL | Navigo 6 SO<br>Navigo 6 CO |
| Pertamina | Medripal 307 |
| Petrobras | Marbrax CAD−308 |
| PetroChina | KunLun DCC3008<br>KunLun DCC3005H 2) |
| Shell | Melina S30<br>Melina 30 |
| SINOPEC | Marine System Oil 3005<br>Marine System Oil 3006<br>Marine System Oil 3008 |
| SK | Supermar AS |
| Total | Atlanta Marine D 3005 |

1) Applicable only for RT-flex and W-X engines built after February 2012.

2) These cylinder lubricating oils are not applicable at this time.

## 8.4 Lubricants − Flywheel and Pinion Gear Teeth

To apply correctly the lubricant oils given in Table 6, refer to the Maintenance Manual 3206-1.

**Table 6: List of Lubricants − Flywheel and Pinion Gear Teeth (Last Update: October 2012)**

| Supplier | Brand |
|---|---|
| Lubrication Engineers Inc. | LE 5182<br>PYROSHIELD |
| Klüber Lubrication<br>München KG | Klüberfluid<br>C−F 3 ULTRA |

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# Operating Media
## Cooling Water

## 1. General

An applicable treatment is used to give the cooling water the correct properties, which will prevent service problems. Cooling water that has not had treatment can soon cause problems in the cooling system from corrosion, sediment and hard particles.

## 2. Raw Water – Closed Cooling Water Circuits

**CAUTION**

**Damage Hazard: Do not use seawater as raw water. Seawater has a high salt content and causes damage to the cooling water system.**

Before you fill the system, the raw water must be fully desalinated. Condensate water from e.g. the fresh water generators or from auxiliary steam systems can be used, but must have additives. Condensate water is highly corrosive and must have corrosion inhibitors to prevent problems.

Use potable water or process water from the local mains only as a last option. The hardness of this water must not be more than 10°dH (German hardness degrees). If the hardness is more than this limit, desalinate the water to the values given in the Table 1.

**Table 1: Water Data**

| Parameter | Value | Test Method |
|---|---|---|
| pH, (see Note) | 6.5 to 8.5 | ASTM D 1287 or D 1293 |
| Hardness | Maximum 10°dH | ASTM D 1126 |
| Chlorides ($Cl^-$) | Maximum 80 mg/l | ASTM D 512 or D 4327 |
| Sulphates ($SO_4^{2-}$) | Maximum 150 mg/l | ASTM D 516 or D 4327 |

**Note: For reverse osmosis technologies, the minimum pH value is 6.0.**

If you think there is a problem, do an analysis of the water. Send the results of the analysis to Wärtsilä Services Switzerland Ltd. to get advice.

Corrosion protection oils (emulsion oils) are not recommended for the treatment of the cooling water. If instructions about the use of corrosion protection oils are not obeyed and coolant checks are not sufficient, then water / oil emulsion can occur. This can cause the cooling system to become clogged.

## 3. Cooling Water during Operation

The cooling water must have the correct corrosion inhibitor. Inhibitors that contain the agents Nitrite and Borate, and are related to the Organic Acid Technology (OAT) are known to be satisfactory. You can get a list of recommended products from Wärtsilä Services Switzerland Ltd.

The instructions of the manufacturer must be obeyed for the correct quantity of the corrosion inhibitor. You must do regular checks during operation to keep the correct concentration.

It is recommended that you choose such suppliers of inhibitors who can also give specified advice for the new cooling water, and for during operation.

If there are leaks, you must add the correct quantity of water with the correct concentration of inhibitor. If evaporation causes a decrease of the coolant, add the applicable quantity of raw water (see paragraph 2 above). This will make sure that the concentration of inhibitors is not too much.

The water in the cooling system must have a pH value of 8 to a maximum of 10.

## 4. Cleaning the Cooling Water System

For new cooling water, the full system must be clean. The system must not contain grease, oil or unwanted particles.

During operation oil or sediment can go into the system, which can cause a decrease in the heat transfer and cooling effect. Such problems will occur after an unusually short time if the cooling water and system is not monitored correctly. An applicable agent must be used for the treatment of the full system to remove grease and chalk sediment.

Before you fill the cooling water system with new cooling water, the system must be fully flushed. This will remove sediment and oil and make sure that remaining acids are made neutral.

There are many cleaning agents available, which are not in a list here. It is recommended that you speak to specialist companies that can help you.

## 5. Antifreeze

**CAUTION**

**Damage Hazard: Antifreeze decreases the heat transfer rate of the cooling water. This can cause damage to the engine. If the concentration of the antifreeze is more than 20%, you can operate the engine only at decreased load.**

During usual operation, it is not necessary to use antifreeze. We recommend to use antifreeze only if the engine does not operate for a long period in conditions of cold / frost (ambient temperature below the freezing point of water).

Always use the correct water / antifreeze ratio related to the ambient temperature. The instructions of the manufacturer must be obeyed for the correct quantity of antifreeze.

It is possible to use each of the two types of high quality antifreeze that follow:

- Monopropylene glycol (MPG)
- Monoethylene glycol (MEG).

It is recommended that you use MPG, because it is better for the environment.

You must do regular checks during operation to keep the correct concentration.

You must obey the instructions of the manufacturer to prevent problems during operation.

You must make sure that the cooling water system has the correct concentration of corrosion inhibitor (see paragraph 3).

# Operating Media
Gas Fuel

## 1. General

For safety, obey the data given in 0100−1 Safety Precautions and Warnings, paragraph 16, Natural Gas.

When the engine operates in gas mode, the primary fuel is natural gas. The gas fuel is injected at low pressure. The ECS controls electronically the injection timing and gas fuel quantity (for more data, refer to 4002−1 Engine Control System). Pilot fuel ignites the gas-air mixture during operation in gas mode (for more data, refer to 0300−1 Diesel Engine Fuels, paragraph 8.5 Pilot Fuel System).

Usually, the gas fuel is stored as liquified natural gas (LNG) at atmospheric pressure or pressurized. There are different designs of the external gas supply system and the LNG storage. The gas supply system supplies natural gas at the correct temperature and pressure to the engine. For more data, refer to the documentation of the related manufacturer.

**Note: LNG storage tanks can be installed to applicable ship types, operation areas, operation times and engine size (e.g. IMO type A / type B or membrane tanks). Refer to and obey the related IMO regulations.**

For safety, the engine must have a gas detection system. For more data, refer to 4002−1, paragraph 4.4.

For safety, the gas supply pipes in the engine room and on the engine have double walls. There is a shut-off valve for each supply pipe in the system. For more data, refer to 8014−1 Gas Fuel System.

## 2. Specifications

**CAUTION**

**Damage Hazard: Water and hydrocarbon condensates at the gas inlet to the engine are not permitted. Water and hydrocarbon condensates decrease the dew point of natural gas to less than the applicable operation temperature and pressure. Damage to the engine can occur.**

To make sure that the engine operates satisfactorily at continuous operation in gas mode (without a decrease in the rated engine output), you must obey the specifications given in Table 1.

**Table 1: Gas Fuel Specifications at the Engine Inlet**

| Parameter | Value |
|---|---|
| Lower heat value (LHV), (see Note 1) | Minimum 28 MJ/Nm$^3$ |
| Gas methane number (MN), (see Note 2) | Minimum 80 |
| Methane content | Minimum 70% volume |
| Hydrogen sulphide ($H_2S$) | Maximum 0.05% volume |
| Hydrogen ($H_2$), see (Note 3) | Maximum 3% volume |
| Ammonia | Maximum 25 mg/Nm$^3$ |
| Chlorine and fluorines | Maximum 50 mg/Nm$^3$ |
| Particles or solids at GVU inlet (content) | Maximum 50 mg/Nm$^3$ |
| Gas temperature at GVU inlet in usual ambient conditions (ISO) | 0°C to 60°C |
| Gas temperature at GVU inlet in tropical ambient conditions | 20°C to 60°C |
| Gas feed pressure, (see Note 4) | 15 bar(g) to 16 bar(g) |
| Permitted gas pressure fluctuation | Maximum ±0.2 bar / 5 s |

**Note: The fuel gas must not contain condensate, oil or water droplets/mist. Refer to the data given in PNEUROP 661 quality class 4−2−3 or ISO 8573−1 quality class about compressed air.**

Notes to Table 1:

(1) All values given in MJ/Nm$^3$ are at 0°C and 101.3 kPa

(2) To calculate the methane number (MN) of the gas fuel, use the software Methane 3.20 from AVL.

(3) Hydrogen content of more than 3% volume is only permitted for special engine configurations and projects. For more data, speak to or send a message to Winterthur Gas & Diesel Ltd.

(4) The necessary gas supply pressure is related to the lower heat value (LHV).

# Engine Start

## Prepare for Engine Start after a Short Shut-down Period (One or More Days)

**WARNING**

**Injury Hazard: Before you operate the turning gear, make sure that no personnel are near the flywheel, or in the engine.**

**Note: You must obey the data given in 0100−1 Safety Precautions and Warnings.**

**Note: If the engine was shut down for a long period or an overhaul, you must do the procedures given in 0410−1 Prepare for Engine Start after a Long Shutdown Period or an Overhaul.**

**Note: Refer to 4003−2 Page 1 and Page 2 Engine Control Diagram for the item numbers (e.g. 30−8605_E0_6).**

**Note: You can only start the engine in diesel mode.**

## 1. Start Position

For the start position, the engine must be in the condition that follows:

- All components that had an overhaul are correctly assembled and installed.
- All components that had an overhaul have had tests or checks to make sure that they operate correctly.
- All devices, tools and materials are removed from the engine.

## 2. Prepare for Operation

1) Make sure that the ball valves 30−8605_E0_6 and 30−8605_E0_7 are open (when the starting air shut-off valve (30−4325_E0_1) is in the position CLOSED).
2) Do a check of the fluid and gas levels of all the tanks in the engine systems (and the leakage drain tanks).
3) In the cooling water system and lubricating oil system, make sure that all the shut-off valves are in the correct position (refer to 8016−1 Lubricating Oil / Servo Oil System and 8017−1 Cooling Water System).
4) In the shipboard system, open the air supply to the control air supply.
5) In the control air supply at connection A1, open the 3/2-way valve 35.36HB.
6) At connection A6, set the 3/2-way valve 35.36HA to the operation position (refer to 4003−1 Engine Control, paragraph 4.2 and 4605−1 Control Air Supply).
7) Increase the temperature of the lubricating oil to approximately 35°C (through the lube oil separator or heaters in the oil drain tank if installed).
8) Increase the temperature of the cylinder cooling water to a minimum of 65°C.
9) Set to on the engine control system (ECS) and the remote control system.
10) For the cylinder lubricating system, do step a) to step d):
    a) In the control box E44 (engine room), set to on the primary switches. Make sure that the ECS has selected cylinder lubrication.
    b) Make sure that the ball valves are open.
    c) Make sure that there is no air in the cylinder lubrication pumps 25−7206_C#_#.
    d) Make sure that there is no air in the pipes to the lubricating quills. For more data, refer to the Maintenance Manual 2138−1.

**Note: You must only do the air removal procedure:**

- **Before the first commissioning**
- **After maintenance**
- **After a long shut-down period**
- **When there are operation problems (operation pressure, supply rate).**

11) In the power supply box E85, set to on all circuit breakers.
12) Prepare the servo oil system as follows:
    a) Make sure that the ball valve 20-8423_E0_2 upstream of the injector valve is closed.
    b) Make sure that the screw plug 20−5610_E0_7 on the servo oil rail is tight.
13) Start the pumps for the cylinder cooling water, bearing oil and crosshead lubrication. Set the pressures to their specified values (refer to 0230−1 Operating Data Sheet ).
14) Set to on the control box for the automatic filter (refer to the documentation of the automatic filter manufacturer).
15) Prepare the diesel fuel system (refer to 0420−1).
16) Make sure that you correctly release all air from all systems.
17) In the LDU−20 (on the local control panel):
    a) Get the MAIN page.
    b) Get the EXHAUST VALVES page.
    c) Make sure that there is an air spring air supply.
    d) Make sure that all exhaust valves are closed.
18) Manually open and close all exhaust valves until all the air is released in the hydraulic pipes as follows:
    a) In the column Exh. Valve pos., enter 1 in all the fields to manually open all the exhaust valves.
    b) In the column Exh. Valve pos., enter 2 in all the fields to manually close all the exhaust valves.
19) Open the relief valves on all cylinder covers (refer to 2722−1).
20) Operate the turning gear to turn the engine a minimum of one full turn to make sure that all the running gears operate correctly.

    **Note: Oil, water or fuel must not come out of the indicator valves.**
21) If water, oil or fuel comes out of the indicator valves, do a check of the related components that follow:
    - Cylinder liner
    - Cylinder cover
    - Piston
    - Injection valves.
22) Set to on the cylinder lubrication.
23) Close the indicator valves on all cylinders.
24) Make sure that all the clamps lock the crankcase doors.
25) Make sure that the starting air bottles 930−B001 and 930−B002 have the correct pressure.

26) Open the ball valve 35−8353_E0_2 to drain possible condensation.
27) Close the ball valve 35−8353_E0_2.
28) Close the vent valves 35−8353_E0_6 and 35−8353_E0_7.
29) Open the shut-off valves 930−V03 and 930−V04 on the starting air bottles 930−B001 and 930−B002.
30) On the starting air shut-off valve 30−4325_E0_1, turn the handwheel to the position AUTOMAT.
31) In the MAIN page of the LDU−20, make sure that the Control Air field and the Start Air field show a pressure indication.
32) Make sure that the pressure gauges on the instrument panel show starting air pressure and control air pressure.
33) Make sure that a pressure indication shows on the pressure gauges for the control air supply. The different circuits are:
    - Air spring air
    - Control air.

    **Note: For the applicable pressures, refer to 0230−1 Operating Data Sheet.**
34) In the LDU−20 MAIN page (on the local control panel), set to on the auxiliary blowers. Make sure that the indication shows RUNNING.
35) Set to off the servo oil service pump.
36) Disengage the turning gear and lock the lever.
37) On the starting air shut-off valve, open the test valve 35−8353_E0_2 momentarily to get starting air. Make sure that you can hear the starting air shut-off valve open.
38) Close the test valve 35−8353_E0_2.
39) In the LDU−20 MAIN page (on the local control panel), get the USER PARAMETERS page.
40) Select the tab SLOW TURN. The engine will slowly turn one time (see Slow Turning 0430−1, paragraph 3).
41) Make sure that at the location where you want to start the engine, the related LDU−20 has control (e.g. the control room or the local control panel).
42) Tell personnel on the bridge that the engine is prepared for operation.

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# Engine Start
## Prepare for Engine Start after a Long Shutdown Period or an Overhaul

## 1. General

**Note: You can start the engine only in diesel mode.**

For an engine that was shut down after a long period or an overhaul, do the procedures given in 0400–1 Prepare for Engine Start after a Short Shutdown Period and the special procedures in paragraph 2 below.

## 2. Special Procedures

1) Do a check of the engine control as given in 4003–1, Engine Control, paragraph 4, Engine Control System Checks.

2) If parts of the gas fuel system were replaced or removed (for checks) do the checks given in 4003–1 Engine Control, paragraph 4.13, Gas Fuel System.

3) If parts of the pilot fuel fuel system were replaced or removed (for checks) do the checks given in 4003–1 Engine Control, paragraph 4.14, Pilot Fuel Pressure.

4) If bearings or parts of the running gear were replaced or removed (for checks), do a check of the lubricating oil supply at the usual oil pressure (see 0230–1 Operating Data Sheet).

5) Do a visual check through the open running gear doors to see if there is sufficient oil flow from all bearing locations.

During the operation period, it is recommended that you monitor the parts for unusual heat. You monitor the parts as given in paragraph 6) to paragraph 8) below:

6) Start and stop the engine for short intervals. See the data given in 0100–1 Safety Precautions and Warnings, paragraph 9, Temperature.

7) Compare the temperatures of the newest parts with those that were installed before.

8) Start and stop the engine for longer intervals.

9) Compare the temperatures again as given in step 6) to step 8).

**Note: For data about running-in new pistons, piston rings and cylinder liners, refer to 0570–1 Running-in of New Cylinder Liners and Piston Rings.**

10) Make sure that the scavenge air and exhaust gas can flow freely.

11) If the cooling water for the scavenge air cooler was drained, fill and bleed the system.

12) Make sure that the drains in the exhaust gas manifold and on the exhaust gas pipe are closed.

13) Make an analysis of the lubricating oil quality after a long shutdown period (some months), see 0320–1 Lubricating Oils.

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# Engine Start
Prepare the Fuel Systems for Operation

## 1. Diesel Fuel System − Prepare

### 1.1 MDO Operation

1) See 0300−1 Fuel Treatment and Fuel System, Fig. 2 and Fig. 3.
2) Set the automatic change-over unit (16) in the suction line of the low pressure pumps (19) to the correct position. This lets diesel oil flow from the service tank to the pump and to the mixing unit (21).
3) Make sure that the shut-off valves upstream and downstream of the engine are open.
4) Set to on the low pressure pumps (19) and the booster pumps (22).
5) Drain the service tanks (6) and the mixing unit (21).
6) Use the pressure regulating valve (17) to set the pressure in the fuel system.

**Note: When the engine operates with diesel oil (and low fuel temperature) a small over-pressure is sufficient. If a change-over to heavy fuel oil (HFO) is necessary, the setting of the usual pressure is recommended from the start.**

7) Use the pressure retaining valve (27) to set the fuel pressure at the fuel pump return (refer to 0230−1, column Medium, row Downstream of pressure retaining valve).
8) Refer to 8019−1 Fuel System Fig. 1.
9) Make sure that the shut-off valve (6) is open.

### 1.2 HFO Operation

1) Refer to 0300−1, Fig. 2 and Fig. 3.

**Note: The fuel system is not ready for operation until the HFO upstream of the fuel pumps is at the applicable temperature (see 0300−1 paragraph 3.1 Viscosity-Temperature Diagram).**

After a shut-down period of more than 24 hours, increase the temperature of the high pressure circuit on the engine for a minimum of four to six hours. Do not try to start the engine with HFO before you increase the temperature of the fuel.

2) Set to on the heating for the HFO service tank (3) or the HFO/LSHFO service tank (4), mixing unit (21), end-heater (23) and fuel filter (24).
3) Set to on the heating for the fuel system on the engine (fuel rail) (4, refer to 8019−1 Fuel System, Fig. 1), HP fuel pipes (16) and the fuel leakage system.
4) Make sure that the steam pipes are tight. If leakages are found, repair them before the first commissioning or after maintenance on the fuel system.
5) Set the automatic change-over unit (16, 0300−1, Fig. 2 and Fig. 3) in the suction line of of the low pressure pump (19) to the correct position. This lets HFO flow from the HFO service tank (3) to the pump and the mixing unit (21).
6) Drain the settling tanks (1, 2), the service tanks (3, 4), and the mixing unit (21).
7) Make sure that the shut-off valves upstream and downstream of the engine are open.
8) Start the low pressure supply pump (19) and the booster pump (22).

9) Increase the temperature of the HFO. This is necessary to get the HFO to the applicable viscosity (refer to 0300−1, paragraph 3.1).
10) Operate the pressure regulating valve (17, 0300−1, Fig. 2 and Fig. 3) to set the pressure in the fuel oil system.
11) Use the pressure retaining valve (27) to set the fuel pressure at the fuel pump return (refer to 0230−1, column Medium, row Downstream of pressure retaining valve).
12) Refer to 8019−1 Fuel System Fig. 1.
13) Make sure that the drain valve (19) is open.

## 2. Pilot Fuel System − Prepare

1) Refer to 0300−1, Fig. 4.
2) If installed, set to on the heating for the MDO service tank (1).
3) Make sure that the pressure and temperature at the pilot fuel inlet is sufficient. For the applicable values, refer to 0230−1 Operating Data Sheet.
4) Make sure that the duplex filter (3) is serviceable. If necessary, clean or replace the duplex filter.
5) Make sure that the shut-off valves upstream and downstream of the fuel pump unit are open.
6) In the LDU-20 get the PILOT FUEL PRESS. page.
7) Make sure that the pilot fuel pump (4, 0300−1, Fig. 4) is set to on and the pressure is sufficient.
8) In the LDU-20, make sure that no failure message is shown in the Failure List page.
9) Do a visual check of the HP fuel pipes (to the pilot injection valves) for damage or leaks. If damage or leaks are found, replace the defective high pressure fuel pipe. For more data, see the Maintenance Manuel.

## 3. Gas Fuel System − Prepare

The Gas Valve Unit (GVU) has an isolated control system, related to the GVU manufacturer. For more data, refer to the documentation of the GVU manufacturer and 4002−1, paragraph 4.6 Gas Valve Unit.

The GVU has a colored human-machine interface (HMI) panel, attached to the control cabinet. For more data, refer to 8014−1, paragraph 3.3 Gas Valve Unit.

1) Do a visual check of the gas inlet pipes for damage. If damage is found, replace the defective gas inlet pipe immediately. For more data, refer to the Maintenance Manual.
2) Do the procedures given in
   a) 4003−1 Engine Control, paragraph 4.13.1 Gas Fuel System Tests
   b) 4003−1, paragraph 4.13.2 Gas Valve Unit and Valve Test
   c) 4003−1, paragraph 4.13.3 Gas Admission Valve − Manual Valve Test
3) Make sure that no alarm or failure message is shown in the LDU-20.

# Engine Start
Slow Turning

## 1. General

To make sure that the running gear turns freely, it is recommended (as long as the classification society did not make more primary specifications) to turn the crankshaft a minimum of one full turn before start-up.

**Note: This does not apply if the engine was stopped during a maneuvering period.**

## 2. Turning Gear

The turning gear is used to turn the crankshaft (approximately one turn in 10 minutes). An arrow next to the flywheel shows the direction and distance that the crankshaft has turned.

## 3. Slow Turning with Starting Air

The ECS has the command SLOW TURNING for this operation (refer to 4002−2 Local Control Panel / Local Display Unit (LDU-20), paragraph 3.22).

A controlled quantity of starting air is released to turn the running gear at approximately 5 rpm to 10 rpm.

The active control stand is used to start the SLOW TURNING operation:

- From the remote control
- At the ECR manual control panel in the control room
- At the local control panel.

### 3.1 Conditions

**Note: The numbers e.g. 30−4325_E0_1 refer to items in 4003−2 Page 1 and Page 2 Control Diagram.**

1) Before you start the SLOW TURNING operation, do the steps that follow:
   a) Make sure that the turning gear is disengaged.
   b) Make sure that the ECS is set on.
   c) Make sure that the oil pumps operate (main bearing oil and crosshead bearing oil).
   d) Make sure that the related control stand has control.
   e) Make sure that the relief valves in the cylinder cover are closed.
   f) Make sure that the handwheel on the starting air shut-off valve 30−4325_E0_1 is in the position AUTOMAT.
   g) Make sure that the shut-off valves 930−V03 and 930−V04 on the starting air bottles 930−B001 and 930−B002 are open.
   h) Make sure that the air pressure for the air spring is set correctly (refer to 0230−1 Operating Data Sheet).
   i) Make sure that the cylinder lubrication is set to on.

**Note: If there is a pressure decrease during this procedure, refer to 8019−1 Fuel System, paragraph 4.4 Pressure Control Valve − Leakage Check.**

## 3.2 Function

The function below is almost the same as the engine start function:

- The 2/2-way valve 35−4325_E0_5 opens the starting air shut-off valve 30−4325_E0_1.
- Starting air flows through the pressure safety valve 30−8650_E01 to the 3/2-way solenoid valves 30−2728_CX_1 (CV7241−4#C).
- The CCM-20 control the 3/2-way solenoid valves 30−2728_CX_1 (CV7241−4#C) upstream of the starting valves. The starting valves in the cylinder covers open and close for short intervals only.
- You can use the remote control to change the timing of the starting valves (open / close) to get the best slow turning speed.

# Engine Start
## Engine Start Procedure

## 1. General

**Note: You can only start the engine in diesel mode.**

Before you start the engine (also, before trials and using starting air to turn the engine) refer to:

- 0400–1 Prepare for Engine Start after a Short Shutdown Period
- 0410–1 Prepare the Engine Start after a Long Shutdown Period or an Overhaul
- 0420–1 Prepare the Fuel Oil System for Operation

You can start the engine from the locations that follow:

- The bridge or control room with the remote control.
- At the LDU-20 in the control room.
- At the LDU-20 on the local control panel on the engine.

## 2. Engine Start – Control Stand in Control Room

Prepare the engine as follows:

1) At the local control panel, push the button CTRL. TR on the LDU-20 for transfer to ECR remote.
2) At the control room console, make sure that the remote control has control.

For more procedures to start using the remote control, see the documentation of the remote control manufacturer.

**Note: If you move the telegraph from STOP to a different position, a start signal is released automatically.**

## 3. Engine Start – at the Local Control Panel

You use this mode if e.g. the electronic speed control system or the remote control becomes defective.

| CAUTION |
|---|
| **Damage Hazard. The operator must not leave the local maneuvering stand. The operator must regularly monitor the speed indication to immediately adjust the fuel supply if the speed changes.** |

### 3.1 Preparation

1) At the local control panel, push the button CTRL. TR. on the LDU–20 for transfer to Local.

## 3.2 Engine Start Procedure

1) In the LDU, MAIN page push the button ON/OFF to start the auxiliary blowers. Make sure that Running shows in the Auxiliary Blowers field.
2) Use the rotary button to select the Fuel command button.
3) Turn the rotary button to set the fuel injection quantity to approximately 30%.
4) Push the button START AHD or START AST until the engine operates.
5) Slowly turn the rotary button to adjust the fuel injection quantity until the engine operates at the applicable speed. You can see the related value on the display and speed indicator.
6) Read the instructions to increase the speed/power (refer to 0520−1 Maneuvering) and monitor the data (refer to 0230−1 Operating Data Sheet).

You can also do the engine start procedure above from the ECR manual control panel.

**Note: You can use the buttons and rotary button only at the related active control stand.**

# Engine Start
## Problems during Engine Start



For the names and part code numbers, refer to 4003–2, Page 1 and Page 2 Control Diagram.

## 1. Engine does not Turn During Start Sequence

| Possible Causes | Procedure |
|---|---|
| The shut-off valves on the starting air bottles are closed | Open the shut-off valves |
| The starting air pressure is too low | Fill the air bottles |
| The oil pressure, water pressure, or air pressure for the air spring is too low. The pressure switches have activated a SHUTDOWN signal | Reset SHUTDOWN |
| The air spring did not close the exhaust valve (i.e. the top housing is filled with oil because the lubricating oil pump and service pump started too early, or stopped too late). | Set to off the lubricating oil pump and service pump. After approximately 30 minutes, oil flows out of the top housing through the orifice. Start the oil pumps only if all the exhaust valves are closed. |
| The electrical connection(s) are disconnected from the solenoid valve(s) CV7013C and CV7014C in valve unit for start **E** | Connect the electrical connection(s) |
| The starting air shut-off valve 30–4325_E0_1 is in the position CLOSED | Move the starting air shut-off valve 30–4325_E0_1 to the position AUTOMAT |
| The starting air shut-off valve 30–4325_E0_1 does not open, (cannot move), the non-return valve of the starting air shut-off valve cannot move and does not fully open | Do an overhaul of the starting air shut-off valve 30–4325_E0_1 |
| The auxiliary blowers do not operate | Start the auxiliary blowers |
| The air flaps in the scavenge air receiver are defective (no pressure from the auxiliary blowers) | Do an overhaul on, or replace the air flaps |
| No air spring pressure, or pressure is too low | Open the 3/2-way valve 35.36HA, adjust the pressure to 6 bar in control air supply unit **A** |
| The non-return valve on the exhaust valve (air inlet to air spring) is incorrectly installed. You can hear loud noises and the exhaust valve does not fully close | Do a check and install correctly (refer to the Maintenance Manual 2751–2) |
| The starting valves cannot move or the electrical connection is not connected | Do an overhaul of the starting valves or connect the electrical connection |
| Different causes | Try to start the engine in the opposite direction |

# 2. The Engine does not Start

| Possible Causes | Procedure |
|---|---|
| The speed control system is defective. Does not release a controlled fuel injection quantity. | Do a check of the MCM-11 for defects. Refer also to 4002–1 paragraph 3.8.1 |
| The fuel rail pressure is too low. The pressure control valve 10–5562_E0_5 stays open. | Do a check of the pressure control valve 10–5562_E0_5 (refer to 8019–1, paragraph 11) |
| There is heavy leakage in the high pressure circuit (fuel) on the engine | Do a check for leaks, refer to 8019–1, paragraph 4 |
| The fuel booster pressure is not sufficient | Adjust the fuel booster pressure |
| The pressure retaining valve is set too low | |
| The booster pump does not supply fuel | |
| The shut-off valves upstream of the engine are closed (plant) | Open the shut-off valves |
| The fuel pump is defective | Repair the fuel pump (refer to 8019–1–1, paragraph 7) |
| The fuel pump actuator is defective | Repair the fuel pump actuator (see 8019–1, paragraph 8) |
| An injection valve is defective | Repair the injection valve (see 8019–1, paragraph 9) |
| A flow limiting valve is defective | Repair the flow limiter (see 8019–1, paragraph 10) |
| The pressure control valve is defective | Repair the pressure control valve (see 8019–1, paragraph 11) |

## 2.1 Engine does not Start – from Control Room Stand

| Possible Causes | Procedure |
|---|---|
| The control stand has no effect | Push the related button on the LDU-20 for mode transfer or to get control (refer to 4002–2, paragraph 3.4) |
| The remote control system (RCS) and / or telegraph system has a fault | Do a check of the RCS or speak to the RCS supplier |
| The RCS shows a start interlock | Do a check of the indication of starting interlock in RCS (turning gear, shut-down, auxiliary blower), release interlock |
| No signal between the RCS and the engine control system (ECS) | Do a check of the plugs, and CAN open lines, for loose or broken wires |

## 2.2 Engine does not Start – At Engine Control Stand

| Possible Causes | Procedure |
|---|---|
| The control stand has no effect | Push the related button on the LDU−20 for mode transfer or to get control (see 4002−2, paragraph 3.4) |
| The turning gear is engaged, the 3/2-way valve 35.31HA prevents the flow of control air to the valve unit for start **E** | Disengage the turning gear |
| The 2/2-way valve 35−4325_E0_5 to the starting air shut-off valve 30−4325_E0_1 cannot move, or does not open fully | Clean the 2/2-way valve clean the 2/2-way valve 35−4325_E0_5 |
| The solenoid valves CV7013C and CV7014C in valve unit for start **E** become defective | Clean or replace the solenoid valves<br>Do a check of the wiring |

# 3. Engine Moves Back or Does Not Get Speed

| Possible Causes | Procedure |
|---|---|
| A cylinder receives no starting air, or the starting air is not sufficient (blockage in starting air pipe) | Do a check of the starting air pipe, flame arrestor and remove the blockage |
| The solenoid valve(s) CV7241 (to CV7248C) cannot move | Clean or replace the related solenoid valve(s) |
| The cable to the CCM-20 is broken. | Do a check of the electrical signal |
| The starting air pressure is too low | Fill the air bottles |

# 4. No Ignition during Engine Start

| Possible Causes | Procedure |
|---|---|
| The injected fuel quantity is too small | Adjust the speed setting |
| The speed setting is too low. | |
| The fuel is not correct or its viscosity is too high | Prepare the fuel systems (see 0420−1) |
| The starting air pressure is not sufficient to turn the engine with sufficient speed | Fill the air bottles |
| The auxiliary blower or non-return valves in the scavenge air receiver is defective | Do an overhaul or replace the auxiliary blower or non-return valves |
| The compression pressures are too low | Replace the piston rings |
| The piston rings are in an unsatisfactory condition | |
| The exhaust valves do not close correctly | Grind the surfaces of the valve head and valve seat (see the Maintenance Manual) |
| The high pressure circuit has leaks (fuel pumps, HP pipes, fuel rail) | Find the cause and repair the leaks |
| The heating of the high pressure pipe to the injection valves does not operate | Set to on the heating pipes |

## 5. Cylinder does not Fire during Engine Start

| Possible Causes | Procedure |
|---|---|
| The ECS isolates the injection valves (function) | Set to on the injection (refer to 4002–2, paragraph 3.7) |
| Injection is cut out | Cut in the injection (see 8019–1, paragraph 6 and 4002–2, paragraph 3.7) |
| The connections between the injection valve and the flow limiter valve have a leak | Tighten the connections correctly. Grind the sealing faces |
| No electrical signal to the solenoid valve(s) CV7441–48C and CV7461–68C | Do a check of the wiring. If necessary replace the solenoid valve(s). |
| The exhaust valve has a malfunction. No electrical signal to the 4/2-way valves CV7401–08C and CV7421–28C on the exhaust valve control unit. | Do a check of the wiring and 4/2-way valves CV7401–08C and CV7421–28C. If necessary replace the defective 4/2-way valve. |
| The injection nozzles have leaks. The needles do not move. | Replace the injection valve (refer to the Maintenance Manual) |
| The holes in the injection nozzle are blocked | Replace the nozzle tip (refer to the Maintenance Manual) |
| Compression pressure in the cylinder is not sufficient for fuel ignition. | Replace piston rings |
| | Grind the surfaces of valve head and valve seat (refer to the Maintenance Manual) |
| The exhaust valve spindle cannot move | Replace the defective parts |
| The CCM-20, MCM-11 or IOM-10 power supply is disconnected, the connector is removed or incorrectly connected, the internal part(s) have become defective | Set to on the power supply |
| | Connect the electrical connection |
| | Replace the CCM-20, MCM-11 or IOM-10. |
| The piston in the exhaust valve control unit, or the pins in the 4/2-way valves CV7401–08C and CV7421–28C cannot move | Replace the 4/2-way valve CV7401–08C and CV7421–28C, or the exhaust valve control unit |
| Exhaust valve control unit is cut out | Cut in the exhaust valve control unit (refer to 8016–1, paragraph 4.3.3) |
| Starting valves do not open, cannot move, are damaged or receive no signal. | Do an overhaul or replace the starting valves |
| | Do a check of the wiring |

## 6. Violent Firing during Engine Start

| Possible Causes | Procedure |
|---|---|
| Fuel rail pressure is too high, fuel control does not operate correctly | Do a check of the power supply and wiring |
| Cylinders were lubricated too much before starting. Unwanted quantity of cylinder oil in the combustion spaces. | Decrease the speed setting (fuel injection quantity) until the unwanted oil has burned. Do not lubricate too much. |
| Fuel injection quantity (start fuel charge) is set too high | Decrease the speed setting (fuel injection quantity) |
| The fuel injection quantity (start fuel charge) is set too high | Decrease the speed setting (fuel injection quantity) |
| The fuel limiter is set too high | Adjust the setting to the standard value |

# Operation
## Usual Operation

## 1. General

To get the best performance, operate the engine at constant power. You must only change the engine load and / or speed slowly, unless there are unusual conditions.

## 2. Checks and Precautions

During usual operation, you must do regular checks and refer to the precautions. This lets you operate the engine without problems. The most important of these regular checks and precautions are given below:

- You must do regular checks of pressures and temperatures. You must obey the limits given in 0230−1 Operating Data Sheet.
- You must compare the values of the instruments with those given in the acceptance records and include the engine speed and power values. This gives a good indication of engine performance. If there are differences in the values, these must be identified.
- If there is no risk to the engine, replace instruments that are possibly defective. Feel the pipes to compare temperatures.

1) Do a check of the values that follow:
   - Diesel fuel injection quantity
   - Fuel rail pressure
   - Servo oil rail pressure
   - Engine speed
   - Turbocharger speed
   - Scavenge air pressure
   - Exhaust gas temperature upstream of the turbine
   - Gas fuel supply pressure
   - Pilot fuel pressure.

Other important data are the values of the diesel fuel (refer to 0300−1 Diesel Engine Fuels) and the gas fuel (refer to 0340−1 Gas Fuel) that is used each day.

2) Do a check to make sure that all shut-off valves in the cooling water and lubricating oil system are in the correct position (refer to 8016−1 Lubricating Oil / Servo Oil System and 8017−1 Cooling Water System).

3) Make sure that the shut-off valves for the cooling inlets and outlets on the engine are always fully open during operation. These shut-off valves are used only to isolate cylinders from the cooling water system during overhauls.

If there are unusually high or low temperatures at a water outlet, the temperature must be gradually adjusted to the applicable value. Sudden temperature changes can cause damage (refer also to 2124−1 Cylinder Liner and 8017−1 Cooling Water System).

The maximum permitted exhaust temperature at the turbine inlet must not be more than the limit given in 0230−1 Operating Data Sheet.

4) Compare the exhaust gas temperature indications at the cylinder outlet with the related values in the acceptance records. If large differences between the cylinders are shown, you must find the cause.

5) In diesel mode, look at the colors of the exhaust gases from the funnel. No dark smoke must come out.

6) Keep the correct scavenge air temperature downstream of the air cooler with the usual water flow (see 0230−1 Operating Data Sheet). A higher scavenge air temperature will give an unsatisfactory quantity of scavenge air in the cylinder. This will cause more fuel to be used and higher exhaust gas temperatures.

7) Do a check of the scavenge air pressure through the air cooler. Too much resistance will cause a decrease of air to the engine.

**Note: The diesel fuel must be carefully cleaned before use. Refer to the recommendations in 0300−1 Diesel Engine Fuel, paragraph 8 and the documentation of the separator manufacturer.**

**Note: In diesel mode, the temperature of the heavy fuel oil (HFO) must be sufficiently increased. This is to make sure that the viscosity upstream of the fuel pump inlets is in the limits given in 0300−1 Diesel Engine Fuels, paragraph 3.1.**

8) Open the drain valves of all diesel fuel tanks and diesel fuel filters regularly for short periods to drain possible sludge or water (see 0300−1 Diesel Engine Fuels, Fig. 2).

9) Keep the diesel fuel pressure correct downstream of the low pressure pump and the inlet of the mixing unit (see the 0230−1 Operating Data Sheet and 0300−1 Diesel Engine Fuels, paragraph 8).

10) Use the adjustable pressure retaining valve 10−8704_E0_2 in the fuel return pipe to adjust the pressure at the fuel pump inlet. The fuel will flow in the low pressure circuit of the engine at the usual supply capacity of the fuel booster pump 910−D015 (plant).

11) You must do regular checks of the cylinder lubricating oil quantity that is used. Continuous service will give the best cylinder lubricating oil quantity. Do not lubricate the cylinders too much (see 0320−1 Lubricating Oils, paragraph 3 and 7218−3 Feed Rate − Adjustment).

The cooling water pumps must operate at their usual flow capacity i.e. the supply head is related to the given system configuration. The result of the flow rate and temperature difference between the inlet and outlet will approximately relate to the values given in 0230−1 Operating Data Sheet. If the temperature difference is too much, repair or replace the related pump as soon as possible.

To adjust the correct supply head of the cylinder cooling water pump, the supply rate must be controlled in the engine outlet manifold. There must always be positive pressure at the suction side of the pump to prevent air flow through the piston rod gland.

12) Make sure that the vents at the top of the cooling water spaces are kept constantly open to release the air.

13) Do a check of the level in all water and oil tanks, and all the drainage tanks of the leakage pipes. Look for unusual changes.

14) Look at the cooling water. If there is contamination or oil in the cooling water, the cause must be found and the defect repaired.

15) Regularly examine the sight glasses of the condensate collectors to do a check of the water flow (see 8345−1 Drainage System and Wash-water Pipe System).

16) If there is a pressure decrease, do a check of the oil filters. Clean or replace the oil filters if necessary.

17) You must monitor for a period, bearings that are replaced or bearings that are installed after an overhaul. You must obey the precautions to prevent crankcase explosions (see 0120−1 Prevention of Crankcase Explosions).

18) Make sure that the covers of the rail unit are kept closed when the engine operates.

When you listen to the engine, unusual noises will show that there is a possible defect.

Hand-drawn diagrams give data about the combustion process and pressures in the cylinder (see 0580−1 Indicator Diagrams).

When the quality of the fuel used changes (marine diesel oil, HFO, gas fuel from different bunkerings), the maximum pressure in the cylinder at service power must be found as soon as possible. You must compare this pressure to the pressure measured during the related shop trial (speed, power).

If there are large differences in the firing pressures (i.e. too high or too low), adjust the fuel quality setting (FQS) to change the firing pressures (see 4002−2 Local Control Panel / Local Display Unit, paragraph 3.22 User Parameters).

19) Put the lubricating oil through a centrifuge. Get samples at regular intervals and compare these samples with the values given in 0320−1 Lubricating Oils.

20) Do a check of the dirty oil drain pipes from the piston underside to make sure that there are no blockages. Use your hand to touch each drain pipe to feel for a temperature difference. A pipe is blocked when there is a temperature difference along its length. You must clear all blockages as soon as possible.

21) Examine regularly the lubricating oil system for leaks (refer to 8016−1, paragraph 4 Servo Oil Leakage).

22) Examine regularly the fuel system for leaks (refer to 8019−1, paragraph 4 Fuel Leakage System). To find leakages in the rail unit, open the related hinged covers and casings. You must repair leaks as soon as possible.

23) Do regular checks (leak checks) of the GVU related to the data given in the documentation of the GVU manufacturer.

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# Operation
## Problems during Operation – Irregular Operation

# 1. General

## 1.1 Decreased Power Output

In an emergency, when the engine must operate (with one or more cylinders out of operation, turbochargers out of operation or decreased coolant flow etc) the power must be decreased to prevent damage to the engine.

The load indication must always be less than the full load position (fuel injection quantity). The exhaust gas temperature at the turbocharger inlet must always be less than the maximum temperature (see 0230−1 Operating Data Sheet). If necessary decrease the engine speed and power.

Because of torsional vibration, it is possible that the engine has more than one barred speed range. Also, it is possible that the engine has a barred speed range if the axial damper becomes defective. You can find data about the barred speed range near the telegraph on the bridge, and/or near the local control panel.

The exhaust smoke must be monitored because the engine must not operate with dark exhaust smoke. The speed and power must be decreased until the exhaust smoke is satisfactory. For more data, refer to 0550−1 Operation at Low Load.

## 1.2 Cylinders Out of Operation

When one or more cylinders are out of operation the turbocharger can surge. This makes a loud sound. Large differences in the scavenge air pressure will show on the pressure gauge.

If the turbocharger surges for short periods or continuously, you must decrease the speed sufficiently.

**Note: When cylinders are out of operation, it is possible (when an engine has only e.g. five cylinders) that the engine will stop in a position from which it cannot start. This is because none of the serviceable pistons are in the correct position to start the engine again.**

Start the engine momentarily in the opposite direction to get the crankshaft to a different position. It is possible that the engine will not reverse correctly and you must do related precautions together with the bridge.

## 2. Crosshead Bearing Oil − Pressure Decrease

The crosshead bearing oil pressure decreases to the same value as the main bearing oil pressure.

| Possible Causes | Procedure |
|---|---|
| Crosshead bearing oil pump is defective. Oil flows through the non-return valve from main bearing oil system | Decrease the engine load (refer to 3603−1, paragraph 2.1)<br>Repair the crosshead bearing oil pump as soon as possible. Until then, increase the main bearing oil pressure as much as possible. |

## 3. Cylinder Cooling Water

### 3.1 Irregular System Operation

| Possible Causes | Procedure |
|---|---|
| Air collects in the cooling spaces or in the pipes because the pressure release is not sufficient | Release the pressure in the cooling water system |

### 3.2 Outlet Temperature High (All Cylinders)

| Possible Causes | Procedure |
|---|---|
| Plant side is defective (regulating valve, cooling water cooler etc.) | Find the cause and repair the defect, refer to the plant instructions |

### 3.3 Outlet Temperature High (One Cylinder)

| Possible Causes | Procedure |
|---|---|
| The shut-off valves in the pipes of the related cylinders were accidentally closed, or defective | Open the shut-off valves or replace them |
| The pressure in the cooling spaces is not sufficiently released | Release the pressure |
| The cooling water pipes or water channels are blocked. The water flow is not sufficient. | Refer to 0330−1 Cooling Water |
| The piston is too hot | Refer to paragraph 12 |
| The exhaust gases go into the cooling water because of a crack (cylinder liner, cylinder cover, valve cage) | Refer to 8017−1 Cooling Water System, Operation with Water Leakage into the Combustion Chamber |

### 3.4 Quick Pressure Increase/Decrease

| Possible Causes | Procedure |
|---|---|
| There is a decrease of static pressure at the inlet to the cooling water pump. This is because of a blockage in the return pipe or the expansion tank has drained | Refer to the plant instructions |
| The exhaust gases go into the cooling water because of a crack in the cylinder liner, cylinder cover or valve cage | Refer to 8017−1 Cooling Water System, Operation with Water Leakage into the Combustion Chamber |

## 4. Cylinder Lubricating Oil − No Flow

| Possible Causes | Procedure |
|---|---|
| The service tank is empty | Fill the service tank |
| The ball valve 25−8475_E0_1 upstream of the lubricating oil filter is closed | Open the ball valve |
| The filter element is clogged | Clean, or replace the filter element |
| There is air in the cylinder lubricating system | Refer to the Maintenance Manual to bleed the cylinder lubricating system (the filter, the pump and the pipes to the lubricating quills). |
| One or more lubricating quills in the cylinder liner are blocked. | Do a check of the lubricating quill(s). If necessary do an overhaul of the quill(s) or replace the defective parts |

## 5. Cylinder Lubricating Oil Pump − Defect

| Possible Causes | Procedure |
|---|---|
| There is no servo oil pressure, or the servo oil pressure is too low | Open the 2-way shut-off valve 20−5610_E0_3<br>Do a check of the servo oil pressure<br>If necessary, adjust the pressure reducing valve 20−5610_E0_4, or do a check and adjust the settings of the shut-off valve on the cylinder lubricating pump |
| The 4/2-way solenoid valve (CV7131−3#C) is defective | Replace the defective parts (send the defective pump to Wärtsilä Services Switzerland Ltd. for an overhaul) |
| The pressure transmitter (PT3131−3#C) is defective | |
| The pump body is defective | |

# 6. Engine

## 6.1 Irregular Operation or Misfires

| Possible Causes | Procedure |
|---|---|
| There is high water quantity in the fuel | Refer to 0300−1, paragraph 8 |
| The fuel temperature upstream of the fuel pumps is too low or too high | Refer to 0530−1, paragraph 2 |
| The pressure in the fuel rail is too low | Refer to 8019−1, paragraph 10. Do a check of the pressure control valve |
| The pressure control valve is defective | |
| One of the fuel pumps does not supply fuel | |

## 6.2 Speed Decrease

| Possible Causes | Procedure |
|---|---|
| The speed setting from the speed control system is decreased or not in the specified limits | Do a check of the speed control system |
| The fuel injection quantity from the speed control system decreased to prevent too much load in heavy sea | A procedure is not necessary. Usual operation |
| Hull resistance increased because of growth, age of hull, propeller damage | Refer to 0220−1 The Relation between Engine and Propeller |
| A diesel injection valve is defective | Cut out or replace the related part (refer to 8019−1 paragraph 9 and paragraph 6.1) |
| An injection pipe is defective | |
| The air and exhaust gas pipes are clogged | See Scavenge air pressure decreases |

## 6.3 Unwanted Stop

| Possible Causes | Procedure |
|---|---|
| The diesel fuel service tank is empty | Fill the service tank |
| The fuel filters are blocked | Clean the filter |
| The fuel supply is stopped | Find the cause and repair the defect |
| The booster pump is defective | Find the cause and repair the defect |
| Defective switching | Find the cause and repair the defect |
| The fuel rail pressure is too low | Find the cause and repair the defect |
| The fuel system leaks. | Find and repair leaks |
| There is no electrical power supply to the ECS | Repair the cause and start the ECS |
| The speed setting system is defective | Repair the fault (e.g. broken cables) |
| The engine stops in heavy sea | Set the Heavy Sea Mode to on (refer to 4002−2, paragraph 3.22) |

# 7. Exhaust – Excessive Smoke (Diesel Mode)

<table>
<tr><th>Possible Causes</th><th>Procedure</th></tr>
<tr><td>The air supply is not sufficient. There is unwanted material in the:<br>● exhaust side or air side of the TC<br>● scavenge air cooler<br>● air flaps in the receiver<br>● scavenge ports in cylinder liners<br>● the exhaust boiler</td><td>See Scavenge air pressure decreases</td></tr>
<tr><td>The engine has too much load</td><td>Decrease the fuel injection quantity</td></tr>
<tr><td>The engine operates with too much cylinder lubricating oil</td><td>Refer to 7218–1, paragraph 8.4 and 7218–2</td></tr>
<tr><td>Injection nozzles do not completely change the diesel fuel into a spray</td><td>Find the cause (e.g. because there trumpets, worn or blocked spray holes). Clean the parts. Do a check to adjust the parts, or replace the parts</td></tr>
<tr><td>The diesel fuel is incorrect</td><td rowspan="3">Refer to 0530–1, paragraph 2</td></tr>
<tr><td>The viscosity of the diesel fuel is too high</td></tr>
<tr><td>The diesel fuel is not sufficiently heated</td></tr>
<tr><td>The compression pressure is too low</td><td rowspan="3">Replace the piston rings, grind the valve seat and head (refer to the Maintenance Manual)</td></tr>
<tr><td>The piston rings have leaks</td></tr>
<tr><td>The exhaust valve has a leak</td></tr>
<tr><td>Bores in the top housing of the exhaust valve are clogged (the exhaust valves close too late)</td><td>Do a check and clean the parts</td></tr>
<tr><td>The servo oil pressure is too low</td><td rowspan="3">Do a check of the oil flow. Find and repair the leaks</td></tr>
<tr><td>The servo oil pump control is defective</td></tr>
<tr><td>There is a servo oil leakage</td></tr>
<tr><td>An auxiliary blower operates at part load</td><td rowspan="2">Set the auxiliary blowers to on</td></tr>
<tr><td>The two auxiliary blowers do no operate.</td></tr>
</table>

# 8. Exhaust Gas

## 8.1 Temperature Decrease (Cylinder)

| Possible Causes | Procedure |
|---|---|
| The diesel injection nozzles are in an unsatisfactory condition | Replace nozzle tip or flow limiter valve |
| The nozzle tip is broken | Replace the nozzle tip |
| The flow limiter valve cannot move | Replace the flow limiter valve |
| The related cylinder receives less diesel fuel because of a leakage in the high pressure pipes or injection valves | Grind the sealing faces or replace defective parts (refer to the Maintenance Manual) |
| The exhaust valve does not open | Cut out the injection and exhaust valve control unit of the related cylinder (refer to 8019−1, paragraph 5 and 8016−1, paragraph 4) |
| The exhaust valve control unit or its hydraulic pipe is defective | |
| The exhaust thermometer of the related cylinder is defective | Replace the exhaust thermometer |

## 8.2 Temperature Increase (Cylinder)

| Possible Causes | Procedure |
|---|---|
| The air flaps in the scavenge air receiver are dirty or defective | Clean, overhaul or replace the air flaps |
| The diesel injection nozzles are worn | Replace with the spare kit |
| The scavenge ports in the cylinder liner are dirty | Clean the scavenge ports |
| There is a fire in the piston underside space | Refer to 0400−1, paragraph 2.5 |
| The exhaust valve has a leak | Grind the valve seat and head (refer to the Maintenance Manual) |
| The exhaust thermometer of a related cylinder is defective | Replace the exhaust thermometer |

## 8.3 Temperature Increase (Upstream of the TC)

| Possible Causes | Procedure |
|---|---|
| The air supply is not sufficient because of a defect | Clean the turbocharger during operation, refer to the manual of the turbocharger manufacturer. Also, refer to 6606−1, paragraph 3. |
| The turbocharger, silencer or scavenge air cooler is very dirty | |
| The air flaps in the scavenge air receiver are dirty or defective | Clean, do an overhaul or replace the air flaps |
| The injection nozzles are worn | Replace the injection nozzles |
| The intake temperature upstream of the turbocharger is high | Make sure that the air intake is clear |
| The scavenge ports in the cylinder liner are dirty | Clean the scavenge ports |

# 9. Exhaust Valve

## 9.1 Does not Close

| Possible Causes | Procedure |
|---|---|
| The air spring pressure is too low (less than 2.0 bar) | Find the cause: leakage, pressure reducing valve, pressure in starting air bottles |
| The exhaust valve or piston cannot move | Replace, or do an overhaul |

## 9.2 Does not Open

| Possible Causes | Procedure |
|---|---|
| The non-return valve 35–2751_CX_1 in the exhaust valve is defective. | Do an overhaul, or replace the non-return valve 35–2751_CX_1 |
| The piston in the exhaust valve control unit cannot move | Replace the piston or do an overhaul |
| The solenoid valve CV7401–0#C is defective or the cable connection is loose | Replace the solenoid valve CV7401–0#C or connect the cable connection (refer to 8016–1, paragraph 4.2.4) |

## 9.3 Unwanted noise

| Possible Causes | Procedure |
|---|---|
| Piston in exhaust valve is defective | Do an overhaul, or replace |
| The orifice or filter in the exhaust valve control unit is clogged | Clean the orifice or the filter (see the Maintenance Manual 5612–1) |
| The strainer holes in the orifice to the exhaust valve are much larger (wear) | Replace the orifice |
| The hydraulic pipe has a leak | Repair the leak, or replace the hydraulic pipe |

# 10. Firing Pressure (Cylinder) – Decrease

| Possible Causes | Procedure |
|---|---|
| In diesel mode, the flow limiter valve cannot move | Make sure the flow limiter valve is serviceable. If the flow limiter valve is unserviceable, replace it. |

## 11. Oil Mist Detector – Alarm in the ECS

**WARNING**

**Injury Hazard: If an oil mist detector activates an alarm, keep away from engine. There is a risk of explosion. Do not go into the areas adjacent to the explosion relief valves**

**Note: For more data, refer to 0120–1 Instructions about the Prevention of Crankcase Explosions.**

| Possible Causes | Procedure |
|---|---|
| Part of a running gear is too hot | Decrease the load (rpm) immediately<br>Stop the engine as soon as possible<br>Find the cause, repair as much as possible (refer to paragraph 13) |

## 12. Piston – Hot Operation

The possible indications of a piston that operates at a temperature that is too hot, but where combustion is correct are as follows:

- A temperature increase at the piston cooling oil outlet (TE2501–07A sends an alarm)
- A temperature increase at the cooling water outlet of the cylinder jacket (TE1121–27A sends an alarm)
- A temperature increase of the piston underside. (TE4081–87A sends an alarm)

| Possible Causes | Procedure |
|---|---|
| Exhaust gas flows through defective or worn piston rings | Cut out the injection of the related cylinder for a short time (refer to 8019–1, paragraph 5) |
| There are scratches on the surface of the cylinder liner because the cylinder lubricating oil has decreased too much | On the related cylinder, increase the feed rate of the cylinder lubricating oil (refer to 7218–1 paragraph 8.4 and 7218–2<br>If the temperature does not decrease, or increases more after injection is cut in, cut out the injection again (see 8019–1, paragraph 5). Stop the engine as soon as possible, then let the temperature of the cylinder and piston decrease<br>Do a check of the running surface of the piston and the cylinder liner<br>If the damaged areas are small, use an oil stone to repair these areas.<br>If there is much damage, replace the piston, piston skirt and cylinder liner (refer to the Maintenance Manual)<br>If a replacement of these parts is not possible, remove the piston (refer to the Maintenance Manual 3403–1). When the piston is removed, refer to 3403–2 |

## 13. Running Gear Parts − Hot Operation

| Possible Causes | Procedure |
|---|---|
| An oil pipe or pipe connection is defective | Decrease the speed (power) and increase the bearing oil pressure |
| There is water in the lubricating oil (the journals have corrosion) | If the temperature continues to increase, stop the engine to let it become cool |
| The lubricating oil is dirty | |
| There was damage to the bearing or journals during the install procedure | Make sure that you know the necessary precautions for preventing crankcase explosions (see 0120−1) |
| The bearing clearance is not sufficient | Disassemble and inspect the bearing that was hot |
| Bearing has deformation (waisted studs were not tightened in accordance with the instructions) | Do an overhaul, replace the damaged parts, or remove the defective running gear |
| Bearing oil pressure is not sufficient (do a check of the pressure gauge and oil pressure monitoring system) | |
| The level in the oil tank is too low | |
| The pump supplies an air and oil mixture | |

## 14. Scavenge Air

### 14.1 Pressure Decrease

| Possible Causes | Procedure |
|---|---|
| The scavenge air cooler is dirty on the air side | Clean the scavenge air cooler, refer to 6606−1, paragraph 3 |
| The water separator is clogged | |
| The intake temperature upstream of turbocharger is high | Make sure that the air intake is clear |
| The diffuser, blower and inducer to the turbocharger is dirty or damaged | Clean the turbocharger during operation, refer to the manual of the turbocharger manufacturer |
| The silencer upstream of the turbocharger is dirty | |
| The turbine rotor blade is dirty or damaged | |
| The nozzle ring of the turbocharger is damaged | |
| The exhaust gas boiler (plant side) is clogged. | Clean as soon as possible |

### 14.2 Pressure Increase

| Possible Causes | Procedure |
|---|---|
| The nozzle ring of the turbocharger is dirty or clogged | Clean the turbocharger during operation, refer to the manual of the turbocharger manufacturer |

## 15. Turbocharger − Surge

| Possible Causes | Procedure |
|---|---|
| There is too much load, or the air is not sufficient. | Refer to the manual of the turbocharger manufacturer and 6606−1, paragraph 3 SAC Air Side − Clean during Operation |
| The cylinder is defective (injection, exhaust valve control) | Do a check of the injection and exhaust valve control |

# Operation
## Manoeuvring

## 1. General

Correct maneuvering, with a subsequent increase in engine load up to service power and a decrease in load from service power, is very important.

Engine loads in the higher power ranges that are changed too quickly can cause increased wear and contamination, specially on piston rings and cylinder liners.

Slow load changes let the piston rings adapt to the new conditions and therefore make sure of the best sealing.

There must always be sufficient power available in a short time for safe manoeuvring in ports and waterways.

## 2. Maneuvering

Maneuvering is the operation between leaving port and release to sea speed and from the approach to port until finished with engine. This also includes all changes during usual operation e.g. changes of direction.

The manoeuvring range is the speed range between FULL AHEAD and FULL ASTERN. This range is usually divided into four manoeuvring steps with related given speeds in each direction.

**Note: Because of torsional vibration, it is possible that the engine has more than one barred speed range. Also, it is possible that the engine has a barred speed range if the axial damper becomes defective. Data about the barred speed range can be found near the telegraph on the bridge, and/or near the local control panel.**

Usually, the full maneuvering speed, for engines that have fixed pitch propellers, is related to approximately 70% of the maximum rated engine speed. This is approximately 35% of the maximum power. This means that when sailing straight ahead, the ship will be at approximately 66% of its maximum speed.

A fully serviceable engine can be manoeuvred in the range given above with no time or performance limits. Fuel and scavenge air necessary for engine operation are controlled electronically.

With controllable pitch propellers the speed and torque can be freely selected. During maneuvering, the limits are the same as for fixed pitch propellers. The time period to change the propeller pitch position from zero pitch to full, must be a minimum of 20 seconds.

If the engine is increased quickly to full maneuvering speed (or the propeller blades move to full pitch), the engine load is momentarily higher when the vessel has no movement. When the vessel is at sea speed, the engine load is decreased.

You can do maneuvering operations from the bridge (if the remote control is installed), from the engine control room or at the local control panel on the engine.

Make sure that you know the special precautions for maneuvering operations from the local control panel.

The diesel fuel used must have sufficient treatment (refer to 0300−1 Diesel Engine Fuels, paragraph 8).

The data given in 0230−1, Operating Data Sheet is also applicable during manoeuvring.

In diesel mode, when HFO is used for maneuvering, the temperature of the fuel must be increased sufficiently. This keeps the viscosity at the fuel pump inlets in the range given in 0300−1, paragraph 3.1 Viscosity / Temperature Diagram.

In gas mode, make sure that the gas fuel has the correct supply pressure (refer to 0230−1 Operating Data Sheet).

The heating of the fuel system must stay set to on. Keep the temperature of the cooling media as close as possible to the higher limits given for usual operation (refer to 0230−1 Operating Data Sheet).

# 3. Usual Operation

## 3.1 Control Room Maneuvering Stand

**Note: You can only start the engine in diesel mode.**

To start the engine in speed mode with a fixed pitch propeller do the procedure that follows:

1) Make sure that the MCM−11 module is set to on.
2) In the LDU−20 MAIN page, select the Speed Setpoint button.
3) Set the applicable speed.
4) Push the START AHD or START AST button.

## 3.2 Local Control Panel

See also 4003−1, paragraph 3 Engine Local Control.

## 3.3 Transfer and Accept Control from ECR Remote to Local

1) At the ECR console LDU−20, get the CONTROL LOC. Page.
2) Push the button Local for control to the local manual control.
3) At the local control panel LDU−20, push the button CTRL. TR. to get control.
4) Get the MAIN page.
5) Use the rotary button to select the Fuel Command button to between 12% and 30%.

**Note: The recommended range for the start fuel setting is between 12% and 30%. A setting of less than 12% will not be sufficient for engine start. A setting of more than 30% will cause too much smoke.**

You can also use the Speed Setpoint button to operate the engine.

Use this operation mode for long periods only when necessary e.g. until defects in the speed control system, or other defects in the remote control can be repaired.

For installations with controllable pitch propellers or clutch couplings, more precautions are necessary. There must be good communication between the bridge and the local manoeuvring stand.

**Note: The speed control is part of the ECS. An engineer must stay at the local manoeuvring stand. The engineer can then make changes immediately if necessary.**

### 3.4 Reversing

1) In the LDU–20, get the MAIN page.
2) Turn the rotary button to select 30% fuel injection quantity.
3) Push the button START AHD or START AST until the engine operates in the applicable direction.

**Note: On ships under way, this procedure can be some minutes, because the flow of water has an effect on the propeller.**

You can also use the ECR manual control panel to do the reversing procedure given above.

You can use the buttons and rotary button only at the related active control stand.

### 3.5 Installations with Controllable Pitch Propeller

For data about installations with controllable pitch propellers, refer to the documentation of the propeller manufacturer.

### 3.6 Installations with Clutch Couplings

You must make sure that the couplings are engaged before you start the engine.

You must not disengage clutch couplings while the engine operates.

## 4. Increase Power after Release to Sea Speed and Decrease

You must only increase and decrease the engine load during a given time. This is usually 40 minutes to 45 minutes between full maneuvering and service power. The time must not be less than that given as follows:

- For an increase in engine load, not less than 30 minutes
- For a decrease in engine load, not less than 15 minutes.

You use the related devices in the engine room to manually increase and decrease the engine load as follows:

For fixed pitch propeller installations:

- Speed setting.

For controllable pitch propeller installations:

- Speed setting
- Propeller pitch setting lever
- Speed and propeller pitch setting lever (combinator).

The time limits given above for speed and power are not applicable if a faster decrease of engine load is necessary when:

- There are critical alarm conditions in the engine room
- A shut-down or slow-down signal is activated.

## 5. Emergency Maneuver

The safety of the vessel is very important. If an emergency manoeuvre is necessary, all the limits specified in paragraphs 2, 3 and 4 are not applicable, i.e. you can use the full power of the engine.

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# Operation
## Change-over from Diesel Oil to Heavy Fuel Oil and Back

## 1. General

In diesel mode, continuous operation with heavy fuel oil (HFO) is recommended for engines and plants. You must only change from HFO to marine diesel oil (MDO) if necessary, for example when:

- The engine is flushed before maintenance
- The heating plant is set to off in the dry dock
- There are environmental conditions.

To make sure that the change-over is safe, refer to the paragraphs that follow:

## 2. Recommended Viscosity at Inlet to Fuel Pumps

For the temperature necessary to make sure that the fuel upstream of the inlet to the fuel pumps is at the correct viscosity, refer to 0300−1, paragraph 3.1, Viscosity / Temperature Diagram.

A viscosimeter controls the temperature increase of the fuel.

**Note: While the engine has stopped, fuel flows through the fuel pumps, fuel rail and fuel pressure control valve and then flows back to the fuel system.**

## 3. Change-over from MDO to HFO

Refer to 0300−1 Diesel Engine Fuels Fig. 3.

### 3.1 Plant Side

To change from diesel oil MDO to HFO, you must make sure that the automatic change-over unit (16, Fig. 3) is in the correct position. When the position of the automatic change-over unit (16) is changed, HFO and MDO are mixed in the mixing unit (21).

The viscosimeter controls the end-heater (23), which keeps the fuel temperature at the necessary viscosity. You must only increase the fuel temperature slowly (i.e. the temperature increase must be a maximum of 2°C each minute).

**Note: It is possible that sudden temperature changes can stop the movement of the fuel pump plungers.**

1) Make sure that the heating for the fuel filter (24), fuel supply and fuel return pipes is set to on until the fuel is at the applicable temperature.

**Note: The temperature is shown on the thermometer upstream of the inlet to the fuel pumps.**

2) Do a check of the fuel pressure downstream of the low pressure feed pump and at the fuel pump inlet. For the values, see 0230−1 Operating Data Sheet.

### 3.2 Engine Side

The trace heating on the engine (fuel pressure pipes and fuel rail) must be set to on when there is a change-over from MDO to HFO in the plant. All covers of the rail unit must be closed.

If the engine room is cold, you must set to on the trace heating approximately one hour before the change-over.

Before you stop the engine, the change-over procedure must be fully completed. This prevents a mixture of MDO and HFO in the fuel rail, which can cause viscosity problems during the next engine start.

It is recommended that for the change-over, the fuel is at the applicable temperature and the CMCR load is not more than 75%.

# 4. Change-over from HFO to MDO

Refer to 0300−1 Diesel Engine Fuels Fig. 3.

## 4.1 Plant Side

To change from HFO to MDO, you must first change the position of the automatic change-over unit (16). HFO and MDO is mixed in the mixing unit (21). The viscosity of the fuel mixture decreases quickly at a specified temperature, which is related to an increased proportion of MDO to HFO. After a short period the heating can be set to off.

## 4.2 Engine Side

**CAUTION**

**Damage Hazard: If you operate the engine with MDO and the electrical trace heating is set to on, damage to the engine will occur. Set to off the electrical trace heating.**

1) Make sure that the electrical trace heating of the fuel pressure pipes and fuel rail is set to off (refer to 4002−2, paragraph 3.22 User Parameters and 8825−1 Electrical Trace Heating System).

**Note: The time to complete a change-over will be longer if the engine operates at low load.**

Before you stop the engine, the change-over procedure must be completed. This prevents a mixture of MDO and HFO in the fuel rail, which can cause viscosity problems during the next engine start.

It is recommended that the CMCR load is less than 50% CMCR power for the change-over from HFO to MDO.

# Operation
## Change-over from Diesel Fuel to Gas Fuel and Back

## 1. General

You can manually change from diesel fuel to gas fuel (Fig. 1) and from gas fuel to diesel fuel (Fig. 2). The change-over is possible only while the engine operates.

When the engine operates in gas mode and the safety system finds a defect or failure, the engine control system (ECS) automatically changes the engine to diesel mode.

## 2. Change-over from Diesel Fuel to Gas Fuel

**Note: You can only change from diesel mode to gas mode when the engine operates on marine diesel oil (MDO). The ECS prevents a change-over when the engine operates on heavy fuel oil (HFO). For the procedure to change over from HFO to MDO, refer to 0530−1 Change-over from Diesel Oil to Heavy Fuel Oil and Back.**

The ECS controls the change-over process, gradually stops the diesel fuel injection and at the same time, starts the gas fuel injection Fig. 1 shows a diagram of the change-over process.

You can manually start the change-over in the LDU-20 at load ranges up to 80% CMCR. For the procedure to manually change-over from diesel fuel to gas fuel, refer to 4003−1, paragraph 3.4 Change-Over from Diesel Mode to Gas Mode.

The ECS only starts the change-over if the checks of the gas fuel system and the pilot fuel system show no failure.

**Note: If there is a defect or failure related to the gas system, the ECS prevents the change-over from diesel fuel to gas fuel. You must find the cause and correct the defect or failure and reset the alarm to change-over from diesel fuel to gas fuel.**

## 3. Change-over from Gas Fuel to Diesel Fuel

**Note: You can only change from gas fuel to marine diesel oil (MDO).**

The ECS controls the change-over process, stops the gas injection and starts the diesel fuel injection immediately.

You can manually start the change-over at all load ranges in the LDU-20 (refer to 4002−2, paragraph 3.8 Fuel Mode Control). For the procedure to manually change-over from diesel fuel to gas fuel, refer to 4003−1, paragraph 3.5 Change-Over from Gas Mode to Diesel Mode.

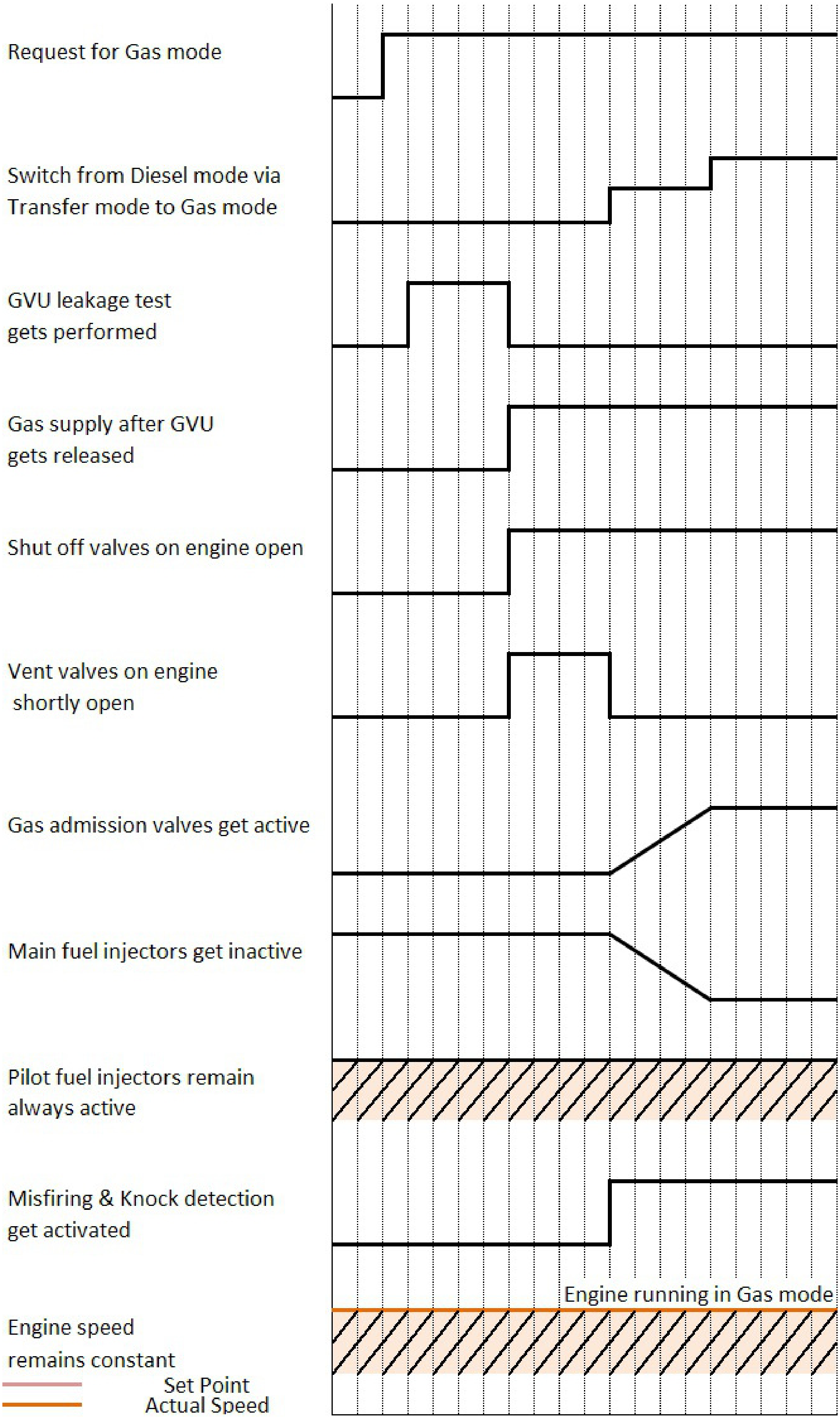


**Fig. 1: Process Diagram – Change-over from Diesel Fuel to Gas Fuel**

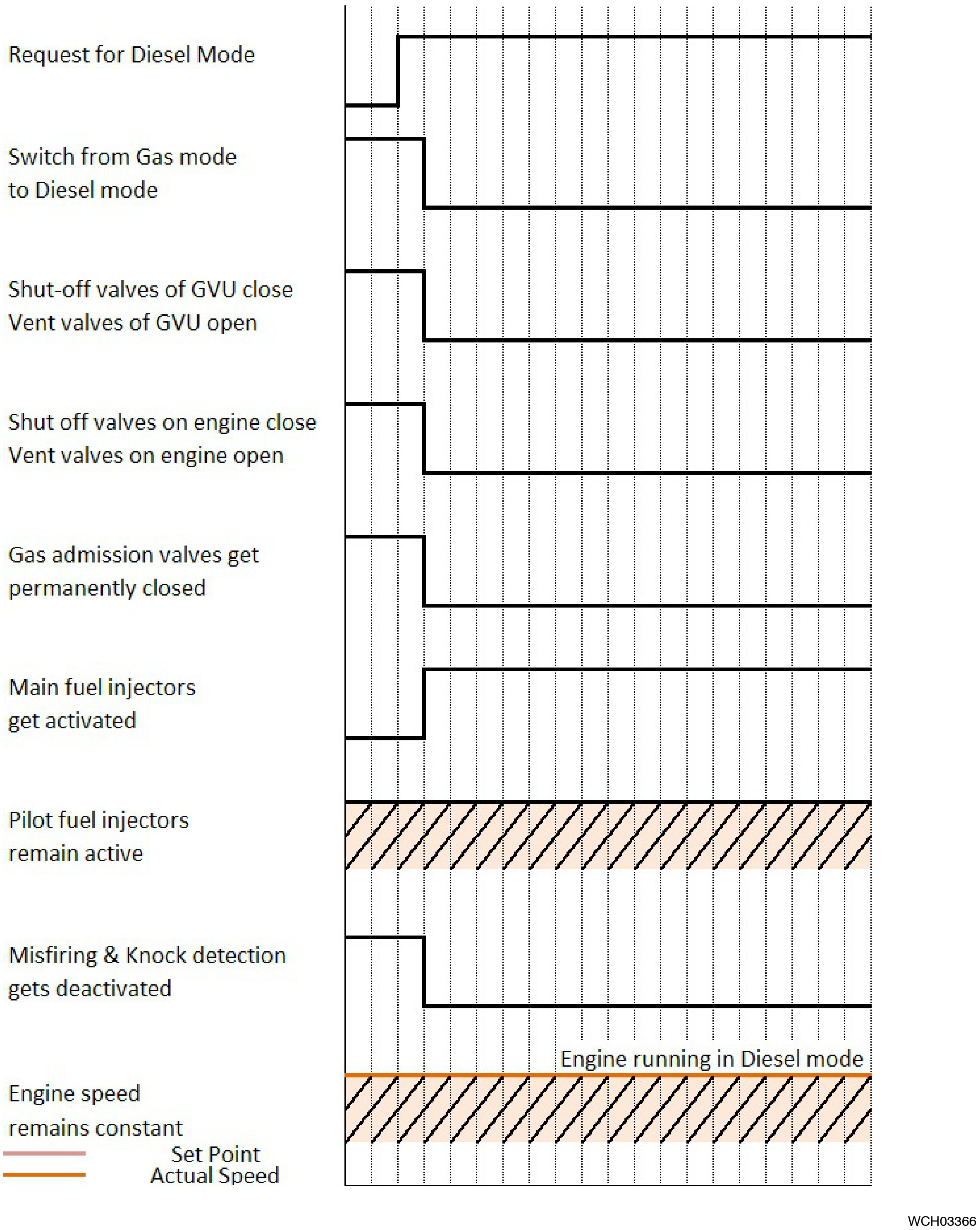


**Fig. 2: Process Diagram – Change-over from Gas Fuel to Diesel Fuel**

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# Operation
## Operation at Low Load

## 1. General

Refer to the data that follow:

- 0500−1 Usual Operation, paragraph 2 Checks and Precautions.
- Electrical trace heating of the diesel fuel system during operation (refer to 8825−1 Electrical Trace Heating System).
- Temperature of the cooling medium in the usual range (see 0230−1 Operating Data Sheet).
- Careful treatment of the fuel (see 0300−1 Diesel Engine Fuels).
- 0320−1 Operating Media, paragraph 3 Cylinder Lubricating Oil.

The cylinder lubricating oil quantity automatically adapts to the lower engine load. The ECS controls the lubricating oil quantities related to the engine load.

## 2. ECS Injection Control

### 2.1 Diesel Mode

At low load, the ECS automatically cuts out one of the three injection valves in each cylinder. This makes sure that the engine has the best fuel and combustion properties, which decreases smoke and fuel consumption.

The ECS cuts out a different injection valve at regular intervals to get an equal thermal load in the combustion chamber.

There is no time limit to operate the engine at low load.

### 2.2 Gas Mode

At low load the ECS automatically adjusts the timing and quantity of the gas supply related to the engine load. Also, the ECS calculates the injection timing and pilot fuel quantity related to the engine speed and power. For more data, refer to 4002−1 Engine Control System, paragraph 3 Engine Control System − Functions.

The gas valve unit (GVU) adjusts the gas inlet pressure related to the setpoint from the ECS, i.e. related to the engine load. For more data about the GVU, refer to 4002−1, paragraph 4.6 Gas Valve Unit, 8014−1 Gas Fuel System, paragraph 3 and the documentation of the GVU manufacturer.

There is no time limit to operate the engine at low load.

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# Operation
## Operation at Overload

### 1. General

**CAUTION**

**Damage Hazard: When the engine operates in gas mode, it is not permitted to operate at overload, i.e. more than 100% of CMCR power. Damage to the engine will occur.**

**Note: For more data, refer to 0220–1, The Relation between Engine and Propeller Fig. 2 Load Range Limits – Gas Mode.**

Usually, the engine is only operated at overload (110% of CMCR power) during sea trials when the engine operates in diesel mode. To operate the engine at overload during sea trials, there must be an authorized representative of the engine builder on board the ship. The limit for operation of the engine at overload in diesel mode is a maximum of one hour each day (see also 0220–1, Fig. 1 Load Range Limits – Diesel Mode).

During operation at overload, you must carefully monitor the engine. If there are unusual indications, you must decrease the load (power).

The load indication (fuel injection quantity) and the exhaust gas temperature upstream of the turbine show the engine load (see 0230–1 Operating Data Sheet, and the Acceptance Records).

The coolant temperatures must stay in their usual ranges.

In usual operation, the full load position of the load indication (fuel injection quantity) must stay in the limits given (refer to the Acceptance Records).

The maximum permitted position of the load indication (fuel injection quantity) is given in the Acceptance Records. The adjustments are only permitted to show the CMCR power during sea trials with an overspeed of 104% to 108% of CMCR power.

The conditions given below affect the speed of the ship:

- Sailing into strong head winds
- Sailing in heavy seas
- Sailing in shallow water
- When there is unwanted heavy growth on the hull.

The governor increases the fuel quantity to keep the speed of the ship constant. The increase in the fuel injection quantity shows on the FUEL INJECTION page in the LDU–20 (see 4002–2, paragraph 3.7 Diesel Fuel Injection).

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# Operation
## Running-in New Cylinder Liners and Piston Rings

### 1. General

It is not necessary to do a special running-in procedure after new components of the piston running system are installed. But, you must obey the data given in paragraph 2.

### 2. Feed Rate Adjustments

After new components of the piston running system are installed, it is necessary to adjust the cylinder lubrication feed rate. This makes sure of sufficient lubrication which prevents damage to the cylinder liner and the piston rings. See Fig. 1 for the applicable running-in cylinder lubrication feed rates with their related running hours.

Wärtsilä Services Switzerland Ltd recommends the inspection of the cylinder liner and piston rings after 24 running hours and after 72 running hours (see the indications 1 in Fig. 1).

After 72 running hours, set the cylinder lubrication feed rate to the usual values. For more data, see 7218–3 Feed Rate – Adjustment.


**Fig. 1: Feed Rate Adjustments – Running-in**

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# Operation
## Indicator Diagrams (Diesel Mode)

## 1. General

**Note: The data that follow are applicable only when the engine operates in diesel mode.**

Indicator diagrams must only be made with a serviceable indicator at constant power and speed, and ships sailing in calm sea and deep water.

To give you data about the indicator diagrams, record the related cylinder number, engine speed, the positions of the load indicator and VIT.

## 2. Description of Cylinder Pressures

Higher compression ratio and fuel injection delay are used to decrease the $NO_x$ value for engines so that the IMO rules are obeyed.

The ratio of the maximum firing pressure to the compression pressure is in the range of 0.90 to 1.25 at 100% load.

The engine rating is related to IMO tuning. This means that the curves in the diagram can be different in the two examples that follow:

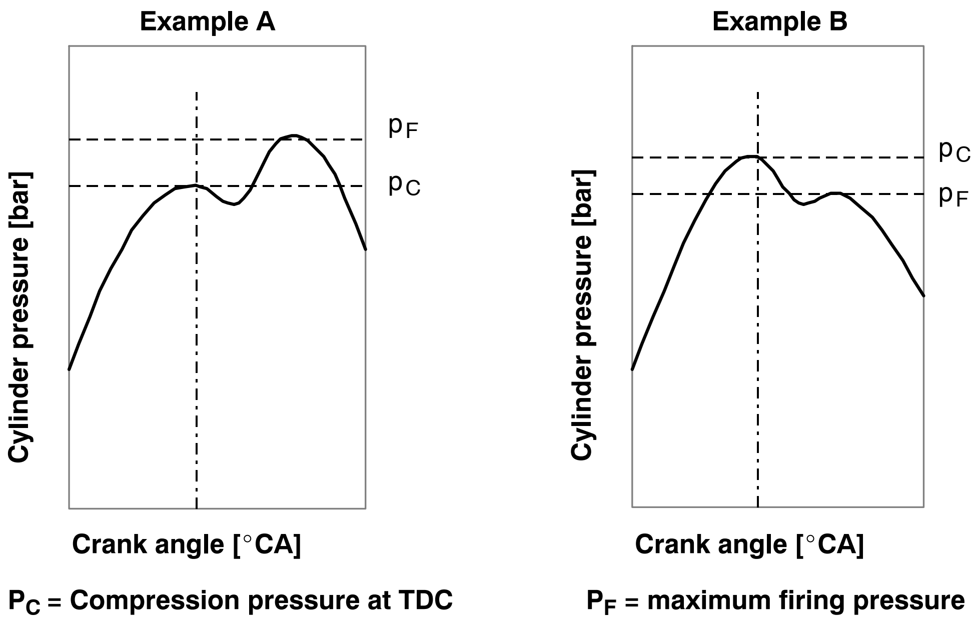
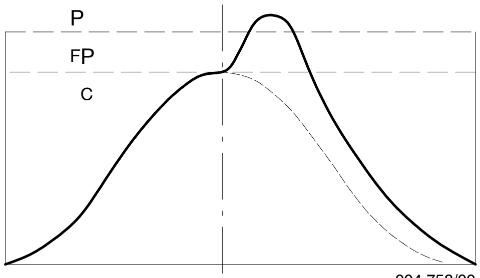



**Fig. 1: Compression Ratios**

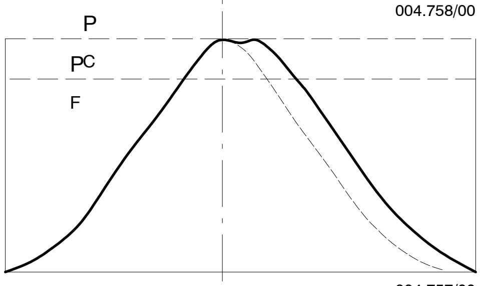
## 3. Indicator Diagrams and Related Engine Adjustments

The diagrams, which were made during the acceptance trial, must be used as references. For reference values about compression and maximum firing pressures for the related load and speed, refer to the trial reports and performance curves.




**Example A**

004.758/00




**Example B**

004.757/00

## 3.1 Maximum Firing pressure Too High at Correct Compression Pressure

Possible causes:

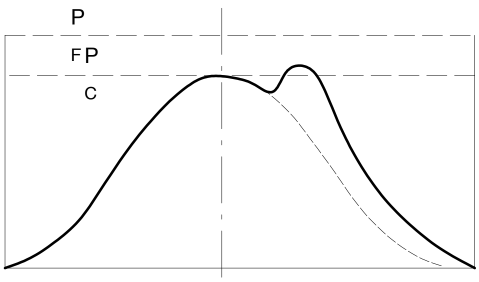
- Ignition (start of injection) too advanced for the fuel type in use.

You must adjust the FQS as follows:

1) From the MAIN page in the LDU−20, (4002−2, paragraph 3.2) go to the USER PARAMETERS page .

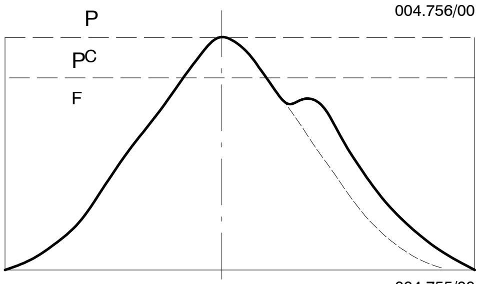
2) In the FQS field, enter a positive (+) setting to correct the ignition pressure.

You can only do a correction of the FQS if all cylinders show the same pressure difference.




**Example A**

004.756/00




**Example B**

004.755/00

## 3.2 Maximum Firing Pressure Too Low at Correct Compression Pressure

Possible causes:

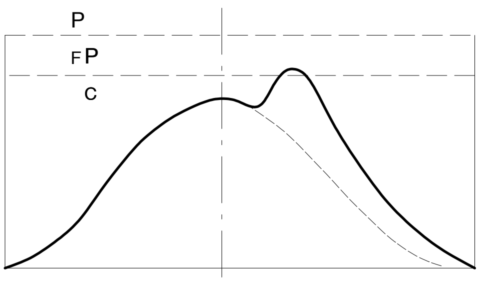
- Unsatisfactory combustion: The nozzle tip has trumpets or is worn.
- Ignition (start of injection) too retarded for the fuel type in use.

1) Do a check of the injection nozzles.

2) In the LDU−20, go to the USER PARAMETERS page.

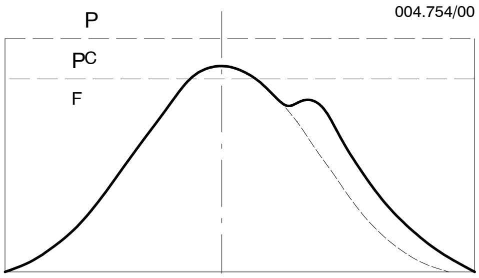
3) In the FQS field, enter a negative (−) setting to correct the ignition pressure.

You can only do a correction of the FQS if all cylinders show the same pressure difference.




**Example A**

004.754/00




**Example B**

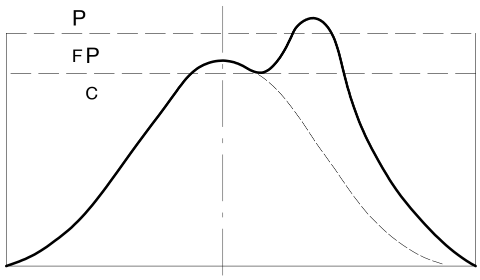
## 3.3 Compression and Maximum Firing Pressure Too Low

Possible causes:

- The load is less than you think.
- The exhaust valve has a leak.
- The scavenge air pressure is too low.
- The suction temperature is too high.
- VEC timing is incorrect i.e. exhaust valve closing time too late (parameter in ECS).

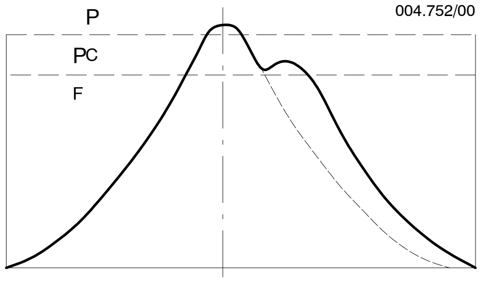
1) Do a check of the exhaust valve.

2) Clean the turbocharger or scavenge air cooler (refer to 6500−1 and 6606−1, paragraph 3).




Example A

004.752/00




Example B

004.751/00

## 3.4 Compression Pressure and Maximum Firing Pressure Too High

Possible causes:

- Engine has too much load.
- VEC timing is incorrect.

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# Engine Stop
## Engine Stop Procedure

## 1. Engine Load Decrease

When possible, it is recommended that the engine load is decreased slowly, refer to 0520−1 Maneuvering.

## 2. Engine Stop − Diesel Mode

### 2.1 Usual Procedures

#### 2.1.1 Engine Stop from the Control Room − Remote Control

Because different types of remote control can be connected to the engine controls, the operation procedure from the manoeuvring stand in the control room is not given. For this procedure, refer to the applicable documentation of the remote control manufacturer.

Usually it is sufficient to move the telegraph to the position STOP.

#### 2.1.2 Engine Stop from the Control Room − ECR Manual Control Panel

Refer to 4003−2 Page 1 and Page 2 Control Diagram and 4002−2 Local Control Panel / Local Display Unit.

When you push the STOP button on the LDU-20, the ECS shuts down the engine after the engine speed/power decreases.

#### 2.1.3 Engine Stop from the Local Control Panel

When you push the STOP button on the LDU−20, the ECS shuts down the engine after the engine speed/power decreases.

**Note: You can use the buttons and rotary button only at the related active control stand.**

### 2.2 Emergency Stop

When you operate the emergency stop button on the local control panel, the engine stops immediately.

In diesel mode, the fuel pressure control valve 10−5562_E0_5 releases the pressure in the fuel rail (see 5562−1 Pressure Control Valve). At the same time, the fuel pump supply decreases to 0 (zero).

**Note: The operator must reset the engine shutdown in the ECS to start the engine again after an emergency stop.**

### 2.3 Last Alternative Selection

| CAUTION |
| --- |
| **Damage Hazard. Do this emergency procedure only as a last alternative selection. Damage to the engine can occur.** |

You can also set to off the electrical power to the ECS in the power supply boxes E85.1 to E85.x to stop the engine.

# 3. Engine Stop – Gas Mode

## 3.1 Usual Procedures

### 3.1.1 Engine Stop

When you push the STOP button on the local control panel, the ECS shuts down the engine after the engine speed/power decreases.

The ECS changes the operation mode to stop mode, the gas valve unit (GVU) stops the gas supply and releases the pressure in the gas inlet pipes. For more data, refer to 8014–1 Gas Fuel System and the documentation of the GVU manufacturer.

The ECS de-energizes the solenoid valve on the gas admission valve (GAV) to stop the gas flow to the cylinder liner (for more data about the GAV, refer to 2140–1 Gas Admission Valve and 4002–1 Engine Control System, paragraph 3.16).

For safety, the pilot injection valves operate longer than the GAV to make sure that all gas in the combustion chamber burns.

For more data, refer to the process diagram given in Fig. 1.

### 3.1.2 Engine Shutdown – Signal can be Cancelled

The engine safety system (ESS) or the ECS automatically sends a shutdown signal (signal can be cancelled), when a related failure or defect occurs. The ECS shuts down the engine after the engine speed/power decreases.

The ECS changes the operation mode to diesel mode, the GVU stops the gas supply and releases the pressure in the gas inlet pipes. The engine will continue to operate in diesel mode until the shutdown (SHD) signal becomes active, thus exhaust airflow is not necessary.

**Note: When the engine changes to diesel mode, you can cancel the shutdown command until the shutdown signal has become active. If you cancel the shutdown command, the engine will continue to operate in diesel mode.**

For more data, see the process diagram given in Fig. 2.

### 3.1.3 Engine Shutdown – Signal cannot be Cancelled

The engine safety system (ESS) or the ECS automatically sends a shutdown signal (signal cannot be cancelled), when a related failure or defect occurs. The ECS shuts down the engine after the engine speed/power decreases.

The ECS changes the operation mode to diesel mode, the GVU stops the gas supply and releases the pressure in the gas inlet pipes. The pilot fuel system is set to off, thus exhaust airflow is necessary.

**Note: You must find the cause and correct the defect or failure and reset the alarm in the LDU-20 to start the engine after an engine shutdown.**

For more data, see the process diagram given in Fig. 3.

## 3.2 Emergency Stop

**WARNING**

**Injury Hazard: When you operate the emergency stop button during operation in gas mode, gas can stay in the combustion chamber and exhaust gas system. There is a risk of explosion. Before you start the engine, make sure that there is no gas in the combustion chamber and exhaust gas system.**

**Note: For more data, refer to:**

- **0100−1 Safety Precautions and Warnings**
- **0130−1 Prevention of Explosions in the Exhaust System**
- **8014−1 Gas Fuel System.**

**Note: The emergency stop is the fastest procedure to manually shut-down the engine.**

When you operate the emergency stop button on the local control panel, the engine stops immediately.

The GVU stops the gas supply and releases the pressure in the gas inlet pipes. The ECS de-energizes the solenoid valve on the GAV to stop the gas flow to the cylinder liner (for more data, refer to 2140−1 Gas Admission Valve and 4002−1, paragraph 3.16).

**Note: You must reset (pull out) the emergency stop button and reset the alarms in the LDU-20 to go back to usual operation after an emergency shutdown.**

For more data, see the process diagram given in Fig. 3.

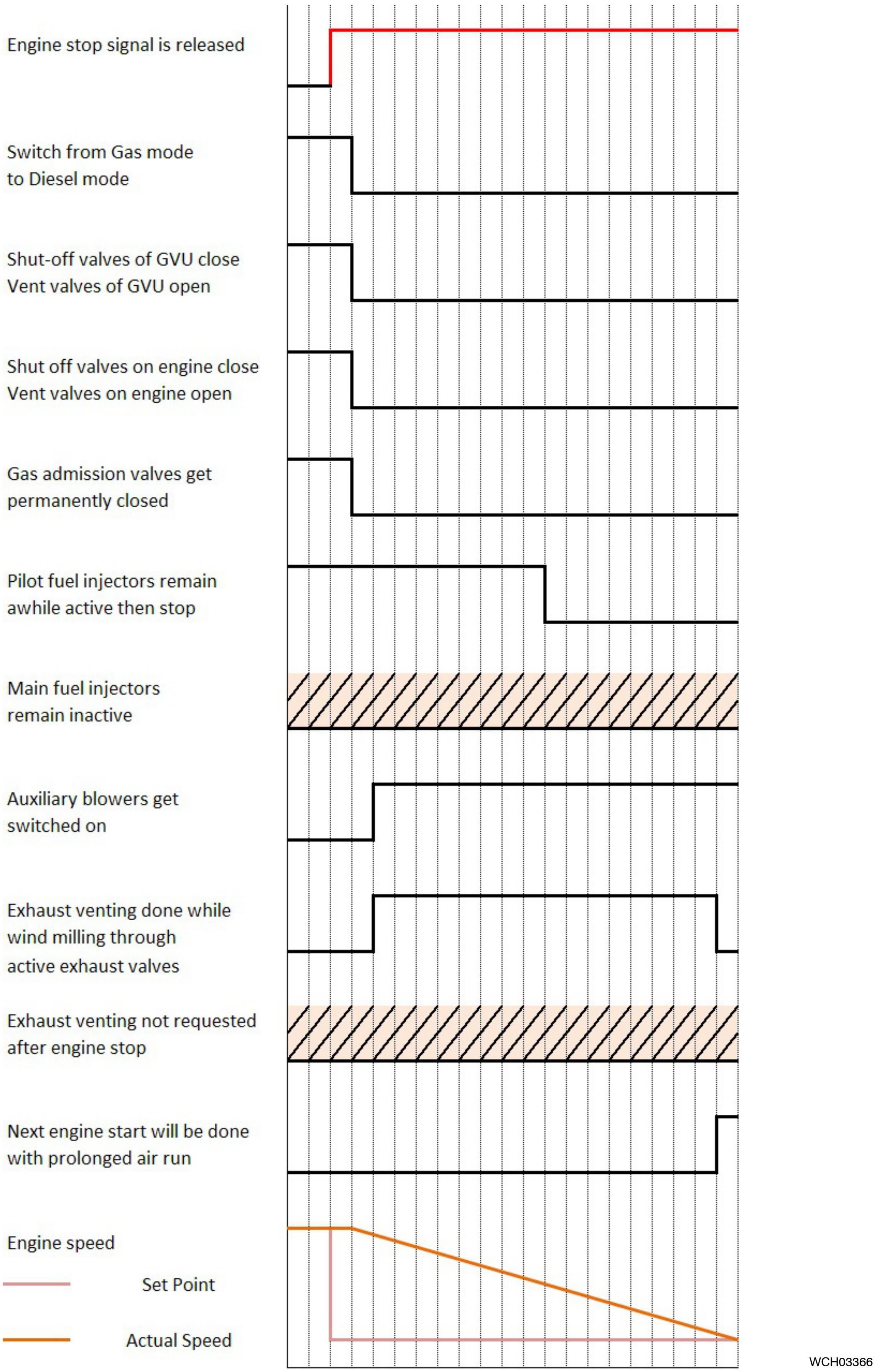


**Fig. 1: Process Diagram − Engine Stop in Gas Mode**

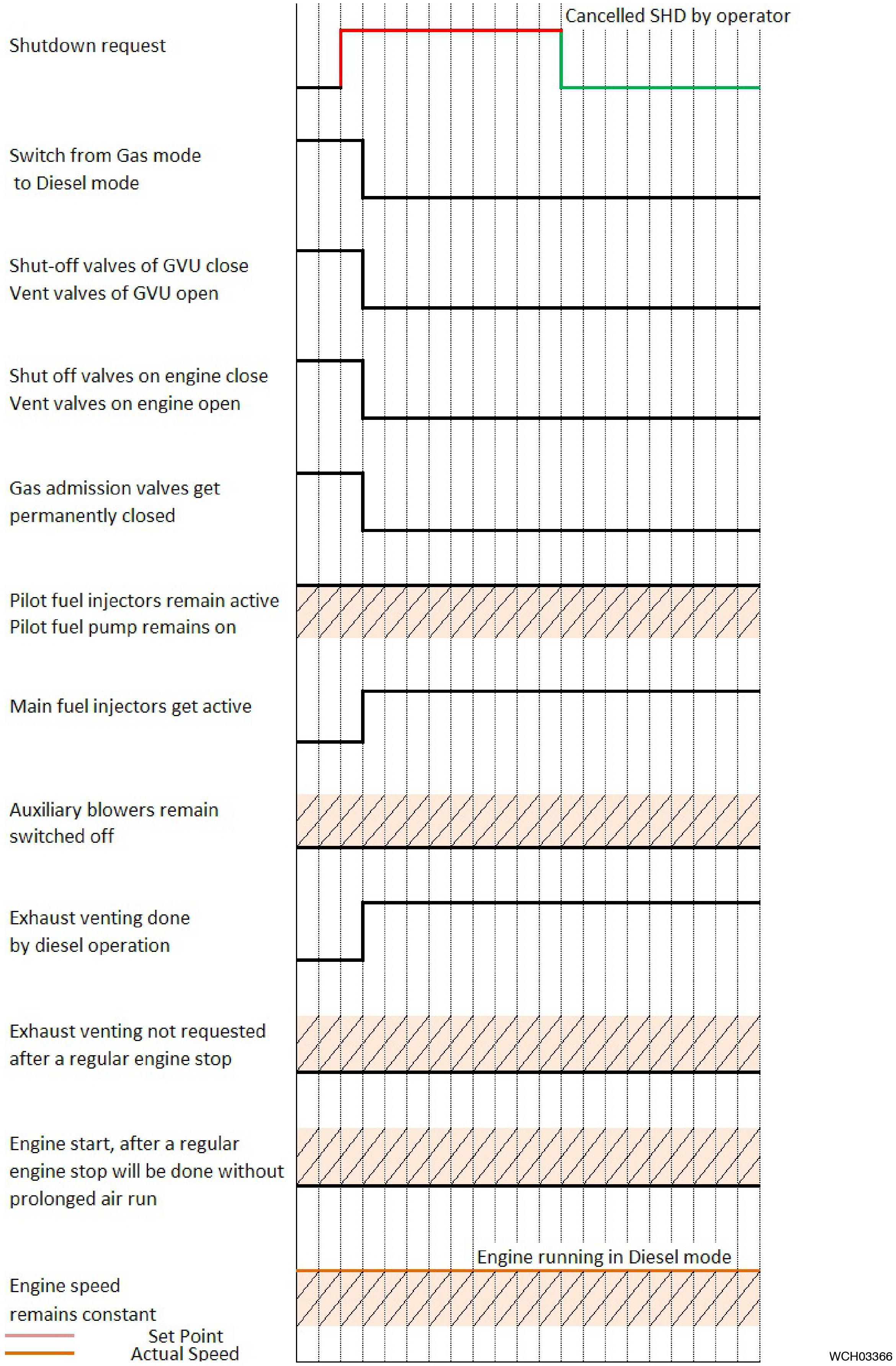


**Fig. 2: Process Diagram − Engine Shutdown in Gas Mode (can be cancelled)**

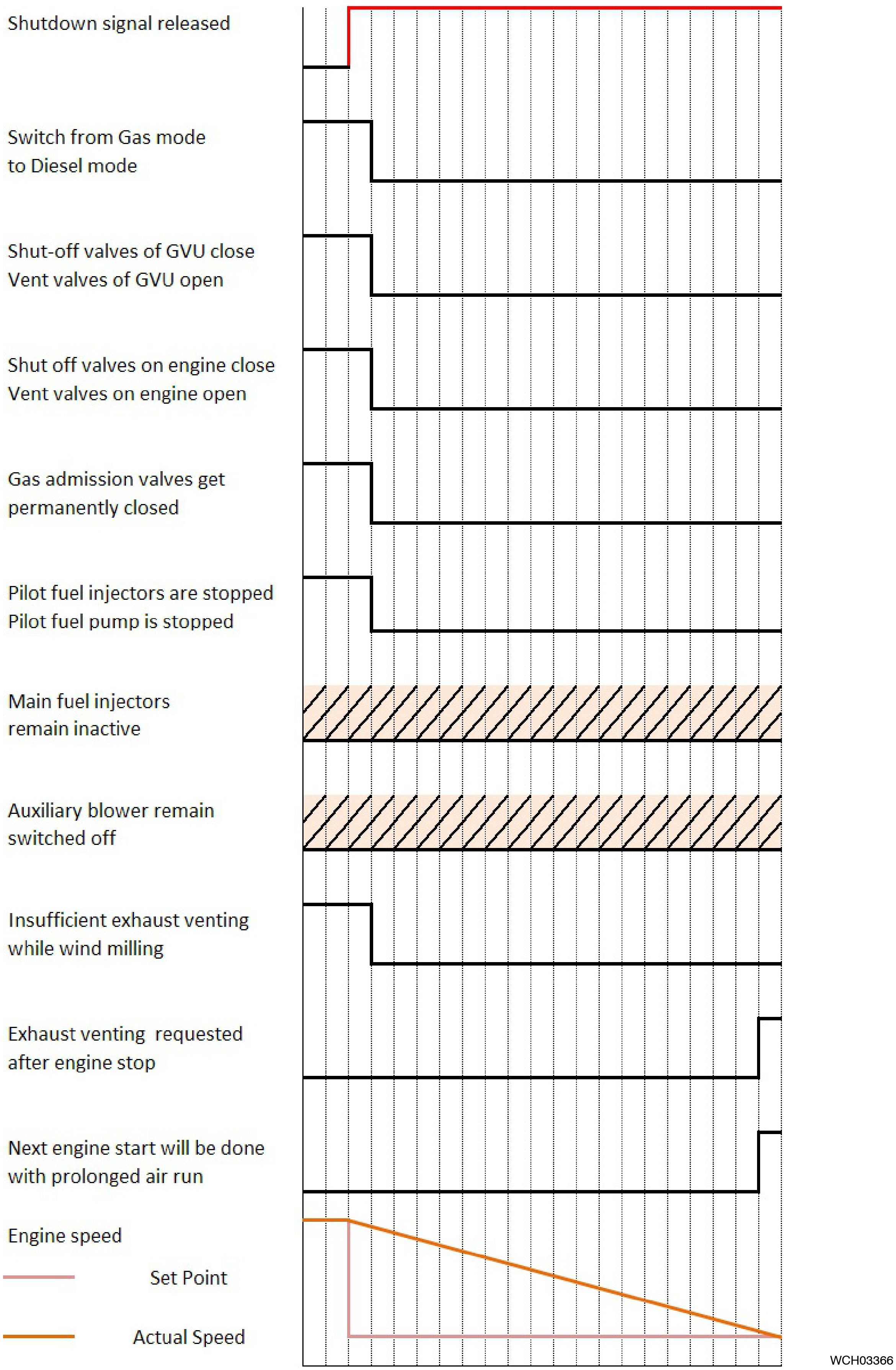


**Fig. 3: Process Diagram – Engine SHD (cannot be cancelled) and Emergency Stop in Gas Mode**

# Engine Stop
## Problems during Engine Stop

## 1. Engine cannot be Stopped

The engine cannot be stopped with the rotary switch or the telegraph in the control room.

The engine cannot be stopped with the rotary switch on the local control panel.

| Possible Causes | Procedure |
|---|---|
| The cable connector is defective | Push the EMERGENCY STOP button to stop the engine. Refer to 0600−1, paragraph 2.2 (diesel mode) and paragraph 3.2 (gas mode). |

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# Engine Stop
## Procedures after Engine Stop

## 1. Procedures for Short Service Breaks (some days to some weeks)

### 1.1 General

**WARNING**

**Injury Hazard: After engine operation in gas mode, gas can stay in the gas inlet pipes. There is a risk of explosion. You must replace the gas fuel with inert gas (e.g. nitrogen). This will prevent injury to personnel and damage to equipment.**

**WARNING**

**Injury Hazard: When you operate the emergency stop button during operation in gas mode, gas can stay in the combustion chamber and exhaust gas system. There is a risk of explosion. Before you start the engine, make sure that there is no gas in the combustion chamber and exhaust gas system.**

**Note: For data about gas leak tests and gas removal, refer to:**

- **The documentation of the gas valve unit (GVU) manufacturer**
- **4002–2, paragraph 3.12 and paragraph 3.13**
- **0100–1 Safety Precautions and Warnings**
- **0130–1 Prevention of Explosions in the Exhaust System)**
- **8014–1 Gas Fuel System, paragraph 3.4.**

### 1.2 Engine is Maneuverable

**Note: Post-lubrication of the cylinders starts automatically during the decrease of engine speed (below 8%).**

If the engine must still be maneuvered after it has stopped, see the conditions that follow:

- The ECS must stay set to on.
- The GVU must stay set to on.
- The pilot fuel system must stay set to on.
- All the pumps for cooling water, lubricating oil and fuel must operate.
- Control air must be available and the starting air bottles must be full.
- The cylinder cooling water must be kept at the correct temperature.
- The temperature of the lubricating oil must not decrease.
- The diesel fuel must be kept at the applicable temperature, related to 0300–1, Diesel Engine Fuels, Fig. 1 Viscosity-Temperature Diagram.

### 1.3 Engine is Not Maneuverable

**Note: Post-lubrication of the cylinders starts automatically during the decrease of engine speed (below 8%).**

If the engine is not maneuverable, see the conditions that follow:

- After the engine has stopped, the cooling water and lubricating oil pumps must operate for a minimum of 20 minutes to let the temperatures become stable. The temperatures of these media must not decrease below their usual inlet temperatures. Thus, the seawater pump can usually be stopped immediately.
- If the engine was shut down during operation with HFO, then the supply must flow through the fuel pumps and the fuel rail. The fuel system must continue to operate.
- If the engine was shut down during operation with HFO, the fuel pipe heating system of the engine must be set to on. If this is not necessary, change the engine operation to marine diesel oil (MDO) before shut-down (refer to 0530−1 Change-over from Marine Diesel Oil to Heavy Fuel Oil and Back.
- The low-pressure supply pump and booster pump can be stopped if the engine was shut down during operation with MDO.
- Where possible, keep the cooling water warm to prevent too much temperature decrease of the engine. The cooling water pump continues to operate unless it is necessary to stop the pump for maintenance.

Do steps 1) to 6) below:

1) Open the relief valves on all cylinder covers.

| WARNING |
|---|
| **Injury Hazard: Before you operate the turning gear, make sure that no personnel are near the flywheel or in the engine.** |

2) Engage the turning gear.

3) Set to on the ECS.

4) At frequent intervals and with the relief valves on all cylinder covers open, operate the turning gear to turn the engine as necessary (this can be done daily in damp climates). Do this procedure while the lubricating oil pump and servo oil service pump operate and set to on the cylinder lubrication at the same time. After this procedure is completed, make sure that the pistons stop in different positions each time.

5) Close the shut-off valve on the control air supply (supply of air from the board system).

6) Repair all the defects found during operation (leaks, etc).

**Note: Make sure that you know the safety precautions before you do repair work or overhauls (see the Maintenance Manual 0011−1 and 0012−1). If necessary, release the pressure from the fuel system.**

**Note: Make sure that the lubricating oil pump is set to off before you bleed the air spring system.**

## 1.4 Starting Air Manifold – Air Release / Starting Air System – Stop

Because of low air pressure after engine stop, the release of air in the starting air manifold (6, Fig. 1) cannot be done correctly. Thus, dirt and grease can stay in the starting air manifold and causes the piston rings of the starting air valve (7) to stick.

Use high-pressure air at regular intervals to make sure that all dirt and grease is removed from the starting air manifold.

**WARNING**

**Injury Hazard: Before you operate the turning gear, make sure that no personnel are near the flywheel or in the engine.**

1) Engage the turning gear.
2) Open the drain and test valve (3) momentarily. If you can hear the starting air flow into the shut-off valve (1), close the drain and test valve (3). The starting air manifold (6) is pressurized with high-pressure starting air.
3) Close the shut-off valves of the starting air bottles.

**Note: You can usually find the vent valve (5) installed at the free end of the starting air manifold. But on some engines the vent valve is installed at the driving end. It is possible that two vent valves are installed on different engine types.**

4) Open the vent valve (5). The high-pressure air is released. Dirt and grease in the starting air manifold are removed.
5) Lift the lever then turn the handwheel (2) to the position CLOSED.
6) Open the vent valve (4) to drain the shut-off valve (1).

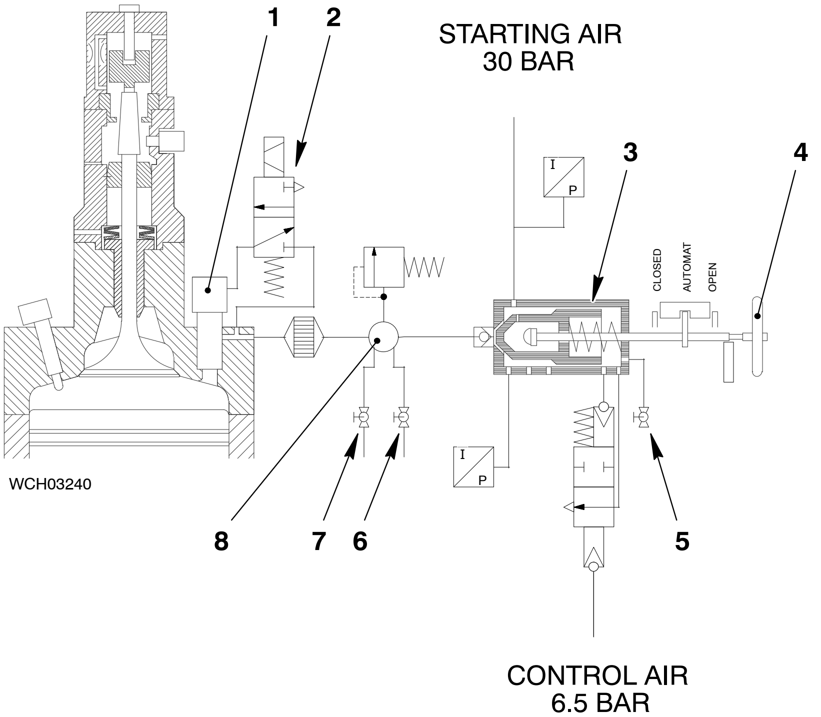


**Fig. 1: Starting Air System**

1 Starting air valve
2 5/2-way solenoid valve
3 Starting air shut-off valve 30−4325_E0_1
4 Handwheel
5 Drain and test valve 35−8353_E0_2
6 Vent valve 30−8605_E0_6
7 Vent valve 30−8605_E0_7
8 Starting air manifold

## 2. Procedures for Service Breaks for a Longer Period (weeks or months)

Refer to paragraph 1.2 and to 0630−1 Prepare the Engine for a Long Shutdown Period

# Engine Stop
## Prepare the Engine for a Long Shutdown Period

## 1. General

When you prepare the engine for a long shutdown period, make sure that you know the correct precautions to protect the engine from corrosion. There are two conditions as follows:

- Condition One has the procedures for when there is less crew on board for a period of some weeks.
- Condition Two has the procedures when, for some months, there is no crew on board.

## 2. Condition One

### 2.1 Procedure

**Note: It is recommended that you operate the engine on marine diesel oil or gas fuel as an alternative to heavy fuel oil for some time before engine shutdown (see 0530−1 Change-over from Diesel Oil to Heavy Fuel Oil and Back).**

**Note: The numbers (e.g. 10−8752_E0_10) refer to items shown in the control diagrams 4003−2, Page 1 and Page 2.**

1) On the starting air bottles 930−B001 and 930−B002, close the shut−off valves 930−V03 and 930−V04.
2) On the starting air shut−off valve 30−4325_E0_1, turn the handwheel to the position CLOSED.
3) Open the ball valve 35−8353_E0_2 to release the pressure in the starting air shut−off valve 30−4325_E0_1.
4) Open the ball valve 30−8605_E0_6 and 30−8605_E0_7 to release the pressure in the starting air manifold.
5) Make sure that the pressure gauges show zero pressure.
6) Engage the turning gear.

**Note: The water and oil pumps must operate for a minimum of 20 minutes after the engine has stopped. This is to make sure that when the engine temperature has decreased, the temperature of engine parts become as stable as possible.**

7) Open the relief valves on all cylinder covers.

**Note: Post-lubrication starts automatically during the slow-down of the engine.**

8) Cut out the fuel pumps (see 5556−2 Fuel Pump − Cutting Out and Cutting In)
9) Close the stop valves on the fuel tanks (see 0300−1 Diesel Engine Fuels).

10) Open the drain valves of the exhaust gas manifold and on the exhaust gas pipe to drain the condensate.

11) Close the drain valves of the exhaust gas manifold and the exhaust gas pipe.

12) Put a cover (e.g. a tarpaulin) on the exhaust gas manifold and the turbocharger silencer to make an airtight seal. This will prevent a flow of air through the engine and thus condensation.

13) For the scavenge air coolers (SAC), refer to the recommended procedures in the documentation of the manufacturer. If this is not available, it is recommended that the SAC are fully drained, or the cooling water pump is operated daily for approximately 30 minutes (with the flow quantity control valves in the same position as for usual operation conditions).

14) Keep the cylinder cooling water at approximately room temperature (monitor the temperature for frost).

15) Repair all the damage and leaks found during the previous operation period and the checks made after shut-down.

16) Do all scheduled overhauls and obey the general guidelines for maintenance (refer to the Maintenance Manual 0011−1 and 0012−1).

17) When the auxiliary engines and boilers do not operate and there is frost, fully drain all of the cooling systems (in such conditions, protect the drained systems from corrosion).

18) In the power supply box E85, set to off the circuit breaker to disconnect electrical power to the ECS.

19) Set to off the pilot fuel system.

20) Set to off the gas valve unit (GVU) (refer to the documentation of the GVU manufacturer).

21) In less than 48 hours after you have completed steps 1) to 21), do steps 22) to 23) below.

22) Open the covers on the rail unit and look for signs of condensation and corrosion.

23) Open the inspection covers on the supply unit (see 5552−1 Supply Unit ) look for signs of condensation and corrosion.

## 2.2 Procedures and Checks

**WARNING**

**Injury Hazard: Before you operate the turning gear, make sure that no personnel are near the flywheel, or in the engine.**

Do steps 1) to 12) below each week:

1) Make sure that the relief valves on all cylinder covers are open.

2) Operate the turning gear to turn the engine until each piston is at 60° before or after TDC (look on the flywheel). Cylinder lubricating oil can then flow directly into the piston ring pack.

3) In the LDU−20, get the MAIN Page (refer to 4002−2, paragraph 3.3).

4) Use the rotary button to select Cylinder Lubrication. The display shows the CYL. LUBRICATION page.

5) In the Manual Lub. To Cyl. # field, select the applicable cylinder number.

**Note: The lubricating oil pump and the service pump must operate (refer to 0400−1 Prepare for Engine Start after a Short Shutdown Period and 7218−1 Cylinder Lubrication).**

6) Operate the turning gear to turn the engine two full turns to apply the cylinder lubricating oil to the cylinder liner wall.

The recommended intervals are:

- Weekly in dry climates
- Daily in damp climates.

7) Stop the engine each time in a different position.

8) Open the covers on the rail unit and look for signs of condensation and corrosion.

9) If there are signs of corrosion, carefully clean the related parts.

10) Apply an anti-corrosion oil to give protection.

11) Decrease the lubrication intervals.

12) Apply oil as a spray to the dry parts.

## 3. Condition Two

If the engine must stop for a long period, it must be fully cleaned and preserved on the inside and the outside (ask for the preserving instructions from Wärtsilä Services Switzerland Ltd.).

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# Bedplate and Tie Rod

# Group 1

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# Main Bearing

## 1. General

The main bearing has a bottom main bearing shell (7, Fig. 1) and a top main bearing shell (5).

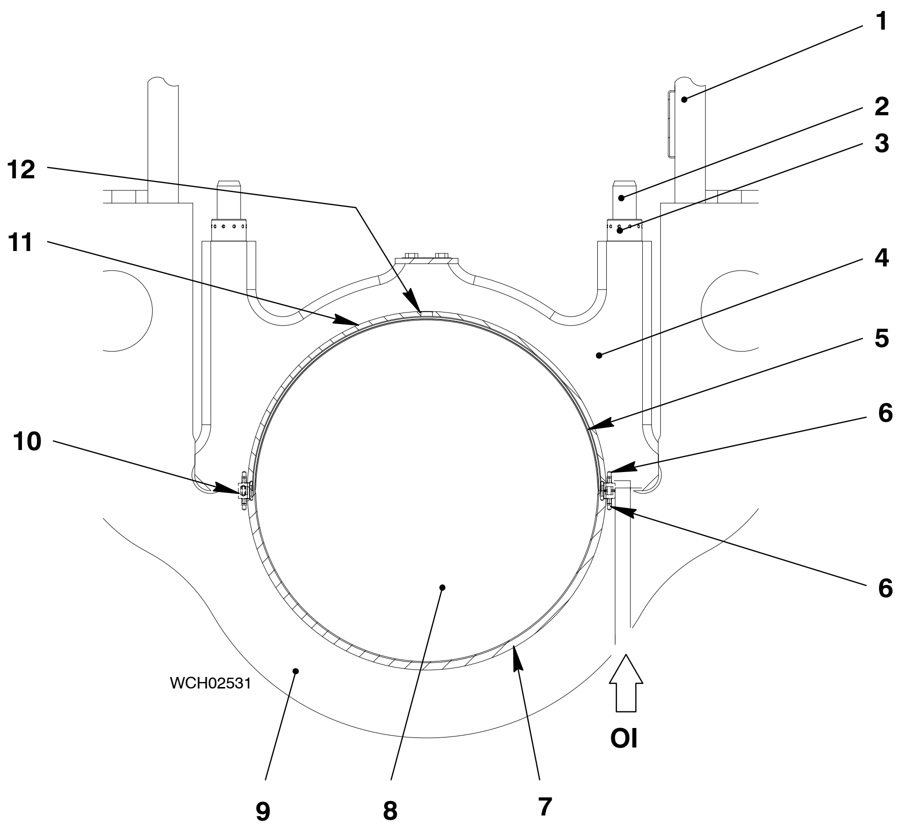
The bottom main bearing shell (7) is is installed in the bearing girder (9) of the bedplate and the top main bearing shell (5) in the bearing cover (4). The screws (6) engage and hold the top main bearing shell and bottom main bearing shell in position.

The spring dowel pin (10) helps to get the bearing cover (4) in position.

The elastic studs (2) have a non-hardening locking compound applied to the threads. Hydraulic tension is applied to the elastic studs during the install procedure. The round nuts (3) keep the bearing cover (4) against the bearing girder (9).

## 2. Lubrication

Oil flows from the bedplate through the oil inlet (OI) to the main bearings. The oil flows through the grooves (OG) and bores (OB) to the running surface of the main bearing.




| | | | |
|---|---|---|---|
| 1 | Column | 9 | Bearing girder |
| 2 | Elastic stud | 10 | Spring dowel pin |
| 3 | Round nut | 11 | Oil groove |
| 4 | Bearing cover | 12 | Oil bore |
| 5 | Top main bearing shell | | |
| 6 | Screw | OI | Oil inlet |
| 7 | Bottom main bearing shell | OG | Oil groove |
| 8 | Crankshaft | OB | Oil bore |

**Fig. 1: Main Bearing**

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# Thrust Bearing

## 1. General

The thrust bearing is installed at the driving end of the engine. The thrust bearing flange transmits the force from the propeller through the thrust pads into the bedplate.

The arbor supports (4, Fig. 1) prevent axial movement of the thrust pads.

There are six thrust pads (5 and 9) on each side of the thrust bearing flange (10, Fig. 2). The thrust pads absorb the axial force from the crankshaft and propeller.

The crankshaft gear wheel moves the intermediate wheel of the supply unit.

### 1.1 Engines with Fixed Pitch Propellers

For clockwise and counterclockwise rotation, six thrust pads are installed on each side of the thrust bearing flange. The thrust pads adapt to the clockwise or counterclockwise rotation.

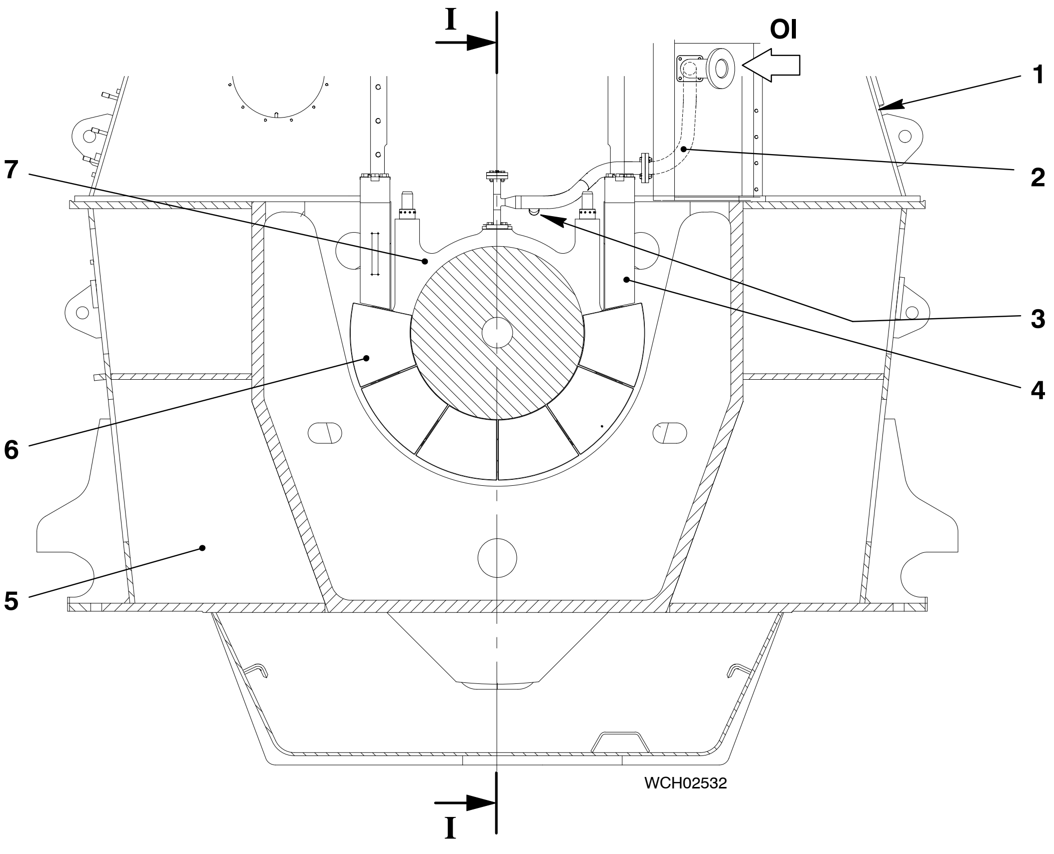



**Fig. 1: Thrust Bearing – Cross Section**

1 Column
2 Oil pipe
3 Nozzle
4 Arbor support
5 Bedplate
6 Thrust pad
7 Bearing cover

OI Bearing oil inlet

## 2. Lubrication

During operation, bearing oil flows through the oil pipe (2) to the two nozzles (3, Fig. 1). The oil flows out of the two nozzles as a spray, which becomes an oil layer between the thrust bearing flange (10) and the thrust pads (5 and 9, Fig. 2).

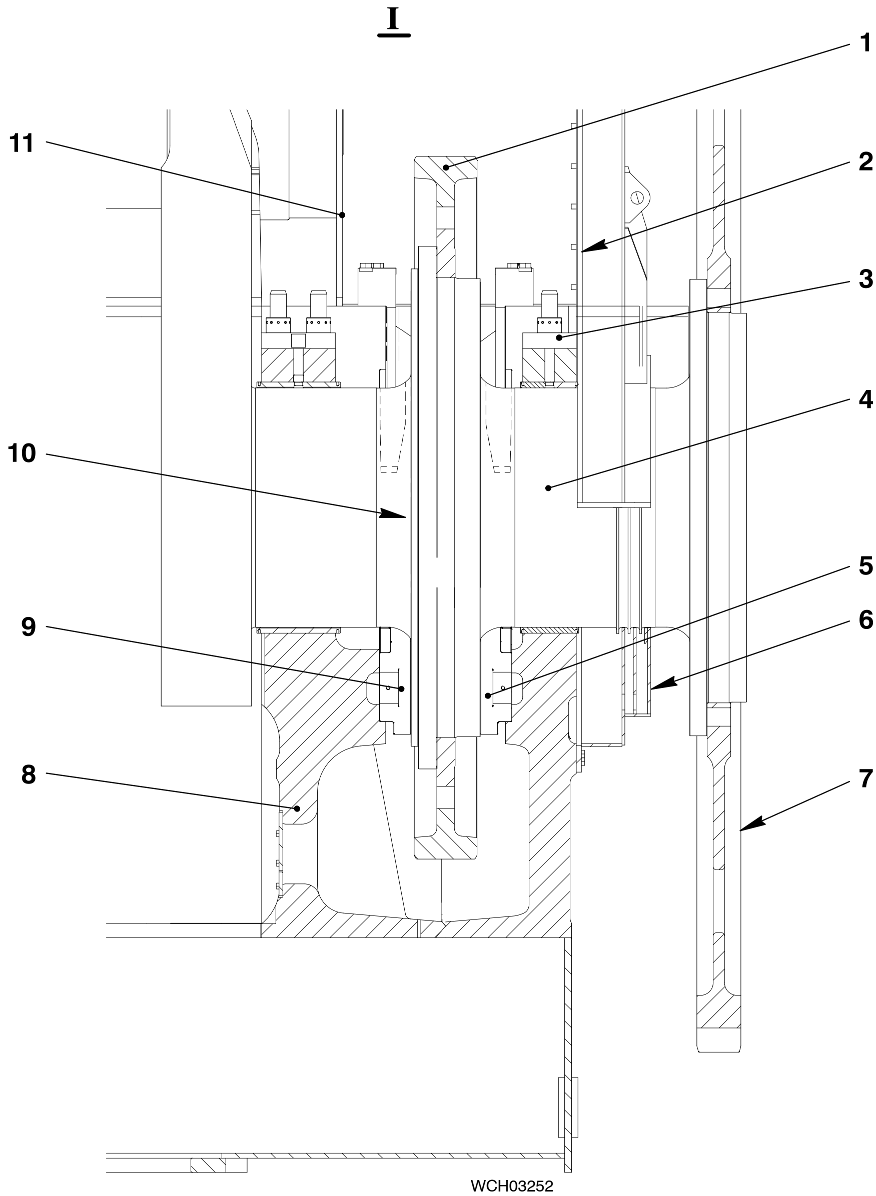


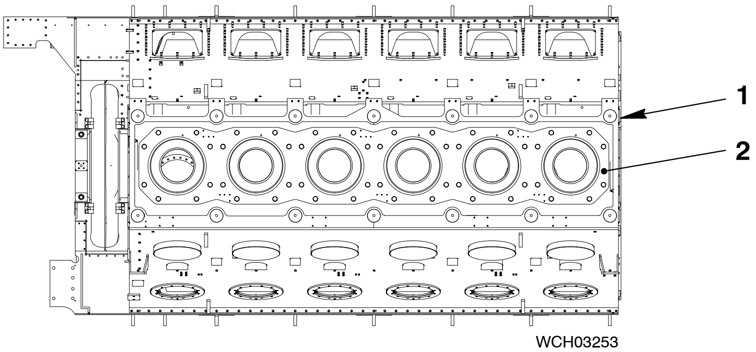

**Fig. 2: Thrust Bearing – Longitudinal Section**

1 Crankshaft gear wheel
2 Bearing cover
3 Bearing cover
4 Crankshaft
5 Thrust pads (driving end)
6 Two-part oil baffle
7 Flywheel
8 Bedplate
9 Thrust pads (free end)
10 Thrust bearing flange
11 Column

# Tie Rod

## 1. General

The tie rods (1, Fig. 1) keep the cylinder block (3), column (4) and bedplate (5) together at four locations around the cylinders.




DATA FOR
6-CYLINDER
ENGINES

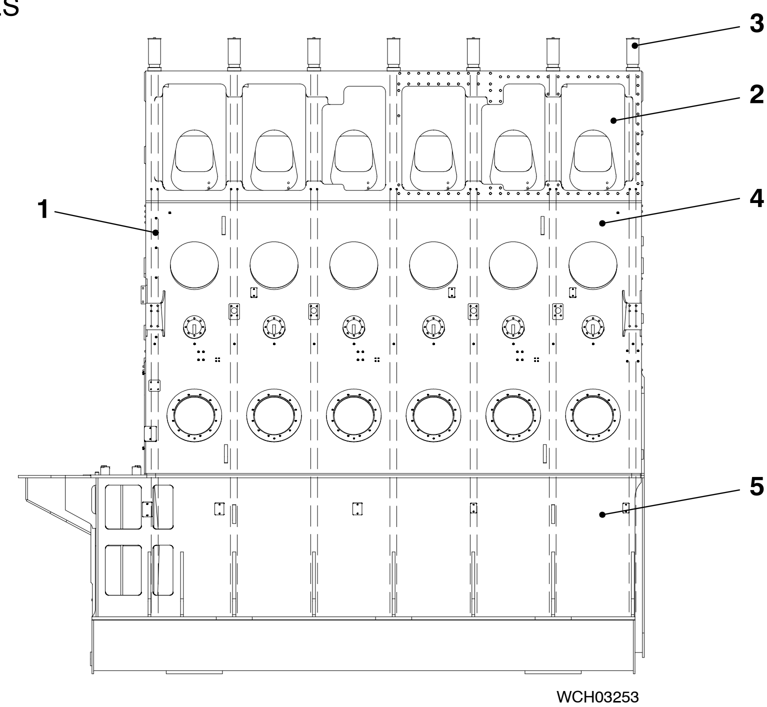



**Fig. 1: Tie Rod Configuration and Locations**

1 Tie rod
2 Cylinder block
3 Protection cover
4 Column
5 Bedplate

The two-part bush (8) is welded on the tie rod (4, Fig. 2). At the bottom of the cylinder block, two set screws (7) keep the two-part bush in position to prevent vibration of the tie rods.

If a tie rod breaks in the bottom area, the holders (11, 14) and screws (13, 15) make sure that the nut (10) does not fall into the crankcase.

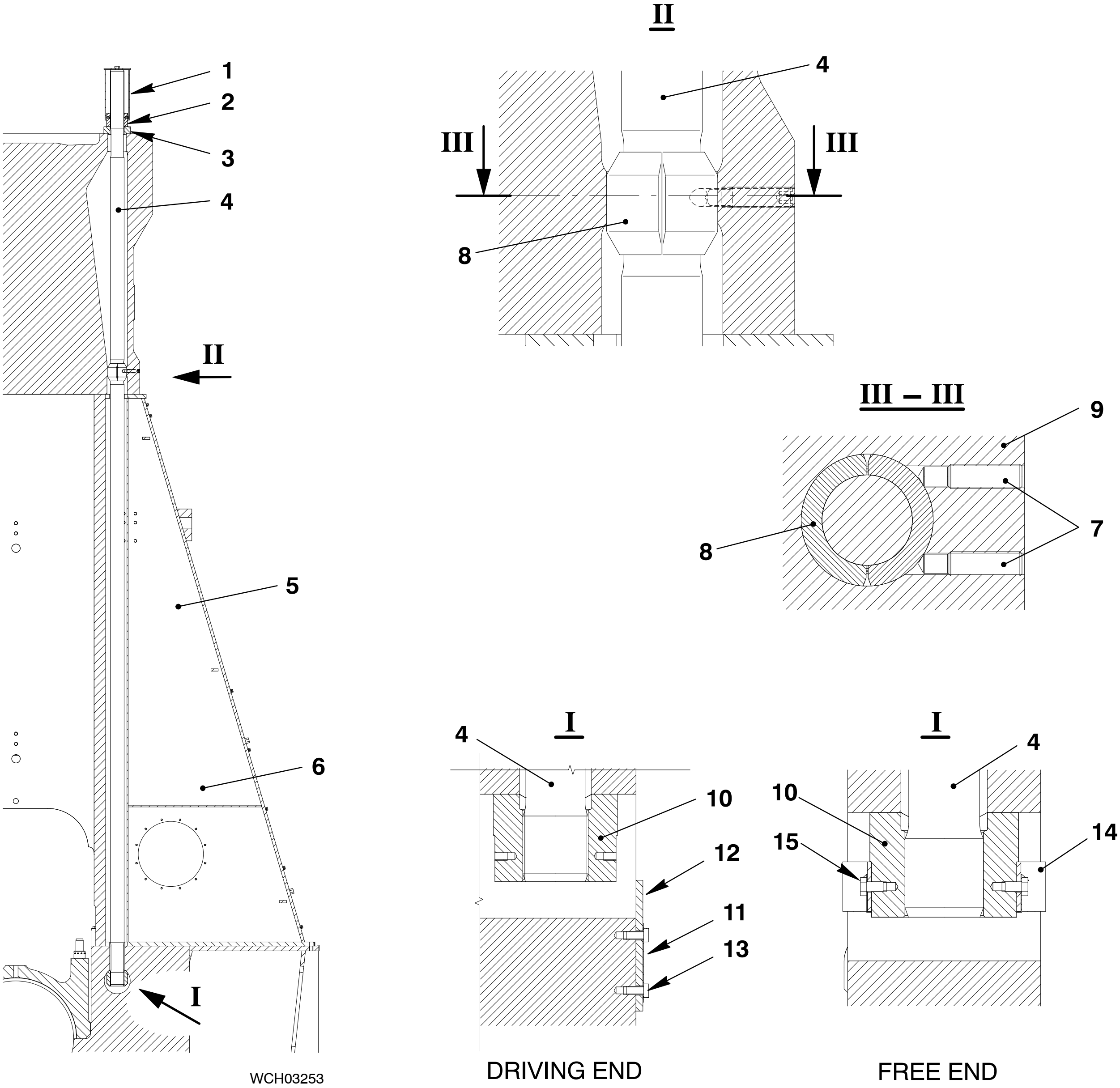



**Fig. 2: Tie Rod Assembly**

1 Protection cover
2 Round nut
3 Intermediate ring
4 Tie rod
5 Column
6 Bedplate
7 Set screw
8 Two-part bush
9 Cylinder jacket
10 Nut
11 Locking plate
12 Holder
13 Screw
14 Holder
15 Screw

# Cylinder Liner and Cylinder Cover — Group 2

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# Cylinder Liner

## 1. General

Screws and holders (not shown) hold the cylinder liner (4, Fig.1) in the cylinder jacket (5). The nuts of the elastic bolts attach the cylinder cover (1), cylinder liner and the top and bottom water guide jacket (2) and (3), to the cylinder jacket.

The surfaces of the cylinder liner (4) and the cylinder jacket (5) make a metallic seal (MS). A non-hardening compound is applied around the surface of the metallic seal (MS) to prevent leakage.

The antipolishing ring (9) is installed in the top part of the cylinder liner (4). The antipolishing ring removes coke contamination at the piston crown during operation.

## 2. Cooling

The cooling water flows through the cooling water inlet inlet (CI) into the bottom water guide jacket (3) to the water space (WS) and around the cylinder liner (4). Cooling water flows also through the tube (12) into the top water guide jacket (2).

From the top water guide jacket (2), the cooling water flows through the cooling bores (8) and the cylinder cover (1) into the exhaust valve cage. The cooling water then flows through the cooling water outlet (6, Fig. 2) and back to the plant.

The O-rings (13, Fig.1) are used to seal the water space (WS). If water leaks you must replace the O-rings as soon as possible (refer to the Maintenance Manual 2124–2).

To prevent unwanted tension in the top part of the cylinder liner (4), the temperature of the cooling water must stay in the permitted range. The maximum permitted temperature ranges are:

- ±2°C at constant load
- ±4°C during load changes.

## 3. Lubrication

Cylinder lubricating oil flows to the running surface of the cylinder liner (4) through six lubricating quills (7). The lubricating grooves (10) are milled around the circumference of the cylinder liner (6) and make sure that the lubricating oil is equally supplied (for more data, refer to 2138–1 Lubricating Quill).

For more data about the cylinder lubrication, see 7218–1.

## 4. Gas Fuel

Gas fuel flows through the gas nozzles (6) into the cylinder. For more data about the gas fuel system, refer to 8014–1 Gas Fuel System.

## 5. Defects

Refer to 8017–1 Cooling Water System, paragraph 3.

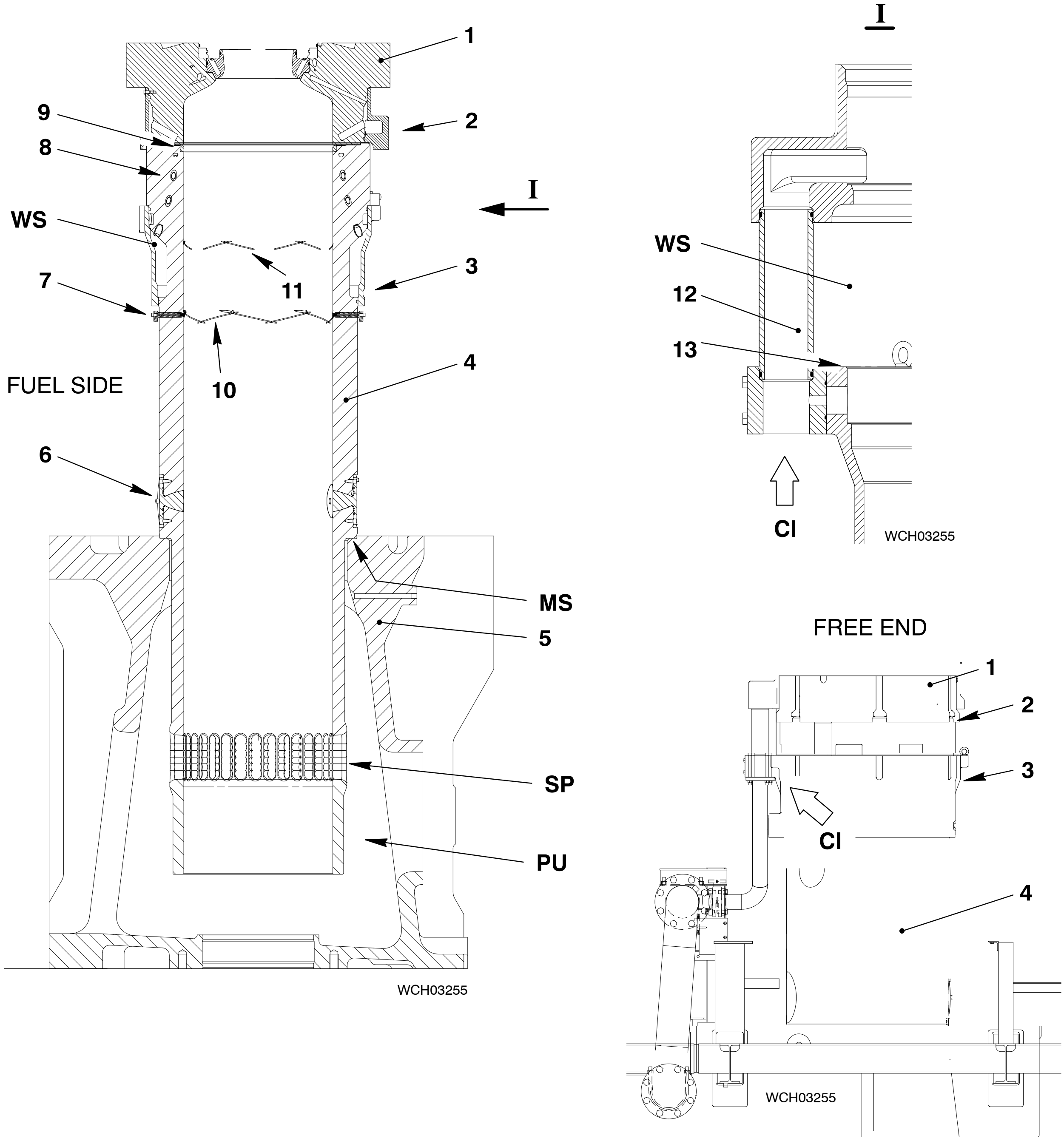


**Fig. 1: Cylinder Liner and Cooling Water Inlet**

| | | | |
|---|---|---|---|
| 1 | Cylinder cover | 11 | Oil grooves |
| 2 | Top water guide jacket | 12 | Tube |
| 3 | Bottom water guide jacket | 13 | O-ring |
| 4 | Cylinder liner | | |
| 5 | Cylinder jacket | | |
| 6 | Gas nozzle | MS | Metallic seal |
| 7 | Lubricating quill | SP | Scavenge ports |
| 8 | Cooling bores | PU | Piston underside |
| 9 | Antipolishing ring | WS | Water space |
| 10 | Lubricating grooves | CI | Cooling water inlet (water guide jacket) |

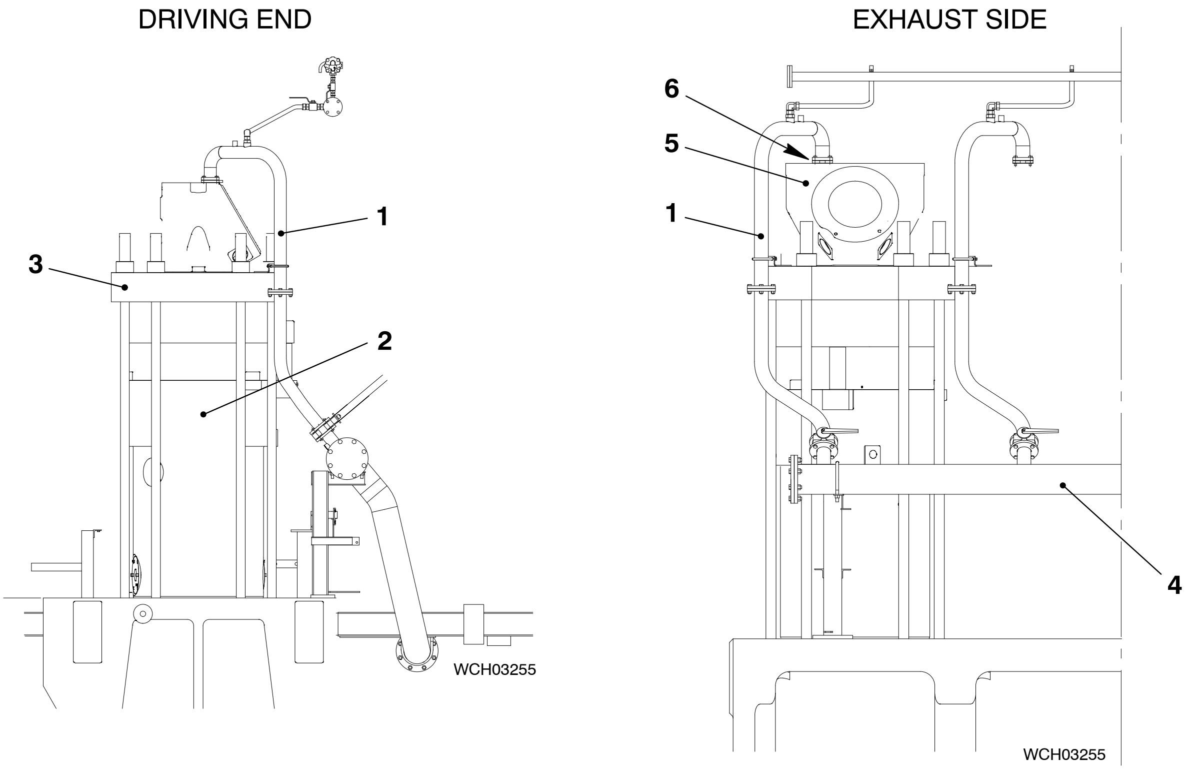


**Fig. 2: Cylinder Liner − Cooling Water Outlet**

1 Cooling water outlet pipe
2 Cylinder liner
3 Exhaust valve cage
4 Collector pipe
5 Exhaust valve cage
6 Cooling water outlet

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# Lubricating Quills on Cylinder Liner

## 1. General

Six lubricating quills (4, Fig. 1) are are installed around the circumference of the cylinder liner (3). The lubricating pump (2) installed on the rail unit (1), supplies lubricating oil through pipes to each lubricating quill (4).

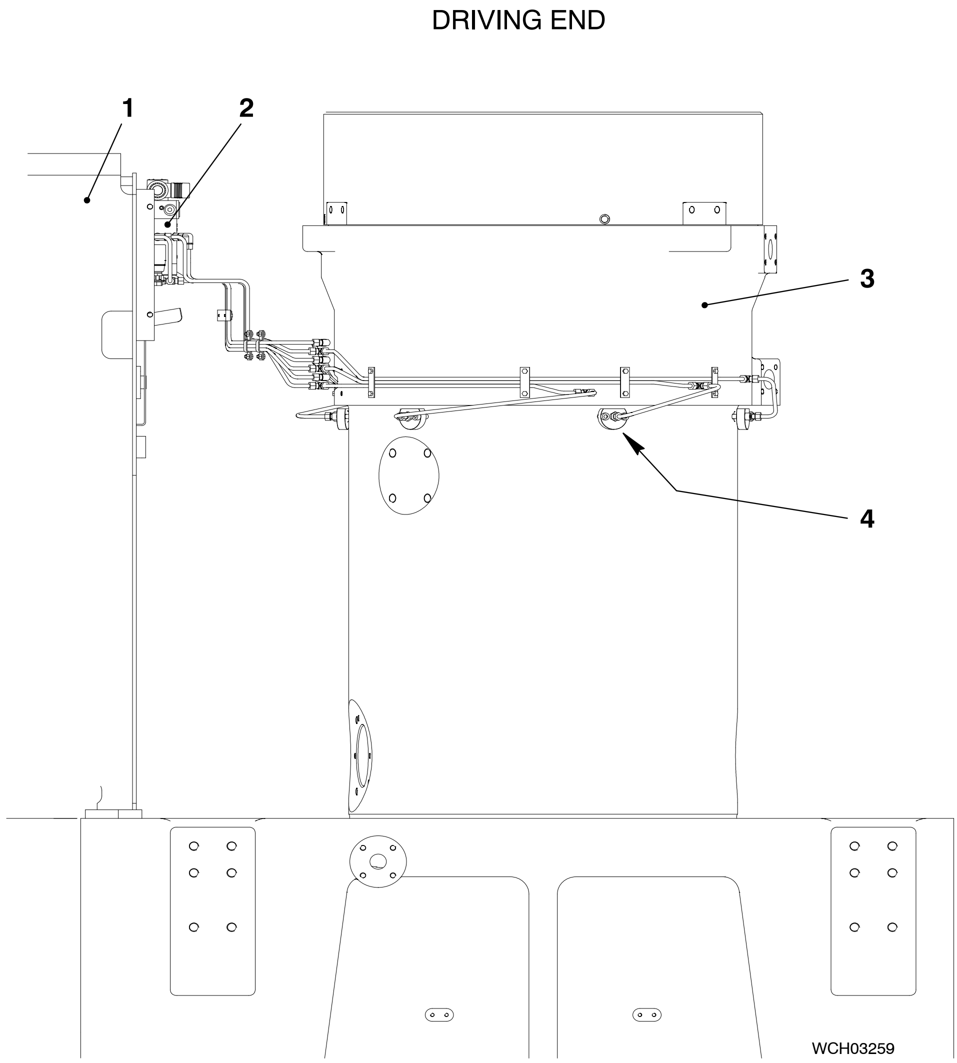



**Fig. 1: Lubricating Quills – Location**

1 Rail unit
2 Lubricating pump
3 Cylinder liner
4 Lubricating quill

## 2. Function

The lubricating pump supplies a specified quantity of lubricating oil at high pressure through the lubricating oil inlet (OI, Fig. 2) into the lubricating quills.

The non-return valve (9) opens and the lubricating oil flows out of the nozzle tip (4) and the lubricating point (5) as a spray. The lubricating oil flows equally into the grooves on the cylinder liner wall (for more data, refer to 2124−1 Cylinder Liner and 7218−1 Cylinder Lubrication).

After a lubrication pulse, the oil pressure decreases and the force of the compression spring (6) closes the non-return valve (9).

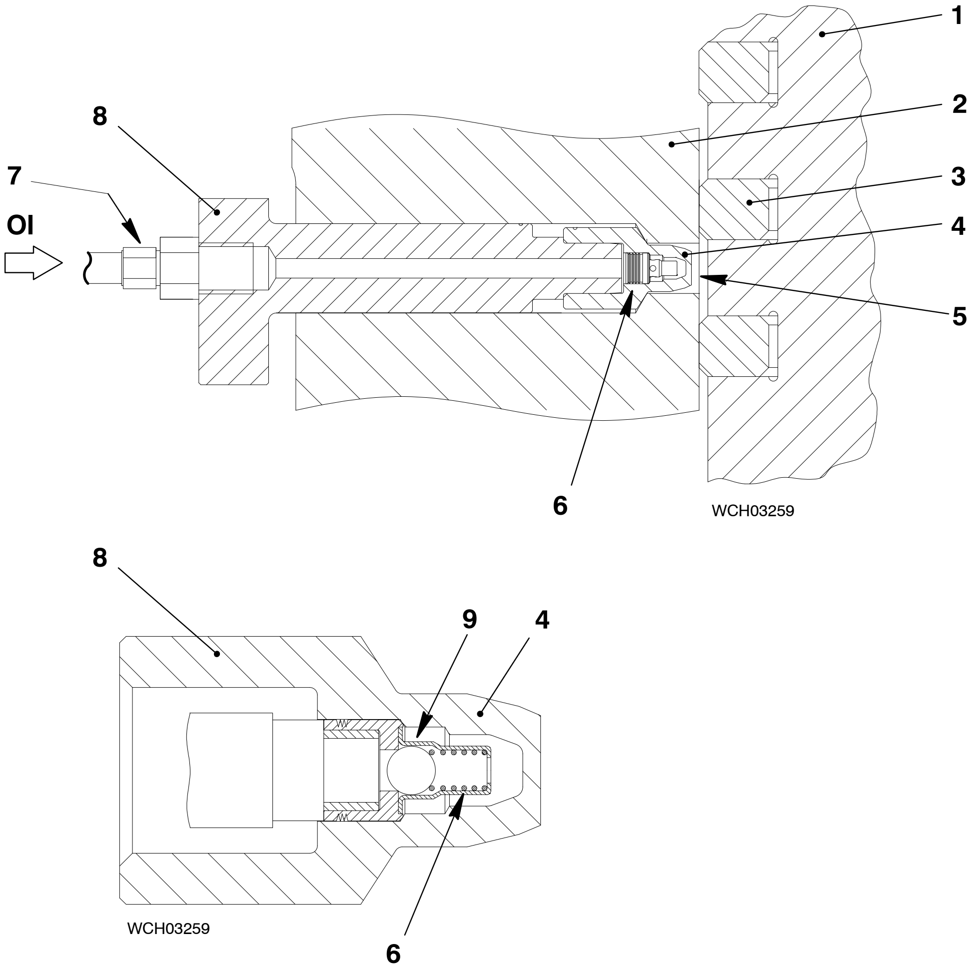



**Fig. 2: Lubricating Quill**

| | | | |
|---|---|---|---|
| 1 | Piston | 7 | Union nut |
| 2 | Cylinder liner | 8 | Holder |
| 3 | Piston ring | 9 | Non-return valve |
| 4 | Nozzle tip | | |
| 5 | Lubricating point in cylinder liner | OI | Lubricating oil inlet |
| 6 | Compression spring | | |

# Gas Admission Valve



## 1. General

Two gas admission valves (GAV) (1, Fig. 1) are installed in each cylinder liner.

The GAV (1) controls the gas flow into the cylinder liner. When the GAV opens, there is an injection of gas into the cylinder liner.

The ECS monitors and controls the GAV (1). The ECS controls the gas quantity independently for each cylinder to adjust the engine load. Servo oil is used to operate hydraulically the GAV.

The valve stroke sensor (8) installed in the cover (6), transmits signals to the ECS. The ECS uses these signals to adjust the timing of the gas supply, which is related to the engine load.

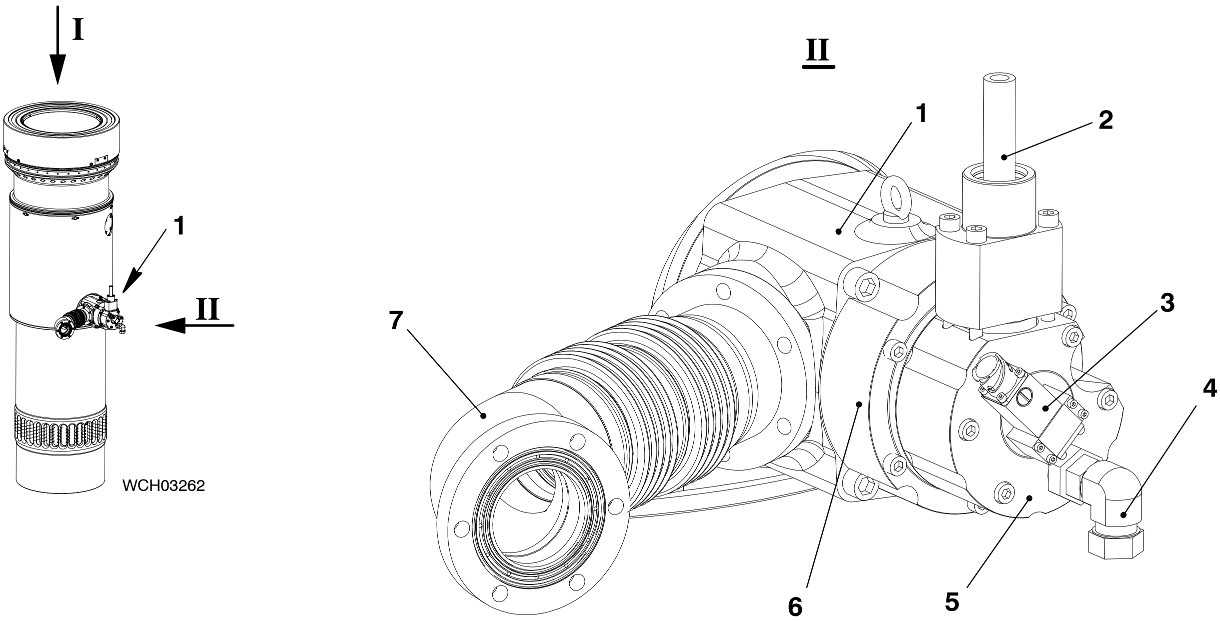
The compression spring (9) closes the GAV (1) when the solenoid valve (3) is de-energized.

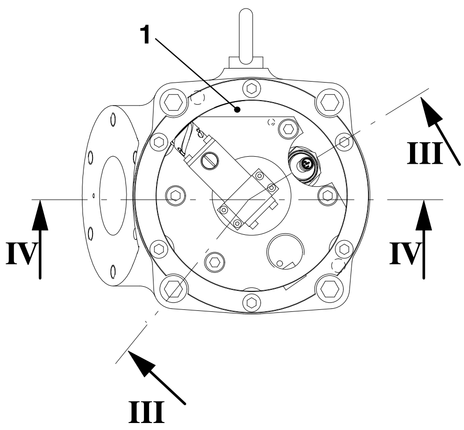
The GAV (1) are single-wall valves. For safety, the manufacturer does a leak test after assembly to make sure that there is no accidental gas flow from the GAV.

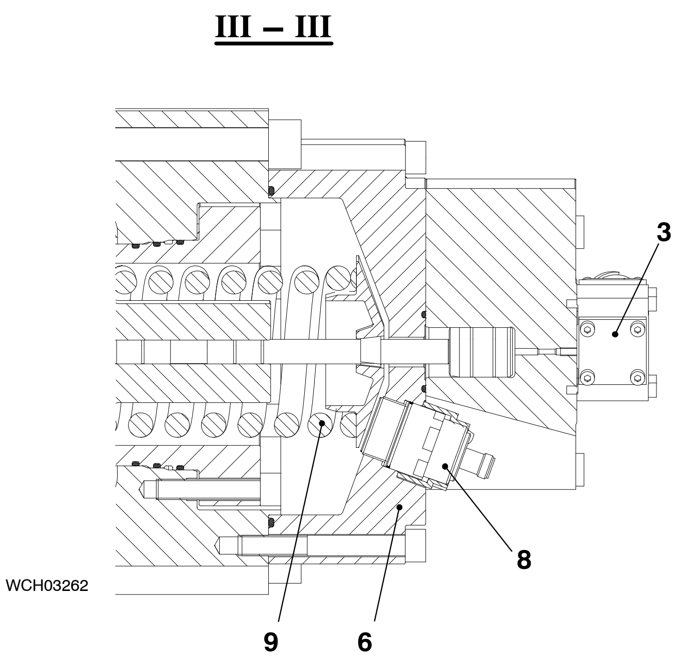
If the GAV (1) has a leak, gas will flow through the bore (14, Fig. 2) in the housing (15) to the space between the walls of the gas supply pipe (double wall). The gas will activate the gas detection sensor and the ECS will show an alarm.

A pressure regulating valve installed in the gas valve unit (GVU) controls the gas inlet pressure for different engine loads. The ECS controls this pressure regulating valve.

For more data about the gas system and the GVU, refer to 8014−1 Gas System.




**For Views I and IV – IV see Fig 2**

**Fig. 1: Gas Admission Valve**

1 Gas admission valve
2 Hydraulic pipe (servo oil inlet)
3 Solenoid valve
4 Oil return pipe
5 Piston cover
6 Cover
7 Gas inlet pipe
8 Valve stroke sensor
9 Compression spring

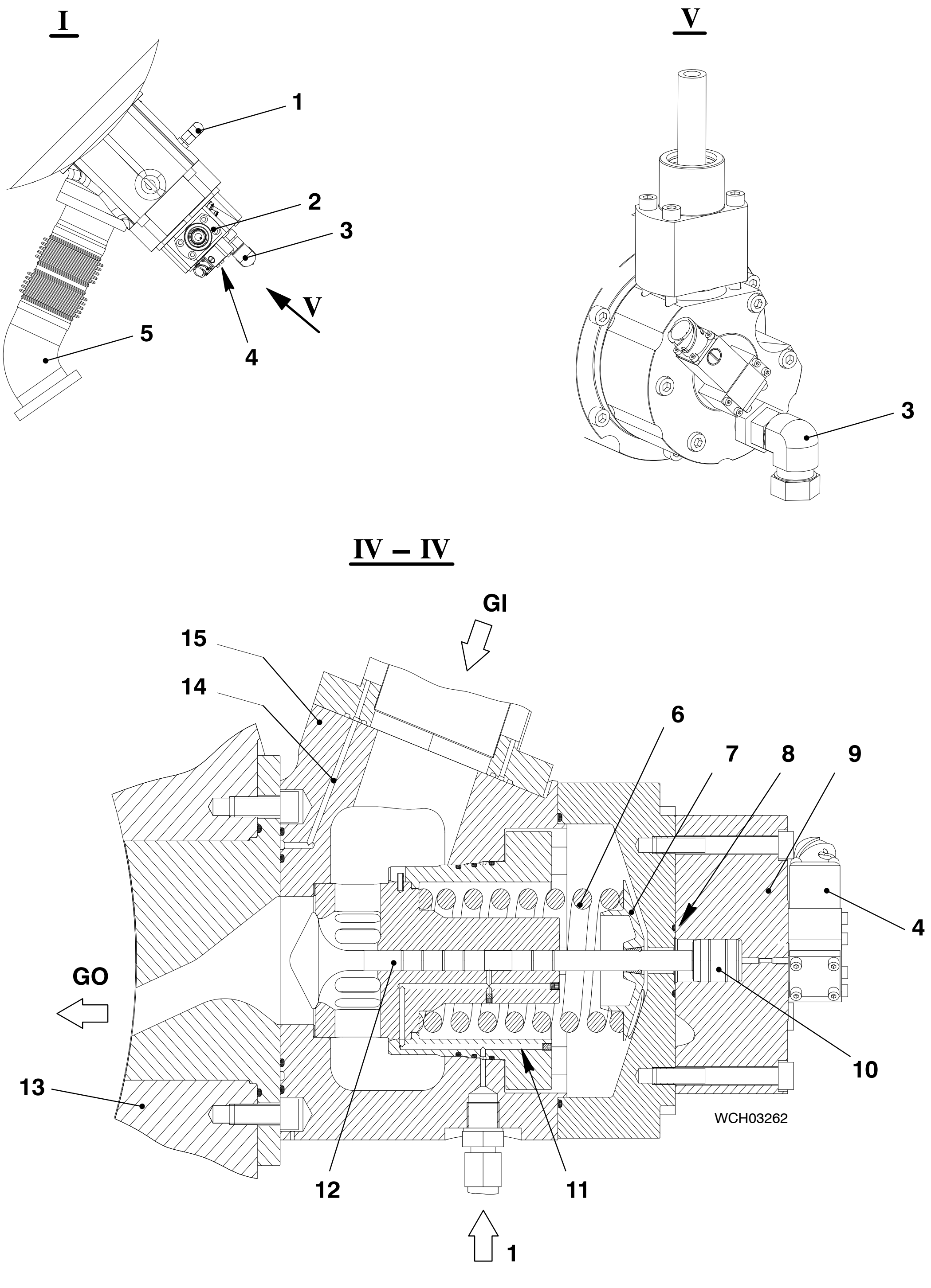



**Fig. 2: Gas Admission Valve – Section Views**

| | | | |
|---|---|---|---|
| 1 | Servo oil inlet (lubrication and oil seal) | 10 | Piston |
| 2 | Hydraulic pipe (servo oil inlet) | 11 | Lubricating bores |
| 3 | Oil return pipe | 12 | Valve spindle |
| 4 | Solenoid valve | 13 | Cylinder liner |
| 5 | Gas inlet pipe | 14 | Bore (to gas supply pipes) |
| 6 | Compression spring | 15 | Housing |
| 7 | Spring carrier | | |
| 8 | O-ring | GI | Gas inlet |
| 9 | Piston cover | GO | Gas outlet (into combustion chamber) |

## 2. Operation

Oil from the servo oil system operates the GAV (6, Fig. 3). The servo oil flows at high pressure from the connection on the servo oil rail (2) through the hydraulic pipes (5) and distributor blocks (4). The servo oil flows from the servo oil inlet into the GAV (6).

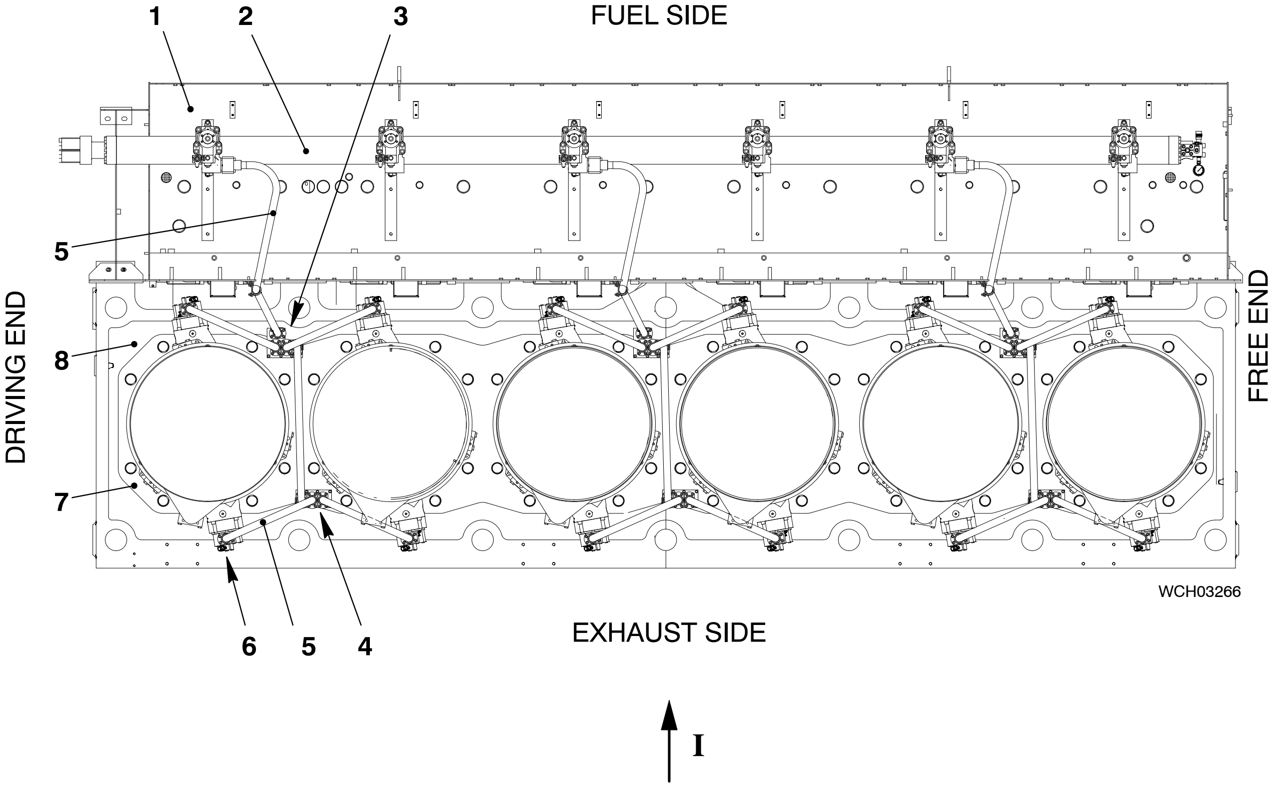
The ECS operates the solenoid valve (4, Fig. 2). The servo oil moves the piston (10) and the valve spindle (12) against the force of the compression spring (6). The valve spindle (12) moves away from the valve seat and gas flows through the gas nozzle into the combustion chamber.

**Note: The gas is mixed with combustion air only in the cylinder liner.**

When the solenoid valve (4) is de-energized, i.e. there is no servo oil pressure on the piston (10), the force of the compression spring (6) moves the valve spindle (12) and valve seat back and the GAV closes.

The servo oil drains through the servo oil drain (11) to the main leakage collector (31, Fig. 4) to the plant.

The ECS independently operates the GAV to make sure that gas that is not burned flows out of the combustion chamber to the exhaust gas system. For more data, refer to 4002−1 Engine Control System.



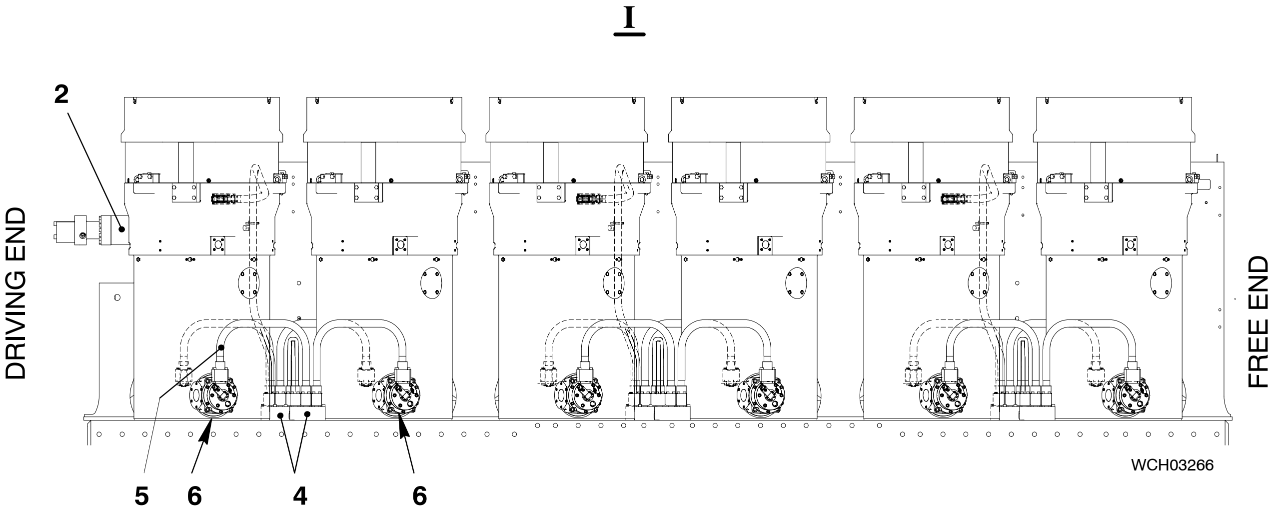




**Fig. 3: Servo Oil Connections (Operation) – Location**

1 Rail unit
2 Servo oil rail
3 Distributor block
4 Distributor block
5 Hydraulic pipe (servo oil inlet)
6 Gas admission valve
7 Cylinder liner
8 Cylinder block

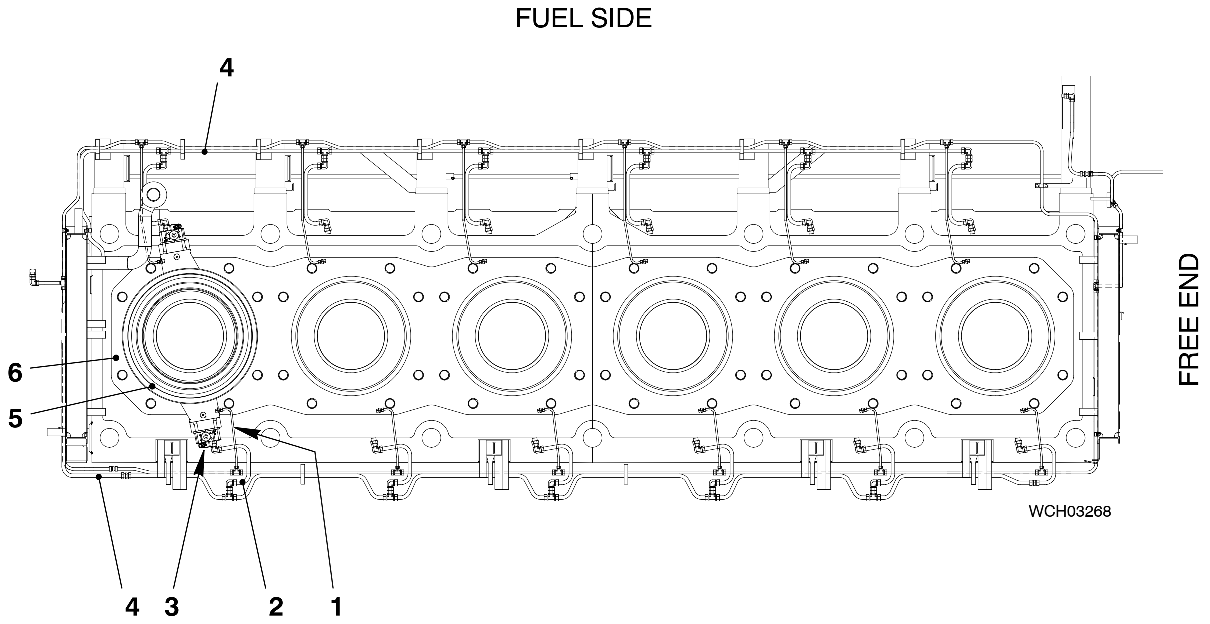
## 3. Lubrication and Oil Seal

Servo oil from the servo oil system lubricates the GAV (3, Fig. 4). The servo oil flows through the pressure reducing valve 90−8492_E0_2 (see 4003−2 Page 2) on the servo oil rail into the servo oil supply pipes (1).

The servo oil flows through the servo oil inlet (1, Fig. 2) into the housing (15) and flows through the lubricating bores (11) to the grooves in the valve spindle (12).

The servo oil drains through the oil return pipe (2) to the servo oil drain pipe (4, Fig. 4).

For safety, the servo oil in the GAV (3) prevents gas flow into the servo oil system.



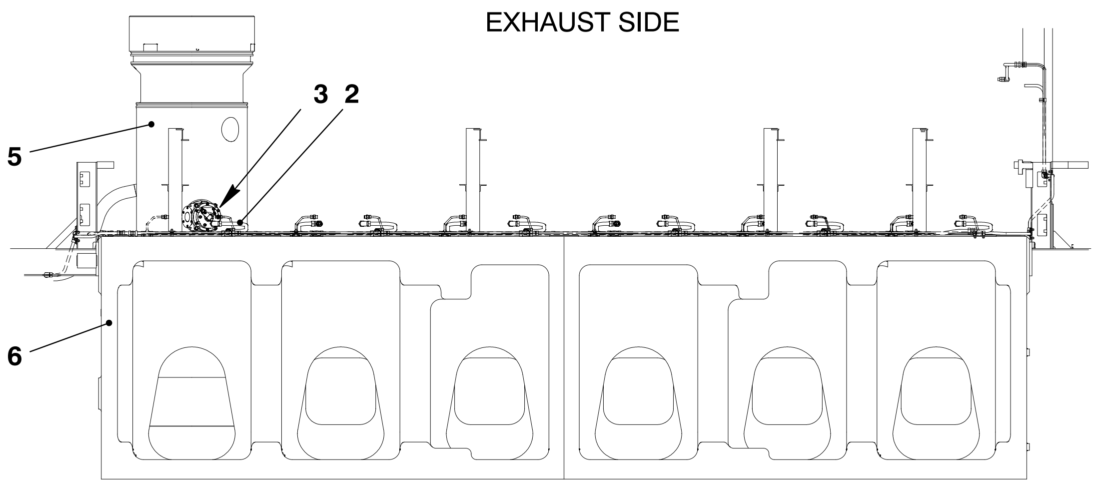




**Fig. 4: Servo Oil Connections (Lubrication and Oil Seal)**

1 Servo oil supply pipe (lubrication and oil seal)
2 Servo oil return pipe
3 Gas admission valve
4 Servo oil drain pipe (lubrication and oil seal)
5 Cylinder liner
6 Cylinder block

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# Piston Rod Gland

## 1. General

**WARNING**

**Danger: The leakage oil drain must not become clogged  There is a dangerous risk of fire if the dirty oil does not flow away from the area.**

**Note: For data about special procedures, refer to 0110–1.**

The piston rod gland (7, Fig. 1) keeps the dirty oil in the scavenge space (1) and prevents contamination of the bearing oil. Also, the piston rod gland seals the scavenge air from the crankcase (2).

Damaged gaskets cause an increase in the quantity of oil in the leakage oil drain. You use the sample port (4) to get an oil sample. You can measure this sample, and/or send the sample to the laboratory to make an analysis.

**Note: Some parts can look different.**

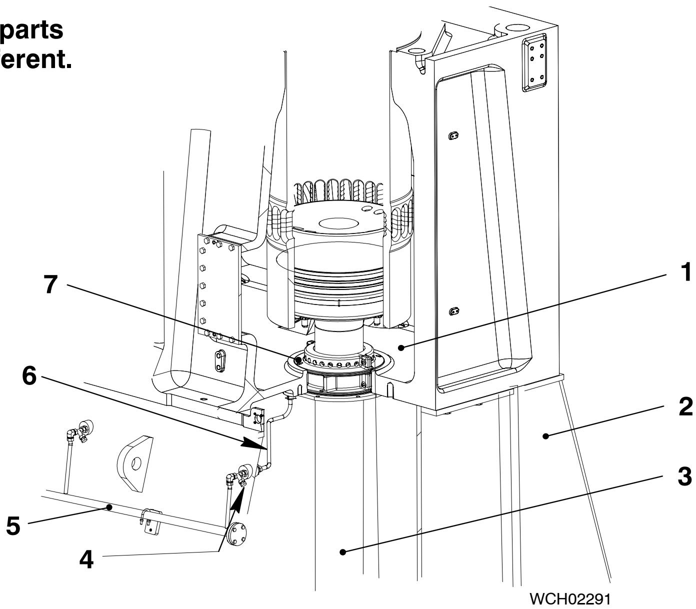


**Fig. 1: Piston Rod Gland Box – Location**

1 Scavenge space
2 Crankcase
3 Piston rod
4 Sample port
5 Leakage oil pipe
6 Leakage oil drain
7 Piston rod gland

## 2. Function

During operation, the two scraper rings (12, Fig. 2) remove dirty oil from the piston rod. The dirty oil flows through the oil bores (1) and collects in the bottom of the scavenge space (SS). The dirty oil flows out through the leakage oil drain on the fuel side.

The two gaskets (9) and (10) prevent the release of scavenge air into the crankcase. The low scavenge air pressure is released through a vent in the plant.

The oil that flows through the relief passages (2) into the neutral space (3) flows into the oil drain.

The four ring supports (4) hold the eight scraper rings (7) in position. The scraper rings (7) remove bearing oil from the piston rod. This bearing oil flows through the bearing oil drain (BD) to the crankcase.

The tension springs, (8) and (11), keep the scraper rings (7) and (12) against the piston rod.

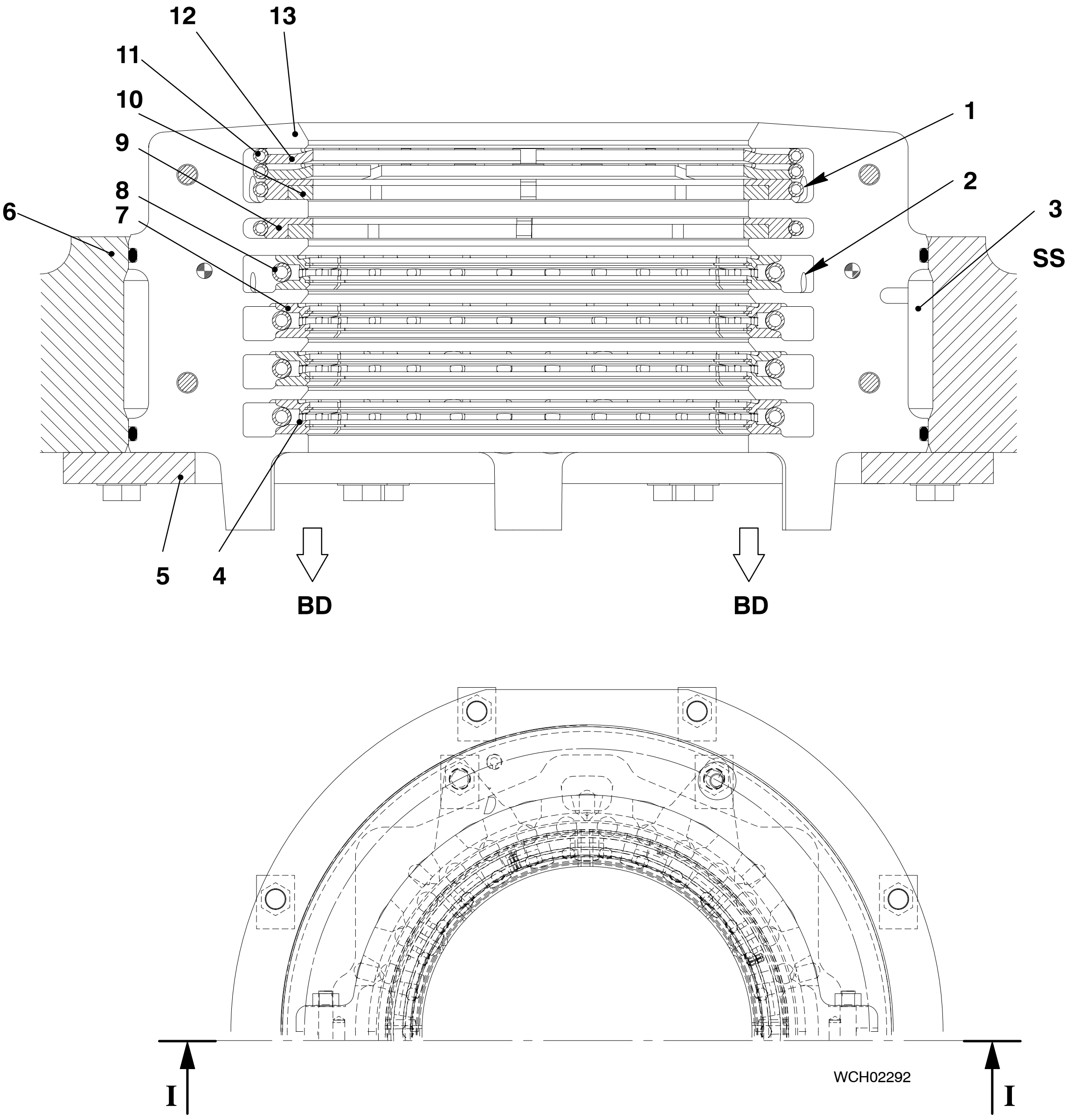


**Fig. 2: Piston Rod Gland**

| | | | |
|---|---|---|---|
| 1 | Oil bore | 10 | Gasket (4-part) |
| 2 | Relief passage | 11 | Tension spring |
| 3 | Neutral space | 12 | Scraper ring (4-part) |
| 4 | Ring support (3-part) | 13 | Housing (2-part) |
| 5 | Support | | |
| 6 | Cylinder jacket | | |
| 7 | Scraper ring (3-part) | | |
| 8 | Tension spring | BD | Bearing oil drain |
| 9 | Gasket (four-part) | SS | Scavenge space |

# Injection Valve

## 1. General

Three injection valves (2, Fig. 1) are installed in each cylinder cover (3).

Fuel is used to operate the injection valves (2). When the injection valve operates and the needle opens, a small quantity of fuel leaks out of the injection valve. This fuel flows back through the fuel return (5, Fig. 2). To prevent contamination of lubricating oil with fuel, the mixture of lubricating oil and fuel leakage (6) drains to the plant. For more data, refer to 8019–1 Fuel System.

To disassemble, assemble and do tests of the injection valves, refer to the Maintenance Manual, Chapter 2722–1.

**WARNING**

**Danger: Do not open the relief valve to release pressure during engine operation. Injury to personnel can occur.**

A relief valve (6) is installed in each cylinder cover. The relief valve releases over-pressure in the combustion chamber. If the relief valve has operated, you must find the cause and repair the defect as soon as possible.

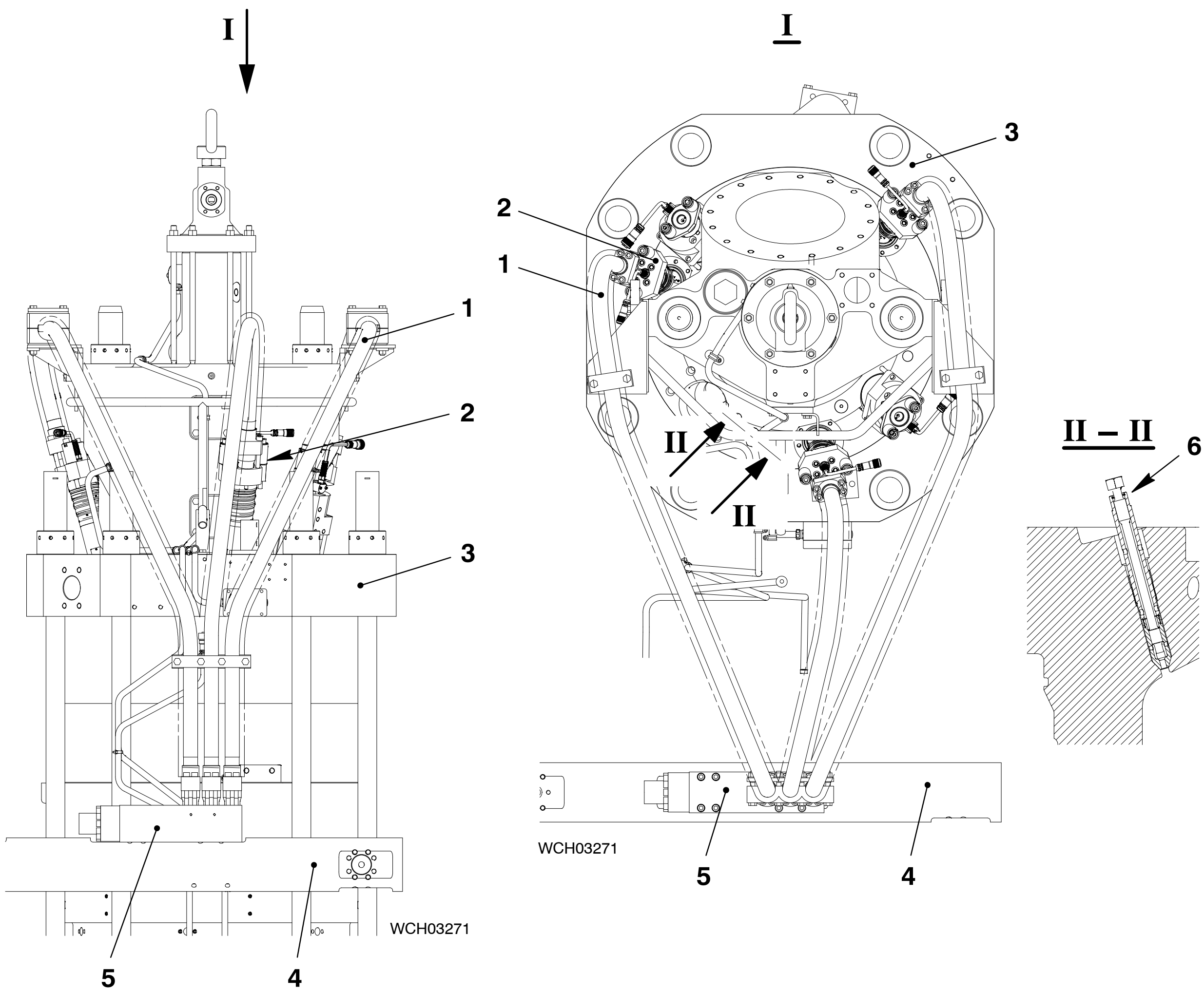


**Fig. 1: Location of Injection Valves**

1 HP fuel pipe (injection valve)
2 Injection valve
3 Cylinder cover
4 Fuel rail
5 Flow limiter valve
6 Relief valve

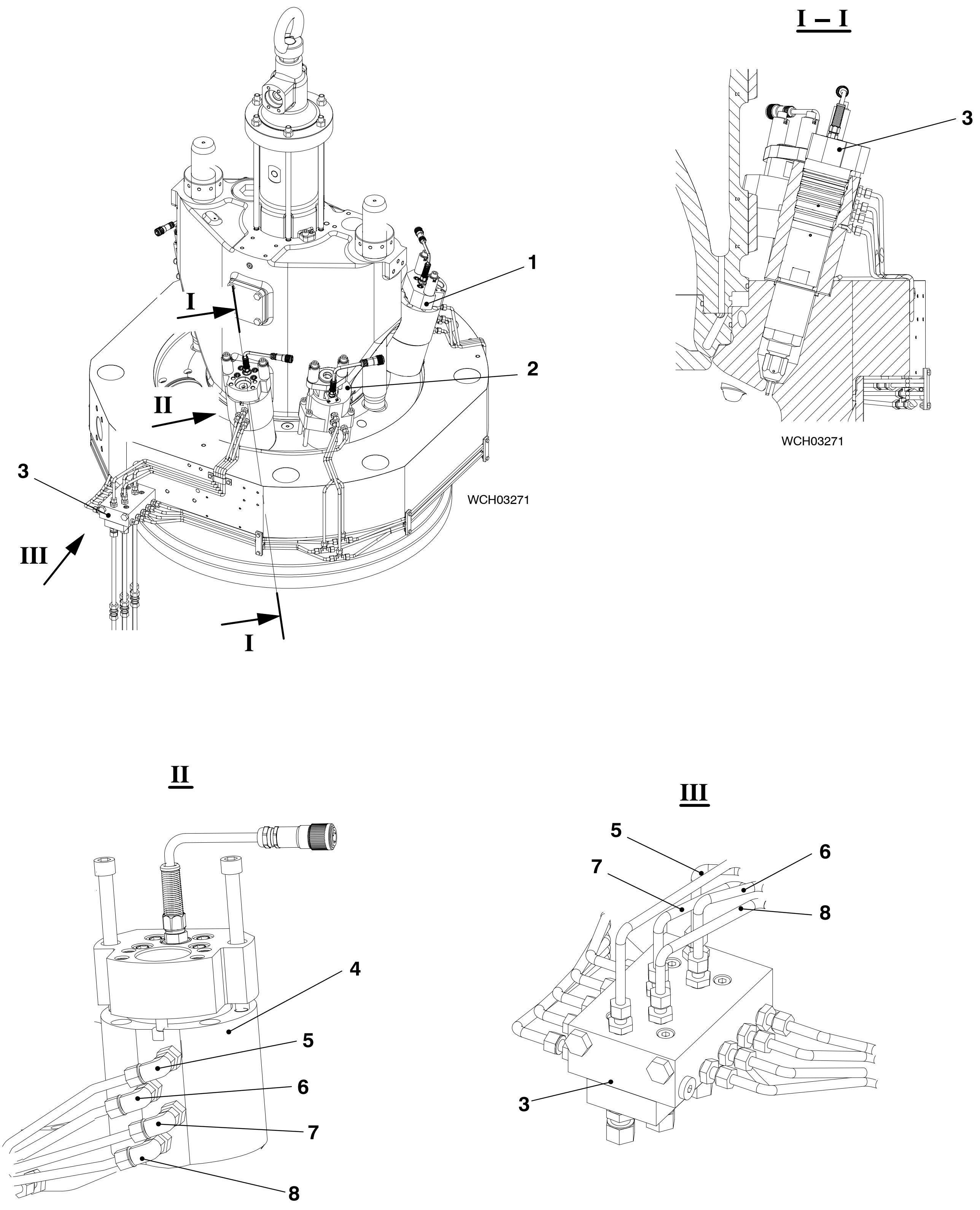


**Fig. 2: Injection Valves and Pipes**

| | | | |
|---|---|---|---|
| 1 | Injection valve | 5 | Control fuel return |
| 2 | Pilot Injection valve | 6 | Fuel / lubricating oil leakage |
| 3 | Connecting plate | 7 | Lubricating oil return |
| 4 | Valve bush | 8 | Lubricating oil inlet |

## 2. Function

Fuel flows through the high pressure (HP) fuel pipes (1, Fig. 1) to the three injection valves.

The control valve for the injection valves is activated, which moves the needle to the open position. Fuel flows through the holes in the nozzle tip (3, Fig. 3) and into the combustion chamber as a spray. A small quantity of fuel flows through the fuel return (main injection).

## 3. Cooling

Oil from the main oil supply lubricates the injection valves and keeps them cool. When the engine has stopped, lubrication also stops. This is because the temperature of the remaining fuel in the injectors would decrease too much.

Oil flows through the lubricating oil inlet (8, Fig. 2) through bores in the injection valve. The oil flows back through the annular grooves in the injection valve through the lubricating oil outlet (7).

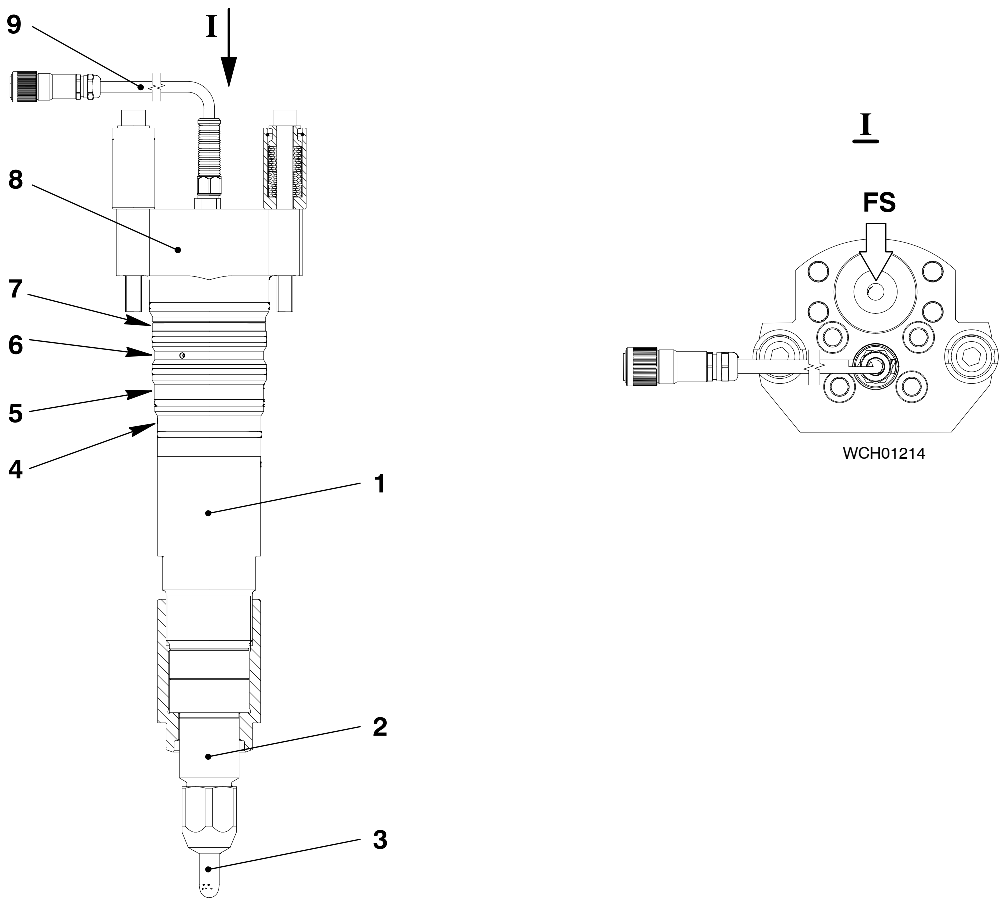


**Fig. 3: Injection Valve**

| | | | |
|---|---|---|---|
| 1 | Injection valve | 6 | Annular groove – fuel / lube oil leakage |
| 2 | Nozzle body | 7 | Annular groove –control fuel return |
| 3 | Nozzle tip | 8 | Valve bush |
| 4 | Annular groove – lube oil inlet | 9 | Electrical cable to control valve |
| 5 | Annular groove – lube oil return | FS | Fuel supply |

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# Starting Valve

## 1. General

A starting valve is installed in each cylinder cover (6, Fig. 1). The starting valves operate to let controlled, pressurized air start the engine, or decrease the engine speed for reversing.

The ECS monitors and controls the starting valve operation (refer to 4002–1 Engine Control System, paragraph 3.3). The Cylinder Control Modules (CCM–20) open the starting valves (2) electronically at the correct crank angle to release starting air into the combustion chamber.

The parameter settings of the starting valves are adjustable. The ECS gives access to the parameter settings.

For more data, refer to the schematic diagrams, 4003–2 Page 1 and Page 2.

## 2. Function

### 2.1 Initial Conditions

Starting air (SA) pressurizes the air chamber ($P_2$). The compression spring (4) keeps the valve closed. The pipe (7) in the cover (1) has the starting air pressure.

### 2.2 Engine Start

The CCM–20 activates the 3/2-way solenoid valve (8). The air chamber ($P_1$) is pressurized, the valve opens and starting air flows into the combustion chamber. The piston (2) moves down, starting air flows into the combustion chamber and the engine starts to turn.

When combustion starts, the higher pressure (firing pressure) in the combustion chamber keeps the starting air valve closed.

### 2.3 Engine Slow-down (to Reverse the Engine)

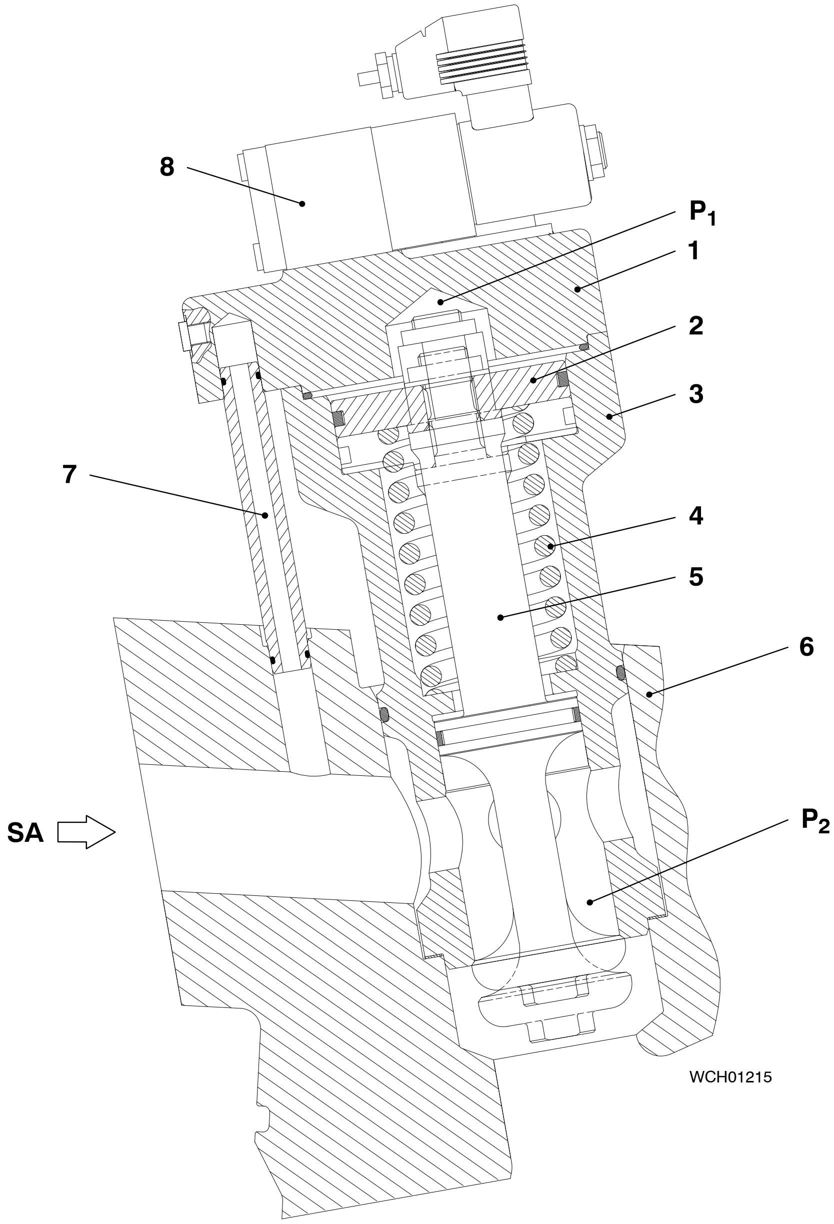
If the combustion and thus the propulsion stops (or a slower speed is selected from the remote control), the movement of the ship continues. The flow of water has an effect on the propeller.

**Note: You can only start the engine in diesel mode.**

To start the engine in the opposite direction, it is necessary to slow the engine speed to below the set limit. This operation is related to the engine speed and propeller configuration, and can be some minutes.

At the specified engine speed, the ECS opens the starting valve at approximately 100° before TDC. The starting air flows into the combustion chamber. The piston in the cylinder moves up, compresses the air and the engine speed decreases and then stops.

The engine then turns in the opposite direction and starts. For more data about reversing, see 0520–1, paragraph 3.4.




1 Cover
2 Piston
3 Housing
4 Compression spring
5 Valve spindle
6 Cylinder cover
7 Pipe
8 3/2-way solenoid valve

$P_1$ Air chamber
$P_2$ Air chamber

**Fig. 1: Starting Valve**

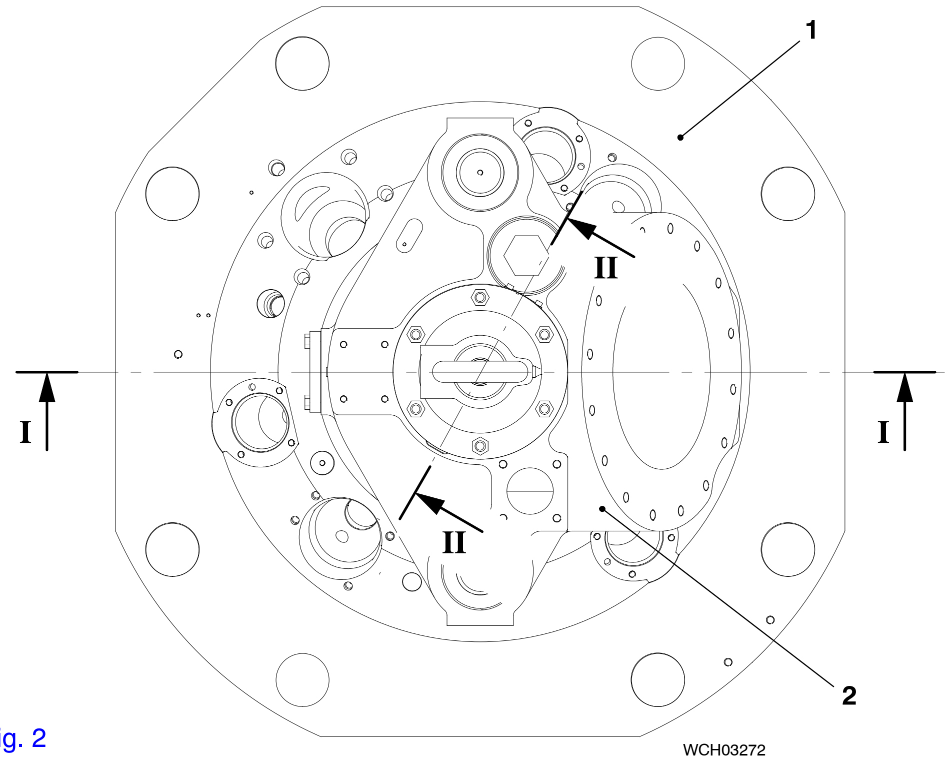
# Exhaust Valve



## 1. General

The exhaust valve (2, Fig. 1) is installed in the centre of the cylinder cover (1) and has the parts that follow:

- Top housing
- Housing
- Valve cage
- Valve spindle
- Valve seat.




I – I See Fig. 2
II – II See Fig. 2

**Fig. 1: Location of Parts in Cylinder Cover**

1 Cylinder cover 2 Exhaust valve

The air spring (AS, Fig. 2) is below the air spring piston (9).

The valve stroke sensor (19) monitors and transmits the open and closed positions of the valve spindle (16) to the ECS.

If there is a large pressure difference between when the exhaust valve opens and the pressure in the air spring (AS), damage can occur to the exhaust valve (2). Thus, for safety the cup springs (10) are installed to absorb vibration and shock.

The thrust piece (6) prevents damage to the inner piston (5) and the top of the valve spindle (16) when the exhaust valve operates.

**Note: Before the lubricating oil pump and service pump are set to on, the air spring must have pressure and the exhaust valves must be closed. The engine cannot start if the exhaust valves are not fully closed.**

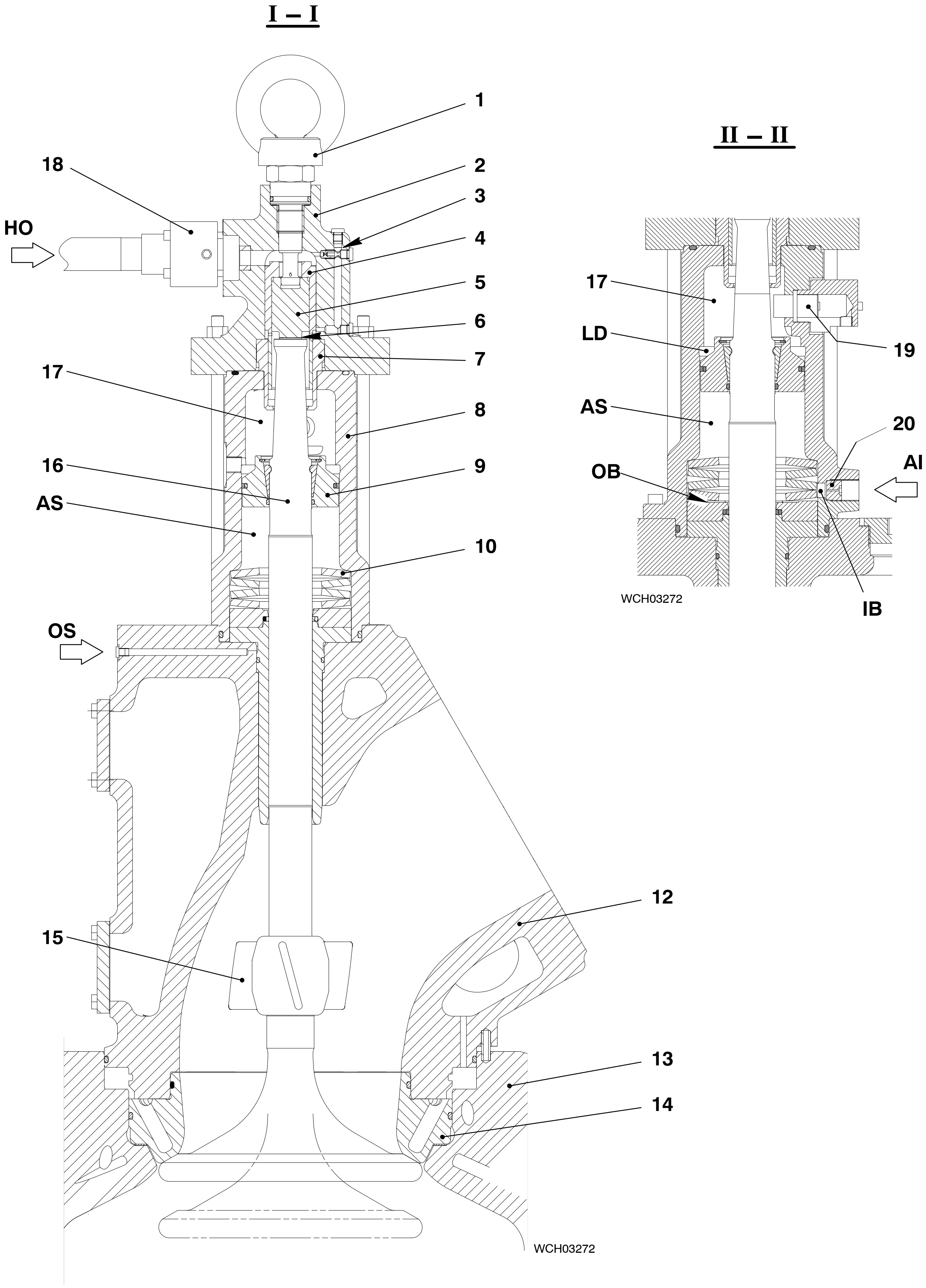



**Fig. 2: Exhaust Valve and Leakage Oil Drain**

**Key to Fig. 2: Exhaust Valve and Leakage Oil Drain**

| | | | |
|---|---|---|---|
| 1 | Damper | 16 | Valve spindle |
| 2 | Top housing | 17 | Leakage oil collection space |
| 3 | Orifice | 18 | Hydraulic oil connection |
| 4 | Outer piston | 19 | Valve stroke sensor |
| 5 | Inner piston | 20 | Non-return valve |
| 6 | Thrust piece | | |
| 7 | Piston guide | | |
| 8 | Housing | AI | Air inlet to air spring |
| 9 | Air spring piston | IB | Inlet bore (to air spring) |
| 10 | Cup spring | OB | Oil bath |
| 11 | Guide bush | AS | Air spring |
| 12 | Valve cage | LD | Leakage oil drain |
| 13 | Cylinder cover | OS | Oil supply (to valve guide) |
| 14 | Valve seat | AS | Air spring |
| 15 | Rotation wing | HO | Hydraulic oil inlet |

# 2. Function

## 2.1 Open

When the piston in the valve control unit (VCU) operates, hydraulic oil (HO) flows through the hydraulic oil connection (18, Fig. 2) into the top housing (2). The outer piston (4) and the inner piston (5) move down.

The air spring piston (9), which is attached to the valve spindle (16), moves down against the pressure in the air spring (AS) and the exhaust valve opens. The force of the exhaust gas on the rotation wing (15) turns the valve spindle (16).

## 2.2 Close

When the hydraulic oil pressure from the VCU decreases (i.e. when the control rod in the VCU opens the related relief bores) the pressure in the air spring (AS) pushes the air spring piston (9) up.

The valve spindle (16) then pushes the inner piston (5) and the outer piston (4) up and the exhaust valve closes. The hydraulic oil in the top housing (2) flows back to the VCU.

## 2.3 Hydraulic System

Hydraulic oil and air in the system flow continuously from the top housing (2), outer piston (4) and inner piston (5) into the leakage oil collection space (17). This leakage oil / air then drains though the leakage oil drain (LD).

The hydraulic oil that flows through the internal bores of the VCU continuously keeps the correct oil quantity in the hydraulic system.

## 2.4 Air Supply to Air Spring

Compressed air flows into the air inlet connection (AI) and through the non-return valve (20) to the inlet bore (IB). The compressed air then flows into the air spring (AS).

When the exhaust valve opens the air spring piston (9) moves down, which compresses the air in the air spring (AS). Some of the compressed air flows back through the inlet bore (IB). After the exhaust valve closes, compressed air flows again into the air spring (AS).

## 3. Lubrication

Leakage oil from the outer piston (4, Fig. 2) and inner piston (5) lubricates the air spring piston (9). Oil in the leakage oil collection space (17) drains to the leakage oil drain (LD).

While the exhaust valve closes, oil flows through the air spring piston (9) and into the air spring (AS). The air from the air inlet (AI) changes the oil that collects at the bottom of the air spring (at the inlet bore (IB)) into a mist. The mist lubricates the top part of the valve spindle (16).

When the exhaust valve opens, unwanted oil flows out of the air spring (AS) through the air spring pipe to an accumulator. The oil in the accumulator automatically drains through the leakage oil pipe at the driving end of the exhaust valves into the crankcase.

Oil from the oil bath (OB) lubricates the bottom part of the valve spindle (16).

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# Pilot Injection Valve

## 1. General

Two pilot injection valves (1, Fig. 1) are installed in each cylinder cover (10).

The pilot injection valves (1) have built-in solenoid valves. The ECS electronically controls the pilot injection valves and calculates the injection timing and pilot fuel quantity related to the engine load. For more data, refer to 4002−1, Engine Control System, paragraphs 3.19 and 3.20.

The pilot injection valves (1) have a combustion prechamber (7, Fig. 2) to get the best ignition timing and a stable combustion process. The cooling water system keeps cool the prechamber. For more data, refer to 8017−1 Cooling Water System.

To prevent contamination of the lubricating oil with fuel, the mixture of lubricating oil and fuel leakage (5) from the pilot injection valves (1) drains to the sludge tank.

For the related pilot fuel pages in the LDU-20, refer to 4002−2, Local Control, paragraphs 3.9 Pilot Fuel and 3.10 Pilot Fuel Pressure.

For more data about the pilot fuel system, refer to 0300−1, paragraph 8.5 Pilot Fuel System.

To disassemble, assemble and do tests of the pilot injection valves, refer to the Maintenance Manual, Chapter 2790−1.

## 2. Function

**Note: The pilot fuel is diesel fuel that flows into the cylinder during gas mode to ignite the gas/air mixture. The injection timing and pilot fuel quantity is electronically controlled.**

Pilot fuel flows from the pilot fuel pump unit (4) through the high pressure (HP) fuel pipes (3, 6 and 8 Fig. 1) to the two pilot injection valves (1).

The ECS activates the solenoid valve in the pilot injection valves (1) and the needle moves to the open position. Pilot fuel flows through the holes in the nozzle into the prechamber (7, Fig. 2). The pilot fuel flows through the hole in the bottom housing (10) of the prechamber (7) and into the combustion chamber as a spray. A small quantity of pilot fuel flows through the pilot fuel return (11) back to the plant.

## 3. Cooling

The system oil (from the main oil supply) keeps cool the pilot injection valves (1).

Oil flows through the lubricating oil inlet (4) through bores in the pilot injection valve (1). The oil flows back through the bores in the pilot injection valve (1) through the lubricating oil outlet (3).

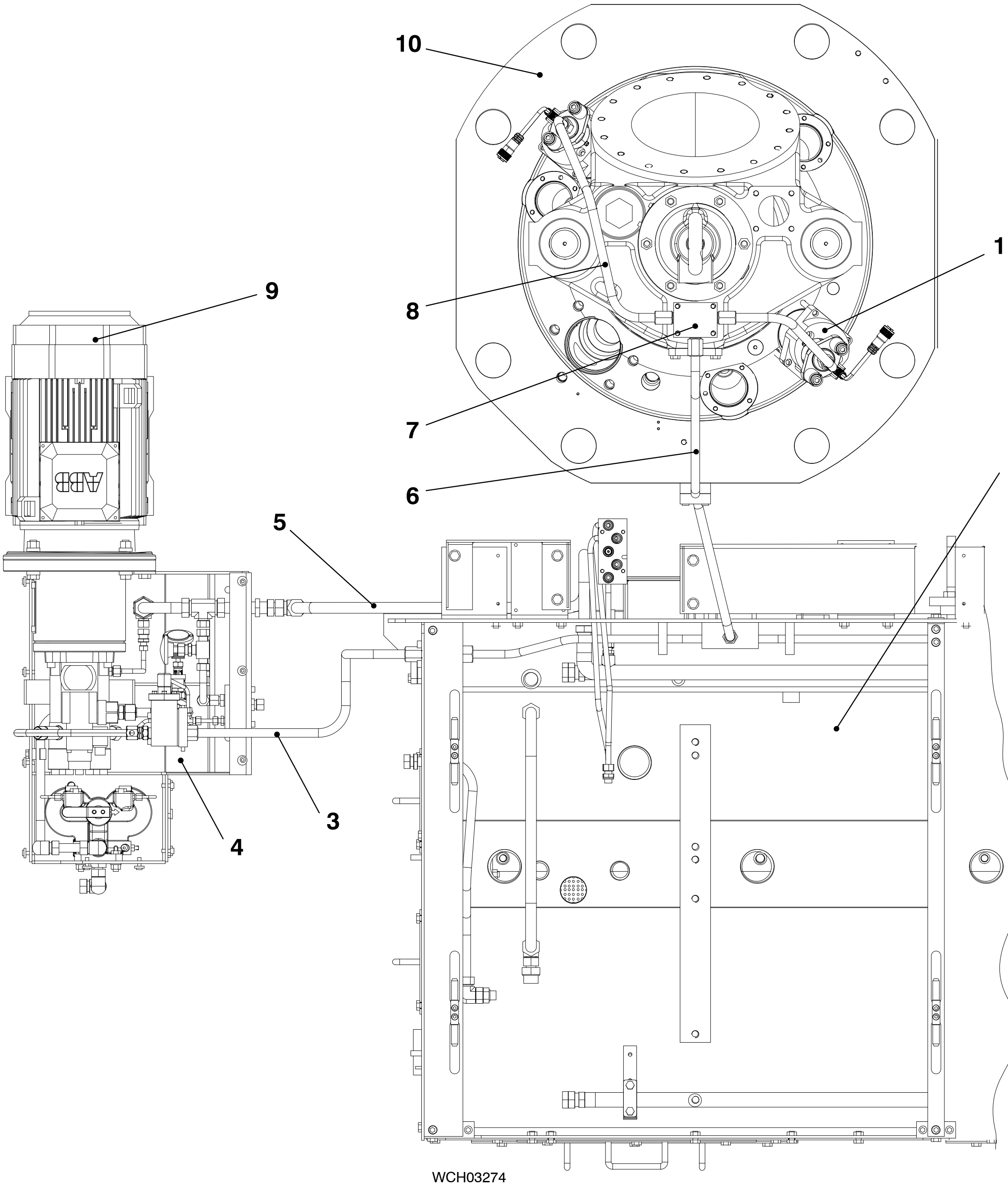


**Fig. 1: Location of Pilot Injection Valves**

| | | | |
|---|---|---|---|
| 1 | Pilot injection valve | 6 | HP pilot fuel pipe |
| 2 | Rail unit | 7 | Distributor block |
| 3 | HP pilot fuel pipe | 8 | HP pilot fuel pipe |
| 4 | Pilot fuel pump supply unit | 9 | HP pilot fuel pump |
| 5 | Fuel leakage pipe | 10 | Cylinder cover |

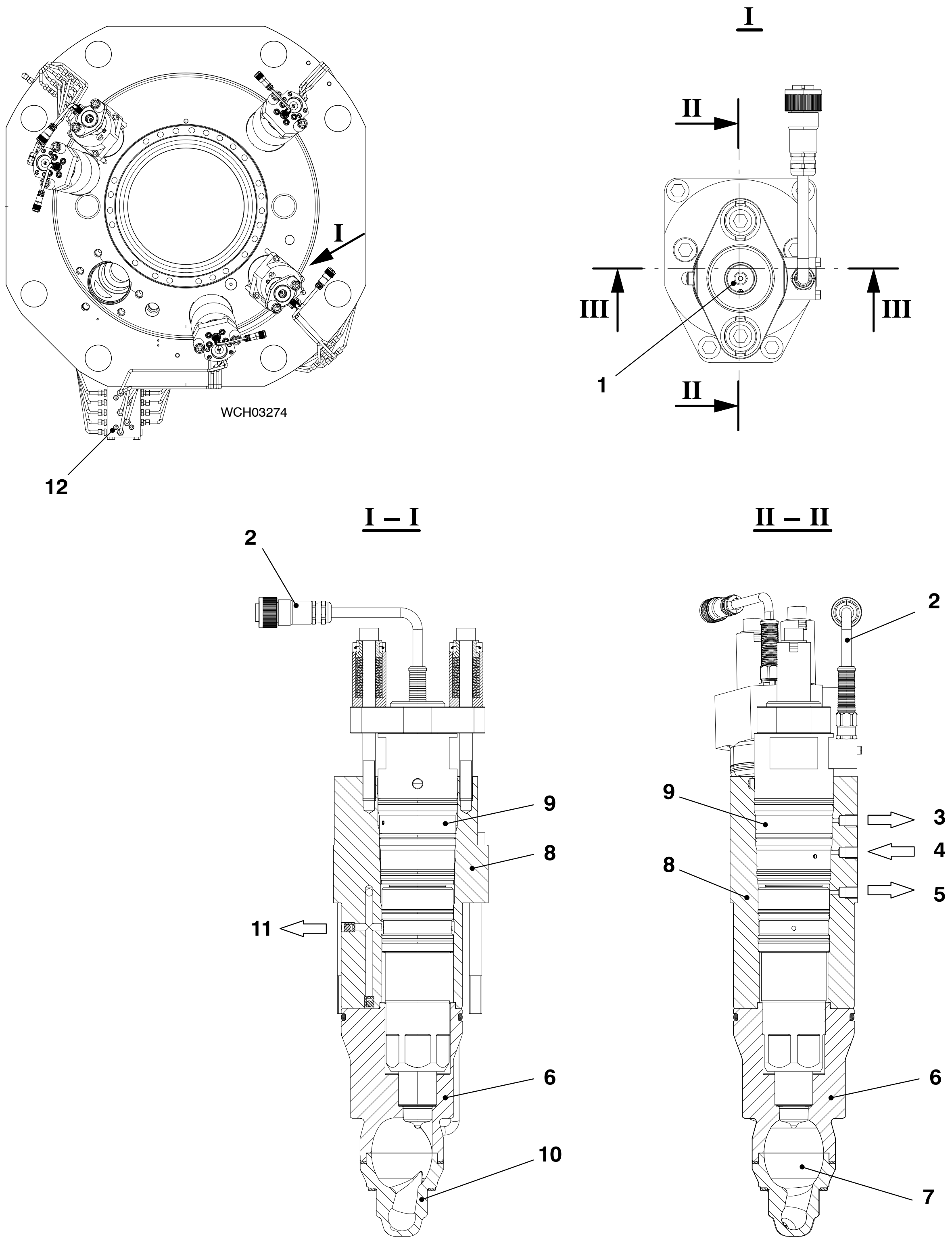


**Fig. 2: Pilot Injection Valve**

| | | | |
|---|---|---|---|
| 1 | Pilot fuel inlet (from pilot fuel pump unit) | 7 | Prechamber |
| 2 | Electrical cable to solenoid valve | 8 | Flange |
| 3 | Lubricating oil outlet | 9 | Pilot injection valve |
| 4 | Lubricating oil inlet | 10 | Bottom housing |
| 5 | Lubricating oil and fuel leakage mixture | 11 | Pilot fuel return (pilot injection) |
| 6 | Top housing | 12 | Connecting plate |

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# Crankshaft, Connecting Rod and Piston — Group 3

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# Axial Damper

## 1. General

The engine has a built-in axial damper. The function of the axial damper is to decrease the axial vibrations.

The axial damper includes a top cylinder half (3, Fig. 1) and a bottom cylinder half (4) attached with bolts to the last bearing girder.

**CAUTION**

**Damage Hazard: Do not operate the engine if there is no oil supply to the axial damper. Damage to the engine will occur.**

## 2. Function

Bearing oil flows from the oil inlet (OI) through the oil pipe (5) into the two inlet pipes (1). The bearing oil then flows through the non-return valves (2) into the groove in the crankshaft (10) (i.e. into the annular spaces (9) on each side of the middle part of the cylinder halves (3) and (4)).

Most of the oil can only flow through the pressure reducing nozzle (7) from one annular space (9) to the other when the crankshaft turns.

The remaining oil drains because of the radial and axial clearances of the sealing rings (11) and (12) and the vent bore in the pressure reducing nozzle (7).

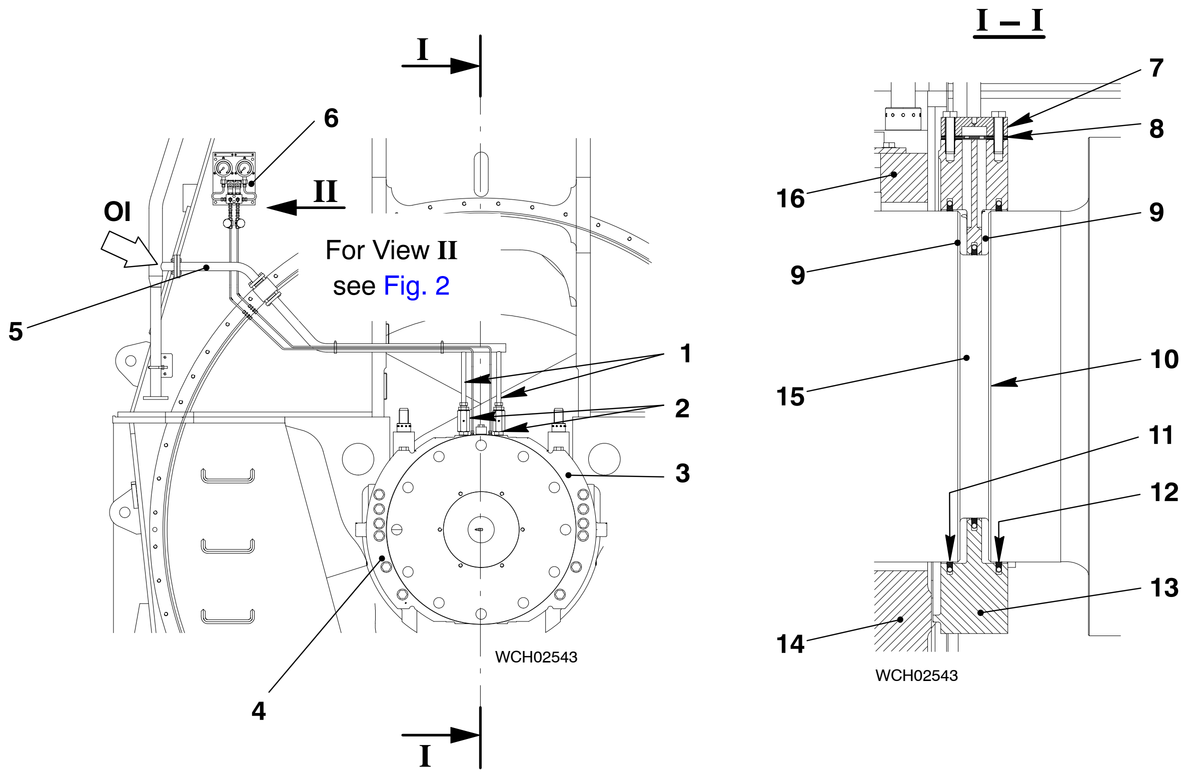


**Fig. 1: Axial Damper**

1 Inlet pipes
2 Non-return valves
3 Top cylinder half
4 Bottom cylinder half
5 Oil pipe
6 Axial damper monitor
7 Pressure reducing nozzle
8 Orifice
9 Annular space
10 Groove in crankshaft
11 Large sealing ring
12 Small sealing ring
13 Vibration damper
14 Bearing girder (part of bedplate)
15 Crankshaft
16 Bearing cover

OI Oil inlet

# 3. Axial Damper Monitor

The engine has a system that monitors the axial damper. The axial damper monitor is installed at the free end above the end casing (Fig. 2). This system monitors the oil pressure in the front and rear spaces of the axial damper.

If the oil pressure decreases below a set value, an alarm is activated (for more data about the setting values, refer to 0230−2 Alarms and Safeguards).

The cause of this alarm must be investigated and the problem corrected. The possible causes are as follows:

- The orifices in the pressure gauge pipes are clogged.
- The shut-off valves are closed in the pressure gauge pipes.
- There is low oil pressure and / or high oil temperature in the bearing oil system.
- The sealing rings are worn too much, e.g. dirt particles (clearance is too large).
- A non-return valve is blocked.

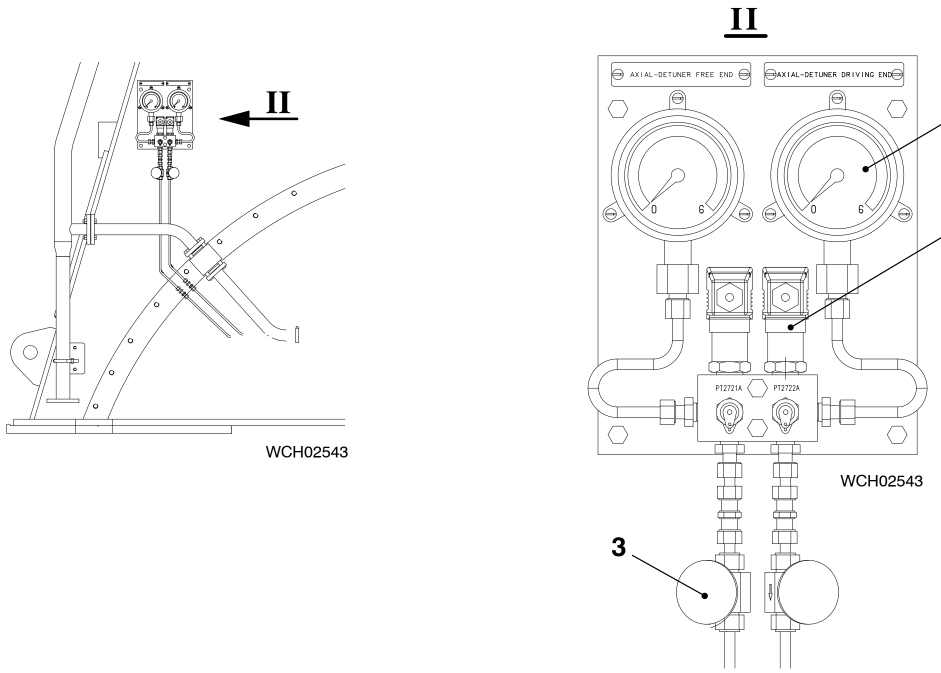


**Fig. 2: Axial Damper Monitor**

1 Pressure gauge
2 Pressure transmitter
3 Needle valve

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# Connecting Rod and Connecting Rod Bearing

## 1. General

The connecting rod connects the crosshead with the crankshaft and converts the linear movement of the piston into a circular movement.

The bearing shells (4, 7, and 9, Fig. 1) (that you can replace) are installed on the connecting rod (12) for the bottom end bearing and top end bearing.

The top bearing cover (1) is lined with white metal.

## 2. Lubrication

Crosshead lubricating oil flows through the guide shoe into the crosshead pin (for data about the crosshead and guide shoe, refer to 3326−1). A hole in the crosshead pin lets lubricating oil flow to the lubricating oil inlet (13).

Crosshead lubricating oil flows through the oil bore (11) in the connecting rod (1) to the bottom end bearing.

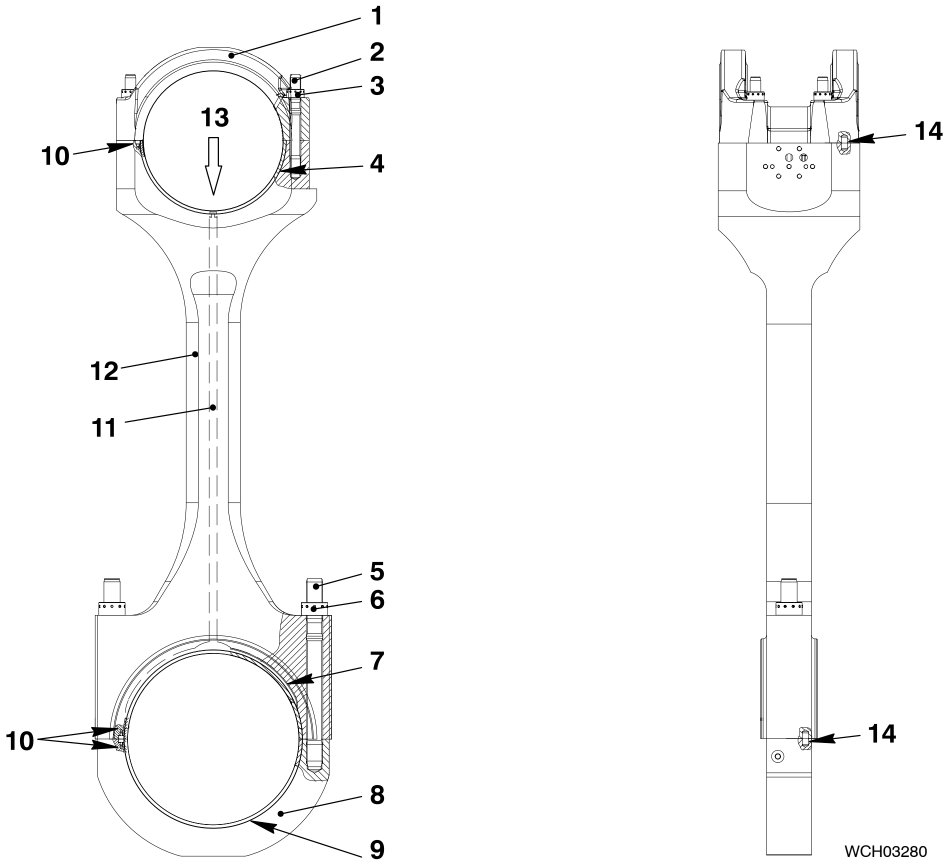



**Fig. 3: Connecting Rod and Connecting Rod Bearing**

1 Top bearing cover
2 Elastic bolts (top end bearing)
3 Round nut
4 Bearing shell (top end bearing-crosshead)
5 Elastic bolts (bottom end bearing)
6 Round nut
7 Top bearing shell (bottom end bearing)
8 Bottom bearing cover
9 Bottom bearing shell (bottom end bearing)
10 Allen screw
11 Oil bore
12 Connecting rod
13 Lubricating oil inlet
14 Dowel pin

**Intentionally blank**

# Crosshead and Guide Shoe

## 1. General

The crosshead guides the piston rod (10) and absorbs the lateral forces that come from the connecting rod (4) (see Fig. 1 and Fig. 2).

The piston rod (10) is attached to the compression shim (8) and the crosshead pin (6) with screws. The bearing oil necessary to keep the piston cool, flows through the oil bore (9) in the crosshead pin (6) and the oil bore (OB) to the piston. The oil return (OR) from the piston flows back to the crosshead pin (6) through the oil pipe (1) and returns to the crankcase through the drain (OD).

The guide shoes (3) stay in position on the crosshead pin (6) and move up and down in the guide rails (12), which are in the guide ways of the column (11).

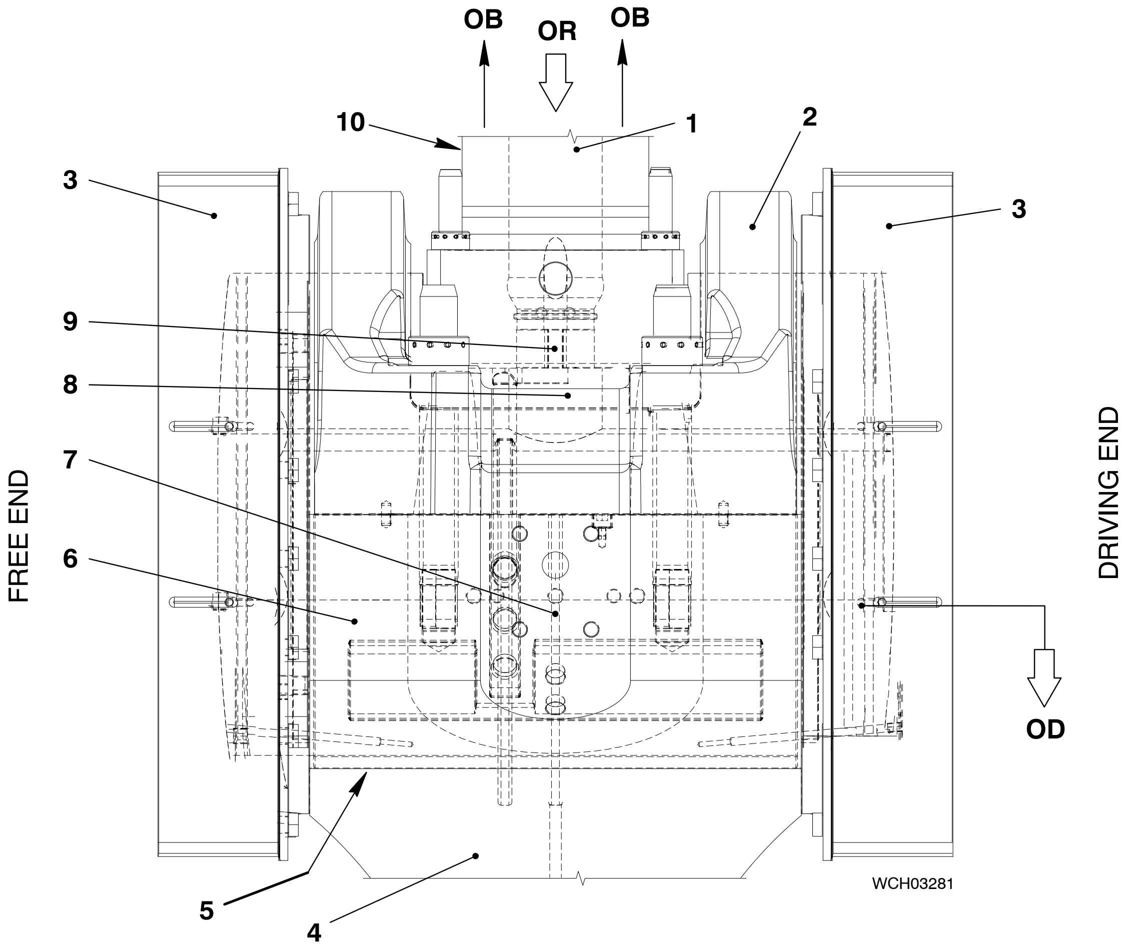



**Fig. 1: Crosshead and Guide Shoe (Side View)**

| | | | |
|---|---|---|---|
| 1 | Oil pipe (to piston) | 8 | Compression shim |
| 2 | Top bearing cover (top end bearing) | 9 | Oil bore (to piston rod) |
| 3 | Guide shoe | 10 | Piston rod |
| 4 | Connecting rod | | |
| 5 | Bearing shell (top end bearing) | OB | Oil bore to piston |
| 6 | Crosshead pin | OR | Oil return from piston |
| 7 | Oil bore (to top end bearing) | OD | Oil drain to crankcase |

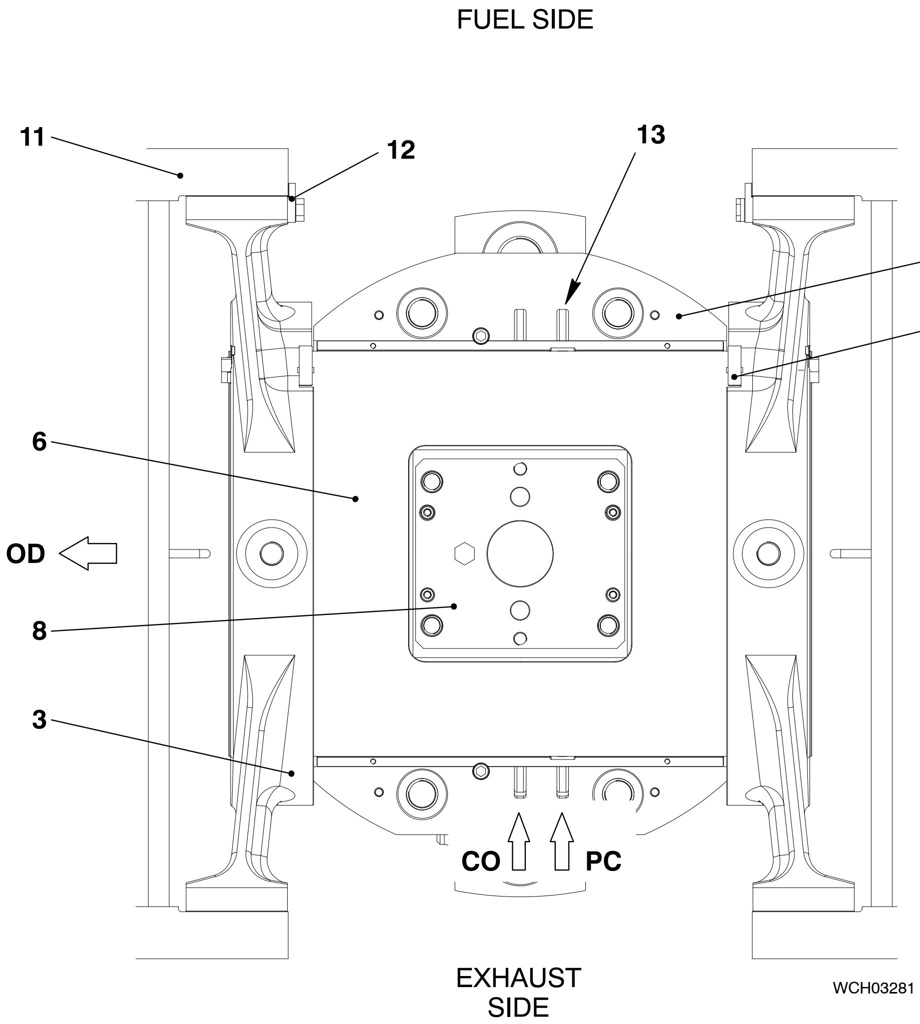



**Fig. 2: Crosshead and Guide Shoe (Top View)**

| | | | |
|---|---|---|---|
| 3 | Guide shoe | 12 | Guide rail |
| 4 | Connecting rod | 13 | Groove (in connecting rod) |
| 6 | Crosshead pin | | |
| 8 | Compression shim | OD | Oil drain into crankcase |
| 11 | Column | CO | Crosshead lubricating oil inlet |
| | | PC | Piston cooling oil inlet |

# Piston

## 1. General

The piston has the parts that follow:

- Piston crown (1, Fig. 1)
- Piston rings (2)
- Piston skirt (3)
- Piston rod (4)
- Oil pipe (5)
- Compression shim (7).

Eight elastic bolts (10) and round nuts (11) attach the piston crown (1) and the piston rod (4) together. The piston skirt (3) is attached to the piston rod with screws.

The piston rod (4) is attached to the crosshead pin (8) in a specified position. The compression shim (7) is installed between the piston rod and crosshead pin. The thickness of the compression shim is related to the compression ratio.

**Note: The mark TOP on all piston rings must point up. For more data about the piston rings, see the Maintenance Manual 3425–1.**

## 2. Piston Cooling

Lubricating oil is used to keep cool the piston crown (1). This oil flows from the crosshead pin (8) into the two oil inlets (9). The oil then flows through the oil pipe (5) (inside the piston rod (4) to the spray plate (12).

The oil comes out as a spray (OS) from the nozzles in the spray plate (12) into the cooling bores of the piston crown (1). The oil then flows through the oil return (OR) into the crosshead pin (8) and out through the oil bores to the crankcase.

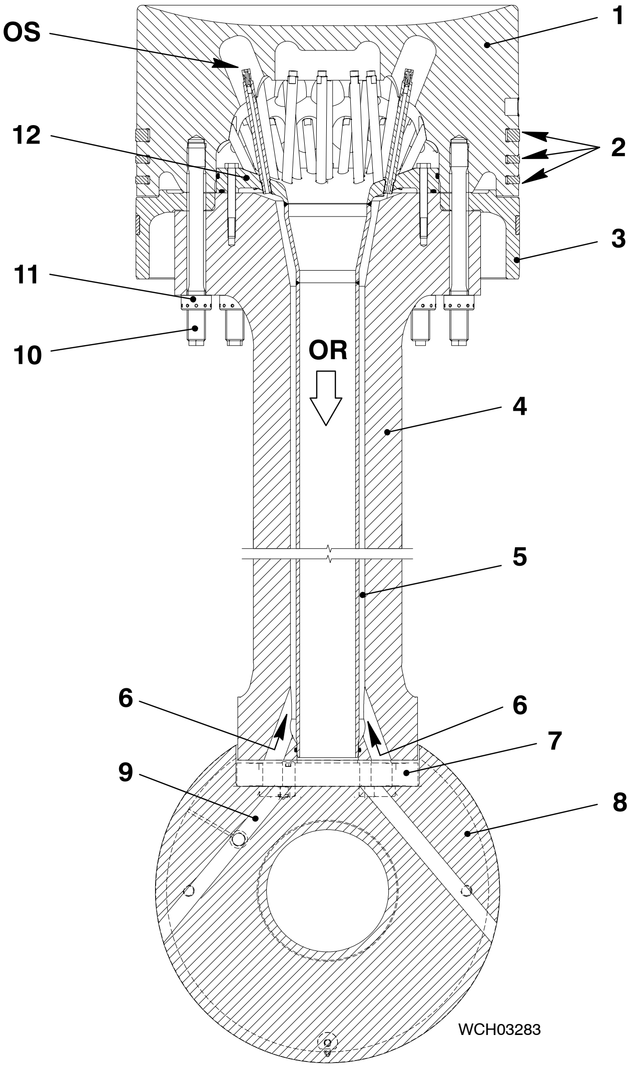
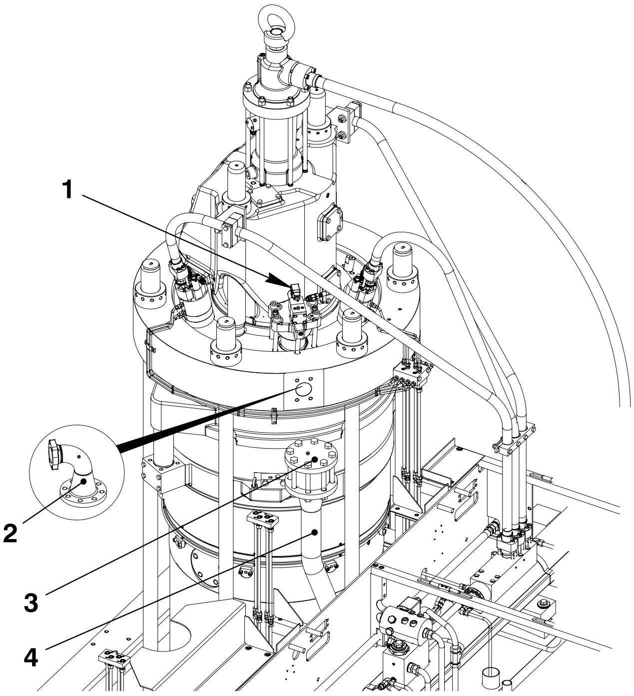



**Fig. 1: Piston**

| | | | |
|---|---|---|---|
| 1 | Piston crown | 8 | Crosshead pin |
| 2 | Piston rings | 9 | Oil inlet |
| 3 | Piston skirt | 10 | Elastic bolt |
| 4 | Piston rod | 11 | Round nut |
| 5 | Oil pipe (to spray plate) | 12 | Spray plate |
| 6 | Oil bore (piston cooling) | OS | Oil spray |
| 7 | Compression shim | OR | Oil return (from piston crown) |

# Operation with Running Gear Partially or Fully Removed

**Note: Some parts can look different.**



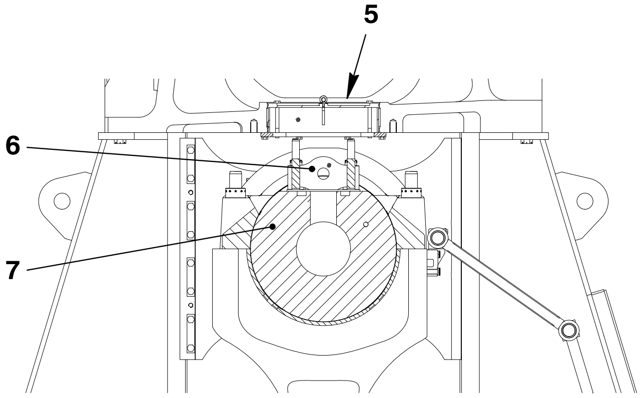




**Fig. 1: Tools 9486–01 and 9423–01**

## 1. General

If the engine must operate with a defect in the running gear, which cannot be immediately repaired, do the procedures given in paragraph 2 to paragraph 3.

**Note: You can operate the engine only at decreased load.**

The exhaust gas temperature must be less than the maximum limit of 515° C (refer to 0230–2 Alarms and Safeguards).

## 2. Piston Removed

### 2.1 Problems

- The piston is cracked or has a leak.
- There is damage to the piston and/or cylinder liner.
- There is damage to the piston rod gland and/or piston rod.

### 2.2 Preparation

1) Cut out the injection to the related cylinder (refer to 8019–1 paragraph 5).
2) Cut out the exhaust valve control unit (VCU) (refer to 8016–1, paragraph 4.3).
3) Make sure that the exhaust valve is closed (refer to 4002–2, paragraph 3.17).
4) If necessary, close the cooling water supply and the return pipe of the related cylinder.

### 2.3 Procedure

1) Disconnect the electrical connection from the starting air valve (1, Fig. 1).
2) Remove the elbow (2) from the starting air pipe (4).
3) Install the blank flange (3, tool 9486–01) to the starting air pipe (4).
4) Install the cover and the lifting plate (6) (tool 9433–03) on to the crosshead (7).
5) Install the cover plate (5, tool 9423–01) in the position of the piston rod gland.

**Note: Some parts can look different.**

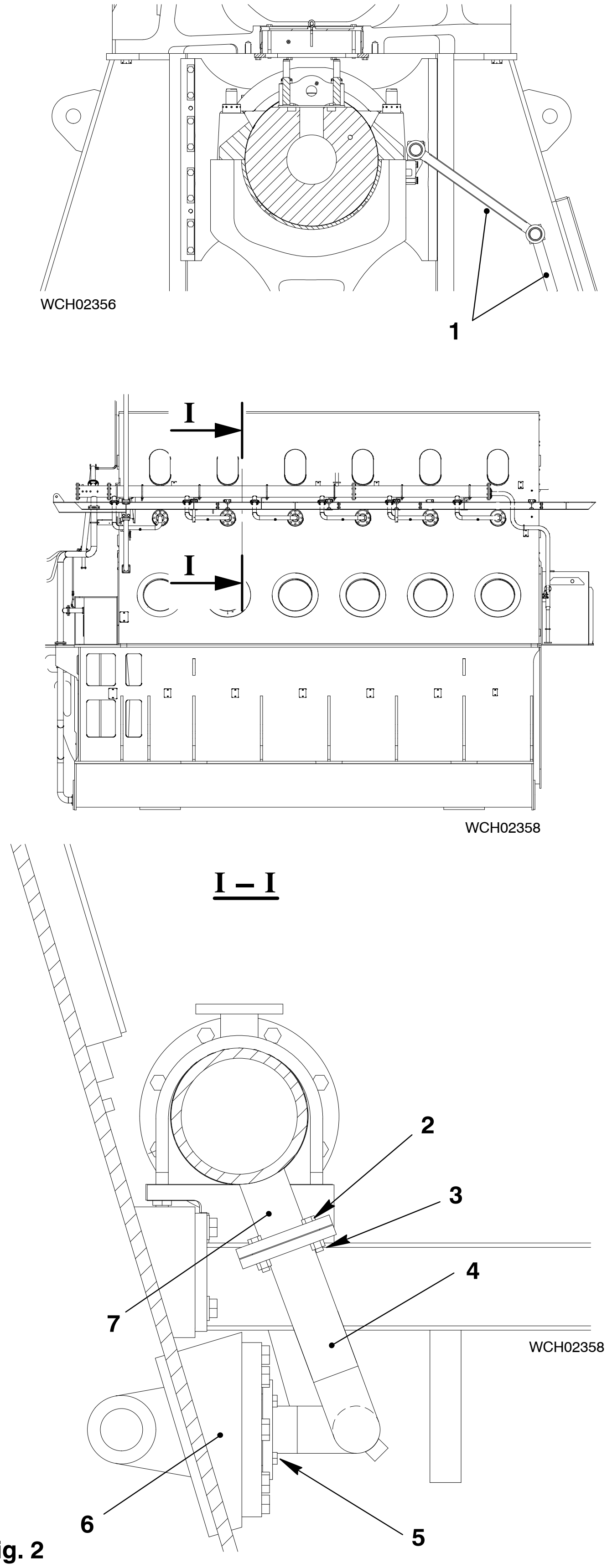



**Fig. 2**

# 3. Piston, Crosshead and Connecting Rod Removed

## 3.1 Problems

The problems can be as follows:

- The crosshead or guide shoes are defective.
- The connecting rod bearing is damaged.
- The crosshead pin or the connecting rod is defective.

## 3.2 Preparation

1) Cut out the injection to the related cylinder (refer to 8019–1 paragraph 5).
2) Cut out the VCU (refer to 8016–1, paragraph 4.3).
3) If necessary, close the cooling water supply and the return pipe of the related cylinder.

## 3.3 Procedure

1) Do the procedure given in paragraph 2.3 above.
2) Remove the top and bottom levers (1) (see Fig. 2).
3) Remove the screws (5) from the flange of the pipe (4).
4) Hold the pipe (4) and remove the nuts (3) and the screws (2).
5) Remove the pipe (4).
6) Install blanks to the oil inlet (6) and the oil supply pipe (7).

**Note: You can operate the engine only at decreased speed/load. Speak to the engine manufacturer for data.**

# Crosshead Lubrication and Piston Cooling



## 1. General

Lubricating oil keeps the pistons cool. Bearing oil lubricates the crosshead. Each oil system operates independently. The oil from each system flows through a double articulated lever to the crosshead.

## 2. Crosshead Lubrication

The crosshead lubricating oil flows from the oil inlet (OI, Fig. 1) through the support (2), the bottom lever (4) and the top lever (5) to the connection piece (6). The connection piece is attached to the connecting rod (10). The oil enters the ring space (RS) through the bore (7). The crosshead pin (8) is lubricated through bores in the top end bearing shell (9). The oil flows through the bore (OB) through the connecting rod (10) to the bottom end bearing.

### 2.1 Operation without Crosshead Lubricating Oil Pump

**CAUTION**

**Damage Hazard: If the crosshead lubricating oil pump becomes defective, the engine power must not be more than 25% to 30%. Damage to the engine will occur.**

**CAUTION**

**Damage Hazard: If the crosshead lubricating oil pump becomes defective, do not operate the engine for long periods. Damage to the engine will occur.**

**Note: For more data, refer to 0510−1 Problems during Operation, paragraph 2.**

**Note: The crosshead lubricating oil pump must be repaired or replaced as soon as possible and set to on.**

If the crosshead lubricating oil pump becomes defective, the crosshead bearing oil system operates at a lower pressure of the main bearing oil. For more data, refer to 8016−1 Lubricating Oil / Servo Oil System and 0230−1 Operating Data Sheet.

At decreased load (SLD, 25% to 30%), the engine can continue to operate for a short time until the crosshead lubricating oil pump is repaired or replaced.

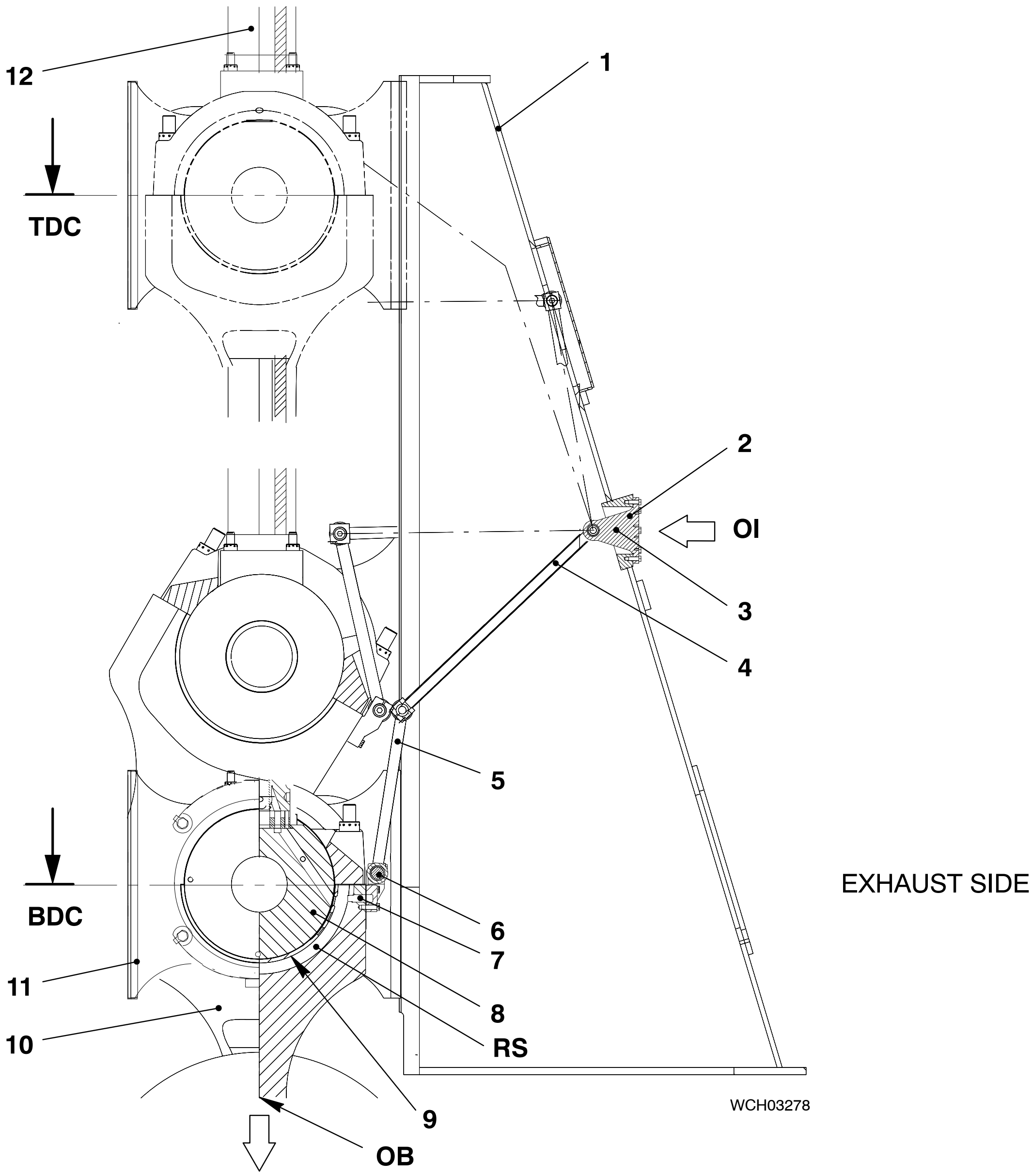



**Fig. 1: Crosshead Lubrication and Piston Cooling – Location**

1 Column
2 Support
3 Oil inlet (crosshead lubrication)
4 Bottom lever
5 Top lever
6 Connection piece
7 Bore (crosshead lubricating oil)
8 Crosshead pin
9 Top end bearing shell
10 Connecting rod
11 Guide shoe
12 Piston rod
OB Oil bore (crosshead lubricating oil to bottom end bearing)
OI Oil inlet
RS Ring space (crosshead lubricating oil)

# 3. Piston Cooling

Bearing oil flows from the oil inlet pipe (OI, Fig. 1 and Fig. 2) through the support (2) the bottom lever (4) and the top lever (5) to the connection piece (6). The oil flows through the bore (7) into the ring space in the crosshead pin (8), through bores in the top end bearing shell (9). The oil flows through the outer part of the oil pipe (13) through the piston rod (12) to the piston.

The oil then flows down through the inner part of the oil pipe (13) through the oil return (OR) to the center bore in the crosshead pin (8). Some of the piston cooling oil is used to lubricate the guide shoes (11) and the guide shoe pins. The remaining oil flows into the crankcase.

For data about the crosshead and guide shoe, refer to 3326−1.

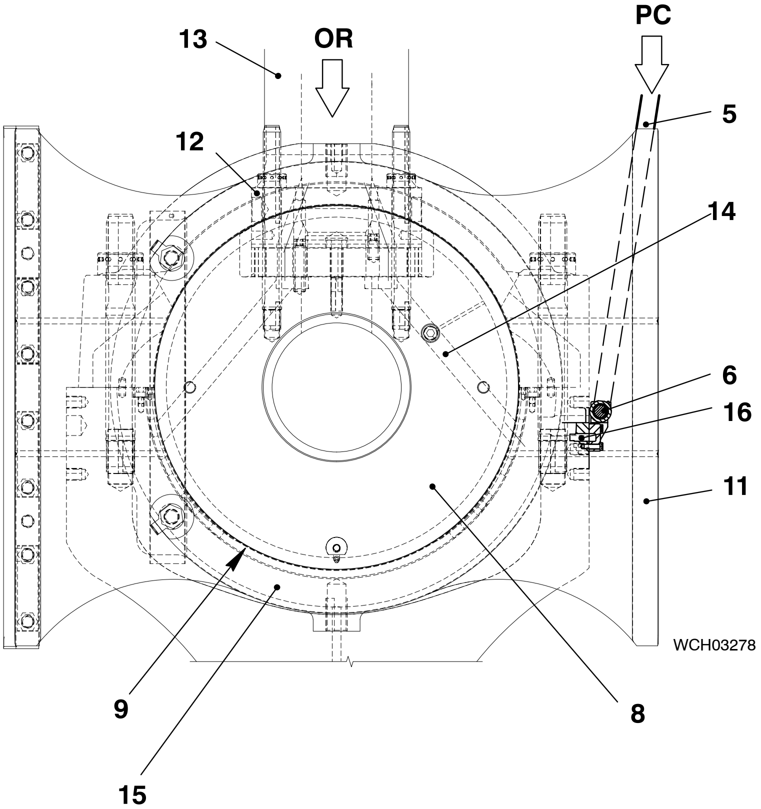



**Fig. 2: Cross-section through Crosshead**

| | | | |
|---|---|---|---|
| 5 | Top lever | 13 | Oil pipe |
| 6 | Connection piece | 14 | Bore (in the crosshead pin) |
| 8 | Crosshead pin | 15 | Ring space (piston cooling oil) |
| 9 | Top end bearing shell | 16 | Bore (piston cooling oil) |
| 10 | Connecting rod | | |
| 11 | Guide shoe | PC | Piston cooling (oil inlet) |
| 12 | Piston rod | OR | Oil return |

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# Engine Control and Control Elements **Group 4**

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# Engine Control System

# 1. General

The engine control system (ECS) is an embedded that has a modular design. Some parts and functions in the ECS system configuration are optional and are related to the application.

**Note: The name of the Wärtsilä engine control system is UNIfied Controls Flex (UNIC−flex).**

The system uses modern bus technologies for the transmission of signals.

Data buses transmit signals between the external systems:

- Propulsion Control System (PCS) (see paragraph 4.2)
- Alarm and Monitoring System (AMS) (see paragraph 4.3)
- Gas Detection System (see paragraph 4.4)
- Gas Supply System (see paragraph 4.5)
- Gas Valve Unit (see paragraph 4.6)

These data buses are the interface between the operator and engine control.

**CAUTION**

**Damage Hazard: Software updates must be done only with the supervision of a Wärtsilä service engineer and in accordance with regulations that Wärtsilä Services Switzerland Ltd. has set. Damage to the control system and the engine can occur.**

## 2. System Description

The engine control system on the W−X engine is a modular system that has the items that follow:

- Two local display units (LDU-20) (1, Fig. 1). One LDU-20 is installed at the local maneuvering stand at the free end. The other LDU-20 is installed in the engine control room (ECR). External control systems transmit data to the LDU-20. The LDU-20 gives the operator a graphical user interface for access to data and system adjustments. For more data about the LDU−20, refer to 4002−2, paragraph 3 LDU-20.
- One input/output module (IOM-10) (2), installed at the rail unit in the terminal box E90. The IOM-10 has the engine control functions (e.g. exhaust waste gate control), gas operation functions (e.g. gas pressure control, GVU interface, pilot fuel pressure control) and redundant sensor and actuator signals of the MCM-11.
- Two cylinder control modules (CCM-20) (3) for each cylinder, installed on the rail unit in the terminal box E95. The CCM-20 has different cylinder-related and engine-related control functions for diesel mode and gas mode. The CCM-20 also has redundant global functions for engine control.
- One main control module (MCM-11) (4), installed at the rail unit in the terminal box E25. The MCM-11 has functions for speed control, engine control, common gas operation functions (e.g. fuel mode control) and common engine functions (e.g. start valve control). External control systems transmit data to the MCM-11.

Redundant CAN system busses connect all the modules (see paragraph 2.3).

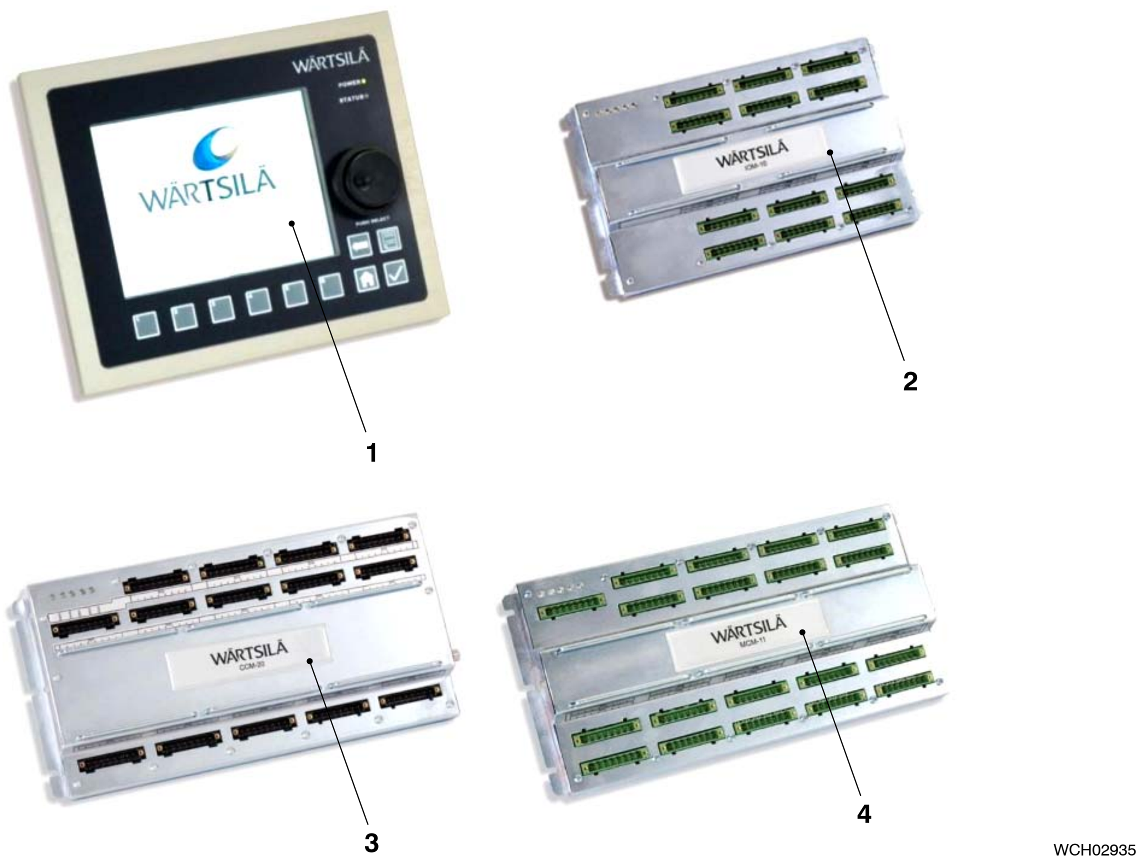


**Fig. 1: ECS Modules**

1 Local display unit (LDU-20)
2 Input output module (IOM-10)
3 Cylinder control module (CCM-20)
4 Main control module (MCM-11)

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## Engine Control System

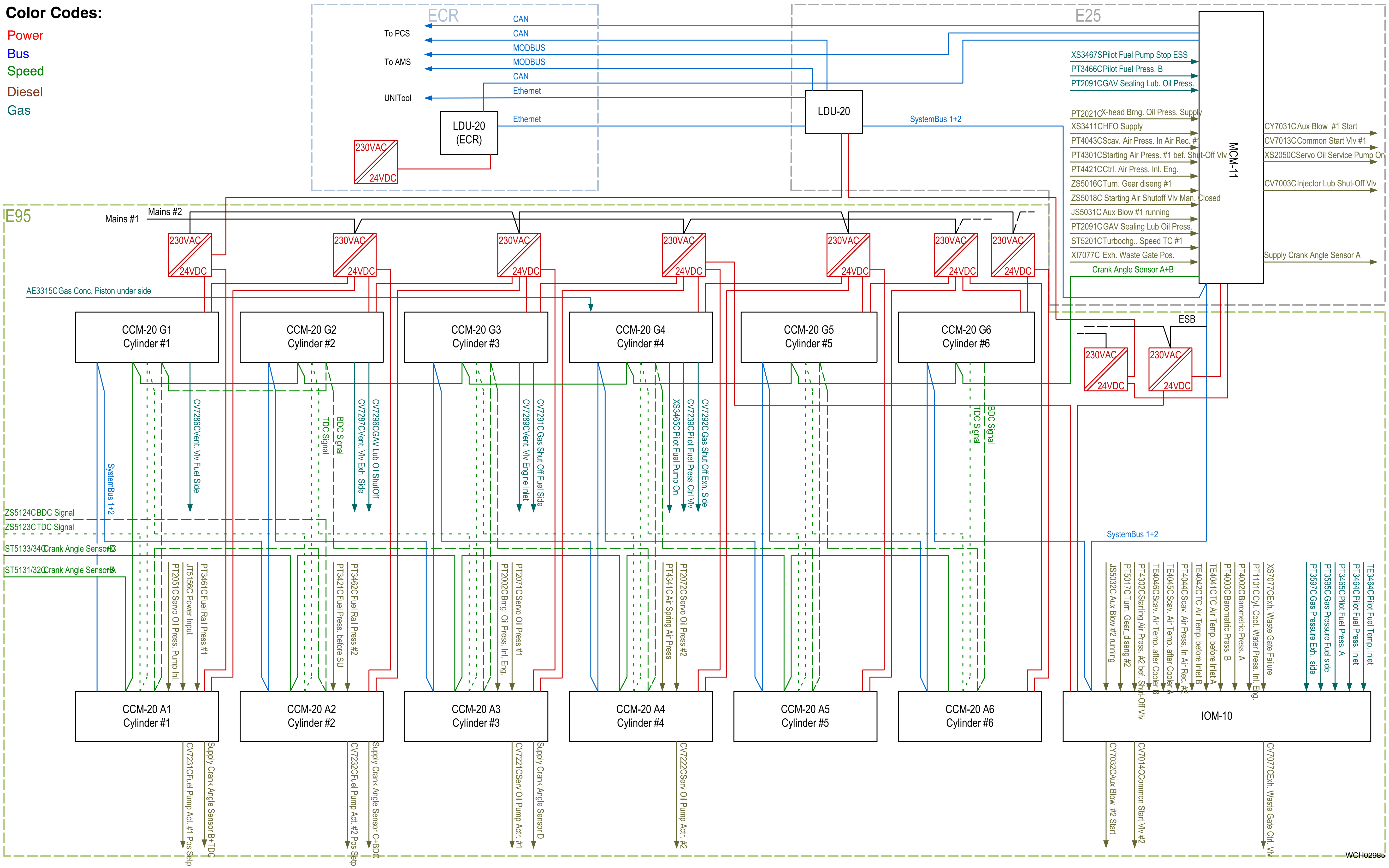


Fig. 2: Schematic Diagram – Bus Routing Connections (without cylinder-related signals)

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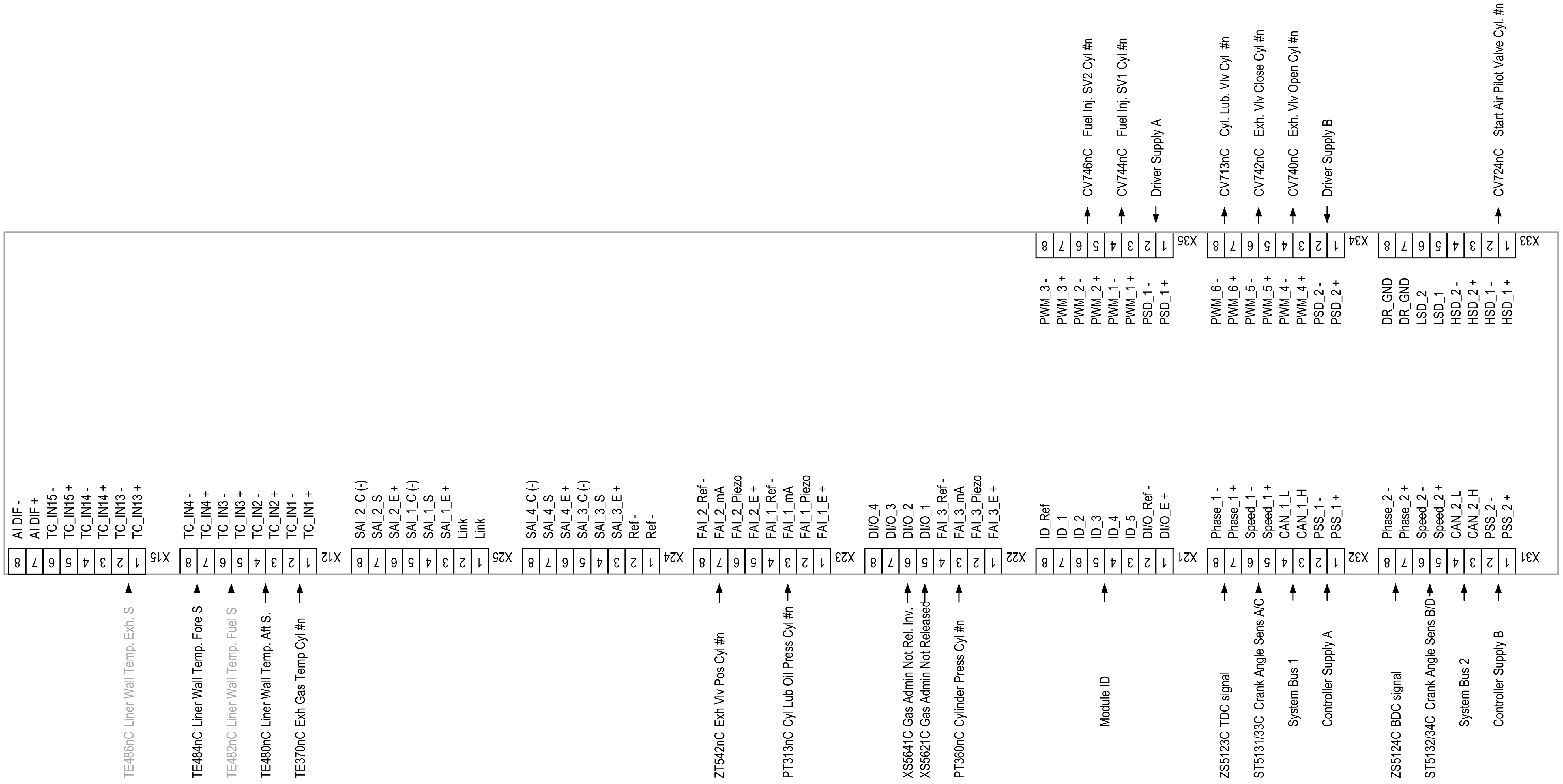


**Fig. 3: CCM-20A – Overview Connections Diesel**

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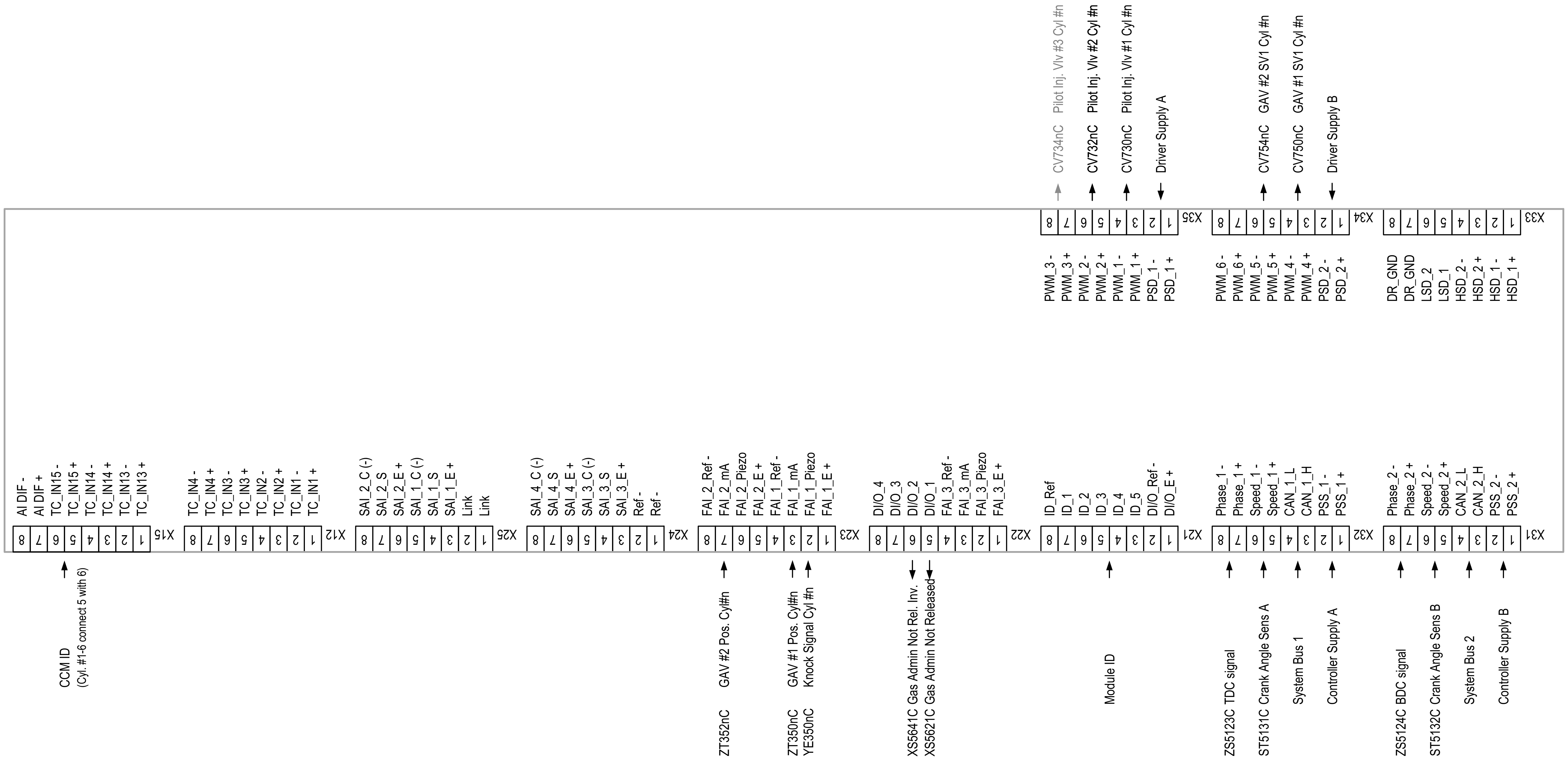

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**Fig. 4: CCM-20G – Overview Connections Gas**

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## Engine Control System

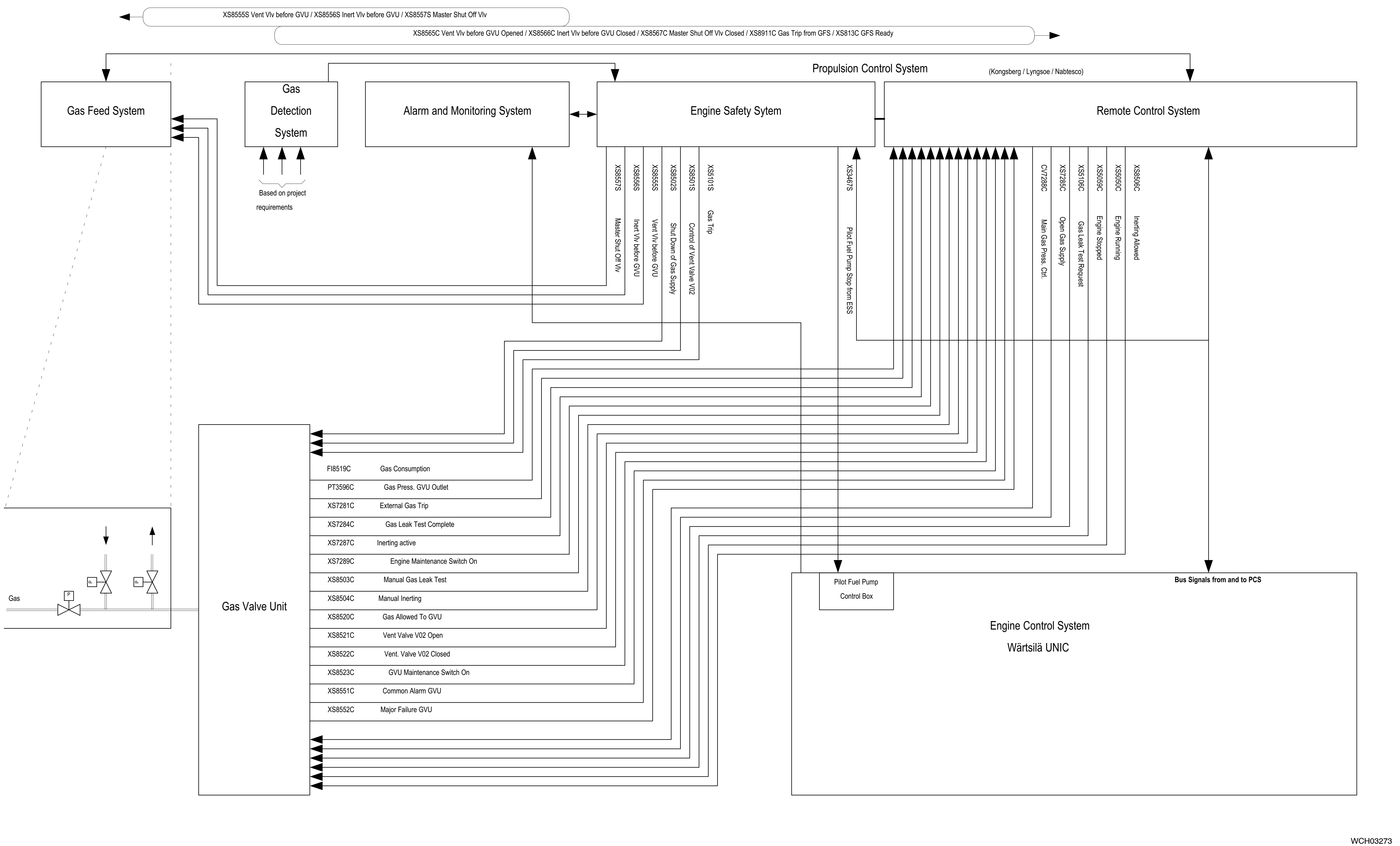


**Fig. 5: Electrical Connections Diagram – External Control Systems**

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## 2.1 Power Supplies

Two 230 VAC supplies from the ship installation, supply electrical power to E85.1 to E85.n. The two 230 VAC supplies are isolated (see Fig. 2).

**WARNING**

**Injury Hazard: The power supplies have redundancy. If it is necessary to isolate the ECS, make sure that each of the two 230 VAC power supplies are set to off. This will prevent injury to personnel.**

**Note: Each module and the LDU-20 at the local maneuvering stand have two 24 V power supplies. This makes sure of redundancy. An AC/DC converter from the ship installation supplies the LDU-20 in the engine control room (ECR). If one power supply becomes defective, the failure causes an alarm in the Alarm and Monitoring System (AMS).**

## 2.2 Installation on the Engine

The engine control system is an embedded system and has no central computer. The ECS modules are installed on the engine near the sensors and different actuators.

The CCM-20 are installed in the terminal box E95.

The IOM-10 is installed in the terminal box E90. The terminal box E90 is attached to the rail unit at the free end of the engine.

The MCM-11 and LDU-20 are installed in the local control box E25. The local control box E25 is installed at the free end of the engine.

For more data, refer to 9362–1 Location of ECS Electronic Components.

## 2.3 Redundancy

Each control function that is important for engine operation has redundancy in the engine control system (ECS).

If a CCM-20A (diesel module) becomes defective, the related cylinder will be shut off and a decrease in engine load will follow (slowdown). Each CCM-20A receives reference data for the injection period (fuel quantity) from the speed controller through the double CAN communication busses (see paragraph 3.8).

If a CCM-20G (gas module) becomes defective, the ECS automatically changes to diesel mode.

If a sensor is defective (e.g. fuel rail pressure sensor), the failure causes an alarm in the AMS. The failure is shown on the LDU-20.

Redundant sensors are used for all important parameters (e.g. if one speed sensor is defective, engine operation will continue).

If the speed controller or the MCM-11 become defective, you can operate the engine from the LDU-20 at the local maneuvering stand or from the LDU-20 in the ECR.

## 3. Engine Control System – Functions

The functions of the ECS are as follows:

- Engine speed and crank angle sensor (see paragraph 3.1)
- Turning gear position (see paragraph 3.2)
- Starting valve control (see paragraph 3.3)
- Auxiliary blower and scavenging control (see paragraph 3.4)
- Servo oil pressure control (see paragraph 3.5)
- Exhaust valve control (see paragraph 3.6)
- Cylinder lubrication control (see paragraph 3.7)
- Speed control (see paragraph 3.8)
- External power/torque data (see paragraph 3.9)
- Cylinder pressure balancing control (see paragraph 3.10)
- Cylinder liner wall temperature data (see paragraph 3.11)
- Diesel fuel injection control (see paragraph 3.12)
- Diesel fuel pressure control (see paragraph 3.13)
- Cylinder pressure setpoint and injection timing control (see paragraph 3.14)
- Gas fuel pressure control (see paragraph 3.15)
- Gas admission control (see paragraph 3.16)
- Vent valve control (gas supply) (see paragraph 3.17)
- Sealing oil system data and gas detection (see paragraph 3.18)
- Pilot fuel pressure control (see paragraph 3.19)
- Pilot fuel injection control (see paragraph 3.20)
- Knock control (see paragraph 3.21)
- Misfire control (see paragraph 3.22)
- Air/gas fuel ratio control (see paragraph 3.23).

## 3.1 Engine Speed and Crank Angle Sensor

Four proximity sensors (A and B, C and D) are installed near the crankshaft gear wheel (see Fig. 6). While the crankshaft gear wheel turns, the proximity sensors sense the movement of the teeth and calculate the crankshaft position.

The proximity sensors (speed pickups) A and B are connected to CCM-20 A1 and then looped through CCM-20 G1 to CCM-20 Gn to the MCM-11.

The proximity sensors (speed pickups) C and D are connected to CCM-20 A2 and then looped through to CCM-20 An.

One proximity sensor for TDC and one proximity sensor for BDC is installed near the flywheel. These proximity sensors sense the reference marks attached to the flywheel.

In each CCM−20, pulses are counted from the movement of the gear wheel teeth to calculate the crank angle.

Other sensors find the TDC and BDC reference positions. The reference points are the centers of the TDC and BDC marks.

To find the direction in which the gear wheel turns, there is always a pair of gear wheel sensors (A and B, C and D). If one of the sensors becomes defective, the data is available on the CAN−bus.

The reference sensor signals synchronize the related position to the absolute crankshaft angle.

For more data, refer to 9223−1 Crank Angle Sensor Unit.

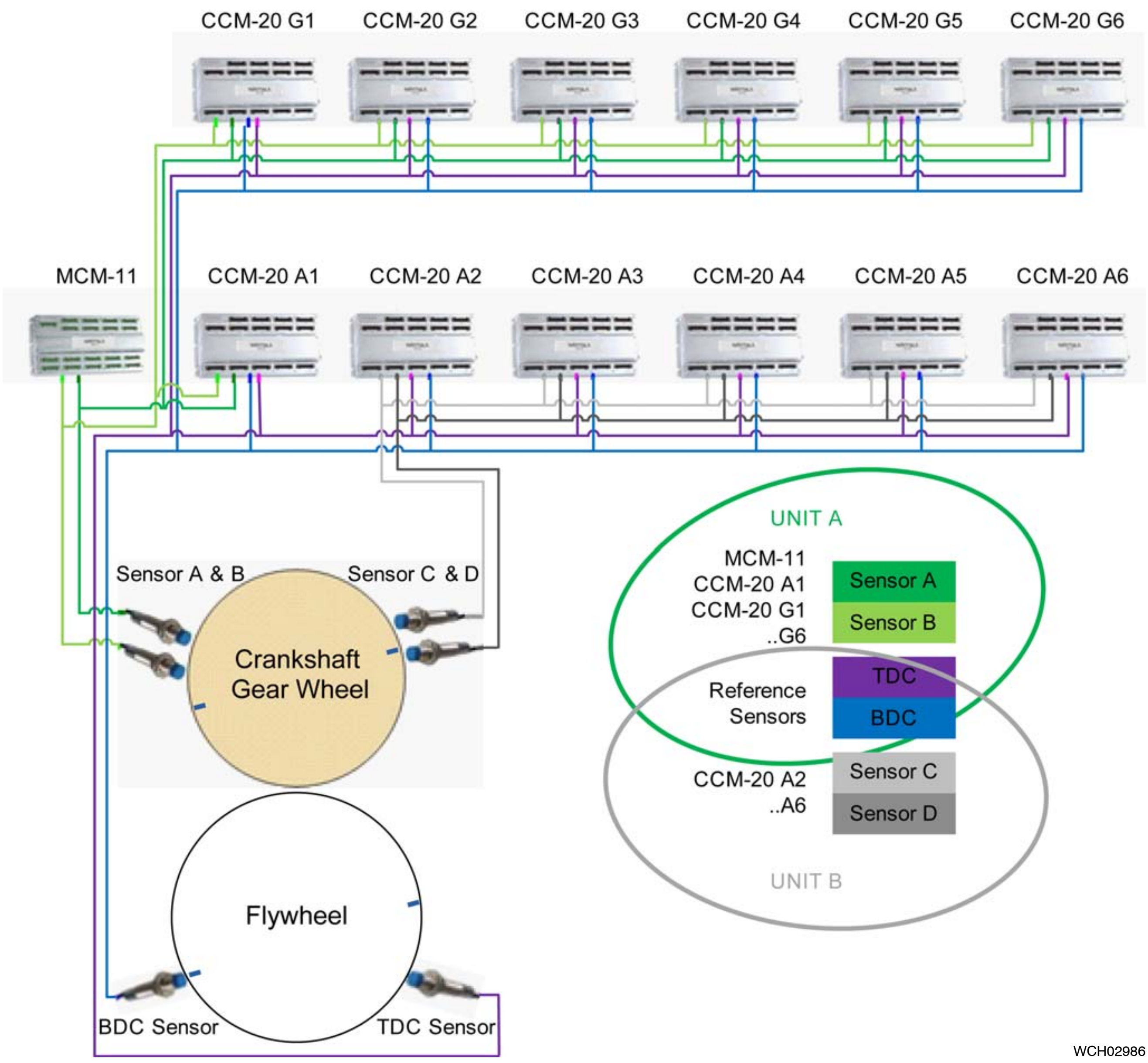



**Fig. 6: Crank Angle Sensors**

## 3.2 Turning Gear Position

The engine control system (ECS) monitors the position of the turning gear (engaged/disengaged) with the binary position binary switch ZS5016C and a pressure transmitter. The position switch ZS5016C is connected to the MCM-11 (see Fig. 2). For safety, if the turning gear is engaged (ZS5016C contact closed), the ECS will disable an engine start.

The status of the turning gear is shown on the LDU-20 main page (see 4002−2 Local Control Panel/Local Display Unit LDU-20).

The ECS also sends the status signal to external control systems (e.g. propulsion control system).

## 3.3 Starting Valve Control

The CCM-20 A of each cylinder opens and closes the starting valve CV724nC during the engine start sequence at a specified crank angle until the conditions for engine operation on fuel oil are found. For data about the starting valve, refer to 2728−1 Starting Valve.

The MCM-11 controls the common start valves CV7013C. The IOM-10 controls the common start valve CV7014C. This makes sure of redundancy.

## 3.4 Auxiliary Blower and Scavenging Control

The engine control system (ECS) controls the two auxiliary blowers. During usual operation, the ECS automatically controls the auxiliary blower operation. After engine stop, the operator can manually control the auxiliary blowers in the LDU-20 (see 4002−2 Local Control Panel/Local Display Display Unit) and the propulsion control system (PCS). If the engine operates in emergency operation, the operator can also manually control the auxiliary blowers.

The ECS monitors the operation of the auxiliary blowers. If there is a failure of an auxiliary blower, the ECS sends an alarm to the AMS. If one auxiliary blower is defective, the engine can operate at low load. If each of the two auxiliary blowers are defective, the engine cannot start.

For more data about the auxiliary blower, refer to 6545−1 Auxiliary Blower and Switch Box.

## 3.5 Servo Oil Pressure Control

### 3.5.1 Pressure Setpoint

The servo oil pumps have an internal controller. These controllers keep the servo oil pressure at the basic level.

CCM−20A3 (with the signal CV7221C to servo oil pump #1) and CCM-20 A4 (with the signal CV7222C to servo oil pump #2) control the load related changes in the servo oil pressure.

To close the control loop, the feedback signal from the pressure transmitter PT2071C (on the servo oil rail) goes to CCM20−A3, and from PT2072C to CCM-20 A4.

### 3.5.2 Emergency Mode

If one servo oil pump becomes defective, the system will continue to operate. The other servo oil pump will continue to supply the necessary pressure to the servo oil rail. If each of the two servo oil pumps have an electrical failure, the engine can continue to operate at low load.

### 3.5.3 Monitored Items

The servo oil pressure is monitored. If the servo oil pressure is out of the tolerance, a failure indication is shown on the LDU-20.

The sensors are monitored. If the sensors are out of range, an alarm is activated in the AMS and a failure indication is shown on the LDU-20. If each of the two servo oil pressure sensors have a failure, the engine can continue to operate at low load.

The leakage of the servo oil pumps is monitored. If there is a too much servo oil leakage, the AMS activates an alarm.

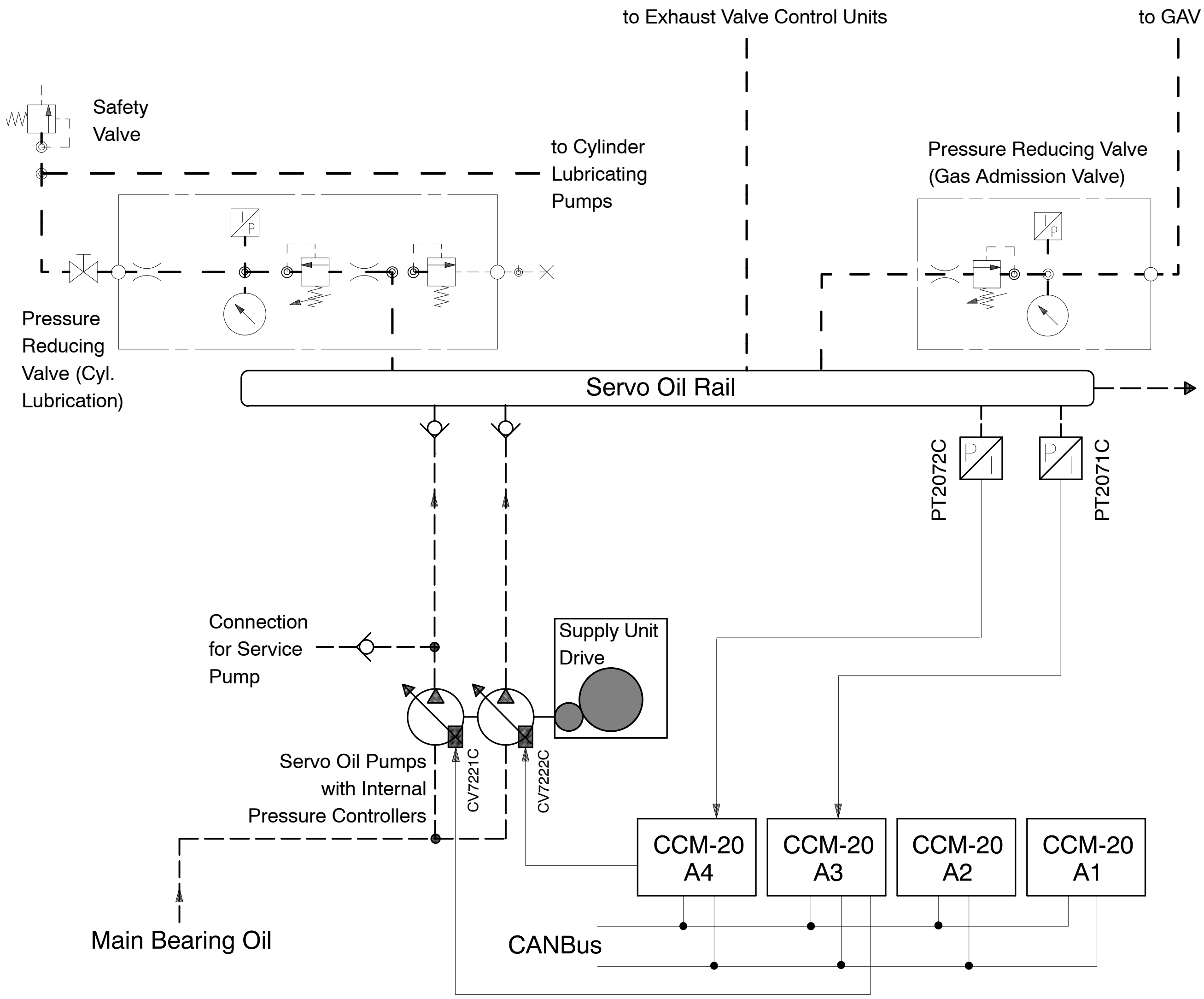



**Fig. 7: Servo Oil Pressure Setpoint**

## 3.6 Exhaust Valve Control

### 3.6.1 Exhaust Valve – Function

While the engine operates, the exhaust valve opens and closes once during each full turn of the crankshaft, which is related to the calculated crank angle position (Fig. 8).

The control valves CV7401–08C and CV7421–08C are installed on the exhaust valve control unit. These control valves are connected to the CCM-20A on each cylinder (see Fig. 2 and Fig. 3).

The engine control system activates the control valve CV7401–08C to open the exhaust valve.

The valve stroke sensor ZT5421–28C monitors the movement of the exhaust valve. On each cylinder, the CCM-20A adjusts the stroke and timing to the correct values.

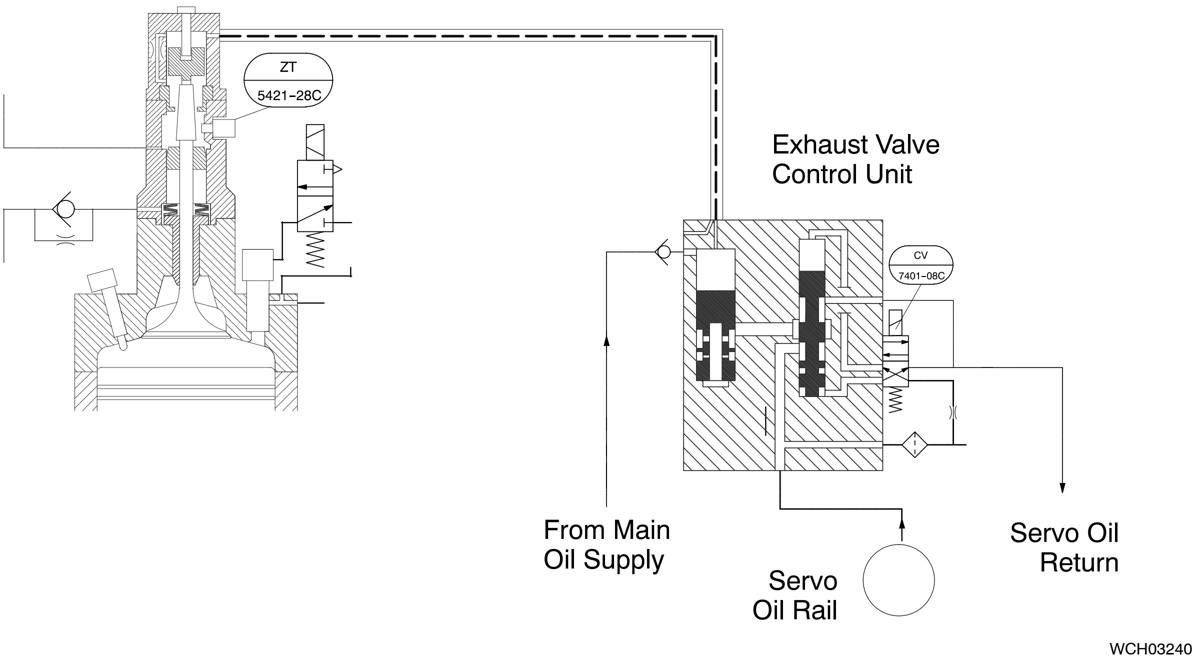



**Fig. 8: Exhaust Valve Control**

### 3.6.2 Exhaust Valve – Control

The exhaust valve movement is controlled as follows:

- The crank angle and the variable exhaust opening (VEO) are used to calculate the open command of the exhaust valve.
- The open deadtime, the time between the open command and 15% of the valve stroke, is measured.
- The crank angle and the variable close command (VEC) are used to calculate the close command of the exhaust valve.
- The close deadtime, from the close command to 15% of the valve stroke, is measured.
- After one full turn of the crankshaft, the timing for the next cycle is adjusted in accordance with the deadtime of the cycle before.

### 3.6.3 Emergency Mode

If a valve stroke sensor becomes defective (and there are no deadtime values from the other cylinder control units available) the system default time settings are used for the open and close deadtimes of the related exhaust valve. If the system default values are used, the related cylinder operates at reduced power.

## 3.7 Cylinder Lubricating Control

### 3.7.1 General

The cylinder lubricating system (see Fig. 9) is a time-based system, which supplies lubricating oil to the cylinder liner wall.

Each CCM-20A controls the solenoid valves CV7131–38C which activate an oil injection on the related cylinder. The pressure sensors PT3131–38C, attached to the lubricating pump, give measurements about the injection pressure of the cylinder lubricating oil. The engine control system uses these measured values to adjust the injection timing to compensate for hydraulic and mechanical delays in the system.

The timing and vertical oil supply can be set to the applicable values related to the engine type and engine design. A controlled quantity of lubricating oil then flows above, into and below the piston and piston ring pack (for more data, refer to 7218–1 Cylinder Lubrication, paragraph 8.3 Vertical Oil Supply).

The quantity (g/kWh) of cylinder lubricating oil is related to the engine speed and engine load in a specified time period. The basic input to the control functions are the base feed rate settings (see 7218–1, paragraph 8.4 Feed Rate – Adjustment and 4002–2, Local Control Panel / Local Display Unit LDU-20, paragraph 3.21).

### 3.7.2 Emergency Mode

If a CCM-20A, solenoid valve or pressure sensor becomes defective, an indication shows on the LDU-20. The indication is also sent to the AMS. If a CCM-20A or 4/2-way solenoid valve becomes defective, the engine power output will be limited to engine slowdown level. If a CCM-20A becomes defective, refer to the data given in 4002–3 CCM-20 Failure.

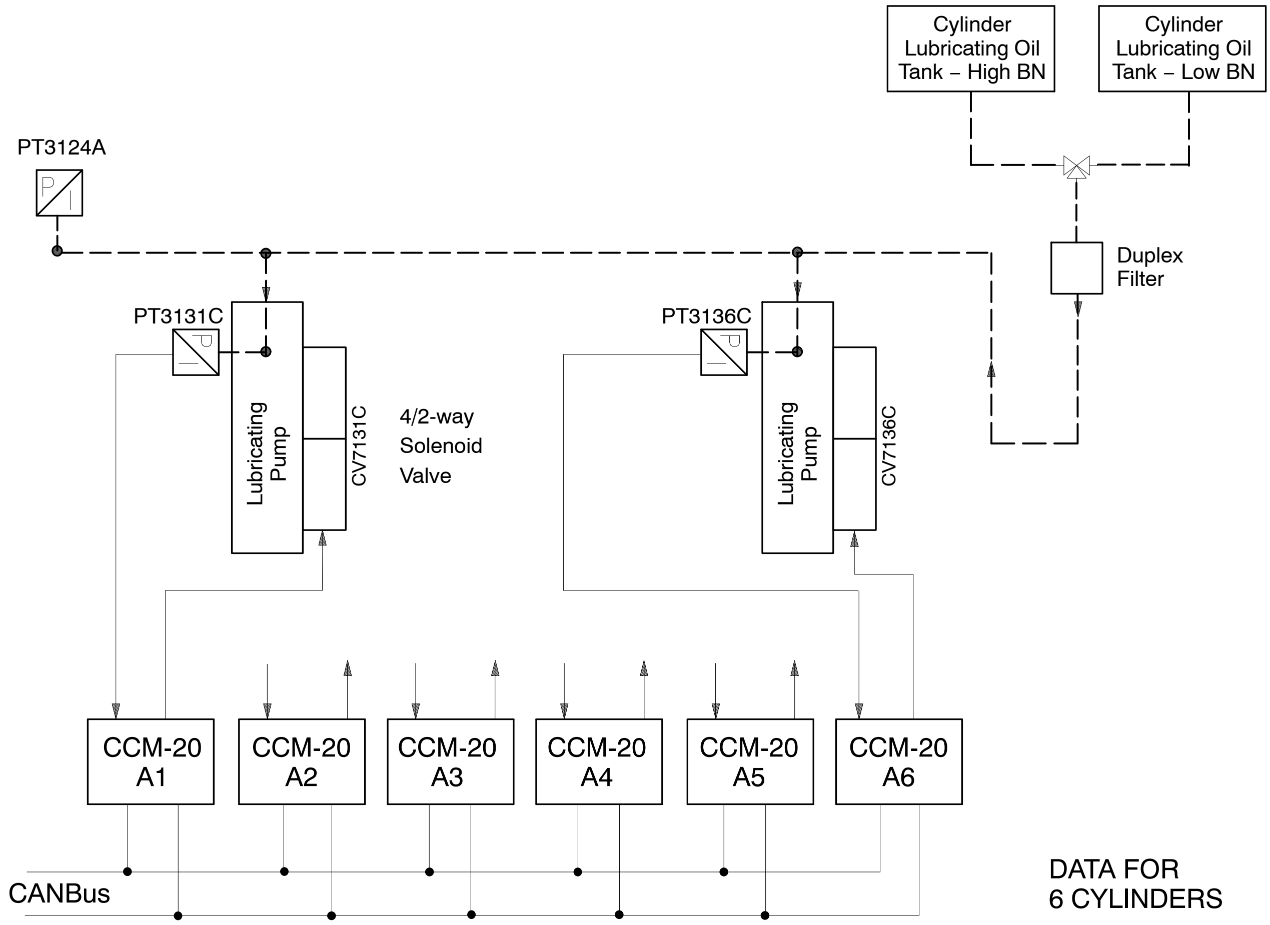



**Fig. 9: Cylinder Lubricating System**

## 3.8 Speed Control

The speed control algorithm in the engine control system (ECS) compares the value from the speed pickup with the measured engine speed value.

The speed control algorithm in the engine control system (ECS) compares the speed setpoint value with the measured engine speed value from the speed pickups (see paragraph 3.1). The ECS uses the calculated difference as the input for a proportional-integral-derivative (PID) controller. The output of the PID controller is the fuel command signal. The PID controller changes the fuel command signal to adjust the actual measured speed to the applicable speed setpoint value. Each CCM-20A uses the fuel command signal to calculate the related injection signal for each cylinder.

The speed controller is installed in the MCM-11 (see Fig. 2). If the engine operates in diesel mode and the MCM-11 becomes defective, the ECS will hold the last fuel command value until the operator can control manually the fuel control.

If the engine operates in gas mode and the MCM-11 becomes defective, the ECS automatically changes to diesel mode.

During engine start and idle operation mode, the engine operates in an open-loop control mode. For engine operation at more than the idle speed, the engine operates in a closed-loop control mode.

**Note: The speed controller parameters are set during the tests at the engine test bed. Usually it is not necessary to change these parameters. If it becomes necessary to change the parameters, an ECS service tool is available. For more data, speak to or send a message to Wärtsilä Services Switzerland Ltd.**

### 3.8.1 Defective Speed Control System

Defects in the speed control system must be repaired as soon as possible. If this is not possible, you can operate the engine in diesel mode and control the engine from the local control panel (see 4002−2 Local Control Panel / Local Display Unit LDU-20).

If the engine operates in gas mode, the ECS automatically changes to diesel mode.

If the engine operates in diesel mode and the fuel command signal from the speed control system is missing, the speed control system will continue to operate. The last known fuel command will be used.

| CAUTION |
|---|
| **Damage Hazard: You must only operate the engine during unusual conditions when necessary. You must not leave the maneuvering stand. You must monitor the engine speed frequently to make sure that procedures are immediately done if large differences in engine speed occur.** |

## 3.9 External Power/Torque Data

An external power/torque meter measures the engine power/torque. The estimated power signal of the engine is calculated in the engine control system (ECS), related to the engine speed and the used fuel command (only when the engine operates in diesel mode).

The measured power/torque value from the external power/torque meter is used as the primary signal for dual fuel engine operation. The estimated power value is used as a secondary signal.

If the primary signal is not available, the engine can only operate in diesel mode (secondary signal).

If the engine operates in gas mode and the primary signal is not available, the ECS changes automatically to diesel mode.

## 3.10 Cylinder Pressure Balancing Control

The ECS adjusts the combustion process to balance the cylinder pressure for all cylinders. The pressure transmitters PT3601−0#C on each cylinder are connected to the related CCM-20A (see Fig. 2 and Fig. 3).

The ECS calculates and adjusts the compression pressure balancing with the parameters that follow:

- Exhaust valve close timing
- In diesel mode, the timing of each cylinder injection start
- In gas mode, the adjustment of the quantity of gas fuel.

The cylinder balancing functions are applicable only in a specified load range when the auxiliary blowers are set to off. This makes sure of usual engine operation independently from the condition of the cylinder balancing functions.

## 3.11 Cylinder Liner Wall − Temperature Data

A single-stage cooling water system is used to keep the cylinder at the correct operation temperature (for more data, refer to 8017−1 Cooling Water System).

The AMS and ESS monitor the cylinder cooling water system (cooling water inlet pressure and cooling water inlet/outlet temperature).

The ECS monitors the cylinder liner wall temperature with two sensors (TE4801−0#C and TE4841−4#C, Fig. 10). The temperature sensors from each cylinder are connected to the related CCM-20A (see Fig. 2 and Fig. 3). The temperatures are shown in the LDU-20 (see 4002−2, paragraph 3.23 Temperatures − Cylinder Liner Wall and Exhaust Gas).

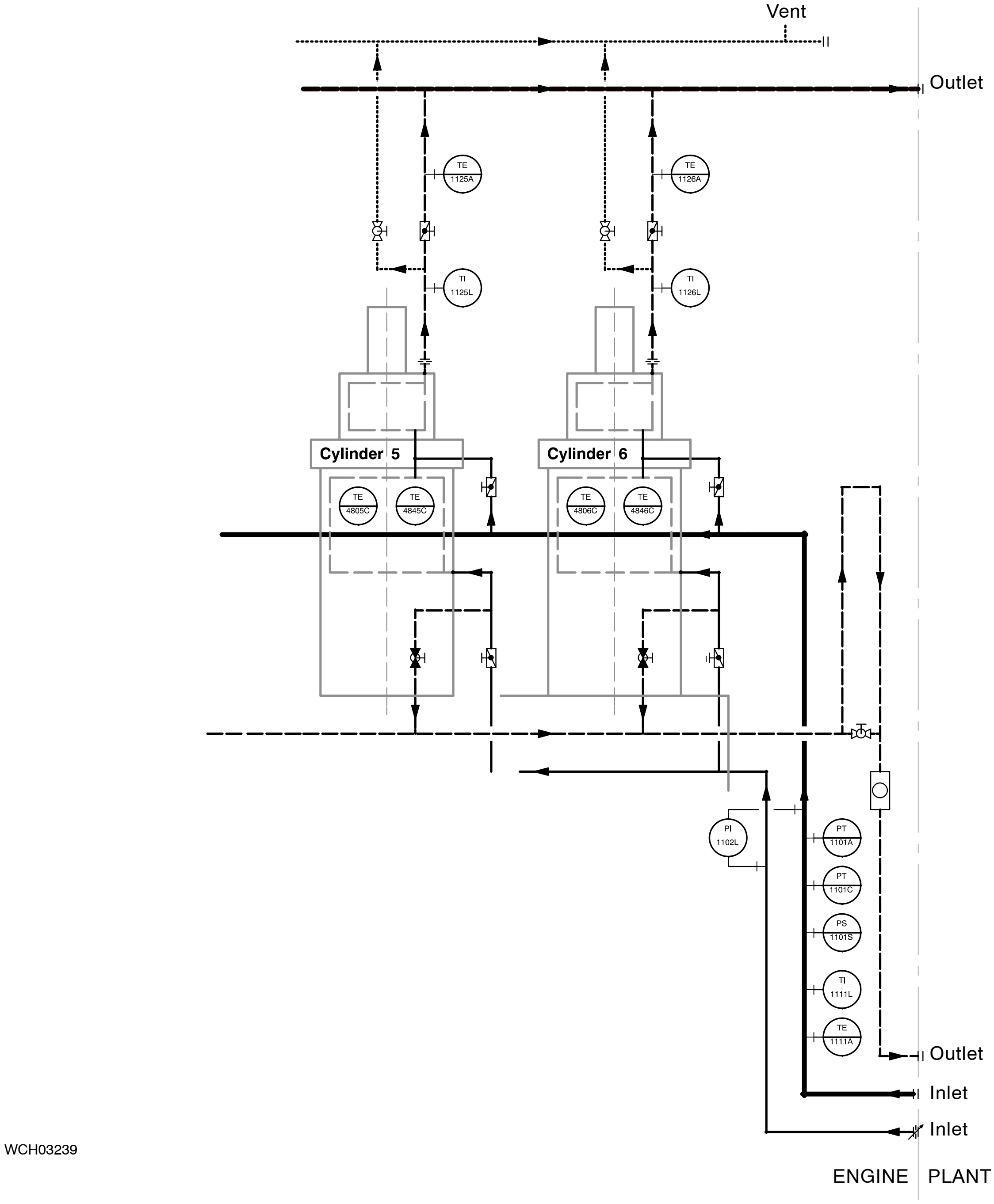



**Fig. 10: Cylinder Cooling System**

## 3.12 Diesel Fuel Pressure Control

### 3.12.1 Engine Start

At engine start, the fuel pump actuators are set to the start position (see Fig. 11).

### 3.12.2 Engine Operation

The fuel pressure is related to the engine load. The control loop for the fuel rail pressure is given as follows:

- The engine control system (ECS) activates a control signal, which is related to the engine speed and the fuel command.
- The signals from the CCM-20A control the fuel pump actuators. Each actuator controls the related fuel pump through the toothed rack.

  **Note: The data that follows is applicable only for 5-cylinder to 6-cylinder engines.**

  - CCM-20 A1 controls the fuel quantity of fuel pump No.1. The ECS sends a signal to the control valve CV7231C.
  - CCM-20 A2 controls the fuel quantity of fuel pump No.2. The ECS sends a signal to the control valve CV7232C.
- Two pressure transmitters PT3461C and PT3462C measure the fuel pressure. This fuel pressure data is transmitted back to the CCM-20 A1 and CCM-20 A2.

### 3.12.3 Engine Shutdown

If the fuel rail pressure must be quickly released, the fuel pump actuators are set to the position zero. The pressure control valve (PCV) opens to release the pressure in the fuel rail.

The PCV also operates as a safety valve. For more data, see 5562−1 Pressure Control Valve.

### 3.12.4 Emergency Mode

If the CCM-20A that is in control or fuel pump becomes defective, the remaining fuel pump keeps the fuel rail pressurized and the engine can continue to operate.

### 3.12.5 Monitored Items

The fuel rail pressure is monitored. If the pressure is out of the tolerance, a failure indication shows.

The sensors are monitored. If the sensors are out of range, a failure indication shows.

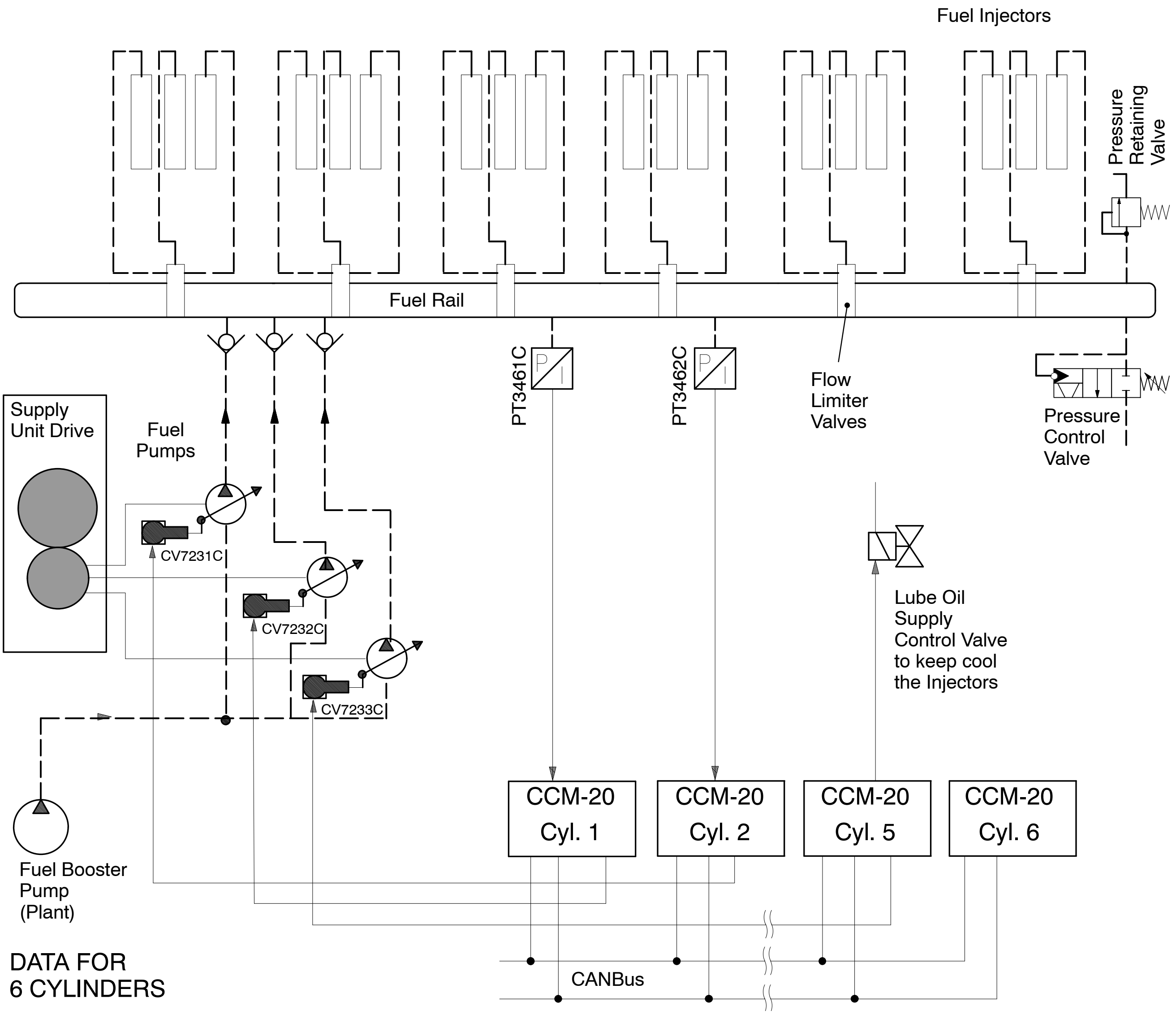



**Fig. 11: Fuel Pressure Control System**

## 3.13 Diesel Fuel Injection Control

### 3.13.1 Injection Valve Control

Each injection valve, related to the solenoid valve in each cylinder, is controlled independently (see Fig. 12).

Usually, the three injection valves on each cylinder operate at the same time. Special operation modes enable fuel injection with one, two or three injection valves, or with multi-shot spray patterns.

To improve the spray at low load, one injection valve is cut out automatically (see 0550-1 Operation at Low Load).

The CCM-20A increases the control outputs up to the applicable signal level for the injection control valves.

### 3.13.2 Injection Control

A higher current level (pull-in current) at the start of the injection is used to make sure that the injector opens quickly (cycle-to-cycle). The lower current (hold-in current) is set to on when the injector has opened. This lower current (and energy) level will decrease the temperature in the CCM-20A driver circuit and the solenoid valve.

The fuel injection is controlled as follows:

- The CCM-20A calculates the fuel injection quantity (injection period). The input (specified as a Fuel Command), is related to the output from the speed controller.
- The related signal from the speed controller is changed into injection values. These values give the duration of the fuel injection, i.e. the quantity of fuel injected into each cylinder. This quantity is related to the engine load.
- If necessary, adjustments can be made for differences in the fuel supply to each injector.
- The fuel rail pressure has an effect on the last injection timing values that the engine control system uses. For the last injection timing process, each CCM-20A receives accurate data about the angular position from the speed sensors and crank angle sensors.
- The firing order and angular displacements of the cylinder are programmed in the CCM-20A. The ECS uses different injection timing for each cylinder to get the best operation results for all engine load ranges.

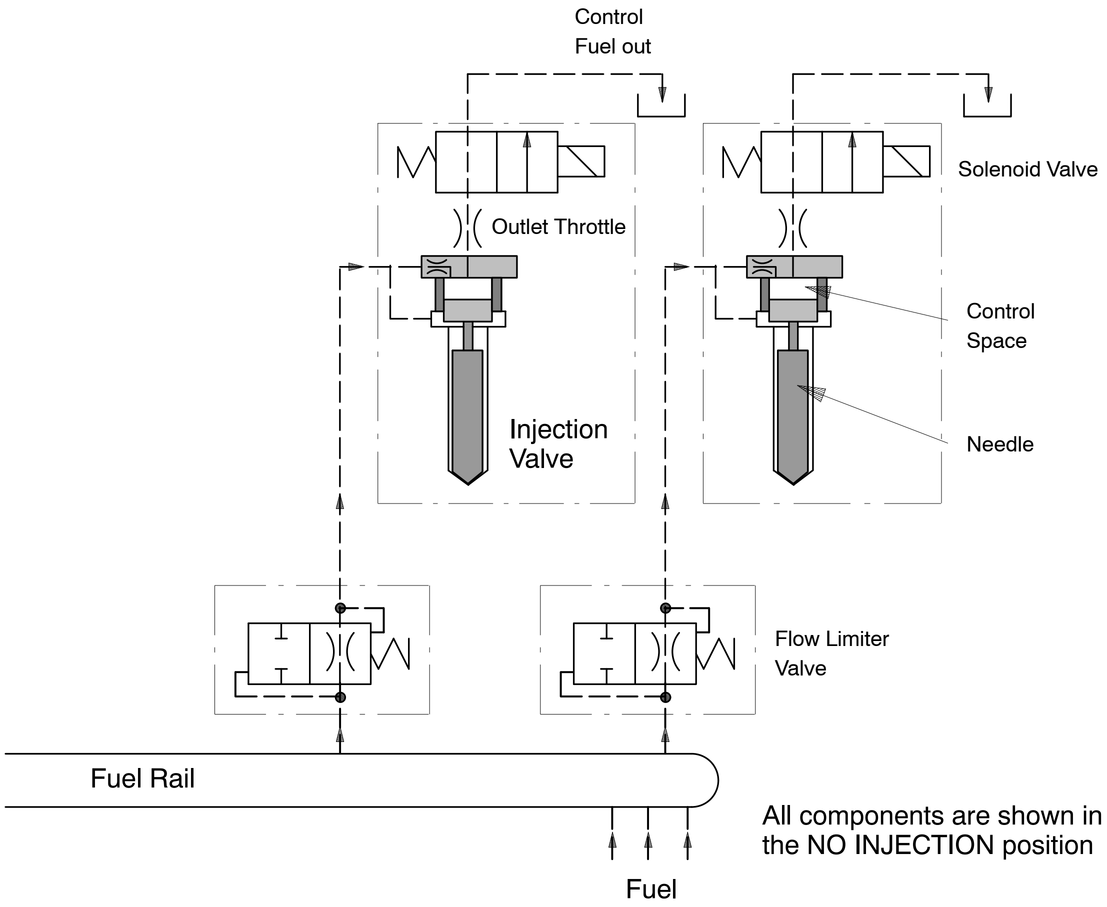



**Fig. 12: Fuel Injection Control**

## 3.14 Cylinder Pressure Setpoint and Injection Timing Control

For diesel mode, the engine control system (ECS) has the functions that follow:

- Set point control of the combustion pressure, related to the engine load
- Common injection-start timing control, to adjust the average combustion pressure of all cylinders.

**Note: The injection-start timing control is shown on the related fuel injection page in the LDU-20 as Inj. begin offset.**

Ambient conditions have an effect on the combustion pressure. The ECS uses the parameters that follow to adjust the cylinder pressure set point for the best results:

- Barometric pressure/Blower inlet pressure (PT4002C and PT4003C)
- Blower inlet temperature (TE4041C and TE4042C)
- Scavenge air temperature (TE4045C and TE4046C)

The sensors are connected to the IOM-10 (see Fig. 2).

The ECS used the engine specified Technical File for the setpoint of the automatic firing pressure control. This makes sure of the specified $N_{ox}$ performance of the engine.

See the illustrations that follow for the manual and automatic adjustment of the injection-start timing.

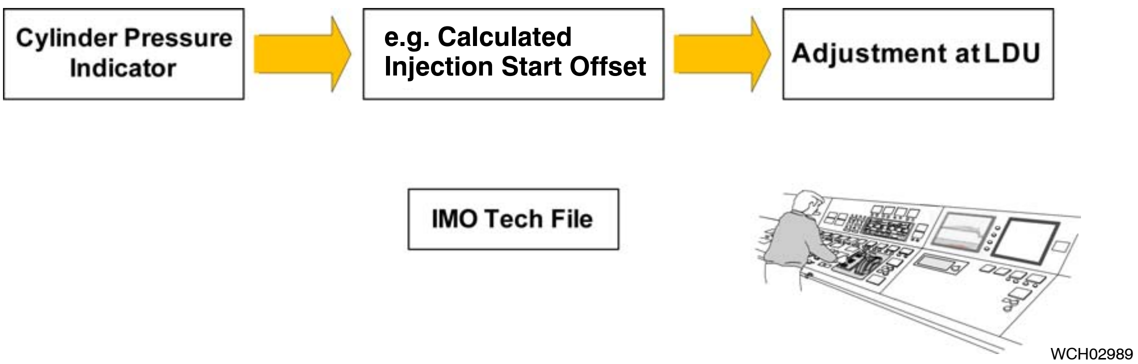



**Fig. 13: Manual Adjustment Procedure**

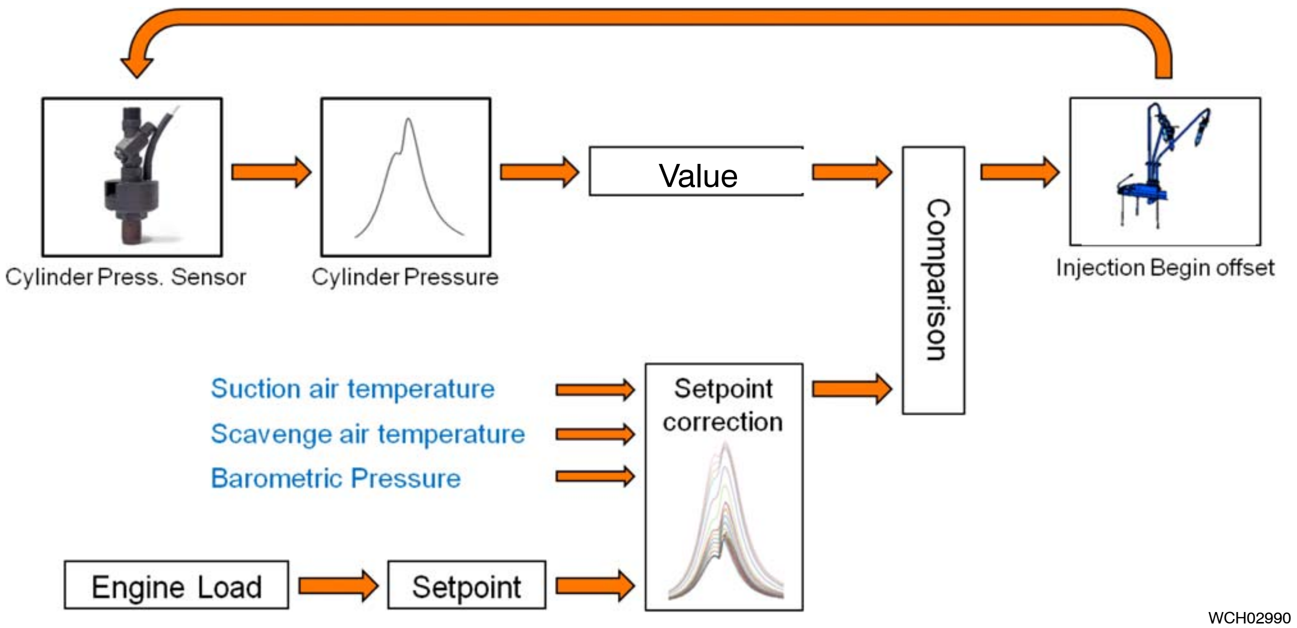



**Fig. 14: Schematic Diagram – Offset Control of Automatic Injection Start**

## 3.15 Gas Fuel Pressure Control

The gas fuel system operates in a closed-loop control mode. The gas fuel pressure adjusts to a given setpoint, which is related to the engine load and speed.

The ECS measures the gas inlet pressure at the exhaust side (PT3597C) and the fuel side (PT3595C) upstream of the engine (see Fig. 15). Also, the gas pressure downstream of the gas pressure control valve in the gas valve unit (GVU) is measured. The GVU operates the gas pressure control valve to adjust the gas inlet pressure related to the setpoint from the ECS.

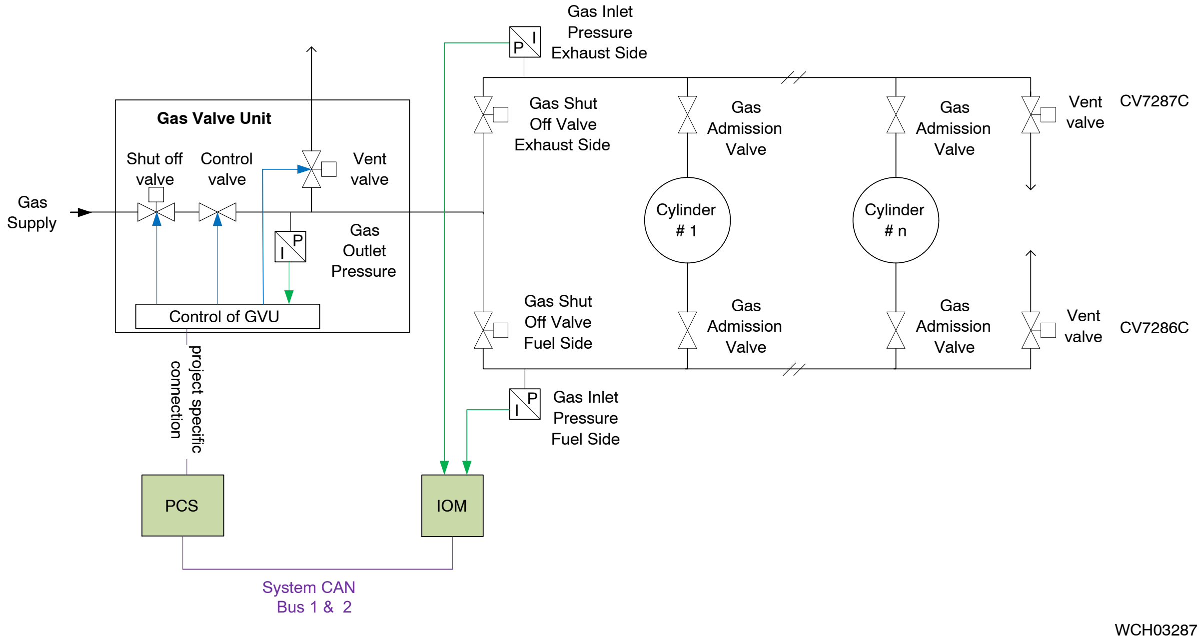



**Fig. 15: Pressure Control – Gas Fuel**

## 3.16 Gas Admission Valve – Control

The ECS controls independently each gas admission valve (GAV). The gas supply pressure is related to the engine load (see paragraph 3.15).

The valve stroke sensors (ZT3521–28C and ZT3501–08C, Fig. 16) are attached to the GAV (for data about the gas admission valve, refer to 2140–1). The ECS uses feedback related to the engine load to adjust the timing and quantity of the gas admission.

The ECS controls the quantity of gas to each cylinder related to the engine speed and power. The CCM-20G calculates the gas admission quantity (injection period). The input is related to the output from the speed controller (see paragraph 3.8).

The related signal from the speed controller changes to gas admission values. These values give the quantity of gas that flows into each cylinder.

The gas supply pressure is monitored. The pressure transmitters PT3595C (fuel side) and PT3597C (exhaust side) are connected to the IOM-10 (see Fig. 2 and Fig. 15). The gas valve unit (GVU) adjusts the gas supply pressure with the pressure regulating valve. The ECS uses the pressure regulating valve (installed in the GVU) related to control the engine load. For more data, refer to the documentation of the GVU manufacturer.

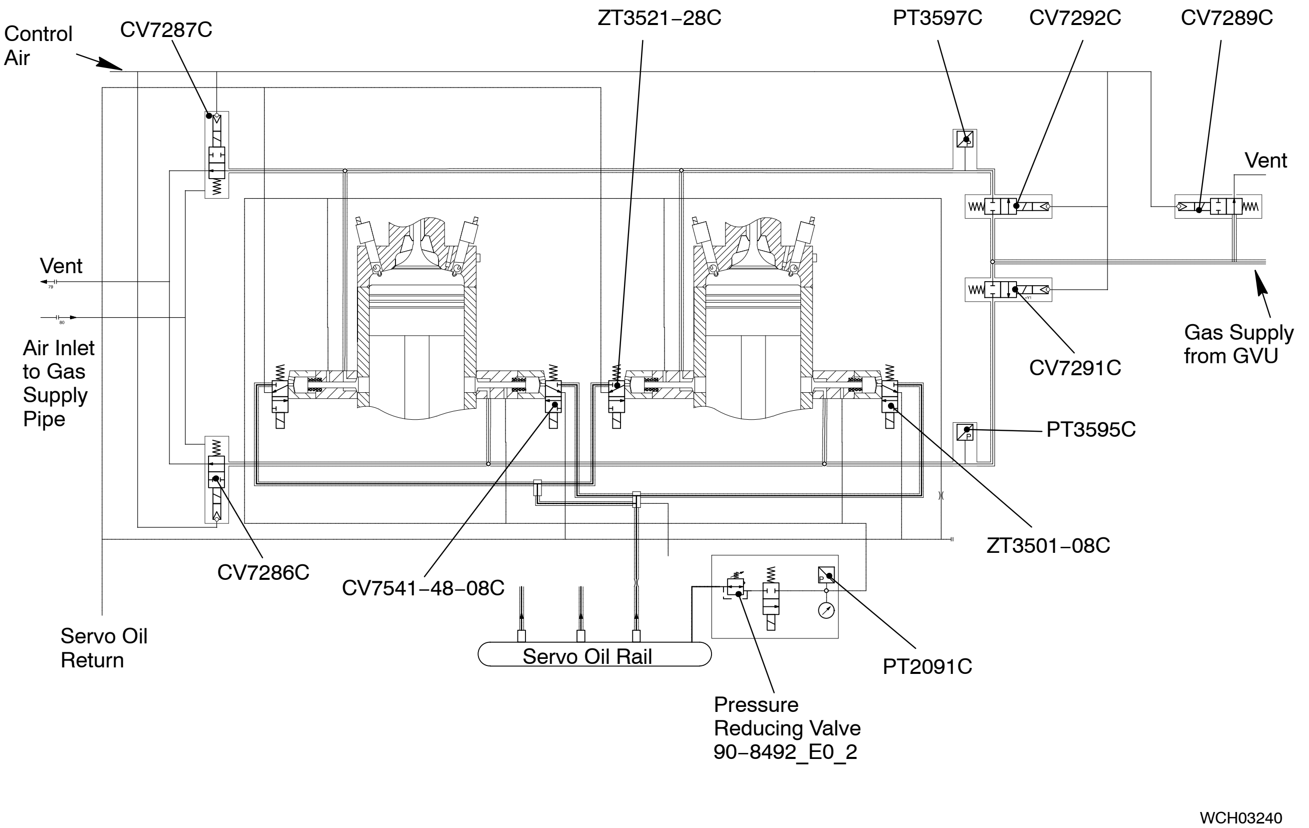



**Fig. 16: Schematic Diagram – Gas Admission Valve Control**

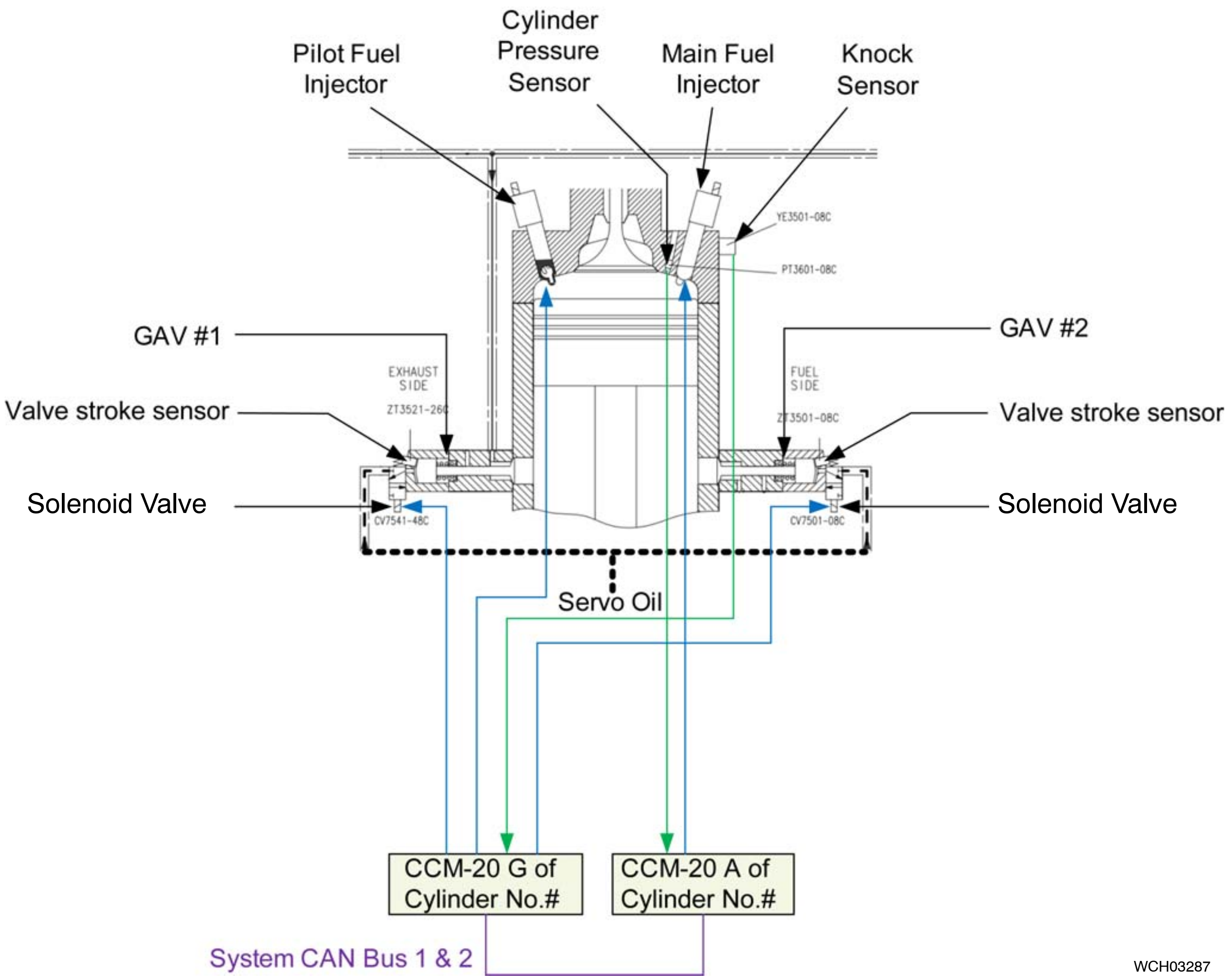



**Fig. 17: Gas Admission Valve Control – Electrical Connections**

### 3.16.1 Functions that Monitor Combustion Pressure and Control

The ECS monitors the cylinder compression and combustion pressure. If there is a specified difference between the compression and combustion pressure, the ECS adjusts the timing and quantity of the gas supply for the related cylinder. For safety, if the difference does not change in a specified time, the ECS automatically changes to diesel mode.

## 3.17 Vent Valve Control (Gas Supply)

For safety, an automatic gas vent system is installed (see Fig. 2 and Fig. 18). To release the air in the gas inlet pipes, the ECS sends a signal to the GVU. For more data, refer to the documentation of the GVU manufacturer.

Air from the control air system operates the control valves (for more data, refer to 4605−1 Control Air Supply).

The vent valves CV7286C and CV7287C are installed at the free end of the engine. The CCM-20 G1 controls the vent valve CV7286C (fuel side). The CCM-20 G2 controls the vent valve CV7287C (exhaust side).

The vent valves CV7286C and CV7287C release the pressure in the gas supply pipes. This makes sure that there is no gas pressure in the supply pipes when:

- There is a defect in the gas system, or
- The operator changes the mode from gas to diesel.

The vent valve CV7289C is installed at the driving end of the engine after the gas inlet from the GVU. The CCM-20 G3 controls the vent valve CV7289C.

The vent valve CV7289C releases the pressure in the gas supply pipes between the GVU and the shut-off valve valves CV7291C and CV7292C. This makes sure that there is no gas pressure in the supply pipes when:

- There is a defect in the gas system, or
- The operator changes the mode from gas to diesel.

The gas detector AE3315C continuously monitors the concentration of gas in the piston underside. The gas detector is installed on the fuel side of the engine. The gas detector AE3315C is connected to the CCM-20 G4 (see Fig. 2). If there is a high gas concentration, the gas detector sends the gas concentration signal to the CCM-20 G4. If there is a high concentration, the ECS activates an alarm. The engine safety system (ESS) automatically opens the vent valves CV7286C and CV7287C and flushes the supply pipes with inert gas.

For safety, the gas system has an automatic gas shut-off system (see Fig. 2). To close the gas inlet to the gas supply pipes, the ECS sends a signal to the gas shut-off valves CV7291C and CV7292C. These gas shut-off valves are installed at the driving end of the engine. The CCM-20 G3 controls the gas shut-off valve valve CV7291C on the fuel side. The CCM-20 G4 controls the gas shut-off valve valve CV7292C on the exhaust side. For more data, refer to 4003−9 and 4003−12.

For more data about the gas fuel system, refer to 8014−1 Gas Fuel System.

## 3.18 Sealing Oil System Data and Gas Detection

The gas admission valves have a sealing oil system to prevent gas leakage. The ECS monitors the sealing oil pressure (PT2091C). For safety, if the sealing oil pressure is less than the set value, the ECS automatically changes to diesel mode.

For more data about the gas detection system, see paragraph 4.4 and the documentation of the gas detection system manufacturer.

## 3.19 Pilot Fuel Pressure Control

The CCM-20G on each cylinder controls the injection of pilot fuel into the cylinder during gas mode for the ignition of the air/gas mixture. For more data, refer to 0300−1 Diesel Engine Fuels, paragraph 8.5 and 2790−1 Pilot Injection Valve.

The ECS monitors the pilot fuel pressure inlet to prevent damage to the pilot fuel pump. The pressure transmitter PT3464C for the pilot fuel pressure inlet is installed in the pilot fuel supply unit (see Fig. 18). The pressure transmitter PT3464C is connected to the IOM-10. For data about the pilot fuel system, refer to 8790−1.

The temperature sensor TE3464C monitors the temperature of the pilot fuel at the inlet of the pilot fuel pump.

The pressure transmitters PT3465C and PT3466C are installed on the distributor block for the last and next to last cylinder. The pressure transmitter PT3465C on the last cylinder is connected to the IOM-10. The pressure transmitter PT3466C for the pilot fuel pressure on the next to last cylinder is connected to the MCM-11.

The pressure safety valve 10−555_E0_4 is installed in the pilot fuel pump control unit.

For more data, refer to Fig. 2.

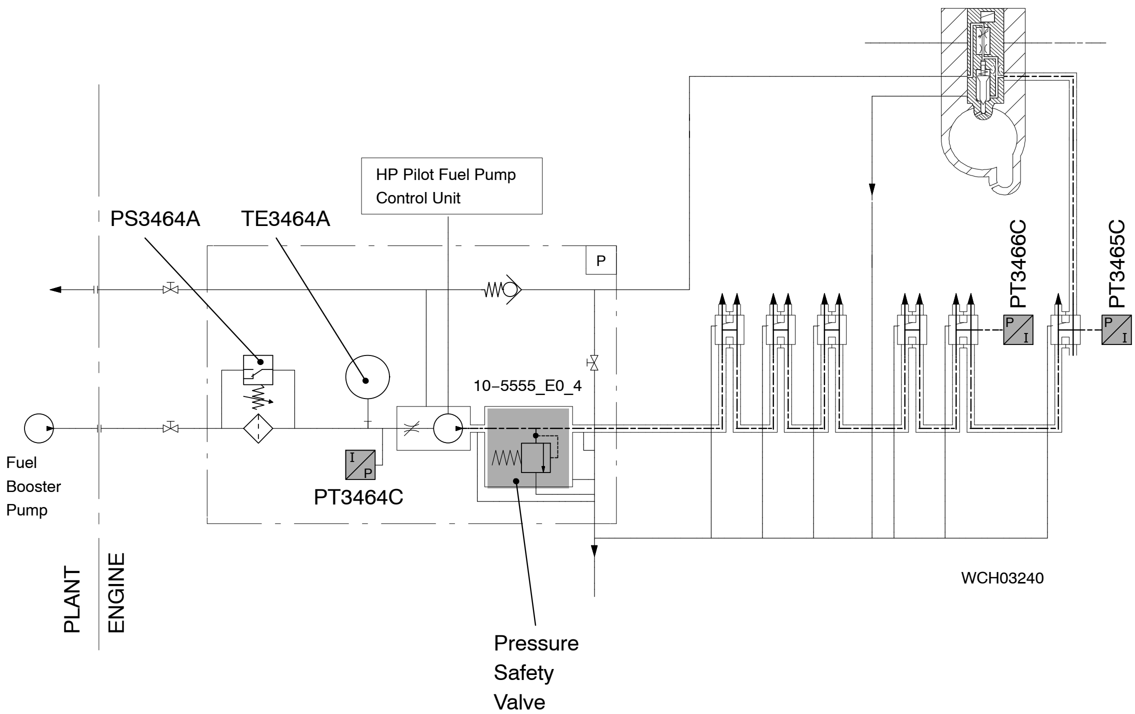



**Fig. 18: Pilot Fuel Pressure Control**

## 3.20 Pilot Fuel Injection Control

The control valves CV7301–08C and CV7321–28C are connected to each CCM-20G (see Fig. 2 and Fig. 20). The engine control system (ECS) controls the control valves CV7301–08C and CV7321–28C electronically for each cylinder. The engine control system calculates the injection timing and pilot fuel quantity related to the engine speed and power.

The control valves CV7301–08C and CV7321–28C (solenoid valves) are installed in the pilot injection valves. For more data, refer the documentation of the pilot injection valve manufacturer.

The control valve CV7301–08C controls the pilot injection valve No.1. The control valve CV7321–28C controls the pilot injection valve No.2.

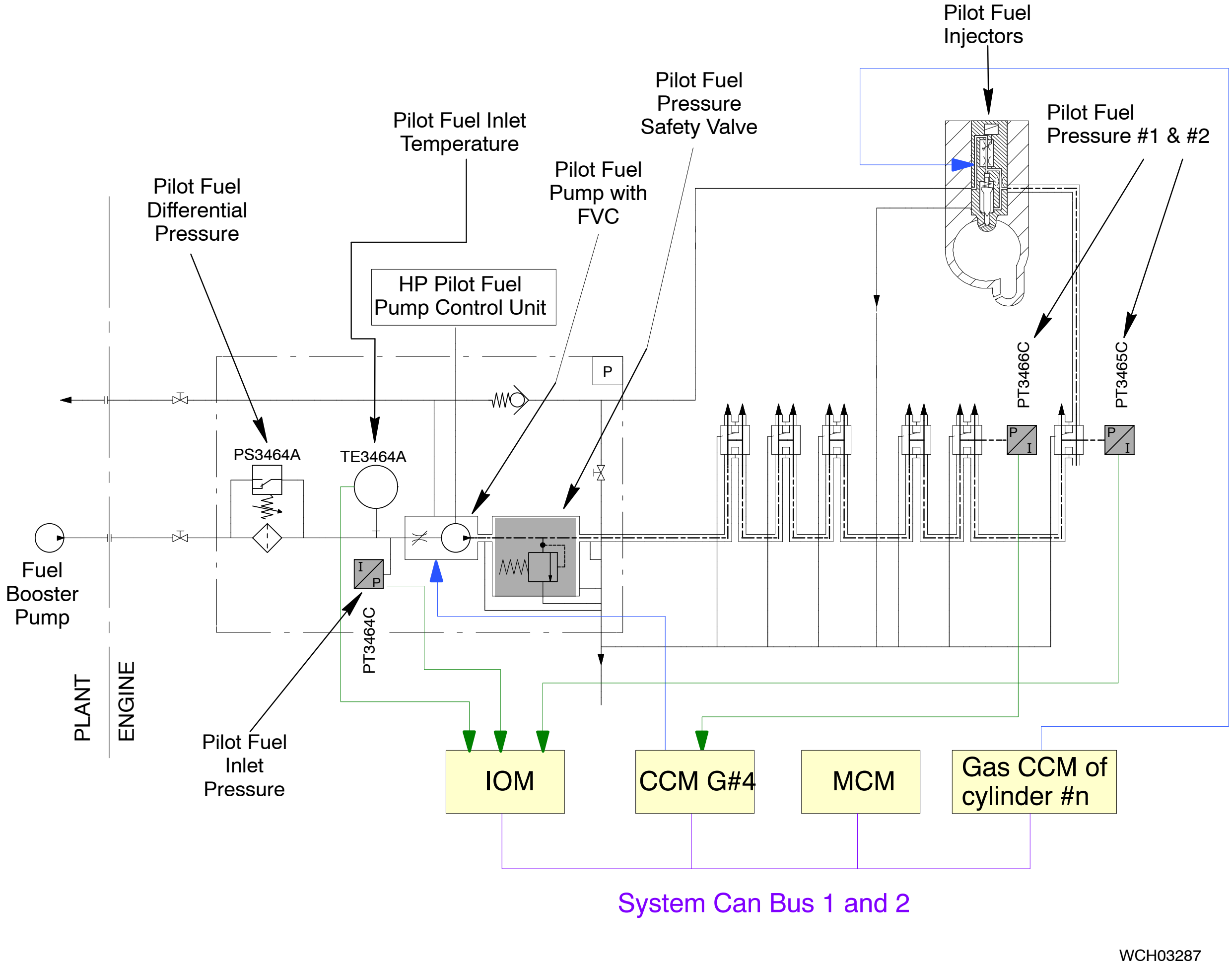



**Fig. 19: Pilot Fuel Injection Valve Control**

## 3.21 Knock Control

The ECS monitors the combustion process for knocking. Knocking in diesel engines is defined as sharp sounds. The combustion of parts of the compressed air/fuel mixture in the cylinder before the calculated ignition causes knocking. Because of a high compression ratio and a lean gas/air mixture, knocking can occur in two-stroke low-pressure diesel engines.

The knock sensors YE3501−08C are installed on each cylinder cover and are connected to each CCM-20G (see Fig. 2 and Fig. 20). If the knock sensors YE3501−08C sense combustion that is too fast (knocking) the ECS activates an alarm. The knock sensors YE3501−08C monitor the combustion process in a specified range of the nominal engine load. The ECS monitors different knocking ranges, e.g. light knocking and heavy knocking.

If there is light knocking on one cylinder, the ECS decreases the gas quantity to adjust the gas/air ratio, or adjusts the pilot fuel injection timing of the related cylinder. This will prevent knocking. If the knocking stops, the ECS goes back to the usual parameters.

If there is heavy knocking on one or more cylinders, the ECS automatically changes to diesel mode.

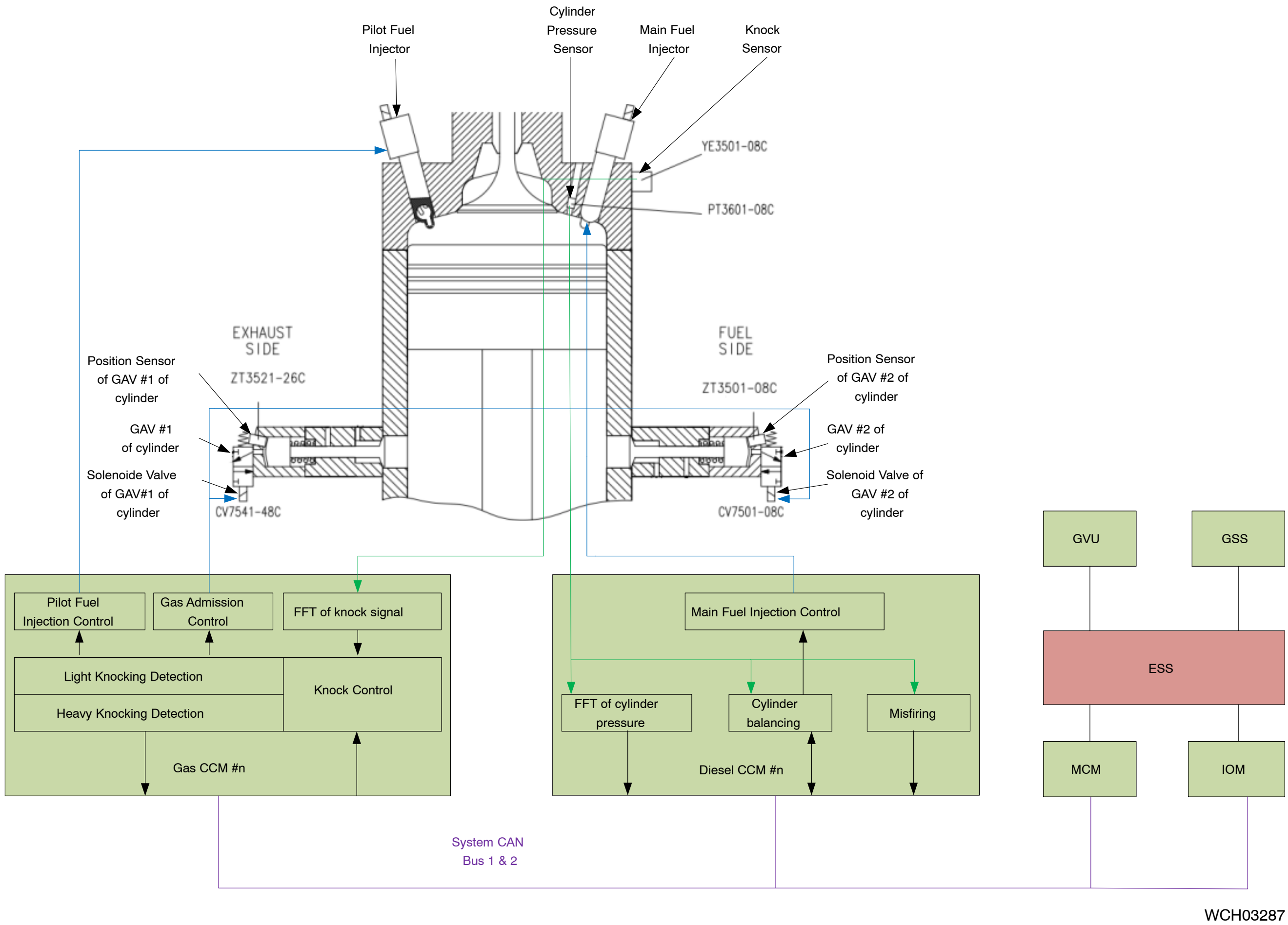



Fig. 20: Knock Control

## 3.22 Misfire Control

The ECS uses two different algorithms to monitor the combustion process for misfires. If a misfire occurs on one or more cylinders, the ECS automatically changes to diesel mode.

## 3.23 Air/Gas Fuel Ratio Control

The ECS monitors the proportion of air and gas fuel to decrease the gases to a minimum and prevent knocking (see paragraph 3.21) and misfires (see paragraph 3.22).

The air mass flow is a closed-loop control related to the scavenge air pressure (see Fig. 21). The exhaust waste gate (see 8135–1 Exhaust Waste Gate) adjusts the scavenge air pressure, related to the engine load and speed.

If necessary, the ECS adjusts the fuel command, to prevent too much scavenge air pressure or too much turbocharger speed.

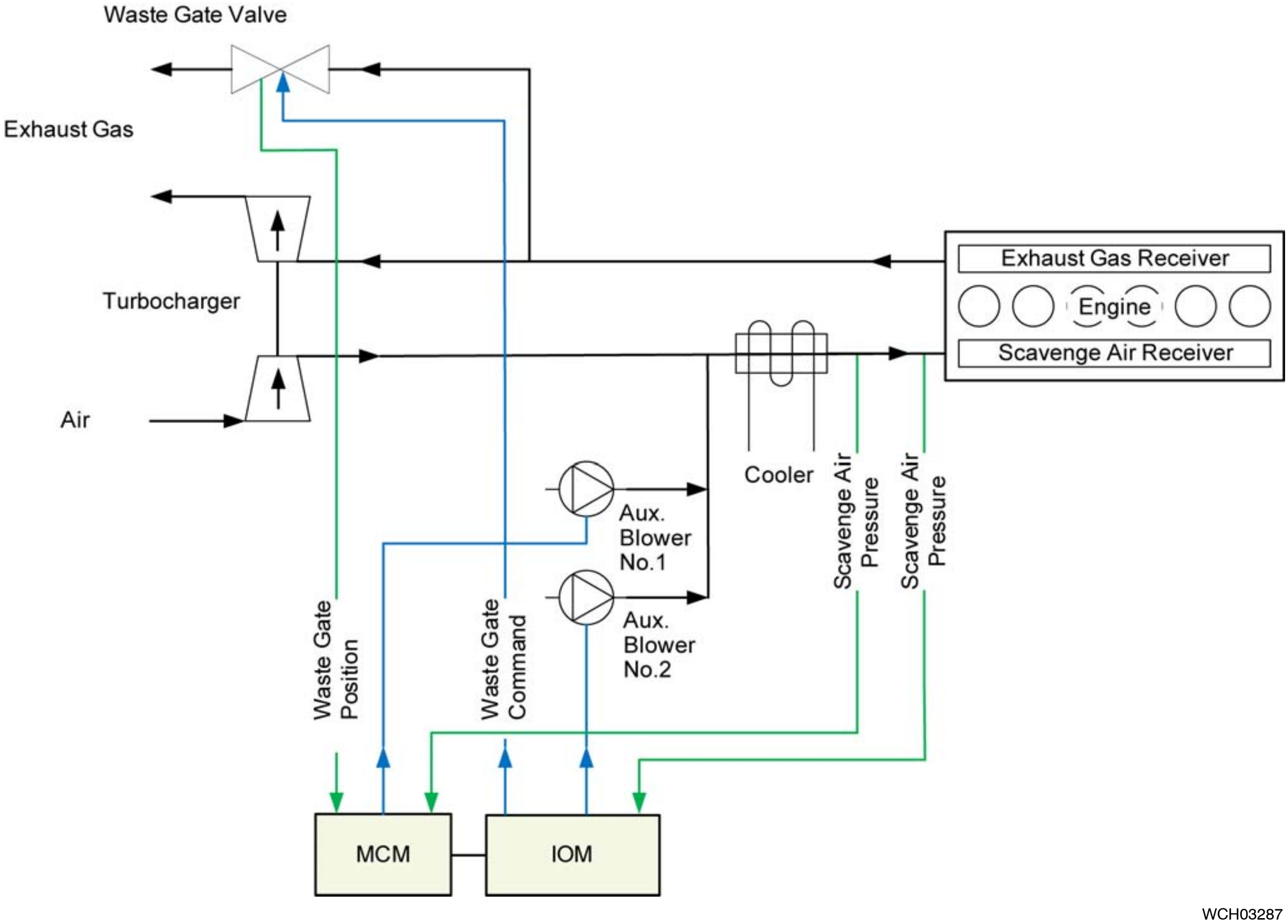



**Fig. 21: Air/Fuel Ration Control**

# 4. External Control Systems

## 4.1 Communication between ECS and External Systems

The Diesel Engine CoNtrol and Optimizing Specification (DENIS) and the ECS are designed so that different remote controls can be used. All nodes are fully specified. The terminal boxes are installed on the engine, to which the cable ends from the control room or from the bridge can be connected.

The engine control has all the parts necessary to operate and monitor the engine, and for the safety of the engine.

The ECS supplies the data communications to the:

- Propulsion control system (PCS)
- Alarm and monitoring system (AMS)
- Gas detection system
- Gas supply system
- Gas valve unit (GVU)

The standard version of ECS includes the external communications that follow:

- Two redundant CANBus lines to the PCS (one CANbus connection to MCM-11 and one connection to the LDU-20 in the engine control room).
- Two redundant Modbus lines to the AMS (one Modbus connection to MCM-11 and one connection to the LDU-20 in the engine control room).

For more data, refer to Fig. 2 and Fig. 22.

**Note: The communications between the systems can be different. See the related documentation from the approved propulsion control system manufacturer.**

## 4.2 Propulsion Control System

The PCS has the subsystems that follow:

- Remote control system (RCS)
- Engine safety system (ESS)
- Telegraph system

**Note: The ESS and telegraph systems operate independently and are fully serviceable if the RCS is defective.**

### 4.2.1 Remote Control System

The RCS has the primary functions that follow:

- Start, stop and reverse
- Automatic slow turning.

Data about the ECS status is available in the RCS. This includes measured values of sensors, defects and other indications (refer to the documentation of the remote control manufacturer).

All commands to operate the engine (e.g. AHEAD or ASTERN), come from the RCS.

If the ECS finds a defect, it sends a signal to the AMS, or a slowdown/shutdown signal to the ESS.

### 4.2.2 Engine Control Room – Manual Control Panel

The manual control panel in the engine control room (ECR) is part of the ECS and installed in the ECR console. The same control functions of the manual control panel are available at the local control panel (see also 4002–2 Local Control Panel/Local Display Display Unit LDU-20).

### 4.2.3 Engine Safety System

The ESS has the primary functions that follow:

- Emergency stop
- Overspeed protection
- Automatic shutdown
- Automatic slowdown.

If there is a defect, the ECS sends a signal to the ESS.

### 4.2.4 Telegraph System

The telegraph system transmits maneuvering signals from the bridge to the ECR and local control panel.

## 4.3 Alarm and Monitoring System

The alarm and monitoring system (AMS) is an external system and monitors the engine. The AMS gives the operator alarms and status data of the engine to make sure of safe and satisfactory engine operation.

The functions of the AMS are specified in the DENIS. The AMS sends signals to the engine safety system to slow down or shut down the engine (see Fig. 2 and Fig. 22.).

For more data, see the documentation of the AMS manufacturer.

## 4.4 Gas Detection System

The gas detection system collects the signals of the gas detectors of the gas supply system and the engine room. If the gas concentration is too high, the gas detection system activates the ESS.

The gas detection system is related to the specified engine, GVU and engine room design. For more data, refer to the documentation of the gas detection system manufacturer.

## 4.5 Gas Supply System

The gas supply system is connected to the RCS and the ESS. The gas supply system controls the gas flow into the GVU and changes between gas fuel and inert gas.

For more data, refer to the documentation of the GVU manufacturer.

## 4.6 Gas Valve Unit

The Gas Valve Unit (GVU) has an isolated control system and is connected to the RCS (control signals) and the ESS (signals for GVU vent and purging). The GVU has a colored human-machine interface (HMI) panel, attached to the control cabinet. The display shows the data that follows:

- Status of the GVU
- Valve position and values from the sensors
- Alarm history
- If applicable, active alarms.

For more data, refer to 8014−1 Gas Fuel System, paragraph 3 and the documentation of the GVU manufacturer.

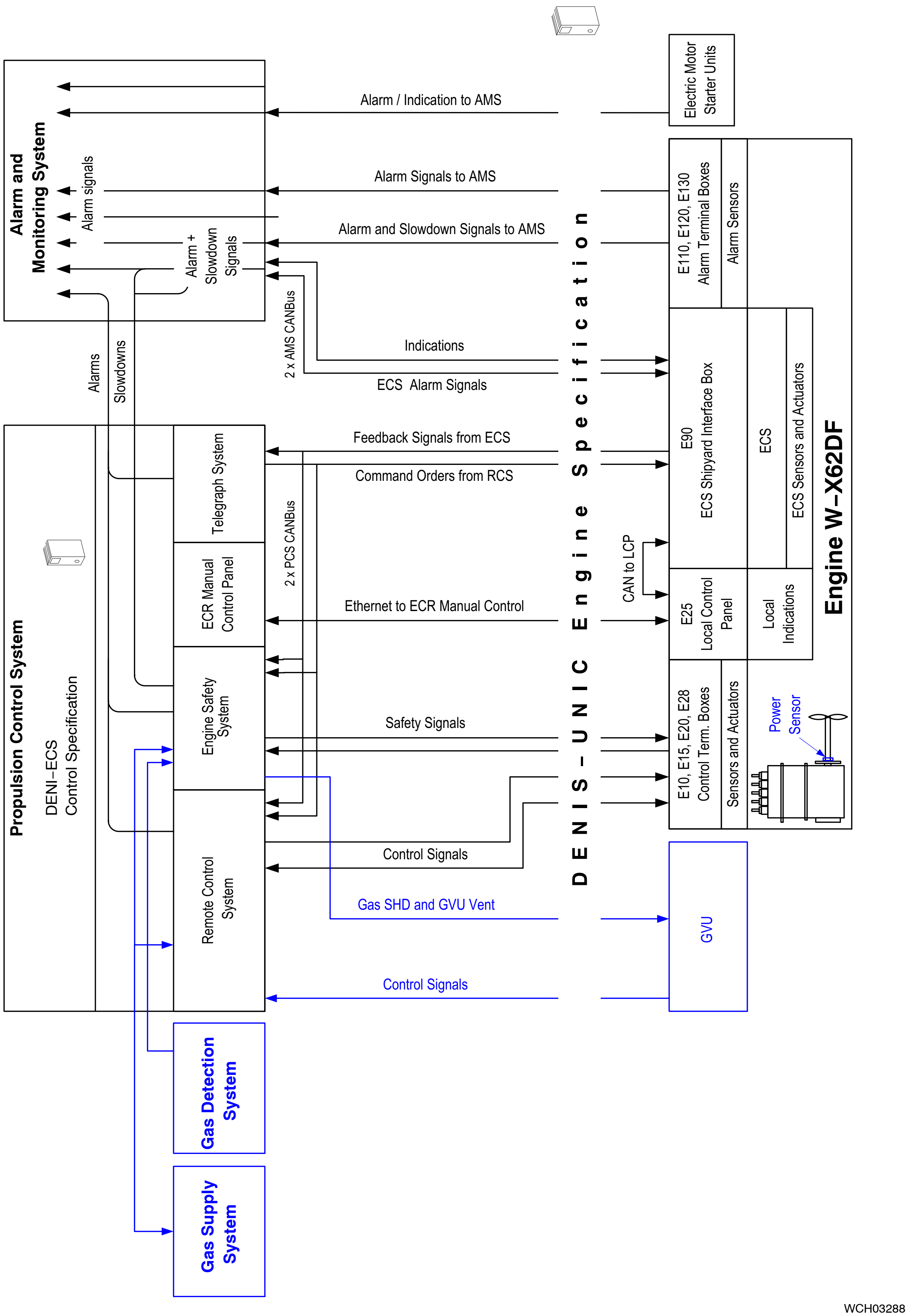



**Fig. 22: Signal Flow Diagram − DENIS-ECS**

# Local Control Panel / Local Display Unit (LDU–20)

# 1. General

The local control panel is attached to the engine at the free end and has the components necessary for engine operation. Because the remote control manufacturer supplies the local control panel, some components can look different.

For data about maneuvering instructions, refer to 4003−1, Engine Control paragraph 3 and 0520−1 Maneuvering.

# 2. Installed Components

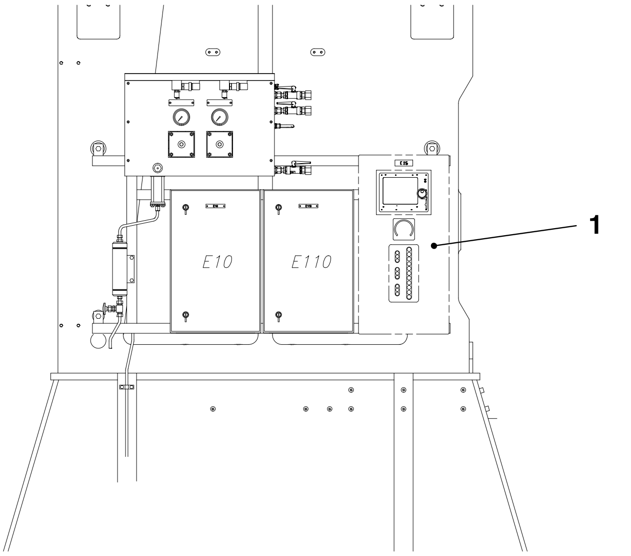
## 2.1 Electronic Components

The local control panel has the electronic components that follow:

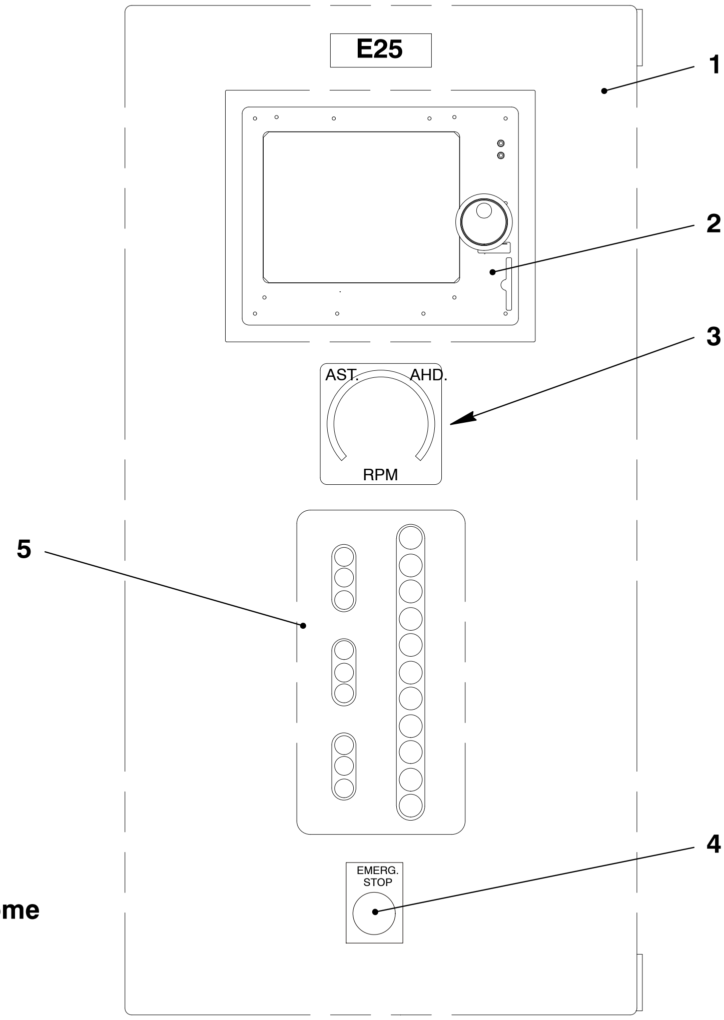
- LDU-20
- ME tachometer
- Emergency stop button
- Telegraph system.

## 2.2 LDU−20

There are two LDU-20 (2, Fig. 1). One LDU-20 is installed in the local control panel. The other LDU-20 is installed in the engine control room. The LDU-20 operate independently from the remote control system. For more data about the LDU-20 and the system description, refer to 4002−1 Engine Control System, paragraph 2.




WCH03289




**Note: Some parts can look different. Some items can be in different positions**

**Fig. 1: Local Control Panel − Location**

1 Local control panel
2 LDU−20
3 ME tachometer
4 Emergency stop button
5 Telegraph receiver

## 2.3 ME Tachometer

The ME tachometer (3, Fig. 1) shows the engine speed in the ahead or astern directions.

## 2.4 Emergency Stop Button

When you operate the emergency stop button (4), the engine stops immediately.

In diesel mode, the fuel pressure control valve 10−5562_E0_5 releases the pressure supply decreases to 0 (zero). For more data, refer to 0600−1 Engine Stop, in the fuel rail (see 5562−1 Pressure Control Valve). At the same time, the fuel pump paragraph 2 Engine Stop − Diesel Mode.

**WARNING**

**Danger: When you operate the emergency stop button during operation in gas mode, gas can stay in the combustion chamber and exhaust gas system. There is a risk of explosion.**

**Note: Before you start the engine, make sure that there is no gas in the combustion chamber and exhaust gas system (refer to 0130−1 Prevention of Explosions in the Exhaust System). For more data, see 0100−1 Safety Precautions and Warnings and 8014−1 Gas Fuel System.**

In gas mode, the engine control system (ECS) automatically changes to diesel mode and the gas shut-off valves and GAV will be closed. For more data, see 0600−1 Engine Stop Procedure, paragraph 3 Engine Stop − Gas Mode.

The operator must reset the engine shutdown in the ECS to start the engine.

## 2.5 Telegraph

The telegraph system is part of the propulsion control system.

## 2.6 Components

The local control panel (1) has the components that follow:

- LDU−20
- Emergency stop button
- Telegraph receiver
- ME tachometer.

## 2.7 Remote Control

### 2.7.1 Components

The remote control has the components that follow:

- RPM indication
- Emergency stop
- Telegraph receiver (auxiliary).

### 2.7.2 Faults

If a fault occurs in the remote control, which prevents engine control from the control room, you can operate the engine from the local control panel.

**CAUTION**

**Damage Hazard: You must only operate the engine during unusual conditions when necessary. You must not leave the maneuvering stand. You must monitor the engine speed frequently to make sure that procedures are immediately done if large differences in engine speed occur.**

# 3. LDU-20

## 3.1 General

The LDU-20 is a multi-purpose module that has an LCD color display (1, Fig. 2), ten multi-function buttons (3 to 7) and a rotary button (2). You can also push the rotary button to select a function.

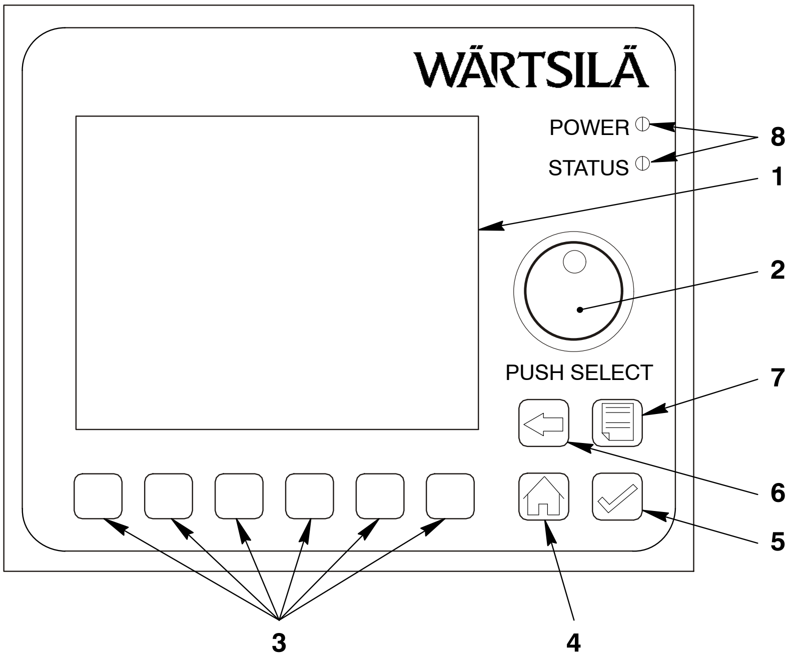



**Fig. 2: LDU–20**

1 Color display
2 Rotary button (16 steps in one turn. Push to select)
3 Multi-function buttons (function is shown on the display)
4 HOME button (shows the main page)
5 CHECK button (used to accept the action or enter data)
6 BACK button (cancels the action or deletes the data)
7 ALARM LIST button (no function)
8 Power/Status LED

## 3.2 User Guide

The LDU-20 shows different pages for each application. After boot–up, or when you push the HOME button, the MAIN page is shown (Fig. 3).

1) To show other pages, push and hold the rotary button for 3 seconds.

The navigation menu shows on the display. You use the rotary button to select a page.

When you push the rotary button, the navigation menu closes and the selected page shows.

2) If no more pages are necessary, push the BACK button to close the navigation menu.

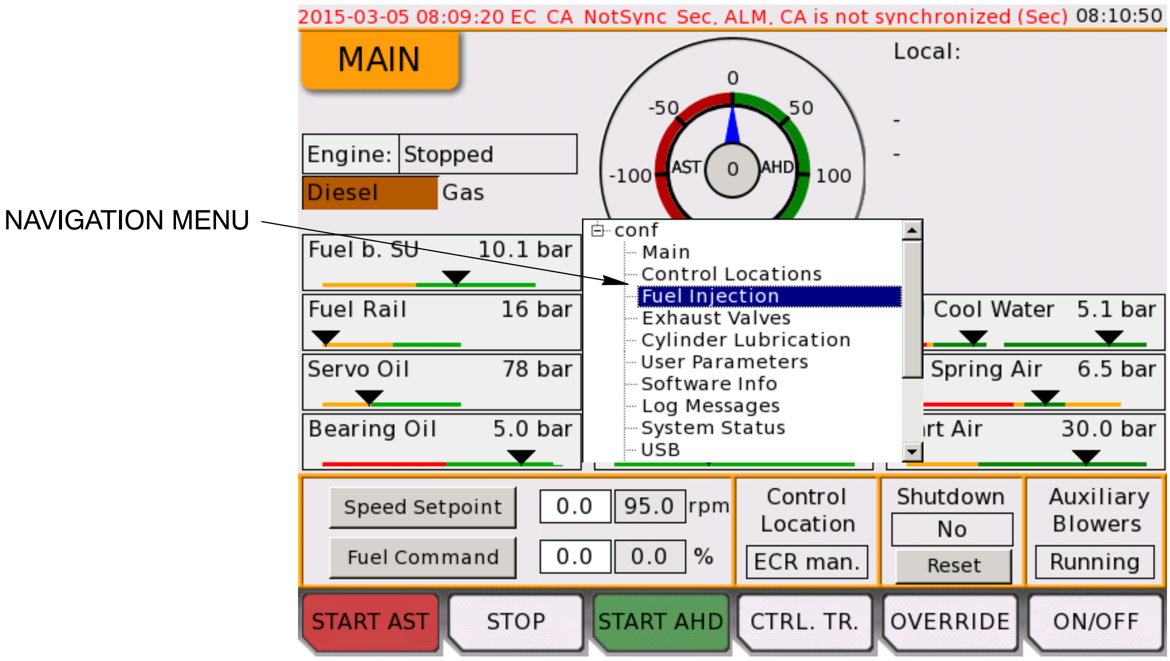



**Fig. 3: User Guide**

On all pages, you use the rotary button to navigate through the on-screen items. A black cursor frame around the item (Fig. 4) shows that the item is active. You turn the rotary button one step clockwise to highlight / access the next item. You turn the rotary button counterclockwise to highlight / access the item before.


**Fig. 4: Cursor Frame**

Some elements are shown on all pages as follows:

- In the top right-hand corner, the system time is shown above the title bar.
- Below the system time, Local or Control is shown. If the LDU is the active control location, the words In Control are shown.
- The bottom of the screen has some space to show the function of the multi-function buttons.

## 3.3 MAIN Page

The MAIN page shows:

- After you start the LDU–20, or
- When the HOME button is pushed during LDU–20 operation.

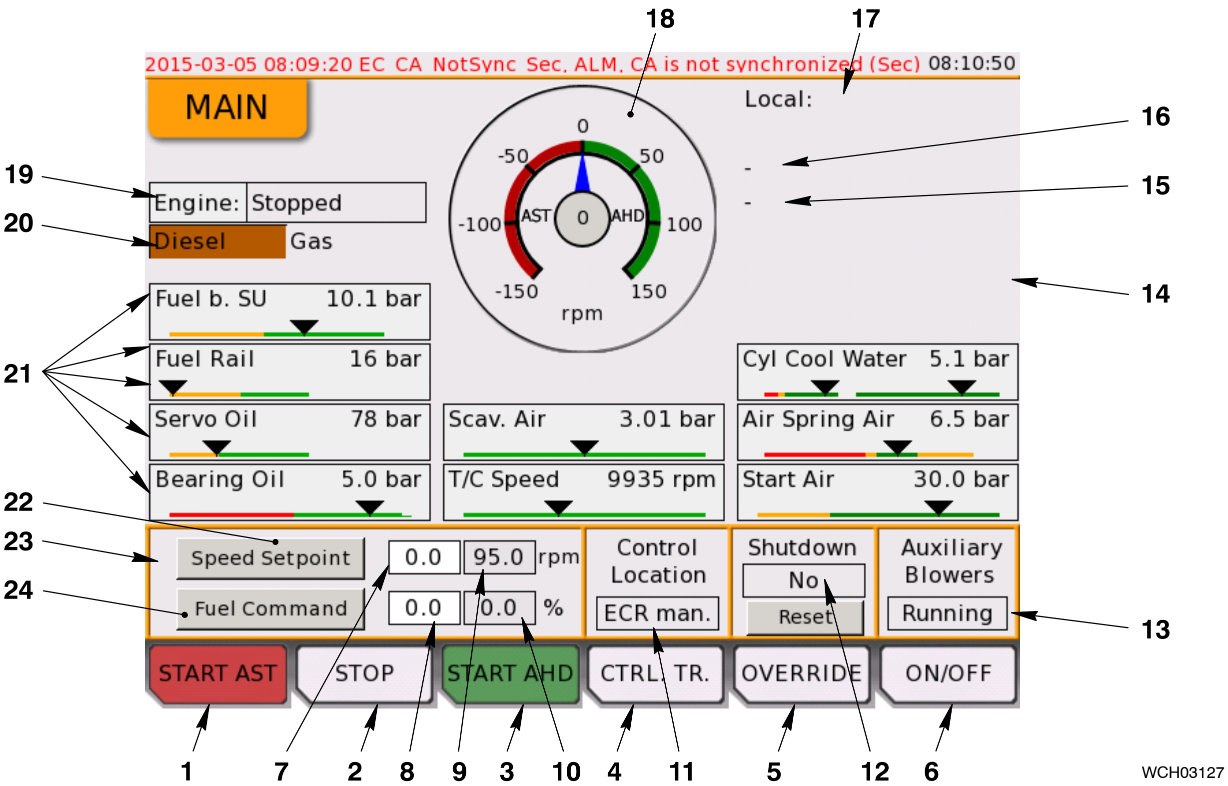



**Fig. 5: MAIN Page**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST tab | Starts the engine in astern direction |
| 2 | STOP tab | Stops the engine |
| 3 | START AHD tab | Starts the engine in ahead direction |
| 4 | CTRL. TR. tab | Sends a signal for a control transfer to this LDU |
| 5 | OVERRIDE tab | Cancels shutdown from the safety system |
| 6 | ON/OFF button | Sets the auxiliary blowers off or on |
| 7 | Manual speed setpoint | The rotary button is used to adjust between 0 rpm to maximum rpm. The maximum value is related the installation specifications (rating etc) |
| 8 | Manual fuel command setpoint | The rotary button is used to adjust between 0% and 150% |
| 9 | External speed setpoint | Shows the setpoint sent to the ECS from the remote control system |
| 10 | Used fuel command | Shows the fuel command used for injection |
| 11 | Control location | Can be Local, ECR manual, ECR remote or Bridge |

| Item | Function | Effect |
|---|---|---|
| 12 | Indication of shutdown | Shows either Yes or No |
| 13 | Auxiliary Blower status | Shows either Stopped or Running |
| 14 | Turning gear status | Shows the conditions that follow: Turning gear ENGAGED or no data available. |
| 15 | Starting air shut-off valve status | Shows the conditions that follow: Starting air shut-off valve CLOSED or no data available. |
| 16 | Control transfer request indication | Text flashes to show a transfer request if one control location requests a control transfer |
| 17 | Indication of this LDU | Shows if Local has control, or does not have control |
| 18 | Engine speed gauge | Shows engine rpm in ahead (AHD) or astern (AST) direction |
| 19 | Engine status | Shows the engine status<br>Shows: Start interlock, Stopped, Slow turning, Air Run, Starting, Heavy Start, Running or Shut-down |
| 20 | Operation mode status | Shows the operation mode. Either DIESEL or GAS is highlighted in orange |
| 21 | Different sensor indications | Necessary to operate the engine locally |
| 22 | Speed Setpoint button | Arrows shows the selected mode: Speed control mode or Fuel control mode |
| 23 | Indication of active manual control mode | The rotary button is used to change to manual speed control mode |
| 24 | Fuel Command button | The rotary button is used to change to manual fuel command mode |

### 3.3.1 Procedures – Operate the Engine from the Main Page

1) To operate the engine from the main page, first make sure that the LDU-20 is the active control location (11 and 17, Fig. 5). If necessary, select the CTRL.TR button to transfer control.

2) To change modes, move the cursor on the related button (23 or 24) then push the rotary button.

**Note: If the MCM-11 becomes defective, a fuel command mode is selected automatically.**

3) To adjust the speed or fuel command setpoint, move the cursor to the related field (7 or 8) then push the rotary button to enter the edit mode.

- While in edit mode, the text field has an orange frame. Turn the rotary button to adjust the set point (turn clockwise to increase, counterclockwise to decrease).

**Note: The changes have an immediate effect on the engine.**

4) To go out of the edit mode, push the rotary button again.

## 3.4 Control Locations

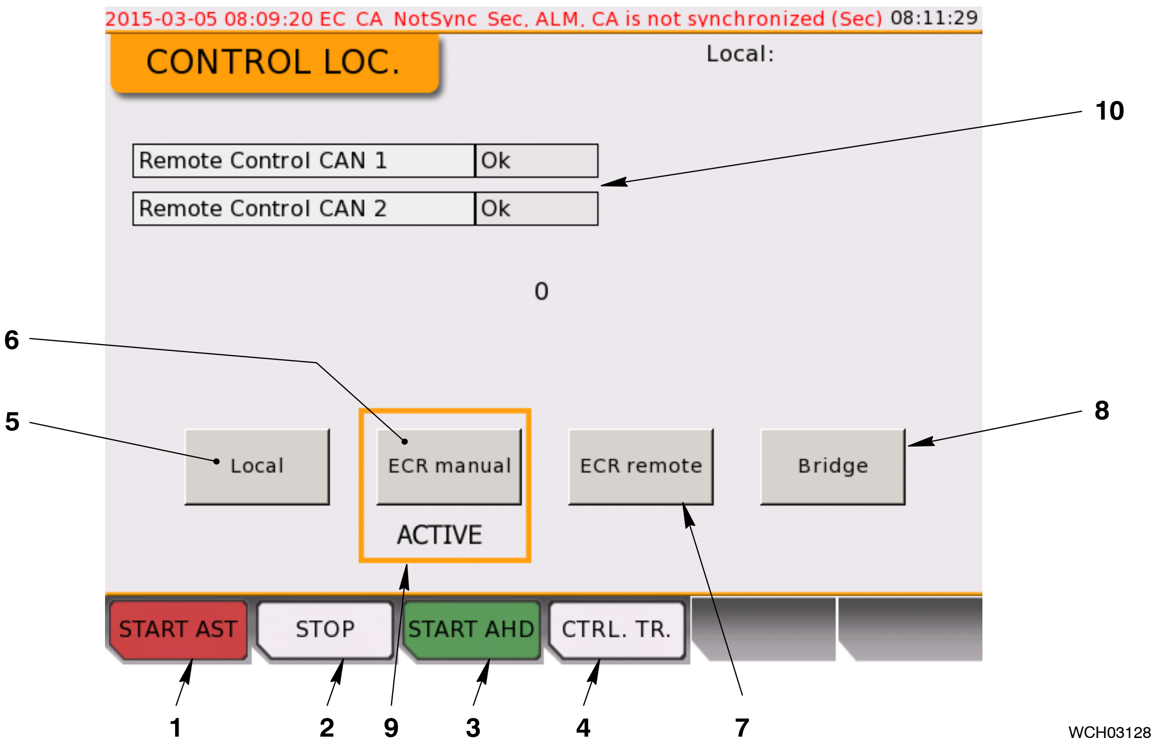



**Fig. 6: Control Locations Page**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP button | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for control to this LDU |
| 5 | Local on-screen button | Sends a signal, or accepts a control transfer to/from the LDU on the engine |
| 6 | ECR manual button | Sends a signal, or accepts a control transfer to/from the LDU in the ECR |
| 7 | ECR remote button | Sends a signal, or accepts a control transfer to/from the remote control system in the ECR |
| 8 | Bridge button | Sends a signal, or accepts a control transfer to/from the remote control system on the bridge |
| 9 | ACTIVE frame | Indicates which of the four possible locations is in control of the engine |
| 10 | CAN 1/2 status | Shows the status of the two redundant CANbus lines between the ECS and the remote control system. Shows Ok, or Error |

### 3.4.1 Procedure – Change the Control Location

1) Push the CTRL. TR. button (4, Fig. 6) to accept control to the LDU at your location.
2) To get/accept control to/from a different location, select the related on-screen button, then push the CHECK ✓ button (5, Fig. 2).

## 3.5 Cylinder Balancing (Diesel Mode)

This cylinder balancing page shows data about the combustion process for each cylinder and related sensor indications in diesel mode (Fig. 7). For more data about the cylinder balancing, refer to 4002–1, Engine Control System, paragraph 3.10.

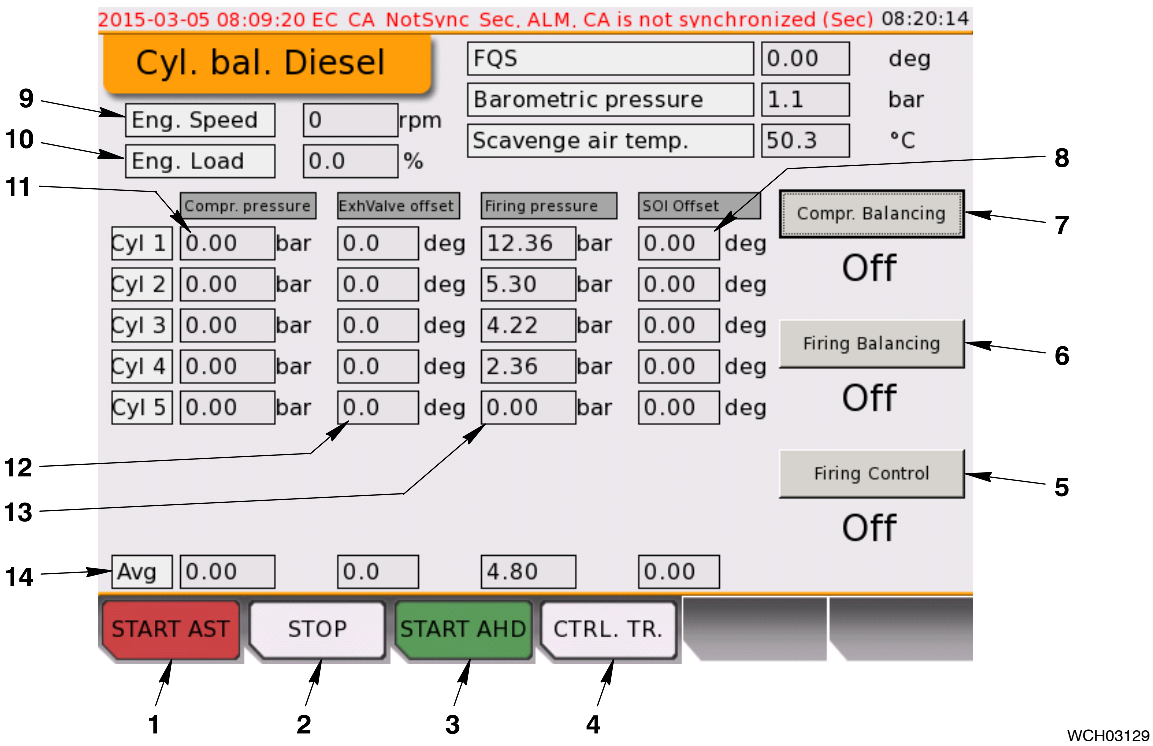



**Fig. 7: Cylinder Balancing Control Page (Diesel Mode)**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP tab | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for control transfer to this LDU |
| 5 | Firing control status | Shows either OFF or ON |
| 6 | Firing balancing status | Shows either OFF or ON |
| 7 | Compression balancing status | Shows either OFF or ON |
| 8 | Start of injection (SOI) offset | Shows the injection time offset for each cylinder |
| 9 | Engine Speed | Shows the engine speed in revolutions per minute (rpm) |
| 10 | Engine Load | Shows the engine load in percent (%) |
| 11 | Compression pressure | Shows the compression pressure for each cylinder |
| 12 | Exhaust valve offset | Shows the exhaust valve closing time offset for each cylinder |
| 13 | Firing pressure | Shows the firing pressure for each cylinder |
| 14 | Average value | Shows the average value of the related column |

## 3.6 Cylinder Balancing (Gas Mode)

This cylinder balancing page shows data about the combustion process for each cylinder and related sensor indications in gas mode (see Fig. 8). For more data about cylinder balancing, refer to 4002–1, paragraph 3.10.

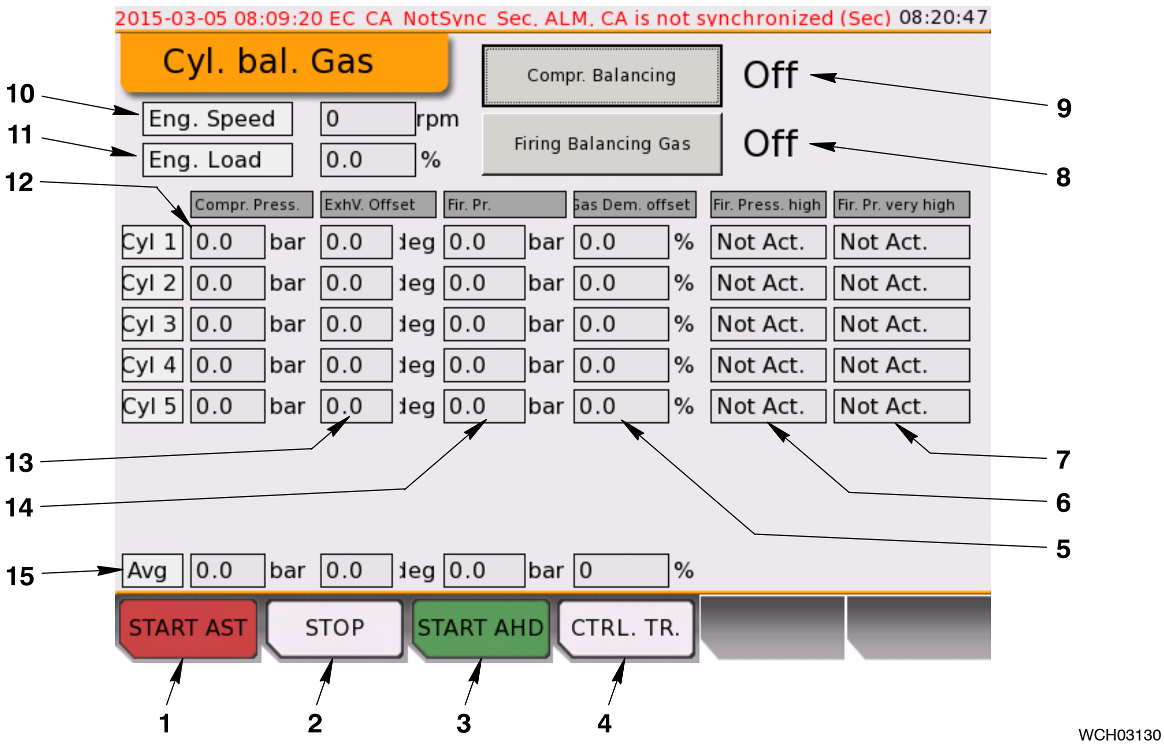



**Fig. 8: Cylinder Balancing Control Page Gas**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP tab | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for a control transfer to this LDU |
| 5 | Gas dem. offset | Shows the individual offsets of the gas demand |
| 6 | Firing pressure high | Shows either NOT ACTIVE or ACTIVE |
| 7 | Firing pressure very high | Shows either NOT ACTIVE or ACTIVE |
| 8 | Firing balancing gas status | Shows either OFF or ON |
| 9 | Compression balancing status | Shows either OFF or ON |
| 10 | Engine Speed | Shows the engine speed in revolutions per minute (rpm) |
| 11 | Engine Load | Shows the engine load in percent (%) |
| 12 | Compression pressure | Shows the compression pressure for each cylinder |
| 13 | Exhaust valve offset | Shows the exhaust valve closing time offset for each cylinder |
| 14 | Firing pressure | Shows the firing pressure for each cylinder |
| 15 | Average | Shows the average value of the related column |

## 3.7 Diesel Fuel Injection

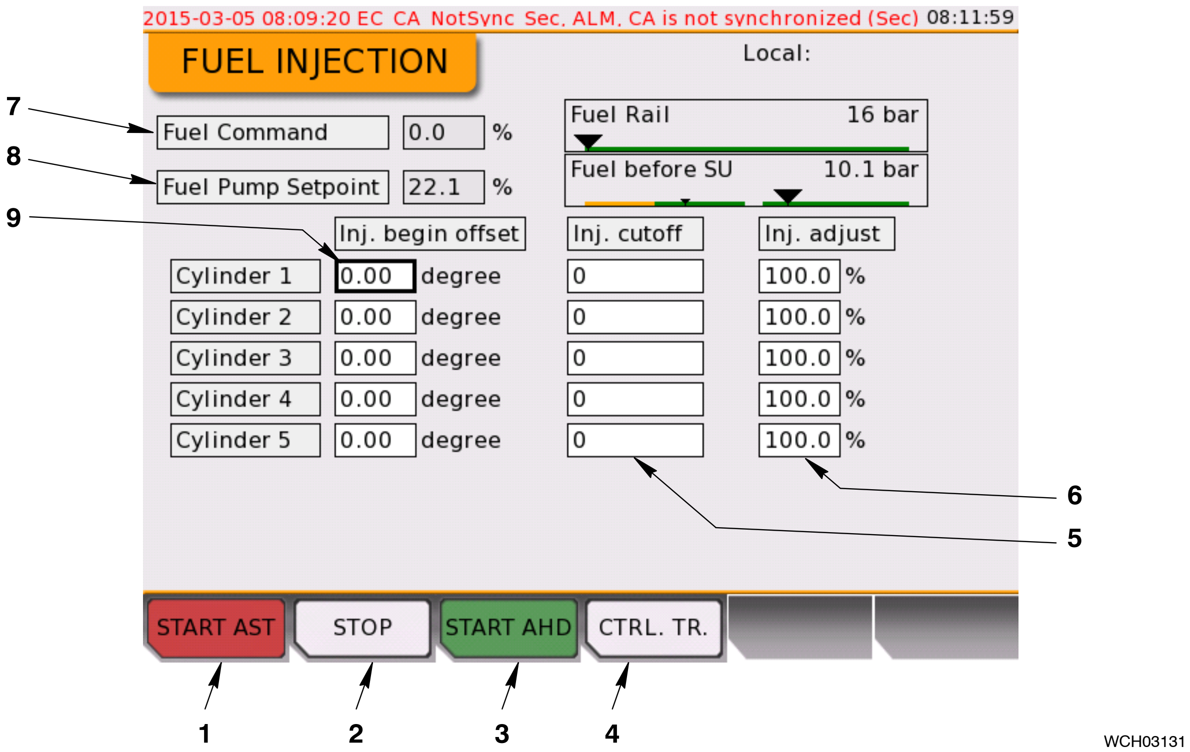



**Fig. 9: Fuel Injection Page**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP tab | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for a control transfer to this LDU |
| 5 | Injection cutoff | Adjustable parameter; 0 = usual operation<br>1 = cylinder cut-off (no injection)<br>Can be used to stop fuel injection to a specified cylinder if necessary (e.g. liner/piston ring problems or damaged injection system).<br>The exhaust valve stays in usual operation. |
| 6 | Injection adjust | Used to fine-tune the total amount of injected fuel for each cylinder. Can be adjusted from 80% to 110%<br>100% = usual injection quantity<br>Can be decreased to 80% for each cylinder<br>Used to operate in one cylinder or if there are operation problems in more than one cylinder |
| 7 | Fuel Command | Shows the used fuel command value for injection (0% to 150%) |
| 8 | Fuel Pump Setpoint | Shows the capacity at which the fuel pumps must operate (0% to 100%) |
| 9 | Injection begin offset | Adjustable parameter: ±1.5 degrees<br>Cylinder pressure fine tuning in service:<br>Lets you adjust to the maximum firing pressure |

### 3.7.1 Procedure – Adjust the Diesel Fuel Injection Parameters

1) To adjust the diesel fuel injection parameters, turn the rotary button to move the cursor to the related text field (see Fig. 9). Push the rotary button to enter the edit mode.
2) Turn the rotary button to adjust the value (turn clockwise to increase, or counterclockwise to decrease). Push the rotary button again to go out of the edit mode.

## 3.8 Fuel Mode Control

The fuel mode page shows data about the selected fuel mode of the engine (see Fig. 10). The operator can see the applicable data (e.g. engine status, engine speed) and can manually change from one fuel mode to the other (diesel mode or gas mode).

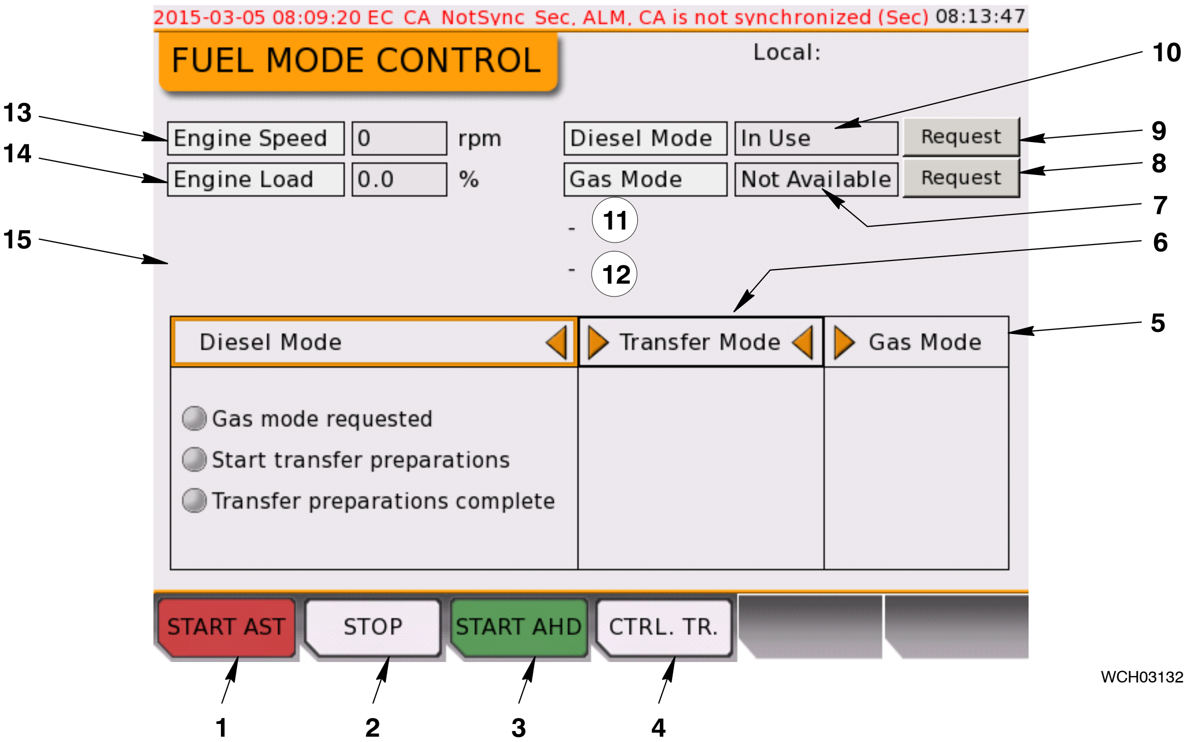



**Fig. 10: Fuel Mode Page**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Start the engine in astern direction |
| 2 | STOP tab | Stop the engine |
| 3 | START AHD button | Start the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for a control transfer to this LDU |
| 5 | Gas Mode | Use the rotary button to select the GAS MODE item. An orange frame shows if the item is active. |
| 6 | Transfer Mode | Use the rotary button to select the Transfer Mode item. An orange frame shows if the item is active. Data messages that are shown in the transfer mode column give data about available fuel modes. |
| 7 | Gas Mode Status | Shows if the gas mode or the transfer to the gas mode is possible. Shows either Available or Not Available |
| 8 | Gas Mode Request | Sends a signal for a transfer to gas mode |
| 9 | Diesel Mode Request | Sends a signal for a transfer to diesel mode |
| 10 | Diesel Mode Status | Shows the status of the diesel mode. Shows either In Use or Limited Gas Mode Request button (NA) |

| Item | Function | Effect |
|---|---|---|
| 11 | Data Messages | Shows data messages if the engine operates in gas mode and a signal to transfer to diesel mode is sent (also if the diesel mode shows LIMITED) |
| 12 | Data Messages | Shows data messages. If the messages displayed before are shown, the operator must push the diesel mode request button again. If the operator does not push the diesel mode request button after a period, all messages will disappear and the engine continues to operate in gas mode. |
| 13 | Engine Speed | Shows the engine speed in revolutions per minute (rpm) |
| 14 | Engine Load | Shows the engine load in percent (%) |
| 15 | Diesel Mode | Use the rotary button to select the DIESEL MODE item.<br>An orange frame shows if the item is active.<br>In the diesel mode column data is given as follows:<br>● GAS MODE REQUEST – The indicator shows green when the gas mode signal is accepted<br>● START TRANSFER PREPARATIONS – The indicator shows green when the transfer from diesel mode to gas mode starts<br>● TRANSFER PREPARATIONS COMPLETE – The indicator shows green when the preparations are done and the gas admission is active |

## 3.9 Pilot Fuel

The pilot fuel page shows data about the pilot fuel injection system (Fig. 11). The operator can see necessary data (e.g. engine speed, injection pressure and setpoint).

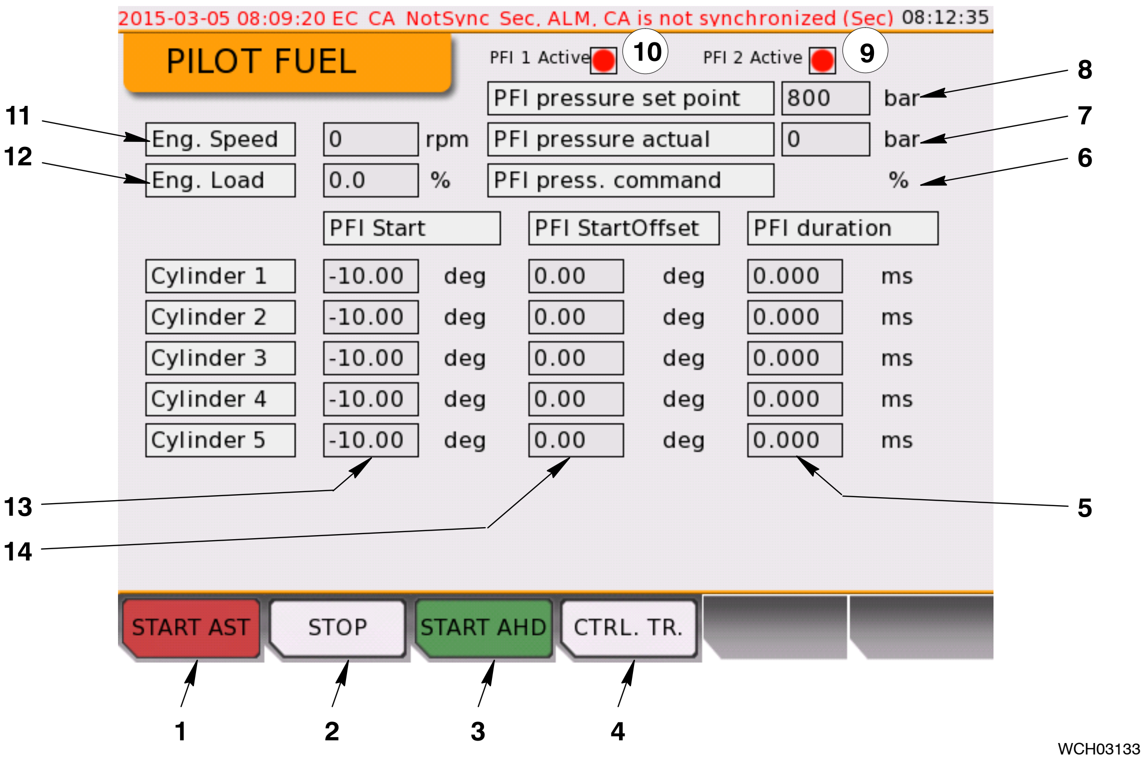



**Fig. 11: Pilot Fuel Page**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP tab | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for a control transfer to this LDU |
| 5 | PFI duration | Shows the period of the pilot fuel injection for each cylinder |
| 6 | PFI pressure command | Shows the used pilot fuel control command value (%) for the pilot fuel pump |
| 7 | PFI pressure actual | Shows the pilot fuel pressure (bar) |
| 8 | PFI pressure set point | Shows the used pilot fuel pressure setpoint (bar) |
| 9 | PFI 1 active | Shows the operation status of pilot fuel valve No. 1. An indicator shows green (active) or red (not active). |
| 10 | PFI 2 active | Shows the operation status of the pilot fuel valve No. 2. An indicator shows green (active) or red (not active). |
| 11 | Engine speed | Shows the engine speed in revolutions per minute (rpm) |
| 12 | Engine load | Shows the engine load in percent (%) |
| 13 | PFI start | Shows the pilot fuel start for each cylinder |
| 14 | PFI StartOffset | Shows the start offset for each cylinder |

## 3.10 Pilot Fuel Pressure

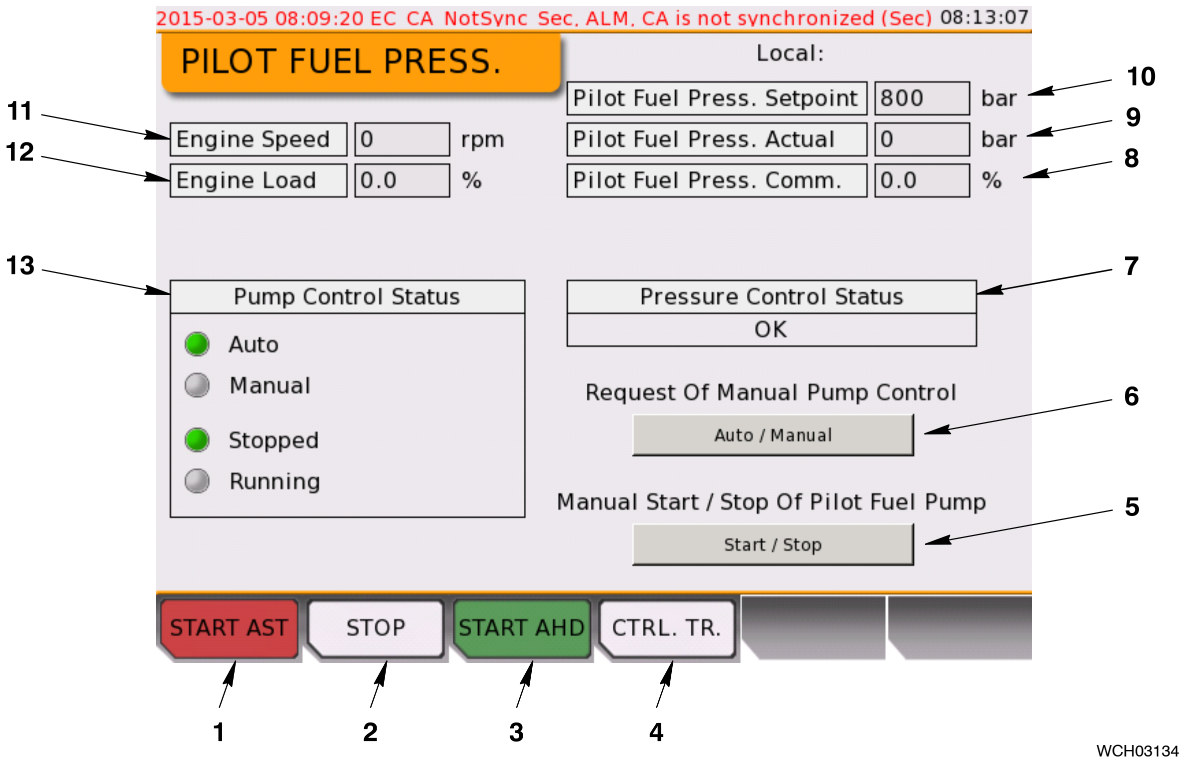



**Fig. 12: Pilot Fuel Pressure Page**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP tab | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for a control transfer to this LDU |
| 5 | Manual Start/Stop of the pilot fuel pump | Sends a signal for a manual start/stop of the pilot fuel pump.<br>Move the cursor to the related button, then push the rotary button to start/stop the pilot fuel pump |
| 6 | Manual pilot fuel pump control request | Sends a signal for the manual control of the pilot fuel pump.<br>Move the cursor to the related button, then push the rotary button to change the pilot fuel pump control (either AUTO or MANUAL) |
| 7 | Pilot fuel pressure control status | Shows either OK or FAILED |
| 8 | Pilot fuel pressure command | Shows the used value (%) of the pilot fuel pressure control command for the pilot fuel pump |
| 9 | Pilot fuel pressure actual | Shows the pilot fuel pressure (bar) |
| 10 | Pilot fuel pressure set point | Shows the used pilot fuel pressure setpoint (bar) |

| Item | Function | Effect |
|---|---|---|
| 11 | Engine Speed | Shows the engine speed in revolutions per minute (rpm) |
| 12 | Engine Load | Shows the engine load in percent (%) |
| 13 | Pump Control Status | Shows the conditions that follow: Pilot fuel pump control AUTO or MANUAL and pilot fuel pump operation STOPPED or RUNNING. A green indicator shows which item is active. |

## 3.11 Gas Fuel

The gas fuel page shows data about the gas fuel system (Fig. 13). The operator can see the necessary data (e.g. engine speed, gas pressure and gas flow).

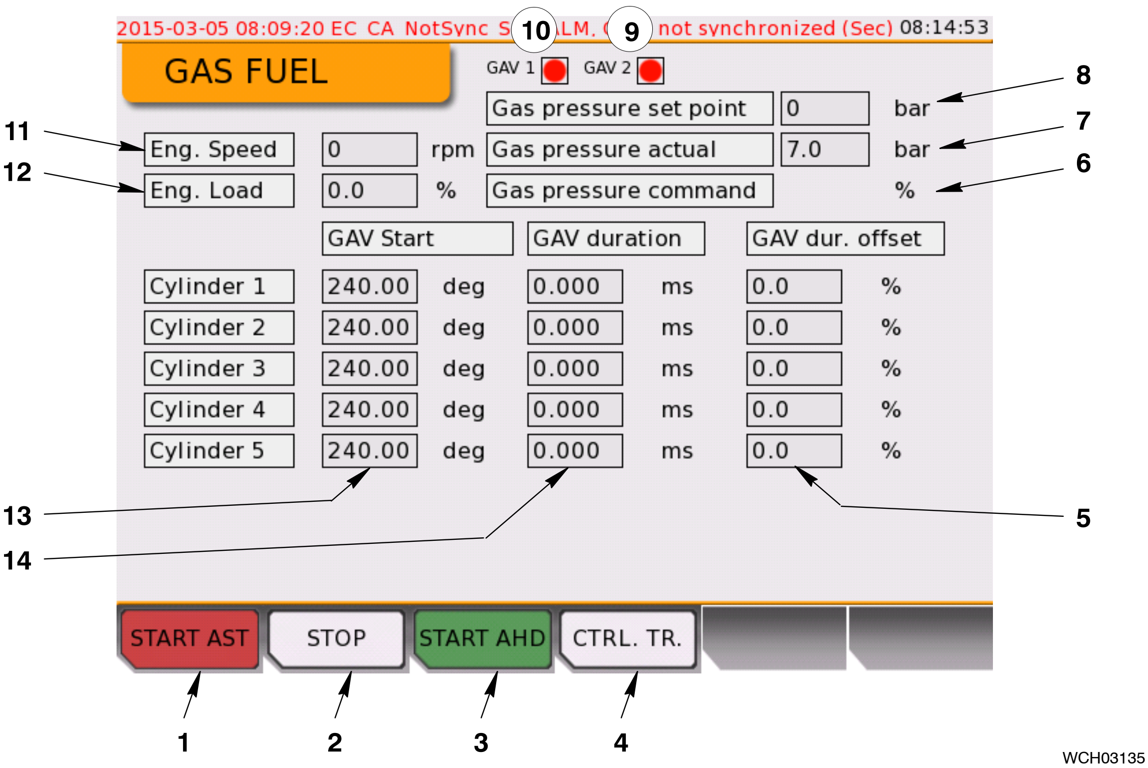



**Fig. 13: Gas Fuel Page**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP tab | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for a control transfer to this LDU |
| 5 | GAV dur. offset | Shows the gas admission valve start-offset for each cylinder |
| 6 | Gas pressure command | Shows the used value (%) of the gas fuel pressure control for the pressure regulating valve |
| 7 | Gas pressure actual | Shows the gas fuel pressure (bar) |
| 8 | Gas pressure set point | Shows the used gas fuel pressure setpoint (bar) |

| Item | Function | Effect |
|---|---|---|
| 9 | GAV 2 | Shows the operation status of the gas admission valve No. 2. An indicator shows green (active) or red (not active). |
| 10 | GAV 1 | Shows the operation status of the gas admission valve No. 1. An indicator shows green (active) or red (not active). |
| 11 | Engine speed | Shows the engine speed in revolutions per minute (rpm) |
| 12 | Engine load | Shows the engine load in percent (%) |
| 13 | GAV start | Shows the gas admission valve operation start for each cylinder |
| 14 | GAV duration | Shows the duration of the gas admission valve operation. |

## 3.12 Gas Fuel Pressure

The pilot fuel page shows data about the gas fuel system (Fig. 14). The operator can see the necessary data (e.g. engine speed, gas pressure).

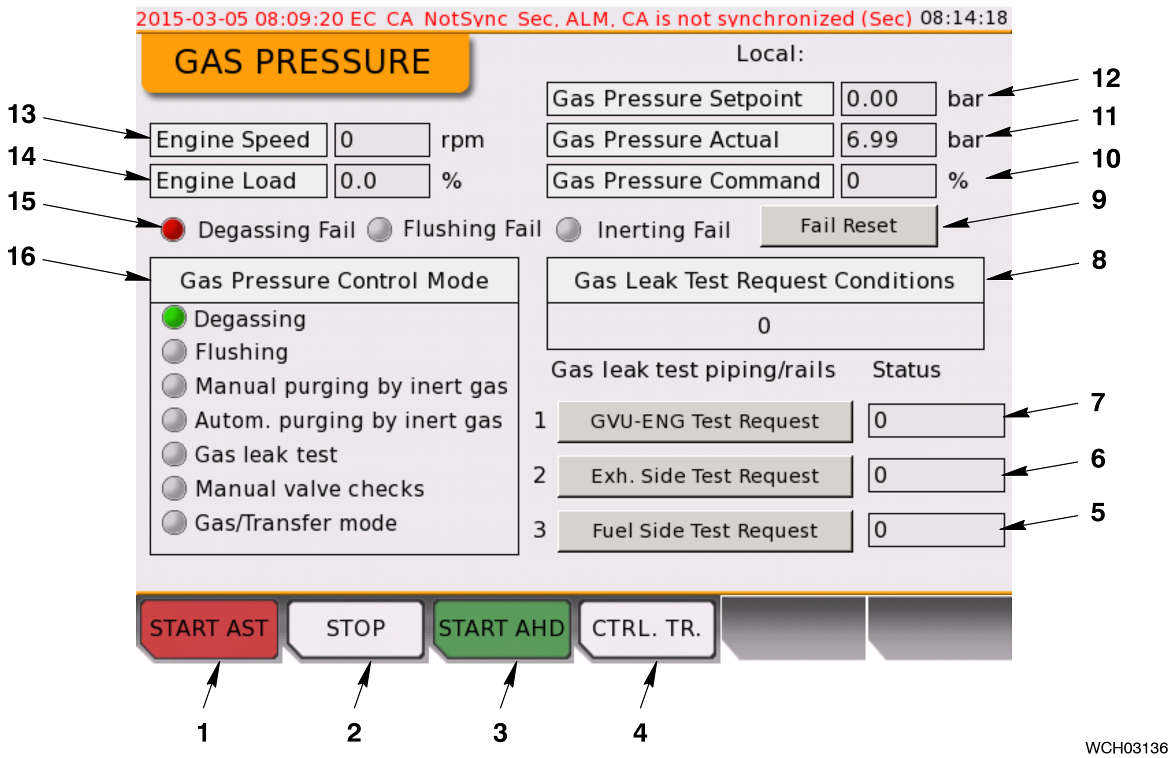



**Fig. 14: Gas Fuel Pressure Page**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP tab | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for a control transfer to this LDU |
| 5 | Fuel side test request (gas leak test pipes/rails) | Sends a signal for a gas leak test of the pipes (fuel side). Move the cursor to the related button, then push the rotary button to send a signal. |
| 6 | Exhaust side test request (gas leak test pipes/rails) | Sends a signal for a gas leak test of the pipes (exhaust side).<br>Move the cursor to the related button, then push the rotary button to send a signal. |
| 7 | GVU–ENG test request (gas leak test pipes/rails) | Sends a signal for a gas leak test of the pipes between the gas valve unit (GVU) and the engine.<br>Move the cursor to the related button, then push the rotary button to send a signal. |
| 8 | Gas leak test request conditions | Shows the condition of the gas leak test.<br>0 = not satisfactory<br>1 = satisfactory |

| Item | Function | Effect |
|---|---|---|
| 9 | Failure reset | Sets again the failures (degassing, flushing, inerting) |
| 10 | Gas pressure command | Shows the used value (%) of the gas fuel pressure control command for the pressure regulating valve |
| 11 | Gas pressure actual | Shows the gas fuel pressure (bar) |
| 12 | Gas pressure set point | Shows the used gas fuel pressure setpoint (bar) |
| 13 | Engine Speed | Shows the engine speed in revolutions per minute (rpm) |
| 14 | Engine Load | Shows the engine load in percent (%) |
| 15 | Failure status | Shows active failures (degassing, flushing, inerting). A red indicator shows which item is active. |
| 16 | Gas pressure control mode | Shows the active mode of the gas pressure control. A green indicator shows which item is active. |

## 3.13 GVU and Shut-off Valve Test

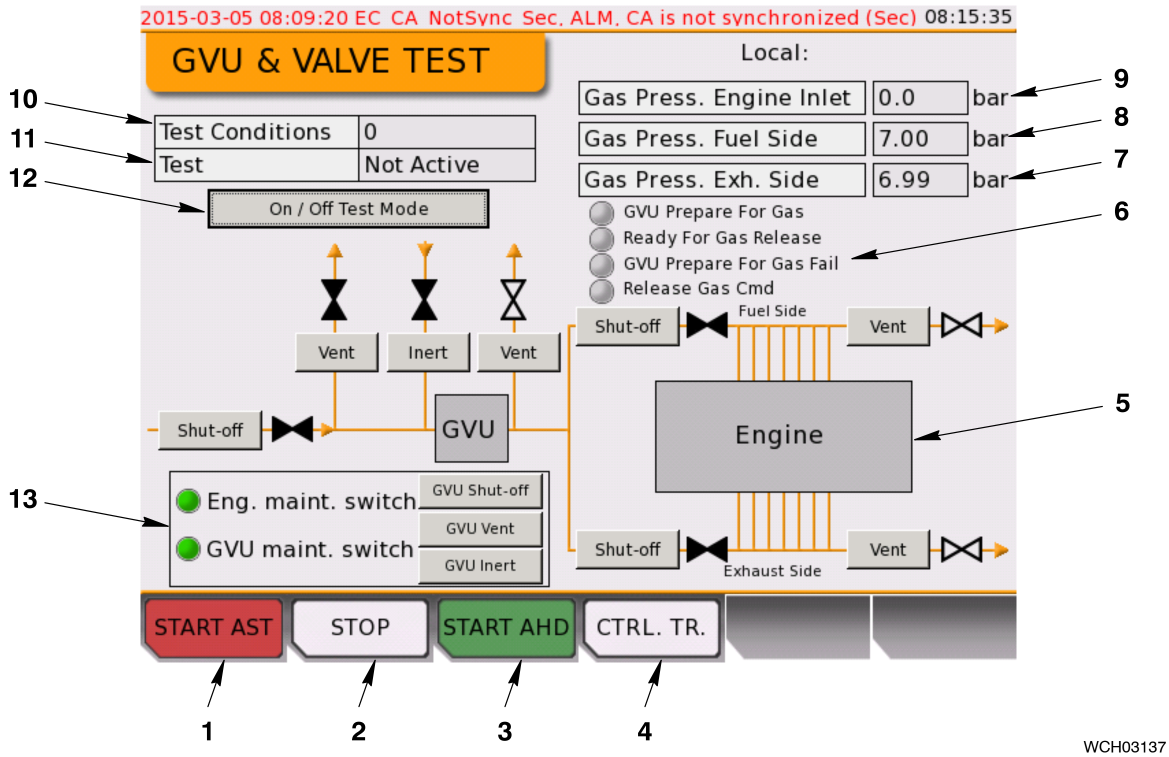



**Fig. 15: GVU and Shut-off Valve Test Page**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP tab | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for a control transfer to this LDU |
| 5 | Engine schematic | Shows the status of the GVU/Valve test<br>In Fig. 15 above, the valve symbol shows the status of the related valve as follows:<br>● black fill = valve closed<br>● no fill = valve open |
| 6 | Test mode status | Shows data about the control sequence of the GVU/Valve test (between the GVU and ECS). |
| 7 | Gas pressure exhaust side | Shows the gas pressure (exhaust side) |
| 8 | Gas pressure fuel side | Shows the gas pressure (fuel side) |
| 9 | Gas pressure engine inlet | Shows the gas pressure at the engine inlet. |
| 10 | Test conditions | Shows the test condition<br>0 = not satisfactory<br>1 = satisfactory |

| Item | Function | Effect |
|---|---|---|
| 11 | Test status | Shows the test status (ACTIVE or NOT ACTIVE) |
| 12 | On/Off Test Mode button | Sets the GVU/Valve test to ON or OFF.<br>Move the cursor to the related button, then push the rotary button to start/stop the pilot fuel pump |
| 13 | Maintenance mode status | Shows the control mode status of the GVU. A green indicator shows if an item is active.<br>If each of the two indicators (engine maintenance switch and GVU maintenance switch) show green the GVU is in automatic mode.<br>If one indicator (engine maintenance switch or GVU maintenance switch) shows green the GVU is in maintenance mode.<br>The buttons have the functions that follows:<br>• GVU SHUT-OFF − Starts the operation (open/close) of the GVU shut-off valves<br>• GVU VENT − Starts the operation of the GVU vent valves<br>• GVU INERT − If the GVU maintenance mode is active, this button sends a signal for the inert procedure of the GVU |

## 3.14 GAV Manual Valve Test

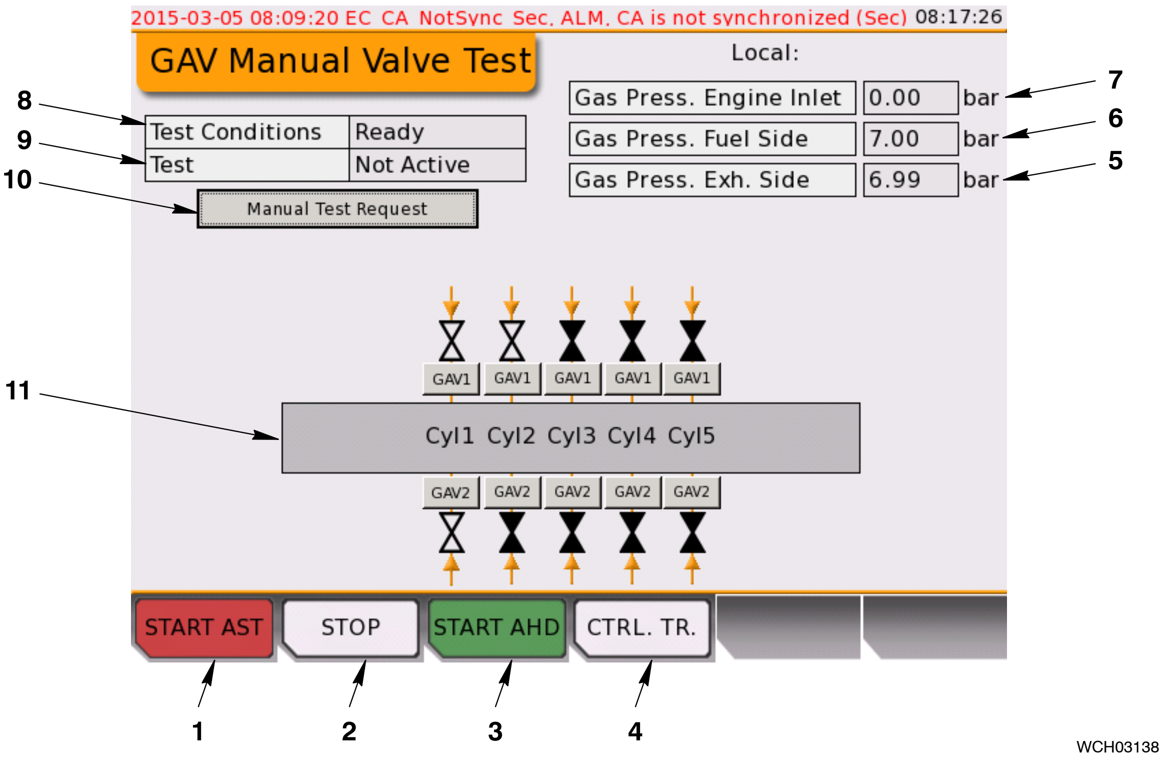



**Fig. 16: GAV Manual Valve Test Page**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP tab | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for a control transfer to this LDU |
| 5 | Gas pressure exhaust side | Shows the gas pressure (exhaust side) |
| 6 | Gas pressure fuel side | Shows the gas pressure (fuel side) |
| 7 | Gas pressure engine inlet | Shows the gas pressure at the engine inlet. |
| 8 | Test conditions | Shows the active test condition (READY or NOT READY) |
| 9 | Test status | Shows the test status (ACTIVE or NOT ACTIVE) |
| 10 | Manual test request | Sends a signal for a manual test of the gas admission valves.<br>Move the cursor to the related button, then push the rotary button to send a signal. |
| 11 | Engine schematic diagram | Shows a schematic diagram of the gas admission valves on the cylinders. In the schematic diagram, the valve symbol shows the status of the related valve as follows:<br>● black fill = valve closed<br>● no fill = valve open |

## 3.15 Knock Status

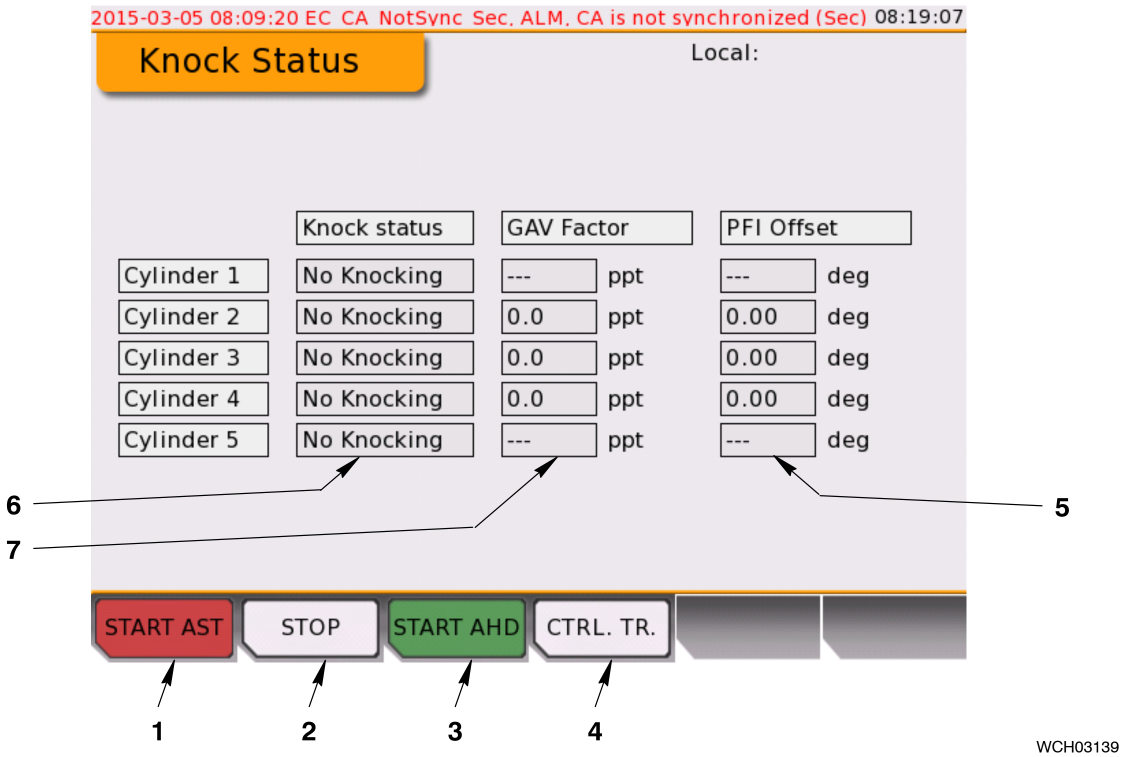



Fig. 17: Knock Status Page

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP tab | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for a control transfer to this LDU |
| 5 | PFI Offset | Shows the pilot fuel injection offset (deg) |
| 6 | Knock status | Shows the knock status (No Knocking, Light Knocking or Heavy Knocking) |
| 7 | GAV factor | Shows the GAV correction factor |

## 3.16 Crank Angle

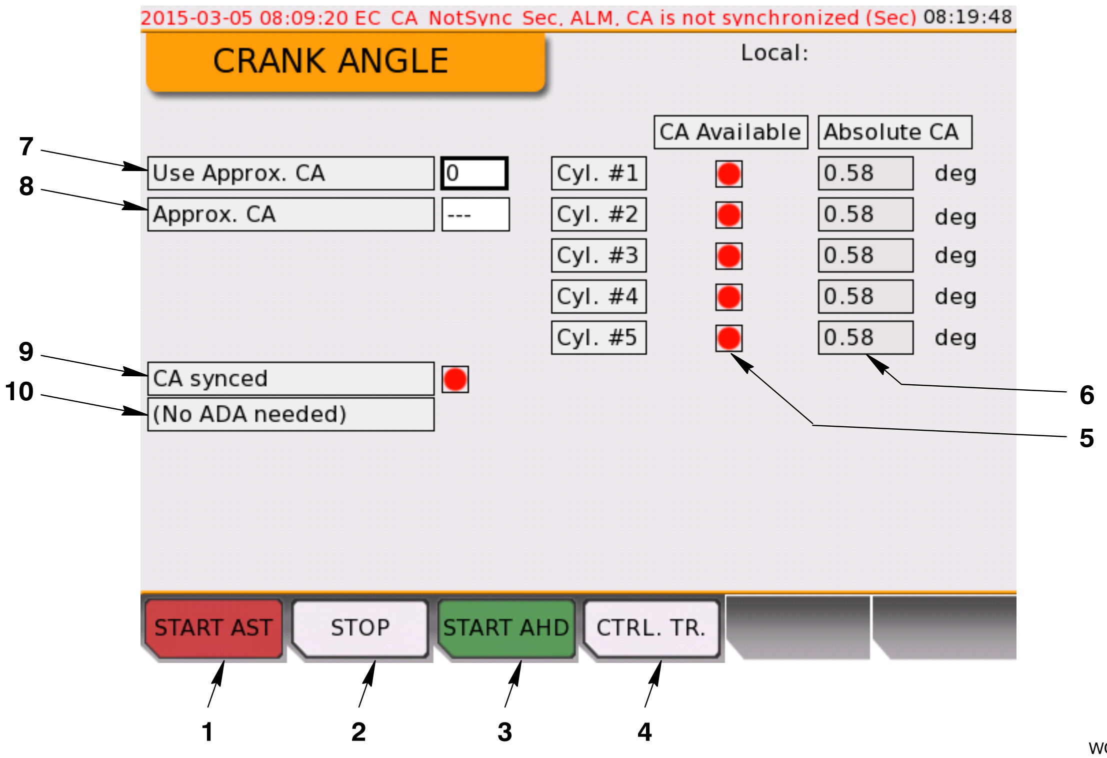



**Fig. 18: Crank Angle Page**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP tab | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for a control transfer to this LDU |
| 5 | CA available | Shows if the crank angle value for the related cylinder is available. A red indicator shows which item is available. |
| 6 | Absolute CA | Shows the absolute crank angle value for each cylinder (deg). |
| 7 | Use approximate CA | n/a (used only for tests) |
| 8 | Approximate CA | Shows the crank angle value |
| 9 | CA synced | Shows the crank angle synchronisation status. |
| 10 | ADA | Shows if the angle determination algorithm (ADA) is necessary. |

## 3.17 Exhaust Valve

The manual exhaust valve operation is only available on the local LDU–20 (at the local control stand), while the engine is stopped.

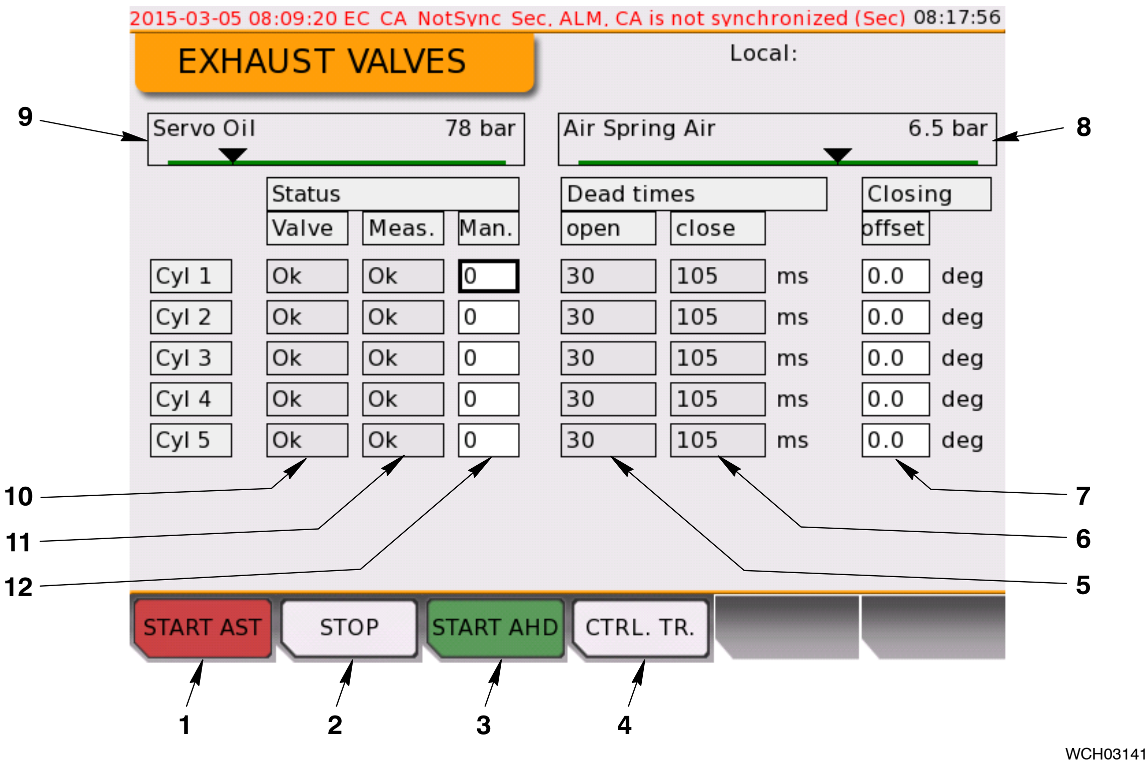



**Fig. 19: Exhaust Valve Page**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP button | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for a control transfer to this LDU |
| 5 | Exhaust valve open dead times in milliseconds | The time between the open/close command to the solenoid valve of VCU and the exhaust valve stroke |
| 6 | Exhaust valve close dead times in milliseconds | The time between the open/close command to the solenoid valve of VCU and the exhaust valve stroke |
| 7 | Exhaust valve closing offset in degrees | The exhaust valve stroke moves more than 15% of the offset of the close commands |
| 8 | Air spring air | Shows the pressure of the air spring air |
| 9 | Servo oil status | Shows the pressure the servo oil |
| 10 | Exhaust valve status | Shows the status of the exhaust valve. OK or FAIL (activated or timing failure). |
| 11 | Meas. status | Shows OK, or FAIL (if the stroke signal disappears) |
| 12 | Manual exhaust valve operation | 0 = automatic, 1 = manually open |

### 3.17.1 Procedure to Open the Exhaust Valve for Inspection

To open the exhaust valve for inspection, do steps 1) to 4).

1) Move the cursor to the related text field (6, Fig. 19), then push the rotary button to enter the edit mode.
2) Turn the rotary button to adjust the value to 1 to open the exhaust valve. Adjust the value to 0 to go back to automatic mode. Push the rotary button again to go out of the edit mode.
3) After the engine has stopped, use the manual exhaust valve operation to manually open and close an exhaust valve. (This can be used for tests and bleed procedures, e.g. after maintenance.)
4) The conditions that follow in step a) and step b) are necessary:
   a) You must set to on the service pump to get some pressure in the servo oil rail (refer to 8016−1 Lubricating Oil / Servo Oil System, paragraph 3.1).
   b) Make sure that there is air spring air pressure.

## 3.18 Exhaust Ventilation

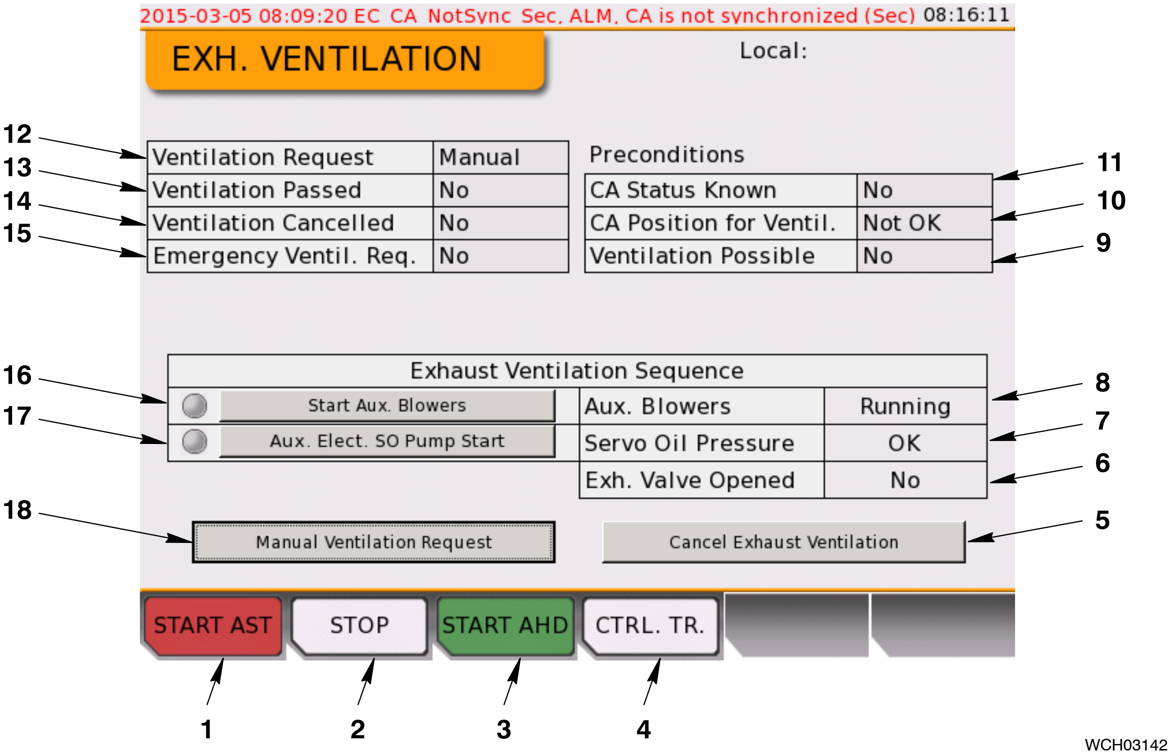



**Fig. 20: Exhaust Ventilation Page**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP tab | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for a control transfer to this LDU |
| 5 | Cancel exhaust ventilation | Cancels the exhaust ventilation procedure. |
| 6 | Exhaust valve opened | Shows the open status of the exhaust valve. Shows YES or NO. For more data see paragraph 3.17. |
| 7 | Servo oil pressure status | Shows the status of the servo oil system pressure. Shows OK or NOT OK |
| 8 | Auxiliary blowers status | Shows the status of the auxiliary blowers. Shows STOPPED or RUNNING. For more data see paragraph 3.3. |
| 9 | Ventilation possible | Shows if the ventilation procedure is possible. Shows YES or NO. |
| 10 | CA position for ventilation | Shows if the crank angle position is applicable for the ventilation procedure (a necessary condition for the ventilation procedure). Shows OK or NOT OK. |

| Item | Function | Effect |
|---|---|---|
| 11 | CA status known | Shows if the crank angle status is known and available for the ventilation procedure (a necessary condition for the ventilation procedure). Shows YES or NO. |
| 12 | Ventilation request | Shows the status of the signal sent for ventilation. Shows MANUAL or AUTO or NONE. |
| 13 | Ventilation passed | Shows if the ventilation procedure is done. Shows YES or NO. |
| 14 | Ventilation cancelled | Shows if the ventilation procedure was cancelled. Shows YES or NO. |
| 15 | Emergency ventilation request | Shows if an emergency ventilation procedure is necessary. Shows YES or NO. |
| 16 | Start auxiliary blowers | Sends a signal for a manual start/stop of the auxiliary blowers. Move the cursor to the related button, then push the rotary button to start/stop the auxiliary blowers. A green indicator shows that you must start the auxiliary blowers. |
| 17 | Start auxiliary electrical servo oil pump (service pump) | Sends a signal for a manual start/stop of the service pump. Move the cursor to the related button, then push the rotary button to start/stop the electrical servo oil pump (service pump). A green indicator shows that you must start the service pump. |
| 18 | Manual ventilation request | Sends a signal for a manual start of the exhaust ventilation procedure. Move the cursor to the related button, then push the rotary button to manually start/stop the exhaust ventilation procedure. |

## 3.19 Performance Data

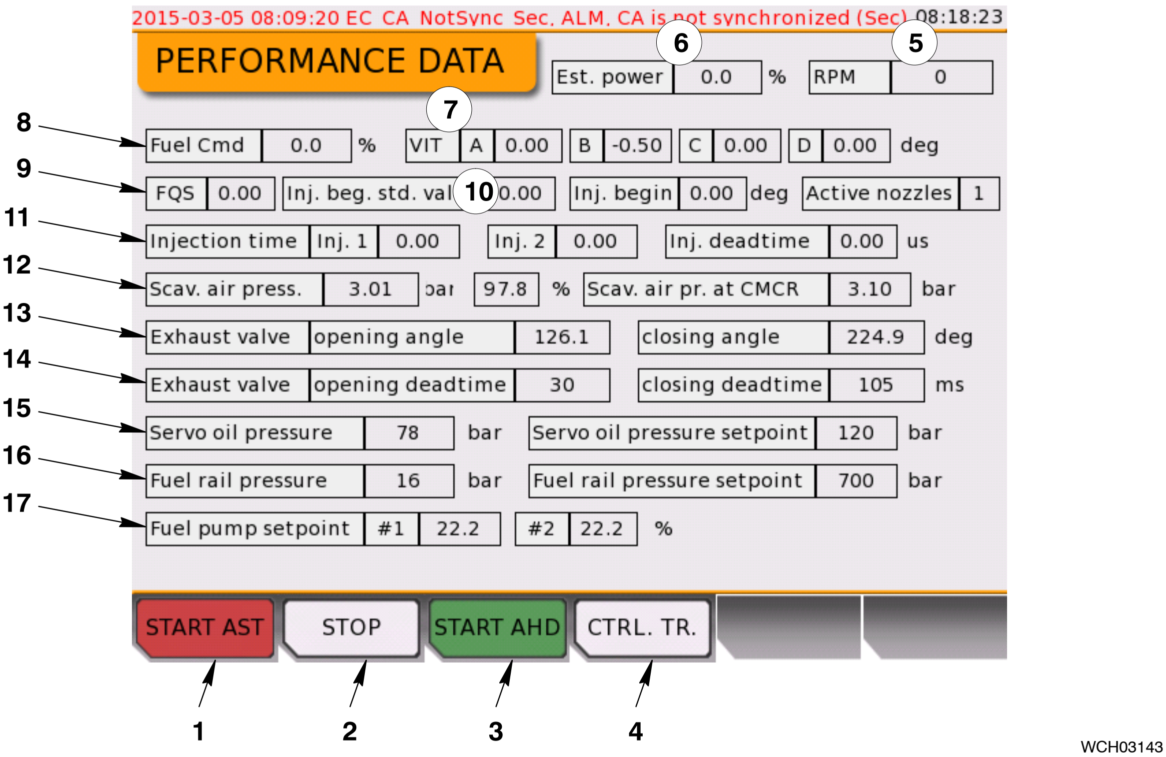



**Fig. 21: Performance Data Page**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP tab | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for a control transfer to this LDU |
| 5 | Engine Speed | Shows the engine speed in revolutions per minute (rpm) |
| 6 | Engine Load | Shows the estimated engine power in percent (%) |
| 7 | Variable injection timing (VIT) | Shows the variable injection timing (VIT) in degrees (deg), specified for different performance descriptions (VIT A, VIT B, VIT C or VIT D) |
| 8 | Fuel command | Shows the used fuel command in percent (%) |
| 9 | Fuel quality setting (FQS) | Shows the used fuel quality setting (FQS) |
| 10 | Definitions of the injection control | Shows the standard value of the injection start, the injection start in degrees (deg) and the number of injection nozzles that operate. |
| 11 | Injection time/Injection dead time | Shows the injection time for primary fuel injector No.1 and primary fuel injector No. 2.<br>Shows the injection dead time |

| Item | Function | Effect |
|---|---|---|
| 12 | Scavenge air pressure/ Scavenge air pressure at CMCR | Shows the scavenge air pressure in bar (bar) and percent (%).<br>Shows the scavenge air pressure at CMCR (bar). |
| 13 | Exhaust valve (opening/ closing angle) | Shows the exhaust valve opening angle and closing angle in degrees (deg). |
| 14 | Exhaust valve (opening/ closing dead time) | Shows the exhaust valve opening dead time and closing deadtime in milliseconds (ms). |
| 15 | Servo oil pressure/Servo oil pressure setpoint | Shows the servo oil pressure and the servo oil pressure setpoint (bar). |
| 16 | Fuel rail pressure/Fuel rail pressure setpoint | Shows the fuel rail pressure and the fuel rail pressure setpoint (bar). |
| 17 | Fuel pump setpoint | Shows the setpoints for fuel pump No. 1 and fuel pump No. 2. |

## 3.20 Scavenge Air – EWG

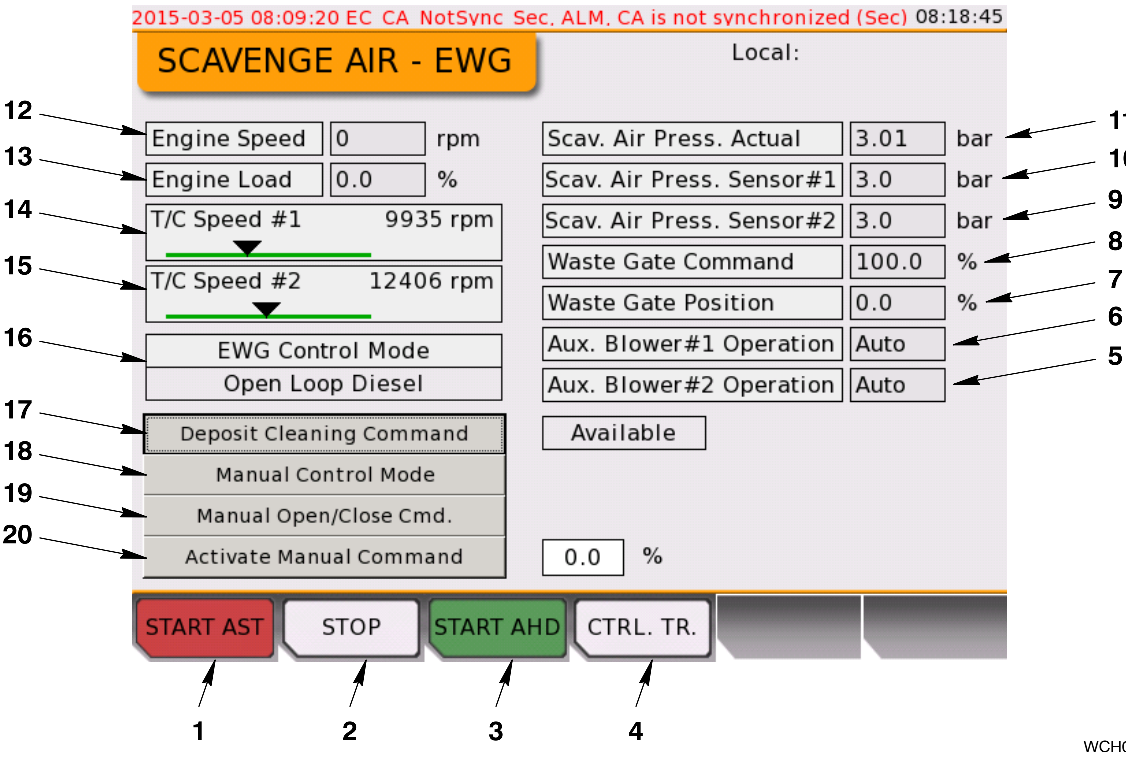



Fig. 22: Scavenge Air – EWG Page

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP tab | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for a control transfer to this LDU |
| 5 | Auxiliary Blower #2 operation | Shows the operation status of auxiliary blower No. 2. Shows AUTO or MANUAL. For more data see paragraph 3.3. |
| 6 | Auxiliary Blower #1 operation | Shows the operation status of auxiliary blower No. 1. Shows AUTO or MANUAL. For more data see paragraph 3.3. |
| 7 | Waste gate position | Shows the position of the exhaust waste gate (EWG) position in percent (%). |
| 8 | Waste gate command | Shows the exhaust waste gate (EWG) command in percent (%). |
| 9 | Scavenge air pressure sensor #2 | Shows the scavenge air pressure (bar) from sensor No. 2. |
| 10 | Scavenge air pressure sensor #1 | Shows the scavenge air pressure (bar) from sensor No. 1. |

| Item | Function | Effect |
|---|---|---|
| 11 | Scavenge air pressure actual | Shows the scavenge air pressure (bar). |
| 12 | Engine Speed | Shows the engine speed in rpm. |
| 13 | Engine Load | Shows the engine load in percent (%). |
| 14 | T/C speed #1 | Shows the speed of turbocharger No.1 in rpm. |
| 15 | T/C speed #2 | Shows the speed of turbocharger No. 2 in rpm. |
| 16 | EWG control mode | Shows the status of the exhaust waste gate (EWG) control mode. Shows Open Loop, Closed Loop, Manual or Auto. |
| 17 | Deposit cleaning command | Sends a signal for the start of the cleaning command. Move the cursor to the related button, then push the rotary button to start the cleaning command.<br>Shows Available or Not Available . |
| 18 | Manual control mode | Sends a signal for a mode change. Move the cursor to the related button, then push the rotary button to change to the manual control mode. |
| 19 | Manual open/close command | Sends a signal for a manual command to open/close exhaust waste gate. Move the cursor to the related button, then push the rotary button to open/close the exhaust waste gate. |
| 20 | Activate manual command | Activates the manual exhaust waste gate command. Move the cursor to the related button, then push the rotary button to change the open/close command value from 0.0% to 100%. |

## 3.21 Cylinder Lubrication

Manual lubrication can be used to inject a specified number of lubricating oil pulses to the cylinders before engine start (see Fig. 23).

### 3.21.1 Speed/Load Mode Description

The number of turns until the next lubrication pulse is calculated in relation to the set parameters. The values for the dry protect mode are set during the commissioning. When the value is less than the set Dry Protect parameter, the speed/load mode becomes active. For more data about the Mode Dry Protect, see paragraph 3.21.2.

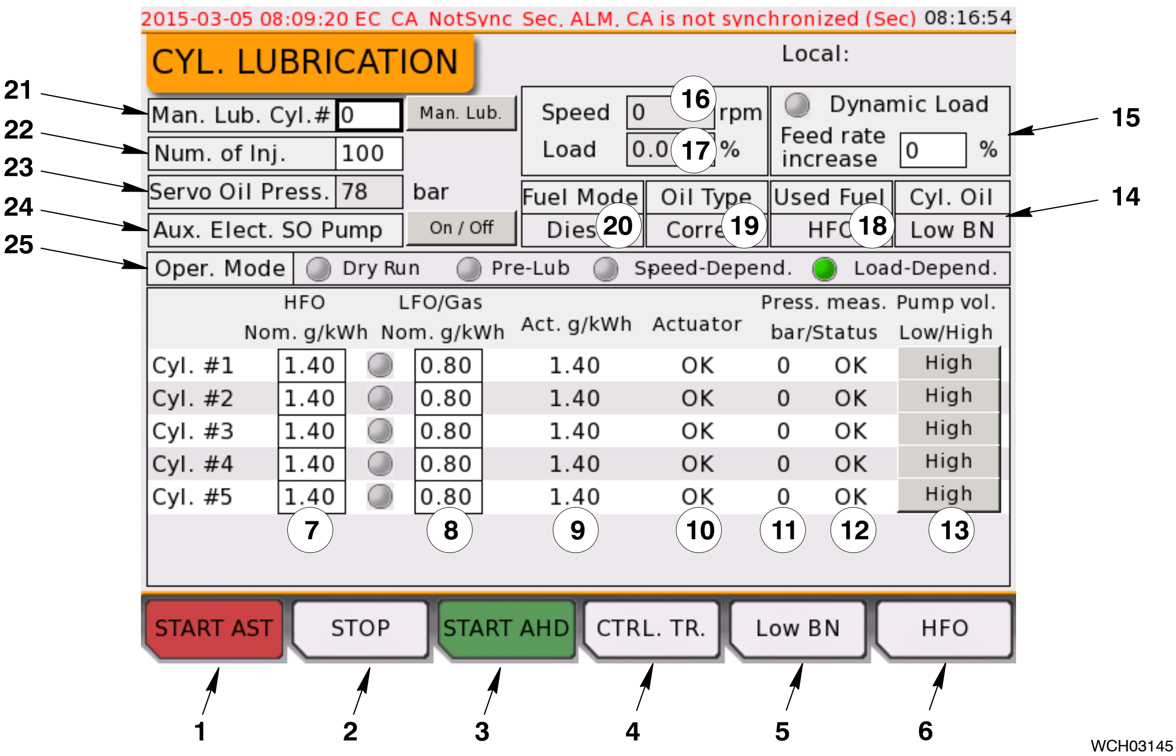



Fig. 23: Cylinder Lubrication

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP button | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for a control transfer to this LDU |
| 5 | Low BN/High BN button | The operator can select the cylinder lubricating settings for engine operation with a low base number lubricating oil (Low BN) or a high base number lubricating oil (High BN) |
| 6 | HFO/LFO MDO button | The operator can select the cylinder lubricating settings for engine operation with heavy fuel oil (HFO) or light fuel oil/ marine diesel oil (LFO/MDO) |
| 7 | Nominal feed rate of cylinder at CMCR (HFO) | Sets the nominal lubrication feed rate in g/kWh for engine operation with HFO. The value shown is not related to the manual lube adjustment. |

| Item | Function | Effect |
|---|---|---|
| 8 | Nominal feed rate of cylinder at CMCR (LFO/Gas) | Sets the nominal lubrication feed rate in g/kWh for engine operation with LFO/Gas. The value shown does not relate to the manual lube adjustment. |
| 9 | Actual feed rate per cylinder | Shows the feed rate. The value is calculated in relation to the engine load. |
| 10 | Actuator | Shows the status of the cylinder lubricating pump actuator. Shows OK or NOT OK. |
| 11 | Pressure measurement value | Shows the measured cylinder lubricating oil injection pressure (bar) |
| 12 | Pressure measurement status | Shows the status of cylinder lubricating oil pressure. Shows OK or NOT OK. |
| 13 | Pump volume low/high | Changes between a high or low volume of the cylinder lubricating oil pump. Shows High or Low. For more data refer to 7218–1 Cylinder Lubrication and 7218–2 Cylinder Lubrication – LFR and HFR Bushes. |
| 14 | Lubrication oil base number | Shows the base number of the cylinder lubricating oil. Shows Low BN or High BN. For more date, refer to 0320–1 Lubricating Oils and 7218–3 Feed Rate – Adjustment. |
| 15 | Dynamic load/Feed rate increase | During a fast change of engine load the feed rate is increased |
| 16 | Engine Speed | Shows the engine speed in rpm |
| 17 | Engine Load | Shows the engine load in percent (%) |
| 18 | Used fuel | Shows the type of fuel, HFO or MDO/LFO |
| 19 | Oil type | Shows the type of cylinder lubricating oil. Shows Correct or Wrong |
| 20 | Fuel mode | Shows the fuel mode. Shows Diesel or Gas |
| 21 | Manual lubrication to specified cylinder | The operator can select a cylinder (1 to 5) or set the value to 100 for all cylinders.<br>Move the cursor to the related button, then push the rotary button to start manual lubrication. |
| 22 | Number of manual lubrication pulses | Range 0 to 100 |
| 23 | Servo oil pressure | Shows the servo oil pressure (bar) |
| 24 | Auxiliary electrical servo oil pump (servo oil service pump) | Sets the auxiliary electrical servo oil pump (service pump) to on or off.<br>Move the cursor to the related button, then push the rotary button to set the service pump to on or off. |
| 25 | Operation Mode data | Shows the mode of operation (Dry Run, Pre-Lub., Speed-Depend. or Load-Depend.). A green indicator shows the operation mode. |

### 3.21.2 Dry Protect Mode Description

The number of revolutions until the next lubrication pulse is calculated in relation to the set parameters. The values for the dry protect mode are set during the commissioning. When the calculated value is more than the set dry protect parameter, the dry protect mode becomes active.

## 3.22 User Parameters

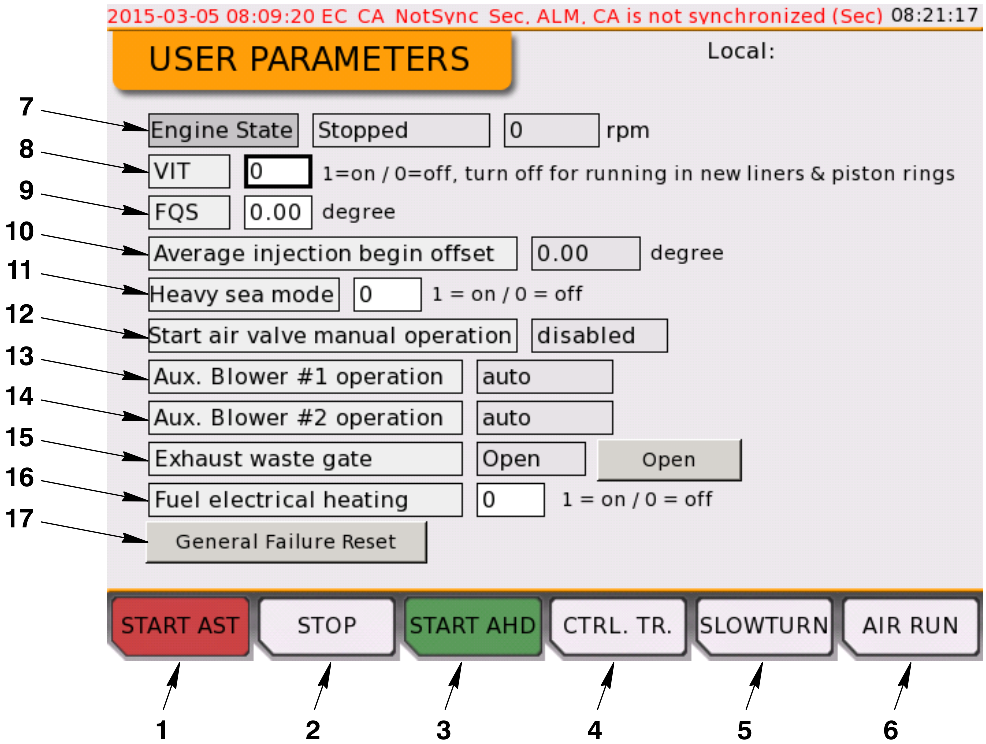



**Fig. 24: User Parameters**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP button | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for a control transfer to this LDU |
| 5 | SLOWTURN button | Puts the engine in slow turning mode<br>Push the button once to start slow turning<br>Engine goes back to stopped mode after it has turned for some revolutions |
| 6 | AIR RUN button | Puts the engine in air run mode<br>Air run operates while the button is pushed |
| 7 | Engine status | Shows the engine status and the engine speed (rpm)<br>Shows: Start interlock, Stopped, Slow turning, Air Run, Starting, Heavy Start, Running or Shutdown |
| 8 | Variable Injection Timing (VIT) | Set to 1 to activate VIT. Set to 0 to deactivate VIT.<br>VIT must be deactivated for running-in<br>Deactivate means the injection starts at the nominal angle independently of the engine power |

| Item | Function | Effect |
|---|---|---|
| 9 | Fuel Quality Setting (FQS) | Adjusts the parameter range from −5° to +5°<br>The FQS can be set to adjust maximum firing pressure to the nominal value<br>A negative correction angle will advance the injection start and increase maximum pressure<br>A positive correction angle will retard the injection start and decrease maximum firing or combustion pressure |
| 10 | Average injection begin offset | Shows the average injection begin offset value in degree (deg) |
| 11 | Heavy sea mode | Set to 1 to activate heavy sea mode<br>Set to 0 to deactivate heavy sea mode<br>Can be set to on in heavy sea<br>This function sets the fuel rail pressure to a constant value<br>VIT function is off. Sequential injection is off and all injection nozzles operate<br>Pressure control becomes more stable<br>Set to off when weather conditions are usual and before manoeuvring |
| 12 | Start air valve manual operation | Gives data about functional checks of control valves on the common start valve for starting air |
| 13 | Manual auxiliary blower #1 operation | Disabled<br>auto/off auxiliary blowers before engine start |
| 14 | Manual auxiliary blower #2 operation | Disabled<br>auto/off auxiliary blowers before engine start |
| 15 | Exhaust waste gate | Select Open to open the butterfly valve in the waste gate.<br>Select Close to close the butterfly valve in the waste gate.<br>This function can only operate for binary exhaust waste gates (EWG). |
| 16 | Fuel electrical heating | Set to 1 to activate<br>Set to 0 to deactivate<br>The electrical trace heating increases the temperature of the fuel to the applicable temperature |
| 17 | General failure reset | Select the button to reset all general failures. |

## 3.23 Temperatures – Cylinder Liner Wall and Exhaust Gas

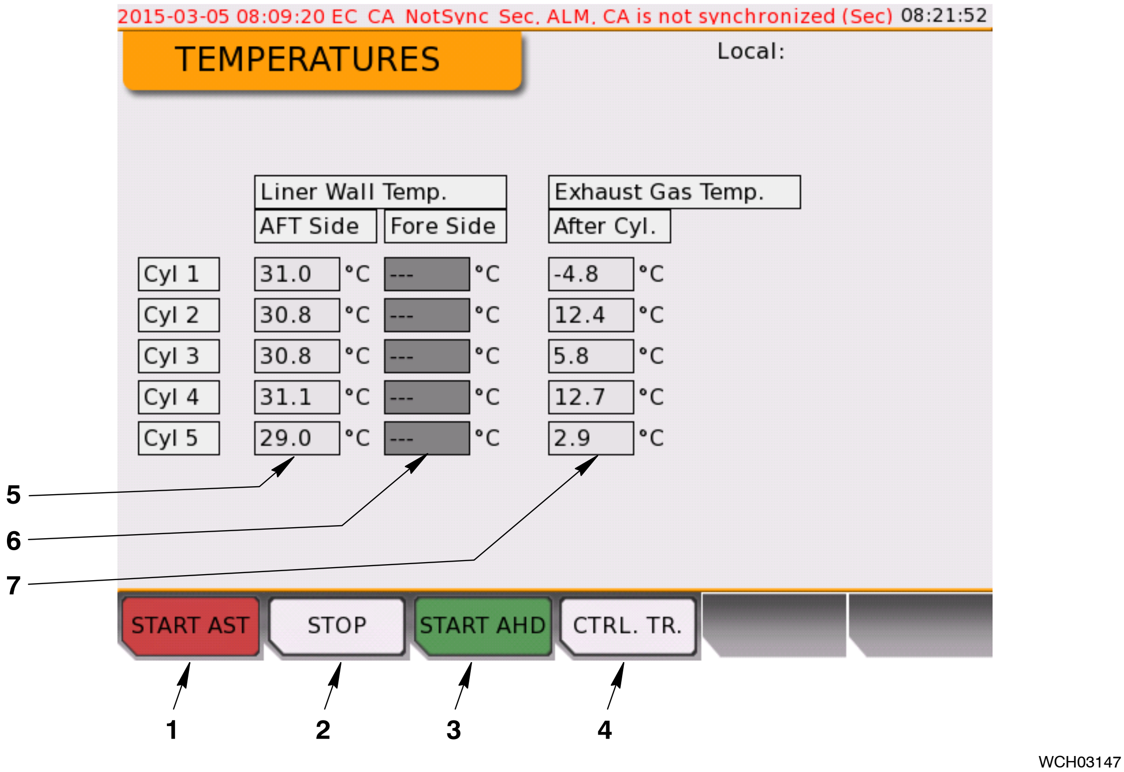



**Fig. 25: Temperature – Cylinder Liner Wall and Exhaust Gas**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP button | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for a control transfer to this LDU |
| 5 | Liner Wall Temp. AFT side | Shows the cylinder liner wall temperature at rear of each cylinder. |
| 6 | Liner Wall Temp. Fore Side | Shows the cylinder liner wall temperature at the front of each cylinder. |
| 7 | Exhaust Gas Temp. After Cyl. | Shows the exhaust gas temperature downstream of each cylinder. |

## 3.24 Software Info

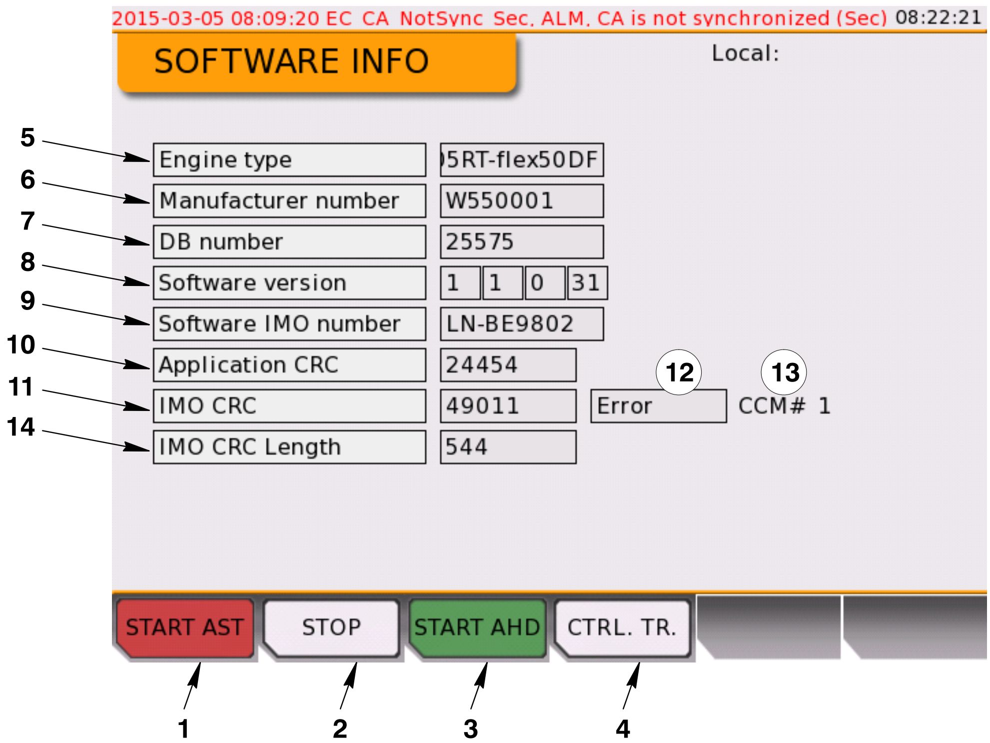



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**Fig. 26: Software Info**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP button | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a a signal for a control transfer to this LDU |
| 5 | Engine type | Shows the applicable engine |
| 6 | Manufacturer number | Shows the software (SW) manufacturer number |
| 7 | DB number | Shows the identification number of the installation |
| 8 | Software version numbers | [major][middle][minor]<br>(for example 1.0.16) |
| 9 | Software IMO number | As given by IMO |
| 10 | Application CRC (Cyclic Redundancy Check) | Checksum of the application binary |
| 11 | IMO CRC | Checksum of the IMO parameters |
| 12 | Result of CRC check | Shows Error on the module that has an incorrect IMO CRC |
| 13 | Identifier of incorrect CRC | Shows which CCM–20 has the incorrect CRC |
| 14 | IMO CRC Length | Number of bytes that went into the CRC calculation |

## 3.25 Failure List

You can use the Filters field (6, Fig. 27) to filter the list of log messages to only show specified types of messages.

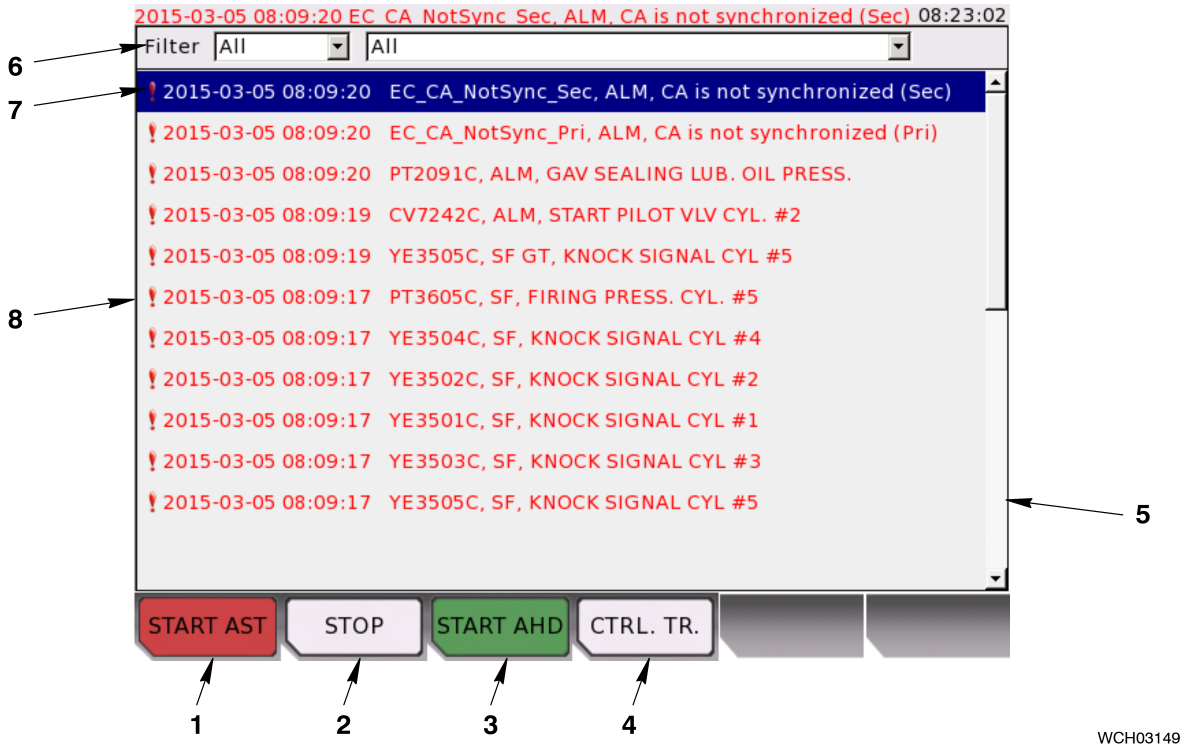


**Fig. 27: Failure Messages**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP button | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for a control transfer to this LDU |
| 5 | Scroll bar | Scrolls through the failure list |
| 6 | Filter setting | Use the BACK button for this function |
| 7 | Selected failure message | Has a blue background |
| 8 | List of failure messages | The latest message is at the top of the list |

### 3.25.1 Procedure – Change the Filter Settings

To change the filter settings, do step 1) to step 7).

1) Push the BACK button to put the cursor on the Filters field.
2) Push the rotary button to display the list of available filters e.g. All/Safety/Event/Info/Error.
3) Use the rotary button to move the cursor up or down in the list of available filters.
4) Push the rotary button to select or deselect the filters.
5) Push the BACK button two times to move the cursor back to the list of failure messages.
6) Use the rotary button to scroll the list up or down.
7) When the cursor is on a selected failure message, you push the rotary button. This shows a different screen, which has more data about this failure entry.

## 3.26 Log Messages

You can use the Filters field (7, Fig. 28) to filter the list of log messages to only show specified types of messages.

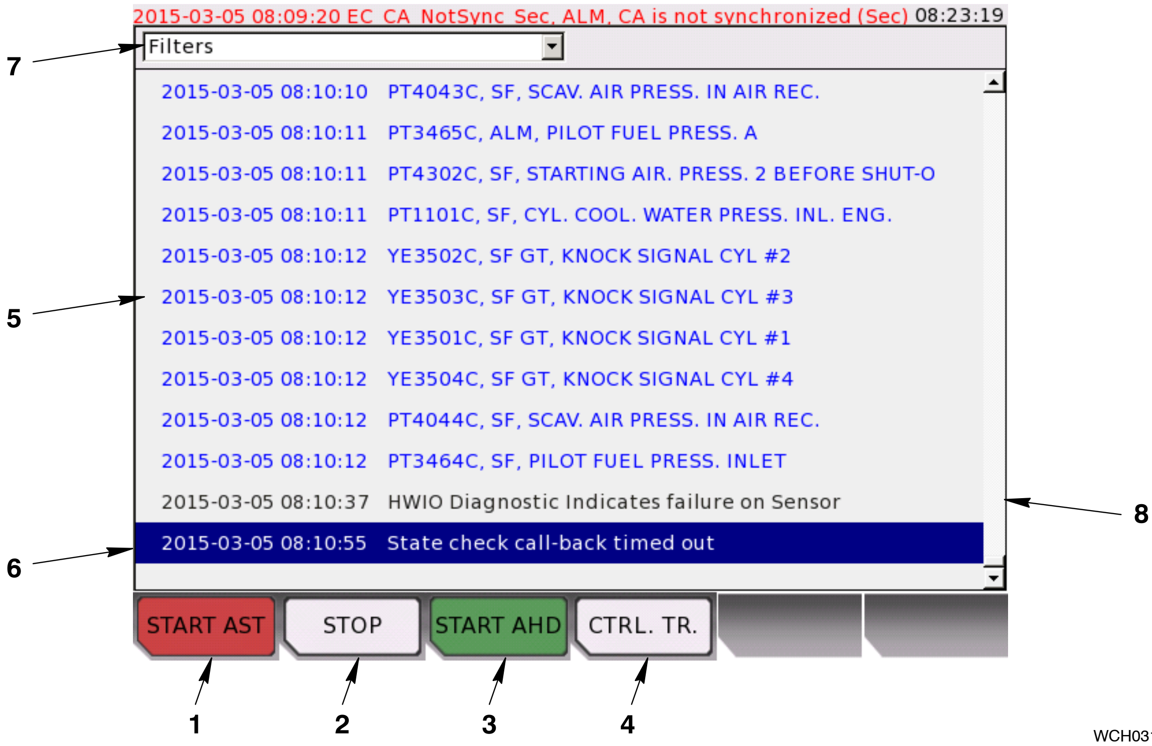


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**Fig. 28: Log Messages**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP button | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for a control transfer to this LDU |
| 5 | List of log messages | The latest message at the bottom of the list |
| 6 | Selected log message | Has a blue background |
| 7 | Filter setting | Use the BACK button for this function |
| 8 | Scroll bar | Scrolls through the log messages |

### 3.26.1 Procedure − Change the Filter Settings

To change the filter settings, do step 1) to step 7).

1) Push the BACK button to put the cursor on the Filters field.
2) Push the rotary button to display the list of available filters e.g. All/Safety/Event/Info/Error.
3) Use the rotary button to move the cursor up or down in the list of available filters.
4) Push the rotary button to select or deselect the filters.
5) Push the BACK button two times to move the cursor back to the list of log messages.
6) Use the rotary button to scroll the list up or down.
7) When the cursor is on a selected log message, you push the rotary button. This shows a different screen, which has more data about this log entry (see Fig. 29).

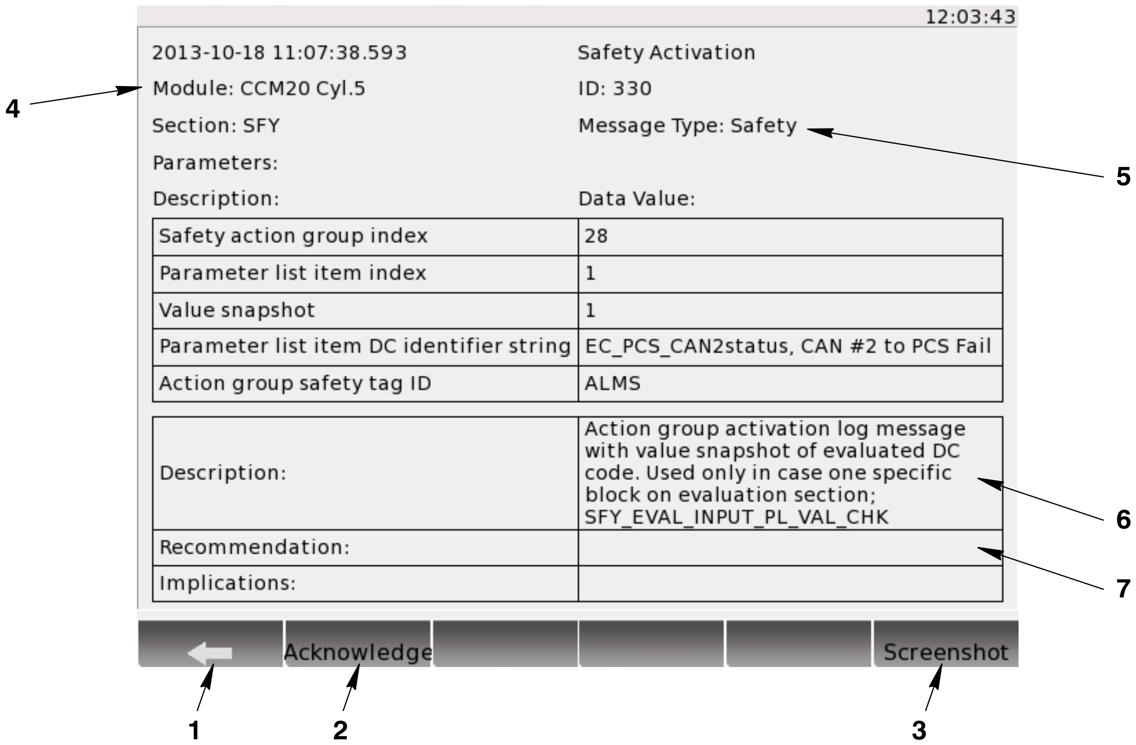



**Fig. 29: Log Entry Data**

| Item | Function | Effect |
|---|---|---|
| 1 | BACK button | When selected, the screen goes back to the message list |
| 2 | Acknowledge button | This button has no function |
| 3 | Screenshot button | Saves a picture (in .png format) of this screen to a USB drive (if connected) |
| 4 | Module identifier | Shows the source module that sent this log entry |
| 5 | Message type | Info/Error/Event/Safety |
| 6 | Description | General data about the log entry |
| 7 | Recommended action | Recommended action that the operator can do to get a solution to the problem |

**Note: Some data on this screen are only applicable to Wärtsilä SW developers, i.e. the ID and status flag numbers.**

### 3.26.2 Procedure – Export a Screenshot of the Log Entry Page

1) If an important problem occurs, do step a) to step d):
   a) Take a screenshot of the applicable page.
   b) Connect a USB drive to the USB port on the rear of the LDU.
   c) Save the screenshot to the USB drive.
   d) Send the saved .png file to Wärtsilä Services.

## 3.27 System Status

The LDU–20 have a full backup of all application and configuration files for all modules in the system (Fig. 30). When a module starts, all files are compared to the backup files in the LDU–20. Different versions found have a red background in the status list.

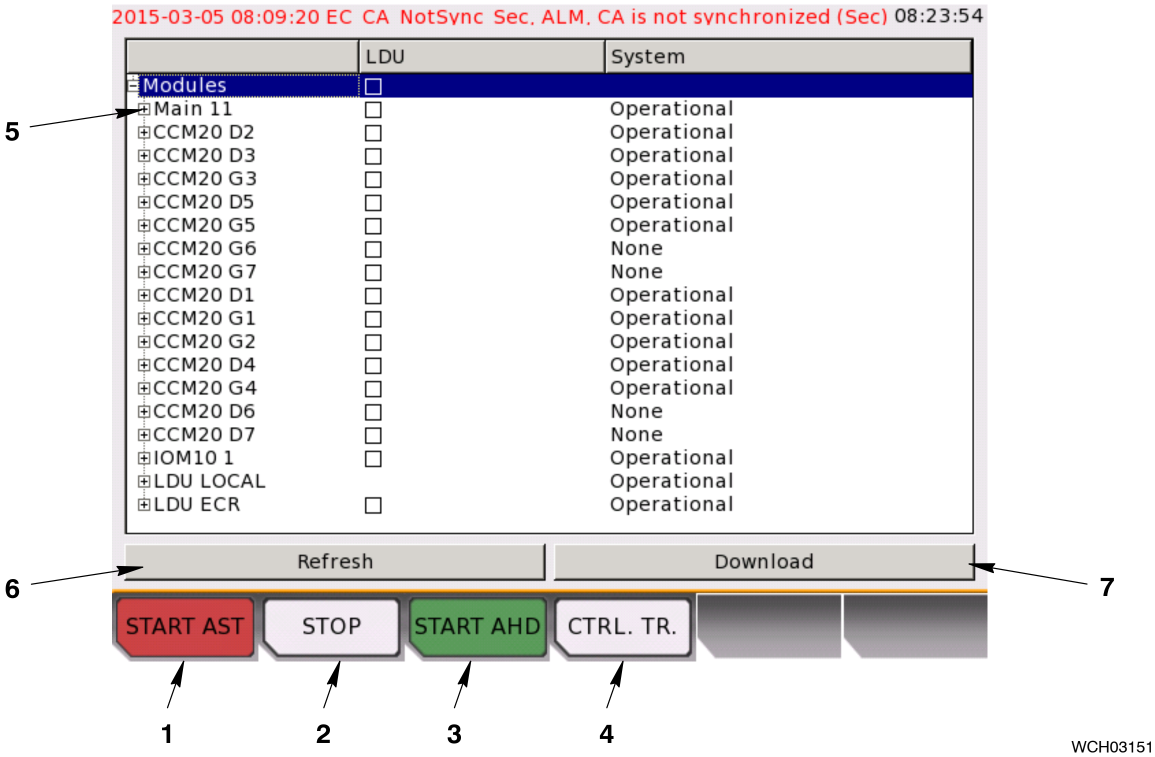



**Fig. 30: System Status**

| Item | Function | Effect |
|---|---|---|
| 1 | START AST button | Starts the engine in astern direction |
| 2 | STOP button | Stops the engine |
| 3 | START AHD button | Starts the engine in ahead direction |
| 4 | CTRL. TR. button | Sends a signal for a control transfer to this LDU |
| 5 | Status indications for each module<br>Possible states are: | Application running: Module operates as usual<br>No still alive: Module is set to off or disconnected from the CAN bus<br>Difference found: Different version of application/ configuration/DSP is found<br>SW download is necessary to align the module with the rest of the system |
| 6 | Refresh button | Uses the rotary button to select. Updates the module status list |
| 7 | Download button | Use the rotary button to select.<br>Does a SW download on the selected modules |

### 3.27.1 Procedure – Download Backup Files

1) Use the rotary switch (turn then push) to select the Download button. A dialog box is shown. This dialog box gives an option to download, or not to download the backup files to the selected modules.
2) Select Yes to start the download backup files procedure. Select No to cancel the procedure.

## 3.28 USB Page

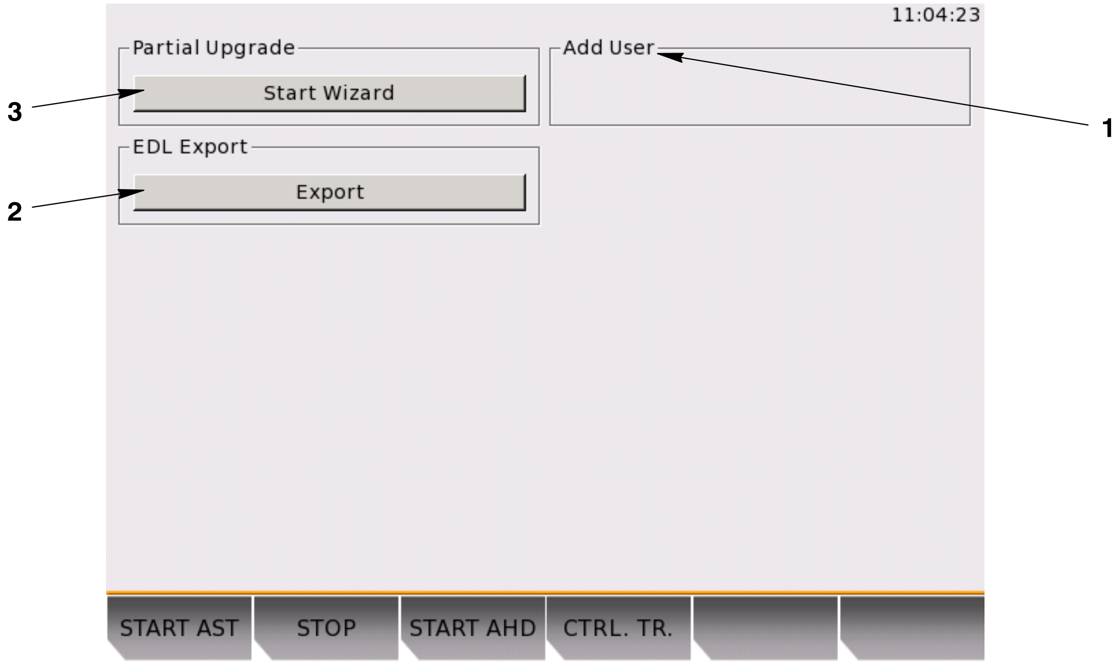



**Fig. 31: USB Page**

| Item | Function | Effect |
|---|---|---|
| 1 | Add User | Not used |
| 2 | Export button | Exports all log messages to a file on a USB drive (if connected) |
| 3 | Start Wizard button | Starts the partial upgrade wizard |

### 3.28.1 Procedure − Export All Log Messages

1) Connect a USB drive to the USB port on the rear of the LDU before you select the Export button (2, Fig. 31).
2) Use the rotary button to put the cursor on the Export button (2). Push the rotary button to select Export.

The file name EDL Export YYYYMMDD_hhmmss.wxml is saved to the USB drive. The timestamp display YYYYMMDD_hhmmss is shown as year/month/day_hours/minutes/seconds. This file has the full system log and can be sent to Wärtsilä Services for troubleshooting.

You use the partial upgrade wizard to adjust software parameters, which the operator does not usually have access. A file (from Wärtsilä) stored on a USB drive is necessary.

3) To apply the partial upgrade, connect the USB drive to the USB port on the rear of the LDU.
4) Use the rotary button to put the cursor on the Start Wizard button (5).
5) Push the rotary button to select Start Wizard.

A screen shows you the available upgrade packages on the USB drive and helps you through the upgrade process (see Fig. 32).

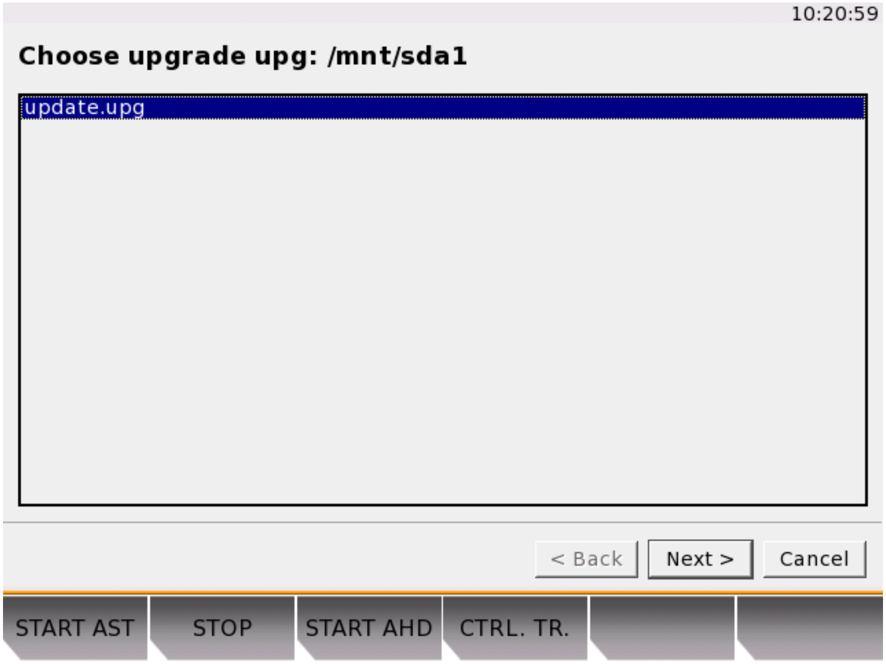



**Fig. 32: Choose Upgrade Page**

## 3.29 System Settings

This page (Fig. 33) contains three sub-pages to adjust the LDU−20 system settings .

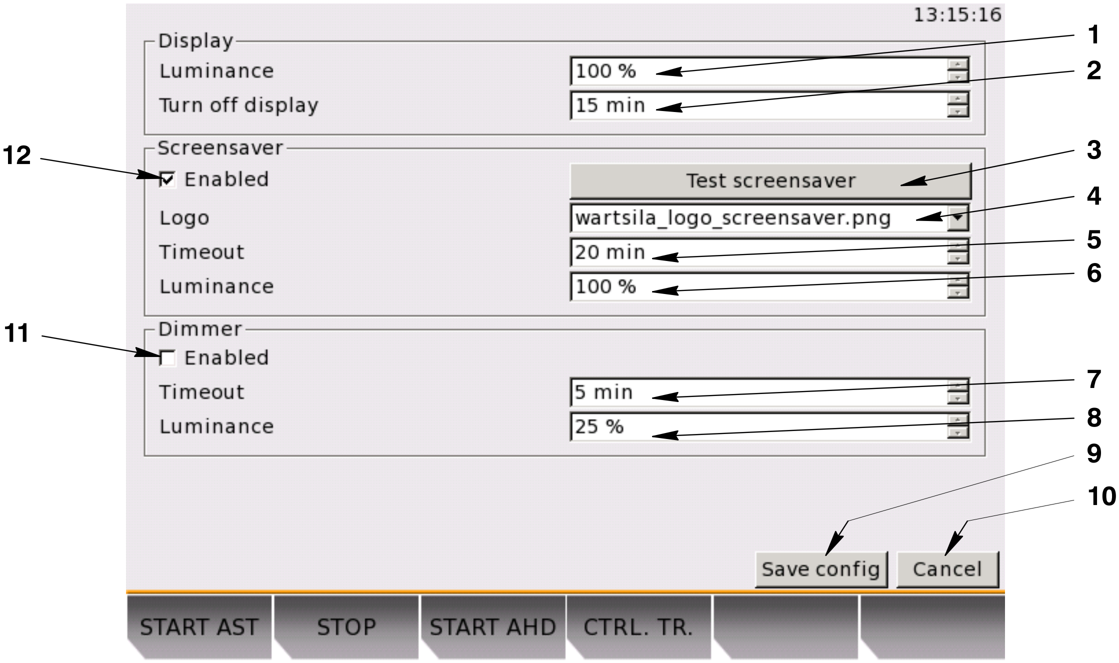



**Fig. 33: System Settings Page**

| Item | Function | Effect |
|---|---|---|
| 1 | Display luminance setting | Adjusts the brightness of the display: 1% to 100% |
| 2 | Turn off display | Adjusts the time to set to off the display after a period of no inputs<br>Set to between 0 minutes and 100 minutes<br>Set to 0 to keep the display set to on |
| 3 | Test screensaver | Select to see the screensaver. Push a button to go out of the test mode |
| 4 | Logo | Browse for picture selection. Select the picture to use in screensaver mode |
| 5 | Timeout | Adjusts the time to set to off the display after a period of no inputs. Set to between 1 min and 100 min |
| 6 | Screensaver luminance | Adjusts the display brightness for the screensaver mode from 1% to 100% |
| 7 | Timeout | Adjusts the time to dim the display after a period of no inputs. Set to between 1 min and 100 min |
| 8 | Dimmer luminance | Adjusts the display brightness for the dimmer mode from 1% to 100% |
| 9 | Save config button | Saves the configuration settings |
| 10 | Cancel button | Reject the changes and go back to the last saved settings |
| 11 | Enable/Disable dimmer | Used to decrease the display brightness after a specified period of no inputs. |
| 12 | Enable/Disable screensaver | Put a check mark in the check box to enable the screensaver. Remove the check mark to disable. |

## 3.30 Ethernet

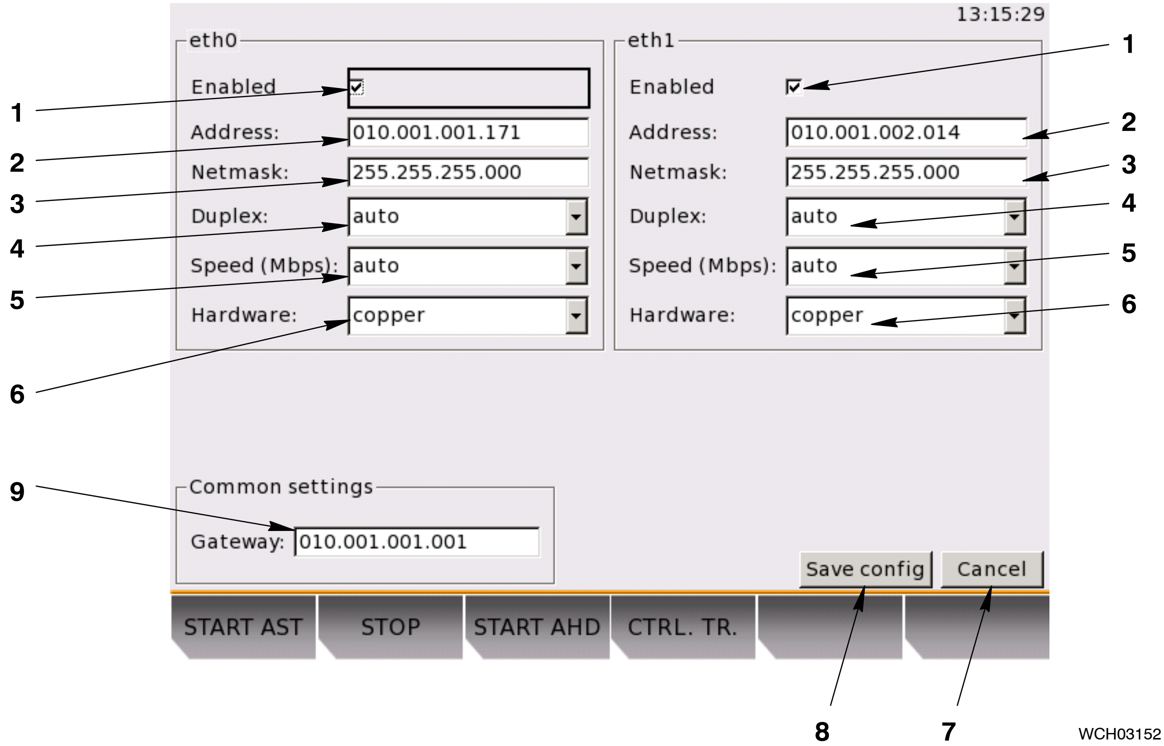



**Fig. 34: Ethernet Page**

| Item | Function | Effect |
|---|---|---|
| 1 | Enable/Disable ethernet ports | eth0 = plug X31<br>eth1 = plug X32<br>The two ports must be enabled by default |
| 2 | Address field | TCP/IP configuration address for each ethernet port<br>Default settings:<br>LDU−20 Local: eth0 = 10.1.1.171 eth1 = 10.1.2.14<br>LDU−20 ECR: eth0 = 10.1.1.173 eth1 = 10.1.2.14 |
| 3 | Netmask field | TCP/IP configuration netmask<br>Default 255.255.255.000 for the two ports on each LDU−20 |
| 4 | Duplex field | Ethernet duplex mode<br>Can be: half, full or auto<br>Default is: auto |
| 5 | Speed (Mbps) field | Ethernet speed<br>Can be: 10, 100 or auto<br>Default is: auto |
| 6 | Hardware field | Choose ethernet hardware interface<br>Can be: copper or fiber<br>Default is: copper |
| 7 | Cancel button | Reject the changes and go back to the last saved settings |
| 8 | Save config button | Save the configuration settings |
| 9 | Gateway field | TCP/IP gateway address<br>Default is 10.1.1.1 |

## 3.31 Date

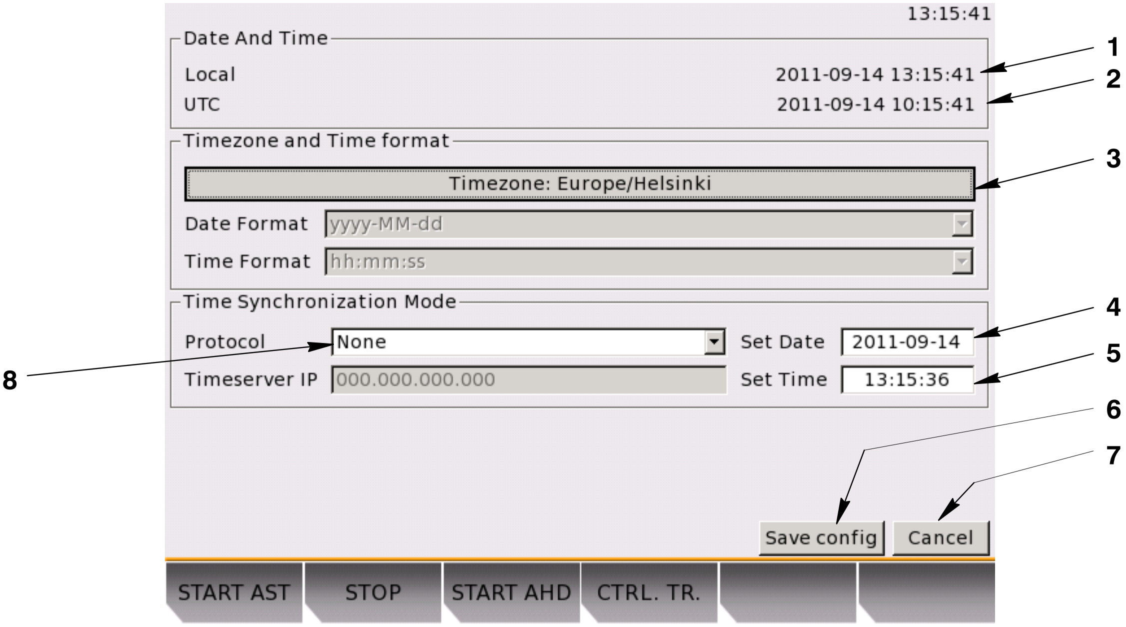



**Fig. 35: Date Page**

| Item | Function | Effect |
|---|---|---|
| 1 | Local time | Includes time offset from UTC |
| 2 | UTC time | Coordinated universal time |
| 3 | Select time zone | Use the rotary button to get a list with all available time zones |
| 4 | Set Date field | Use the rotary button to adjust the date setting |
| 5 | Set Time field | Use the rotary button to adjust the time setting |
| 6 | Save config button | Save the configuration settings |
| 7 | Cancel button | Reject changes and revert to the last saved settings |
| 8 | Configure time synchronization mode | Option to use Network Time Protocol (NTP).<br>Not used |

## 3.32 Screenshot

The last entry in the navigation menu is the screenshot function. This function saves a screenshot of the page to a USB drive (if connected). The saved screenshot is a 640 x 480 pixel image in the .png format.

When you save a screenshot, the pop-up text Screenshot saved, shows on the bottom right-hand corner of the display. If no USB drive is connected, or if there was an error during the save process to the USB drive, the pop-up message shows USB Mounting failed.

# CCM–20 Failure

## 1. Identification

The alarm Module Fail CCM#X shows in the engine control system (ECS). Fig. 1 shows a schematic diagram of the CCM–20 in usual configuration.

## 2. Cause

The CCM-20 of cylinder X is defective, thus the related cylinder has no lubrication.

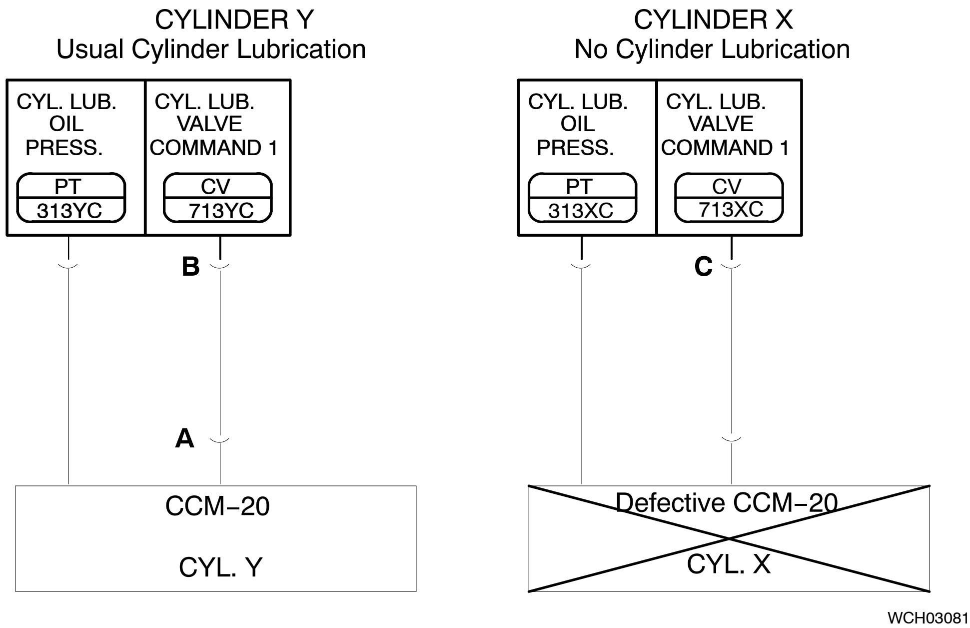



**Fig. 1: Schematic Diagram – Usual Configuration**

## 3. Procedure

If a CCM-20 has a failure, you use the two terminal boxes (tool 94929) to bypass the defective CCM–20 and give emergency lubrication to the related cylinder.

Do steps1) to 7) to install the terminal boxes (see Fig. 1 and Fig. 2).

1) Attach the terminal box to the cylinder block near the applicable cylinder lubrication pump. The terminal box has magnets installed in the base.
2) Disconnect the connection A (from the valve CV713YC) on the cylinder lube pump on Cylinder Y.
3) Connect Socket A on the terminal box, to the connection A (valve CV713YC).
4) Connect Socket B on the terminal box to to the connection B (valve CV713YC) of the cylinder lube pump on Cylinder Y.
5) Disconnect the connection C (from the valve CV713XC) on Cylinder X.
6) Connect Socket C on the terminal box to the connection C (valve CV713XC) of the cylinder lube pump of Cylinder X.

**Note: The piston that has emergency lubrication will operate, but will not fire.**

7) If the defective CCM-20 operates correctly again, disconnect the terminal boxes and connect all valves to their related CCM-20 modules.

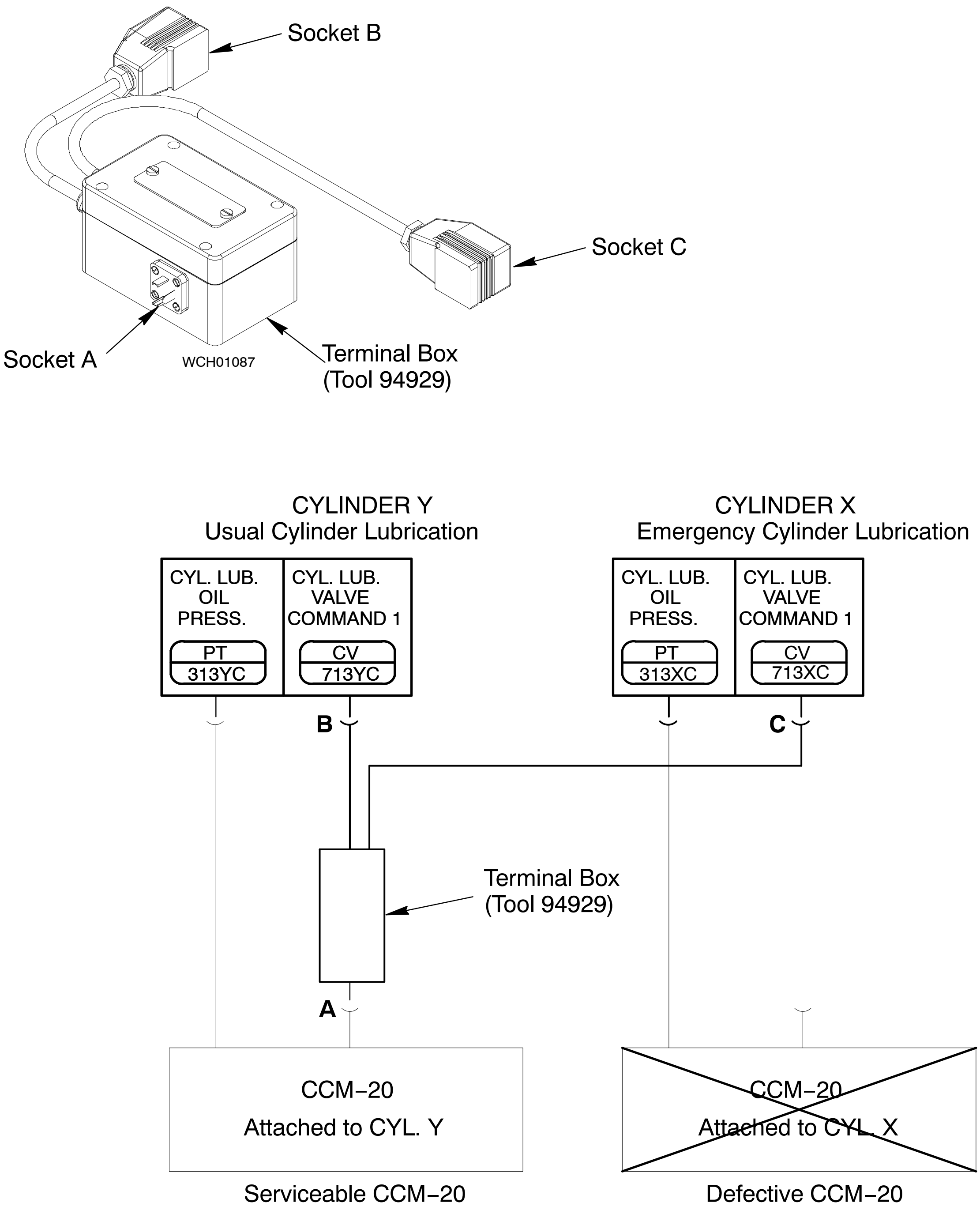



**Fig. 2: Schematic Diagram − Emergency Lubrication**

# Engine Control



## 1. General

The Control Diagram is a schematic diagram of all control components and their connections.

All code numbers and names used in the data that follow are found in the control diagrams, refer to 4003−2, Page 1 and Page 2 Engine Control Diagram.

## 2. Engine Control Functions

The engine control system (ECS) has the functions that follow:

- Engine start, operation, maneuvering and shut-down
- Engine speed control
- A function to monitor the engine.

# 3. Engine Local Control

You can operate the engine from the local control panel (see 4002−2 Local Control Panel/Local Display Unit (LDU-20).

For data about the speed controller, refer to 4002−1 Engine Control System, paragraph 3.8, Speed Control).

**Note: The operator must not leave the local maneuvering stand. The operator must monitor regularly the engine speed to immediately adjust the fuel supply when necessary.**

## 3.1 Preparation

1) On the LDU-20, select the CTRL. TR. button. The CONTROL LOC page shows (see 4002−2 Local Control Panel/Local Display Unit (LDU-20), paragraph 3.4).
2) Select the Local button for mode transfer to local manual control.
3) Push the rotary button to go back to the MAIN page.

## 3.2 Engine Start

**Note: You can only start the engine in diesel mode.**

1) On the LDU-20, select the button ON/OFF to start the auxiliary blowers.
2) Use the rotary button to select the Fuel Command mode.
3) Turn the rotary button to set the manual fuel command setpoint to approximately 15%.
4) Select the button START AHD or START AST until the engine operates.
5) Turn slowly the rotary button to adjust the fuel injection quantity until the engine operates at the applicable speed. You can see the related value on the display and speed indicator.

**Note: You can also use the ECR manual control panel for the engine start procedure. But the buttons and rotary button operate only when the related LDU-20 has control.**

## 3.3 Reverse

**Note: You can only reverse the engine in diesel mode.**

1) On the LDU-20, turn the rotary button to set the manual fuel command setpoint to approximately 15%.
2) Select the button START AHD or START AST until the engine operates in the correct direction.

**Note: On ships under way, this procedure can be a long period because of propeller drag.**

## 3.4 Change from Diesel Mode to Gas Mode

1) On the LDU-20 select the FUEL MODE CONTROL page (refer to 4002−2, paragraph 3.8, Fuel Mode Control).
2) Use the rotary button to select the Gas Mode Request button.
3) Push the rotary button.

For more data about the change from diesel mode to gas mode, refer to 0275−1, paragraph 2, Change-over from Diesel Fuel to Gas Fuel.

### 3.5 Change from Gas Mode to Diesel Mode

1) On the LDU-20 select the FUEL MODE CONTROL page (refer to 4002-2, paragraph 3.8, Fuel Mode Control).
2) Use the rotary button to select the Diesel Mode Request button.
3) Push the rotary button.

For more data about the change from gas mode to diesel mode, refer to 0275–1, paragraph 3, Change-over from Gas Fuel to Diesel Fuel.

### 3.6 Engine Stop

1) Turn the rotary button to decrease the engine speed/load.
2) Push the STOP button.

For more data about engine stop in gas mode, refer to 0600–1 Engine Stop Procedure, paragraph 3.

## 4. Engine Control System Checks

If parts of the pneumatic control system were disassembled, removed or replaced during an overhaul, you must do a general check before commissioning.

| CAUTION |
|---|
| **Equipment Hazard: Leaks can cause faults in the engine control systems and damage to engine components.** |

**Note: Leaks that are found during the engine control system checks must be repaired.**

You can do checks on all functions. Interlocks give protection against, and prevent, maneuvering errors.

For data about the applicable pressure and temperature ranges, refer to 0230–1 Operating Data Sheet, Pressure and Temperature Ranges at Continuous Service Power MCR.

For data about alarms and safeguards, see 0230–2 Operating Data Sheet, Alarm and Safeguards at Continuous Service Power.

### 4.1 General

**Note: For data about the item numbers (e.g. 30–4325_E0_1), refer to 4003–2 Control Diagram, Page 1 and Page 2.**

1) Make sure that there is no pressure in the combustion space.
2) On the starting air bottles 930B–001, close the shut-off valves 930V–03 and 930V–04.
3) Use the handwheel to close the starting air shut-off valve 30–4325_E0_1.
4) Open the ball valves 35–833_E0_2 to release the pressure in the starting air shut-off valve 30–4325_E0_1.
5) Open the ball valves 30–8605_E0_6 and 30–8605_E0_7 to release the pressure in the starting air manifold.
6) Release the pressure in the control air bottle 35–287HA.
7) Engage the turning gear.
8) Remove the roller lifting tools if installed.
9) Make sure that the service pump 20–8445_E0_1 is set to off (main switch).

## 4.2 Control Air Supply Unit

1) At the connection A1, open the shut-off valve 35.36HB to get the 7 bar to 9 bar control air board supply.
2) Operate the pressure reducing valve 35.23HA to adjust the air pressure for the air spring air to 6.5 bar.
   - Do a check of the pressure on the pressure gauge PI4401L.
   - Do a check of the pressure on the LDU-20, MAIN page.
3) Make sure that air flows to the 3/2-way valve 31.35HA on the turning gear.

## 4.3 ECS Start

1) In the power supply boxes E85.1 to E85.x, set to on all the circuit breakers.
2) On all the CCM-20, MCM-11, IOM-10 and the two LDU-20, make sure that all green LED indications come on.

## 4.4 Safety and Alarm System

1) Make sure that the items that follow are set to on:
   - The remote control system (RCS)
   - The engine safety system (ESS)
   - The alarm and monitoring system (AMS).
2) On the control room console and the local control panel, push the EMERGENCY STOP button. Make sure that the fuel pressure control valve 10−5562_E0_5 is electrically operated (i.e. the coil is energized).
3) Connect the pressure calibration hand-pump (tool 94050, see the Maintenance Manual 9403−5) to the applicable pipe (e.g. the pipe that has the pressure sensor PS1101S).
4) Use the pressure calibration hand-pump (tool 94050) to increase the pressure to more than the reference pressure given in Table 1.

**Table 1: Pressure Calibration**

| Medium | Code No. | Pressure | Action | Time Interval |
|---|---|---|---|---|
| Cylinder cooling water pressure (engine inlet) | PS1101S | less than 4.0 bar (contract closed) | Shutdown | 60 sec |
| Main bearing oil supply pressure | PS2002S | less than 3.3 bar (contact closed) | Shutdown | 10 sec |
| Air spring air pressure | PS4341S | less than 4.5 bar (contact closed) | Shutdown | 0 sec |
| ABB Turbocharger bearing oil pressure inlet | PS2611S and PS2612S | less than 0.6 bar (contact closed) | Shutdown | 5 sec |
| MET Turbocharger bearing oil pressure inlet | PS2611S and PS2612S | less than 0.4 bar (contact closed) | Shutdown | 5 sec |

**Note: The data shown above are for reference only. For the applicable settings, refer to 0230–2 Operating Data Sheet.**

5) Make sure that the pressure switch opens.

6) Decrease the pressure in the pipe to set the pressure switch to the correct pressure (e.g. 3.5 bar). Make sure that the pressure switch stays open.

7) Disconnect the pressure calibration hand-pump (tool 94050) from the pipe.

8) Do the steps above for the pressure switches PS2002S, PS4341S, PS2611S and PS2612S.

9) To monitor the passive failures, connect an applicable resistor (see Table 3) between connections 2 and 3 of the pressure switches that follow:

- PS1101S
- PS2002S
- PS4341S.

The values of resistors that are related to the different remote controls are given in Table 2:

**Table 2: Resistor Values**

| Supplier | Resistor | Power |
|---|---|---|
| KONGSBERG Maritime | 10 kOhm | 0.6 W |
| NABTESCO | 3.9 kOhm | 0.6 W |
| SAM/Lyngsø | 8.2 kOhm | 0.6 W |

### 4.4.1 Oil Mist Detector

1) To activate an alarm in the oil mist detection system, do steps a) to c):
   a) Remove a plug from the junction box, or start the Test Menu in the control unit.
   b) Connect the smoke test instrument (tool) to the test connection of a sensor.
   c) Simulate oil mist to activate an alarm in the safety system.

### 4.4.2 Speed Pick-ups

**WARNING**

**Injury Hazard: Before you operate the turning gear, make sure that no personnel are near the flywheel or in the engine.**

**Note: You must obey the data given in 0100−1 Safety Precautions and Warnings.**

1) Do a check of the pick-ups for speed measurement and crank angle sensor unit as follows:
   a) Engage the turning gear.
   b) Operate the turning gear to turn the crankshaft.
   c) Make sure that all LED on the speed pick-ups come on and go off when the crank angle mark and a flywheel tooth move across the proximity sensor face.
   d) Disengage the turning gear.

### 4.4.3 Level Switches

1) Do a check of the level switch in the condensate collectors as follows:
   a) Manually operate the float switch to activate a high-level alarm.
2) Do a check of the level switch in the leakage oil return as follows:
   a) Manually move the selector switch on the sensor to Min to activate a high-level alarm.

## 4.5 Auxiliary Blowers

1) Set to on the electrical power supply for each auxiliary blower.
2) On the LDU-20 MAIN Page, select the button CTRL. TR. to get control at the local control panel (refer to 4002−2 Local Control Panel/Local Display Unit LDU-20, paragraph 3.3).
3) Select the button ON/OFF. Make sure that:
   a) Auxiliary blower 1 starts immediately.
   b) Auxiliary blower 2 starts after an interval of between 3 seconds to 6 seconds.
4) Make sure that the two auxiliary blowers turn in the correct direction.
5) Do step 3 again from the ECR manual control panel.
6) Connect the pressure calibration hand-pump (tool 94050, see the Maintenance Manual 9403−5) to the pressure transmitters PT4043C and PT4044C. This will simulate a scavenge air pressure (0 bar to 6.0 bar).
7) On the MCM−11 (PT4043C), disconnect the cable from X41 terminal 1
8) On the IOM−10 (PT4044C) disconnect the cable from X13 terminal 2.

9) Connect an ampere meter between the connection and the related cable.

10) Make sure that the transmitter output (4 mA to 20 mA) is related to the simulated pressure (0 bar to 6.0 bar). If necessary replace the transmitter(s).

11) On the MCM−11 (PT4043C), connect the cable to X41 terminal 1.

12) On the IOM−10 (PT4044C), connect the cable to X13 terminal 2.

**Note: The auxiliary blower start/stop hysteresis (0.8 bar to 1.0 bar) is adjusted in the ECS.**

13) Disconnect the pressure calibration hand-pump (tool 94050).

### 4.5.1 Test of Auxiliary Blowers from LDU-20 ECR

1) On the MCM−11, disconnect terminal X11.

2) On the IOM−10, disconnect terminal X33.

**Note: Command and feedback of auxiliary blowers must continue to operate.**

3) If the auxiliary blowers do not operate, do a check of the wiring to the starter box(es).

4) On the MCM−11, connect terminal X11.

5) On the IOM−10, connect terminal X33.

### 4.5.2 Test of Auxiliary Blower from LDU-20 Local

1) On the MCM−11, disconnect terminal X11.

2) On the IOM−10, disconnect terminal X33.

**Note: Command and feedback of auxiliary blowers must continue to operate.**

3) If the auxiliary blowers do not operate, do a check of the wiring to the starter box(es).

4) On the MCM−11, connect terminal X11.

5) On the IOM−10, connect terminal X33.

## 4.6 Servo Oil System

1) Start the main bearing oil pump and make sure that the operating pressure is correctly adjusted.

2) Start the servo oil service pump 20−8445−_E0_1.

3) Adjust the pressure in the servo oil rail 20−5610_E0_6 to approximately 100 bar. The LDU-20 shows the related value (refer to 4002−2, paragraph 3.3).

## 4.7 Exhaust Valve Drive

1) In the LDU-20, get the EXHAUST VALVES page, (refer to 4002−2, paragraph 3.17).

2) In the MANUAL EXHAUST VALVE OPERATION field, use the rotary button to set the CYL. 1 value to 1. This will manually open the exhaust valve 50−2751_CX_1 of cylinder number 1.

3) When the exhaust valve opens, record the value shown in the Open/close deadtimes column.

**Note: You must record this value immediately after the exhaust valve opens, because the valve automatically closes slowly.**

4) Close the exhaust valve 50−2751_CX_1 of cylinder No. 1.

5) When the exhaust valve closes, record the value shown in the Open/close deadtimes column.

6) Do step 1) to step 5) above for each exhaust valve.

**Note: The values shown must be approximately the same for all cylinders. If the values are not the same, the exhaust valve is not fully open, or the sensors are defective.**

7) In the LDU-20, Exh. valve pos. column, use the rotary button to set the value to 0 (automatic mode) for each exhaust valve.

## 4.8 Cylinder Lubrication

1) Release the air in all cylinder lubrication pumps 25–7206_C#_1 (refer to the Maintenance Manual 7218–1).

2) Release the air in the pipes to the lubricating quills (refer to the Maintenance Manual 7218–1).

3) In the LDU-20 get the CYL. LUBRICATION page (refer to 4002–2, paragraph 3.21).

4) In the Manual lub. Cyl. # field, use the rotary button to enter the applicable cylinder number.

**Note: You can change the number of lube pulses (range 0 to 100 lube pulses) in the Num. of Inj. field.**

5) In the Feed Rate columns for HFO or LFO/Gas operation, set the parameter for the feed rate, e.g. 1.2 g/kWh, for running-in (see 7218–1 Cylinder Lubrication, 7218–2 Cylinder Lubrication – LFR and HFR Bushes, 7218–3 Feed Rate – Adjustment, and 0570–1 Running-in New Cylinder Liners and Piston Rings).

**Note: You change the parameter in the Feed Rate column to get different feed rates in the related cylinders.**

## 4.9 Diesel Fuel System

1) Set to on the fuel booster pump 910–D015 (plant).

2) Make sure that the pressure retaining valve 10–5562_E0_6 is set to give a return pressure of between 3.0 bar and 5.0 bar.

The inlet pressure and outlet pressure of the pressure retaining valve is shown on the pressure gages PI3421L and PI3431L (for the setting values, refer to 0230–1 Operating Data Sheet).

3) Push all the EMERGENCY STOP buttons to activate a shut-down signal.

The pressure control valve 10–5562_E0_5 must open immediately, and the pressure in the fuel rail 10–5532_E0_1 must decrease to 0 bar. This pressure decrease is shown on the LDU-20.

4) Set the EMERGENCY STOP buttons so the system can operate again.

## 4.10 Starting System and Start Interlock

### 4.10.1 Start Interlock

1) Make sure that the starting air shut-off valve 30−4325_E0_1 is closed and pressure is released in the starting air supply pipes.
2) Do the check that follows when you engage and disengage the turning gear:
   a) Make sure that while the clearance between the flywheel tooth and the turning gear pinion is not more than 10 mm, no air comes out of the pipe.
3) Engage the turning gear.
4) At E6, loosen the pipe connection to the valve unit **E**. Make sure that no air comes out of the pipe.
5) Slowly disengage the turning gear.
6) At E6, tighten the pipe connection.

### 4.10.2 Starting Air Shut-off Valve

1) On the valve unit **E**, remove the check valve 115HA. Make sure that the three O-rings do not fall out of the valve.
2) In the LDU-20, get the CONTROL LOC. Page (refer to 4002−2, paragraph 3.4), then select the button CTRL. TR. to get control.
3) In the LDU-20, get the USER PARAMETERS page, then select the button AIR RUN (see 4002−2, paragraph 3.22) and make sure that:
   - The solenoid valves CV7013C and CV7014C are energized (use a screwdriver or a magnet tester).
   - In the valve unit **E**, control air comes out at each outer bore at the check valve position.
4) Make sure that:
   - The starting air shut-off valve 30−4325_E0_1 is manually closed.
   - No shut-down signals are released.
   - The turning gear is disengaged.
5) In the LDU-20, get the MAIN page.
6) Select the button ON/OFF to set the auxiliary blowers to off.
7) In the LDU-20 MAIN page, select the button START AHD. Make sure that Auxiliary Blowers Stopped is shown. No start command is released.
8) In the LDU-20 MAIN page, select the button START AST. Make sure that Auxiliary Blowers Stopped is shown. No start command is released.
9) Select the button ON/OFF to set the auxiliary blowers to on then:
   a) Select START AHD and do step 3 to step 8 again.
   b) Select START AST. and do step 3 to step 8 again.

The auxiliary blowers start and in the valve unit **E**, control air comes out of each outer bore at the check valve position.

10) Make sure that the O-rings are in position in the check valve 115HA.
11) Install the check valve 115HA in the valve unit **E**.

### 4.10.3 Turning Gear Interlocks

1) Make sure that the turning gear is engaged.
2) Make sure that the pressure transmitter PT5017C and the switch ZS5016C do not operate (open contacts).

**Note: The pressure transmitter PT5017C operates at 2.0 bar.**

3) Make sure that the indication Turning Gear Engaged shows on each LDU-20 (at the control room console and local maneuvering stand).
4) Make sure that the engine is ready for operation as follows:
   a) Make sure that the starting air shut-off valve 30-4325_E0_1 is in the CLOSED position.
   b) Make sure that there is no air in the starting air supply pipe.
5) On the LDU-20, select the button CTRL. TR. to get control.
6) Select the button START AHD.
7) Make sure that the indication Turning Gear Engaged is shown on each LDU-20. No start command is released.
8) Do steps 1) to 7) from the LDU-20 on the ECR manual control panel, and with the remote control.
9) Disengage the turning gear.

**Note: On each LDU-20, the indication changes to Turning Gear Disengaged. The start command is canceled in the remote control.**

## 4.11 Overspeed Limit

The overspeed monitor is included in the safety system.

## 4.12 Engine Start on Diesel Fuel

The engine is ready for operation (see 0400−1 Prepare for Engine Start after a Short Shut-down Period). For more data, see also 0440−1 Engine Start Procedure.

**Note: You can only start the engine in diesel mode**

1) In the LDU-20, get the CONTROL LOC. Page (see 4002−2, paragraph 3.4), then select the button CTRL. TR. to get control.
2) In the LDU-20, get the USER PARAMETERS page, then select the button AIR RUN (see 4002−2, paragraph 3.22) to turn the engine with air.
3) In the LDU-20, get the MAIN page.
4) Use the rotary button to select the Fuel Command button.
5) Use the rotary button to set the fuel injection quantity to approximately 15%.
6) Select the button START AHD to start the engine.
7) Use the rotary button to control the speed and fuel injection quantity. Operate the engine until all cylinders fire regularly.
8) Select the button STOP. The engine stops.
9) Select the button CTRL. TR. for mode transfer to the ECR remote control.

10) Make sure that the control transfer and the operation from the ECR remote operates correctly.
11) Select the button CTRL. TR. for mode transfer to the bridge.
12) Make sure that the control transfer and the operation from the ECR remote operates correctly.
13) After mode transfer, you can start the engine from the ECR remote control.

## 4.13 Gas Fuel System

### 4.13.1 Gas Fuel System Tests

1) In the LDU-20, get the CONTROL LOC. Page, then select the button CTRL. TR. to get control.
2) In the LDU-20, get the GAS PRESSURE page, then select the button GVU−Eng Test Request (refer to 4002−2, paragraph 3.12) to start the gas leak test.
3) In the GAS PRESSURE page, select the button Exh. Side Test Request to start the gas leak test.
4) In the GAS PRESSURE page, select the button Fuel Side Test Request to start the gas leak test.
5) Make sure that no alarm or failure message is shown on the LDU-20.

### 4.13.2 Gas Valve Unit and Valve Test

1) In the LDU-20, get the CONTROL LOC. Page (see 4002−2, paragraph 3.4), then select the button CTRL. TR. to get control.
2) In the LDU-20, get the GVU & VALVE TEST page, then select the button On/Off Test Mode (see 4002−2, 3.13) to start the GVU and shut-off valve test.
3) Use the rotary button to select the related valve.
4) Push the rotary button to start the test procedure for the related valve.
5) Do step 3) and step 4) for all vent valves and shut-off valves.
6) Make sure that the related solenoid valves are energized (use a screwdriver or a magnet tester). See also, 4002−1 Engine Control System, paragraph 3.17, Vent Valve Control (Gas Supply).
7) Make sure that no alarm or failure message is shown on the LDU-20 (see 4002−2, paragraph 3.13).

### 4.13.3 Gas Admission Valve − Manual Valve Test

1) In the LDU-20, get the CONTROL LOC. Page (see 4002−2, paragraph 3.4), then select the button CTRL. TR. to get control.
2) In the LDU-20, get the GAV MANUAL VALVE TEST page, then select the button Manual Test Request (see 4002−2, paragraph 3.14) to start the GAV test.
3) Use the rotary button to select the related gas admission valve (GAV).
4) Push the rotary button to start the test procedure for the related GAV.
5) Do step 3) and step 4) for all GAV.
6) Make sure that the solenoid valves CV7501−08C are energized (use a screwdriver or a magnet tester). See also 4002−1, Engine Control System, paragraph 3.17, Vent Valve Control (Gas Supply).
7) Make sure that no alarm or failure message is shown on the LDU-20 (see 4002−2, paragraph 3.14).

## 4.14 Pilot Fuel Pressure

1) In the LDU-20, get the CONTROL LOC. Page (see 4002−2, paragraph 3.4), then select the button CTRL. TR. to get control.
2) In the LDU-20, get the PILOT FUEL PRESS. page, then select the button AUTO/MANUAL (see 4002−2, paragraph 3.12) to request the manual pilot fuel pump control.
3) Use the rotary button to select the button START/STOP.
4) Push the rotary button to manually start the pilot fuel pump.
5) Check the status of the pilot fuel pump and the pilot fuel pressure.
6) Make sure that the Pressure Control Status shows OK.
7) Make sure that no alarm or failure message is shown on the LDU-20 (see 4002−2, paragraph 3.14).

# Identification of Parts



## 1. General

The identification of parts include those given in: 4003−1, 4003−2, Page 1 and Page 2, 4003−3, 4003−4, 4003−5, 4003−6, 4003−7, 4003−8, 4003−9, 4003−10 4003−11 and 4003−12.

## 2. Area Codes in the Control Diagram

The list of area codes in the control diagram are shown in Table 1.

**Table 1: Area Codes**

**A** – Control air supply unit
**B** – Servo oil supply
**D** – Servo oil supply
**E** – Valve unit for start
**K** – Local control panel
**P** – Pilot fuel pump unit

## 3. System Codes in the Control Diagram

The primary system codes in the control diagram are shown in Table 2. The system codes for the related components are shown in Table 3.

**Table 2: Primary System Codes**

Code 10 – Fuel System
Code 20 – Oil System
Code 25 – Cylinder Lubrication System
Code 30 – Starting Air System
Code 35 – Control Air System
Code 40 – HT Cooling Water System
Code 48 – Cylinder Cooling Water System CCO
Code 50 – Exhaust Gas System
Code 70 – Miscellaneous Systems
Code 80 – Automation System
Code 90 – Gas Fuel System
Code 99 – Pipe Diagram
Code 900 – Engine Room

# 4. Process Codes – Description

The process codes and their descriptions are shown in Fig. 1 and Table 3.

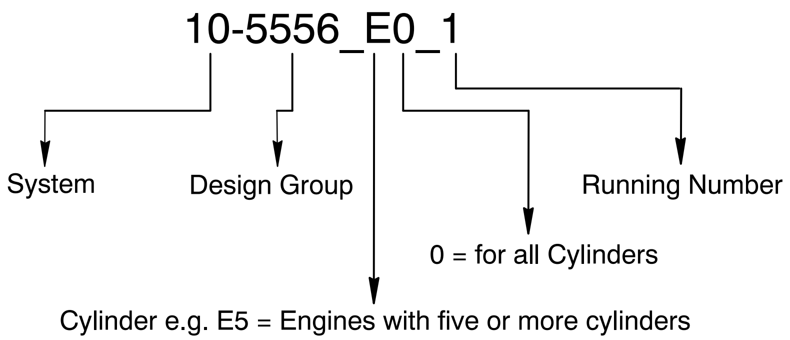



**Fig. 1: Process Codes – Identification**

**Table 3: System Codes – Components (page 1, 4003–2)**

| Process Code | Description |
|---|---|
| 10–2710_CX_Y | Fuel injection valve (L'Orange) |
| 10–5556_E0_1 | Fuel pump 1 |
| 10–5556_E0_2 | Fuel pump 2 |
| 10–5556_E0_3 | Fuel pump 3 |
| 10–5562_C1_2 | Flow limiting valve Cyl. 1 |
| 10–5562_E0_1 | Single wall fuel rail |
| 10–5562_E0_2 | Non return valve |
| 10–5562_E0_3 | Non return valve |
| 10–5562_E0_4 | Non return valve |
| 10–5562_E0_5 | Pressure control and relief valve |
| 10–5562_E0_6 | Pressure retaining valve |
| 10–5562_E0_7 | Filling valve |
| 10–5562_E0_8 | Drain valve |
| 10–8704_E0_2 | Adjustable pressure retaining valve |
| 10–8744_E0_5 | Ball valve |
| 10–8752_E0_10 | Connection piece |
| 10–8752_E0_11 | Connection piece |

Table 3 continued.

| Process Code | Description |
|---|---|
| 20–5551_E0_1 | Servo oil pump 1 |
| 20–5551_E0_2 | Servo oil pump 2 |
| 20–5610_E0_1 | Non-return valve |
| 20–5610_E0_2 | Non-return valve |
| 20–5610_E0_3 | 2-way shut-off valve |
| 20–5610_E0_4 | Pressure safety valve |
| 20–5610_E0_6 | Single wall servo oil rail |
| 20–5612_CX_2 | Solenoid valve |
| 20–5612_CX_3 | Filter VCU |
| 20–5612_CX_4 | Restrictor |
| 20–5614_E0_1 | Pressure reducing valve |
| 20–5614_E0_5 | Restrictor |
| 20–5614_E0_6 | Pressure safety valve |
| 20–8406_E0_5 | Ball valve |
| 20–8423_E0_1 | Injector oil supply valve |
| 20–8423_E0_2 | Ball valve |
| 20–8423_E0_8 | Filter, fuel pump 1 |
| 20–8423_E0_9 | Filter, fuel pump 2 |
| 20–8445_E0_1 | Servo oil service pump |
| 20–8445_E0_2 | Pressure safety vale |
| 20–8445_E0_3 | Pressure retaining vale |
| 20–8447_E0_1 | Connection piece |
| 20–8455_E0_2 | Non return valve |
| 25–8475_E0_1 | Ball valve |
| 25–8475_E0_2 | 3/3-way valve |
| 25–8475_E0_6 | Filter |
| 25–8475_E0_7 | Filter |
| 30–2728_CX_1 | 3/2-way valve |
| 30–4325_E0_1 | Starting air shut-off valve |
| 30–8605_E0_6 | Ball valve |
| 30–8605_E0_7 | Ball valve |
| 30–8650_E0_1 | Pressure safety valve |
| 30–8605_CX_1 | Flame arrester |

Table 3 continued.

| Process Code | Description |
|---|---|
| 35−115HA | Double check valve |
| 35−19HA | Pressure reducing valve |
| 35−23HA | Pressure reducing valve |
| 35−274HA | Pressure safety valve |
| 35−274HD | Pressure safety valve |
| 35−2751_CX_1 | Non-return valve |
| 35−2751_CX_2 | Restrictor |
| 35−287HA | Control air bottle |
| 35−31HA | 3/2-way valve |
| 35−342HA | Non return valve |
| 35−342HB | Non return valve |
| 35−351HA | Air filter |
| 35−36HA | 3/2-way valve |
| 35−36HB | 3/2-way valve |
| 35−36HC | 3/2-way valve |
| 35−4325_E0_2 | 3/2-way valve |
| 35−4325_E0_3 | 3/2-way valve |
| 35−4325_E0_5 | 2/2-way valve |
| 35−4605_E0_6 | 2-way shut-off valve |
| 35−4605_E0_8 | 2-way shut-off valve |
| 35−4605_E0_9 | Restrictor |
| 35−4606_E0_2 | 2-way shut-off valve |
| 35−4606_E0_3 | Bottle |
| 35−4606_E0_4 | Needle valve |
| 35−8353_E0_2 | Ball valve |
| 35−8606_E0_3 | Collector (leakage oil from air spring) |
| 35−8606_E0_4 | Ball valve |
| 50−2751_CX_1 | Exhaust valve |
| 50−8135_E0_1 | 2/2-way valve |
| 50−8135_E0_2 | 3/2-way valve |
| 910−D015 | Fuel booster pump |
| 910−V113 | 2-way shut-off valve |
| 910−V121 | 2-way shut-off valve |
| 925−B001 | Cylinder lube oil tank |

Table 3 continued.

| Process Code | Description |
|---|---|
| 995–07 | SAC-LT-cooling water inlet |
| 995–08 | SAC-LT-cooling water outlet |
| 995–25 | Main lubricating oil inlet |
| 995–30 | Lubricating oil crosshead inlet |
| 995–33 | Cylinder lub oil inlet |
| 995–34 | Leakage oil driving end outlet |
| 995–35 | Leakage oil free end outlet |
| 995–45 | Control air supply inlet |
| 995–49 | Fuel inlet |
| 995–50 | Fuel return outlet |
| 995–51 | Fuel leakage rail unit outlet |
| 995–52 | Fuel leakage outlet |
| 995–57 | Various leakage outlet |

**Table 4: System Codes – Components (page 2, 4003–2)**

| Process Code | Description |
|---|---|
| 10–2790_CX_Y | Pilot injector |
| 10–5555_E0_1 | Filter |
| 10–5555_E0_2 | Adjustable restrictor |
| 10–5555_E0_3 | High pressure fuel pump |
| 10–5555_E0_4 | Pressure safety valve |
| 10–5555_E0_5 | Pressure retaining valve |
| 10–5555_E0_6 | 2-way shut-off valve |
| 10–8790_C1_1 | Pilot fuel collector |
| 10–8790_C2_1 | Pilot fuel collector |
| 10–8790_C3_1 | Pilot fuel collector |
| 10–8790_C4_1 | Pilot fuel collector |
| 10–8790_C5_1 | Pilot fuel collector |
| 10–8790_C6_1 | Pilot fuel collector |
| 10–8790_E0_1 | 2-way shut-off valve |
| 10–8790_E0_2 | 2-way shut-off valve |

Table 4 continued.

| Process Code | Description |
|---|---|
| 20−5610_E0_6 | Single wall servo oil rail |
| 20−8490_E0_2 | Restrictor |
| 20−8492_E0_1 | Restrictor |
| 20−8492_E0_3 | Injector oil supply valve |
| 90−2112_E0_1 | Cylinder block |
| 90−2140_C1_1 | Gas valve |
| 90−2140_C1_2 | Gas valve |
| 90−2140_C2_1 | Gas valve |
| 90−2140_C2_2 | Gas valve |
| 90−2705_C1_1 | Dual fuel combustion room |
| 90−2705_C2_1 | Dual fuel combustion room |
| 90−8490_C1_1 | Servo oil collector |
| 90−8490_C1_2 | Servo oil collector |
| 90−8492_E0_2 | Pressure reducing valve |
| 90−8903_E0_2 | Shut-off valve |
| 90−8903_E0_3 | Shut-off valve |
| 90−8903_E0_4 | Auxiliary vent valve |
| 90−8903_E0_5 | Vent valve |
| 90−8903_E0_6 | Vent valve |
| 910−P001 | Fuel booster pump |
| 995−76 | High pressure fuel pilot valve inlet |
| 995−77 | High pressure fuel pilot valve outlet |
| 995−79 | Gas venting driving end outlet |
| 995−80 | Gas venting free end outlet |
| 995−82 | Gas venting free end outlet |

# 5. Sensors and Transmitters

## 5.1 Signal Codes – Identification

Fig. 2 shows an example of a signal code and gives data about the identification of the function, type and related system (see Table 3, Table 4 and Table 5). The signal codes and their descriptions are shown in paragraph 3.2.

The sensors, transmitters and their descriptions are shown in Table 4.

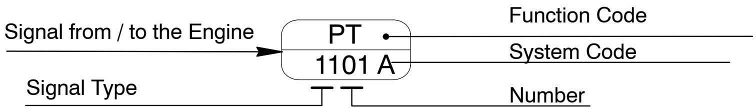



**Fig. 2: Code Identification**

For example, PT1101A is a pressure transmitter (see Table 4) for the cooling water system (see Table 5) and transmits signals to the Alarm and Monitoring System (see Table 6).

**Table 5: Signal Code – Function**

| Code | Function – First Position | Function – Second Position |
|---|---|---|
| A | Analysis | n/a |
| C | Control | Control |
| E | n/a | Element |
| F | Flow | n/a |
| G | Gauges | n/a |
| H | Hand | n/a |
| I | n/a | Indication |
| J | Power | n/a |
| L | Level | n/a |
| P | Pressure | n/a |
| S | Speed | Switch |
| T | Temperature | Transmitter |
| V | n/a | Valve |
| X | Unclassified | Unclassified |
| Y | Vibration | Relay |
| Z | Position (Binary) | n/a |

**Table 6: Signal Code – Type**

| Code | Signal Type | System |
|---|---|---|
| 10– | Signals from the engine | Cooling water |
| 20– | Signals from the engine | System / Cooling oil |
| 31– | Signals from the engine | Cylinder lubrication |
| 34– | Signals from the engine | Fuel oil |
| 35– | Signals from the engine | Gas |
| 40– | Signals from the engine | Air |
| 50– | Signals from the engine | Miscellaneous |
| 60– | Signals from the engine | Spare |
| 70– | Signals to the engine | Miscellaneous |
| 80– | Signals to the engine | Miscellaneous |

**Table 7: Signal Code – System**

| Code | Description |
|---|---|
| A | Alarm and monitoring system |
| C | Control system |
| S | Safety system |
| X | Unclassified |

## 5.2 Signals – Engine Safety System (ESS)

**Table 8: Signals Engine Safety System – Input**

| Signal Code | Description |
|---|---|
| PS1101S | Cylinder Cooling Water Pressure Engine Inlet |
| PS2002S | Main Bearing Oil Pressure Supply |
| AS2401S | Oilmist Concentration in Crankcase |
| FS2521–27S | Piston Cooling Oil Flow Monitoring Cyl. #01 – 07 |
| FS2521–27S | Piston Cooling Oil Flow Monitoring Cyl. #01 – 07 |
| PS2611–12S | Turbocharger Bearing Oil Press. Inlet TC #1–2 |
| PS2611–12S | Turbocharger Bearing Oil Press. Inlet TC #1–2 |
| PS4341S | Air Spring Air Pressure |
| TS4521S | Thrust Bearing Temp. fore side |
| ST5111–12S | Engine Speed |

**Table 9: Signals Engine Safety System – Output**

| Signal Code | Description |
|---|---|
| ZV7061S | Fuel Shutdown Pilot Valve |
| XS3467S | Pilot Fuel Pump Stop from ESS |

**Table 10: Signals Engine Safety System – Output from AMS to PCS**

| Signal Code | Description |
|---|---|
| XS9301S | Common Slowdown Request from AMS |

## 5.3 Signals – Alarm and Monitoring System (AMS)

**Table 11: Signals – Input from Alarm and Monitoring System (AMS)**

| Signal Code | Description |
|---|---|
| PT1101A | Cylinder Cooling Water Pressure Engine Inlet |
| TE1111A | Cylinder Cooling Water Temp. Engine Inlet |
| TE1121–27A | Cyl. Cool. Water Temp. Outlet Cyl. #01–07 |
| PT1361A | Scav. Air Cooling Water Pressure Inlet Cooler |
| TE1371A | Scav. Air Cool. Water Temp. Inlet Cooler |
| TE1381–82A | Scav. Air Cool. Water Temp. Outlet Cooler #1–2 |
| PT2001A | Bearing Oil Pressure Engine Inlet |
| PT2003A | Bearing Oil Press.,before Injectors |
| TE2011A | Bearing Oil Temperature Engine Inlet |
| PT2021A | Crosshead Brng. Oil Press. Supply |
| PT2041A | Cyl. Lub. Servo Oil Pressure |
| LS2055A | Servo Oil Leakage Supply Unit |
| FS2061–62A | Servo Oil Flow Pump #1–2 |
| TE2101–09A | Main Bearing Oil Temp. Outlet Bearing #01–09 |
| TE2201–07A | Crank Bearing Oil Temp. Outlet Bearing #01–07 |
| TE2301–07A | Crosshead. Brg. Oil Temp. Outlet Bearing #01–07 |
| AE2401–07A | Oil mist Concentration in Crankcase |
| AS2401A | Oil mist Concentration in Crankcase |
| XS2411A | Oilmist Detector Failure |
| AE2415A | Oil mist Concentration in Crankcase Gear Case |
| AE2421A | Oil mist Concentration in Supply Unit |
| TE2501–07A | Piston Cool. Oil Temp. Outlet Cylinder #01–07 |
| TE2601–02A | TC Bearing Oil Temp. Outlet TC #1–2 |
| TE2601–02A | TC Bearing Oil Temp. Outlet TC #1–2 |
| TE2601–02A | TC Bearing Oil Temp. Outlet TC #1–2 |
| PT2611–12A | TC Bearing Oil Pressure Inlet TC #1–2 |
| PT2611–12A | TC Bearing Oil Pressure Inlet TC #1–2 |
| PT2611–12A | TC Bearing Oil Pressure Inlet TC #1–2 |
| TE2621A | TC Bearing Oil Temperature Inlet |
| TE2621A | TC Bearing Oil Temperature Inlet |
| PT2711A | CS built Geislinger Damper Oil Pressure Inlet |
| PT2721A | Axial Detuner Oil Pressure Aft. Side |
| PT2722A | Axial Detuner Oil Press. Fore Side |

Table 11 continued.

| Signal Code | Description |
|---|---|
| PT3124A | Cyl. Lub. Oil Pressure Supply |
| TE3411A | Fuel Oil Temperature Supply Unit |
| PT3421A | Fuel Oil Pressure Supply Unit |
| LS3426A | Fuel Oil Leakage Supply Unit |
| LS3444A | Fuel Oil General Leakage Rail Unit |
| LS3446A | Fuel Oil Pipe Leakage |
| XS3463A | Fuel Heating Failure |
| PS3464A | Pilot Fuel Filter Diff. Pressure |
| TE3701–07A | Exhaust Gas Temp. after Cylinder #01–07 |
| TE3721–22A | Exhaust Gas Temp. before TC #1–2 |
| TE3731–32A | Exhaust Gas Temp. after TC #1–2 |
| TE4031–32A | Scavenge Air Temp. after Air Cooler #1 |
| LS4071–72A | Cond. Water Detection in Air Receiver 1–2 |
| LS4075–76A | Scav. Air Cond. Water Detection before Water Sep. #1–2 |
| TE4081–87A | Scavenge Air Temp. Piston Underside Cylinder #01–07 |
| PT4341A | Air Spring Air Pressure |
| LS4351A | Air Spring Oil Leakage Level Drive End |
| LS4352A | Air Spring Oil Leakage Level Free End |
| PT4401A | Control Air Pressure Supply |
| PT4411A | Control Air Pressure Supply |
| PT4421A | Control Air Pressure Engine Inlet |
| TE4521A | Thrust Bearing Temp. fore side |
| XS5046A | Fuel Pump Actuator Failure E98 |
| ST5201–02A | TC Overspeed, TC #1–2 |
| ST5201–02A | TC Overspeed, TC #1–2 |
| PS3464A | Pilot Fuel Filter Diff. Pressure |

**Table 12: Signals AMS – Input from Propulsion Control System (PCS)**

| Signal Code | Description |
|---|---|
| XS9001A | Propulsion Control Failure |
| XS9002A | Propulsion Control Passive Failure |
| XS9003A | Propulsion Control Speed Meas. Failure |
| XS9005A | Engine Standstill |
| XS9006A | Any Aux. Blower Failed |
| XS9008A | Engine Load above 30% of scaled Fuel Command Signal |
| XS9011A | Safety System Respond |
| XS9012A | Safety System Off / Failure |
| XS9013A | Safety System Respond Speed meas. Failure |
| XS9021A | Telegraph System Failure |
| XS9031A | Speed Control Minor Failure |
| XS9032A | Speed Control Major Failure |

**Table 13: Signals AMS – Miscellaneous**

| Signal Code | Description |
|---|---|
| SI5101M | Engine Speed |
| XS5716A | Servo Oil Service Pump Run |
| XS5716A | Servo Oil Service Pump Starter Overload |

## 5.4 Signals – Engine Control System (ECS)

**Table 14: Signals – Engine Control System**

| Signal Code | Description |
|---|---|
| PT3131–37C | Cyl. Lubrication Oil Pressure Cyl. #1 – 7 |
| PT3601–07C | Cyl. Press. Cyl. #1 – 7 |
| TE3701–07C | Exh. Gas Temp. Cyl. #1 – 7 |
| TE4801–07C | Liner Wall Temp. Aft Side Cyl. #1 – 7 |
| TE4801–07C | Liner Wall Temp. Aft Side Cyl. #1 – 7 |
| TE4841–47C | Liner Wall Temp. Fore Side Cyl. #1 – 7 |
| TE4841–47C | Liner Wall Temp. Fore Side Cyl. #1 – 7 |
| ZS5123C | TDC Signal |
| ZS5124C | BDC Signal |
| ST5131– 32C | Gear Wheel Sensor A + B |
| ST5133–34C | Gear Wheel Sensor C + D |
| ZT5421–27C | Exhaust Valve Position Cyl. #1 – 7 |
| XS5621C | Gas Admission Not Released A |
| XS5641C | Gas Admission Not Released B |
| CV7131–37C | Cyl. Lub. Solenoid Vlv #1, Cyl. #1 – 7 |
| CV7241–47C | Start Air Pilot Vlv Cyl. #1 – 7 |
| CV7401–07C | Exh. Ctrl. Vlv. Open Cyl. #1 – 7 |
| CV7441–47C | Fuel Inj. SV 1 Cyl. #1 – 7 |
| CV7461–67C | Fuel Inj. SV 2 Cyl. #1 – 7 |
| CV7481–87C | Fuel Inj. SV 3 Cyl. #1 – 7 |
| XS8011–17C | CCM–20 ID Cyl. #1 – 7 |
| YE3501–07C | Knock Signal Cyl. #1 – #7 |
| ZT3501–07C | Gas Admission Valve #1 Position Cyl. #1 – #7 |
| ZT3521–27C | Gas Admission Valve #2 Position Cyl. #1 – #7 |
| ZS5123C | TDC Signal |
| ZS5124C | BDC Signal |
| ST5131–32C | Gear Wheel Sensor A + B |
| XS5621C | Gas Admission Not Released A |
| XS5641C | Gas Admission Not Released B |
| CV7301–07C | Pilot Injector Valve #1 Cyl. #1 – #7 |
| CV7321–27C | Pilot Injector Valve #2 Cyl. #1 – #7 |
| CV7501–07C | Gas Admission Valve #1 Cyl. #1 – #7 |
| CV7541–47C | Gas Admission Valve #2 Cyl. #1 – #7 |

Table 14 continued.

| Signal Code | Description |
|---|---|
| PT2051C | Servo Oil Press. Pump Inlet |
| PT3461C | Fuel Rail Press. #1 |
| JT5156C | Power Input [kW] |
| CV7231C | Fuel Pump Actuator, #1 |
| CV7286C | Vent Valve Fuel Side |
| PT3421C | Fuel Pressure, before supply unit |
| PT3462C | Fuel Rail Press. #2 |
| CV7232C | Fuel Pump Actuator, #2 |
| CV7287C | Vent Valve Exh. Side |
| CV7296C | GAV Lub. Oil Shut Off Valve |
| PT2002C | Bearing Oil Pressure, Inlet Engine |
| PT2071C | Servo Oil Press. #1 |
| CV7221C | Servo Oil Pump #1, Press. Ctrl. Vlv |
| CV7289C | Vent Valve Engine Inlet |
| CV7291C | Gas Shut Off Fuel Side |
| PT2072C | Servo Oil Press. #2 |
| PT4341C | Air Spring Air Press. |
| CV7222C | Servo Oil Pump #2, Press. Ctrl. Vlv |
| AE3315C | Gas Conc. Piston Under Side |
| XS3465C | Pilot Fuel Pump ON |
| CV7239C | Pilot Fuel Press. Ctrl. Vlv |
| CV7292C | Gas Shut Off Exh. Side |
| CV7233C | Fuel Pump Actuator #3 |
| PT2021C | Crosshead Brng. Oil Press. Supply |
| XS2050C | Servo Oil Service Pump On |
| PT2091C | GAV Sealing Lub. Oil Pressure |
| PT3466C | Pilot Fuel Press. B |
| PT4043C | Scav. Air Press. in Air Rec. #1 |
| PT4301C | Starting Air Press. #1 before Shutoff Valve |
| PT4421C | Control Air Pressure Inlet Engine |
| ZS5016C | Turning Gear Diseng. #1 |
| ZS5018C | Main Start Vlv, manually closed |
| JS5031C | Aux. Blower #1 Running |
| ST5131−32C | Gear Wheel Sensor A + B |
| ST5201C | Turbo Charger Speed #1 |
| CV7003C | Injector Lubrication Shut−OFF Vlv |
| CV7013C | Common Start valve 1 |

Table 14 continued.

| Signal Code | Description |
|---|---|
| CY7031C | Aux Blower #1 Start |
| XI7077C | Exhaust Waste Gate Pos. |
| PT1101C | Cyl. Cooling Water Press., Inlet Engine |
| PT3464C | Pilot Fuel Press. Inlet |
| TE3464C | Pilot Fuel Temp. Inlet |
| PT3465C | Pilot Fuel Press. A |
| PT3595C | Gas Press., Fuel Side |
| PT3597C | Gas Press., Exh. Side |
| PT4002–03C | Barometric Pressure |
| TE4041–42C | T/C Air Temp. before inlet #1–2 |
| PT4044C | Scavenge Air Press. #2, in Air Receiver |
| TE4045–46C | T/C Air Temp. After air cooler #1–2 |
| PT4302C | Starting Air Press. #2, before Shutoff Valve |
| PT5017C | Turning Gear Diseng. #2 |
| JS5032C | Aux Blower #2 Running |
| ST5202C | Turbo Charger Speed #2 |
| CV7014C | Common Start Vlv #2 |
| CY7032C | Aux Blower #2 Start |
| CV7077C | Exh. Waste Gate Ctrl. Vlv |

**Table 15: Signals – Input to Remote Control System (RCS)**

| Signal Code | Description |
|---|---|
| ST5101–04C | Engine Speed |
| JS5031C | Aux. Blower #1 Running |
| JS5032C | Aux. Blower #2 Running |
| JS5037C | Any Aux. Blower Running ECRMC |
| JS5038C | Any Aux. Blower Running LMC |

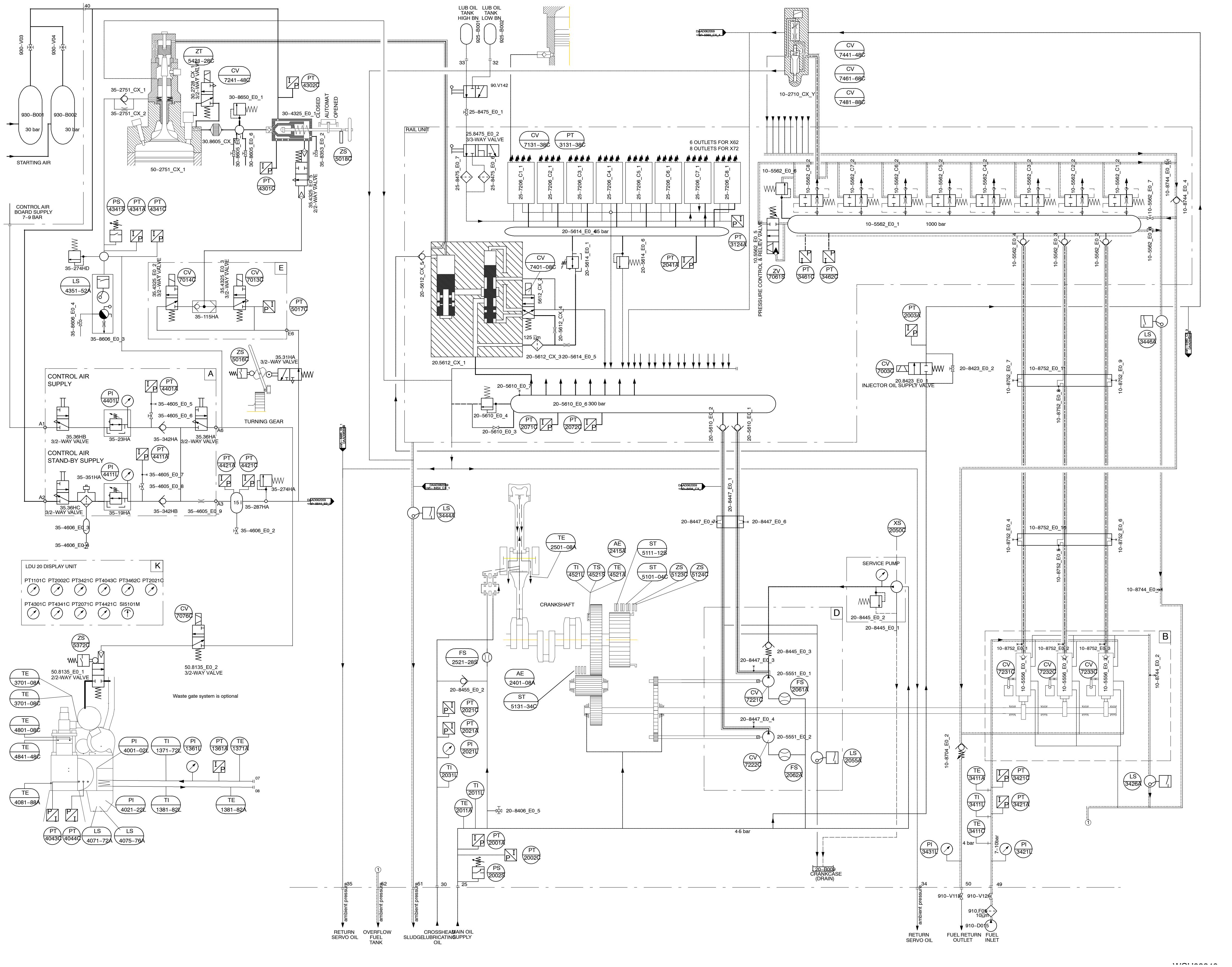
**Table 16: Signals – Output from Remote Control System (RCS)**

| Signal Code | Description |
|---|---|
| CY7031C | Aux. Blower #1 Start |
| CY7032C | Aux. Blower #2 Start |

**Table 17: Signals Remote Indication**

| Signal Code | Description |
|---|---|
| ST5201C | Turbocharger, Speed TC #1–2 (ABB Axxx) |
| ST5201C | Turbocharger, Speed TC #1–2 (MHI MET) |

# Control Diagram



A Control air supply unit
B Fuel supply
D Servo oil supply
E Valve unit for engine start
K Local control panel
P Pilot fuel pump unit

Low pressure oil circuits
High pressure oil circuits
Low pressure fuel circuits
High pressure fuel circuits
Heating
Control air circuits
Starting air circuits
Gas circuit

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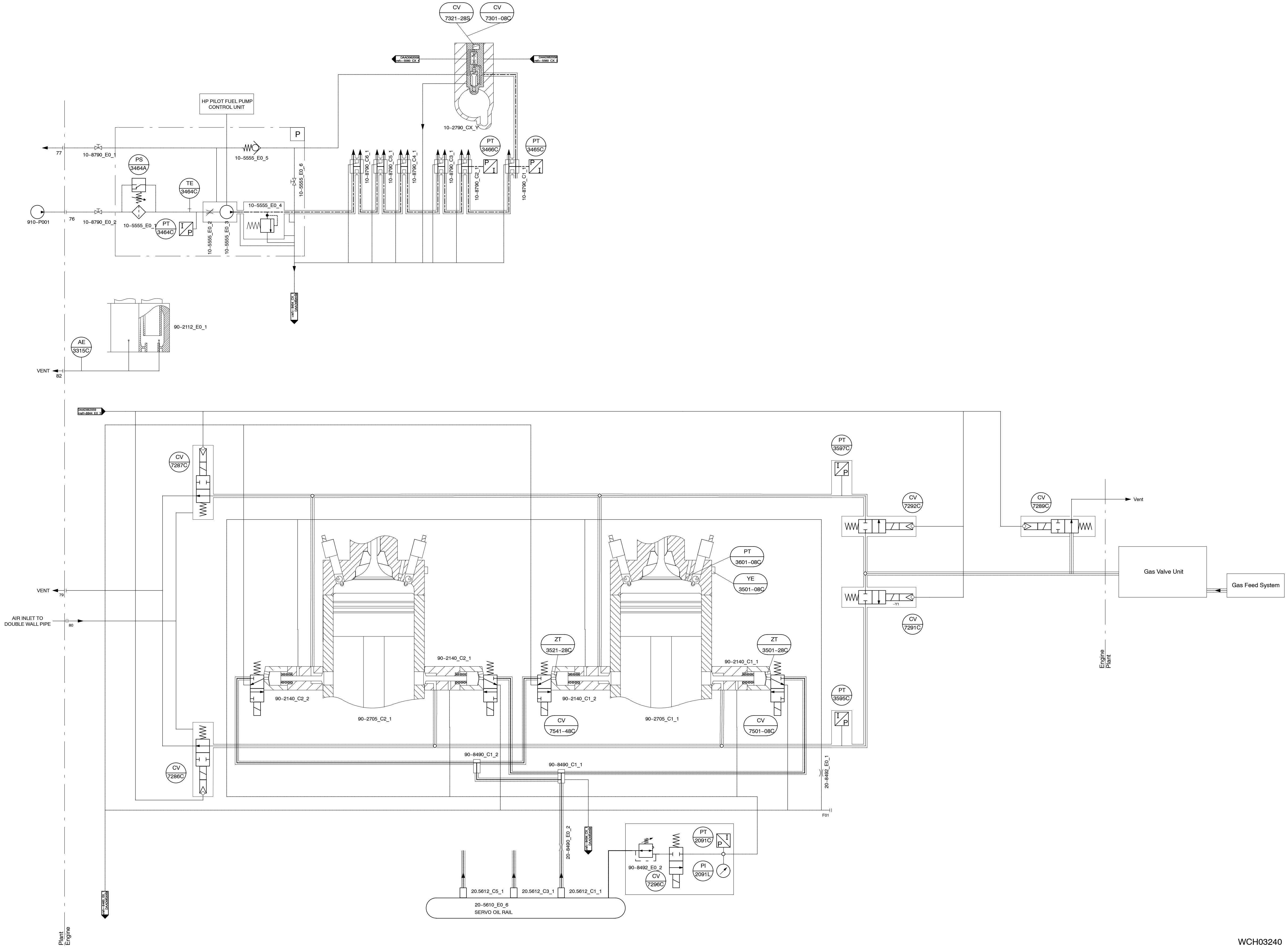
# Control Diagram



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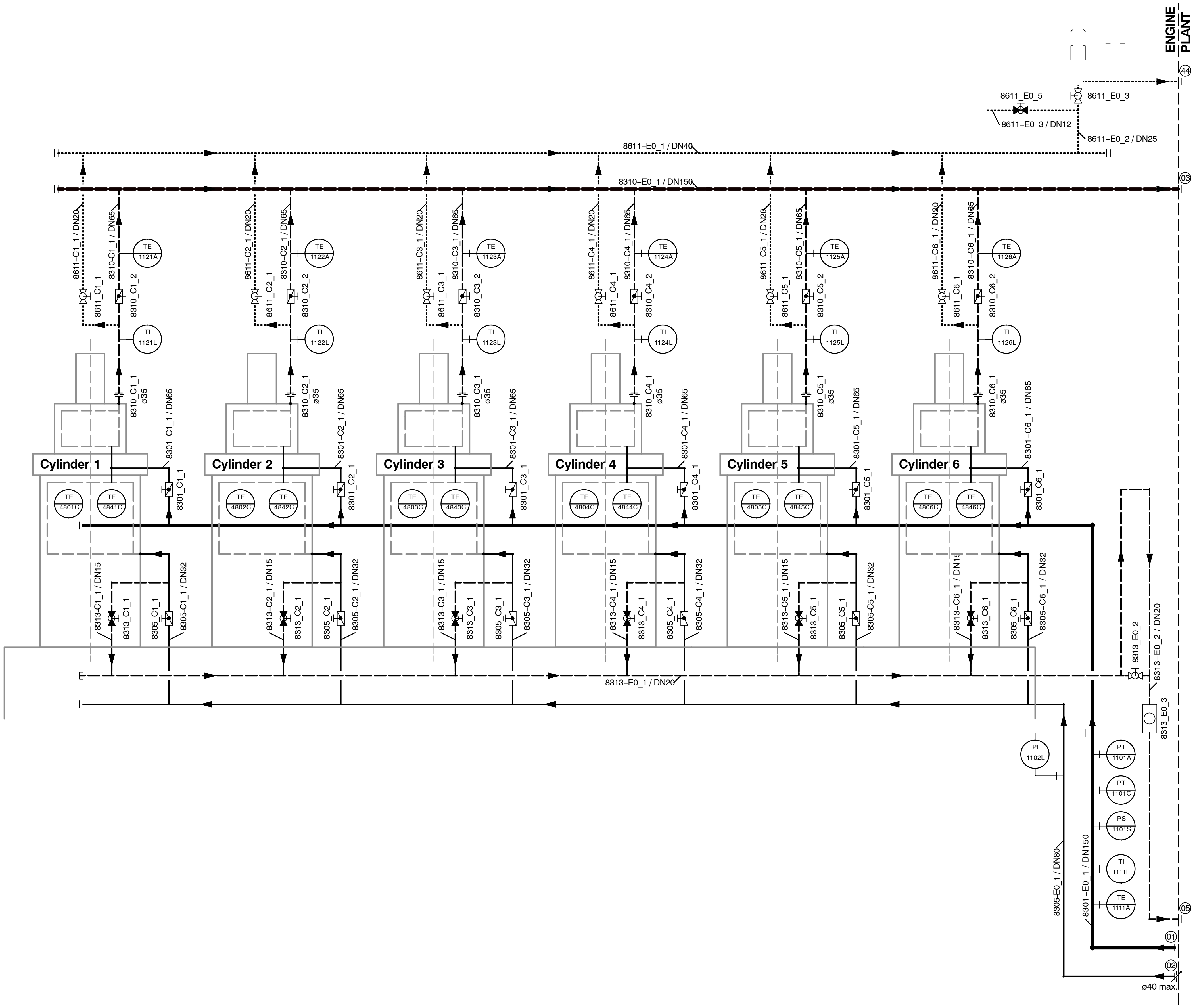
# Pipe Diagram – Water System (Cylinder Cooling)



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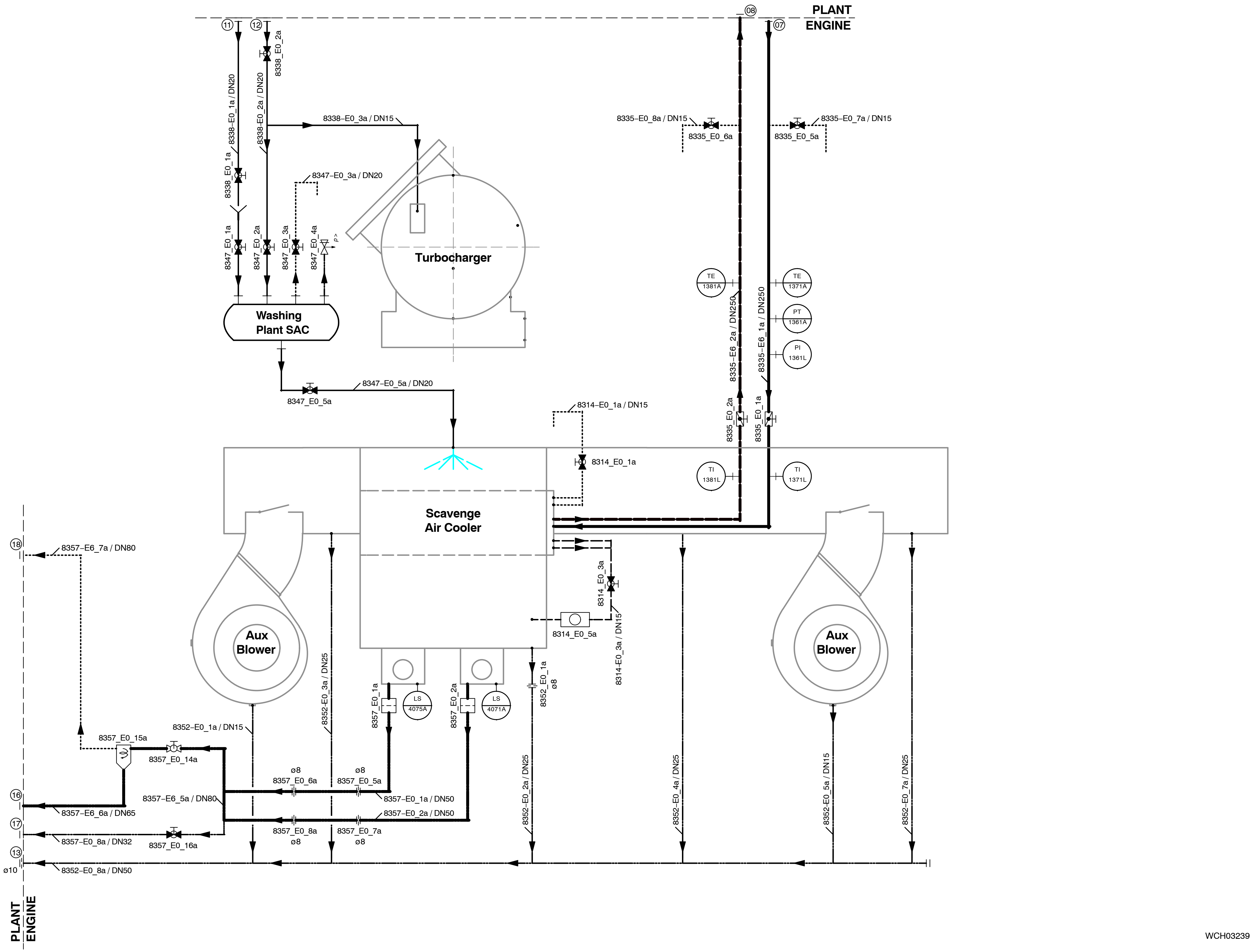
## Pipe Diagram – Water System (Scavenge Air Receiver and Turbocharger)



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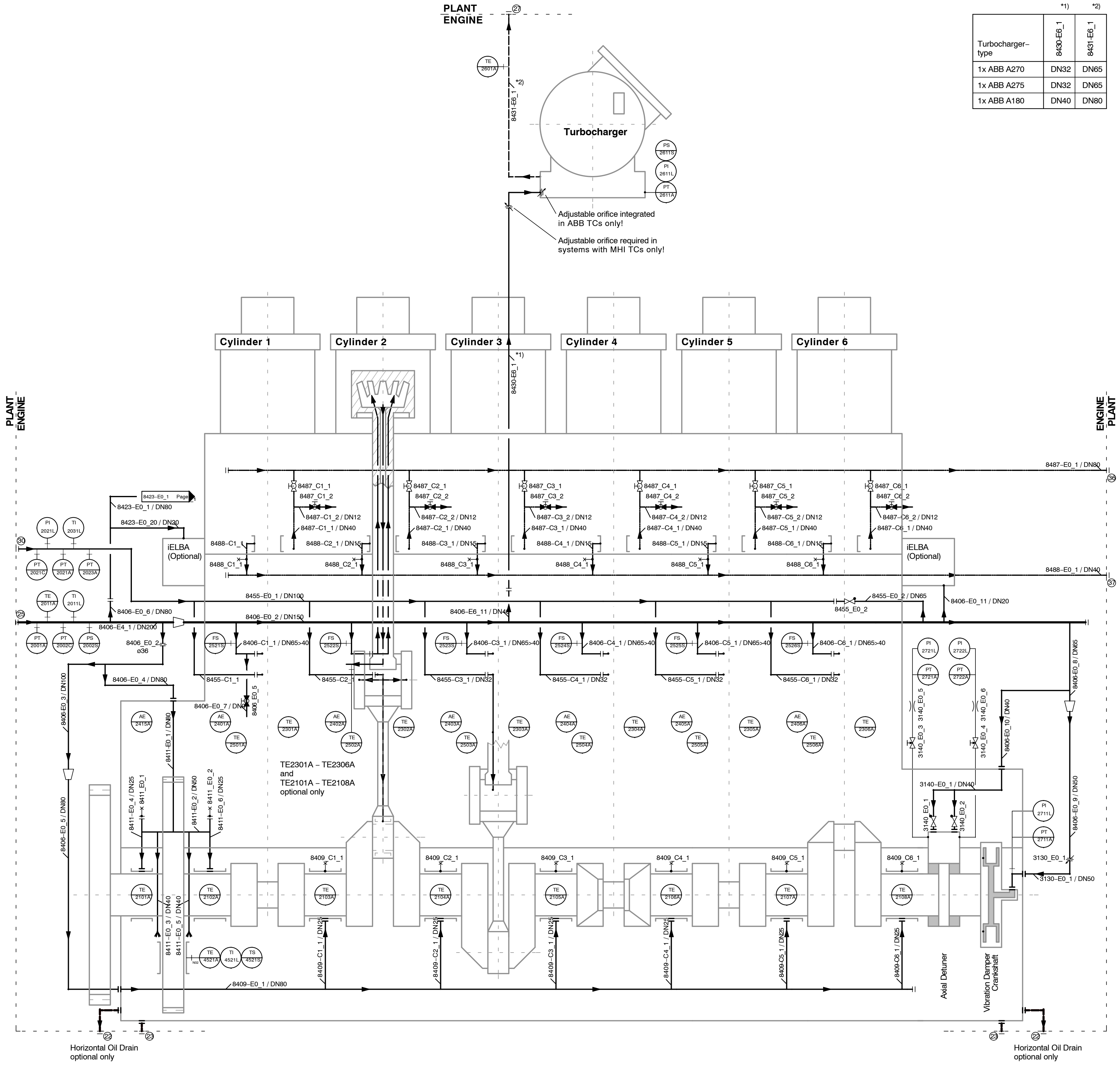
# Pipe Diagram – Oil Systems (System Oil and Internal Turbocharger Oil Supply)




| Turbocharger-type | 8430-E6_1 *1) | 8431-E6_1 *2) |
|---|---|---|
| 1x ABB A270 | DN32 | DN65 |
| 1x ABB A275 | DN32 | DN65 |
| 1x ABB A180 | DN40 | DN80 |

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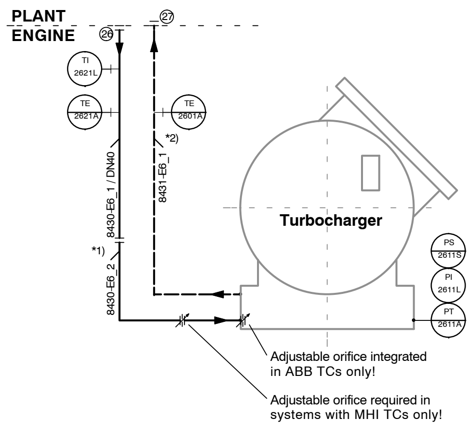
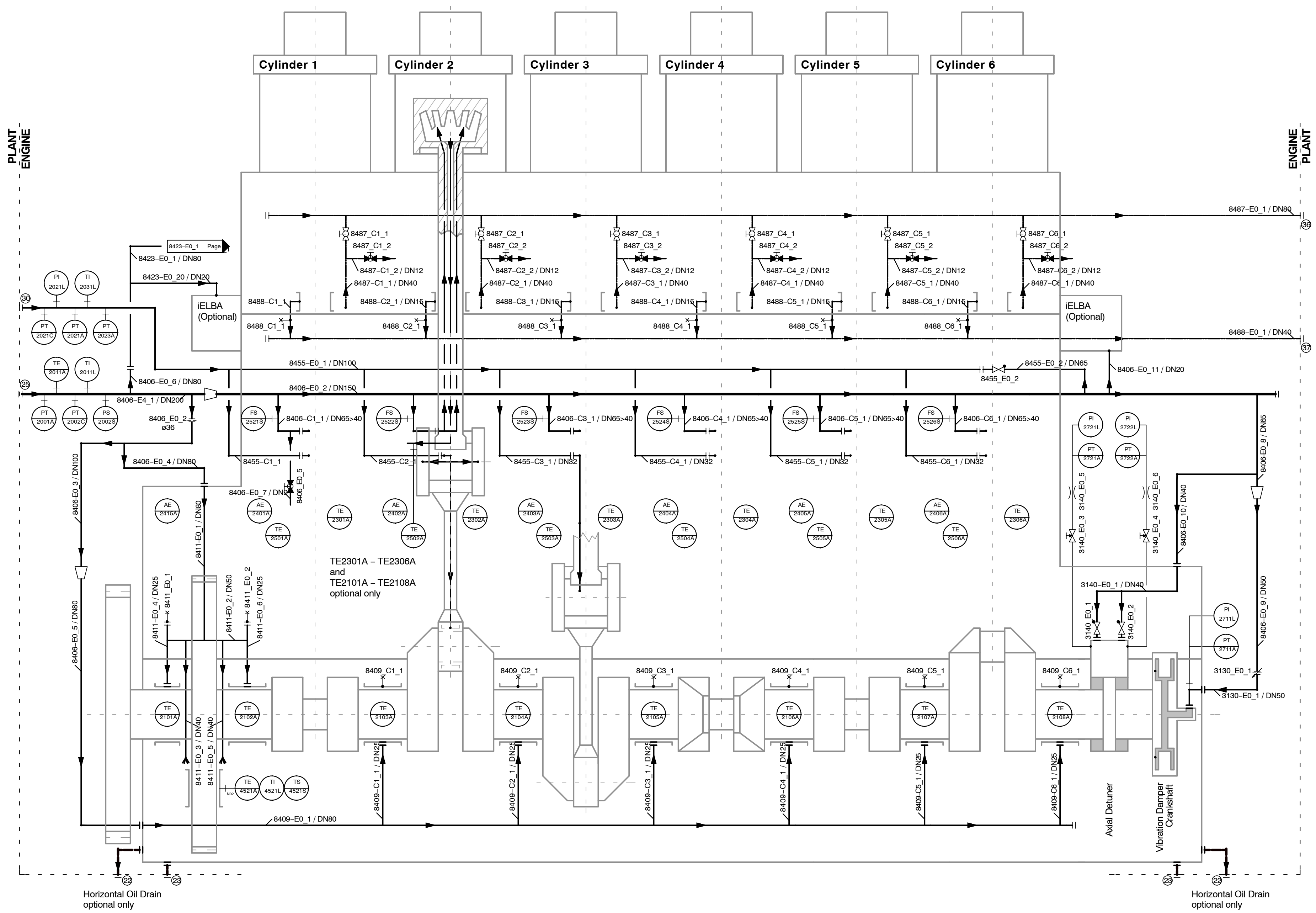
# Pipe Diagram – Oil Systems (System Oil and External Turbocharger Oil Supply)




| Turbocharger-type | 8430-E6_2 *1) | 8431-E6_1 *2) |
|---|---|---|
| 1x ABB A270 | DN32 | DN65 |
| 1x ABB A275 | DN32 | DN65 |
| 1x ABB A180 | DN40 | DN80 |

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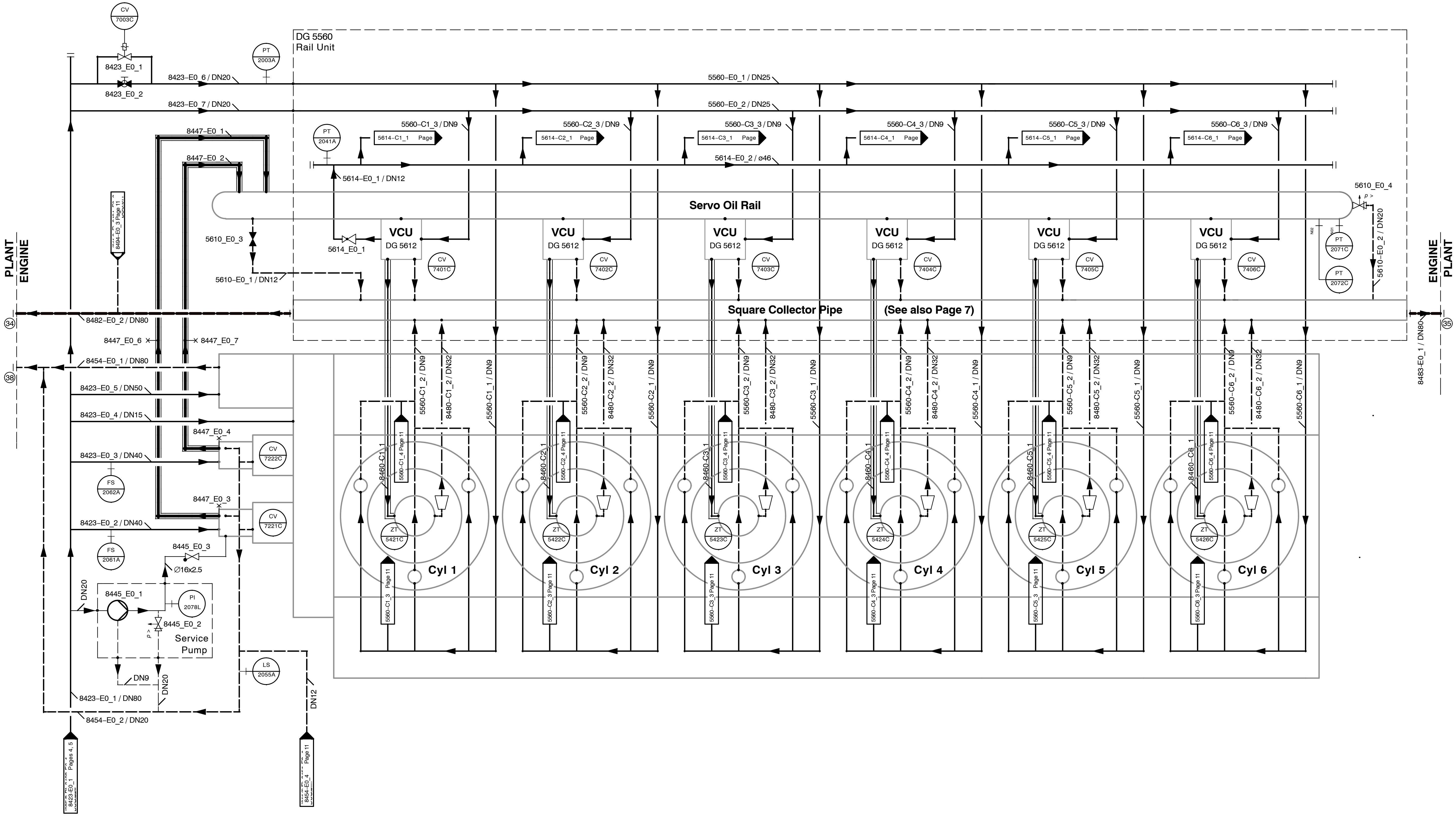
# Pipe Diagram – Oil Systems (Servo Oil and Supply Unit Pipes)



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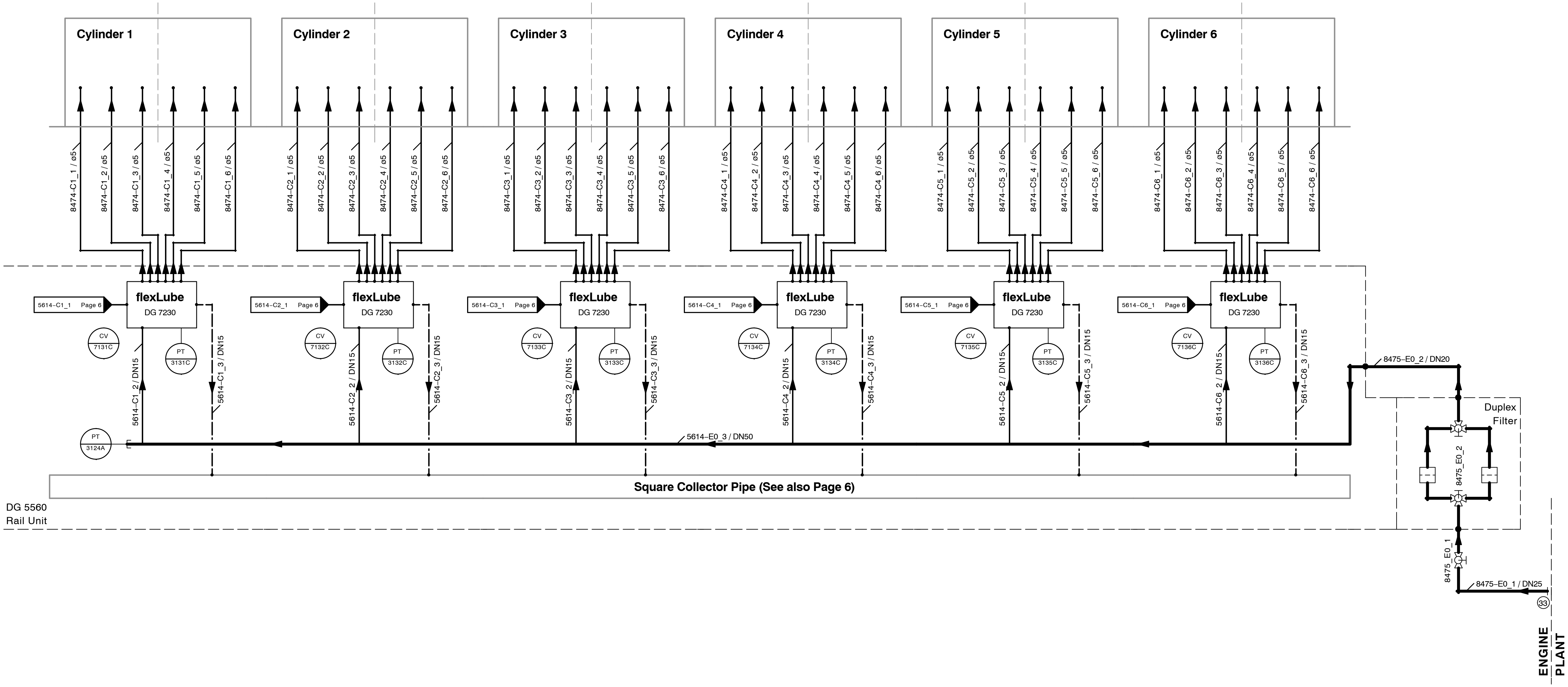
# Pipe Diagram – Oil Systems (Cylinder Lubrication)



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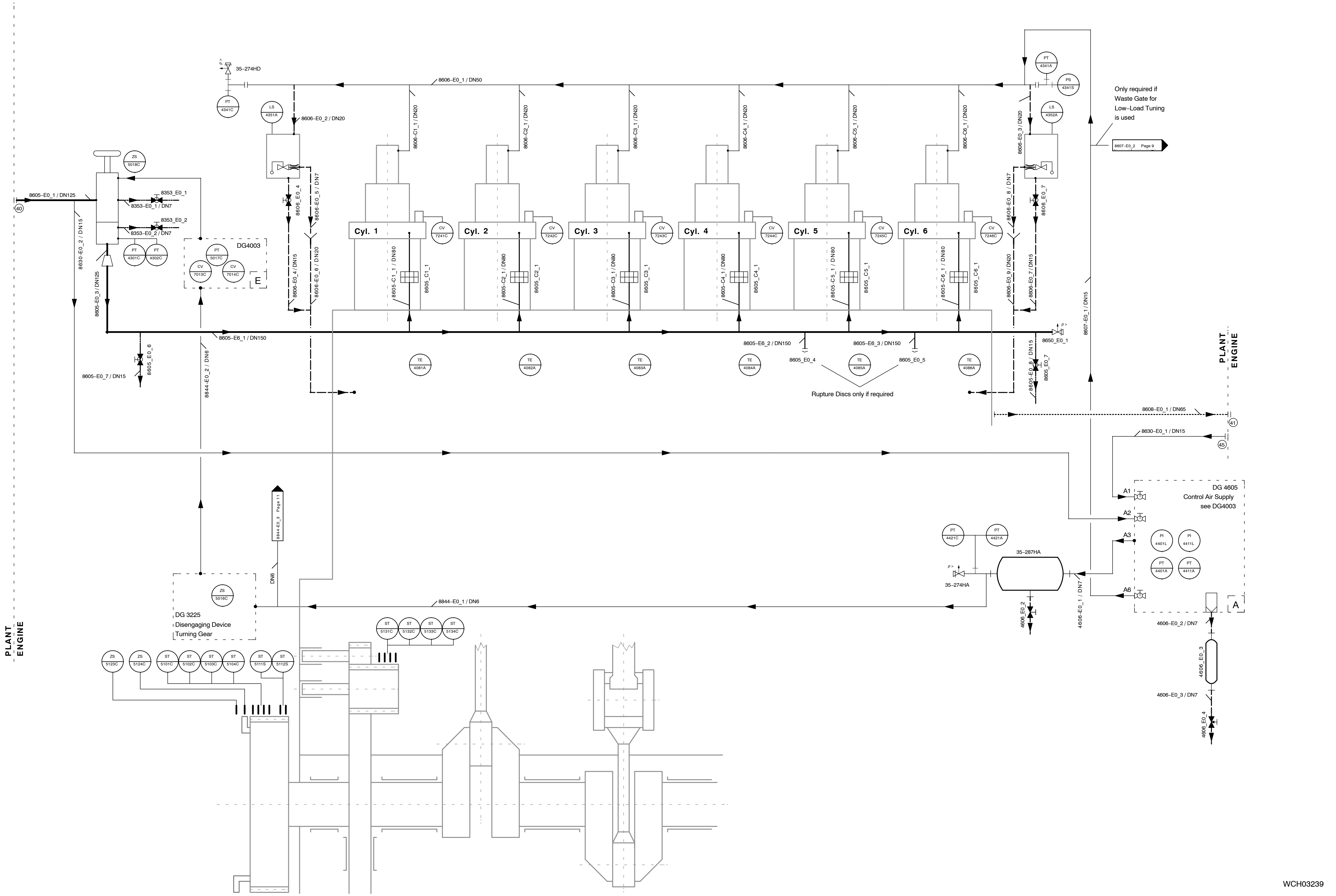
# Pipe Diagram – Air Systems (Starting Air and Control Air)



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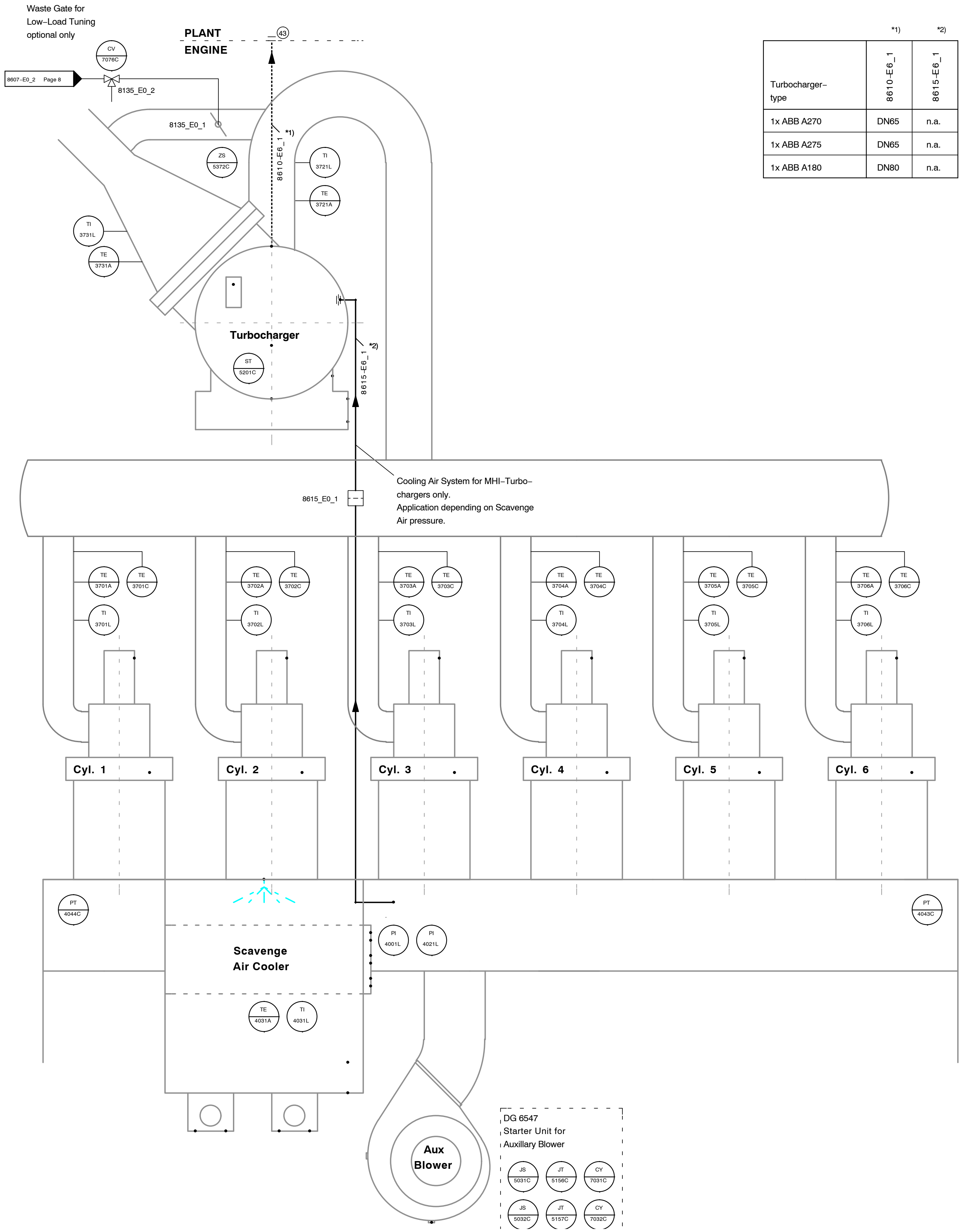
# Pipe Diagram – Air Systems (Exhaust Gas and Scavenge Air)




| Turbocharger–type | 8610–E6_1 *1) | 8615–E6_1 *2) |
|---|---|---|
| 1x ABB A270 | DN65 | n.a. |
| 1x ABB A275 | DN65 | n.a. |
| 1x ABB A180 | DN80 | n.a. |

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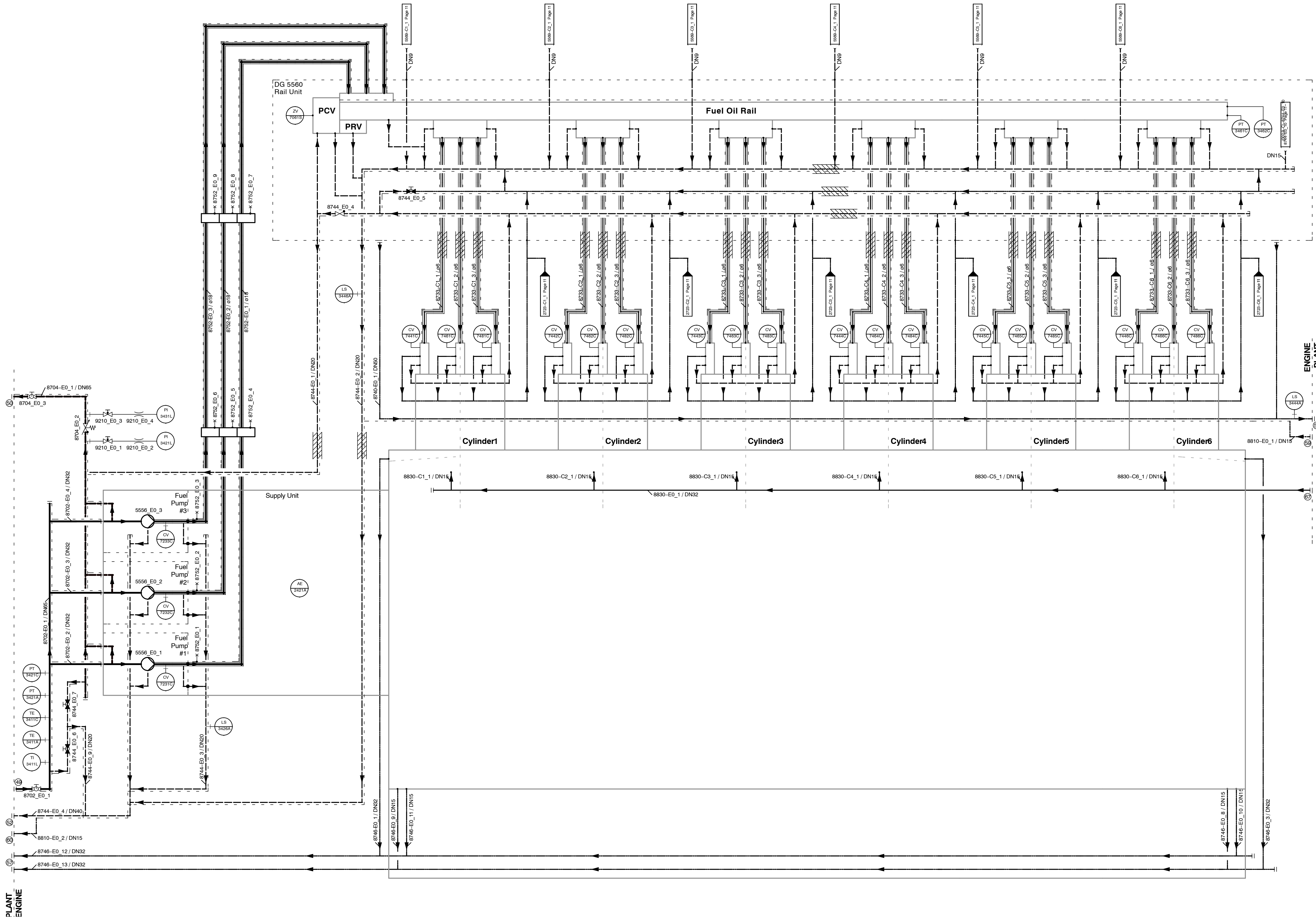
# Pipe Diagram − Fuel, Drain and Extinguishing Systems



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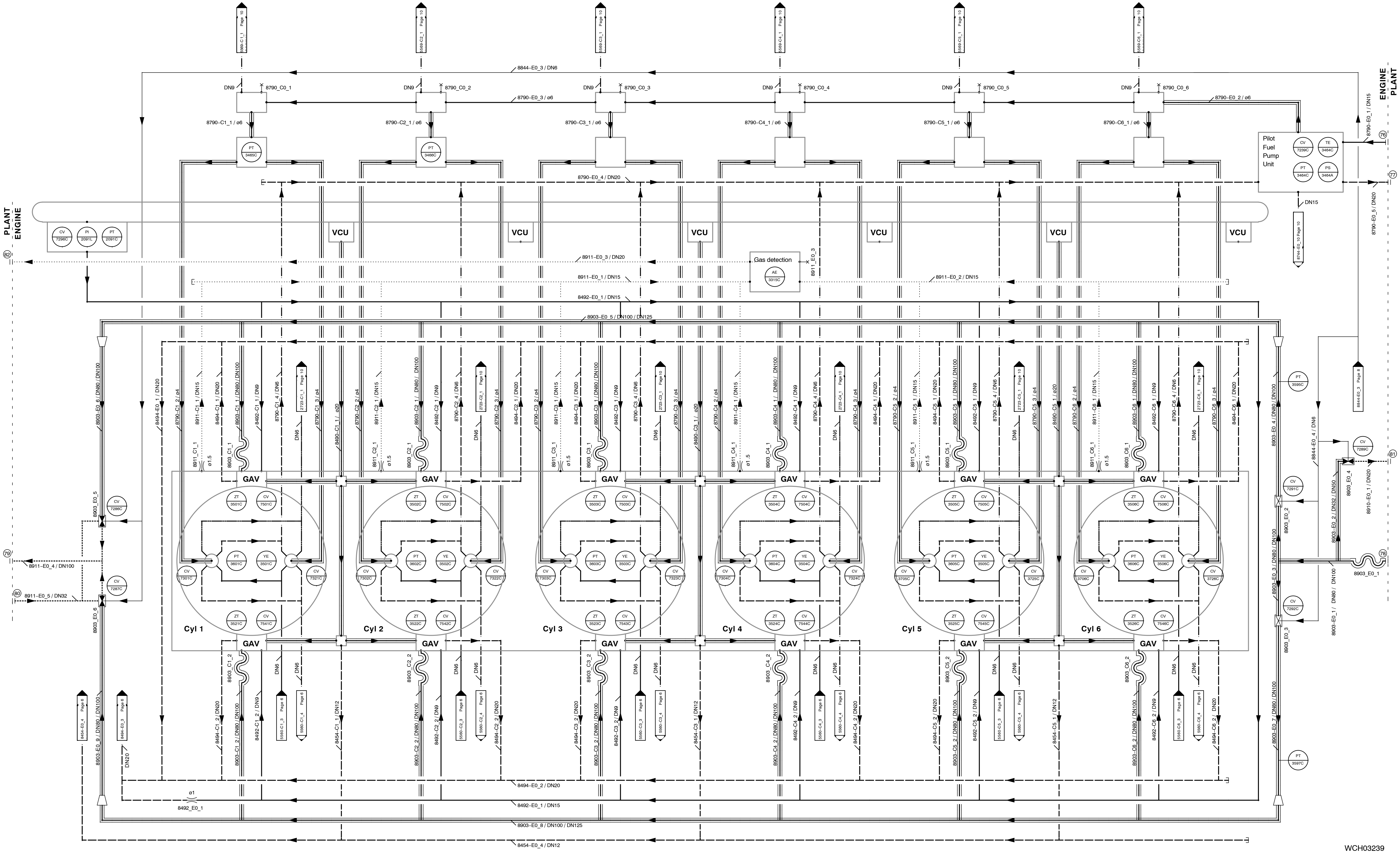
# Pipe Diagram − Gas Mode Related Systems



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# Supply Unit Drive

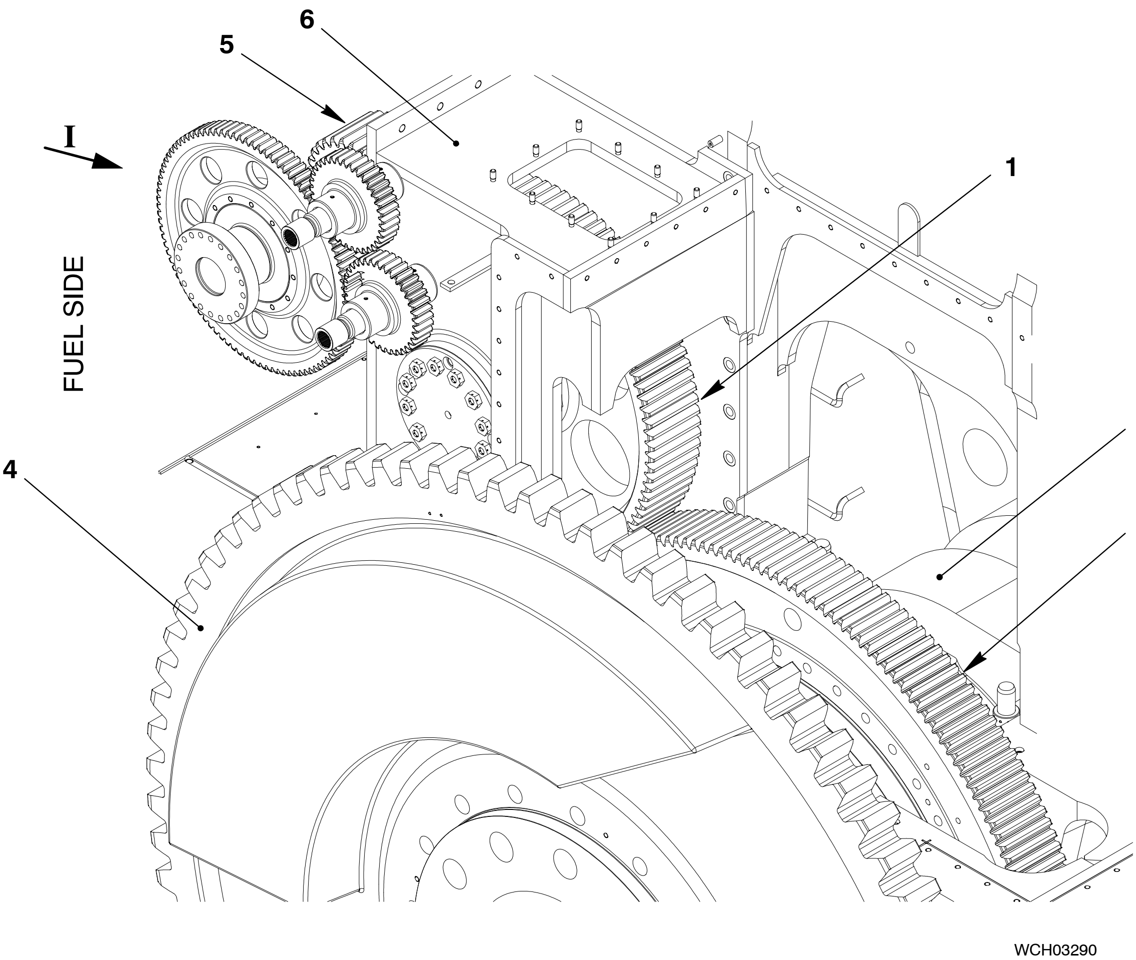
## 1. General

The supply unit drive is installed at the driving end of the engine on the fuel side.

The crankshaft gear wheel (3, Fig. 1) moves the intermediate wheel (1) and the intermediate wheel (5).

You must do regular checks of the tooth profile condition. Also, it is very important that you do frequent checks of new gear wheels after a short running-in period.

If you hear unusual noises from the area of the gear train, you must find the cause immediately.




For View I, see Fig. 2

**Fig. 1: View of Supply Unit Drive**

1 Intermediate wheel (supply unit drive)
2 Crankshaft
3 Crankshaft gear wheel
4 Flywheel
5 Intermediate wheel (supply unit)
6 Bearing housing

## 2. Lubrication

The intermediate wheel (3, Fig. 2) operates the gear wheels (1) and (2) for the servo oil pumps. The camshaft of the intermediate wheel (4) also operates the fuel pumps.

The bearings of the gear wheels (1) and (2) are lubricated through an oil inlet. Oil flows through the nozzles (3) in the bearing housing to lubricate the teeth of the gear wheels and the intermediate wheel (4).

For more data, refer to 5552–1 Supply Unit and 8016–1 Lubricating Oil / Servo Oil System.

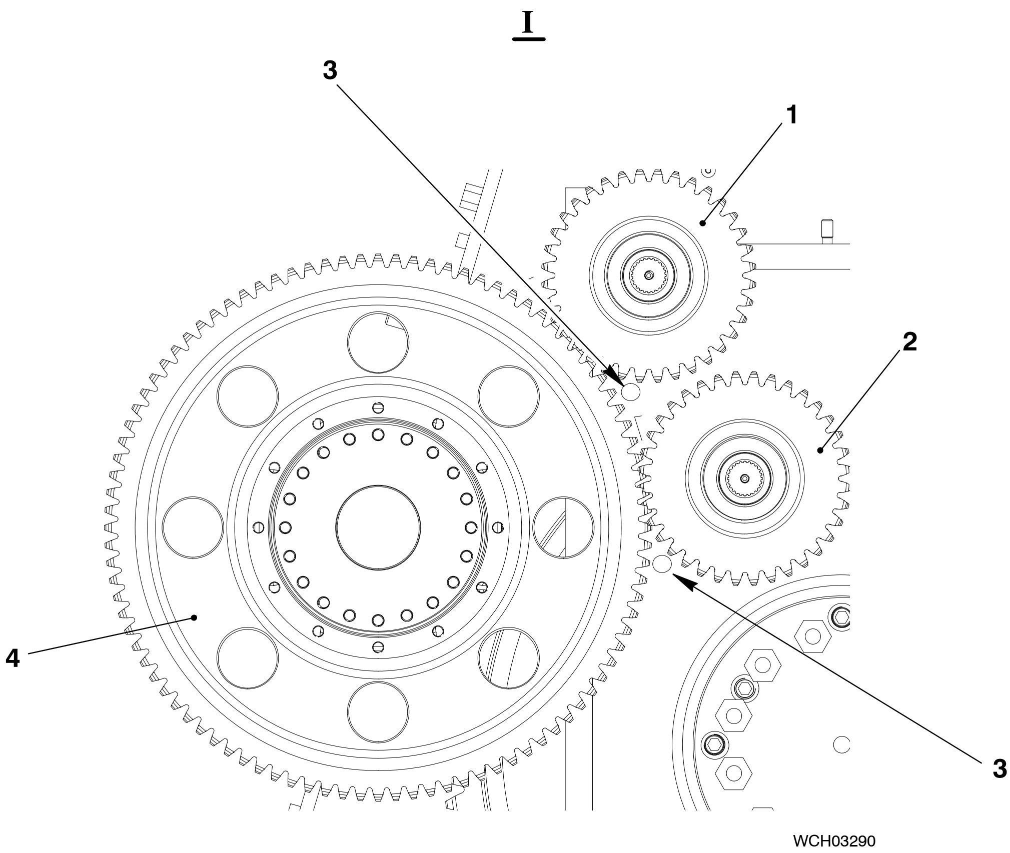



**Fig. 2: View of Gear Wheels**

1 Gear wheel (for servo oil pump No.1)
2 Gear wheel (for servo oil pump No.2)
3 Nozzles
4 Intermediate wheel

# Starting Air Shut-off Valve

## 1. General

The starting air shut-off valve (shut-off valve) stops or releases the starting air to the engine. You use the handwheel (3, Fig. 1) to put the shut-off valve in the positions that follow:

- CLOSED
- AUTOMAT
- OPENED.

When the engine is in stand-by mode or during operation, the shut-off valve is in the AUTOMAT position. The lever (14) holds the shut-off valve in this position.

To do a test of the shut-off valve, you must operate the ball valve 35−8353_E0_2 (see step 1).

1) Operate the ball valve 35−8353_E0_2 to make sure that the valve (5) opens. The shut-off valve opens, which you can hear clearly, but the engine will not start.
2) When the engine is not in operation, do step a) to step e).
   a) Close the shut-off valves 930-V03 and 930-V04 on the starting air bottles (plant).
   b) Push the lever (14) down, then use the handwheel (3) to move the shut-off valve to the position CLOSED.
   c) Open the vent valve to release the pressure in the shut-off valve and air supply pipes.
   d) Open the vent valve to release the pressure in the starting air supply pipes.
   e) Engage the turning gear.

After each maneuvering period, open the vent valves in the supply pipe to drain the condensate water (see also 8018−1 Starting Air Diagram).

For more data, refer to the Control Diagram 4003−2, Page 1 and Page 2.

## 2. Function

### 2.1 Ready to Start

Starting air flows through the inlet pipe (IP) into the inlet chamber (8), then through the balance bore (6) into the space (9). The spring (4) and the pressure in the space (9) keep the valve (5) closed.

### 2.2 Start Sequence

The related CCM−20 module operates the common start valve (11) or (13) (see also 4002−1, paragraph 3.3 Engine-related Control Functions).

The control air (CA) opens the control valve (1) through the solenoid valve CV7014C (11) and releases the pressure in the space (9). The valve (5) opens and starting air from the inlet chamber (8) flows through the non-return valve (7) into the starting air supply pipe (SA).

### 2.3 End of Start Sequence

When the control valve (1) closes, starting air flows through the balance bores (6) and fills the inlet chamber (8) again. The valve (5) closes.

### 2.4 Function Check

When the control valve operates on the ready-to-start engine, the pressure in the space (9) is released. You can hear the valve (5) as it opens.

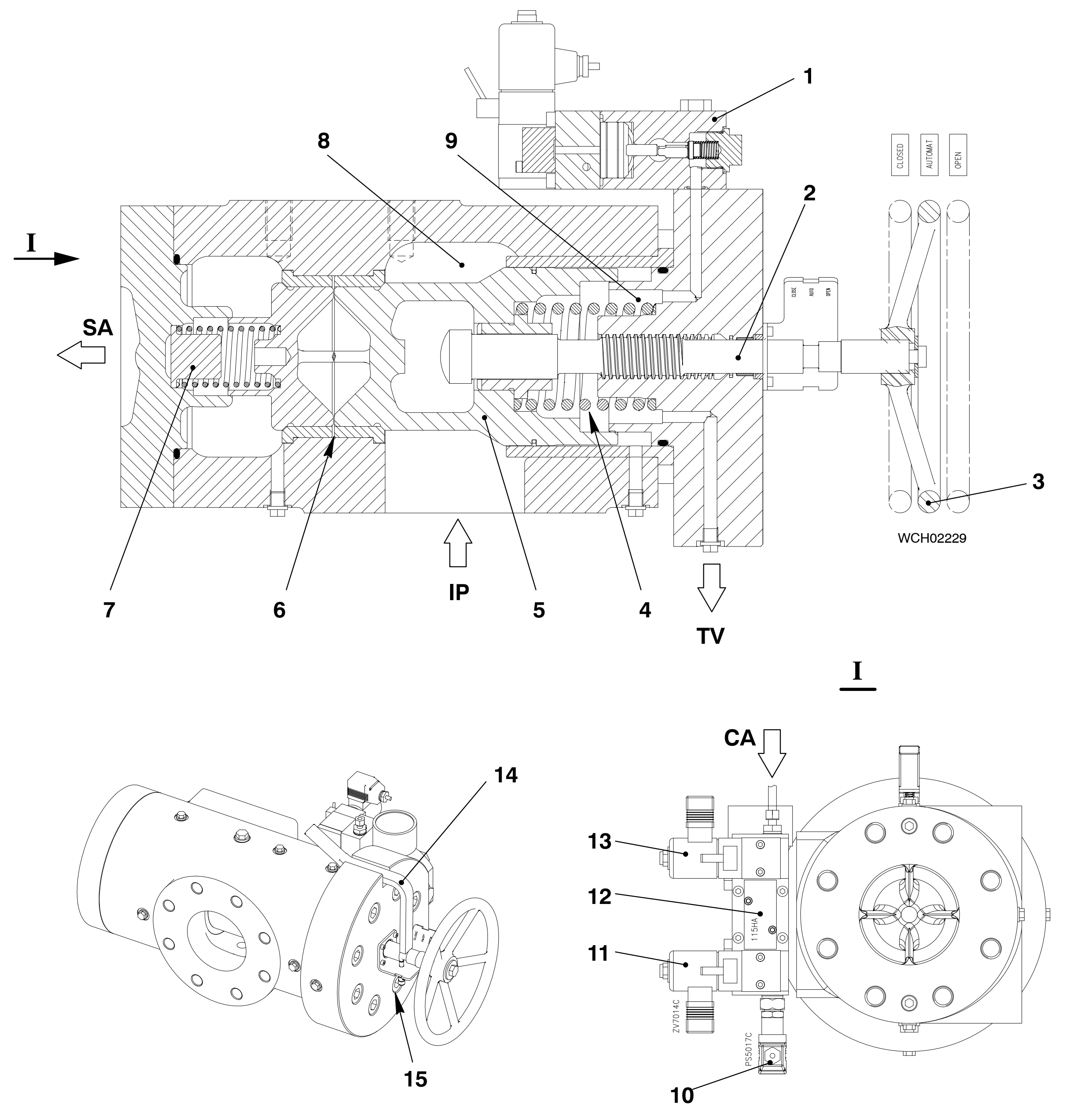



**Fig. 1: Starting Air Shut-off Valve**

1 Control valve
2 Spindle
3 Handwheel
4 Spring
5 Valve
6 Balance bore
7 Non-return valve
8 Inlet chamber
9 Valve space
10 Pressure switch PS5017C
11 Solenoid Valve CV7014C
12 Double check valve 35-115HA
13 Solenoid Valve CV7013C
14 Lever
15 Proximity sensor ZS5018C

IP Inlet pipe
SA To starting air supply pipe and valves 30-2728_CX_1 to CX_#
CA Control air
TV To test valve

# Control Air Supply

## 1. General

The compressed air necessary for the air springs in the exhaust valves and the turning gear interlock comes from the control air board supply. The air must be clean and dry to prevent blockages in the control units.

If the control air board supply system becomes defective, a decreased quantity of compressed air will come from the starting air system.

The shut-off valves, pressure reducing valve, filters etc. that are necessary to supply air to the different units are shown in the control air supply unit (see Fig. 1, Fig. 2 and Fig. 3).

The alpha-numeric titles (e.g. 35−36HB) that identify the parts in the illustrations are the same as those in the Control Diagram 4003−2, Page 1, Section **A**.

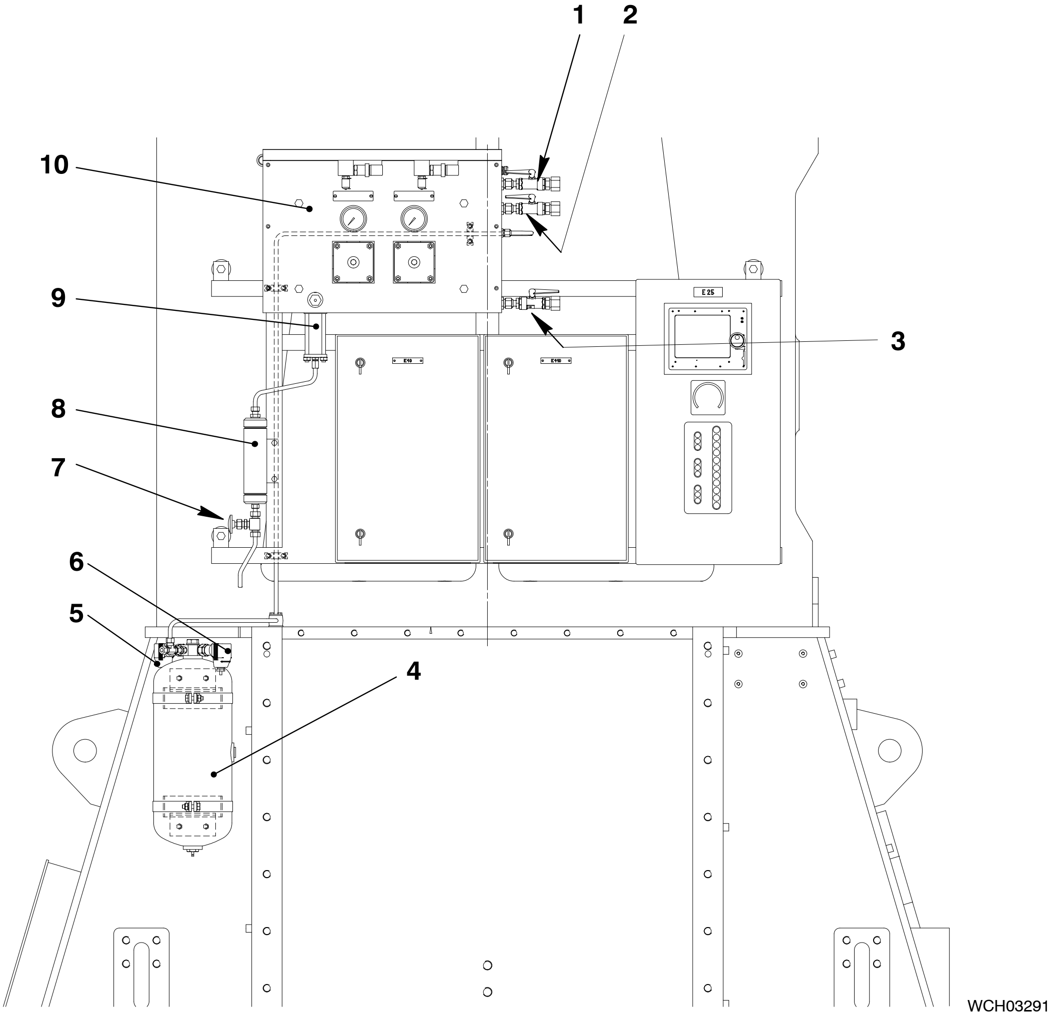



**Fig. 1: Location of Control Air Supply**

1 3/2−way valve 35-36HB (control air)
2 3/2−way valve 35-36HC
3 3/2−way valve 35-36HA
4 Pressure transmitter PT4421C
5 Pressure transmitter PT4421A
6 Air tank
7 Needle valve
8 Bottle
9 Filter 35-351HA
10 Control air supply unit (Section **A)**

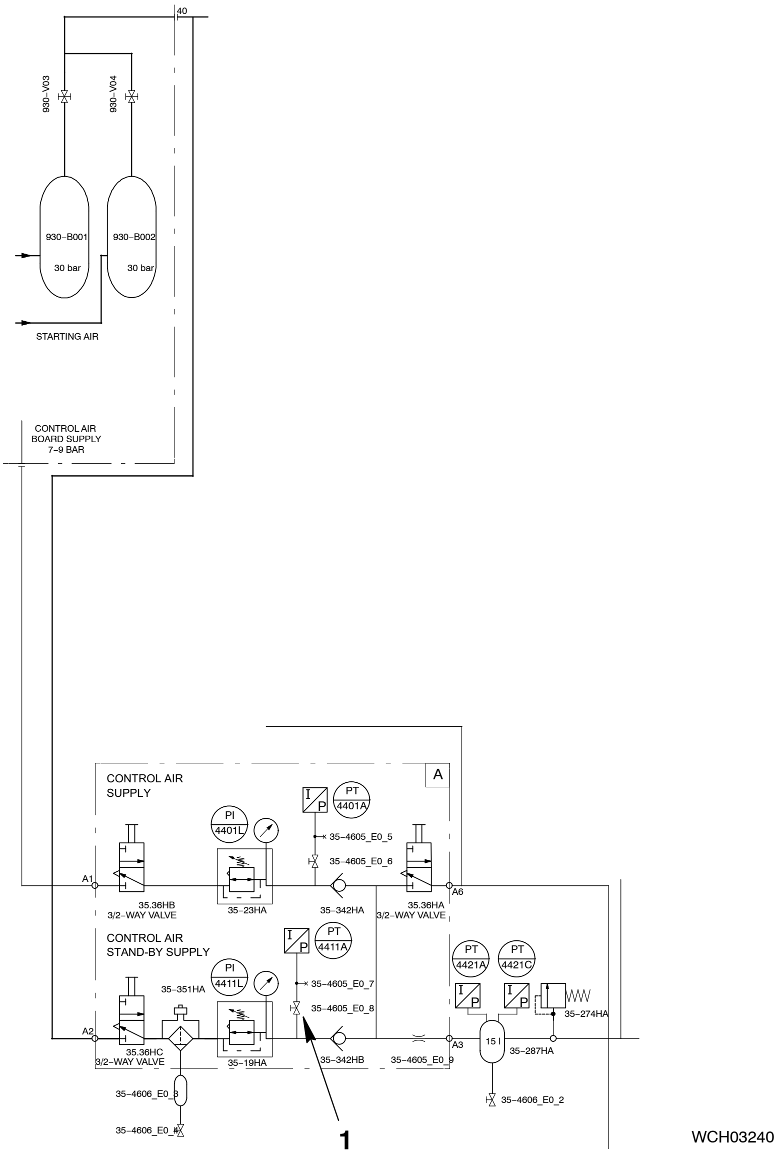



**Fig. 2:Configuration of Control Air Supply**

1 2-way shut-off valve 35-4605_E0_8

A1 Control air from board system
A2 Starting air from starting air system
A3 Connection to air tank 287HA
A6 Air supply to air spring

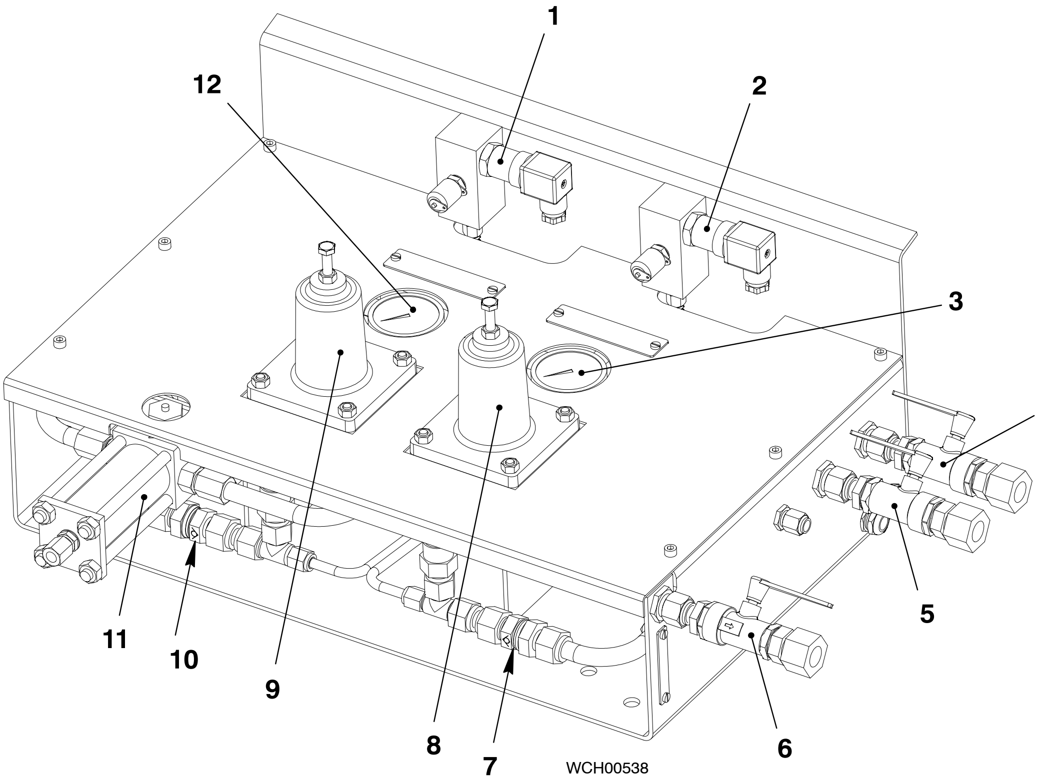



**Fig. 3: Control Air Supply Unit**

| | | | |
|---|---|---|---|
| 1 | Pressure transmitter PT4411A | 7 | Non-return valve 35-342HA |
| 2 | Pressure transmitter PT4401A | 8 | Pressure reducing valve 35-23HA |
| 3 | Pressure gauge PI4401L | 9 | Pressure reducing valve 35-19HA |
| 4 | 3/2-way valve 35-36HB | 10 | Non-return valve 35-342HB |
| 5 | 3/2-way valve 35-36HC | 11 | Filter 35-351HA |
| 6 | 3/2-way valve 35-36HA | 12 | Pressure gauge PI4411L |

# Pick-up for Speed Measurement

## 1. General

To measure the engine speed (rpm), six proximity sensors are installed in a speed pick-up unit, attached to the support of the fuel pump unit.

For safety, there are three electrically isolated proximity sensor groups as follows:

- Speed identification in the remote control system (RCS)
- Overspeed safety system
- Speed control system.

## 2. Function

The proximity sensors (5, 6, 7, 9, 10 and 11 Fig. 1) measure the speed of the flywheel (1). When the flywheel turns, the proximity sensors sense the movement of the teeth. Signals are sent through the engine control system to the RCS to monitor the load and speed-related functions. Data are also sent to the speed indication instruments.

**Note: The top view I shows the proximity sensors with the cover (3) removed.**

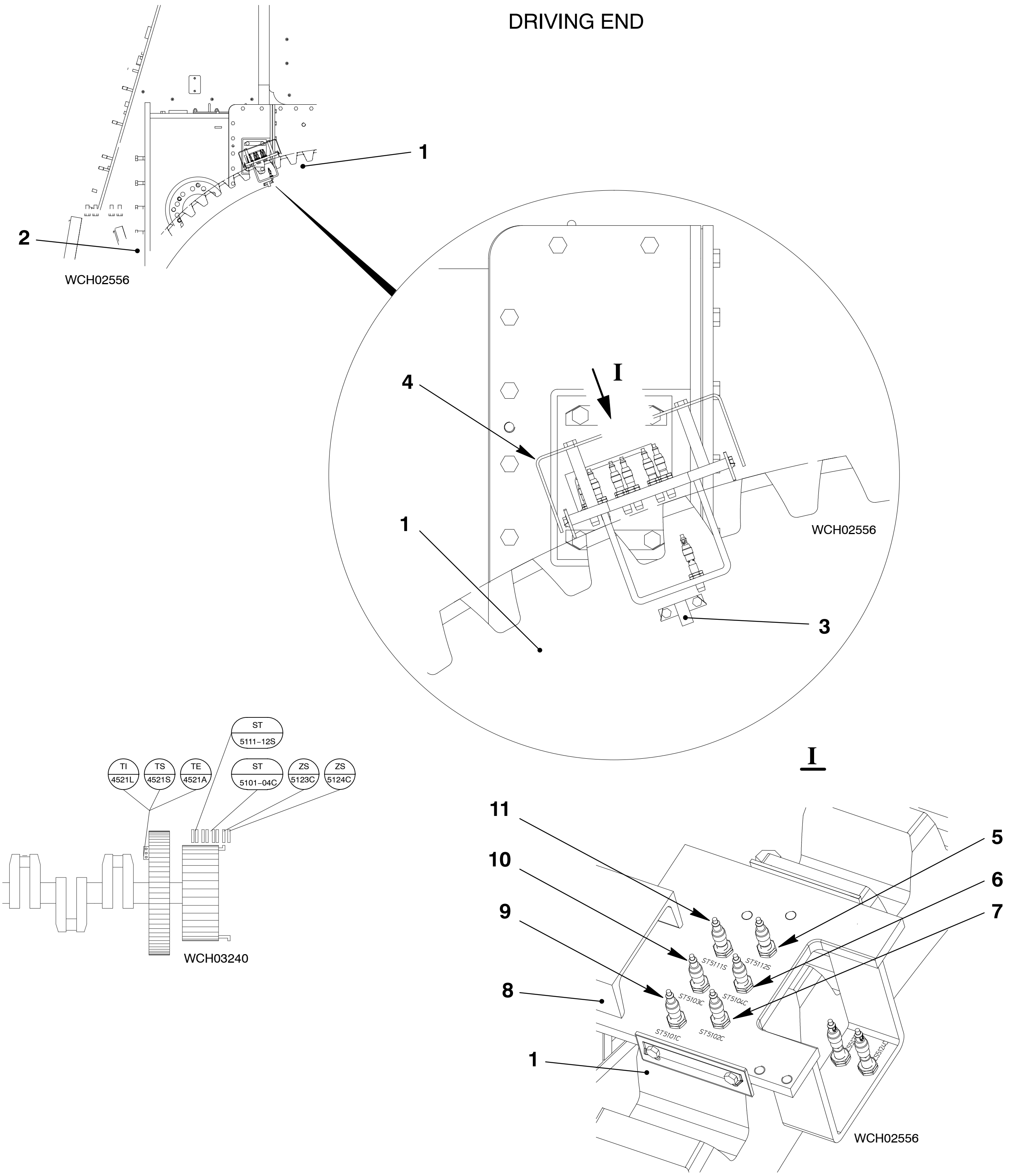



**Fig. 1: Location of Proximity Sensors**

1 Flywheel
2 Bedplate
3 Crank angle mark
4 Cover
5 Proximity sensor ST51412S
6 Proximity sensor ST5104C
7 Proximity sensor ST5102C
8 Pick-up holder
9 Proximity sensor ST5101C
10 Proximity sensor ST5103C
11 Proximity sensor ST51412S

# Supply Unit, Servo Oil Pump and Fuel Pump — Group 5

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# Servo Oil Pump

## 1. General

The servo oil pumps (3 and 5, Fig. 1) are attached to, and part of, the supply unit (6). These pumps supply servo oil to open the exhaust valves, to operate the gas admission valves and cylinder lubricating pumps.

For more data about the supply unit, refer to 5552-1.

The flow sensors (1, 4), monitor the oil supply in each inlet pipe (2) of the servo oil pumps. A malfunction of a servo oil pump will show in the alarm and monitoring system.

## 2. Function

| CAUTION |
|---|
| **Damage Hazard: If a servo oil pump becomes defective, do not operate the engine for too long. If the other servo oil pump becomes defective, the engine cannot operate. You must replace the defective servo oil pump as soon as possible (refer to the Maintenance Manual 5552-1).** |

During usual operation, the servo oil pumps supply hydraulic pressure equally for the full load range.

The nominal pressure value is related to the engine load. The electrically controlled system adjusts the system pressure for the full load range, i.e. high pressure (approximately 300 bar) at high engine load, and decreased pressure at low engine load.

**Note: If a servo oil pump cannot turn, the safety device (4, Fig. 2) will break. This will prevent too much damage to the intermediate wheel (6).**

If one pump becomes defective, the engine can continue to operate at full load.

For more data, refer to the Maintenance Manual 5551-2.

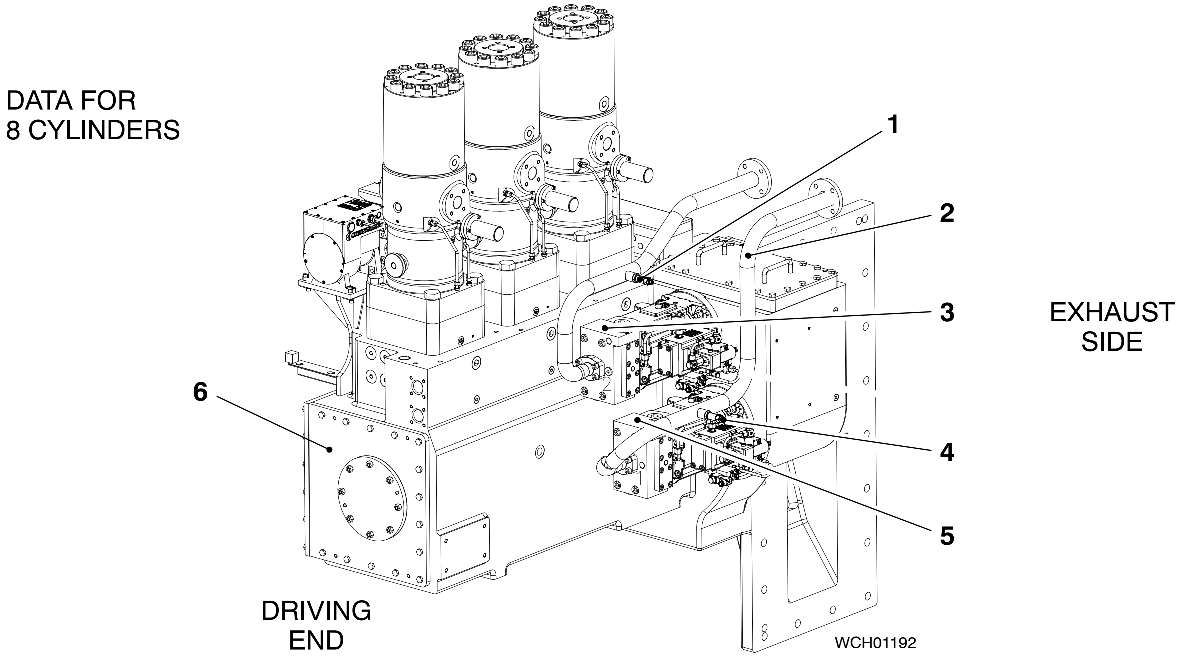



**Fig. 1: Location of Servo Oil Pumps**

1 Flow sensor FS2062A
2 Inlet pipe
3 Servo oil pump No.2
4 Flow sensor FS2061A
5 Servo oil pump No.1
6 Supply unit

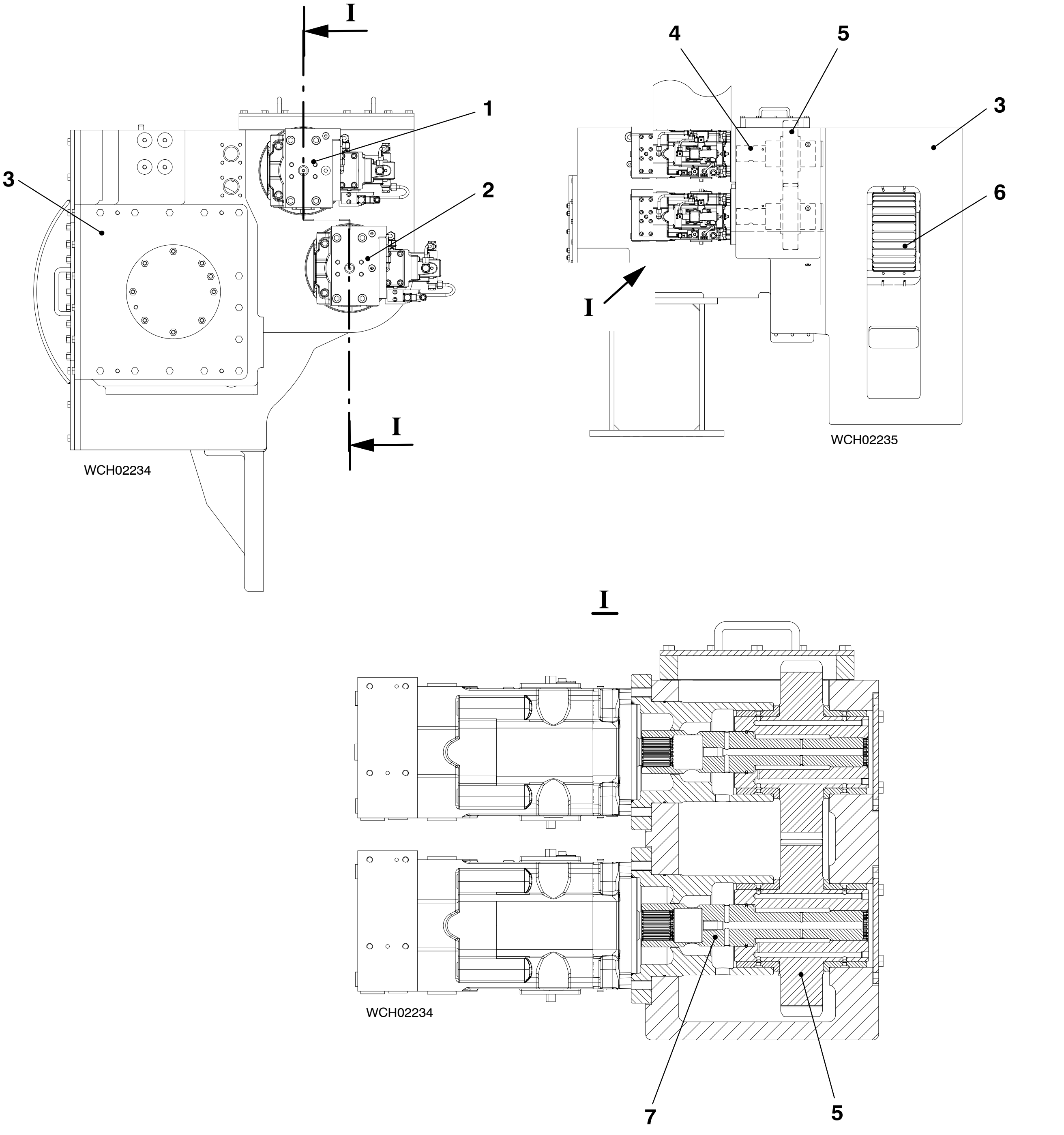



**Fig. 2: Servo Oil Pumps – Operation**

1 Servo oil pump (20-5551_E0_1)
2 Servo oil pump (20-5551_E0_2)
3 Supply unit
4 Safety device (waisted part)
5 Pinion
6 Intermediate wheel (supply unit)
7 Shaft

# Supply Unit

## 1. General

The supply unit is installed on the column at the driving end (for more data, refer to 4104–1 Supply Unit Drive).

The supply unit has the servo oil supply, fuel supply, gear wheels and drive wheels. The components in the paragraphs that follow are part of, or attached to, the housing.

### 1.1 Servo Oil Pumps

Two servo oil pumps (1 and 2, Fig. 1) are attached to the front of the supply unit. The intermediate wheel operates the servo oil pumps (see 4104-1 Supply Unit Drive).

For more data about the servo oil pumps, refer to 5551-1 Servo Oil Pump.

### 1.2 Fuel Pumps

For 5-cylinder to 7-cylinder engines, two fuel pumps (6) are installed. For engines with 8-cylinders, three fuel pumps are installed.

For more data about the fuel pumps (6), refer to 5556-1, Fuel Pump.

### 1.3 Fuel Pump Actuator and Regulating Linkage

Each fuel pump (6) has an electrically-operated fuel pump actuator (4). The regulating linkage (5) connects the fuel pump actuator (4) to the fuel pump (6).

For more data about the fuel pump actuator (4) and the regulating linkage (5), refer to 5583–1 Fuel Pump Actuator.

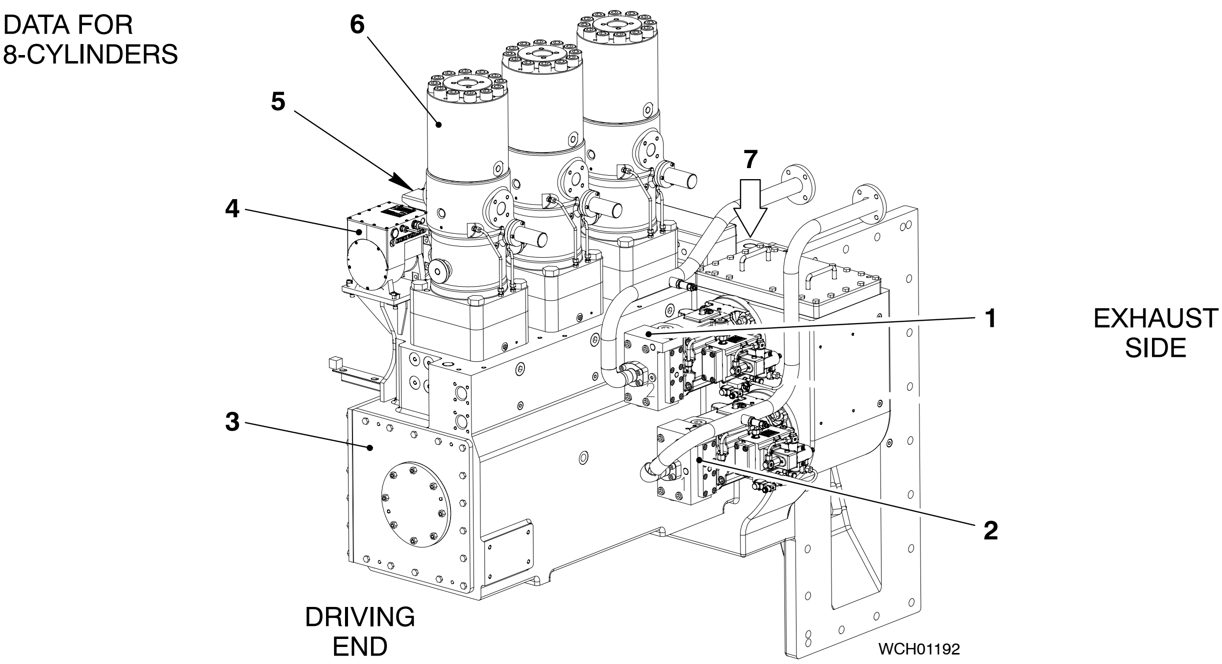



**Fig. 1: Supply Unit**

1 Servo oil pump No. 1
2 Servo oil pump No. 2
3 Housing
4 Fuel pump actuator
5 Regulating linkage
6 Fuel pump
7 Oil inlet

## 2. Lubrication

Oil flows through bores in the housing (8, Fig. 2) to lubricate the bearings and fuel pumps. Oil also flows through the nozzles (6) to lubricate the intermediate wheel (7) and the gear wheel (5).

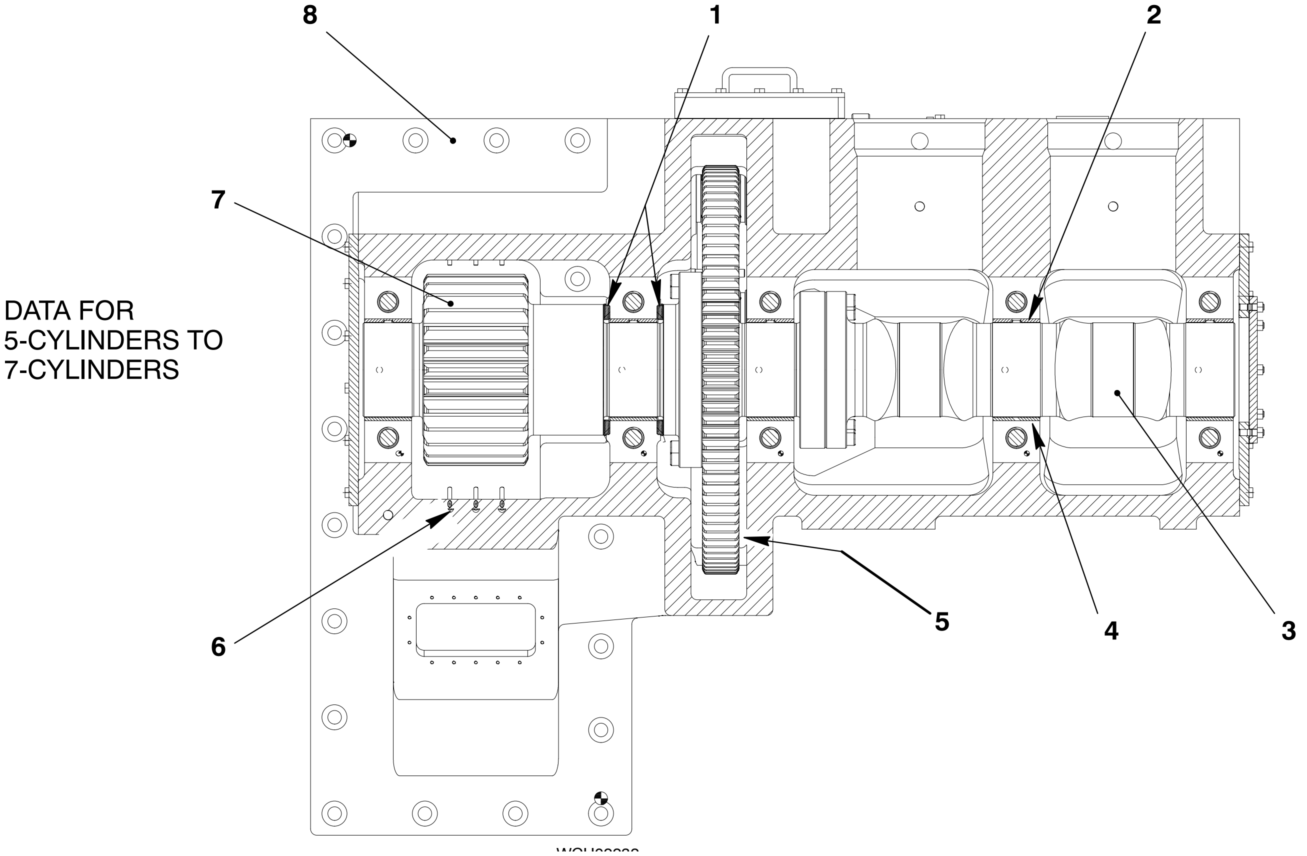



**Fig. 2: Location of Items**

1 Thrust bearing ring half
2 Top bearing shell half
3 Camshaft
4 Bottom bearing-shell half
5 Gear wheel
6 Nozzle
7 Intermediate wheel
8 Housing

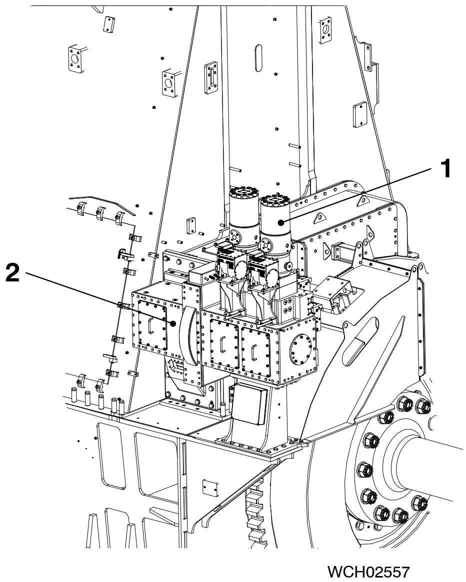
# Fuel Pump

## 1. General

The fuel pumps (1, Fig. 1) are part of the supply unit (2).

The fuel pumps supply fuel through high pressure pipes to the fuel rail (see 8019−1, Fuel System). The fuel pumps are controlled to supply the applicable load-related fuel pressure (up to 1000 bar) in the fuel rail.

For more data about the supply unit, refer to 5552−1.




Data for 5-cylinder to 7-cylinder

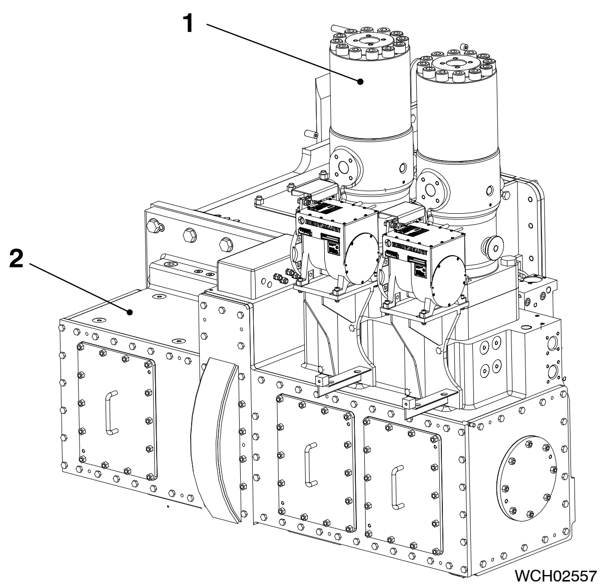



**Fig. 1: Location of Fuel Pumps**

1 Fuel pump

2 Supply unit

## 2. Function

The compression spring (9, Fig. 2) keeps the bottom spring carrier (2) against the guide piston (6), which keeps the roller (4) against the cam (5). When the cam (5) moves the roller (4) up, the guide piston (6) moves up and the bottom spring carrier (2) compresses the compression spring (9). The pump plunger (18) then moves up. The control grooves in the pump plunger (18) control the fuel quantity.

When the toothed rack (12) moves, the teeth engage with the teeth on the regulating sleeve (17) and the regulating sleeve turns. The regulating sleeve (17) turns the driver (10) and thus the pump plunger (18).

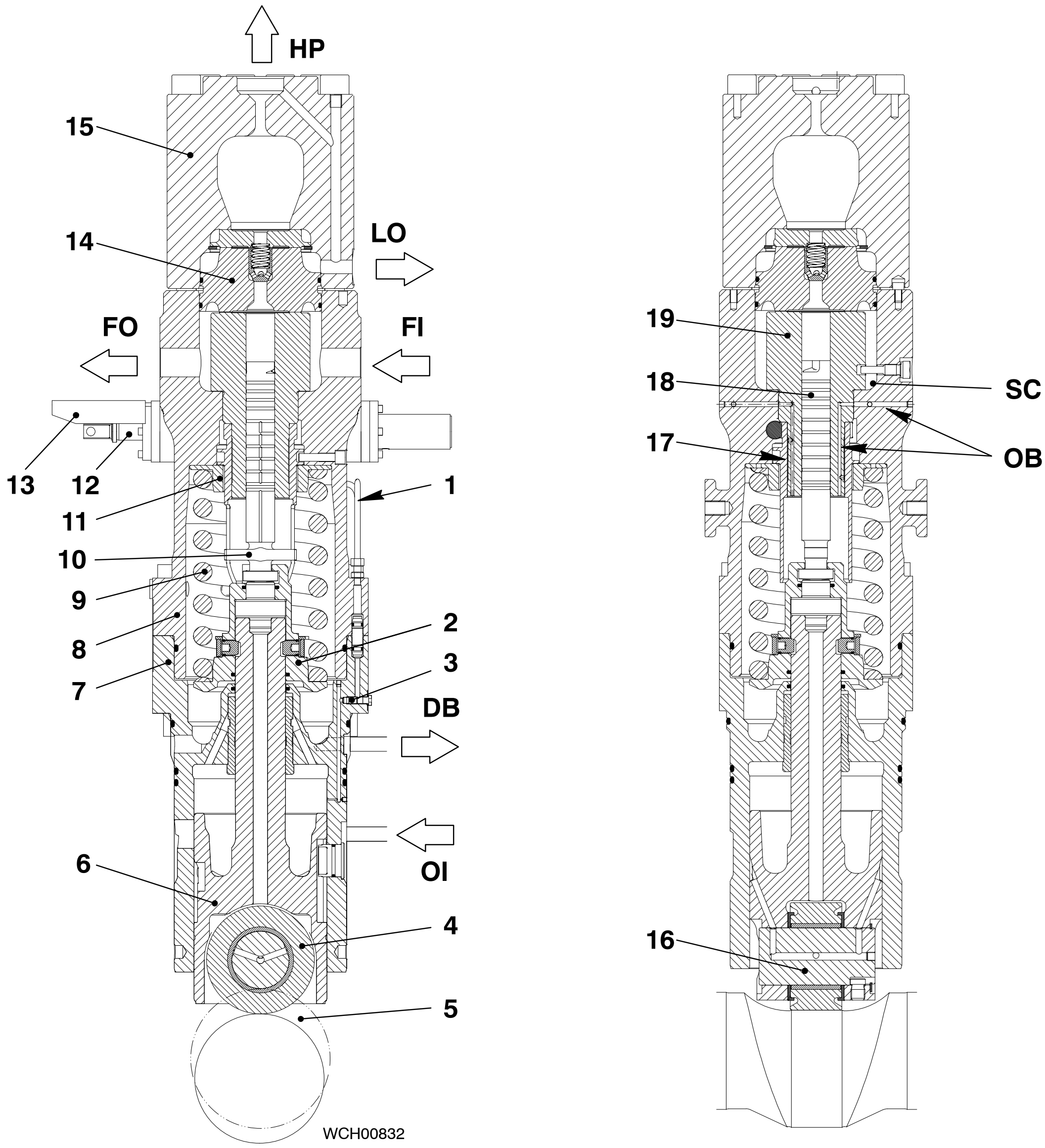



**Fig. 2: Fuel Pump**

| | | | |
|---|---|---|---|
| 1 | Oil pipe | 16 | Roller pin |
| 2 | Bottom spring carrier | 17 | Regulating sleeve |
| 3 | Orifice | 18 | Pump plunger |
| 4 | Roller | 19 | Pump cylinder |
| 5 | Cam | | |
| 6 | Guide piston | | |
| 7 | Bottom housing | | |
| 8 | Top housing | DB | Leakage fuel drain bore |
| 9 | Compression spring | FI | Fuel inlet |
| 10 | Driver (of pump plunger) | FO | Fuel outlet |
| 11 | Top spring carrier | HP | HP fuel to fuel rail |
| 12 | Toothed rack | LO | Leakage fuel outlet |
| 13 | Cover (toothed rack) | OB | Lubricating oil bore |
| 14 | Non-return valve | OI | Lubricating oil inlet |
| 15 | Pump cover | SC | Suction chamber |

When the pump plunger (18) passes BDC, fuel flows through the two inlet bores (5, Fig. 3) and the two control grooves (2) into the plunger chamber (1). The quantity of fuel that goes into the plunger chamber (1) is related to the control position (between 0 for zero supply and 10 for maximum supply).

**Note: No fuel is supplied in the position 0 (zero).**

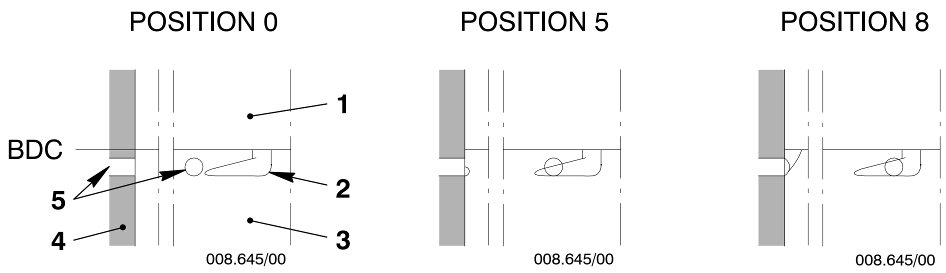



**Fig. 3: Control Grooves of Pump Plunger**

1 Plunger chamber
2 Control groove
3 Pump plunger
4 Pump cylinder
5 Inlet bore

## 3. Lubrication

Engine lubricating oil, which flows through the lubricating oil inlet (OI, Fig. 2) into the bottom housing (7), lubricates the fuel pump.

Some of the engine lubricating oil lubricates the guide piston (6), roller pin (16) and roller (4) through the spot faces, annular groove and bores in the guide piston (6). Engine lubricating oil that flows down lubricates the surface of the cam (5).

Engine lubricating oil also flows through the oil bores (OB) in the top housing (8) and the pump cylinder (19) to lubricate the regulating sleeve (17).

Leakage fuel lubricates the pump plunger (18). The leakage fuel and the engine lubricating oil from the regulating sleeve (17), flows through the drain bore (DB), into an internal bore in the housing of the fuel pump unit.

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# Fuel Pump – Cutting Out and Cutting In



## 1. General

If a fuel pump is unserviceable (e.g. the pump plunger cannot move) or the HP fuel pipe is broken (between the fuel pump and the fuel rail) the fault must be repaired immediately.

If the fault cannot be repaired, because the engine must operate, it is possible to cut out the unserviceable fuel pump.

**WARNING**

**Injury Hazard: The fuel pump system has high pressure. You can only do the cutting out and cutting in procedures when the engine has stopped.**

**CAUTION**

**Damage Hazard: You must not operate the engine with a fuel pump removed. This will decrease the supply of oil, i.e. there could be a decrease of lubrication to the other fuel pumps.**

**Note: If one fuel pump is cut out, there is almost no limit in engine operation. If more than one pump is cut out, you can only operate the engine at decreased load. When a fuel pump is cut out, oil in the system will decrease.**

# 2. Cutting Out and Cutting In

## 2.1 Cutting Out Procedure

1) Stop the engine.
2) Remove the applicable HP fuel pipe from the related fuel pump (see Fig. 1 and the Maintenance Manual 8752−1, Removal).
3) Install the blank flange (tool 94569) to the fuel pump (2).
4) Attach the blank flange (tool 94569a) to the intermediate piece (1).
5) Remove the applicable cover (3).
6) Find the position of the related cam.

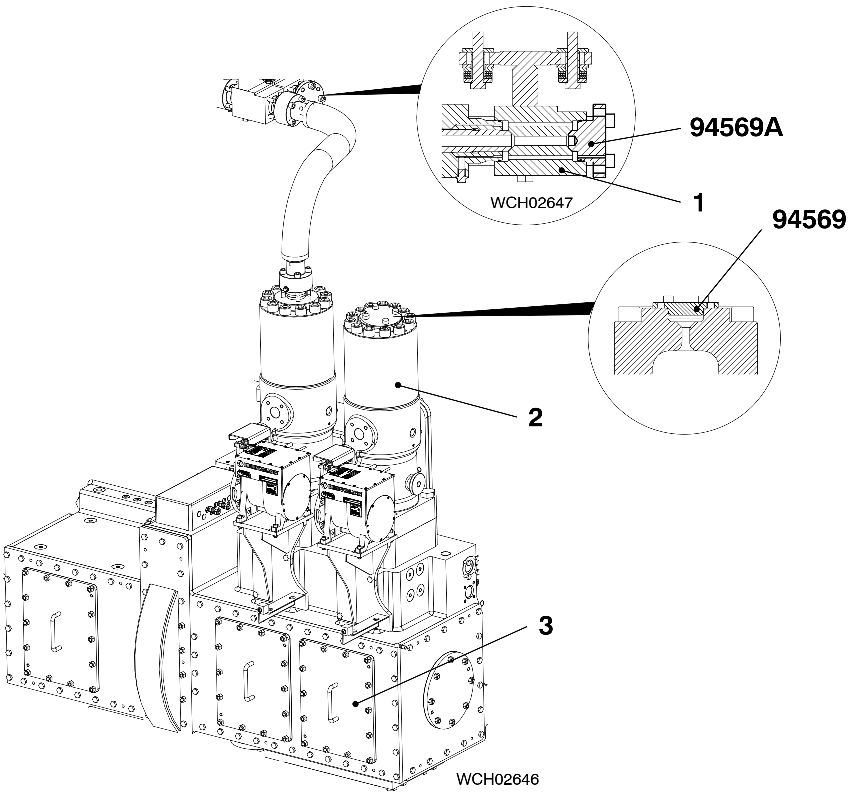


**Fig. 1**

**WARNING**

**Injury Hazard: Before you operate the turning gear, make sure that no personnel are near the flywheel, or in the engine.**

7) Operate the turning gear until the roller (1, Fig. 2) of the guide piston (2) is at the highest position (cam peak).
8) Turn fully the elastic bolt (3) together with the pad (4).
9) Put the tool (94430) in position.
10) Turn the round nut (5) until it touches the pad (4). Make sure that the pad (4) touches the guide piston (2) and the casing (9).
11) Put the pre-tensioner (94430A) on to the elastic bolt (3). The pre-tensioner must touch the pad (4).
12) Make sure that the vent screw (7) on the pre-tensioner (94430A) is open.

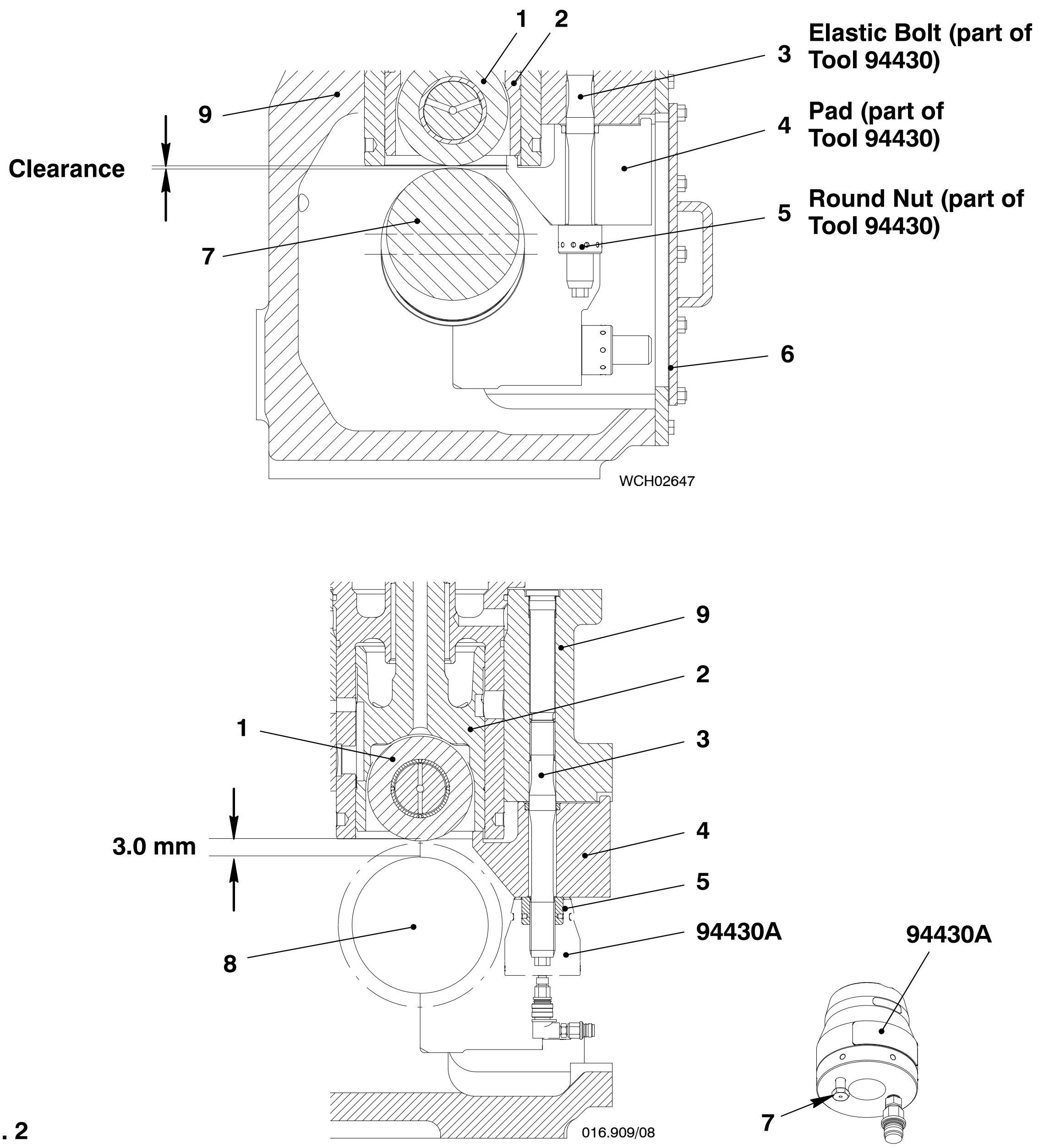


Fig. 2

13) Adjust the tension on the elastic bolt (3, Fig. 2) to 1500 bar (refer to the procedure in the Maintenance Manual 9403–4).
14) Make sure that the roller (1) has moved up approximately 3.0 mm from the cam (7).
15) Turn the round nut (5) until it touches the pad of the tool (94330) (the turned angle of the round nut must be approximately 84°).
16) Remove the pre-tensioner (94330A) (refer to the procedure in the Maintenance Manual 9403–4).
17) Make sure that the roller (1) stays approximately 3.0 mm above the cam (8).
18) Install the cover (6).

**Note: For the torque values and lubrication of the applicable screws, see the Maintenance Manual 0352–1.**

## 2.2 Cutting In

1) Stop the engine.
2) Remove the cover (6).
3) Find the position of the related cam (8).

**WARNING**

**Injury Hazard: Before you operate the turning gear, make sure that no personnel are near the flywheel, or in the engine.**

4) Operate the turning gear until the roller (1) of the guide piston (2) is at the highest position (cam peak).
5) Put the pre-tensioner (94430A) on to the elastic bolt (3). The pre-tensioner must touch the pad (4).
6) Make sure that the vent screw (7) on the pre-tensioner is open.
7) Adjust the tension on the elastic bolt (3) to 1530 bar (refer to the procedure in the Maintenance Manual 9403–4).
8) Remove the round nut (5).
9) Remove the pre-tensioner (94430A) (refer to the procedure in the Maintenance Manual 9403–4).
10) Remove the elastic bolt (3) and the pad (4).
11) Attach the round nut (5) to the elastic bolt (3) on the pad (4) with your hand.

## 2.3 Completion

1) Install the cover (5, Fig. 1).
2) Remove the blank flanges (94569a) and (94569).
3) Install the HP fuel pipe (2) (refer to the Maintenance Manual 8752–1 paragraph 3).

# Pressure Control Valve

## 1. General

### 1.1 Operation

The engine control system (ECS) controls the fuel pressure. The pressure in the fuel rail is always less than that necessary to open the pressure control valve (PCV). The PCV (1, Fig. 1) is usually closed.

The PCV can also operate as a pressure relief valve and will open if the fuel pressure is more than the specified pressure of approximately 1050 bar.

For more data, refer to 4002–1, paragraph 3.12 Diesel Fuel Pressure Control).

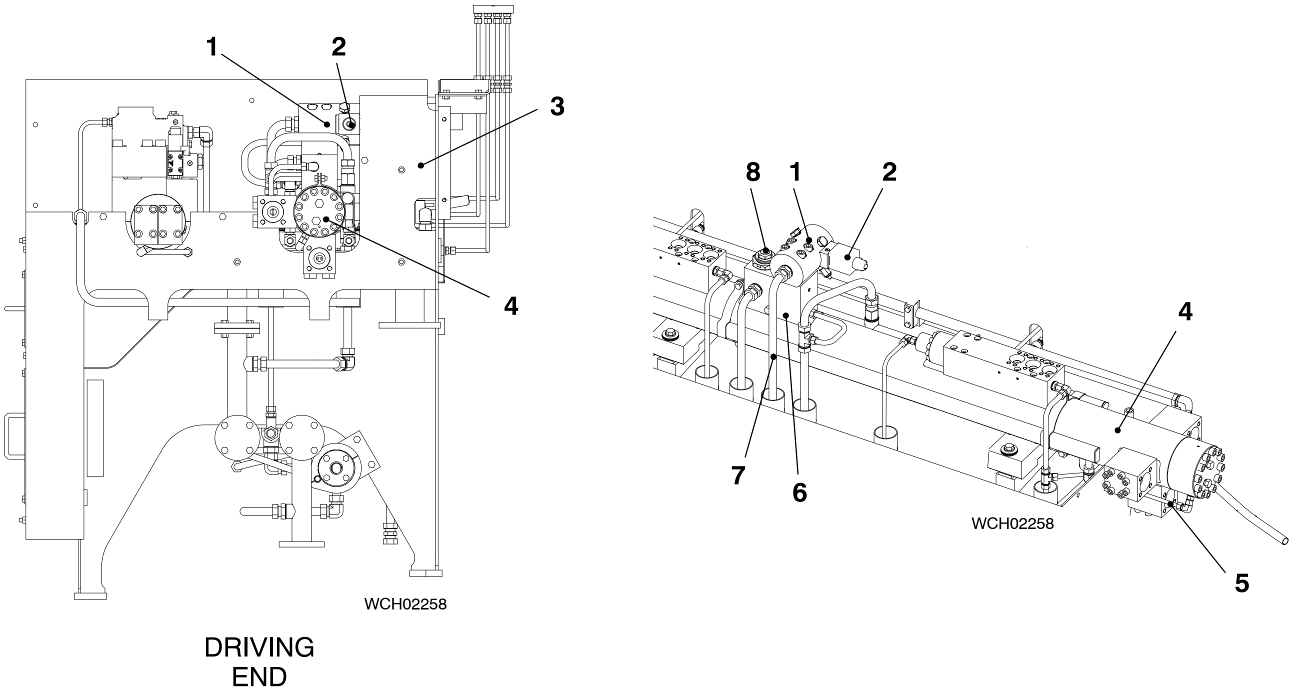


**Fig. 1: Location of Pressure Control Valve**

1 Pressure control valve 10-5562_E0_5
2 Control valve (ZV7061S)
3 Rail unit
4 Fuel rail
5 Drain pipe
6 Valve block
7 Fuel return pipe
8 Relief valve

### 1.2 Emergency Stop

The safety system operates the control valve (2), which decreases the fuel pressure to less than 200 bar (usually to 0 bar). Thus, fuel injection is not possible.

The PCV is one of three devices that can shut down the engine. The other devices are:

- Immediate injection stop (engine software)
- Fuel pump supply moved to 0 (engine software).

### 1.3 Emergency Operation

If the fuel pressure control system becomes defective, the PCV will control the pressure in the system when:

- There are missing or incorrect control signals
- A flow control valve of a fuel pump is unserviceable.

When no control signal is received, the fuel pumps are set to the maximum supply position.

If the fuel pressure is more than the specified pressure (approximately 1050 bar), the PCV will open to gradually drain sufficient fuel to keep the adjusted maximum pressure. If this occurs, longer engine operation time must be prevented.

The PCV must be replaced after a longer operation time during emergency operation.

**CAUTION**

**Damage Hazard: Always do a check of the PCV operation pressure after emergency operation (e.g. no fuel pump control when the PCV is used for pressure control in the fuel rail). Damage can occur if the operation pressure is incorrect.**

**Note: When the PCV opens, fuel will drain and you can hear a loud noise like a whistle.**

## 2. Functions

### 2.1 Control Function

The PCV (1, Fig. 1) has a primary piston. A pressure balance between the high pressure side and the control side of the PCV controls this primary piston. When the pressure decreases on the control side through a small opening in the primary piston (because of the control valve or the pneumatic actuator), the pressure difference causes the primary piston to move. The PCV then releases fuel through the return bore.

### 2.2 Supply Function

During engine stand-by the PCV (1) will open automatically to supply fuel through the fuel pumps, the HP fuel pipes and fuel rail (4) to keep the fuel warm. Downstream from the PCV, fuel collects in the fuel return pipe (7) and flows back to the booster circuit at 4.0 bar (for more data, refer to 8019–1 Fuel System).

### 2.3 Emergency Stop Function

If the control valve (2) is energized, the fuel pressure in the fuel rail is immediately released.

# Fuel Pump Actuator

## 1. General

Each fuel pump (1, Fig. 1) has an electrically-operated actuator (3). The regulating linkage (2) connects the fuel pump actuator (3) to the fuel pump (1). The lever (8) moves the connecting element (7), which moves the toothed rack (6) to the applicable position to control the fuel flow through the fuel pump (1).

## 2. Function

The ECS controls each fuel pump actuator (3). The fuel pump actuator (3) controls the fuel quantity and keeps the necessary pressure in the fuel rail.

During operation, the fuel pump actuators (3) move at the same time i.e. the control positions and the fuel quantity that flows through the fuel pumps (1) are the same.

**Note: If a pump plunger does not move, which blocks the toothed rack (6), do not disconnect the electrical power to the related fuel pump actuator (3). There is an overload protection installed.**

### 2.1 5-cylinder to 7-cylinder

If a fuel pump actuator (3) becomes defective, its lever (8) stays in position or turns slowly to the zero supply position. The other fuel pump actuator (3) gets control of the fuel quantity supply (for more data, refer to 8019−1, Defective Fuel Pump Actuator, paragraph 8).

### 2.2 8-cylinder

If a fuel pump actuator (3) becomes defective, its lever (8) stays in position or turns slowly to the zero supply position. The other fuel pump actuators (3) get control of the fuel quantity supply (for more data,refer to 8019−1−1, Defective Fuel Pump Actuator).

**Note: In the lower load range (at lower fuel consumption) the fuel pressure control valve 10-5562_E0_5 controls the fuel pressure regulating function. This is because the fuel pump actuators (3) cannot decrease the fuel quantity supply (see also 5562−1 Pressure Control Valve).**

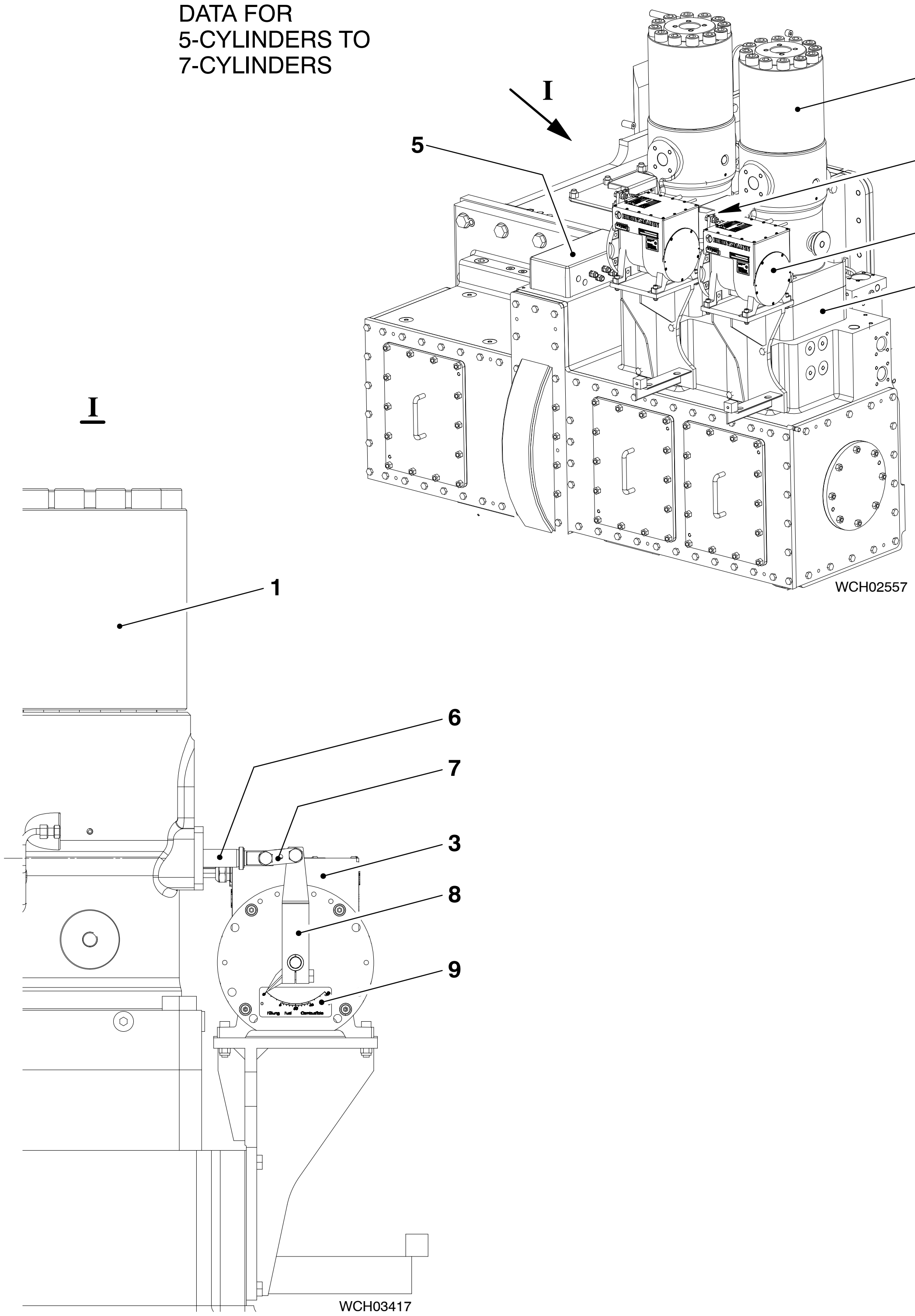


**Fig. 1: Fuel Pump Actuator**

1 Fuel pump
2 Regulating linkage
3 Fuel pump actuator
4 Supply unit
5 Terminal box
6 Toothed rack
7 Connecting element
8 Lever
9 Indicator (analogue fuel feedback)

# Scavenge Air System Group 6

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# Scavenge Air Receiver

## 1. General

The scavenge air receiver (8, Fig. 1) is a welded assembly attached to the cylinder block on the exhaust side. The scavenge air receiver (8) has the parts that follow:

- Receiver
- Turbocharger support
- Diffuser
- Scavenge air cooler casing
- Charging unit.

The longitudinal wall (21, Fig. 2) divides the receiver into the receiver space (19) and air space (22). The flaps (23) are attached to the longitudinal wall (21).

## 2. Function

**WARNING**

**Injury Hazard: Do not go into the receiver space during engine operation. Access into the receiver space through the covers is possible only when the engine has stopped. This will prevent injury to personnel.**

**WARNING**

**Injury Hazard: The dirty oil drains must not be blocked. There is a risk of fire if dirty oil does not flow off. This will prevent injury to personnel and damage to equipment.**

During operation, the turbocharger blows scavenge air through the scavenge air cooler (SAC), (2) into the charging unit, through the water separator (18) and then into the air space (22). The air then flows through the flaps (23) into the receiver space (19) and through openings in the cylinder block to the piston underside (20). The scavenge air flows through the scavenge ports when the piston is near BDC. The flaps (23) prevent back-flow into the air space (22).

Two auxiliary blowers (7, Fig. 1) are attached to the scavenge air receiver. During engine start or at low engine load, the auxiliary blowers (7) come on and move scavenge air from the air space (22, Fig. 2) through the duct to the receiver space (19). The flaps (23) prevent the back-flow of air when the auxiliary blowers (7) are set to off.

The relief valve (9, Fig. 1), installed on the scavenge air receiver, opens when the air pressure increases to more than the permitted value (4.6 ±0.2 bar) in the air space (22).

**Note: If the turbocharger becomes defective, refer to 6500−1 Turbocharging, Defective Turbocharger.**

**Note: If an auxiliary blower becomes defective, refer to 6545−1 Auxiliary Blower and Switch Box, Defective Auxiliary Blowers.**

**Note: When the engine has stopped, you can do an inspection of the running surface of the piston, cylinder liner, piston rings and the piston rod gland from the receiver space (19).**

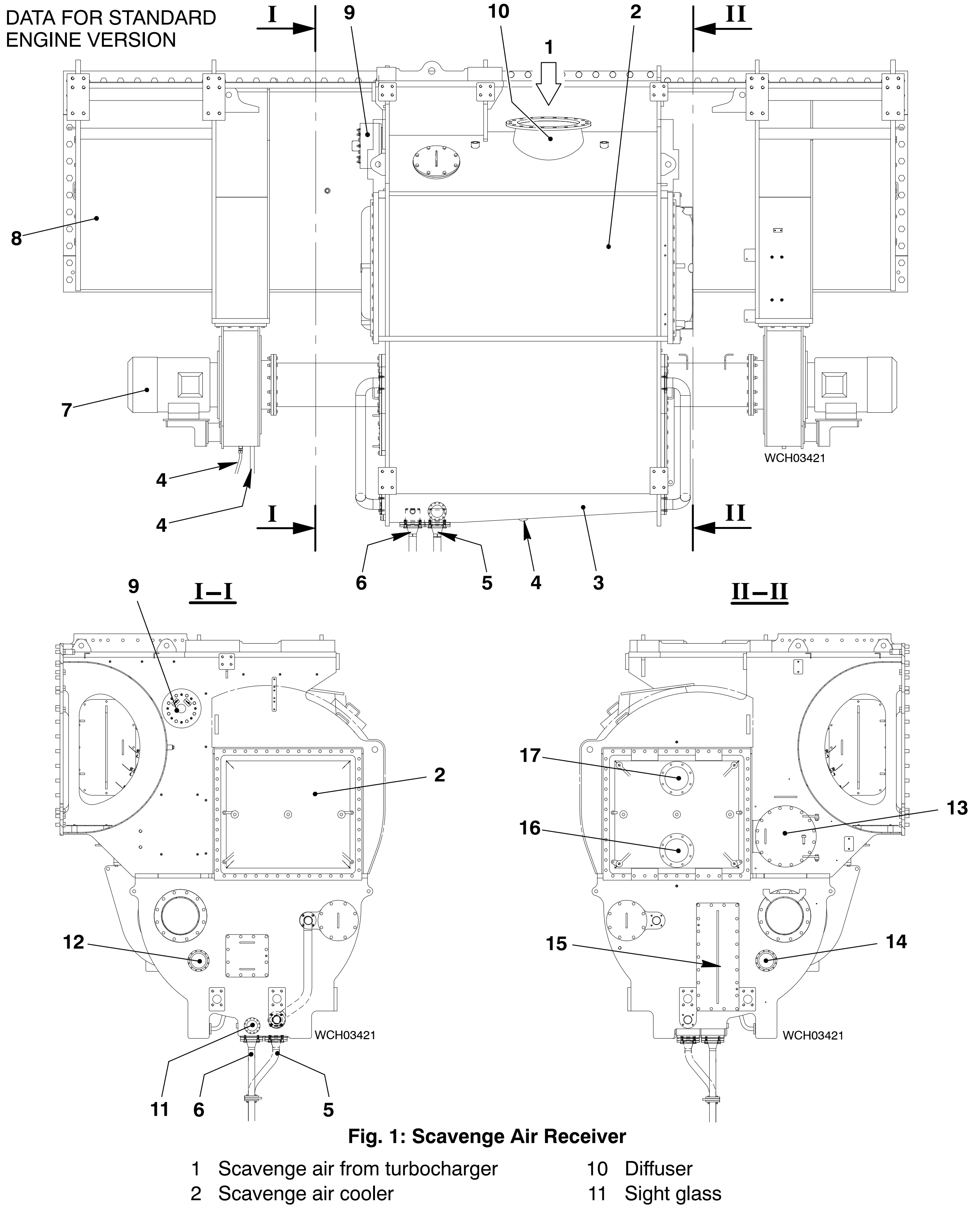


**Fig. 1: Scavenge Air Receiver**

1 Scavenge air from turbocharger
2 Scavenge air cooler
3 Collector pipe
4 Drain (oily water)
5 Water drain (from scavenge air cooler)
6 Water drain (from water separator)
7 Auxiliary blower
8 Scavenge air receiver
9 Relief valve
10 Diffuser
11 Sight glass
12 Sight glass
13 Cover
14 Sight glass
15 Cover (water separator behind cover)
16 Scavenge air cooler inlet
17 Scavenge air cooler outlet

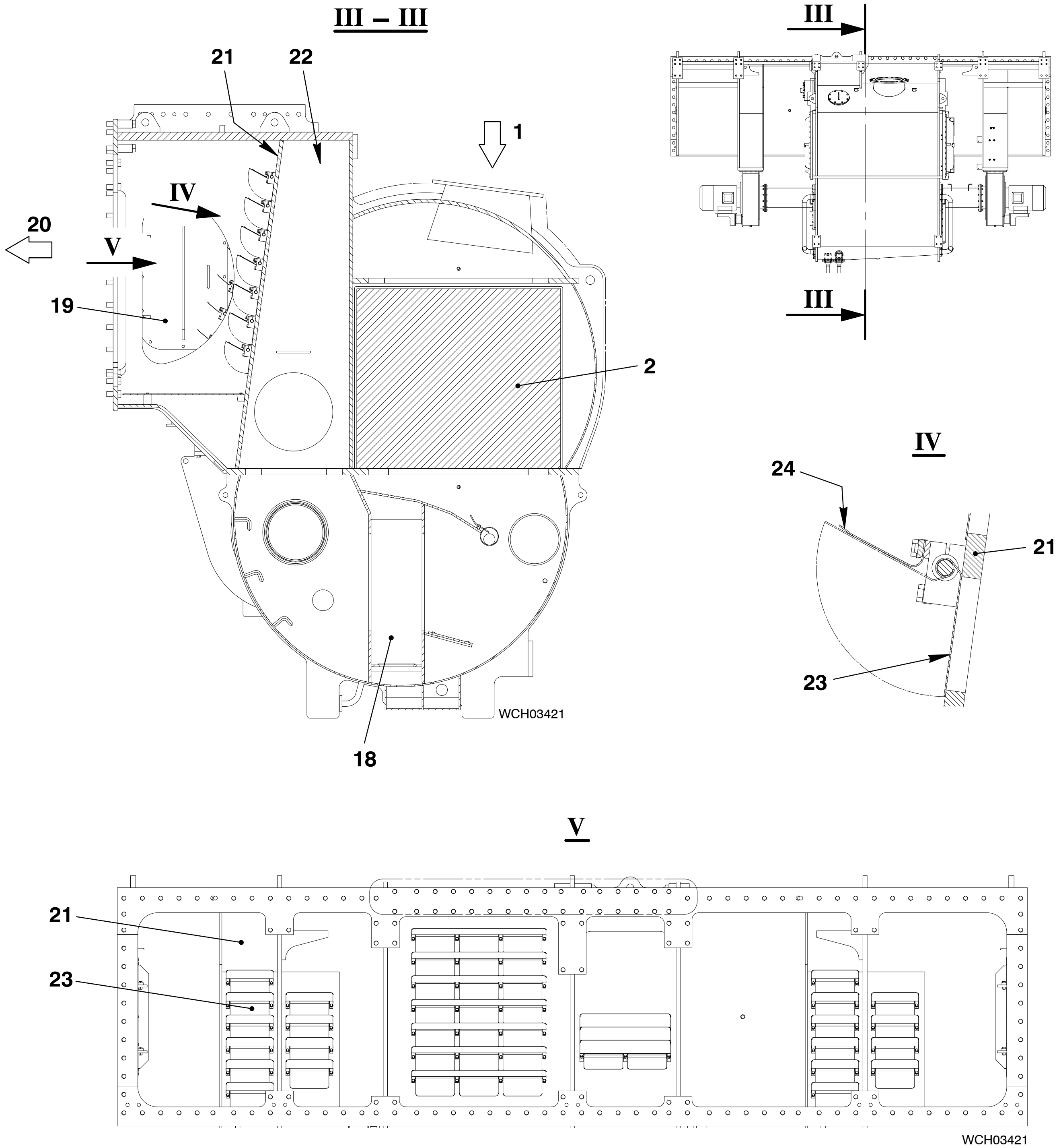


**Fig. 2: Scavenge Air Receiver**

1 Scavenge air from turbocharger
2 Scavenge air cooler
18 Water separator
19 Receiver space
20 Piston underside
21 Longitudinal wall
22 Air space
23 Flap
24 Stop plate

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# Turbocharging



## 1. General

**CAUTION**

**Damage Hazard: If you operate the engine with a turbocharger cut out, you must obey the operation limits given in the Service Bulletin RT–162 to prevent damage to the engine.**

The turbocharger is accurately tuned to the engine and related to the number of cylinders, service output, mode of operation etc.

Data about operation, maintenance and servicing are given in the related documentation of the manufacturer (which is part of the Operation Instruction).

## 2. Function

Exhaust gas (EG, Fig. 1) from the cylinders collects in the manifold (15). The exhaust gas moves the turbine (16), then flows out through the exhaust gas outlet (EO) to the exhaust system of the vessel. The exhaust gas turns the turbine and the compressor (2), which is attached to the same shaft. The compressor pulls fresh air (FA) from the engine room through a filter/silencer.

The compressor compresses and heats the scavenge air (SA). The hot compressed air flows into the charging unit (5) through the scavenge air cooler (SAC) (3), which decreases the air temperature to a lower range. Because of the high humidity in the air, the SAC produces a large quantity of condensation. The water separator (4) removes the condensation, which flows through the drains (WD and CD).

The scavenge air flows from the air space (AS) through the flaps (18) to the receiver space (RS) and then into the piston underside (PU).

When the piston (9) is near BDC, scavenge air flows through the open inlet ports (10) into the cylinder (12).

After the compression, combustion, and expansion process, the exhaust valve (14) opens and exhaust gas (EG) flows into the manifold (15), which completes the cycle.

During engine start, or low load operation the auxiliary blowers (8) supply air from the air space (AS) to the receiver space (RS).

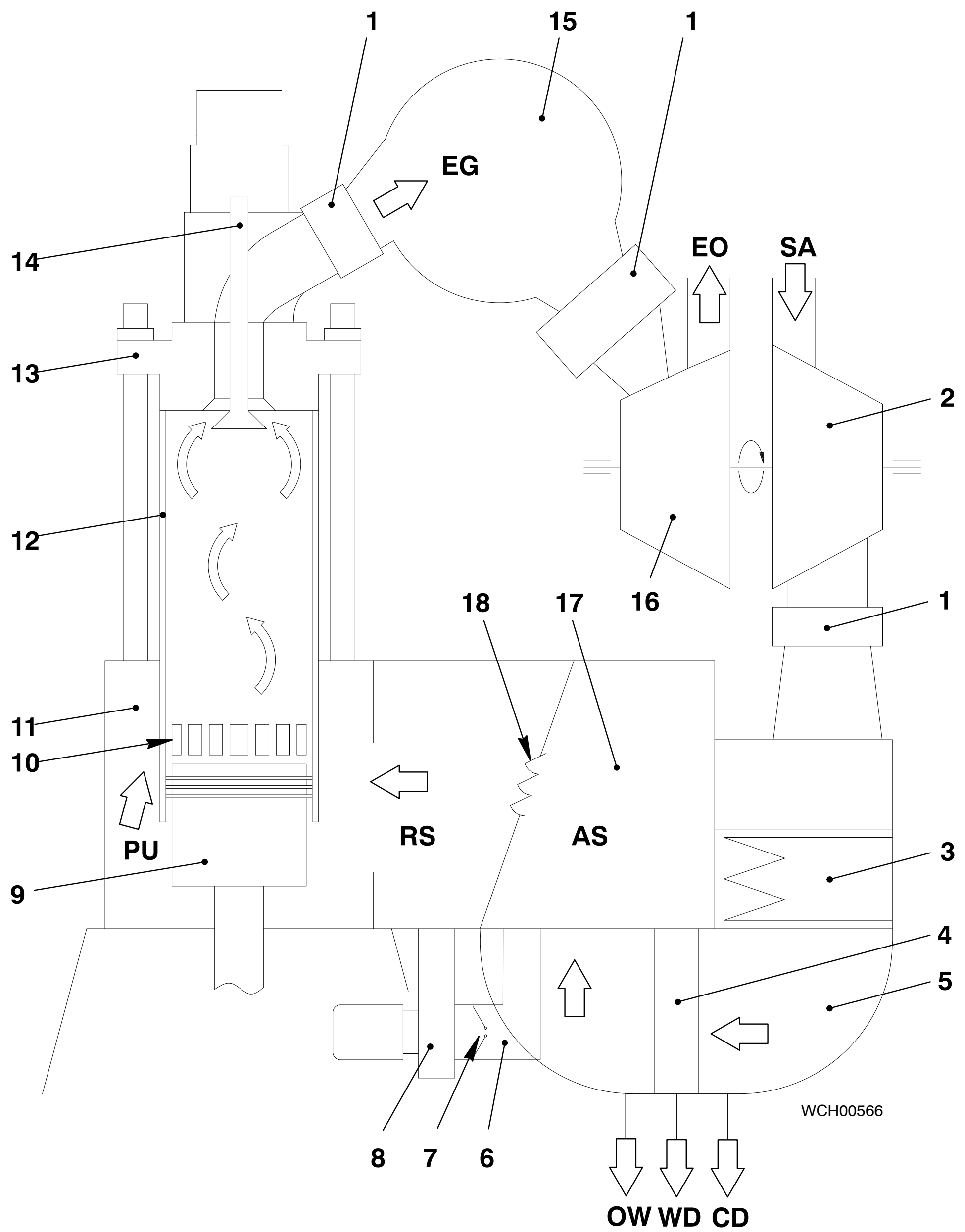


**Fig. 1: Schematic Diagram − Turbocharger Operation**

| | | | |
|---|---|---|---|
| 1 | Expansion piece | 15 | Manifold |
| 2 | Compressor | 16 | Turbine |
| 3 | Scavenge air cooler | 17 | Receiver |
| 4 | Water separator | 18 | Flaps |
| 5 | Charging unit | AS | Air space |
| 6 | Air inlet duct | CD | Condensation drain from air cooler |
| 7 | Non-return valve | EG | Exhaust gas from cylinder |
| 8 | Auxiliary blower | EO | Exhaust gas, outlet |
| 9 | Piston | FA | Fresh air |
| 10 | Inlet ports | OW | Oily water drain |
| 11 | Cylinder block | PU | Piston underside |
| 12 | Cylinder liner | RS | Receiver space |
| 13 | Cylinder cover | SA | Scavenge air |
| 14 | Exhaust valve | WD | Water drain from water separator |

## 3. Clean during Operation

The turbochargers have a system to clean the turbine and the compressor. It is possible to clean the turbine and the compressor while the turbocharger operates. Regular procedures to clean the turbine and the compressor prevent or decrease contamination and increase the time between overhauls.

If the quantity of dirt becomes too much (scavenge air pressure decreases and exhaust gas temperature increases), the turbocharger must be disassembled and cleaned in accordance with the instructions given in the turbocharger manual. Refer to 0230−1, Operating Data Sheet for the permitted pressure decrease.

To keep the silencer in a clean and serviceable condition, regular visual checks and procedures are necessary. Clean the silencer and filter only when the engine is stopped and in accordance with the instructions given in the applicable turbocharger manual.

**Note: One more filter mats installed on top of the silencer will keep the contamination on the air side to a minimum, but will cause a loss of pressure.**

If there is an increase in the pressure difference $\Delta p$ (of 50% compared to the shop test value at the same engine load) or the filter mat is dirty, you must clean the filter mat. To clean the filter mat, refer to the instructions given in the turbocharger manual.

You can use the methods that follow to clean regularly the compressor and turbine:

- Wash the compressor
- Dry-clean the turbine (at full service load).

For data about the procedures to clean the turbocharger and the related intervals between the procedures, refer to the applicable turbocharger manual.

## 4. Faults

If a turbocharger becomes defective, you must shut down the engine as quickly as possible to prevent damage.

If repair or replacement of a turbocharger is not immediately possible, the engine can operate in Emergency Operation at decreased load after the procedure below is completed.

In Emergency Operation, you must operate the engine only for as long as necessary (refer to 0510−1, paragraph 2 Decreased Power Output).

The loads (outputs) given are guidance values, which are related to the condition of the engine. It is possible that these values will be decreased.

For a list of the applicable tools, refer to the Maintenance Manual 9403−5 Standard Tools.

## 4.1 Condition One

On engines that have two turbochargers, one turbocharger is defective.

The engine load output is approximately 50% of the CMCR. This is related to the output of the auxiliary blowers.

### 4.1.1 Procedure

1) Lock the rotor of the turbocharger (refer to the turbocharger manual).
2) Remove the expansion joint (1, Fig. 1) from the defective turbocharger and the exhaust manifold.
3) Install the blind flanges (94653A and 94653B).
4) Remove the expansion joint (2) from the defective turbocharger air outlet and the diffusor.

**Note: Install the blind flange (94653C) only if air flows in through a suction duct.**

5) Install the blind flanges (94653C) and (94653D).

The scavenge air pressure, turbocharger speed and firing pressures must not be higher than during usual operation (see 0230−1 Operating Data Sheet).

**Note: Before you start the turbocharger, make sure that you remove the plugs from the oil supply pipes.**

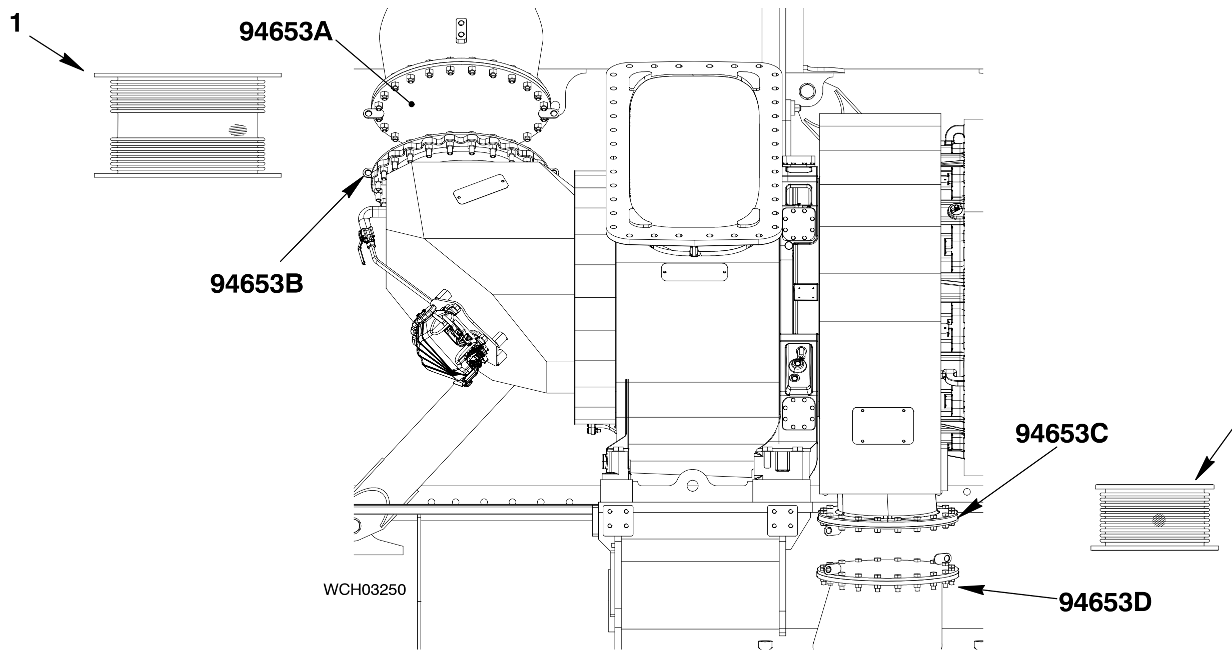


**Fig. 2: Defective Condition One**

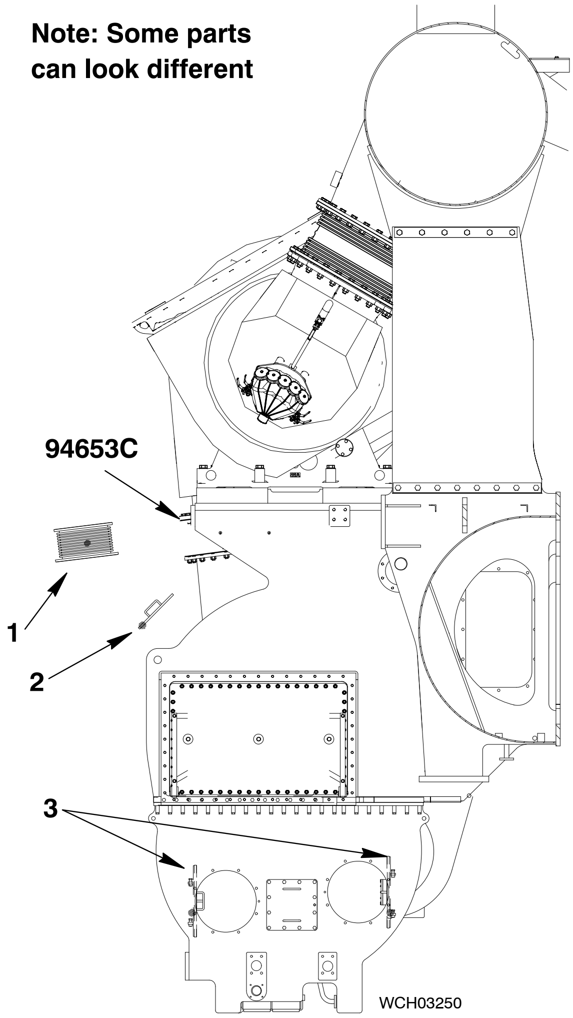


Fig. 2: Defective Condition Two

## 4.2 Condition Two

All turbochargers are defective.

The engine load output is approximately 10% to 15% of the CMCR. This is related to the output of the auxiliary blowers.

### 4.2.1 Procedure

1) Lock the rotor of the defective turbocharger (refer to the turbocharger manual).
2) Remove the expansion joint (1, Fig. 2) from the turbocharger air outlet and the diffuser.
3) Install the blind flange (94653C).
4) Open the covers (2) and (3) on the scavenge air receiver.

**Note: Install the blind flange (94653C) only if air flows in through a suction duct.**

5) Set to on the auxiliary blowers.

The exhaust gas temperature upstream of the turbocharger must not be higher than during usual operation. Thick, black exhaust smoke must be prevented.

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# Auxiliary Blower and Switch Box

## 1. Auxiliary Blower

The electric motors (5, Fig. 1) operate the two auxiliary blowers (1, 3), which are installed on the scavenge air receiver (4). The auxiliary blowers (1, 3) supply air from the air space through the ducts (2) into the receiver space during the engine start and operation at low load. Flaps prevent the back-flow of air to the scavenge air receiver (for more data, refer to 6420-1 Scavenge Air Receiver).

**Note: If an auxiliary blower does not operate for a long period, do the procedure given in 0630–1 Prepare the Engine for a Long Shutdown Period, paragraph 2.2 Procedures and Checks.**

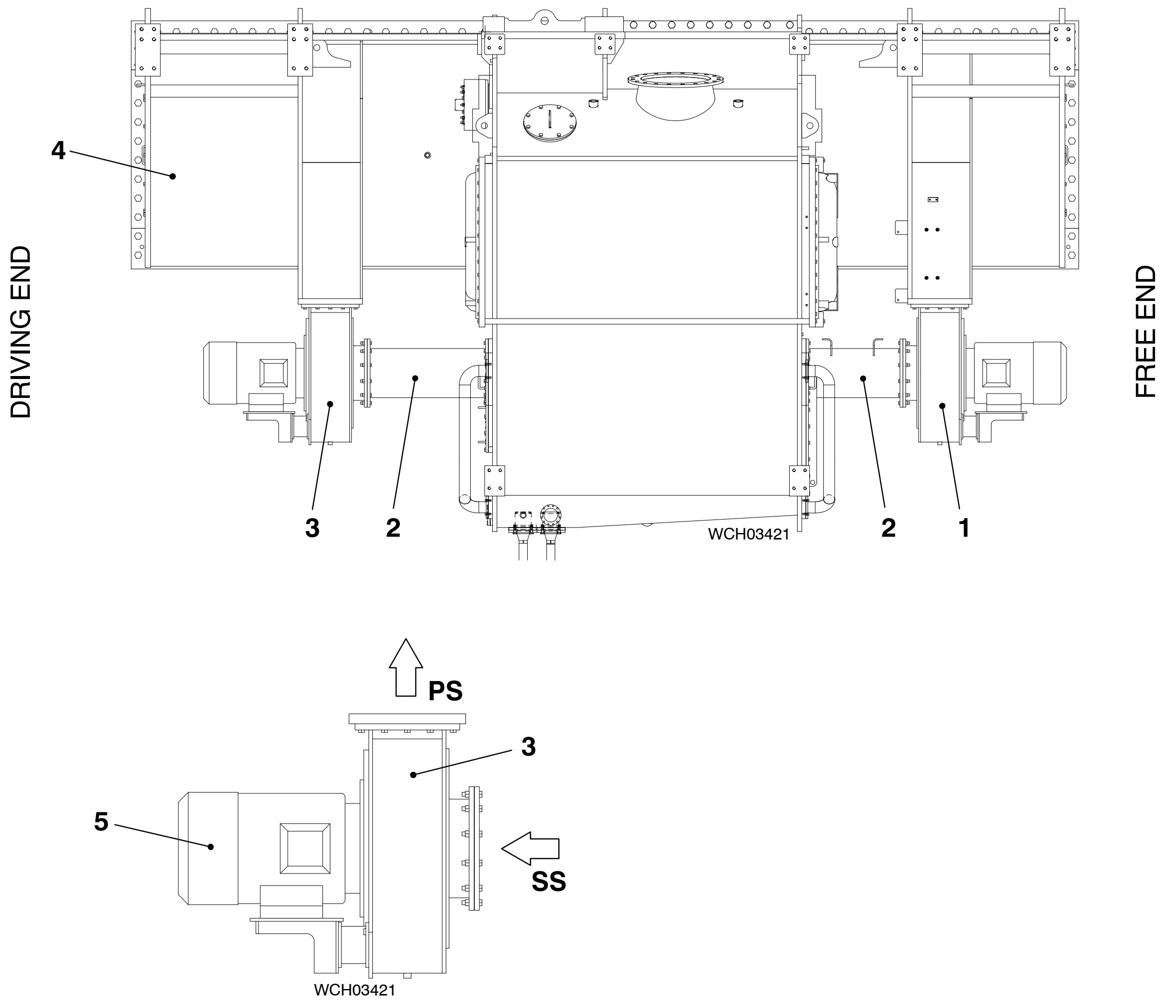


**Fig. 1: Location of Auxiliary Blowers**

| | | | |
|---|---|---|---|
| 1 | Auxiliary blower (left hand design) | 5 | Electric motor |
| 2 | Duct | PS | Pressure side |
| 3 | Auxiliary blower (right hand design) | SS | Suction side |
| 4 | Scavenge air receiver | | |

## 2. Defective Auxiliary Blowers

If one of the auxiliary blowers becomes defective, you can start and operate the engine in diesel mode. At less than full load, there will be more exhaust smoke.

If the two auxiliary blowers become defective, the engine cannot start.

# 3. Switch Box

## 3.1 General

The engine builder supplies an electrical switch box (12, Fig. 2) for each auxiliary blower.

## 3.2 Function

During the engine start procedure, the first auxiliary blower starts immediately. After approximately two to three seconds, the second auxiliary blower starts.

When the turbocharger produces sufficient pressure in the scavenge air receiver, the auxiliary blowers stop.

If the scavenge air pressure decreases below the minimum pressure necessary, the auxiliary blowers operate as given above (for more data, refer to 4003–1, paragraph 4.5 Auxiliary Blowers).

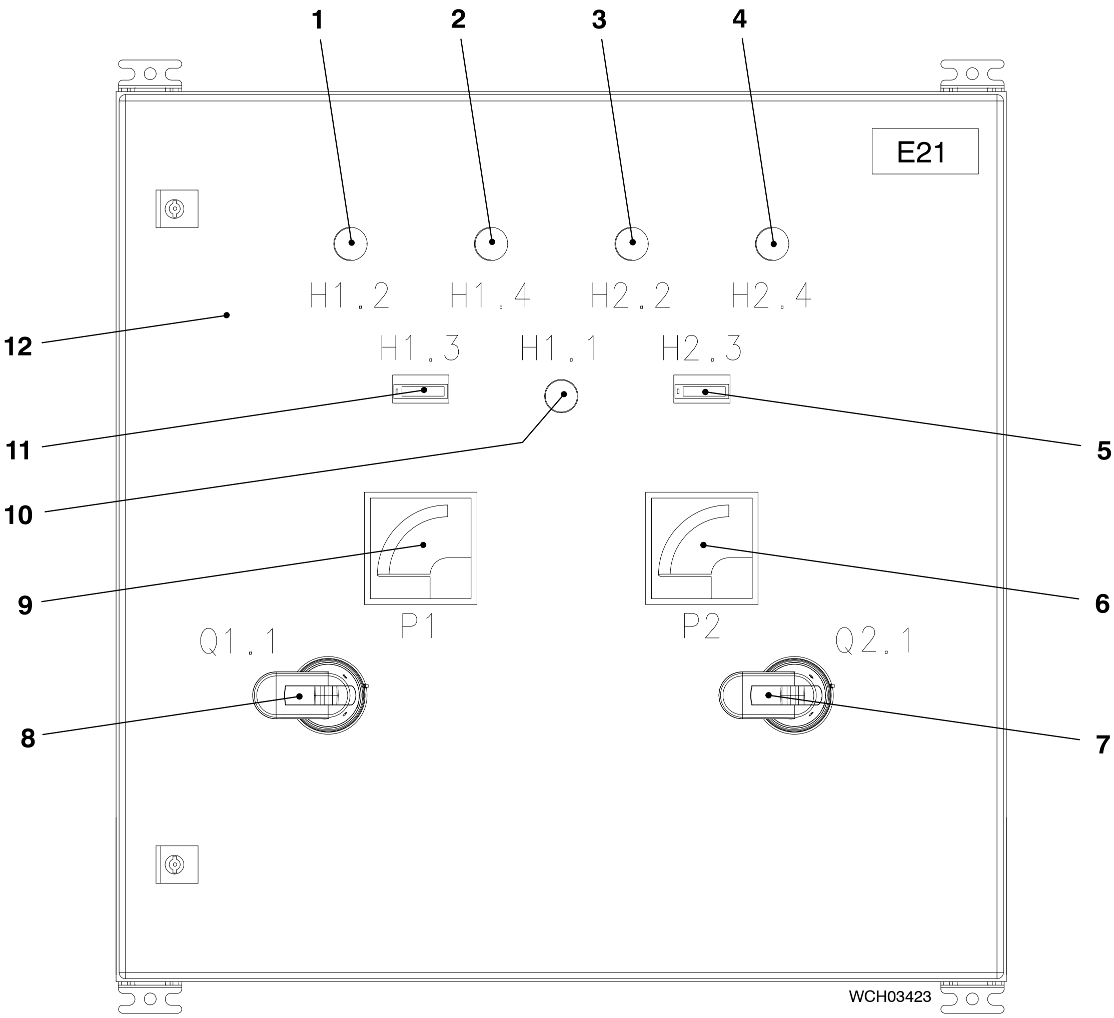


**Fig. 2: Switch Box**

1 Indicator (Auxiliary Blower #1 Running)
2 Indicator (Auxiliary Blower #1 Overload)
3 Indicator (Auxiliary Blower #2 Running)
4 Indicator (Auxiliary Blower #2 Overload)
5 Hour counter (Auxiliary Blower #2)
6 Ampere meter (Auxiliary Blower #2)
7 Main switch (Auxiliary Blower #2)
8 Main switch (Auxiliary Blower #1)
9 Ampere meter (Auxiliary Blower #1)
10 Control voltage indicator
11 Hour counter (Auxiliary Blower #1)
12 Switch box

# Scavenge Air Cooler



## 1. General

A Scavenge Air Cooler (SAC) is installed downstream of the turbocharger. The SAC decreases the temperature of the compressed / heated air that flows from the turbocharger. The standard SAC is a single-stage multi-pass item. The water flows through the cooler in the opposite direction to the air flow more than one time. The temperature difference of the water and scavenge air is thus applied equally along all of the SAC.

## 2. Operation Instructions

If air collects in the cooling water system of the SAC, problems for the engine and the SAC can occur. Thus, the SAC must operate correctly.

You must do regular checks of the SAC temperature. Refer to the data in 0230-1 Data Sheet.

If the level switch (15, Fig. 1) of the condensate collector (9) activates an alarm during operation, the cause (condensate water or SAC cooling water) must be found. If the cause is SAC cooling water, the SAC must be disassembled and repaired (refer to the Maintenance Manual 6606−1).

To prevent damage to the SAC, the cooling water must flow correctly during operation. The cooling water flow must not be decreased at part load, or during maneuvering.

**CAUTION**

**Damage Hazard: Do not use the butterfly valves at the cooling water inlet and outlet pipes to control the flow rate. The water separators (which are plastic) could be damaged because the scavenge air temperatures are too high at higher loads.**

For data about operation with a defective SAC, refer to paragraph 4.

During correct operation of the SAC, record the temperature difference between the scavenge air outlet and the cooling water inlet. You use the temperature difference as a guide. You must do regular checks of the two temperature values and compare them with the temperatures you recorded.

If the temperature difference increases and the engine load and cooling water flow do not change, the SAC is dirty.

If the water side of the SAC is dirty, the scavenge air temperature increases.

If the air side of the SAC is dirty, the pressure difference ($\Delta p$) of the scavenge air through the SAC increases. This does not show the full effect of the dirt because an increased resistance also causes a decreased air flow from the turbocharger. For more data about the SAC during operation, refer to 0230-1 Operating Data Sheet.

Higher scavenge air temperature and decreased air flow cause increased thermal load of the engine and higher exhaust gas temperatures.

You can clean the air side of the SAC during engine operation, refer to paragraph 3.

You can clean the water side of the SAC only when the engine has stopped. For data to clean the water side of the SAC, refer to the Maintenance Manual 6606-1.

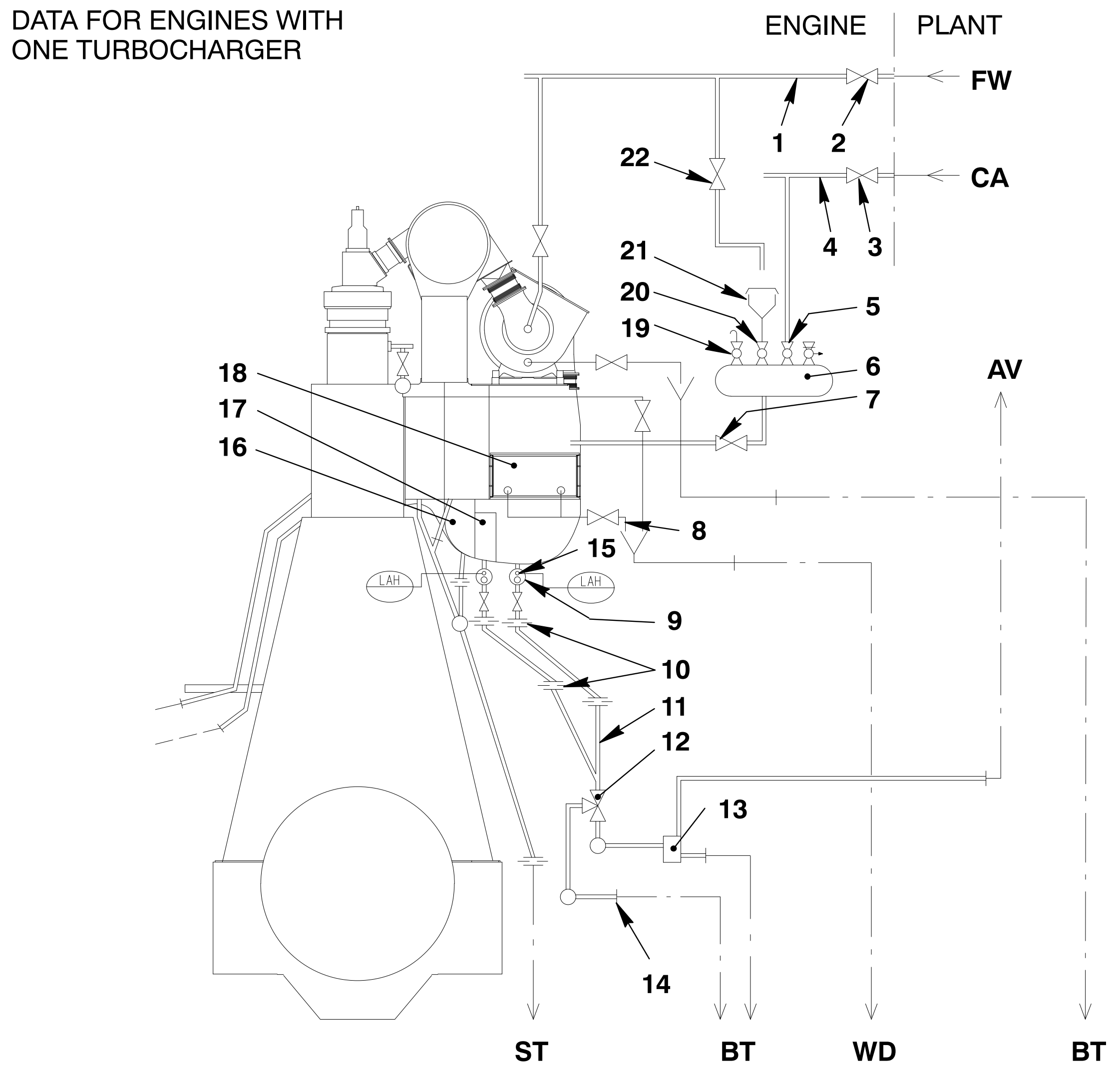


**Fig. 1: Location of Wash-water System Parts**

| | | | |
|---|---|---|---|
| 1 | Fresh water supply pipe | 16 | Receiver |
| 2 | Ball valve | 17 | Water separator |
| 3 | Ball valve | 18 | Scavenge air cooler (SAC) |
| 4 | Compressed air supply pipe | 19 | Shut-off valve (vent) |
| 5 | Shut-off valve | 20 | Shut-off valve |
| 6 | Container | 21 | Funnel |
| 7 | Ball valve | 22 | Shut-off valve |
| 8 | SAC drain | | |
| 9 | Condensate collector | | |
| 10 | Throttle disc | AV | Vent |
| 11 | Condensate and wash-water drain | BT | Drain to bilge water tank |
| 12 | 3-way ball valve | CA | Compressed air from board system 7.0 bar to 9.0 bar |
| 13 | Vent unit | FW | Fresh water 2.5 bar |
| 14 | Cleaning fluid and wash-water drain | ST | Drain to sludge water tank (oleiferous) |
| 15 | Level switch | WD | Drain to water drain tank |

# 3. SAC Air Side – Clean during Operation

The equipment necessary to clean the air side of the SAC is installed on the engine.

## 3.1 Intervals

Initially, it is recommend that you clean the SAC one time each week. If there is no change in the pressure difference ($\Delta p$) through the SAC, the interval can be extended (e.g. one time each month).

The pressure difference must not be more than the maximum limit ($\Delta p$ increase of 50% compared to the shop test value at the same engine load). For more data, refer to the Maintenance Manual 0380-1).

The quantity of contamination in the SAC is related to the condition of the airflow into the SAC and the maintenance of the air suction filter on the turbocharger.

**Note: It is recommended that you do not clean the SAC in tropical conditions because of increased condensation.**

## 3.2 Cleaning Agents

Use cleaning agents only from recommended suppliers. You must obey the instructions in the supplier documentation for the applicable water/cleaning fluid ratios.

For in-service cleaning, use only those fluids that have a sufficiently high flash point.

## 3.3 Procedure

Clean the SAC while the engine operates at less than 50% load (refer also the instruction panel on the engine). The air temperature downstream of the compressor (turbocharger) must not be more than 100°C. This is because heat will change too much of the cleaning agent to a gas.

1) Decrease the engine power to the value given before.

2) Make sure that compressed air and fresh water are available at the shut-off valves (1 and 12, Fig. 2).

DATA FOR ENGINES WITH
ONE TURBOCHARGER

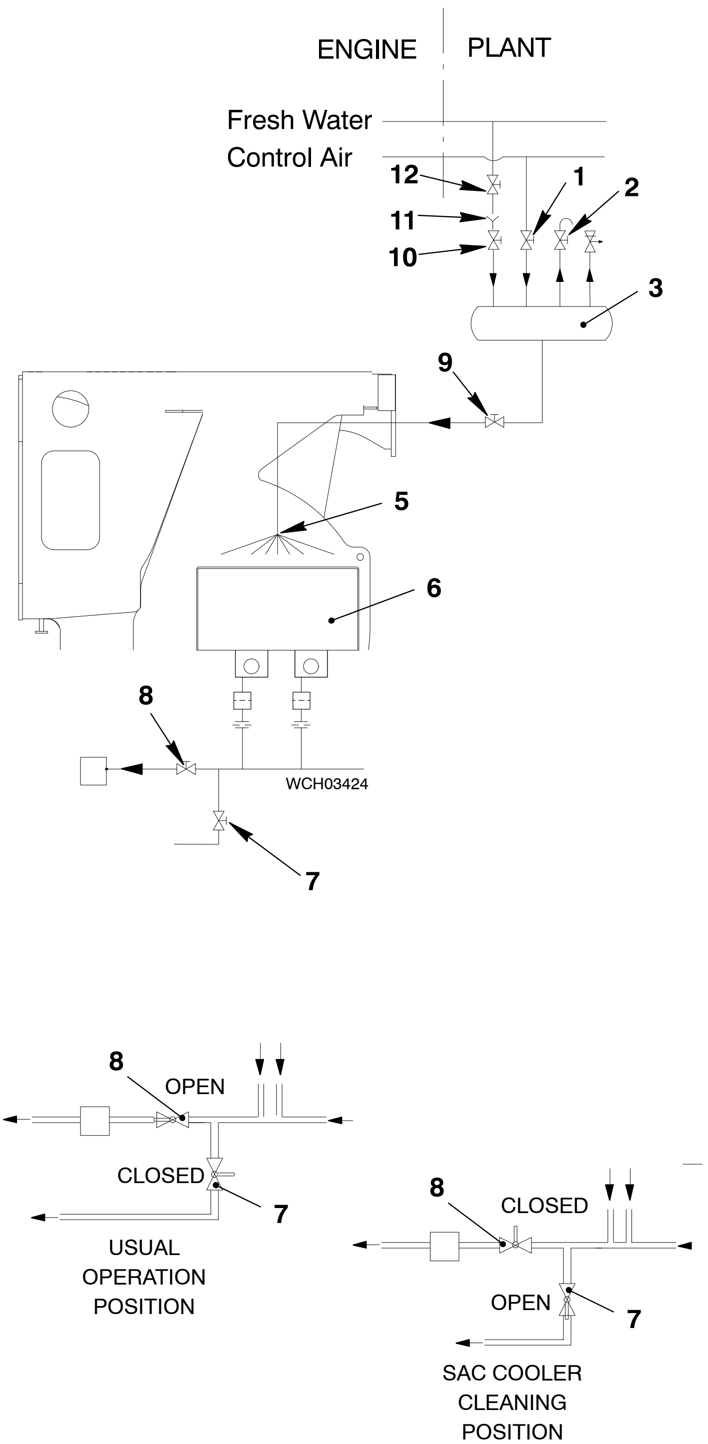


**Fig. 2**

3) Open the ball valves (2 and 10, Fig. 2).
4) Carefully open the ball valve (12) sufficiently to prevent back-flow of water in the funnel (11).
5) Fill the tank (3) through the funnel (11) with fresh water and the specified quantity of cleaning fluid (max 20 liters) (see paragraph 3.2).

**Note: You can also use a hand-held container filled with cleaning fluid mixed with fresh water to put into the funnel (11). When you use this method, make sure that the shut-off valve (12) stays closed.**

6) Close the ball valves (2 and 10).
7) Open the ball valve (1).
8) Open the ball valve (9). The water/cleaning fluid comes out of the nozzles (5) as a spray into the SAC (6) for approximately one minute.
9) Close the ball valve (8).
10) Open the ball valve (7).
11) Close the ball valve (1).
12) Close the ball valve (9).
13) Open the ball valve (2) until the air tank has no pressure.
14) After 10 minutes, do the procedure again with only fresh water (do not use cleaning fluid).
15) Open the ball valve (8).
16) Close the ball valve (7)
17) The procedure is completed.

**Note: Dirt particles that are loosened from the cooling fins can collect in the water separator or the scavenge air receiver. Do a check of the cooling fins and clean if necessary (refer to the Maintenance Manual).**

**Note: For engines with two turbochargers, do the procedure for each scavenge air cooler.**

## 4. Faults

When a scavenge air cooler (SAC) is defective, water can go into the scavenge air receiver. The water then goes out through the condensate collector of the SAC drain. The related level switch activates an alarm.

**Note: If you see water flow through the sight glass of the SAC drain when the engine has stopped, do a check for defects as soon as possible.**

If there is a fault in the SAC, it is recommended that you do the procedure given in step 1) to step 4).

1) Replace the defective SAC with the spare as soon as possible.

**Note: Step 2) is only possible with two systems of SAC and turbochargers.**

2) Shut down and drain the defective SAC.

3) Seal the cooling water supply and return pipes of the defective SAC.

4) Open the vent and drain valves. The vent and drain valves must stay open.

Leakage water that goes into the receiver flows away through the drain pipes of the SAC and water separator into the collector pipe.

During operation in this mode, the scavenge air temperature and exhaust gas temperature will increase.

You can only increase the load on the engine so that the scavenge air temperature (measured downstream of the SAC) is not more than the usual limit at service output (see 0230−2 Alarms and Safeguards). You must continuously and carefully monitor the scavenge air temperature.

If the scavenge air temperature increase is too high, the engine speed must be decreased (for the maximum permitted scavenge air temperature downstream of the SAC, see 0230−2 Alarms and Safeguards).

**Note: In these conditions, you can operate the engine only at approximately 25% load.**

## 5. Instruction Leaflets

Data about operation, maintenance and repair of the SAC are given in the Instruction Leaflets from the engine manufacturer or supplier.

You can get these Instruction Leaflets directly from the manufacturers. It is also possible to send an order for Instruction Leaflets from the engine manufacturer or supplier.

When you send an order for Instruction Leaflets, you must give the data that follows:

- The engine type and number
- The engine supplier
- The SAC manufacturer and type
- The applicable language.

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# Cylinder Lubrication Group 7

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# Cylinder Lubrication



## 1. General

The cylinder lubricating system operates independently to lubricate the cylinder liners and pistons. The engine control system (ECS) controls the adjustable load-related supply rate of cylinder lubricating oil to each lubrication point.

### 1.1 Cylinder Lubricating Oil

During usual operation, a high-additive, alkaline cylinder lubricating oil is necessary. The alkalinity of the cylinder lubricating oil that is chosen is related to the sulphur content of the fuel (refer to 0320–1, paragraph 3 Cylinder Lubricating Oil).

### 1.2 Running-in

For running-in of new components of the piston running system, it is necessary to adjust the cylinder lubrication feed rate. For more data, refer to 0570–1.

### 1.3 Cylinder Lubricating Oil Tanks (Plant Side)

There are two cylinder lubricating oil tanks (1 and 2, Fig. 1) installed in the plant. The cylinder lubricating oil tanks are installed at a specified height above the engine. This lets static pressure move the cylinder lubricating oil down through the duplex filter (10).

# 2. Lubricating Oil System – Overview

Fig. 1 shows the full system, which has the components that follow:

- One cylinder lubricating oil tank (1) for cylinder lubricating oil with a high base number (BN) (plant side).
- One cylinder lubricating oil tank (2) for cylinder lubricating oil with a low base number (BN) (plant side).
- Duplex filter (10) with a lever to change filters.
- Lubricating quills (3) with an injection nozzle and non-return valve.
- System control from the engine control system ECS (for more data, refer to 4002–1, paragraph 3.7 Cylinder Lubricating Control).

The cylinder lubricating pumps 25–7206_C#_1 (6) (one for each cylinder) have the parts that follow:

- Cylinder control module 20 (CCM-20)
- Control valves CV7131C to CV7138C (4) (4/2-way solenoid valve)
- Pressure transmitters PT3131C to PT3138C (5).

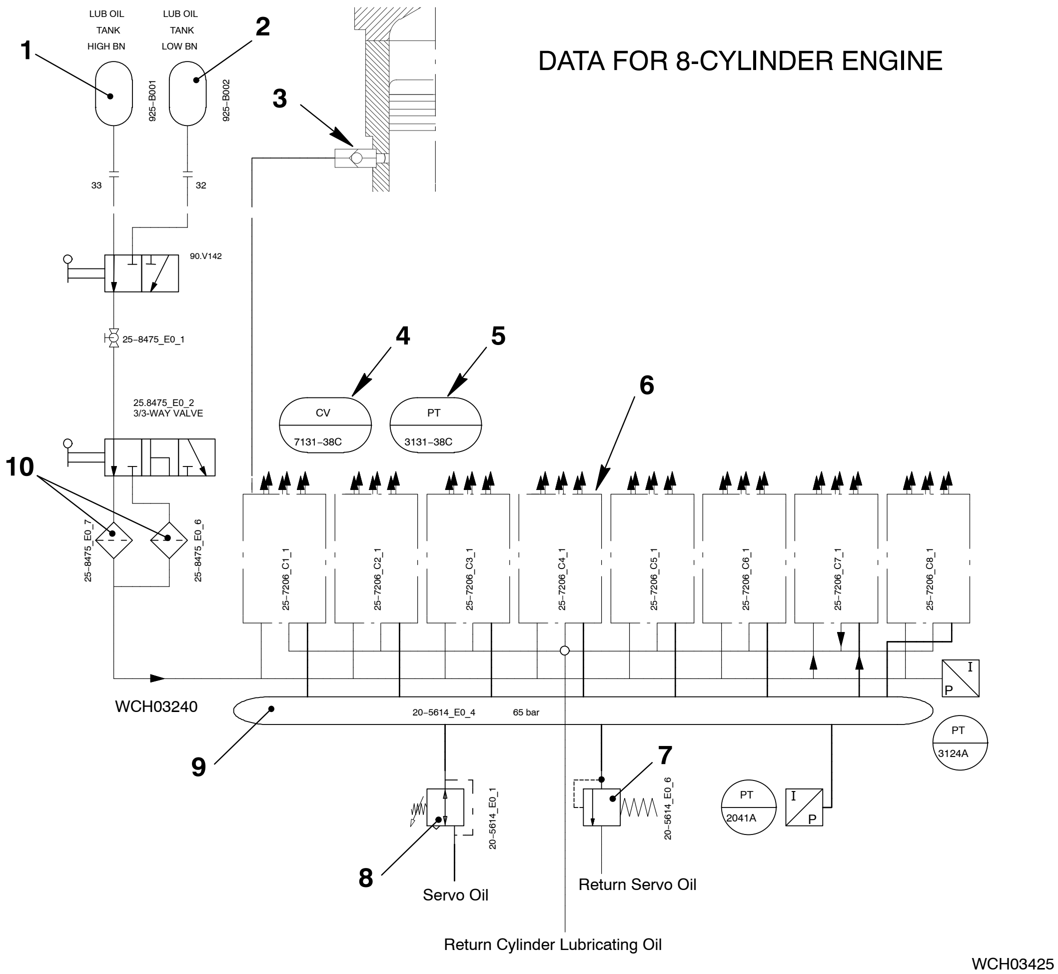


**Fig. 1: Schematic Diagram – Cylinder Lubricating System**

| | | | |
|---|---|---|---|
| 1 | Lub Oil Tank (high BN) | 6 | Cylinder lubricating pump |
| 2 | Lub Oil Tank (low BN) | 7 | Pressure safety valve |
| 3 | Lubricating quill | 8 | Pressure reducing valve |
| 4 | Control valve CV7131C to CV7138C | 9 | Servo oil supply pipe |
| 5 | Pressure transmitter PT3131C to PT313#C | 10 | Duplex filter |

## 3. Cylinder Lubricating Oil Supply

Cylinder lubricating oil from the cylinder lubricating oil tanks (1 and 2, Fig. 1) flows through the lubricating oil inlet pipe (5, Fig. 2) to the duplex filter (6). The filtered cylinder lubricating oil flows through the lubricating oil inlet pipe (8) to the cylinder lubricating pumps (9).

During usual operation, the cylinder lubricating pumps (9) supply the necessary oil pressure to the six lubricating quills on each cylinder. The pressure transmitters PT3131C to PT313#C are connected to the ECS and monitor the pressure.

The pressure transmitter PT3124A (1, Fig. 3) monitors the pressure in the lubricating oil supply pipe (2, Fig. 2). If there is no lubricating oil supply pressure (less than 0.1 bar), the pressure transmitter PT3124A sends an alarm signal (Pulse lubrication inlet pressure Low) to the ECS (for more data, refer to 4002−1 Engine Control System, paragraph 3.7 Cylinder Lubricating Control).

For more system data, refer to 4003-2 Control Diagram and 4003−8 Cylinder Lubrication.

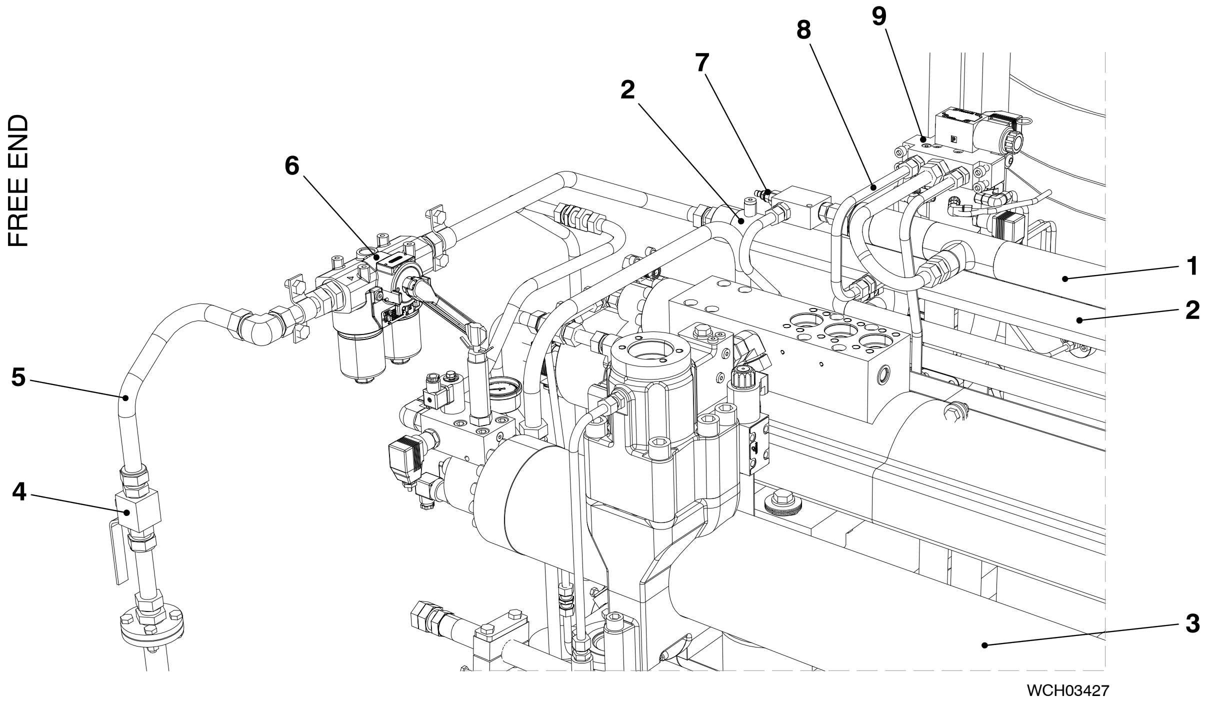


**Fig. 2: Cylinder Lubricating Oil Supply**

1 Servo oil supply pipe
2 Lubricating oil supply pipe
3 Servo oil rail
4 Ball valve
5 Lubricating oil inlet pipe
6 Duplex filter
7 Relief valve
8 Lubricating oil inlet pipe
9 Cylinder lubricating pump

# 4. Servo Oil Supply

Servo oil from the servo oil rail (10, Fig. 3) flows through the exhaust valve control unit (11) to the servo oil inlet pipe (9). Servo oil then flows through the servo oil supply pipe (3) and the servo oil inlet (4) into the cylinder lubricating pumps (7). The servo oil operates the cylinder lubricating pumps. For more data, refer to paragraph 5.

The servo oil flows from the cylinder lubricating pumps (7) through the servo oil outlet (5) into the servo oil return pipe and back to the plant.

The pressure transmitter PT2041A (2) monitors the pressure in the servo oil supply pipe (3). If there is no servo oil supply pressure or the supply pressure is less than 40 bar, the pressure transmitter PT2041A sends an alarm signal to the ECS. For the alarm values, refer to 0230−2 Operating Data Sheet.

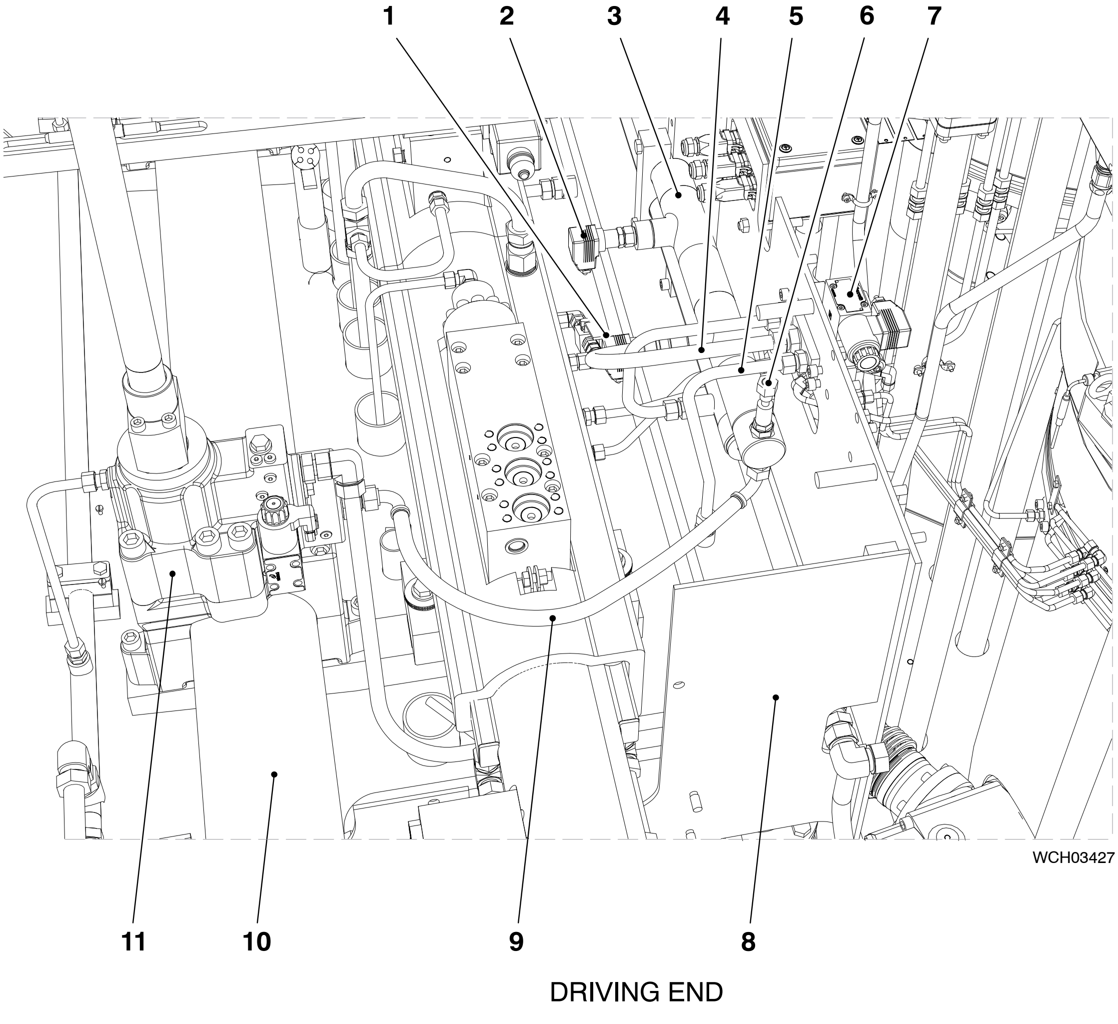


**Fig. 3: Cylinder Lubricating System − Servo Oil Supply**

1 Pressure Transmitter PT3124A
2 Pressure Transmitter PT2041A
3 Servo oil supply pipe
4 Servo oil inlet
5 Servo oil outlet
6 Pressure reducing valves
7 Cylinder lubricating pump
8 Rail unit
9 Servo oil inlet pipe
10 Servo oil rail
11 Exhaust valve control unit

# 5. Cylinder Lubricating Pump

## 5.1 General

Each cylinder has a self-contained cylinder lubricating pump (see Fig. 4) on a support in the rail unit. All of the cylinder lubricating pumps. All of the cylinder lubricating pumps are connected to supply pipes in the rail unit. Servo oil flows into a collector pipe installed below the rail unit.

Servo oil operates the cylinder lubricating pumps when the related control signals are released from the ECS.

**Note: If a cylinder lubricating pump becomes defective and the safety system releases a slow-down signal, the fuel injection of the related cylinder must be cut out (refer to 8019−1. Paragraph 5).**

The cylinder lubricating pump has a pump body, control valve (6) and a pressure transmitter (4).

Two bushes are installed in the cylinder lubricating pump. The low feed rate (LFR) bush (3) is installed on the screw at the bottom of the cylinder lubricating pump. This bush is for usual operation. The high feed rate (HFR) bush is installed in the stowage position (5). For more data about these bushes and the related change procedure, refer to 7218−2 Cylinder Lubrication − LFR and HFR Bushes.

## 5.2 Function

When the ECS sends a signal to the control valve CV713#C (6) on one of the cylinder lubricating pumps, the control valve CV713#C (6) operates. This causes a high pressure injection of cylinder lubricating oil.

A specified quantity of high pressure cylinder lubricating oil is flows through the outlet ports (1) of the cylinder lubricating pump. This high pressure cylinder lubricating oil flows through the oil pipes (2) to the lubricating quills on the related cylinder.

## 5.3 Cylinder Lubricating Pump − Bleed

To bleed the cylinder lubricating pump, the cylinder lubricating system must be ready for operation (refer to 0400−1 Prepare for Engine Start after a Short Shutdown Period (One or More Days).

To bleed the cylinder lubricating pump, refer to the procedure given in the Maintenance Manual, 7218-1.

## 5.4 Cylinder Lubricating Pump / Components − Maintenance

For an overhaul, or a replacement of the cylinder lubricating pump, send the pump / components to the manufacturer.

For faults, causes and repair procedures, refer to 0510−1, paragraph 5 Cylinder Lubrication Oil Pump − Defect and the supplier documentation for the cylinder lubricating pumps.

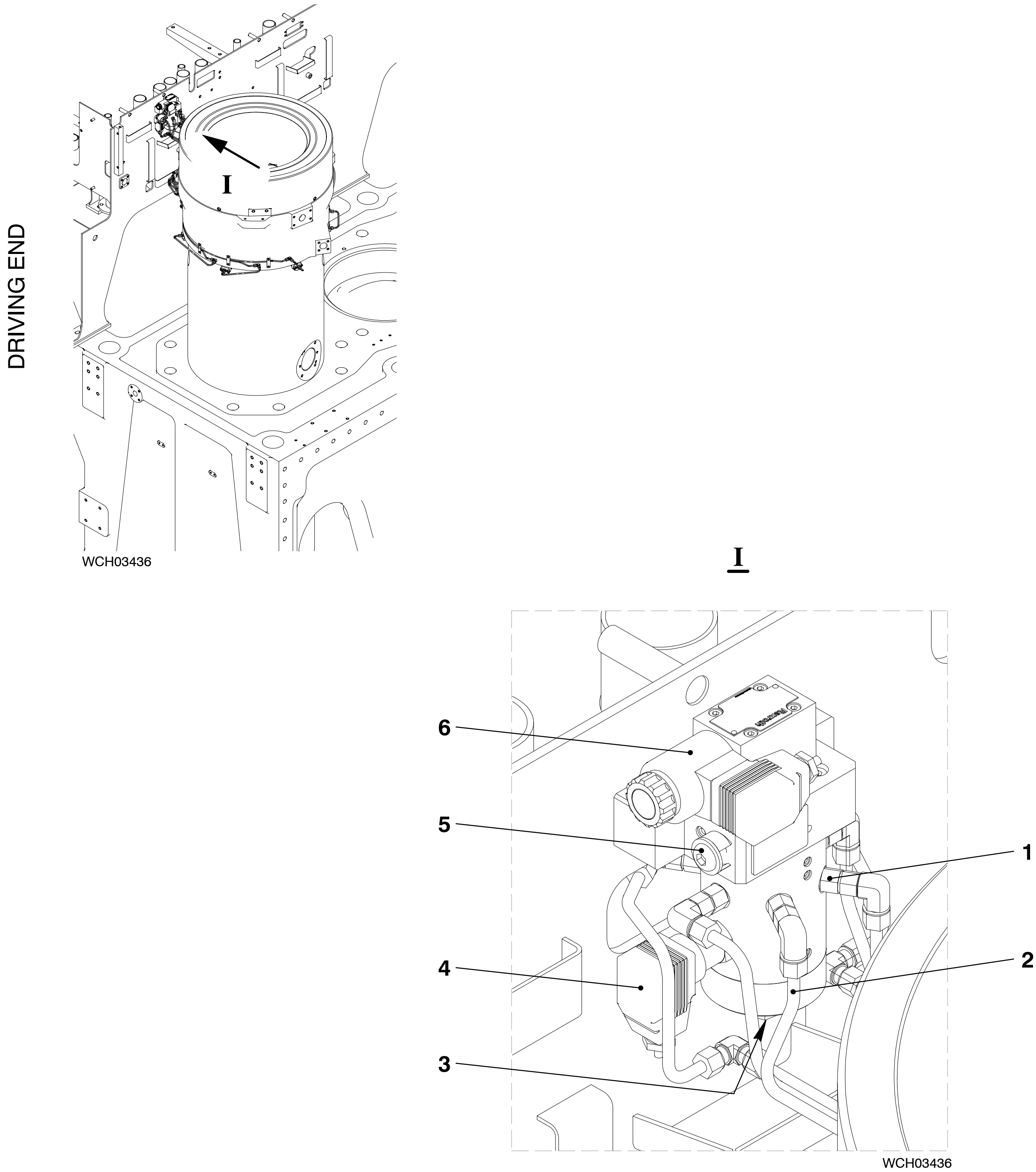


**Fig. 4: Cylinder Lubricating Pump**

1 Outlet port
2 Oil pipes
3 LFR bush (for usual engine operation)
4 Pressure transmitter PT3131C − PT313#C
5 Storage position for HFR bush)
6 4/2-way solenoid valve (CV7131−3#C)

## 6. Cylinder Lubricating System − Bleed

To bleed the lubrication oil supply pipe (2, Fig. 2), and the cylinder lubricating pumps, refer to the procedure given in the Maintenance Manual 7218−1.

After you bleed the lubrication oil supply pipe (2), and the cylinder lubricating pumps, it is necessary to bleed the oil pipes (5, Fig. 5) to the lubricating quills (2) as follows:

1) Refer to 4002−2, paragraph 3.2 User guide and paragraph 3.21 Cylinder Lubrication.
2) In the LDU-20, get the MAIN page.
3) In the navigation menu, select Cylinder Lubrication.
4) In the CYL. LUBRICATION page, field Manual lub. to Cyl. #, select the applicable cylinder number.

**Note: If necessary, it is possible to change the number of lubricating pulses (in the range 0 to 200) in the field # of Manual Lub. Pulses. When 100 is entered in the field Manual lub. to Cyl. #, all cylinders are lubricated in sequence.**

5) Do the procedure given in the Maintenance Manual 7218-1.

# 7. Lubricating Quill

Cylinder lubricating oil is injected on to the cylinder liner wall (1, Fig. 5) through the six lubricating quills (2) installed on the circumference of the support ring.

For the function of the lubricating quill, refer to 2138-1.

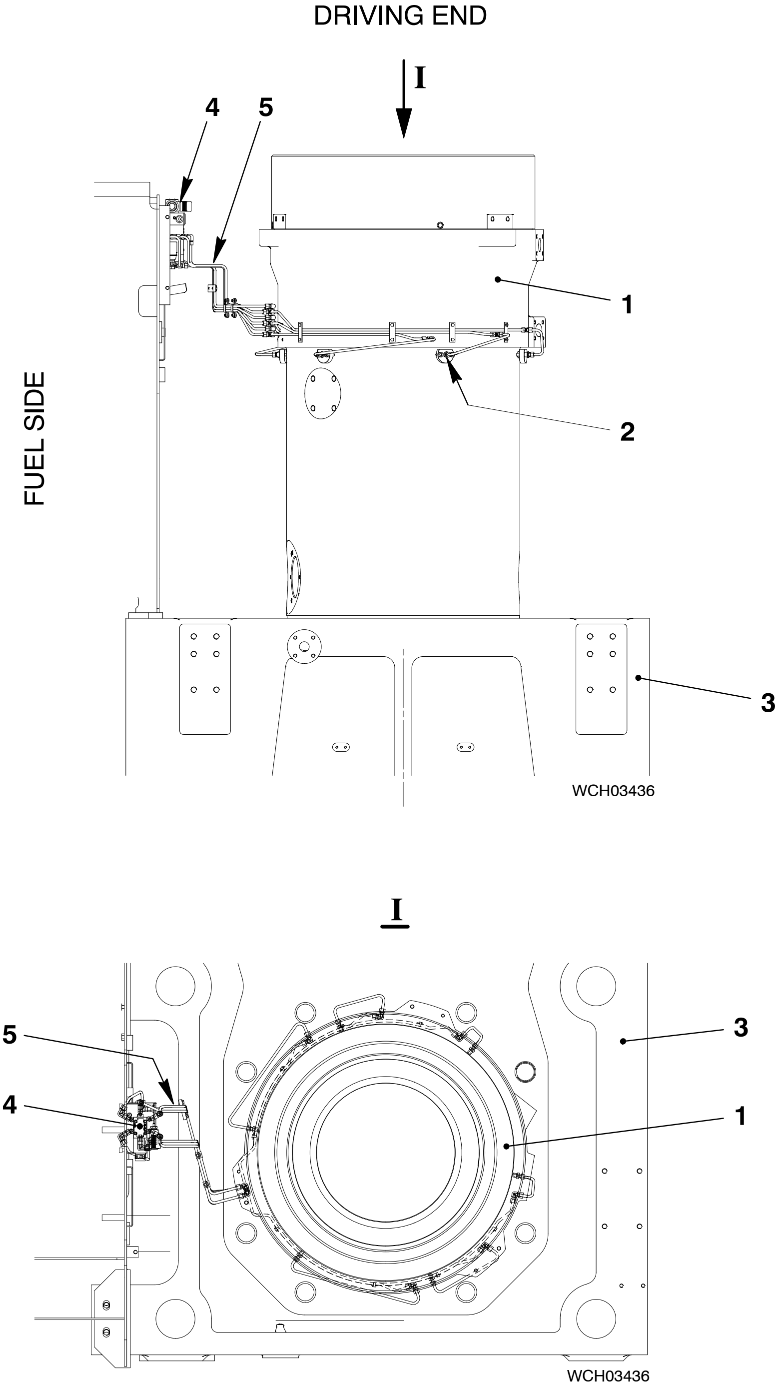


**Fig. 5: Cylinder Lubricating Quills**

1 Cylinder liner
2 Lubricating quill 25-2138_CX_Y
3 Cylinder block
4 Cylinder lubricating pump 25_7230_C#_1
5 Oil pipes

# 8. Cylinder Lubricating System – Control

## 8.1 Control System

The cylinder lubricating system (Fig. 6) is a time-based system, which supplies lubricating oil on to the cylinder liner wall.

For more data about the cylinder lubricating control, refer to 4002–1, paragraph 3.7 Cylinder Lubricating Control.

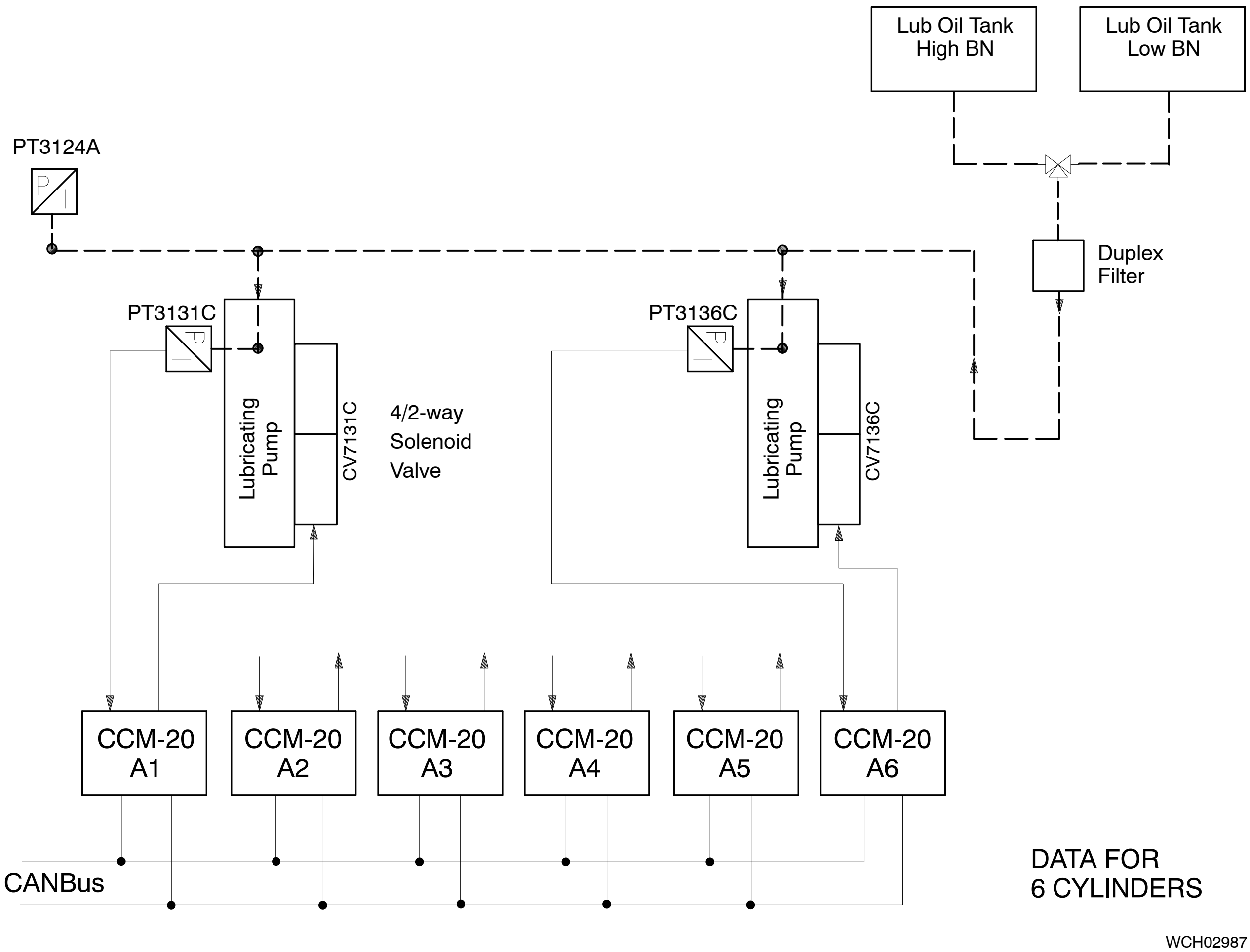


**Fig. 6: Control System**

## 8.2 Radial Oil Supply

The nozzle tip in the lubricating quill has holes in specified positions. The lubricating oil flows out of these holes at high pressure. This gives equal lubrication on to the cylinder liner wall (Fig. 7).

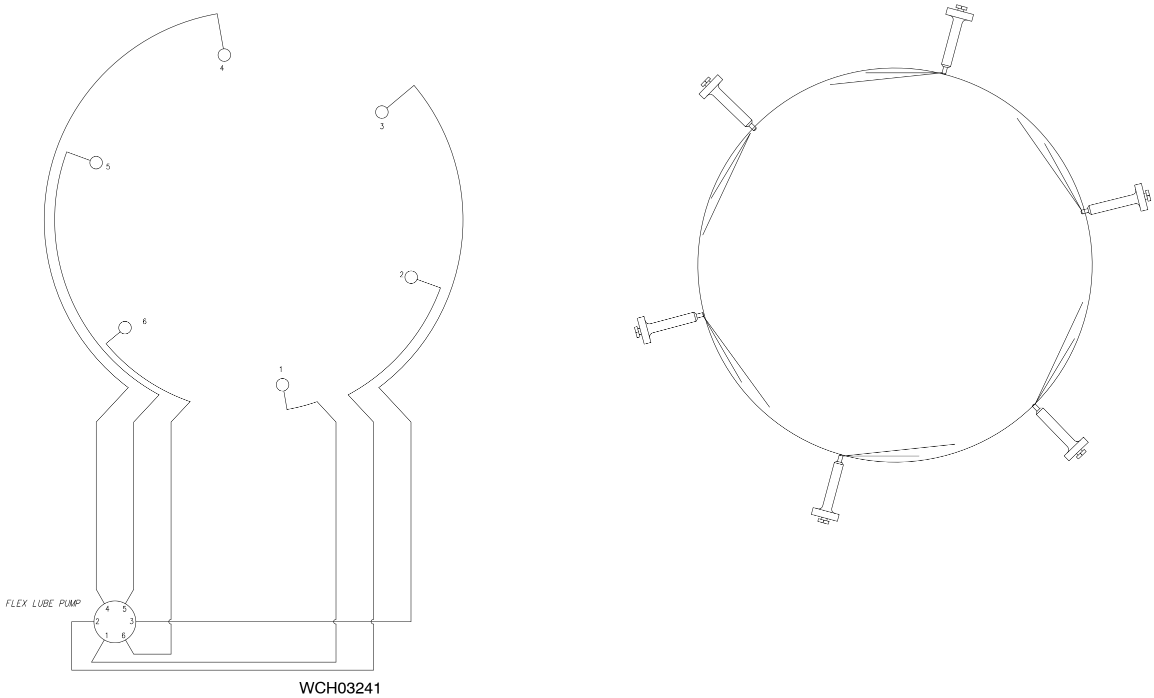


**Fig. 7: Radial Oil Supply**

## 8.3 Vertical Oil Supply

The ECS parameters adjust the timing, which gives the position and percentage of cylinder lubricating oil on the cylinder liner wall and between the piston rings (Fig. 8).

The ECS parameters also adjust the timing (with its percentage supply of the feed rate) during the first commissioning.

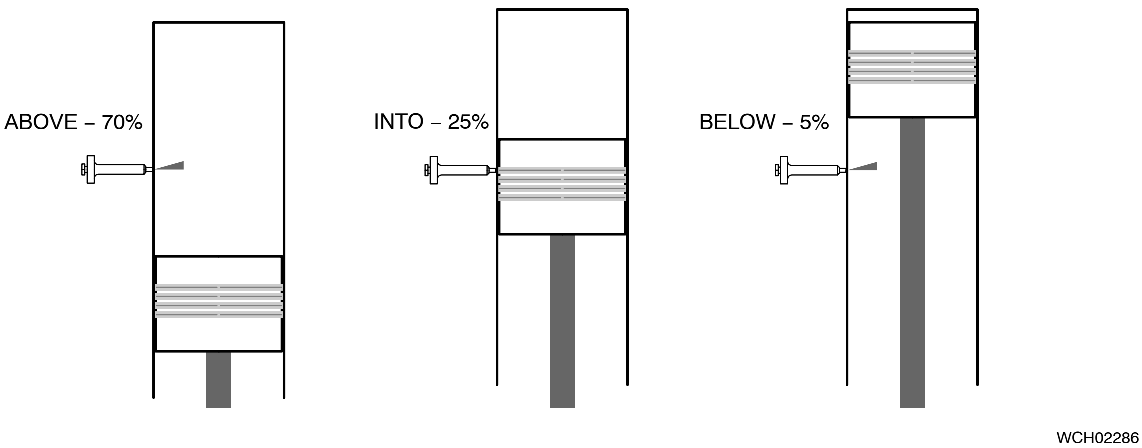


**Fig. 8: Vertical Oil Supply**

## 8.4 Lubricating Oil Feed Rate – Adjustment

It is possible to adjust the lubricating oil feed rate in steps of 0.1 g/kWh. Use the parameters in the columns Feed Rate and Adjustment for one cylinder, or for all cylinders (refer to 4002–1, paragraph 3.21 Cylinder Lubrication).

For more data about the adjustment of the lubricating oil feed rate, refer to 7218–3 Feed Rate – Adjustment.

For data about the adjustment of the lubricating oil feed rate for running-in of new components of the piston running system, refer to 0570–1, paragraph 2 Feed Rate Adjustment.

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# Cylinder Lubrication – LFR and HFR Bushes

## 1. Description

There are two bushes installed on each cylinder lubricating pump (1, Fig. 1).

The low feed rate (LFR) bush (3) is installed on the stroke adjustment screw (2) at the bottom of the cylinder lubricating pump. This bush is for usual operation.

**Note: For usual operation, it is not necessary to change the bushes during operation. The control system always uses the correct value to calculate the appropriate pump capacity. The correct value in the control system is set after the shop test.**

The high feed rate (HFR) bush (4), is installed in the stowage position. This bush is used when it is necessary to change the output of the cylinder lubricating pump (e.g. for running-in or other unusual operations).

**Note: When you install the HFR bush, the output of the cylinder lubricating pump increases by 34%, compared to the output when the LFR bush is installed.**

To change the bushes, refer to the procedure in paragraphs 2.1 and 2.2.

## 2. Change Procedure

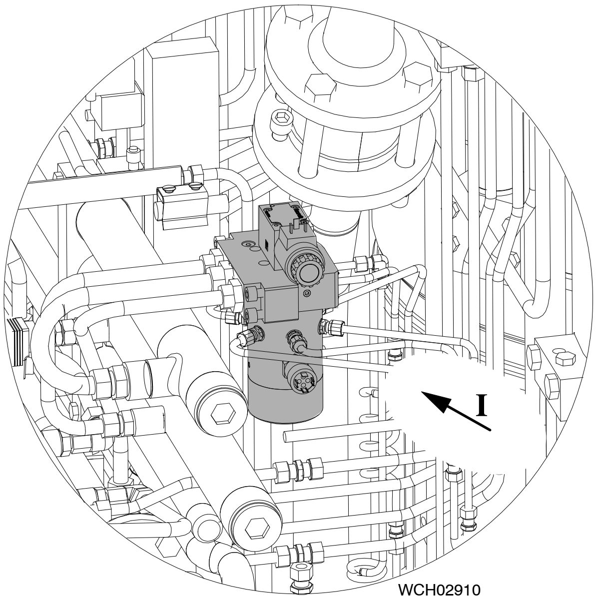
### 2.1 LFR Bush to HFR Bush

1) Carefully loosen the stroke adjustment screw (2), then remove the LFR bush (3).
2) Loosen the screw (5), then remove the HFR bush (4) from the stowage position.
3) Put the HFR bush (4) in position on the screw (2).
4) Torque the stroke adjustment screw (2) to 40 Nm.
5) Put the LFR bush in the stowage position on the screw (5).
6) Tighten the screw (5).

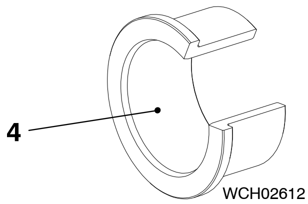
### 2.2 HFR Bush to LFR Bush

1) Carefully loosen the stroke adjustment screw (2), then remove the HFR bush (4).
2) Loosen the screw (5), then remove the LFR bush (3) from the stowage position.
3) Put the LFR bush (3) in position on the stroke adjustment screw (2).
4) Torque the stroke adjustment screw (2) to 40 Nm.
5) Put the HFR bush in the stowage position on the screw (5).
6) Tighten the screw (5).

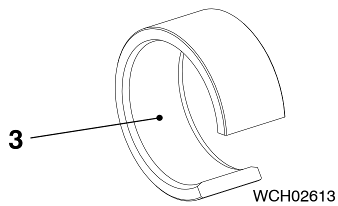
DRIVING END




High Feedrate Bush




Low Feedrate Bush



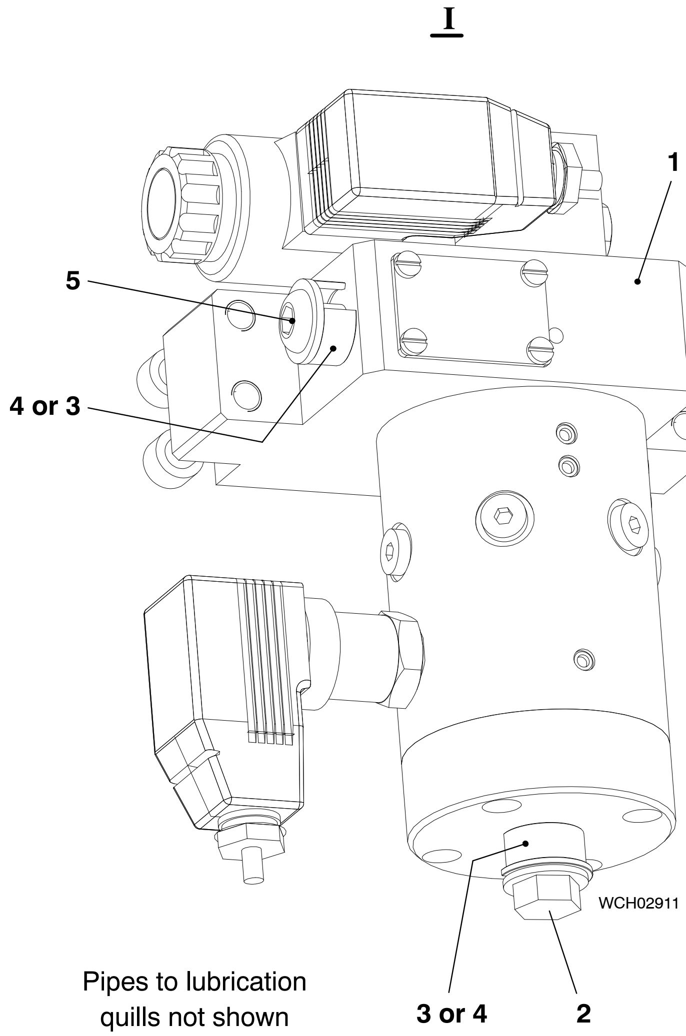




**Fig. 1: Cylinder Lubricating Pump**

1 Cylinder lubricating pump
2 Stroke adjustment screw
3 Low feed rate bush
4 High feed rate bush
5 Screw

# Feed Rate – Adjustment



## 1. General

To set the applicable cylinder lubricating oil feed rate, it is very important to monitor the piston running performance of the engine. The procedures that follow are necessary:

- Use an on-board monitoring programme to monitor the piston underside (PU) drain oil. Make an analysis of the Fe content, Cr content and the residual base number (BN) from the PU drain oil. For more data, refer to 0320–1, Lubricating Oils, paragraph 3.2.
- At regular intervals, visually examine the PU.
- Make an analysis of the fuel quality. If possible, send a sample of the fuel to a laboratory to make an analysis of the sulfur content. Do the analysis before you use the fuel for the first time. For more data, refer to 0300–1 Diesel Engine Fuels.

**Note: Engines with the same design can have different piston running performances (because of different operation modes, the properties of the used cylinder lubricating oil, or engine tuning). The most important problem is cold corrosion, which causes the piston running components to become quickly worn.**

To find an applicable cylinder lubricating oil, refer to the data given in 0320–1 Lubricating Oils, paragraph 3 and paragraph 8.2.

For data about corrosion, refer to 0320–1 Lubricating Oils, paragraph paragraph 3.3.

# 2. Feed Rate Adjustment

**CAUTION**

**Equipment Hazard: The results of the bunker analysis and the values given in the Bunker Delivery Note (BDN) can be different. Always use the higher sulfur content value to adjust the feed rate. This makes sure that the engine operates safely.**

To prevent damage to the engine, it is necessary to set the feed rate in relation to the fuel used and cylinder lubricating oil.

To set the applicable feed rate, it is necessary to make an analysis of the PU drain oil. Set the feed rate related to the analysis of the residual base number (BN) and the iron content of the PU drain oil. For more data and the procedure to get a sample of PU drain oil, refer to 0320–1 Lubricating Oils, paragraph 3.2.

To adjust the feed rate of the cylinder lubricating oil, use the data that follows:

- The feed rate (g/kWh)
- Residual base number (BN) and iron content of the PU drain oil
- The sulfur content (% m/m) of the used heavy fuel oil (HFO)
- The BN (mg KOH/g) of the used cylinder lubricating oil.

## 2.1 Empirical Data Collection

To adjust the feed rate to an applicable value, it is necessary to collect empirical data for each engine.

Start to collect the empirical data after the first running-in period of the engine. For the procedure, Wärtsilä Services Switzerland Ltd recommends to use lubricating oil with the highest available BN in relation to the fuel used. Use a baseline feed rate of 0.9 g/kWh. For more data, refer to 0320–1 Lubricating Oils.

Collect the data of the PU drain oil samples at different engine loads. For the procedure to get a sample of PU drain oil, refer to 0320–1 Lubricating Oils, paragraph 3.2. Make sure that you always operate the engine in the safe operation area (see Fig. 1, Fig. 2 and Fig. 3). If necessary, adjust the feed rate and/or the lubricating oil base number. For specified recommendations related to the selected feed rate, refer to the Wärtsilä PU Drain Oil Analysis Tool.

Fig. 1 shows the relation between the residual BN and the total iron content of the PU drain oil. This data is only applicable when fuel with a sulphur content between 0.5% m/m and 3.5% m/m and cylinder lubricating oil with a BN between 40 and 100 is used. For data about cylinder lubricating oils with a base number less than 40, refer to 0320–1 Lubricating Oils.

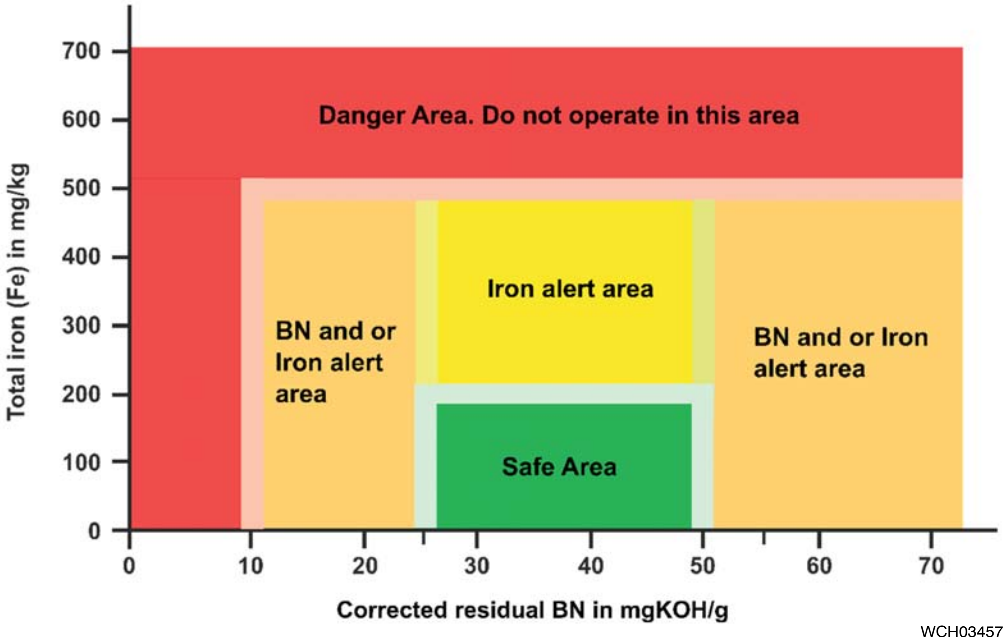



**Fig. 1: PU Drain Oil – Relation between Residual BN and Total Iron**

The empirical data can be used for operation with the same cylinder lubricating oil and fuel with the same sulphur content (± 0.125 % m/m). When you use your empirical data, Wärtsilä Services Switzerland Ltd recommends that you get a PU oil sample. This makes sure that the feed rate used is applicable. For more data, refer to Service Bulletin RT-161 Issue 4 Cylinder Lubrication.

**CAUTION**

**Equipment Hazard: The Wärtsilä PU Drain Oil Analysis Tool and its recommendations are only applicable for cylinder lubricating oils with a base number more than or equal to 40 (BN ≥ 40).**

You can use the Wärtsilä PU Drain Oil Analysis Tool to collect your data. You can see examples of its analysis in Fig. 2 and Fig. 3.

The tool is available at http://www.wartsila.com/products/marine-oil-gas/engines-generating-sets/low-speed-rt-flex-engines

For more data, speak to or send a message to Wärtsilä Services Switzerland Ltd.

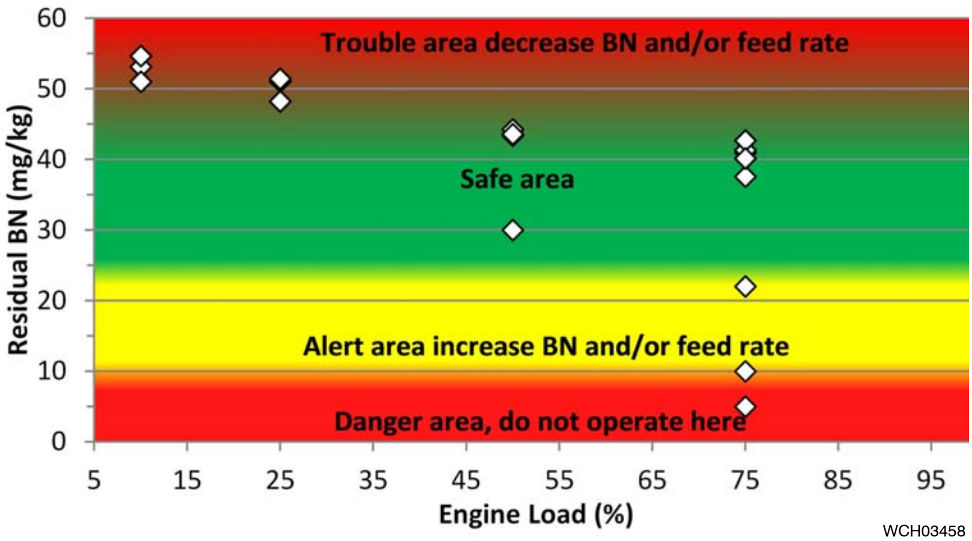



**Fig. 2: PU Drain Oil Analysis Tool – Residual BN in Relation to the Engine Load**

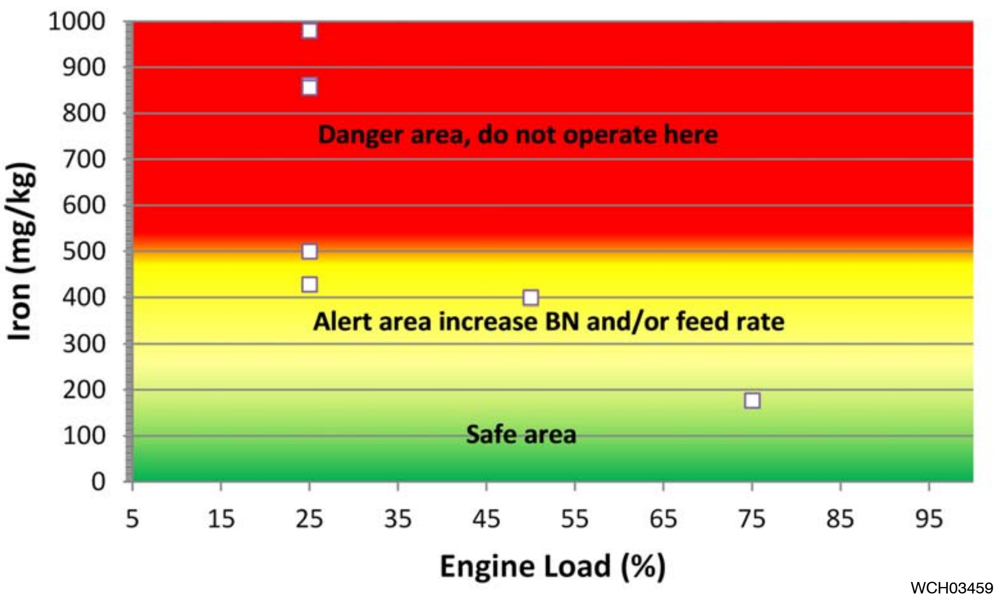



**Fig. 3: PU Drain Oil Analysis Tool – Iron Content in Relation to the Engine Load**

**Note: If the engine operates with fuel that has a sulphur content less than 0.1% m/m (and a cylinder lubricating oil with a base number (BN) between 15 and 25) the minimum value of the residual BN value is 10 mg/kg. For more data, refer to 0320–1 Lubricating Oils.**

### 2.2 How to Set the Best Applicable Feed Rate

Use the empirical data (paragraph 2.1) from the PU drain oil samples to adjust the feed rate to get the best applicable feed rate.

**Note: You must make sure that the feed rate is not less than the minimum permitted value of 0.6 g/kWh.**

If the residual BN is in the safe area (Fig. 2), adjust the feed rate in steps of 0.05 g/kWh to get the iron content value to approximately 200 mg/kg. You must get PU drain oil samples regularly to make sure that the feed rate used is applicable.

Wärtsilä Services Switzerland Ltd recommends that you do a check of the coating thickness of the piston rings each 1500 to 2000 running hours.

For more data, refer to Service Bulletin RT-161 Issue 4 Cylinder Lubrication.

## 3. Running-in New Cylinder Liners and Piston Rings

For data about the running-in procedure for new cylinder liners and piston rings, refer to 0570–1 Running-in New Cylinder Liners and Piston Rings.

# 4. Blending on Board

You can use the Wärtsilä Blending on Board (BoB) system to adjust the BN of the cylinder lubricating oil.

The system oil is used as a base oil and the correct additive package is added to make an applicable cylinder lubricating oil. The BoB system gives the best results related to the applicable neutralization and detergency properties of the cylinder lubricating oil.

You can make different BN lubricating oils on board. With an applicable cylinder lubricating oil it is not necessary to adjust the feed rate to different operation modes (i.e. the base feed rate is not changed, but the cylinder oil BN is adjusted).

Use the BoB system together with an on-board monitoring system for the PU drain oil (e.g. SEA-Mate© B2000 blender combined with the SEA-Mate© M2000 XRF analyzer) to make a lubricating oil that has the correct BN. The correct BN improves the corrosion protection, and the properties to clean the lubricating oil.

The BoB system is applicable for vessels that operate on a wide range of different fuels (related to the fuel sulfur content) and operation modes.

As a general recommendation, refer to the data given in Table 1, but, adjust the values as a function of the engine performance for each engine. For more data, speak to, or send a message to Wärtsilä Services Switzerland Ltd.

**Table 1: BN Values Related to Sulfur Content for a Base Feed Rate of 0.8 g/kWh**

| Sulfur Content [%] | Usual Operation (above 60% CMCR) | Low Load Operation (below 60% CMCR) | Safeguard Operation |
|---|---|---|---|
| 1.0 | 40 | 40 | 40 |
| 1.1 | 40 | 40 | 40 |
| 1.2 | 40 | 40 | 40 |
| 1.3 | 40 | 40 | 40 |
| 1.4 | 40 | 40 | 40 |
| 1.5 | 40 | 40 | 50 |
| 1.6 | 50 | 50 | 50 |
| 1.7 | 50 | 50 | 50 |
| 1.8 | 50 | 50 | 60 |
| 1.9 | 50 | 50 | 60 |
| 2.0 | 50 | 50 | 60 |
| 2.1 | 50 | 50 | 60 |
| 2.2 | 50 | 70 | 60 |
| 2.3 | 50 | 70 | 70 |
| 2.4 | 50 | 70 | 70 |
| 2.5 | 50 | 70 | 70 |
| 2.6 | 50 | 70 | 70 |
| 2.7 | 50 | 70 | 80 |
| 2.8 | 50 | 70 | 80 |
| 2.9 | 51 | 72 | 80 |
| 3.0 | 53 | 75 | 90 |
| 3.1 | 55 | 77 | 90 |
| 3.2 | 57 | 80 | 90 |
| 3.3 | 59 | 82 | 100 |
| 3.4 | 61 | 85 | 100 |
| 3.5 | 63 | 87 | 100 |

# Integrated Electric Balancer



## 1. Description

An optional integrated electric balancer (ELBA) can be installed on the engine. The ELBA decreases the free $2^{nd}$ order moments in 4-cylinder to 6-cylinder engines.

**Note: An integrated ELBA can be installed at the driving end and the free end.**

Two shafts (6, Fig. 1) that have gear wheels (1, 2) and balance weights (3, 4) are installed at the driving end of the column.

An electric motor (5) is installed on the column at the free end and the driving end. These electric motors operate two shafts and the balancer gear. For more data, refer to paragraph 2.

A frequency converter electronically controls the electric motor (5). This frequency converter, the control system and the safety devices are installed in an electrical cabinet in the control room. These items can also be installed in the engine room. For more data about the control system, refer to paragraph 2.2.

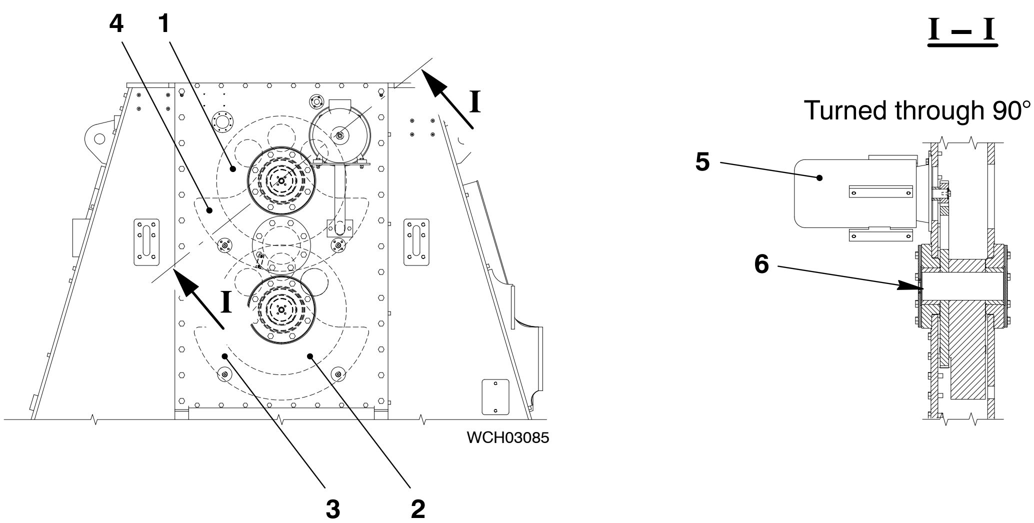



**Fig. 1: Location of ELBA**

1 Gear wheel
2 Gear wheel
3 Balance weight
4 Balance weight
5 Electric motor
6 Shaft

# 2. Operation

## 2.1 Integrated Electrical Balancer

The two shafts (6 and 7, Fig 2) are installed in the housing (5). These shafts turn in opposite directions at two times the engine speed. When the gear wheels (1, 4) turn, the two balance weights (2, 3) cancel each effect of the horizontal centrifugal forces. A vertical force moves up and down two times for each revolution of the engine.

Each of the two shafts transmit the balance forces through the bearings (8, 9).

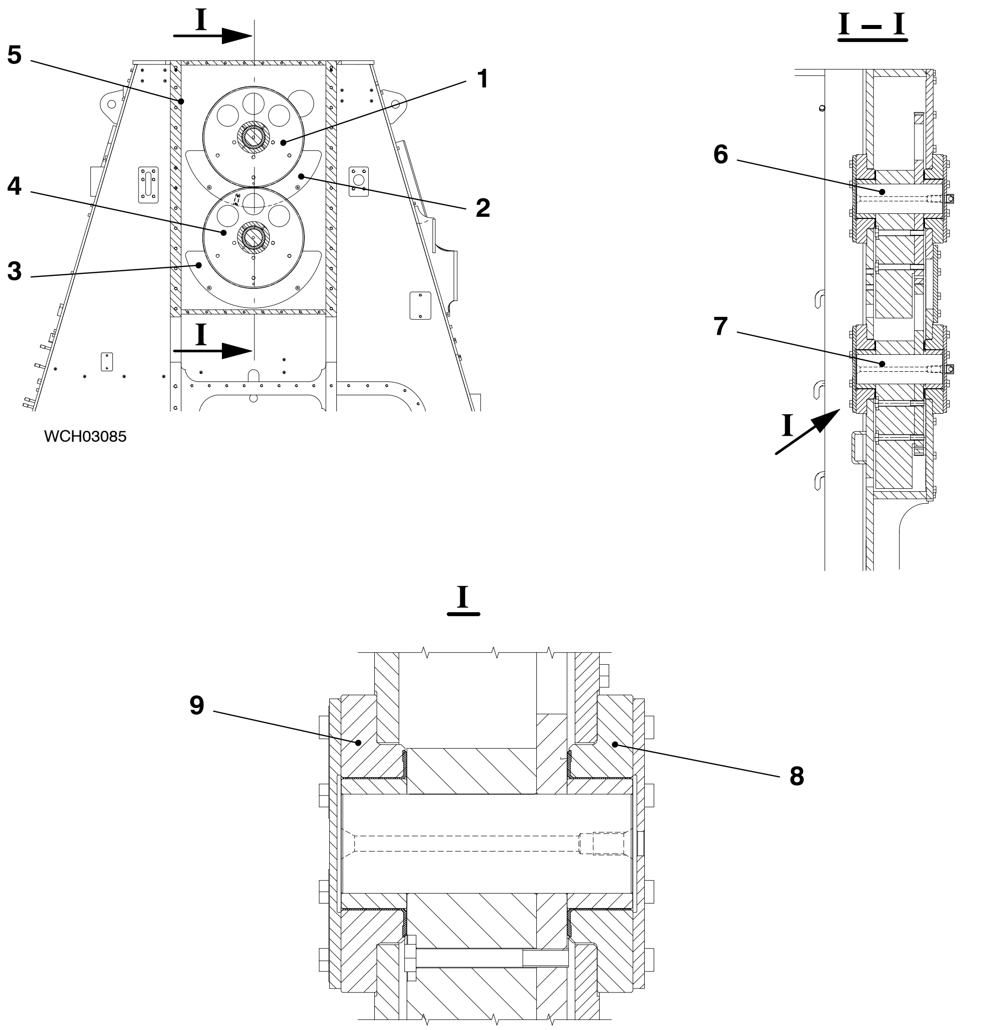



**Fig. 2: Electrical Balancer and Shafts**

1 Gear wheel
2 Balance weight
3 Balance weight
4 Gear wheel
5 Housing
6 Shaft
7 Shaft
8 Bearing
9 Bearing

## 2.2 Control System

The control system has the functions that follow:

- At the driving end, the proximity sensor ZS5401C senses the tooth movement of the balance weight. The signals are then transmitted through the terminal box 38.1 (2, Fig. 3) to the control unit.
- At the free end, the proximity sensor ZS5405C senses the tooth movement of the balance weight. The signals are then transmitted through the terminal box 38.1 (2) to the control unit.
- The proximity sensors (ZS5141C and ZS5142C) transmit the speed of the flywheel (1) and the TDC position along the cables (3) to the terminal box 38.1 (2) at the driving end. These signals then go to the control unit. Attached to the electric motor is a resolver, which sends the motor speed to the control system.

Control of the ELBA is automatic. The ELBA activates when the engine speed is more than 60 rpm. When the engine speed decreases to less than 50 rpm, the ELBA de-activates.

A manual operation mode can also be selected. On the door of the electrical cabinet, a mode switch has the label Heavy Sea Mode. When selected, the ELBA operates at different higher engine speeds. Also, the engine RPM is not in the given limits.

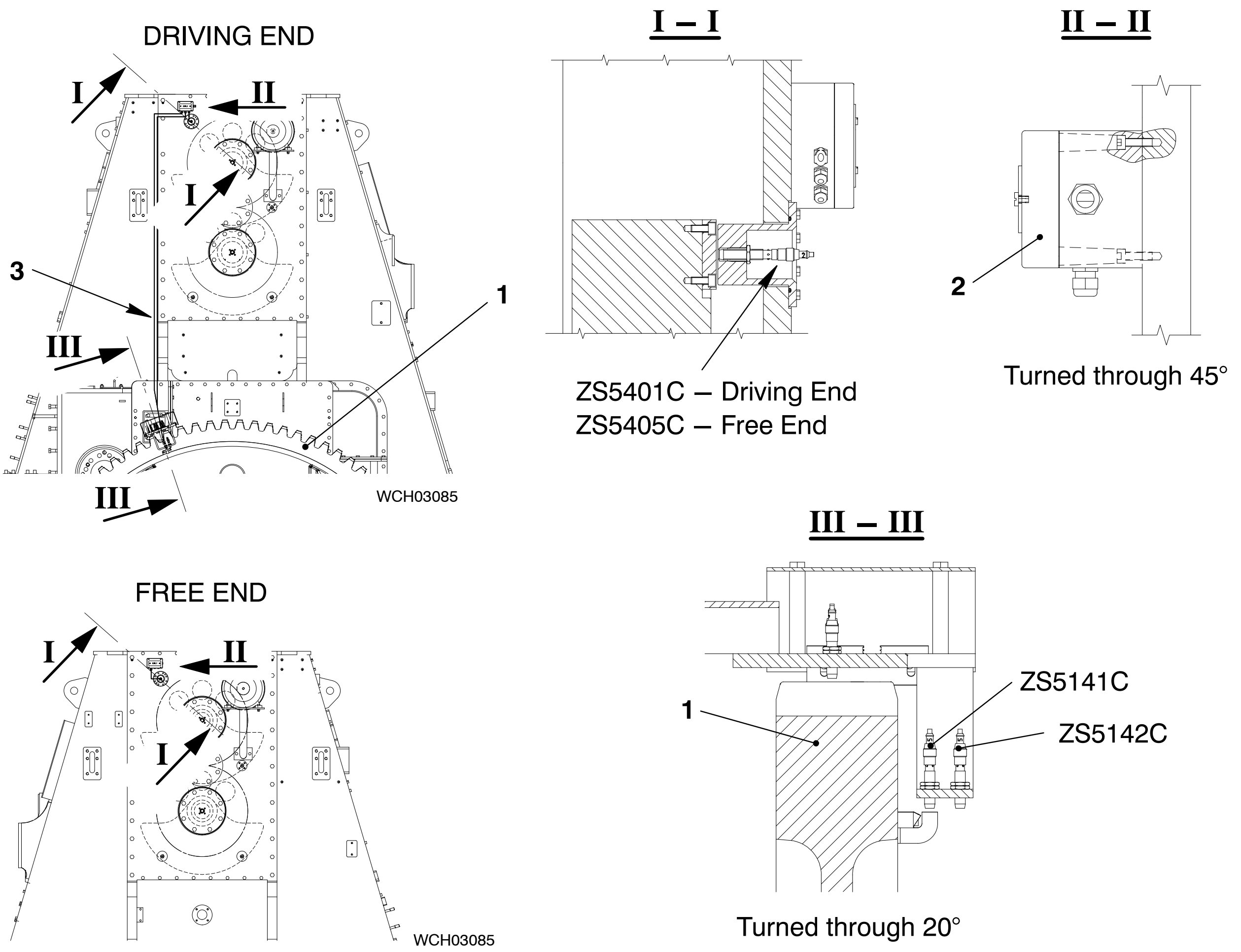



**Fig. 3: Control System**

1 Flywheel
2 Terminal box 38.1
3 Cable

## 2.3 Lubrication

The lubrication system of the ELBA is connected to the low-pressure oil system of the engine. In the housing (1, Fig. 4) lubricating oil (3) flows through the pipes (2) to the shafts to lubricate the gear wheels. Oil that is not used flows through the oil return to the crankcase.

**Note: Damage to the gear wheels can occur if the oil supply to the ELBA system stops.**

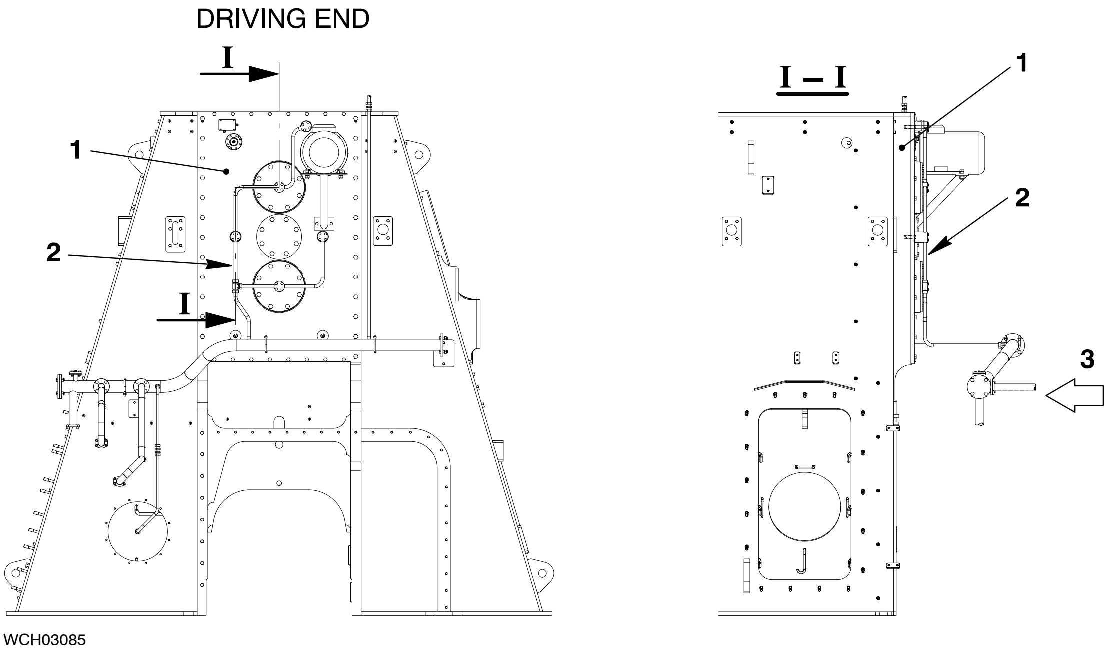



**Fig. 4: ELBA Lubrication System**

1 Housing
2 Pipe
3 Oil inlet

## 2.4 ELBA Failure

If the ELBA becomes defective, the engine can continue to operate, but there could be an increase of 2$^{nd}$ order vibration at some engine speeds. Table 1 shows the error modes and descriptions.

### 2.4.1 Procedure

If there is damage to, or problems with the electric motor, control system or gear wheels do the procedure that follows:

**Note: Do not set to OFF the main switch in the terminal box.**

1) In the terminal box in the control room, set to OFF the monitor switch.
2) Refer to the documentation of the manufacturer and send a report to Wärtsilä Services, Switzerland.

Refer to the Maintenance Manual 7722−1 for the procedures that follow:

- Removal and Installation of the bearings
- Checks
- Permitted limits of clearances.

**Table 2: Error Modes and Descriptions**

| | Error Mode | Error Description |
|---|---|---|
| 1 | DC-bus under-voltage | No voltage available for the drive in X100 (power input). |
| 2 | Engine maximum speed exceeded | Diesel engine speed is more than permitted. |
| 3 | Balancer maximum speed exceeded | Electric motor speed is more than permitted. |
| 4 | Balancer BDC missing | Balancer BDC not found. Sensor is defective, or has become disconnected. Replace the defective sensor, refer to the Maintenance Manual 7762–1. |
| 5 | Engine BDC missing | Engine BDC not found. Sensor is defective, or has become disconnected. Replace the defective sensor, refer to the Maintenance Manual 7762–1. |
| 6 | Engine TDC missing | Engine TDC not found. Sensor is defective, or has become disconnected. Replace the defective sensor, refer to the Maintenance Manual 7762–1. |
| 7 | Servo drive over-temperature | Servo drive internal temperature too high |
| 8 | Emotor over-temperature | Electric motor internal temperature too high |
| 9 | Brake resistor over-temperature | Brake resistor internal temperature too high |
| 10 | Communication broken | CAN communication between cabinets broken |
| 11 | No synchronisation with engine | The synchronisation with the engine is not done in the specified time |
| 12 | No synchronisation between the balancers | The synchronisation between the balancers is not done in the specified time |
| 13 | Starting exceeding maximum times | The running state takes too long |

You can read the errors (3, Fig. 5) from the small display (2) in the control cabinet. The red drive error indicator (1) flashes when there is an error.


**Fig. 5: Lenze Drive – Error Messages**

1 Drive error indicator
2 Display
3

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# Piping Systems Group 8

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# Gas Fuel System



## 1. General

The gas fuel system (see Fig. 1) has an internal gas system, gas valve unit (GVU) and an external gas supply system.

The gas system is continuously monitored. If there is a gas leak, gas detectors (GD) installed in the gas supply pipes will activate an alarm.

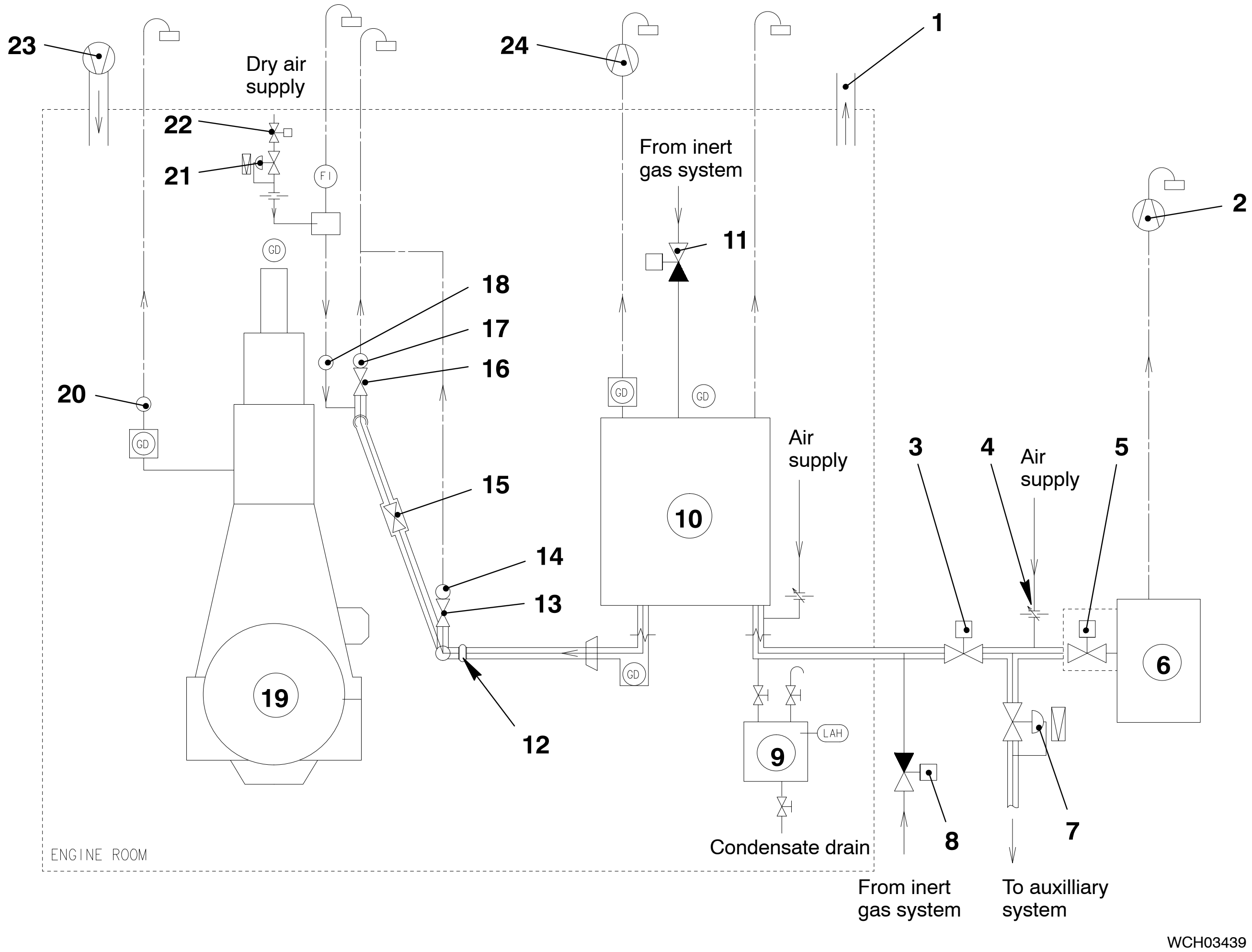


**Fig. 1: Gas Fuel System and Gas Valve Unit**

| | | | |
|---|---|---|---|
| 1 | Vent from engine room | 13 | Vent valve (gas inlet side) |
| 2 | Extractor fan | 14 | Gas system vent (inert gas outlet) |
| 3 | Shut-off valve | 15 | Shut-off valve |
| 4 | Adjustable throttle | 16 | Vent valve |
| 5 | Master gas fuel valve (shut-off valve) | 17 | Gas system vent (outlet) |
| 6 | Tank room (storage/treatment system) | 18 | Air inlet (to double wall pipe system) |
| 7 | Pressure regulating valve | 19 | Main engine |
| 8 | Purge valve | 20 | Piston underside gas detection (outlet) |
| 9 | Condensate drain valve | 21 | Pressure regulating valve |
| 10 | Gas valve unit (GVU−ED™) | 22 | Shut-off valve |
| 11 | Purge valve | 23 | Fresh air to engine room |
| 12 | Gas inlet engine | 24 | Outlet from engine room |

# 2. Internal Gas Fuel System

The primary components of the internal gas fuel system on the engine are as follows:

- Gas admission valves
- Gas supply pipes
- Shut-off valves
- Vent valves.

## 2.1 Gas Admission Valve

**Note: In Fig. 2, the GVU is not installed in the engine room.**

The gas admission valve (2) is electro-hydraulically operated. A spring closes the gas admission valve when there is no servo oil pressure available. A stroke sensor is installed, which gives feedback from the gas admission valve to the engine control system (ECS) (refer to 4002−1 Engine Control System, paragraph 3.16 Gas Admission Valve Control). For more data about the gas admission valve, refer to 2140−1/A1.

## 2.2 Gas Supply Pipes (Engine Side)

**WARNING**

**Injury Hazard and Damage Hazard: Before you do maintenance on the gas supply pipes, you must put inert gas into the system to remove the gas fuel. This will prevent injury to personnel and damage to equipment.**

The gas supply pipes (1) on the engine have double walls. There is a shut-off valve for each supply pipe on the engine system (for more data, refer to 4003−3 Control and Auxiliary Systems − Gas System Engine).

The gas fuel flows through the gas supply pipes. These pipes are installed along the engine. Flexible pipes are attached between the gas supply pipes (1) and the gas admission valves (2) on each cylinder. For more data refer to 2140−1.

When the engine does not operate with gas fuel, the pressure is released from the gas supply pipes. For more data refer to 0275−1.

## 2.3 Shut-off Valves and Vent Valves

The shut-off valves (CV7291C) on the fuel side and (CV7292C) on the exhaust side are installed in the primary gas supply pipes (see Fig. 2). During operation, these control valves let gas fuel flow to the gas admission valves. If there is a gas leak, the shut-off valves close to isolate the gas pipes on the engine from the gas supply pipe. This makes sure that no more gas is supplied to the engine.

The vent valves on the engine (CV7286C on the fuel side and CV7287C on the exhaust side) can quickly release the gas pressure from the gas supply pipes (1). This makes sure that when operation with gas fuel has stopped, there is no gas pressure in the gas fuel system. To release the pressure in the gas supply pipe from the GVU, the gas supply valve in the GVU is closed and the vent valves are opened.

The air inlet (3) supplies air to the annular spaces in the double wall pipes. The air flows through the annular spaces to the GVU where a fan removes the air to the outside of the engine room (see Fig. 1).

There is a fresh air supply from outside that flows into the engine room.

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## Gas Fuel System

For data about the
pilot fuel system, see 8790−1

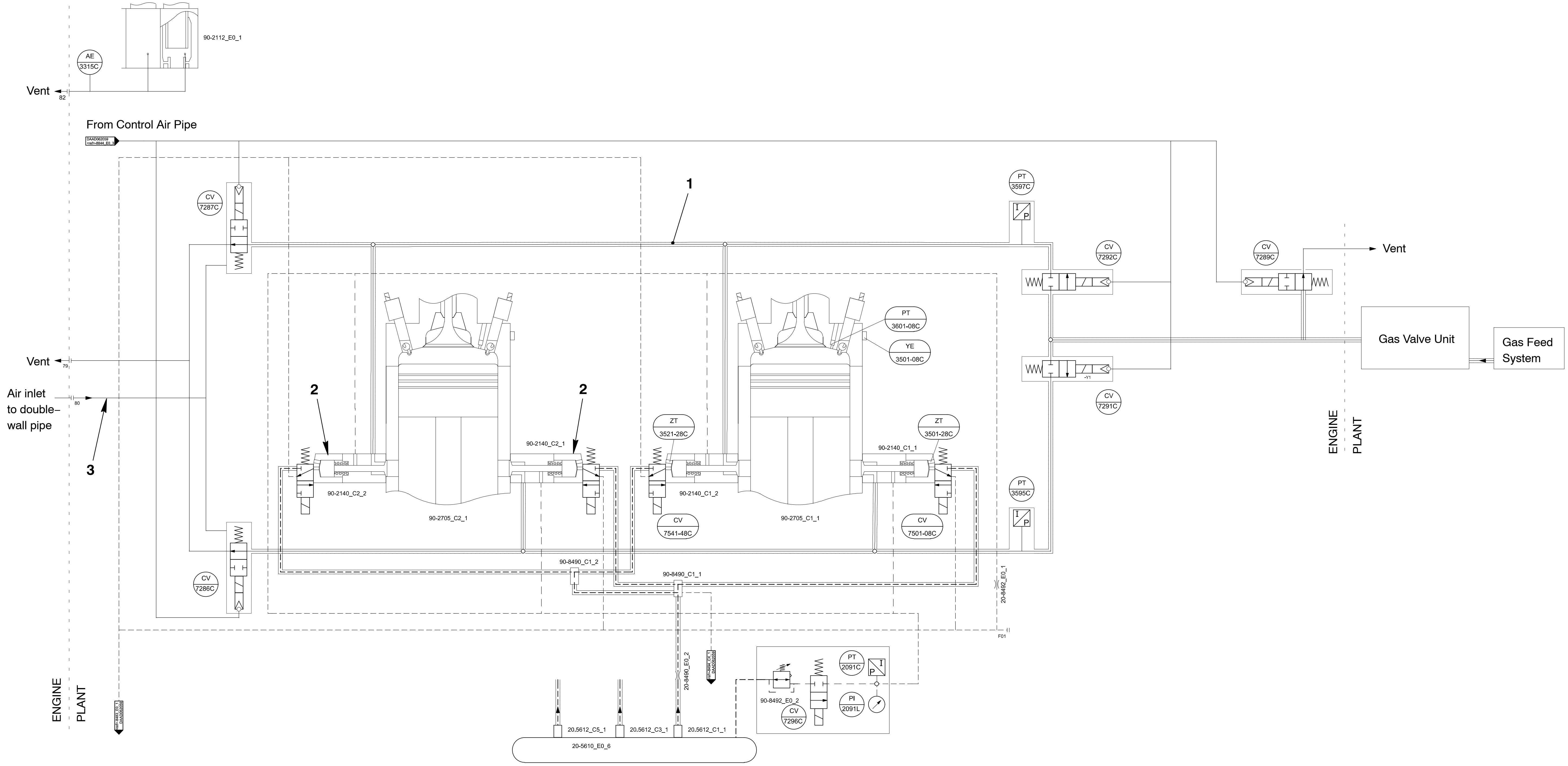


**Fig. 2: Schematic Diagram − Gas Fuel System**

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# 3. Gas Valve Unit and External Gas Supply System

The external gas supply system upstream of the gas valve unit (GVU) has the gas supply pipes and the pressurized gas supply.

**Note: The gas valve units can look different.**

## 3.1 Gas Supply Pipes

The supply pipes between the gas storage area and the engine room are in a closed area. The supply pipes have double walls, or are installed in a closed ventilated duct. This duct has a gas detector to find gas and gas flow.

## 3.2 Shut-off Valve

The propulsion control system (PCS) controls this shut-off valve (refer to 4002−1 Engine Control System, paragraph 4 External Control System). During usual operation, the shut-off valve for the GVU is used to shut-off the gas supply to the engine room. The shut-off valve can be closed from the engine room, engine control room and bridge. In some conditions, the shut-off valve is automatically closed.

## 3.3 Gas Valve Unit

It is necessary for dual fuel engines to have accurate control of gas pressure and changes in load conditions.

The primary functions of the GVU are as follows:

- Gas pressure control:
  - a) The gas pressure is controlled and related to the engine load.
  - b) The signal for the applicable gas pressure comes from the ECS.
- Leak test sequence:
  - a) The sequence is done before the engine changes to gas mode.
  - b) The sequence makes sure that the valves of the GVU operate correctly and that there is no internal leakage.
- Inert gas:
  - a) The GVU has a function that uses inert gas and pressure release sequences automatically.
  - b) The sequence is safe during usual operation and if there is interference to the system.

There are two versions of the GVU as follows:

- GVU−ED™ (Enclosed Design) see paragraph 3.3.1
- GVU−OD™ (Open Design) see paragraph 3.3.2.

### 3.3.1 GVU−ED

GVU−ED™ (Enclosed Design). This design (see Fig. 3) has pipes with double walls installed in a gas-tight area. This gas-tight area has continuous sufficient airflow. This design can be installed safely in in engine rooms, i.e. there is no hazard from the release of gas. The design is in proportion to the bore dimensions of the engine and the cylinder configuration.

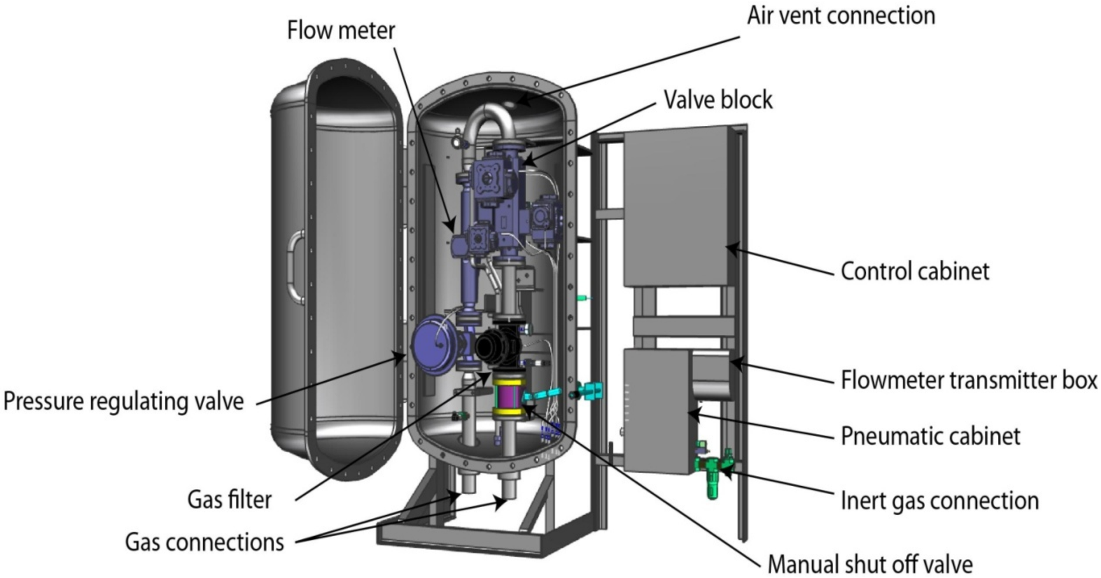



**Fig. 3: GVU−ED™ Enclosed Design**

The air vent connects to an extractor fan to move air from the gas-tight area. The dimensions of the extractor fan are sufficient to replace the volume of air in the gas-tight area and double wall pipes. The extractor fan keeps a constant negative pressure in the gas-tight area and this negative pressure is monitored.

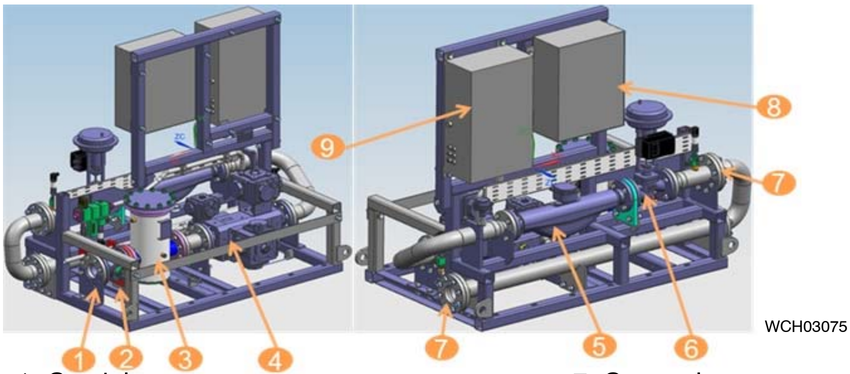
If the extractor fan becomes defective, the engine automatically changes to diesel mode. The pressure in the gas pipe between the GVU and the engine is released. If there is an over-pressure, inert gas replaces the gas in the gas pipe. The outlet of the air vent connects to an external area that has good airflow away from the engine room.

To make sure that the airflow is sufficient, the ventilation system of the GVU−ED™ must operate independently from all other ventilation systems.

Gas detectors constantly monitor the double wall pipes and the GVU for concentrations of gas. If gas is found, the safety system activates a mode change to diesel operation. The gas pressure is released and inert gas flows into the pipes.

### 3.3.2 GVU–OD

GVU–OD™ (Open Design). The open design (see Fig. 4) does not have a closed area or pipes with double walls. This design is installed externally in an isolated room with sufficient airflow (e.g. a gas valve room). The design is in proportion to the bore dimensions of the engine and the cylinder configuration.




1. Gas inlet
2. Manual valve
3. Gas Filter
4. Valve block
5. Flow meter
6. Pressure control valve
7. Gas outlet
8.Junction box
9. Solenoid valve cabinet

**Fig. 4: GVU–OD™ Open Design**

The isolated room (GVU room in Fig. 5) is gas-tight and has the standards that follow:

- All electrical equipment obey the standards in the ATEX directives (Atmospheres EXplosibles).
- An ATEX approved airlock, of sufficient dimensions for one person, is installed at the entrance to the GVU room.
- Large ATEX approved fans (that have redundancy) are installed. These fans keep sufficient negative pressure in the GVU room. The air in the GVU room and pipes is replaced 30 times each hour.
- The gas pipes between the GVU room and the engine have double walls.
- The maximum GVU room capacity for pressurized gas (e.g. if a gas pipe becomes broken) must be calculated.
- The maximum GVU room pressure resistance (e.g. if a gas pipe becomes broken) must be calculated.
- To make sure that the airflow is sufficient, the ventilation system of the GVU–OD™ must operate independently from all other ventilation systems.

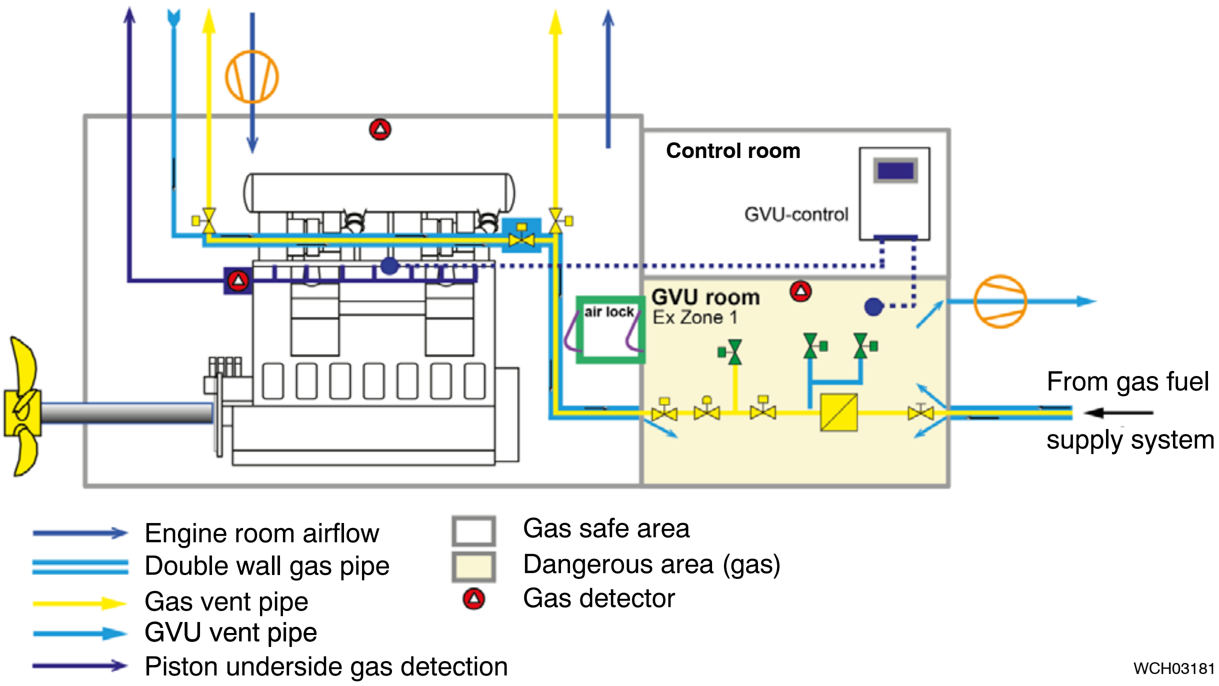



**Fig. 5: GVU–OD™ Installation – Schematic Diagram**

### 3.3.3 GVU Control Panel

The control system (built-in for GVU–ED™ and remote for GVU–OD™) controls all functions of the GVU. The control system sends signals to solenoids that control pneumatically activated valves.

A human machine interface (HMI) panel (see Fig 6) is installed on the GVU control panel. The parameters that follow can be monitored:

- The status of the GVU
- The valve positions and data from the sensors
- Possible alarms.

**Note: The GVU control panel, which does not obey the ATEX standards, is installed in a different room (e.g the control room).**


WCH03181

**Fig. 6: GVU Control Panel**

## 3.4 Gas Fuel Pipes – Purge

Inert gas (e.g. nitrogen) is used to remove/replace the gas fuel in the gas pipes. This process makes sure that there is no gas leakage into the engine room and removes possible risks.

If gas fuel is found in the GVU, or the annular space in the double wall pipes, the safety system automatically changes the operation of the engine to diesel mode. Also, a valve ($N_2$ Engine, Fig. 7) opens automatically and lets pressurized inert gas flow into the gas pipes (downstream of the GVU and the engine) and through the open vent valves. This sequence, which is calibrated, replaces the volume in the gas pipes a minimum of three times to remove gas fuel that could stay in the system.

Before maintenance on the engine / GVU, it is necessary to do the gas fuel removal procedure. This will make sure that gas will not flow into the engine room. One more $N_2$ valve is installed upstream of the GVU. This valve is for the removal of gas fuel in the GVU. The operators do this procedure manually. For the pipes on the engine, the procedure is the same as that given above.

For the procedure to remove gas fuel from the gas pipes, refer to 4002–2, paragraph 3.12 and the documentation of the GVU manufacturer.

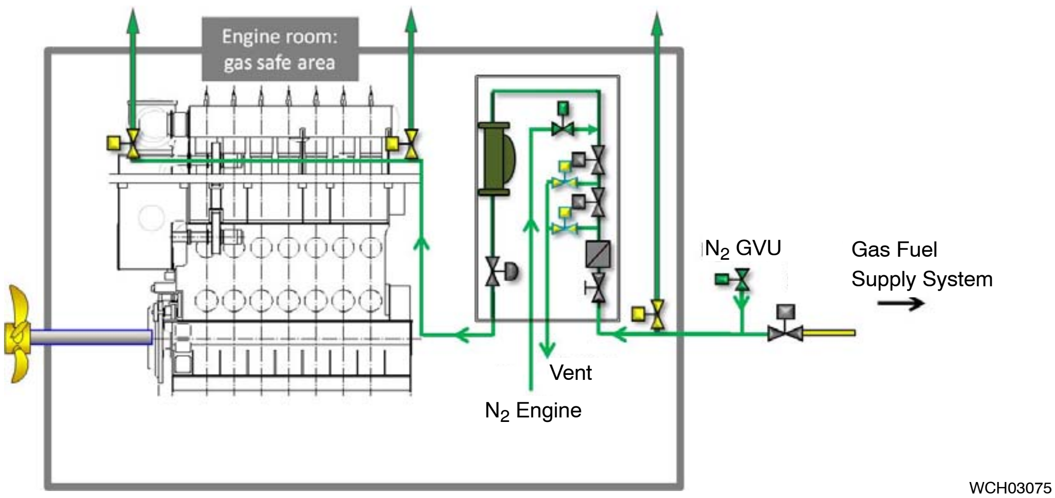



**Fig. 7: Schematic Diagram – Gas Fuel Removal from Gas Pipes**

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# Lubricating Oil / Servo Oil System



## 1. General

The oil pump supplies the necessary pressure to control and lubricate the engine (this does not include cylinder lubrication). For data about the pressure values, refer to Operating Data Sheet 0230–1.

The oil supply to the different lubricating points is shown in the schematic diagrams Fig. 1 and Fig. 2.

The locations of the pumps, filters, heat exchangers, etc is shown on the plant diagram which is supplied separately from the engine documentation.

For data about the cylinder lubrication, refer to 7218–1 Cylinder Lubrication.

## 2. Lubricating Oil System

The oil flows from the oil inlet pipe (29, Fig. 2) on the driving end to the supply pipes (24) and (21), through bores in the bearing girders to lubricate the main bearings (20).

Oil flows through the supply pipe (28), through the toggle levers (27) to lubricate the crosshead pins (26) and bottom end bearings (19). From the crosshead pins (26), the oil flows up the piston rods to keep cool the pistons (for more data about the piston, refer to 3403–1).

The oil also lubricates and keeps cool the axial damper (16) and the vibration damper (17).

Oil from the supply pipe (25) flows to the nozzles (22) in the thrust bearing (23).

Oil flows from the inlet pipe (29) through the oil pipe (4) to the turbochargers. The oil returns through the oil pipe (1) to the oil system (plant).

You use the ball valves (5) and (6) to get dirty oil samples from the piston underside (for more data, refer to 0320–1, paragraph 3.2).

**Note: During operation, the ball valves (5) are open and the ball valves (6) are closed.**

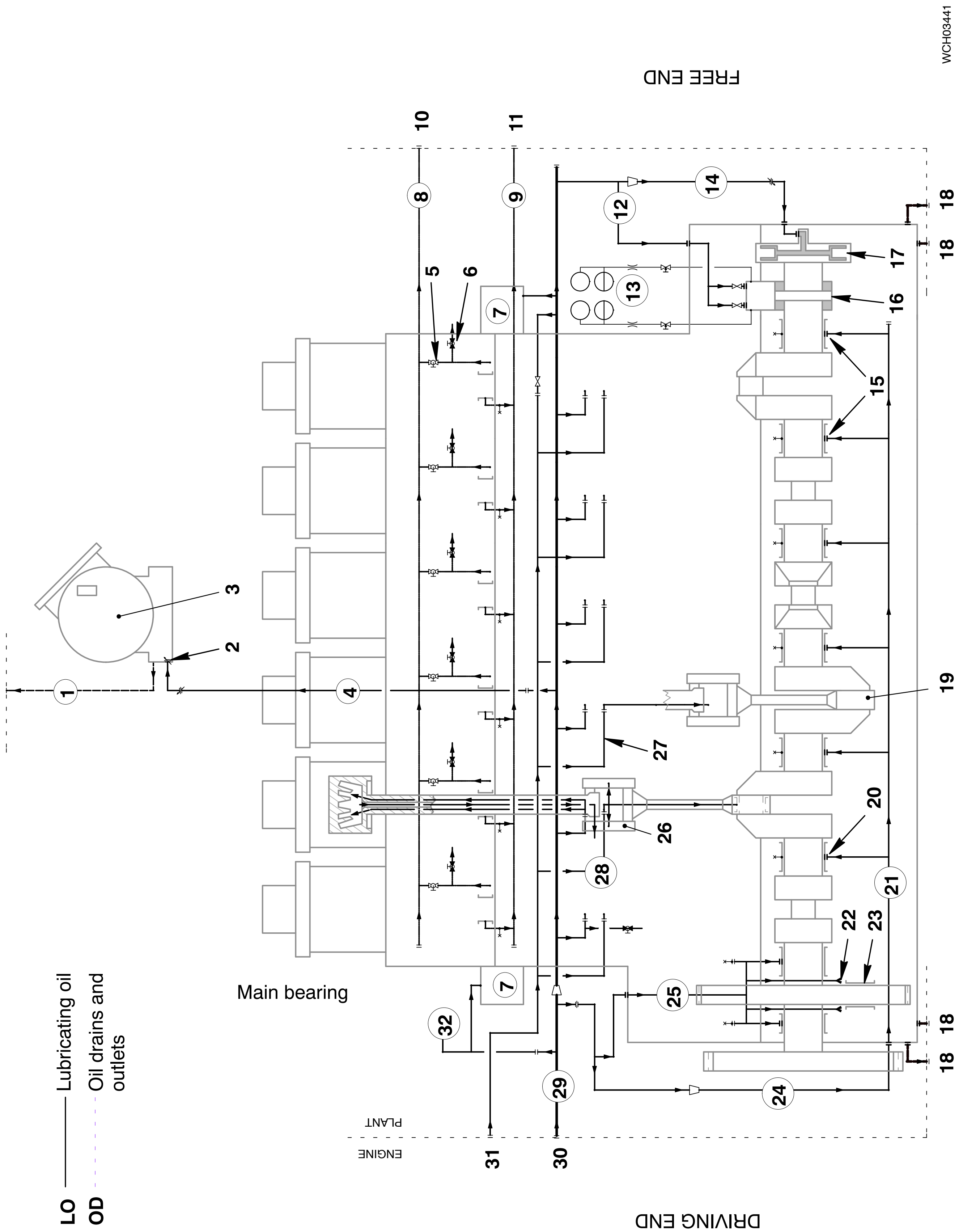


**Fig. 1: Lubricating Oil System**

**Key to Fig. 1**

| | | | |
|---|---|---|---|
| 1 | Oil pipe – TC outlet | 17 | Vibration damper – crankshaft |
| 2 | Adjustable built-in orifice (ABB TC) | 18 | Oil drain |
| 3 | Turbocharger | 19 | Bottom end bearing |
| 4 | Oil pipe – TC inlet | 20 | Main bearing |
| 5 | Ball valve (piston underside) | 21 | Oil pipe (main bearing) |
| 6 | Ball valve (oil samples piston underside) | 22 | Nozzle |
| 7 | iELBA (optional) | 23 | Thrust bearing |
| 8 | Main collector (dirty oil, piston underside) | 24 | Supply pipe (main bearing) |
| 9 | Main collector (leak oil – gland box) | 25 | Supply pipe (thrust bearing) |
| 10 | Dirty oil – piston underside | 26 | Crosshead pin |
| 11 | Leakage oil outlet – gland box | 27 | Toggle lever |
| 12 | Supply pipe (axial damper) | 28 | Supply pipe (piston cooling, crosshead bearing) |
| 13 | Axial damper monitor | 29 | Oil inlet pipe |
| 14 | Supply pipe – vibration damper | 30 | Inlet from main oil supply |
| 15 | Bottom end bearing | 31 | Inlet from crosshead lubricating oil supply |
| 16 | Axial damper | 32 | Oil pipe (bearing drive, supply unit, servo oil) |

## 2.1 Dirty Oil Samples

### 2.1.1 Preparation

1) Write the applicable data on the oil analysis form (e.g. operation conditions, fuel parameters, cylinder lubricating oil feed rate etc).

2) Make sure that the labels on the sample bottles refer to the related cylinders.

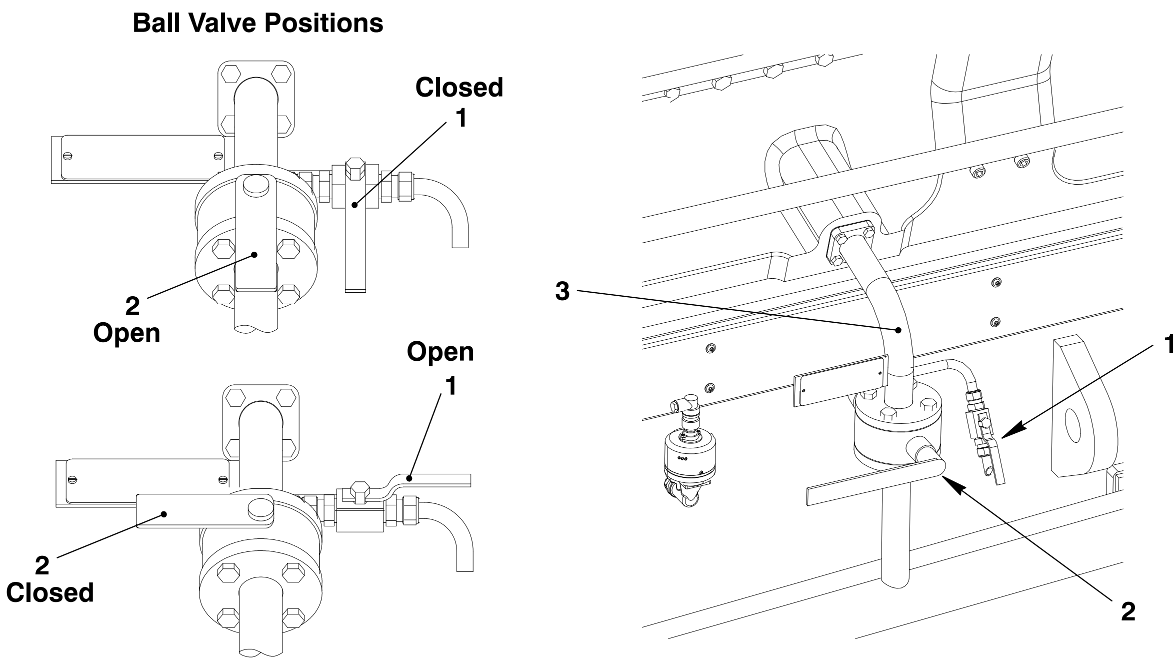


**Fig. 2: Location of Ball Valves for Dirty Oil Samples**

### 2.1.2 Procedure

1) Close the ball valve (2, Fig. 1) for approximately 30 minutes to 60 minutes.

**Note: Some parts can look different.**

2) Slowly open the ball valve (1) to flush out oil and possible dirt.
3) Put an applicable container under the ball valve (1).
4) Close the ball valve (1).
5) Open the ball valve (2) to drain the remaining oil from the dirty oil pipe (3).
6) Close the ball valve (2).
7) Put the sample bottle under the ball valve (1).
8) After approximately 10 minutes to 60 minutes, slowly open the ball valve (1) to fill the sample bottle.
9) Close the ball valve (1).
10) Open the ball valve (2) to drain the oil that collected in the dirty oil pipe (3).
11) Do the steps 1) to 10) again on each cylinder.

**Note: Winterthur Gas & Diesel Ltd. recommends that you get an oil sample of the cylinder lubricating oil downstream of the duplex filter. Send the oil sample to the laboratory to make an analysis to make sure the initial cylinder lubricating oil had the correct quality and no contamination.**

12) Make sure that the sample bottles are tightly closed and use an applicable package.
13) Send the samples to the laboratory to make an analysis.

# 3. Servo Oil System

The servo oil system controls the exhaust valve movement. Oil from the lubricating oil system is used in the servo oil system.

## 3.1 Servo Oil

Oil flows through the oil pipe (1, Fig. 2) (bearing drive) and the supply pipe (14) to the servo oil pumps (17).

**Note: Do not operate the engine if the oil does not flow to the servo oil pumps.**

The servo oil pumps supply oil at sufficient pressure through the HP servo oil pipes (11) to the servo oil rail. The necessary oil pressure is related to the engine load.

The leakage oil pipe (12) is located at a connecting block near the servo oil pumps.

The flow sensors (20) (installed upstream of each servo oil pump) monitor the oil supply to the servo oil pumps.

**Note: If a servo oil pump becomes defective, an alarm is activated through the alarm and monitoring system (see 5551–1 Servo Oil Pump).**

Servo oil flows from the servo oil rail to the Valve Control Units (VCU) and their 4/2-way control valves.

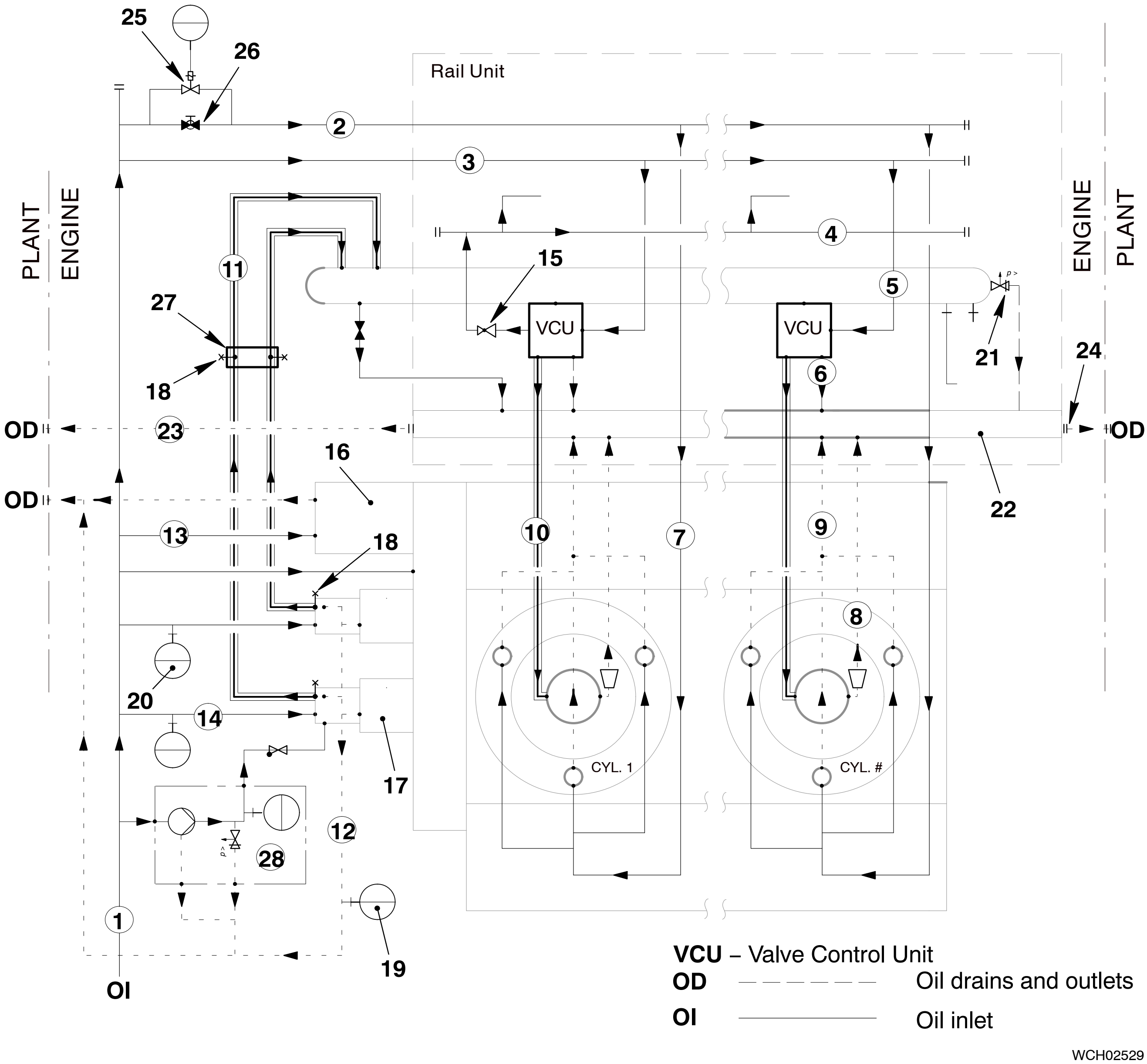


**Fig. 3: Servo Oil System**

1 Oil pipe – bearing drive, supply unit, servo oil
2 Supply pipe – cooling oil, injectors
3 Supply pipe
4 Cylinder lubrication drive
5 Supply pipe – VCU
6 Leakage pipe – VCU
7 Cooling oil supply – fuel injection valve
8 Drain from exhaust valve
9 Cooling oil return – fuel injection valve
10 Hydraulic pipe – exhaust valve
11 HP servo oil pipes
12 Leakage oil pipe
13 Supply pipe – supply unit
14 Supply pipe – servo oil pump
15 Pressure reducing valve
16 Supply unit
17 Servo oil pump
18 Leakage inspection points – servo oil pipes
19 Level switch LS2055A
20 Flow sensors FS2061−62A
21 Pressure safety valve
22 Main oil collector
23 Leakage oil outlet DE
24 Leakage oil outlet FE
25 Control valve CV2003C (injection valve cooling)
26 Ball valve
27 Intermediate piece
28 Servo oil service pump
OI Inlet from main oil supply

## 3.2 Servo Oil Leakage

### 3.2.1 Leakage and Oil Drains

Some of the oil flows from the oil drains (18, Fig. 1) through the servo oil return in the plant and back to the main oil supply.

Leakage oil from the HP servo oil pipes (11, Fig. 2) drains through the leakage oil pipe (12).

Leakage oil from the exhaust valves flows through the leakage oil pipe (8) to the main collector (22) then through the leakage oil outlets (23) and (24). This leakage oil then flows back to the plant.

The level switch LS2055A monitors leakages from the HP servo oil pipes.

Leakage oil from inside the rail unit, flows through a drain to the sludge tank.

If there is a large quantity of leakage oil, the related alarm is activated. See the table below:

| Level switch | Monitored components |
|---|---|
| LS3444A | Monitors fuel and oil leakage from the rail unit (see 8019-1 Fuel System, Fig. 1). The leakage flows to the sludge tank. |
| LS2055A | Leakages from HP servo oil pipes. |

## 3.3 Leakage Inspection Points

### 3.3.1 HP Servo Oil Pipes

If there is a leak in the HP servo oil pipes, the leakage inspection points (18, Fig. 2) are used to find the pipe that has the leakage.

### 3.3.2 Exhaust Valve Control Unit

If oil flows from the leakage inspection point (3, Fig. 4) in the VCU, the related hydraulic pipe (1) has a leak (for more data, refer to paragraph 4.3).

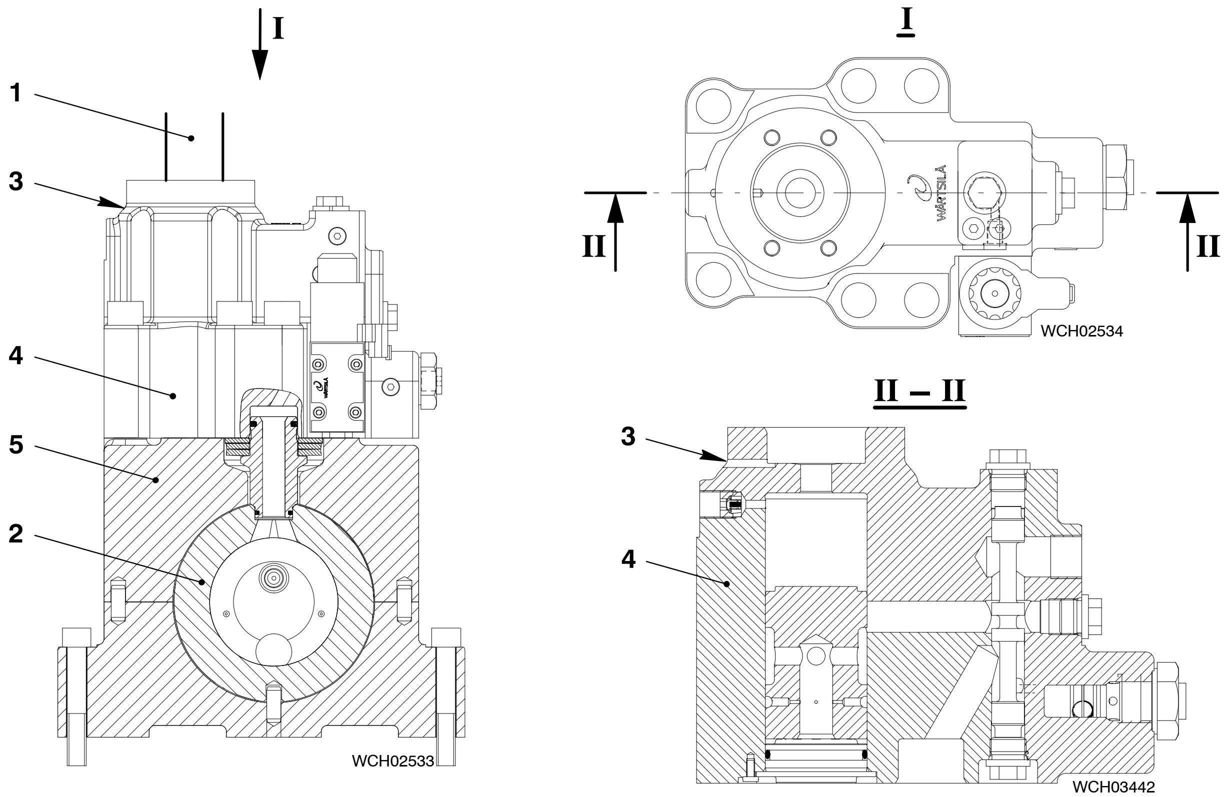


**Fig. 4: Leakage Inspection Point – VCU**

1 Hydraulic pipe
2 Servo oil rail
3 Leakage inspection point
4 Valve control unit (VCU)
5 Holder

**Note: If one of the two HP servo oil pipes has a leak (and thus is unserviceable), the engine can operate fully until the defective pipe is replaced.**

### 3.3.3 Procedure

If the level switch (LS2055A) activates an alarm, do the procedure that follows:

**Note: Each of the two HP servo oil pipes (2, Fig. 5) has a screw plug (5) at the leakage inspection points.**

**WARNING**

**Injury Hazard: Always put on gloves and safety goggles when you do work on hot components and pressurized systems. When you loosen the screw plugs, high pressure oil can come out as a spray and cause injury.**

1) Carefully loosen the screw plug (5, Fig. 5), a maximum of one turn and look for oil.
2) If there is no oil, tighten the screw plug (5).

**Note: If oil flows from the screw plug (5), the related HP servo oil pipe (2) has a leak.**

3) If necessary, replace the defective HP servo oil pipe (2) (see the Maintenance Manual, 8447-1).
4) Do step 1) to step 3) above for the other screw plugs (5).

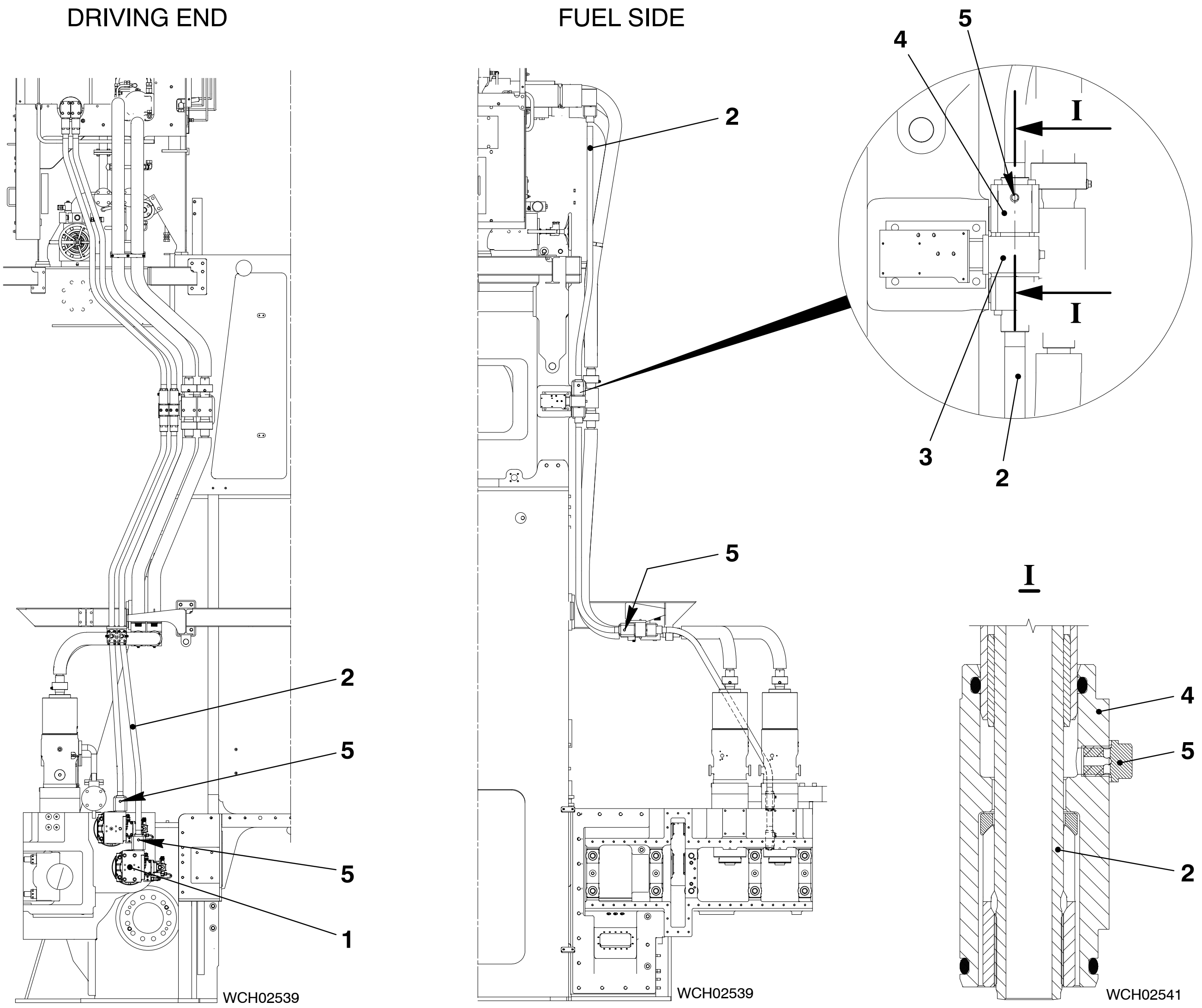


**Fig. 5: Leakage Inspection Points – HP Servo Oil Pipes**

1 Servo oil pump
2 HP servo oil pipe
3 Intermediate piece
4 Flange
5 Screw plug

## 3.4 Servo Oil Rail

### 3.4.1 Pressurization

The servo oil pumps (17, Fig. 2) supply high pressure oil to the HP servo oil pipes (11). The oil pressure opens the non-return valves and oil flows into the servo oil rail. The oil then flows into the VCU and hydraulic pipes (10) (for more data, refer to 2751–1 Exhaust Valve).

1) Make sure that the stop valve downstream of automatic filter is open.
2) Start the bearing oil pump.
3) Set to on the servo oil service pump (28).
4) Do a function check of the exhaust valve movement.
5) Do a leak check of the servo oil system.

### 3.4.2 Pressure Release

To release the pressure in the servo oil rail, do the procedure that follows:

| WARNING |
|---|
| **Injury Hazard: Always put on gloves and safety goggles when you do work on hot components and pressurized systems. When you loosen the screw plugs, high pressure oil can come out as a spray and cause injury.** |

**Note: If the screw plug (1) stays open after the servo oil pumps start, pressure in the oil rail cannot increase and high pressure oil can come out.**

1) Carefully loosen half of one turn, the screw (4, Fig. 6).
2) Carefully loosen a maximum of two turns, the screw (5).
3) Make sure that there is no pressure in the servo oil rail (2).
4) Tighten the screw (5).
5) Tighten the screw (4).

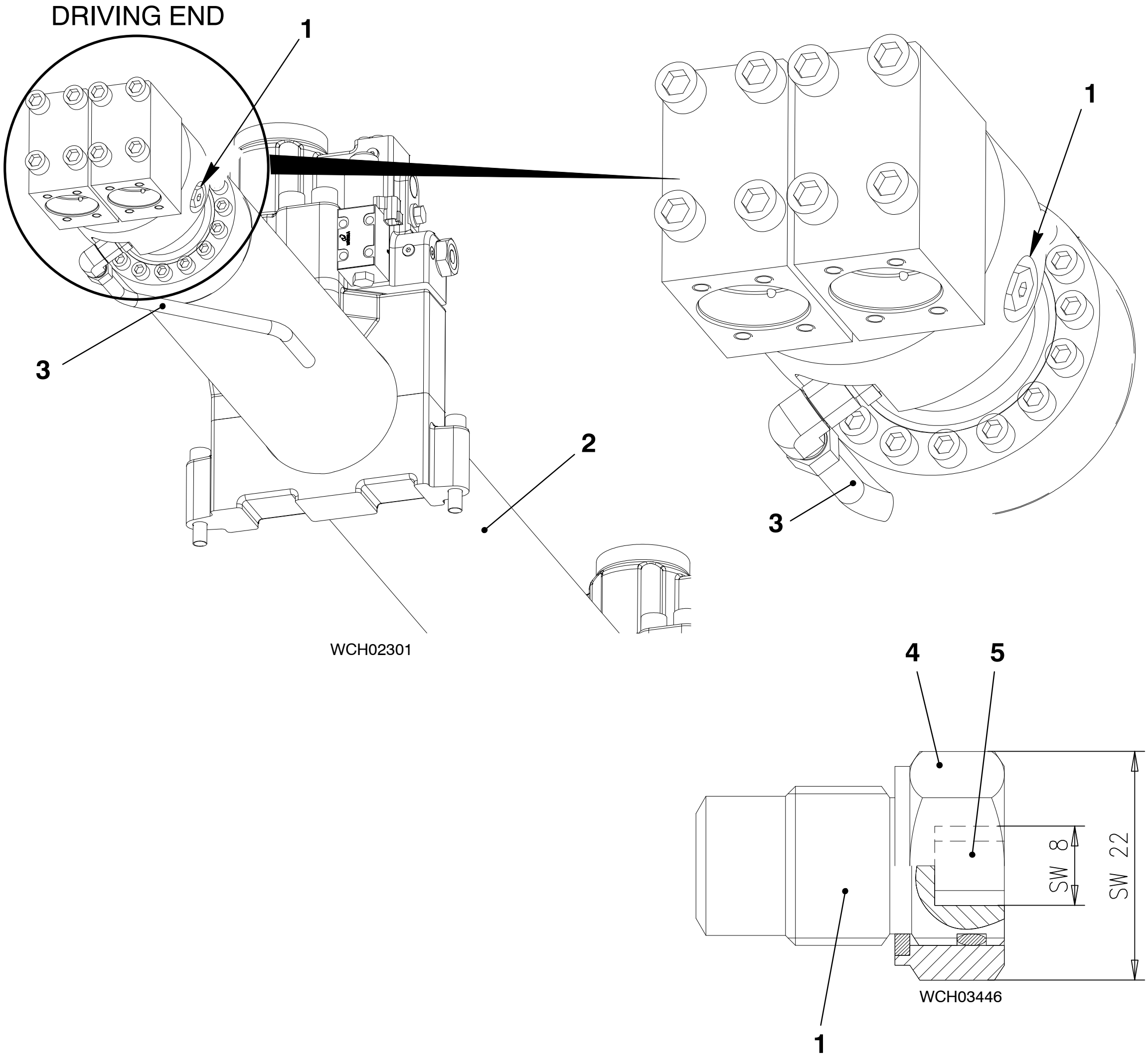


**Fig. 6: Servo Oil Rail**

1 Screw plug
2 Servo oil rail
3 Drain pipe (to square collector)
4 Screw (SW22)
5 Screw (SW8)

# 4. Faults

**Note: The data that follow are applicable only when the engine operates in diesel mode. If the engine operates in gas mode and a related failure occurs, the ECS automatically changes to diesel mode (for more data, refer to 4002−1 Engine Control System).**

If there is a defect in an exhaust valve control unit (VCU), on the hydraulic pipes or on an exhaust valve, you must repair the defective item immediately.

If this is not possible because the engine must continue to operate, do the procedures that follow.

## 4.1 Defective Servo Oil Pump

### 4.1.1 Identification

The flow sensors FS2061A and FS2062A show if a servo oil pump does not supply oil, i.e. an alarm is activated in the alarm and monitoring system (Servo oil pump No. 1 or No. 2 no flow).

### 4.1.2 Causes

- The servo oil pump has damage.
- The safety device on the pump drive has sheared.
- The actuators CV7221C and CV7222C are defective.
- There is no control current (the cable coupling is defective).

### 4.1.3 Procedure

**CAUTION**

**Damage Hazard: Do not operate the engine with one unserviceable servo oil pump for a long period. If the other servo oil pump becomes defective, damage can occur and the engine cannot operate.**

If one servo oil pump becomes defective, the engine can continue to operate through the full load range.

1) Replace the defective servo oil pump as soon as possible (refer to the Maintenance Manual 5551−2 Supply Unit).

## 4.2 Defective Solenoid Valve CV7401–0#C on the VCU

### 4.2.1 Identification

- The ECS shows an alarm indication in the Log Messages page of the LDU–20 Refer to 4002–2, paragraph 3.17 Exhaust Valve and paragraph 3.26 Log Messages.
- The fuel injection is cut out automatically on the related cylinder, and a slow down signal is released (Inj. CUT OFF).
- The exhaust valve does not open or close.

### 4.2.2 Causes

- The solenoid valve CV7401–0#C on the exhaust valve control unit (VCU) is defective.

### 4.2.3 Procedure – Replace

Replace the defective solenoid valve (6, Fig. 7) on the VCU as soon as possible.

1) Stop the engine.
2) Make sure that the servo oil service pump is set to off.
3) Set to off the main bearing oil supply.
4) Carefully loosen the drain screw (4) to release the pressure in the servo oil rail (2). Make sure that the servo oil rail has no pressure.
5) Disconnect the electrical connection (5) from the 4/2-way valve (6).
6) Remove the four screws (7), together with the solenoid valve (6).
7) In the new 4/2-way valve, make sure that the correct new three O-rings are installed.
8) Make sure that the mating surfaces of the solenoid valve (6) and the VCU (1) are clean.
9) Make sure that the small M6 orifice is installed in one of the four ports (P-port) in the VCU (1).
10) Put the solenoid valve (6) in position. Make sure that the bores are correctly aligned.
11) Tighten the four screws (7).
12) Close the screw plug (4).
13) Connect the electrical connection (5) to the solenoid valve (6). Make sure that the electrical connection is tight.
14) Set to on the main bearing oil supply.
15) Start the servo oil service pump.
16) Do a function check of the exhaust valve drive, refer to 4003–1, paragraph 4.7 Exhaust Valve Drive and 4002–2 paragraph 3.26 Log Messages.

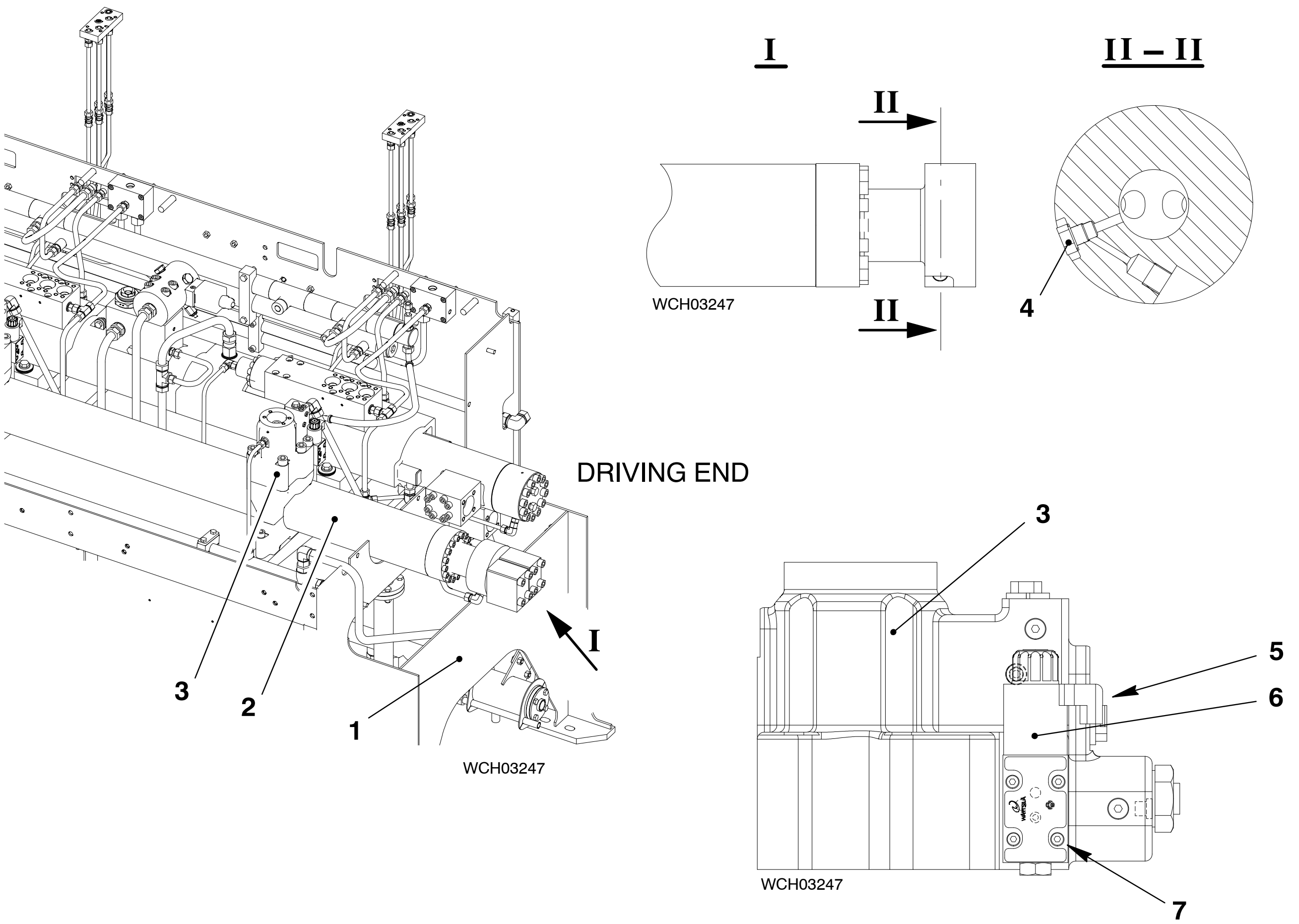


**Fig. 7: Servo oil and VCU**

1 Rail unit
2 Servo oil rail
3 Exhaust valve control unit
4 Screw plug
5 Electrical connection
6 Solenoid valve CV7401−0#C
7 Screw

## 4.3 Defective Exhaust Valve Control Unit or Hydraulic Pipe

### 4.3.1 Identification

- The ECS shows an alarm indication in the Log Messages page of the LDU−20. Refer to 4002−2, paragraph 3.17 Exhaust Valve and paragraph 3.26 Log Messages.
- The fuel injection is cut out automatically on the related cylinder, and a slow down signal is released (Inj. CUT OFF).
- The level switch LS3444A activates an alarm because there are leakages in the hydraulic pipes to the exhaust valves (refer to paragraph 3.2).
- There is a large difference between the closing or opening time of the exhaust valve.

### 4.3.2 Causes

- The piston, or the slide rod in the VCU cannot move.
- A hydraulic pipe to the exhaust valve is broken.

### 4.3.3 Procedure − Replace

Replace the defective VCU or hydraulic pipe as soon as possible (refer to the Maintenance Manual 5612−1 Servo Oil Rail and 8460−1 Hydraulic Pipe for Exhaust Valve Drive).

1) Cut out the VCU:
   a) Cut out the injection to the related cylinder (refer to 8019−1, paragraph 5).
   b) In the LDU-20 get the EXHAUST VALVES page (see 4002−2, paragraph 3.17 Exhaust Valve).
   c) In the column Man., select 0 to set the applicable cylinder to automatic.
   d) Disconnect the electrical connection (5) from the 4/2-way valve (6, Fig. 7) of the related cylinder.
   e) The exhaust valve stays closed.
2) After the procedures in step 1) are completed, the engine can operate again.

   **Note: With one or more VCU cut out, you can operate the engine only in diesel mode at decreased load. Read and obey the data in 0510−1. Also, the exhaust gas temperature on the cylinders must not be more than the maximum limit of 515°C.**
3) Replace the defective VCU or Hydraulic Pipe:
   a) Stop the engine.
   b) Make sure that the servo oil service pump is set to off.
   c) Set to off the main bearing oil supply.
   d) Carefully open the screw plug (4) to release the pressure in the servo oil rail (2).
   e) Close the screw plug (4).
   f) Replace the defective VCU or the hydraulic pipe (see the Maintenance Manual 5612−1 and 8460−1).
   g) Connect the electrical connection (5) to the 4/2-way valve (6).
   h) Start the injection (refer to 8019−1, paragraph 6 Injection Start).
   i) Set to on the main bearing oil supply.
   j) Do a function check of the exhaust valve drive, refer to 4003−1, paragraph 4.7 Exhaust Valve Drive and 4002−2 paragraph 3.26 Log Messages.
   k) Do a visual check for leaks.

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# Cooling Water System



## 1. General

The schematic diagram (see Fig.1) shows the cylinder cooling water system in the engine.

The location of pumps, coolers, fresh water generator, heater, expansion tank, valves and throttling discs for flow control etc are found in the plant documentation (shipyard side). Also the configurations of raw water for the scavenge air, lubricating oil and water coolers for the cylinder jackets are shown in the layout diagram.

The cooling water system is a closed circuit and connected to an expansion tank in the plant. The cooling water keeps cool the cylinder liners, cylinder covers and exhaust valve cages.

The cooling water must have treatment with an approved inhibitor to prevent corrosion, sludge and scale particles in the system (for more data, refer to 0330-1 Cooling Water.

A heater installed in the plant, applies heat to increase the water to the correct temperature before engine operation.

| CAUTION |
|---|
| **Damage Hazard: If the engine does not operate for a long period in cold/frosty conditions, you must drain the cooling water system. The water has a chemical treatment and you must decontaminate the water in accordance with local environmental regulations.** |

For data about antifreeze, refer to 0330-1 Cooling Water, paragraph 5.

### 1.1 Automatic Temperature Control

The temperature of the cooling water outlet is kept as stable as possible during all load conditions. This prevents too much expansion and contraction of the combustion chamber components e.g. cylinder liners and cylinder covers.

The maximum permitted temperature tolerances are:

- ± 2°C at constant load
- ± 4°C during load changes.

For data about pressures, temperature ranges, alarm and safety setting points, refer to the Operating Data Sheets 0230−1 and 0230−2.

## 2. Function

The cooling water pump supplies cooling water, through the supply pipe (18, Fig.1) on the exhaust side, to the cylinders. The cooling water flows through the cylinder liner (9), water guide jacket (10), cylinder cover (11) and exhaust valve cage (12). The vent pipe (20) is connected to the expansion tank. When the automatic vent unit (1) and ball valve (2) are open, the system continuously releases pressure.

**Note: If problems occur, refer to the instruction plate on the vent unit (1).**

The water flows from the outlet pipe (17) through a temperature control valve to the cooler and back to the pump. A throttle (13) is installed in the outlet pipe of each cylinder. This throttle controls the flow rate of cooling water through the cylinder.

The butterfly valve (7) and ball valve (8) are used to isolate the cylinders from the cooling water system. The ball valve (8) is used to drain the water from isolated cylinders.

If it is necessary to remove only the cylinder cover, the ball valve (8) must stay closed. You open the ball valve (5), to let the cooling water flow out through the drain pipe (22).

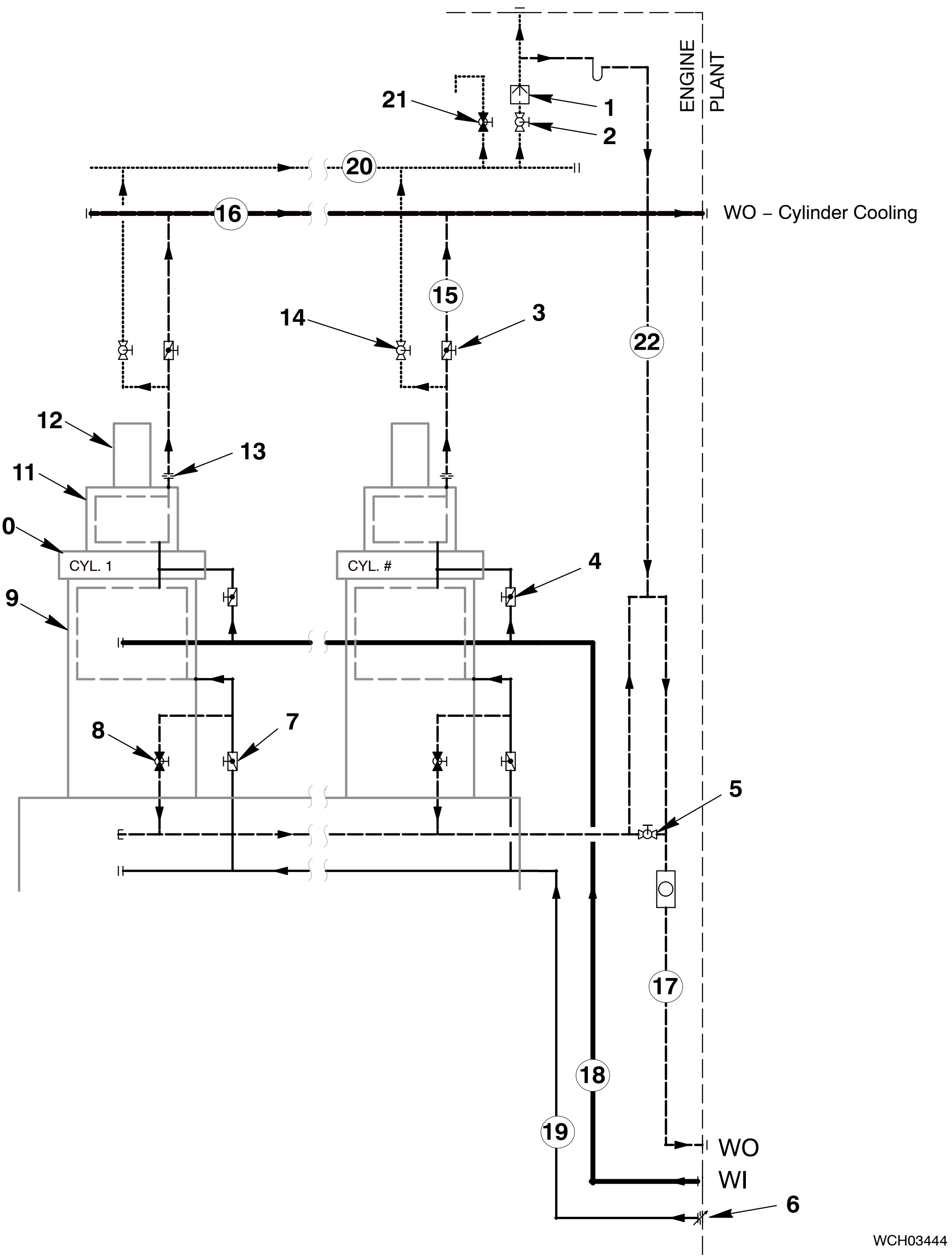



**Fig. 1: Lubricating Oil System**

| | | | |
|---|---|---|---|
| 1 | Automatic vent unit | 13 | Throttle (cylinder outlet) |
| 2 | Ball valve | 14 | Ball valve |
| 3 | Butterfly valve (cylinder outlet) | 15 | Cylinder outlet |
| 4 | Butterfly valve (cylinder inlet) | 16 | Outlet pipe (cylinder cooling water) |
| 5 | Ball valve (to drain the system) | 17 | Outlet pipe (cooling water) |
| 6 | Adjustable throttle (water inlet) | 18 | Supply pipe |
| 7 | Butterfly valve (cylinder liner inlet) | 19 | Inlet pipe (to cylinder liner inlet) |
| 8 | Ball valve (to drain the cylinder) | 20 | Vent pipe |
| 9 | Cylinder liner | 21 | Ball valve (vent) |
| 10 | Water guide jacket | 22 | Drain pipe |
| 11 | Cylinder cover | WI | Cooling water inlet |
| 12 | Exhaust valve cage | WO | Cooling water outlet |

# 3. Faults

## 3.1 Water Leakage into the Combustion Chamber

**Note: The data that follow are applicable only when the engine operates in diesel mode. If the engine operates in gas mode and a related failure occurs, the ECS automatically changes to diesel mode (for more data, refer to 4002–1 Engine Control System).**

If there is water leakage into the combustion chamber (e.g. a crack in the cylinder cover or cylinder liner) the defective part must be replaced immediately.

If it is not possible to replace the defective parts but the engine must continue to operate, do the procedures that follow for the related cylinder:

1) Isolate the related cylinder from the cooling water system:

   a) On the related cylinder, close the valves to the cooling water inlet and outlet (i.e. isolate the cylinder from the cooling water system). See Fig. 1.

   b) Drain the cooling water through the drain pipe.

2) Cut out the injection (refer to 8019–1, paragraph 5).

3) Cut out the exhaust valve control unit:

   a) In the LDU–20, get the EXHAUST VALVES page, (refer to 4002–2 Local Control Panel / Local Display Unit (LDU–20), paragraph 3.17).

   b) In the Man. column, use the rotary button to set the value for the related cylinder to 1. This will manually open the exhaust valve 50–2751_CX_1 of the related cylinder.

4) Lock the exhaust valve in the open position:

   **Note: If the cooling flow of the cylinder is stopped, there is a risk of that the combustion chamber will become too hot because of compression heat. Thus, the exhaust valve must be opened to prevent damage to other components.**

   a) Stop the engine.

   b) Make sure that the servo oil service pump is set to off.

   c) Set to off the main bearing oil supply.

   d) Remove the damper (1, Fig. 2) from the top housing (5).

   e) In the control air supply **A**, close the 3/2-way valve 35.36HA (refer to 4605–1 Control Air Supply and 4003–2 Page 1 Control Diagram). This releases the pressure in the air pipe to the exhaust valves and the exhaust valve stays open.

   f) Apply a thin layer of oil to the thread of the pressure element (2, tool 94259).

   g) Install the pressure element (2).

      **Note: Make sure that you do not lose the shim(s) (3). The shim(s) must stay in position when the pressure element (2) is installed.**

      **Note: For safety, the pressure element (2) must also be installed if an exhaust valve is caught in the open position.**

h) Disconnect the electrical connection (4, Fig. 3) from the solenoid valve CV7401−0#C (5) of the related VCU (3).

i) Open the 3/2-way valve 35.36HA to the operation position.

j) Set to on the main bearing oil supply.

k) Disconnect the control signal connection from the starting air valve.

l) Make sure that the faces of the valve seat and the valve head are in good condition (no hard dirt particles).

**Note: If there are hard dirt particles on the faces of the valve seat and valve head, an overhaul is necessary. Refer to the Maintenance Manual 2751−3 and 2751−4.**

m) Set to on the servo oil service pump.

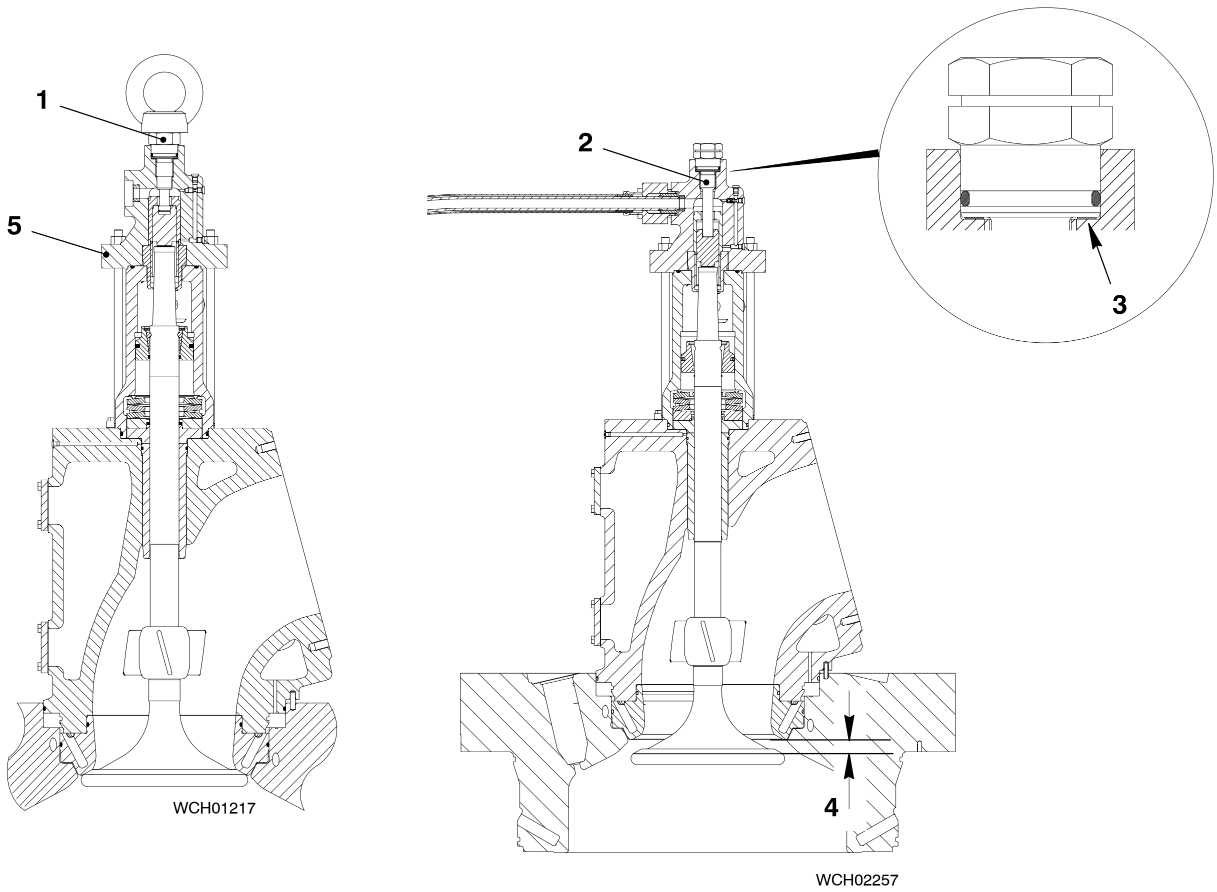
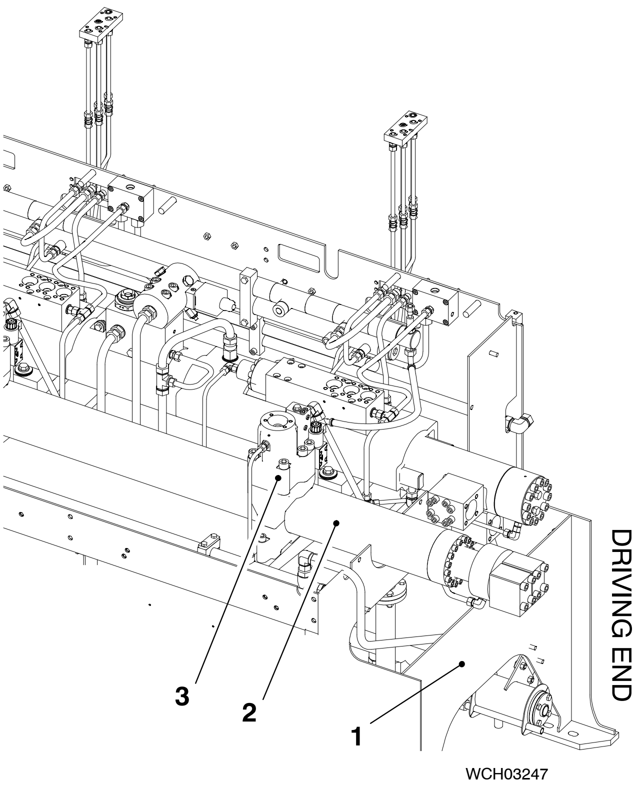



**Fig. 2: Exhaust Valve / Pressure Element**

1 Damper
2 Pressure element (tool 94259)
3 Shim
4 Maximum exhaust valve stroke
5 Top housing



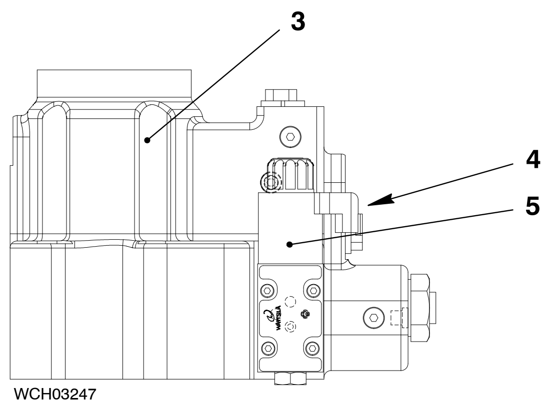




**Fig. 3: Servo oil and VCU**

1 Rail unit
2 Servo oil rail
3 Exhaust valve control unit
4 Electrical connection
5 Solenoid valve CV7401−0#C

5) After the procedures above are completed, the engine can operate again. Refer to the procedures given in 0440−1 Engine Start Procedure.

**Note: With one or more VCU cut out, you can operate the engine only in diesel mode at decreased load. Read and obey the data in 0510−1. Also, the exhaust gas temperature on the cylinders must not be more than the maximum limit of 515°C.**

**Note: Do not operate the engine for a long period after the emergency procedures are completed. Replace the defective cylinder liner or cylinder cover as soon as possible.**

6) Replace the defective cylinder liner or cylinder cover. Refer to the Maintenance Manual 2124−1 and 2708−1.

7) When the defective parts are replaced and the engine is serviceable again, set the exhaust valve for usual operation. Do the procedures that follow for the related cylinder:

a) Make sure that the servo oil service pump is set to off.

b) Set to off the main bearing oil supply.

c) Close the 3/2-way valve 35.36HA in the control air supply **A**. This removes all of the air from the air pipe to the exhaust valves. The exhaust valve stays open.

d) Remove the pressure element (2, Fig. 2). Make sure that you do not lose the shim(s) (3).

e) Apply a thin layer of oil to the thread of the damper (1).

f) Install the damper (1).

g) Open the 3/2-way valve 35.36HA to the operation position.

h) Connect the electrical connection (4, Fig. 3) to the solenoid valve CV7401−0#C (5).

i) In the LDU-20, set to on the injection for the related cylinder (see 8019−1 Diesel Fuel System, paragraph 5).

j) In the LDU-20, set to on the exhaust valve control unit for the related cylinder.

k) Connect the related cylinder with the cooling water system.

l) Set to on the servo oil service pump.

m) Connect the control signal connection to the starting air valve.

n) Set to on the main bearing oil supply.

o) Refer to the procedures given in 0440−1 Engine Start Procedure.

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# Starting Air Diagram

## 1. General

The starting air system is shown in the schematic diagram (Fig. 1).

The control air supply unit (7) and air bottle (6) supply the necessary control air for the engine.

For more data, refer to the Pipe Diagram − Air System 4003-9.

You must make sure that the compressed air is clean and dry.

You must open the drain valves regularly to remove condensation from the starting air system.

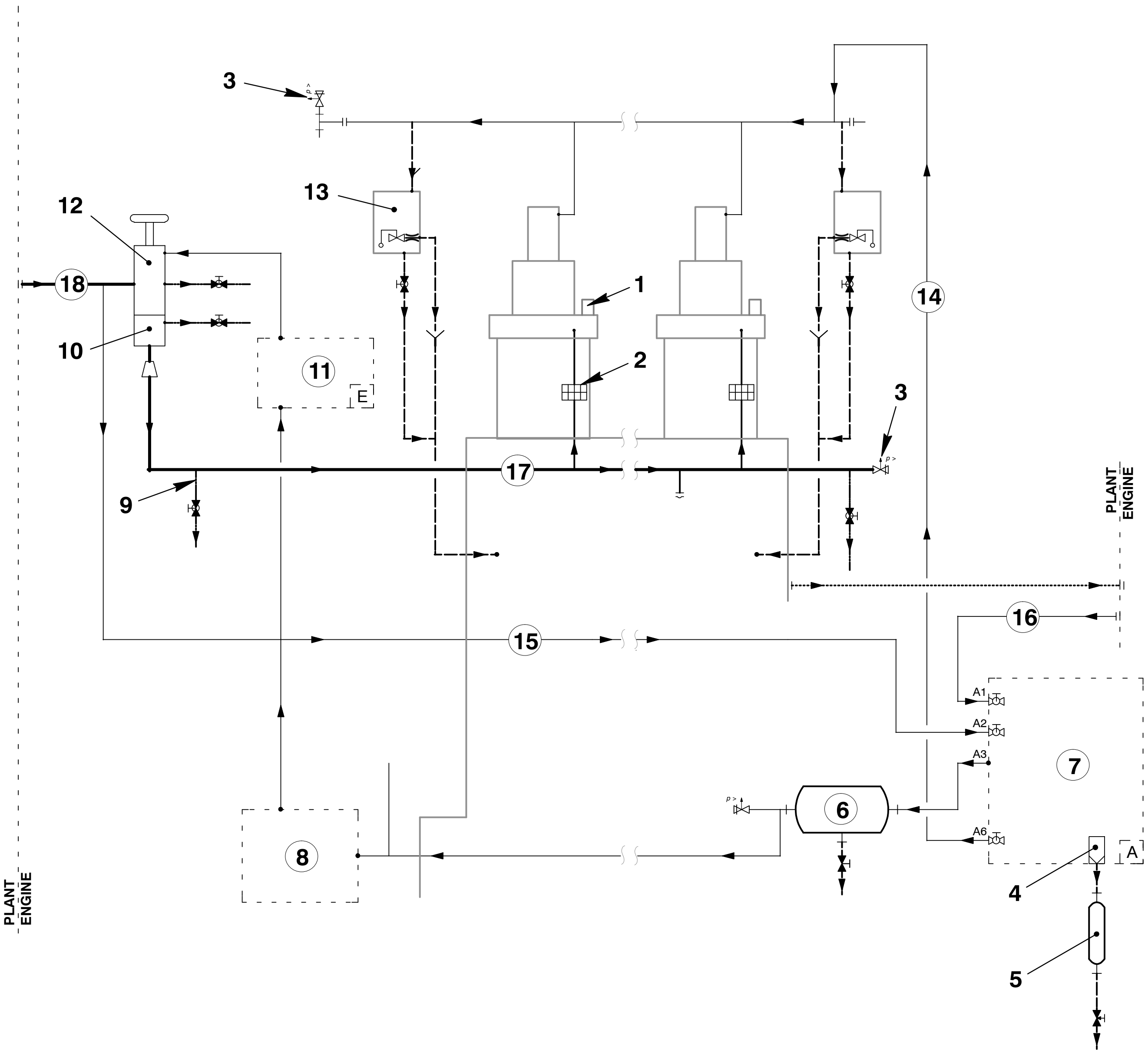



**Fig. 1: Schematic Diagram – Starting and Control Air**

1 Starting valve
2 Flame arrestor
3 Pressure safety valve
4 Air filter
5 Water bottle
6 Air bottle (control air supply)
7 Control air supply unit
8 Disengaging device turning gear
9 Vent / drain
10 Non-return valve
11 Control valve and valve unit for start
12 Starting air shut-off valve
13 Oil leakage return (from air spring)
14 Air spring air supply
15 Starting air
16 Control air (board supply)
17 Starting air pipe
18 Starting air inlet

# Diesel Fuel System



## 1. General

For heavy fuel oil operation, all pipes to the fuel rail have adjacent insulated heating pipes (see Fig. 1). The heating pipes increase the temperature of the fuel. These heating pipes also keep the fuel warm during short periods when the engine has stopped.

For safety, the fuel rail is installed in the rail unit (28). All pipes in the high pressure circuit that are out of the rail unit have double walls.

For data about the pilot fuel system, refer to 8790–1 Pilot Fuel System.

## 2. Low Pressure Circuit

A booster pump (installed in the plant) supplies the fuel through the fuel inlet pipe (1) to the fuel pumps (3). The fuel quantity that the fuel pumps supply is more than necessary for the engine. The adjustable pressure retaining valve (12) controls the pressure difference upstream and downstream of the supply pumps. The unwanted fuel flows back to the system through the fuel outlet pipe (5).

Leakage fuel from the main collector in the rail unit flows back to the sludge tank (43). For more data, refer to 0300–1 Diesel Engine Fuels, paragraph 8.

### 2.1 Adjustable Pressure Retaining Valve – Setting

For the values of the adjustable pressure retaining valve, see the indications fuel inlet and return (fuel pump) given in 0230–1 Operating Data Sheet, Diesel Fuel.

## 3. High Pressure Circuit

The fuel pumps (3) supply high pressure fuel through the high pressure (HP) fuel pipes (8) to the fuel rail (10). The fuel pumps supply fuel as necessary to keep the pressure in the fuel rail constant (see 5556–1 Fuel Pump).

The pressure control valve (PCV) (15) controls the fuel pressure. The PCV also lets fuel flow through the fuel pumps, HP fuel pipes and fuel rail during engine stand-by. This keeps the fuel warm (for more data, refer to 5562–1 Pressure Control Valve).

High pressure fuel flows from the fuel rail through the flow limiting valves (11). These flow limiting valves control the volume of fuel through the HP fuel pipes (13) to the injector valves (14).

The non-return valves (9) prevent a pressure decrease in the fuel rail (10) if there is damage to an HP fuel pipe (8).

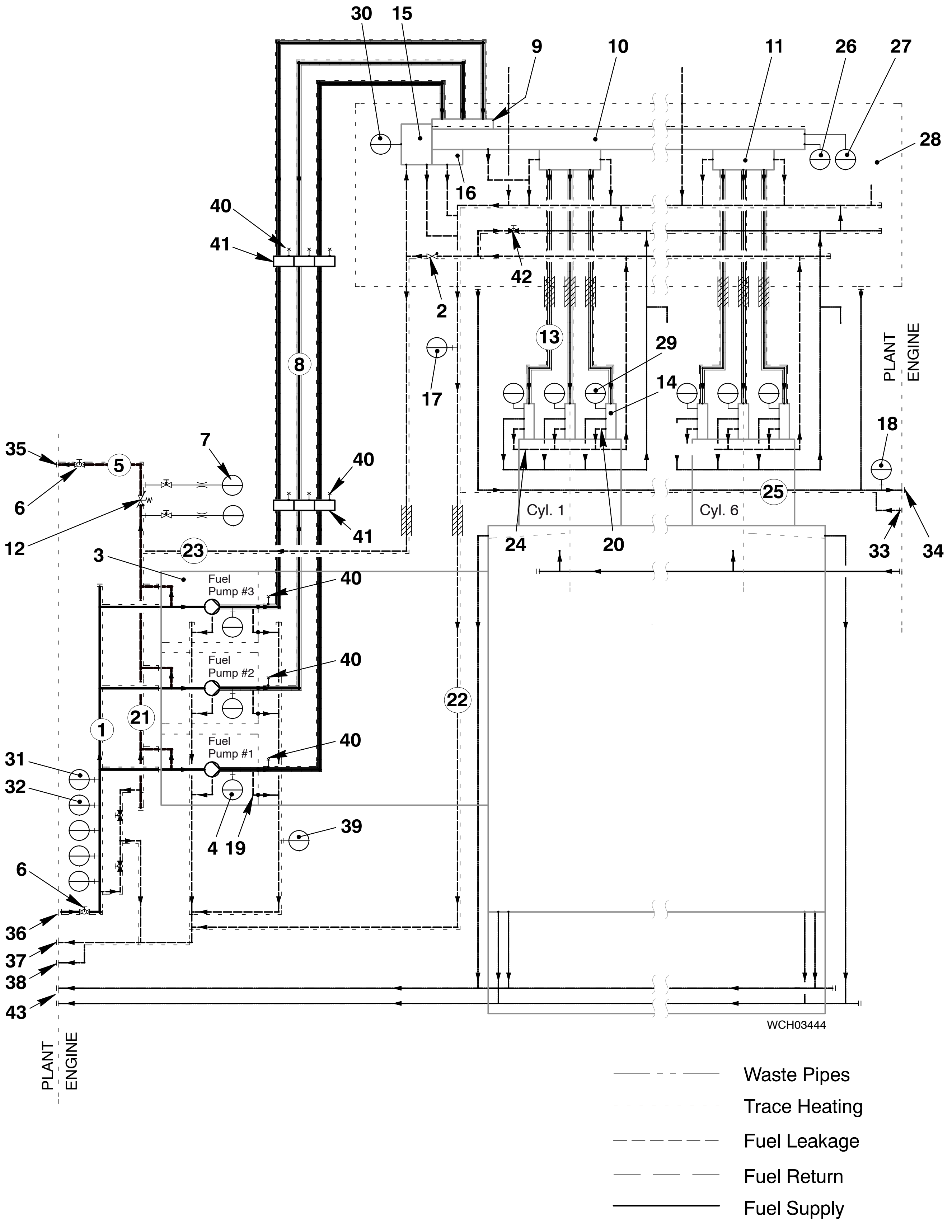



**Fig. 1: Fuel System**

**Key to Fig. 1**

| | | | |
|---|---|---|---|
| 1 | Fuel inlet pipe | 23 | Drain pipe to fuel return |
| 2 | Non-return valve | 24 | Fuel leakage pipe (injection valves) |
| 3 | Fuel pump | 25 | Fuel leakage outlet pipe (rail unit) |
| 4 | Flow control valve | 26 | Pressure transmitter PT3461C |
| 5 | Fuel outlet pipe | 27 | Pressure transmitter PT3462C |
| 6 | Shut-off valve (plant) | 28 | Rail unit |
| 7 | Pressure gages | 29 | Control valve (on injection valve) |
| 8 | HP fuel pipe | 30 | Solenoid valve ZV7061S |
| 9 | Non-return valve | 31 | Pressure transmitter PT3421A |
| 10 | Fuel rail | 32 | Pressure transmitter PT3422A |
| 11 | Flow limiting valve | 33 | Trace heating inlet |
| 12 | Adjustable pressure retaining valve | 34 | Fuel leakage outlet (rail unit) |
| 13 | HP fuel pipe (to injection valve) | 35 | Fuel return outlet |
| 14 | Injection valve | 36 | Fuel inlet |
| 15 | Pressure control valve | 37 | Fuel leakage outlet |
| 16 | Pressure relief valve | 38 | Trace heating outlet |
| 17 | Level switch LS3446A | 39 | Level switch LS3426A |
| 18 | Level switch LS3444A | 40 | Leakage inspection point |
| 19 | Fuel leakage pipe (from HP fuel pipes) | 41 | Intermediate piece |
| 20 | Control fuel outlet pipe | 42 | Ball valve (fuel drain for service) |
| 21 | Fuel return pipe | 43 | Fuel leakage outlet to sludge tank |
| 22 | Fuel leakage pipe | | |

# 4. Fuel Leakage System

The level switches (LS) monitor all important leakages in the fuel system.

If there is too much leakage, the related alarm is activated.

| Level switch | Monitored components |
|---|---|
| LS3444A | Leakages (fuel and servo oil) from the rail unit |
| LS3446A | HP fuel pipes to injection valves (13, Fig. 1) |
| LS3426A | HP fuel pipes (8) and fuel leakage pipes (19) |

## 4.1 Leakage Inspection Points

You use the leakage inspection points (40) to help you find possible leakages from the HP fuel pipes (8).

## 4.2 HP Fuel Pipes – Leakage

**WARNING**

**Injury Hazard: Always put on gloves and safety goggles when you do work on hot components and pressurized systems. When you open the screw plugs, fuel can come out as a spray and cause injury.**

**WARNING**

**Injury Hazard: The fuel system has high pressure. Replace a defective HP fuel pipe only when the engine has stopped.**

**Note: If the HP fuel pipe cannot be replaced immediately (or the engine must continue to operate), the fuel supply of the related fuel pump must be set to 0% (refer to 4002–2, paragraph 3.7 Diesel Fuel injection).**

**Note: When a fuel pump is cut out, operate the engine only at decreased load (see 5556-2 Fuel Pump – Cutting Out and Cutting In).**

If the level switch (39) (LS3426A) has activated an alarm, an HP fuel pipe (8) has a leak. Do the procedure that follows:

1) Carefully loosen a maximum of two turns, each of the screw plugs (8, Fig. 2) on the flange (5) of the HP fuel pipe (1).
2) Do a check to see if fuel flows out or not as follows:
   a) If fuel flows out, the related HP fuel pipe (1) is defective.
   b) If fuel does not flow out, tighten the screw plugs (8).
3) Carefully loosen a maximum of two turns, each of the screw plugs (9) on the flange (6) of the HP fuel pipes (2).
4) Do a check to see if fuel flows out or not as follows:
   a) If fuel flows out, the related HP fuel pipe (2) is defective.
   b) If fuel does not flow out, tighten the screw plugs (9).
5) Carefully loosen a maximum of two turns, each of the screw plugs (10) on the flange (7) of the HP fuel pipes (3).
6) Do a check to see if fuel flows out or not as follows:
   a) If fuel flows out, the related HP fuel pipe (3) is defective.
   b) If fuel does not flow out, tighten the screw plugs (10).
7) If necessary, replace the defective HP fuel pipe, refer to the Maintenance Manual 8752-1.

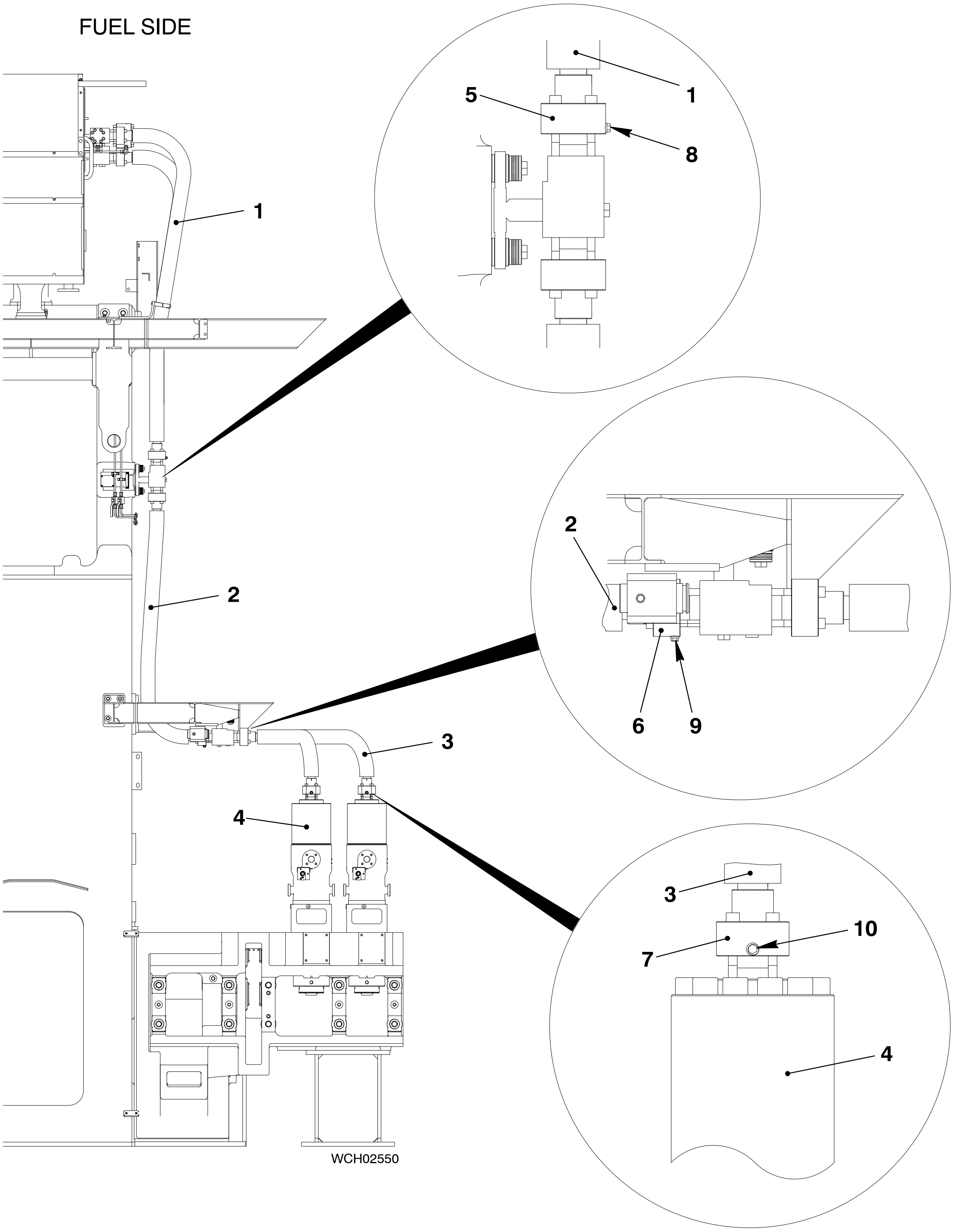



**Fig. 2: Leakage Inspection Points**

| | | | |
|---|---|---|---|
| 1 | HP fuel pipes (top section) | 6 | Flange |
| 2 | HP fuel pipes (middle section) | 7 | Flange |
| 3 | HP fuel pipes (bottom section) | 8 | Screw plug |
| 4 | Fuel pumps | 9 | Screw plug |
| 5 | Flange | 10 | Screw plug |

### 4.3 HP Fuel Pipes to Injection Valves – Leakage

**WARNING**

**Injury Hazard: Always put on gloves and safety goggles when you do work on hot components and pressurized systems. When drain screws and plugs are opened, fuel can come out as a spray and cause injury.**

**WARNING**

**Injury Hazard: The fuel system has high pressure. Replace a defective HP fuel pipe only when the engine has stopped.**

**Note: If the HP pipe (1) cannot be replaced immediately, the injection of the related cylinder must be cut out (see paragraph 5).**

**Note: When the injection is cut out (Inj. CUT OFF), you can operate the engine only at decreased load.**

If the level switch (17, Fig. 1) (LS3446A) activates an alarm, you must find the related cylinder. Start at cylinder No.1 (driving end) and do the steps that follow on each cylinder until you find the leakage:

1) On the fuel leakage pipe (6, Fig. 3), carefully loosen the screw-in union (5) approximately two turns.

2) Do a check for fuel flow. If there is no fuel flow from the screw-in union (5) do the procedure given in paragraph 4.4.

3) If fuel flows from the screw-in union (5), do step 4).

4) Make sure that the screws (4) are tightened to 60 Nm as follows:

   a) Tighten symmetrically the screws to 30 Nm.

   b) tighten symmetrically the screws to 60 Nm.

5) Do a check for fuel. If fuel continues to flow, an HP fuel pipe (1) is defective.

6) Remove each of the three HP fuel pipes (1) until you find the defective HP fuel pipe (refer to the Maintenance Manual 8733–1, paragraph 1).

7) Do a check for damage on the sealing face (7) of the defective HP fuel pipe (1). If you find damage, you must grind the sealing face (refer to the Maintenance Manual 8733–1, paragraph 3).

8) If it is necessary to replace the defective HP fuel pipe (1), refer to the Maintenance Manual 8733–1 and paragraph 5).

The related flow limiting valve will stay closed until the engine is stopped and the pressure in the fuel rail (3) is fully released.

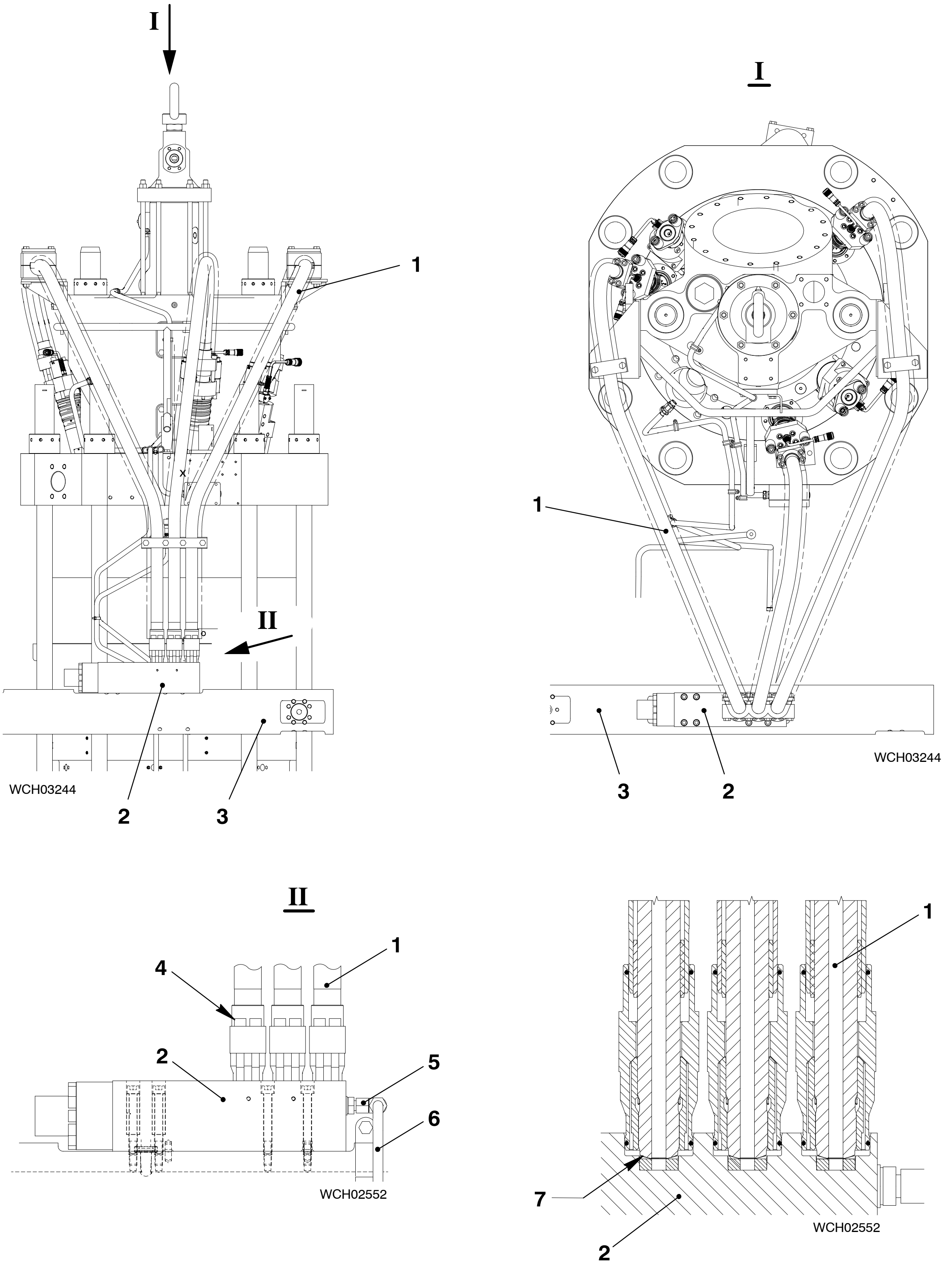



**Fig. 3: Leakage Inspection Point – HP Fuel Pipes to Injection Valves**

1 HP fuel pipe to injection valve
2 Flow limiter valve
3 Fuel rail
4 Screw
5 Screw-in union
6 Fuel leakage pipe
7 Sealing face

## 4.4 Pressure Control Valve – Leakage Check

**WARNING**

**Injury Hazard: Always put on gloves and safety goggles when you do work on hot components and pressurized systems. Fuel can come out as a spray and cause injury.**

**WARNING**

**Injury Hazard: The fuel system has high pressure. Replace the defective pressure control valve only when the engine has stopped.**

Do the following procedures after emergency operation or maintenance on the fuel system.

Make sure that the engine is ready for operation (refer to 0400–1, paragraph 2 Prepare for Operation).

1) In the LDU-20, get the USER PARAMETERS page.
2) Select the button AIR RUN to turn the engine with air.
3) If the pressure decrease is unusually high during the air run, do a check of the PCV (1, Fig. 4) (see the procedure given in the Maintenance Manual 5562-1).
4) Start the engine (refer to 0440–1 Engine Start Procedure).
5) Open the cover (11) on the rail unit (12).
6) Do a check for unusual noise from the PCV (1).
    a) If you hear an unusual noise (a continuous sound like a whistle whistle), stop the engine and do a check of the PCV (1) (see the Maintenance Manual 5562-1).
    b) If necessary, replace the PCV (1) immediately, refer to the Maintenance Manual 5562-1 Fuel Pressure Control Valve.
7) On the fuel return pipe (6) do a check of the temperature.
    a) If the fuel return pipe (6) is hot, stop the engine and do a check of the PCV (1) (refer to the Maintenance Manual 5562-1).
    b) If necessary, replace the PCV (1) immediately (refer to the Maintenance Manual 5562-1).
8) Close the cover (11) on the rail unit (12).

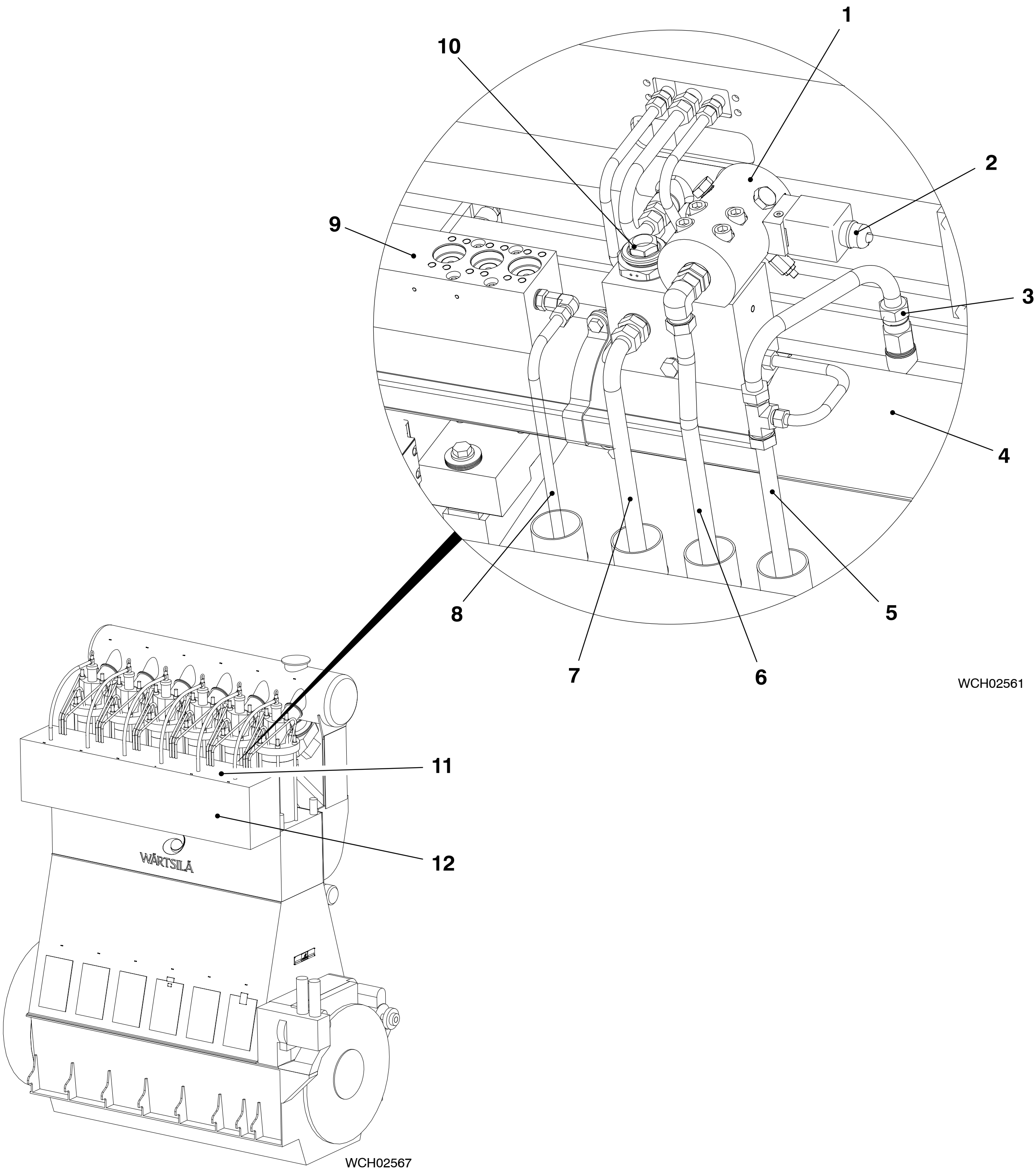



**Fig. 4: Pressure Control Valve**

1 Pressure control valve
2 Button (for pressure release)
3 Non-return valve
4 Fuel rail
5 Fuel return pipe (10 bar)
6 Fuel return pipe (0 bar)
7 Fuel return pipe (0 bar and monitored)
8 Fuel leakage pipe
9 Flow limiter valve
10 Pressure relief valve
11 Cover
12 Rail unit

# 5. Operation with Injection Cut-out (One or More Cylinders)

**Note: The data that follow are applicable only when the engine operates in diesel mode. If the engine operates in gas mode and a related failure occurs, the ECS automatically changes to diesel mode (refer to 4002–1 Engine Control System).**

If the injection of one or more cylinders must be cut out, do the procedure give in step 1) to step 5).

1) In the LDU-20, get the FUEL INJECTION page.

2) In the Inj. Cutoff column, set the parameter for the applicable cylinder to 1 to isolate the injection.

**Note: If there is a defect in the injection system (injection valve, high pressure pipe, etc) only cut out the injection of the related cylinder. If possible, the exhaust valve must always operate.**

3) Disconnect the electrical connection (6, Fig. 5) from the injection valve (2).

If it is necessary to operate the engine with the injection cut out for an extended period, do step 4 and step 5.

4) Record the settings of the lubricating oil feed rate.

5) In the LDU–20, get the CYL. LUBRICATION page (refer to 4002–2, paragraph 3.21 Cylinder Lubrication).

6) Decrease the lubricating oil feed rate for the related cylinder to the minimum setting .

# 6. Injection Start

| WARNING |
|---|
| **Injury Hazard: You must put on gloves and safety goggles when you do work on hot components. Oil can come out as a spray and cause injury.** |

Replace the defective injection valve (2) (refer to the Maintenance Manual 2722–1 Injection valve).

## 6.1 Defective High Pressure Pipe

Replace the defective high pressure pipe to the fuel injection valve as given in step 1) to step 3):

1) Stop the engine.

2) Disconnect the plug (6) from the injection valve (2).

3) Replace the defective high pressure fuel pipe (1) (refer to the Maintenance Manual 8733–1 Fuel Pressure Pipes).

**Note: If an HP fuel pipe, between the fuel pumps and the fuel rail (4) has a leak, do the procedures given in paragraph 4 above to find the leak.**

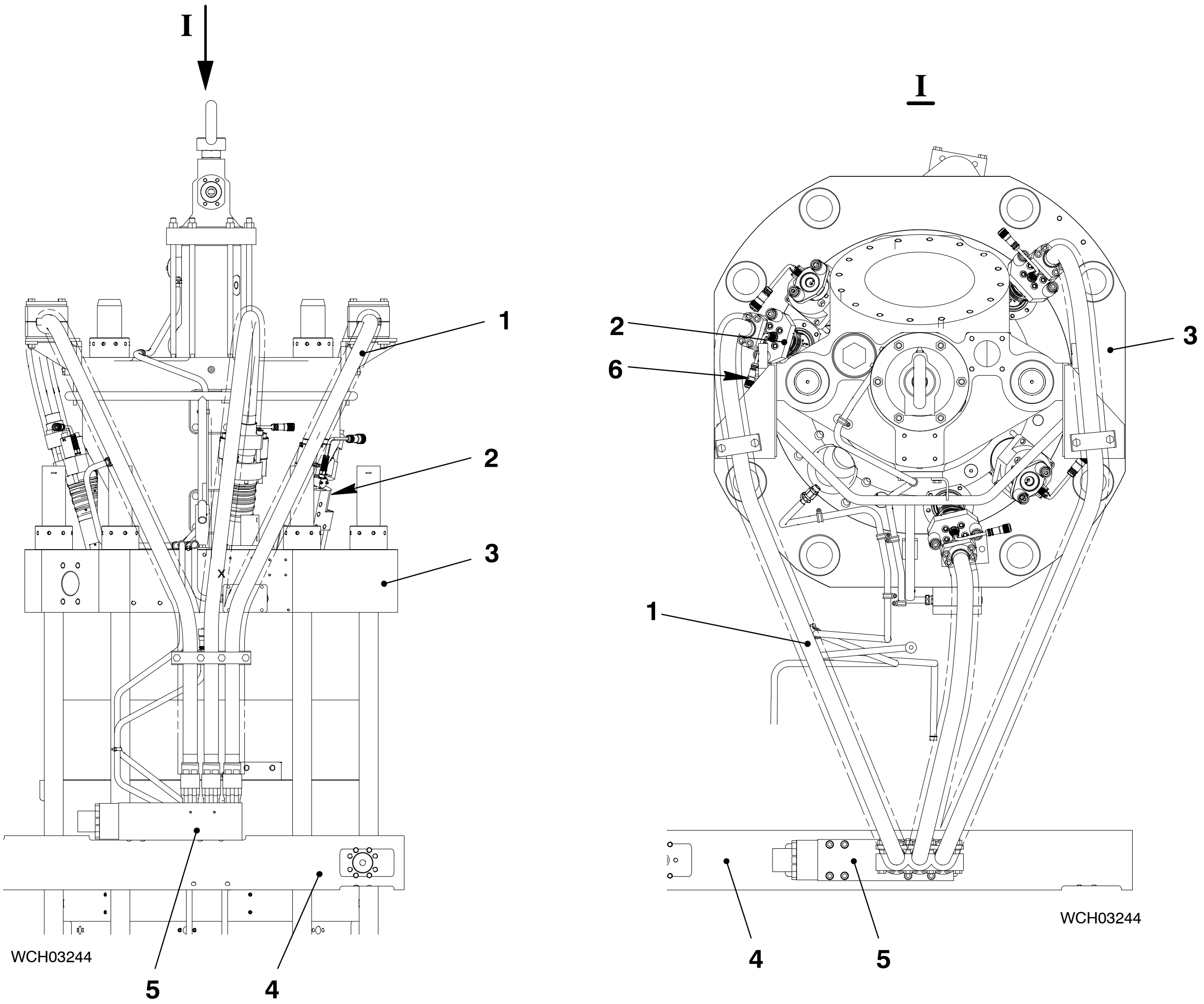



**Fig. 5: Location of High Pressure Pipes**

| | | | |
|---|---|---|---|
| 1 | HP fuel pipe (injection valve) | 4 | Fuel rail |
| 2 | Injection valve | 5 | Flow limiter valve |
| 3 | Cylinder cover | 6 | Electrical connection |

# 7. Defective Fuel Pump

**Note: The data that follow are applicable only when the engine operates in diesel mode. If the engine operates in gas mode and a related failure occurs, the ECS automatically changes to diesel mode (see 4002−1 Engine Control System).**

## 7.1 Fault Identification

Fault identification is as follows:

- Failure indication in the Log Messages page in the LDU−20.
- Higher regulating sleeve positions on the fuel pumps at the same output compared with the acceptance report.
- Unusual noises e.g. knocks, scrapes and rings.
- The level switch LS3426A shows an alarm (for more data, refer to paragraph 4 and 4003−2 Page 1 Engine Control Diagram).

### 7.2 Causes

The causes of the defects are given below:

- The pump plunger cannot move. The spring is broken. The regulating sleeve is blocked.
- The roller is blocked. There is damage to the cam. The roller guide is seized.
- An HP pipe is broken.
- The regulating linkage or toothed rack are blocked.

### 7.3 Procedure

**WARNING**

**Injury Hazard: The fuel system has high pressure. High pressure fuel can come out as a spray and cause injury. Replace the defective fuel pump only when the engine has stopped. The HP fuel pipes and the fuel rail must have zero pressure.**

You must replace the defective fuel pump or high pressure (HP) fuel pipe as soon as possible.

1) Stop the engine.
2) Cut out the related fuel pump, refer to 5556–2 Supply Unit and the Maintenance Manual 8752–1 HP Fuel Injection Pipes).
3) Replace the defective parts as soon as possible (refer to the Maintenance Manual 5552–2 Supply Unit).

## 8. Defective Fuel Pump Actuator

### 8.1 Fault Identification

If an actuator becomes defective, its output stays the same or changes slowly to zero supply. The toothed rack does not change when the load changes.

A failure message from the ECS shows on the Log Messages page of the LDU–20.

The fuel pumps stay in their last position when no control signal is received.

At high engine load, the remaining serviceable fuel pump actuators control the fuel quantity.

At low engine load, the PCV 10–5662_E0_5 controls the fuel pressure function.

**Note: If all the actuators become defective, their regulating outputs stay in position or turn slowly to zero supply. The toothed rack does not change when the load changes. Fuel quantity control is not possible at a lower fuel quantity. The PCV has the fuel pressure control function for decreased fuel quantity. The fuel released from the PCV flows into the fuel return.**

Operation with these control functions must be prevented if possible, or kept for only a short time. The fuel rail pressure must be decreased (paragraph 12.3 and 5562–2 Pressure Control Valve 10–5662_E0_5).

If there is an overpressure in the HP fuel system (i.e. the PCV becomes defective), the pressure retaining valve 10–5662_E0_6 opens (opening pressure 1050 bar) and the level switch LS3446A activates an alarm.

### 8.2 Causes

The causes of a defective fuel pump actuator are as follows:

- Electrical interference (defective cable connections, broken cable etc.).
- A fuel pump actuator is defective.

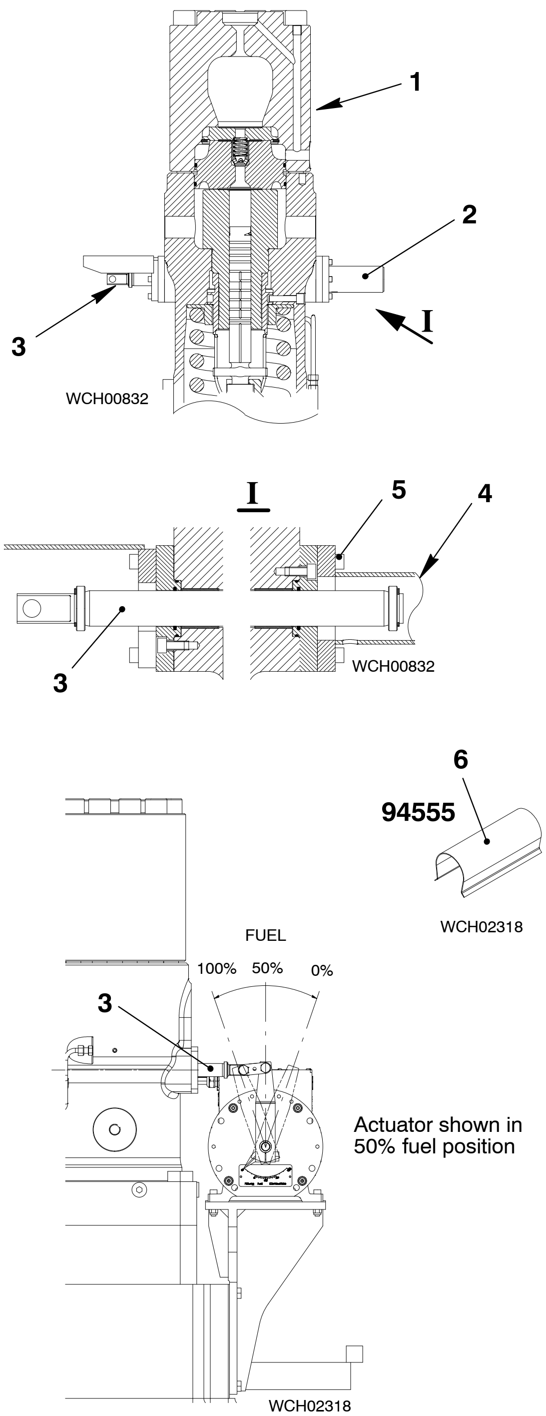



**Fig. 6: Fuel Pump Actuator**

### 8.2.1 One Actuator is Defective

1) Do a check of the control signals from the ECS and the electrical cables. If necessary, replace the electrical cables.

2) Make sure that the toothed rack (3) moves freely (see Fig. 6).

3) Move the toothed rack (3) to the 0% fuel position.

4) Install two distance pieces (6, tool 94555) to the toothed rack (3) on the fuel pump (1) that has the defective actuator.

5) Replace the defective actuator as soon as possible (refer to the Maintenance Manual, 5801−1 Regulating Linkage).

6) If different power outputs are necessary, you can lock the actuator in other positions (50% fuel, or 100% fuel) see step 7 to step 9.

7) Remove the six screws from the cover (2) then remove the cover.

8) For 50% fuel, do steps a) and step b):

   a) Move the toothed rack (3) to the 50% fuel position.

   b) Install one distance piece (6) on each end of the toothed rack (3).

9) For 100% fuel, do step a) and step b):

   a) Move the toothed rack to the 100% fuel position.

   b) Install two distance pieces (6) on the toothed rack.

**Note: Fuel pressure control through the PCV 10−5562_E0_5 must be prevented if possible.**

### 8.2.2 All Actuators are Defective

**Note: Do not operate the engine for long periods when all actuators are defective. Replace the defective actuators (3, Fig. 6) as soon as possible.**

1) To install the distance pieces (6) to the toothed racks (3), do step a) or step b):

   a) For engines with two fuel pumps, install the distance pieces (2, Tool 94555) to get:

      - One fuel pump in the 0% fuel position and the other fuel pump in the 100% position.

   b) For engines with three fuel pumps, install the distance pieces (6) to get:

      - One of the fuel pumps in the 0% fuel position and the other two fuel pumps in the 100% position.

**Note: For higher loads, set more fuel pumps to the 100% position.**

# 9. Defective Injection Valve

For general data about the injection valve, refer to 2722−1 Injection Valve and 4002−1 Engine Control System.

During engine operation, the open/short circuit of the injector is monitored.

When you manually activate the Injector Analysis Mode, only one injector operates in the related cylinder (this is done in cylinder balancing in an engine load range of between 20% and 30%).

When there is an external change command from the cylinder balancing function, the next injector operates (for more data, refer to 4002−1 Engine Control System, paragraph 3.10). See the data that follows:

- When the Injector Analysis Mode = 0, all injectors operate
- When the Injector Analysis Mode = 1, injector No.1 operates until the next change command, then
- When the Injector Analysis Mode = 2, injector No.2 operates until the next change command, then
- When the Injector Analysis Mode = 0, all injectors operate again.

The command change occurs after a specified time. The cylinder balancing function records the firing pressure and exhaust gas temperature data.

## 9.1 Fault Identification

- Failure indication from the ECS is shown in the Log Messages page of the LDU−20.
- The fuel injection is cut out automatically (Inj. CUT OFF) on the related cylinder, which activates a SLOW DOWN signal.
- The level switch LS3446A shows an alarm because of leakage of the high pressure fuel pipes to the injection valve (for more data, refer to paragraph 4 Fuel Leakage System).

## 9.2 Causes

- Electrical interference (cable connections are defective, broken cable etc).
- The solenoid valve is defective.
- The needle cannot move from the closed position.
- The needle cannot move from the open position.
- The injection valve is defective.
- Leakage from the sealing surfaces at one, or the two ends of the high pressure pipe.

## 9.3 Procedures

### 9.3.1 Injection Valve

1) The fuel injection must be cut out immediately (if not automatically cut-out). Refer to paragraph 5 Injection Cut Out.

**Note: When the injection is cut out (Inj. CUT OFF) the engine can only be operated at decreased load.**

2) Replace the defective injection valve as soon as possible (refer to the Maintenance Manual 2722–1 Injection Valve).

### 9.3.2 Injection Pipe

**CAUTION**

**Damage Hazard: If the fuel rail pressure continues to decrease because of the leak, replace the high pressure fuel pipe immediately. Damage to the engine can occur.**

1) If an HP fuel pipe to the injection valve breaks, cut out the injection (refer to paragraph 5 Injection Cut Out).
2) Replace the defective high pressure fuel pipe as soon as possible (refer to paragraph 6.1 and the Maintenance Manual 2733–1 Injection Valve).

# 10. Defective Flow Limiter Valve

For general data about the flow limiter valve, refer to 4002−1 Engine Control System.

The flow limiter valve prevents a pressure release in the fuel rail if an HP fuel pipe to the fuel injectors breaks.

The flow limiter valve does not shut off the fuel flow when smaller problems cause an increase in fuel injection to the cylinder (e.g. one fuel injector closes incorrectly, or the nozzle is damaged). To make sure that the engine can continue to operate, the related cylinder must be cut out (see paragraph 5).

If the cylinder pressure and exhaust gas temperature of a cylinder have large differences when compared to other cylinders, the indications show that:

- The injector does not close
- The injection nozzle has damage.

In this condition, you must cut out the related cylinder.

If the exhaust gas temperature and in-cylinder pressure continues to have large differences (after the injection is cut out), there is leakage from the injector into the cylinder.

To prevent fuel flow through the defective injector, select manually the flow limiter valve. All injectors of the related cylinder will inject the maximum fuel quantity at a specified late injection start (e.g. energize time at 20% load). This manual check is only possible below e.g. 20% load.

# 11. Defective Pressure Control Valve

For general data about the PCV, refer to 5562−1 Pressure Control Valve, 4002−1 Engine Control System.

## 11.1 Fault Identification

Fault identification of a defective PCV is as follows:

- The engine load decreases or the engine stops.
- The fuel system pressure is too low (alarm).
- The fuel pump supply is higher than usual or at maximum.
- You can hear a sound like a whistle when the engine operates.

## 11.2 Causes

The causes are as follows:

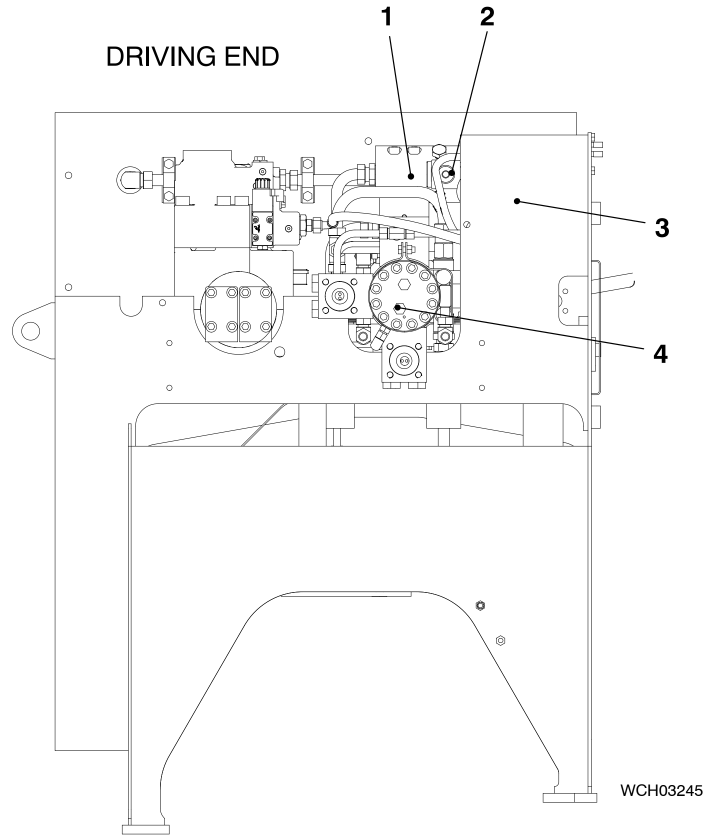
- The PCV is defective.
- The PCV has opened or has a leak.

## 11.3 Procedure

**WARNING**

**Injury Hazard: The fuel system has high pressure. High pressure fuel can come out as a spray and cause injury. Replace the PCV only when the engine has stopped. Make sure that the fuel rail has zero pressure before you do maintenance work.**

1) Stop the engine.
2) Replace the defective PCV (1, Fig. 7) as soon as possible.
3) Make sure that there is no pressure in the fuel rail (7) as follows:
   a) In the plant, set to off the fuel booster pump.
   b) Close the shut-off valves to the fuel inlet and return.
   c) Operate the button on the PCV.
   d) On the fuel rail (7), loosen the drain screw (4) a maximum of two turns.
4) Replace the defective PCV (refer to the Maintenance Manual 5562–1).



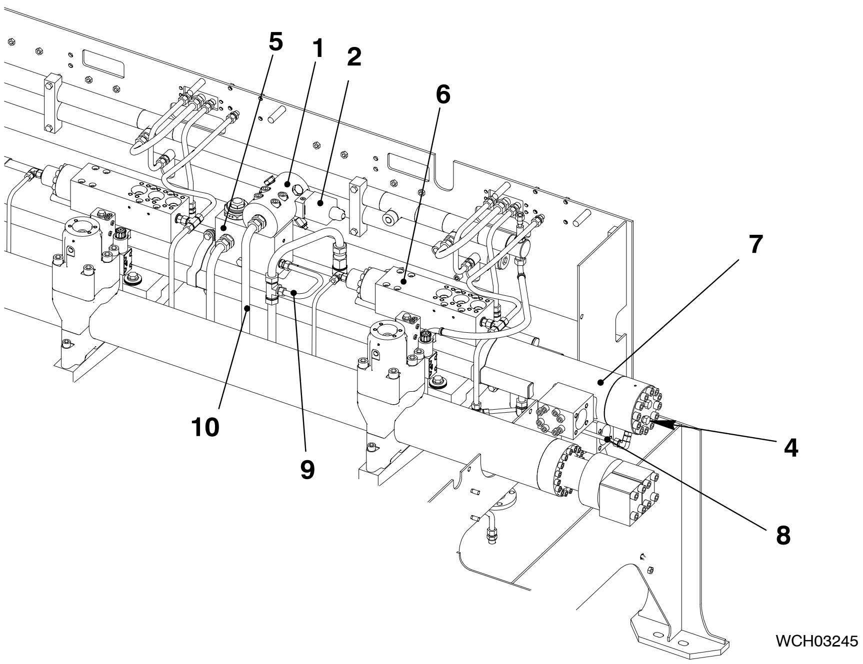




**Fig. 7: Location of Pressure Control Valve**

1 Pressure control valve 10−5562_E0_5
2 Solenoid valve (CV7061S)
3 Rail unit
4 Drain screw
5 Valve block
6 Flow limiter valve
7 Fuel rail
8 Drain pipe
9 Fuel supply pipe
10 Fuel return pipe

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# Exhaust Waste Gate



## 1. General

The exhaust waste gate (EWG) is installed at the exhaust side of the engine (see Fig. 2).

The exhaust waste gate has different functions when the engine operates in gas mode and diesel mode. Refer to the data given in paragraph 2.

The control air system supplies control air to the actuator (5). For more data about the control air supply unit, refer to 4605–1 Control Air Supply.

The engine control system (ECS) electronically controls the exhaust waste gate (refer to 4002–1 Engine Control System and 4003–2 Engine Control Diagram). The status of the exhaust waste gate is shown on the related LDU-20 page (e.g. control mode, position, command). For more data, see 4002–2 Local Control Panel/Local Display Unit (LDU-20), paragraph 3.20 Scavenge Air – EWG.

If the exhaust waste gate becomes defective, alarm messages are activated in the ECS and shown in the alarm and monitoring system (see 0510–1 Problems during Operation – Irregular Operation and 4003–2 Identification of Parts, paragraph 3.3 Signal Codes – Alarm and Monitoring System (AMS).

**Note: The turbocharger with the related layout field is designed for engine operation in gas mode. For more data, refer to 6500–1 Turbocharging.**

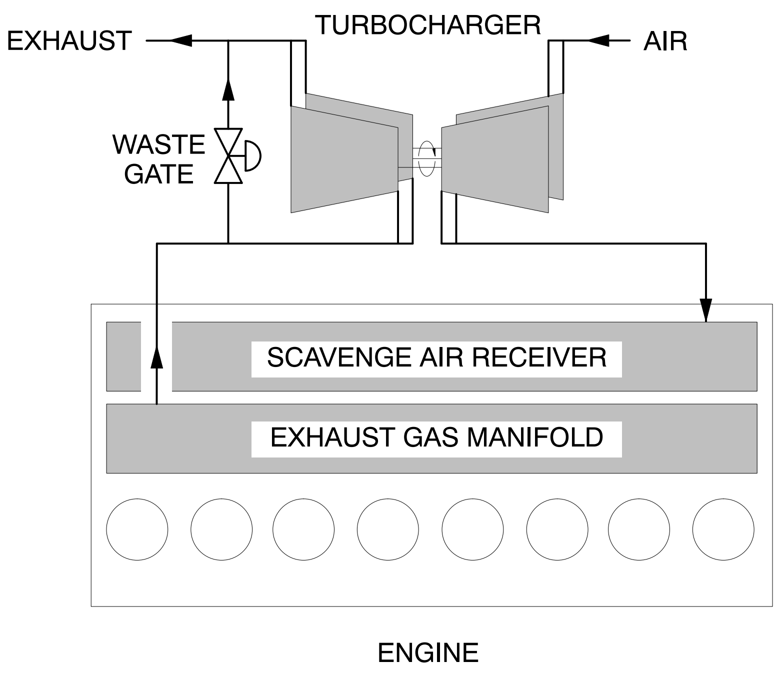



**Fig. 1: Schematic Diagram Exhaust Waste Gate**

# 2. Function

## 2.1 Engine Operation in Gas Mode

When the engine operates in gas mode, the exhaust waste gate controls the air/gas fuel ratio. The engine control system (ECS) electronically controls the exhaust waste gate, related to the engine load and engine speed. The correct air/fuel ratio gives the best ignition and combustion. This decreases the gases to a minimum and prevents knocking and misfire. For more data, refer to 4002–1 Engine Control System, paragraph 3.23 Air/Gas Fuel Ratio Control.

### 2.1.1 Open

When the ECS energizes the 3/2-way solenoid valve CV7077C (6, Fig. 2 and Fig. 3), control air is released. The control air flows through the control air pipe (10) to the actuator (5) and the butterfly valve (3) opens to the applicable position. The position sensor XI7077C sends data about the position of the butterfly valve (3) to the ECS.

### 2.1.2 Close

The ECS de-energizes the 3/2-way solenoid valve CV7077C (6) and the air supply stops. The pressure in the system is released and the spring in the actuator (5) closes the butterfly valve (3) to the applicable position. The position sensor XI7077C sends data about the position of the butterfly valve (3) to the ECS.

## 2.2 Engine Operation in Diesel Mode

During engine operation in diesel mode, turbocharger overspeed can cause damage to the turbocharger. The EWS prevents this damage.

The butterfly valve of the EWS only opens when the scavenge air pressure is more than the boost pressure setpoint in the ECS. For example, the boost pressure setpoint at R1 rating is approximately more than 90% engine load. For engines with lower ratings the setpoint is different. For data about the different engine ratings and related setpoints, speak to or send a message to Winterthur Gas & Diesel Ltd.

When the scavenge air pressure is less than the boost pressure setpoint, the EWG is in the closed position.

If the turbocharger delivers too much scavenge air pressure, the ECS does not fully open the exhaust waste gate. This make sure that the scavenge air pressure is always sufficient.

**Note: The applicable boost pressure setpoint is set in the ECS. The boost pressure setpoint is set for diesel mode operation. This is because of more exhaust heat content in diesel mode operation compared to gas mode operation. This prevents damage to the turbocharger because of overspeed.**

### 2.2.1 Open

The scavenge air pressure increases to more than the set limit. The ECS energizes the 3/2-way solenoid valve CV7077C (6). Control air is released through the control air pipe (10) to the actuator (5) and the butterfly valve (3) opens to the applicable position. The position sensor XI7077C sends data about the position of the butterfly valve (3) to the ECS.

### 2.2.2 Close

The scavenge air pressure decreases to less than the set limit. The ECS de-energizes the 3/2-way solenoid valve CV7077C (6) and the air supply stops. The pressure in the system is released and the spring in the actuator (5) closes the butterfly valve (3). The position sensor XI7077C sends data about the position of the butterfly valve (3) to the ECS.

# 3. Exhaust Waste Gate – Clean

## 3.1 General

When the engine operates for long periods with the exhaust waste gate (EWG) closed, it is necessary to remove dirt (particles) from the EWG.

To remove dirt (particles) from the EWG, there is a special function in the engine control system (ECS). The ECS opens the butterfly valve of the EWG approximately 2% for a short time. This will remove dirt (particles) from the EWG. If necessary, the operator must start this procedure manually (refer to paragraph 3.2).

**Note: You can use this procedure to clean the EWG during long periods of operation, it is not necessary to stop the engine.**

## 3.2 Procedure

1) In the LDU-20, get the SCAVENGE AIR – EWG page (see 4002–2, paragraph 3.20, Scavenge Air – EWG).
2) Use the rotary button to select the DEPOSIT CLEANING COMMAND button.
3) Push the rotary button to start the procedure.

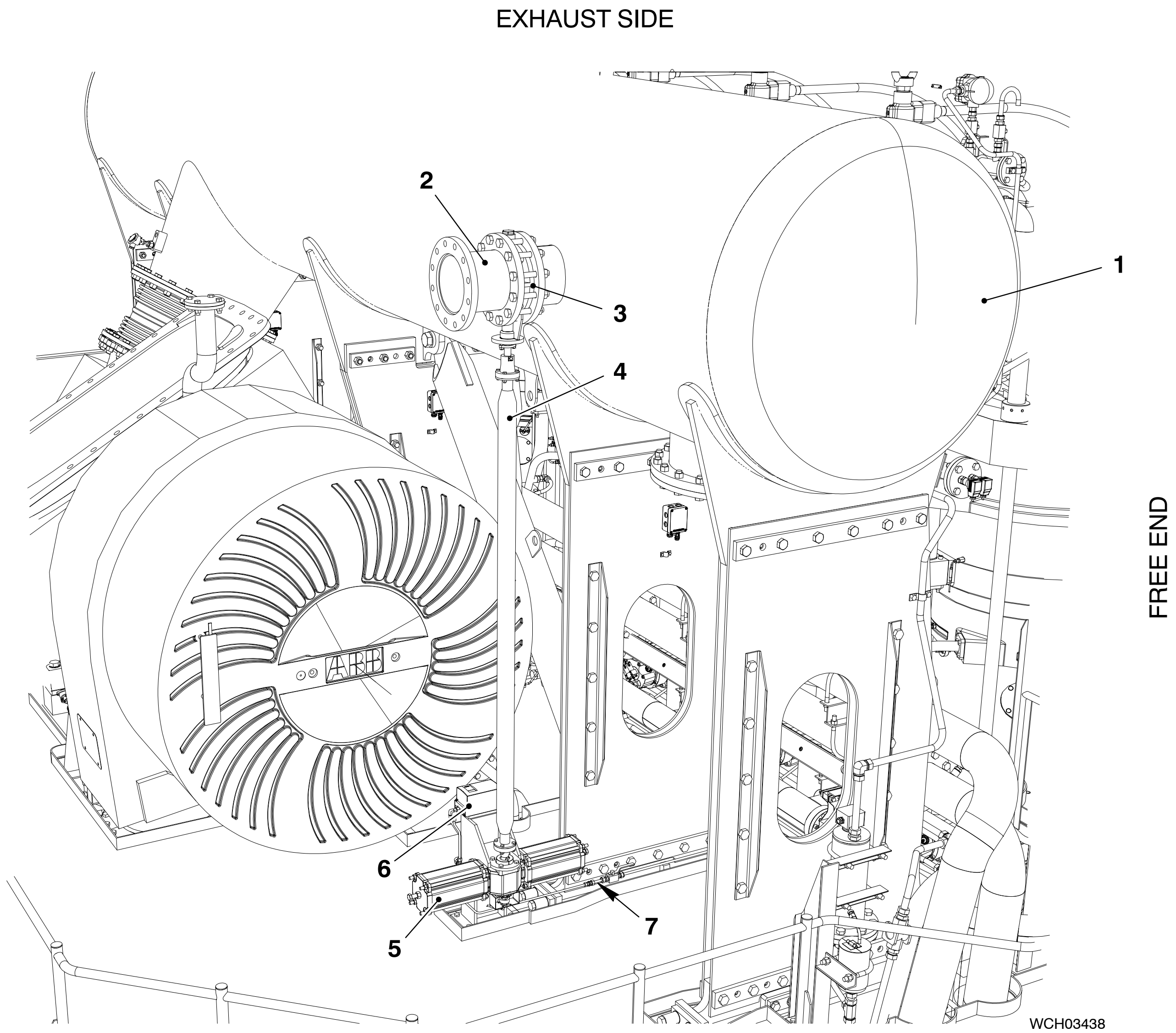



**Fig. 2: Exhaust Waste Gate**

1 Exhaust manifold
2 Exhaust by-pass line
3 Butterfly valve
4 Cardan rod
5 Actuator
6 Positioner
7 Air spring air pipe

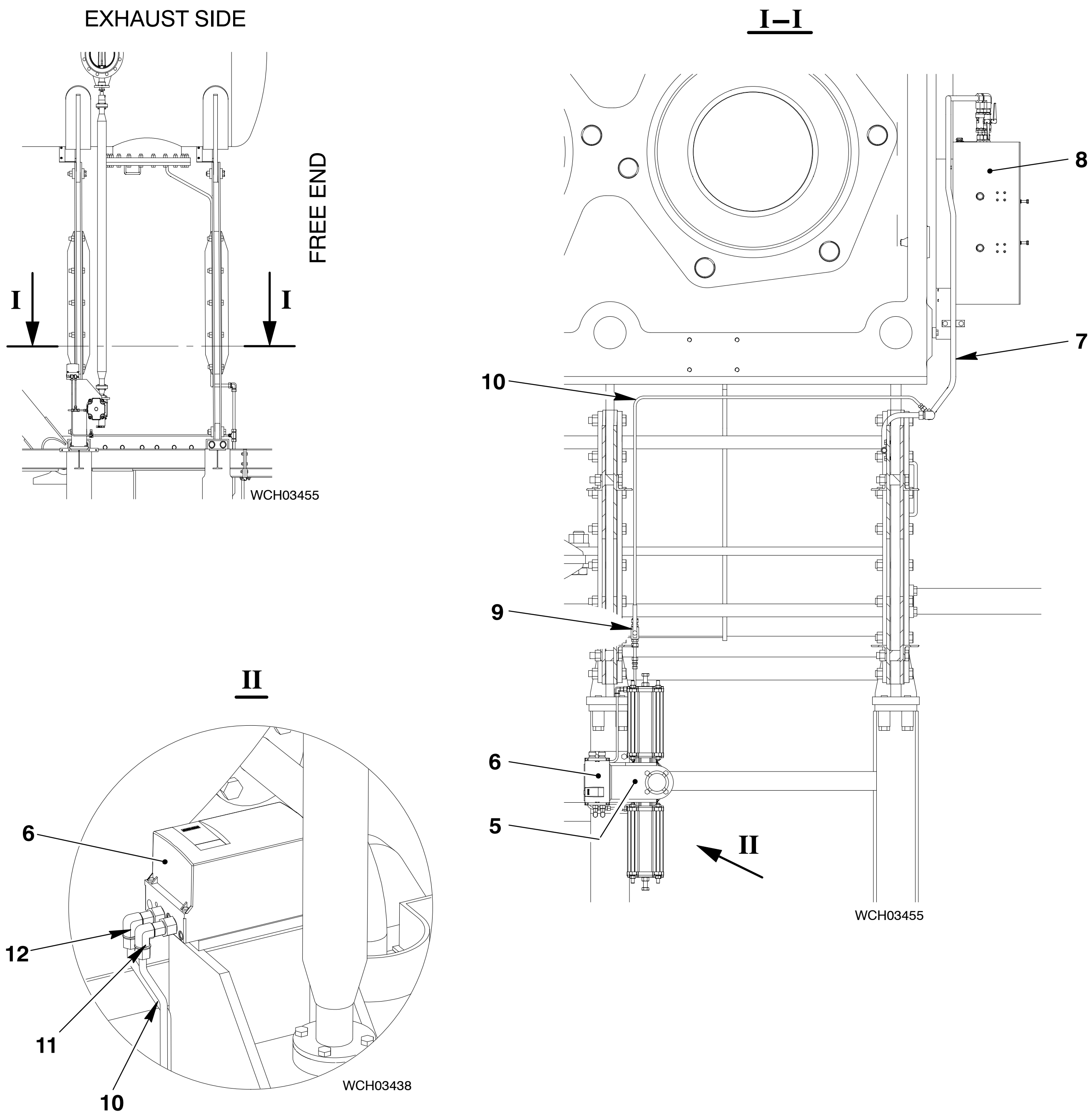



**Fig. 3: Air Supply − Exhaust Waste Gate**

| | | | |
|---|---|---|---|
| 5 | Actuator (ZS5372C) | 9 | Ball valve |
| 6 | 3/2-way solenoid valve (CV7077C) | 10 | Control air pipe |
| 7 | Air spring air pipe | 11 | Control air outlet |
| 8 | Control air supply unit | 12 | Control air inlet |

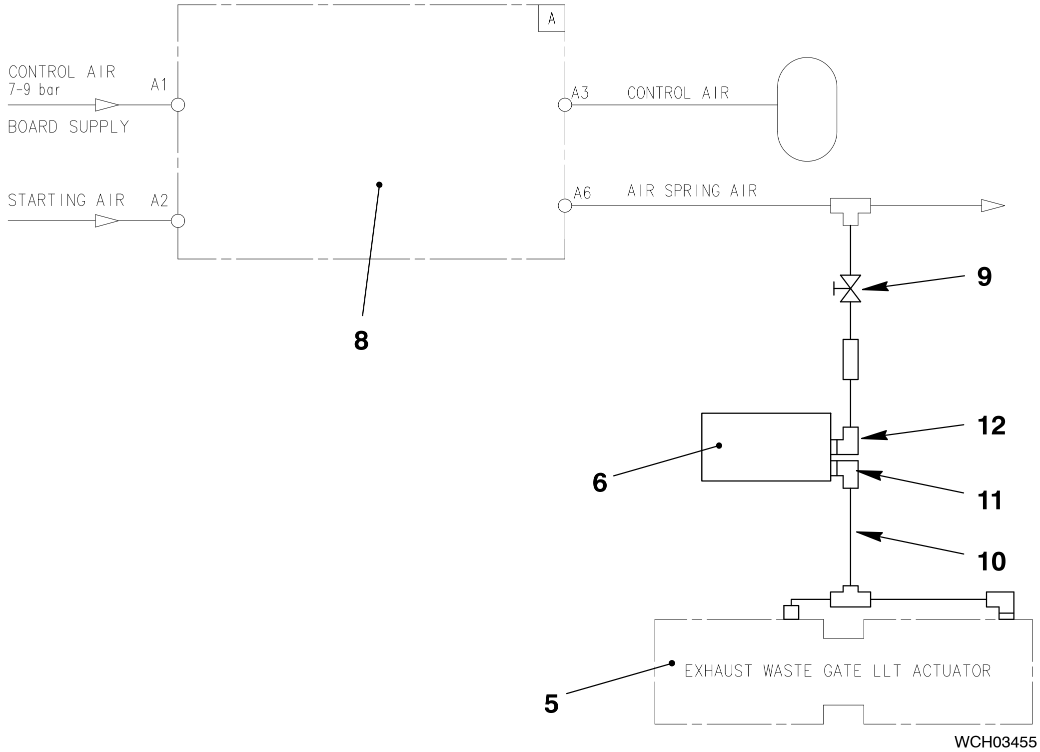



**Fig. 4: Schematic diagram air supply**

5 Actuator (ZS5372C)
6 3/2-way solenoid valve (CV7077C)
8 Control air supply unit
9 Ball valve
10 Control air pipe
11 Control air outlet
12 Control air inlet

# Drainage System and Wash-water Pipe System

## 1. General

You must do checks at regular intervals to make sure that all drain pipes are not blocked. The checks on the drain pipes from the piston rod gland box (20) and the piston underside (9) are important (see Fig. 1).

The ambient temperature and humidity can cause condensate to flow out upstream and downstream of the scavenge air cooler (14). Very high ambient conditions can make up to 0.16 kg/kWh of condensate.

## 2. Condensate Drain

**Note: Blocked drains let too much condensate collect in the scavenge air receiver. The water / water vapor has an unwanted effect on piston operation and increases wear on the piston rings and cylinder liners.**

The condensate drain must operate correctly as follows (for more data, refer to 0500–1 Usual Operation, paragraph 2):

1) Make sure that all valves in the condensate drain pipe are fully open.

2) Make sure that the ball valves (18) and (19) are in the position USUAL OPERATION (see Fig. 1).

**Note: The condensate collectors (12) collect dirt particles.**

3) At regular intervals, remove dirt particles from the condensate collector (12) when the engine has stopped (refer to the Maintenance Manual 0380-1 Maintenance Schedule).

4) At regular intervals, look at the sight glasses of the condensate collector (12) to make sure that water flows (refer to the Maintenance Manual 0380-1 Maintenance Schedule).

**Note: For engines with two turbochargers there are two more level switches (LS4072A and LS4076A) installed. For more data refer to, 4003-4 Pipe Diagram – Water Systems (Scavenge Air Receiver and Turbocharger).**

If one, or the two level switches LS4071A (10), LS4075A (13) activates an alarm (condensate level too high), you must find the cause immediately and correct the defect. The possible causes of the alarm are as follows:

- The ball valves (18) and (19) are in the position CLOSED (see Fig. 1).
- The scavenge air cooler (14) is defective (see 6606–1).
- If the orifices (11) are blocked and / or there is too much contamination in the condensate collector (12) (the filter is blocked).

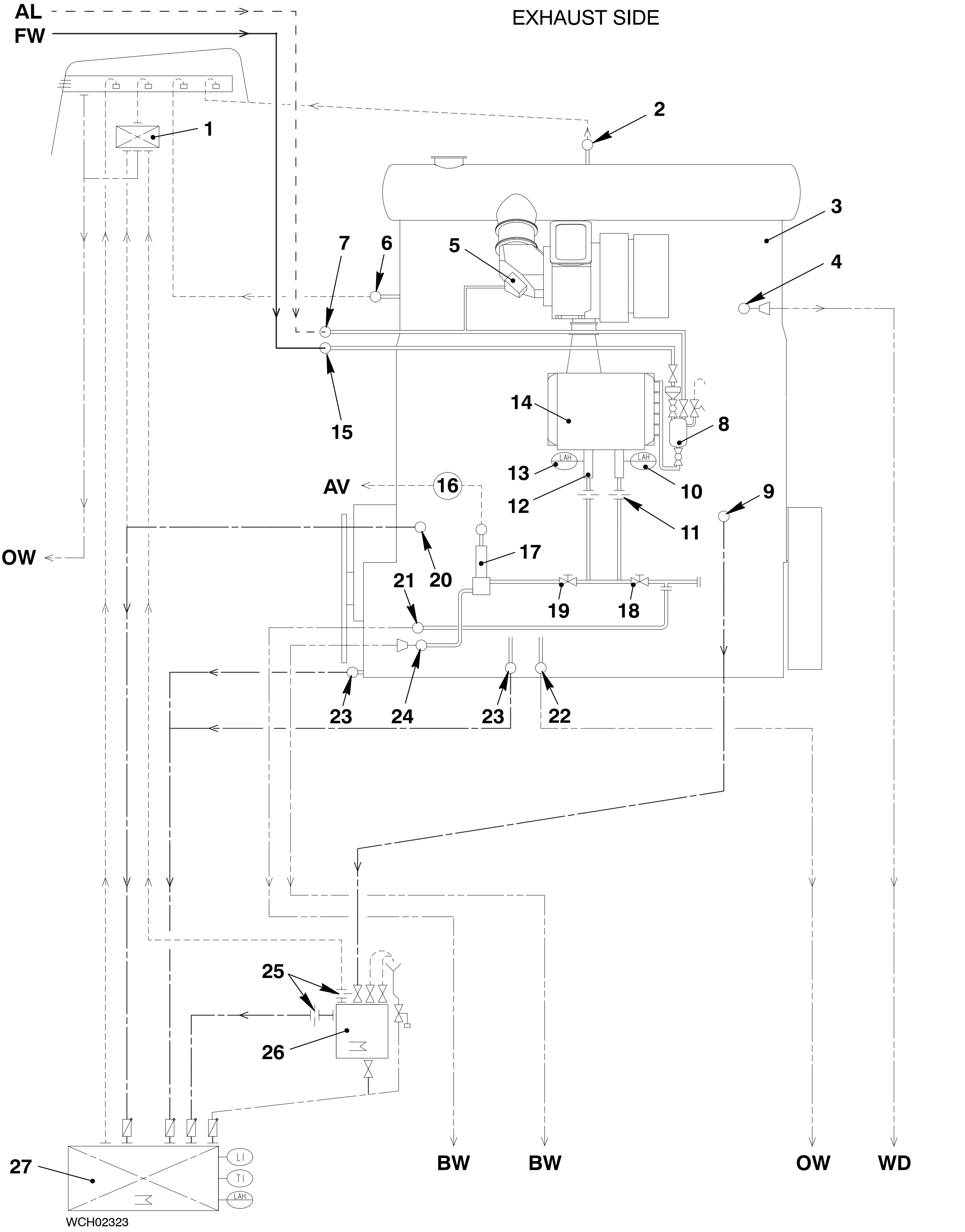
5) To clean the condensate collector (12) and the orifice (11) do step a) to step c).

   a) Stop the engine.

   b) Clean the condensate collector (12).

   c) Clean the orifice (11).

**Note: You must clean the filters in the condensate collector (12) and the orifices (11) as soon as possible.**




DATA FOR ENGINES WITH ONE TURBOCHARGER

**Fig. 1: Schematic diagram**

**Key to Fig. 1**

| | | | |
|---|---|---|---|
| 1 | Air vent manifold | 18 | Ball valve |
| 2 | Vent – turbocharger outlet | 19 | Ball valve |
| 3 | Main engine | 20 | Leak gland box – outlet |
| 4 | Cylinder cooling water drain – outlet | 21 | SAC wash water – outlet |
| 5 | Dry cleaning device (TC) | 22 | Oily water from SAC – outlet |
| 6 | Vent crankcase – outlet | 23 | Leak outlets (main engine) |
| 7 | Air for wash plant TC and SAC – inlet | 24 | SAC condensate water – outlet |
| 8 | SAC wash plant | 25 | Orifice |
| 9 | Dirty oil piston underside – outlet | 26 | Sludge oil trap |
| 10 | Level switch (LS 4071A) | 27 | Sludge tank |
| 11 | Orifice | | |
| 12 | Condensate collector | AL | Air line from board system |
| 13 | Level switch (LS 4075A) | AV | Air vent |
| 14 | Scavenge air cooler | BW | Drain to bilge water tank |
| 15 | Water for wash plant SAC – inlet | FW | from fresh–water system |
| 16 | SAC Vent | OW | Drain to oil / water drain tank |
| 17 | Vent unit | WD | Drain to water drain tank |

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# Pilot Fuel System

## 1. General

Pilot fuel is diesel fuel (marine diesel oil) that is injected into the cylinder to ignite the gas/air mixture during engine operation in gas mode. The injection timing and pilot fuel quantity is electronically controlled (refer to 4002−1, Engine Control System, paragraph 3.19 Pilot Fuel Pressure Control and paragraph 3.20 Pilot Fuel Injection Control).

**Note: The pilot fuel system also operates with a decreased quantity of fuel injection during engine operation in diesel mode. This prevents contamination on the ends of the pilot injection valves and the pre-combustion chambers.**

The pilot fuel system (Fig. 1 and Fig. 2) has the supply unit, HP pipes and pilot injection valves. For the schematic diagram of the pilot fuel system on the plant side, refer to 0300−1 Diesel Engine Fuels, paragraph 8.

The supply unit is installed on the free end of the engine and has the items that follow:

- Electrically-operated pilot fuel pump, which has a built-in relief valve
- Duplex filter
- Needle valve
- HP pipes
- Main leakage collector
- Leakage pipes.

## 2. Function

The pilot fuel pump (3, Fig. 3) increases the pressure of the pilot fuel to the applicable level (for the values, refer to 0230−1 Operation Data Sheet). The pilot fuel pump (3) is an electrically operated radial piston pump with a built-in overpressure bypass valve.

HP pilot fuel flows through the HP fuel pipes (3 and 5, Fig. 2), the supply blocks (9) and connector blocks to the pilot injection valves (10) on each cylinder. The connector block (1) on cylinder No.1 has the pressure transmitters PT3465C. The connector block (2) on cylinder No.2 has the pressure transmitters PT3466C.

Leakage fuel flows from the connector blocks to the main collector in the rail unit.

All of the high pressure pipes have double walls. The HP fuel pipes absorb sudden differences in pressure.

Leakage fuel that collects in the annular space in the pipes flows into a collector. This collector has a leakage sensor.

The pilot injection valves have built-in solenoid valves. The engine control system (ECS) controls these solenoid valves for accurate timing and duration of the fuel injection. For more data refer to 4002−1 Engine Control System, paragraph 3.20.

The prechambers, which are a part of the pilot injection valves, give the best ignition and combustion stability. For more data about the pilot injection valves, refer to 2790−1 Pilot Injection Valve.

HT water from the cylinder cover and system oil keep cool the prechambers.

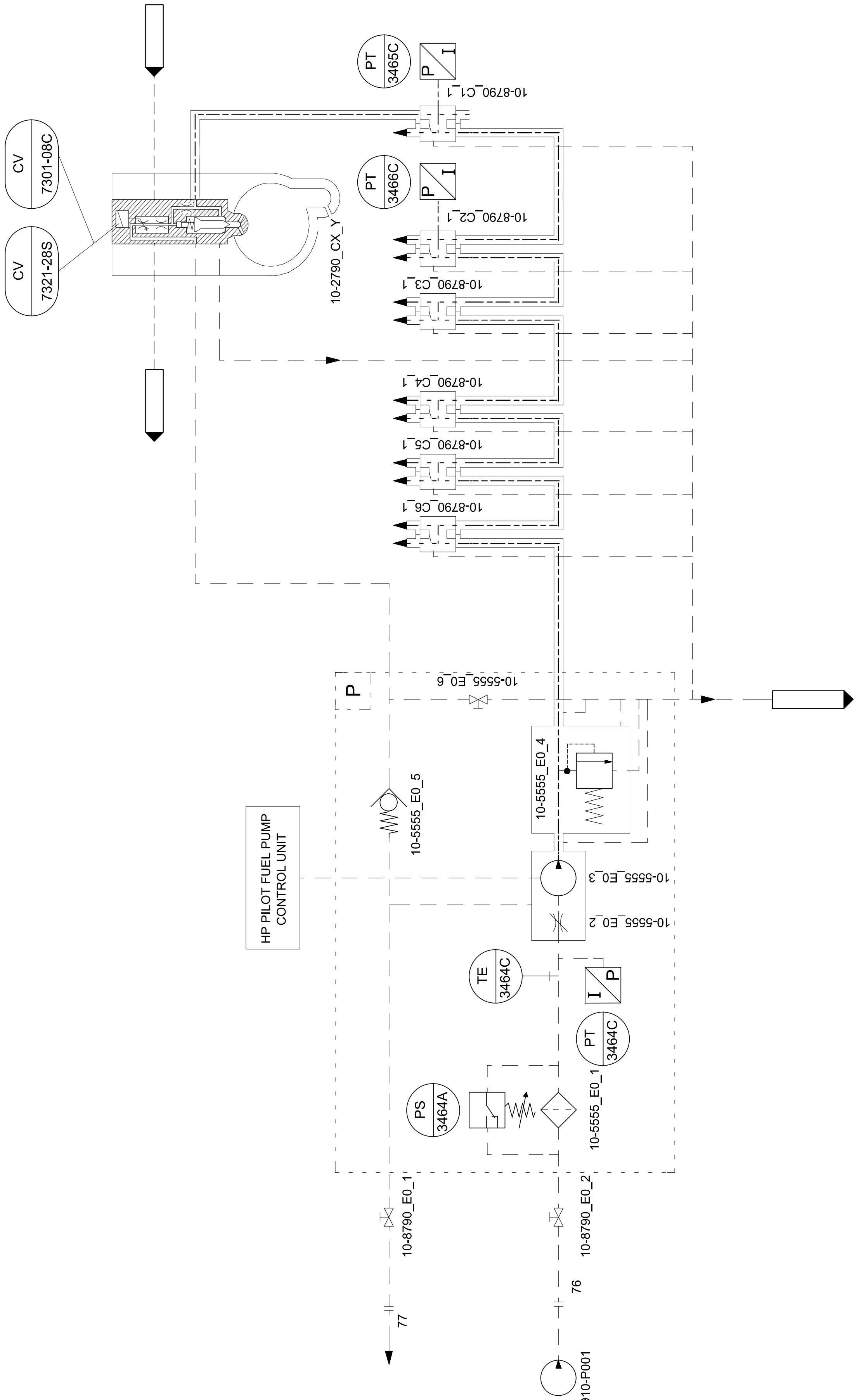



**Fig. 1: Pilot Fuel System − Schematic Diagram**

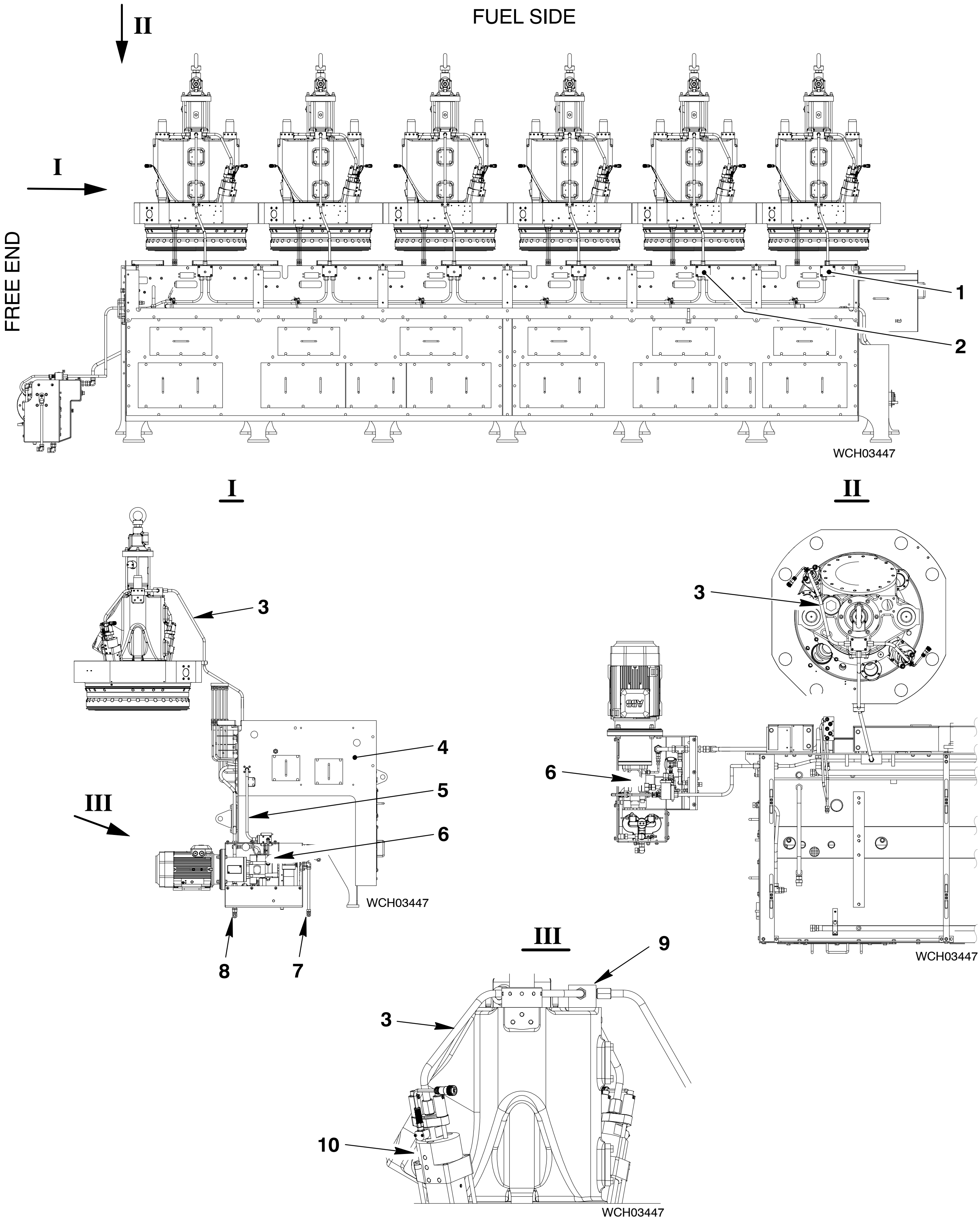



**Fig. 2: Pilot Fuel System**

1 Connector block (with pressure transmitters PT3465C)
2 Connector block (with pressure transmitters PT3466C)
3 HP fuel pipe − pilot valve
4 Rail unit
5 HP fuel pipe − pilot valve
6 Supply unit for pilot fuel system
7 Pilot fuel inlet
8 Pilot fuel return
9 Supply block
10 Pilot injection valve

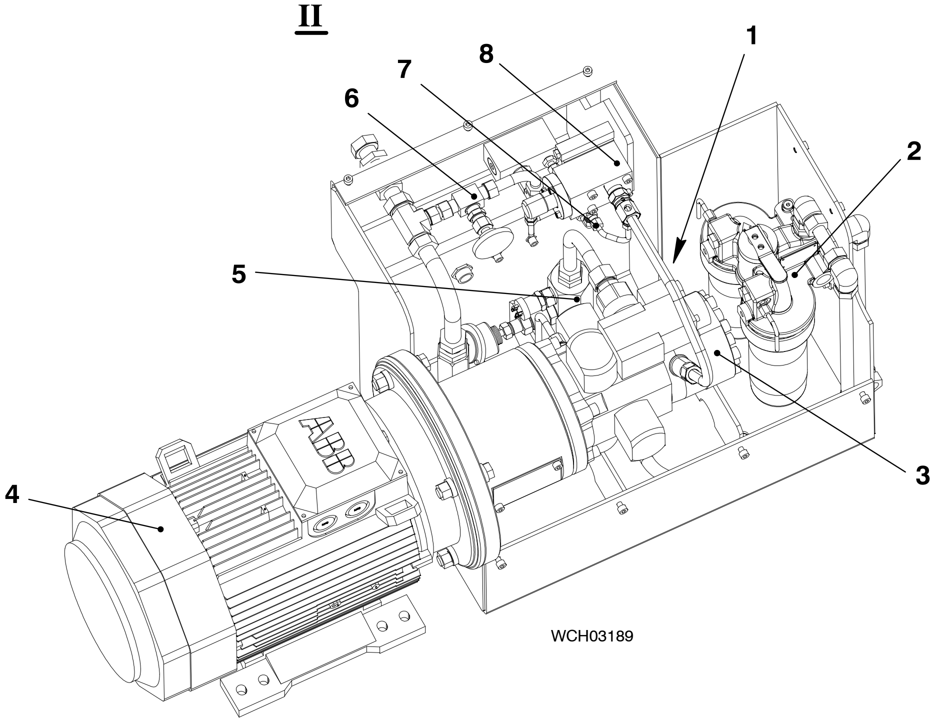



**Fig. 3: Supply Unit for Pilot Fuel System**

1 HP fuel pipe − pilot valve
2 Duplex filter
3 Pilot fuel pump (electrically operated)
4 Electric motor
5 Measuring unit
6 Needle valve
7 Leakage pipe
8 Relief valve

# Electrical Trace Heating System



## 1. General

The main and emergency switchboards supply a single phase 230 VAC supply to the control box E88 (see Fig. 1 and Fig. 2). The control box E88 is installed in the engine room near the engine.

The control box E88 also supplies 24 VDC to the XS3411C HFO supply and to the temperature element TE3411C.

## 2. Electrical Trace Heating

The control box E88 supplies electrical power to the terminal box E89. The terminal box E89 supplies power to each connection box E89.01 to E89.0X (see Fig. 1).

The connection boxes E89.01 to E89.0X supply power to the trace heating cables for each fuel injection pipe (see Fig. 2 and Fig. 3).

The electrical trace heating system increases the temperature of the fuel injection pipes to the target temperature of 130°C ± 10% and keeps this temperature stable.

The electrical heating cables are the self-control type i.e. the electrical current absorbed decreases in relation to an increase in temperature until a stable condition occurs. The power consumption is related to the temperature of the electrical heating cables.

When the heating cable is at the target temperature, the heating cable stays on, but at the lowest power consumption.

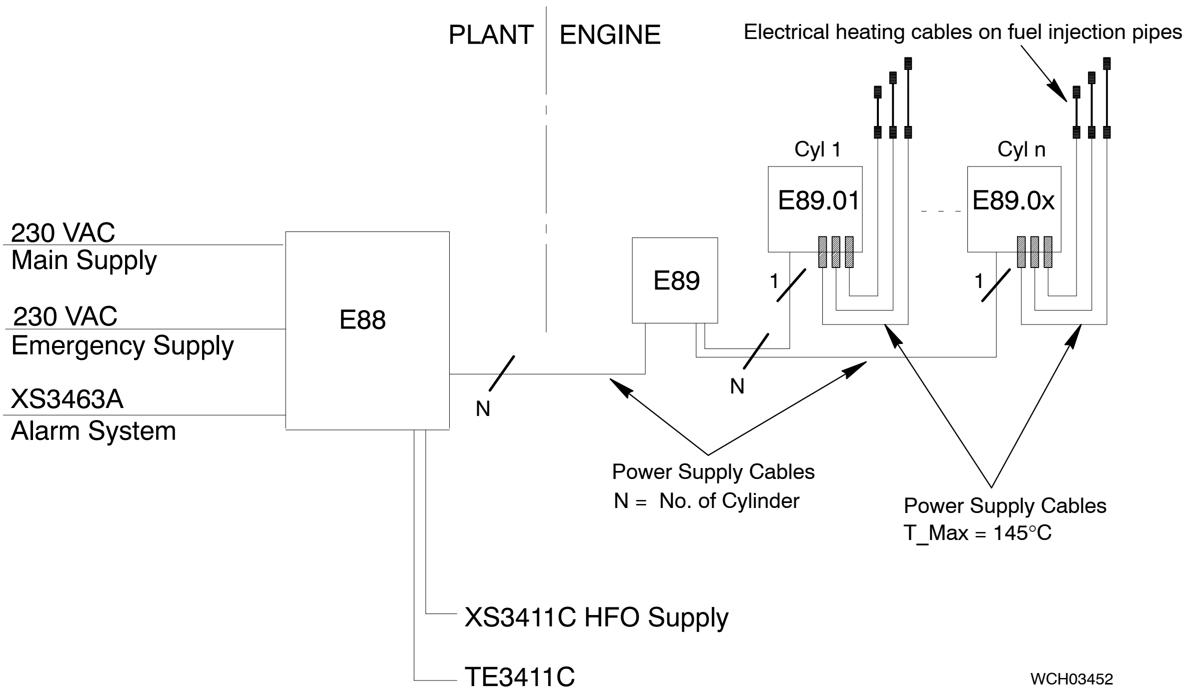



Fig. 1: Schematic Diagram – Electrical Heating System

## 2.1 Power Values

The table below gives an estimate for the power values for the heating cables installed on the engine:

| **Number of Cylinders** | **4** | **5** | **6** | **7** | **8** |
|---|---|---|---|---|---|
| **Power Used (W)** Worst Case T_Amb = 0°C | 2200 | 2700 | 3300 | 3800 | 4300 |
| **Power Used (W)** Stable Operation Conditions | 1300 | 1600 | 1900 | 2200 | 2500 |

You must do a resistance insulation test at regular intervals (a minimum of four each year) for each electrical trace heating circuit. The results must be monitored and recorded (refer to the Maintenance Manual 8825-1).

## 2.2 Usual Operation

When the engine operates with:

- Marine Diesel Oil (MDO): The heating cables must be set to off.
- Heavy Fuel Oil (HFO): It is recommended that the heating cables are set to on. This keeps the HFO at the correct temperature.

When the engine has stopped after operation with:

- MDO − The heating cables must be set to off.
- HFO − The heating cables must be set to on.

## 2.3 Operation Modes

The electrical heating system can operate in manual mode or automatic mode.

In the control box E88, you set the switch to the applicable position as follows:

- On
- Off
- Auto.

In Auto mode, the temperature measured on the fuel inlet pipe, sets the electrical trace heating system to on or off.

If available, you can also use the MDO/HFO switch in the plant to set to on or off, the electrical heating system (MDO − open contact, HFO − closed contact).

## 2.4 MDO / HFO Supply Status (E88 to ECS)

The temperature element TE3411C (8, Fig. 2) measures the fuel temperature in the fuel inlet pipe (7).

The control box E88 gives the status signal XS3411C HFO Supply to the ECS in relation to the measured temperature if:

- The temperature is less than 60°C, then the contact is open (when the engine operates with MDO)
- The temperature is equal to or more than 60°C, then the contact is closed (when the engine operates with HFO).

The status is shown on the LDU-20 on the related page (see 4002−2, paragraph 3.22 User Parameters).

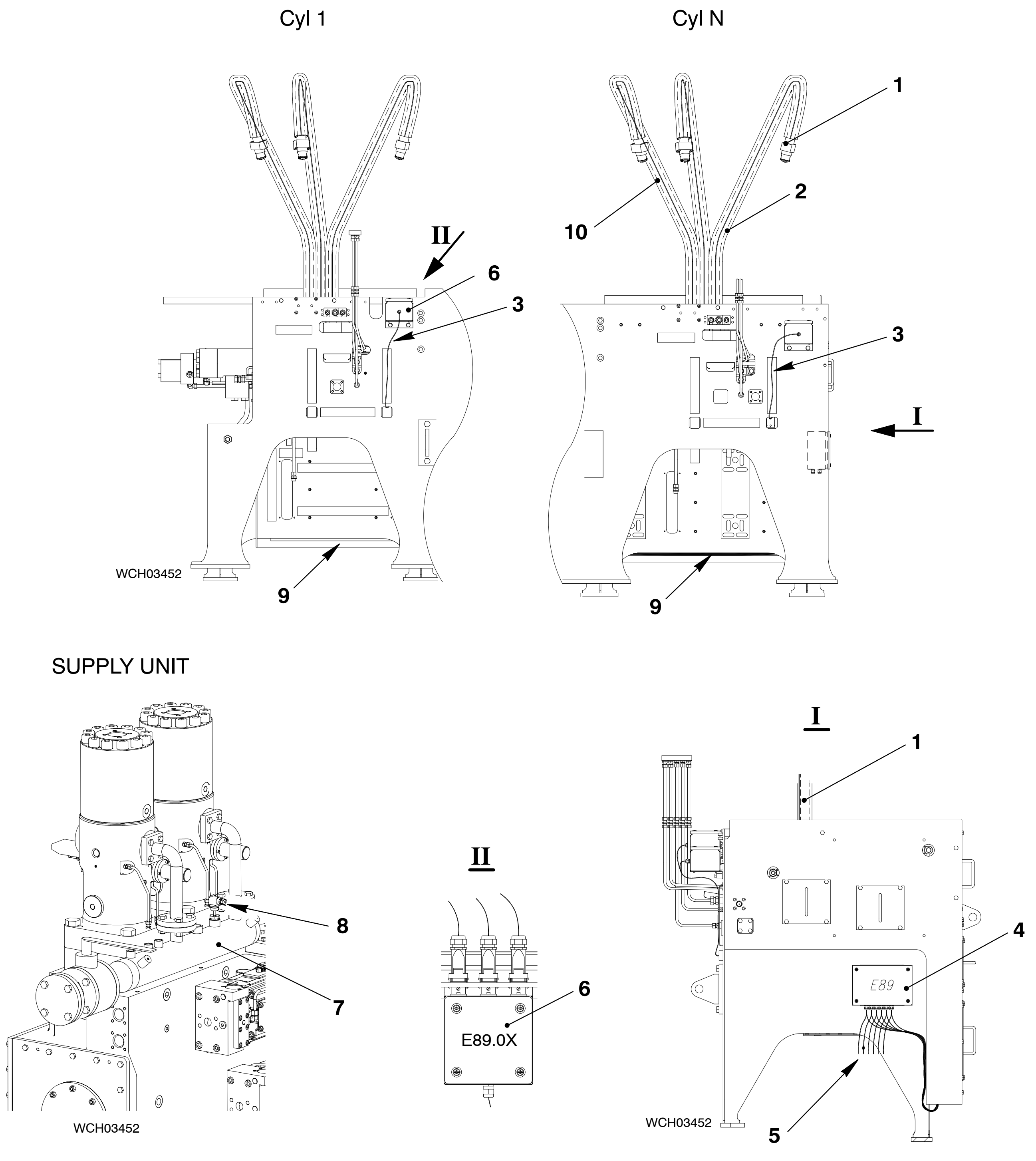



**Fig. 2: Electrical Trace Heating**

1 Fuel injection pipes
2 Heating cables
3 Power supply cable (to connection box E89.0X)
4 Terminal box E89
5 Power supply cables (to E88)
6 Connection box E89.0X
7 Fuel inlet pipe
8 Temperature element TE3411C
9 Power supply cables (to next E89.0X)
10 Insulation

## 2.5 Alarms from E88 to the Alarm and Monitoring System

The control box E88 gives a digital output signal XS3463A to the alarm and monitoring system (AMS) as follows:

- No alarm: The contact is closed.
- Alarm on: The contact is open.

The control box E88 activates an alarm when there is a minimum of one of the conditions that follow:

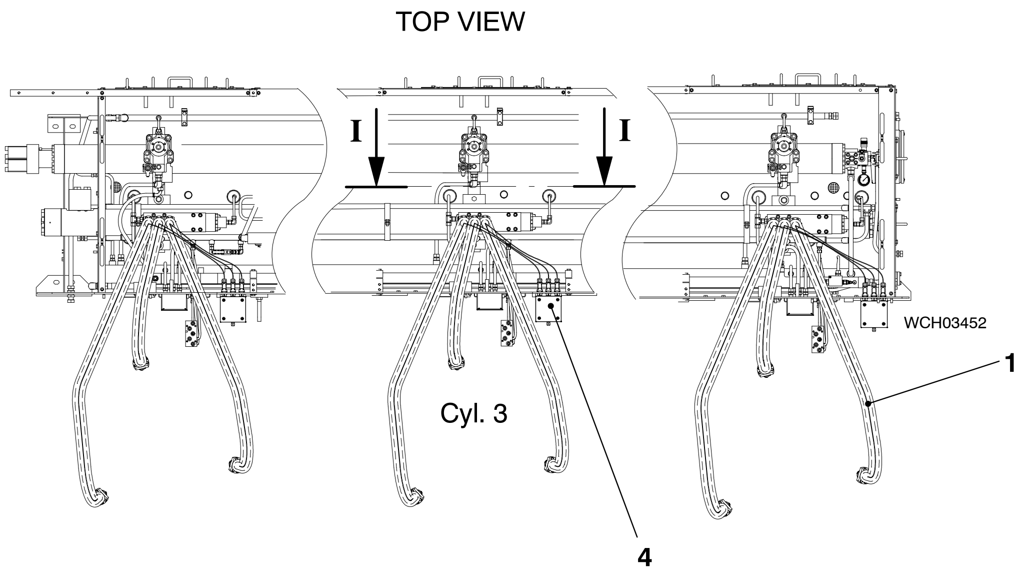
- Manual ON mode when the engines is supplied with MDO
- Manual OFF mode when the engine is supplied with HFO
- There is an internal 24 VDC power supply failure in the control box E88.
- The temperature sensor TE3411C is disconnected, broken or out of range.
- In the control box E88, a minimum of one residual current protection device finds a leakage current, which is equal to, or more than 300 mA (power supply output for the heating cables)
- The control box E88 is not connected to the emergency switchboard
- The control box E88 is not connected to the main switchboard.

## 2.6 230 VAC Emergency Switchboard Supply to E88

The control box E88 is connected to the main and emergency switchboards. The default 230 VAC supply is from the main switchboard.

If the main switchboard becomes defective, the emergency switchboard will supply 230 VAC to the control box E88. When the main switchboard becomes serviceable again, the emergency switchboard will continue to supply 230 VAC. The control box E88 sets to on the related yellow indication (see Fig. 4).

It is recommended that you set to off then on, the main switch in the control box E88. This will make sure that the main switchboard supplies 230 VAC to E88.



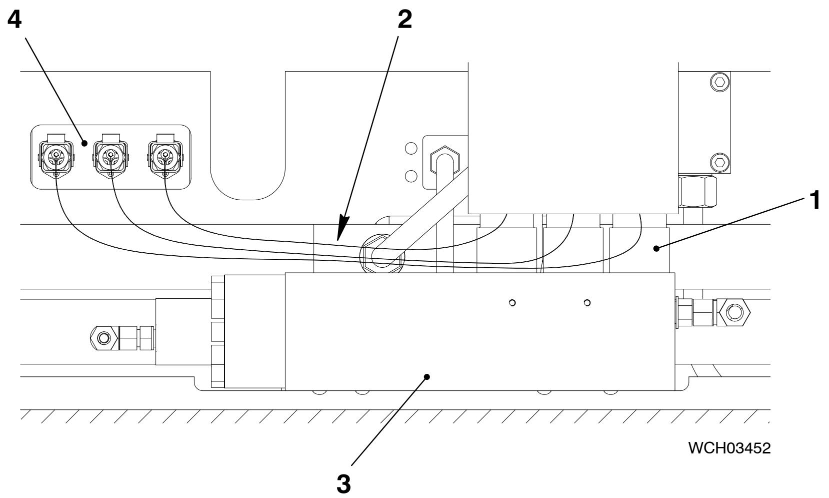




**Fig. 3: Connection Box E89.03**

1 Fuel injection pipes
2 Heating cables
3 Flow limiter valve 10-5560_CX_2
4 Connection box E89.03 (Cyl. 3)

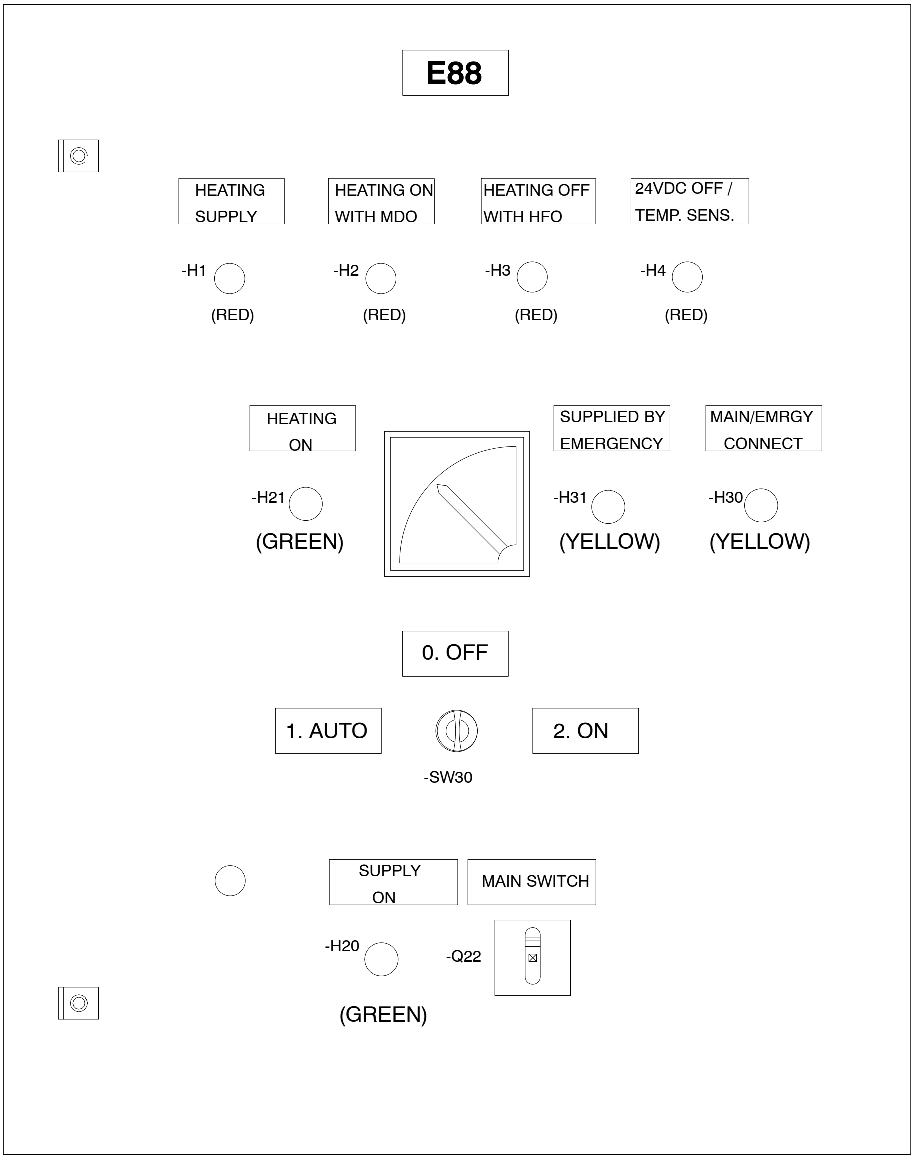



**Fig. 4: Control box E88**

# Engine Monitoring

# Group 9

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# Crank Angle Sensor Unit

## 1. General

The crank angle sensor unit is installed on the supply unit drive (7, Fig. 1) at the driving end.

There are two crank angle systems that monitor the teeth on the intermediate wheel. The two sets of proximity sensors (2, 3 and 4, 5) operate independently to sense the teeth on the intermediate wheel (1).

Two more proximity sensors (10) and (11) are used to find the crank angle marks for TDC and BDC on the flywheel (8) (see Fig. 2).

All proximity sensors are connected to each CCM−20. For more data, refer to 4002−1, paragraph 3.1.

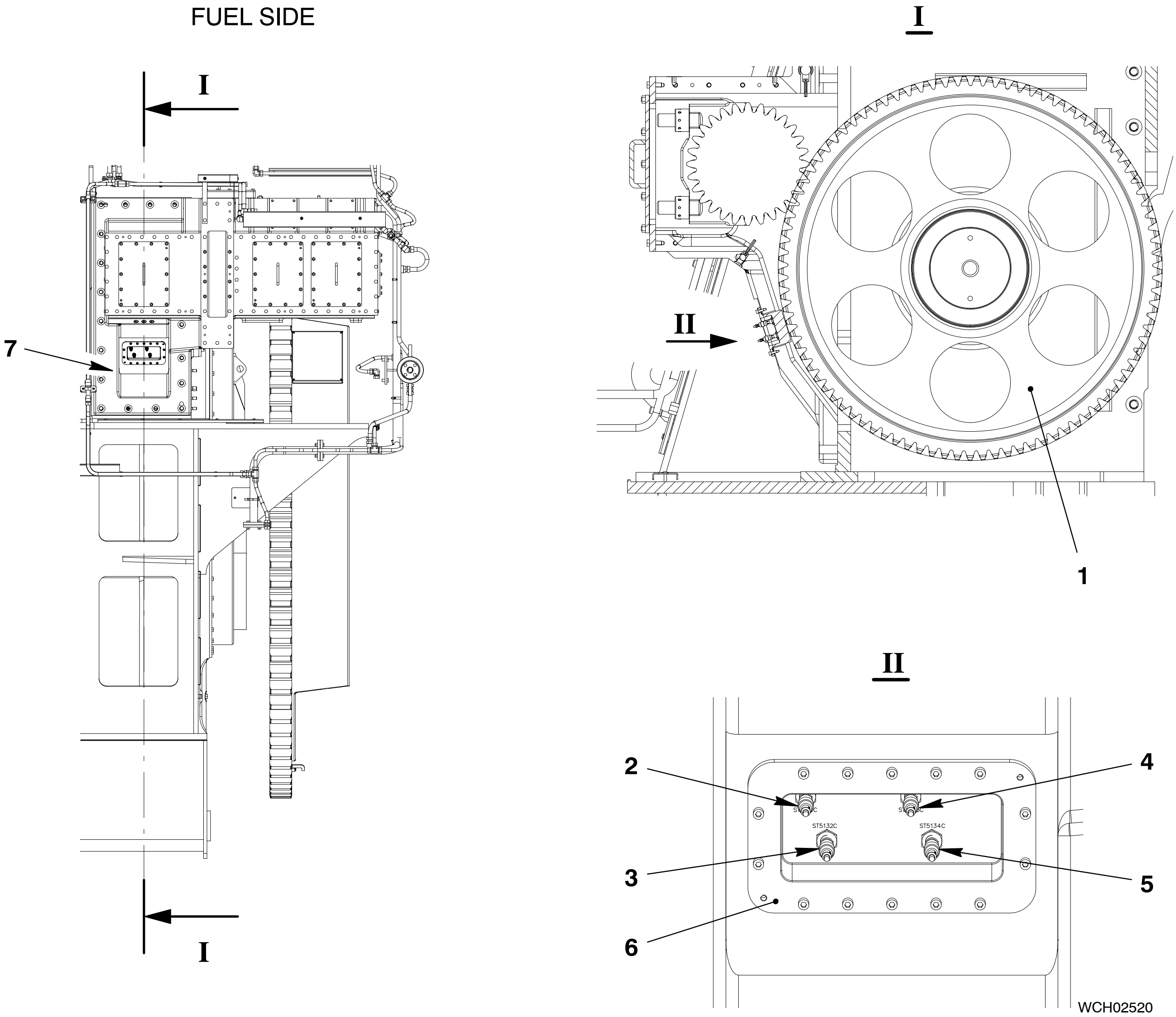



**Fig. 5: Crank angle sensor unit**

1 Crankshaft gear wheel
2 Proximity sensor ZS5124C (BDC)
3 Proximity sensor ST5132C
4 Proximity sensor ST5131C
5 Proximity sensor ZS5123C (TDC)
6 Proximity sensor ST5133C
7 Proximity sensor ST5134C
8 Supply unit drive

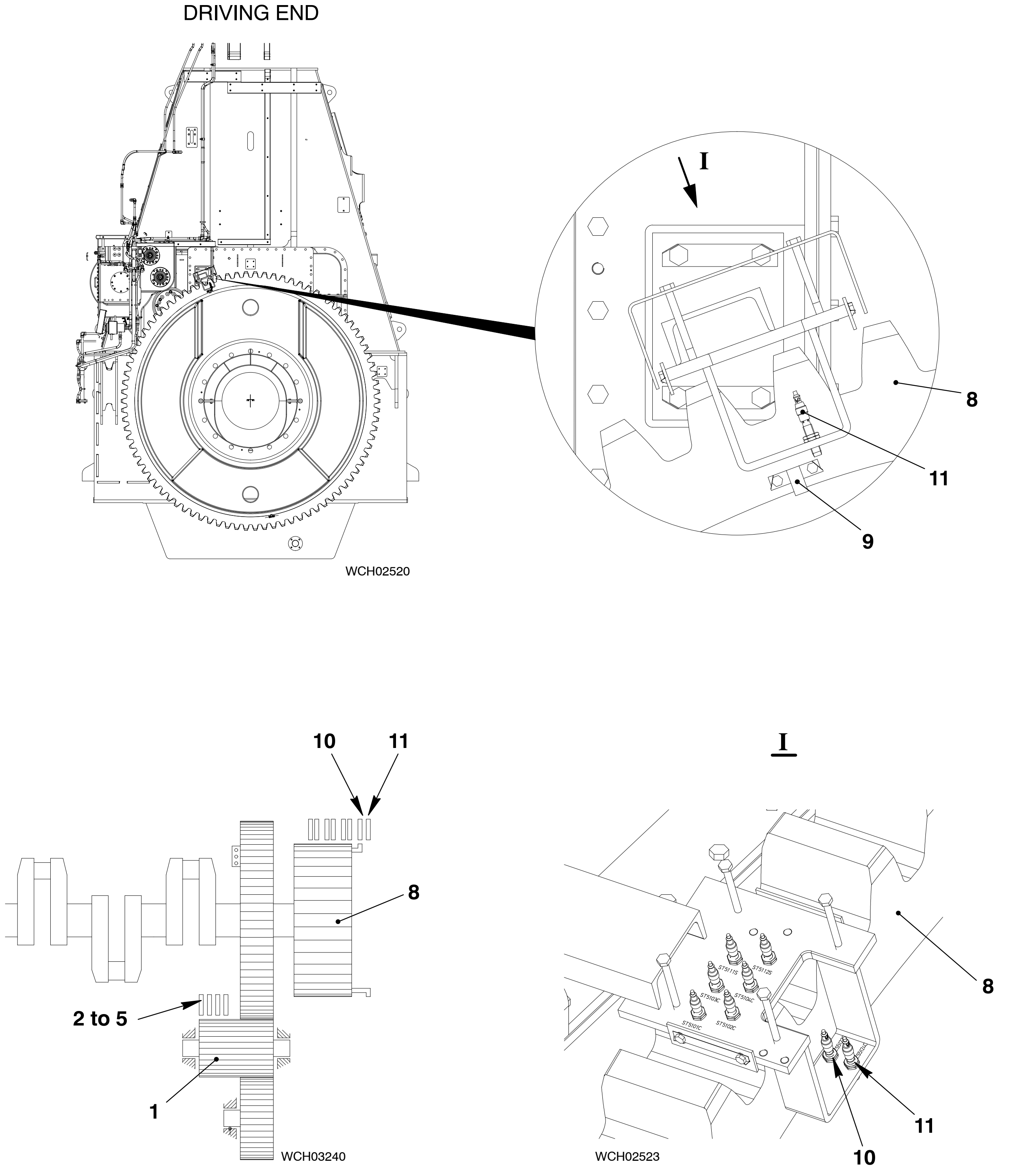



**Fig. 6: Crank Angle Sensor Unit**

1 Intermediate wheel
2 Proximity sensor ST5131C
3 Proximity sensor ST5132C
4 Proximity sensor ST5133C
5 Proximity sensor ST5134C
8 Flywheel
9 Crank angle mark
10 Proximity sensor ZS5123C
11 Proximity sensor ZS5124C

# Oil Mist Detector (Graviner)

## 1. General

The engine has an oil mist detection system. The system includes the sensors (2) and the control unit (1) on the engine (see Fig. 1).

A display unit (8) is installed in the control room (Fig. 2).

The sensors (2) are installed on the fuel side of the engine for:

- Each cylinder of the divided crankcase
- The supply unit drive
- The supply unit.

The oil mist detection system continuously monitors the concentration of oil mist in the crankcase, supply unit drive and the supply unit. If there is a high oil mist concentration, the oil mist detector activates an alarm.

Damage to the bearings is quickly found and explosions in the crankcase are prevented. For more data, refer to 0120−1 Prevention of Crankcase Explosions.

DATA FOR SIX CYLINDERS

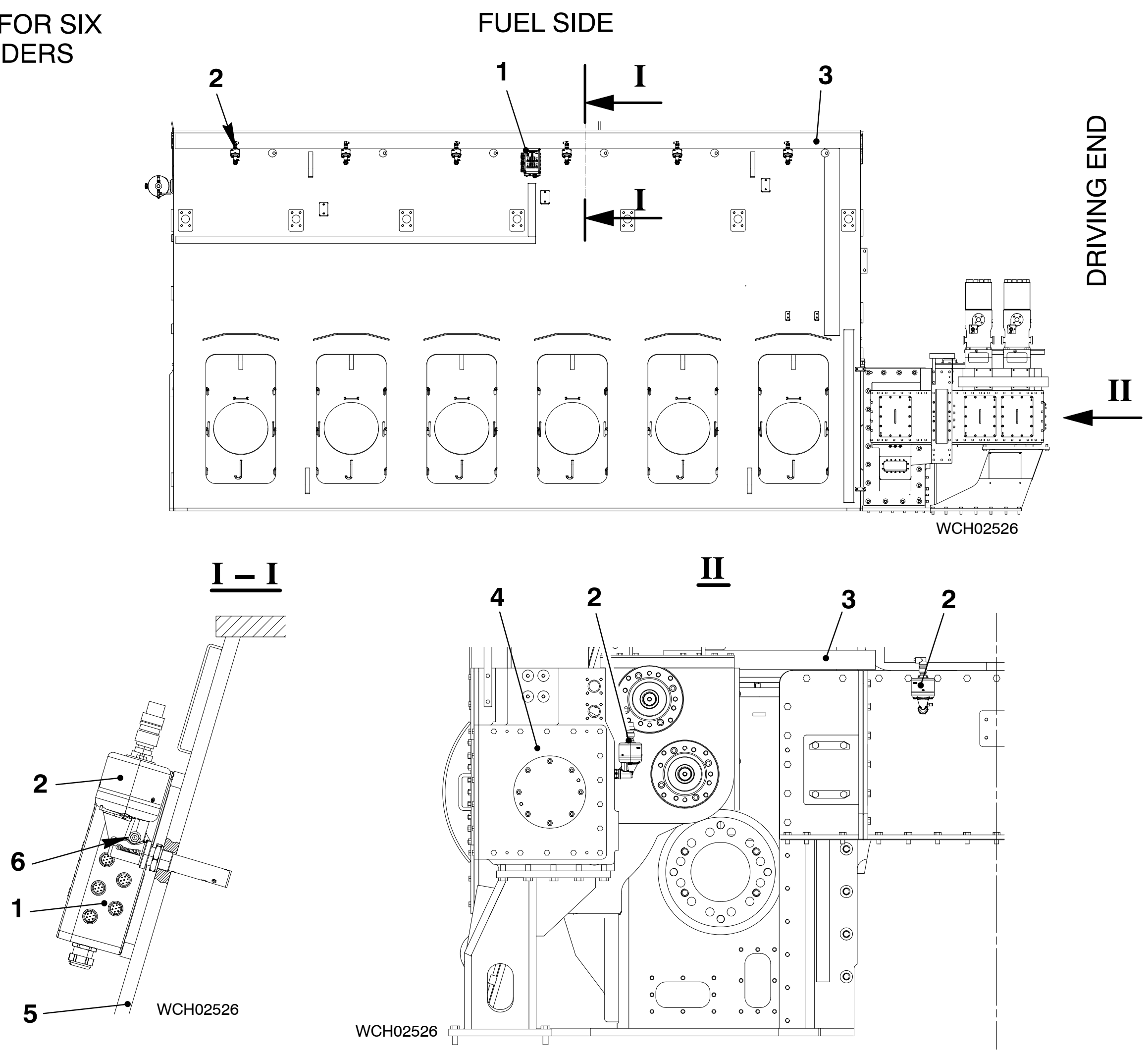



**Fig. 1: Location of Sensors**

| | | | |
|---|---|---|---|
| 1 | Control unit E15.1 | 4 | Supply unit |
| 2 | Sensor | 5 | Column |
| 3 | Cable guide | 6 | Test connection |

## 2. Function

Each sensor (5, Fig. 2) optically monitors the concentration of oil mist. Each sensor has a self-test function to make sure that there are no internal faults.

Data communication is between the control unit (2) and the display unit (1).

The adjustments can be programmed in the display unit (1).

The menu-driven software has three user levels:

- User: Read-only of data.
- Operator: Password-protected level for access to most adjustments and functions.
- Service: Password-protected level for authorized staff of the manufacturer and service personnel.

**Note: Instructions that relate to adjustments, commissioning, troubleshooting, and maintenance are given in the related documentation of the manufacturer.**

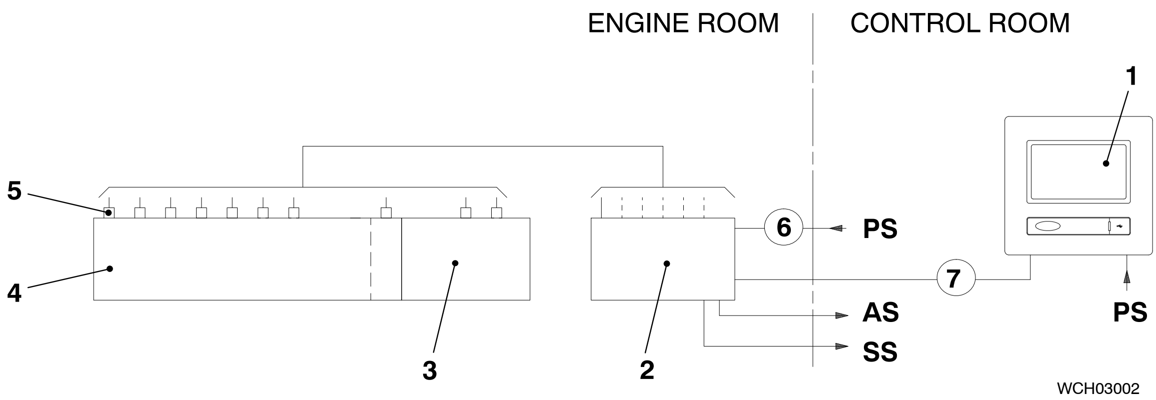



**Fig. 2: Schematic Diagram**

| | | | |
|---|---|---|---|
| 1 | Display unit | 6 | Power cable |
| 2 | Control unit E15.1 | 7 | Data cable |
| 3 | Supply unit | PS | Power supply |
| 4 | Crankcase and gear box | AS | to alarm system |
| 5 | Sensor | SS | to safety system |

# Oil Mist Detector (Specs Type Vision IIIC)

## 1. General

The engine has an oil mist detection system. The system includes the sensors (2) and the junction box (1) on the engine (see Fig. 1).

A display unit (8) is installed in the control room (Fig. 2).

The sensors (2) are installed on the fuel side of the engine for:

- Each cylinder of the divided crankcase
- The supply unit drive
- The supply unit.

The oil mist detection system continuously monitors the concentration of oil mist in the crankcase, supply unit drive and the supply unit. If there is a high oil mist concentration, the oil mist detector activates an alarm.

Damage to the bearings is quickly found and explosions in the crankcase are prevented. For more data, refer to 0120−1 Prevention of Crankcase Explosions.

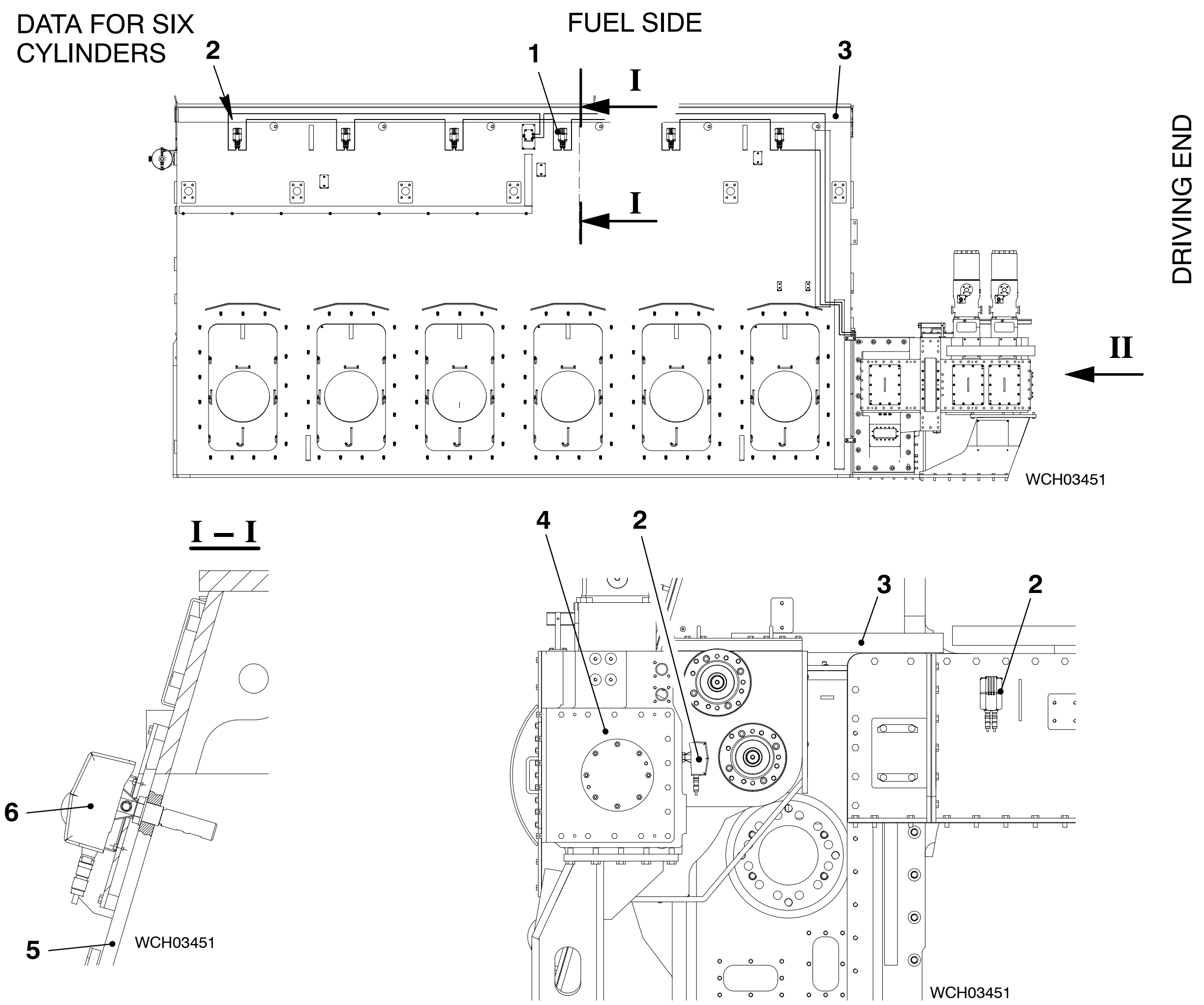



**Fig. 1: Location of Sensors**

1 Junction box
2 Sensor
3 Cable guide
4 Supply unit
5 Column

## 2. Function

Each sensor (5, Fig. 2) optically monitors the concentration of oil mist. Each sensor has three indications that show power, fault and alarm statuses.

Data communication is between the junction box (2) and the control panel (1).

The functions can be programmed and shown in the control panel (1).

The menu-driven software has three user levels:

- User: Read-only of data.
- Operator: Password-protected level for access to most adjustments and functions.
- Service: Password-protected level for authorized personnel of the manufacturer and service personnel.

**Note: Instructions that relate to adjustments, commissioning, troubleshooting, and maintenance are given in the related documentation of the manufacturer.**

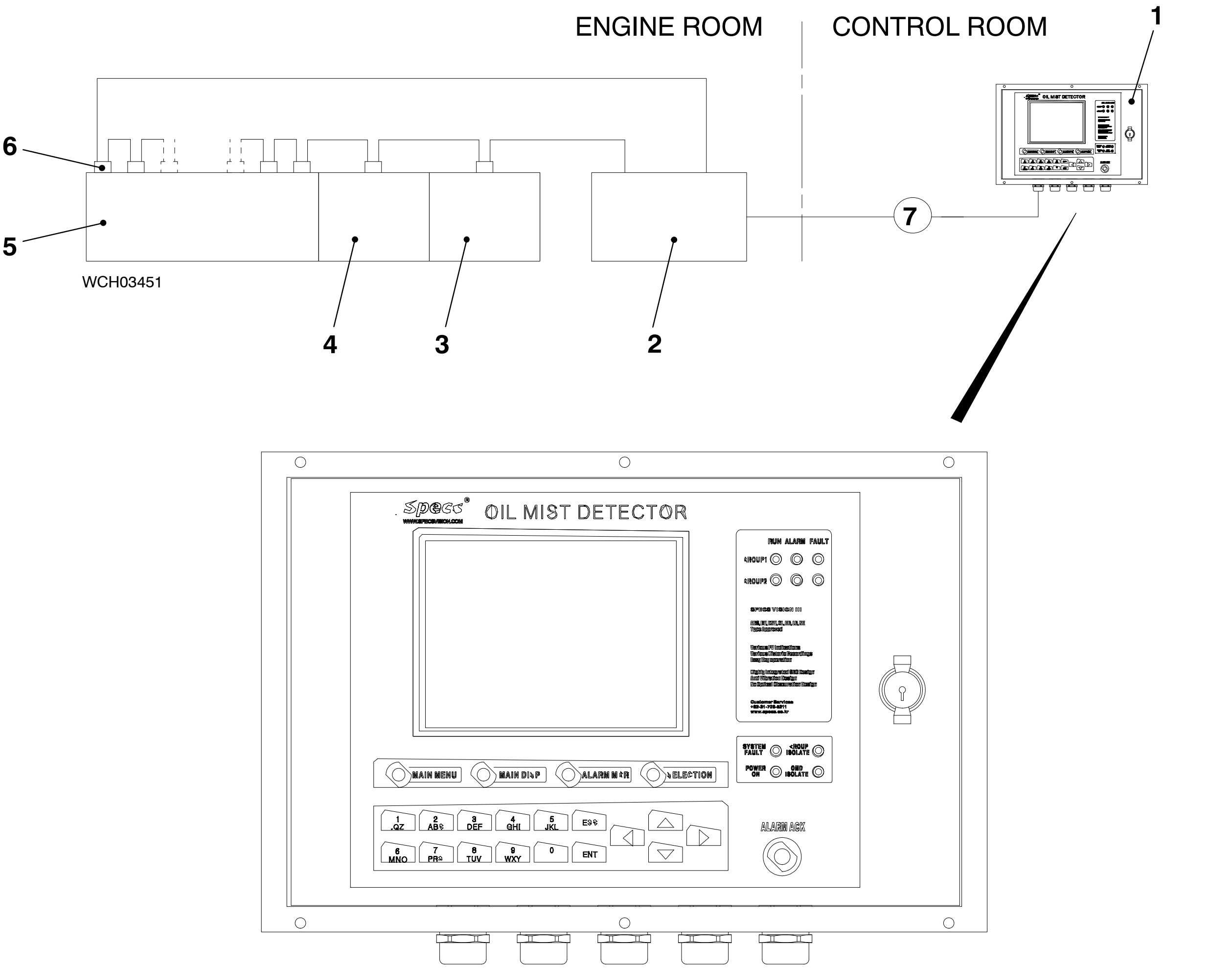



**Fig. 2: Schematic Diagram**

1 Control panel
2 Junction box
3 Supply unit
4 Gearbox
5 Crankcase
6 Sensor
7 Power / data cable
PS 24V DC Power supply

# Location of ECS Electronic Components

## 1. General

Most of the electronic components necessary for the ECS are installed on the engine.

The power supply box E85 (not shown) is installed near the engine.

## 2. Control boxes

Data about the most important control boxes and power supply boxes are given as follows:

### 2.1 E85

The E85 has the two 230 VAC power supplies for the CCM-20, MCM-11 and the LDU-20. The power supply box E85 also has circuit breakers to isolate the MCM-11 and each CCM-20.

### 2.2 E90

The E90 control box (8, Fig. 1) is attached to the fuel side of the rail unit. This control box (shipyard interface box) contains the terminals that give communication to the external systems.

### 2.3 E25

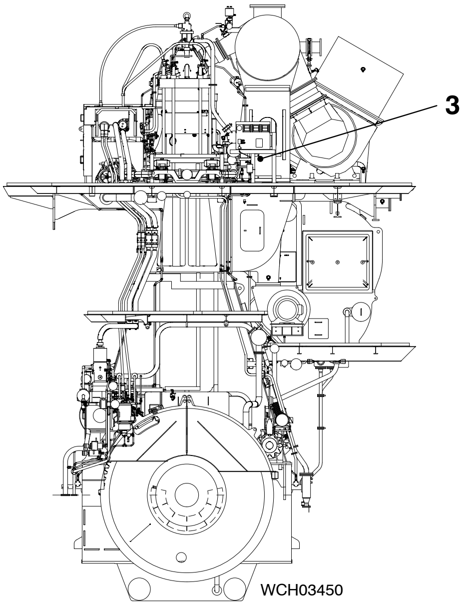
The E25 local control box (1) is attached to the free end of the engine. The E25 has the local control panel, the LDU-20 and the main control module (MCM-11).

### 2.4 E95.01 to E95.0#

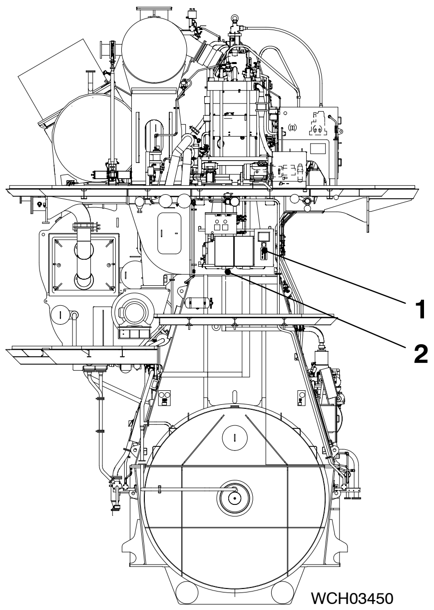
The control boxes E95.21 to E95.2# (4) and E95.41 to E95.4# (5) are attached to the related cylinders on the fuel side of the rail unit. Each control box has a CCM-20.

**Note: The power supplies have redundancy. If it is necessary to isolate the ECS, make sure that each of the two power supplies are set to off (for more data, refer to 4002–1 Engine Control System, paragraph 2.1).**

DRIVING END




FREE END




FUEL SIDE

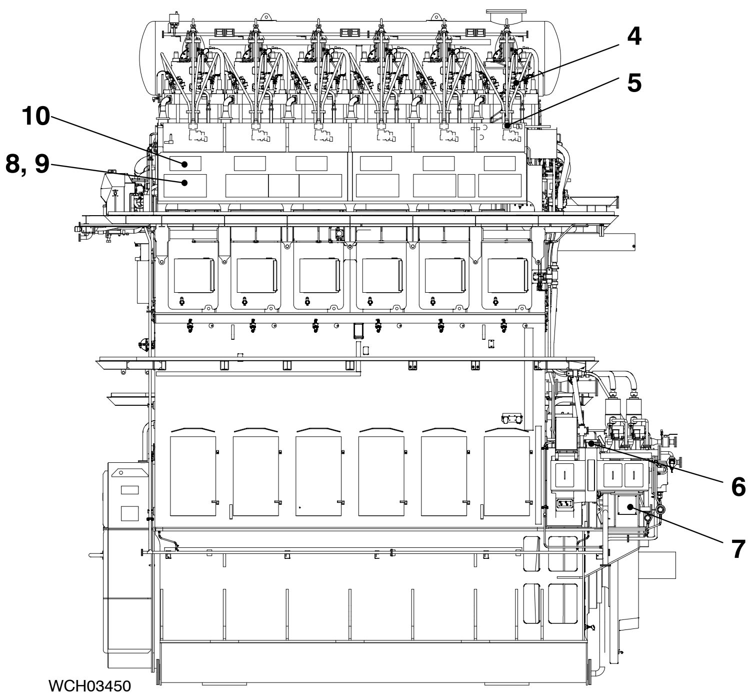



**Fig. 1: ECS Electronic Components**

1 Local control box E25
2 Terminal box E10
3 Control box E31
4 Terminal boxes E95.2# to E95.2#
5 Terminal boxes E95.4# to E95.4#
6 Terminal box E98
7 Terminal box E20
8 Terminal box E90
9 Terminal box E95
10 Terminal boxes E85.0 to E85.#