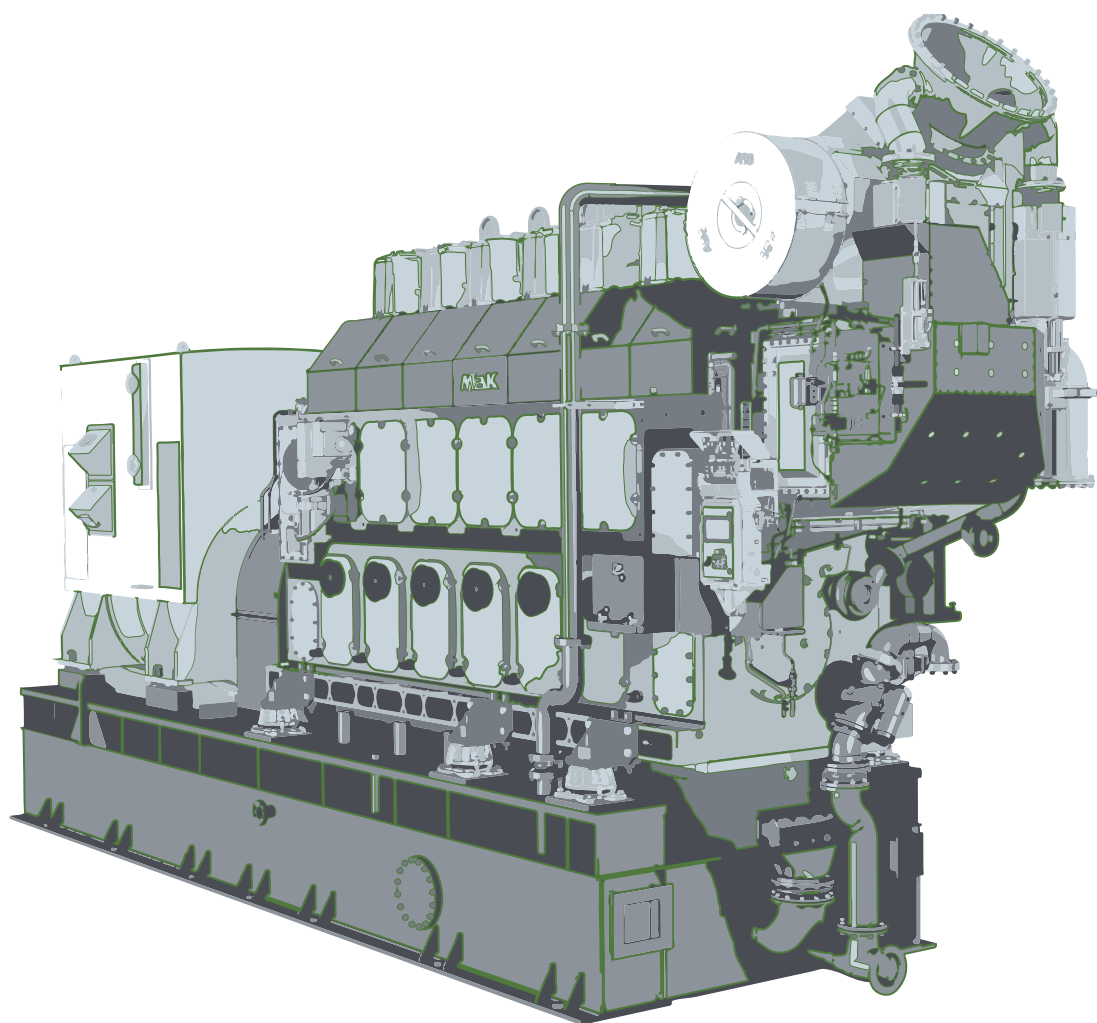


# M 46 DF

PROJECT GUIDE / GENERATOR SET



## INTRODUCTION

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**Caterpillar Motoren GmbH & Co. KG**

**P. O. Box, D-24157 Kiel**

**Germany**

**Phone +49 431 3995-01**

**Telefax +49 431 3995-2193**

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## INTRODUCTION

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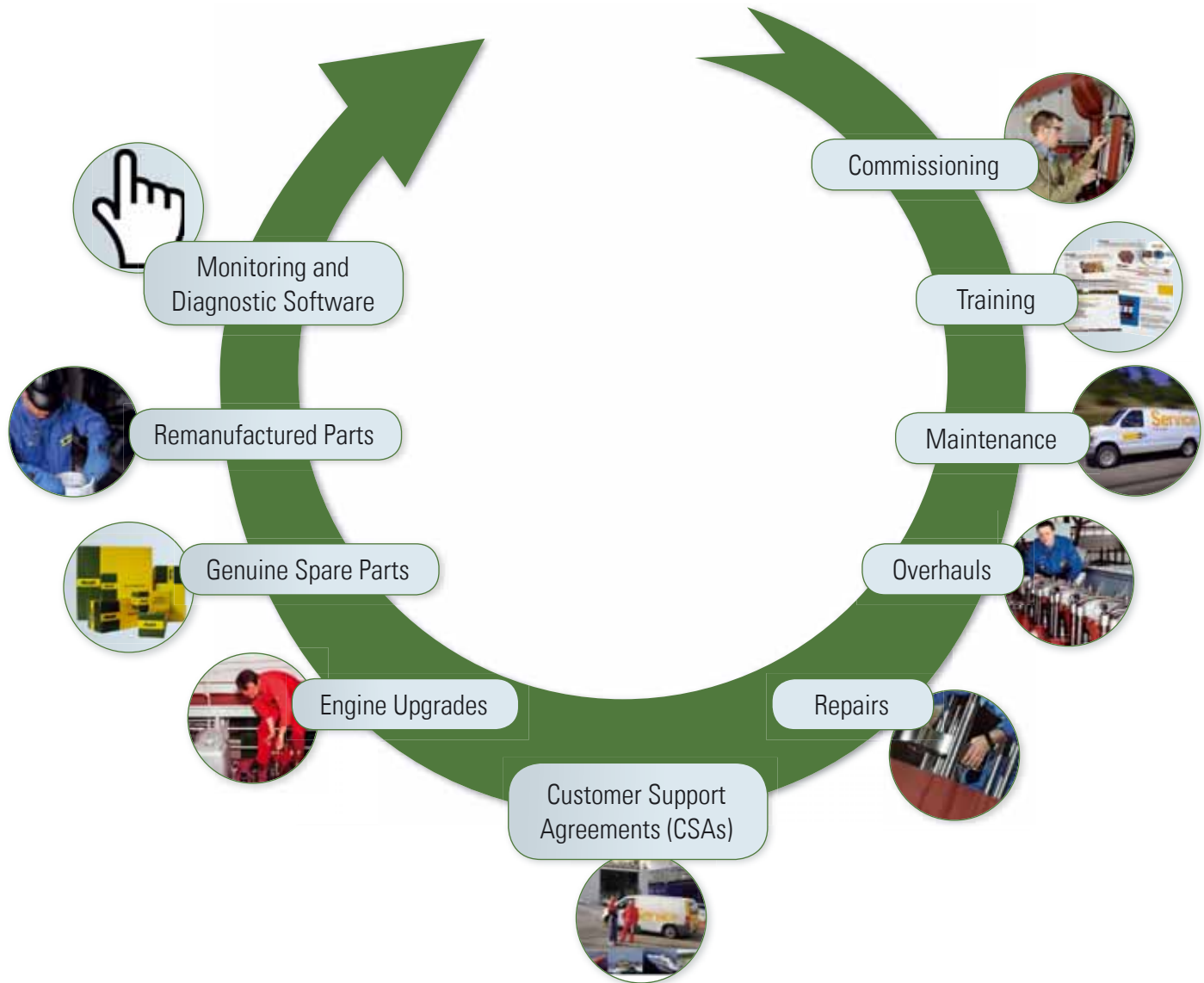
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INTRODUCTION

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|--|--|--|
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## CONTENTS

**1. GENSET DESCRIPTION**

|       |   |   |
|-------|---|---|
| 1.1   | Definitions .....                       | 1 |
| 1.2   | Main components and systems .....       | 2 |
| 1.2.1 | Main features and characteristics ..... | 2 |
| 1.2.2 | Description of components.....          | 3 |
| 1.3   | Prospective life times .....            | 5 |

**2. GENERAL DATA AND OUTPUTS**

|       |   |    |
|-------|---|----|
| 2.1   | General definition of reference conditions .....                  | 6  |
| 2.2   | Reference conditions regarding fuel consumption.....              | 6  |
| 2.3   | Lube oil consumption.....   | 6  |
| 2.4   | Emissions.....  | 7  |
| 2.4.1 | Exhaust gas 900 kW/Cyl., 500/514 rpm (HFO/MDO) – preliminary..... | 7  |
| 2.4.2 | Exhaust gas 965 kW/Cyl., 500 rpm (MDO only) – preliminary.....    | 8  |
| 2.4.3 | Exhaust gas 965 kW/Cyl., 514 rpm (MDO only) – preliminary.....    | 9  |
| 2.4.4 | Nitrogen oxide emissions (NO <sub>x</sub> -values).....           | 10 |
| 2.4.5 | Engine International Air Pollution Prevention Certificate .....   | 10 |
| 2.5   | Engine dimensions and weight – preliminary.....                   | 11 |
| 2.6   | System connecting points – preliminary.....                       | 12 |

## CONTENTS

### 3. OPERATING RANGES

|       |  |    |
|-------|--|----|
| 3.1   | Restrictions for low load operation .....      | 14 |
| 3.1.1 | Load restrictions in diesel mode .....         | 14 |
| 3.1.2 | Load restrictions in gas mode .....            | 15 |
| 3.2   | Emergency operation without turbocharger ..... | 16 |
| 3.3   | Operation in inclined position .....           | 16 |
| 3.4   | Load application and recovery behaviour .....  | 17 |
| 3.5   | Fuel changeover and recovery behaviour .....   | 19 |
| 3.6   | Derating .....                                 | 20 |

### 4. TECHNICAL DATA

|         |  |    |
|---------|--|----|
| 4.1     | Diesel, mechanical.....  | 21 |
| 4.1.1   | Output 900 kW/Cyl. in HFO, MDO and gas operation.....                | 21 |
| 4.1.2   | Output 965 kW/Cyl. in MDO and gas operation only – preliminary ..... | 24 |
| 4.1.2.1 | Output 965 kW/Cyl. at 500 rpm – preliminary .....                    | 24 |
| 4.1.2.2 | Output 965 kW/Cyl. at 514 rpm – preliminary .....                    | 27 |

### 5. FUEL OIL SYSTEM

|       |  |    |
|-------|--|----|
| 5.1   | MGO / MDO operation.....   | 30 |
| 5.1.1 | Acceptable MGO / MDO characteristics.....                                      | 30 |
| 5.1.2 | Internal fuel oil system .....   | 31 |
| 5.1.3 | External fuel oil system .....   | 32 |
| 5.2   | HFO operation .....  | 41 |
| 5.2.1 | CIMAC – Requirements for residual fuels for diesel engines (as delivered)..... | 43 |
| 5.2.2 | Fuel booster and supply system .....   | 48 |
| 5.2.3 | Fuel booster and supply module.....  | 56 |
| 5.3   | Switching over from HFO to diesel oil.....                                     | 60 |

## CONTENTS

### 6. GAS FUEL SYSTEM

|         |  |    |
|---------|--|----|
| 6.1     | General.....   | 61 |
| 6.1.1   | Gas fuel quality requirements .....                  | 61 |
| 6.1.2   | Inert gas quality requirements .....                 | 62 |
| 6.2     | Gas system overview.....                             | 63 |
| 6.2.1   | Gas valve unit (GVU).....                            | 64 |
| 6.2.2   | Ignition fuel system .....                           | 65 |
| 6.2.2.1 | Ignition fuel quality requirements .....             | 65 |
| 6.2.2.2 | Ignition fuel components .....                       | 65 |
| 6.2.3   | Engine ventilation system .....                      | 68 |
| 6.2.4   | Engine ventilation module .....                      | 68 |
| 6.2.5   | Exhaust gas ventilation system .....                 | 69 |
| 6.2.6   | Exhaust gas ventilation module .....                 | 69 |
| 6.2.7   | Crankcase gas detection .....                        | 70 |
| 6.2.8   | Explosion relief valves for exhaust gas system ..... | 70 |
| 6.2.9   | Slow turn .....                                      | 70 |
| 6.3     | Gas system – GVU inside gas safe machinery room..... | 71 |
| 6.3.1   | GVU housing .....                                    | 71 |
| 6.3.2   | GVU ventilation module.....                          | 71 |



## CONTENTS

### 7. LUBE OIL SYSTEM

|       |  |    |
|-------|--|----|
| 7.1   | Lube oil requirements.....                 | 72 |
| 7.2   | Internal lube oil system .....             | 74 |
| 7.3   | External lube oil system .....             | 76 |
| 7.4   | Circulating tanks.....                     | 80 |
| 7.5   | Crankcase ventilation system .....         | 80 |
| 7.5.1 | Crankcase ventilation pipe dimensions..... | 80 |
| 7.5.2 | Crankcase ventilation pipe layout .....    | 80 |
| 7.5.3 | Gas detection sensor .....                 | 80 |

### 8. COOLING WATER SYSTEM

|       |  |    |
|-------|--|----|
| 8.1   | General.....   | 81 |
| 8.1.1 | Two circuit cooling system .....                               | 81 |
| 8.1.2 | Secondary circuit cooling system .....                         | 81 |
| 8.2   | Water quality requirements.....                                | 81 |
| 8.2.1 | General .....  | 81 |
| 8.2.2 | Requirements.....  | 82 |
| 8.2.3 | Supplementary information.....                                 | 82 |
| 8.2.4 | Treatment before operating the engine for the first time ..... | 82 |
| 8.3   | Recommendation for cooling water system.....                   | 82 |
| 8.3.1 | Pipes and tanks.....   | 82 |
| 8.3.2 | Drain tank with filling pump .....                             | 82 |
| 8.3.3 | Electric motor driven pumps .....                              | 83 |
| 8.4   | Cooling water system .....                                     | 83 |
| 8.4.1 | General .....  | 83 |
| 8.4.2 | Components.....  | 87 |

## CONTENTS

|            |  |     |
|------------|--|-----|
| 8.5        | System diagrams heat balance .....                         | 91  |
| 8.6        | Preheating (separate module) .....                         | 95  |
| 8.6.1      | Electrically heated .....                                  | 95  |
| 8.6.2      | Other preheating systems .....                             | 96  |
| 8.7        | Box coolers system.....                                    | 96  |
| 8.8        | Cooling circuit layout.....                                | 96  |
| <b>9.</b>  | <b>COMPRESSED AIR SYSTEM</b>                               |     |
| 9.1        | General.....   | 97  |
| 9.2        | Internal compressed air system .....                       | 97  |
| 9.3        | Compressed air system.....                                 | 98  |
| 9.3.1      | Compressor AC1 / AC2.....                                  | 99  |
| 9.3.2      | Air receiver AT1 / AT2.....                                | 100 |
| 9.4        | Compressed air quality.....                                | 102 |
| 9.5        | Slow turn.....   | 102 |
| 9.6        | Equipment.....   | 103 |
| <b>10.</b> | <b>COMBUSTION AIR SYSTEM</b>                               |     |
| 10.1       | Engine room ventilation.....                               | 104 |
| 10.2       | Combustion air system design .....                         | 104 |
| 10.2.1     | Air intake from engine room (standard) .....               | 104 |
| 10.2.2     | Air intake from outside .....                              | 104 |
| 10.2.3     | Air intake temperature from engine room from outside ..... | 104 |
| 10.3       | Cooling air.....   | 104 |
| 10.4       | Condensed water from charge air duct .....                 | 104 |

## CONTENTS

### 11. EXHAUST GAS SYSTEM

|        |                                 |     |
|--------|---------------------------------|-----|
| 11.1   | Components .....                | 105 |
| 11.1.1 | Exhaust gas nozzle.....         | 105 |
| 11.1.2 | Exhaust gas compensator.....    | 106 |
| 11.1.3 | Exhaust gas piping system ..... | 107 |
| 11.1.4 | Silencer .....                  | 109 |
| 11.1.5 | Exhaust gas boiler .....        | 110 |
| 11.2   | Turbocharger .....              | 110 |
| 11.2.1 | Turbine cleaning system .....   | 110 |
| 11.2.2 | Compressor cleaning system..... | 111 |

### 12. FLEXIBLE CAMSHAFT TECHNOLOGY (FCT)

|      |  |     |
|------|--|-----|
| 12.1 | Flexible Camshaft Technology (FCT) ..... | 112 |
|------|--|-----|

### 13. CONTROL AND MONITORING SYSTEM

|        |  |     |
|--------|--|-----|
| 13.1   | Local control panel (LCP).....               | 113 |
| 13.2   | Data link overview.....                      | 114 |
| 13.3   | Components .....                             | 116 |
| 13.4   | Genset control .....                         | 118 |
| 13.5   | Control cabinet .....                        | 119 |
| 13.6   | Requirements.....                            | 120 |
| 13.6.1 | Requirements on power management system..... | 120 |
| 13.6.2 | Requirements on gas system .....             | 121 |
| 13.6.3 | Uninterruptable power supply (UPS) .....     | 122 |
| 13.7   | Alarm indication .....                       | 123 |
| 13.8   | Local and remote indicators.....             | 125 |

## CONTENTS

|  |     |
|--|-----|
| 13.9 Cat Connect for Marine provided by Caterpillar Marine Asset Intelligence (MAI)..... | 126 |
| 13.9.1 MAI – MaK engine solution only .....  | 126 |
| 13.9.2 MAI – Extended solution .....   | 127 |
| 13.9.3 General information.....  | 127 |
| <b>14. SAFETY</b>  |     |
| 14.1 Safety .....  | 129 |
| 14.1.1 Safety concept .....  | 129 |
| 14.1.2 Gas safe machinery space.....   | 129 |
| 14.1.3 Gas related safety equipment .....  | 131 |
| <b>15. INSTALLATION AND ARRANGEMENT</b>  |     |
| 15.1 Resilient mounting of genset.....   | 132 |
| 15.1.1 Conical mountings .....   | 132 |
| 15.2 Earthing of engine .....  | 133 |
| <b>16. VIBRATION AND NOISE</b>   |     |
| 16.1 Data for torsional vibration calculation.....                                       | 134 |
| 16.2 Sound levels.....   | 138 |
| 16.2.1 Airborne noise .....  | 138 |
| 16.3 Vibration.....  | 138 |
| <b>17. POWER TRANSMISSION</b>  |     |
| 17.1 Flexible coupling.....  | 139 |

## CONTENTS

### 18. PIPING DESIGN

|      |                                 |     |
|------|---------------------------------|-----|
| 18.1 | Pipe dimensions .....           | 140 |
| 18.2 | Flow velocities in pipes .....  | 140 |
| 18.3 | Trace heating .....             | 140 |
| 18.4 | Insulation .....                | 140 |
| 18.5 | Flexible pipe connections ..... | 141 |

### 19. ENGINE ROOM LAYOUT

|        |   |     |
|--------|---|-----|
| 19.1   | Genset center distances .....                                 | 142 |
| 19.2   | Space requirement for maintenance .....                       | 143 |
| 19.2.1 | Removal of charge air cooler and turbocharger cartridge ..... | 143 |
| 19.2.2 | Removal of piston and cylinder liner .....                    | 144 |

### 20. PAINTING, PRESERVATION

|        |  |     |
|--------|--|-----|
| 20.1   | Inside preservation .....  | 145 |
| 20.1.1 | Factory standard N 576-3.3 – Inside preservation .....   | 145 |
| 20.2   | Outside preservation .....   | 145 |
| 20.2.1 | Factory standard N 576-3.2 – Outside preservation VCI 368 .....                                      | 145 |
| 20.2.2 | Factory standard N 576-4.1 – Clear varnish .....   | 146 |
| 20.2.3 | Factory standard N 576-4.3 – Painting .....  | 147 |
| 20.2.4 | Factory standard N 576-5.2 – VCI packaging .....   | 147 |
| 20.2.5 | Factory standard N 576-5.2 Suppl. 1 – Information panel for VCI preservation<br>and inspection ..... | 148 |
| 20.3   | Factory standard N 576-6.1 – Protection period, check and represervation .....                       | 149 |
| 20.3.1 | Protection period .....  | 149 |
| 20.3.2 | Protection check .....   | 149 |
| 20.3.3 | Represervation as per factory standard N 576-6.1 .....   | 149 |

## CONTENTS

### **21. TRANSPORT, DIMENSIONS AND WEIGHTS**

|  |     |
|--|-----|
| 21.1 Lifting of engines .....            | 150 |
| 21.2 Dimensions of main components ..... | 150 |

### **22. STANDARD ENGINE ACCEPTANCE TEST RUN**

|   |     |
|---|-----|
| 22.1 Standard acceptance test run ..... | 152 |
|---|-----|

### **23. ENGINE PARTS**

|   |     |
|---|-----|
| 23.1 Required spare parts (Marine Classification Society MCS) ..... | 153 |
| 23.2 Recommended spare parts .....                                  | 154 |

### **24. CATERPILLAR MARINE**

|  |     |
|--|-----|
| 24.1 Gas sytems technology – Scope of supply ..... | 156 |
| 24.2 Caterpillar Propulsion .....                  | 157 |

01

02

03

04

05

06

07

08

09

10

11

12

13

14

15

16

17

18

19

20

21

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## GENSET DESCRIPTION

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### 1.1 Definitions

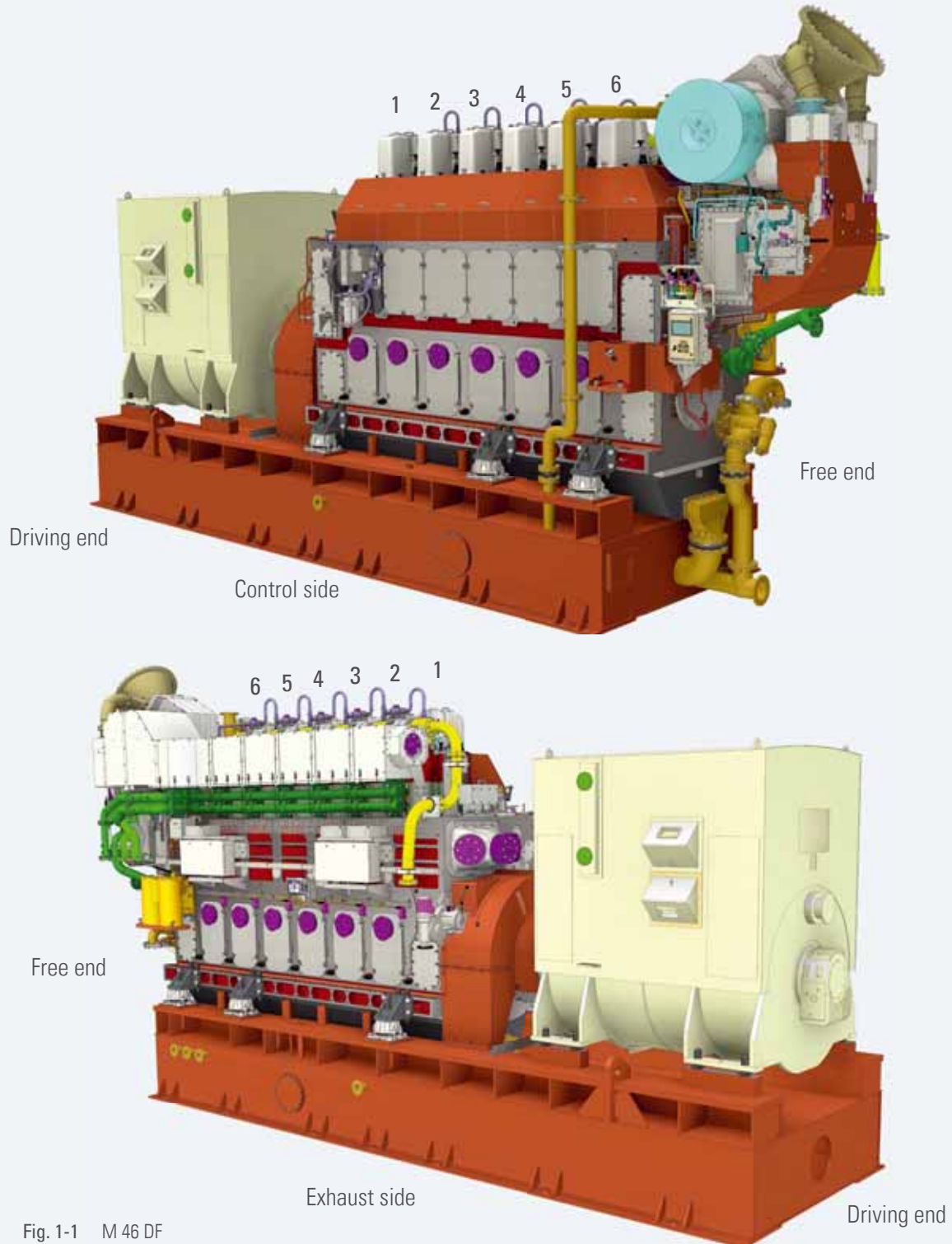


Fig. 1-1 M 46 DF

|                      |       | 6 M 46 DF | 7 M 46 DF | 8 M 46 DF | 9 M 46 DF |
|----------------------|-------|-----------|-----------|-----------|-----------|
| Output (HFO and MDO) | [kWe] | 5,179     | 6,042     | 6,905     | 7,768     |
| Output (MDO only)    | [kWe] | 5,553     | 6,478     | 7,403     | 8,329     |



## GENSET DESCRIPTION

01

|    |                         |                                      |
|----|-------------------------|--------------------------------------|
| 02 | Cylinder configuration: | 6, 7, 8, 9 in-line                   |
| 03 | Bore:                   | 460 mm                               |
| 04 | Stroke:                 | 610 mm                               |
| 05 | Output/cyl:             | 900 kW /965 kW                       |
| 06 | BMEP:                   | 20.7 - 22.8 bar                      |
| 07 | Revolutions:            | 500/514 rpm                          |
| 08 | Mean piston speed:      | 10.2/10.5 m/s                        |
| 09 | Turbocharging:          | single log                           |
| 10 | Direction of rotation:  | counter-clockwise, option: clockwise |

### 1.2 Main components and systems

#### 1.2.1 Main features and characteristics

Building on its marine engine legacy Caterpillar Motoren designed the inherently gas safe M 46 DF for a variety of marine applications without sacrificing the typical MaK marine engine attributes like operational reliability and efficiency as well as service and maintenance simplicity.

Capable to operate on multiple fuels (NG/MDO/HFO) the M 46 DF is designed to meet stringent conditions of upcoming exhaust gas emission- and fuel sulphur regulations, providing the operational flexibility for vessel operating in regulated- as well as lesser emission regulated areas.

The optimized design of the M 46 DF in combination with the system solutions provided by Caterpillar Motoren is the basis for the installation and engine/engine room type approval simplicity, reducing changes to engine and engine related systems at the same time.

Low emissions and high engine efficiency, paired with fast service access and service and maintenance simplicity make the MaK M 46 DF the perfect choice for single engine main propulsion installations as well as multiple engine installations.

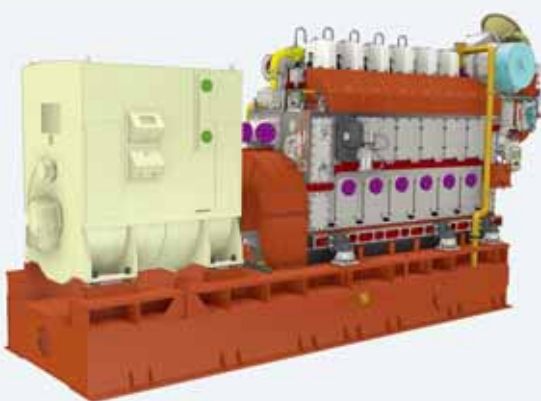


Fig. 1-2 Control side and driving end



Fig. 1-3 Exhaust side and free end

## GENSET DESCRIPTION

01

### 1.2.2 Description of components

#### Cylinder head

- The cylinder heads are made of nodular cast iron with 2 inlet and 2 exhaust valves, which are equipped with valve rotators.
- The exhaust valve seats are directly water cooled.
- The injection nozzles for heavy fuel operation are cooled by engine lube oil.

#### Connecting rod and piston

- The pistons are of composite type with steel crown and forged steel or nodular cast iron skirt.
- The piston ring sets consist of two compression rings, first ring with chromium diamond plated running surfaces, the second ring with chromium plated running surfaces, and one chromium diamond plated oil scraper ring.
- All ring grooves are located in the steel crown, which is cooled by lube oil.
- The ring grooves are hardened.
- 3-piece connecting rod, supporting removal of the piston without opening the big end bearing.

#### Engine block

Core element of the M 46 DF is the engine block, which is made of nodular cast iron in one piece.

#### The advantages of the engine block design are:

- The one-piece design makes the engine block extremely robust and warp resistant.
- The charge air manifold is cast integral, which avoids vibration and leakage problems.
- Lube oil lines are routed through the block in cast and drilled holes, reducing the number of connecting points and leakage problems to a minimum.
- The camshaft housing contains a camshaft, which is made of sections per cylinder allowing a removal of the segments sideways.
- The underslung crankshaft allows the removal of the complete crankshaft without disassembly of the entire engine.
- The engine block is not integrated into the cooling water circuit, therefore the engine block is completely dry.

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## GENSET DESCRIPTION

01

**Safe and simple power train**

The safe and simple designed power train of cylinder head, piston with liner, connecting rod and camshaft is parted in cylinder compartments, while the crankshaft is one-piece. The advantage is simplification of maintenance work saving costs.

**Additional advantages are:**

- Service friendly distribution of media in maintenance-free plugged pipes and cast blocks
- 2-stage fresh water cooling system with 2-stage charge air cooler
- Turbocharger supplied with inboard plain bearings which are lubricated by engine lube oil
- Service friendly ignition fuel injector location

## GENSET DESCRIPTION

01

### 1.3 Prospective life times

#### General

The expectable TBO (time between overhaul) and actual life time may deviate significantly as a result of, fuel quality, load and operating profile, conditions, the quality of maintenance and other external factors.

| Core components                                | Life time operating hours [h] |     |        |             |
|--|-------------------------------|-----|--------|-------------|
|  | M 46 DF Generator Set         |     |        |             |
|  | Gas                           | MDO | HFO    | TBO M 46 DF |
| Piston crown (life time incl. 2 stages rework) | 90,000                        |     |        | 30,000      |
| Piston skirt cast iron (standard)              | 60,000                        |     |        | —           |
| Piston skirt steel (optional)                  | 90,000                        |     |        | —           |
| Piston skirt Aluminium                         | —                             |     |        | —           |
| Piston rings                                   | 30,000                        |     |        | —           |
| Piston pin bearing                             | 60,000                        |     |        | —           |
| Cuff / Antipolishing ring                      | 30,000                        |     |        | —           |
| Cylinder liner                                 | 90,000                        |     | 60,000 | —           |
| Cylinder head                                  | 90,000                        |     |        | 15,000      |
| Inlet valve                                    | 30,000                        |     |        | 15,000      |
| Exhaust valve                                  | 30,000                        |     |        | 15,000      |
| Nozzle element                                 | 7,500                         |     | 5,000  | —           |
| Gas admission valve                            | 7,500                         |     |        | —           |
| Cylinder pressure sensor                       | 7,500                         |     |        | —           |
| Pump element                                   | 15,000                        |     |        | —           |
| Pilot injector                                 | 7,500                         |     |        | —           |
| HD-pump  | 7,500                         |     |        | —           |
| Main bearing                                   | 30,000                        |     |        | —           |
| Big end bearing                                | 30,000                        |     |        | —           |
| Camshaft bearing                               | 45,000                        |     |        | —           |
| Turbocharger plain bearing                     | 12,000                        |     |        | —           |
| Vibration damper camshaft                      | 15,000                        |     |        | —           |
| Vibration damper crankshaft                    | 60,000                        |     |        | 30,000      |

The above mentioned data are only indicative and relate to an average component life time under favourable operating conditions.

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24

## GENERAL DATA AND OUTPUTS

| Type      | in HFO and MDO mode<br>500/514 rpm |       | in MDO mode only<br>500/514 rpm |       |
|-----------|------------------------------------|-------|---------------------------------|-------|
|           | [kW]                               | [kWe] | [kW]                            | [kWe] |
| 6 M 46 DF | 5,400                              | 5,179 | 5,790                           | 5,553 |
| 7 M 46 DF | 6,300                              | 6,042 | 6,755                           | 6,478 |
| 8 M 46 DF | 7,200                              | 6,905 | 7,720                           | 7,403 |
| 9 M 46 DF | 8,100                              | 7,768 | 8,685                           | 8,329 |

The maximum fuel rack position is mechanically limited to 100 % output for CPP applications.

## 2.1 General definition of reference conditions

The maximum continuous rating (locked output) stated by Caterpillar Motoren refers to the following reference conditions according to „IACS“ (International Association of Classification Societies) for main and auxiliary engines (tropical conditions):

|                       |                 |
|-----------------------|-----------------|
| Air pressure:         | 100 kPa (1 bar) |
| Air temperature:      | 318 K (45 °C)   |
| Relative humidity:    | 60 %            |
| Seawater temperature: | 305 K (32 °C)   |

## 2.2 Reference conditions regarding fuel consumption

Fuel consumption data is based on the following reference conditions:

|   |                         |
|---|-------------------------|
| Intake temperature:                         | 298 K (25 °C)           |
| Charge air temperature:                     | 318 K (45°C)            |
| Charge air coolant inlet temperature:       | 298 K (25°C)            |
| Net heating value of the diesel oil:        | 42,700 kJ/kg            |
| Net heating value of the natural gas:       | 43.3 MJ/Nm <sup>3</sup> |
| Tolerance:                                  | 5 %                     |
| Fuel gas minimum lower heating value (LHV): | 28.0 MJ/Nm <sup>3</sup> |
| Fuel gas methane number for rated output:   | > 80                    |

Specification of fuel consumption data without engine driven pumps;

For engine driven oil pump: n=const. 1% at 100%, 1.2% at 85%, 1.3% at 75%, 2% at 50%, 4% at 25%.

For engine driven cooling water pump: 0.4% at 100%, 0.47% at 85%, 0.53% at 75%, 0.8% at 50%, 1.6% at 25%.

## 2.3 Lube oil consumption

- 0.6 g/kWh
- Value is based on rated output
- Tolerance  $\pm 0.3$  g/kWh

### NOTE:

Please also compare the technical data (see chapter 4).

## GENERAL DATA AND OUTPUTS

### 2.4 Emissions

#### 2.4.1 Exhaust gas 900 kW/Cyl., 500/514 rpm (HFO/MDO) – preliminary

Tolerance: 5 %      Relative humidity: 60 %  
 Atmospheric pressure: 100 kPa (1 bar)      Constant speed 500/514 rpm

| Engine  | Output | Output [%]     |               |               |               |               |               |
|---|--------|----------------|---------------|---------------|---------------|---------------|---------------|
|   | [kW]   | [kg/h]         |               |               |               |               |               |
|   |        | [°C]           |               |               |               |               |               |
|   |        | 100            | 90            | 80            | 70            | 60            | 50            |
| Intake air temperature 25 °C – Diesel operation |        |                |               |               |               |               |               |
| 6 M 46 DF                                       | 5,400  | 39,510<br>345  | 36,180<br>335 | 32,160<br>330 | 28,650<br>340 | 24,865<br>355 | 21,075<br>376 |
| 7 M 46 DF                                       | 6,300  | 46,100<br>343  | 42,200<br>350 | 37,500<br>345 | 33,425<br>350 | 29,000<br>360 | 24,550<br>385 |
| 8 M 46 DF                                       | 7,200  | 52,675<br>335  | 48,725<br>330 | 43,310<br>325 | 38,585<br>330 | 33,485<br>345 | 28,380<br>375 |
| 9 M 46 DF                                       | 8,100  | 59,300<br>335  | 54,815<br>335 | 48,725<br>330 | 43,405<br>335 | 37,670<br>360 | 31,925<br>380 |
| Intake air temperature 25 °C – Gas operation    |        |                |               |               |               |               |               |
| 6 M 46 DF                                       | 5,400  | 33,885<br>385  | 31,150<br>397 | 27,690<br>400 | 25,175<br>400 | 21,985<br>405 | 18,800<br>417 |
| 7 M 46 DF                                       | 6,300  | 39,650<br>383  | 36,450<br>396 | 32,400<br>397 | 29,460<br>400 | 25,725<br>408 | 22,000<br>416 |
| 8 M 46 DF                                       | 7,200  | 45,300<br>375  | 41,660<br>390 | 36,940<br>392 | 33,585<br>402 | 29,330<br>404 | 25,100<br>415 |
| 9 M 46 DF                                       | 8,100  | 51,000<br>375  | 46,870<br>392 | 41,600<br>395 | 37,783<br>405 | 33,000<br>407 | 28,240<br>418 |
| Intake air temperature 45 °C – Diesel operation |        |                |               |               |               |               |               |
| 6 M 46 DF                                       | 5,400  | 37,930<br>365  | 34,735<br>355 | 30,875<br>350 | 27,505<br>360 | 23,870<br>376 | 20,235<br>398 |
| 7 M 46 DF                                       | 6,300  | 44,255<br>363  | 40,510<br>371 | 36,000<br>366 | 32,100<br>371 | 27,840<br>382 | 23,570<br>408 |
| 8 M 46 DF                                       | 7,200  | 50,570<br>355  | 46,775<br>350 | 41,580<br>344 | 37,040<br>350 | 32,145<br>366 | 27,245<br>397 |
| 9 M 46 DF                                       | 8,100  | 56,928<br>355  | 52,625<br>355 | 46,775<br>350 | 41,670<br>355 | 36,165<br>382 | 30,650<br>397 |
| Intake air temperature 45 °C – Gas operation    |        |                |               |               |               |               |               |
| 6 M 46 DF                                       | 5,400  | 32,530<br>408  | 29,905<br>421 | 26,583<br>424 | 24,170<br>424 | 21,105<br>429 | 18,050<br>442 |
| 7 M 46 DF                                       | 6,300  | 38,065<br>406  | 34,995<br>420 | 31,105<br>421 | 28,285<br>424 | 24,700<br>432 | 21,120<br>441 |
| 8 M 46 DF                                       | 7,200  | 433,488<br>397 | 39,995<br>413 | 35,462<br>415 | 32,242<br>426 | 28,157<br>428 | 24,100<br>440 |
| 9 M 46 DF                                       | 8,100  | 48,960<br>397  | 44,995<br>415 | 39,940<br>419 | 36,272<br>429 | 31,680<br>431 | 27,110<br>443 |

## GENERAL DATA AND OUTPUTS

## 2.4.2 Exhaust gas 965 kW/Cyl., 500rpm (MDO only) – preliminary

Tolerance: 5 %      Relative humidity: 60 %  
 Atmospheric pressure: 100 kPa (1 bar)      Constant speed 500 rpm

| Engine  | Output | Output [%]    |               |               |               |               |               |
|---|--------|---------------|---------------|---------------|---------------|---------------|---------------|
|   | [kW]   | [kg/h]        |               |               |               |               |               |
|   |        | [°C]          |               |               |               |               |               |
|   |        | 100           | 90            | 80            | 70            | 60            | 50            |
| Intake air temperature 25 °C – Diesel operation |        |               |               |               |               |               |               |
| 6 M 46 DF                                       | 5,790  | 42,325<br>336 | 38,713<br>327 | 34,410<br>322 | 30,655<br>332 | 26,605<br>347 | 22,550<br>368 |
| 7 M 46 DF                                       | 6,755  | 49,380<br>334 | 45,155<br>342 | 40,125<br>338 | 35,765<br>342 | 31,030<br>352 | 26,270<br>377 |
| 8 M 46 DF                                       | 7,720  | 56,485<br>326 | 52,135<br>322 | 46,340<br>317 | 41,285<br>322 | 35,830<br>338 | 30,365<br>367 |
| 9 M 46 DF                                       | 8,685  | 63,560<br>326 | 58,650<br>327 | 52,135<br>322 | 46,443<br>328 | 40,310<br>352 | 34,160<br>372 |
| Intake air temperature 25 °C – Gas operation    |        |               |               |               |               |               |               |
| 6 M 46 DF                                       | 5,790  | 38,514<br>366 | 35,200<br>378 | 31,300<br>381 | 28,450<br>381 | 24,845<br>386 | 21,245<br>398 |
| 7 M 46 DF                                       | 6,755  | 44,935<br>364 | 36,450<br>377 | 32,400<br>378 | 29,460<br>381 | 25,725<br>389 | 22,000<br>397 |
| 8 M 46 DF                                       | 7,720  | 51,400<br>358 | 41,660<br>373 | 36,940<br>375 | 33,585<br>385 | 29,330<br>387 | 25,100<br>398 |
| 9 M 46 DF                                       | 8,685  | 57,840<br>358 | 46,870<br>375 | 41,600<br>378 | 37,783<br>388 | 33,000<br>390 | 28,240<br>401 |
| Intake air temperature 45 °C – Diesel operation |        |               |               |               |               |               |               |
| 6 M 46 DF                                       | 5,790  | 39,785<br>356 | 36,390<br>347 | 32,345<br>341 | 28,815<br>352 | 25,010<br>368 | 21,200<br>390 |
| 7 M 46 DF                                       | 6,755  | 46,420<br>354 | 42,445<br>362 | 37,720<br>358 | 33,620<br>362 | 29,170<br>373 | 24,695<br>400 |
| 8 M 46 DF                                       | 7,720  | 53,100<br>345 | 49,010<br>341 | 43,560<br>336 | 38,810<br>341 | 33,680<br>358 | 28,545<br>389 |
| 9 M 46 DF                                       | 8,685  | 59,750<br>345 | 55,130<br>347 | 48,010<br>341 | 43,660<br>348 | 37,890<br>373 | 32,110<br>394 |
| Intake air temperature 45 °C – Gas operation    |        |               |               |               |               |               |               |
| 6 M 46 DF                                       | 5,790  | 36,025<br>388 | 33,090<br>401 | 29,420<br>404 | 26,745<br>404 | 23,355<br>409 | 19,970<br>422 |
| 7 M 46 DF                                       | 6,755  | 42,240<br>386 | 34,265<br>400 | 30,456<br>401 | 27,690<br>404 | 24,180<br>412 | 20,680<br>421 |
| 8 M 46 DF                                       | 7,720  | 48,315<br>379 | 39,160<br>395 | 34,725<br>397 | 31,570<br>408 | 27,570<br>410 | 23,595<br>422 |
| 9 M 46 DF                                       | 8,685  | 54,370<br>379 | 44,060<br>397 | 39,105<br>401 | 35,515<br>411 | 31,020<br>413 | 26,545<br>425 |

## GENERAL DATA AND OUTPUTS

### 2.4.3 Exhaust gas 965 kW/Cyl., 514 rpm (MDO only) – preliminary

Tolerance: 5 %      Relative humidity: 60 %  
 Atmospheric pressure: 100 kPa (1 bar)      Constant speed 514 rpm

| Engine  | Output | Output [%]    |               |               |               |               |               |
|---|--------|---------------|---------------|---------------|---------------|---------------|---------------|
|   | [kW]   | [kg/h]        |               |               |               |               |               |
|   |        | [°C]          |               |               |               |               |               |
|   |        | 100           | 90            | 80            | 70            | 60            | 50            |
| Intake air temperature 25 °C – Diesel operation |        |               |               |               |               |               |               |
| 6 M 46 DF                                       | 5,790  | 41,474<br>336 | 37,938<br>327 | 33,720<br>322 | 30,040<br>332 | 26,075<br>347 | 22,100<br>368 |
| 7 M 46 DF                                       | 6,755  | 48,389<br>334 | 44,250<br>342 | 39,320<br>338 | 35,050<br>342 | 30,410<br>352 | 25,745<br>377 |
| 8 M 46 DF                                       | 7,720  | 55,360<br>326 | 51,090<br>322 | 45,415<br>317 | 40,460<br>322 | 35,115<br>338 | 29,760<br>367 |
| 9 M 46 DF                                       | 8,685  | 62,295<br>326 | 57,480<br>327 | 51,090<br>322 | 45,515<br>328 | 39,505<br>352 | 33,480<br>372 |
| Intake air temperature 25 °C – Gas operation    |        |               |               |               |               |               |               |
| 6 M 46 DF                                       | 5,790  | 37,742<br>366 | 34,495<br>378 | 30,675<br>381 | 27,880<br>381 | 24,350<br>386 | 20,820<br>398 |
| 7 M 46 DF                                       | 6,755  | 44,035<br>364 | 35,720<br>377 | 31,750<br>378 | 28,870<br>381 | 25,210<br>389 | 21,560<br>397 |
| 8 M 46 DF                                       | 7,720  | 50,380<br>358 | 40,825<br>373 | 36,200<br>375 | 32,915<br>385 | 28,745<br>387 | 24,600<br>398 |
| 9 M 46 DF                                       | 8,685  | 56,688<br>358 | 45,930<br>375 | 40,770<br>378 | 37,030<br>388 | 32,340<br>390 | 27,675<br>401 |
| Intake air temperature 45 °C – Diesel operation |        |               |               |               |               |               |               |
| 6 M 46 DF                                       | 5,790  | 38,985<br>358 | 35,662<br>349 | 31,700<br>343 | 28,240<br>354 | 24,510<br>370 | 20,775<br>393 |
| 7 M 46 DF                                       | 6,755  | 45,485<br>354 | 41,595<br>365 | 36,960<br>358 | 32,950<br>365 | 28,585<br>373 | 24,200<br>400 |
| 8 M 46 DF                                       | 7,720  | 52,040<br>348 | 48,025<br>343 | 42,690<br>338 | 38,030<br>341 | 33,010<br>358 | 27,975<br>389 |
| 9 M 46 DF                                       | 8,685  | 58,560<br>348 | 54,030<br>347 | 48,025<br>341 | 42,785<br>348 | 37,135<br>373 | 31,470<br>394 |
| Intake air temperature 45 °C – Gas operation    |        |               |               |               |               |               |               |
| 6 M 46 DF                                       | 5,790  | 35,480<br>388 | 32,425<br>401 | 28,835<br>404 | 26,210<br>403 | 22,890<br>409 | 19,570<br>422 |
| 7 M 46 DF                                       | 6,755  | 41,395<br>386 | 33,580<br>400 | 29,845<br>401 | 27,140<br>403 | 23,700<br>412 | 20,270<br>421 |
| 8 M 46 DF                                       | 7,720  | 47,360<br>379 | 38,375<br>395 | 34,030<br>397 | 30,940<br>408 | 27,020<br>410 | 23,125<br>422 |
| 9 M 46 DF                                       | 8,685  | 53,290<br>379 | 43,175<br>397 | 38,325<br>401 | 34,810<br>411 | 30,400<br>413 | 26,015<br>425 |



## GENERAL DATA AND OUTPUTS

### 2.4.4 Nitrogen oxide emissions (NO<sub>x</sub>-values)

|   |                         |
|---|-------------------------|
| NO <sub>x</sub> -limit values according to IMO II:  | 10.54 g/kWh (n=500 rpm) |
| Main engine: DE-drive acc. to cycle E2:             | 10.3 g/kWh              |
| Auxiliary genset acc. cycle D2:                     | 10.3 g/kWh              |
| NO <sub>x</sub> -limit values according to IMO III: | 2.60 g/kWh (n=500 rpm)  |
| Gas mode (cycle E2 and D2):                         | 2.60 g/kWh              |

### 2.4.5 Engine International Air Pollution Prevention Certificate

The MARPOL Diplomatic Conference has agreed about a limitation of NO<sub>x</sub> emissions, referred to as Annex VI to MARPOL 73/78.

When testing the engine for NO<sub>x</sub> emissions, the reference fuel is marine diesel oil (distillate) and the test is performed according to ISO 8178 test cycles:

|                  | Test cycle type E2 |       |       |       | Test cycle type D2 |       |       |       |       |
|------------------|--------------------|-------|-------|-------|--------------------|-------|-------|-------|-------|
| Speed            | 100 %              | 100 % | 100 % | 100 % | 100 %              | 100 % | 100 % | 100 % | 100 % |
| Power            | 100 %              | 75 %  | 50 %  | 25 %  | 100 %              | 75 %  | 50 %  | 25 %  | 10 %  |
| Weighting factor | 0.2                | 0.5   | 0.15  | 0.15  | 0.05               | 0.25  | 0.3   | 0.3   | 0.1   |

Subsequently, the NO<sub>x</sub> value is calculated using different weighting factors for different loads that have been corrected to ISO 8178 conditions.

A NO<sub>x</sub> emission evidence will be issued for each engine showing that the engine complies with the regulation. The evidence will come as EAPP (Engine Air Pollution Prevention) Statement of Compliance, EAPP Document of Compliance or EIAPP (Engine International Air Pollution Prevention) Certificate according to the authorization by the flag state and related technical file. For the most part on basis of an EAPP Statement of Compliance or an EAPP Document of Compliance an EIAPP certificate can be applied for.

According to the IMO regulations, a technical file shall be provided for each engine. This technical file contains information about the components affecting NO<sub>x</sub> emissions, and each critical component is marked with a special IMO number. Such critical components are piston, cylinder head, injection nozzle (element), camshaft section, fuel injection pump, turbocharger and charge air cooler. The allowable settings and parameters for running the engine are also specified in the technical file.

The marked components can be easily identified on-board of the ship by the surveyor and thus an IAPP (International Air Pollution Prevention) certificate for the ship can be issued on basis of the EIAPP certificate and the on-board inspection.

## 2.5 Engine dimensions and weight – preliminary

Turbocharger at free end

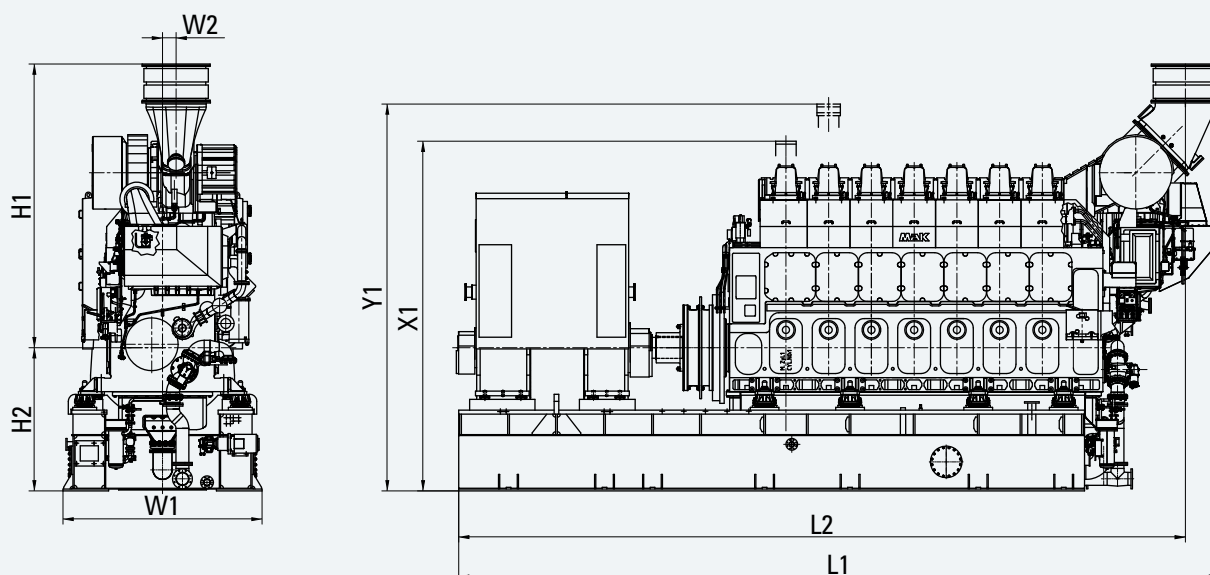


Fig. 2-1 Turbocharger at free end

| Type      | Dimensions [mm] |        |       |       |       |     | Dry weight <sup>*)</sup><br>[t] |
|-----------|-----------------|--------|-------|-------|-------|-----|---------------------------------|
|           | L1              | L2     | H1    | H2    | W1    | W2  |                                 |
| 6 M 46 DF | 12,202          | 11,651 | 4,358 | 2,444 | 3,400 | 215 | 178.0                           |
| 7 M 46 DF | 12,999          | 12,414 | 4,849 | 2,444 | 3,400 | 232 | 195.0                           |
| 8 M 46 DF | 13,729          | 13,144 | 4,849 | 2,444 | 3,400 | 232 | 210.0                           |
| 9 M 46 DF | 14,459          | 13,874 | 4,849 | 2,444 | 3,400 | 232 | 240.0                           |

<sup>\*)</sup> Depending on generator weight

## 2.6 System connecting points – preliminary

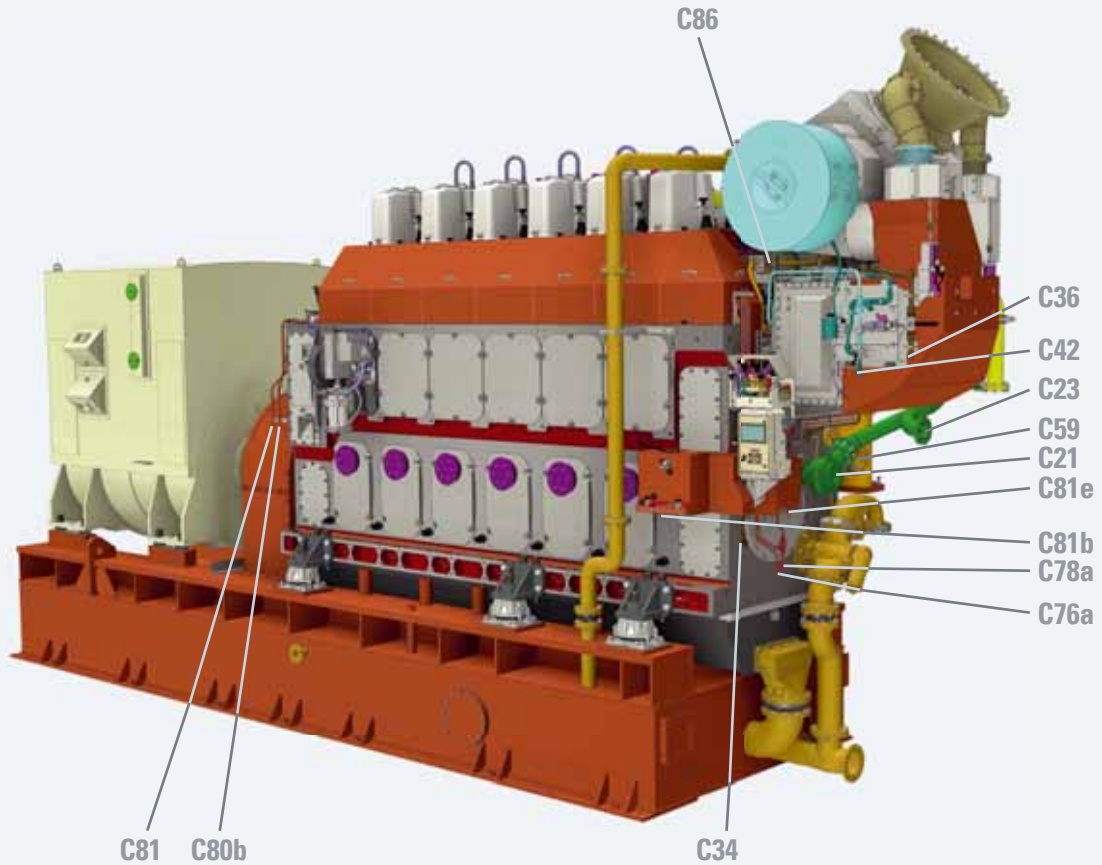


Fig. 2-2 Connecting points at the engine – 1

|             |                             |             |                                     |
|-------------|-----------------------------|-------------|-------------------------------------|
| <b>C21</b>  | Fresh water pump HT, inlet  | <b>C78a</b> | Pilot fuel, outlet                  |
| <b>C23</b>  | Fresh water pump HT, outlet | <b>C80b</b> | Drip fuel connection (cut off pump) |
| <b>C34</b>  | Drain, condensate separator | <b>C81</b>  | Drip fuel connection                |
| <b>C36</b>  | Drain, turbocharger washing | <b>C81b</b> | Drip fuel connection (filter pan)   |
| <b>C42</b>  | Turbine cleaning connection | <b>C81e</b> | Drip fuel connection, pilot fuel    |
| <b>C59</b>  | Lube oil, inlet             | <b>C86</b>  | Connection starting air             |
| <b>C76a</b> | Pilot fuel, inlet           |             |                                     |

## GENERAL DATA AND OUTPUTS

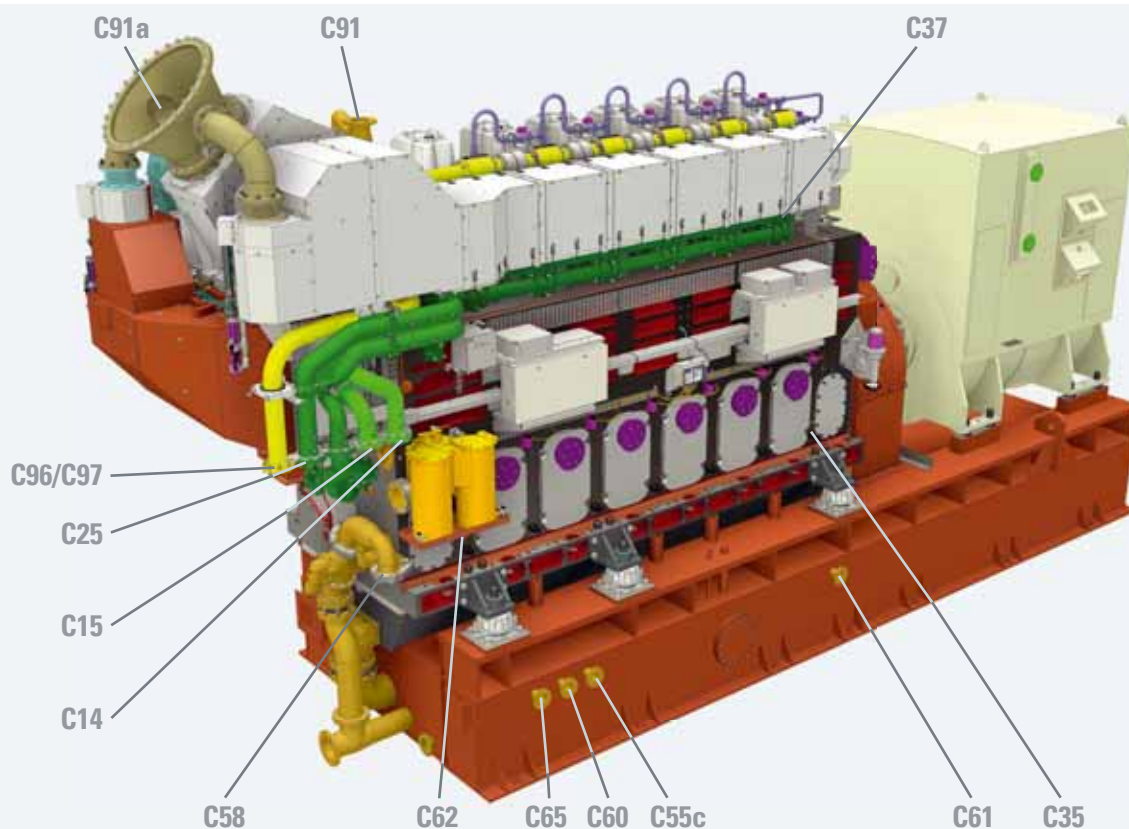


Fig. 2-3 Connecting points at the engine – 2

|             |   |             |  |
|-------------|---|-------------|--|
| <b>C14</b>  | Charge air cooler LT, inlet               | <b>C61</b>  | Separator connection, delivery side      |
| <b>C15</b>  | Charge air cooler LT, outlet              | <b>C62</b>  | Drip oil, pan duplex filter              |
| <b>C25</b>  | Cooling water, engine outlet              | <b>C65</b>  | Lube oil filling socket                  |
| <b>C35</b>  | Charge air duct, drain                    | <b>C91</b>  | Crankcase ventilation to stack           |
| <b>C37</b>  | Vent                                      | <b>C91a</b> | Exhaust gas outlet                       |
| <b>C55c</b> | Connection flushing pipe automatic filter | <b>C96</b>  | Gas inlet                                |
| <b>C58</b>  | Force pump, delivery side                 | <b>C97</b>  | Flushing connection gas pipe (inert gas) |
| <b>C60</b>  | Separator connection, suction side        |             |  |

## OPERATING RANGES

### 3.1 Restrictions for low load operation

#### 3.1.1 Load restrictions in diesel mode

The engine can be started, stopped and run on heavy fuel oil under all operating conditions. The HFO system of the engine remains in operation and keeps the HFO at injection viscosity. The temperature of the engine injection system is maintained by circulating hot HFO and heat losses are compensated. The lube oil treatment system (lube oil separator) remains in operation, the lube oil is separated continuously. The operating temperature of the engine cooling water is maintained by the cooling water preheater. Below 25 % output heavy fuel operation is neither efficient nor economical. A change-over to diesel oil is recommended to avoid disadvantages as e.g. increased wear and tear, contamination of the air and exhaust gas systems and increased contamination of lube oil.

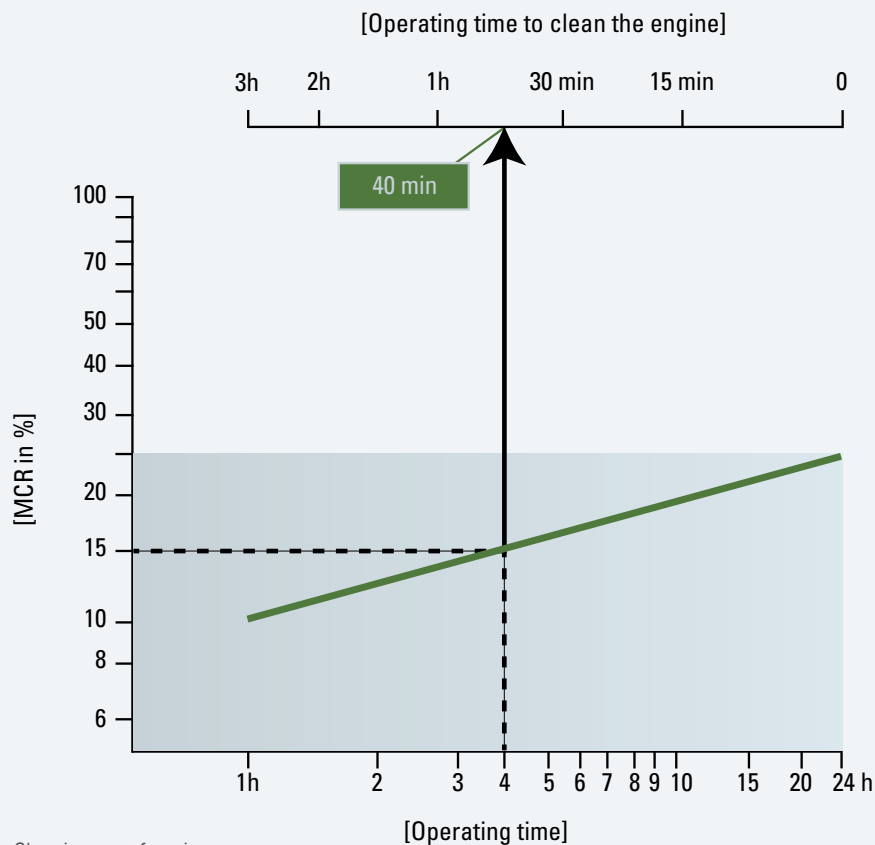


Fig. 3-1 Cleaning run of engine

## OPERATING RANGES

### 3.1.2 Load restrictions in gas mode

A gas operation above 100% load is prohibited. A gas operation below 15 % (965 kW/cyl.) or 10 % (900 kW/cyl.) load is not possible or limited for a certain time. The ability to start the engine in gas operation is optional available.

A direct fuel change over from HFO operation to gas operation is prohibited. The engine needs to run a certain time with MDO before change over to gas operation.

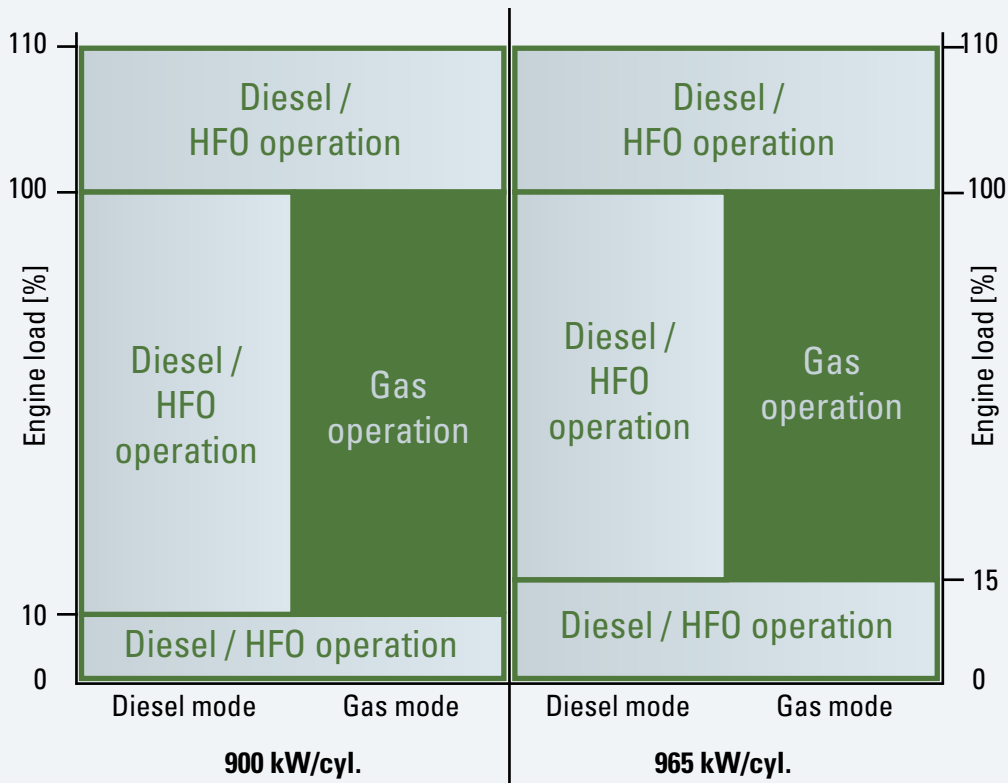


Fig. 3-2 Load restrictions in gas mode

## OPERATING RANGES

**3.2 Emergency operation without turbocharger**

Emergency operation is permissible with MDO only up to approx. 15% of the MCR.

**3.3 Operation in inclined position**

Inclination angles of ships at which engine running must be possible:

**Rotation X-axis:**

Heel to each side:  $15^\circ$

Rolling to each side:  $22.5^\circ$

**Rotation Y-axis:**

Trim by head and stern:  $5^\circ$

Pitching:  $\pm 7.5^\circ$

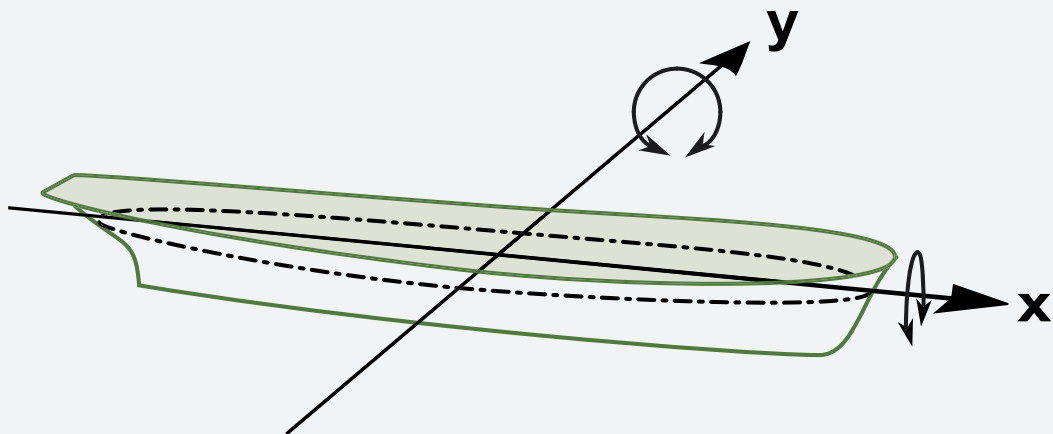


Fig. 3-3 Rotation axis

## OPERATING RANGES

### 3.4 Load application and recovery behaviour

Our standard loading up procedure for M 46 DF engines is to achieve recovery behaviour in accordance with class requirements.

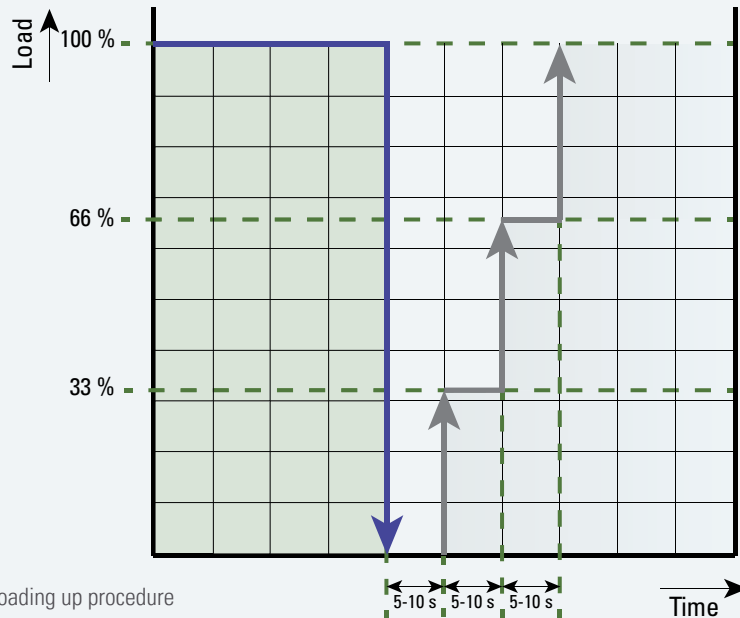


Fig. 3-4 Standard loading up procedure

| Steps       | Power [%] |        |        |
|-------------|-----------|--------|--------|
|             | 1.        | 2.     | 3.     |
| Diesel mode | 33.3 %    | 33.3 % | 33.3 % |



## OPERATING RANGES

| Steps       | Power [%] |        |        |        |        |
|-------------|-----------|--------|--------|--------|--------|
|             | 1.        | 2.     | 3.     | 4.     | 5.     |
| Diesel mode | 33.3 %    | 33.3 % | 33.3 % |        |        |
| Gas mode    | 33.0 %    | 17.0 % | 17.0 % | 16.0 % | 17.0 % |

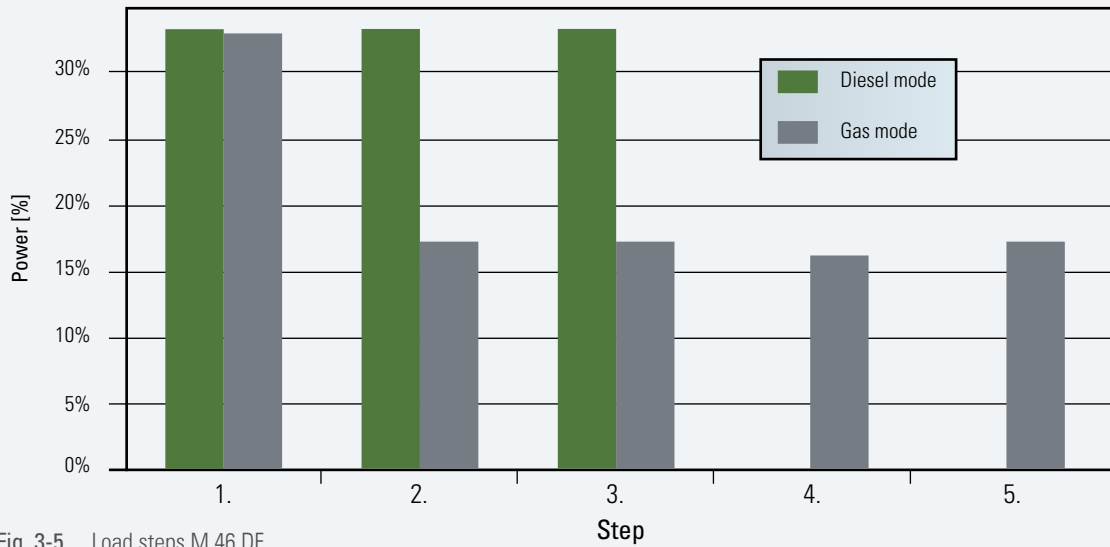


Fig. 3-5 Load steps M 46 DF

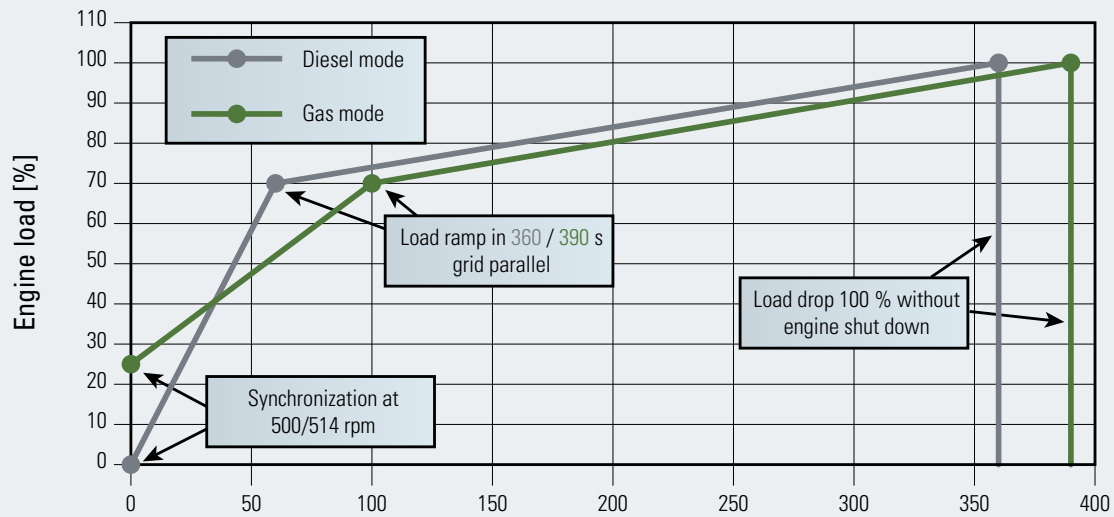


Fig. 3-6 Overview of engine load increment - diesel and gas

### Remarks:

Instant loading with recovery time in 5 seconds, Tol.:  $\pm 5$  seconds, engine warmed up in operating conditions

Minimum operating time 10 minutes

Lube oil  $> 50^{\circ}\text{C}$

Coolant  $> 65^{\circ}\text{C}$

## OPERATING RANGES

**3.5 Fuel changeover and recovery behaviour****a) Changeover from gas to diesel operation:**

- Changeover from gas to diesel fuel operation is done within approx. 1 second at any load, if required due to emergency switch over. The normal switchover takes approx. 300 seconds.
- Changeover can be started manually by operator or automatically by MACS, if the gas operation conditions are not given anymore (e.g. load window for gas operation has been left).
  - Main liquid fuel injection activated
  - Gaseous fuel slowly cut back / liquid fuel amount rises
  - FCT: Valve timing adjusts depending on running condition (e.g. load)
  - Air fuel ratio control is shut-off (Blow-Off and Waste Gate)
  - Pilot injection is still active

**b) Changeover from diesel to gas operation:**

- Changeover from diesel to gas fuel operation is possible in the load range between 15% and 100% power.
- If gas mode is activated, the load is constant in the correct range and all systems are running, the engine control will change over to gas operation:
  - Start air fuel ratio control with exhaust Waste Gate and Blow-Off
  - Change valve timing over to gas operation depending on running conditions
  - Start gas supply and raise gas amount, if gas pressure is sufficient
  - Main liquid fuel injection cuts back and switches off, if minimum fuel rack position is reached
- The procedure will take approx. 2 minutes, which depends on gas supply system and self check procedures.
- If the procedure is completed, power ramp up to 100% power or instant loading is possible.

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## OPERATING RANGES

### 3.6 Derating

In case of a fuel gas methane number lower than 80, the power output has to be redetermined in gas operation.

For an alternative derating curve please consult Caterpillar Motoren in advance.

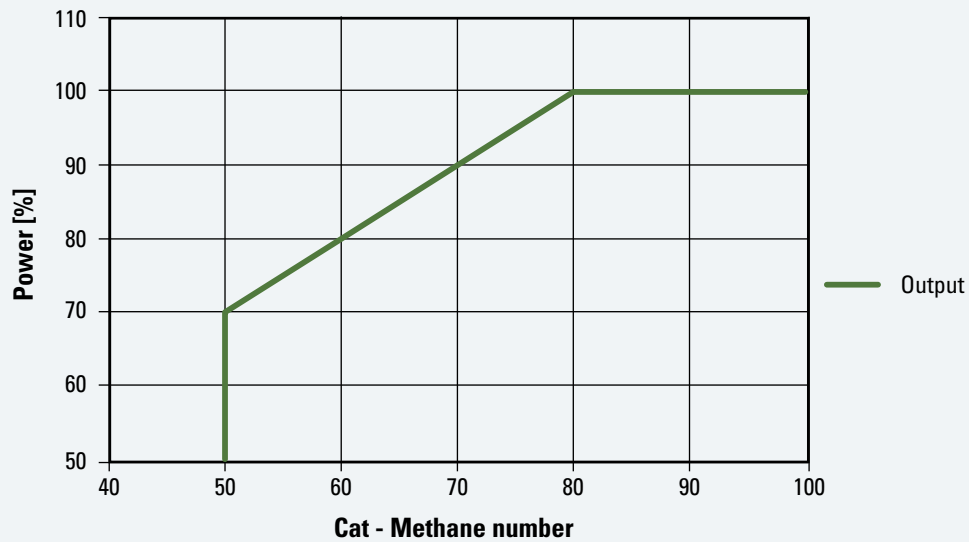


Fig. 3-7 Power as function of methane number

## TECHNICAL DATA

### 4.1 Diesel, mechanical

#### 4.1.1 Output 900 kW/Cyl. in HFO, MDO and gas operation

| Output 900 kW/Cyl. (HFO, MDO and gas)            |                  | 6 M 46 DF | 7 M 46 DF | 8 M 46 DF | 9 M 46 DF |
|--|------------------|-----------|-----------|-----------|-----------|
| <b>Performance data</b>                          |                  |           |           |           |           |
| Maximum continuous rating acc. ISO 3046/1        | [kW]             | 5,400     | 6,300     | 7,200     | 8,100     |
| Speed  | [rpm]            | 500/514   | 500/514   | 500/514   | 500/514   |
| Minimum speed                                    | [rpm]            | 300       | 300       | 300       | 300       |
| Brake mean effective pressure                    | [bar]            | 21.3/20.7 | 21.3/20.7 | 21.3/20.7 | 21.3/20.7 |
| Charge air pressure                              | [bar]            | 3.55      | 3.55      | 3.55      | 3.55      |
| Firing pressure (max. allowed, tolerance +/- 3%) | [bar]            | 190       | 190       | 190       | 190       |
| Combustion air demand (ta=20°C)                  | [m³/h]           | 32,050    | 37,380    | 42,720    | 48,060    |
| Max. load acceptance                             | [kW/s]           | 33        | 39        | 45        | 50        |
| Specific fuel oil consumption diesel/gas         |                  |           |           |           |           |
| n = const <sup>1)</sup>                          |                  |           |           |           |           |
| 100 %  | [g/kWh] [kJ/kWh] | 186/7,400 | 186/7,400 | 186/7,400 | 186/7,400 |
| 85 %   | [g/kWh] [kJ/kWh] | 185/7,524 | 185/7,524 | 185/7,524 | 185/7,524 |
| 75 %   | [g/kWh] [kJ/kWh] | 187/7,457 | 187/7,457 | 187/7,457 | 187/7,457 |
| 50 %   | [g/kWh] [kJ/kWh] | 192/7,929 | 192/7,929 | 192/7,929 | 192/7,929 |
| Lube oil consumption <sup>2)</sup>               | [g/kWh]          | 0.6       | 0.6       | 0.6       | 0.6       |
| NO <sub>x</sub> -emission (diesel) <sup>6)</sup> | [g/kWh]          | 10.3      | 10.3      | 10.3      | 10.3      |
| NO <sub>x</sub> -emission (gas) <sup>6)</sup>    | [g/kWh]          | 2.6       | 2.6       | 2.6       | 2.6       |
| Methane slip, sp. pilot oil injection            |                  |           |           |           |           |
| 100 %  | [% kJ/kWh]       | 2.0/72    | 2.0/72    | 2.0/72    | 2.0/72    |
| 50 %   | [% kJ/kWh]       | 2.1/96    | 2.1/96    | 2.1/96    | 2.1/96    |
| 15 %   | [% kJ/kWh]       | 6.9/272   | 6.9/272   | 6.9/272   | 6.9/272   |
| CO <sub>2</sub> 100% (diesel/gas)                | [%]              | 5.4/4.5   | 5.4/4.5   | 5.4/4.5   | 5.4/4.5   |
| Turbocharger type                                |                  | ABB TPL71 | ABB TPL76 | ABB TPL76 | ABB TPL76 |
| <b>Fuel</b>                                      |                  |           |           |           |           |
| Engine driven booster pump                       | [m³/h] [bar]     | —/—       | —/—       | —/—       | —/—       |
| Stand-by booster pump                            | [m³/h] [bar]     | 4.2/10    | 4.9/10    | 5.6/10    | 6.3/10    |
| Mesh size MDO fine filter                        | [mm]             | 0.025     | 0.025     | 0.025     | 0.025     |
| Mesh size HFO automatic filter                   | [mm]             | 0.010     | 0.010     | 0.010     | 0.010     |
| Mesh size HFO fine filter                        | [mm]             | 0.034     | 0.034     | 0.034     | 0.034     |

## TECHNICAL DATA

| Output 900 kW/Cyl. (HFO, MDO and gas)                                  |              | 6 M 46 DF | 7 M 46 DF | 8 M 46 DF | 9 M 46 DF |
|--|--------------|-----------|-----------|-----------|-----------|
| <b>Lube oil</b>  |              |           |           |           |           |
| Engine driven pump   | [m³/h] [bar] | 146/10    | 146/10    | 203/10    | 203/10    |
| Independent pump   | [m³/h] [bar] | 120/10    | 140/10    | 160/10    | 180/10    |
| Working pressure on engine inlet                                       | [bar]        | 4 - 5     | 4 - 5     | 4 - 5     | 4 - 5     |
| Engine driven suction pump   | [m³/h] [bar] | —/—       | —/—       | —/—       | —/—       |
| Independent suction pump   | [m³/h] [bar] | 175/3     | 175/3     | 240/3     | 240/3     |
| Priming pump pressure / suck pump                                      | [m³/h] [bar] | 16/5      | 16/5      | 20/5      | 20/5      |
| Sump tank content / dry sump content                                   | [m³]         | 8.4       | 9.8       | 11.2      | 12.6      |
| Temperature at engine inlet  | [°C]         | 60 - 65   | 60 - 65   | 60 - 65   | 60 - 65   |
| Temperature controller NB  | [mm]         | 125       | 125       | 150       | 150       |
| Double filter NB   | [mm]         | 150       | 150       | 150       | 150       |
| Mesh size double filter  | [mm]         | 0.08      | 0.08      | 0.08      | 0.08      |
| Mesh size automatic filter   | [mm]         | 0.03      | 0.03      | 0.03      | 0.03      |
| <b>Fresh water cooling</b>   |              |           |           |           |           |
| Engine content   | [m³]         | 0.6       | 0.7       | 0.8       | 0.9       |
| Pressure at engine inlet min/max                                       | [bar]        | 2.5/6.0   | 2.5/6.0   | 2.5/6.0   | 2.5/6.0   |
| Header tank capacity   | [m³]         | 0.6       | 0.6       | 0.6       | 0.6       |
| Temperature at engine outlet   | [°C]         | 80 - 90   | 80 - 90   | 80 - 90   | 80 - 90   |
| <b>Two circuit system</b>  |              |           |           |           |           |
| Engine driven pump HT  | [m³/h] [bar] | 100/4.5   | 100/4.5   | 120/4.3   | 120/4.3   |
| Independent pump HT  | [m³/h] [bar] | 100/4.5   | 110/4.5   | 120/4.5   | 130/4.5   |
| HT-controller NB   | [mm]         | 125       | 125       | 150       | 150       |
| Water demand LT-charge air cooler                                      | [m³/h]       | 80        | 80        | 100       | 100       |
| Temperature LT-charge air cooler inlet                                 | [°C]         | 38        | 38        | 38        | 38        |
| <b>Heat dissipation <sup>*)</sup></b>                                  |              |           |           |           |           |
| Specific jacket water heat   | [kJ/kWh]     | 496       | 496       | 496       | 496       |
| Specific lube oil heat   | [kJ/kWh]     | 500       | 500       | 500       | 500       |
| Lube oil cooler  | [kW]         | 750       | 875       | 1,000     | 1,120     |
| Jacket water   | [kW]         | 745       | 870       | 995       | 1,115     |
| Charge air cooler <sup>3)</sup>  | [kW]         | —         | —         | —         | —         |
| Charge air cooler (HT-stage) <sup>3)</sup>                             | [kW]         | 1,770     | 2,065     | 2,360     | 2,655     |
| Charge air cooler (LT-stage) <sup>3)</sup><br>(HT-stage before engine) | [kW]         | 500       | 585       | 665       | 750       |
| Heat radiation engine  | [kW]         | 255       | 300       | 340       | 380       |

<sup>\*)</sup> NOTE: Tolerance for heat and exhaust flow +/- 10 %, tolerance of +10 % for rating coolers

## TECHNICAL DATA

| Output 900 kW/Cyl. (HFO, MDO and gas)  |                    | 6 M 46 DF | 7 M 46 DF | 8 M 46 DF | 9 M 46 DF |
|--|--------------------|-----------|-----------|-----------|-----------|
| <b>Exhaust gas</b>   |                    |           |           |           |           |
| Silencer / spark arrestor NB   | [mm]               | 900       | 1,000     | 1,000     | 1,000     |
| Pipe diameter NB after turbine   | [mm]               | 900       | 1,000     | 1,000     | 1,000     |
| Exhaust gas temperature after turbine (intake air 25 °C, diesel) <sup>5)</sup> | [°C]               | 345       | 343       | 335       | 335       |
| Exhaust gas mass flow (intake air 25 °C, diesel) <sup>5)</sup>                 | [kg/h]             | 39,510    | 46,100    | 52,675    | 59,300    |
| Exhaust gas temperature after turbine (intake air 25 °C, gas) <sup>5)</sup>    | [°C]               | 385       | 383       | 375       | 375       |
| Exhaust gas mass flow (intake air 25 °C, gas) <sup>5)</sup>                    | [kg/h]             | 33,885    | 39,650    | 45,300    | 51,000    |
| Maximum exhaust gas pressure drop  | [bar]              | 0.03      | 0.03      | 0.03      | 0.03      |
| <b>Starting air</b>  |                    |           |           |           |           |
| Maximum starting air pressure  | [bar]              | 30        | 30        | 30        | 30        |
| Minimum starting air pressure  | [bar]              | 14        | 14        | 14        | 14        |
| Air consumption per start <sup>4)</sup>  | [Nm <sup>3</sup> ] | 2.6       | 2.7       | 3.2       | 3.3       |
| Air consumption per slow turn maneuver <sup>4)</sup>                           | [Nm <sup>3</sup> ] | 5.2       | 5.4       | 6.4       | 6.6       |
| Max. allowed crankcase pressure, ND ventilation pipe                           | [mmWs/mm]          | 15/150    | 15/150    | 15/150    | 15/150    |

1) Reference conditions: LCV = 42,700 kJ/kg, ambient temperature 25 °C, charge air coolant temperature 25 °C, tolerance 5 %, for engine driven oil pump +1% at 100%, 1.2% at 85%, 1.3% at 75%, 2% at 50%, 4% at 25%, for engine driven cooling water pump +0.4% at 100%, 0.47% at 85%, 0.53% at 75%, 0.8% at 50%, 1.6% at 25%, in propeller operation for engine driven oil pump +1% at 100%, 1.1% at 85%, 1.2% at 75%, 1.4% at 50%, 2% at 25%, for engine driven cooling water pump +0.4% at 100/85/75/50/25%, additions to fuel consumption must be considered before tolerance is taken into account. / 2) Standard value, tolerance ± 0.3 g/kWh, related on full load / 3) Charge air heat based on 45 °C ambient temperature / 4) Preheated engine / 5) Tolerance 10 %, rel. humidity 60 % / 6) Marpol 73/78, Annex VI, cycle E2, D

## TECHNICAL DATA

## 4.1.2 Output 965 kW/Cyl. in MDO and gas operation only – preliminary

## 4.1.2.1 Output 965 kW/Cyl. at 500 rpm – preliminary

| Output 965 kW/Cyl., 500 rpm (MDO and gas only)   |                  | 6 M 46 DF | 7 M 46 DF | 8 M 46 DF | 9 M 46 DF |
|--|------------------|-----------|-----------|-----------|-----------|
| Performance data                                 |                  |           |           |           |           |
| Maximum continuous rating acc. ISO 3046/1        | [kW]             | 5,790     | 6,755     | 7,720     | 8,685     |
| Speed  | [rpm]            | 500       | 500       | 500       | 500       |
| Minimum speed                                    | [rpm]            | 300       | 300       | 300       | 300       |
| Brake mean effective pressure                    | [bar]            | 22.8      | 22.8      | 22.8      | 22.8      |
| Charge air pressure                              | [bar]            | 4.0       | 4.0       | 4.0       | 4.0       |
| Firing pressure (max. allowed, tolerance +/- 3%) | [bar]            | 190       | 190       | 190       | 190       |
| Combustion air demand (ta=20°C)                  | [m³/h]           | 34,240    | 39,950    | 45,700    | 51,425    |
| Max. load acceptance                             | [kW/s]           | 33        | 39        | 45        | 50        |
| Specific fuel oil consumption diesel/gas         |                  |           |           |           |           |
| n = const <sup>1)</sup> 100 %                    | [g/kWh] [kJ/kWh] | 185/7,350 | 185/7,350 | 185/7,350 | 185/7,350 |
| 85 %   | [g/kWh] [kJ/kWh] | 183/7,445 | 183/7,445 | 183/7,445 | 183/7,445 |
| 75 %   | [g/kWh] [kJ/kWh] | 184/7,490 | 184/7,490 | 184/7,490 | 184/7,490 |
| 50 %   | [g/kWh] [kJ/kWh] | 188/7,740 | 188/7,740 | 188/7,740 | 188/7,740 |
| Lube oil consumption <sup>2)</sup>               | [g/kWh]          | 0.6       | 0.6       | 0.6       | 0.6       |
| NO <sub>x</sub> -emission (diesel) <sup>6)</sup> | [g/kWh]          | 10.3      | 10.3      | 10.3      | 10.3      |
| NO <sub>x</sub> -emission (gas) <sup>6)</sup>    | [g/kWh]          | 2.6       | 2.6       | 2.6       | 2.6       |
| Methane slip, sp. pilot oil injection            |                  |           |           |           |           |
| 100 %  | [% kJ/kWh]       | 2.0/72    | 2.0/72    | 2.0/72    | 2.0/72    |
| 50 %   | [% kJ/kWh]       | 2.1/96    | 2.1/96    | 2.1/96    | 2.1/96    |
| 15 %   | [% kJ/kWh]       | 6.9/272   | 6.9/272   | 6.9/272   | 6.9/272   |
| CO <sub>2</sub> 100% (diesel/gas)                | [%]              | 5.4/4.5   | 5.4/4.5   | 5.4/4.5   | 5.4/4.5   |
| Turbocharger type                                |                  | ABB TPL71 | ABB TPL76 | ABB TPL76 | ABB TPL76 |
| Fuel   |                  |           |           |           |           |
| Engine driven booster pump                       | [m³/h] [bar]     | —/—       | —/—       | —/—       | —/—       |
| Stand-by booster pump                            | [m³/h] [bar]     | 4.2/10    | 4.9/10    | 5.6/10    | 6.3/10    |
| Mesh size MDO fine filter                        | [mm]             | 0.025     | 0.025     | 0.025     | 0.025     |

## TECHNICAL DATA

| Output 965 kW/Cyl., 500 rpm (MDO and gas only)                         |              | 6 M 46 DF | 7 M 46 DF | 8 M 46 DF | 9 M 46 DF |
|--|--------------|-----------|-----------|-----------|-----------|
| <b>Lube oil</b>  |              |           |           |           |           |
| Engine driven pump   | [m³/h] [bar] | 146/10    | 146/10    | 203/10    | 203/10    |
| Independent pump   | [m³/h] [bar] | 120/10    | 140/10    | 160/10    | 180/10    |
| Working pressure on engine inlet                                       | [bar]        | 4 - 5     | 4 - 5     | 4 - 5     | 4 - 5     |
| Engine driven suction pump   | [m³/h] [bar] | —/—       | —/—       | —/—       | —/—       |
| Independent suction pump   | [m³/h] [bar] | 175/3     | 175/3     | 240/3     | 240/3     |
| Priming pump pressure / suck pump                                      | [m³/h] [bar] | 16/5      | 16/5      | 20/5      | 20/5      |
| Sump tank content / dry sump content                                   | [m³]         | 8.4       | 9.8       | 11.2      | 12.6      |
| Temperature at engine inlet  | [°C]         | 60 - 65   | 60 - 65   | 60 - 65   | 60 - 65   |
| Temperature controller NB  | [mm]         | 125       | 125       | 150       | 150       |
| Double filter NB   | [mm]         | 150       | 150       | 150       | 150       |
| Mesh size double filter  | [mm]         | 0.08      | 0.08      | 0.08      | 0.08      |
| Mesh size automatic filter   | [mm]         | 0.03      | 0.03      | 0.03      | 0.03      |
| <b>Fresh water cooling</b>   |              |           |           |           |           |
| Engine content   | [m³]         | 0.6       | 0.7       | 0.8       | 0.9       |
| Pressure at engine inlet min/max                                       | [bar]        | 2.5/6.0   | 2.5/6.0   | 2.5/6.0   | 2.5/6.0   |
| Header tank capacity   | [m³]         | 0.6       | 0.6       | 0.6       | 0.6       |
| Temperature at engine outlet   | [°C]         | 80 - 90   | 80 - 90   | 80 - 90   | 80 - 90   |
| <b>Two circuit system</b>  |              |           |           |           |           |
| Engine driven pump HT  | [m³/h] [bar] | 100/4.5   | 100/4.5   | 120/4.3   | 120/4.3   |
| Independent pump HT  | [m³/h] [bar] | 100/4.5   | 110/4.5   | 120/4.5   | 130/4.5   |
| HT-controller NB   | [mm]         | 125       | 125       | 150       | 150       |
| Water demand LT-charge air cooler                                      | [m³/h]       | 80        | 80        | 100       | 100       |
| Temperature LT-charge air cooler inlet                                 | [°C]         | 38        | 38        | 38        | 38        |
| <b>Heat dissipation <sup>*)</sup></b>                                  |              |           |           |           |           |
| Specific jacket water heat   | [kJ/kWh]     | 480       | 480       | 480       | 480       |
| Specific lube oil heat   | [kJ/kWh]     | 482       | 482       | 482       | 482       |
| Lube oil cooler  | [kW]         | 775       | 905       | 1,035     | 1,160     |
| Jacket water   | [kW]         | 775       | 900       | 1,030     | 1,155     |
| Charge air cooler <sup>3)</sup>  | [kW]         | —         | —         | —         | —         |
| Charge air cooler (HT-stage) <sup>3)</sup>                             | [kW]         | 2,000     | 2,330     | 2,665     | 2,995     |
| Charge air cooler (LT-stage) <sup>3)</sup><br>(HT-stage before engine) | [kW]         | 530       | 615       | 705       | 790       |
| Heat radiation engine  | [kW]         | 270       | 320       | 365       | 410       |

<sup>\*)</sup> NOTE: Tolerance for heat and exhaust flow +/- 10 %, tolerance of +10 % for rating coolers



## TECHNICAL DATA

| Output 965 kW/Cyl., 500 rpm (MDO and gas only)                                 |                    | 6 M 46 DF | 7 M 46 DF | 8 M 46 DF | 9 M 46 DF |
|--|--------------------|-----------|-----------|-----------|-----------|
| <b>Exhaust gas</b>   |                    |           |           |           |           |
| Silencer / spark arrestor NB   | [mm]               | 900       | 1,000     | 1,000     | 1,000     |
| Pipe diameter NB after turbine   | [mm]               | 900       | 1,000     | 1,000     | 1,000     |
| Exhaust gas temperature after turbine (intake air 25 °C, diesel) <sup>5)</sup> | [°C]               | 336       | 334       | 326       | 326       |
| Exhaust gas mass flow (intake air 25 °C, diesel) <sup>5)</sup>                 | [kg/h]             | 42,325    | 49,380    | 56,485    | 63,560    |
| Exhaust gas temperature after turbine (intake air 25 °C, gas) <sup>5)</sup>    | [°C]               | 366       | 364       | 358       | 358       |
| Exhaust gas mass flow (intake air 25 °C, gas) <sup>5)</sup>                    | [kg/h]             | 38,514    | 44,935    | 51,400    | 57,840    |
| Maximum exhaust gas pressure drop  | [bar]              | 0.03      | 0.03      | 0.03      | 0.03      |
| <b>Starting air</b>  |                    |           |           |           |           |
| Maximum starting air pressure  | [bar]              | 30        | 30        | 30        | 30        |
| Minimum starting air pressure  | [bar]              | 14        | 14        | 14        | 14        |
| Air consumption per start <sup>4)</sup>  | [Nm <sup>3</sup> ] | 2.6       | 2.7       | 3.2       | 3.3       |
| Air consumption per slow turn maneuver <sup>4)</sup>                           | [Nm <sup>3</sup> ] | 5.2       | 5.4       | 6.4       | 6.6       |
| Max. allowed crankcase pressure, ND ventilation pipe                           | [mmWs/mm]          | 15/150    | 15/150    | 15/150    | 15/150    |

1) Reference conditions: LCV = 42,700 kJ/kg, ambient temperature 25 °C, charge air coolant temperature 25 °C, tolerance 5 %, for engine driven oil pump +1% at 100%, 1.18% at 85%, 1.33% at 75%, 2% at 50%, 4% at 25%, for engine driven cooling water pump +0.4% at 100%, 0.47% at 85%, 0.53% at 75%, 0.8% at 50%, 1.6% at 25%, additions to fuel consumption must be considered before tolerance is taken into account. / 2) Standard value, tolerance ± 0.3 g/kWh, related on full load / 3) Charge air heat based on 45 °C ambient temperature / 4) Preheated engine / 5) Tolerance 10 %, rel. humidity 60 % / 6) Marpol 73/78, Annex VI, cycle E2, D

## TECHNICAL DATA

### 4.1.2.2 Output 965 kW/Cyl. at 514 rpm – preliminary

| Output 965 kW/Cyl., 500 rpm (MDO and gas only)   |                  | 6 M 46 DF | 7 M 46 DF | 8 M 46 DF | 9 M 46 DF |
|--|------------------|-----------|-----------|-----------|-----------|
| Performance data                                 |                  |           |           |           |           |
| Maximum continuous rating acc. ISO 3046/1        | [kW]             | 5,790     | 6,755     | 7,720     | 8,685     |
| Speed  | [rpm]            | 514       | 514       | 514       | 514       |
| Minimum speed                                    | [rpm]            | 300       | 300       | 300       | 300       |
| Brake mean effective pressure                    | [bar]            | 22.2      | 22.2      | 22.2      | 22.2      |
| Charge air pressure                              | [bar]            | 3.83      | 3.83      | 3.83      | 3.83      |
| Firing pressure (max. allowed, tolerance +/- 3%) | [bar]            | 190       | 190       | 190       | 190       |
| Combustion air demand (ta=20°C)                  | [m³/h]           | 33,555    | 39,150    | 44,790    | 50,400    |
| Max. load acceptance                             | [kW/s]           | 33        | 39        | 45        | 50        |
| Specific fuel oil consumption diesel/gas         |                  |           |           |           |           |
| n = const <sup>1)</sup>                          |                  |           |           |           |           |
| 100 %  | [g/kWh] [kJ/kWh] | 186/7,350 | 186/7,350 | 186/7,350 | 186/7,350 |
| 85 %   | [g/kWh] [kJ/kWh] | 184/7,460 | 184/7,460 | 184/7,460 | 184/7,460 |
| 75 %   | [g/kWh] [kJ/kWh] | 185/7,490 | 185/7,490 | 185/7,490 | 185/7,490 |
| 50 %   | [g/kWh] [kJ/kWh] | 189/7,740 | 189/7,740 | 189/7,740 | 189/7,740 |
| Lube oil consumption <sup>2)</sup>               | [g/kWh]          | 0.6       | 0.6       | 0.6       | 0.6       |
| NO <sub>x</sub> -emission (diesel) <sup>6)</sup> | [g/kWh]          | 10.3      | 10.3      | 10.3      | 10.3      |
| NO <sub>x</sub> -emission (gas) <sup>6)</sup>    | [g/kWh]          | 2.6       | 2.6       | 2.6       | 2.6       |
| Methane slip, sp. pilot oil injection            |                  |           |           |           |           |
| 100 %  | [% kJ/kWh]       | 2.0/72    | 2.0/72    | 2.0/72    | 2.0/72    |
| 50 %   | [% kJ/kWh]       | 2.1/96    | 2.1/96    | 2.1/96    | 2.1/96    |
| 15 %   | [% kJ/kWh]       | 6.9/272   | 6.9/272   | 6.9/272   | 6.9/272   |
| CO <sub>2</sub> 100% (diesel/gas)                | [%]              | 5.4/4.5   | 5.4/4.5   | 5.4/4.5   | 5.4/4.5   |
| Turbocharger type                                |                  | ABB TPL71 | ABB TPL76 | ABB TPL76 | ABB TPL76 |
| Fuel   |                  |           |           |           |           |
| Engine driven booster pump                       | [m³/h] [bar]     | —/—       | —/—       | —/—       | —/—       |
| Stand-by booster pump                            | [m³/h] [bar]     | 4.2/10    | 4.9/10    | 5.6/10    | 6.3/10    |
| Mesh size MDO fine filter                        | [mm]             | 0.025     | 0.025     | 0.025     | 0.025     |

## TECHNICAL DATA

| Output 965 kW/Cyl., 500 rpm (MDO and gas only)                         |              | 6 M 46 DF | 7 M 46 DF | 8 M 46 DF | 9 M 46 DF |
|--|--------------|-----------|-----------|-----------|-----------|
| <b>Lube oil</b>  |              |           |           |           |           |
| Engine driven pump   | [m³/h] [bar] | 146/10    | 146/10    | 203/10    | 203/10    |
| Independent pump   | [m³/h] [bar] | 120/10    | 140/10    | 160/10    | 180/10    |
| Working pressure on engine inlet                                       | [bar]        | 4 - 5     | 4 - 5     | 4 - 5     | 4 - 5     |
| Engine driven suction pump   | [m³/h] [bar] | —/—       | —/—       | —/—       | —/—       |
| Independent suction pump   | [m³/h] [bar] | 175/3     | 175/3     | 240/3     | 240/3     |
| Priming pump pressure / suck pump                                      | [m³/h] [bar] | 16/5      | 16/5      | 20/5      | 20/5      |
| Sump tank content / dry sump content                                   | [m³]         | 8.4       | 9.8       | 11.2      | 12.6      |
| Temperature at engine inlet  | [°C]         | 60 - 65   | 60 - 65   | 60 - 65   | 60 - 65   |
| Temperature controller NB  | [mm]         | 125       | 125       | 150       | 150       |
| Double filter NB   | [mm]         | 150       | 150       | 150       | 150       |
| Mesh size double filter  | [mm]         | 0.08      | 0.08      | 0.08      | 0.08      |
| Mesh size automatic filter   | [mm]         | 0.03      | 0.03      | 0.03      | 0.03      |
| <b>Fresh water cooling</b>   |              |           |           |           |           |
| Engine content   | [m³]         | 0.6       | 0.7       | 0.8       | 0.9       |
| Pressure at engine inlet min/max                                       | [bar]        | 2.5/6.0   | 2.5/6.0   | 2.5/6.0   | 2.5/6.0   |
| Header tank capacity   | [m³]         | 0.6       | 0.6       | 0.6       | 0.6       |
| Temperature at engine outlet   | [°C]         | 80 - 90   | 80 - 90   | 80 - 90   | 80 - 90   |
| <b>Two circuit system</b>  |              |           |           |           |           |
| Engine driven pump HT  | [m³/h] [bar] | 100/4.5   | 100/4.5   | 120/4.3   | 120/4.3   |
| Independent pump HT  | [m³/h] [bar] | 100/4.5   | 110/4.5   | 120/4.5   | 130/4.5   |
| HT-controller NB   | [mm]         | 125       | 125       | 150       | 150       |
| Water demand LT-charge air cooler                                      | [m³/h]       | 80        | 80        | 100       | 100       |
| Temperature LT-charge air cooler inlet                                 | [°C]         | 38        | 38        | 38        | 38        |
| <b>Heat dissipation <sup>*)</sup></b>                                  |              |           |           |           |           |
| Specific jacket water heat   | [kJ/kWh]     | 480       | 480       | 480       | 480       |
| Specific lube oil heat   | [kJ/kWh]     | 482       | 482       | 482       | 482       |
| Lube oil cooler  | [kW]         | 775       | 905       | 1,035     | 1,160     |
| Jacket water   | [kW]         | 775       | 900       | 1,030     | 1,155     |
| Charge air cooler <sup>3)</sup>  | [kW]         | —         | —         | —         | —         |
| Charge air cooler (HT-stage) <sup>3)</sup>                             | [kW]         | 2,000     | 2,330     | 2,665     | 2,995     |
| Charge air cooler (LT-stage) <sup>3)</sup><br>(HT-stage before engine) | [kW]         | 530       | 615       | 705       | 790       |
| Heat radiation engine  | [kW]         | 270       | 320       | 365       | 410       |

<sup>\*)</sup> NOTE: Tolerance for heat and exhaust flow +/- 10 %, tolerance of +10 % for rating coolers

## TECHNICAL DATA

| Output 965 kW/Cyl., 500 rpm (MDO and gas only)                                 |                    | 6 M 46 DF | 7 M 46 DF | 8 M 46 DF | 9 M 46 DF |
|--|--------------------|-----------|-----------|-----------|-----------|
| <b>Exhaust gas</b>   |                    |           |           |           |           |
| Silencer / spark arrestor NB   | [mm]               | 900       | 1,000     | 1,000     | 1,000     |
| Pipe diameter NB after turbine   | [mm]               | 900       | 1,000     | 1,000     | 1,000     |
| Exhaust gas temperature after turbine (intake air 25 °C, diesel) <sup>5)</sup> | [°C]               | 336       | 334       | 326       | 326       |
| Exhaust gas mass flow (intake air 25 °C, diesel) <sup>5)</sup>                 | [kg/h]             | 41,474    | 48,389    | 55,360    | 62,295    |
| Exhaust gas temperature after turbine (intake air 25 °C, gas) <sup>5)</sup>    | [°C]               | 366       | 364       | 358       | 358       |
| Exhaust gas mass flow (intake air 25 °C, gas) <sup>5)</sup>                    | [kg/h]             | 37,742    | 44,035    | 50,380    | 56,688    |
| Maximum exhaust gas pressure drop  | [bar]              | 0.03      | 0.03      | 0.03      | 0.03      |
| <b>Starting air</b>  |                    |           |           |           |           |
| Maximum starting air pressure  | [bar]              | 30        | 30        | 30        | 30        |
| Minimum starting air pressure  | [bar]              | 14        | 14        | 14        | 14        |
| Air consumption per start <sup>4)</sup>  | [Nm <sup>3</sup> ] | 2.6       | 2.7       | 3.2       | 3.3       |
| Air consumption per slow turn maneuver <sup>4)</sup>                           | [Nm <sup>3</sup> ] | 5.2       | 5.4       | 6.4       | 6.6       |
| Max. allowed crankcase pressure, ND ventilation pipe                           | [mmWs/mm]          | 15/150    | 15/150    | 15/150    | 15/150    |

1) Reference conditions: LCV = 42,700 kJ/kg, ambient temperature 25 °C, charge air coolant temperature 25 °C, tolerance 5 %, for engine driven oil pump +1% at 100%, 1.18% at 85%, 1.33% at 75%, 2% at 50%, 4% at 25%, for engine driven cooling water pump +0.4% at 100%, 0.47% at 85%, 0.53% at 75%, 0.8% at 50%, 1.6% at 25%, additions to fuel consumption must be considered before tolerance is taken into account. / 2) Standard value, tolerance ± 0.3 g/kWh, related on full load / 3) Charge air heat based on 45 °C ambient temperature / 4) Preheated engine / 5) Tolerance 10 %, rel. humidity 60 % / 6) Marpol 73/78, Annex VI, cycle E2, D

## FUEL OIL SYSTEM

**5.1 MGO / MDO operation****General**

MaK diesel engines are designed to burn a wide variety of fuels.

See the information on fuel requirements in section MDO / MGO and HFO operation or consult the Caterpillar Motoren technical product support.

For proper operation of MaK engines the minimum Caterpillar Motoren requirements for storage, treatment and supply systems have to be observed, as shown in the following sections.

**5.1.1 Acceptable MGO / MDO characteristics**

Two fuel product groups are permitted for MaK engines:

|                         |   |
|-------------------------|---|
| Pure distillates:       | Gas oil, marine gas oil, diesel fuel          |
| Distillate/mixed fuels: | Marine gas oil (MGO), marine diesel oil (MDO) |

The difference between distillate/mixed fuels and pure distillates are higher density, sulfur content and viscosity.

## FUEL OIL SYSTEM

### Marine distillate fuels

| Parameter  | Unit                 | Limit | DMX                          | DMA  | DMZ  | DMB               |
|--|----------------------|-------|------------------------------|------|------|-------------------|
| Viscosity at 40 °C   | [mm <sup>2</sup> /s] | max   | 5.5                          | 6.0  | 6.0  | 11.0              |
| Viscosity at 40 °C   | [mm <sup>2</sup> /s] | min   | 1.4                          | 2.0  | 3.0  | 2.0               |
| Micro Carbon residue at 10 % residue                                     | [% m/m]              | max   | 0.3                          | 0.0  | 0.3  | –                 |
| Density at 15 °C   | [kg/m <sup>3</sup> ] | max   | –                            | 890  | 890  | 900               |
| Micro Carbon residue   | [% m/m]              | max   | –                            | –    | –    | 0.3               |
| Sulfur <sup>a)</sup>   | [% m/m]              | max   | 1.0                          | 1.5  | 1.5  | 2.0               |
| Water  | [% V/V]              | max   | –                            | –    | –    | 0.3 <sup>b)</sup> |
| Total sediment by hot filtration   | [% m/m]              | max   | –                            | –    | –    | 0.1 <sup>b)</sup> |
| Ash  | [% m/m]              | max   | 0.01                         | 0.01 | 0.01 | 0.01              |
| Flash point  | [°C]                 | min   | 43                           | 60   | 60   | 60                |
| Pour point, summer   | [°C]                 | max   | –                            | 0    | 0    | 6                 |
| Pour point, winter   | [°C]                 | max   | –                            | -6   | -6   | 0                 |
| Cloud point  | [°C]                 | max   | -16                          | –    | –    | –                 |
| Calculated Cetane Index  |                      | min   | 45                           | 40   | 40   | 35                |
| Acid number  | [mgKOH/g]            | max   | 0.5                          | 0.5  | 0.5  | 0.5               |
| Oxidation stability  | [g/m <sup>3</sup> ]  | max   | 25                           | 25   | 25   | 25 <sup>c)</sup>  |
| Lubricity, corrected wear scar diameter (wsd 1.4 at 60 °C) <sup>d)</sup> | [µm]                 | max   | 520                          | 520  | 520  | 520 <sup>c)</sup> |
| Hydrogen sulfide <sup>e)</sup>   | [mg/kg]              | max   | 2.0                          | 2.0  | 2.0  | 2.0               |
| Appearance   |                      |       | clear & bright <sup>f)</sup> |      |      | b), c)            |

a) A Sulphur limit of 1.00 % m/m applies in the Emission Control Areas designated by the International Maritime Organization. As there may be local variations, the purchaser shall define the maximum Sulphur content according to the relevant statutory requirements, notwithstanding the limits given in this table. / b) If the sample is not clear and bright, total sediment by hot filtration and water test shall be required. / c) Oxidation stability and lubricity tests are not applicable if the sample is not clear and bright. / d) Applicable if Sulphur is less than 0.050% m/m. /

e) Effective only from 1 July 2012. / f) If the sample is dyed and not transparent, water test shall be required. The water content shall not exceed 200 mg/kg (0.02% m/m).

### 5.1.2 Internal fuel oil system

#### General

The fuel injectors are utilized to deliver the correct amount of fuel to the cylinders precisely at the moment it is needed. The diesel fuel supply system must ensure a permanent and clean supply of diesel fuel to the engine internal fuel oil system.

NOTE: In diesel mode operation the ignition fuel system is always active.

#### Fuel fine filter (duplex filter) DF1 (fitted)

Duplex change over type (mesh size of 25 µm) is fitted on the engine.

## FUEL OIL SYSTEM

### 5.1.3 External fuel oil system

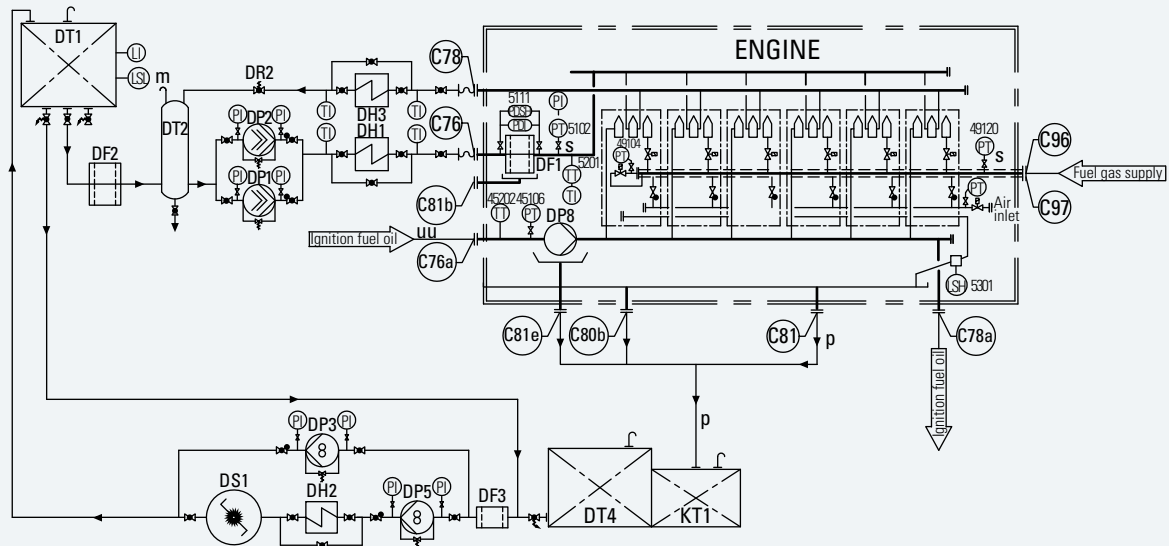


Fig. 5-1 External fuel oil system diagram with intermediate tank

|      |                                     |      |   |
|------|-------------------------------------|------|---|
| DF1  | Fuel fine filter (duplex filter)    | C76  | Duplex filter, inlet  |
| DF2  | Fuel primary filter (duplex filter) | C76a | Pilot fuel, inlet   |
| DH3  | Diesel oil cooler                   | C78  | Fuel outlet   |
| DP1  | Diesel oil feed pump                | C78a | Ignition fuel, outlet   |
| DP2  | Diesel oil stand-by feed pump       | C80b | Drip fuel connection (sealing oil injection pump)   |
| DP8  | Common rail high pressure pump      | C81  | Drip fuel connection  |
| DR2  | Fuel pressure regulating valve      | C81b | Drip fuel connection  |
| DT1  | Diesel oil day tank                 | C81e | Drip fuel connection, pilot fuel  |
| DT2  | Diesel oil intermediate tank        | C96  | Gas inlet   |
| KT1  | Drip fuel tank                      | C97  | Flushing connection gas pipe (inert gas)  |
| LI   | Level indicator                     | m    | Lead vent pipe beyond service tank level.   |
| LSH  | Level switch high                   | p    | Free outlet required.   |
| LSL  | Level switch low                    | s    | Please refer to the measuring point list regarding design of the monitoring devices.  |
| PDI  | Diff. pressure indicator            | uu   | Only MDO fuel types DMA and DMZ acc. to ISO 8271 are to be used. For usage of DMB or DMX please consult Caterpillar Motoren in advance. |
| PDSH | Diff. pressure switch high          |      |   |
| PI   | Pressure indicator                  |      |   |
| PT   | Pressure transmitter                |      |   |
| TI   | Temperature indicator               |      |   |
| TT   | Temperature transmitter (PT100)     |      |   |

# FUEL OIL SYSTEM

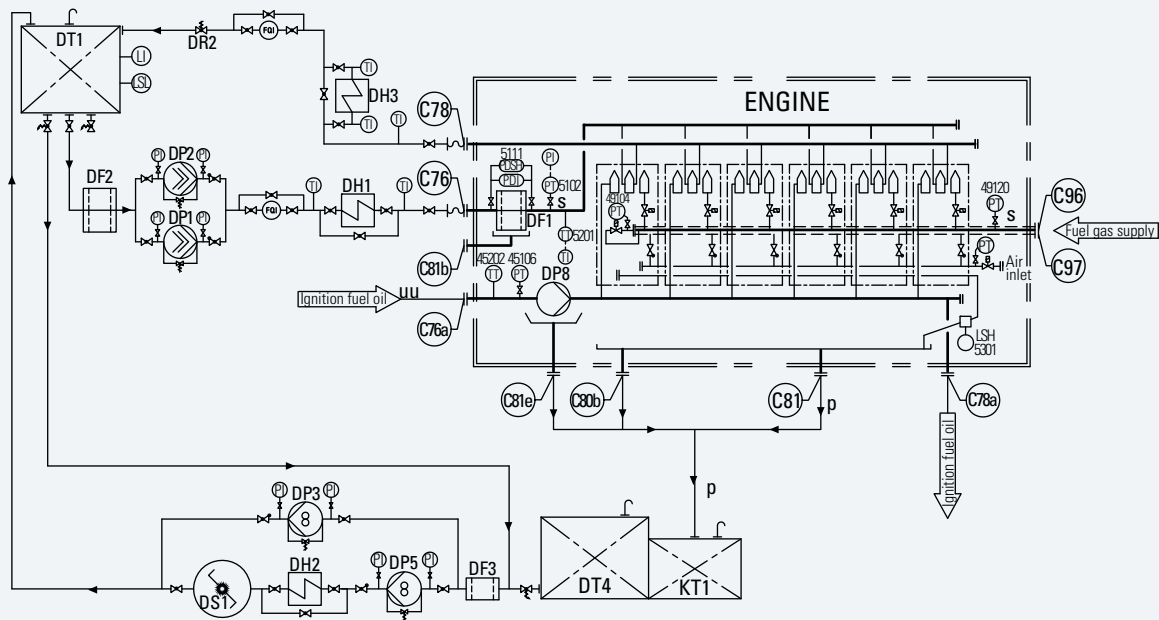


Fig. 5-2 External fuel oil system diagram without intermediate tank

|      |                                     |      |   |
|------|-------------------------------------|------|---|
| DF1  | Fuel fine filter (duplex filter)    | C76  | Duplex filter, inlet  |
| DF2  | Fuel primary filter (duplex filter) | C76a | Pilot fuel, inlet   |
| DH3  | Gas oil cooler                      | C78  | Fuel outlet   |
| DP1  | Diesel oil feed pump                | C78a | Ignition fuel, outlet   |
| DP2  | Diesel oil stand-by feed pump       | C80b | Drip fuel connection (sealing oil injection pump)   |
| DP8  | Common rail high pressure pump      | C81  | Drip fuel connection  |
| DR2  | Fuel pressure regulating valve      | C81b | Drip fuel connection  |
| DS1  | Diesel oil separator                | C81e | Drip fuel connection, pilot fuel  |
| DT1  | Diesel oil day tank                 | C96  | Gas inlet   |
| DT4  | Diesel oil storage tank             | C97  | Flushing connection gas pipe (inert gas)  |
| KT1  | Drip fuel tank                      |      |   |
| FQI  | Flow quantity indicator             | p    | Free outlet required.   |
| LI   | Level indicator                     | s    | Please refer to the measuring point list regarding design of the monitoring devices.  |
| LSH  | Level switch high                   | uu   | Only MDO fuel types DMA and DMZ acc. to ISO 8271 are to be used. For usage of DMB or DMX please consult Caterpillar Motoren in advance. |
| PDI  | Diff. pressure indicator            |      |   |
| PDSH | Diff. pressure switch high          |      |   |
| PI   | Pressure indicator                  |      |   |
| PT   | Pressure transmitter                |      |   |
| TI   | Temperature indicator               |      |   |
| TT   | Temperature transmitter (PT100)     |      |   |



## FUEL OIL SYSTEM

### General

The design of the fuel oil system may vary from ship to ship, the system itself has to provide sufficient, permanent and clean fuel oil of the required viscosity and pressure to each engine. Fuel storage, treatment, temperature and pressure control as well as sufficient circulation must be ensured.

### Diesel oil storage tank DT4

The tank design, sizing and location are according to classification society requirements and based on ship application. No heating is necessary because all marine distillate fuels are suitable for pumping.

### Diesel oil separator DS1

Depending on the fuel oil quality a diesel oil separator DS1 is recommended for the use of MGO and required for MDO by Caterpillar Motoren. Any fuel oil must always be considered as contaminated upon delivery and should therefore be thoroughly cleaned to remove solid and liquid contaminants before use. Most of the solid contaminants in the fuel are rust, sand, dust.

Liquid contaminants are mainly water, i.e. fresh water or salt water.

Impurities in the fuel oil can result in

- damage to fuel injection pumps and injectors,
- increased cylinder liner wear,
- deterioration of the exhaust valve seats
- increased fouling of turbocharger blades.

If a diesel oil separator is installed a total diesel oil separator capacity of 100 % of the full load fuel consumption is recommended.

HT-water or electrical heating is normally used as heating medium.

The nominal capacity should be based on a separation time of 22h/day:

$$V_{\text{eff.}} [\text{l/h}] = 0.28 \cdot P_{\text{eng.}} [\text{kW}]$$

$$V_{\text{eff.}} = \text{Volume effective} [\text{l/h}]$$

$$P_{\text{eng.}} = \text{Power engine} [\text{kW}]$$

### Diesel oil day tank DT1

The day tank collects clean / treated fuel oil, compensates irregularities in the treatment plant and its standstill periods. Two day tanks are to be provided, each with a capacity according to classification rules. The tank should be provided with a sludge space including a sludge drain valve and an overflow pipe from the MDO/MGO service tank to the settling/storage tank. The level of the tank must ensure a positive static pressure on the suction side of the fuel feed pumps. Usually tank heating is not required.

## FUEL OIL SYSTEM

### Fuel primary filter (duplex filter) DF2

The fuel primary filter protects the fuel meter and feed pump from major solids. A duplex change over type with mesh size of 320 µm is recommended.

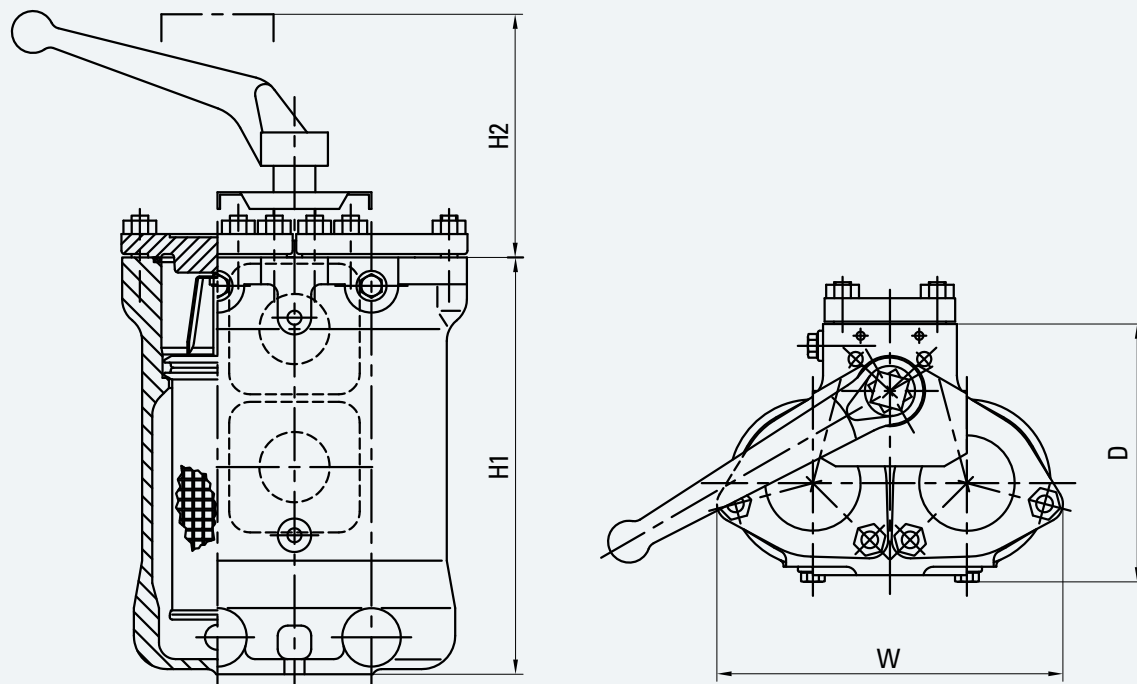


Fig. 5-3 Fuel primary filter DF2

| Engine output<br>[kW] | DN | Dimensions [mm] |     |     |     |
|-----------------------|----|-----------------|-----|-----|-----|
|                       |    | H1              | H2  | W   | D   |
| ≤ 10,000              | 65 | 523             | 480 | 260 | 355 |
| ≤ 20,000              | 80 | 690             | 700 | 370 | 430 |

### Flow quantity indicator FQI

One fuel meter is sufficient if the return fuel from the engine is connected to the diesel intermediate tank DT2.

If the fuel return from engine is connected to the day tank, an additional fuel meter in the return line to day tank has to be provided.

A minimum static fuel pressure head of at least 0.2 bar has to be considered. The fuel may be provided by gravity flow from the day tank. The static pressure must exceed the back pressure of the flow meter and prefilter.

## FUEL OIL SYSTEM

### Diesel oil intermediate tank DT2

In the intermediate tank DT2 the warm return fuel from the engine mixes with the fuel from the day tank. The tank shall be vented as an open system, with the ventilation line guided to above the day tank level.

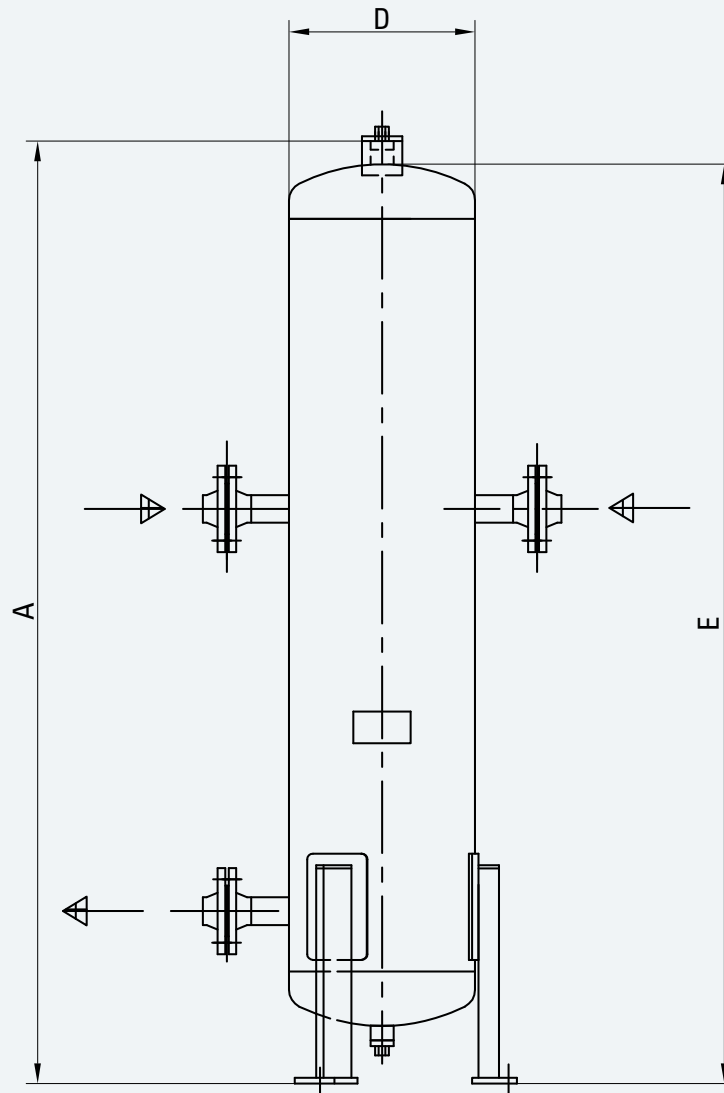


Fig. 5-4 Diesel oil intermediate tank DT2

| Plant output | Volume | Dimensions [mm] |     |       | Weight |
|--------------|--------|-----------------|-----|-------|--------|
| [kW]         | [l]    | A               | D   | E     | [kg]   |
| ≤ 10,000     | 100    | 1,700           | 323 | 1,500 | 120    |
| > 10,000     | 200    | 1,700           | 406 | 1,500 | 175    |

## FUEL OIL SYSTEM

### Diesel oil preheater DH1 (hot water)

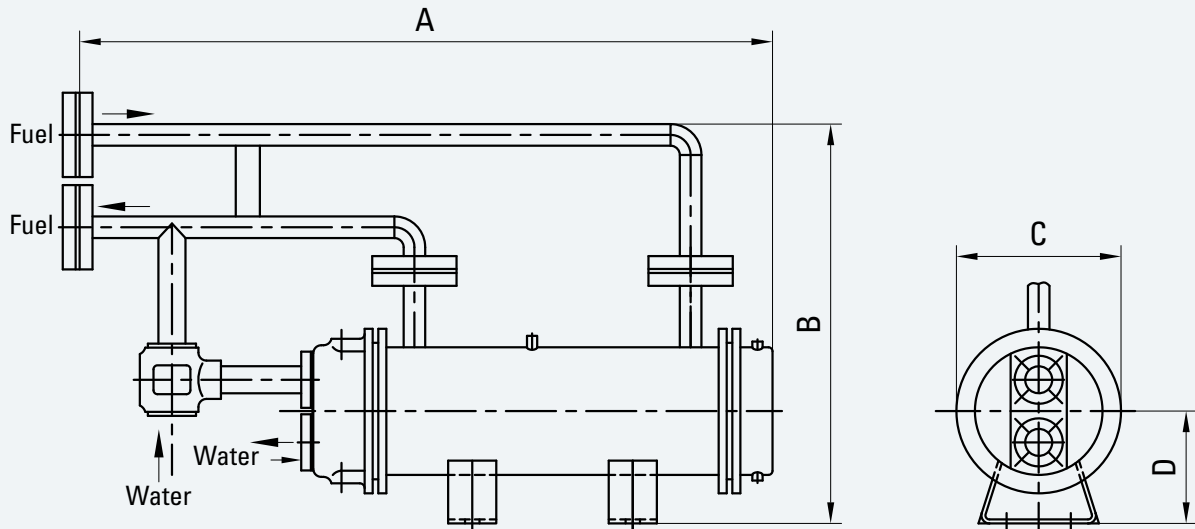


Fig. 5-5 Diesel oil preheater DH1

| Engine      | Dimensions [mm] |     |       |     | Weight<br>[kg] |
|-------------|-----------------|-----|-------|-----|----------------|
|             | A               | B   | C     | D   |                |
| 6-9 M 46 DF | 1,468           | 484 | Ø 205 | 140 | ca. 75         |

The capacity of the MDO preheater is to determine on the required fuel temperature up to approx. 50 °C.

Heating capacity:  $Q \text{ [kW]} = \frac{P_{\text{eng.}} \text{ [kW]}}{166}$

Q = Heating capacity [kW]

P<sub>eng.</sub> = Power engine [kW]

A diesel oil preheater is not required

- for gas oil operation.
- with preheated day tanks.

## FUEL OIL SYSTEM

### Feed pump DP1/DP2 (separate)

The feed pump DP1/DP2 delivers fuel through the filter DF1 to each injection pump.  
 The feed pump maintains the pressure at the injection pumps and circulates the fuel in the system.  
 The capacity is slightly oversized to transfer the heat, which occurs during the injection process, away from the fuel injection system.  
 A positive static pressure is required at the suction side of the pump.  
 Capacity see technical data.

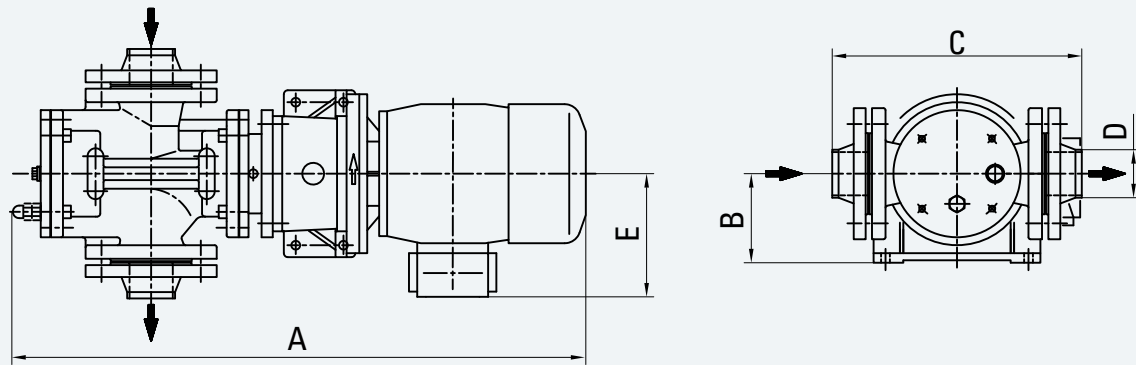


Fig. 5-6 Feed pump DP1/DP2

| Engine        | Dimensions [mm] |     |     |      |     | Weight<br>[kg] | Motorpower<br>[kW] | Voltage /<br>Frequency<br>[V/Hz] |
|---------------|-----------------|-----|-----|------|-----|----------------|--------------------|----------------------------------|
|               | A               | B   | C   | D    | E   |                |                    |                                  |
| 6-9 M 46 DF   | 805             | 132 | 314 | 60.3 | 180 | 72             | 3.0                | 400/50                           |
| 6 M 46 DF     | 775             | 132 | 314 | 60.3 | 180 | 70             | 2.6                | 440/60                           |
| 7/8/9 M 46 DF | 805             | 132 | 314 | 60.3 | 180 | 72             | 3.6                | 440/60                           |

## FUEL OIL SYSTEM

### Fuel oil cooler DH3

To ensure a fuel oil temperature below 50 °C at any time a cooling of diesel oil may be required. The need for a fuel cooler is system specific and depends on fuel circuit design and type of fuel oil. In case of more than one engine connected to the same fuel supply system, the MDO-cooler capacity has to be increased accordingly.

The heat transfer load into the diesel oil system is approx. 3.1 kW/cyl.

LT-water is normally used as cooling medium.

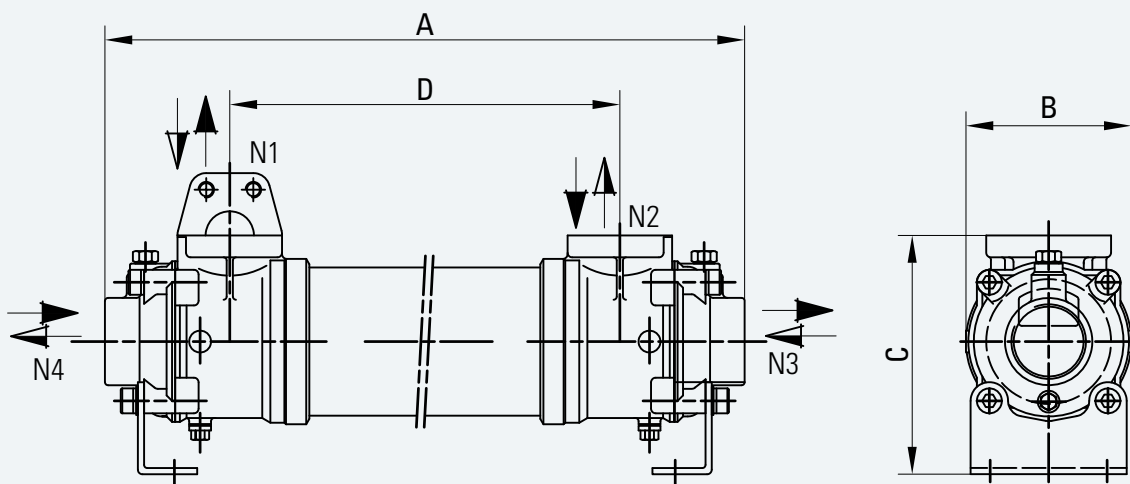


Fig. 5-7 Fuel oil cooler for MDO operation DH3

| Engine      | Dimensions [mm] |     |     |     |         |          | Weight [kg] |
|-------------|-----------------|-----|-----|-----|---------|----------|-------------|
|             | A               | B   | C   | D   | N1 + N2 | N3 + N4  |             |
| 6-9 M 46 DF | 940             | 148 | 225 | 702 | DN50    | 1 ½" BSP | 39          |

## FUEL OIL SYSTEM

### Fuel pressure regulating valve DR2

To ensure a sufficient diesel oil pressure at engine inlet, a fuel pressure regulating valve DR2 has to be installed and adjusted during commissioning of the engine.

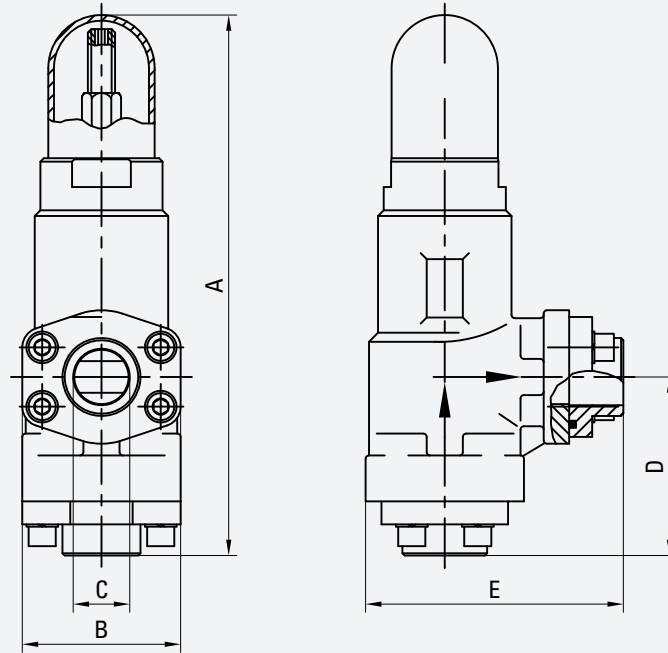


Fig. 5-8 Fuel pressure regulating valve

| Plant output | Dimensions [mm] |    |      |     |       | Weight |
|--------------|-----------------|----|------|-----|-------|--------|
| [kW]         | A               | B  | C    | D   | E     | [kg]   |
| ≤ 6,000      | 248             | 70 | Ø 25 | 88  | 122.5 | 3.6    |
| > 6,000      | 279             | 94 | Ø 38 | 109 | 150.5 | 8.4    |

## 5.2 HFO operation

The following section is based on the experiences gained in the operation of heavy fuel installations. Stable and correct viscosity of the fuel before injection pumps (see technical data) must be maintained at any time. Sufficient circulation through every engine connected to the same circuit must be ensured in all operating conditions.

The fuel treatment system should comprise at least one settling tank and two separators. Correct dimensioning of HFO separators is of great importance, and therefore the recommendations of the separator manufacturer must be closely followed.

Poorly purified fuel is harmful to the engine. A high content of water may also damage the fuel feed system.

Injection pumps generate pressure pulses into the fuel feed and return piping. The fuel pipes between the feed unit and the engine must be clamped properly to rigid structures. The distance between the fixing points should be at close distance next to the engine. (See chapter piping design, treatment and installation.)

### ATTENTION:

In multiple engine installations, where several engines are connected to the same fuel feed circuit, it must be possible to close the fuel supply and return lines connected to the engine individually. (This is a SOLAS requirement.)

### NOTE:

It is further stipulated that the means of isolation shall not affect the operation of the other engines, and it shall be possible to close the fuel lines from a position that is not rendered inaccessible due to fire on any of the engines.

In HFO mode operation the ignition fuel system is always active.

### Fuel oil system

A pressurized fuel oil system, as shown in Fig. 5-10, is necessary when operating on high viscosity fuels. When using high viscosity fuels requiring high preheating temperatures, the fuel oil from the engine fuel oil system to the return line will also have a relatively high temperature. The fuel oil pressure measured on the engine (at fuel pump level) should be about 5 bar. This maintains a pressure margin against gasification and cavitation in the fuel system, even at 150 °C preheating.

In order to ensure correct atomization, the fuel oil temperature must be adjusted according to the specific fuel oil viscosity used. An inadequate temperature can influence the combustion and could cause increased wear on cylinder liners and piston rings, as well as deterioration of the exhaust valve seats. A too low heating temperature, i.e. too high viscosity, could also result in excessive fuel consumption. Therefore, optimum injection viscosity of 10 – 12 cSt must be maintained at any rate and with all fuel grades.

Deviations from design recommendations are possible, however, they should be discussed with Caterpillar Motoren.

Trace heating for all heavy fuel pipes is recommended.

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# FUEL OIL SYSTEM

## Viscosity temperature sheet

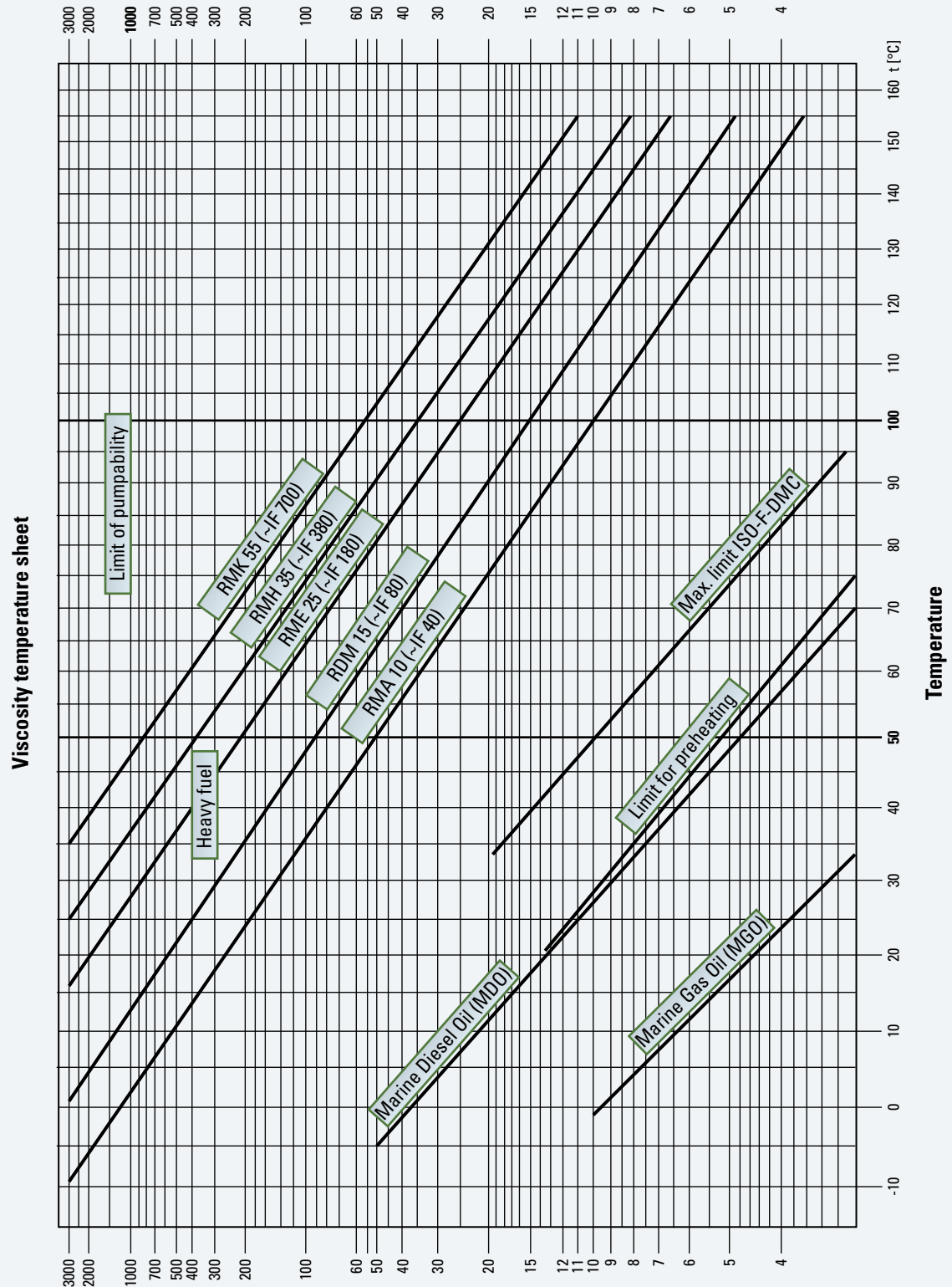


Fig. 5-9 Viscosity / temperature diagram

## FUEL OIL SYSTEM

### 5.2.1 CIMAC – Requirements for residual fuels for diesel engines (as delivered)

- Fuel shall be free of used lube oil.
- Requirements for residual fuels for diesel engines please see table next page.

| Characteristic            | Designation        | CIMAC A10         | CIMAC B10         | CIMAC C10 | CIMAC D15         | CIMAC E25        | CIMAC F25 | CIMAC G35 | CIMAC H35 | CIMAC H45 | CIMAC K45 | CIMAC H55 | CIMAC K55 |
|---------------------------|--------------------|-------------------|-------------------|-----------|-------------------|------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Density at 15°C           | kg/m <sup>3</sup>  | 950 <sup>2)</sup> | 975 <sup>3)</sup> |           | 980 <sup>4)</sup> | 991              |           | 991       | 991       | 991       | 1,010     | 991       | 1,010     |
| Kin. viscosity at 100°C   | cSt. <sup>1)</sup> |                   | 10                |           | 15                | 25               |           | 35        | 35        | 45        |           | 55        |           |
| Kin. viscosity at 100°C   | cSt. <sup>1)</sup> | 6 <sup>5)</sup>   |                   |           |                   | 15 <sup>5)</sup> |           |           |           |           |           |           |           |
| Flash point               | °C                 |                   | 60                |           | 60                | 60               |           | 60        | 60        | 60        |           | 60        |           |
| Pour point winter         | °C                 | 0                 |                   |           |                   |                  |           |           |           |           |           |           |           |
| Pour point summer         | °C                 | 6                 | 24                |           | 30                | 30               |           | 30        | 30        | 30        |           | 30        |           |
| Carbon residue            | % (m/m)            | 12 <sup>6)</sup>  |                   | 14        | 14                | 15               | 20        | 18        | 22        | 22        |           | 22        |           |
| Ash                       | % (m/m)            |                   | 0.10              |           | 0.10              | 0.10             | 0.15      | 0.15      | 0.15      | 0.15      |           | 0.15      |           |
| Total sedim. after ageing | % (m/m)            |                   | 0.10              |           | 0.10              | 0.10             |           |           | 0.10      | 0.10      |           | 0.10      |           |
| Water                     | % (V/V)            |                   | 0.5               |           | 0.5               | 0.5              |           |           | 0.5       | 0.5       |           | 0.5       |           |
| Sulphur                   | % (m/m)            |                   | 3.5               |           | 3.5               | 3.5              |           |           | 3.5       | 3.5       |           | 3.5       |           |
| Vanadium                  | mg/kg              | 150               | 300               |           | 150               | 150              | 500       | 350       | 350       | 450       |           | 450       |           |
| Aluminum + Silicon        | mg/kg              |                   | 40                |           | 40                | 50               |           |           | 60        | 60        |           | 60        |           |
| Zink                      | mg/kg              |                   | 15                |           | 15                | 15               |           |           | 15        | 15        |           | 15        |           |
| Phosphor                  | mg/kg              |                   | 15                |           | 15                | 15               |           |           | 15        | 15        |           | 15        |           |
| Calcium                   | mg/kg              |                   | 30                |           | 30                | 30               |           |           | 30        | 30        |           | 30        |           |

1) An indication of the approximate equivalents in kinematic viscosity at 50°C and Redw. I sec 100°F is given below:

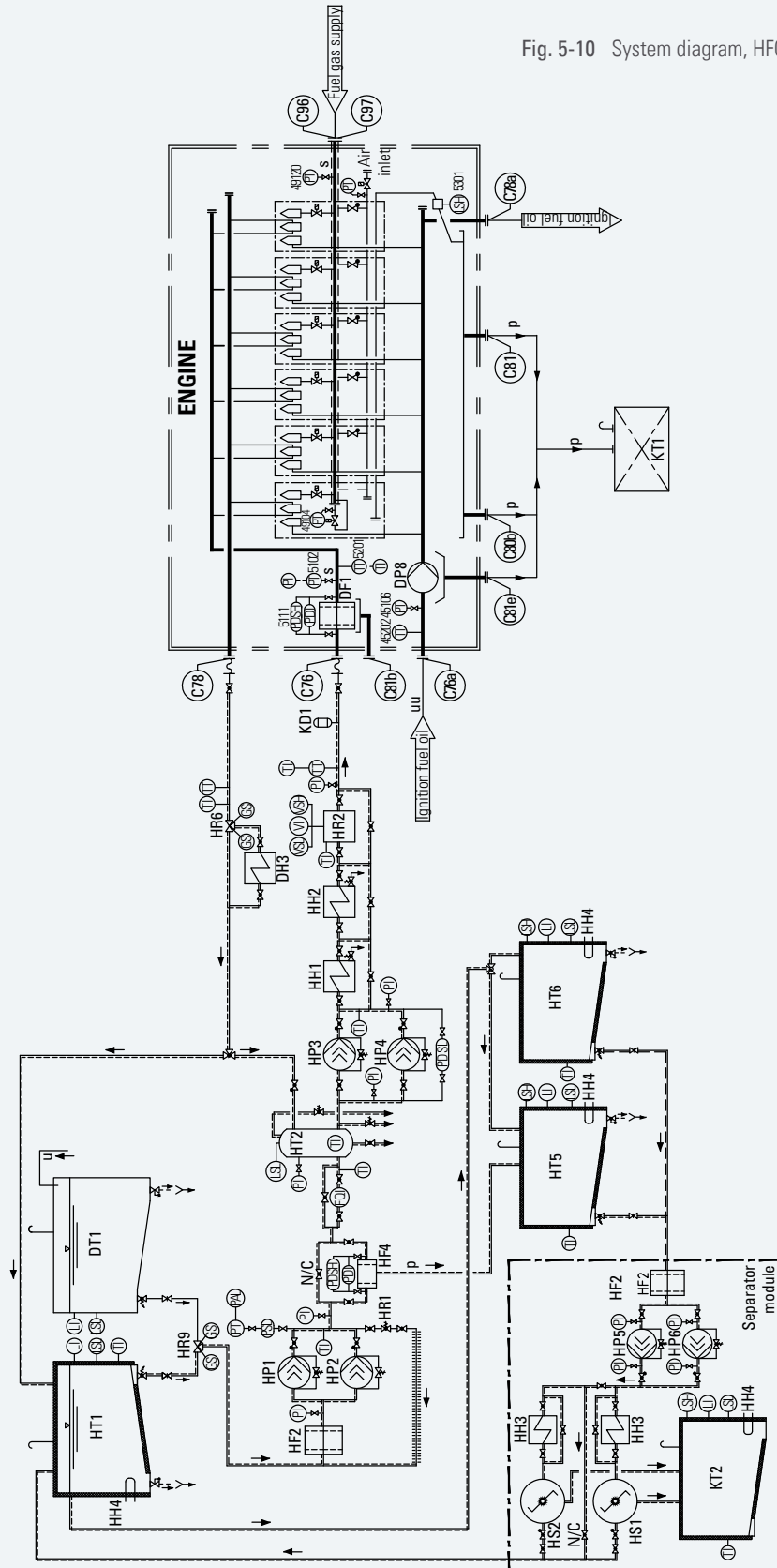
Kinematic viscosity at 100°C [mm<sup>2</sup>/s] [cSt.] 7 10 15 25 35 45 55

Kinematic viscosity at 50°C [mm<sup>2</sup>/s] [cSt.] 30 40 80 180 380 500 700

Kinematic viscosity at 100°F Redw. [I sec.] 200 300 600 1,500 3,000 5,000 7,000

2) ISO: 960 / 3) ISO: 960 / 4) ISO: 975 / 5) ISO: not limited / 6) ISO: carbon residue 10

Fig. 5-10 System diagram, HFO operation



## FUEL OIL SYSTEM

### General

For location, dimensions and design (e.g. flexible connection) of the disconnecting points see engine installation drawing.

No valve fittings with loose cone must be installed by the shipyard in admission and return lines.

|              |                                      |             |  |
|--------------|--------------------------------------|-------------|--|
| <b>DF1</b>   | Fuel fine filter (Duplex filter)     | <b>FQI</b>  | Flow quantity indicator                              |
| <b>DH3</b>   | Gas oil cooler                       | <b>GS</b>   | Limit switch   |
| <b>DP8</b>   | Common rail high pressure pump       | <b>LI</b>   | Level indicator                                      |
| <b>DT1</b>   | Diesel oil day tank                  | <b>LSH</b>  | Level switch high                                    |
| <b>HF2</b>   | Primary filter (duplex filter)       | <b>LSL</b>  | Level switch low                                     |
| <b>HF4</b>   | Self cleaning filter                 | <b>PAL</b>  | Pressure alarm low                                   |
| <b>HH1</b>   | Heavy fuel final preheater           | <b>PDI</b>  | Diff. pressure indicator                             |
| <b>HH2</b>   | Stand-by final preheater             | <b>PDSH</b> | Diff. pressure switch high                           |
| <b>HH3</b>   | Heavy fuel preheater (separator)     | <b>PDSL</b> | Diff. pressure switch low                            |
| <b>HH4</b>   | Heating coil                         | <b>PI</b>   | Pressure indicator                                   |
| <b>HP1</b>   | Fuel pressure pump                   | <b>PSL</b>  | Pressure switch low                                  |
| <b>HP2</b>   | Fuel stand-by pressure pump          | <b>PT</b>   | Pressure temp.                                       |
| <b>HP3</b>   | Fuel circulating pump                | <b>TI</b>   | Temperature indicator                                |
| <b>HP4</b>   | Stand-by circulating pump            | <b>TT</b>   | Temperature transmitter (PT100)                      |
| <b>HP5/6</b> | Heavy fuel transfer pump (separator) | <b>VI</b>   | Viscosity indicator                                  |
| <b>HR1</b>   | Fuel pressure regulating valve       | <b>VSH</b>  | Viscosity control switch high                        |
| <b>HR2</b>   | Viscosimeter                         | <b>VSL</b>  | Viscosity control switch low                         |
| <b>HR6</b>   | Change over valve                    |             |  |
| <b>HR9</b>   | Fuel change over main valve          | <b>C76</b>  | Duplex filter, inlet                                 |
| <b>HS1/2</b> | Heavy fuel separator                 | <b>C76a</b> | Pilot fuel, inlet                                    |
| <b>HT1</b>   | Heavy fuel day tank                  | <b>C78</b>  | Fuel outlet  |
| <b>HT2</b>   | Mixing tank                          | <b>C78a</b> | Ignition fuel, outlet                                |
| <b>HT5/6</b> | Settling tank                        | <b>C80b</b> | Drip fuel connection<br>(sealing oil injection pump) |
| <b>KD1</b>   | Pressure absorber                    | <b>C81</b>  | Drip fuel connection                                 |
| <b>KT1</b>   | Drip fuel tank                       | <b>C81b</b> | Drip fuel connection                                 |
| <b>KT2</b>   | Sludge tank                          | <b>C81e</b> | Drip fuel connection, pilot fuel                     |
|              |                                      | <b>C96</b>  | Gas inlet  |
|              |                                      | <b>C97</b>  | Flushing connection gas pipe (inertgas)              |

All heavy fuel pipes have to be insulated.

----- Heated pipe

===== Fintube heat exchanger

|           |   |
|-----------|---|
| <b>p</b>  | Free outlet required  |
| <b>s</b>  | Please refer to the measuring point list regarding design of the monitoring devices.  |
| <b>u</b>  | Fuel from separator or from transfer pump   |
| <b>uu</b> | Only MDO fuel types DMA and DMZ acc. to ISO 8271 are to be used. For usage of DMB or DMX please consult Caterpillar Motoren in advance. |

## FUEL OIL SYSTEM

**Storage tanks**

The tank design, sizing and location must comply with classification society requirements and are based on ship application.

Heating coils are necessary and are to be designed so that the HFO temperature is at least 10K above the pour point to ensure a pumping viscosity below 1,000 cSt.

Heating is possible by steam, thermal oil, electrical current or hot water.

**Settling tanks HT5, HT6**

The tank design, sizing, location must comply with classification society requirements and are based on ship application. Two settling tanks are to be provided.

Its function is to remove water and solids by gravity due to higher fuel oil temperature and reduced turbulences. Provide constant oil temperature and avoid interruption of treatment system, due to overflow from HFO day tank. Thermal insulation of the settling tanks is recommended to avoid heat losses.

In order to ensure a sufficient settling effect, the following settling tank designs are permitted:

- 2 settling tanks, each with a capacity sufficient for 24 hours full load operation of all consumers or
- 1 settling tank with a capacity sufficient for 36 hours full load operation of all consumers and automatic filling

Settling tank temperature shall be 70 - 80 °C; the charging level shall be 70 - 90 %.

**Heavy fuel preheater (separator) HH3**

Heavy fuel oil needs to be heated up to a certain temperature before separating.

The most common heaters on board of ships are steam heaters. Other fluid heating sources are hot water, thermal oil or electrical heaters. Overheating of the fuel may cause fuel cracking. Thus the maximum electric load on the heater element should not exceed 1 Watt/cm<sup>2</sup>.

In a cleaning system for HFO the usual processing temperature is 98 °C.

The separator manufacturer's guidelines have to be observed.

**Heavy fuel transfer pumps (separator) HP5, HP6**

The separator feed pumps shall be installed as close as possible to the settling tanks.

The separator manufacturer's guidelines have to be observed.

## FUEL OIL SYSTEM

### Heavy fuel separators HS1, HS2

Any fuel oils whether heavy fuel oil, diesel oil or crude oil must always be considered as contaminated upon delivery and should therefore be thoroughly cleaned before use.

Therefore self-cleaning types should be selected.

The purpose of any fuel treatment system is to clean the fuel oil by removal of water, solids, and suspended matter to protect the engine from excessive wear and corrosion.

Liquid contaminants are mainly water, i.e. either fresh water or salt water.

Impurities in the fuel can cause damage to fuel injection pumps and injectors, and can result in increased cylinder liner wear and deterioration of the exhaust valve seats as well as increased fouling of turbocharger blades.

Two separators with independent electrically driven pumps must be provided.

#### Separator sizing:

The correct sizing of the separators is based on the max. fuel oil consumption at maximum continuous rating (MCR) of the engines. The following formula can be used:

(The fuel consumption of auxiliary engines and boilers, if there are any, must be included)

$$V_{\text{eff.}} = 0.28 P \text{ (l/h)}$$

$V_{\text{eff.}}$  = Volume effective [l/h]

$P_{\text{eng.}}$  = Power engine [kW]

The cleaning capacity of the separator must always be higher than the entire fuel consumption of the plant, incl. aux. equipment.

#### ATTENTION:

The separator outlet pressure is limited, so the pressure in the pipe line between separator outlet and day tank must be observed carefully. Follow the separator manufacturer's guidelines.

### Heavy fuel day tank HT1

The tank design, sizing and location must comply with classification society requirements based on ship application. Two day tanks are to be provided. Each day tank capacity must be designed for full load operation of all consumers according to classification requirements. An overflow system into the settling tanks is required. HFO day tanks shall be provided with heating coils and sufficient insulation. Heating is possible by steam, thermal oil or hot water. The day tank temperature shall be above 90 °C.

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## FUEL OIL SYSTEM

### 5.2.2 Fuel booster and supply system

The booster system shall provide a pre-pressure to the mixing tank of approx. 4 - 5 bar. The circulating system provides sufficient flow of the required viscosity to the injection pumps. The circulation flow rate is typically 3.5 - 4 times the fuel consumption at MCR to prevent overheating of the fuel injection system and thus avoiding evaporation in the injection pumps.

#### Fuel change over main valve HR9

A manually operated three-way valve for changing over from MDO/MGO to HFO operation and back to MDO/MGO equipped with limit switches is necessary.

#### Primary filter (duplex filter) HF2

A protection strainer with a mesh size 320 µm has to be installed before fuel pressure pumps to prevent any large particles entering the pump.

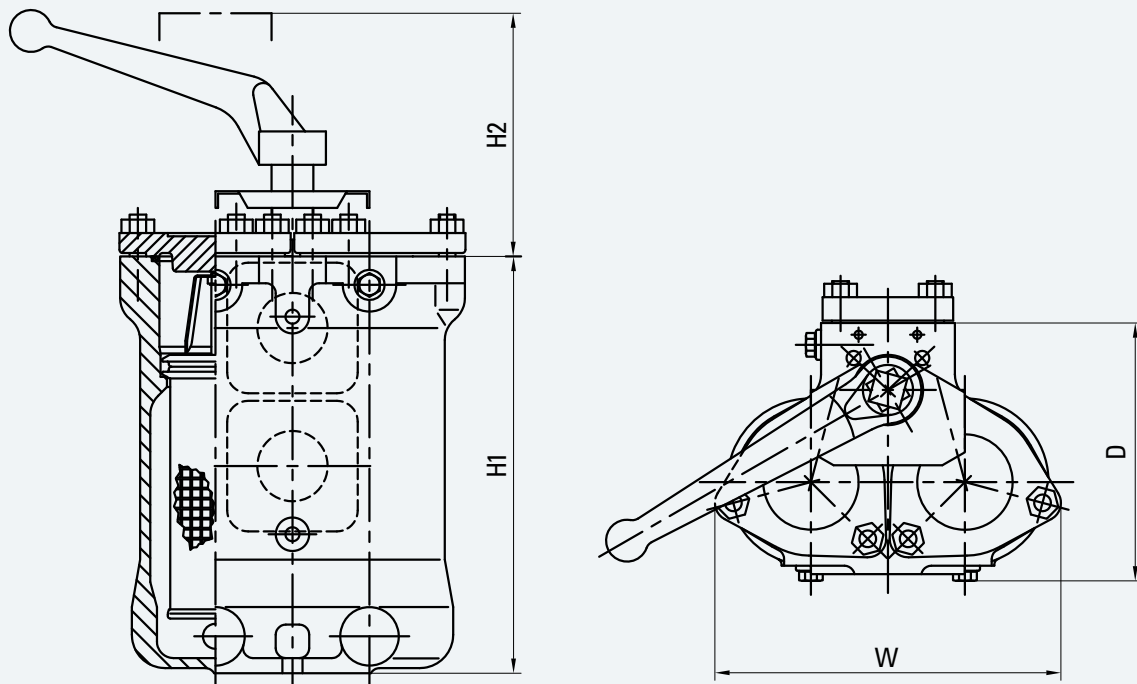


Fig. 5-11 Primary filter HF2

| Engine output<br>[kW] | DN | Dimensions [mm] |     |     |     |
|-----------------------|----|-----------------|-----|-----|-----|
|                       |    | H1              | H2  | W   | D   |
| ≤ 10,000              | 40 | 330             | 300 | 250 | 210 |
| ≤ 20,000              | 65 | 523             | 480 | 260 | 355 |
| > 20,000              | 80 | 690             | 700 | 370 | 430 |

## FUEL OIL SYSTEM

### Fuel pressure pump HP1, fuel stand-by pressure pump HP2

Two supply pumps in parallel are recommended, one in operation and one on stand-by.

The capacity of the pump must be sufficient to prevent pressure drop during flushing of the automatic filter.

A suction strainer with a mesh size of 320 µm should be installed before each pump.

- Screw type pump with mechanical seal.
- Vertical or horizontal installation is possible.
- Delivery head 5 bar.

Capacity  $V \text{ [m}^3/\text{h}] = 0.4 \cdot \frac{P_{\text{eng.}} \cdot [\text{kW}]}{1,000}$

$V =$  Volume [m<sup>3</sup>/h]  
 $P_{\text{eng.}} =$  Power engine [kW]

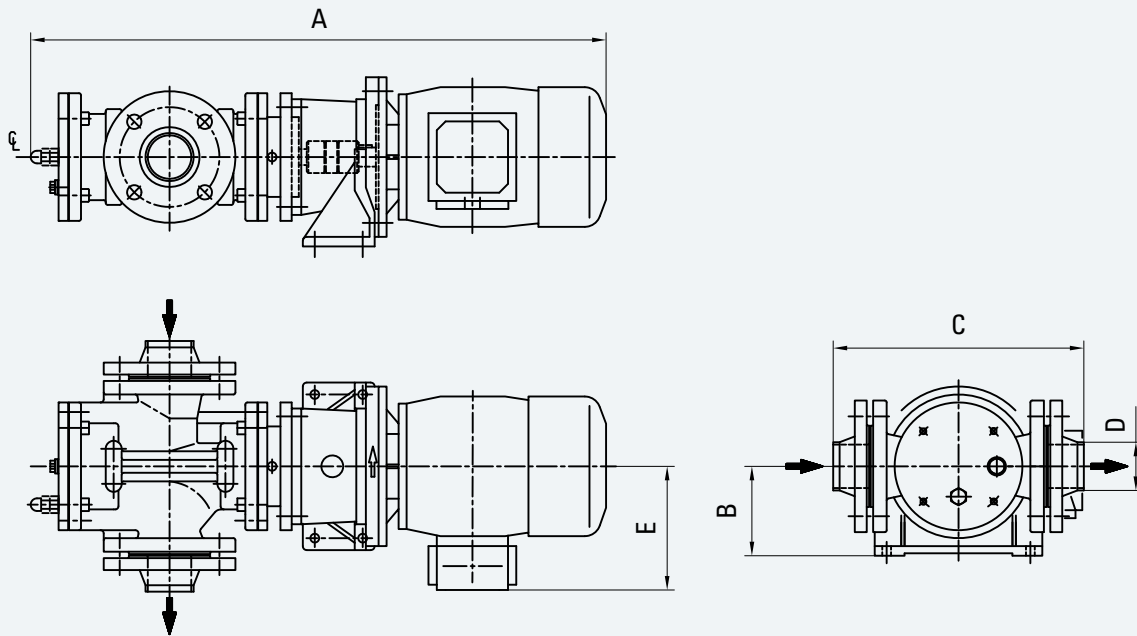


Fig. 5-12 Fuel pressure pump HP1; fuel stand-by pressure pump HP2

| Plant output    | Dimensions [mm] |     |     |      |     | Weight | Voltage / frequency |
|-----------------|-----------------|-----|-----|------|-----|--------|---------------------|
| [kW]            | A               | B   | C   | D    | E   | [kg]   | [V/Hz]              |
| 5,400 - 7,720   | 775             | 132 | 314 | 60.3 | 180 | 70     | 400/50              |
| 8,100 - 11,580  | 805             | 132 | 314 | 60.3 | 180 | 72     | 400/50              |
| 13,510          | 820             | 132 | 314 | 60.3 | 190 | 80     | 400/50              |
| 14,400 - 17,370 | 980             | 160 | 354 | 88.9 | 210 | 124    | 400/50              |

| Plant output    | Dimensions [mm] |     |     |      |     | Weight | Voltage / frequency |
|-----------------|-----------------|-----|-----|------|-----|--------|---------------------|
| [kW]            | A               | B   | C   | D    | E   | [kg]   | [V/Hz]              |
| 5,400 - 8,685   | 775             | 132 | 314 | 60.3 | 180 | 70     | 440/60              |
| 10,800 - 13,510 | 805             | 132 | 314 | 60.3 | 180 | 70     | 440/60              |
| 14,400 - 17,370 | 820             | 132 | 314 | 60.3 | 190 | 80     | 440/60              |



## FUEL OIL SYSTEM

### Fuel pressure regulating valve HR1

This valve is installed for adjusting a constant and sufficient pressure at engine fuel inlet. Due to the overcapacity of the pressure pumps HP1/HP2 the valve provides a nearly constant pressure under all operating conditions - from engine stop to maximum engine consumption. For MDO/MGO operation the pipes of the fuel return line must be equipped with sufficient fincoolers to reduce the generated heat.

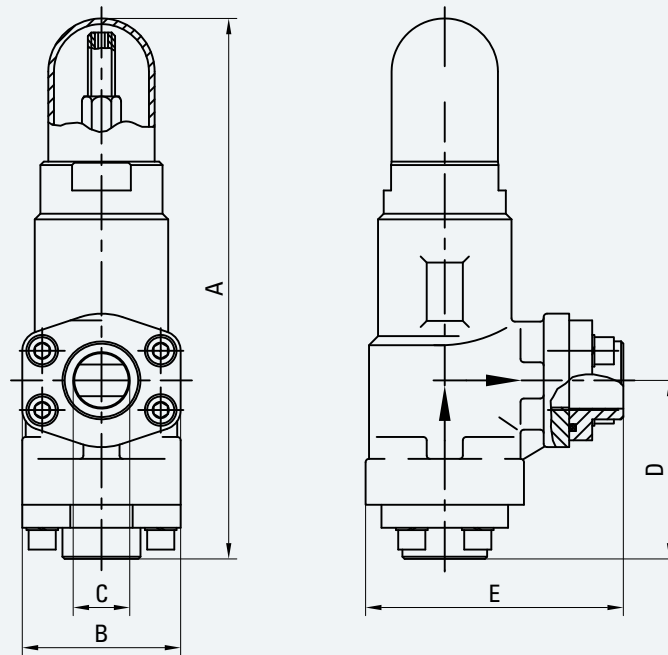


Fig 5-13 Fuel pressure regulating valve

| Plant output | Dimensions [mm] |    |      |     |       | Weight |
|--------------|-----------------|----|------|-----|-------|--------|
| [kW]         | A               | B  | C    | D   | E     | [kg]   |
| ≤ 8,400      | 248             | 70 | Ø 25 | 88  | 122.5 | 3.6    |
| > 8,400      | 279             | 94 | Ø 38 | 109 | 150.5 | 8.4    |

## FUEL OIL SYSTEM

### HFO automatic filter HF4

An automatic filter with a mesh size 10 µm (absolute) is required to remove cat fines from the fuel oil. The filter is installed between day tank and mixing tank.

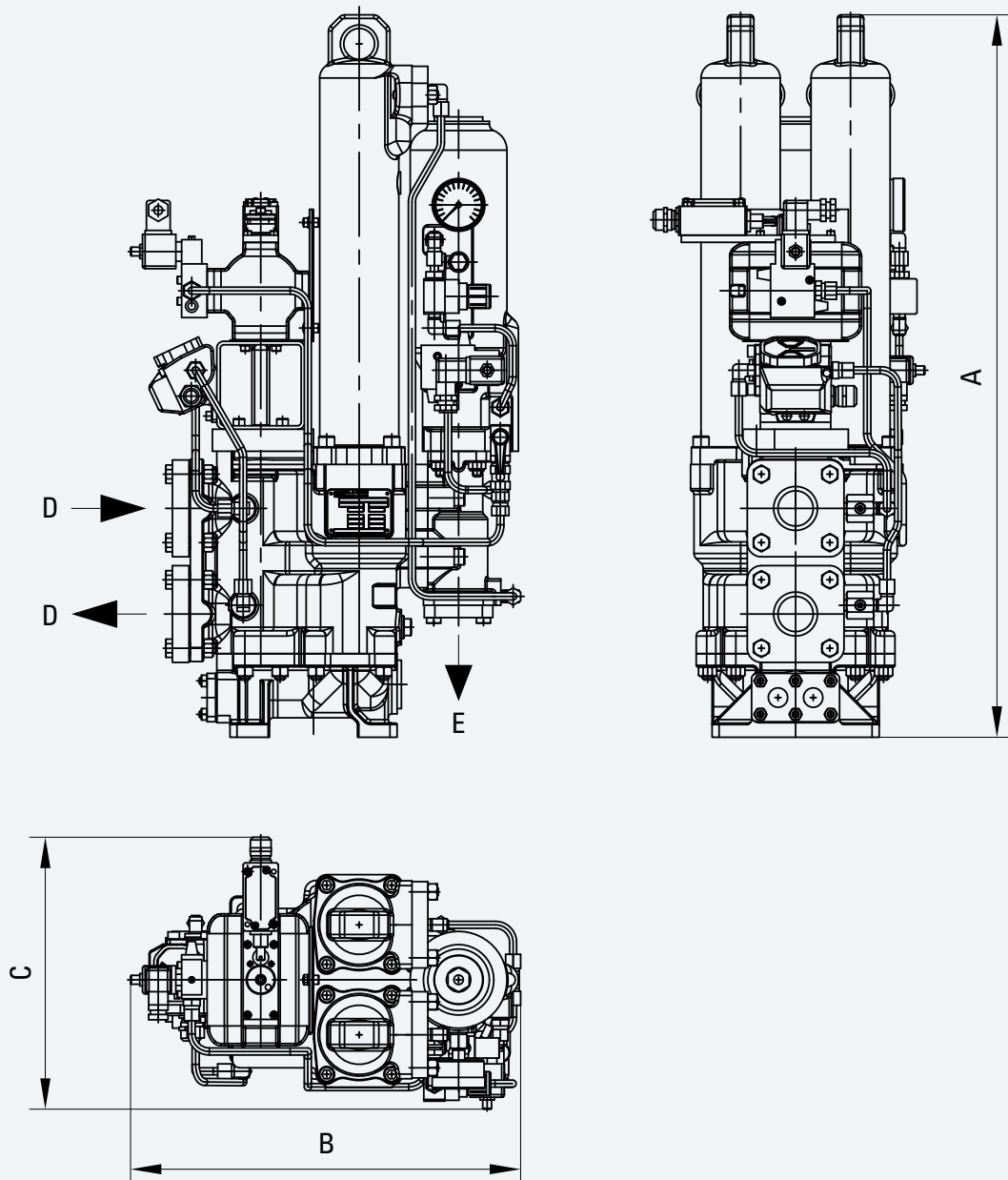


Fig. 5-14 HFO automatic filter HF4

| Plant output | Dimensions [mm] |     |     |       |       |
|--------------|-----------------|-----|-----|-------|-------|
| [kW]         | A               | B   | C   | D     | E     |
| ≤ 12,000     | 890             | 520 | 335 | DN 65 | DN 50 |
| ≤ 19,800     | 975             | 590 | 410 | DN 80 | DN 65 |

## FUEL OIL SYSTEM

### Flow quantity indicator FQ1

The fuel meter has to be installed between feed pumps and mixing tank HT2.

Independent fuel consumption measurements for individual engines can be provided by installing two flow meters per engine, one at the feed line and one at the return line.

### Mixing tank HT2

The mixing tank acts as a buffer for fuel viscosity and/or fuel temperature, when changing over from HFO to diesel oil and vice versa. In the mixing tank the warm return fuel from the engine is mixed with the fuel delivered from the day tank.

Venting to the day tank is required, if level switch is activated, due to accumulated air or gases in the mixing tank.

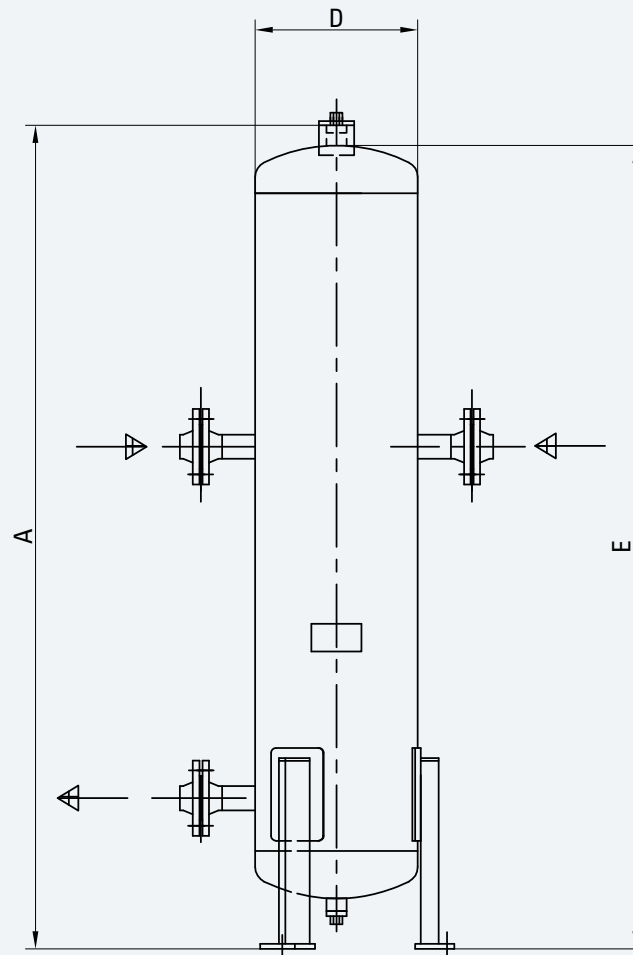


Fig. 5-15 Mixing tank HT2

| Plant output | Volume | Dimensions [mm] |     |       | Weight |
|--------------|--------|-----------------|-----|-------|--------|
| [kW]         | [l]    | A               | D   | E     | [kg]   |
| ≤ 10,000     | 100    | 1,700           | 323 | 1,500 | 120    |
| > 10,000     | 200    | 1,700           | 406 | 1,500 | 175    |

## FUEL OIL SYSTEM

### Fuel circulating pump HP3, stand-by circulating pump HP4

Two fuel circulating pumps in parallel are recommended, one in operation and one on stand-by. The circulating pumps maintain the required fuel circulation through the engine's fuel injection system.

- Screw type pump with mechanical seal
- Vertical or horizontal installation is possible
- Delivery head 5 bar

Capacity  $V \text{ [m}^3/\text{h}] = 0.7 \cdot \frac{P_{\text{eng.}} \cdot [\text{kW}]}{1,000}$

$V =$  Volume  $[\text{m}^3/\text{h}]$   
 $P_{\text{eng.}} =$  Power engine  $[\text{kW}]$

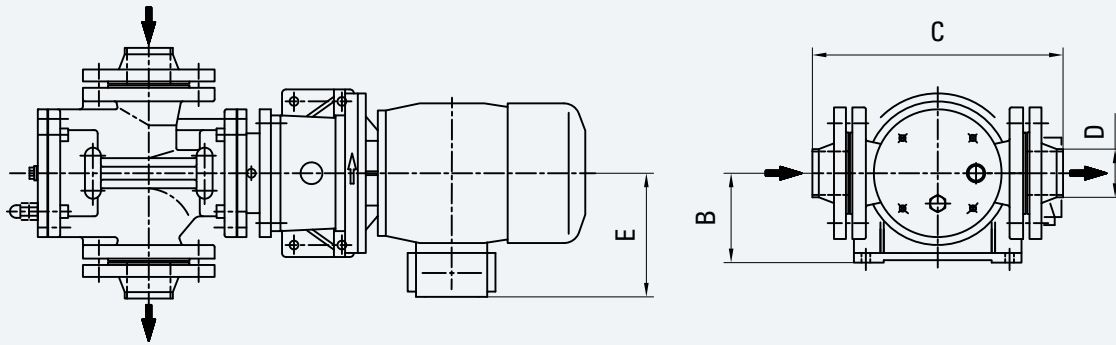


Fig. 5-16 Fuel circulating pump HP3, Stand-by circulating pump HP4

| Plant output | Dimensions [mm] |     |     |      |     | Weight | Voltage / frequency |
|--------------|-----------------|-----|-----|------|-----|--------|---------------------|
| [kW]         | A               | B   | C   | D    | E   | [kg]   | [V/Hz]              |
| ≤ 6,300      | 805             | 132 | 314 | 60.3 | 180 | 72     | 400/50              |
| ≤ 8,100      | 820             | 132 | 314 | 60.3 | 190 | 80     | 400/50              |
| ≤ 12,600     | 980             | 160 | 354 | 88.9 | 210 | 124    | 400/50              |
| ≤ 17,370     | 1,020           | 160 | 354 | 88.9 | 210 | 139    | 400/50              |

| Plant output | Dimensions [mm] |     |     |      |     | Weight | Voltage / frequency |
|--------------|-----------------|-----|-----|------|-----|--------|---------------------|
| [kW]         | A               | B   | C   | D    | E   | [kg]   | [V/Hz]              |
| ≤ 5,400      | 775             | 132 | 314 | 60.3 | 180 | 70     | 440/60              |
| ≤ 8,100      | 805             | 132 | 314 | 60.3 | 180 | 72     | 440/60              |
| ≤ 12,600     | 820             | 132 | 314 | 60.3 | 190 | 80     | 440/60              |
| ≤ 17,370     | 980             | 160 | 354 | 8.9  | 210 | 124    | 440/60              |

## FUEL OIL SYSTEM

### Heavy fuel final preheater HH1, stand-by final preheater HH2

The capacity of the final preheater shall be determined based on the injection temperature at the nozzle, to which 4 K must be added to compensate for heat losses in the piping.

The piping for both heaters shall be arranged for separate and series operation.

Parallel operation with half the flow must be avoided due to the risk of sludge deposits.

The arrangement of only one preheater may be approved where it is ensured that the operation with fuel oil which does not need preheating can be temporarily maintained.

#### NOTE:

Safe return to port requirement, maneuverability must be ensured.

- Two mutually independent final preheaters have to be installed.
- The arrangement of only one preheater may be approved where it is ensured that the operation with fuel oil which does not need preheating can be temporarily maintained.

#### Heating media:

- Electric current (max. surface power density 1.1 W/cm<sup>2</sup>)
- Steam
- Thermal oil

Temperature at engine inlet max. 150 °C

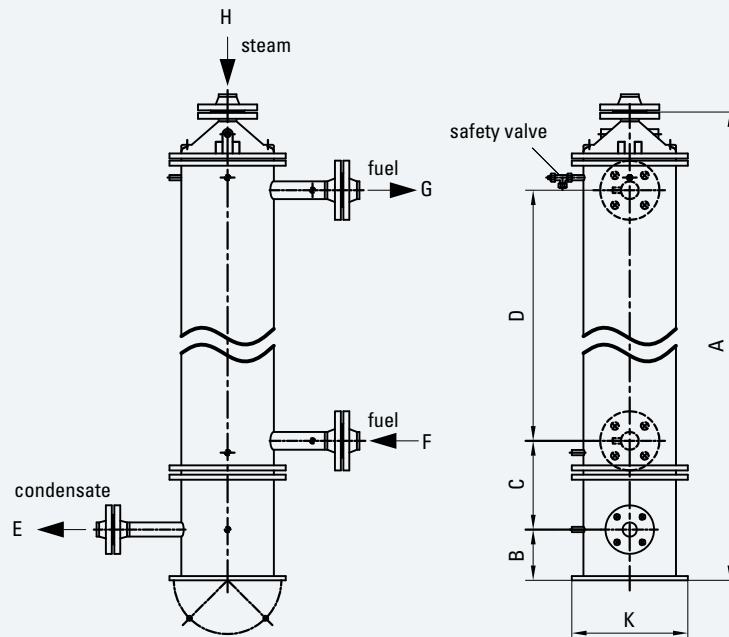


Fig. 5-17 Heavy fuel final preheater HH1, stand-by final preheater HH2 (steam heated)

| Plant output | Dimensions [mm] |     |     |       |       |       |       |       |       | Weight |
|--------------|-----------------|-----|-----|-------|-------|-------|-------|-------|-------|--------|
| [kW]         | A               | B   | C   | D     | E     | F     | G     | H     | K     | [kg]   |
| up to 5,400  | 1,520           | 120 | 210 | 1,005 | DN 25 | DN 32 | DN 32 | DN 32 | Ø 275 | 155    |
| up to 8,800  | 2,065           | 120 | 215 | 1,540 | DN 25 | DN 40 | DN 40 | DN 32 | Ø 275 | 272    |
| up to 14,000 | 1,630           | 130 | 235 | 1,035 | DN 40 | DN 50 | DN 50 | DN 50 | Ø 390 | 265    |
| up to 21,000 | 2,170           | 130 | 235 | 1,555 | DN 40 | DN 65 | DN 65 | DN 50 | Ø 390 | 339    |

## FUEL OIL SYSTEM

### Viscosimeter HR2

The viscosimeter is regulating in conjunction with the final preheater the required fuel injection viscosity. This device automatically regulates the heating of the final preheater depending on the viscosity of the bunkered fuel oil, so that the fuel will reach the nozzles with the viscosity required for injection.

### Pressure absorber KD1 (optional)

During the injection phases of fuel from the supply line, compression and injection as well as the release of unused fuel into the return line, cyclic pressure pulsations may result. The requirement of installing fuel dampers in the external pipe system depends on the design of the external fuel pipe work and its ability to absorb such pulsations sufficiently. Just in case of enhanced damping requirements additional dampers have to be installed.

### Bypass overflow valve HV (optional)

If more than one engine is connected to the fuel booster and supply system a bypass overflow valve between the feed line and the return line can be required.

It serves to secure and stabilize the pressure in the fuel feed line under all circumstances and operation conditions. The overflow valve must be differential pressure operated.

The opening differential pressure should be 2 bar.

### Duplex filter HF1 (fitted)

The fuel duplex filter is installed at the engine.

The two filter chamber construction allows continuous operation without any shut downs for cleaning the filter elements.

The drain connection of the filter is provided with a valve and must be routed to the leak oil tank.

If the filter elements are removed for cleaning, the filter chamber must be emptied. This prevents the dirt particles remaining in the filter casing from migrating to the clean oil side of the filter.

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## FUEL OIL SYSTEM

### Fuel oil cooler DH3

To ensure a fuel oil temp. below 50 °C a cooling of diesel oil may be required.

The need for fuel cooler is system specific and depends on fuel circuit design and type of fuel oil.

In case of more than one engine are connected to the same fuel supply system, the MDO-cooler capacity has to be increased accordingly.

The diesel oil coolers are always installed in the fuel return line (engine connection C78). The heat transfer load into the diesel oil system is approx. 3.1 kW/cyl. LT-water is normally used as cooling medium.

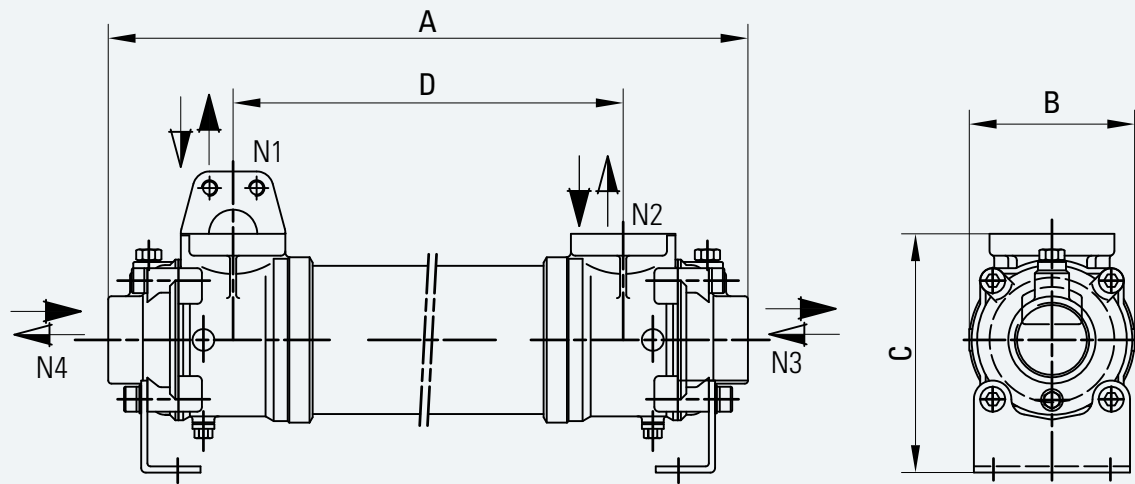


Fig. 5-18 Fuel oil cooler for MDO operation DH3

| Engine      | Dimensions [mm] |     |     |     |         |          | Weight [kg] |
|-------------|-----------------|-----|-----|-----|---------|----------|-------------|
|             | A               | B   | C   | D   | N1 + N2 | N3 + N4  |             |
| 6-9 M 46 DF | 940             | 148 | 225 | 705 | DN50    | 1 ½" BSP | 39          |

### 5.2.3 Fuel booster and supply module

A complete fuel conditioning module, designed for HFO up to 700 cSt / 50 °C, can be supplied.

Caterpillar Motoren standard modules consist of the following components:

- Three-way change over valve
- Booster pumps
- Automatic filter
- Pressure regulating valve
- Fuel flow meter
- Mixing tank
- Circulating pumps
- Fuel preheater (steam, thermal oil or electric)
- Viscosity control
- Diesel oil cooler
- Control cabinet
- Alarm panel

Built on one frame, they include all piping, wiring and trace heating.

## FUEL OIL SYSTEM

## Module controlled automatically with alarms and starters

- Pressure pump starters with stand-by automatic
- Circulating pump starters with stand-by automatic
- PI-controller for viscosity controlling
- Starter for the viscosimeter
- Analog output signal 4 - 20 mA for viscosity

## Alarms

- Pressure pump stand-by start
- Low level in the mixing tank
- Circulating pump stand-by start
- Self-cleaning fine filter clogged
- Viscosity alarm high/low
- The alarms with potential free contacts
- Alarm cabinet with alarms to engine control room and connection interface for remote start/stop and indicating lamp of fuel pressure and circulating pumps

## Size, weight and dimensions

The whole module is tubed and cabled up to the terminal strips in the electric switch boxes which are installed on the module. All necessary components like valves, pressure switches, thermometers, gauges etc. are included. The fuel oil pipes are equipped with trace heating (steam, thermal oil or electrical) where necessary.

## NOTE:

The module will be tested hydrostatically and functionally in the workshop without heating and not connected to the engine.

## Fuel oil standard module

| Module size | Capacity   | Module size (LxWxH)   | Module weight |
|-------------|------------|-----------------------|---------------|
|             | up to [kW] | [mm]                  | [kg]          |
| Size 1      | 1,900      | 2,800 x 1,200 x 2,100 | 1,700         |
| Size 2      | 2,800      | 2,800 x 1,200 x 2,100 | 1,800         |
| Size 3      | 4,200      | 3,000 x 1,200 x 2,100 | 2,200         |
| Size 4      | 6,000      | 3,200 x 1,300 x 2,100 | 2,700         |
| Size 5      | 8,200      | 3,200 x 1,300 x 2,100 | 2,700         |
| Size 6      | 9,300      | 3,400 x 1,400 x 2,100 | 3,000         |
| Size 7      | 11,400     | 3,600 x 1,400 x 2,100 | 3,400         |
| Size 8      | 13,100     | 3,600 x 1,400 x 2,100 | 3,400         |
| Size 9      | 15,900     | 4,200 x 1,600 x 2,100 | 3,800         |
| Size 10     | 19,800     | 5,000 x 1,700 x 2,100 | 4,600         |
| Size 11     | 26,000     | 6,000 x 2,000 x 2,100 | 5,600         |

## NOTE:

Customized modules are possible on request.



# FUEL OIL SYSTEM

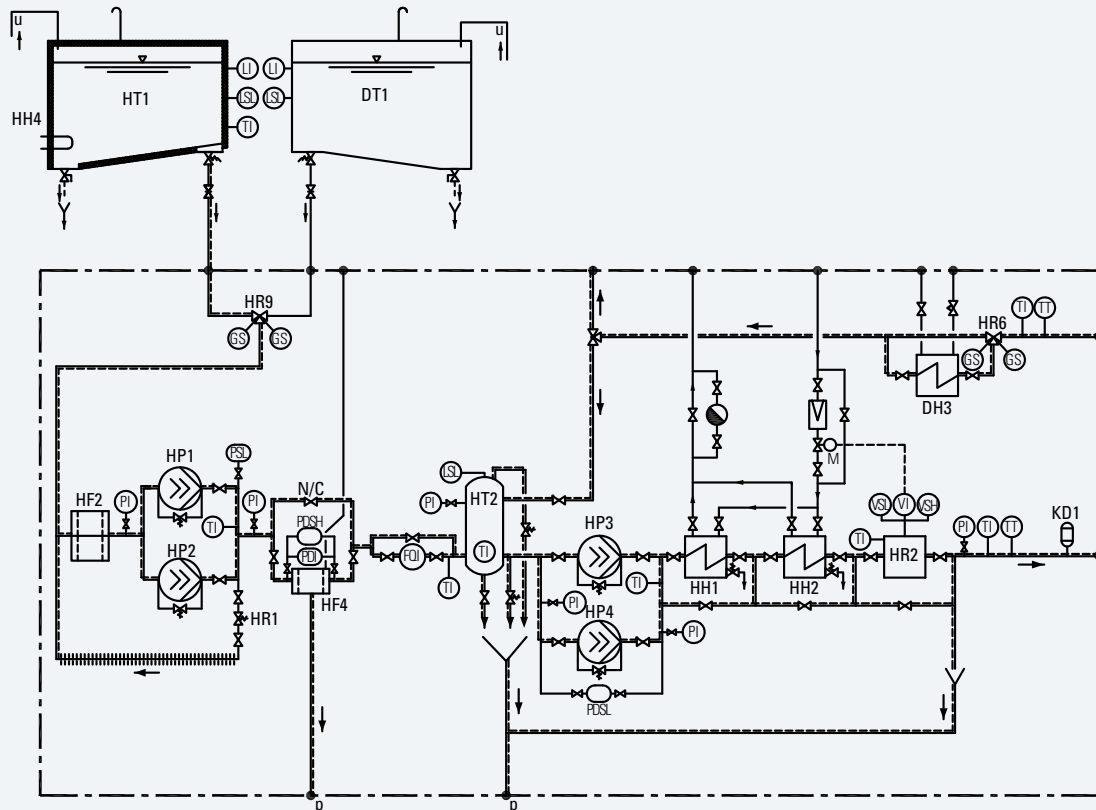


Fig. 5-19 Fuel booster and supply module, system diagram

|     |   |      |                                 |
|-----|---|------|---------------------------------|
| DH3 | Fuel oil cooler for MDO operation                 | KD1  | Pressure absorber               |
| DT1 | Diesel oil day tank                               | FQI  | Flow quantity indicator         |
| HF2 | Primary filter (duplex filter)                    | GS   | Limit switch                    |
| HF4 | HFO automatic filter                              | LI   | Level indicator                 |
| HH1 | Heavy fuel final preheater                        | LSL  | Level switch low                |
| HH2 | Stand-by final preheater                          | PDI  | Diff. pressure indicator        |
| HH4 | Heating coil                                      | PDSH | Diff. pressure switch high      |
| HP1 | Fuel pressure pump                                | PDSL | Diff. pressure switch low       |
| HP2 | Fuel stand-by pressure pump                       | PI   | Pressure indicator              |
| HP3 | Fuel circulating pump                             | PSL  | Pressure switch low             |
| HP4 | Stand-by circulating pump                         | TI   | Temperature indicator           |
| HR1 | Fuel pressure regulating valve                    | TT   | Temperature transmitter (PT100) |
| HR2 | Viscosimeter                                      | VI   | Viscosity indicator             |
| HR6 | Change over valve (HFO/diesel oil)<br>3-way-valve | VSH  | Viscosity control switch high   |
| HR9 | Fuel change over main valve                       | VSL  | Viscosity control switch low    |
| HT1 | Heavy fuel day tank                               |      |                                 |
| HT2 | Mixing tank                                       |      |                                 |

p Free outlet required  
u Fuel separator or from transfer pump

All heavy fuel pipes have to be insulated.

----- Heated pipe

## FUEL OIL SYSTEM

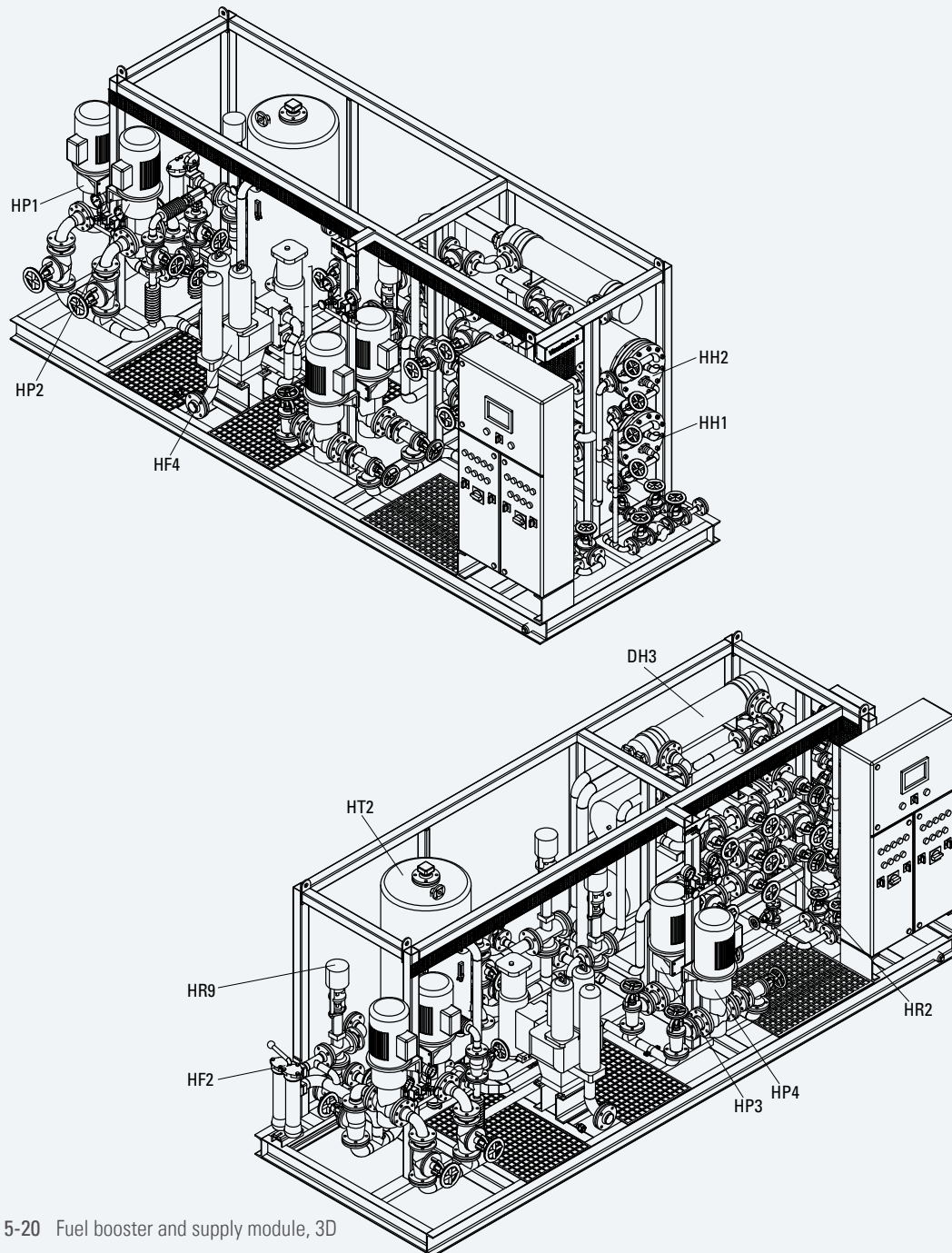


Fig. 5-20 Fuel booster and supply module, 3D

|     |                                   |     |                             |
|-----|-----------------------------------|-----|-----------------------------|
| DH3 | Fuel oil cooler for MDO operation | HP1 | Fuel pressure pump          |
| HF2 | Primary filter (duplex filter)    | HP2 | Fuel stand-by pressure pump |
| HF3 | Coarse filter                     | HP3 | Fuel circulation pump       |
| HF4 | HFO automatic filter              | HP4 | Stand-by circulation pump   |
| HH1 | Heavy fuel final preheater        | HR9 | Fuel change over main valve |
| HH2 | Stand-by final preheater          | HT2 | Mixing tank                 |

## FUEL OIL SYSTEM

### 5.3 Switching over from HFO to diesel oil

Continuous operation with HFO is recommended for engines designed for running mainly on HFO. Starting and stopping the engine on HFO (Pier to Pier) can be provided if a sufficient preheating of the fuel oil system is ensured.

The circulating pumps have to be permanently in service, so that a continuous circulation of warm/hot fuel oil through the engine is ensured.

A frequent change over from HFO to diesel oil is only recommended when necessary for flushing purposes, emergencies, special sea area emission requirements, etc.

Changing the fuel oil too quickly and too often may cause high risk of plunger seizure (thermal shock), fuel injection pump leakages, etc. in the fuel injection pump.

Only a slow switch over will attenuate that effect.

Typical switch over characteristics (HFO to diesel)

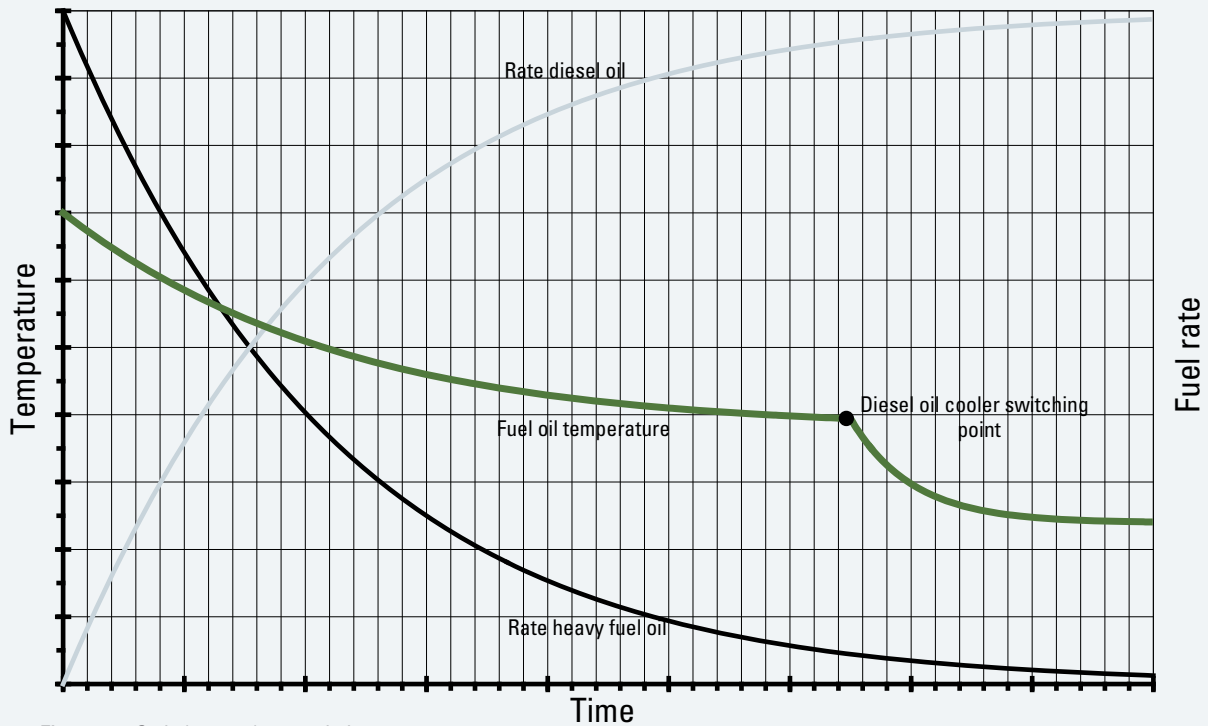


Fig 5-21 Switch over characteristics

## GAS FUEL SYSTEM

## 6.1 General

The gas system provides the fuel gas from the Gas Valve Unit (GVU) to the gas admission valves on the engine.

The complete gas manifold on the engine is double walled and leak detected to comply with the gas safe machinery space requirements. A leakage location system to decrease the maintenance effort is available as an option.

The fuel gas will be port injected by solenoid gas valves, these gas valves are integrated in the cylinder head design.

The GVU is part of the Caterpillar Motoren standard scope of supply. One individual GVU per engine has to be provided. A maximum pipe length of 10 m between the GVU and the engine must not be exceeded. For applications, where the GVU is located directly in the machinery space, a gas-proof cover is available as an option to comply with the gas safe machinery space requirements.

### 6.1.1 Gas fuel quality requirements

Gas fuel to be complied with the Caterpillar gas fuel specification VD8768 for dual fuel engines.

| Gas specification M 46 DF                           |           |   |
|---|-----------|---|
| Gas temperature before engine inlet                 | [°C]      | 0 - 60  |
| Gas pressure before fuel regulating skid            | [bar (g)] | 6.5 - 9   |
| Maximum gas pressure fluctuation                    | [mbar/s]  | +/- 80  |
| Minimum lower heat value                            | [MJ/m³]   | 28  |
| Minimum Cat - Methane number (without power derate) | [MN]      | 80  |
| Maximum Sulphur as H <sub>2</sub> S                 | [mg/m³]   | 20  |
| Maximum Ammonia (NH <sub>4</sub> )                  | [mg/m³]   | 25  |
| Maximum Fluorines                                   | [mg/m³]   | Σ = 50  |
| Maximum Chlorine                                    | [mg/m³]   | Σ = 50  |
| Maximum oil content                                 | [mg/m³]   | 50  |
| Maximum particles content                           | [mg/m³]   | 50  |
| Maximum particles size                              | [µm]      | 5   |
| Maximum tar content                                 | [mg/m³]   | 10  |
| Maximum Silicium                                    | [mg/m³]   | 10  |
| Maximum water                                       |           | Saturated fuel or water and condensates at gas control unit are not allowed |

## GAS FUEL SYSTEM

### 6.1.2 Inert gas quality requirements

Inert gas to be complied with the Caterpillar inert gas specification VD8836 for dual fuel engines.

| Inert gas specification M 46 DF                                 |                      |                                      |
|---|----------------------|--------------------------------------|
| Gas temperature range at interfaces to engine                   | [°C]                 | 0 - 60                               |
| Minimum pressure difference<br>(min. inert gas - max. fuel gas) | [bar(g)]             | 1                                    |
| Maximum inert gas pressure                                      | [bar(g)]             | 10                                   |
| Allowed gases   |                      | Nitrogen ≥ 95 %<br>Carbon Dioxid 2.5 |
| Maximum Sulphur as H <sub>2</sub> S                             | [%]                  | 0,05 (= 770 mg/mn <sup>3</sup> )     |
| Maximum Ammonia (NH <sub>3</sub> )                              | [mg/m <sup>3</sup> ] | 25                                   |
| Maximum Fluorines   | [mg/m <sup>3</sup> ] | Σ = 50                               |
| Maximum Chlorine  | [mg/m <sup>3</sup> ] | Σ = 50                               |
| Maximum oil content   | [mg/m <sup>3</sup> ] | 50                                   |
| Maximum particles content                                       | [mg/m <sup>3</sup> ] | 50                                   |
| Maximum particle size   | [µm]                 | 5                                    |
| Maximum dew point   | [°C]                 | -20                                  |

# GAS FUEL SYSTEM

## 6.2 Gas system overview

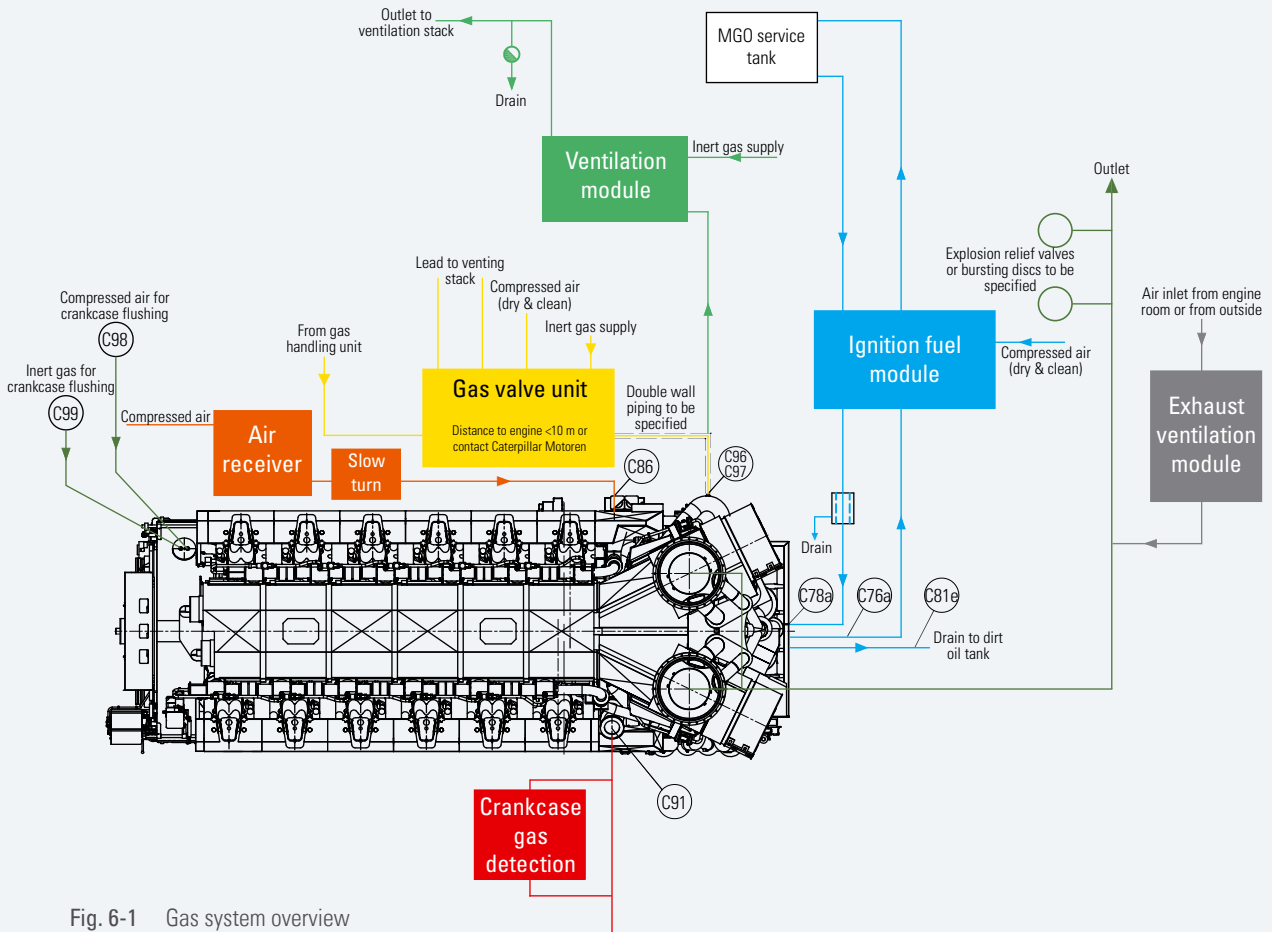


Fig. 6-1 Gas system overview

## GAS FUEL SYSTEM

### 6.2.1 Gas valve unit (GVU)

The gas valve unit provides the engine with the desired fuel gas pressure and fuel gas quantity. It is controlled by the engine's control and monitoring system and the engine's speed governor. The maximum distance between the GVU and the engine is 10 m. If more distance is requested please contact Caterpillar Motoren.

It has several features to safely cut the engine from the gas train and to remove the gas fuel from the piping system (flushing). In case of flushing the gas fuel is pushed by inert gas over the engine via the GVU towards the ship's vent system.

The shown GVU's are an example. GVU's can be supplied in horizontal and vertical design, as U-type and also mounted within an enclosure.

The gas valve unit is an off-engine component. GVU is single walled designed and needs to be installed in an ESD compliant machinery space or within an enclosure.

The GVU is optionally available with a gas fuel flow meter.

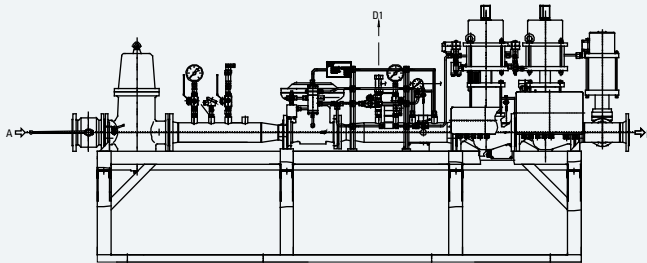


Fig. 6-2 Gas valve unit

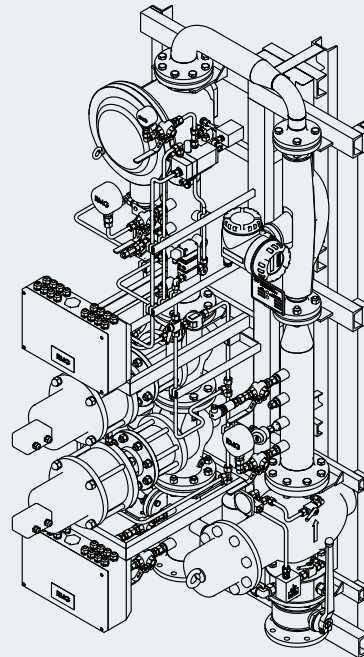


Fig. 6-3 Gas valve unit, U-form vertical

## GAS FUEL SYSTEM

### 6.2.2 Ignition fuel system

The MaK dual fuel engine is equipped with an ignition fuel system to ignite the gas fuel / air mixture in the combustion chamber. This ignition system is a common rail system which injects only a small amount of MDO fuel.

Ignition fuel is to be used also during operation with liquid fuel, for cooling of injector needles. To achieve the cleanliness of the ignition fuel a filtering system is required.

#### 6.2.2.1 Ignition fuel quality requirements

Only MDO fuel types DMA and DMZ acc. to ISO 8271 are to be used. For usage of DMB or DMX please consult Caterpillar Motoren in advance.

A filter module to provide the required ignition fuel cleanliness is part of MaK standard scope of supply.

#### 6.2.2.2 Ignition fuel components

##### Ignition fuel module

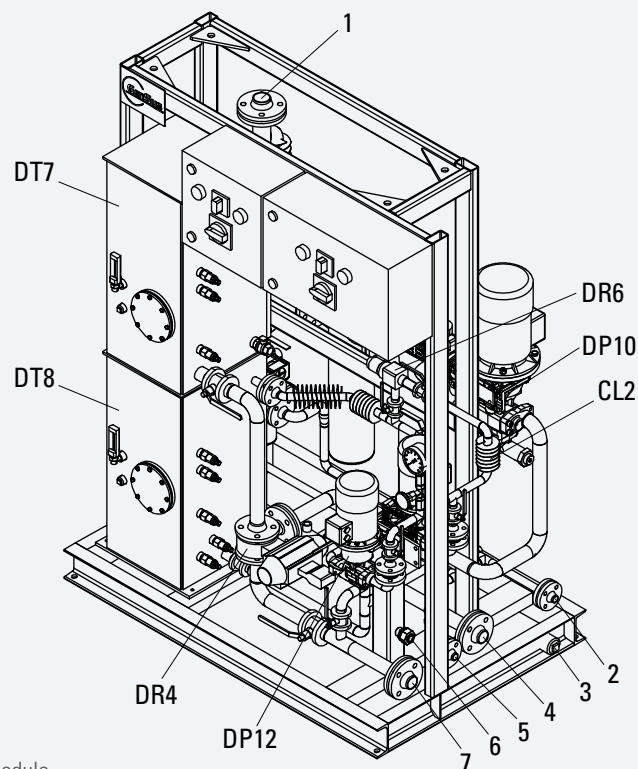


Fig. 6-4 Ignition fuel module

|   |                                     |      |                           |
|---|-------------------------------------|------|---------------------------|
| 1 | Vent to the top of day tank         | CL2  | Fin cooler                |
| 2 | Return fuel from engine             | DP10 | Gear pump                 |
| 3 | Drain module                        | DP12 | Gear pump                 |
| 4 | Drain filter and tank               | DR4  | Change over valve         |
| 5 | DF to pilot injection system engine | DR6  | Pressure regulating valve |
| 6 | Supply compressed air (dry & clean) | DT7  | Mixing tank               |
| 7 | DF from diesel oil day tank         | DT8  | Mixing tank               |



## GAS FUEL SYSTEM

### Ignition fuel fine filter

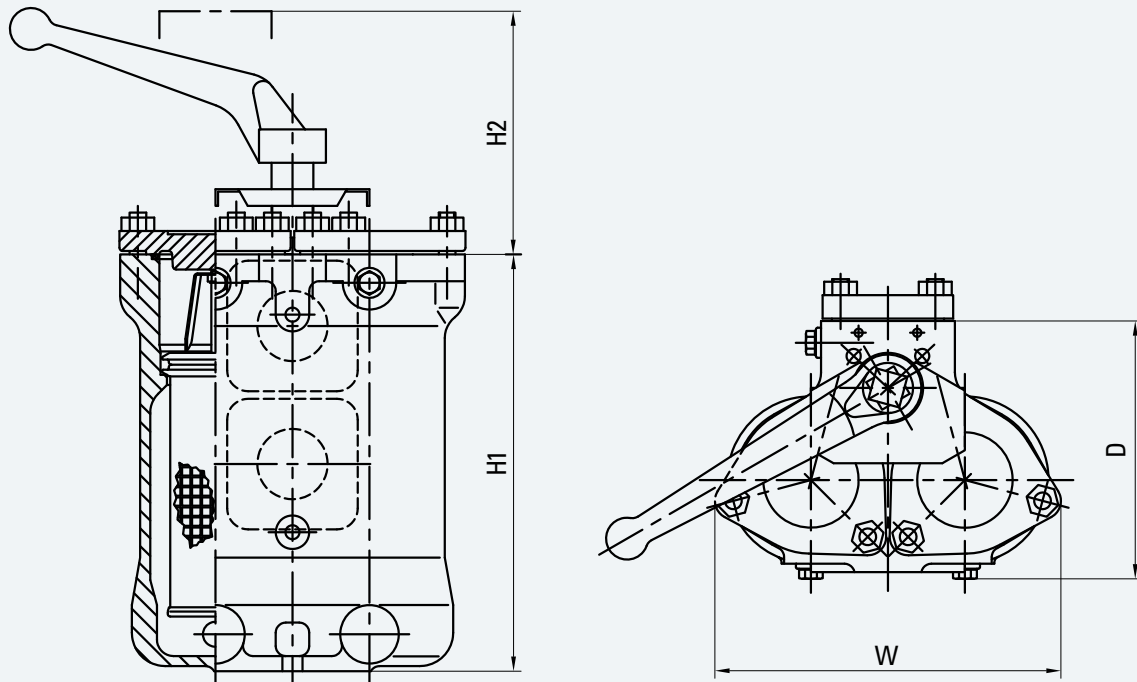


Fig. 6-5 Ignition fuel fine filter

| Engine output<br>[kW] | DN | Dimensions [mm] |     |     |         |
|-----------------------|----|-----------------|-----|-----|---------|
|                       |    | H1              | H2  | W   | D       |
| 6-9 M 46 DF           | 25 | 200             | 170 | 206 | ca. 150 |

## GAS FUEL SYSTEM

### Ignition fuel injector

Weight: 5.9 kg

The ignition fuel injector enables the injection of pressurized fuel directly into the cylinder.

The injector design is simple and compact, the key features are:

- Electronically controlled
- Flexible injection timing and duration
- Flow limiter



Fig. 6-6 Ignition fuel injector

### High pressure pump

Weight: 36 kg

One high pressure pump delivers the required amount of ignition fuel to the injectors and provides the desired pressure in closed loop control. The pump itself is based on a proved design.



Fig. 6-7 High pressure pump

## GAS FUEL SYSTEM

### 6.2.3 Engine ventilation system

The ventilation module supplies permanent ventilation for continuous monitoring / leakage detection by vacuum pump and gas sensor. This pump is able to handle any kind of ignitable gases.

Nitrogen connection on the module, for flushing of the annular space of the double walled piping system and fuel gas supply line of the engine.

Depending on class requirements redundant equipment might be requested.

The standard design is for the use in an inherent safe engine room and is therefore of non-hazardous type.

The ventilaion module shall be installed in the engine room as close as possible to the gas valve unit.

### 6.2.4 Engine ventilation module

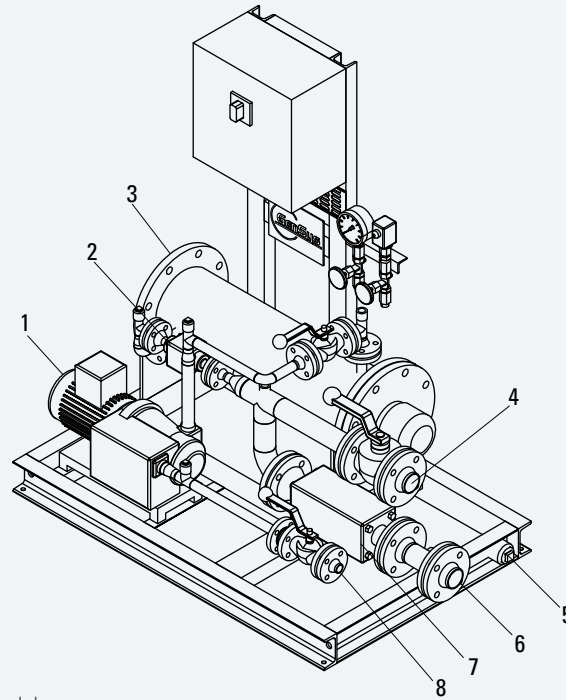


Fig. 6-8 Engine ventilation module

- |   |   |   |                        |
|---|---|---|------------------------|
| 1 | Vacuum pump                                     | 5 | Drain module           |
| 2 | Electro-magnetic valve                          | 6 | Nitrogen, inlet        |
| 3 | Gas sensor                                      | 7 | Electro-magnetic valve |
| 4 | Jacketed pipe system, inlet<br>Nitrogen, outlet | 8 | Outlet to drain        |

### 6.2.5 Exhaust gas ventilation system

The exhaust gas ventilation module is installed to ventilate the ship side exhaust gas system after an emergency stop of the engine in gas mode. The module consists of a ventilation fan, a separated butterfly valve and exhaust gas compensator for the connection to the exhaust gas system. The butterfly valve separates the exhaust gas system under all conditions to protect the engine room against exhaust gas inrush except the case of a stop of the engine in gas mode. The ventilator is sized to remove the total volume of the exhaust gas system, incl. silencer, stack, boiler and duct three times. The engine start is blocked, if the valve is not completely closed, monitored by a position switch.

### 6.2.6 Exhaust gas ventilation module

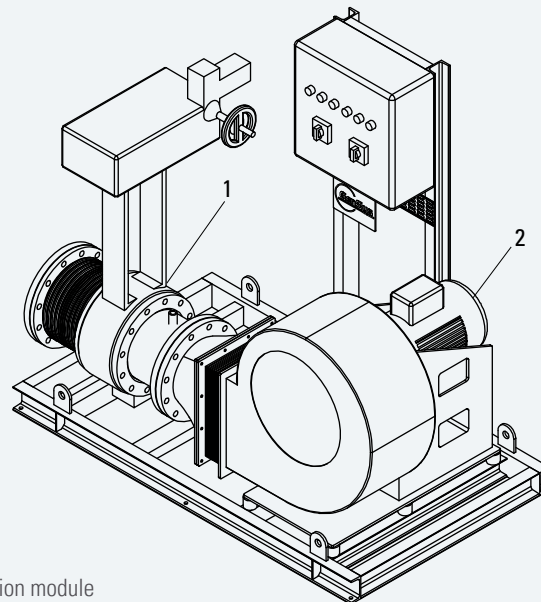


Fig. 6-9 Exhaust gas ventilation module

- 1 Isolation valve
- 2 Exhaust fan

## GAS FUEL SYSTEM

### 6.2.7 Crankcase gas detection

The crankcase needs several protection devices to provide a reliable and safe operation of the dual fuel engine. Due to the normal blow-by special care needs to be taken to detect fuel gas before it reaches an explosive concentration.

This system detects an abnormal amount of fuel gas in the crankcase. The gas sensor will sense for fuel gas and will monitor the actual fuel gas concentration in percent of the lower explosion limit (% LEL). Before the LEL is reached an alarm will be triggered and without recovery of the LEL within a certain time, latest before the concentration of fuel gas will reach 100 % LEL, the engine will switch back to fuel oil to ensure that an explosive atmosphere will not occur due to fuel gas blow-by.

If abnormal blow-by occurs the pressure sensor will trigger an alarm, showing that at least one of the piston rings has worn and the switch over to fuel oil might occur soon.

A gas detection system might also be required to detect fuel gas in HT expansion tank and lube oil circulating tank, depending on authority.

### 6.2.8 Explosion relief valves for exhaust gas system

Exhaust gas piping in which explosive atmosphere can accumulate is routed steadily ascending to avoid gas accumulations. Additionally it is protected against overpressure by explosion pressure relief valves. These relief valves discharge the overpressure in case of any explosion within the exhaust gas system. The positioning and amount of explosion relief valves must be adjusted according to the design and layout of the existing exhaust gas system.

In case of an explosion in the exhaust gas system the explosion relief valves open quickly. This reduces explosion overpressure inside the exhaust gas system to a safe level without any flame transmission to the surrounding area. After the explosion pressures subsides, the valves reseal, so that the engine could be restarted or further operated.

### 6.2.9 Slow turn

The slow turn module can turn the engine automatically in predefined intervals with pressure reduced starting air. This air supply is limited in such a way that the ignition engine speed will not be reached. A fuel injection will be disabled during this process. If the crankshaft will only start to oscillate during slow turning and will not come to a continuous rotation it must be assumed that water has accumulated in one of cylinders. In that case a starting interlock will be set

For more information, please see also chapter 9.5

### 6.3 Gas system – GUV inside gas safe machinery room

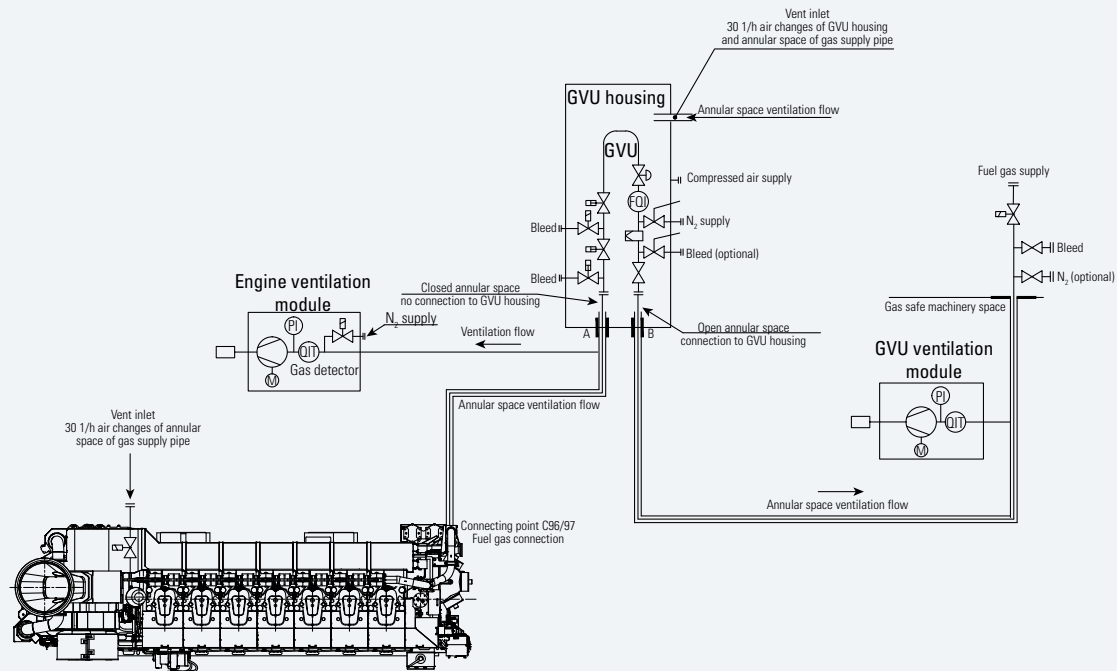


Fig. 6-10 Gas valve unit inside machinery room

#### 6.3.1 GUV housing

In case of installing the GUV inside the machinery room and to ensure its definition as a safe machinery room the GUV needs to be encased and the gas pipe needs to be of double wall pipe. The GUV housing is seen as an extension of the annular space of double wall fuel gas pipe in front of the GUV.

#### 6.3.2 GUV ventilation module

Similar to the engine ventilation module the GUV ventilation module is used for permanent ventilation of the GUV housing and its double walled pipe inside machinery space.

The vent flow will be through the GUV housing and the annular space of the double wall fuel gas line by an explosion proofed fan. A gas detector will be installed close to the exhaust fans inside the extraction flow. The GUV housing is always connected to open atmosphere by the annular space and hereby not considered as a pressure vessel.

## LUBE OIL SYSTEM

### General

The lube oil performs several basic functions:

- It cleans the engine by carrying dirt and wear particles until the filters can extract and store them.
- It cools the engine by carrying heat away from the piston, cylinder walls, valves and cylinder heads to be dissipated in the engine oil cooler.
- It cushions the engines bearings from the shocks of cylinder firing.
- It lubricates the wear surfaces, reducing friction.
- It neutralizes the corrosive combustion products.
- It seals the engines metal surfaces from rust.
- It lubricates the turbocharger bearings.
- It cools the injection nozzles.

### 7.1 Lube oil requirements

#### NOTE:

The viscosity class SAE 40 is required.

Wear and tear and thus the service life of the engine depend on the lube oil quality.

Therefore high requirements are made for lubricants:

- Constant uniform distribution of the additives at all operating conditions
- Perfect cleaning (detergent effect) and dispersing power, prevention of deposits from the combustion process in the engine
- Sufficient alkalinity in order to neutralize acid combustion residues
- The TBN (total base number) must be 30 KOH/g at HFO operation  
The TBN is 12 - 20 KOH/g for MDO operation depending on Sulfur content

## LUBE OIL SYSTEM

| Manufacturer                  | Diesel oil /<br>MDO operation  | I                          | II     | HFO operation  | I                | II |
|-------------------------------|--|----------------------------|--------|--|------------------|----|
| AGIP                          | DIESEL SIGMA S<br>CLADIUM 120  |                            | X<br>X | CLADIUM 300 S<br>CLADIUM 400 S   | X<br>X           |    |
| BP                            | ENERGOL HPDX 40<br>ENERGOL DS 3-154<br>ENERGOL IC-HFX 204<br>VANELLUS C3                         | X<br>X<br>X                |        | ENERGOL IC-HFX 304<br>ENERGOL IC-HFX 404                               | X<br>X           |    |
| CAT                           | DEO  | X                          |        |  |                  |    |
| CHEVRON,<br>CALTEX,<br>TEXACO | DELO 1000 MARINE<br>DELO SHP<br>TARO 12 XD<br>TARGO 16 XD<br>TARGO 20 DP<br>TARGO 20 DPX         | X<br>X<br>X<br>X<br>X<br>X |        | TARO 30 DP<br>TARO 40 XL<br>TARO 40 XLX                                | X<br>X<br>X      |    |
| CASTROL                       | MARINE MLC<br>MHP 154<br>TLX PLUS 204  | X<br>X<br>X                |        | TLX PLUS 304<br>TLX PLUS 404   | X<br>X           |    |
| CEPSA                         | KORAL 1540   |                            | X      |  |                  |    |
| ESSO                          | EXXMAR 12 TP<br>EXXMAR CM+<br>ESSOLUBE X 301   | X                          | X<br>X | EXXMAR 30 TP<br>EXXMAR 30 TP PLUS<br>EXXMAR 40 TP<br>EXXMAR 40 TP PLUS | X<br>X<br>X<br>X | X  |
| MOBIL                         | MOBILGARD 412<br>MOBILGARD ADL<br>MOBILGARD M430<br>MOBILGARD 1-SHC <sup>1)</sup><br>DELVAC 1640 | X<br>X<br>X<br>X           |        | MOBILGARD M430<br>MOBILGARD M440<br>MOBILGARD M 50                     | X<br>X<br>X      |    |
| SHELL                         | GADINIA<br>GADINIA AL<br>ARGINA S<br>ARGINA T  | X<br>X<br>X<br>X           |        | ARGINA T<br>ARGINA X   | X<br>X           |    |
| TOTAL<br>LUBMARINE            | RUBIA FP<br>DISOLA M 4015<br>AURELIA TI 4030<br>CAPRANO M40                                      | X<br>X<br>X<br>X           | X      | AURELIA TI 4030<br>AURELIA TI 4040                                     | X<br>X           |    |
| LUKOIL                        | NAVIGO 12/40<br>NAVIGO 15/40   | X<br>X                     |        | NAVIGO TPEO 30/40<br>NAVIGO TPEO 40/40                                 | X<br>X           |    |
| GULF                          |  |                            |        | SEA POWER 4030<br>SEA POWER 4040                                       | X<br>X           |    |

I Approved in operation / II Permitted for controlled use. When these lube oils are used, Caterpillar Motoren GmbH & Co. KG must be informed because at the moment there is insufficient experience available for engines. Otherwise the warranty is invalid. / 1) Synthetic oil with a high viscosity index (SAE 15 W/40). Only permitted if the oil inlet temperatures can be decreased by 5 - 10 °C.

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## LUBE OIL SYSTEM

## 7.2 Internal lube oil system

### Lube oil force pump LP1 (fitted)

The lube oil force pump is a gear pump, fitted on the engine and mechanically driven by the crankshaft. The lube oil force pump provides the lube oil from the circulating tank LT1 to the engine. It is designed to provide a sufficient amount of lube oil at the required pressure to the engine even when running at the designed minimum engine speed. Capacity, see technical data.

### Duplex filter LF1 (fitted)

The duplex filter shall indicate a failure of the self-cleaning filter LF2.

Mesh size: 80  $\mu\text{m}$  (absolute)

One chamber of the duplex filter is in operation, while the second chamber is in stand-by. Change over can be done during engine operation.



Fig. 7-1 Self-cleaning lube oil filter LF2

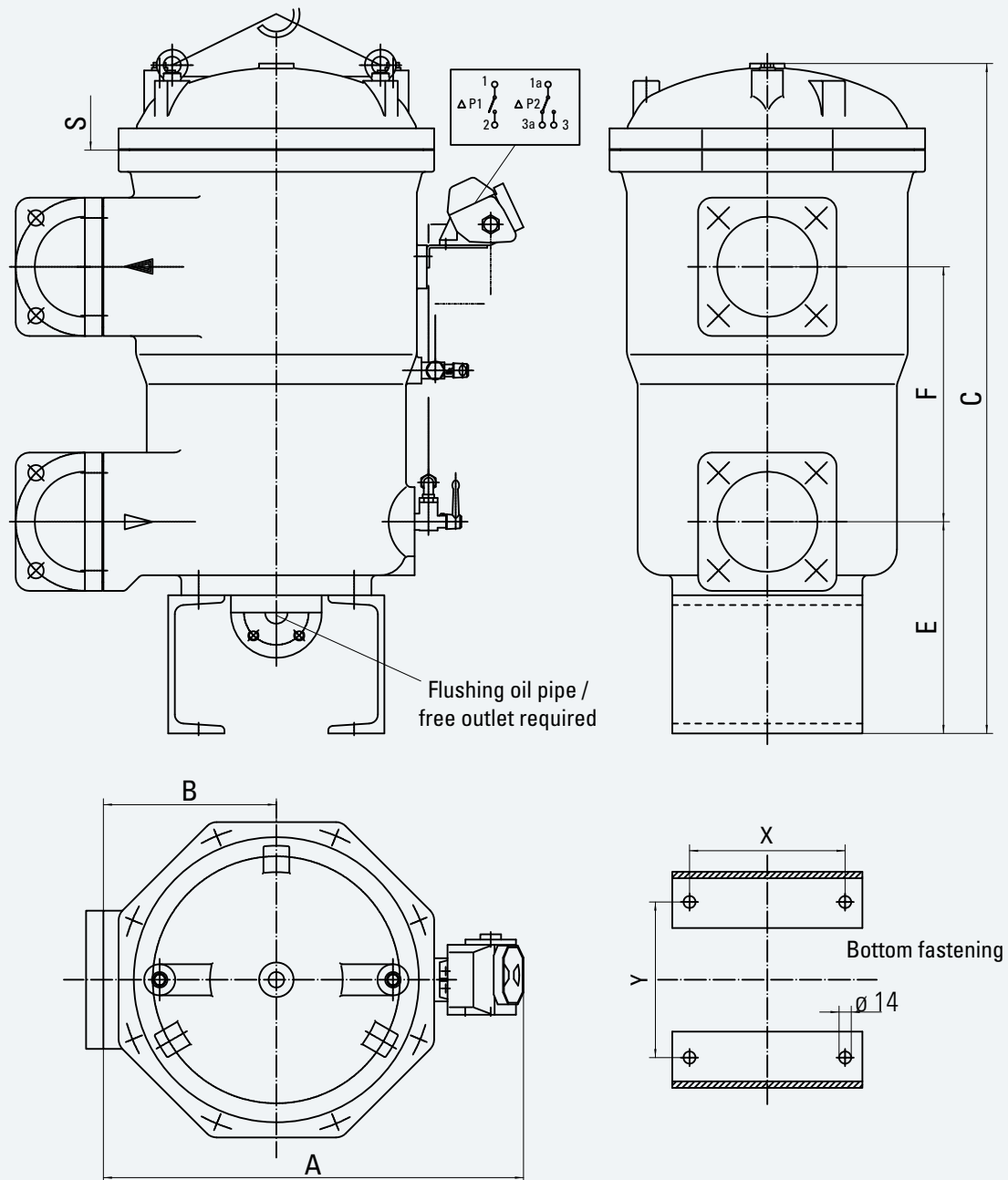
**Back flushing filter LF2 (separate), option**


Fig. 7-2 Back flushing filter LF2

|             | Dimensions [mm] |     |     |     |     |     |     |     | Weight |
|-------------|-----------------|-----|-----|-----|-----|-----|-----|-----|--------|
|             | A               | B   | C   | E   | F   | S   | X   | Y   | [kg]   |
| 6/7 M 46 DF | 580             | 260 | 950 | 245 | 350 | 600 | 220 | 220 | 195    |
| 8/9 M 46 DF | 655             | 300 | 950 | 245 | 375 | 600 | 290 | 260 | 250    |

The back flushing filter protects the engine from dirt particles which may accumulate in the circulating tank LT1. Mesh size: 30 µm (absolute)

The filter is continuously flushing into the circulating tank without flushing oil treatment, without bypass filter.

# LUBE OIL SYSTEM

## 7.3 External lube oil system

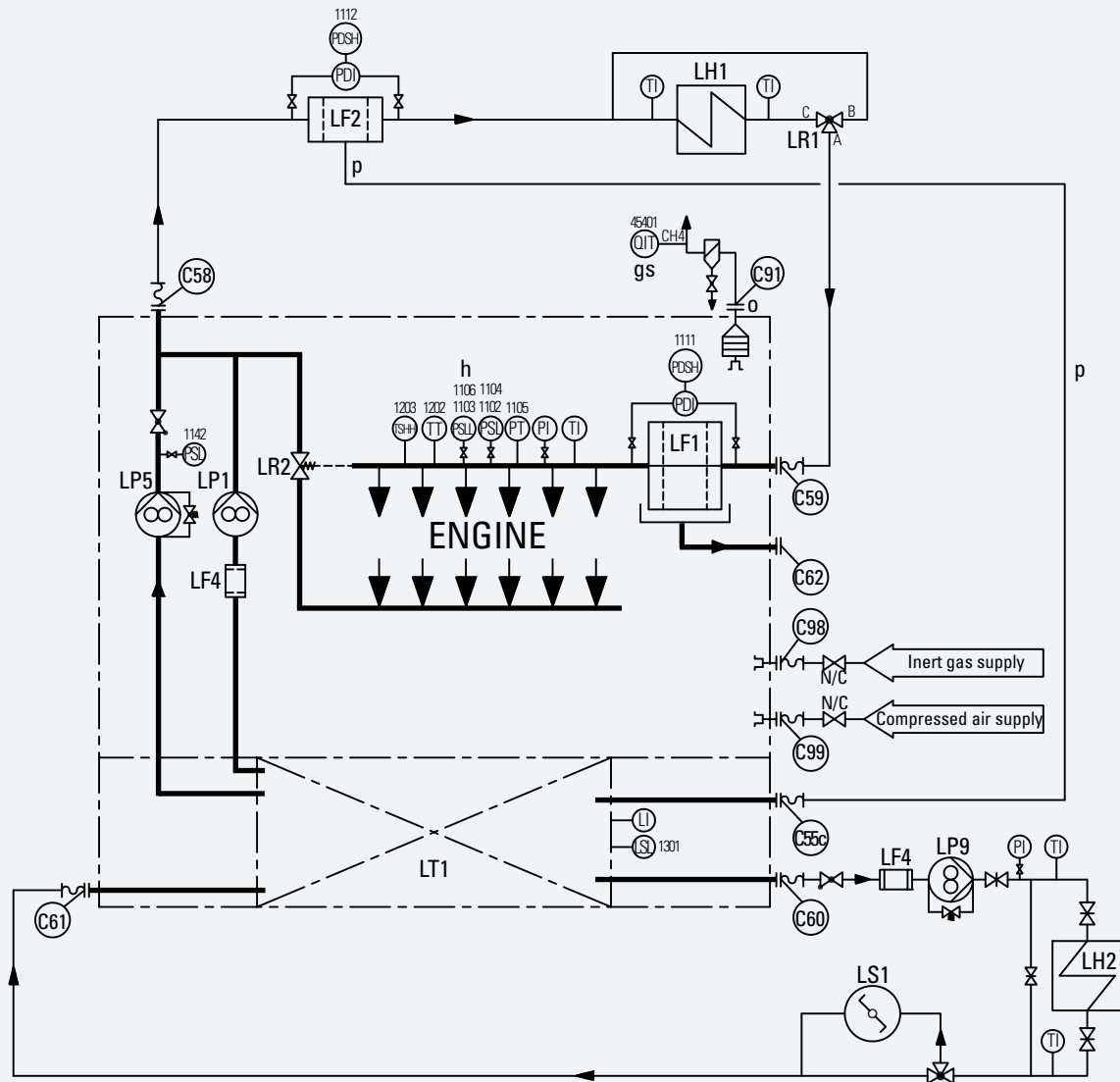


Fig. 7-3 External lube oil system diagram

|     |                               |     |                                    |
|-----|-------------------------------|-----|------------------------------------|
| LF1 | Duplex lube oil filter        | LP5 | Prelubrication pump                |
| LF2 | Self-cleaning lube oil filter | LP9 | Transfer pump (separator)          |
| LF4 | Suction strainer              | LR1 | Lube oil temperature control valve |
| LH1 | Lube oil cooler               | LR2 | Oil pressure regulating valve      |
| LH2 | Lube oil preheater            | LS1 | Lube oil separator                 |
| LP1 | Lube oil force pump           | LT1 | Sump tank                          |

## LUBE OIL SYSTEM

|      |                                 |      |  |
|------|---------------------------------|------|--|
| LI   | Level indicator                 | C55c | Connection flushing pipe automatic filter  |
| LSL  | Level switch low                | C58  | Force pump, delivery side  |
| PDI  | Diff. pressure indicator        | C59  | Lube oil inlet, lube oil cooler  |
| PDSH | Diff. pressure switch high      | C60  | Separator connection, suction side   |
| PI   | Pressure indicator              | C61  | Separator connection, delivery side  |
| PSL  | Pressure switch low             | C62  | Drip oil, pan duplex filter  |
| PSLL | Pressure switch low             | C91  | Crankcase ventilation to stack   |
| PT   | Pressure transmitter            | C98  | Flushing connection crankcase (inertgas)   |
| QIT  | Gas indicator and transmitter   | C99  | Flushing connection crankcase (air)  |
| TI   | Temperature indicator           |      |  |
| TSHH | Temperature switch high high    | gs   | Position gas sensor min. 5m behind C91.  |
| TT   | Temperature transmitter (PT100) | h    | Please refer to the measuring point list regarding design of the monitoring devices. |
|      |                                 | o    | See "crankcase ventilation" installation instructions 4-A-9570.                      |
|      |                                 | p    | Free outlet required.  |

### Lube oil temperature control valve LR1

A wax operated control valve will be used to control the oil inlet temperature into the engine. It has an emergency manual adjustment. Option: Electric driven valve with electronical controller.

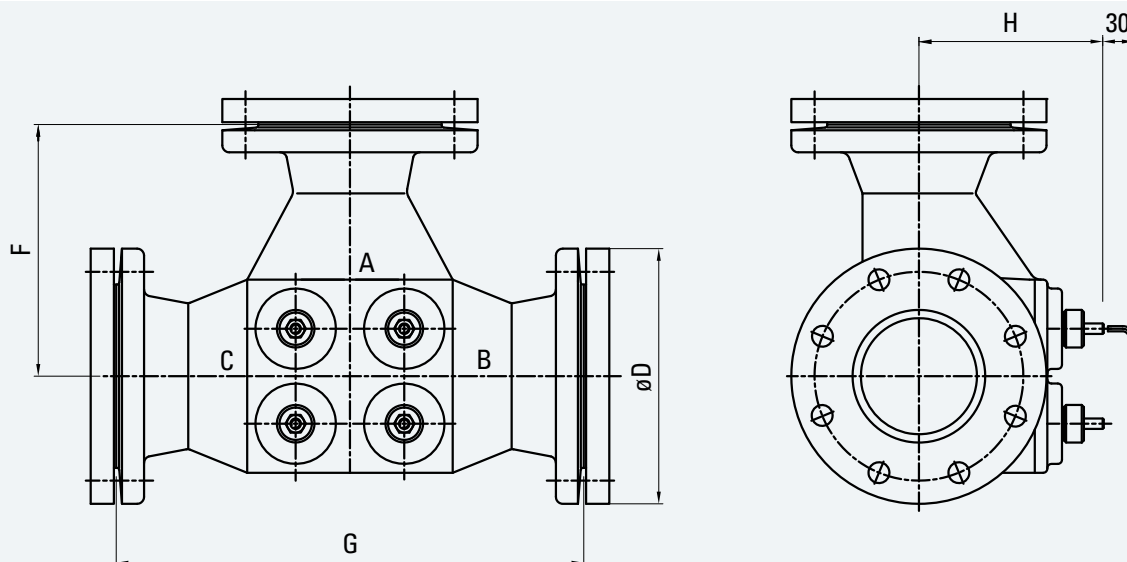


Fig. 7-4 Lube oil temperature control valve LR1

|             | Dimensions [mm] |     |     |     |     | Weight [kg] |
|-------------|-----------------|-----|-----|-----|-----|-------------|
|             | DN              | D   | F   | G   | H   |             |
| 6/7 M 46 DF | 125             | 250 | 241 | 489 | 200 | 67          |
| 8/9 M 46 DF | 150             | 285 | 254 | 489 | 200 | 80          |

## LUBE OIL SYSTEM

### Prelubricating pump LP5

This pump is mounted at the baseframe. This pump can only be used for prelubricating, not as stand-by for the force pump. Capacity see technical data.

### Oil pressure regulating valve LR2 (fitted)

The pressure control valve controls the lube oil pressure at engine inlet by giving only the adequate oil flow to the engine. Excessive oil flow will be led back into the engine oil pan.

### Lube oil cooler LH1 (separate)

A plate cooler with plates of stainless steel will be used to dissipate the heat to the LT fresh water system. It is mounted at the baseframe

Option: separate

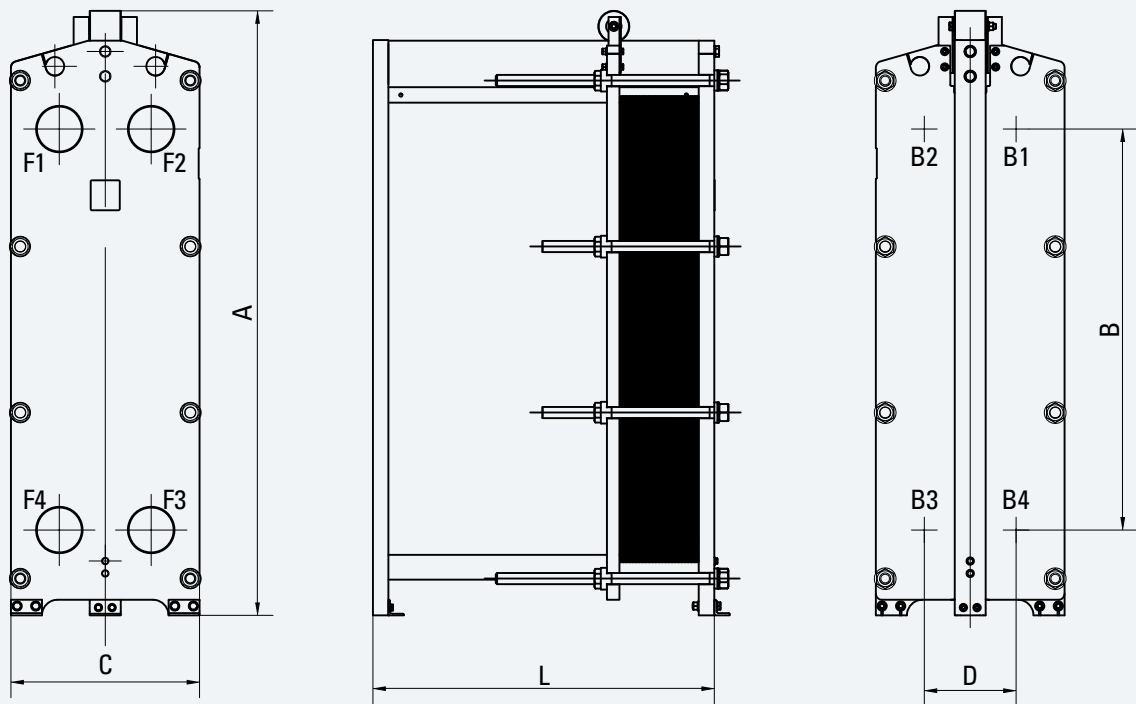


Fig. 7-5 Lube oil cooler LH1

|           | Dimensions |       |      |      |       | Weight |
|-----------|------------|-------|------|------|-------|--------|
|           | A          | B     | C    | D    | L     |        |
|           | [mm]       | [mm]  | [mm] | [mm] | [mm]  |        |
| 6 M 46 DF | 1,715      | 1,365 | 480  | 225  | 1,034 | 662    |
| 7 M 46 DF | 1,948      | 1,292 | 608  | 296  | 1,100 | 1,151  |
| 8 M 46 DF | 1,948      | 1,292 | 608  | 296  | 1,100 | 1,182  |
| 9 M 46 DF | 1,948      | 1,292 | 608  | 296  | 1,100 | 1,224  |

## LUBE OIL SYSTEM

### Lube oil temperature control valve LR1 (electric driven valve), option

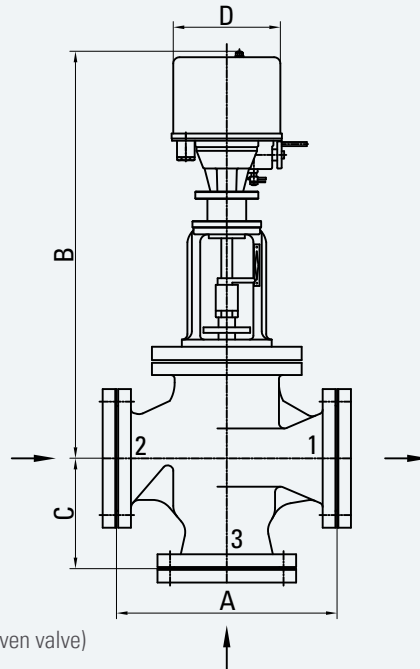


Fig. 7-6 Lube oil temperature control valve LR1 (electric driven valve)

|             | Dimensions [mm] |     |     |     |     | Weight [kg] |
|-------------|-----------------|-----|-----|-----|-----|-------------|
|             | DN              | A   | B   | C   | D   |             |
| 6/7 M 46 DF | 125             | 400 | 717 | 200 | 170 | 110         |
| 8/9 M 46 DF | 150             | 480 | 742 | 240 | 170 | 149         |

### Lube oil separator LS1 (separate)

The most effective cleaning of lube oil is carried out by means of separation. Separation is mandatory for HFO driven plants and highly recommended for MGO/MDO operation.

#### Layout for MGO/MDO and gas operation

Automatic self-cleaning separator; Operating temperature 85 - 95 °C

$$V [l/h] = 0.18 \cdot P_{eng} [kW]$$

$$P_{eng} = \text{Power engine [kW]}$$

#### Layout for HFO and gas operation

Automatic self-cleaning separator; Operating temperature 95 °C

$$V [l/h] = 0.29 \cdot P_{eng} [kW]$$

$$P_{eng} = \text{Power engine [kW]}$$

For the layout of separators, please follow the separator manufacturer's guidelines.

## 7.4 Circulating tanks

The circulating tank LT1 is mounted at the baseframe.

## 7.5 Crankcase ventilation system

### 7.5.1 Crankcase ventilation pipe dimensions

- The crankcase ventilation connecting point is DN 150.
- The engine main ventilation line must be at least DN 150.

### 7.5.2 Crankcase ventilation pipe layout

- The pipes should run upwards.
- Free ventilation under all trim conditions is required.
- To avoid backflow of condensate, a permanent drain of the ventilation pipe is required.

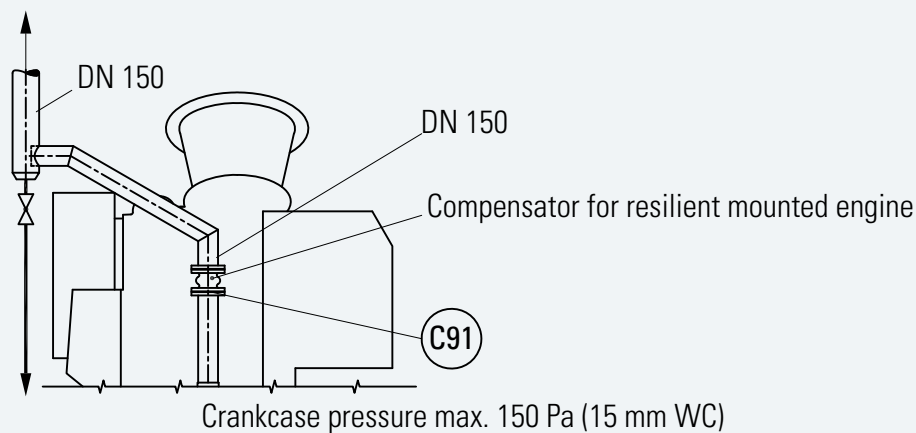


Fig. 7-7 Crankcase ventilation

C91 Crankcase ventilation to stack

### 7.5.3 Gas detection sensor

A gas detection sensor has to be installed in the crankcase vent pipe.

## COOLING WATER SYSTEM

### 8.1 General

MaK engines are cooled by two cooling circuits:

- A high temperature (HT) and
- A low temperature (LT) cooling circuit

The cooling water needs to be treated according to Caterpillar Motoren requirements for MaK engines.

#### 8.1.1 Two circuit cooling system

In this system arrangement, the two cooling systems are designed as two separate water circuits. Each circuit needs to be fitted with a header tank and a fresh water cooler.

#### 8.1.2 Secondary circuit cooling system

In the "secondary circuit cooling system", HT and LT cooling circuits are combined in sequence to one water circuit.

In order to use the different temperature levels, the HT suction side is connected to the LT delivery side. The HT circuit uses an amount of warm LT water and further heats it up by cooling the engine. The amount of LT water, that is used by the HT system, depends on the current temperature and engine power. The overrun of the fixed flow of the fresh water pump (fitted on engine) HT (FP1) circulates via bypass line from the temperature control valve HT (FR1) to the suction side as usual.

The advantage of the secondary circuit system is it's simplicity. It uses just one water circuit and there is only one header tank and one fresh water cooler instead of two.

In addition also the amount of piping is reduced.

### 8.2 Water quality requirements

#### 8.2.1 General

The engine cooling water must be carefully selected, treated and controlled.

The use of untreated cooling water will cause corrosion, erosion and cavitation on the surfaces of the cooling system. Deposits can impair the heat transfer and may result in thermal overload on components to be cooled.

Therefore the treatment with an anti-corrosion agent has to be effected before the very first commissioning of the plant.



## COOLING WATER SYSTEM

### 8.2.2 Requirements

The characteristic of the untreated cooling water must be within the following limits:

- Distillate or freshwater free from foreign matter (no seawater or waste water)
- A total hardness of max. 10° dH
- pH-value 6.5 – 8
- Chloride ion content of max. 50 mg/l

### 8.2.3 Supplementary information

**Distillate:**

If a distillate or fully desalinated water is available, this should preferably be used as engine cooling water.

**Hardness:**

Water with more than 10° dGH (German total hardness) must be mixed with distillate or softened.

### 8.2.4 Treatment before operating the engine for the first time

Treatment with an anti-corrosion agent must be done before the engine is operated for the first time to prevent irreparable initial damage.

## 8.3 Recommendation for cooling water system

### 8.3.1 Pipes and tanks

Galvanized material should not be used in tanks and pipes, it can cause zinc attack in the engine.

### 8.3.2 Drain tank with filling pump

It is recommended to collect the treated water in a separate drain tank when carrying out maintenance work (to be installed by the yard).

## COOLING WATER SYSTEM

### 8.3.3 Electric motor driven pumps

Pumps should be applicable for use in fresh water as well as sea water circuits, vertical design.

Rough calculation of power demand for the electric balance:

$$p = \frac{\rho \cdot H \cdot V}{367 \cdot \eta} [\text{kW}]$$

P = Power [kW]

P<sub>M</sub> = Power of electr. motor [kW]

V = Flow rate [m³/h]

H = Delivery head [m]

ρ = Density [kg/dm³]

η = Pump efficiency, 0.70 for centrifugal pumps

P<sub>M</sub> = 1.5 · P < 1.5 kW

P<sub>M</sub> = 1.25 · P 1.5 - 4 kW

P<sub>M</sub> = 1.2 · P 4 - 7.5 kW

P<sub>M</sub> = 1.15 · P 7.5 - 40 kW

P<sub>M</sub> = 1.1 · P > 40 kW

### 8.4 Cooling water system

General note: The following system diagrams should be regarded as typical examples. Their purpose is to explain the general function of the engine's systems. Numerous other variants and arrangements are possible and can be discussed and developed with the mechanical MaK A&I department.

#### 8.4.1 General

The high temperature (HT) system provides the HT side of the charge air cooler and the engine's cylinder heads and cylinder liner water rings with cooling water. In order to reduce the thermal tension in water-cooled engine parts, it is important to keep the drop in temperature low and therefore the flow high. Therefore the fresh water pump (fitted on engine) HT (FP1) delivers its full flow over the engine. The HT outlet temperature of 90 °C is controlled by the temperature control valve HT (FR1). In case the temperature decreases, the valve delivers more water to the bypass (connection B for mechanical, connection 3 for electrical driven valves) back to the HT pump's suction side.

In order to use the thermal energy of the HT circuit, a heat recovery can be installed as shown in the cooling water diagrams (FH3). For heat recoveries, especially for fresh water generators a high flow over the heat consumer (FH3) is recommended. This can be achieved by using a flow temperature control valve HT (FR3). This valve raises the HT flow temperature and therefore reduces the amount of water that is circulated over the bypass of FR1 and increases the flow through the heat recovery heat consumer (FH3) and the fresh water cooler HT (FH1).

## COOLING WATER SYSTEM

The low temperature (LT) cooling circuit provides cooling for the LT stage of the charge air cooler, the lube oil and the diesel oil coolers and possible other consumers like e.g. gear box and generator coolers. The LT flow temperature is controlled by FR2. The cooling system is laid out for 38 °C under tropical conditions and full engine load. For better performance, the LT temperature is to be controlled to 32 °C. Caterpillar Motoren can deliver mechanic P-controllers with a set point range of 20 to 30 °C or electric driven valves with electronic controllers, which must be set to 32 °C. Depending on the plant design the HT fresh cooling water pump can be fitted on the engine or be supplied separate with an electrical drive.

### Cooling water system diagram

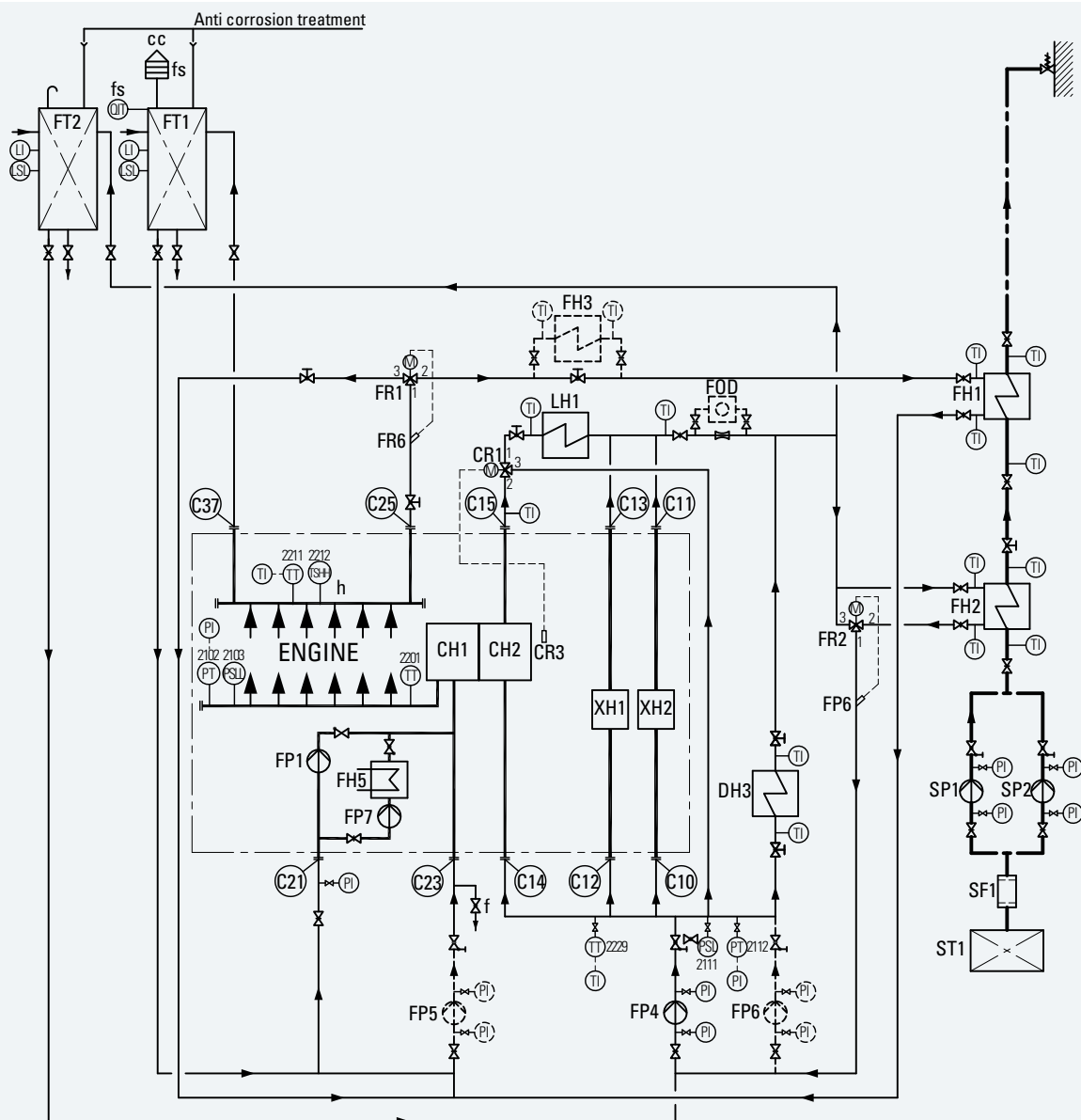


Fig. 8-1 Cooling water system diagram - Two circuit system

In plants with skin or box coolers not required: seawater system (SP1, SP2, SF1, ST1).

## COOLING WATER SYSTEM

|     |   |      |  |
|-----|---|------|--|
| CH1 | Charge air cooler HT                    | FOD  | Oil in water detector (optional)   |
| CH2 | Charge air cooler LT                    | LI   | Level indicator  |
| CR1 | Charge air thermostat                   | LSL  | Level switch low   |
| DH3 | Fuel oil cooler for MDO operation       | PI   | Pressure indicator   |
| FH1 | Fresh water cooler HT                   | PSL  | Pressure switch low  |
| FH2 | Fresh water cooler LT                   | PSLL | Pressure switch low  |
| FH3 | Heat consumer                           | PT   | Pressure transmitter   |
| FH5 | Fresh water preheater                   | QIT  | Gas alarm and transmitter  |
| FP1 | Fresh water pump HT                     | TI   | Temperature indicator  |
| FP4 | Fresh water pump (separate) LT          | TSHH | Temperature switch high  |
| FP5 | Fresh water stand-by pump HT            | TT   | Temperature transmitter  |
| FP6 | Fresh water stand-by pump LT            |      |  |
| FP7 | Preheating pump                         | C10  | Connection, HT-controller, generator bearing, inlet                                  |
| FR1 | Temperature control valve HT            | C11  | Generator bearing, outlet  |
| FR2 | Temperature control valve LT            | C12  | Generator cooler, inlet  |
| FR6 | Sensor for temperature control valve LT | C13  | Generator cooler, outlet   |
| FT1 | Compensation tank HT                    | C14  | Charge air cooler LT, inlet  |
| FT2 | Compensation tank LT                    | C15  | Charge air cooler LT, outlet   |
| LH5 | Oil cooler C.P. propeller               | C21  | Fresh water pump, inlet  |
| SF1 | Seawater filter                         | C23  | Stand-by pump HT, inlet  |
| SP1 | Seawater pump                           | C25  | Cooling water, engine outlet   |
| SP2 | Seawater stand-by pump                  | C37  | Vent   |
| ST1 | Sea chest                               |      |  |
| XH1 | Generator cooler                        | cc   | Flame arrestor must be provided.   |
| XH2 | Generator bearing cooler                | f    | Drain.   |
|     |   | h    | Please refer to the measuring point list regarding design of the monitoring devices. |
|     |   | fs   | Depending on classification society..  |

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### Cooling water system diagram – Secondary circuit

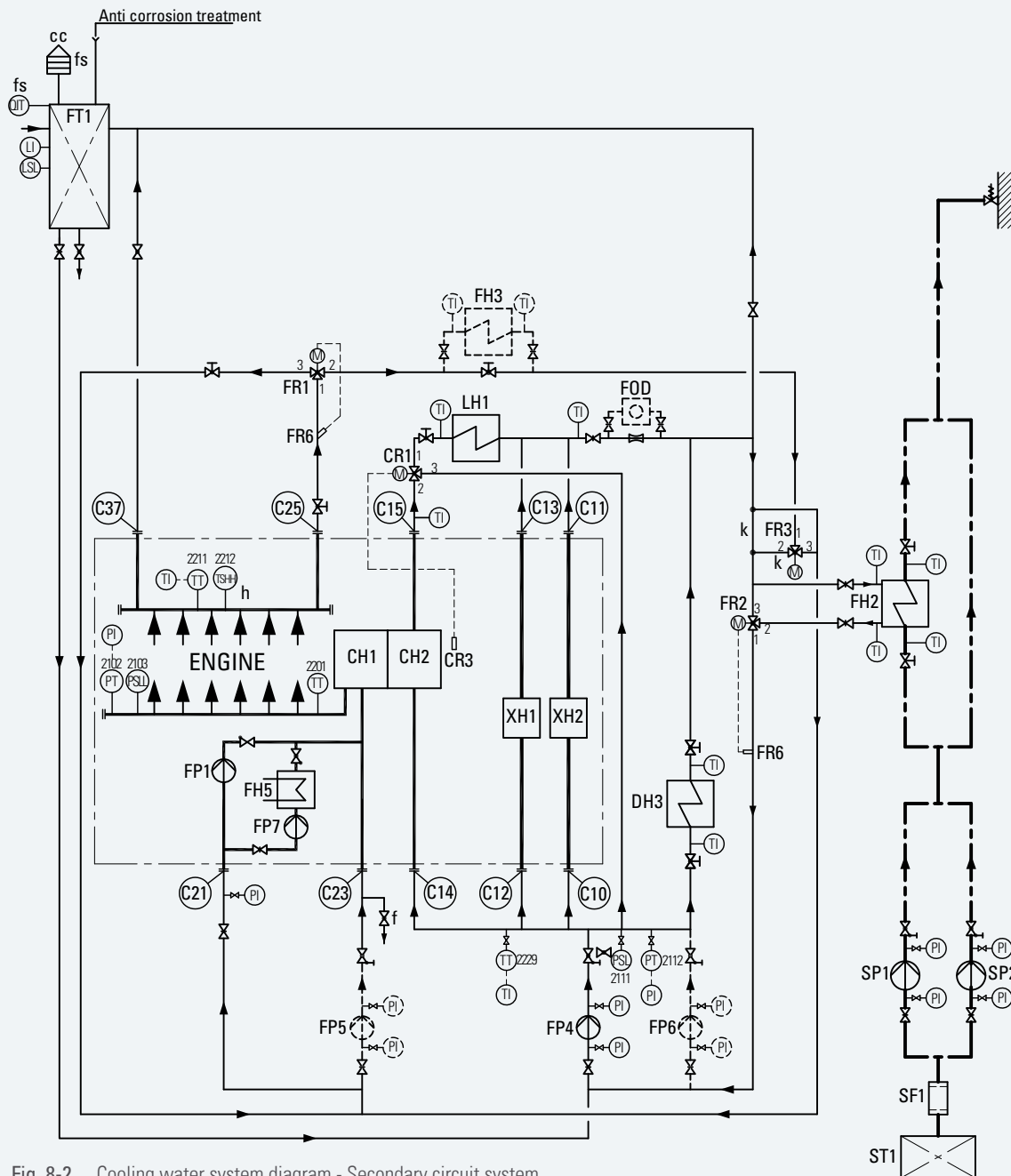


Fig. 8-2 Cooling water system diagram - Secondary circuit system

In plants with skin or box coolers not required: seawater system (SP1, SP2, SF1, ST1).

## COOLING WATER SYSTEM

|     |   |      |  |
|-----|---|------|--|
| CH1 | Charge air cooler HT                            | FOD  | Oil in water detector (optional)   |
| CH2 | Charge air cooler LT                            | LI   | Level indicator  |
| CR1 | Charge air thermostat                           | LSL  | Level switch low   |
| CR3 | Sensor for charge air temperature control valve | PI   | Pressure indicator   |
| DH3 | Fuel oil cooler for MDO operation               | PSL  | Pressure switch low  |
| FH2 | Fresh water cooler LT                           | PSLL | Pressure switch low  |
| FH3 | Heat consumer                                   | PT   | Pressure transmitter   |
| FH5 | Fresh water preheater                           | QIT  | Gas alarm and transmitter  |
| FOD | Oil water detector                              | TI   | Temperature indicator  |
| FP1 | Fresh water pump HT                             | TSHH | Temperature switch high  |
| FP2 | Fresh water pump (fitted on engine) LT          | TT   | Temperature transmitter  |
| FP7 | Preheating pump                                 |      |  |
| FR1 | Temperature control valve HT                    | C10  | Connection, HT-controller, generator bearing, inlet                                  |
| FR2 | Temperature control valve LT                    | C11  | Generator bearing, outlet  |
| FR3 | Flow temperature control valve HT               | C12  | Generator cooler, inlet  |
| FR6 | Sensor for temperature control valve LT         | C13  | Generator cooler, outlet   |
| FT2 | Compensation tank LT                            | C14  | Charge air cooler LT, inlet  |
| LH1 | Lube oil cooler                                 | C15  | Charge air cooler LT, outlet   |
| LH3 | Gear lube oil cooler                            | C21  | Fresh water pump, inlet  |
| SF1 | Seawater filter                                 | C23  | Stand-by pump HT, inlet  |
| SP1 | Seawater pump                                   | C25  | Cooling water, engine outlet   |
| SP2 | Seawater stand-by pump                          | C37  | Vent   |
| ST1 | Sea chest                                       |      |  |
| XH1 | Generator cooler                                | cc   | Flame arrestor must be provided.   |
| XH2 | Generator bearing cooler                        | f    | Drain.   |
|     |   | h    | Please refer to the measuring point list regarding design of the monitoring devices. |
|     |   | fs   | Depending on classification society.   |
|     |   | k    | Distance min. 1 m.   |

### 8.4.2 Components

#### Freshwater cooler LT FH2 (separate)

Plate type, size depending on the total heat to be dissipated.

Most ship cooling systems dump the engines' waste heat in seawater cooled fresh water coolers.

Caterpillar Motoren offers standardized titanium plate heat exchangers for this purpose.

The size of these coolers will always be individually calculated for the heat dissipation demand of the respective systems.

Alternatively box coolers, radiators and other heat exchanger arrangements and any kind of combined cooling systems can be laid out and delivered.

## COOLING WATER SYSTEM

### Compensation tank HT FT1 / LT FT2

- Arrangement: Min. 4 / max. 16 m above crankshaft center line (CL).
- Size according to technical engine data.
- All continuous vents from engine are to be connected.

#### Main functions of the cooling water header tank:

- It produces static pressure for the cooling water pumps in order to prevent cavitation. Therefore it has to be connected to each pump suction side or in case of a combined system to the suction side of the central cooling water pump.
- The vent lines continuously deliver a small water flow to the header tank. In this flow, air bubbles are carried away and the system gets de-aerated.
  - Vent lines should also be installed in the highest points of the circuits in order to get rid of all air bubbles that accumulate there.
  - Vent lines may not be too large in order to keep the flow over the header tank low. DN 20 is recommended and also valves for adjusting the flow must be installed.
- The flow of the vent lines gradually heats up the header tank by means of the constantly delivered hot water. This flow returns to the system via the pump suction side. As this circulation is very small in relation to the flow of the pump (if adjusted correctly), the temperature rise in the system will not be noticeable.
- The header tanks water volume balances the entire system volume, which changes due to thermal expansion and possibly due to leakages.

**NOTE:** Some marine classification societies require the HT compensation tank to be equipped with a gas sensor.

### Electric driven charge air temperature control valve CR1 (separate)

|             | Dimensions [mm] |     |     |     |     | Weight [kg] |
|-------------|-----------------|-----|-----|-----|-----|-------------|
|             | DN              | A   | B   | C   | D   |             |
| 6/7 M 46 DF | 100             | 350 | 646 | 175 | 170 | 70          |
| 8/9 M 46 DF | 125             | 400 | 717 | 200 | 170 | 110         |
| —           | 150             | 480 | 742 | 240 | 170 | 149         |

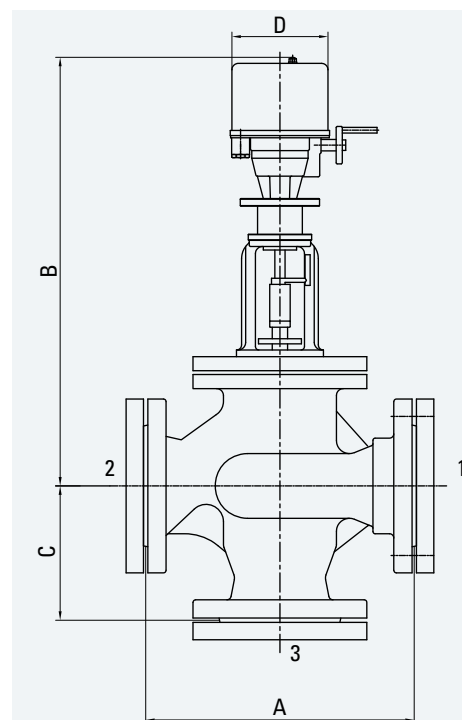


Fig. 8-3 Charge air temperature control valve CR1

## COOLING WATER SYSTEM

### Fresh water pump (separate) HT FP3/FP5 and LT FP4/FP6

Capacity: acc. to heat balance.

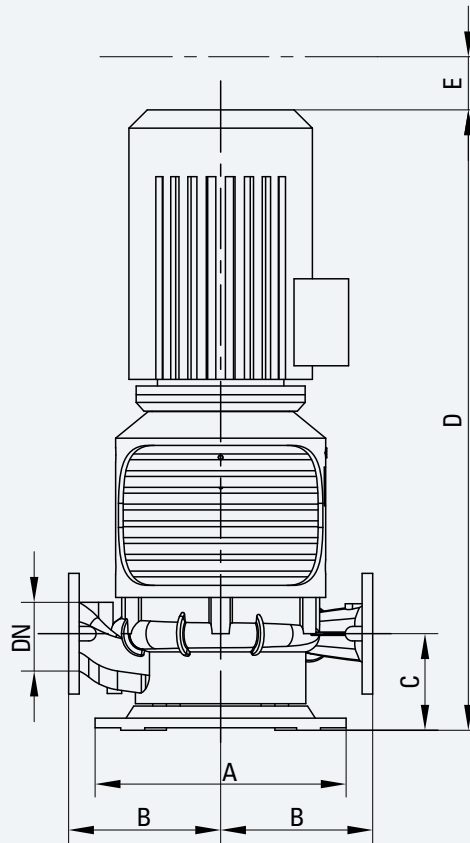


Fig. 8-4 Fresh water pump

| Flow<br>[m³/h] | Pressure<br>[bar] | Dimensions [mm] |     |         |       |         |     | Weight<br>[kg] |
|----------------|-------------------|-----------------|-----|---------|-------|---------|-----|----------------|
|                |                   | DN              | A   | B       | C     | D       | E   |                |
| 70             | 3                 | 80              | 460 | 260/200 | 158   | 913     | 110 | 130            |
| 100            | 3                 | 125             | 510 | 285/225 | 183   | 889     | 110 | 180            |
| 140            | 3                 | 150             | 510 | 285/225 | 183   | 889     | 110 | 182            |
| 180            | 3                 | 150             | 735 | 380/355 | 251.5 | 1,082.5 | 110 | 330            |



## COOLING WATER SYSTEM

### Temperature control valve HT FR1 / LT FR2 / HT flow FR3

P-controller with manual emergency adjustment (basis).

Option: PI-controller with electric drive. See charge air temperature control valve (CR1).

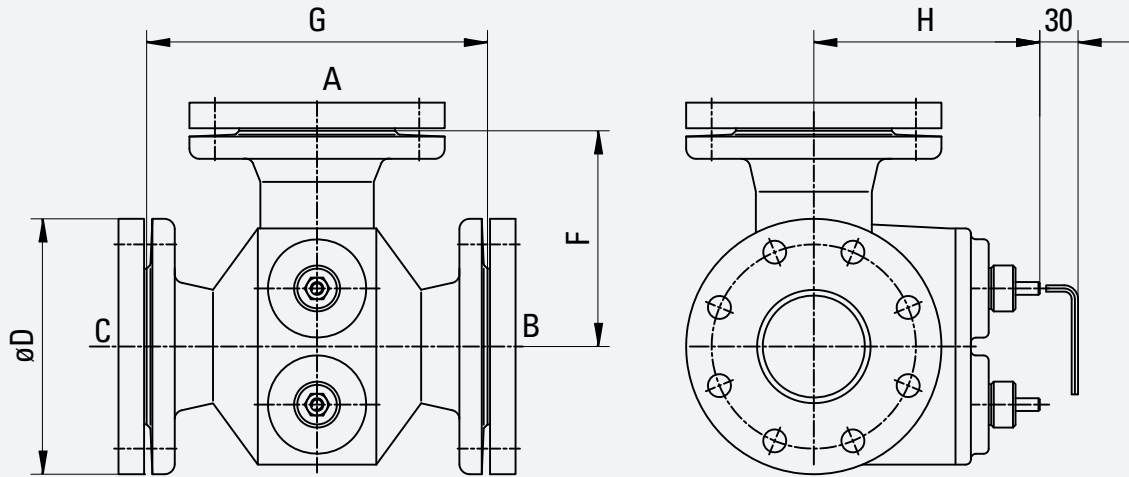


Fig. 8-5 Temperature control valve HT FR1

|                 |    | Dimensions [mm]   |     |     |     |     | Weight |
|-----------------|----|-------------------|-----|-----|-----|-----|--------|
|                 |    | DN                | D   | F   | G   | H   | [kg]   |
| 6/7 M 46 DF     | HT | 125               | 250 | 241 | 489 | 200 | 67     |
| 8/9 M 46 DF     | HT | 150               | 285 | 254 | 489 | 200 | 80     |
| 6/7/8/9 M 46 DF | LT | 150 <sup>*)</sup> | 285 | 254 | 489 | 200 | 80     |

<sup>\*)</sup> Minimum depending on total cooling water flow

# COOLING WATER SYSTEM

## 8.5 System diagrams heat balance

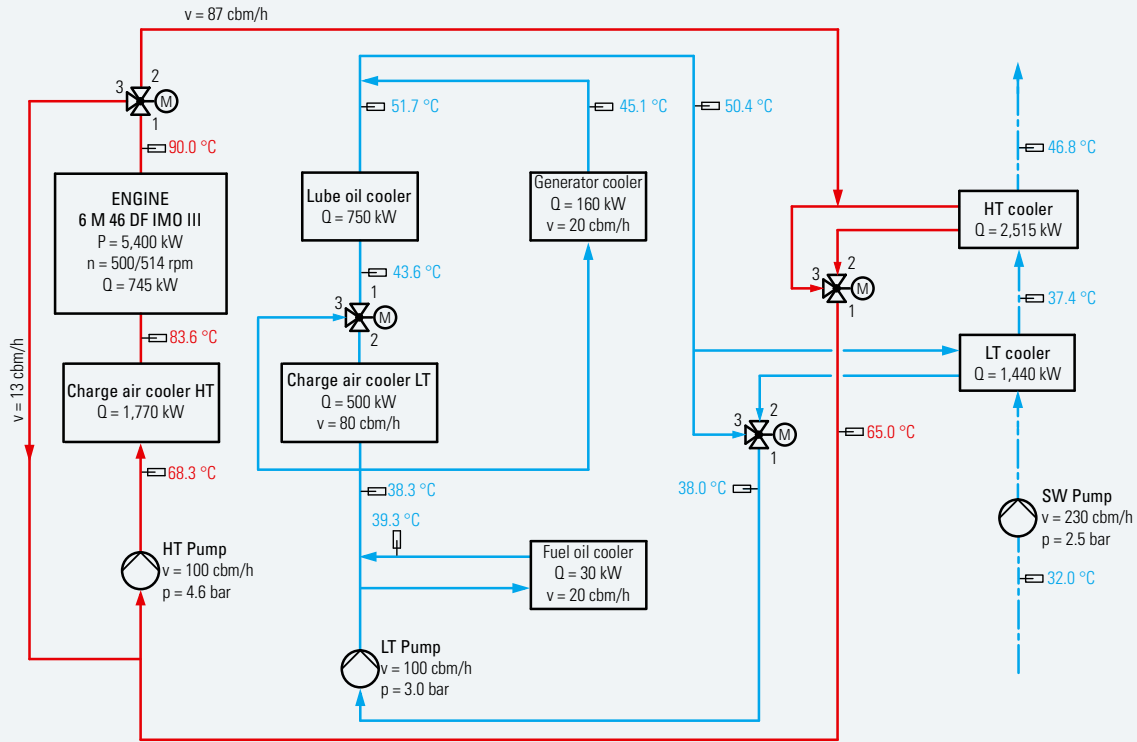


Fig. 8-6 Heat balance, system diagram 6 M 46 DF, 900 kW/Cyl.

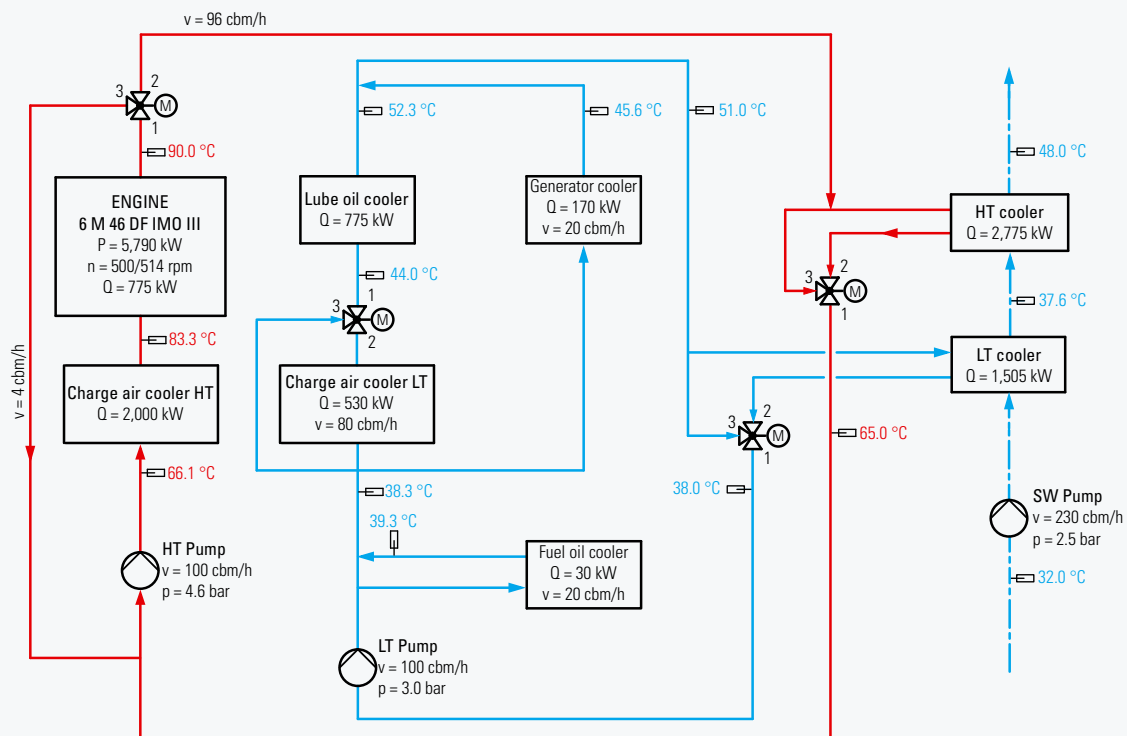


Fig. 8-7 Heat balance, system diagram 6 M 46 DF, 965 kW/Cyl.

# COOLING WATER SYSTEM

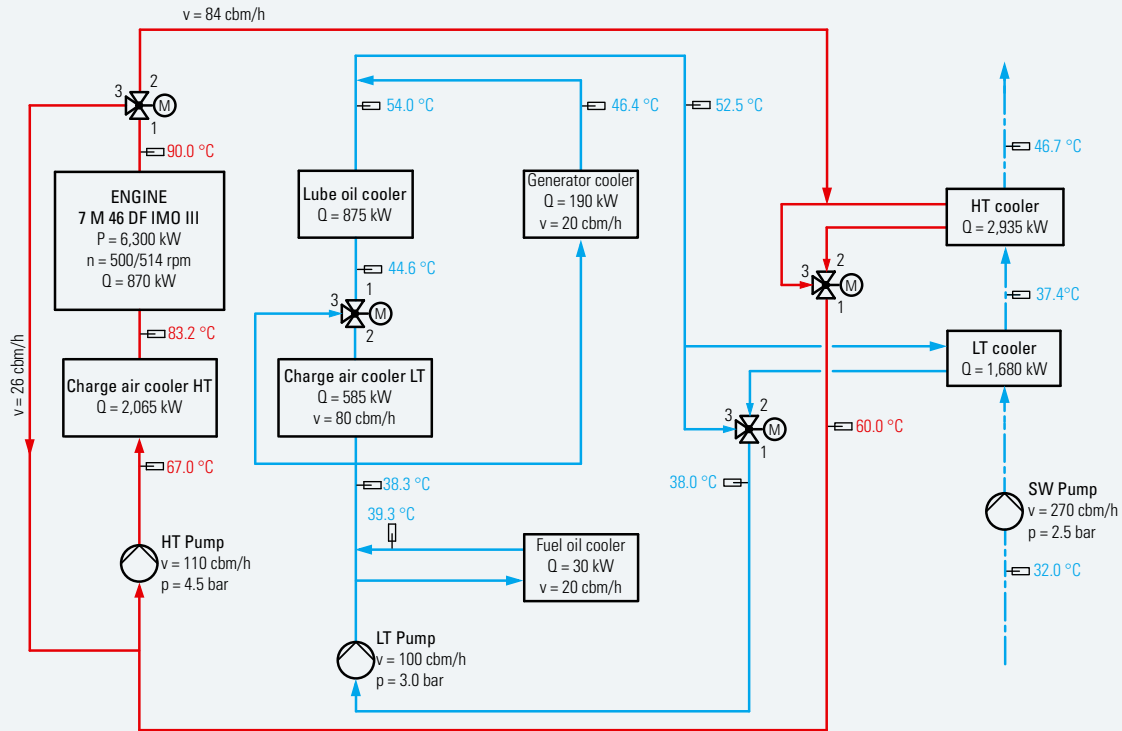


Fig. 8-8 Heat balance, system diagram 7 M 46 DF, 900 kW/Cyl.

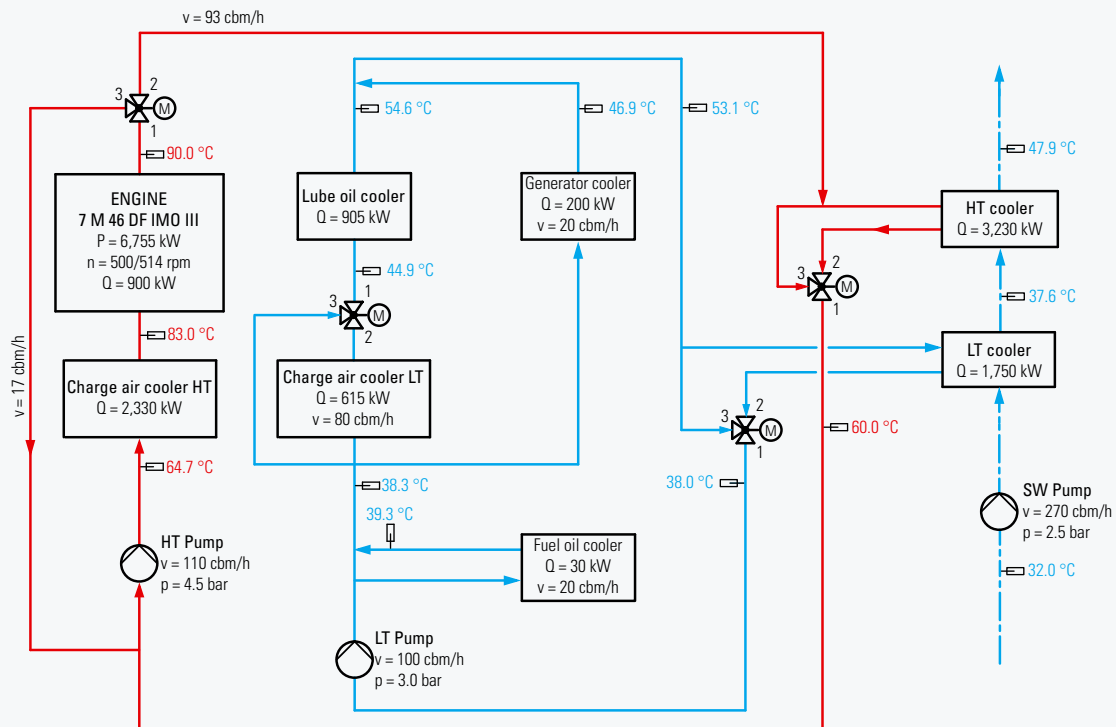


Fig. 8-9 Heat balance, system diagram 7 M 46 DF, 965 kW/Cyl.

# COOLING WATER SYSTEM

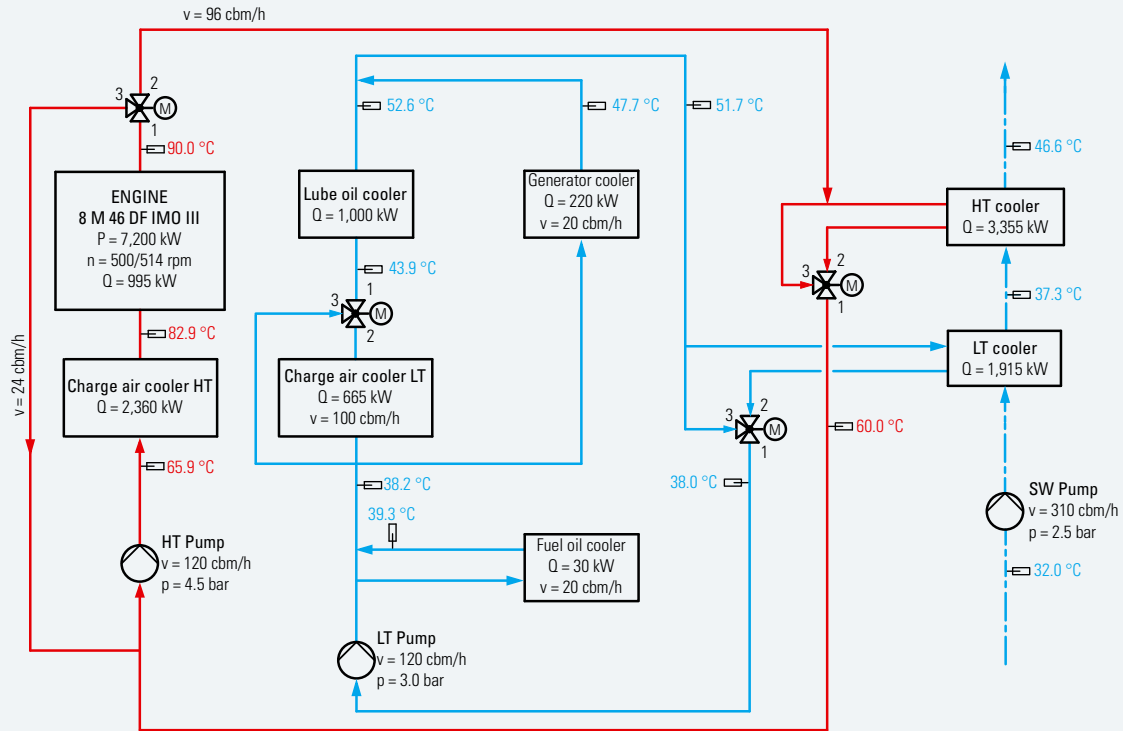


Fig. 8-10 Heat balance, system diagram 8 M 46 DF, 900 kW/Cyl.

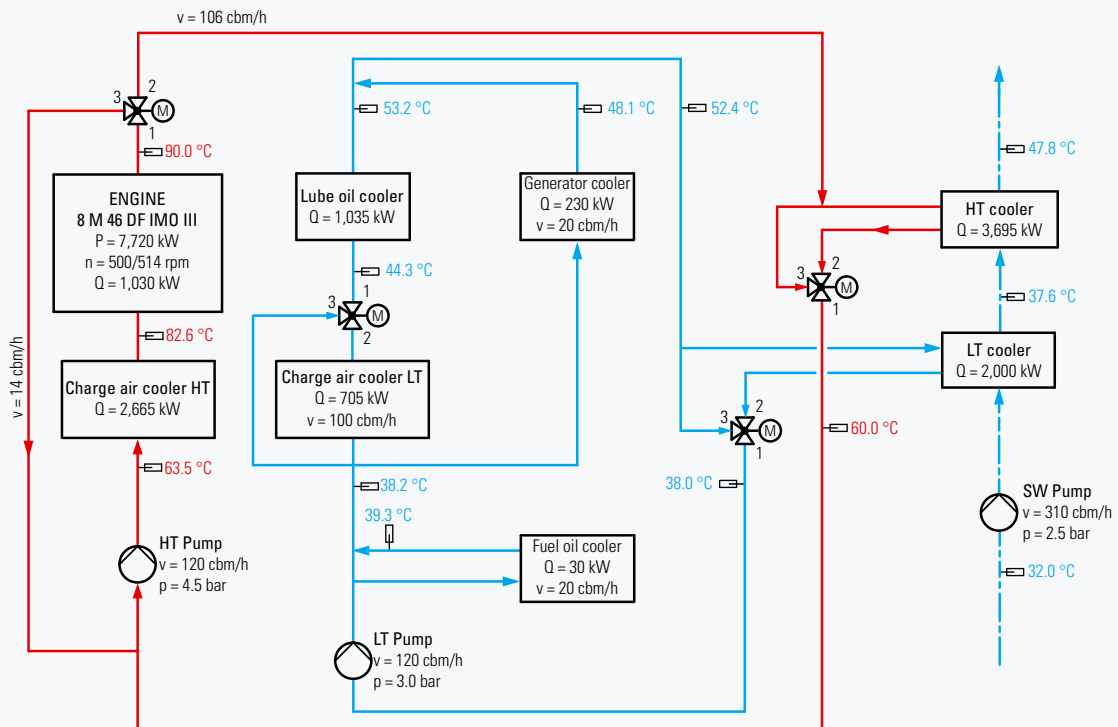


Fig. 8-11 Heat balance, system diagram 8 M 46 DF, 965 kW/Cyl.

# COOLING WATER SYSTEM

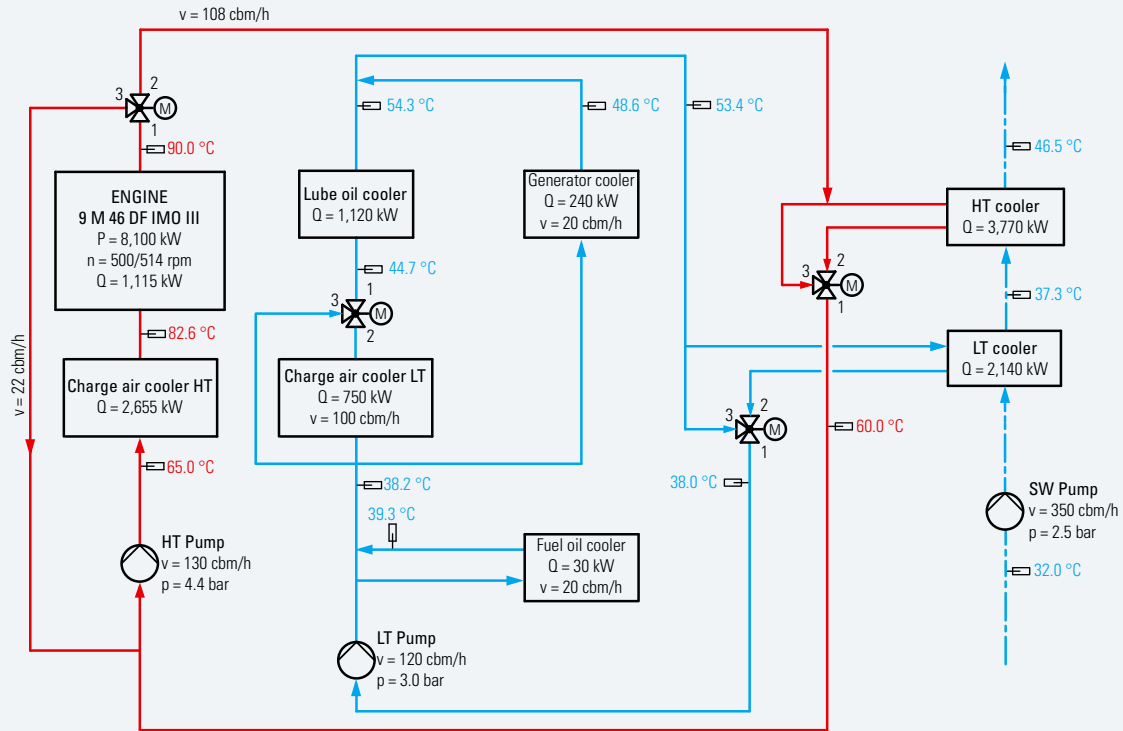


Fig. 8-12 Heat balance, system diagram 9 M 46 DF, 900 kW/Cyl.

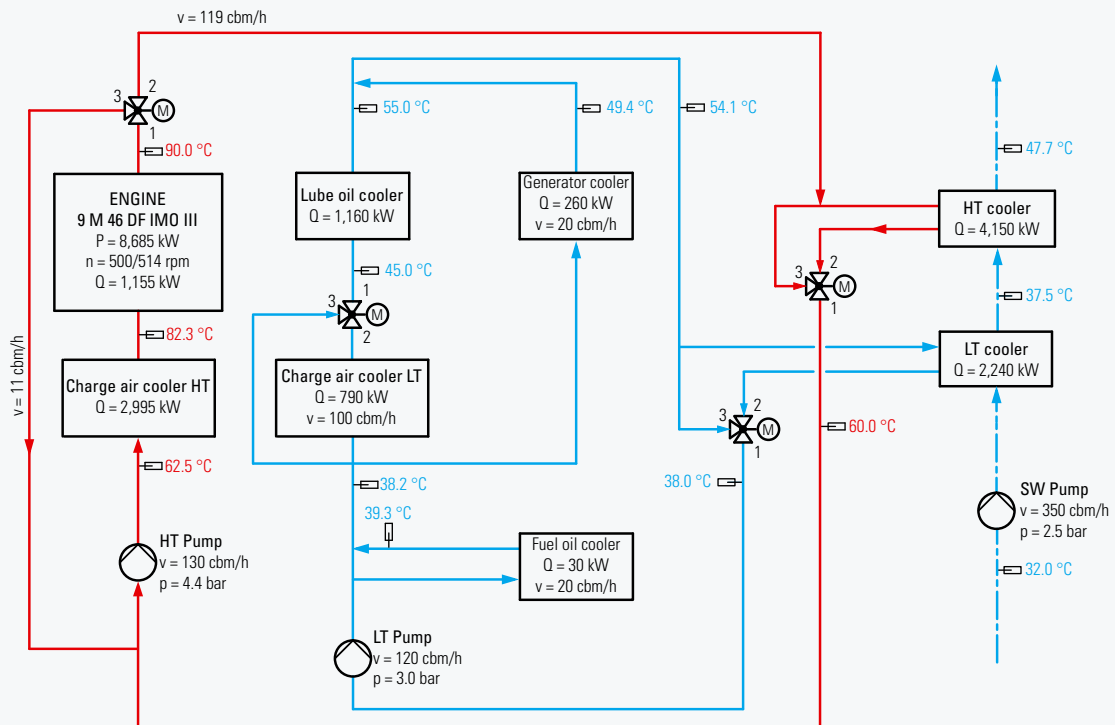


Fig. 8-13 Heat balance, system diagram 9 M 46 DF, 965 kW/Cyl.

## 8.6 Preheating (separate module)

### 8.6.1 Electrically heated

- The standard preheating system in plants delivered by Caterpillar Motoren is electrically heated.
- Consisting of baseframe mounted preheating pump FP7 (12 m³/h), electric heater FH5 (48 kW) and separate switch cabinet.

Voltage 400 - 690, frequency 50/60 Hz.

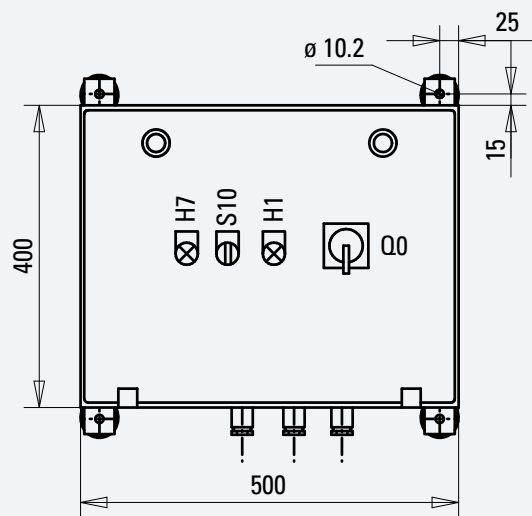


Fig. 8-14 Freshwater preheater FH5, preheating pump FP7

## COOLING WATER SYSTEM

### 8.6.2 Other preheating systems

On request preheating systems heated by thermal oil or steam can be laid out and delivered by Caterpillar Motoren.

### 8.7 Box coolers system

On request box coolers can be laid out and delivered by Caterpillar Motoren.

### 8.8 Cooling circuit layout

The engine driven cooling water pumps are designed to provide the engine and it's systems with cooling water.

For a rough layout of these circuits, a pressure drop of 0.5 bar per component can be calculated:

Taking the total estimated pressure loss of the whole circuit in account, the flow delivered by the pump can be read out from the pump performance curve.

Engine driven cooling water pumps  
Performance curve

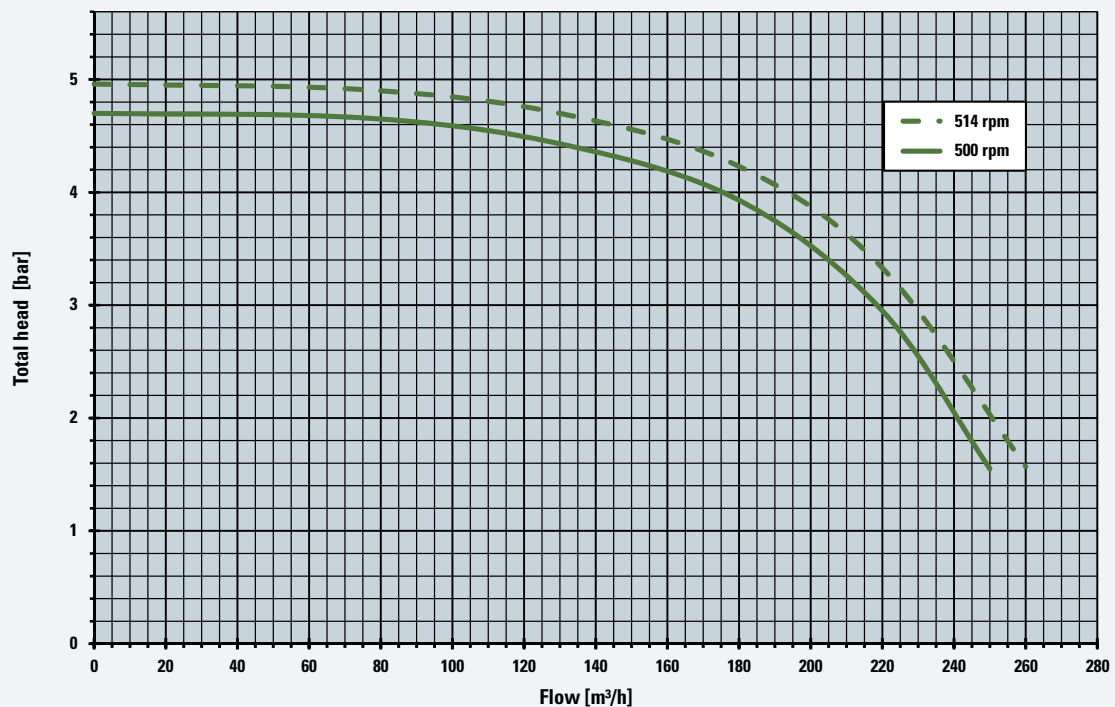


Fig. 8-15 Pump curve

## COMPRESSED AIR SYSTEM

### 9.1 General

M 46 DF engines require compressed air for starting the engine and providing actuating energy for safety and control devices as well as for Flexible Camshaft Technology (FCT).

The compressed air system consists at least of two compressors, two air receivers and its accessories such as filters, dryers, regulating and control valves and the piping system, of a capacity and air delivery rating dependent of the load profile of the ship and to meet the requirements of the respective classification society.

To ensure always the functionality of the compressed air system, it has to be free of solid particles and oil, see chapter 9.4 Compressed air quality.

### 9.2 Internal compressed air system

The M 46 DF engine is started by means of compressed air with a nominal pressure of 30 bar.

The start is performed by direct injection of starting air into the cylinder through the starting air valves in the cylinder heads.

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## COMPRESSED AIR SYSTEM

### 9.3 Compressed air system

Clean and dry starting air is required. A starting air filter has to be installed before engine, if required. Module P&ID's must be considered for detailed description.

Caterpillar Motoren recommends installing automatic drain valves.

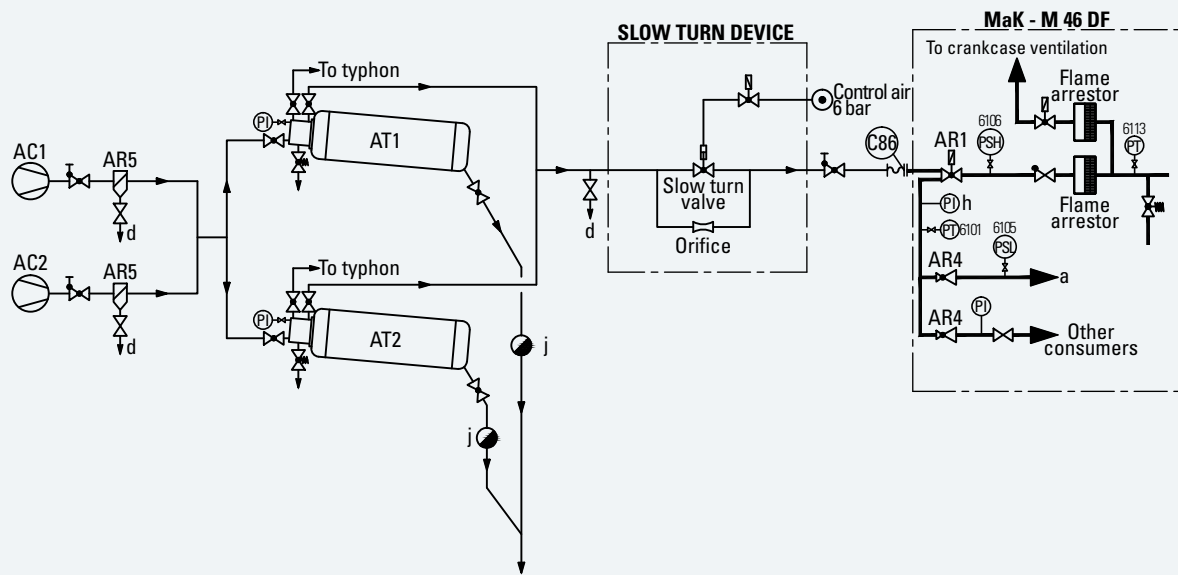


Fig. 9-1 External compressed air system, system diagram

|     |   |   |   |
|-----|---|---|---|
| AC1 | Compressor                                | a | Control air   |
| AC2 | Stand-by compressor                       | d | Water drain (to be mounted at the lowest point)           |
| AR1 | Starting valve                            | h | Please refer to the measuring point list regarding design |
| AR4 | Pressure reducing valve                   | j | Automatic drain required                                  |
| AR5 | Oil and water separator                   |   |   |
| AT1 | Starting air receiver (air bottle)        |   |   |
| AT2 | Starting air receiver (air bottle)        |   |   |
| PI  | Pressure indicator                        |   |   |
| PSH | Pressure switch high                      |   |   |
| PSL | Pressure switch low, only for main engine |   |   |
| PT  | Pressure transmitter                      |   |   |
| C86 | Connection / starting air                 |   |   |

#### AT1/AT2 Option:

- Typhon valve
- Relief valve with pipe connection

### 9.3.1 Compressor AC1 / AC2

According to the requirements of the Marine Classification Society there should be minimum 2 starting air compressors with 50% total performance each.

The total performance has to be sufficient for refilling the starting air receivers to their normal pressure of 30 bar within one hour.

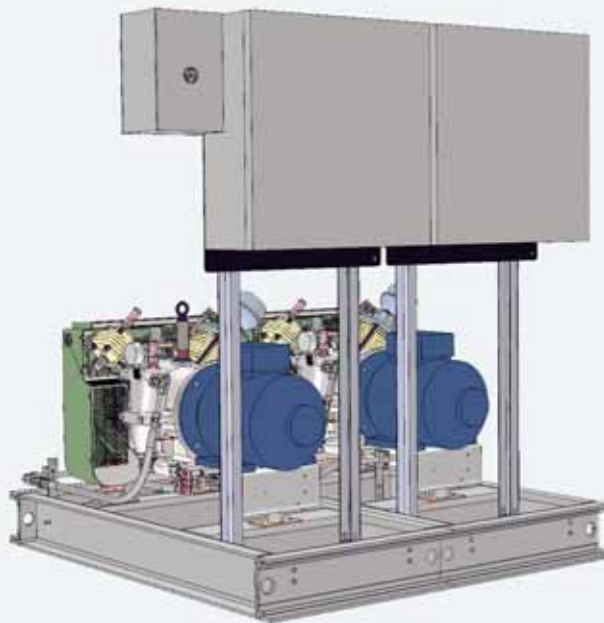


Fig. 9-2 Compressor AC1, AC2

**Capacity:**

$$V \text{ [m}^3\text{/h]} = \Sigma V_{\text{Rec.}} \cdot 30$$

$V_{\text{Rec.}}$  Total receiver volume [m<sup>3</sup>]

## COMPRESSED AIR SYSTEM

### 9.3.2 Air receiver AT1 / AT2

The starting air receivers are to be dimensioned for a nominal pressure of 30 bar.

M 46 DF engines require at least 14 bar as a minimum starting air pressure.

The total amount of air receivers and their capacity depend on the requirements of the classification societies and the type of installation.

It is required to install the receivers in a way, so that it can always sufficiently be drained manually or automatically at the deepest point of the receivers.

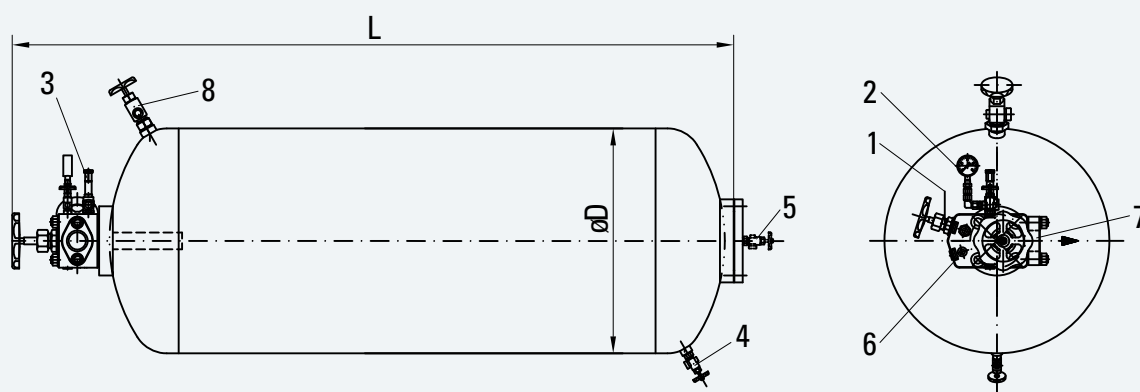


Fig. 9-3 Air receiver AT1, AT2

- 1 Filling valve
- 2 Pressure gauge G 1/4
- 3\* Relief valve DN 7
- 4 Drain valve DN 8
- 5 Drain position vertical

- 6 Connection G 1/2 with plug
  - 7 Outlet of starting valve at engine
  - 8 Typhon valve DN 16
- Option: \* with pipe connection G 1/2

## COMPRESSED AIR SYSTEM

## Normal requirements of classification societies:

No. of starts: 6 + 1 Slow turn

No. of receivers: min. 2

## Calculation of air receiver volumes:

$$V = \frac{V_2 \cdot n \cdot P_{\text{atm}}}{P_{\text{max}} - P_{\text{min}}}$$

V = Air receiver volume

 $V_2$  = Air consumption per start [Nm<sup>3</sup>]

n = Required number of starting procedures in sequence

 $P_{\text{atm}}$  = Ambient pressure [bar] $P_{\text{max}}$  = Maximum receiver pressure (30 bar) $P_{\text{min}}$  = Minimum receiver pressure (14 bar)

## Receiver capacity acc. to GL recommendation AT1/AT2

|             | Single-engine plant | Twin-engine plant |
|-------------|---------------------|-------------------|
| 6/7 M 46 DF | 2 x 750 l           | 2 x 1,500 l       |
| 8/9 M 46 DF | 2 x 1,000 l         | 2 x 2,000 l       |

| Receiver capacity | L     | øD   | Valve head | Weight       |
|-------------------|-------|------|------------|--------------|
| [l]               | [mm]  | [mm] |            | approx. [kg] |
| 250               | 2,037 | 480  | DN 38      | 280          |
| 500               | 3,501 | 480  | DN 50      | 460          |
| 750               | 3,033 | 650  | DN 50      | 625          |
| 1,000             | 3,853 | 650  | DN 50      | 810          |
| 1,500             | 3,753 | 800  | DN 50      | 1,150        |
| 2,000             | 4,903 | 800  | DN 50      | 1,490        |

When CO<sub>2</sub> fire extinguishing plants are arranged in the engine room, the blow-off connection of the safety valve is to be piped to the outside.

## COMPRESSED AIR SYSTEM

### 9.4 Compressed air quality

For a proper operation of the engine a compressed air quality of class 4 according ISO 8573-1 is required.

#### Instrument air specification

|                           |             |
|---------------------------|-------------|
| Max. particle size:       | 15 µm       |
| Max. particle density:    | 8 mg/m³     |
| Water pressure dew point: | 3 °C        |
| Water:                    | 6.000 mg/m³ |
| Residual oil content:     | 5 mg/m³     |

- **Oil content**  
(Specification of aerosols and hydrocarbons which may be contained in the compressed air.)
- **Particle size and density**  
(Specification of size and concentration of particles which still may be contained in the compressed air.)
- **Pressure dew point**  
(Specification of the temperature on which the compressed air can cool down without the steam contained in it condensing. The pressure dew point changes with the air pressure.)

### 9.5 Slow turn

A slow turning device is mandatory and has to be installed, one per engine.

This is a precaution in case a cylinder has had oil or water leak into it, which would cause damage to the engine when starting.

If the engine completes two full revolutions on slow turn, the automatic main starting air will open for starting the engine.

|   | 6 M 46 DF | 7 M 46 DF | 8 M 46 DF | 9 M 46 DF |
|---|-----------|-----------|-----------|-----------|
| Air consumption per slow turn manoeuvre [Nm³] | 5.2       | 5.4       | 6.4       | 6.6       |

## 9.6 Equipment

### Compressor module

Caterpillar Motoren can design, offer and deliver integrated compressor modules: Starting air receiver and compressors can be combined individually. For further information please contact Caterpillar Motoren, technical department.



Fig. 9-4 Compressor module

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## COMBUSTION AIR SYSTEM

**10.1 Engine room ventilation**

To obtain good working conditions in the engine room and to ensure a trouble free operation of all equipment a properly designed engine room ventilation system with cooling air and combustion air is required.

**10.2 Combustion air system design**

Combustion air describes the air the engine requires to burn fuel.  
Combustion air demand see chapter 4, technical data.

**10.2.1 Air intake from engine room (standard)**

- Fans are to be designed for a slight overpressure in the engine room.
- On system side the penetration of water, sand, dust, and exhaust gas must be avoided.
- When operating under tropical conditions, the air flow must be conveyed directly to the turbocharger.

**10.2.2 Air intake from outside**

- The intake air duct is to be provided with a filter. Penetration of water, sand, dust and exhaust gas must be avoided.
- Connection to the turbocharger is to be established via an expansion joint.  
For this purpose the turbocharger will be equipped with a connection socket.

**10.2.3 Air intake temperature from engine room and from outside**

- Standard engine operation is possible with an air temperature at the turbocharger inlet above 0 °C.
- Engine operation below 0 °C requires an ignition pressure reduction via waste gate interaction (standard scope of supply) which could occur in a load reduction and / or in higher fuel consumption.

**10.3 Cooling air**

Cooling air refers to the flow of air that removes radiant heat from the engine, generator, other driven equipment and other engine room components.  
To dissipate the radiated heat a slight and evenly distributed air flow is to be led along the engine exhaust gas manifold starting from the turbocharger.

**NOTE:**

Radiated heat see technical data.

**10.4 Condensed water from charge air duct**

Operating the engine in tropical conditions, high ambient temperature and high humidity, may generate condensate (water) that needs to be drained.

## EXHAUST GAS SYSTEM

The exhaust gas system discharges the exhaust gases, emitted from the engine, through a piping system to the atmosphere. To provide maximum efficiency of the engine, the resistance to the gas flow should be minimized. The back pressure directly after the turbocharger, influenced by the design of the exhaust gas piping and all installed components like exhaust gas boilers, catalysts and scrubbers is limited to 30 mbar. Higher values will increase the thermal load of the engine and may lead to higher fuel consumption.

### 11.1 Components

#### 11.1.1 Exhaust gas nozzle

For an optimal integration of the engine in the engine room, regarding the discharge of the emitted exhaust gases different orientations of the exhaust gas nozzle are possible.

The basic orientation of the exhaust gas nozzle for all M 46 DF engines is 45 °.

Transition pieces are available also for orientations of 0 °, 30 °, 60 ° and 90 ° from the vertical line.

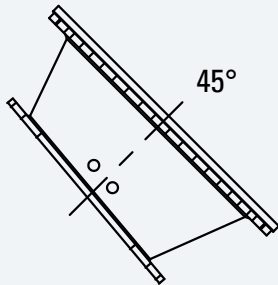


Fig. 11.1 Basic orientation

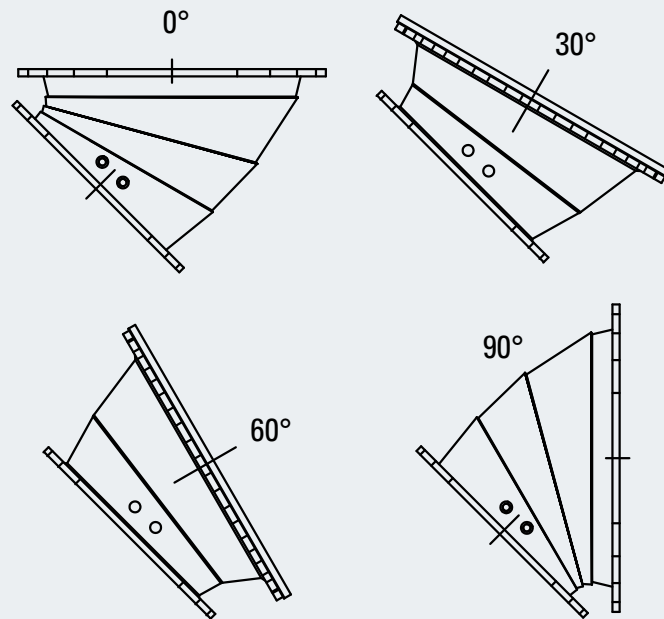


Fig. 11-2 Orientations with transition pieces



## EXHAUST GAS SYSTEM

### 11.1.2 Exhaust gas compensator

The connection of the engine to the piping system of the ship has to be flexible to compensate possible engine vibrations, movements of resilient mounted engines and to reduce the forces generated by the thermal expansion of the exhaust gas piping acting to the turbocharger. For this connection a special type approved exhaust gas compensator which is flexible in all directions is available.

It is highly recommended to install the exhaust gas compensator directly after the above mentioned exhaust gas nozzle. If it is necessary to isolate the compensator area it must be possible that the compensator is able to expand and contract freely.

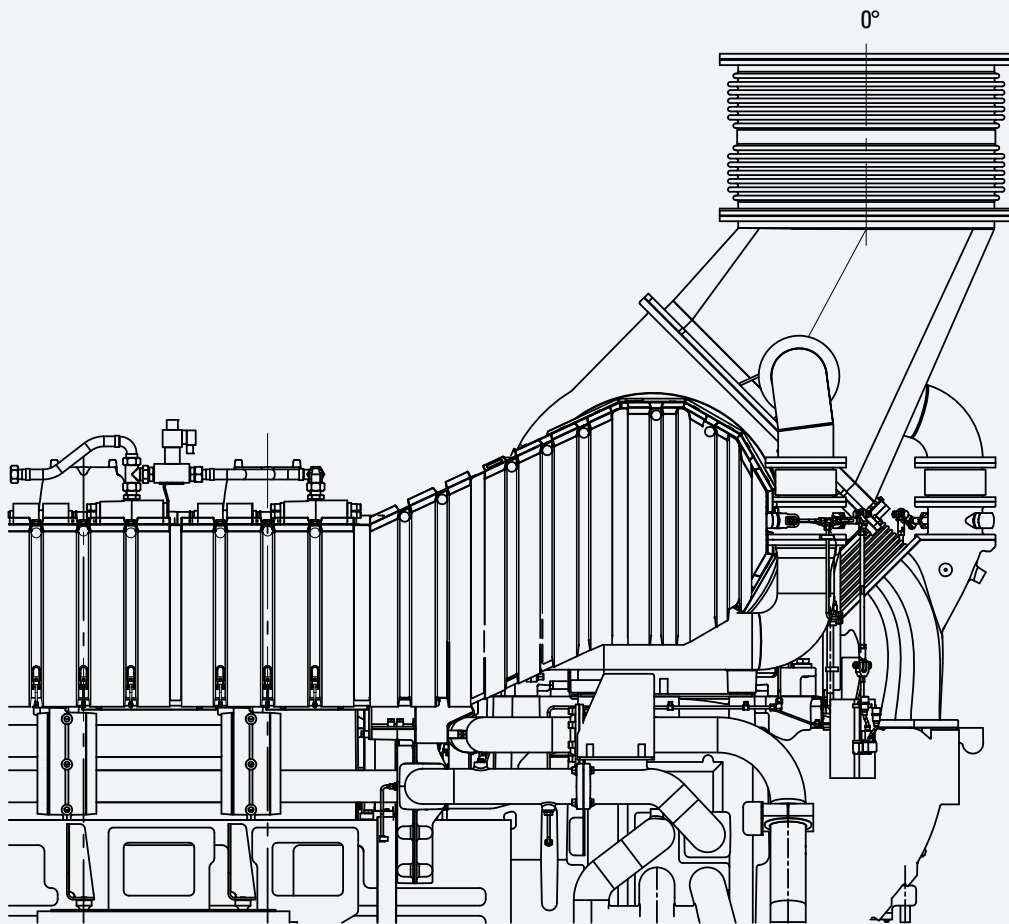


Fig. 11-3 Exhaust gas compensator

Basic design values of the standard exhaust gas compensators.

| Type          | Diameter | Length | Weight |
|---------------|----------|--------|--------|
|               | [mm]     | [mm]   | [kg]   |
| 6 M 46 DF     | 900      | 500    | 158    |
| 7/8/9 M 46 DF | 1,000    | 620    | 209    |

## EXHAUST GAS SYSTEM

### 11.1.3 Exhaust gas piping system

To minimize the forces acting through the compensator to the turbocharger and to guarantee a long lifetime of the compensator it is highly recommended to position a fixed point piping support directly after the compensator.

Each engine requires a separate exhaust gas pipe. The exhaust gas piping system of two or more engines is not allowed, otherwise exhaust gases from engines under operation be forced into cold engines not operating and causes engine damages as a result of condensed water from the exhaust gas.

Also the exhaust gas pipes and/or silencers should be equipped with water separating pockets and a drainage.

In order to minimize the pressure loss of the complete exhaust gas system it is recommended to use a suitable pipe diameter for the entire exhaust gas line.

According to the dimensions of the compensators (see table chapter 11.1.2) there are standard diameters proposed for the respective engine type in relation to the exhaust gas mass flow. In case of multiple of bends and other components integrated in the exhaust gas system it might be necessary to increase the pipe diameter.

For guidance the exhaust gas flow velocity should be less than 40 m/s.

For flushing the exhaust gas piping system after engine operation in gas mode an installation of a forced ventilation system is required.

According to class requirements explosion relief valves for single main engines and for multi-engine installations at least burst discs for explosion release device has to be installed in the exhaust gas system. For each individual installation the number and size of these devices will be determined by a simulation.

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# EXHAUST GAS SYSTEM

## Resistance in exhaust gas piping

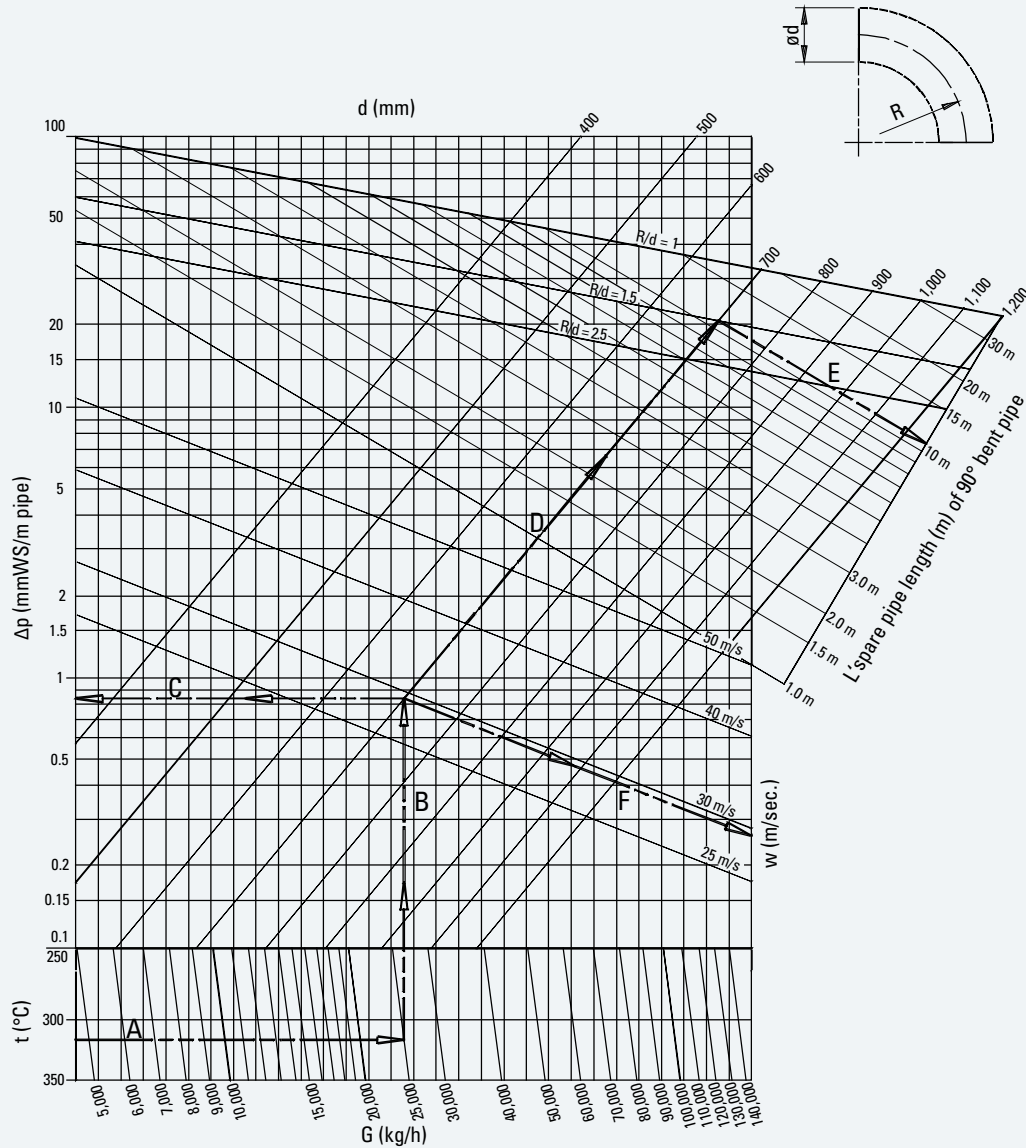


Fig. 11-4 Resistance in exhaust gas piping

Example (based on diagram data A to E):

$T = 335^{\circ}\text{C}$ ,  $G = 25,000 \text{ kg/h}$

$L = 15 \text{ m}$  straight pipe length,  $d = 700 \text{ mm}$

3 off  $90^{\circ}$  bend  $R/d = 1.5$

1 off  $45^{\circ}$  bend  $R/d = 1.5$

$\Delta P_g = ?$

$\Delta p = 0.83 \text{ mm WC/m}$

$L' = 3 \cdot 11 \text{ m} + 5.5 \text{ m}$

$L = L + L' = 15 \text{ m} + 38.5 \text{ m} = 53.5 \text{ m}$

$\Delta P_g = \Delta p \cdot L = 0.83 \text{ mm WC/m} \cdot 53.5 \text{ m} = 44.4 \text{ mm WC}$

$t$  = Exhaust gas temperature [ $^{\circ}\text{C}$ ]

$G$  = Exhaust gas massflow [ $\text{kg/h}$ ]

$\Delta p$  = Resistance/m pipe length [ $\text{mm WC/m}$ ]

$d$  = Inner pipe diameter [ $\text{mm}$ ]

$w$  = Gas velocity [ $\text{m/s}$ ]

$L$  = Straight pipe length [ $\text{m}$ ]

$L'$  = Spare pipe length of  $90^{\circ}$  bent pipe [ $\text{m}$ ]

$L$  = Effective substitute pipe length [ $\text{m}$ ]

$\Delta P_g$  = Total resistance [ $\text{mmWC}$ ]

## EXHAUST GAS SYSTEM

### 11.1.4 Silencer

The exhaust noise emission of the engine has to be reduced by an integration of at least one suitable silencer in the exhaust gas system to fulfil either the specifications of the relating classification company or legal regulations according to noise emissions or just to meet the clients comfort demand at open deck. Standard silencers which are especially designed for each engine type are available. As the silencers are of the absorptive type the flow resistance is low so just a back pressure of approximately 100 mmWC will arise. Long fibre absorbing heat resistant material is used for the noise absorption.

The noise attenuation of the standard silencers reaches at least 35 dB(A) and covers a wide frequency range. If necessary also silencers with a higher attenuation can be offered.

As standard the silencer can be provided either with or without a spark arrestor which will be provided with a soot collecting chamber. Each silencer is equipped with a water drain to draw out the condensed water. The silencer will be delivered with counter flanges, screws and gaskets. The mounting brackets for either horizontal or vertical installation as the insulation are not included. Optional the silencers can be delivered with loose or welded on mounting brackets according clients requirements.

Special attention has to be paid to the positioning of the silencer in the exhaust gas system to avoid resonance effects in the piping system. A wrong positioning of the silencer in the system can cause high noise levels before or after the silencer and can lead to extreme noise at the funnel end.

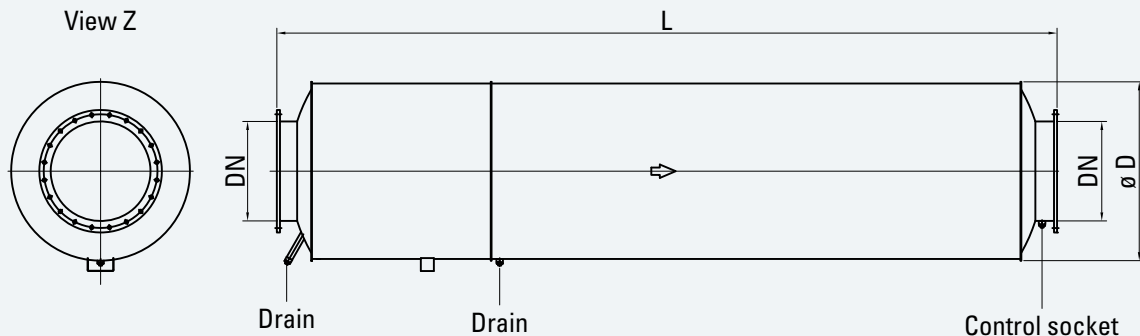


Fig. 11-5 Silencer

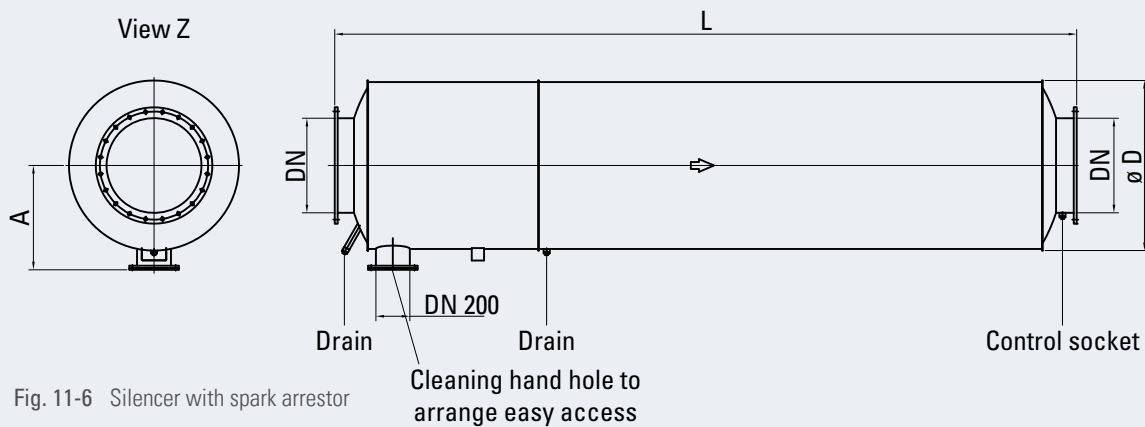


Fig. 11-6 Silencer with spark arrestor

| Type          | Dimensions [mm] |       |       |       | Weight | Weight with spark arrestor |
|---------------|-----------------|-------|-------|-------|--------|----------------------------|
|               | DN              | A     | D     | L     | [kg]   | [kg]                       |
| 6 M 46 DF     | 900             | 1,110 | 1,700 | 6,150 | 3,400  | 2,950                      |
| 7/8/9 M 46 DF | 1,000           | 1160  | 1,800 | 6,460 | 3,900  | 3,540                      |

# EXHAUST GAS SYSTEM

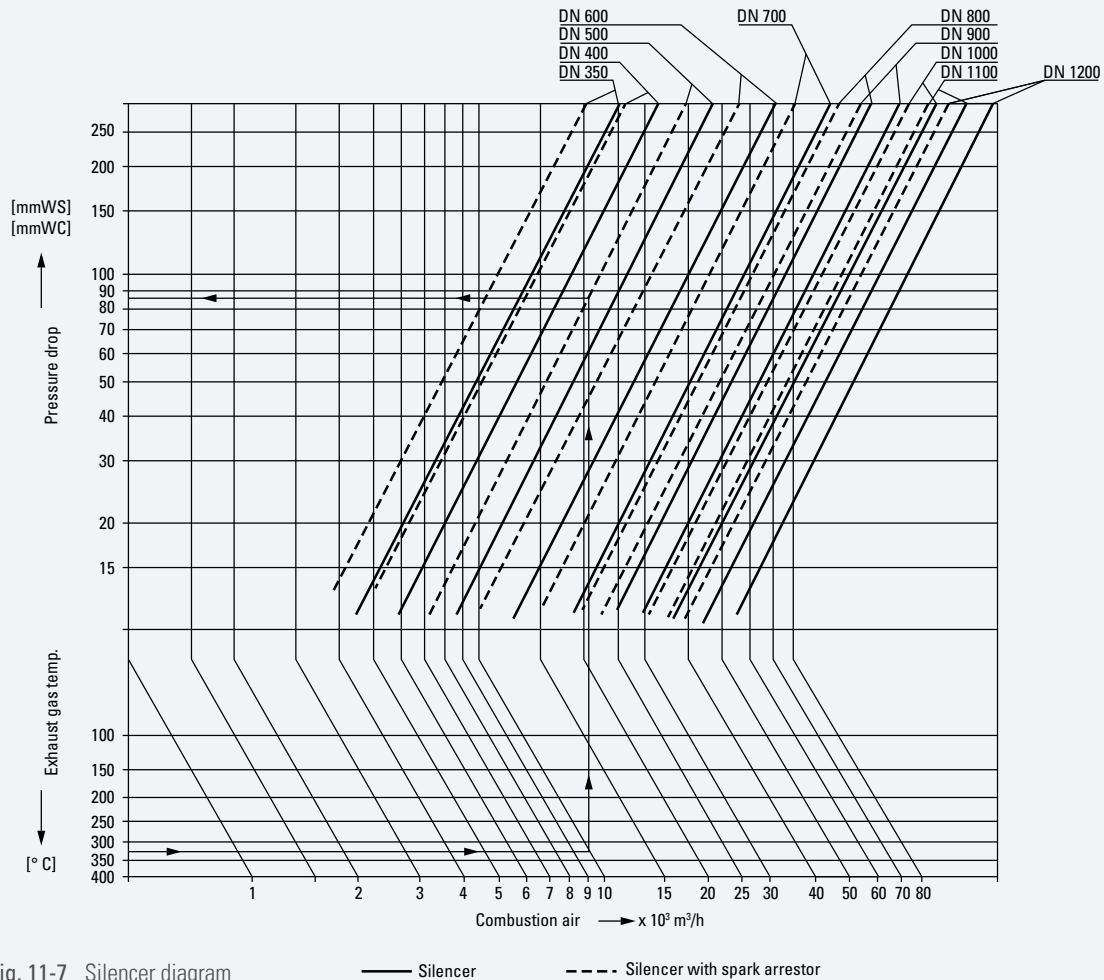


Fig. 11-7 Silencer diagram

## 11.1.5 Exhaust gas boiler

If exhaust gas boilers are used in the exhaust gas line each engine should have a separate boiler. If a common boiler is used for two or more engines the gas sections have to be separated. Particularly when exhaust gas boilers are installed attention must be paid not to exceed the maximum recommended back pressure.

## 11.2 Turbocharger

### 11.2.1 Turbine cleaning system

Turbine cleaning is required for HFO operation. The cleaning is carried out with clean fresh water „wet cleaning” during low load operation at regular intervals, depending on the fuel quality, 150 hours.

## EXHAUST GAS SYSTEM

**NOTE:**

Duration of the cleaning period is approx. 15 minutes (2 intervals). Fresh water of 2 - 2.5 bar is required.

**NOTE:**

During cleaning the water drain should be checked. Therefore, the shipyard has to install a funnel after connection point C36.

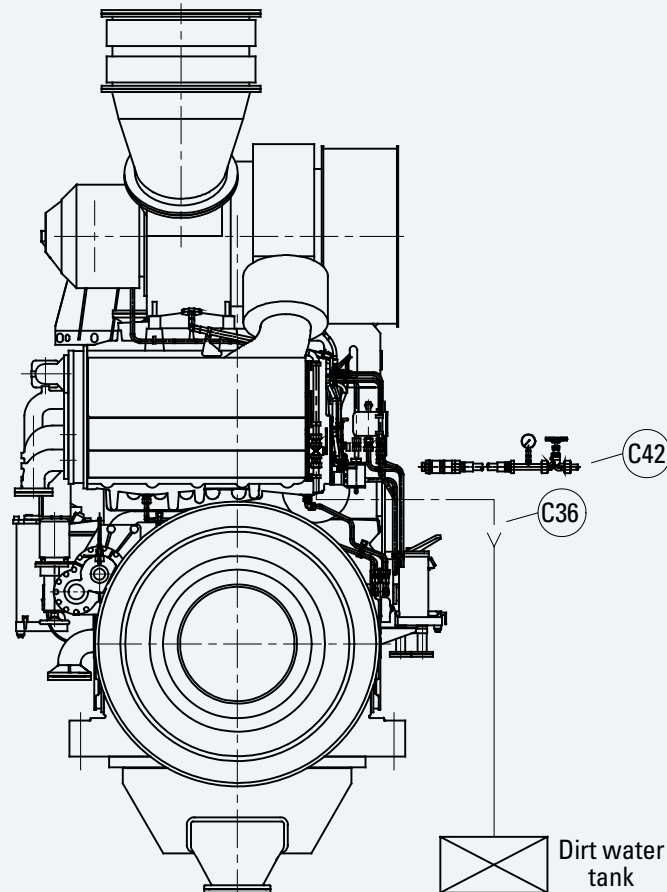


Fig. 11-8 Connection points fresh water and drain

- C42 Fresh water supply, DN 12  
C36 Drain, DN 30

| Type          | Water flow | Injection time |
|---------------|------------|----------------|
|               | [l/min]    | [min]          |
| 6 M 46 DF     | 23 - 27    | 10             |
| 7/8/9 M 46 DF | 32 - 38    | 10             |

### 11.2.2 Compressor cleaning system

The components for cleaning (dosing vessel, pipes, shut-off valve) are engine mounted.

**NOTE:**

Water is fed every 24 hours before compressor wheel via injection pipes during full load operation.

## FLEXIBLE CAMSHAFT TECHNOLOGY (FCT)

**12.1 Flexible Camshaft Technology (FCT)**

The dual fuel engine has a modified FCT system, to ensure an optimal engine operation in all operating modes over the entire load range. The FCT system is basically known from the M 32 C diesel engine, where this technology is already validated.

**Benefits:**

- High potential for smoke reduction
- Low complexity
- Low technical risk-application of existing technology
- Increase knock margin at higher engine loads

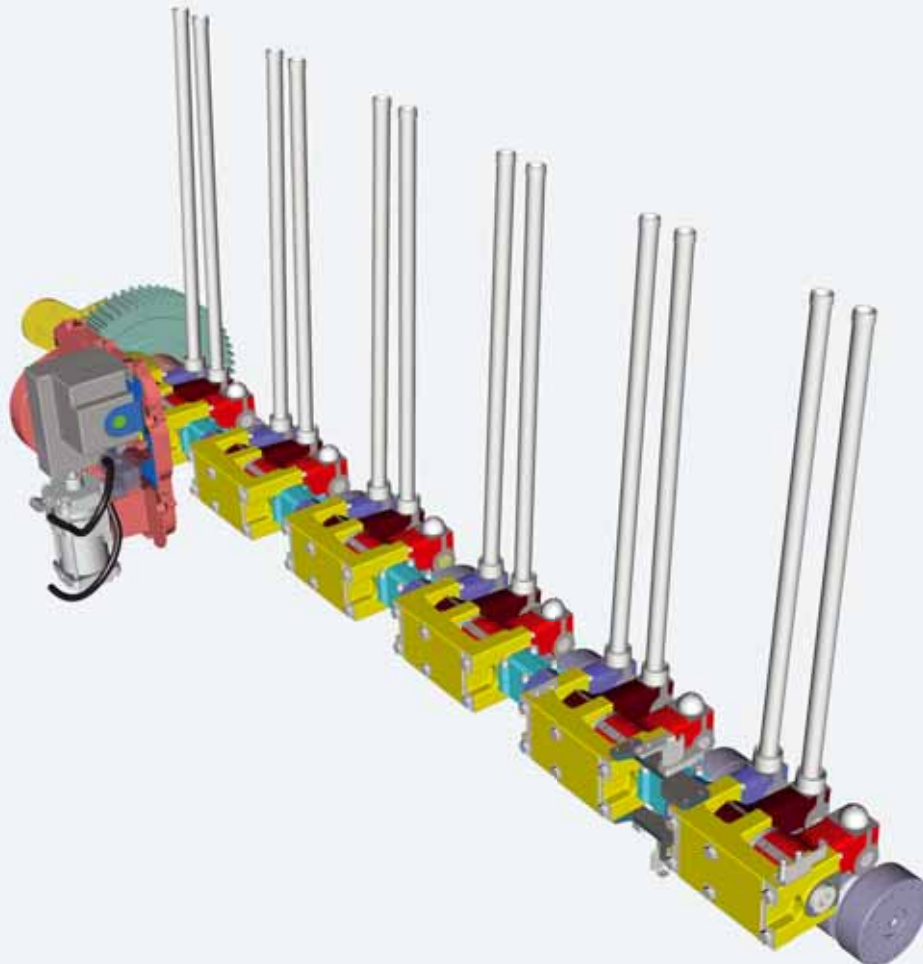


Fig. 12-1 Valve train with Flexible Camshaft Technology

### 13.1 Local control panel (LCP)

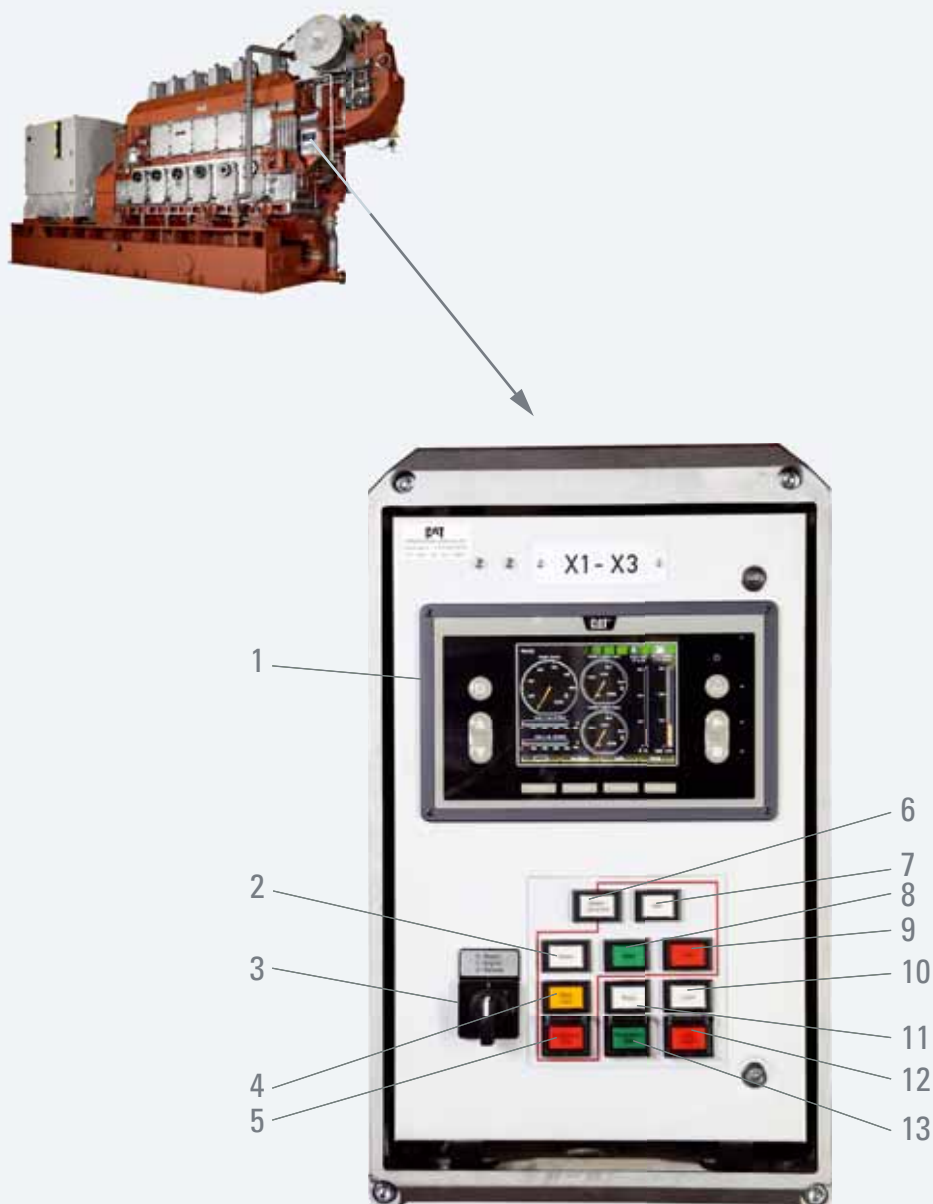
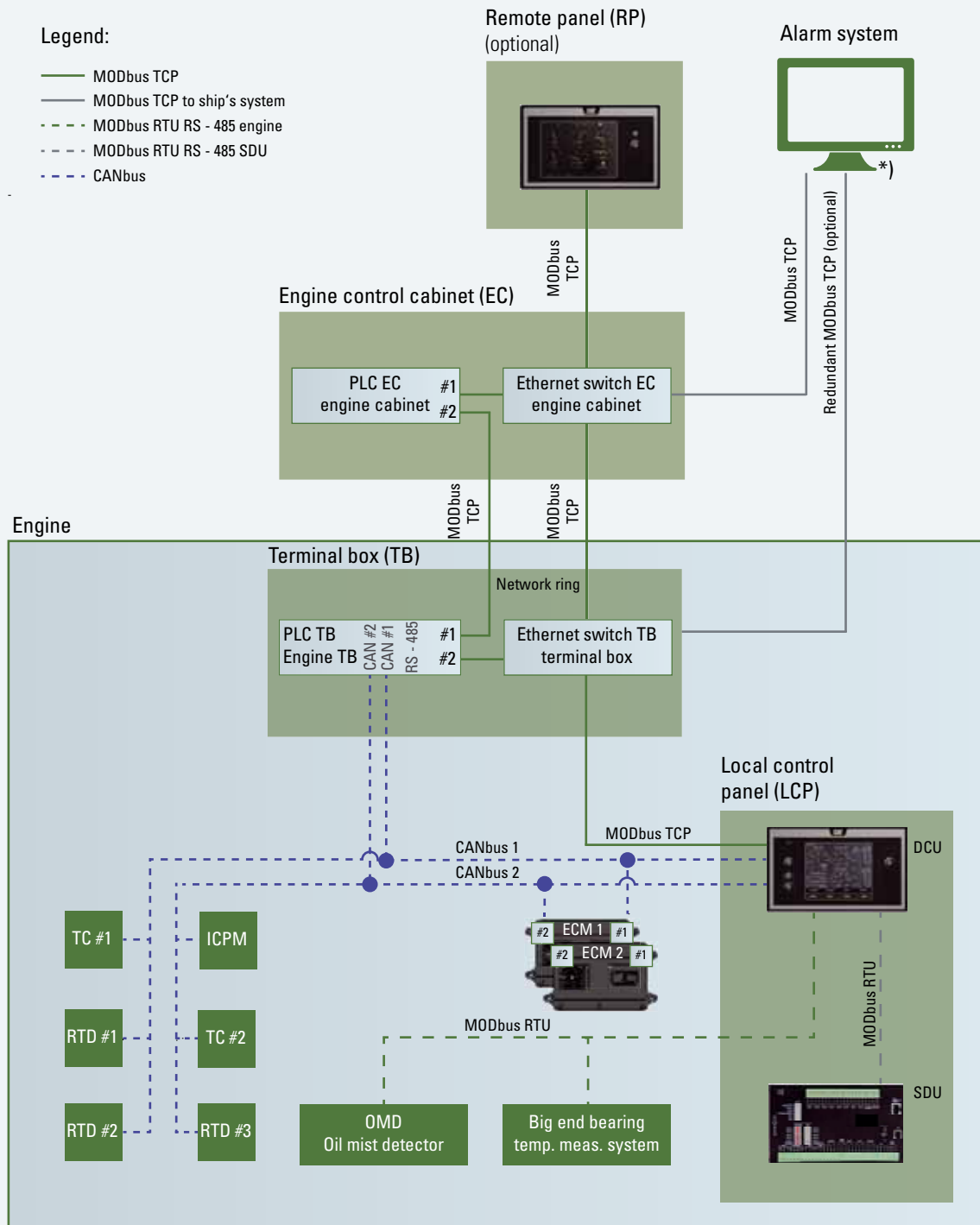


Fig. 13-1 Local control panel

- |   |                                    |    |                 |
|---|------------------------------------|----|-----------------|
| 1 | DCU (Display and alarm system)     | 8  | Start           |
| 2 | Reset                              | 9  | Stop            |
| 3 | 0 = Repair, 1 = Engine, 2 = Remote | 10 | Lower           |
| 4 | Slow turn                          | 11 | Raise           |
| 5 | Emergency stop                     | 12 | Gas shut-off    |
| 6 | Diesel mode indication, lamp test  | 13 | Emergency start |
| 7 | Gas mode indication                |    |                 |



## 13.2 Data link overview



\*) MODbus RTU for alarm system in optionally available

Fig. 13-2 Data link overview - M 46 DF

## CONTROL AND MONITORING SYSTEM

### SDU

Protection system in local control panel

### DCU

Display and alarm system in local control panel

### PLC

PLC in engine cabinet (EC)

PLC in engine terminal box on engine (TB)

### RTD

PT100 module for charge air temperature, lube oil temperature, cooling water HT/LT temperature and main bearing temperature

### TC

Thermocouple modules for exhaust gas temperature

### RP

Remote panel (optional)

External display for engine alarm and monitoring system

### ECM

Engine control module

### OMD

The oil mist detector measures each cylinder.

### CTM

Big end bearing temperature monitoring

Each cylinder compartment of the cylinder crankcase is measured by the CTM.

### ICPM

The "In-cylinder pressure monitoring" computes combustion characteristics for each cylinder including knock intensity per cylinder

Regardless of RTU or TCP, the MODbus address registers are the same. Just the hardware protocol differs.

### MODbus TCP

At MODbus TCP a connection between server and client will be established. Therefore an IP address will be assigned.

### MODbus settings

Type: MODbus TCP

Interface: ethernet

IP: will be assigned

Baud rate: 10 mbit/s / 100 mbit/s

Connector: RJ45

## MACS

### Modular Alarm Control System

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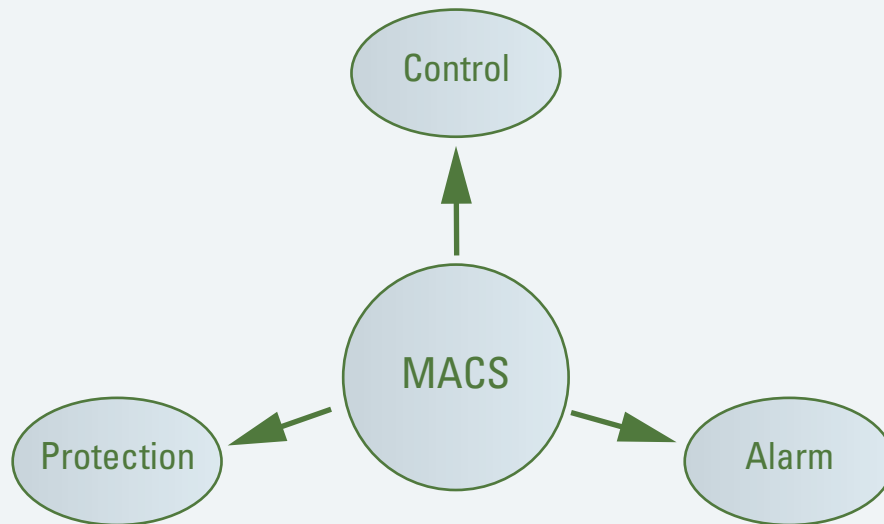
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## CONTROL AND MONITORING SYSTEM

### 13.3 Components

#### Modular Alarm and Control System (MACS)



The M 46 DF engines will be provided with a new Modular Alarm and Control System, called MACS. The basic engine control and monitoring system will be installed in the local control panel. Where extension modules are necessary external plc based I/O extension modules will be installed.

The main functions of the control systems are:

- Alarm management
- Local start and stop, emergency start and stop from the engine control panel
- Remote start and stop from the power management system (PMS)
- Start and stop sequence control
- Critical parameter monitoring
- Slow turn control
- Flexible camshaft technology (FCT monitoring)
- Exhaust gas temperature monitoring
- Main and big end bearings temperature monitoring

For the following modules the control and monitoring is integrated in MACS:

- Ignition fuel module
- Ventilation module
- Crankcase gas detection

## CONTROL AND MONITORING SYSTEM

### Engine control module (ECM)

The engine control module controls the fuel system, air fuel ratio, engine speed and Flexible Camshaft Technology (FCT). The module has its own set of sensors for all control relevant functions and can operate independently from start/stop system, alarm system (DCU) or protection system (SDU).

For multiple engine operation the ECM provides also load sharing functions. An isochronous load distribution by master/slave principle or droop operation is possible.

### Oil mist detector (OMD)

The oil mist detector measures the oil mist concentration for each cylinder compartment and generate an alarm for high oil mist concentration. The data is available by MODbus RTU at the DCU. Hardwired outputs are also provided.

### Big end bearing temperature measuring system (CTM)

The big end bearing temperature measuring system measures the temperature for each big end bearing and generates an alarm for high temperature. The data is available by MODbus RTU at the DCU. Hardwired outputs are also provided.

### Gas valve unit (GVU)

The gas valve unit provides the engine with the desired gas fuel pressure and is controlled by the engine's control and monitoring system (MACS). It has several features (e.g. double block and bleed valve) to safety cut the engine from the gas train and to remove the gas fuel from the piping system (flushing).

### Crankcase gas detection (CGD)

The crankcase gas detection system monitors the actual concentration of explosive atmosphere in the crankcase in means of methane concentration in lower explosion limit (LEL). If the concentration increases above a fixed value an alarm is triggered and in a second step the engine switches back to diesel mode.

### Ventilation module (VM)

The aim of the ventilation module is to detect a leakage in the double walled gas pipes downstream the gas valve unit all the way over the engine. The air in the double walled gas pipe will be ventilated and the gas concentration will be measured.

### Ignition fuel module (IFM)

The ignition fuel control system provides the required ignition fuel oil quality for the engine's ignition system.

### Exhaust gas module (EGV)

The exhaust gas module is installed to ventilate the ship side exhaust gas system after an emergency stop of the engine in gas operation. The module consists of a ventilation fan, a separation butterfly valve and exhaust gas compensator for the connection to the exhaust gas system.

### Slow turn device (STD)

The slow turn function is used to detect water in the combustion chamber, e.g. after a long non-operation period.

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## CONTROL AND MONITORING SYSTEM

### 13.4 Genset control

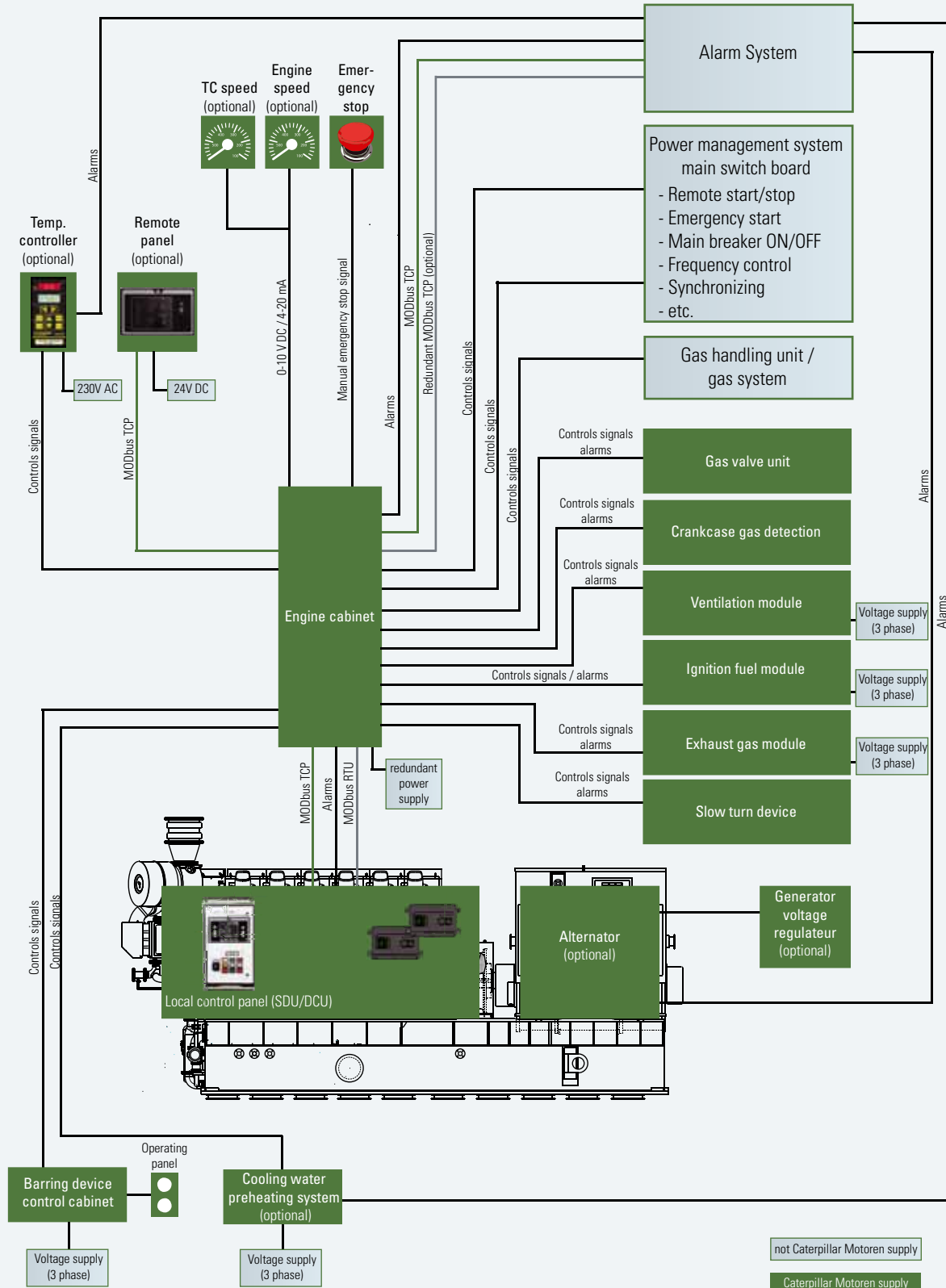


Fig. 13-3 Generator set control M 46 DF

## CONTROL AND MONITORING SYSTEM

### 13.5 Control cabinet

Each engine is equipped with a separate control cabinet. The control cabinet acts as an interface between engine and external devices. Information about the engine status are available via MODbus TCP or MODbus RTU (optionally).

External signals for the engine control, monitoring and alarm system (for example power management system, main switch board, gas system,...) can be transferred as 4-20 mA, binary, or PT100 signals.

Safety relevant signals to the PLC are wire break and short circuit monitored.

The remote panel or the temperature controller can be optionally integrated in the control cabinet.

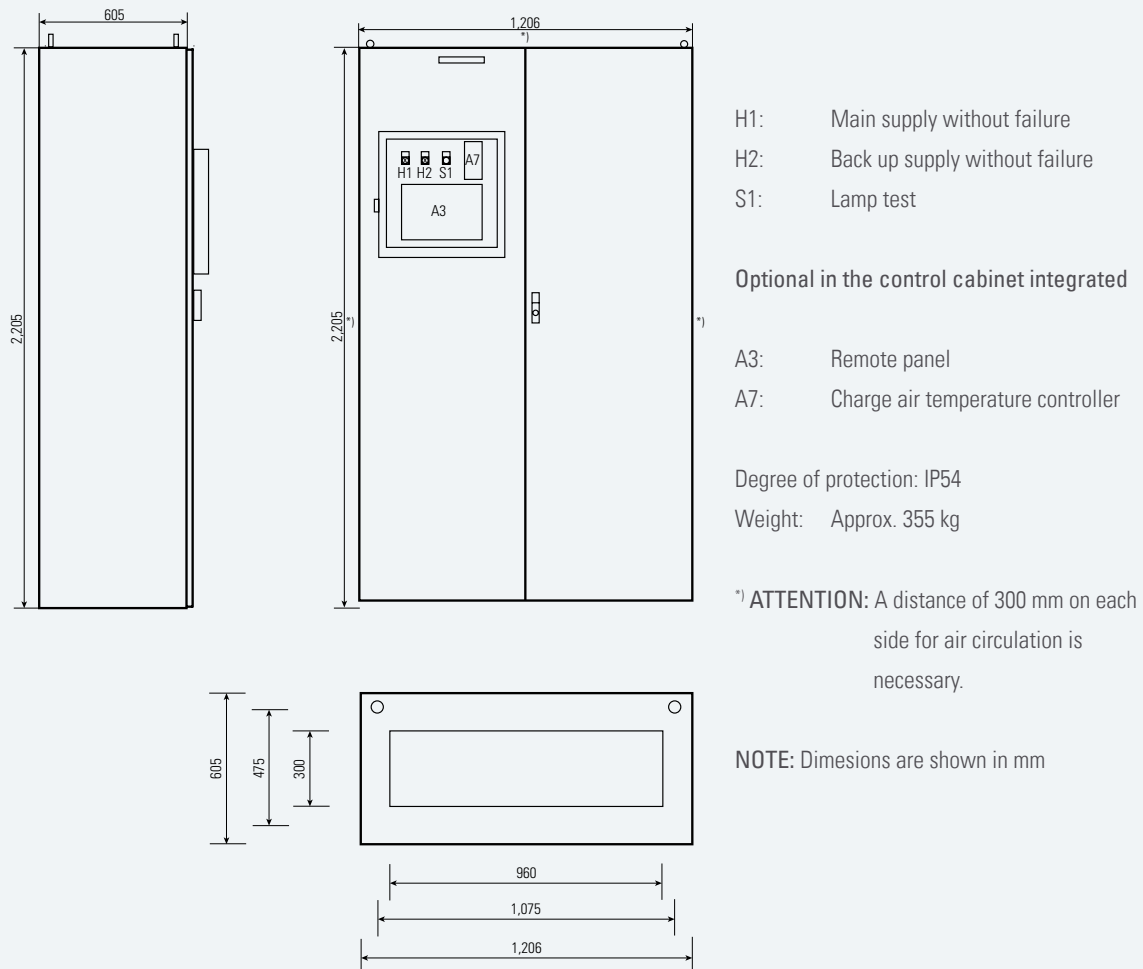


Fig. 13-4 Control panel

## CONTROL AND MONITORING SYSTEM

### 13.6 Requirements

#### 13.6.1 Requirements on power management system

Standard interface to power management system / main switch board

|   |                                       |                |   |                 |   |             |
|---|---------------------------------------|----------------|---|-----------------|---|-------------|
| Power management system / main switch board | External starting interlock           | Binary contact | ➔ | 24 V DC         | External starting interlock                                   | Main engine |
|   | External engine shutdown              | Binary contact | ➔ | 24 V DC         | External engine shutdown                                      |             |
|   | Blackout                              | Binary contact | ➔ | 24 V DC         | Blackout (start release of starting interlock prelubrication) |             |
|   | Indication shutdown undelayed/delayed | 24 V DC        | ➔ | Binary contact  | Shutdown undelayed/delayed                                    |             |
|   | Load signal from kW transducer *)     | 4-20 mA        | ➔ | Max. load 250 Ω | Load signal from kW transducer                                |             |
|   | Raise / lower (remote)                | Binary contact | ➔ | 24 V DC         | Raise / lower (remote)  |             |
|   | Isochronous / droop *)                | Binary contact | ➔ | 24 V DC         | Isochronous / droop   |             |
|   | Status circuit breaker                | Binary contact | ➔ | 24 V DC         | Circuit breaker closed (on for closed)                        |             |
|   | Bus tie signal                        | Binary contact | ➔ | 24 V DC         | Bus tie is closed   |             |
|   | Manual activation slow turn           | Binary contact | ➔ | 24 V DC         | Slow turn mode change   |             |
|   | Automatic slow turn                   | Binary contact | ➔ | 24 V DC         | Slow turn selected for automatic                              |             |
|   | Start/stop remote                     | Binary contact | ➔ | 24 V DC         | Start/stop in remote mode                                     |             |
|   | Change genset                         | 24 V DC        | ➔ | Binary contact  | Engine fault - change genset                                  |             |
|   | Normal stop indication                | 24 V DC        | ➔ | Binary contact  | Normal stop indication  |             |
|   | Start initiation indication           | 24 V DC        | ➔ | Binary contact  | Start initiation indication                                   |             |
|   | Starting interlock indication         | 24 V DC        | ➔ | Binary contact  | Starting interlock indication                                 |             |
|   | Remote control active                 | 24 V DC        | ➔ | Binary contact  | Remote control active   |             |
|   | Ready to start, indication            | 24 V DC        | ➔ | Binary contact  | Ready to start, indication                                    |             |
|   | False start indication                | 24 V DC        | ➔ | Binary contact  | False start indication  |             |
|   | rpm contact                           | 24 V DC        | ➔ | Binary contact  | rpm contact   |             |
|   | Offload *)                            | Binary contact | ➔ | 24 V DC         | Offload   |             |
|   | Isochronous selected *)               | 24 V DC        | ➔ | Binary contact  | Isochronous selected  |             |
|   | Emergency stop from PMS               | Binary contact | ➔ | 24 V DC         | External emergency stop (from PMS)                            |             |

\*) For optionally isochronous load sharing.

## CONTROL AND MONITORING SYSTEM

### 13.6.2 Requirements on gas system

The table below shows the standard interface between the gas system and the dual fuel engine.

#### Standard interface to the gas system

|            |   |         |   |                 |                |
|------------|---|---------|---|-----------------|----------------|
| Gas system | Indication diesel mode                              | 24 V DC | ← | binary          | Engine cabinet |
|            | Indication gas mode                                 | 24 V DC | ← | binary          |                |
|            | Activate gas supply to gas valve unit               | 24 V DC | ← | binary          |                |
|            | Switch over to gas operation failed                 | 24 V DC | ← | binary          |                |
|            | Gas operation shut off machinery space              | 24 V DC | ← | binary          |                |
|            | Gas operation shut off engine                       | 24 V DC | ← | binary          |                |
|            | Gas mode interlock                                  | 24 V DC | ← | binary          |                |
|            | Gas operation shut down                             | binary  | → | 24 V DC         |                |
|            | Gas mode interlock                                  | binary  | → | 24 V DC         |                |
|            | Diesel mode select                                  | binary  | → | 24 V DC         |                |
|            | Gas mode select                                     | binary  | → | 24 V DC         |                |
|            | Inert gas supply pressure                           | 4-20 mA | → | Analogue output |                |
|            | Pressure transmitter fuel gas supply to engine room | 4-20 mA | → | Analogue output |                |

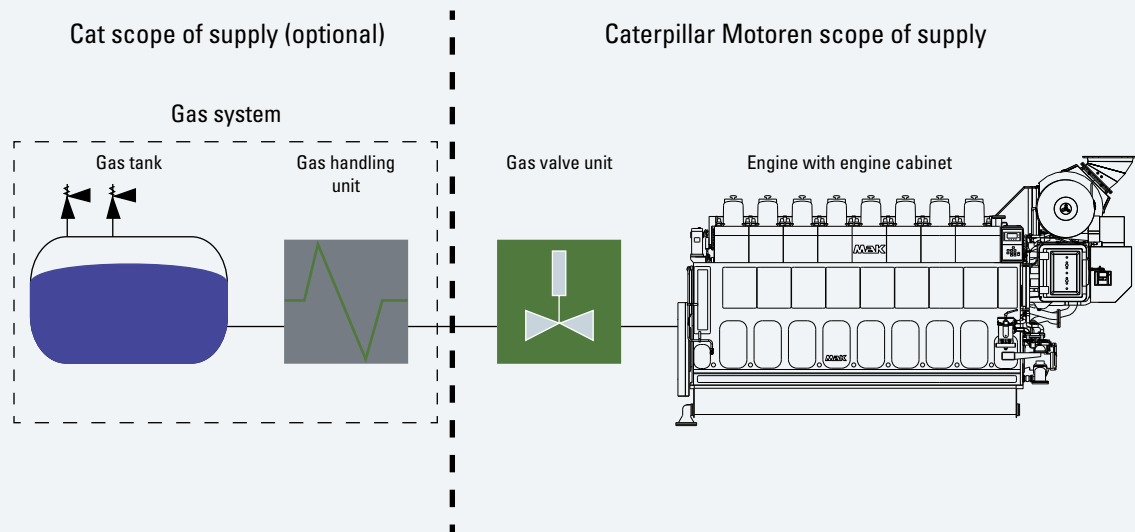


Fig. 13-5 Basic overview: dual fuel engine gas system



## CONTROL AND MONITORING SYSTEM

### 13.6.3 Uninterruptable power supply (UPS)

For the control and monitoring system an uninterruptable power supply (UPS) with a back-up power supply is needed (class requirement). The standard power supply is 24 V DC but on demand another power supply is possible (e.g. 230 V AC or 480 V AC three phase current).

The engine control cabinet has an integrated voltage distribution for the control and monitoring systems at the engine (see fig. 13-3). Each cabinet has its DC/DC converter and its insulation monitoring device.

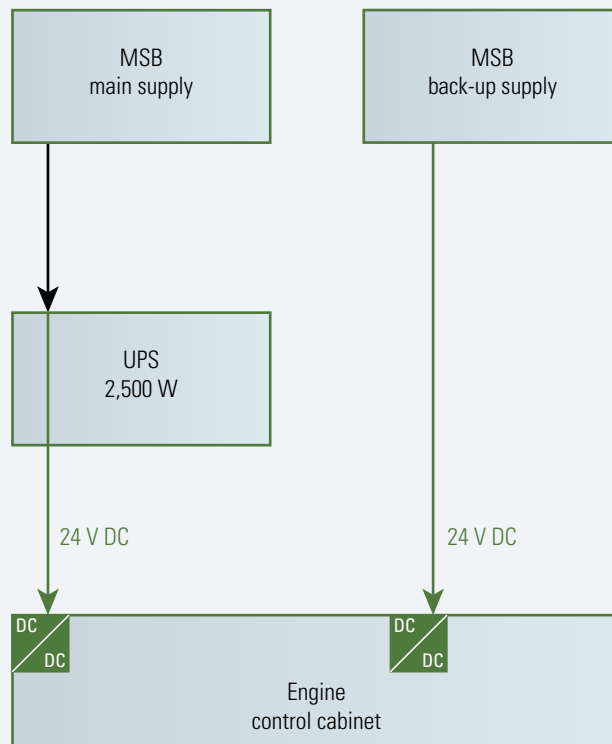


Fig. 13-6 Uninterruptable power supply - variants

## CONTROL AND MONITORING SYSTEM

### 13.7 Alarm indication

In general, the engine is equipped with the relevant alarm and safety sensors according to classification society rules.

MACS provides an engine alarm system which is located in the local control panel. The engine alarm system and the local control display are consolidated in the DCU. The complete alarm management is handled by the DCU. All information is visualized via the screen in the LCP and additional several remote panels can be added.

The DCU receives measurement values and data from all I/O modules, PLC's and the engine control system (ECM). Furthermore it provides all measurement values, status values and alarm via MODbus TCP (MODbus RTU, optional) for the vessel's system and the remote monitoring system. The engine's alarm system determines critical engine conditions and activates alarms. The DCU has the ability of actuating the secondary safety stop valve. That means the DCU also works as well as a shut down unit and is able to stop the engine as reliable as the shut down unit (SDU). All alarms are stored in an alarm history and are shown in a manner requested by the MACS.



Fig. 13-7 Remote panel



Fig. 13-8 DCU (display and alarm system)

For the interface to ship alarm system (IAMCS) the following functions are applicable:

- Transmitting measurement data to IAMCS
- Transmitting engine status to IAMCS
- Transmitting alarm to IAMCS
- Receiving ship's time stamp from IAMCS

All data is available via MODbus TCP. Upon request MODbus RTU is also possible. Device fault from the different MACS devices and some special alarms are provided as hardwired alarms.

## CONTROL AND MONITORING SYSTEM

The table below shows an example of an overview of the different engine systems/modules with their safety functions.

A project related list of measuring points with all necessary MODbus information will be created for each order.

|                                 | IND/<br>FUNC | STBL | Alarm | CHG | SHD | GMI | SHOGE | SHOGM |
|---------------------------------|--------------|------|-------|-----|-----|-----|-------|-------|
| Lube oil                        | X            | X    | X     | X   | X   |     |       |       |
| Oil mist detector               | X            | X    | X     |     | X   |     |       |       |
| Fresh water HT                  | X            |      | X     |     | X   |     |       |       |
| Fresh water LT                  | X            |      | X     |     |     |     |       |       |
| Air supply                      | X            | X    | X     |     |     |     |       |       |
| Charge air                      | X            |      | X     |     |     |     | X     |       |
| FCT                             | X            |      | X     |     | X   |     | X     |       |
| Electrical status               | X            | X    | X     |     |     | X   |       |       |
| Engine status                   | X            | X    | X     |     | X   |     |       |       |
| Combustion monitoring           | X            |      | X     |     | X   | X   | X     |       |
| Exhaust gas                     | X            |      | X     | X   |     |     | X     |       |
| Big end bearing                 | X            |      | X     |     | X   |     |       |       |
| Main bearing                    | X            |      | X     |     | X   |     |       |       |
| Load share unit (optional)      |              |      | X     |     | X   |     |       |       |
| ECM                             | X            |      | X     |     |     |     | X     |       |
| Inert gas flushing              | X            |      |       |     |     | X   | X     | X     |
| Ignition fuel system engine     | X            | X    | X     |     | X   | X   | X     |       |
| Fuel gas system engine          | X            |      |       |     |     |     | X     |       |
| Fuel gas leakage monitoring     | X            |      | X     |     |     | X   | X     |       |
| Diesel gas mode control signals | X            |      | X     |     |     | X   | X     | X     |
| Gas valve unit                  | X            |      | X     |     |     | X   | X     | X     |
| Ignition fuel module            | X            | X    | X     |     |     |     | X     |       |
| Crankcase gas detection         | X            |      | X     |     |     |     | X     |       |
| Exhaust gas module              | X            | X    |       |     | X   | X   | X     |       |
| Slow turn                       | X            | X    |       |     |     |     |       |       |
| Ventilation modules             | X            |      |       |     |     |     |       |       |

Furthermore an evaluation of sensor faults is integrated. Depending on the importance of the failure it causes a STBL, E-STBL, CHG, GMI and SHOGE.

### NOTE:

An active gas operation shut off (SHOGE/SHOGM) will activate gas mode interlock (GMI) and an engine shutdown will activate a starting interlock (STBL) as well as a gas shut off for the engine (SHOGE).

## CONTROL AND MONITORING SYSTEM

|               |   |
|---------------|---|
| <b>FUNC</b>   | Used in software function   |
| <b>IND</b>    | Only for indication   |
| <b>A</b>      | Alarm   |
| <b>STBL</b>   | Starting interlock (overrideable by E-start or blackout start)  |
| <b>E-STBL</b> | Emergency starting interlock (not overrideable by E-start or blackout start)  |
| <b>CHG</b>    | Change generator set  |
| <b>SHD</b>    | Shutdown  |
| <b>GMI</b>    | Gas mode interlock  |
| <b>SHOGE</b>  | Gas shut off for engine / Shut off gas supply to engine.<br>The double block and bleed group in the gas valve unit (GVU) is closed. |
| <b>SHOGM</b>  | Gas shut off for engine and machinery space.<br>The master gas valve has to be closed.  |

**13.8 Local and remote indicators**

| Local indication  | Remote indicators        |
|---|--------------------------|
| Installed at the engine                                       | 96 x 96 mm<br>(optional) |
| Fuel oil temperature at engine inlet                          | X <sup>2)</sup>          |
| Fuel oil differential pressure at filter                      |                          |
| Lube oil temperature at engine inlet                          | X <sup>2)</sup>          |
| Lube oil differential pressure at filter                      |                          |
| Fresh water temp. at engine inlet (HT circuit)                |                          |
| Fresh water temp. at engine outlet (HT circuit)               | X <sup>2)</sup>          |
| Fresh water temperature (LT circuit)                          | X <sup>2)</sup>          |
| Fresh water temperature cooler inlet                          |                          |
| Fresh water temperature cooler outlet                         |                          |
| Charge air temperature cooler inlet                           |                          |
| Charge air temperature engine inlet                           | X <sup>2)</sup>          |
| Fuel oil pressure   | X <sup>2)</sup>          |
| Lube oil pressure   | X <sup>2)</sup>          |
| Fresh water pressure (HT circuit)                             | X <sup>2)</sup>          |
| Fresh water pressure (LT circuit)                             | X <sup>2)</sup>          |
| Start air pressure  | X <sup>2)</sup>          |
| Charge air pressure cooler outlet                             | X <sup>2)</sup>          |
| Stop air pressure   |                          |
| Engine speed  | X <sup>1)</sup>          |
| Turbocharger speed  | X <sup>1)</sup>          |
| Charge air temp. cooler inlet (digital value)                 |                          |
| Exhaust gas temp. after cylinder (digital value)              |                          |
| Exhaust gas temp. before / after turbocharger (digital value) |                          |

1) 144 x 144 mm possible / 2) Signal is supplied by the alarm system

## CONTROL AND MONITORING SYSTEM

### 13.9 Cat Connect for Marine provide by Caterpillar Marine Asset Intelligence (MAI)

**MAI provides technology enabled solutions and services, that**

- Provide remote monitoring and automated analytics via the internet.
- Combines equipment and application information.
- Applies predictive analytics.
- Utilizes interpretive expertise.

#### 13.9.1 MAI - MaK engine solution only

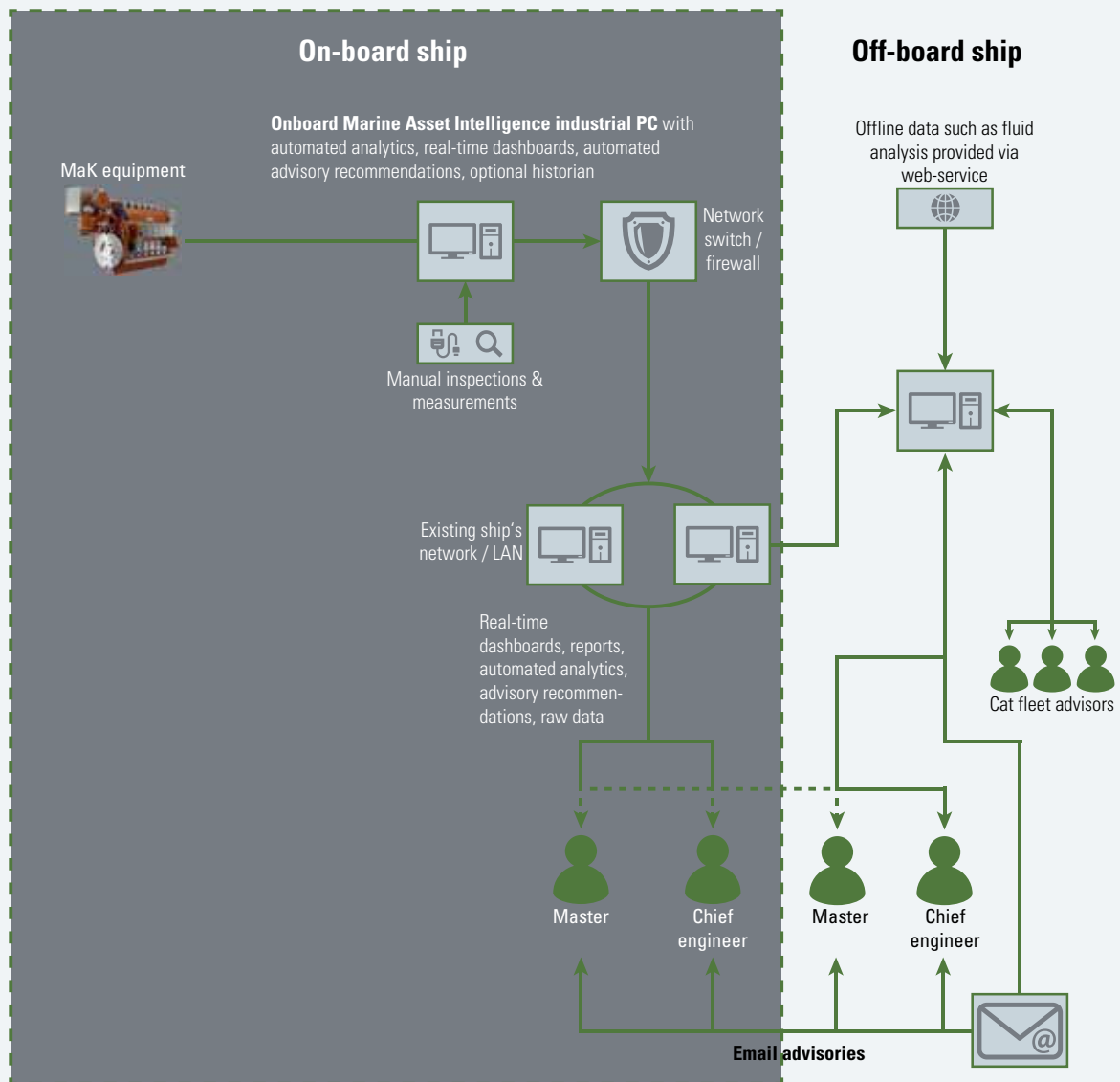


Fig. 13-9 MAI – MaK engine solution only

## CONTROL AND MONITORING SYSTEM

### 13.9.2 MAI - Extended solution

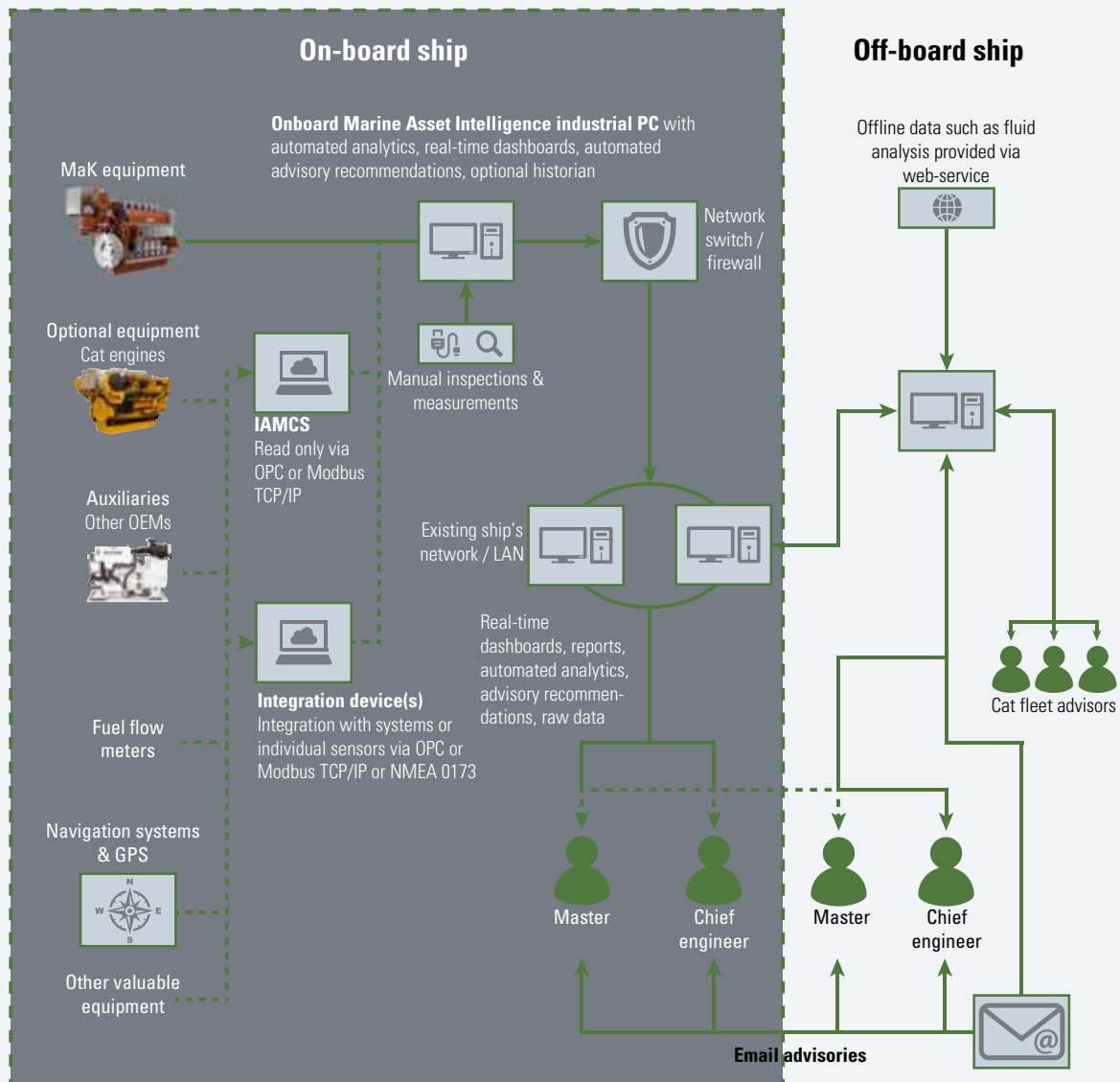


Fig. 13-10 MAI – Extended solution

### 13.9.3 General information

#### Capabilities

- Consolidates data and analyzes across all five condition monitoring elements.
- Analyzes data using multiple engines to identify and highlight exceptions.
- Creates a complete view of the equipment and performance.
- Allows more knowledgeable planned maintenance and scheduled repairs.
- Enables optimized tuning of equipment to maximize fuel efficiency.

## CONTROL AND MONITORING SYSTEM

### Comprehensive scope possible

- Monitors and analyzes variety of systems across the total vessel, based on what is important for each vessel.
- Can monitor Caterpillar/MaK equipment as well as non-Caterpillar/MaK equipment.
- Can monitor diesel engines and non-diesel engines.
- **Primary services available:**
  - Protect: Identify potential problems with equipment before there is a failure, assist onboard crew with remote expert troubleshooting.
  - Improve: Optimize fuel consumption for individual equipment through better maintenance and for entire vessel through operations and maintenance optimization.
  - Optimize: Move to condition based maintenance.
- **Supporting services available:**
  - Account: Ensure fuel accountability, measure and track fuel bunkering and consumption.
  - Save: Create visibility for unsafe operations or equipment condition.
  - Comply: Ensure equipment is operated and performs in compliance with regulations.
  - Manage: Customized dash-boards for different levels of management without custom software development.
  - Integrate: Integrate with other enterprise systems, such as Computerized Maintenance Management System (CMMS).

### System Benefits

- Support most cost efficient operation.
- Provides optimized planning of service activities.
- Helps to avoid unexpected downtime.
- Helps reduce fuel cost for both the individual equipment and the entire vessel (depending on scope included).

### Scope of delivery

- Electrical engine equipment MACS and Modbus interface for data streaming.
- Industrial PC with interfaces for connection to ship's network, automation system and other onboard systems.
- Software for real-time dashboard with online data view via ship's network (from any computer connected to ship's network).
- Network router with firewall for data replication via internet.
- Configuration of shore interface for shore customer users.
- Analytics with flexible reports and dashboards that can be configured and modified by the customer.
- Option: connection with additional systems beyond MaK/Caterpillar engines, to include other engines/generators, auxiliary systems, other systems, individual sensors such as fuel flow sensors, torque meters, anemometers, GPS/ECDIS, etc via OPC, Modbus or NMEA data protocols.

### Customer assumption

- Network infrastructure and data transfer via satellite communication to be provided by customer.

## SAFETY CONCEPT

### 14.1 Safety

| Potential operation<br>Selected mode | Diesel operation | Gas operation |
|--------------------------------------|------------------|---------------|
| Diesel mode                          | Yes              | No            |
| Gas mode                             | Possible         | Yes           |

"Mode" specifies the desired engine operation.

"Operation" specifies the actually burned fuel.

Fig. 14-1 Definition: "Mode" vs. "Operation"

Additional safety requirements need to be fulfilled to operate a dual fuel engine in a marine application. The safety concept for the MaK dual fuel engine is designed according the upcoming IGF code (draft international code of safety for ships using gases or other low-flashpoint fuels) to provide a gas safe machinery space.

#### 14.1.1 Safety concept

The main intention of the safety concept is to avoid any hazardous situation. To this aim the safety concept for the dual fuel engine has to prevent the formation of any hazardous explosive atmosphere. Therefore a detection system is used in combination with automatic safety actions that will finally result in a changeover to diesel mode and flushing the fuel gas supply line with inert gas to avoid any endangering. Additionally a ventilation system for the exhaust pipe will inhibit an accumulation of fuel gas. Already during the design phase ignition sources have been considered and were excluded where possible.

To ensure highest level of safety CFD (Computational Fluid Dynamics) simulations were used and based on those data safety valves with sufficient relief areas were applied is necessary.

#### 14.1.2 Gas safe machinery space

The safety concept for the dual fuel engine is based on a gas safe machinery space. The aim of this concept is that no hazardous atmosphere can occur in the machinery space. In case of any malfunction, the dual fuel engine will not shut down, instead the fuel supply will switch over to fuel oil as there are MDO and MGO. After reaching the diesel mode the engine can be switched over to HFO.

The switch over from fuel oil to fuel gas or vice versa will be bumpless and without any losses in power performance of the engine.

To avoid any hazardous area in the machinery space the fuel gas pipes in the machinery space are of double walled design from entering the engine room, via the gas valve unit throughout the cylinders. For detection of any leakage a suitable monitoring system is installed.



## SAFETY CONCEPT

To fulfill the requirements of a gas safe machinery room according to IMO resolution MSC.285(86) the following measures are taken:

- Fuel gas piping inside the machinery space must be of double walled design.
- All parts of the engine's fuel gas supply system inside the machinery space are double walled.
- The double wall is permanently monitored for leakage while the inner pipes are containing fuel gas.
- Flushing the fuel gas line with inert gas must be possible.
- Gas concentration must be monitored in the crankcase ventilation pipe.
- The lube oil system must be suitable for gas, class requirements have to be observed.
- The cooling water system must be suitable for gas, class requirements have to be observed.
- Means must be provided to inert and vent the crankcase for maintenance reasons.
- No direct access to gas hazardous areas must be possible.
- In case of a starting failure or an emergency shutdown of the engine while running on fuel gas the exhaust system will be ventilated automatically after emergency stop.
- In case of an emergency shutdown of the fuel gas supply or the engine, while the engine is running on fuel gas, the fuel gas supply lines will be flushed automatically with inert gas.
- Furthermore the system integrator needs to pay special attention to
  - The machinery room.
  - The gas handling room.
  - All rooms adjacent to possibly hazardous areas.

The engine control, monitoring and protection system, called MACS (Modular Alarm Control System), consists of different functional components. It includes the start-stop system, the gas management, the monitoring system and the engine protection system. A screen is fitted in the local control panel and shows measurement data as well as diagnostics and engine status.

## SAFETY CONCEPT

### 14.1.3 Gas related safety equipment

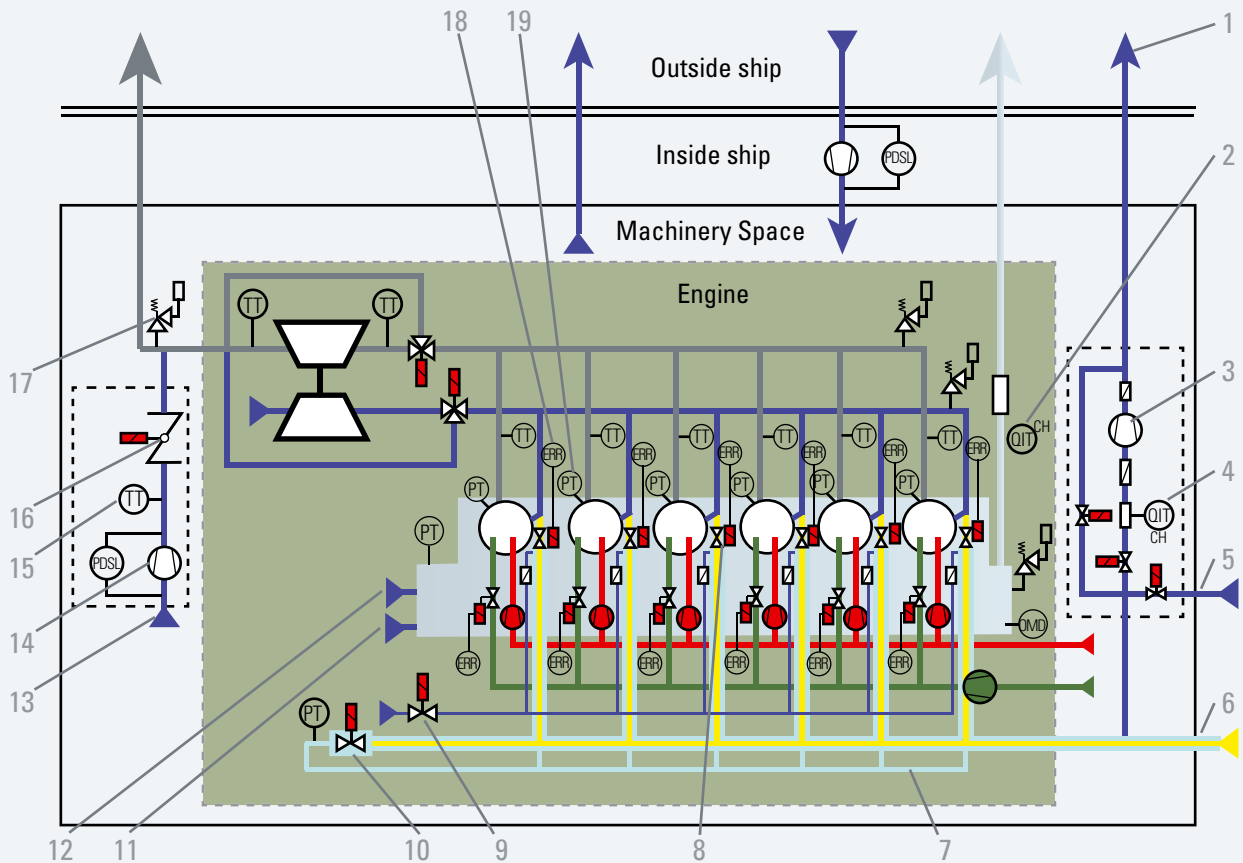


Fig. 14-2 Gas related safety equipment

- |    |  |    |  |
|----|--|----|--|
| 1  | Inertgas ventilation outlet              | 11 | Crankcase flushing valve for inertgas      |
| 2  | Gas sensor in crankcase ventilation line | 12 | Crankcase purging valve for compressed air |
| 3  | Vacuum pump in ventilation module        | 13 | Air inlet for exhaust gas duct purging     |
| 4  | Gas sensor in ventilation module         | 14 | Fan for exhaust gas duct purging           |
| 5  | Inertgas supply inlet                    | 15 | Temperature transmitter                    |
| 6  | Fuel gas supply                          | 16 | Butterfly isolation valve                  |
| 7  | Inertgas compartment                     | 17 | Explosion relief valve                     |
| 8  | GAV (Gas Admission Valve)                | 18 | In cylinder pressure sensor                |
| 9  | Fresh air flushing valve                 | 19 | In cylinder pressure transmitter           |
| 10 | Inertgas flushing valve                  |    |  |

## INSTALLATION AND ARRANGEMENT

### 15.1 Resilient mounting of genset

#### Basic design and arrangement

The engine is resiliently mounted on the baseframe and all pipe connections to the baseframe are flexible. The generator is connected with the engine via a high flexible coupling and rigidly mounted on the baseframe. This design ensures high vibration isolation between engine and the baseframe generator arrangement.

The resilient mounting arrangement of the engine is designed to reach the best possible load distribution of the engine weight in respect of the maximal permissible deflection of the conical rubber element. The whole genset is rigidly connected with the vessel's foundation via bolts. The vessels' foundation itself does not require machining, but unevenness between the baseframe and the foundation has to be compensated either using welded-on sheets and shims or resin chocks.

#### 15.1.1 Conical mountings

##### General

The used conical design provides high deflection and load capacity combined with long service life. The life expectancy of the rubber elements will be approx. 20 years in ideal circumstances. In fact of bad influences out of environmental circumstances the (working) life expectancy will be approx. 10 years.

##### Specifications

The used conical mountings have been approved from all relevant classification societies. All mounting rubber inserts are individual tested and selected on stiffness by our supplier. An adjustable central buffer controls the mounted equipment displacements due to ship movements vertically and horizontally within defined limits.

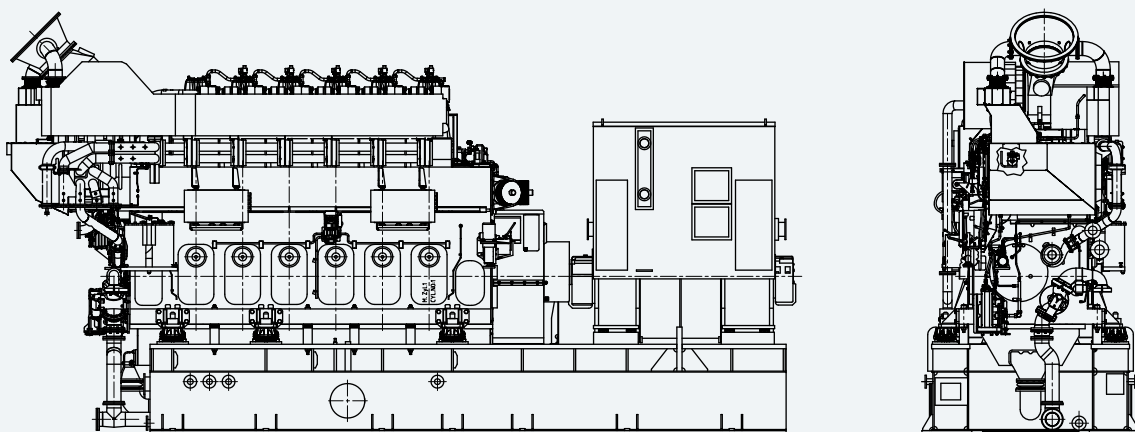


Fig. 15-1 Elastic mounted genset with conical elements

## 15.2 Earthing of engine

### Information about the execution of the earthing

The earthing has to be carried out by the shipyard during the assembly on board.

The engine is already equipped with M 16, 25 mm deep threaded holes in the lower part of the baseframe.

If the engine is resiliently mounted it is important to use flexible conductors.

In case of using welding equipment it is important to earth the welding equipment close to the welding area (the distance should not exceed 10 m).

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## 16.1 Data for torsional vibration calculation

To determine the location and resonance points of each engine and equipment Caterpillar Motoren calculates the torsional vibration behaviour of the engine, including all components, such as coupling, gearboxes, shaft lines and propellers, pumps, and generators.

The normal as well as the emergency operating mode is covered.

The classification societies require a complete torsional vibration calculation.

To be able to provide a correct torsional vibration calculation, we would like to ask you to fill in the documents in the appendix, according to your scope of supply.

Please send the completed data to your local dealer 6 month prior to the engine delivery at the latest. For further information please compare the data sheet for torsional vibration calculation. (following 3 pages).

# VIBRATION AND NOISE

|  |   |  |  |   |  |  |   |  |  |   |  |  |   |  |   |   |  |  |                       |  |                                 |   |  |  |  |  |
|--|---|--|--|---|--|--|---|--|--|---|--|--|---|--|---|---|--|--|-----------------------|--|---------------------------------|---|--|--|--|--|
| <p><b>Additional engine plant data part "B"</b></p>  | <input type="checkbox"/> Main drive<br><input type="checkbox"/> Aux. Engine<br><input type="checkbox"/> DE drive<br>Ktr.-No.: _____ | Shipyard: _____<br>Shipowner: _____<br>Type of vessel: _____<br>Newbuilding No.: _____ |  |   |  |  |   |  |  |   |  |  |   |  |   |   |  |  |                       |  |                                 |   |  |  |  |  |
| <p><b><u>Remark:</u></b></p> <p>Please note that the application and installation drawings will be delivered not later than 6 weeks after receiving the completed "Additional engine plant data sheet" part "B". The "Additional engine plant data sheet" part "A" to be delivered together with the order.</p>  |   |  |  |   |  |  |   |  |  |   |  |  |   |  |   |   |  |  |                       |  |                                 |   |  |  |  |  |
| <p><b><u>General information, required for all applications:</u></b></p> <p>Flag state (needed for EIAPP cert): _____</p> <p>Please note that Caterpillar Motoren will issue an "EAPP Document of Compliance" or an "EIAPP Certificate" as per flag state authorization only in case the flag state information is provided at <u>least eight (8) weeks prior to the engine delivery date</u> as per the Sales Contract (Appendix 1). In case such information has not been provided to Caterpillar Motoren until such date, Caterpillar Motoren will provide an "EAPP Statement of Compliance" which has to be converted into "EAPP Documents of Compliance" or an "EIAPP Certificate" as per flag state authorization. In this case the application and costs for the before mentioned conversion has to be borne by the Buyer.</p>  |   |  |  |   |  |  |   |  |  |   |  |  |   |  |   |   |  |  |                       |  |                                 |   |  |  |  |  |
| <p><b>Alarm system</b></p> <p><input type="checkbox"/> yard    maker: _____    type: _____    yard contact manager: _____</p>  |   |  |  |   |  |  |   |  |  |   |  |  |   |  |   |   |  |  |                       |  |                                 |   |  |  |  |  |
| <p><b>Make of automation/bus system</b></p> <p><input type="checkbox"/> yard    maker: _____    type: _____    yard contact manager: _____</p>   |   |  |  |   |  |  |   |  |  |   |  |  |   |  |   |   |  |  |                       |  |                                 |   |  |  |  |  |
| <p><b><u>Additional information for cooling water system:</u></b></p> <p>Add. heat exchanger integrated in LT system, <input type="checkbox"/> Yes    <input type="checkbox"/> No, if " <b>Yes</b> " please provide the following data:</p> <table style="width: 100%; border: none;"> <tr> <td style="width: 33%;"><input type="checkbox"/> number of aux. engine _____</td> <td style="width: 33%;"><input type="checkbox"/> required water flow _____ m³/h</td> <td style="width: 33%;"><input type="checkbox"/> pressure drop _____ bar</td> </tr> <tr> <td><input type="checkbox"/> heat dissipation _____ kW</td> <td><input type="checkbox"/> number of cooler _____</td> <td></td> </tr> <tr> <td><input type="checkbox"/> oil cooler gear box</td> <td><input type="checkbox"/> required water flow _____ m³/h</td> <td><input type="checkbox"/> pressure drop _____ bar</td> </tr> <tr> <td><input type="checkbox"/> heat dissipation _____ kW</td> <td><input type="checkbox"/> number of air cond. unit _____</td> <td></td> </tr> <tr> <td><input type="checkbox"/> air cond. unit</td> <td><input type="checkbox"/> required water flow _____ m³/h</td> <td><input type="checkbox"/> pressure drop _____ bar</td> </tr> <tr> <td><input type="checkbox"/> heat dissipation _____ kW</td> <td>Please specify: _____</td> <td></td> </tr> <tr> <td><input type="checkbox"/> others</td> <td><input type="checkbox"/> required water flow _____ m³/h</td> <td><input type="checkbox"/> pressure drop _____ bar</td> </tr> <tr> <td><input type="checkbox"/> heat dissipation _____ kW</td> <td></td> <td></td> </tr> </table> |   |  | <input type="checkbox"/> number of aux. engine _____ | <input type="checkbox"/> required water flow _____ m³/h | <input type="checkbox"/> pressure drop _____ bar | <input type="checkbox"/> heat dissipation _____ kW | <input type="checkbox"/> number of cooler _____ |  | <input type="checkbox"/> oil cooler gear box | <input type="checkbox"/> required water flow _____ m³/h | <input type="checkbox"/> pressure drop _____ bar | <input type="checkbox"/> heat dissipation _____ kW | <input type="checkbox"/> number of air cond. unit _____ |  | <input type="checkbox"/> air cond. unit | <input type="checkbox"/> required water flow _____ m³/h | <input type="checkbox"/> pressure drop _____ bar | <input type="checkbox"/> heat dissipation _____ kW | Please specify: _____ |  | <input type="checkbox"/> others | <input type="checkbox"/> required water flow _____ m³/h | <input type="checkbox"/> pressure drop _____ bar | <input type="checkbox"/> heat dissipation _____ kW |  |  |
| <input type="checkbox"/> number of aux. engine _____   | <input type="checkbox"/> required water flow _____ m³/h   | <input type="checkbox"/> pressure drop _____ bar                                       |  |   |  |  |   |  |  |   |  |  |   |  |   |   |  |  |                       |  |                                 |   |  |  |  |  |
| <input type="checkbox"/> heat dissipation _____ kW   | <input type="checkbox"/> number of cooler _____   |  |  |   |  |  |   |  |  |   |  |  |   |  |   |   |  |  |                       |  |                                 |   |  |  |  |  |
| <input type="checkbox"/> oil cooler gear box   | <input type="checkbox"/> required water flow _____ m³/h   | <input type="checkbox"/> pressure drop _____ bar                                       |  |   |  |  |   |  |  |   |  |  |   |  |   |   |  |  |                       |  |                                 |   |  |  |  |  |
| <input type="checkbox"/> heat dissipation _____ kW   | <input type="checkbox"/> number of air cond. unit _____   |  |  |   |  |  |   |  |  |   |  |  |   |  |   |   |  |  |                       |  |                                 |   |  |  |  |  |
| <input type="checkbox"/> air cond. unit  | <input type="checkbox"/> required water flow _____ m³/h   | <input type="checkbox"/> pressure drop _____ bar                                       |  |   |  |  |   |  |  |   |  |  |   |  |   |   |  |  |                       |  |                                 |   |  |  |  |  |
| <input type="checkbox"/> heat dissipation _____ kW   | Please specify: _____   |  |  |   |  |  |   |  |  |   |  |  |   |  |   |   |  |  |                       |  |                                 |   |  |  |  |  |
| <input type="checkbox"/> others  | <input type="checkbox"/> required water flow _____ m³/h   | <input type="checkbox"/> pressure drop _____ bar                                       |  |   |  |  |   |  |  |   |  |  |   |  |   |   |  |  |                       |  |                                 |   |  |  |  |  |
| <input type="checkbox"/> heat dissipation _____ kW   |   |  |  |   |  |  |   |  |  |   |  |  |   |  |   |   |  |  |                       |  |                                 |   |  |  |  |  |
| <p><b>Comments/Remarks:</b></p> <p>.....</p> <p>.....</p> <p>.....</p> <p>.....</p>  |   |  |  |   |  |  |   |  |  |   |  |  |   |  |   |   |  |  |                       |  |                                 |   |  |  |  |  |

Caterpillar Confidential: Green

Fig. 16-1 Additional engine plant data, part "B" (1/3)

# VIBRATION AND NOISE

| CAT®   |  | Additional engine plant data, part "B"  |  |
|--|--|---|--|
| <b>TVC data - Information for main engine(s) only:</b>   |  |   |  |
| <b>Flex. coupling main engine:</b>   |  |   |  |
| Supplied by Caterpillar <input type="checkbox"/> Yes <input type="checkbox"/> No, if "No" please provide the following data:   |  |   |  |
| <input type="checkbox"/> Vulkan<br>Type: _____   | <input type="checkbox"/> Stromag<br>Size: _____<br><input type="checkbox"/> Drawing attached | <input type="checkbox"/> Centa<br><input type="checkbox"/> TVC scheme attached<br><input type="checkbox"/> Drawing attached |  |
| <input type="checkbox"/> Other maker _____<br>Type: _____  | Size: _____  | <input type="checkbox"/> TVC scheme attached<br><input type="checkbox"/> Drawing attached                                   |  |
| Normal torque [kNm]: _____   |  | Perm. vibratory torque [kNm]: _____   |  |
| Perm. power loss [kW]: _____   |  | Perm. rotational speed [1/min]: _____   |  |
| Dyn. torsional stiffness[kNm/rad]: _____   |  | Relative damping: _____   |  |
| <b>Flex. coupling engine PTO shaft (on engine free-end)</b>  |  |   |  |
| Supplied by Caterpillar <input type="checkbox"/> Yes <input type="checkbox"/> Not applicable <input type="checkbox"/> No, if "No" please provide the following data: |  |   |  |
| <input type="checkbox"/> Vulkan<br>Type: _____   | <input type="checkbox"/> Stromag<br>Size: _____<br><input type="checkbox"/> Drawing attached | <input type="checkbox"/> Centa<br><input type="checkbox"/> TVC scheme attached<br><input type="checkbox"/> Drawing attached |  |
| <input type="checkbox"/> Other maker _____<br>Type: _____  | Size: _____  | <input type="checkbox"/> TVC scheme attached<br><input type="checkbox"/> Drawing attached                                   |  |
| Normal torque [kNm]: _____   |  | Perm. vibratory torque [kNm]: _____   |  |
| Perm. power loss [kW]: _____   |  | Perm. rotational speed [1/min]: _____   |  |
| Dyn. torsional stiffness[kNm/rad]: _____   |  | Relative damping: _____   |  |
| <b>Flex. coupling gearbox PTO</b>  |  |   |  |
| Supplied by Caterpillar <input type="checkbox"/> Yes <input type="checkbox"/> Not applicable <input type="checkbox"/> No, if "No" please provide the following data: |  |   |  |
| <input type="checkbox"/> Vulkan<br>Type: _____   | <input type="checkbox"/> Stromag<br>Size: _____<br><input type="checkbox"/> Drawing attached | <input type="checkbox"/> Centa<br><input type="checkbox"/> TVC scheme attached<br><input type="checkbox"/> Drawing attached |  |
| <input type="checkbox"/> Other maker _____<br>Type: _____  | Size: _____  | <input type="checkbox"/> TVC scheme attached<br><input type="checkbox"/> Drawing attached                                   |  |
| Normal torque [kNm]: _____   |  | Perm. vibratory torque [kNm]: _____   |  |
| Perm. power loss [kW]: _____   |  | Perm. rotational speed [1/min]: _____   |  |
| Dyn. torsional stiffness[kNm/rad]: _____   |  | Relative damping: _____   |  |
| <b>Gearbox</b>   |  |   |  |
| Supplied by Caterpillar <input type="checkbox"/> Yes <input type="checkbox"/> No, if "No" please provide the following data:   |  |   |  |
| Maker: _____   | Type: _____  | <input type="checkbox"/> TVC scheme attached  |  |
| Max. permissible PTO output [kW]: _____  |  | <input type="checkbox"/> Drawing attached   |  |
| <b>Front gearbox for engine PTO</b>  |  |   |  |
| Supplied by Caterpillar <input type="checkbox"/> Yes <input type="checkbox"/> Not applicable <input type="checkbox"/> No, if "No" please provide the following data: |  |   |  |
| Maker: _____   | Type: _____  | <input type="checkbox"/> TVC scheme attached  |  |
| Max. permissible PTO output [kW]: _____  |  | <input type="checkbox"/> Drawing attached   |  |
| <b>PTO shaft generator/fire fighting pump or similar consumer, driven by engine PTO shaft/front step up gear</b>   |  |   |  |
| Supplied by Caterpillar <input type="checkbox"/> Yes <input type="checkbox"/> Not applicable <input type="checkbox"/> No, if "No" please provide the following data: |  |   |  |
| Maker: _____   | Type: _____  | <input type="checkbox"/> TVC scheme attached  |  |
| Output [kW]: _____   | rpm [1/min]: _____   | <input type="checkbox"/> Drawing attached   |  |
| <input type="checkbox"/> Plain bearing, external lubrication   |  |   |  |

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Fig. 16-2 Additional engine plant data, part "B" (2/3)

|   |  |
|---|--|
| <b>CAT<sup>®</sup></b>  | <b>Additional engine plant data, part "B"</b>  |
| <b><u>TVC data - Information for main engine(s) only:</u></b>   |  |
| <b>PTO shaft generator, driven via gearbox</b>  |  |
| Supplied by Caterpillar <input type="checkbox"/> Yes <input type="checkbox"/> Not applicable <input type="checkbox"/> No, if " <b>No</b> " please provide the following data:   |  |
| Maker: _____  | Type: _____  |
| Output [kVA]: _____   | rpm [1/min]: _____ <input type="checkbox"/> TVC scheme attached  |
| <input type="checkbox"/> PTI operation  | PTI output [kW]: _____   |
| <b>Shaft arrangement between engine - gearbox</b>   |  |
| Supplied by Caterpillar <input type="checkbox"/> Yes <input type="checkbox"/> No, if " <b>No</b> " please provide the following data:   |  |
| Maker: _____  | <input type="checkbox"/> TVC scheme attached    detail drawing: _____  |
| <b>Propeller and propeller shafting data:</b>   |  |
| Supplied by Caterpillar <input type="checkbox"/> Yes <input type="checkbox"/> No, if " <b>No</b> " please provide the following data:   |  |
| <input type="checkbox"/> CPP <input type="checkbox"/> FPP <input type="checkbox"/> Voith <input type="checkbox"/> Rudder FPP/ CPP <input type="checkbox"/> Others _____   |  |
| numbers of blades: _____  | Ø propeller [mm]: _____  |
| Moments of inertia in water [kgm <sup>2</sup> ]: _____  | Moments of inertia in air [kgm <sup>2</sup> ]: _____   |
| Maker: _____  | <input type="checkbox"/> TVC scheme attached    or detail drawing: _____   |
| <b>Propeller and propeller shafting information:</b>  |  |
| Supplied by Caterpillar <input type="checkbox"/> No <input type="checkbox"/> Yes, <u>in case of "Yes"</u> please provide the following data:  |  |
| <input type="checkbox"/> Wake field attached  | <input type="checkbox"/> Propulsion test attached <input type="checkbox"/> Length of shafting incl. drawing attached |
| (tank test)   |  |
| <b>Comments/Remarks:</b>  |  |
| <div style="border-bottom: 1px dotted black; height: 15px; margin-bottom: 2px;"></div> <div style="border-bottom: 1px dotted black; height: 15px; margin-bottom: 2px;"></div> <div style="border-bottom: 1px dotted black; height: 15px; margin-bottom: 2px;"></div> <div style="border-bottom: 1px dotted black; height: 15px; margin-bottom: 2px;"></div> <div style="border-bottom: 1px dotted black; height: 15px; margin-bottom: 2px;"></div> <div style="border-bottom: 1px dotted black; height: 15px; margin-bottom: 2px;"></div> <div style="border-bottom: 1px dotted black; height: 15px; margin-bottom: 2px;"></div> <div style="border-bottom: 1px dotted black; height: 15px; margin-bottom: 2px;"></div> <div style="border-bottom: 1px dotted black; height: 15px; margin-bottom: 2px;"></div> <div style="border-bottom: 1px dotted black; height: 15px; margin-bottom: 2px;"></div> |  |

Confirmed by buyer: \_\_\_\_\_

Date: \_\_\_\_\_

Stamp and signature: \_\_\_\_\_

Caterpillar cannot be held liable for any mistakes made by the buyer.  
 Components not mentioned in Cat's technical specification/No. \_\_\_\_\_, dd. \_\_\_\_\_ and essential for  
 installation/operation of the equipment will be buyer's scope of supply.

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Fig. 16-3 Additional engine plant data, part "B" (3/3)

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## VIBRATION AND NOISE

### 16.2 Sound levels

#### 16.2.1 Airborne noise

The airborne noise level requirement in the engine room specified by IMO Resolution A.468 will be satisfied by M 46 DF (even for multiple installations).

The airborne noise level is measured in a test cell according to EN ISO 9614-2.

### 16.3 Vibration

The vibration level of M 46 DF engines complies with ISO 20283-4 and ISO 10816-6.

From these ISO standards, the following values are an applicable guideline:

|                        |                  |                         |   |
|------------------------|------------------|-------------------------|---|
| Displacement           | $S_{\text{eff}}$ | < 0.448 mm              | $f > 2 \text{ Hz} < 10 \text{ Hz}$      |
| Vibration velocity     | $V_{\text{eff}}$ | < 28.2 mm/s             | $f > 10 \text{ Hz} < 250 \text{ Hz}$    |
| Vibration acceleration | $a_{\text{eff}}$ | < 44.2 m/s <sup>2</sup> | $f > 250 \text{ Hz} < 1,000 \text{ Hz}$ |

## 17.1 Flexible coupling

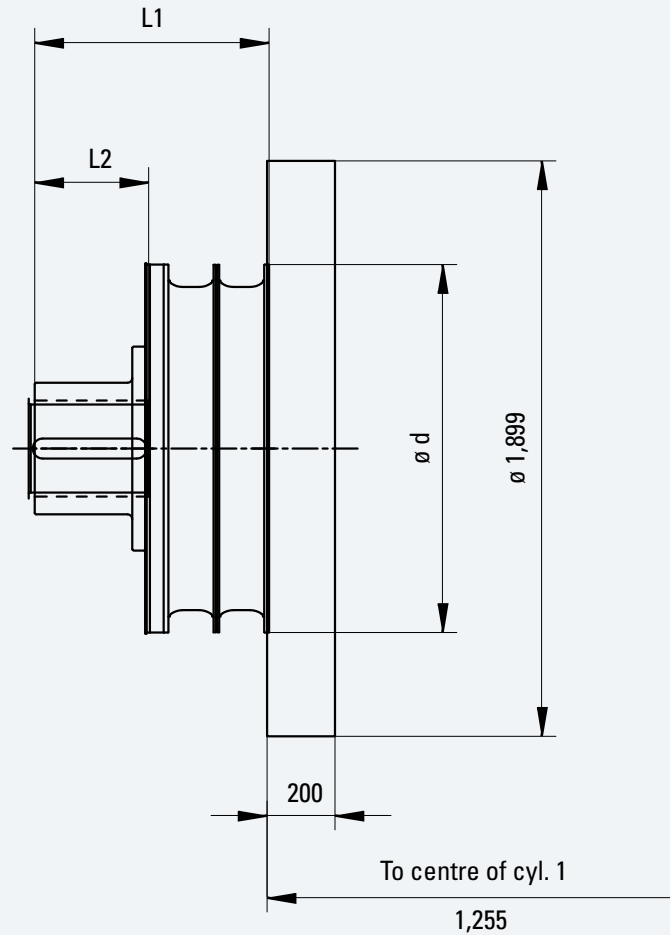


Fig. 17-1 Flexible coupling

|           | Power                        | Speed   | Nominal torque of coupling |       |                  |                  | Weight |
|-----------|------------------------------|---------|----------------------------|-------|------------------|------------------|--------|
|           | [kW]                         | [rpm]   | [kNm]                      | d     | L1 <sup>2)</sup> | L2 <sup>1)</sup> | [kg]   |
| 6 M 46 DF | 5,400<br>5,790 <sup>*)</sup> | 500/514 | 125                        | 1,240 | 729              | 385              | 1,200  |
| 7 M 46 DF | 6,300<br>6,755 <sup>*)</sup> | 500/514 | 160                        | 1,240 | 745              | 385              | 1,500  |
| 8 M 46 DF | 7,200<br>7,720 <sup>*)</sup> | 500/514 | 160                        | 1,240 | 745              | 385              | 1,500  |
| 9 M 46 DF | 8,100<br>8,685 <sup>*)</sup> | 500/514 | 200                        | 1,460 | 954              | 480              | 2,100  |

<sup>\*)</sup> MDO operation only / 1) Length of hub / 2) Alignment control (recess depth 8 mm)

## PIPING DESIGN

### 18.1 Pipe dimensions

The external piping systems are to be installed and connected to the engine by the shipyard.

Piping systems are to be designed so as to keep the pressure losses at a reasonable level.

To achieve this at justifiable costs, it is recommended to keep flow rates as indicated below (see chapter 18.2).

Nevertheless, depending on specific conditions of piping systems, it may be necessary to adopt even lower flow rates.

#### ATTENTION:

Generally it is not recommended to adopt higher flow rates.

### 18.2 Flow velocities in pipes

|                             | Recommended flow rates [m/s] |               |                                     |
|-----------------------------|------------------------------|---------------|-------------------------------------|
|                             | Suction side                 | Delivery side | Kind of system                      |
| Fresh water (cooling water) | 1.5 - 3.0                    | 1.5 - 3.0     | Closed                              |
| Lube oil                    | 0.5 - 1.0                    | 1.5 - 2.5     | Open                                |
| Sea water                   | 1.0 - 1.5                    | 1.5 - 2.5     | Open                                |
| Diesel fuel oil             | 0.5 - 1.0                    | 1.5 - 2.5     | Open                                |
| Heavy fuel oil              | 0.3 - 0.8                    | 1.0 - 1.5     | Open / closed<br>pressurized system |
| Exhaust gas                 | 20 - 40                      |               | Open                                |

### 18.3 Trace heating

Trace heating is highly recommended for all pipes carrying HFO or leak oil. For detailed explanation see fuel oil diagrams, showing the trace heated pipes marked as           .

### 18.4 Insulation

All pipes with a surface temperature > 60 °C should be insulated to avoid risk of physical injury.

This applies especially to exhaust gas piping.

To avoid thermal loss, all trace heated pipes should be insulated.

Additionally, lube oil circulating pipes, the piping between engine and lube oil separator as well as the cooling water pipes between engine and preheater set should be insulated.

## 18.5 Flexible pipe connections

Flexible pipe connections become necessary to connect resilient mounted engines with external piping systems. These components have to compensate the dynamic movements of the engine in relation to the external piping system.

The shipyard's pipe system must be exactly arranged so that the flanges or screw connections fit without lateral or angular offset. It is recommended to adjust the final position of the pipe connections after engine alignment is completed.

It is important to support as close as possible to the flex connection and stronger than normal. The pipes outside the flexible connection must be well fixed and clamped to prevent from vibrations, which could damage the flexible connections.

### Installation of steel compensators

Steel compensators can compensate movements in line and transversal to their center line. They are not suitable for compensating twisting movements. Compensators are very stiff against torsion.

It is very important that all steel compensators are not allowed to be installed on resilient mounted engines in vertical direction.

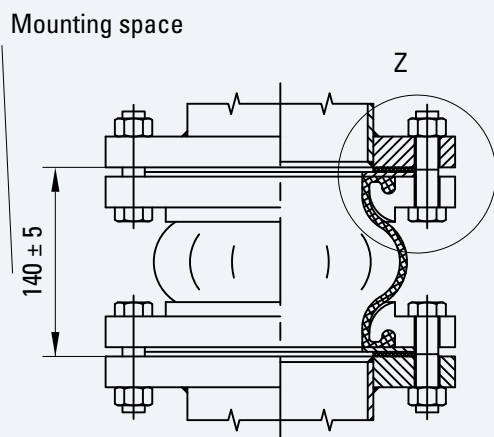


Fig. 18-1 Rubber expansion joint

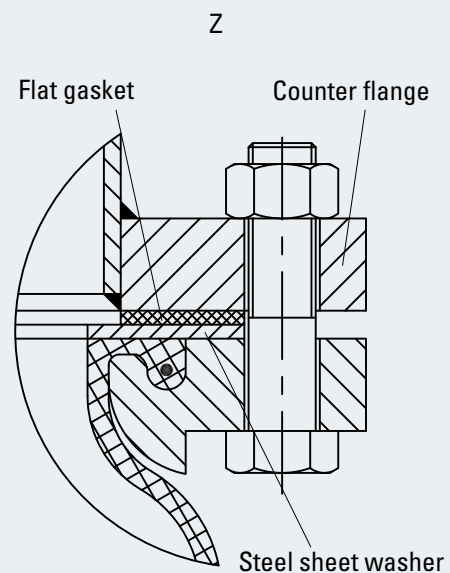


Fig. 18-2 Rubber expansion joint, detail Z

## ENGINE ROOM LAYOUT

### 19.1 Genset center distances

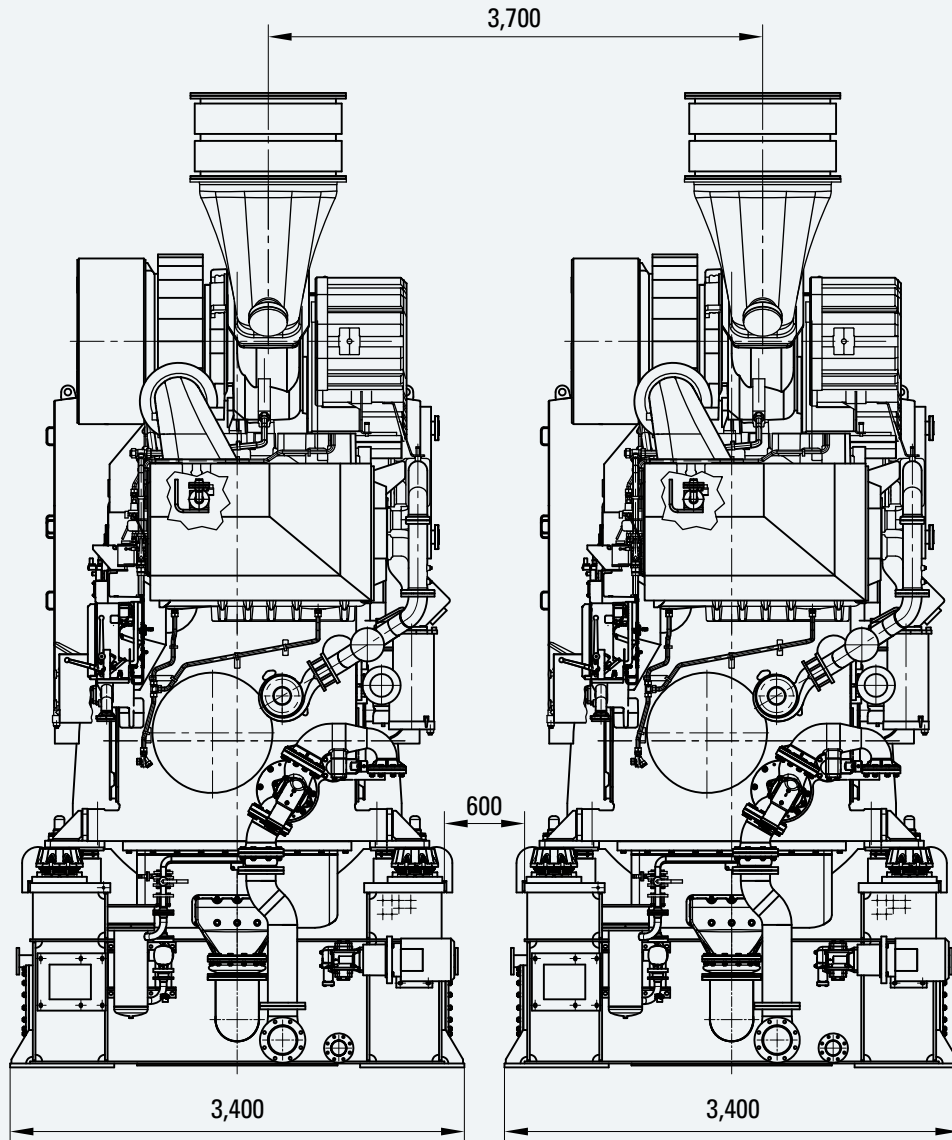


Fig. 19-1 Center distance of twin-engine plants

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| Type            | Dimensions [mm] |
|-----------------|-----------------|
|                 | A               |
| 6/7/8/9 M 46 DF | 3,700           |

## 19.2 Space requirement for maintenance

### 19.2.1 Removal of charge air cooler and turbocharger cartridge

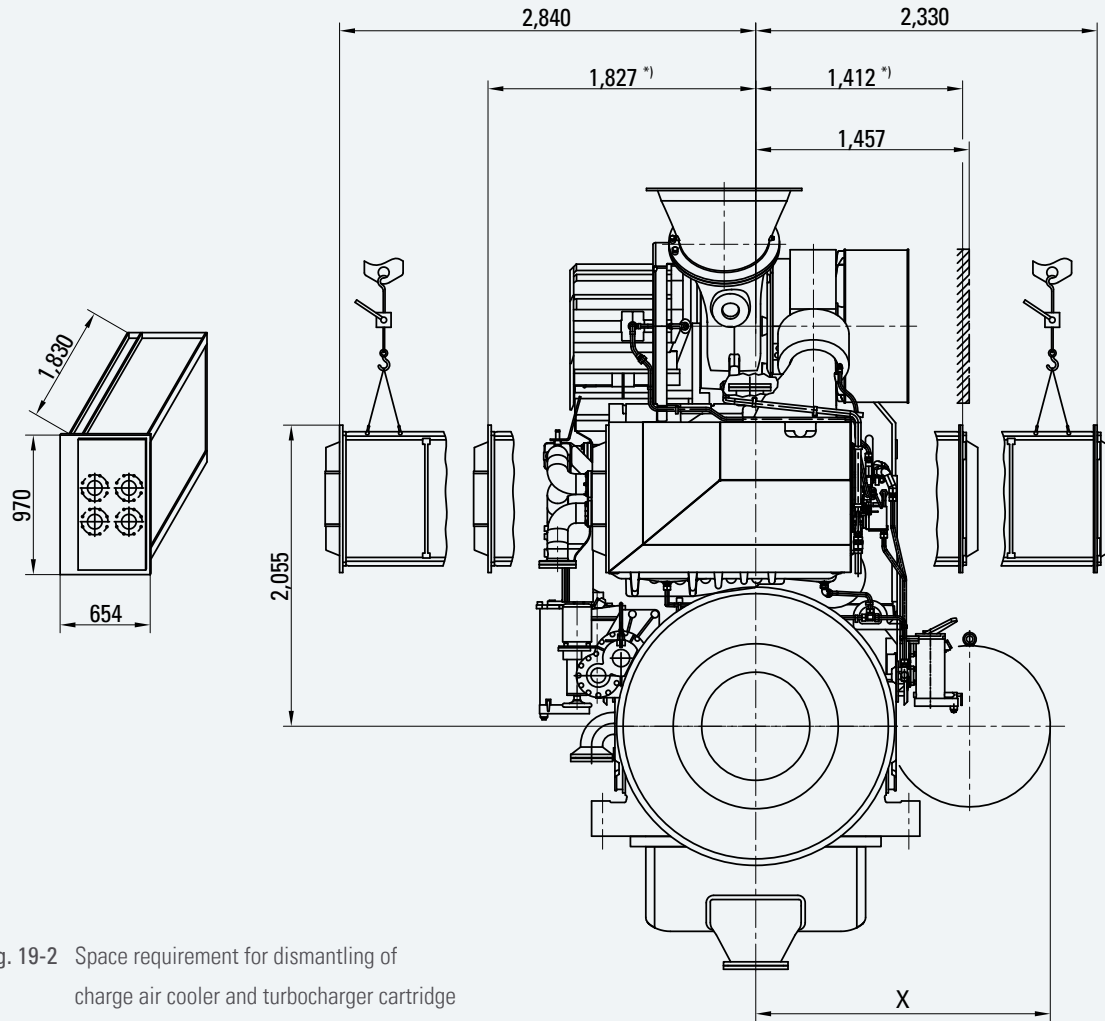


Fig. 19-2 Space requirement for dismantling of charge air cooler and turbocharger cartridge

| Type          | Weight charge air cooler | Weight turbocharger cartridge |  |
|---------------|--------------------------|-------------------------------|--|
|               | [kg]                     | [kg]                          |  |
| 6 M 46 DF     | 1,138                    | 460                           |  |
| 7/8/9 M 46 DF | 1,124                    | 820                           |  |

| Type      | Damper ø | Weight | X     |
|-----------|----------|--------|-------|
|           | [mm]     | [kg]   | [mm]  |
| 6 M 46 DF | 1,100    | 960    | 2,010 |
| 7 M 46 DF | 1,340    | 1,538  | 2,250 |
| 8 M 46 DF | 1,480    | 2,527  | 2,390 |
| 9 M 46 DF | 1,480    | 2,527  | 2,390 |

\*) Splitted charge air cooler

#### Charge air cooler cleaning

Cleaning is carried out with charge air cooler dismantled. A container to receive the cooler and cleaning liquid is to be supplied by the yard. Intensive cleaning is achieved by using ultra sonic vibrators.

#### Turbocharger dismantling

To provide a lifting rail with a travelling trolley right above the center of the turbocharger in order to carry out scheduled maintenance work is recommended..

## ENGINE ROOM LAYOUT

### 19.2.2 Removal of piston and cylinder liner

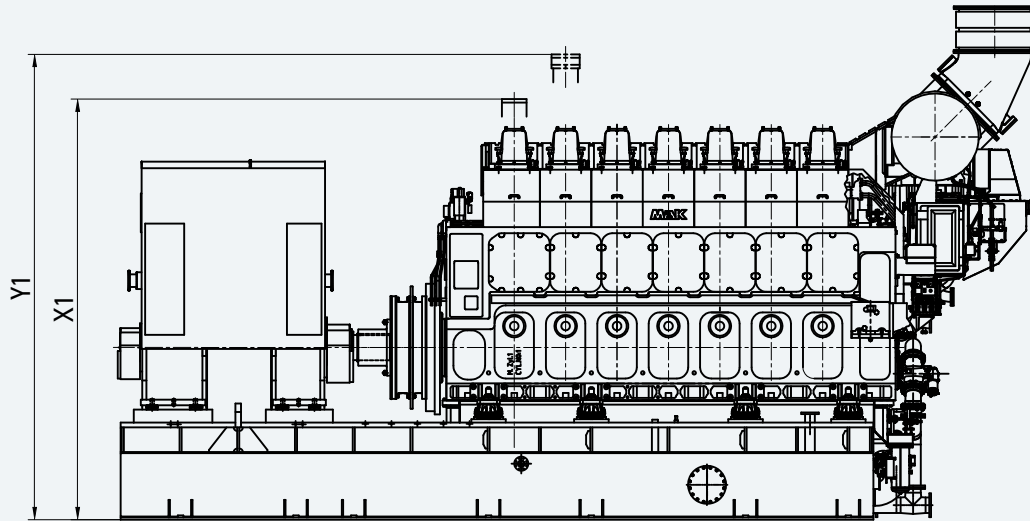


Fig. 19-3 Removal of piston and cylinder liner

Removal of:

Piston: in transverse direction  $X1 = 5,974 \text{ mm}$

Cylinder liner: in transverse direction  $Y1 = 6,609 \text{ mm}$

## PAINTING, PRESERVATION

### 20.1 Inside preservation

#### 20.1.1 Factory standard N 576-3.3 – Inside preservation

##### Components

- Main running gear and internal mechanics

##### Application

- Max. 2 years

##### NOTE:

Inside preservation does not have to be removed when the engine is commissioned.

### 20.2 Outside preservation

#### 20.2.1 Factory standard N 576-3.2 – Outside preservation VCI 368

##### Conditions

- Europe and overseas
- Sea and land transportation
- Storage in the open, protected from moisture max. 2 years with additional VCI packaging

##### Appearance of the engine

- Castings with red oxide antirust paint
- Pipes and machined surfaces left as bare metal
- Attached components with colours of the manufacturers

##### NOTE:

Outside preservation must be removed before commissioning of the engines.

Environmentally compatible disposal is to be ensured.

Durability and effect depend on proper packaging, transportation, and storage (i.e. protected from moisture, stored at a dry place and sufficiently ventilated). Inspections are to be carried out at regular intervals.

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## PAINTING, PRESERVATION

### 20.2.2 Factory standard N 576-4.1 – Clear varnish

#### Conditions

- Europe
- Roofed land transportation
- Storage in a dry and tempered atmosphere, protected from moisture max. 1 year with additional VCI packaging

#### NOTE:

Clear varnish is not permissible for sea transportation of engine and storage of engines in the open, even if they are covered with tarpaulin.

#### Appearance of the engine

- Castings with red oxide antirust paint
- Pipes and machined surfaces left as bare metal
- Attached components with colours of the manufacturers
- Surfaces sealed with clear varnish
- Bare metal surfaces provided with VCI 368 preservation

#### NOTE:

VCI packaging as per factory standard N 576-5.2 is generally required!

Durability and effect depend on proper packaging, transportation, and storage (i.e. the engine is to be protected from moisture, VCI film not ripped or destroyed).

Inspections are to be carried out at regular intervals.

If the above requirements are not met, all warranty claims in connection with corrosion damage shall be excluded.

## PAINTING, PRESERVATION

**20.2.3 Factory standard N 576-4.3 – Painting****Conditions**

- Europe and overseas
- Sea and land transportation
- Short-term storage in the open, protected from moisture up to max. 4 weeks
- Longer than 4 weeks VCI packaging as per factory standard N 576-5.2 is required
- Max. 2 years with additional VCI packaging

**Appearance of the engine**

- Surfaces mostly painted with varnish
- Bare metal surfaces provided with VCI 368 preservation

**NOTE:**

Durability and effect depend on proper packaging, transportation, and storage (i.e. the engine is to be protected from moisture, VCI film not ripped or destroyed).

Inspections are to be carried out at regular intervals.

**20.2.4 Factory standard N 576-5.2 – VCI packaging****Conditions**

- Engines with outside preservation VCI 368 as per factory standard N 576-3.2
- Engines with clear varnish as per factory standard N 576-4.1

**NOTE:**

These engines are always to be delivered with VCI packaging!

Nevertheless, they are not suitable for storage in the open!

- Engine or engine generator sets with painting as per factory standard N 576-4.3
- Europe and overseas
- Storage in the open, protected from moisture

**NOTE:**

Durability and effect depend on proper packaging, transportation, and storage (i.e. the engine is to be protected from moisture, VCI film not ripped or destroyed).

Inspections are to be carried out at regular intervals.

## PAINTING, PRESERVATION

**Apperance of the engine**

- Bare metal surfaces provided with VCI 368 or VCI oil
- VCI impregnated flexible PU foam mats attached to the engine using tie wraps.  
Kind and scope depending on engine type.  
The attached mats should not come into contact with the painted surface.
- Cover the engine completely with air cushion film VCI 126 LP. Air cushions are to face inwards!  
The air cushion film is fastened to the transportation skid (wooden frame) by means of wooden laths.  
Overlaps at the face ends and openings for the lifting gear are to be closed by means of PVC scotch tape. In case of engines delivered without oil pan, the overhanging VCI film between engine and transport frame is to be folded back upwards before fastening the air cushion film.

**ATTENTION:**

The corrosion protection is only effective if the engine is completely wrapped in VCI film. The protective space thus formed around the component can be openend for a short time by slitting the film, but afterwards it must be closed again with adhesive tape.

**20.2.5 Factory standard N 576-5.2 Suppl. 1 – Information panel for VCI preservation and inspection**

An information panel for VCI preservation and inspection will be supplied.

**Application**

- Engines with VCI packaging as per factory standard N 576-5.2

**Description**

- This panel provides information on initial preservation and instructions for inspection.
- Arranged on the transport frame on each side so as to be easily visible.

## 20.3 Factory standard N 576-6-1 – Protection period, check, and represervation

### 20.3.1 Protection period

There will only be an effective corrosion protection of the engine if the definitions and required work according to factory standard N 576-6.1 are duly complied with.

Normally, the applied corrosion protection is effective for a period of max. 2 years, if the engine or engine generator set is protected from moisture.

After two years represervation must be carried out.

However, depending on the execution of the preservation or local conditions shorter periods may be recommended.

### 20.3.2 Protection check

Every 3 months specific inspections of the engine or engine generator set are to be carried out at defined inspection points.

Any corrosion and existing condensation water are to be removed immediately.

### 20.3.3 Represervation as per factory standard N 576-6.1

After 2 years represervation must be carried out.

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## TRANSPORT, DIMENSIONS AND WEIGHTS

### 21.1 Lifting of engines

For more information regarding the lifting of the engine, please contact Caterpillar Motoren.

### 21.2 Dimensions of main components

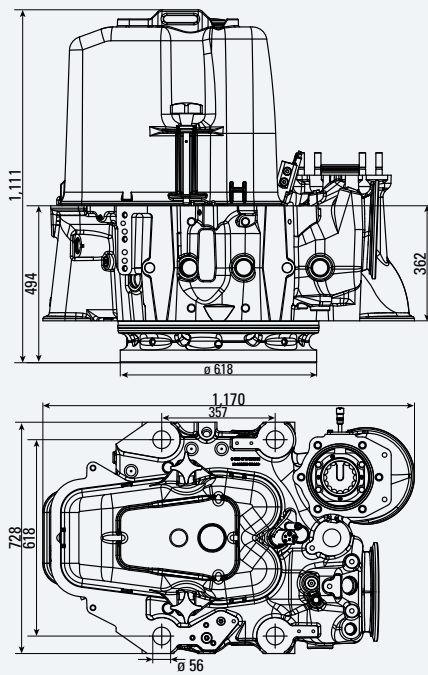


Fig. 21-1 Cylinder head (2D), weight 1,147 kg

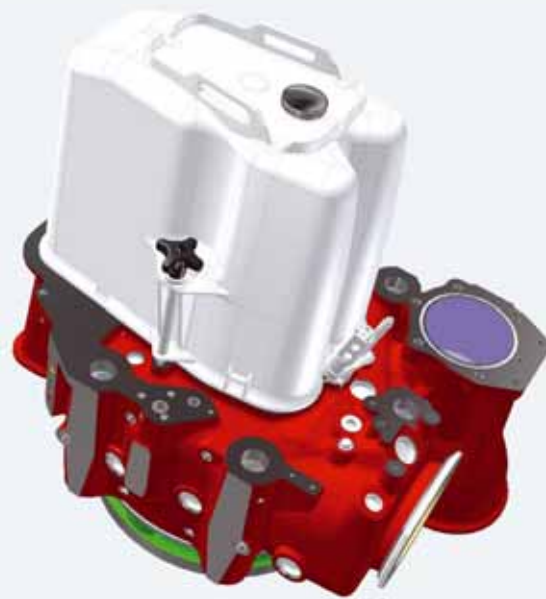


Fig. 21-2 Cylinder head (3D)

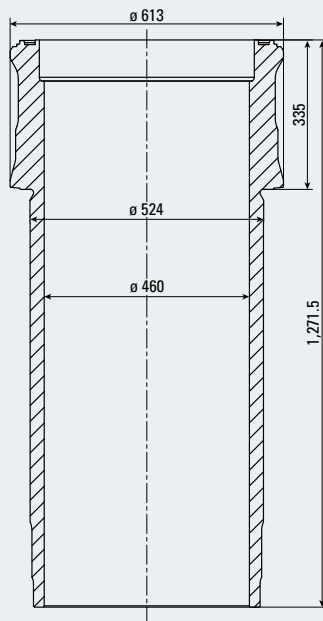


Fig. 21-3 Cylinder liner (2D), weight 560 kg



Fig. 21-4 Cylinder liner (3D)

## TRANSPORT, DIMENSIONS AND WEIGHTS

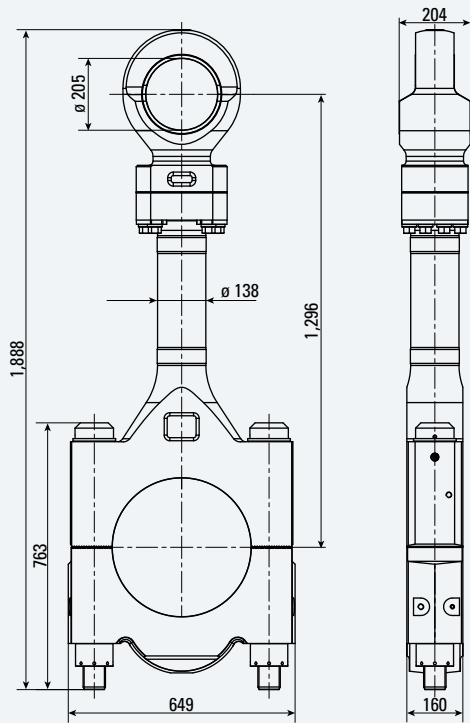


Fig. 22-5 Connecting rod (2D), weight 560 kg



Fig. 22-6 Connecting rod (3D)

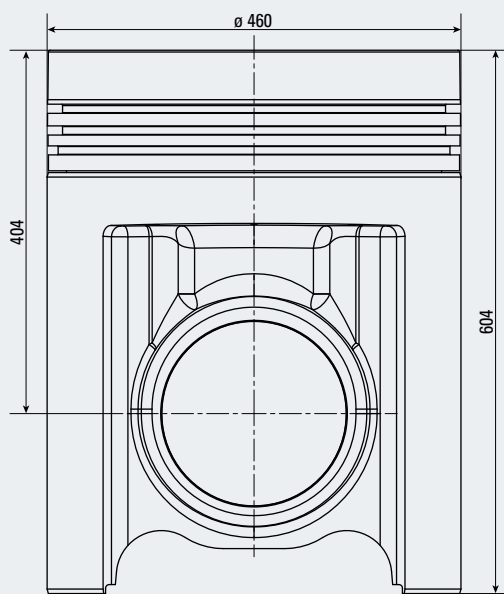


Fig. 22-7 Piston (2D), weight 230 kg



Fig. 22-8 Piston (3D)

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## STANDARD ENGINE ACCEPTANCE TEST RUN

### 22.1 Standard acceptance test run

The acceptance test run is carried out on the testing bed with customary equipment and auxiliaries using exclusively MDO and under the respective ambient conditions of the testing bed. During this test run the fuel rack will be blocked at the contractual output value. In case of deviations from the contractual ambient conditions the fuel consumption will be converted to standard reference conditions.

The engine will be run at the following load stages according to the rules of the classification societies.

#### Diesel mode

| Load [%]           | Duration [min] |
|--------------------|----------------|
| <b>Diesel mode</b> |                |
| 25                 | 20             |
| 50                 | 20             |
| 75                 | 20             |
| 85                 | 20             |
| 100                | 60             |
| 110                | 30             |
| <b>Gas mode</b>    |                |
| 25                 | 20             |
| 50                 | 20             |
| 75                 | 20             |
| 85                 | 20             |
| 100                | 60             |

The load stages above can vary according to the requirements of the classification societies.

After reaching steady state conditions of pressures and temperatures these will be recorded and registered according to the form sheet of the acceptance test certificate.

#### Additional functional tests

In addition to the acceptance test run the following functional tests will be carried out:

- Governor test
- Overspeed test
- Emergency shut-down via minimum oil pressure
- Start/stop via central engine control
- Starting trials up to a minimum air pressure of 10 bar
- Measurement of crank web deflection (cold/warm condition)

After the acceptance, main running gear, camshaft drive and timing gear train will be inspected through the opened covers. Individual inspection of special engine components such as piston or bearings is not intended, because such inspections are carried out by the classification societies at intervals on series engines.

## ENGINE PARTS

### 23.1 Required spare parts (Marine Classification Society MCS)

| Classification societies                              | GL               | RS               | KR              | CCS                 |
|---|------------------|------------------|-----------------|---------------------|
| Rules references                                      | Pt. 1,<br>Ch. 17 | Pt. 7,<br>Ch. 10 | Pt. 5,<br>Ch. 1 | Ch. 15,<br>Sec. 1&2 |
| <b>Parts</b>  |                  |                  |                 |                     |
| Main bearing  | 1                | 1                | 1               | 1                   |
| Thrust washer   | 1                | 1                | 1               | 1                   |
| Cylinder liner, complete                              | 1                | 1                | 1               | 1                   |
| Cylinder head, complete                               | 1                | 1                | 1               | 1                   |
| Cylinder head, only with valves (w/o injection valve) | —                | —                | —               | —                   |
| Set of gaskets for one cylinder head                  | —                | —                | —               | —                   |
| Set bolts and nuts for cylinder head                  | 1/2              | 1/2              | 1/2             | 1/2                 |
| Set of exhaust valves for one cylinder head           | 1                | (2)*             | 2               | 2                   |
| Set of intake valves for one cylinder head            | 1                | (1)*             | 1               | 1                   |
| Starting air valve, complete                          | 1                | 1                | 1               | 1                   |
| Relief valve, complete                                | 1                | 1                | 1               | 1                   |
| Injection valve, complete                             | —                | —                | —               | —                   |
| Set of injection valves, complete, for one engine     | 1                | 1                | 1               | 1                   |
| Set of conrod top & bottom bearing for one cylinder   | 1                | 1                | 1               | 1                   |
| Piston, complete                                      | 1                | 1                | 1               | 1                   |
| Piston, without piston pin + piston rings             | —                | —                | —               | —                   |
| Connecting rod  | 1                | 1                | 1               | 1                   |
| Big end bearing                                       | —                | —                | —               | —                   |
| Gudgeon pin with bushing for one cylinder             | 1                | 1                | 1               | 1                   |
| Set of piston rings                                   | 1                | 1                | 1               | 1                   |
| Fuel injection pump                                   | 1                | 1                | 1               | 1                   |
| Fuel injection piping                                 | 1                | 1                | 1               | 1                   |
| Set of gaskets and packing for one cylinder           | 1                | 1                | 1               | 1                   |
| Exhaust compensators between cylinders                | 1                | —                | 1               | 1                   |
| Turbocharger rotor, complete                          | —                | (1)*             | —               | —                   |
| Set of gear wheels                                    | —                | —                | —               | —                   |
| ECU   | 1                | 1                | 1               | 1                   |
| Speed pick up camshaft                                | 1                | 1                | 1               | 1                   |
| Speed pick up crankshaft                              | 1                | 1                | 1               | 1                   |
| DCU   | 1                | —                | —               | —                   |
| <b>Only for electronic speed setting</b>              | —                | —                | —               | —                   |
| Pick up for electronic speed setting                  | —                | —                | —               | —                   |
| <b>Only if oil mist detector is provided</b>          | —                | —                | —               | —                   |
| Sintered bronze filter (for crankcase monitor)        | —                | —                | —               | —                   |

\* Recommendation only



## ENGINE PARTS

### 23.2 Recommended spare parts

| Classification societies   | ABS                       | DNV                        | LR                          | BV **                      | RINA **                    |
|--|---------------------------|----------------------------|-----------------------------|----------------------------|----------------------------|
| Rules references   | Pt. 4,<br>Ch. 2<br>Sec. 1 | Pt. 4,<br>Ch. 1,<br>Sec. 5 | Pt. 5,<br>Ch. 16,<br>Sec. 1 | Pt. A,<br>Ch. 1,<br>Sec. 1 | Pt. A,<br>Ch. 1,<br>Sec. 1 |
| <b>Parts</b>   |                           |                            |                             |                            |                            |
| Main bearing   | 1                         | 1                          | 1                           | —                          | —                          |
| Thrust washer  | 1                         | 1                          | 1                           | —                          | —                          |
| Cylinder liner, complete   | 1                         | —                          | 1                           | —                          | —                          |
| Cylinder head, complete  | 1                         | —                          | 1                           | —                          | —                          |
| Cylinder head, only with valves (w/o injection valve)  | —                         | —                          | —                           | —                          | —                          |
| Set of gaskets for one cylinder head   | —                         | —                          | —                           | —                          | —                          |
| Set bolts and nuts for cylinder head   | 1/2                       | —                          | 1/2                         | —                          | —                          |
| Set of exhaust valves for one cylinder head  | 2                         | 2                          | 2                           | —                          | —                          |
| Set of intake valves for one cylinder head   | 1                         | 1                          | 1                           | —                          | —                          |
| Starting air valve, complete   | 1                         | 1                          | 1                           | —                          | —                          |
| Relief valve, complete   | 1                         | 1                          | 1                           | —                          | —                          |
| Injection valve, complete  | —                         | —                          | —                           | —                          | —                          |
| Set of injection valves, complete, for one engine  | 1                         | 1/2                        | 1                           | —                          | —                          |
| Set of conrod top & bottom bearing for one cylinder  | 1                         | 1                          | 1                           | —                          | —                          |
| Piston, complete   | 1                         | —                          | 1                           | —                          | —                          |
| Piston, without piston pin + piston rings  | —                         | —                          | —                           | —                          | —                          |
| Connecting rod   | 1                         | —                          | 1                           | —                          | —                          |
| Big end bearing  | —                         | —                          | —                           | —                          | —                          |
| Gudgeon pin with bushing for one cylinder  | 1                         | 1                          | 1                           | —                          | —                          |
| Set of piston rings  | 1                         | 1                          | 1                           | —                          | —                          |
| Fuel injection pump  | 1                         | 1                          | 1                           | —                          | —                          |
| Fuel injection piping  | 1                         | 1                          | 1                           | —                          | —                          |
| Set of gaskets and packing for one cylinder  | 1                         | 1                          | 1                           | —                          | —                          |
| Exhaust compensators between cylinders   | 1                         | —                          | 1                           | —                          | —                          |
| Turbocharger rotor, complete   | —                         | —                          | —                           | —                          | —                          |
| Set of gear wheels   | 1                         | —                          | —                           | —                          | —                          |
| ECU  | 1                         | 1                          | 1                           | 1                          | 1                          |
| Speed pick up camshaft   | 1                         | 1                          | 1                           | 1                          | 1                          |
| Speed pick up crankshaft   | 1                         | 1                          | 1                           | 1                          | 1                          |
| <b>Only for electronic speed setting</b><br>Pick up for electronic speed setting               | —                         | —                          | —                           | —                          | —                          |
| <b>Only if oil mist detector is provided</b><br>Sintered bronze filter (for crankcase monitor) | —                         | —                          | —                           | —                          | —                          |

\* Recommendation only / \*\* Owner's responsibility

## ENGINE PARTS

| Caterpillar recommendation                            | Caterpillar |
|---|-------------|
| Rules references                                      |             |
| <b>Parts</b>  |             |
| Main bearing  | 1           |
| Thrust washer   | —           |
| Cylinder liner, complete                              | 1           |
| Cylinder head, complete                               | —           |
| Cylinder head, only with valves (w/o injection valve) | 1           |
| Set of gaskets for one cylinder head                  | 1           |
| Set bolts and nuts for cylinder head                  | 1/2         |
| Set of exhaust valves for one cylinder head           | —           |
| Set of intake valves for one cylinder head            | —           |
| Starting air valve, complete                          | —           |
| Relief valve, complete                                | —           |
| Injection valve, complete                             | 1           |
| Set of injection valves, complete, for one engine     | —           |
| Set of conrod top & bottom bearing for one cylinder   | —           |
| Piston, complete                                      | —           |
| Piston, without piston pin + piston rings             | 1           |
| Connecting rod  | —           |
| Big end bearing                                       | 1           |
| Gudgeon pin with bushing for one cylinder             | —           |
| Set of piston rings                                   | 1           |
| Fuel injection pump                                   | 1           |
| Fuel injection piping                                 | 1           |
| Set of gaskets and packing for one cylinder           | —           |
| Exhaust compensators between cylinders                | 1           |
| Turbocharger rotor, complete                          | —           |
| Set of gear wheels                                    | —           |
| ECU   | 1           |
| Speed pick up camshaft                                | 1           |
| Speed pick up crankshaft                              | 1           |
| DCU   | 1           |
| Gas admission valve                                   | 2           |
| Ignition injector                                     | 2           |
| Cylinder pressure sensor                              | 1           |
| Set of dual fuel gaskets                              | 1           |
| Rail pressure sensor                                  | 1           |
| Gas compensator                                       | 1           |
| Ignition fuel high pressure pump                      | 1           |

## 24.1 Gas systems technology – Scope of supply

Beside the gas / dual fuel engines itself Caterpillar offers also the whole gas system which is needed to operate the engine onboard the vessel.

Whether on a new building or for a retrofit project, the service can include:

- Gas / dual fuel engines
- FEED study (Front End Engineering and Design study)
- A&I engineering
- Bunker station
- LNG storage tank
- Gas handling system
- Gas and LNG piping
- Gas valve unit
- Control & monitoring
- Safety systems

The customer can benefit from getting a whole solution from one hand. Supported by our strong dealer and customer support organizations.

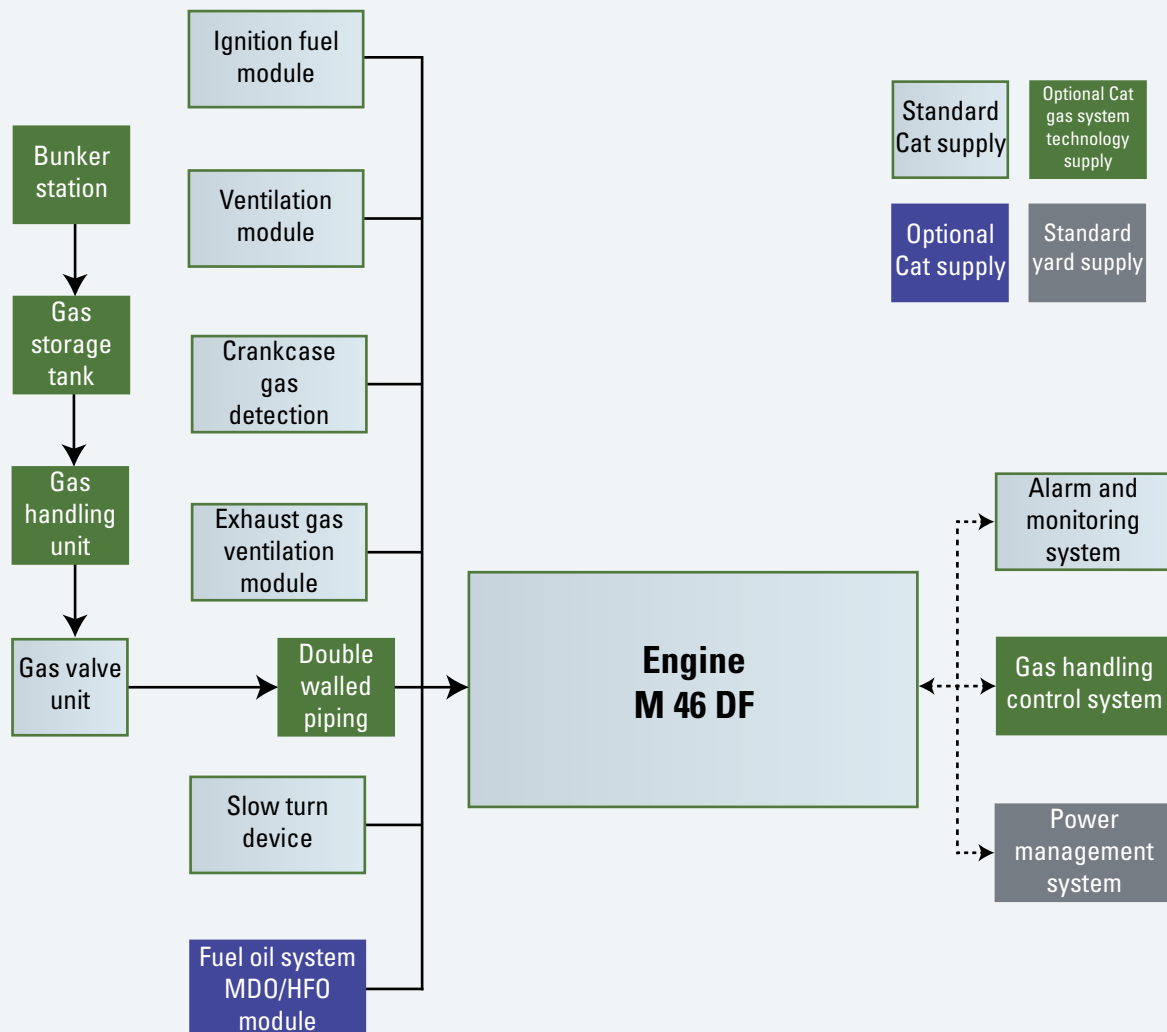


Fig. 24-1 Scope of supply M 34 DF Gas systems technology – block diagram

## 24.2 Caterpillar Propulsion

### Performance You Can Rely On

Caterpillar Propulsion supplies complete, world-leading propulsion systems.

Custom-designed and optimized for uptime and cost-effective operations, our top-of-the-line controllable pitch propellers, thrusters, control systems, and hubs are all manufactured at our state-of-the-art production facilities in Sweden and Singapore.

We are experts in innovative hydrodynamics to ensure heavy-duty, reliable performance for our customers.

### How we deliver uptime

Our guiding principle is to deliver maximum uptime for our customers' peace-of-mind and profitability.

For us, this means using more material to ensure our propulsion systems are built to last even in the most extreme conditions. And with extreme attention to detail, we study your vessel's design, the job at hand – anything and everything that affects the hydrodynamics.

Using all our expertise, we're not finished until the system is as optimized and reliable as possible. Please visit us at [catpropulsion.com](http://catpropulsion.com).



Fig. 24-2 Controllable pitch propeller



Fig. 24-3 Azimuth thrusters



Fig. 24-4 Tunnel thrusters



Fig. 24-5 Remote control system

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## The Power You Need.

The Cat® and MaK™ brands of Caterpillar Marine offer premier high- and medium-speed propulsion, auxiliary, and generator set solutions, as well as optional dual fuel, diesel-electric, and hybrid system configurations. With the launch of Caterpillar Propulsion our comprehensive and evolving product line gives customers one source for the most extensive engine power range available, complete propulsion systems, controllable pitch propellers, transverse and azimuth thrusters, and controls. Cat and MaK products and technologies are proven reliable and are built to last in all marine applications, demonstrating superior productivity and the lowest lifecycle cost.

The Cat Global Dealer Network, more than 2,200 global service locations strong, ensures that you'll have local expertise, highly-trained technicians, rapid parts delivery, and the proper equipment and services to keep you working – anytime, anywhere.

Construction, term, or repower financing through Cat Financial helps you make Cat and MaK power a reality. With our knowledge of customer needs, local markets, and legal and regulatory requirements, we've been providing tailored financing solutions and exceeding expectations since our start in 1986.

For more information and to find your local dealer, please visit our website: [www.cat.com/marine](http://www.cat.com/marine)

Visit Cat Financial at: [CatPowerFinance.com](http://CatPowerFinance.com)

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### Caterpillar Marine

#### Europe, Africa, Middle East

Caterpillar Marine  
A Division of  
Caterpillar Motoren GmbH & Co. KG  
Neumühlen 9  
22763 Hamburg  
Germany

Phone: +49 40 2380-3000  
Telefax: +49 40 2380-3535

#### Americas

MaK Americas Inc.  
3450 Executive Way  
Miramar Park of Commerce  
Miramar, FL 33025/USA

Phone: +1 954 885 3200  
Telefax: +1 954 885 3131

#### Asia Pacific

Caterpillar Marine Trading  
(Shanghai) Co., Ltd.  
25/F, Caterpillar Marine Center  
1319, Yan'an West Road  
200050 Shanghai/P.R. China

Phone: +86 21 6226 2200  
Telefax: +86 21 6226 4500

Caterpillar Marine Asia  
Pacific Pte Ltd.  
No. 5 Tukang  
Innovation Grove  
Singapore 618304  
Republic of Singapore

Phone: +65 68287-600  
Telefax: +65 68287-625

For more information please visit our website:  
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