Technical Documentation

Project Guide

L23/30DF

Design Specification:	**IMO Tier III**
Plant No.	**L23/30DF**
Date	**2023-02-24**

2023-02-24

Original instructions

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Introduction to project guide

Introduction

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

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

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

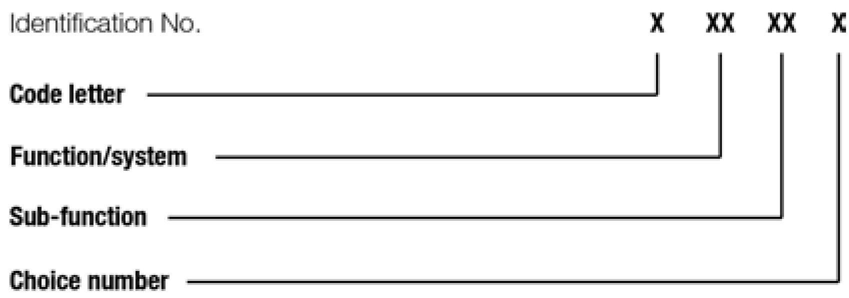
All figures, values, measurements and/or other information about performance stated in the project guides are for guidance only and shall not be used for detailed design purposes or as a substitute for specific drawings and instructions prepared for such purposes. MAN Energy Solutions makes no representations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

MAN Energy Solutions will issue an Installation Manual with all project related drawings and installation instructions when the contract documentation has been completed.

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

All data provided in this document is non-binding and serves informational purposes only. Depending on the subsequent specific individual projects, the relevant data may be subject to changes and will be assessed and determined individually for each project. This will depend on the particular characteristics of each individual project, especially specific site and operational conditions.

Code numbers



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

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

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

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

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

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

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

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

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

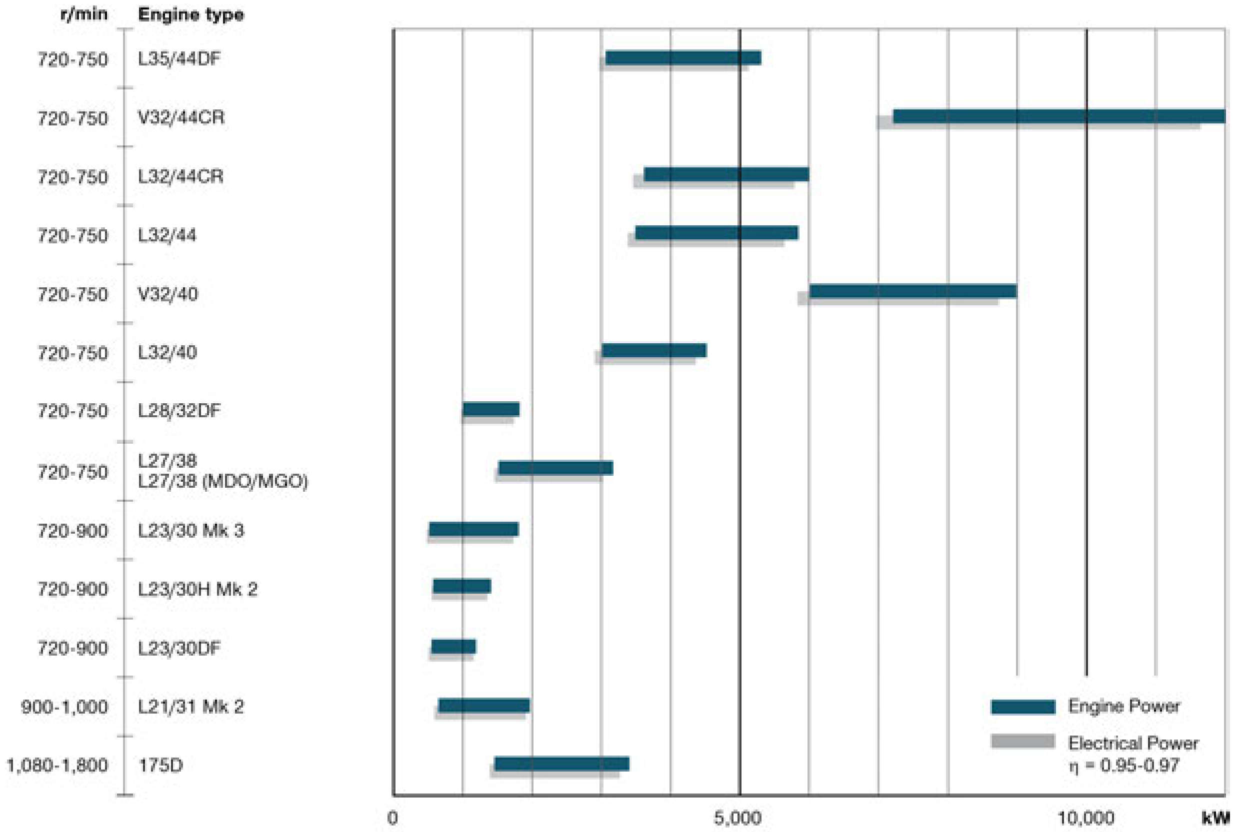
NOTICE

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

Engine programme - MAN four-stroke marine GenSets

Description

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



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Key for engine designation

Key for engine designation

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

6 L 28/32 H

No. of cylinders

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

Engine type

L : In-line
V : V-built

Cyl. diam/stroke

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

Design variant

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

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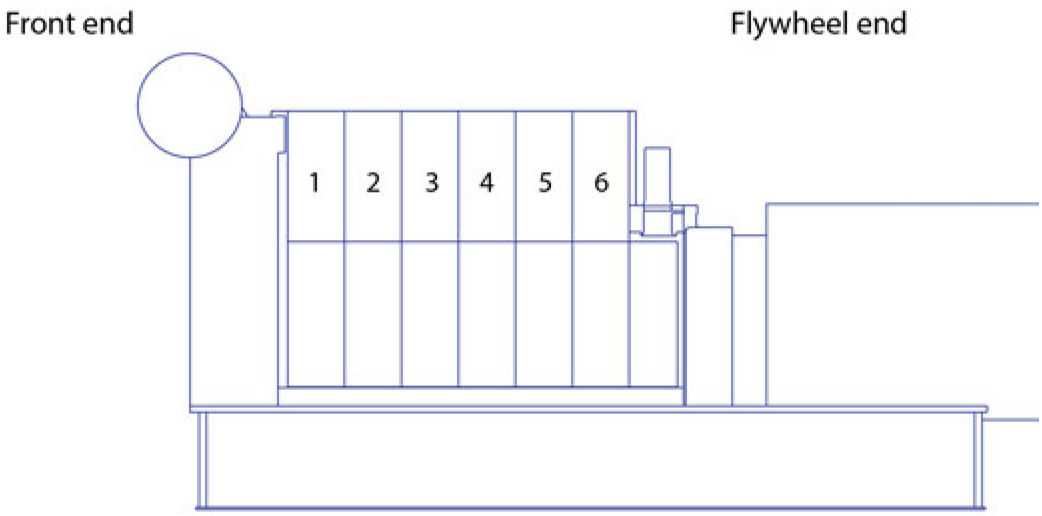
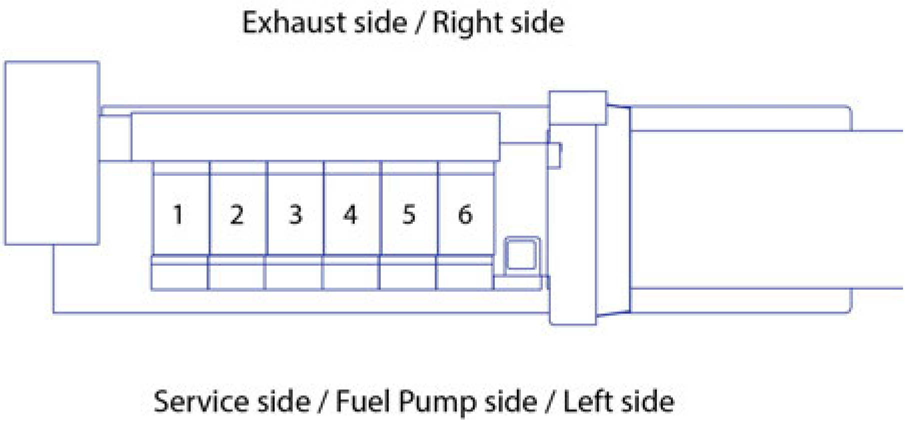
Designation of cylinders

General





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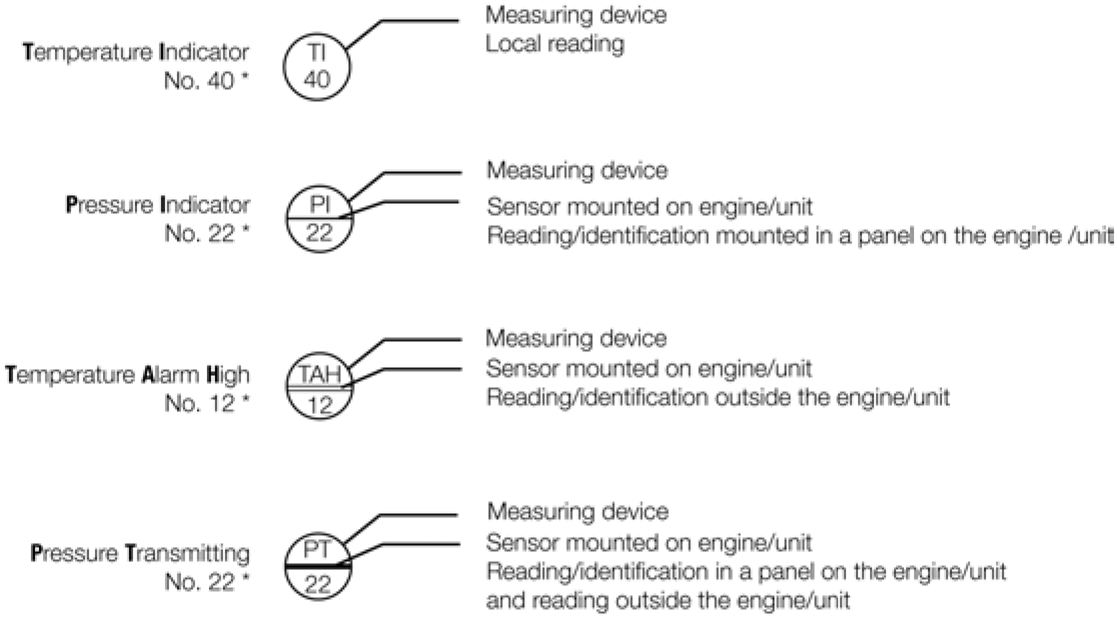
Code identification for instruments

Explanation of symbols



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

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

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Code identification for instruments

Description

Standard text for instruments

Diesel engine/alternator

LT water system

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

HT water system

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

Lubricating oil system

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

Charging air system

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

Fuel oil system

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

Nozzle cooling system

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

Exhaust gas system

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

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Compressed air system

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

Load speed

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

Miscellaneous

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

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Symbols for piping

General

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

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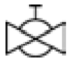
2.12		Cap nut	3.14		Ball valve (cock)

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

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

List of Symbols

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

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Symbols for piping

Description

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

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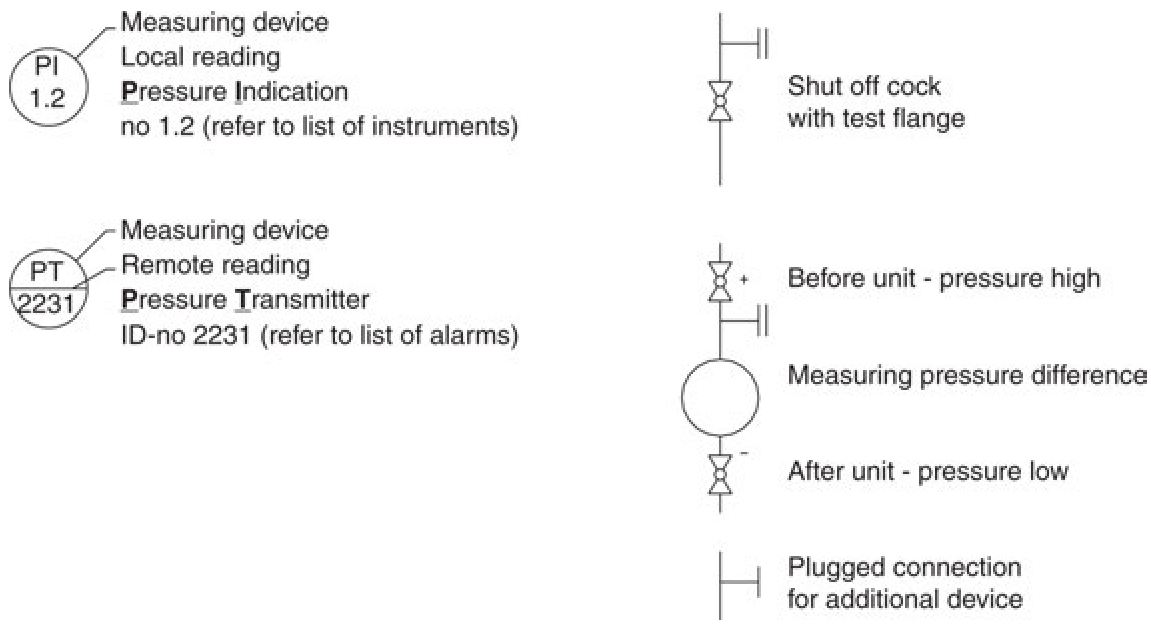
General



Specification of letter code for measuring devices

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

General

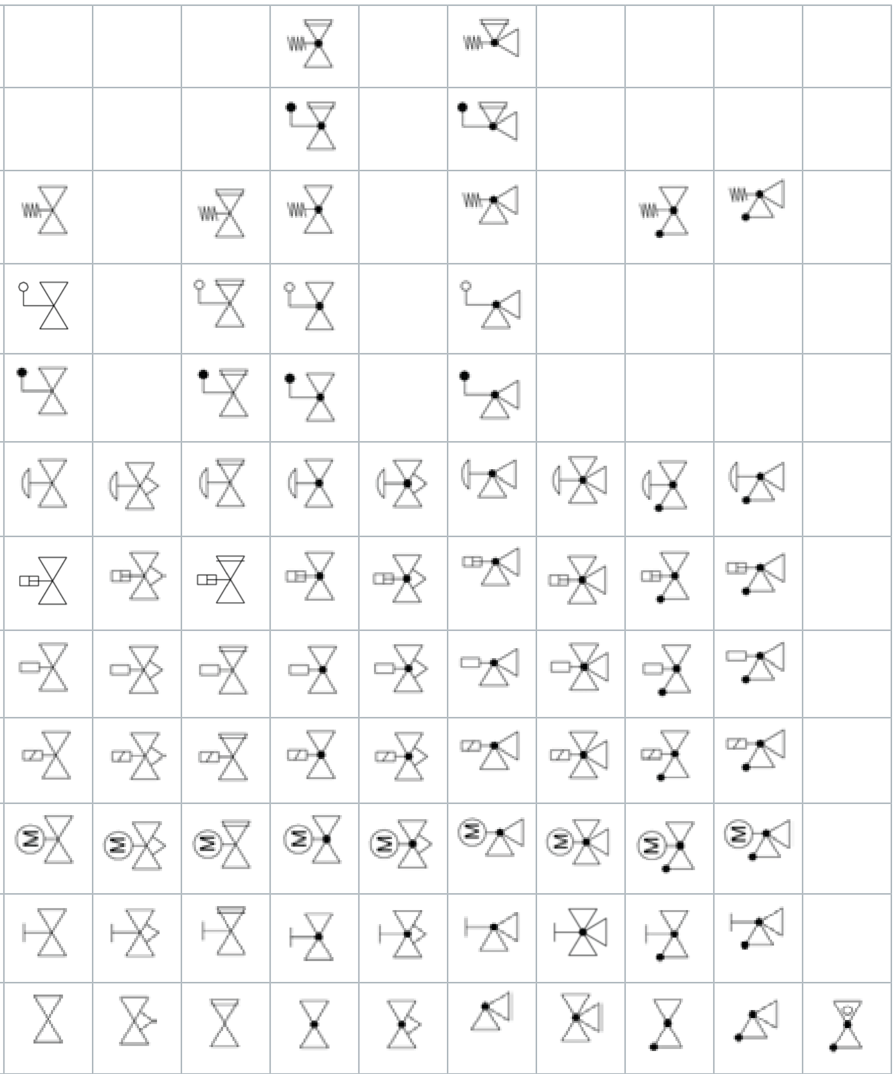
Specification of ID-no code for measuring signals/devices

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

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

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

Basic symbols for piping



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

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

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Symbols for piping
Description

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

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

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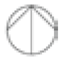
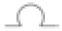
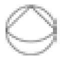
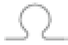
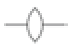
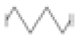
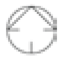
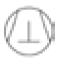
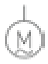
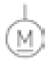
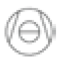
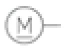
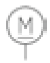
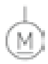
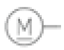
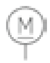
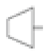
No	Symbol	Symbol designation	No	Symbol	Symbol designation
Miscellaneous			972		Pipe threaded connection
582		Funnel	xxx		Blind
581		Atomizer	Tanks		
583		Air venting	631		Tank with domed ends
6.25		Air venting to the outside	771		Tank with conical ends
299		Normal opening/ closing speed	yyy		Electrical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

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

List of capacities

Please Note

The following list of capacities is for guidance only - Test ongoing

Contact MAN Diesel & Turbo for present result

2017-03-30 - en

Capacities

720 rpm			5	6	7	8
Engine output		kW	710	852	994	1136
Speed		rpm	720	720	720	720
Heat to be dissipated [3]						
Cooling water cylinder		kW	190	230	270	310
Charge air cooler; cooling water HT (1 stage cooler: no HT-stage)		kW	-	-	-	-
Charge air cooler; cooling water LT		kW	299	356	413	470
Lubricating oil cooler		kW	71	86	101	116
Heat radiation engine		kW	30	36	42	48
Air data						
Charge air temp. at charge air cooler outlet, max.		°C	55	55	55	55
		m^3/h [5]	4792	5750	6708	7667
Air flow rate		kg/kWh	7.39	7.39	7.39	7.39
Charge air pressure		bar (abs)	3.08	3.08	3.08	3.08
Air required to dissipate heat radiation (eng.) (t_2-t_1=10°C)		m^3/h	9756	11708	13659	15610
Exhaust gas data [6]						
Volume flow (temperature turbocharger outlet)		m^3/h [7]	9516	11419	13323	15226
Mass flow		t/h	5.4	6.5	7.5	8.6
Temperature at turbine outlet		°C	342	342	342	342
Heat content (190°C)		kW	244	293	341	390
Permissible exhaust back pressure		mbar	< 30	< 30	< 30	< 30
Permissible exhaust back pressure (SCR)		mbar	< 50	< 50	< 50	< 50
Pumps						
Engine driven pumps [4]						
HT cooling water pump	1-2.5 bar	m^3/h	36	36	36	36
LT cooling water pump	1-2.5 bar	m^3/h	55	55	55	55
Lubrication oil	3-5 bar	m^3/h	16	16	20	20
External pumps [8]						
Diesel oil pump	4 bar at fuel oil inlet A1	m^3/h	0.52	0.62	0.73	0.83
Fuel oil supply pump	4 bar discharge pressure	m^3/h	0.25	0.31	0.36	0.41
Fuel oil circulating pump [9]	8 bar at fuel oil inlet A1	m^3/h	0.53	0.63	0.74	0.84
Cooling water pumps						
"Internal cooling water system 1"						
LT cooling water pump	1-2.5 bar	m^3/h	35	42	48	55
"Internal cooling water system 2"						
HT cooling water pump	1-2.5 bar	m^3/h	20	24	28	32
LT cooling water pump	1-2.5 bar	m^3/h	35	42	48	55
Lubricating oil pump	3-5 bar	m^3/h	14	15	16	17
Starting air system						
Air consumption per start		Nm^3	1.40	1.43	1.50	1.54

Conditions

Reference condition : Tropic		
Air temperature LT water temperature inlet engine (from system) Air pressure Relative humidity	°C °C bar %	45 36 1 50
Temperature basis: Set point HT cooling water engine outlet [1)] Set point LT cooling water engine outlet [2)] Set point lubrication oil inlet engine	 °C °C °C	 82°C nominal *(Range of mech. thermostatic element 79-88°C)* 35°C nominal *(Range of mech. thermostatic element 29-41°C)* 66°C nominal *(Range of mech. thermostatic element 63-72°C)*

Remarks to capacities

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

NOTICE

High temperature alarms can occur for some engine types running 100% MCR with SCR catalyst (50 mbar exhaust back pressure) and tropical condition (ambient air 45°C & LT-water 36°C).

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List of capacities

Please Note

The following list of capacities is for guidance only - Test ongoing

Contact MAN Energy Solutions for present result

Capacities

900 rpm			6	7	8
Engine output Speed		kW rpm	1050 900	1225 900	1400 900
Heat to be dissipated [3)] Cooling water cylinder Charge air cooler; cooling water HT 1 stage cooler: no HT-stage Charge air cooler; cooling water LT Lubricating oil cooler Heat radiation engine		 kW kW kW kW kW	 265 - 441 126 35	 311 - 512 148 41	 357 - 581 170 47
Air data Temp. of charge air at charge air cooler outlet, max. Air flow rate Charge air pressure Air required to dissipate heat radiation (eng.) (t_2-t_1=10°C)		 °C m^3/h [5)] kg/kWh bar (abs) m^3/h	 55 7355 7.67 3.1 11383	 55 8581 7.67 3.1 13334	 55 9806 7.67 3.1 15285
Exhaust gas data [6)] Volume flow (temperature turbocharger outlet) Mass flow Temperature at turbine outlet Heat content (190°C) Permissible exhaust back pressure Permissible exhaust back pressure (SCR)		 m^3/h [7)] t/h °C kW mbar mbar	 15280 8.3 371 447 < 30 < 50	 17826 9.6 371 521 < 30 < 50	 20373 11.0 371 595 < 30 < 50
Pumps Engine driven pumps [4)] HT cooling water pump LT cooling water pump Lubrication oil External pumps [8)] Diesel oil pump Fuel oil supply pump Fuel oil circulating pump [9)] Cooling water pumps "Internal cooling water system 1" LT cooling water pump "Internal cooling water system 2" HT cooling water pump LT cooling water pump Lubricating oil pump	 1-2.5 bar 1-2.5 bar 3-5 bar 4 bar at fuel oil inlet A1 4 bar discharge pressure 8 bar at fuel oil inlet A1 1-2.5 bar 1-2.5 bar 1-2.5 bar 3-5 bar	 m^3/h m^3/h m^3/h m^3/h m^3/h m^3/h m^3/h m^3/h m^3/h m^3/h	 45 69 20 0.74 0.36 0.75 52 30 52 17	 45 69 20 0.87 0.43 0.88 61 35 61 18	 45 69 20 0.99 0.49 1.01 70 40 70 19
Starting air system Air consumption per start		 Nm^3	 1.43	 1.50	 1.54

2019-01-04 - en

Conditions

Reference condition : Tropic		
Air temperature LT water temperature inlet engine (from system) Air pressure Relative humidity	°C °C bar %	45 36 1 50
Temperature basis: Set point HT cooling water engine outlet [1)] Set point LT cooling water engine outlet [2)] Set point lubrication oil inlet engine	 °C °C °C	 82°C nominal *(Range of mech. thermostatic element 79-88°C)* 35°C nominal *(Range of mech. thermostatic element 29-41°C)* 66°C nominal *(Range of mech. thermostatic element 63-72°C)*

Remarks to capacities

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

NOTICE

High temperature alarms can occur for some engine types running 100% MCR with SCR catalyst (50 mbar exhaust back pressure) and tropical condition (ambient air 45°C & LT-water 36°C).

2019-01-04 - en

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List of capacities

Please Note

The following list of capacities is for guidance only - Test ongoing

Contact MAN Energy Solutions for present result

Capacities

750 rpm			5	6	7	8
Engine output		kW	740	888	1036	1184
Speed		rpm	750	750	750	750
Heat to be dissipated [3]						
Cooling water cylinder		kW	195	235	276	317
Charge air cooler; cooling water HT (1 stage cooler: no HT-stage)		kW	-	-	-	-
Charge air cooler; cooling water LT		kW	327	390	452	514
Lubricating oil cooler		kW	72	86	102	117
Heat radiation engine		kW	30	36	42	48
Air data						
Charge air temp. at charge air cooler outlet, max.		°C	55	55	55	55
		m^3/h [5]	4994	5993	6992	7991
Air flow rate		kg/kWh	7.39	7.39	7.39	7.39
Charge air pressure		bar (abs)	3.08	3.08	3.08	3.08
Air required to dissipate heat radiation (eng.) (t_2-t_1=10°C)		m^3/h	9756	11708	13659	15610
Exhaust gas data [6]						
Volume flow (temperature turbocharger outlet)		m^3/h [7]	9918	11902	13885	15869
Mass flow		t/h	5.6	6.7	7.9	9.0
Temperature at turbine outlet		°C	342	342	342	342
Heat content (190°C)		kW	254	305	356	407
Permissible exhaust back pressure		mbar	< 30	< 30	< 30	< 30
Permissible exhaust back pressure (SCR)		mbar	< 50	< 50	< 50	< 50
Pumps						
Engine driven pumps [4]						
HT cooling water pump	1-2.5 bar	m^3/h	36	36	36	36
LT cooling water pump	1-2.5 bar	m^3/h	55	55	55	55
Lubrication oil	3-5 bar	m^3/h	16	16	20	20
External pumps [8]						
Diesel oil pump	4 bar at fuel oil inlet A1	m^3/h	0.52	0.62	0.73	0.83
Fuel oil supply pump	4 bar discharge pressure	m^3/h	0.25	0.31	0.36	0.41
Fuel oil circulating pump [9]	8 bar at fuel oil inlet A1	m^3/h	0.53	0.63	0.74	0.84
Cooling water pumps						
"Internal cooling water system 1"						
LT cooling water pump	1-2.5 bar	m^3/h	35	42	48	55
"Internal cooling water system 2"						
HT cooling water pump	1-2.5 bar	m^3/h	20	24	28	32
LT cooling water pump	1-2.5 bar	m^3/h	35	42	48	55
Lubricating oil pump	3-5 bar	m^3/h	14	15	16	17
Starting air system						
Air consumption per start		Nm^3	1.40	1.43	1.50	1.54

Conditions

Reference condition : Tropic		
Air temperature	°C	45
LT water temperature inlet engine (from system)	°C	36
Air pressure	bar	1
Relative humidity	%	50
Temperature basis:		
Set point HT cooling water engine outlet [1)]	°C	82°C nominal *(Range of mech. thermostatic element 79-88°C)*
Set point LT cooling water engine outlet [2)]	°C	35°C nominal *(Range of mech. thermostatic element 29-41°C)*
Set point lubrication oil inlet engine	°C	66°C nominal *(Range of mech. thermostatic element 63-72°C)*

Remarks to capacities

1) HT cooling water flows first through HT stage charge air cooler, then through water jacket and cylinder head, water temperature outlet engine regulated by mechanical thermostat.
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NOTICE

High temperature alarms can occur for some engine types running 100% MCR with SCR catalyst (50 mbar exhaust back pressure) and tropical condition (ambient air 45°C & LT-water 36°C).

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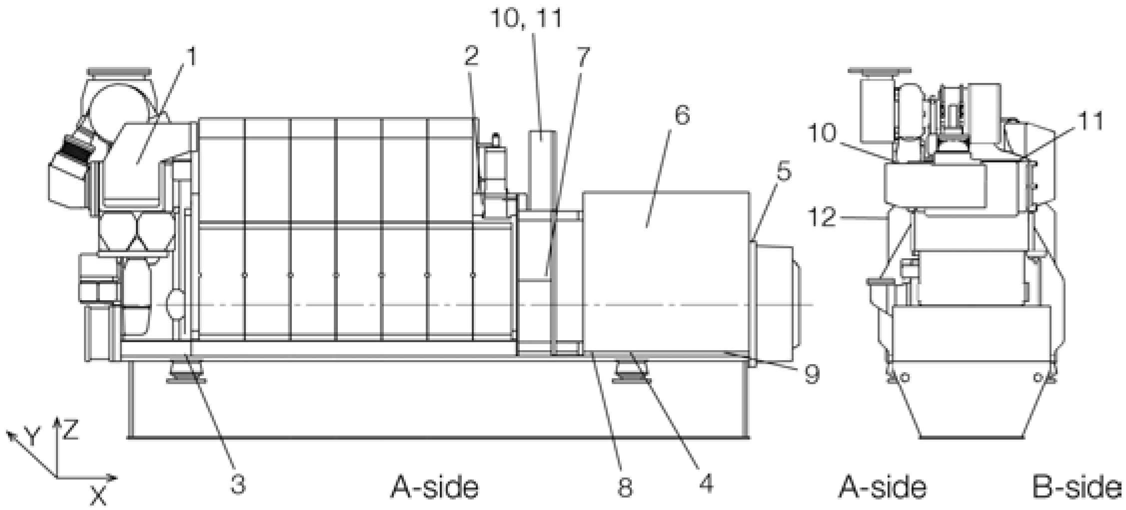
Vibration limits and measurements

GenSet



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

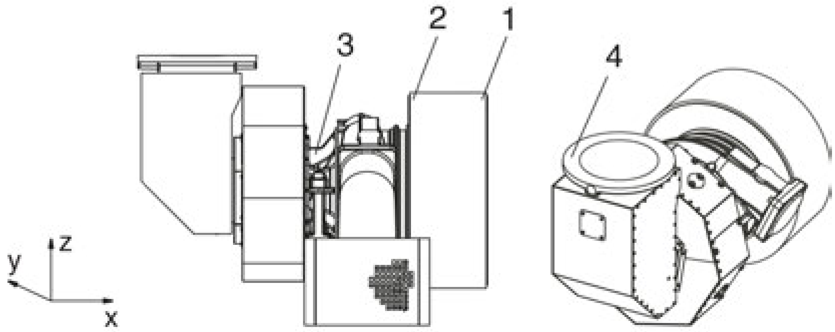
Engine: VDI 2063T
Alternator: ISO 8528-9, DIN 6280-11
Note: All measurements are specified as mm/s r.m.s.

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

Value 1 or 2 are depending on alternator make

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

Turbocharger



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

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

Turbocharger vibration limit values - measuring point

Date	Running Hours	Load %	Vertical (z) (Turbocharger oriented)			
			1	2	3	4
Shop test		100				
			Crosswise (y) (Turbocharger oriented)			
		100				
			Longitudinal (x) (Turbocharger oriented)			
		100				

Description of sound measurements

General

Purpose

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

Measuring equipment

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

Definitions

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

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

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

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

Measuring conditions

All measurements are carried out in one of MAN Energy Solutions' test bed facilities.

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

Sound Power is normally determined from Sound Pressure measurements.

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

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

Sound measuring "on-site"

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

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

Standards

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

2021-06-20 - en

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

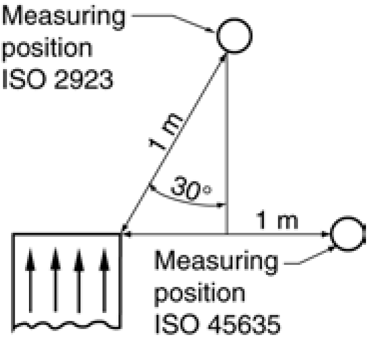


Figure 1: .

Description of structure-borne noise

Introduction

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

References

References and guidelines according to ISO 9611 and ISO 11689.

Operating condition

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

Frequency range

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

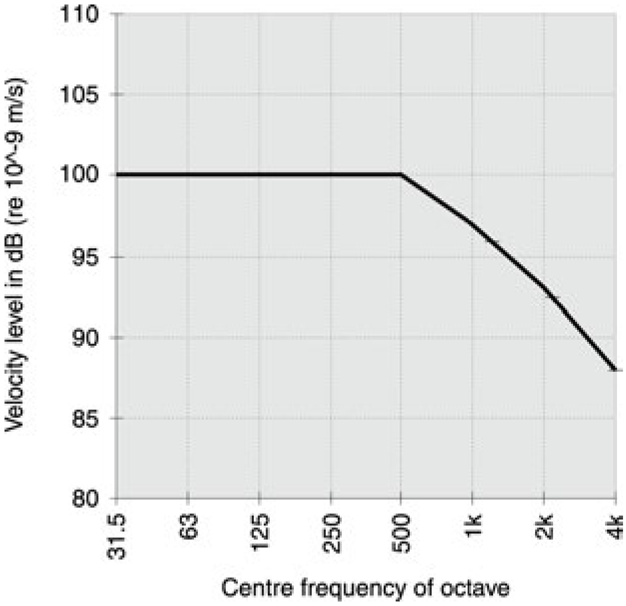


Figure 1: Structure-borne noise on resiliently mounted GenSets

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Exhaust gas components

Exhaust gas components of medium speed four-stroke diesel engines

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

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

Carbon dioxide CO_2

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

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

Sulphur oxides SO_X

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

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

Nitrogen oxides NO_X

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

Carbon monoxide CO

Carbon monoxide (CO) is formed during incomplete combustion.

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

Hydrocarbons HC

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

Particulate matter PM

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

2021-07-05 - en

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

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

Additional suspended exhaust gas constituents, PM[5)]	approx. [mg/Nm³]		approx. [g/kWh]	
	operating on		operating on	
	MGO[6)]	HFO[7)]	MGO[6)]	HFO[7)]
Soot (elemental carbon)[8)]	50	50	0.3	0.3
Fuel ash	4	40	0.03	0.25
Lube oil ash	3	8	0.02	0.04
Note! At rated power and without exhaust gas treatment.				

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

NOx emission

Maximum allowed emission value NOx

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

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

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

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

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

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

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

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

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

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

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Moment of inertia

GenSet

No. of cyl.	Generator type	Max. cont. rating kW	Speed rpm	Moment of inertia (J)			
				Engine kgm²	Flywheel kgm²	Generator *** kgm²	Total kgm²
6	DIDBN* 121k/10	780	720	37.4	273.5	132.0	442.9
	DIDBN* 121i/8	810	750	37.4	273.5	94.0	404.9
	LSA** 52B L9/8p	960	900	65.5	273.5	83.0	422.0
7	DIDBN* 131h/10	910	720	61.4	100.0	170.0	331.4
	DIDBN* 121k/8	945	750	61.4	100.0	110.0	271.4
	LSA** 54 VS4/8p	1120	900	47.9	111.3	120.0	279.2
8	DIDBN* 131i/10	1040	720	49.6	100.0	200.0	349.6
	DIDBN* 131h/8	1080	750	49.6	100.0	152.0	301.6
	LSA** 54 VS5/8p	1280	900	78.5	273.5	133.3	485.3

*	Generator, make A. van Kaick
**	Generator, make Leroy Somer
***	If other generator is chosen the values will change.
	Moment of intertia : $GD^2 = J \times 4$ (kgm^2)

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Moment of inertia
Description

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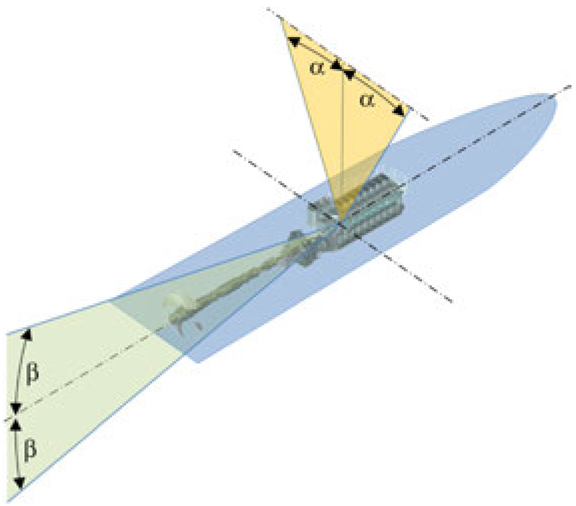
Inclination of engines

Description

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

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

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



α Athwartships β Fore and aft

Figure 1: Angle of inclination.

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NOTICE

For higher requirements contact MAN Energy Solutions. Arrange engines always lengthwise of the ship.

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Green Passport

Green Passport

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

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

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

This material declaration can be provided on request.

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Overhaul recommendation, maintenance and expected life time

Component	Overhaul Recommendations, Maintenance and Expected Life Time	Time between overhauls (TBO) Hours **	Expected life time Hours
Main bearings	Inspection Retightening *	32.000	64.000
Connecting rod	Inspection	32.000	64.000
Big-end bearing	Inspection Retightening *	32.000	64.000
Camshaft	Inspection of cams surface	8.000	64.000
Piston	Overhaul and measuring of ring grooves Replacement of compression rings and scraper rings	32.000 32.000	64.000 32.000
Cylinder liner	Inspection, measuring and honing of running surface condition	32.000	64.000
Cylinder head		32.000	64.000
Valve clearance	Checking and adjustment	8.000	
Fuel injection valve	Checking, cleaning and adjustment of opening pressure [1]	Based on observation	8000 [1]
Inlet and Exhaust valve	Overhaul and regrinding of spindle	32.000	64.000
Valve seat ring	Exchange and grinding	32.000	32.000
Rotorcap	Function check of rotation	2.000	32.000
Valve guide	Measuring of inside diameter	32.000	64.000
Cylinder head nuts	Retightening *		
Fuel pump	Fuel pump barrel/plunger assembly.	Based on observation	32.000
Gas System	Check of gas detectors in jacket pipe	Quarterly	
Sogav	Gas injection valve	Based on observation	16.000
Rig saver	Function test of rig saver valve	Quarterly	
Lub. Oil pump	Overhaul	32.000	64.000
Cooling water pumps	Overhaul	32.000	64.000
Air Cooler	Cleaning and pressure testing	32.000	64.000
Compr. air system	Check of compressed air system, air starter	32.000	
Autolog reading	Check once a year or in connection with disassembly/assembly with alternator and coupling	Once a year	
Lub. oil filter cartr.	Replacement based on observations of pressure drop		1.500
Regulating system	Function check of overspeed and shutdown devices. Check that the control rod of each individual fuel pump can easily go to "stop" position	Quarterly	
Flexible mountings	Check anti-vibration mountings	Quarterly	
Vibration viscodamper	Check of condition and wear	28-32.000	
Turbocharger	Water washing of compressor side Water washing of turbine side Dry cleaning of turbine side Air filter replacement	Based on observation Based on observation Based on observation Based on observation	

* After starting up and before loading engine.
** Time between overhauls: It is a precondition for the validity of the values stated above, that the engine is operated in accordance with our instructions and recommendations for cleaning of fuel and lub. oil and original spare parts are used.

In the Project Guide, see:
Lub. oil treatment in section B 12 00 0.
Fuel oil specification in section B 11 00 0.

In the Instruction Manual see:
Lub. oil treatment and Fuel oil specification in section 504/604.

1) See work card in instruction manual, section 514/614 for fuel injection valve
2) Time can be adjusted according to performance observations

Overhaul recommendation, maintenance and expected life time

Component	Overhaul Recommendations, Maintenance and Expected Life Time	Time between overhauls (TBO) Hours **	Expected life time Hours
Main bearings	Inspection Retightening *	20.000	60.000
Connecting rod	Inspection	20.000	60.000
Big-end bearing	Inspection Retightening *	20.000	40.000
Camshaft	Inspection of cams surface	8.000	60.000
Piston	Overhaul and measuring of ring grooves Replacement of compression rings and scraper rings	20.000 20.000	60.000 20.000
Cylinder liner	Inspection, measuring and honing of running surface condition	20.000	60.000
Cylinder head		20.000	60.000
Valve clearance	Checking and adjustment	8.000	
Fuel injection valve	Checking, cleaning and adjustment of opening pressure 1)	Based on observation	8000 1)
Inlet and Exhaust valve	Overhaul and regrinding of spindle	20.000	40.000
Valve seat ring	Exchange and grinding	20.000	20.000
Rotorcap	Function check of rotation	2.000	40.000
Valve guide	Measuring of inside diameter	20.000	40.000
Cylinder head nuts	Retightening *		
Fuel pump	Fuel pump barrel/plunger assembly.	Based on observation	20.000
Gas System	Check of gas detectors in jacket pipe	Quarterly	
Sogav	Gas injection valve	Based on observation	16.000
Rig saver	Function test of rig saver valve	Quarterly	
Lub. Oil pump	Overhaul	20.000	60.000
Cooling water pumps	Overhaul	20.000	60.000
Air Cooler	Cleaning and pressure testing	20.000	60.000
Compr. air system	Check of compressed air system, air starter	20.000	
Autolog reading	Check once a year or in connection with disassembly/assembly with alternator and coupling	Once a year	
Lub. oil filter cartr.	Replacement based on observations of pressure drop		1.500
Regulating system	Function check of overspeed and shutdown devices. Check that the control rod of each individual fuel pump can easily go to "stop" position	Quarterly	
Flexible mountings	Check anti-vibration mountings	Quarterly	
Vibration viscodamper	Check of condition and wear	28-32.000	
Turbocharger	Water washing of compressor side Water washing of turbine side Dry cleaning of turbine side Air filter replacement	Based on observation Based on observation Based on observation Based on observation	

* After starting up and before loading engine.
** Time between overhauls: It is a precondition for the validity of the values stated above, that the engine is operated in accordance with our instructions and recommendations for cleaning of fuel and lub. oil and original spare parts are used.

In the Project Guide, see:
Lub. oil treatment in section B 12 00 0.
Fuel oil specification in section B 11 00 0.

In the Instruction Manual see:
Lub. oil treatment and Fuel oil specification in section 504/604.

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1) See work card in instruction manual, section 514/614 for fuel injection valve
2) Time can be adjusted according to performance observations

Power, outputs, speed

Engine ratings

Engine type No of cylinders	720 rpm		750 rpm		900 rpm	
	720 rpm	Available turning direction	750 rpm	Available turning direction	900 rpm	Available turning direction
	kW	CW [1]	kW	CW [1]	kW	CW [1]
5L23/30DF	625	Yes	625	Yes	–	–
6L23/30DF	750	Yes	750	Yes	900	Yes
7L23/30DF	875	Yes	875	Yes	1050	Yes
8L23/30DF	1000	Yes	1000	Yes	1200	Yes
[1] CW clockwise						

Table 1: Engine ratings for emission standard.

Definition of engine ratings

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

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

Table 2: Standard reference conditions.

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Available outputs

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

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

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

Table 3: Available outputs / related reference conditions.

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

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

De-rating

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

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

[1] Overpressure

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

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

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

with $a \leq 1$

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

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

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

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

Gas mode relevant derating factors

Relevant for a derating in gas mode are the methane number, the charge air temperature before cylinder, the N_2-content of the fuel gas and the ambient air temperature range, that needs to be compensated.

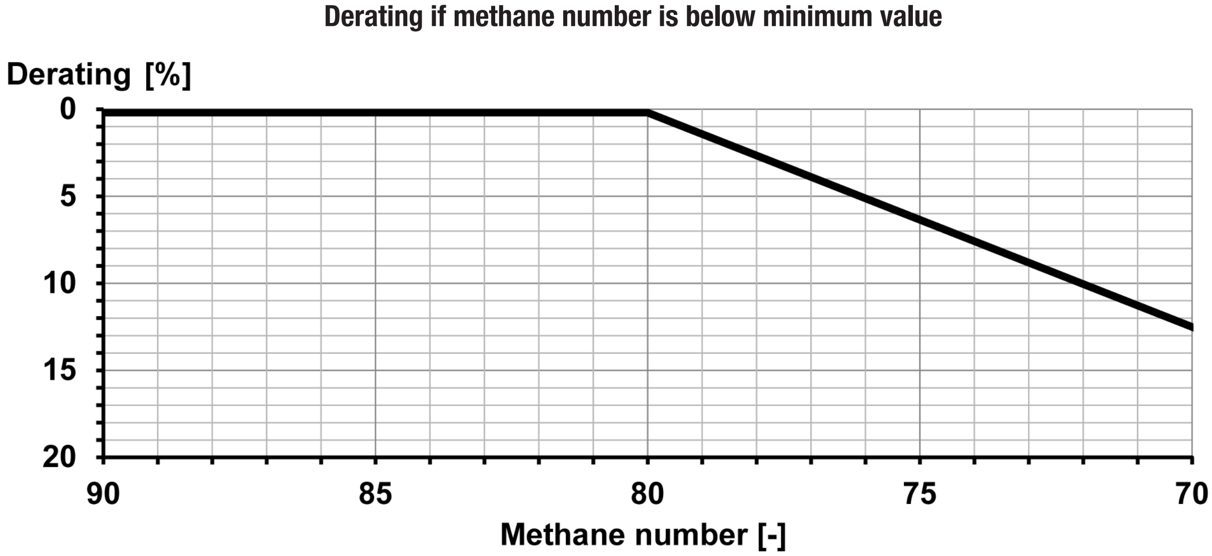
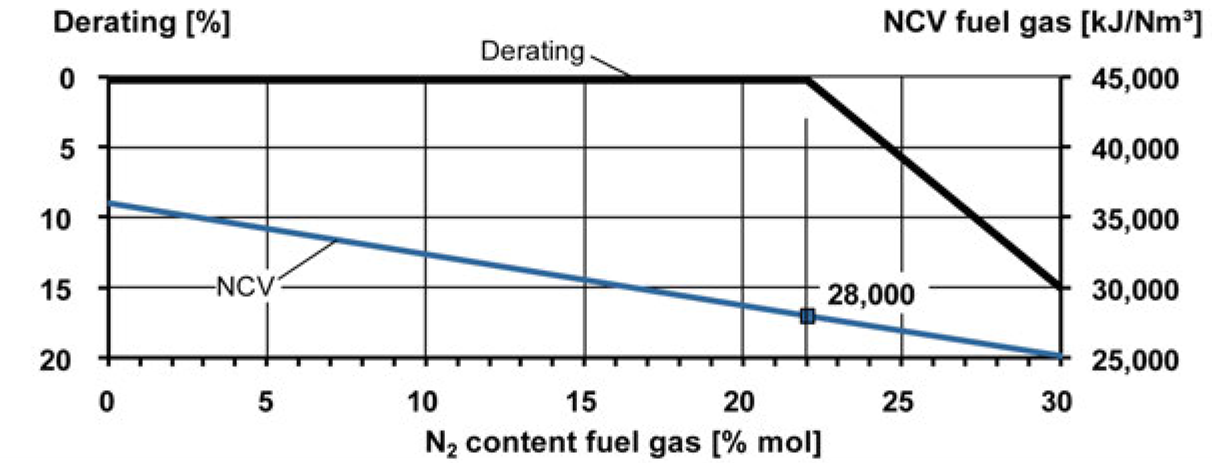


Figure 1: Derating d_{MN} as a function of methane number.

Derating if minimum NCV due to high N_2-content can not be kept

The NCV (Net caloric value) from the gas is influenced by the N_2-content. Up to 22 % of N_2-content no derating is necessary. Above 22 % to 30 % N_2-content derating is required.



Nm^3 corresponds to one cubic meter of gas at 0 °C and 101.32 kPa.

Figure 2: Derating d_{N2} as a function of N_2-content in the fuel gas

Derating if range of ambient air temperature compensation is exceeded

The main control device for air volume ratio adjustment (lambda control) of gas and DF engines is capable to compensate a wide range of changes of the ambient pressure and air temperature. For ambient air temperatures < 5 °C the intake air must be preheated to a minimum temperature of 5 °C before turbocharger. If the ambient air temperature exceeds the engine type relevant limit, the fuel air ratio adjustment is outside it is range and a derating of the engine output is required.

General description

General

The engine is a turbocharged, single-acting, fourstroke diesel engine of the trunk piston type with a cylinder bore of 225 mm and a stroke of 300 mm, the crankshaft speed is 720, 750 or 900 rpm.

The engine can be delivered as an in-line engine with 5 to 8 cylinders.

Engine frame

The engine frame which is made of cast iron is a monobloc design incorporating the cylinder bloc, the crankcase and the supporting flanges.

The charge air receiver, the cooling water jackets and the housing for the camshaft and drive are also integral parts of this one-piece casting.

The main bearings for the underslung crankshaft are carried in heavy supports in the frame plating and are secured by bearing caps. To ensure strong and sturdy bedding of the caps, these are provided with side guides and held in place by means of studs with hydraulically tightened nuts. The main bearings are equipped with replaceable shells which are fitted without scraping.

The crankshaft guide bearing is located at the flywheel end of the engine.

On the sides of the frame there are covers for access to the camshaft, the charge air receiver and crankcase. Some of the covers are fitted with relief valves which will act, if oil vapours in the crankcase should be ignited, for instance in the event of a hot bearing.

Base frame

The engine and alternator are mounted on a common base frame. The rigid base frame construction can be embedded directly on the engine seating or flexibly mounted.

The engine part of the base frame acts as lubricating oil reservoir.

Cylinder liner

The cylinder liner is made of fine grained, pearlite cast iron and fitted in a bore in the engine frame. The liner is clamped by the cylinder head and is guided by a bore at the bottom of the cooling water space of the engine frame. The liner can thus expand freely downwards when heated during the running of the engine. Sealing for the cooling water is obtained by means of rubber rings which are fitted in grooves machined in the liner.

Cooling water is supplied at the bottom of the cooling water space between the liner and the engine frame and leaves through bores in the top of the frame to the cooling water jacket.

Cylinder head

The cylinder head is of cast iron, made in one piece. It has a central bore for the fuel injection valve and bores for two exhaust valves, two inlet valves, indicator valve and cooling water.

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

The cylinder head has a screwed-on coaming which encloses the valves. The coaming is closed with a top cover and thus provides an oil tight enclosure for the valve gear.

Air inlet and exhaust valves

The inlet and exhaust valve spindles are different.

The valves are made of heat-resistant material. Hard metal is welded on to the valve spindle seats.

The valve spindles are fitted with valve rotators which turn the spindles a little each time the valves open.

The cylinder head is equipped with replaceable seat rings for inlet and exhaust valves.

The valve seat rings for inlet and exhaust valves are different due to dual fuel running.

The seat rings are made of heat-resistant steel, hardened on the seating surface and water cooled in order to assure low valve temperature and increased overhaul intervals.

Valve actuating gear

The rocker arms are actuated through rollers, roller guides and push rods. The roller guides for fuel pump and for inlet and exhaust valves are mounted in one common housing for each cylinder. This housing is bolted to the engine frame.

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

The valve actuating gear is pressure-feed lubricated from the centralized lubricating system of the engine. A non-return valve blocks the oil inlet to the rocker arms during prelubricating.

Fuel injection system

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

The injection pump is mounted on the valve gear housing by means of two screws. The pump consists of a pump housing, a centrally placed pump barrel and a plunger. The pump is activated by the fuel cam, and the volume injected is controlled by turning the plunger.

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

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

The shielding tube has two holes in order to ensure that any leakage will be drained off to the cylinder head bore. The bore is equipped with drain channel and pipe.

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

Gas injection equipment

Each Cylinder unit has its own injection equipment, comprising injection valve “SOGAV valve” , casted gas valve housing and injection pipe.

The gas supply parts and gas valve housing is made as double walled parts, which mean that the gas carrying pipes/parts has a pipe outside to catch the gas if a leakage should appear.

The double walled pipe’s/part’s is connected to a suction fan which are venting the room between inner pipe and outer pipe, and a gas detector is mounted in the suction system to see if gas is present.
If gas is present the gas will be shut off and the nitrogen purging system will purge all the gas equipment.

The quantity injected into each cylinder is regulated by the electrical system SACOS.

Nitrogen purging system

In the end of the gas pipe installed on all cylinder heads, is installed a nitrogen purging valve, which will open to purge the gas pipe’s/part’s if a gas leakage should appear.

Piston

The piston, which is oil-cooled and of the composite type, has a body made of nodular cast iron and a crown made of forged deformation resistant steel. It is fitted with 3compression rings and 1 oil scraper ring in hardened ring grooves.

Figure 1: Piston

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

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

Oil is supplied to the cooling oil space through channels from the oil grooves in the piston pin bosses. Oil is drained from the cooling oil space through ducts situated diametrically to the inlet channels.

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

Connecting rod

The connecting rod is die-forged. The big-end has an inclined joint in order to facilitate the piston and connecting rod assembly to be withdrawn up through the cylinder liner. The joint faces on connecting rod and bearing cap are serrated to ensure precise location and to prevent relative movement of the parts.

The connecting rod has bored channels for supply of oil from the big-end to the small-end.

The big-end bearing is of the trimetal type coated with a running layer.

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

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

Crankshaft and main bearings

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

At the flywheel end the crankshaft is fitted with a gear wheel which through an intermediate wheel drives the camshaft.

Also fitted here is a coupling flange for connection of a generator. At the opposite end (front end) there is a claw-type coupling for the lub. oil pump or a flexible gear wheel connection for lub. oil and water pumps.

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

Camshaft and camshaft drive

The inlet and exhaust valves as well as the fuel pumps of the engine are actuated by a camshaft. The camshaft is placed in the engine frame at the control side (left side, seen from the flywheel end).

The camshaft is driven by a gear wheel on the crankshaft through an intermediate wheel, and rotates at a speed which is half of that of the crankshaft.

The camshaft is located in bearing bushes which are fitted in bores in the engine frame. Each bearing is replaceable and locked in position in the engine frame by means of a locking screw.

A guidering mounted at the flywheel end guides the camshaft in the longitudinal direction.

Each section is equipped with fixed cams for operation of fuel pump, air inlet valve and exhaust valve.

The foremost section is equipped with a splined shaft coupling for driving the fuel oil feed pump (if mounted). The gear wheel for driving the camshaft as well as a gear wheel connection for the governor drive are screwed on to the aftmost section.

The lubricating oil pipes for the gear wheels are equipped with nozzles which are adjusted to apply the oil at the points where the gear wheels are in mesh.

Governor

The engine speed is controlled by an electric governor.

Monitoring and control system

All media systems are equipped with thermometers and manometers for local reading and for the most essential pressures the manometers are together with tachometers centralized in an engine-mounted instruments panel.

The number of and type of parameters to have alarm function are chosen in accordance with the requirements from the classification societies.

The engine has as standard shutdown functions for lubricating oil pressure low, cooling water temperature high and for overspeed.

Turbocharger system

The turbocharger system of the engine, which is a constant pressure system, consists of an exhaust gas receiver, a turbocharger, a charging air cooler and a charging air receiver, the latter being intergrated in the engine frame.

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

The turbocharger presses the air through the charging air cooler to the charging air receiver. From the charging air receiver, the air flows to each cylinder, through the inlet valves.

The charging air cooler is a compact tube-type cooler with a large cooling surface. The cooling water is passed twice through the cooler, the end covers being designed with partitions which cause the cooling water to turn.

The cooling water tubes are fixed to the tube plates by expansion.

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

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

In the cooled intermediate piece a thermometer for reading the exhaust gas temperature is fitted and there is also possibility of fitting a sensor for remote reading.

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

Compressed air system

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

The compressed air system comprises a main starting valve, an air strainer, a remote controlled starting valve and an emergency starting valve which will make it possible to start the engine in case of a power failure.

Fuel oil system

The built-on fuel oil system consists of the fuel oil filter and the fuel injection system.

The fuel oil filter is a duplex filter. The filter is equipped with a three-way cock for single or double operation of the filters.

Fuel oil leakage is led to a leakage alarm which is heated by means of fuel return oil.

The fuel leak oil can be reused and led to the fuel oil tank as it not are mixed with the waste oil.

As mentioned above the waste oil is separated from leak oil, and led to the waste oil tank.

Internal nozzle cooling system

The nozzles of the injection valves on the engines are temperature controlled by means of a circuit containing the engines lubricating oil as media.

The system maintains a nozzle surface temperature low enough to prevent formation of carbon trumpets on the nozzle tips during high load operation and high enough to avoid cold corrosion during idling or low-load operation.

Lubricating oil system

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

The lubricating oil pump is of the gear wheel type with built-in pressure control valve. The pump draws the oil from the sump in the base frame, and on the pressure side the oil passes through the lubricating oil cooler and the filter which both are mounted on the engine.

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

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

Cooling water system

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

The water in the low temperature system is passed through the charge air cooler and the lubricating oil cooler, and the alternator if the latter is water cooled.

The low temperature system is normally cooled by fresh water.

The high temperature cooling water system cools the engine cylinders and the cylinder head. The high temperature system is always cooled by fresh water.

Tools

The engine can be delivered with all necessary tools for the overhaul of each specific plant.

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Main particulars

Main particulars

Cycle	:	4-stroke
Configuration	:	In-line
Cyl. nos available	:	5 - 6 - 7 - 8
Power range	:	625 - 1200 kW
Speed	:	720/750/900 rpm
Bore	:	225 mm
Stroke	:	300 mm
Stroke/bore ratio	:	1.33 : 1
Piston area per cyl.	:	398 cm^2
swept volume per cyl.	:	11.9 ltr
Compression ratio	:	12.0 : 1
Max. design combustion pressure	:	145 bar*
Turbocharging principle	:	Constant pressure system and intercooling
Fuel quality acceptance	:	MGO (DMA, DMZ) according ISO8217-2010
Gas/Fuel ratio: at load 20-100%	:	99/1
Gas methane number	:	≥ 80

Power lay-out		MCR version		
Speed	rpm	720	750	900
Mean piston speed	m/sec.	7.2	7.5	9.0
Mean effective pressure	bar	17.5	16.8	16.8
Power per cylinder	kW per cyl.	125	125	150

These values are general. For specific values, please see the acceptance test protocol.

Firing order

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

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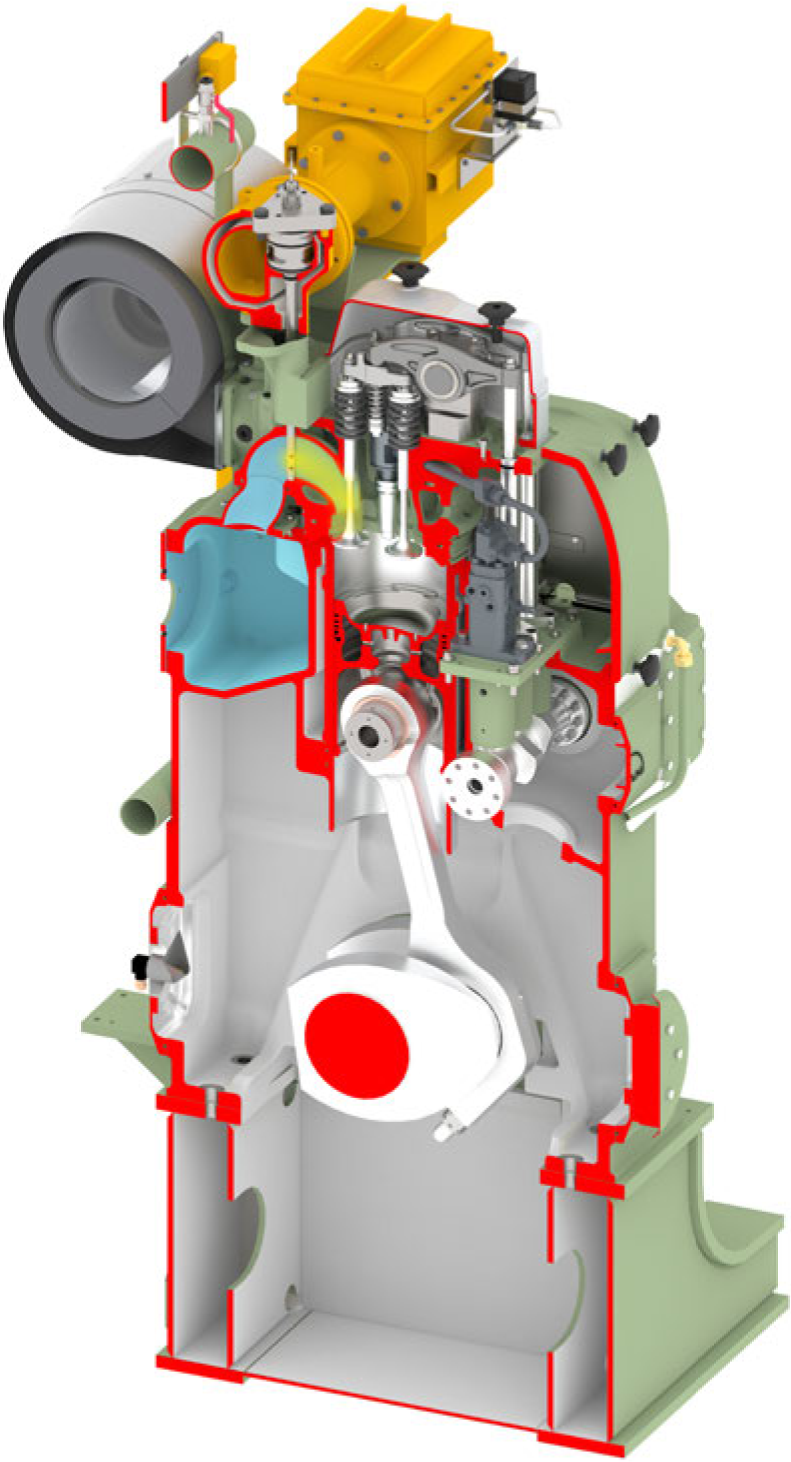
Cross section

Cross section



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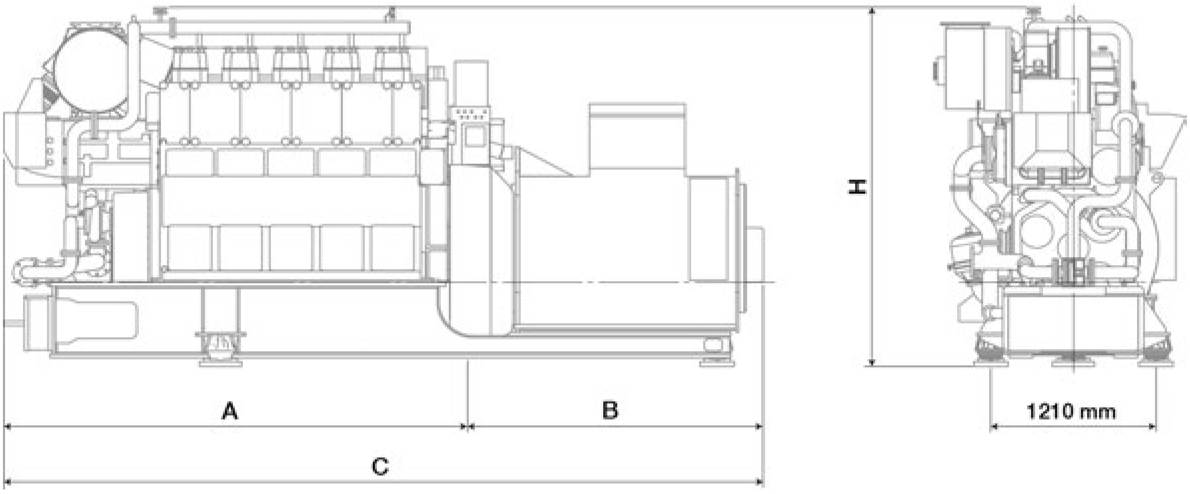
Dimensions and weights

Dimensions



Cyl. no	A (mm)	B (mm)	* C (mm)	H (mm)	** Dry weight GenSet (t)
5 cyl. engine (720/750 rpm	3469	2202	5671	2749	17.3
6 cyl. engine (720/750 rpm)	3839	2252	6091	2749	19.0
6 cyl. engine (900 rpm)	3839	2252	6091	2749	19.2
7 cyl. engine (720/750 rpm)	4209	2302	6511	2749	21.4
7 cyl. engine (900 rpm)	4276	2302	6578	2749	21.4
8 cyl. engine (720/750 rpm)	4579	2352	6931	2749	23.3
8 cyl. engine (900 rpm)	4896	2352	7248	2749	23.4

Free passage between the engines, width 600 mm and height 2000 mm
Distance between engines - see page 2

* Depending on alternator
** Weight included a standard alternator

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

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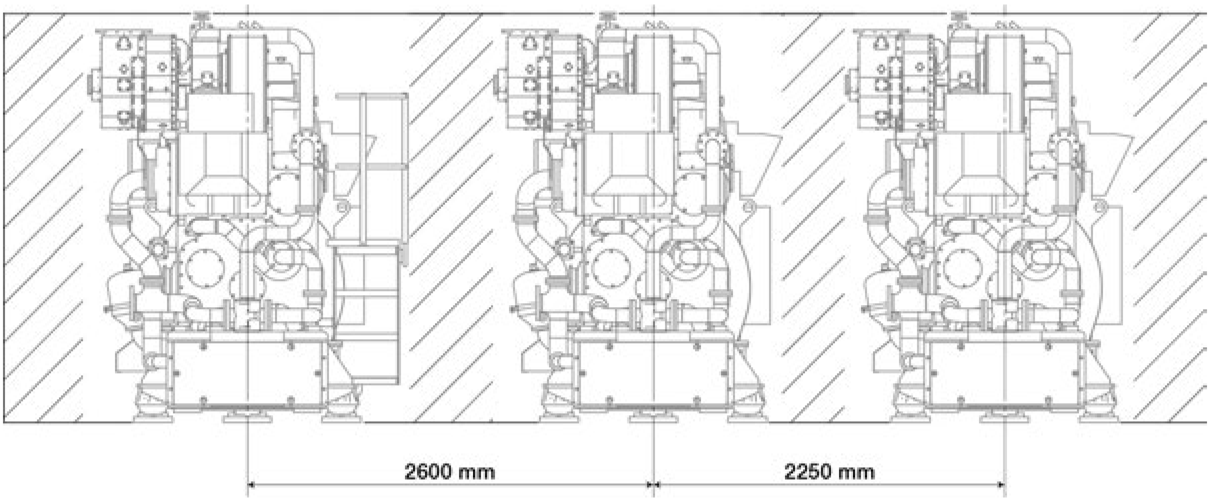
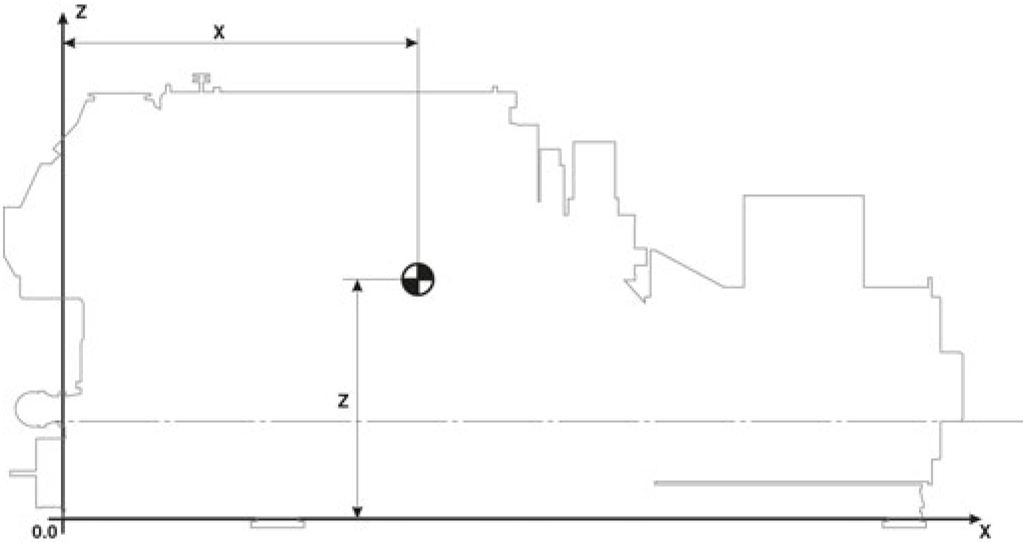
Distance between engines



Centre of gravity

Description



cyl. no	X (mm) 720/750 rpm	Z (mm) 720/750 rpm	X (mm) 900 rpm	Z (mm) 900 rpm
5 cyl. engine	2310	1035		
6 cyl. engine	2530	1045	2535	1040
7 cyl. engine	2775	1045	2765	1045
8 cyl. engine	3025	1050	3010	1045

X = Horizontal - measured from base frame front
Z = Vertical - measured from base frame bottom

The values here are based on a standardized alternator model

The actual values will depend on the alternator chosen, and other plant specification

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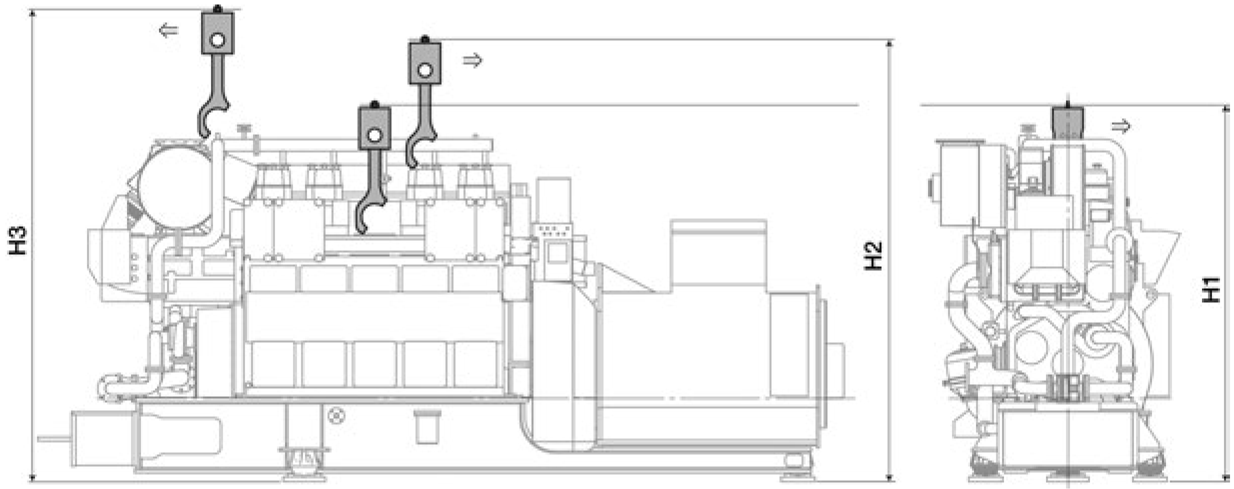
Overhaul areas

Dismantling height for piston



cyl. no	H1 (mm)	H2 (mm)	H3 (mm)
5- 8 cyl. engine	2680	3195	3435

H1: For dismantling of piston and connecting rod at the camshaft side

H2: For dismantling of piston and connecting rod passing the alternator (Remaining cover not removed)

H3: For dismantling of piston and connecting rod passing the turbocharger

If lower dismantling height is required, special tools can be delivered. *See also B 10 01 1, Low dismantling height*

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Dismantling space

Is must be considered that there is sufficient space for pulling the charge air cooler element, air filter on the turbocharger, lubricating oil cooler, lubricating oil filter cartridge and bracing bolt.

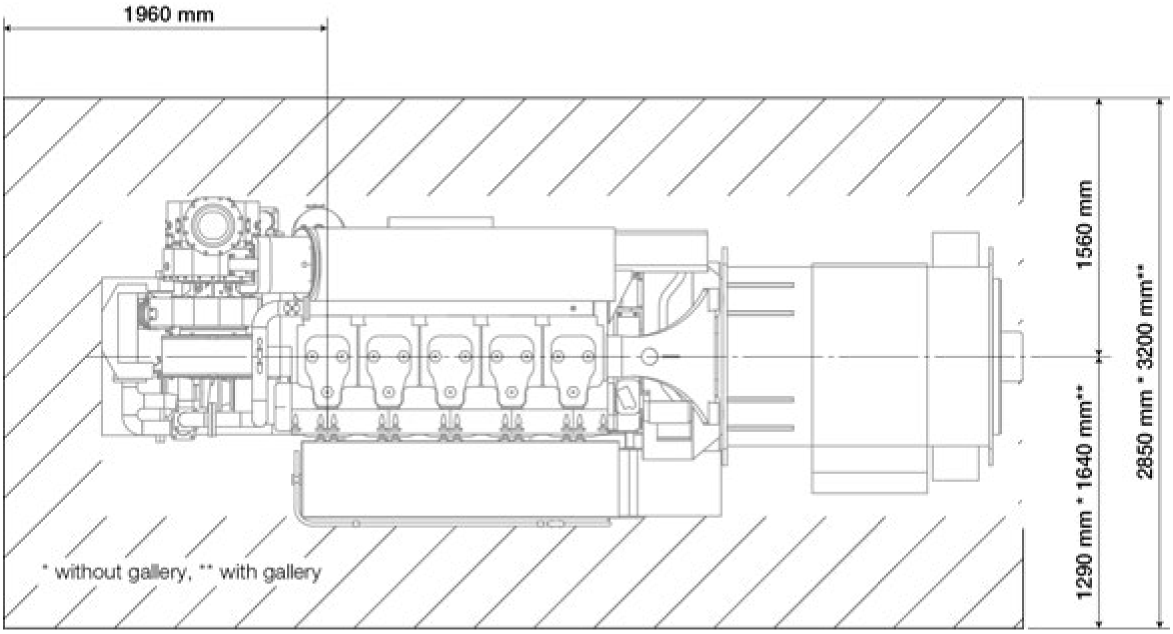

Figure 1: Overhaul areas for charge air cooler element, turbocharger filter element, lubricating oil cooler, lubricating oil filter cartridge and bracing bolt

Low dismantling height

Space requirements

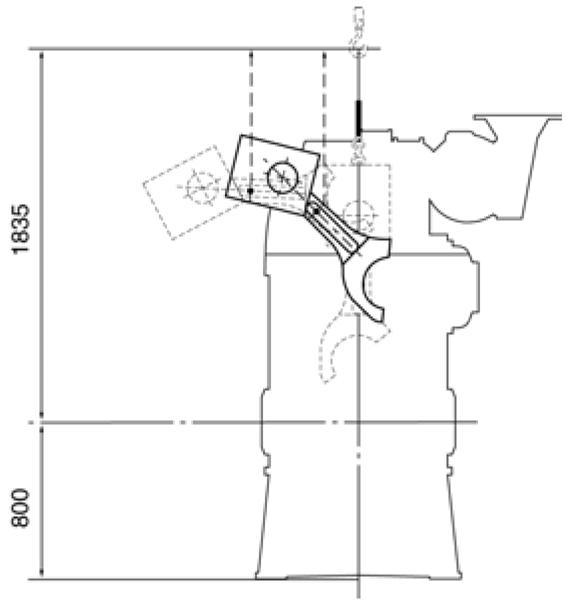

Figure 1: Minimum dismantling height of pistons only with special tools.

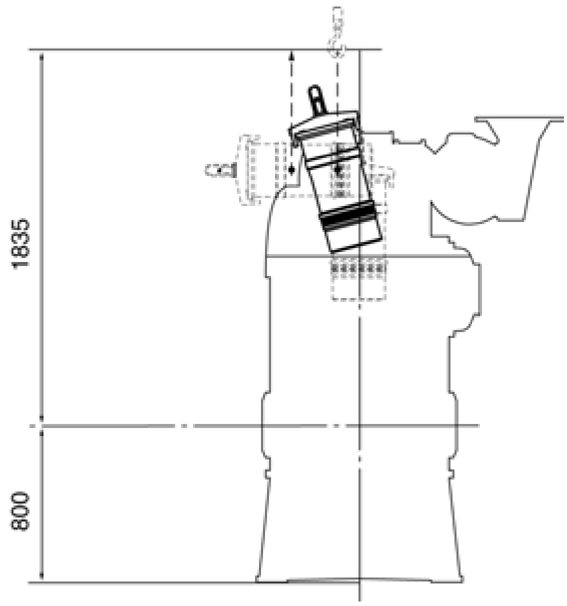

Figure 2: Minimum lifting height of cylinder liner only with special tools.

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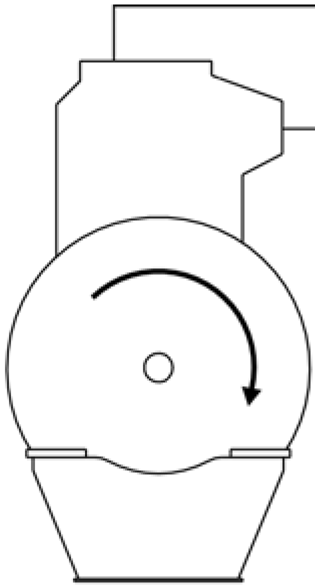
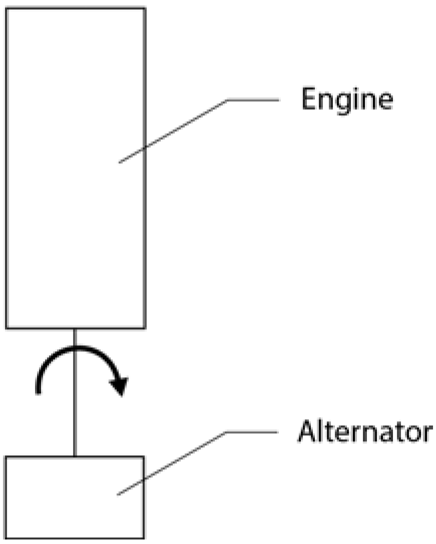
Engine rotation clockwise

Engine rotation clockwise



Direction of rotation seen from flywheel end "Clockwise"



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Internal fuel oil system

Internal fuel oil diagram

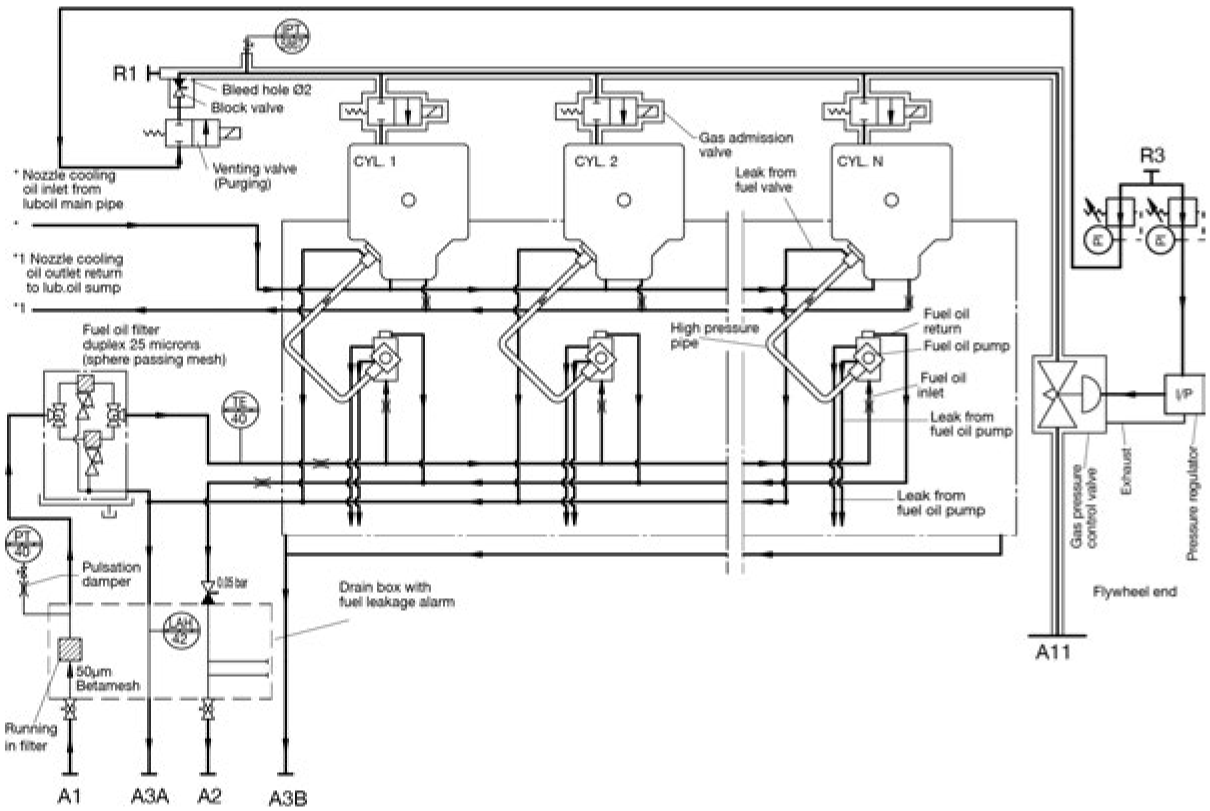

Figure 1: Diagram for internal fuel oil system (for guidance only, please see the plant specific engine diagram)

Pipe description		
A1	Fuel oil inlet	DN20
A2	Fuel oil outlet	DN20
A3A	Clean leak oil to service tank	DN15
A3B	Waste oil outlet to sludge tank	DN15
A11	Gas inlet	DN80
R1	Ø12 pipe connections	Ø10
R3	Inert gas (purge) inlet, 6 bar (g)	DN25

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

General

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

- the running-in filter

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Internal fuel oil system
Description

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- the high-pressure injection equipment
- gas injection equipment
- nitrogen purging system
- an internal nozzle cooling system
- a waste oil system

Fuel oil system

The fuel oil is delivered to the injection pumps by means of an external feed pump through an external safety filter.

The safety filter is a duplex filter of the split type with a filter fineness of 25 microns (sphere passing mesh). The filter is equipped with a common three-way cock for manual change of both the inlet and outlet side.

Running-in filter

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

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

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

Fuel injection equipment

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

The injection equipment and the distribution supply pipes are housed in a fully enclosed compartment thus minimizing heat losses from the preheated fuel.

This arrangement reduces external surface temperatures and the risk of fire caused by fuel leakage.

Fuel oil injection pump

The fuel oil injection pump is installed on the roller guide housing directly above the camshaft, and it is activated by the cam on the camshaft through roller guides fitted in the roller guide housing.

The injection amount of the pump is regulated by transversal displacement of a toothed rack in the side of the pump housing.

By means of a gear ring, the pump plunger with the two helical millings, the cutting-off edges, is turned. Hereby the length of the pump stroke is specified when the plunger closes the inlet holes until the cutting-off edges again uncover the holes.

The release of high pressure through the cutting-off edges presses the oil with great force against the wall of the pump housing. At the spot, two exchangeable plug screws are mounted.

The amount of fuel injected into each cylinder unit is adjusted by means of the governor.

It maintains the engine speed at the preset value by a continuous positioning of the fuel pump racks, via a common regulating shaft and spring-loaded linkages for each pump.

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

Fuel oil injection valve

The joint surface between the nozzle and holder is machine-lapped to make it oil-tight.

The fuel injector is mounted in the cylinder head by means of the integral flange in the holder and two studs with distance pieces and nuts.

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

Fuel oil high pressure pipe

The high-pressure pipe between fuel injection pump and fuel injector is a shielded pipe with coned pipe ends for attachment by means of a union nut, and a nipple nut, respectively.

The high-pressure pipe is led through a bore in the cylinder head, in which it is surrounded by a shielding tube, also acting as union nut for attachment of the pipe end to the fuel injector.

The shielding tube has two holes in order to ensure that any leakage will be drained off to the cylinder head bore. The bore is equipped with drain channel and pipe.

The shielding tube is supported by a sleeve, mounted in the bore with screws.

The sleeve is equipped with O-rings in order to seal the cylinder head bore.

Gas injection equipment

Each Cylinder unit has its own injection equipment, comprising injection valve “SOGAV valve” , casted gas valve housing and injection pipe.

The gas supply parts and gas valve housing is made as double walled parts, which mean that the gas carrying pipes/parts has a pipe outside to catch the gas if a leakage should appear.

The double walled pipe’s/part’s is connected to a suction fan which are venting the room between inner pipe and outer pipe, and a gas detector is mounted in the suction system to see if gas is present.
If gas is present the gas will be shut off and the nitrogen purging system will purge all the gas equipment.

The quantity injected into each cylinder is regulated by the electrical system SACOS.

Nitrogen purging system

In the end of the gas pipe installed on all cylinder heads, is installed a nitrogen purging valve, which will open to purge the gas pipe’s/part’s if a gas leakage should appear.

Internal nozzle cooling system

The nozzles of the injection valves on the engines are temperature controlled by means of a circuit from the engines lubricating oil system.

The system maintains a nozzle surface temperature low enough to prevent formation of carbon trumpets on the nozzle tips during high load operation and high enough to avoid cold corrosion during idling or low-load operation.

Waste oil system

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

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

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

Clean leak fuel tank

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

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

Sludge tank

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

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

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

Optionals

Besides the standard components, the following standard optionals can be built-on:

- Pressure differential alarm high
  - PDAH 43-40 Fuel oil, inlet and outlet filter
- Pressure differential transmitting
  - PDT 43-40 Fuel oil, inlet and outlet filter
- Pressure alarm low
  - PAL 40 Fuel oil, inlet fuel oil pump

- Pressure transmitting
  - PT40 Fuel oil, inlet fuel oil pump
- Temperature element
  - TE40 Fuel oil, inlet fuel oil pump

Data

For pump capacities, see "*D 10 05 0 List of capacities*"

Fuel oil consumption for emissions standard is stated in "*B 11 01 0 Fuel oil consumption for emissions standard*"

Set points and operating levels for temperature and pressure are stated in "*B 19 00 0 operation data & set points*"

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Diesel fuel (DMA, DFA) specifications

General information

Diesel fuel is a middle distillate refined from crude oil. It is also referred to as gas oil, marine gas oil (MGO) and diesel oil. It must not contain any residue from crude oil refining. The fuel may consist of synthetic components (e.g. BtL, CtL, GtL, & HVO).

Selection of suitable diesel fuel

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

Specifications and approvals

The fuel quality varies regionally and is dependent on climatic conditions. All requirements specified in the current edition of ISO 8217 apply.

The following values must be maintained at the engine inlet:

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

Diesel fuel (DMA, DFA) specifications

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

Table 1: Requirements for diesel fuel

Remarks:

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

2) Always in relation to the currently applicable edition.

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

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

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

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

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

8) Determined on 10% distillation residue.

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

The following fuels are approved for use:

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

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

Viscosity

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

Military fuel specification

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

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

Cold suitability

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

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

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

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

Bio-fuel admixture

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

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

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

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

Diesel fuel (DMA, DFA) specifications

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Analyses

Analysis of fuel oil samples is very important for safe engine operation. We can analyse fuel for customers at laboratory PrimeServLab.

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

Diesel fuel (DMA, DFA) specifications

Specification of natural gas

Gas types and gas quality

Natural gas is obtained from a wide range of sources. They can be differentiated not only in terms of their composition and processing, but also their energy content and calorific value.

Combustion in engines places special demands on the quality of the gas composition.

The following section explains the most important gas properties.

Requirements for natural gas

The gas should:

- comply with the general applicable specifications for natural gas, as well as with specific requirements indicated in the table Requirements for natural gas.
- be free of dirt, dry and cooled (free of water, hydrocarbon condensate and oil) when fed to the engine. If the dirt concentration is higher than 50 mg/Nm^3, a gas filter must be installed upstream of the supply system.

You can check the gas quality using a gas analyser.

Measures

In the gas distribution systems of different cities that are supplied by a central natural gas pipeline, if not enough natural gas is available at peak times, a mixture of propane, butane and air is added to the natural gas in order to keep the calorific value of Wobbe index constant. Although this does not actually change the combustion characteristics for gas burners in relation to natural gas, the methane number is decisive in the case of turbocharged gas engines. It falls drastically when these kind of additions are made.

To protect the engine against damage in such cases, the gas engines are provided with antiknock control.

Methane number

The most important prerequisite that must be met by the gas used for combustion in the gas engine is knock resistance. The reference for this evaluation is pure methane which is extremely knock-resistant and is therefore the name used for the evaluation basis:

- Methane number (MN). Calculation according to EN 16726 using GasCalc 2.5.2

Pure methane contains the methane number 100; hydrogen was chosen as the zero reference point for the methane number series as it is extremely prone to knocking. See the table titled Anti-knocking characteristic and methane number.

However, pure gases are very rarely used as fuel in engines. These are normally natural gases that also contain components that are made up of high-quality hydrocarbons in addition to knock-resistant methane and often significantly affect the methane number. It is clearly evident that the propane and butane components of natural gas reduce the anti-knock characteristic. In contrast, inert components, such as N_2 and CO_2, increase the anti-knock characteristic. This means that methane numbers higher than 100 are also possible.

Anti-knock characteristic of different gases expressed as methane number (MN).

Gas	Methane number (MN)
Hydrogen	0.0
N-butane 99 %	2.0

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Gas	Methane number (MN)
Butane	10.5
Butadiene	11.5
Ethylene	15.5
β-butylene	20.0
Propylene	20.0
Isobutylene	26.0
Propane	35.0
Ethane	43.5
Carbon monoxide	73.0
Natural gas	70.0 – 96.0
Natural gas + 8% N_2	92.0
Natural gas + 8% CO_2	95.0
Pure methane	100.0
Natural gas + 15% CO_2	104.4
Natural gas + 40% N_2	105.5

Table 1: Anti-knock characteristic and methane number

Determining the methane number

can determine the gas methane number with high precision by analyzing the gas chemistry.

The gas analysis should contain the following components in vol. % or mol %:

Carbon dioxide	CO_2
Nitrogen	N_2
Oxygen	O_2
Hydrogen	H_2
Carbon monoxide	CO
Water	H_2O
Hydrogen sulphide	H_2S
Methane	CH_4
Ethane	C_2H_6
Propane	C_3H_8
I-butane	$I\text{-}C_4H_{10}$
N-butane	$n\text{-}C_4H_{10}$
Higher hydrocarbons	
Ethylene	C_2H_4
Propylene	C_3H_6

The sum of individual components must be 100 %.

Gas	mol %
CH_4	94.80
C_2H_6	1.03
C_3H_8	3.15
C_4H_{10}	0.16
C_5H_{12}	0.02
CO_2	0.06
N_2	0.78

Table 2: Exemplary composition natural gas MN 80

Fuel specification for natural gas

The fuel at the inlet of the gas engine's gas valve unit must match the following specification.

Fuel		Natural gas	
		Unit	Value
Hydrogen sulphide content (H_2S)	max.	mg/Nm^3	5
Total sulphur content	max.		30
Hydrocarbon condensate	–		not permissible at engine inlet
Humidity	–		200 (max. operating pressure ≤ 10 bar) 50 (max. operating pressure > 10 bar) Condensate not permissible
Total fluorine content	max.		5
Total chlorine content	max.		10
Particle concentration	max.		50
Particle size	max.	µm	10

Table 3: Requirements for natural gas

One Nm^3 is the equivalent to one cubic metre of gas at 0 °C and 101.32 kPa.

Fuel conditions

Fuel conditions	
Type of gas	natural gas
Methane no.	≥ 80

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Specification of natural gas

Description

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Fuel conditions	
Gas fuel LHV	38000 kJ/kg
Pilot fuel	DMA or DMZ
Liquid fuel LHV	42700 kJ/kg

Table 4: Fuel conditions

Description for biofuels

Biofuels

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

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

Liquid biofuels used in MAN 4-stroke small bore engines

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

Non-transesterified biofuel

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

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

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

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

Transesterified biofuel – FAME (fatty acid methyl ester)

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

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

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

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

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

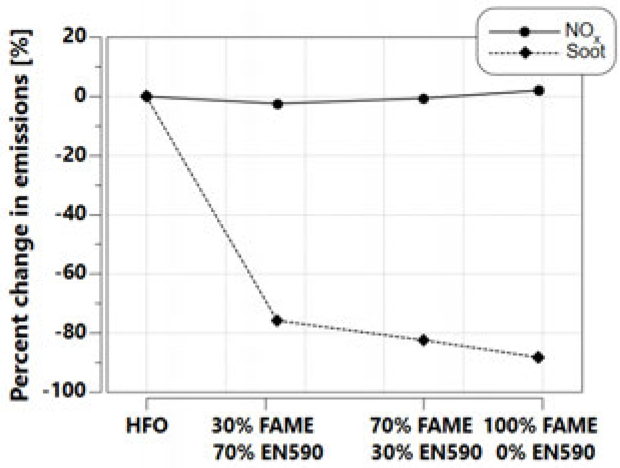

Figure 1: Emission behavior with FAME.

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

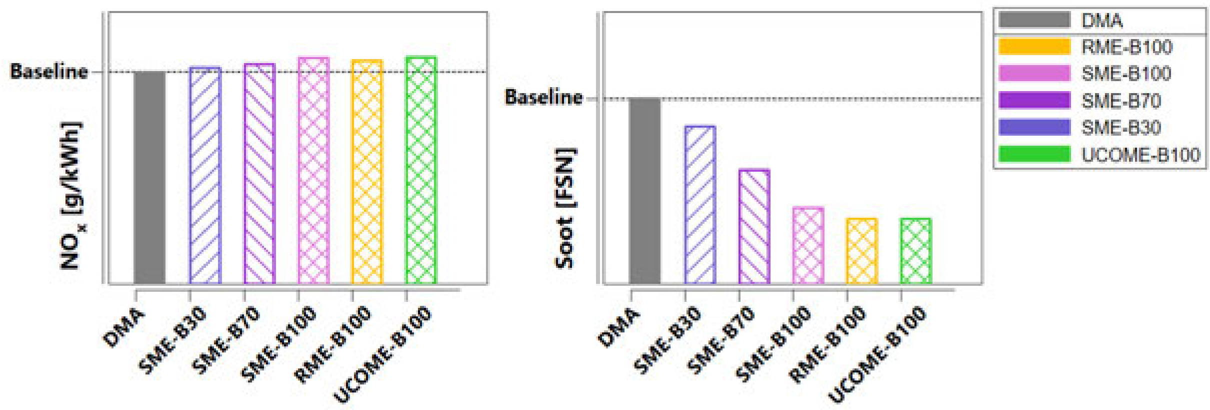

Figure 2: NOx and soot emission trends

HVO (hydrogenated vegetable oil)

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

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

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

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

Operation with biofuel

Please contact MAN Energy Solutions at an early stage of project.

Requirements on plant side

Biofuel has to be divided into 3 categories.

Category 1

Transesterified biofuel

For example:

- Biodiesel (FAME)

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

Category 2

Non-transesterified biofuel and pour point below 20°C

For example:

- Vegetable oil
- Rape-seed oil

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

Category 3

Non-transesterified biofuel and pour point above 20° C

For example:

- Palm oil
- Stearin
- Animal fat
- Frying fat

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

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

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

Additionally

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

Requirements on engine

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

Please be aware

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

Gaseous biofuels used in engines

Biogas

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

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

Synthetic natural gas (SNG)

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

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

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

Implications on engines with the use of biofuels

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

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

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

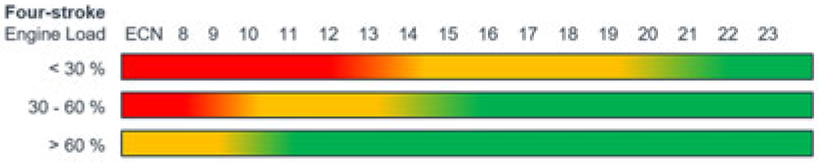

Figure 3: ECN operational reference ranges (CIMAC Fuel quality guide 2011)

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

General

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

Low sulphur HFO

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

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

Low sulphur distillates

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

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

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

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

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

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

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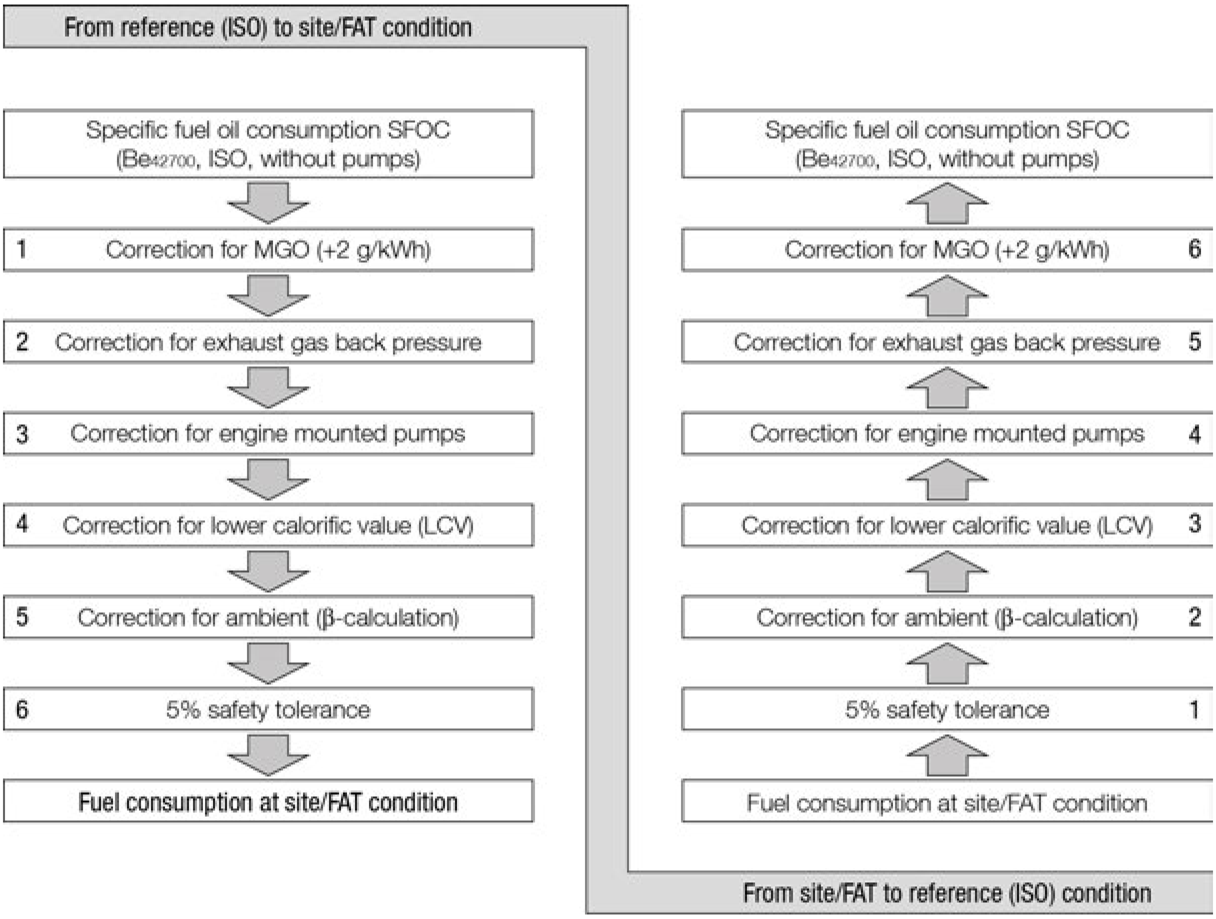
Calculation of specific fuel oil consumption (SFOC)

General

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



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

Fuel consumption (kg/h):

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

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

$$Be0 = (\,\textit{Fuel oil}\,) - (\,\textit{Leak oil}\,)$$

Leak oil

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

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

Tolerance of the values is +/-25%.

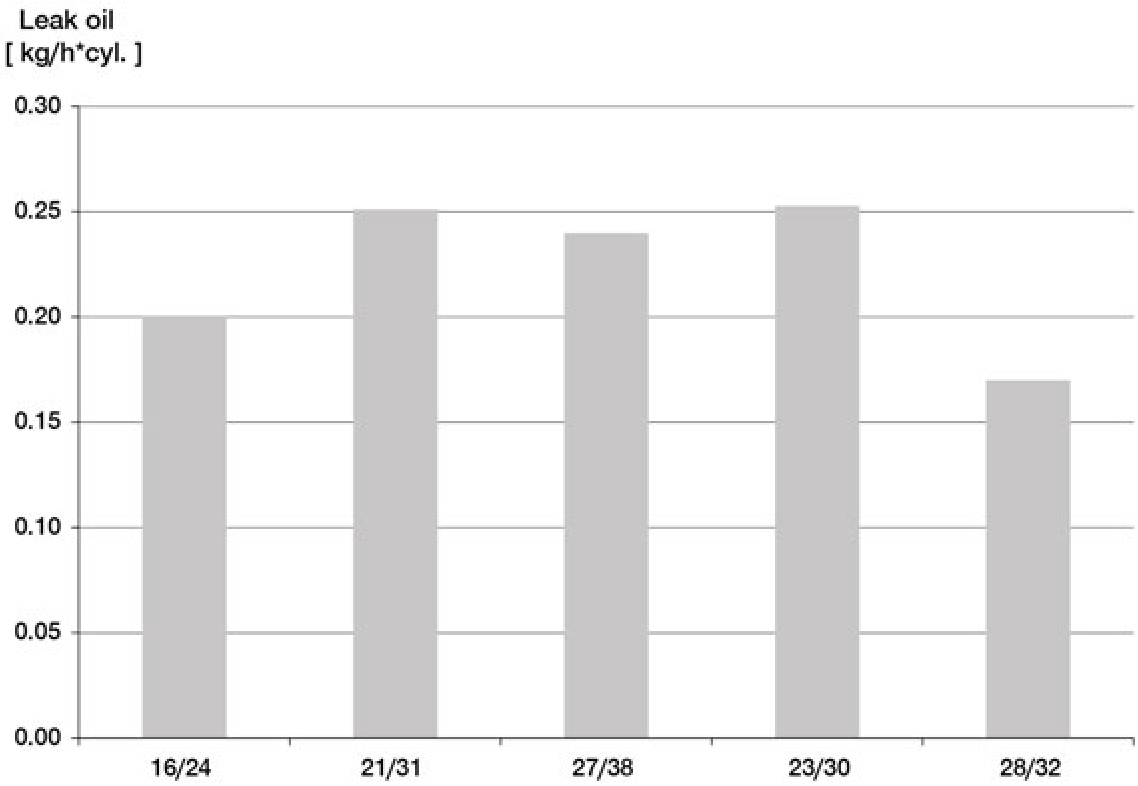


Figure 1: Leak oil on full load for MGO operation (for guidance only)

1) Safety tolerance 5%

Safety tolerance 5% is subtracted from fuel consumption

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

2) Correction for ambient (β-calculation)

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

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

The formula is valid within the following limits:

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

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

β Fuel consumption factor

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

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

Example

Reference values:

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

At site:

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

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

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

3) Correction for lower calorific value (LCV)

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

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

$$Be3 = Be2 * LCV\,f$$

4) Correction for engine mounted pumps

Engine type 16/24, 27/38

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

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

Engine type 21/31

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

6, 7, 8, 9 cyl. engine

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

Engine type 23/30, 28/32

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

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

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

5) Correction for exhaust gas back pressure

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

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

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

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

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

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

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

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

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Fuel oil consumption for emissions standard

L23/30DF - IMO Tier III

% Load	100	75	50	25
L23/30DF - Gas mode				
Specific energy consumption (kJ/kWh) with Gas/MGO without attached pumps [1) 2)]				
5-8 cyl. engines: 125 kW/cyl. @ 720 rpm	8913	9304	9895	12603
5-8 cyl. engines: 125 kW/cyl. @ 750 rpm	8913	9304	9895	12603
6-8 cyl. engines: 150 kW/cyl. @ 900 rpm	8913	9402	9895	12955

[1)] Tolerance for +5%. Please note that the additions to fuel consumption must be considered before the tolerance is taken into account.
[2)] Based on reference conditions, *see "Reference conditions"*
[3)] Pilot fuel is 1.5-2.0% of energy consumption at 100% load.

L23/30DF - Diesel mode				
Specific fuel consumption (g/kWh) with MGO without attached pumps [1) 2)]				
5-8 cyl. engines: 125 kW/cyl. @ 720 rpm	207.0	203.1	206.8	237.4
5-8 cyl. engines: 125 kW/cyl. @ 750 rpm	207	204	208	240
6-8 cyl. engines: 150 kW/cyl. @ 900 rpm	207	206	208	245

[1)] Tolerance for +5%. Please note that the additions to fuel consumption must be considered before the tolerance is taken into account.
[2)] Based on reference conditions, *see "Reference conditions"*

No of cylinders	Fuel oil consumption at idle running (kg/h)			
	5L	6L	7L	8L
Speed 720 rpm	9	11	13	15
Speed 750 rpm	10	12	14	16
Speed 900 rpm	14	17	20	23

All data provided in this document is non-binding and serves informational purposes only. Depending on the subsequent specific individual projects, the relevant data may be subject to changes and will be assessed and determined individually for each project. This will depend on the particular characteristics of each individual project, especially specific site and operational conditions.

IMO Tier III requirements

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

Tier III: NO_x technical code on control of emission of nitrogen oxides from diesel engines.

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

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

Reference conditions (according to ISO 3046-1: 2002; ISO 15550: 2002)

Air temperature before turbocharger t_r	°C	25
Ambient pressure p_r	bar	1
Relative humidity Φr	%	30
Engine type specific reference charge air temperature before cylinder t_{bar} [1)]	°C	34
Net calorific value NCV	kJ/kg	42,700

[1)] Specified reference charge air temperature corresponds to a mean value for all cylinder numbers that will be achieved with 25° C LT cooling water temperature before charge air cooler (according to ISO)

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

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

LT cooling water pump $$0.7 \times \left(\frac{110}{\text{load } \% + 10} \right) \%$$

HT cooling water pump $$0.7 \times \left(\frac{110}{\text{load } \% + 10} \right) \%$$

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MDO / MGO cooler

General

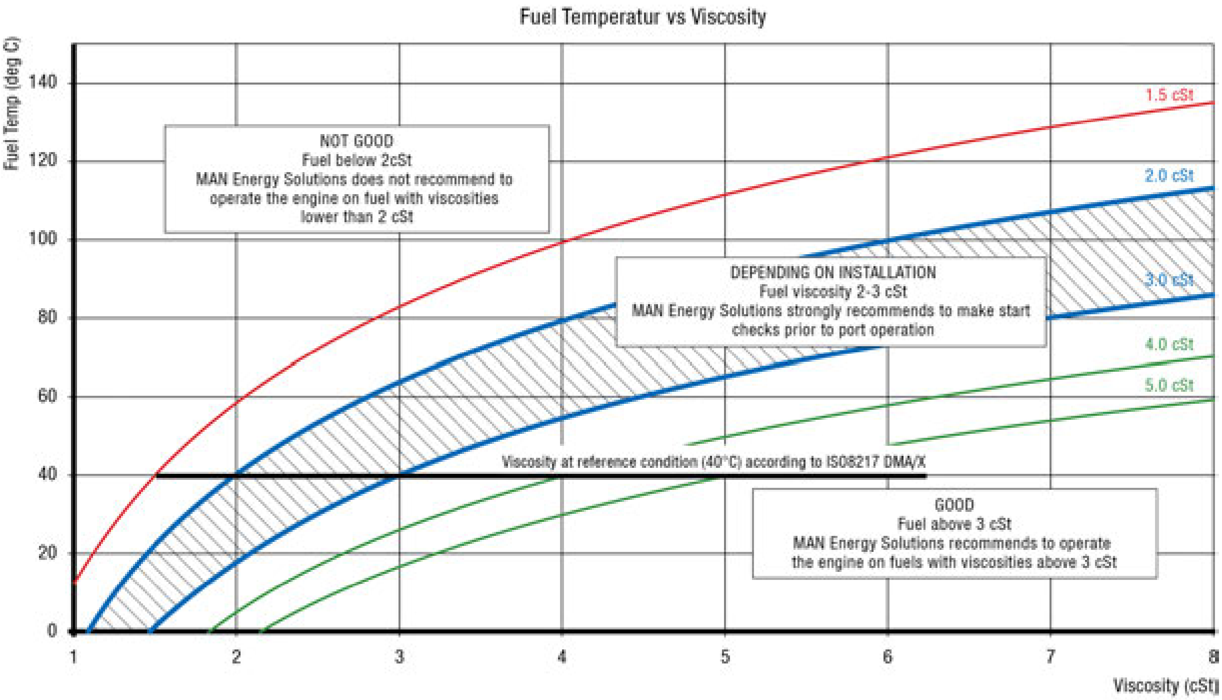

Figure 1: Fuel temperature versus viscosity.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Engine type	kW/cyl.
L16/24, L16/24S	0.5
L21/31, L21/31 Mk 2, L21/31S	1.0
L27/38, L27/38S	1.5

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

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

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

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

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

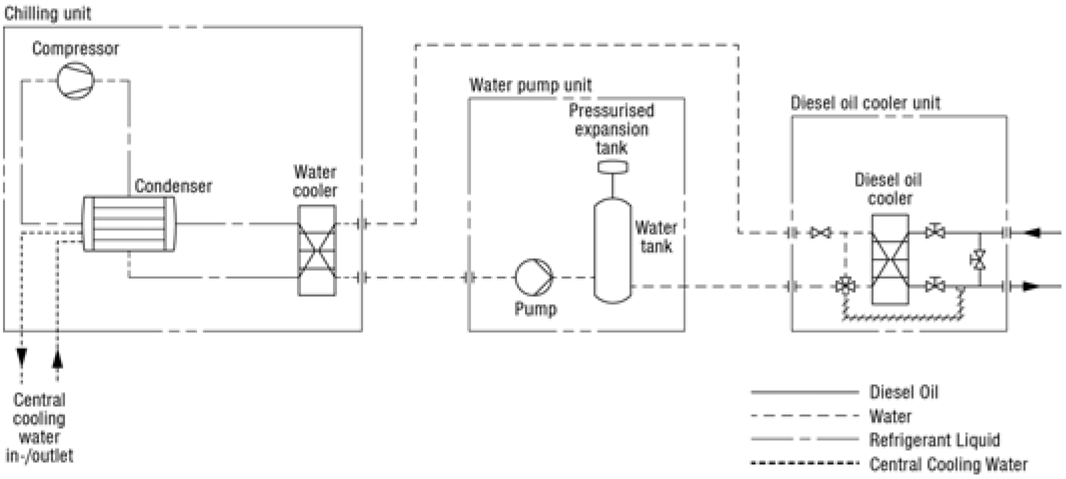

Figure 2: Chiller.

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Internal lubricating oil system

Internal lubricating oil system

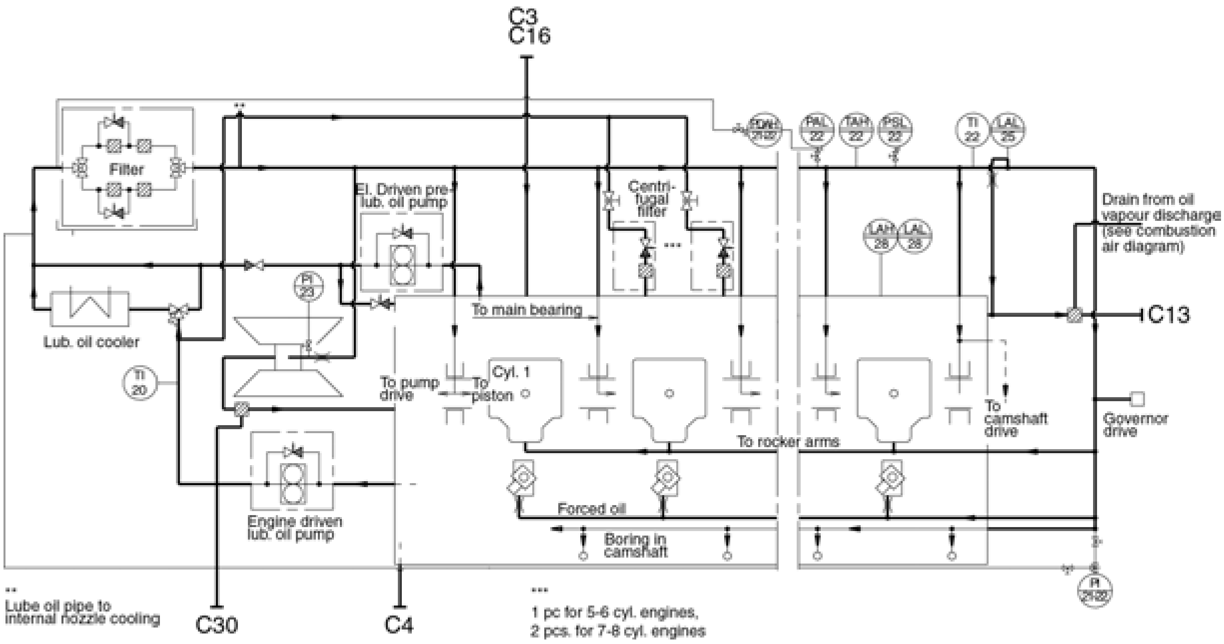

Figure 1: Diagram for internal lubricating oil system (for guidance only, please see the plant specific engine diagram

Pipe description		
C3	Lubricating oil from separator	DN25
C4	Lubricating oil to separator	DN25
C13	Oil vapour discharge*	DN50
C16	Lubricating oil supply	DN25
C30	Venting of oil vapour from TC	DN40

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

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

General

As standard the lubricating oil system is based on wet sump lubrication. All moving parts of the engine are lubricated with oil circulating under pressure in a closed built-on system.

The lubricating oil is furthermore used for the purpose of cooling the pistons.

The standard engine is equipped with built-on:

- Engine driven lubricating oil pump
- Lubricating oil cooler

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- Lubricating oil thermostatic valve
- Duplex full-flow depth filter
- Pre-lubricating oil pump
- Centrifugal by-pass filter

Oil quantities

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

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

Max. velocity recommendations for external lubricating oil pipes:

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

Lubricating oil consumption

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

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

Quality of oil

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

System flow

The lubricating oil pump draws oil from the oil sump and presses the oil through the cooler and filter to the main lubricating oil pipe, from where the oil is distributed to the individual lubricating points. From the lubricating points the oil returns by gravity to the oil sump.

The main groups of components to be lubricated are:

1. Turbocharger
2. Main bearings, big-end bearing etc.
3. Camshaft drive
4. Governor drive
5. Rocker arms
6. Camshaft
7. For priming and during operation, the turbocharger is connected to the lubricating oil circuit of the engine, the oil serves for bearing lubrication.

   The inlet line to the turbocharger is equipped with an orifice in order to adjust the oil flow and a non-return valve to prevent draining during standstill.

The non-return valve has back-pressure function requiring a pressure slightly above the priming pressure to open in normal flow direction. In this way overflooding of the turbocharger is prevented during stand-still periods, where the pre-lubricating pump is running.

8. Lubricating oil for the main bearings is supplied through holes drilled in the engine frame. From the main bearings it passes through bores in the crankshaft to the connecting rod big-end bearings.

   The connecting rods have bored channels for supply of oil from the big-end bearings to the small-end bearings, which has an inner circumferential groove, and a pocket for distribution of oil in the bush itself and for supply of oil to the pin bosses and the piston cooling through holes and channels in the piston pin.

   From the front main bearings channels are bored in the crankshaft for lubricating of the pump drive.

9. The lubricating oil pipes, for the camshaft drive gear wheels, are equipped with nozzles which are adjusted to apply the oil at the points where the gear wheels are in mesh.
10. The lubricating oil pipe, and the gear wheels for the governor drive are adjusted to apply the oil at the points where the gear wheels are in mesh.
11. The lubricating oil to the rocker arms is led through pipes to each cylinder head. It continuos through bores in the cylinder head and rocker arm to the movable parts to be lubricated at rocker arms and valve bridge. Further, lubricating oil is led to the movable parts in need of lubrication.
12. Through a bore in the frame lubricating oil is led to the first camshaft bearing and through bores in the camshaft from where it is distributed to the other camshaft bearings.

Lubricating oil pump

The lubricating oil pump, which is of the gear wheel type, is mounted on the front end of the engine and is driven by means of the crankshaft through a coupling. The oil pressure is controlled by an adjustable spring- loaded relief valve built-on the oil pump.

Lubricating oil cooler

As standard the lubricating oil cooler is of the plate type. The cooler is mounted to the front end of the base frame.

Thermostatic valve

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

Built-on full-flow depth filter

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

Pre-lubricating

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

Running period of the pre-lubricating pump is preferably to be continuous. If intermittent running is required for energy saving purpose, the timing equipment should be set for shortest possible intervals, say 2 minutes of running, 10 minures of stand-still, etc. Further, it is recommended that the pre-lubricating pump is connected to the emergency switch board thus securing that the engine is not started without pre-lubrication.

Centrifugal by-pass filter

The centrifugal filter is a by-pass filter mounted directly on the engine base frame. the centrifugal filter is a supplement to the main filter.

Draining of the oil sump

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

Optionals

Besides the standard components, the following optionals can be built-on:

- Temperature element

  TE 29 Lubricating oil inlet main bearings

Branches for:

- External fine filter

External full/flow filter Branches for separator is standard.

Data

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

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

Crankcase ventilation

Crankcase ventilation

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

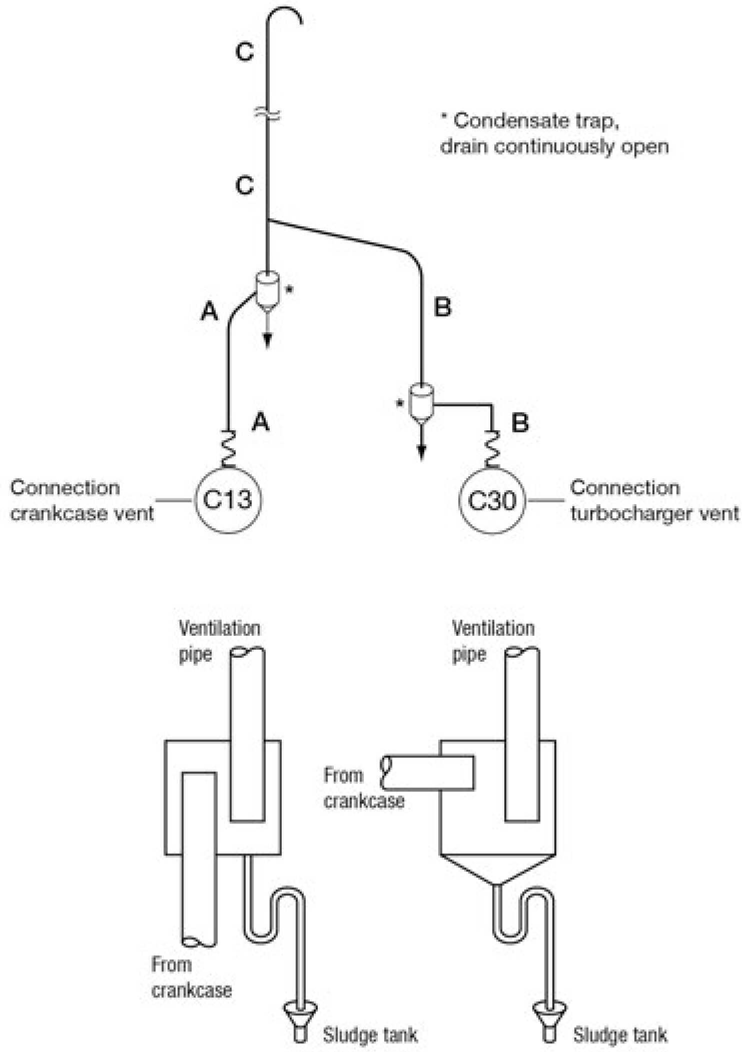

Figure 1: Crankcase ventilation

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

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

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

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

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

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

Table 1: Pipe diameters for crankcase ventilation

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

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

The crankcase ventilation flow rate is in the range of 3.5 – 5.0 ‰ of the combustion air flow rate [m³/h] at 100 % engine load.

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

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

Example :

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

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

$$=5479\ [\mathrm{m^3/h}]$$

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

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

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Prelubricating pump

General

The engine is as standard equipped with an electrically driven pump for pre-lubricating before starting.

The pump which is of the tooth wheel type is self-priming.

The engine shall always be pre-lubricated 2 minutes prior to start if intermittent or continuous pre-lubrication is not installed. Intermittent prelub. is 2 minutes every 10 minutes.

Engine type	T.C.	No. of cyl.	Pump type	m^3/h	Electric motor 230/400 V, 50 Hz (IP 55)	
					kW	Nominal current Amp.
L23/30H L28/32H L28/32S L28/32DF	NR NR+TCR NR+TCR TCR	5-6-7-8 5-6-7-8-9 5-6-7-8-9 5-6-7-8-9	R25/12.5 FL-Z-DB-SO	2.0	0.75	2.9
L23/30H monocoque L23/30H Mk2 L23/30H Mk2 monocoque L23/30S L23/30DF	NR TCR TCR TCR TCR	5-6-7-8 5-6-7-8 5-6-7-8 5-6-7-8 5-6-7-8	R35/25 FL-Z-DB-SO	4.2	1.5	5.5
L23/30H Mk3 monocoque V28/32S	TCR NR	5-6-7-8-9 12-16-18	R35/40 FL-Z-DB-SO	6.8	3.0	9.9

Engine type	T.C.	No. of cyl.	Pump type	m^3/h	Electric motor 265/460 V, 60 Hz (IP 55)	
					kW	Nominal current Amp.
L23/30H L28/32H L28/32S L28/32DF	NR NR+TCR NR+TCR TCR	5-6-7-8 5-6-7-8-9 5-6-7-8-9 5-6-7-8-9	R25/12.5 FL-Z-DB-SO	2.6	0.86	2.96
L23/30H monocoque L23/30H Mk2 L23/30H Mk2 monocoque L23/30S L23/30DF	NR TCR TCR TCR TCR	5-6-7-8 5-6-7-8 5-6-7-8 5-6-7-8 5-6-7-8	R35/25 FL-Z-DB-SO	5.2	1.73	3.0
L23/30H Mk3 monocoque V28/32S	TCR NR	5-6-7-8-9 12-16-18	R35/40 FL-Z-DB-SO	8.7	3.45	5.6

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Specification of lubricating oil (SAE 40) for operation of dual fuel engines

General

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

Doped lubricating oils (HD oils) have a proven track record as lubricants for the drive, cylinder, turbocharger and also for cooling the piston. Doped lubricating oils contain additives that, amongst other things, ensure dirt absorption capability, cleaning of the engine and the neutralisation of acidic combustion products.

Only lubricating oils that have been approved by MAN Energy Solutions may be used. These are listed in the tables below.

Specifications

Base oil

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

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

Properties/Characteristics	Unit	Test method	Limit value
Make-up	–	–	Ideally paraffin based
Low-temperature behaviour, still flowable	°C	ASTM D 2500	–15
Flash point (Cleveland)	°C	ASTM D 92	> 200
Ash content (oxidised ash)	Weight %	ASTM D 482	< 0.02
Coke residue (according to Conradson)	Weight %	ASTM D 189	< 0.50
Ageing tendency following 100 hours of heating up to 135 °C	–	MAN Energy Solutions ageing oven[1]	–
Insoluble n-heptane	Weight %	ASTM D 4055 or DIN 51592	< 0.2
Evaporation loss	Weight %	-	< 2
Spot test (filter paper)	–	MAN Energy Solutions test	Precipitation of resins or asphalt-like ageing products must not be identifiable.
[1] Works' own method			

Table 1: Target values for base oils

Compounded lubricating oils (HD oils)

The base oil to which the additives have been added (doped lubricating oil) must have the following properties:

Additives

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

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

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

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

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

Neutralisation capability The neutralisation capability (ASTM D2896) must be high enough to neutralise the acidic products produced during combustion. The reaction time of the additive must be harmonised with the process in the combustion chamber.

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

Additional requirements The lubricating oil must not contain viscosity index improver. Fresh oil must not contain water or other contaminants.

Lubricating oil selection

Company	Oil brand	TBN
Addinol	Eco gas 4000 XD	7.3
ExxonMobil	Pegasus 710 Pegasus 805	6.5 6.2
Shell	Mysella S3 N Mysella S5 N40	5 4.5
Chevron Texaco Caltex	HDAX 5200 Low Ash SAE 40	4.2
Repsol	Long Life Gas 4005	5.1
Total	Aurelia LNG Nateria MP 40	4.6 4.6
Lukoil	Efforse 4004	5.5

Table 2: Approval list

Lubricating oil additives The use of other additives with the lubricating oil, or the mixing of different brands (oils by different manufacturers), is not permitted as this may impair the performance of the existing additives which have been carefully harmonised with each another, and also specially tailored to the base oil.

Selection of lubricating oils/ warranty Most of the oil manufacturers are in close regular contact with engine manufacturers, and can therefore provide information on which oil in their specific product range has been approved by the engine manufacturer for the particular application. Irrespective of the above, the lubricating oil manufacturers are in any case responsible for the quality and characteristics of their products. If you have any questions, we will be happy to provide you with further information.

Oil during operation

There are no prescribed oil change intervals for MAN Energy Solutions medium-speed engines. The oil properties must be analysed monthly. As long as the oil properties are within the defined threshold values, the oil may be further used. See table Limit values for used lubricating oil.

The quality can only be maintained if it is cleaned using a separator.

Tests

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

⚠ WARNING

Handling of operating fluids

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

- Observe safety data sheets of the operating fluid supplier.

NOTICE

No liability assumed if these oils are used

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

	Limit value	Procedure
Viscosity at 40 °C	100 – 190 mm²/s	ISO 3104 or ASTM D 445
Base number (BN)	min. 3 mg KOH/g	ISO 3771
Water content	max. 0.2 %	ISO 3733 or ASTM D 144
Acid number /TAN)	max. 2.5 mg KOH/g above fresh oil TAN	ASTM D 664
Oxidation	max. 20 Abs/cm	DIN 51453

Table 3: Limit values for used lubricating oil

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Specific lubricating oil consumption - SLOC

General

Engine type	RPM	SLOC [g/kWh]	1) Max. [l/cyl 24h]
L16/24, L16/24S	1000/1200	0.4 - 0.8	2.5
L21/31, L21/31 Mk2, L21/31S	900/1000	0.4 - 0.8	5.0
L23/30H, L23/30DF, L23/30S-DF	720/750	0.4 - 0.8	2.9
L23/30H Mk2, L23/30S	720/750	0.4 - 0.8	3.2
L23/30H Mk3	720/750	0.4 - 0.8	3.8
L23/30H, L23/30DF, L23/30S-DF, L23/30A	900	0.4 - 0.8	3.6
L23/30H Mk2, L23/30S	900	0.4 - 0.8	4.0
L23/30H Mk3	900	0.4 - 0.8	4.5
L27/38, L27/38S (330/340 kW/cyl)	720/750/800	0.4 - 0.8	7.5
L27/38 (350/365 kW/cyl)	720/750/800	0.4 - 0.8	8.2
L28/32H, L28/32S, L28/32DF, L28/32S-DF	720/750	0.4 - 0.8	4.7
L28/32A	775	0.4 - 0.8	5.5
V28/32S	720/750	0.4 - 0.8	5.2

In the Engine performance data calculation program MAN-Projedat the figures 0.6+20% g/kWh are used as an average SLOC value for calculation of Operation Expenses (OPEX), “Total cost of ownership” etc. When the engine is new or newly overhauled the SLOC can be lower than 0.4 g/kWh without causing concerns.

Increased SLOC values might be observed just before overhaul. Note “*1) Max Lubrication oil consumption per cyl per 24 hours*”

Description

Please note

- Only maximum continuous rating (P_{MCR} (kW)) should be used in order to evaluate the SLOC.
- During engine running-in the SLOC may exceed the values stated.

The following formula is used to calculate the SLOC:

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

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

A1:

- Desludging interval and sludge amount from the lubricating oil separator (or automatic lubricating oil filters). The expected lubricating oil content of the sludge amount is 30%.

The following does also have an influence on the SLOC and must be considered in the SLOC evaluation:

A2:

- Lubricating oil evaporation
- Lubricating oil leakages
- Lubricating oil losses at lubricating oil filter exchange

The lubricating oil density, ρ @ 15°C must be known in order to convert ρ to the present lubricating oil temperature in the base frame. The following formula is used to calculate ρ:

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

The engine maximum continuous design rating (P_{MCR}) must always be used in order to be able to compare the individual measurements, and the running hours since the last lubricating oil adding must be used in the calculation. Due to inaccuracy *) at adding lubricating oil, the SLOC can only be evaluated after 1,000 running hours or more, where only the average values of a number of lubricating oil addings are representative.

NOTICE

***) A deviation of ± 1 mm with the dipstick measurement must be expected, which corresponds uptill ± 0.1 g/kWh, depending on the engine type.**

Plant / Ship
Lube oil consumption

Engine type:____________________ **Engine # :__________________**

Lube oil brand/type:____

Density @15 C:_____________ [kg/m3]

Date	Run. hrs	Add. Lube oil	A1 + A2	L.O.Temperature	SLOC	Remarks
	[h]	[dm³]	[dm³]	[°C]	[g/kWh]	

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Separator unit

Separator unit

Continuous lubricating oil cleaning during engine operation is mandatory. An optimal lubricating oil treatment is fundamental for a reliable working condition of the engine.

If the lubricating oil is circulating without a separator unit in operation, the lubricating oil will gradually be contaminated by products of combustion, water and/or acid. In some instances cat-fines may also be present.
In order to prolong the lubricating oil lifetime and remove wear elements, water and contaminants from the lubricating oil, it is mandatory to use a by-pass separator unit.
The separator unit will reduce the carbon residue content and other contaminants from combustion on engines operated on HFO, and keep the amount within MAN Energy Solutions recommendation, on condition that the separator unit is operated according to MAN Energy Solutions recommendations.

When operating a cleaning device, the following recommendations must be observed:

- The optimum cleaning effect is achieved by keeping the lubricating oil in a state of low viscosity for a long period in the separator bowl.
- Sufficiently low viscosity is obtained by preheating the lubricating oil to a temperature of 95°C - 98°C, when entering the separator bowl.
- The capacity of the separator unit must be adjusted according to MAN Energy Solutions recommendations.

Slow passage of the lubricating oil through the separator unit is obtained by using a reduced flow rate and by operating the separator unit 24 hours a day, stopping only for maintenance, according to maker's recommendation.

Lubricating oil preheating

The installed heater on the separator unit ensures correct lubricating oil temperature during separation. When the engine is at standstill, the heater can be used for two functions:

- The oil from the sump is preheated to 95 – 98 °C by the heater and cleaned continuously by the separator unit.
- The heater can also be used to maintain an oil temperature of at least 40 °C, depending on installation of the lubricating oil system.

Cleaning capacity

Normally, it is recommended to use a self-cleaning filtration unit in order to optimize the cleaning period and thus also optimize the size of the filtration unit. Separator units for manual cleaning can be used when the reduced effective cleaning time is taken into consideration by dimensioning the separator unit capacity.

The centrifuging process in separator bowl

Efficient lubricating oil cleaning relies on the principle that - provided the through-put is adequate and the treatment is effective - an equilibrium condition can be reached, where the engine contamination rate is balanced by the centrifuge separation rate i.e.:

- Contaminant quantity added to the lubricating oil per hour = contaminant quantity removed by the centrifuge per hour.

It is the purpose of the centrifuging process to ensure that this equilibrium condition is reached, with the lubricating oil insolubles content being as low as possible.

Since the cleaning efficiency of the centrifuge is largely dependent upon the flow rate, it is very important that this is optimised.

A centrifuge can be operated at greatly varying flow rates (Q).

Practical experience has revealed that the content of insolubles, before and after the centrifuge, is related to the flow rate as shown in Fig. 1.

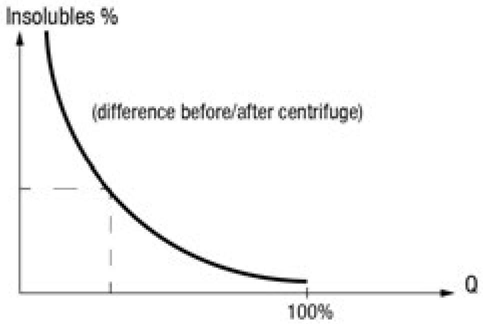


Figure 1: .

Fig. 1 illustrates that the amount of insolubles removed will decrease with rising flow rate (Q).

It can be seen that:

- At low flow rate (Q), only a small portion of the lubricating oil is passing the centrifuge/hour, but is being cleaned effectively.
- At high flow rate (Q), a large quantity of lubricating oil is passing the centrifuge/hour, but the cleaning is less effective.

Thus, by correctly adjusting the flow rate, an optimal equilibrium cleaning level can be obtained (Fig. 2).

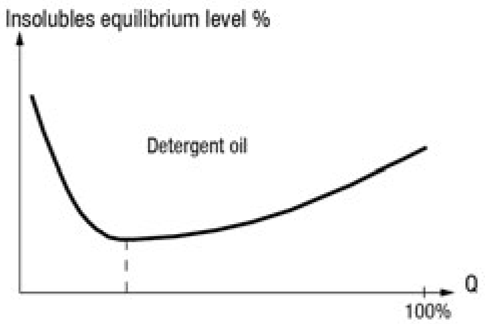


Figure 2: .

This minimum contamination level is obtained by employing a suitable flow rate that is only a fraction of the stated maximum capacity of the centrifuge (*see the centrifuge manual*).

The most important factor is the particle size (risk of scratching and wear of the bearing journals). In general the optimum centrifuge flow rate for a detergent lubricating oil is about 25% of the maximum centrifuge capacity.

Operation flow

In order to calculate the required operation flow through the separator unit, MDT recommends to apply the following formula:

$$Q = \frac{P \times 1.36 \times n}{t}$$

Q	=	required operation flow [l/h]
P	=	MCR (maximum continuous rating) [kW]
t	=	actual effective separator unit separating time per day [hour] (23.5 h separating time and 0.5 h for sludge discharge = 24 h/day)
n	=	number of turnovers per day of the theoretical oil volume corresponding to 1.36 [l/kW] or 1 [l/HP]

The following values for "n" are recommended:

n	=	6 for HFO operation (residual)
n	=	4 for MDO operation
n	=	3 for distillate fuel

Example 1
For multi-engine plants, one separator unit per engine in operation is recommended.

For example, for a 1,000 kW engine operating on HFO and connected to a self-cleaning separator unit, with a daily effective separating period of 23.5 hours, the calculation is as follows:

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

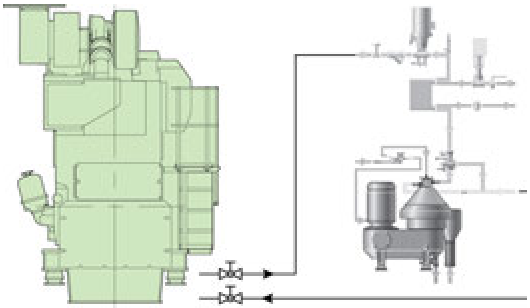


Figure 3: One separator per engine plant

Example 2 (GenSet)
As an alternative, one common separator unit for three engines can be installed, with one in reserve if possible.

For the calculation in this example it is necessary include the combined average power demand of the multi-engine plant. The load profile experienced for the majority of merchant vessels is that the average power demand is around 43-50% of the total GenSet power installed. With three identical engines this corresponds to 1.3-1.5 times the power of one engine.

- Bulk carrier and tankers : ~1.3 times the power of one engine
- Container vessel : ~1.5 times the power of one engine

For example, for a bulk carrier with three 1,000 kW engines operating on HFO and connected to a common self-cleaning separator unit, with a daily effective separating period of 23.5 hours, the calculation is as follows:

$$Q = \frac{1.3 \times 1000 \times 1.36 \times 6}{23.5} = 451 \text{ l/h}$$

Bulk carrier and tankers

With an average power demand higher than 50% of the GenSet power installed, the operation flow must be based on 100% of the GenSet power installed.

Separator unit installation

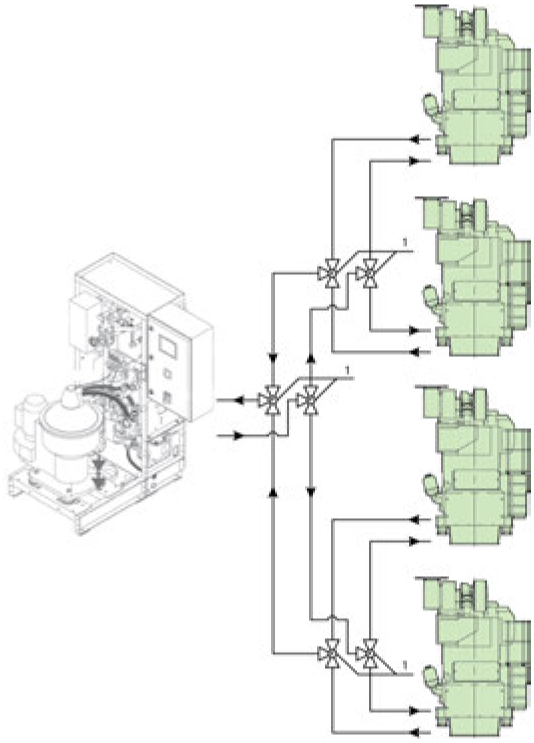
With multi-engine plants, one separator unit per engine in operation is recommended (*see figure 3*), but if only one separator unit is in operation, the following layout can be used:

- A common separator unit (*see figure 4*) can be installed, with one in reserve, if possible, for operation of all engines through a pipe system, which can be carried out in various ways. The aim is to ensure that the separator unit is only connected to one engine at a time. Thus there will be no suction and discharging from one engine to another.

It is recommended that inlet and outlet valves are connected so that they can only be changed over simultaneously.

With only one engine in operation there are no problems with separating, but if several engines are in operation for some time it is recommended to split up the separation time in turns on all operating engines.

With 2 out of 3 engines in operation the 23.5 hours separating time must be split up in around 4-6 hours intervals between changeover.



1 Interconnected valves

Figure 4: One common separator unit for multi-engine installation

Stokes' law

The operating principles of centrifugal separation are based on Stokes' Law.

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

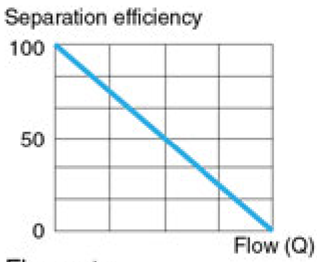
V	=	settling velocity [m/sec]
$r\omega^2$	=	acceleration in centrifugal field [m/sec^2]
d	=	diameter of particle [m]
ρ_p	=	density of particle [kg/m^3]
ρ_l	=	density of medium [kg/m^3]
μ	=	viscosity of medium [kg/m, sec.]

The rate of settling (V) for a given capacity is determined by Stokes' Law. This expression takes into account the particle size, the difference between density of the particles and the lubricating oil, and the viscosity of the lubricating oil.

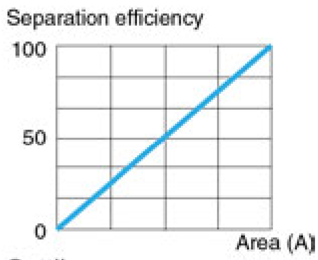
Density and viscosity are important parameters for efficient separation. The greater the difference in density between the particle and the lubricating oil, the higher the separation efficiency. The settling velocity increases in inverse proportion to viscosity. However, since both density and viscosity vary with temperature, separation temperature is the critical operating parameter.

Particle size is another important factor. The settling velocity increases rapidly with particle size. This means that the smaller the particle, the more challen-ging the separation task. In a centrifuge, the term ($r\omega^2$) represents the centrifugal force which is several thousand times greater than the acceleration due to gravitational force. Centrifugal force enables the efficient separation of particles which are only a few microns in size.

The separation efficiency is a function of:

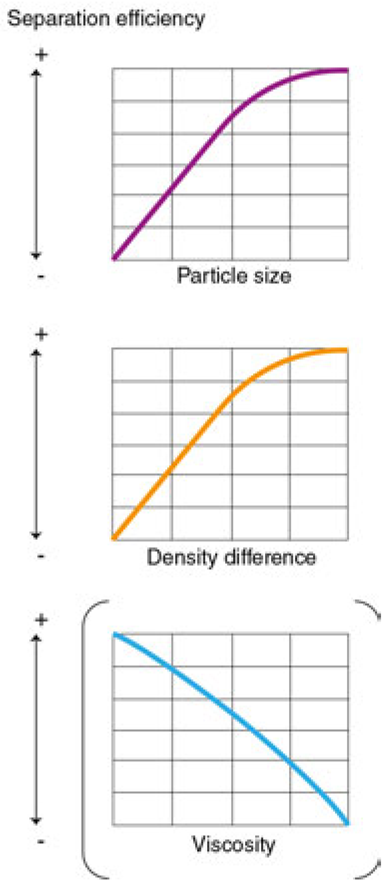


Flow rate



Settling area

Settling velocity



Operating parameters

Various operating parameters affect separation efficiency. These include temperature, which controls both lubricating oil viscosity and density, flow rate and maintenance.

Temperature of lubricating oil before separator unit

It is often seen that the lubricating oil pre-heaters are undersized, have very poor temperature control, the steam supply to the pre-heater is limited or the temperature set point is too low.

Often the heater surface is partly clogged by deposits. These factors all lead to reduced separation temperature and hence the efficiency of the separator unit. In order to ensure that the centrifugal forces separate the heavy contaminants in the relatively limited time that they are present in the separator bowl, the separator unit must always be operated with an inlet temperature of 95-98°C for lubricating oil.

A control circuit including a temperature transmitter and a PI-type controller with accuracy of ±2°C must be installed. If steam-heated, a correctly sized steam valve should be fitted with the right KvS value. The steam trap must be a mechanical float type. The most common heaters on board are steam heaters. This is due to the fact that steam in most cases is available at low cost.

Most ships are equipped with an exhaust boiler utilizing the exhaust gases to generate steam.

A large proportion of smaller tonnage does, however, use electric heaters.

It is essential to keep the incoming oil temperature to the separator unit steady with only a small variation in temperature allowed (maximum ±2°C).

The position of the interface between oil and water in the separator bowl is a result of the density and the viscosity of the oil, which in turn depends on the temperature.

Flow rate

It is known that separation efficiency is a function of the separator unit's flow rate. The higher the flow rate, the more particles are left in the oil and therefore the lower the separation efficiency. As the flow rate is reduced, the efficiency with which particles are removed increases and cleaning efficiency thus improves. It is, however, essential to know at what capacity adequate separation efficiency is reached in the specific case.

In principle, there are three ways to control the flow:

- Adjustment of the built-in safety valve on the pump.

  This method is NOT recommended since the built-on valve is nothing but a safety valve.

  The opening pressure is often too high and its characteristic far from linear.

  In addition, circulation in the pump may result in oil emulsions and cavitation in the pump.
- A flow regulating valve arrangement on the pressure side of the pump, which bypasses the separator unit and re-circulates part of the untreated lubricating oil back to the treated oil return line, from the separator unit and NOT directly back to the suction side of the pump.

  The desired flow rate is set manually by means of the flow regulating valve. Further, the requirement for backpressure in the clean oil outlet MUST also be fulfilled, helping to maintain the correct interface position.
- Speed control of the pump motor with a frequency converter or a 2-speed motor.

This is a relatively cheap solution today and is a good alternative for flow control.

Maintenance

Proper maintenance is an important, but often overlooked operating parameter that is difficult to quantify. If the bowl is not cleaned in time, deposits will form on the bowl discs, the free channel height will be reduced, and flow velocity increases. This further tends to drag particles with the liquid flow towards the bowl's centre resulting in decreased separation efficiency.

Treatment and maintenance of lubricating oil

General

During operation of trunk engines the lubricating oil will gradually be contaminated by small particles originating from the combustion.

Engines operated on heavy fuels will normally increase the contamination due to the increased content of carbon residues and other contaminants.

Contamination of lubricating oil with either freshwater or seawater can also occur.

A certain amount of contaminants can be kept suspended in the lubricating oil without affecting the lubricating properties.

The condition of the lubricating oil must be kept under observation (on a regular basis) by analyzing oil samples. *See Section B 12 15 0 / 504.04 "Criteria for Cleaning/Exchange of Lubricating Oil*".

The condition of the lubricating oil can be maintained / re-established by exchanging the lubricating oil at fixed intervals or based on analyzing oil samples.

The moving parts in the engine are protected by the built-on lubricating oil filter.

Operation on distillate fuels, Marine diesel oil (MDO), Marine gas oil (MGO), Low, Very low & Ultra low sulphur fuel oil (LSFO), (VLSFO), (ULSFO)

We recommend to install a built-on centrifugal filter as an additional filter to the built-on lubricating oil filter.

It is advisable to run bypass cleaning equipment continuously for engines operated on distillate fuels.

Operation on residual fuels, Heavy fuel oil (HFO) Low, Very low & Ultra low sulphur heavy fuel oil (LSFO), (VLSFO) (ULSFO)

HFO-operated engines require effective lubricating oil cleaning. In order to ensure a safe operation it is necessary to use supplementary cleaning equipment together with the built-on lubricating oil filter.

We recommend to install a built-on centrifugal by-pass filter as an additional filter to the built-on lubricating oil filter.

It is also mandatory to run cleaning equipment continuously for engines operated on residual fuels, as an optimal lubricating oil treatment is fundamental for a reliable working condition. Therefore it is mandatory to clean the lubricating oil with a bypass cleaning equipment, so that the wear rates are reduced and the lifetime of the engine is extended.

Bypass cleaning equipment

As a result of normal operation, the lubricating oil contains abraded particles and combustion residues which have to be removed by the bypass cleaning system and to a certain extent by the built-on lubricating oil filter as well.

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With automatic mesh filters this can result in an undesirable and hazardous continuous flushing. In view of the high cost of cleaning equipment for removing micro impurities, this equipment is only rated for a certain proportion of the oil flowing through the engine since it is installed in a bypass.

The bypass cleaning equipment is operate continuously when the engine is in operation or at standstill.

For cleaning of lubricating oil the following bypass cleaning equipment can be used:

- Separator unit
- Decanter unit
- Self cleaning automatic bypass mesh filter
- Bypass depth filter

The decanter unit, the self-cleaning automatic bypass mesh filter and the bypass depth filter capacity must be adjusted according to maker's recommendations.

If the selected bypass cleaning equipment cannot remove water it is recommended to have portable separator available.

In case full flow filtration equipment is chosen, this must only be installed as in-line cleaning upstream to the built-on lubricating oil filter.

The most appropriate type of equipment for a particular application depends on the engine output, the type and amount of combustion residues, the annual operating time and the operating mode of the plant. Even with a relatively low number of operating hours there can be a great deal of combustion residues if, for instance, the engine is inadequately preheated and quickly accelerated and loaded.

Check of lubricating oil system

For cleaning of the lubricating oil system after overhauls and inspection of the lubricating oil piping system the following checks must be carried out:

1. Examine the piping system for leaks.
2. Retighten all bolts and nuts in the piping system.
3. Move all valves and cocks in the piping system. Lubricate valve spindles with graphite or similar.
4. Blow through drain pipes.
5. Check flexible connections for leaks and damages.
6. Check manometers and thermometers for possible damages.
7. Centrifugal by-pass filter can be used as indicator of lubricating oil system condition.
   Define a cleaning interval (ex. 100 hours). Check the sludge weight. If the sludge weight is raising please check separator and lubricating oil system condition in general.

Deterioration of oil

Oil seldomly loses its ability to lubricate, i.e. to form a friction-decreasing oil film, but it may become corrosive to the steel journals of the bearings in such a way that the surface of these journals becomes too rough and wipes the bearing surface.

In that case the bearings must be renewed, and the journals must also be polished. The corrosiveness of the lubricating oil is either due to far advanced oxidation of the oil itself (TAN) or to the presence of inorganic acids (SAN). In both cases the presence of water will multiply the effect, especially sea water as the chloride ions act as an inorganic acid.

Signs of deterioration

If circulating oil of inferior quality is used and the oxidative influence becomes grave, prompt action is necessary as the last stages in the deterioration will develop surprisingly quickly, within one or two weeks. Even if this seldomly happens, it is wise to be acquainted with the signs of deterioration.

These may be some or all of the following:

- Sludge precipitation in the separator unit multiplies
- Smell of oil becomes acrid or pungent
- Machined surfaces in the crankcase become coffee-brown with a thin layer of lacquer
- Paint in the crankcase peels off or blisters
- Excessive carbon is formed in the piston cooling chamber

In a grave case of oil deterioration the system must be cleaned thoroughly and refilled with new oil.

Oxidation of oils

At normal service temperature the rate of oxidation is insignificant, but the following factors will accelerate the process:

High temperature
If the coolers are ineffective, the temperature level will generally rise. A high temperature will also arise in electrical pre-heaters if the circulation is not continued for 5 minutes after the heating has been stopped, or if the heater is only partly filled with oil.

Catalytic action
Oxidation of the oil will be accelerated considerably if catalytic particles are present in the oil. Wear particles of copper are especially harmful, but also ferrous particles and rust are active. Furthermore, the lacquer and varnish oxidation products of the oil itself have an accelerating effect. Continuous cleaning of the oil is therefore important to keep the sludge content low.

Water washing

Water washing of HD oils (heavy duty) must not be carried out.

Water in the oil

If the TAN is low, a minor increase in the fresh water content of the oil is not immediately detrimental while the engine is in operation. Naturally, it should be brought down again as quickly as possible (below 0.2% water content, which is permissible, *see description "B 12 15 0/504.04 criteria for exchange of lube oil*"). If the engine is stopped while corrosion conditions are unsatisfactory, the crankshaft must be turned ½ - ¾ revolution once every hour by means of the turning gear. Please make sure that the crankshaft stops in different positions, to prevent major damage to bearings and journals. The lubricating oil must be circulated and separated continuously to remove water.

Water in the oil may be noted by steam formation on the sight glasses, by appearance, or ascertained by immersing a piece of glass or a soldering iron heated to 200-300°C in an oil sample. If there is a hissing sound, water is present. If a large quantity of water has entered the lubricating oil system, it has to be removed. Either by sucking up sediment water from the bottom, or by replacing the oil in the sump. An oil sample must be analysed immediately for chloride ions.

Criteria for cleaning/exchange of lubricating oil

Replacement of lubricating oil

The expected lubricating oil lifetime in operation is difficult to determine. The lubricating oil lifetime is depending on the fuel oil quality, the lubricating oil quality, the lubricating oil consumption, the lubricating oil cleaning equipment efficiency and the engine operational conditions.

In order to evaluate the lubricating oil condition a sample should be drawn on regular basis at least once every three month or depending on the latest analysis result. The lubricating oil sample must be drawn before the filter at engine in operation. The sample bottle must be clean and dry, supplied with sufficient identification and should be closed immediately after filling. The lubricating oil sample must be examined in an approved laboratory or in the lubricating oil suppliers own laboratory.

A lubricating oil replacement or an extensive lubricating oil cleaning is required when the MAN Energy Solutions exchange criteria's have been reached.

Evaluation of the lubricating oil condition

Based on the analysis results, the following guidance are normally sufficient for evaluating the lubricating oil condition. The parameters themselves can not be jugded alonestanding, but must be evaluated together in order to conclude the lubricating oil condition.

1. Viscosity

Limit value:

	Normal value	min. value	max. value
SAE 30 [cSt@40° C]	95 - 125	75	160
SAE 30 [cSt@100° C]	11 - 13	9	15
SAE 40 [cSt@40° C]	135 - 165	100	220
SAE 40 [cSt@100° C]	13.5 - 15.0	11	19

Unit	:	cSt (mm^2/s)
Possible test method	:	ASTM D-445, DIN51562/53018, ISO 3104

Increasing viscosity indicates problems with insolubles, HFO contamination, water contamination, oxidation, nitration and low load operation. Decreasing viscosity is generally due to dilution with lighter viscosity oil.

2. Flash point

Min. value	:	185° C
Possible test method	:	ASTM D-92, ISO 2719

Normally used to indicate fuel dilution.

3. Water content

Max. value	:	0.2 %
Unit	:	Weight %
Possible test method	:	ASTM D4928, ISO 3733

Water can originate from separator, contaminated fuel oil, an engine cooling water leak or in minor amount formed as part of the combustion process. If water is detected also Sodium, Glycol or Boron content should be checked in order to confirm engine coolant leaks.

If ship installation have no separator unit it is recommend to have a portable separator available to remove water.

4. Base number

Min. value	:	The BN value should not be lower than 50% of fresh lubricating oil value, but minimum BN level never to be lower than 10-12 at operating on HFO!
Unit	:	mg KOH/g
Possible test method	:	ASTM D-2896, ISO 3771

The neutralization capacity must secure that the acidic combustion products, mainly sulphur originate from the fuel oil, are neutralized at the lube oil consumption level for the specific engine type. Gradually the BN will be reduced, but should reach an equilibrium.

5. Total acid number (TAN)

Max. value	:	3.0 acc. to fresh oil value
Unit	:	mg KOH/g
Possible test method	:	ASTM D-664

TAN is used to monitor oil degradation and is a measure of the total acids present in the lubricating oil derived from oil oxidation (weak acids) and acidic products of fuel combustion (strong acids).

6. Insolubles content

Max. value	:	1.5 % generally, depending upon actual dispersant value and the increase in viscosity
Unit	:	Weight %
Possible test method	:	ASTM D-893 procedure B in Heptane, DIN 51592

Additionally test	:	If the level in n-Heptane insolubles is considered high for the type of oil and application, the test could be followed by a supplementary determination in Toluene.

Total insolubles is maily derived from products of combustion blown by the piston rings into the crankcase. It also includes burnt lubricating oil, additive ash, rust, salt, wear debris and abrasive matter.

7. Metal content

Metal content	Remarks	Attention limits
Iron	Depend upon engine type and operating conditions	max. 50 ppm
Chromium		max. 10 ppm
Copper		max. 15 ppm
Lead		max. 20 ppm
Tin		max. 10 ppm
Aluminium		max. 20 ppm
Silicon		max. 20 ppm

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By-pass depth filter

General

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

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

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

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Filter specification

Range of application	:	Diesel engine lube oils
Max. operating pressure	:	7 bar
Test pressure	:	According to class rule
Max. operating temperature	:	120°C
Nominal width of connection flanges	:	DN25
Filter to be replaced at a pressure drop	:	2.1 bar
Grade of filtration	:	3 µm absolute: 98.7% of all solid particles >3 µm 0.8 µm nominal: 50% of all solid particles > 0.8 µm are retained in each pass.

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

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

NOTICE

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

Figure 1: Clean and dirty filter insert

L16/24 - HFO operation

Cylinder [No.]	Engine power [kW]	Filter unit	Pump flow [60/50Hz]
5 (1200/1000 rpm)	500/450	HDU 1x27/108S	80-240
6 (1200/1000 rpm)	660/570	HDU 1x27/108S	80-240
7 (1200/1000 rpm)	770/665	HDU 1x27/108S	80-240
8 (1200/1000 rpm)	880/760	HDU 1x27/108S	80-240
9 (1200/1000 rpm)	990/855	HDU 1x27/108S	80-240

L16/24 - MDO/MGO operation (Exclusively)

Cylinder [No.]	Engine power [kW]	Filter unit	Pump flow [60/50Hz]
5 (1200/1000)	500/450	HDU 1x27/108S	80-240
6 (1200/1000)	660/570	HDU 1x27/108S	80-240
7 (1200/1000)	770/665	HDU 1x27/108S	80-240
8 (1200/1000)	880/760	HDU 1x27/108S	80-240
9 (1200/1000)	990/855	HDU 1x27/108S	80-240

L21/31 +Mk2 - HFO operation

Cylinder [No.]	Engine power [kW]	Filter unit	Pump flow [60/50Hz]
5 (900/1000 rpm)	1000 kW	HDU 1x27/108S	80-240
6 (900/1000 rpm)	1320 kW	HDU 1x27/108S	80-240
7 (900/1000 rpm)	1540 kW	HDU 2x27/108S	160-480
8 (900/1000 rpm)	1760 kW	HDU 2x27/108S	160-480
9 (900/1000 rpm)	1980 kW	HDU 2x27/108S	160-480

L21/31 +Mk2 - MDO/MGO operation (Exclusively)

Cylinder [No.]	Engine power [kW]	Filter unit	Pump flow [60/50Hz]
5 (900/1000 rpm)	1000 kW	HDU 1x27/108S	80-240
6 (900/1000 rpm)	1320 kW	HDU 1x27/108S	80-240
7 (900/1000 rpm)	1540 kW	HDU 1x27/108S	80-240
8 (900/1000 rpm)	1760 kW	HDU 2x27/108S	105-320
9 (900 rpm)	1980 kW	HDU 2x27/108S	105-320
9 (1000 rpm)	1980 kW	HDU 2x27/108S	160-480

L27/38 - HFO operation

Cylinder [No.]	Engine power [kW]	Filter unit	Pump flow [60/50Hz]
5 (720/750 rpm)	1500/1600	HDU 2x27/108S	160-480
6 (720/750 rpm)	1980	HDU 2x27/108S	160-480
7 (720/750 rpm)	2310	HDU 3x27/108S	320-960
8 (720/750 rpm)	2640	HDU 3x27/108S	320-960
9 (720/750 rpm)	2970	HDU 3x27/108S	320-960

L27/38 - MDO/MGO operation (Exclusively)

Cylinder [No.]	Engine power [kW]	Filter unit	Pump flow [60/50Hz]
5 (720/750 rpm)	1500/1600	HDU 1x27/108S	80-240
6 (720/750 rpm)	1980	HDU 1x27/108S	105-320
7 (720/750 rpm)	2310	HDU 2x27/108S	160-480
8 (720/750 rpm)	2640	HDU 2x27/108S	160-480
9 (720/750 rpm)	2970	HDU 3x27/108S	320-960

Cylinder [No.]	Engine power [kW]	Filter unit	Pump flow [60/50Hz]
6 (720/750 rpm)	2100	HDU 2x27/108S	160-480
7 (720/750 rpm)	2450	HDU 2x27/108S	160-480
8 (720/750 rpm)	2800	HDU 3x27/108S	320-960
9 (720/750 rpm)	3150	HDU 3x27/108S	320-960

L23/30H +Mk2 - HFO operation

Cylinder [No.]	Engine power [kW]	Filter unit	Pump flow [60/50Hz]
5 (720/750 rpm)	535/525	HDU 1x27/108S	80-240
5 (720/750 rpm)	650/675	HDU 1x27/108S	80-240
5 (720/750 rpm)	710/740	HDU 1x27/108S	80-240
6 (720/750 rpm)	852/888	HDU 1x27/108S	80-240
6 (900 rpm)	1050	HDU 1x27/108S	105-320
7 (720 rpm)	994	HDU 1x27/108S	80-240
7 (750/900 rpm)	1036/1225	HDU 1x27/108S	105-320
8 (720 rpm)	1136	HDU 1x27/108S	80-240
8 (750 rpm)	1184	HDU 1x27/108S	105-320
8 (900 rpm)	1400	HDU 2x27/108S	160-480

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

Cylinder [No.]	Engine power [kW]	Filter unit	Pump flow [60/50Hz]
5 (720/750)	535/525	HDU 1x27/108S	80-240
5 (720/750)	650/675	HDU 1x27/108S	80-240
5 (720/750)	710/740	HDU 1x27/108S	80-240
6 (720/750/900 rpm)	852/888/1050	HDU 1x27/108S	80-240
7 (720/750/900 rpm)	994/1036/1225	HDU 1x27/108S	80-240
8 (720/750/900 rpm)	1136/1184/1400	HDU 1x27/108S	80-240

L28/32H - HFO operation

Cylinder [No.]	Engine power [kW]	Filter unit	Pump flow [60/50Hz]
5 (720/750 rpm)	1050/1100	HDU 1x27/108S	80-240
6 (720/750 rpm)	1260/1320	HDU 1x27/108S	105-320
7 (720/750 rpm)	1470/1540	HDU 2x27/108S	160-480
8 (720/750 rpm)	1680/1760	HDU 2x27/108S	160-480
9 (720/750 rpm)	1890/1980	HDU 2x27/108S	160-480

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

Cylinder [No.]	Engine power [kW]	Filter unit	Pump flow [60/50Hz]
5 (720/750 rpm)	1050/1100	HDU 1x27/108S	80-240

Cylinder [No.]	Engine power [kW]	Filter unit	Pump flow [60/50Hz]
6 (720/750 rpm)	1260/1320	HDU 1x27/108S	80-240
7 (720/750 rpm)	1470/1540	HDU 1x27/108S	80-240
8 (720/750 rpm)	1680/1760	HDU 1x27/108S	105-320
9 (720/750 rpm)	1890/1980	HDU 1x27/108S	105-320

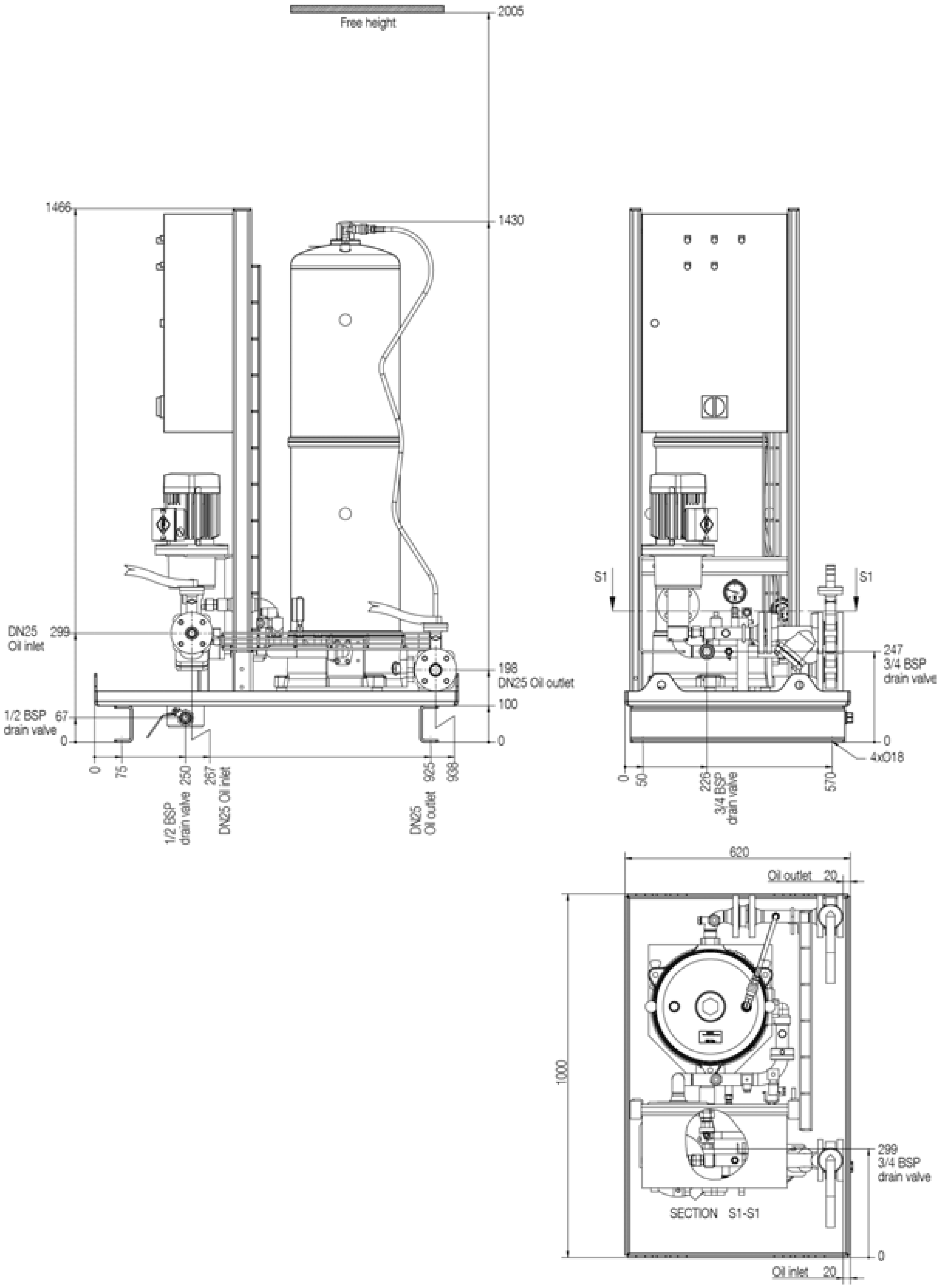
L23/30DF - MDO/MGO operation

Cylinder [No.]	Engine power [kW]	Filter unit	Pump flow [60/50Hz]
5 (720/750 rpm)	625/625	HDU 1x27/108S	80-240
6 (720/750/900 rpm)	750/750/900	HDU 1x27/108S	80-240
7 (720/750/900 rpm)	875/875/1050	HDU 1x27/108S	80-240
8 (720/750/900 rpm)	1000/1000/1200	HDU 1x27/108S	80-240

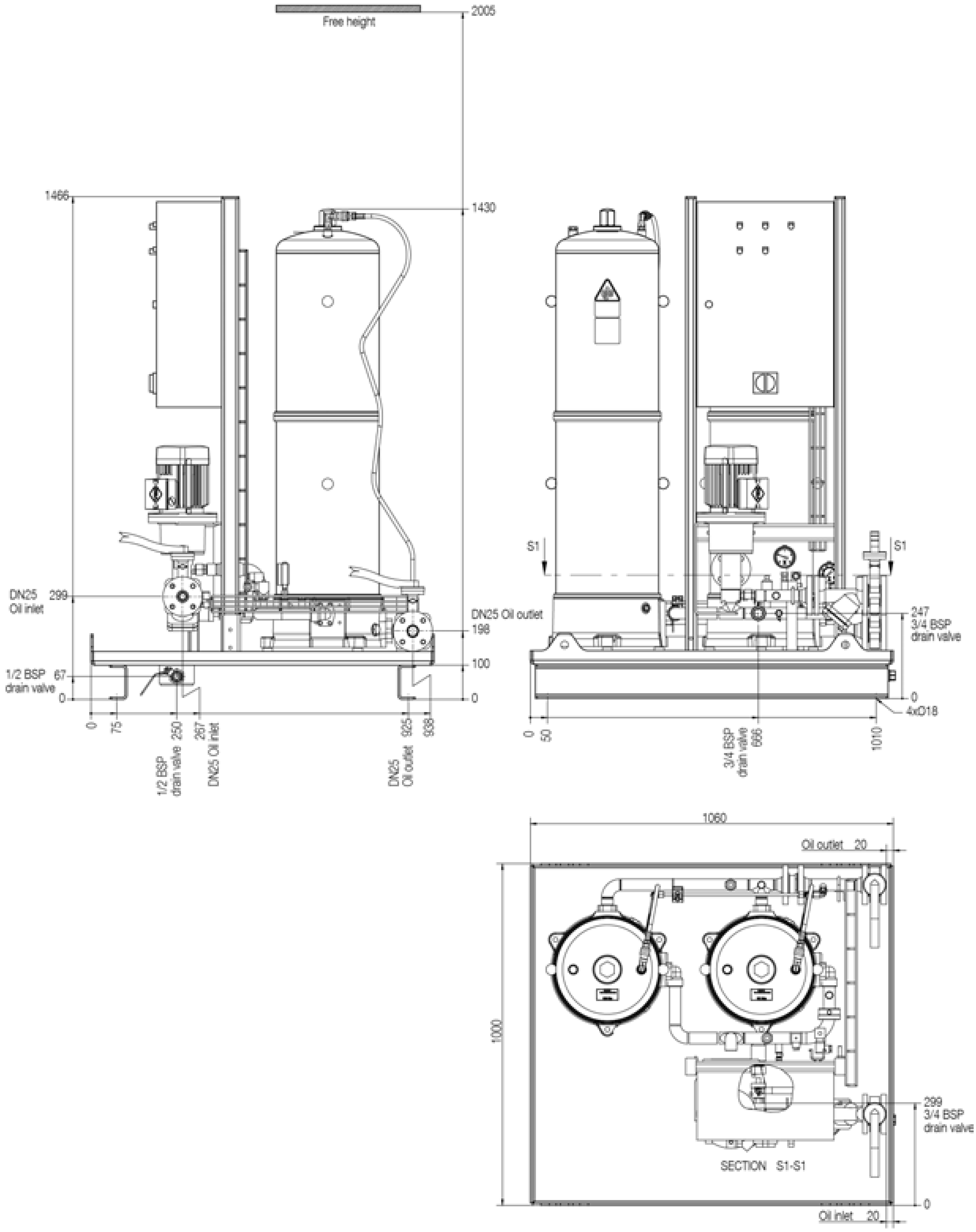
L28/32DF - MDO/MGO operation

Cylinder [No.]	Engine power [kW]	Filter unit	Pump flow [60/50Hz]
5 (720/750 rpm)	1000	HDU 1x27/108S	80-240
6 (720/750 rpm)	1200	HDU 1x27/108S	80-240
7 (720/750 rpm)	1400	HDU 1x27/108S	80-240
8 (720/750 rpm)	1600	HDU 1x27/108S	105-320
9 (720/750 rpm)	1800	HDU 1x27/108S	105-320

HDU 1x27/108S



HDU 2x27/108S



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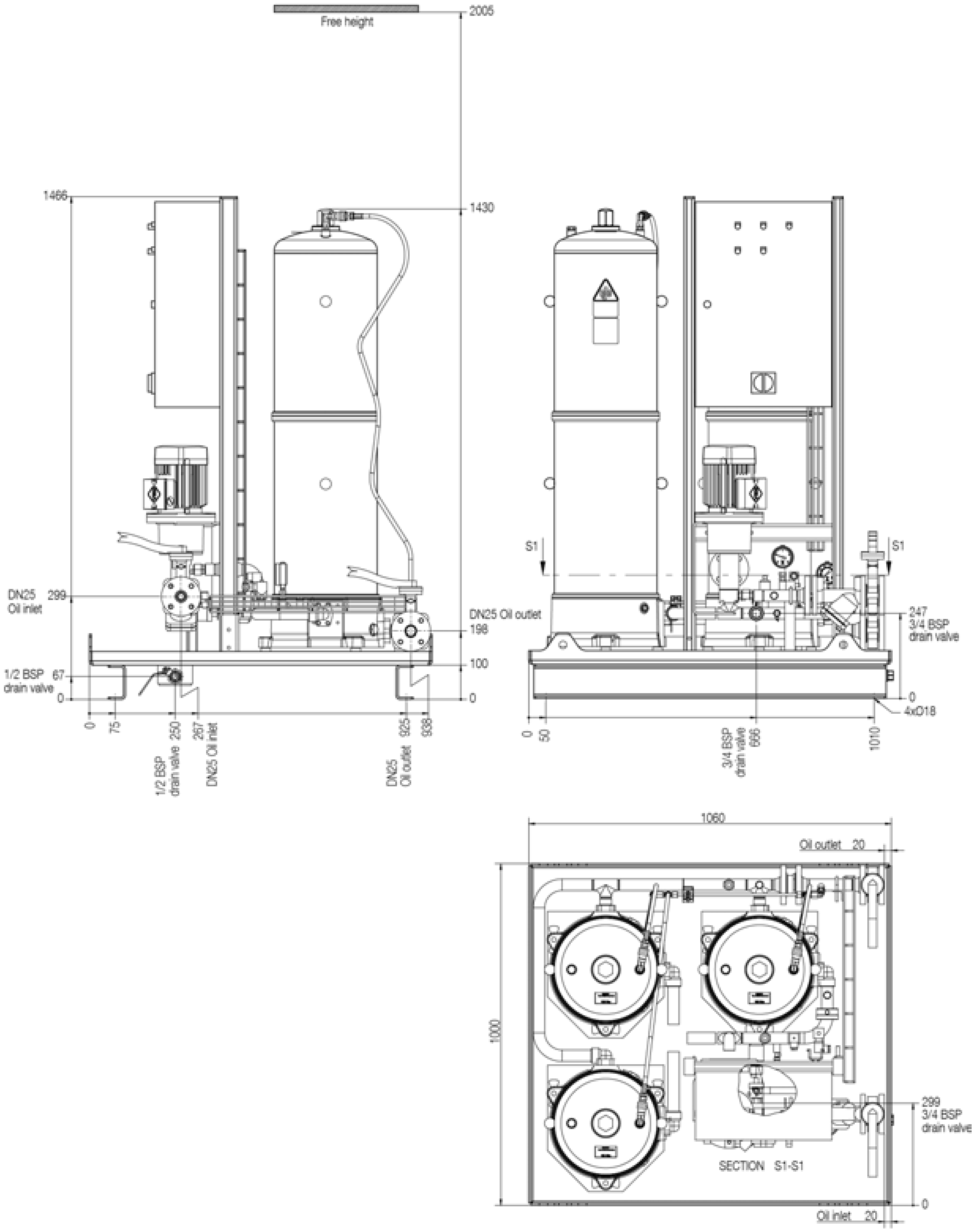

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Internal cooling water system

Internal cooling water system

The engine's cooling water system comprises a low temperature (LT) circuit and a high temperature (HT) circuit. The systems are designed only for treated fresh water.

Low temperature cooling water system

The LT cooling water system includes charge air cooling, lubricating oil cooling and alternator cooling if the latter is water-cooled. The LT system is designed for freshwater (FW) as cooling medium.

In order to prevent a too high charge air temperature, the design freshwater temperature in the LT system should not be too high. Max. 36°C is a convenient choice.

Regarding the lubricating oil cooler, the inlet temperature of the LT cooling water should not be below 10°C.

High temperature cooling water system

The high temperature cooling water is used for the cooling of cylinder liners and cylinder heads.

An engine outlet temperature of 80°C ensures a perfect combustion in the entire load area when running on Heavy Fuel Oil (HFO), i.e. this temperature limits the thermal loads in the high-load area, and hot corrosion in the combustion area is avoided.

In the low-load area, the temperature is sufficiently high to secure a perfect combustion and at the same time cold corrosion is avoided; the latter is also the reason why the engine, in stand-by position and when starting on HFO, should be preheated with a medium cooling water temperature of ≥ 60°C – either by means of cooling water from running engines or by means of a separate preheating system.

System lay-out

MAN Energy Solutions' standard for the internal cooling water system is shown on Basis Diagram 2. The system has been constructed with a view to full integration into the external system.

Temperature regulation in the HT and LT systems takes place in the external system where also pumps and fresh water heat exchangers are situated. This means that these components can be common for propulsion engine(s) and GenSets.

To be able to match every kind of external systems, the internal system can as optional be arranged with two separate circuits or as a single circuit with or without a built-on pump and a thermostatic valve in the HT-circuit, so that engine cooling can be integrated fully or partly into the external system, or can be constructed as a stand-alone unit.

Different internal basis system layouts for these applications are shown on the following pages.

HT-circulating pump

The circulating pump which is of the centrifugal type is mounted on the front cover of the engine and is driven by the crankshaft through a resilient gear transmission.

Technical data: *See "list of capacities" D 10 05 0 and B 13 18 1-2.*

Thermostatic valve

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

Technical data: *See B 13 15 1.*

Preheating arrangement

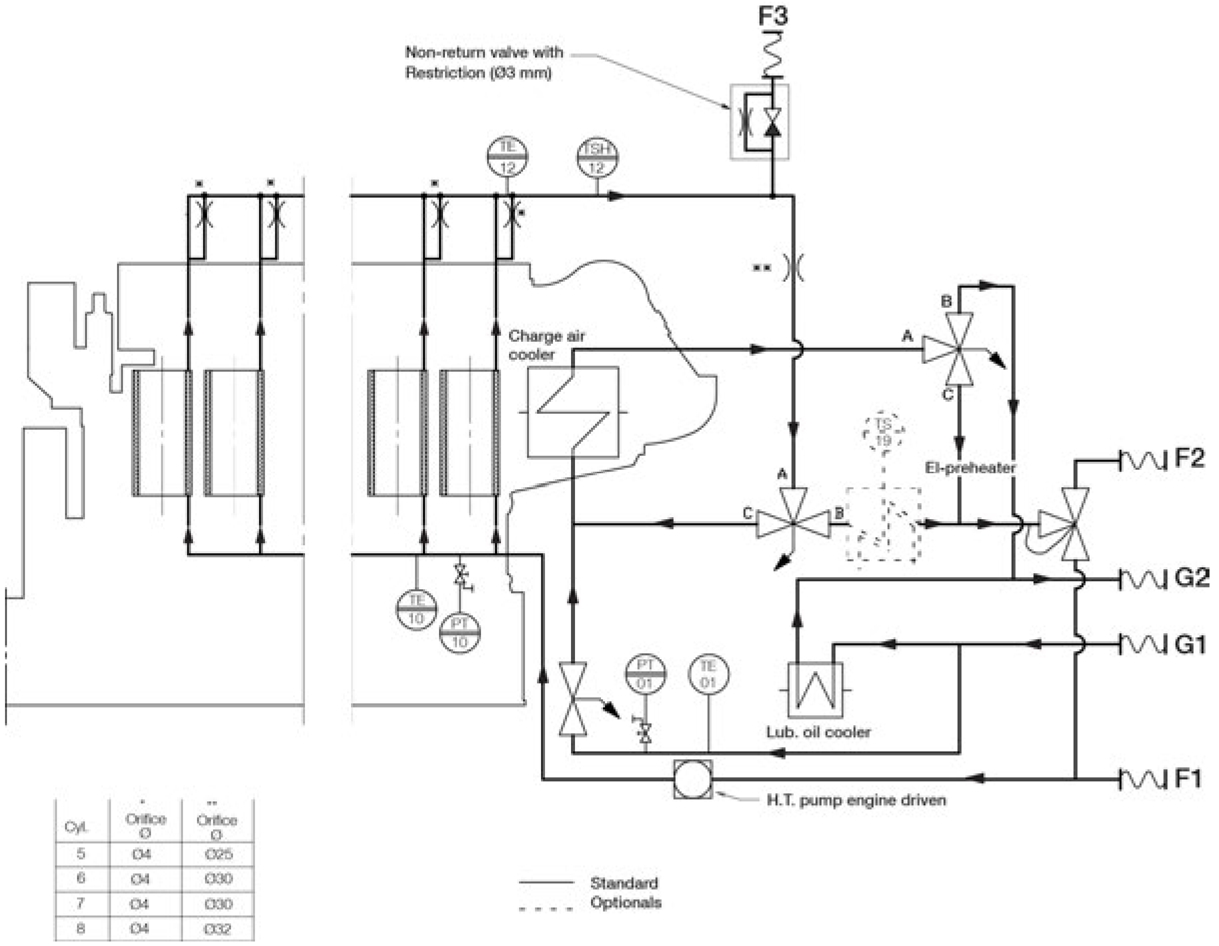
As an optional the engine can be equipped with a built-on preheating arrangement in the HT-circuit including a thermostatic controlled el-heating element and safety valve.

The system is based on thermo-syphon circulation.

For further information *see B 13 23 1.*

Internal cooling water system

System no 5 (2-string)



Cyl.	* Orifice Ø	** Orifice Ø
5	Ø4	Ø25
6	Ø4	Ø30
7	Ø4	Ø30
8	Ø4	Ø32

Figure 1: Diagram for cooling water system no 5 (for guidance only, please see the plant specific engine diagram)

Pipe description

F1	HT fresh water inlet	DN 80
F2	HT fresh water outlet	DN 80
F3	Venting to expansion tank	DN 15
G1	LT fresh water inlet	DN 100
G2	LT fresh water outlet	DN 100

Table 1: Flange connections are standard according to DIN 2501

Description

2-string cooling water system consists of two circuits. The low temperature (LT) circuit and the high temperature (HT) circuit.

The purpose of the two-circuit design is to increase the engine's charge air temperature and thus the combustion temperature when the engine operates in the low-load area, i.e. below 30% of MCR (Max. Continuous Rating).

The charge air temperature is increased by changing the cooling water temperature in the charge air cooler. In conventional systems and during operation with this system in the high-load area, the charge air is cooled by water from the LT-water system.

When an engine equipped with this system enters the low-load area - during start-up or operation – change-over valves are activated automatically, whereby HT-water instead of LT-water is led through the charge air cooler, i.e. the charge air is heated.

Low temperature circuit

The low temperature circuit is used for cooling of the charge air and the lubricating oil.

High temperature circuit

The high temperature circuit is used for cooling of the cylinder units.

Cooling water is led through a distributing pipe to the bottom of the cooling water space between the liner and the frame of each cylinder unit. The water is led out through bores in the top of the frame via the cooling water guide jacket to the bore cooled cylinder head for cooling of this, the exhaust valve seats and the injector valve.

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

High-load mode

In this mode the flow goes from gate A to gate B. The cooling water from the cylinder units will now be led directly to the HT thermostatic valve.

The charge air cooler is connected to the LT-system i.e. the automatically operated butterfly valve, built into the pipe between the charge air cooler and the external LT-system, is open in high-load mode.

Low-load mode

In this mode the flow goes from gate A to gate C. The cooling water from the cylinder units will now be led through the charge air cooler and further on to the HT thermostatic valve. The charge air cooler is now disconnected from the LT-system and connected to the cylinder units in the HT-system.

To avoid HT-water being led back to the LT-system during low-load mode, because of the higher pressure in the HT-system, an automatically operated butterfly valve, built into the pipe between the charge air cooler and the external LT-system, is closed in low-load mode.

Optionals

Alternatively the engine can be equipped with the following:

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- Thermostatic valve on outlet LT-system

Branches for:

- External preheating
- Alternator cooling

If the alternator is cooled by water, the pipes for this can be integrated on the GenSet.

Data

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

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

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

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Specification of engine coolant

Preliminary remarks

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

As is also the case with the fuel and lubricating oil, the engine coolant must be carefully selected, handled and checked. If this is not the case, corrosion, erosion and cavitation may occur at the walls of the cooling system in contact with water and deposits may form. Deposits obstruct the transfer of heat and can cause thermal overloading of the cooled parts. The system must be treated with an anticorrosive agent before bringing it into operation for the first time. The concentrations prescribed by the engine manufacturer must always be observed during subsequent operation. The above especially applies if a chemical additive is added.

Requirements

Limit values

The properties of untreated coolant must correspond to the following limit values:

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

Table 1: Properties of coolant that must be complied with

[1] 1 dGH (German hardness) ≙ 10 mg CaO in 1 litre of water ≙ 17.8 mg $CaCO_3$/l

≙ 0.357 mval/l ≙ 0.178 mmol/l

[2] 1 mg/l ≙ 1 ppm

Testing equipment

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

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

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Additional information

Distillate

If distilled water (from a fresh water generator, for example) or fully desalinated water (from ion exchange or reverse osmosis) is available, this should ideally be used as the engine coolant. These waters are free of lime and salts, which means that deposits that could interfere with the transfer of heat to the coolant, and therefore also reduce the cooling effect, cannot form. However, these waters are more corrosive than normal hard water as the thin film of

Specification of engine coolant

lime scale that would otherwise provide temporary corrosion protection does not form on the walls. This is why distilled water must be handled particularly carefully and the concentration of the additive must be regularly checked.

Hardness

The total hardness of the water is the combined effect of the temporary and permanent hardness. The proportion of calcium and magnesium salts is of overriding importance. The temporary hardness is determined by the carbonate content of the calcium and magnesium salts. The permanent hardness is determined by the amount of remaining calcium and magnesium salts (sulphates). The temporary (carbonate) hardness is the critical factor that determines the extent of limescale deposit in the cooling system.

Water with a total hardness of > 10°dGH must be mixed with distilled water or softened. Subsequent hardening of extremely soft water is only necessary to prevent foaming if emulsifiable slushing oils are used.

Damage to the coolant system

Corrosion

Corrosion is an electrochemical process that can widely be avoided by selecting the correct water quality and by carefully handling the water in the engine cooling system.

Flow cavitation

Flow cavitation can occur in areas in which high flow velocities and high turbulence is present. If the steam pressure is reached, steam bubbles form and subsequently collapse in high pressure zones which causes the destruction of materials in constricted areas.

Erosion

Erosion is a mechanical process accompanied by material abrasion and the destruction of protective films by solids that have been drawn in, particularly in areas with high flow velocities or strong turbulence.

Stress corrosion cracking

Stress corrosion cracking is a failure mechanism that occurs as a result of simultaneous dynamic and corrosive stress. This may lead to cracking and rapid crack propagation in water-cooled, mechanically-loaded components if the coolant has not been treated correctly.

Treatment of engine coolant

Formation of a protective film

The purpose of treating the engine coolant using anticorrosive agents is to produce a continuous protective film on the walls of cooling surfaces and therefore prevent the damage referred to above. In order for an anticorrosive agent to be 100 % effective, it is extremely important that untreated water satisfies the requirements in the paragraph Requirements.

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

Emulsifiable slushing oils are used less and less frequently as their use has been considerably restricted by environmental protection regulations, and because they are rarely available from suppliers for this and other reasons.

Treatment prior to initial commissioning of engine

Treatment with an anticorrosive agent should be carried out before the engine is brought into operation for the first time to prevent irreparable initial damage.

Specification of engine coolant

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NOTICE

Treatment of the coolant
The engine may not be brought into operation without treating the coolant.

Additives for coolants

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

Required release

A coolant additive may only be permitted for use if tested and approved as per the latest directives of the ICE Research Association (FVV) “Suitability test of internal combustion engine cooling fluid additives.” The test report must be obtainable on request. The relevant tests can be carried out on request in Germany at the staatliche Materialprüfanstalt (Federal Institute for Materials Research and Testing), Abteilung Oberflächentechnik (Surface Technology Division), Grafenstraße 2 in D-64283 Darmstadt.

Once the coolant additive has been tested by the FVV, the engine must be tested in a second step before the final approval is granted.

In closed circuits only

Additives may only be used in closed circuits where no significant consumption occurs, apart from leaks or evaporation losses. Observe the applicable environmental protection regulations when disposing of coolant containing additives. For more information, consult the additive supplier.

Chemical additives

Sodium nitrite and sodium borate based additives etc. have a proven track record. Galvanised iron pipes or zinc sacrificial anodes must not be used in cooling systems. This corrosion protection is not required due to the prescribed coolant treatment and electrochemical potential reversal that may occur due to the coolant temperatures which are usual in engines nowadays. If necessary, the pipes must be deplated.

Slushing oil

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

Antifreeze agents

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

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

Antifreeze agents are generally based on ethylene glycol. A suitable chemical anticorrosive agent must be added if the concentration of the antifreeze agent prescribed by the user for a specific application does not provide an appropri-

Specification of engine coolant

ate level of corrosion protection, or if the concentration of antifreeze agent used is lower due to less stringent frost protection requirements and does not provide an appropriate level of corrosion protection. Considering that the antifreeze agents listed in the table Antifreeze agents with slushing properties also contain corrosion inhibitors and their compatibility with other anticorrosive agents is generally not given, only pure glycol may be used as antifreeze agent in such cases.

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

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

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

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

Biocides

If you cannot avoid using a biocide because the coolant has been contaminated by bacteria, observe the following steps:

- You must ensure that the biocide to be used is suitable for the specific application.
- The biocide must be compatible with the sealing materials used in the coolant system and must not react with these.
- The biocide and its decomposition products must not contain corrosion-promoting components. Biocides whose decomposition products contain chloride or sulphate ions are not permitted.
- Biocides that cause foaming of coolant are not permitted.

Prerequisite for effective use of an anticorrosive agent

Clean cooling system

As contamination significantly reduces the effectiveness of the additive, the tanks, pipes, coolers and other parts outside the engine must be free of rust and other deposits before the engine is started up for the first time and after repairs of the pipe system.

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

Loose solid matter in particular must be removed by flushing the system thoroughly as otherwise erosion may occur in locations where the flow velocity is high.

The cleaning agents must not corrode the seals and materials of the cooling system. In most cases, the supplier of the coolant additive will be able to carry out this work and, if this is not possible, will at least be able to provide suitable products to do this. If this work is carried out by the engine operator, he should use the services of a specialist supplier of cleaning agents. The cooling system must be flushed thoroughly after cleaning. Once this has been done, the engine coolant must be immediately treated with anticorrosive agent. Once the engine has been brought back into operation, the cleaned system must be checked for leaks.

Regular checks of the coolant condition and coolant system

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

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

NOTICE

Concentration of chemical additives

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

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

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

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

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

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

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

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

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

Specification of engine coolant

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Protective measures

Anticorrosive agents contain chemical compounds that can pose a risk to health or the environment if incorrectly used. Comply with the directions in the manufacturer's material safety data sheets.

Avoid prolonged direct contact with the skin. Wash hands thoroughly after use. If larger quantities spray and/or soak into clothing, remove and wash clothing before wearing it again.

If chemicals come into contact with your eyes, rinse them immediately with plenty of water and seek medical advice.

Anticorrosive agents are generally harmful to the water cycle. Observe the relevant statutory requirements for disposal.

Auxiliary engines

If the coolant system used in a two-stroke main engine is used in a marine engine of type 16/24, 21/ 31, 23/30H, 27/38 or 28/32H, the coolant recommendations for the main engine must be observed.

Analysis

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

Permitted coolant additives

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

Specification of engine coolant

Coolant
inspecting

Summary

Acquire and check typical values of the operating media to prevent or limit damage.

The fresh water used to fill the coolant circuits must satisfy the specifications. The coolant in the system must be checked regularly in accordance with the maintenance schedule.
The following work/steps is/are necessary:
Acquisition of typical values for the operating fluid,
evaluation of the operating fluid and checking the anticorrosive agent concentration.

Tools/equipment required

Equipment for checking the fresh water quality

The following equipment can be used:

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

Equipment for testing the concentration of additives

When using chemical additives:

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

Testing the typical values of water

Short specification

Typical value/property	Water for filling and refilling (without additive)	Circulating water (with additive)
Water type	Fresh water, free of foreign matter	Treated coolant
Total hardness	≤ 10 dGH[1)]	≤ 10 dGH[1)]
pH value	6.5 – 8 at 20 °C	≥ 7.5 at 20 °C
Chloride ion content	≤ 50 mg/l	≤ 50 mg/l[2)]

Table 1: Quality specifications for coolants (short version)

[1)] dGH German hardness

1 dGH = 10 mg/l CaO
= 17.8 mg/l $CaCO_3$
= 0.178 mmol/L

[2)] 1 mg/l = 1 ppm

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Testing the concentration of rust inhibitors

Short specification

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

Table 2: Concentration of coolant additives

Testing the concentration of chemical additives

The concentration should be tested every week, and/or according to the maintenance schedule, using the testing instruments, reagents and instructions of the relevant supplier.

Chemical anti-corrosion agents can only provide effective protection if the concentration is precisely maintained. Respectively, the concentrations recommended by (quality specifications in volume 010.005 Engine – Operating Instructions 010.000.023-14) must be maintained under all circumstances. These recommended concentrations may deviate from those specified by the manufacturer.

Testing the concentration of anti-freeze agents

The concentration must be checked in accordance with the manufacturer's instructions or the test can be outsourced to a suitable laboratory. If in doubt, consult .

Regular water samplings

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

Testing

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

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

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Coolant system cleaning

Summary

Remove contamination/residue from operating fluid systems, ensure/re-establish operating reliability.

Coolant systems containing deposits or contamination prevent effective cooling of parts. Contamination and deposits must be regularly eliminated.
This comprises the following:
Cleaning the system and, if required,
removal of limescale deposits,
flushing the system.

Cleaning

The coolant system must be checked for contamination at regular intervals. Cleaning is required if the degree of contamination is high. This work should ideally be carried out by a specialist who can provide the right cleaning agents for the type of deposits and materials in the cooling circuit. The cleaning should only be carried out by the engine operator if this cannot be done by a specialist.

Oil sludge

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

Manufacturer	Product	Concentration	Duration of cleaning procedure/temperature
Drew	HDE - 777	4 – 5%	4 h at 50 – 60 °C
Nalfleet	MaxiClean 2	2 – 5%	4 h at 60 °C
Unitor	Aquabreak	0.05 – 0.5%	4 h at ambient temperature
Vecom	Ultrasonic Multi Cleaner	4%	12 h at 50 – 60 °C

Table 1: Cleaning agents for removing oil sludge

Lime and rust deposits

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

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

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

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

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

In emergencies only

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

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

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

Following cleaning

The cooling system must be flushed several times once it has been cleaned using cleaning agents. Replace the water during this process. If acids are used to carry out the cleaning, neutralise the cooling system afterwards with suitable chemicals then flush. The system can then be refilled with water that has been prepared accordingly.

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NOTICE

Only carry out cleaning procedure with cooled engine

Only begin the cleaning procedure when the engine has cooled down. Hot engine parts may not come into contact with cold water. After refilling the cooling system, open the venting pipes. Blocked venting pipes prevent the air from escaping and may cause thermal overload of the engine.

⚠ WARNING

Danger of chemical burns

From cleaning agents poisonous gases and fumes can develop, which may cause light to severe person injuries.

- Wear protective clothing
- Provide adequate ventilation
- Do not inhale developed gases and fumes
- Observe Safety Data Sheets or Operating Instructions of the relevant manufacturer

The applicable instructions for disposing of cleaning agents or acids are to be observed.

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Design data for the external cooling water system

General

This data sheet contains data regarding the necessary information for dimensioning of auxiliary machinery in the external cooling water system for the L23/30 type engine(s).The stated data are for one engine only and are specified at MCR.

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

External pipe velocities

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

Fresh water : 3.0 m/s
Sea water : 3.0 m/s

Pressure drop across engine

The pressure drop across the engines HT system, exclusive pump and thermostatic valve, is approx. 0.5 bar.

Lubricating oil cooler

The pressure drop of cooling water across the built-on lub. oil cooler is approx. 0.3 bar; the pressure drop may be different depending on the actual cooler design.

Thermostatic valve

The pressure drop across the built-on thermostatic valve is approx. 0.5 bar.

Charge air cooler

The pressure drop of cooling water across the charge air cooler is:

$\Delta P = V^2 \times K$ [Bar]

V = Cooling water flow in m^3/h

K = Constant, *see B 15 00 0, Charge Air Cooler*

Pumps

The cooling water pumps should be of the centrifugal type.

	FW	SW
Differential pressure	1-2.5 bar	1-2.5 bar
Working temperature	max. 90°C	max. 50°C

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Expansion tank

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

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

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

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

Minimum recommended tank volume: 0.1 m^3.
For multiplants the tank volume should be min.:

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

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

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

Data for external preheating system

The capacity of the external preheater should be 0.8-1.0 kW/cyl. The flow through the engine should for each cylinder be approx. 1.4 l/min with flow from top and downwards and 10 l/min with flow from bottom and upwards. See also table 1 below.

Cyl. No.	5	6	7	8
Quantity of water in eng: HT-system (litre) LT-system (litre)	 200 55	 240 60	 280 65	 320 70
Expansion vol. (litre)	11	13	15	17
Preheating data: Radiation area (m^2) Thermal coeff. (kJ/°C)	 14.0 2860	 16.1 3432	 18.2 4004	 20.3 4576

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

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External cooling water system

Design of external cooling water system

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

The diagrams on the following pages are principal diagrams, and are MAN Energy Solutions' recommendation for the design of external cooling water systems.

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

1. Simplicity
2. Separate HT temperature regulation for propulsion and alternator engines.
3. HT temperature regulation on engine outlet.
4. Preheating with surplus heat.
5. Preheating in engine top, downwards.
6. As few change-over valves as possible.
7. Possibility for MAN Energy Solutions ICS-system.

Ad 1) Cooling water systems have a tendency to be unnecessarily complicated and thus uneconomic in installation and operation. Therefore, we have attached great importance to simple diagram design with optimal cooling of the engines and at the same time installation- and operation-friendly systems resulting in economic advantages.

Ad 2) Cooling of alternator engines should be independent of the propulsion engine load and vice versa. Therefore, there should be separate cooling water temperature regulation thus ensuring optimal running temperatures irrespective of load.

Ad 3) The HT FW thermostatic valve should be mounted on the engine's outlet side ensuring a constant cooling water temperature above the engine at all loads. If the thermostat valve is placed on the engine's inlet side, which is not to be recommended, the temperature on the engine depends on the load with the risk of overheating at full load.

Ad 4) It has been stressed on the diagrams that the alternator engines in stand-by position as well as the propulsion engine in stop position are preheated, optimally and simply, with surplus heat from the running engines.

Ad 5) If the engines are preheated with reverse cooling water direction, i.e. from the top and downwards, an optimal heat distribution is reached in the engine. This method is at the same time more economic since the need for heating is less and the water flow is reduced.

Ad 6) The systems have been designed in such a way that the change-over from sea operation to harbour operation/stand-by with preheating can be made with a minimum of manual or automatic interference.

Ad 7) If the actual running situations demand that one of the auxiliary engines should run on low-load, the systems have been designed so that one of the engines can be equipped with a cooling system for ICS-operation (Integrated Charge air System).

Fresh water treatment

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

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

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

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

Central cooling system

Central cooling system

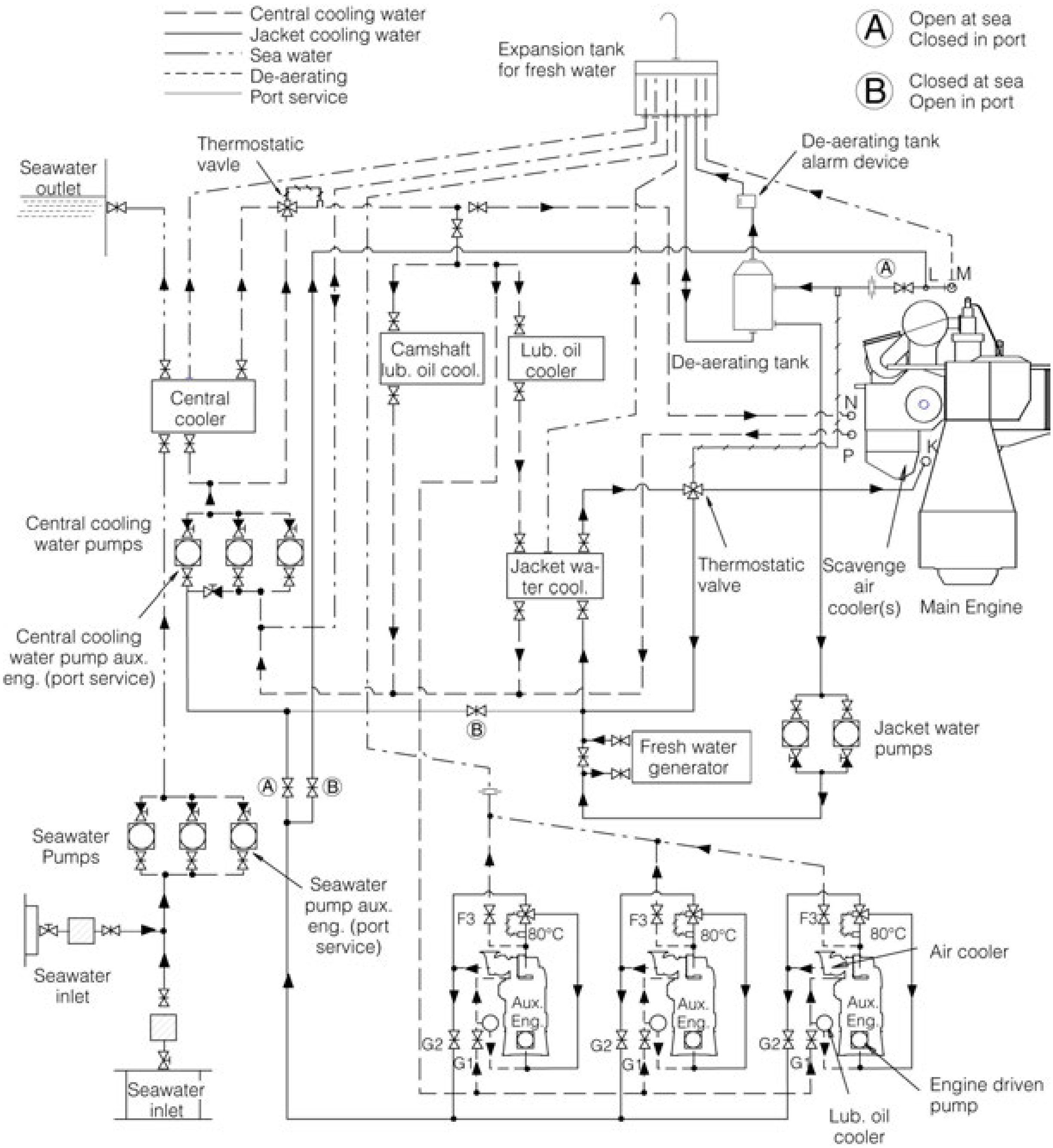

Figure 1: Diagram for central cooling system.

Design features and working principle

This diagram describes the possibilities with regard to the design of a common auxiliary system for a two-stroke main engine of the MC-type and four-stroke GenSets fromMAN Energy Solutions.

The central cooling system is an alternative to the conventional seawater cooling system, based on the same design principles with regard to cooler locations, flow control and preheating, but with a central cooler and one additional set of pumps. The central cooler minimizes maintenance work by being the only component that is in contact with seawater. In all other parts of the system, inhibited fresh water is used in accordance with MAN Energy Solutions' specifications.

Operation at sea

The seawater cooling pumps, item 1, pump seawater from the sea chests through the central cooler, item 2, and overboard. Alternatively, some shipyards use a pumpless scoop system. On the freshwater side, the central cooling water pumps, item 3, circulate the low-temperature fresh water, in a cooling circuit, directly through the lubricating oil coolers, item 4, of the main engine, the auxiliary engines and the air coolers, item 5.

The jacket water cooling system for the auxiliary engines is equipped with engine-driven pumps and a by-pass system integrated in the low-temperature system, whereas the main engine jacket system has an independent pump circuit with jacket water pumps, item 6, circulating the cooling water through the fresh water generator, item 7, and the jacket water cooler, item 8, to the inlet of the engine.

A thermostatically controlled 3-way valve, item 9, at the jacket cooler outlet mixes cooled and uncooled water to maintain an outlet water temperature of 80-82°C from the main engine.

As all fresh cooling water is inhibited and common for the central cooling system, only one common expansion tank, item 10, is necessary, for de-aeration of both the low and high temperature cooling systems. This tank accommodates the difference in the water volume caused by changes in the temperature.

To prevent the accumulation of air in the cooling water system, a de-aeration tank, item 11, is located below the expansion tank. An alarm device is inserted between the de-aeration tank and the expansion tank so that the operating crew can be notified if excess air or gas is released, as this signals a malfunction of engine components.

Operation in port

During operation in port, when the main engine is stopped but one or more auxiliary engines are running, the valve, item A, is closed and the valve, item B, is open. A small central water pump, item 3, will circulate the necessary flow of water for the air cooler, the lubricating oil cooler, and the jacket cooler of the auxiliary engines. The auxiliary engine-driven pumps and the integrated loop mentioned above ensure a satisfactory jacket cooling water temperature at the auxiliary engine outlet.

The main engine is preheated as described for the jacket water system, fig. 1.

Jacket water cooling system

Jacket water cooling system

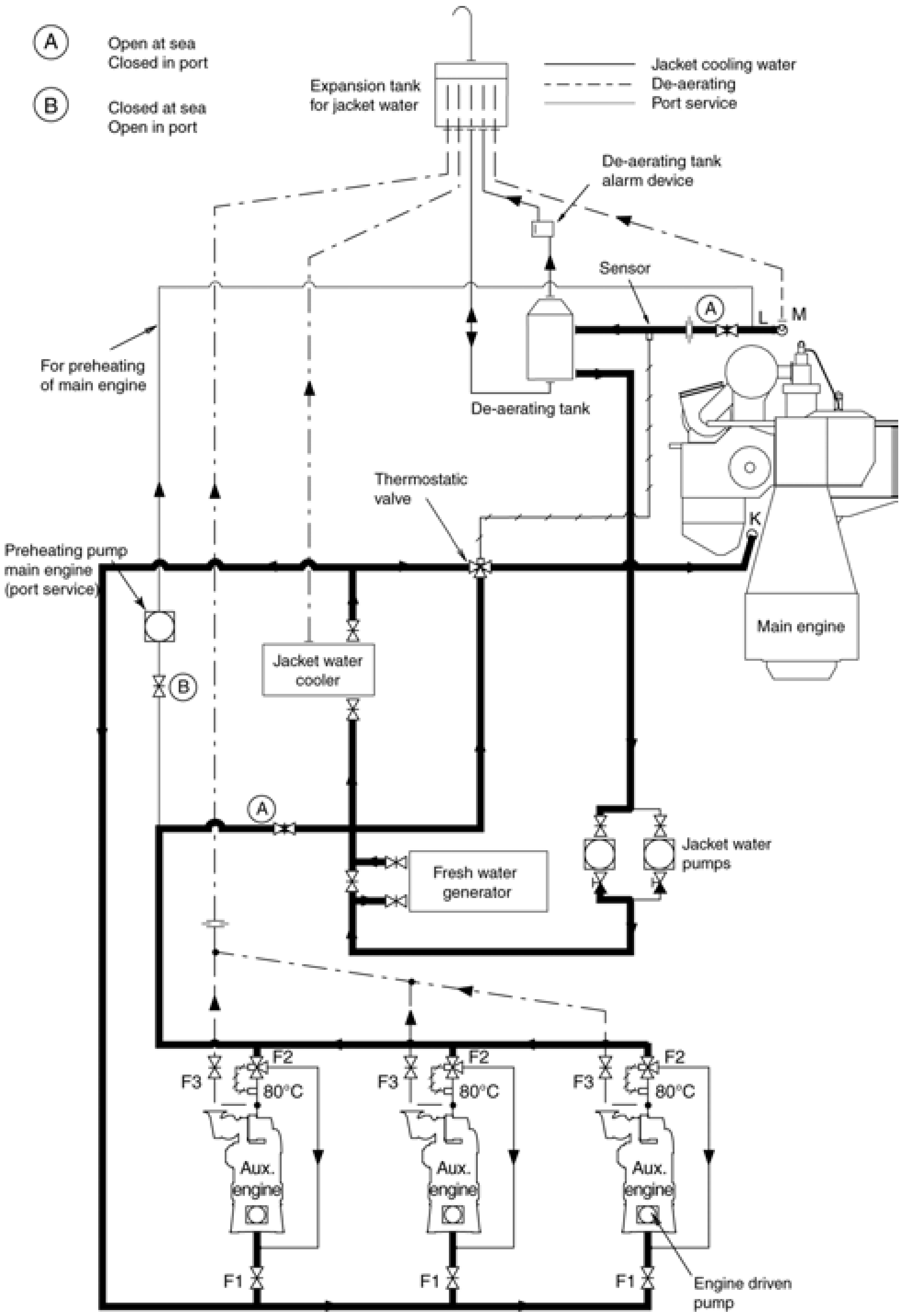

Figure 1: Operating at sea.

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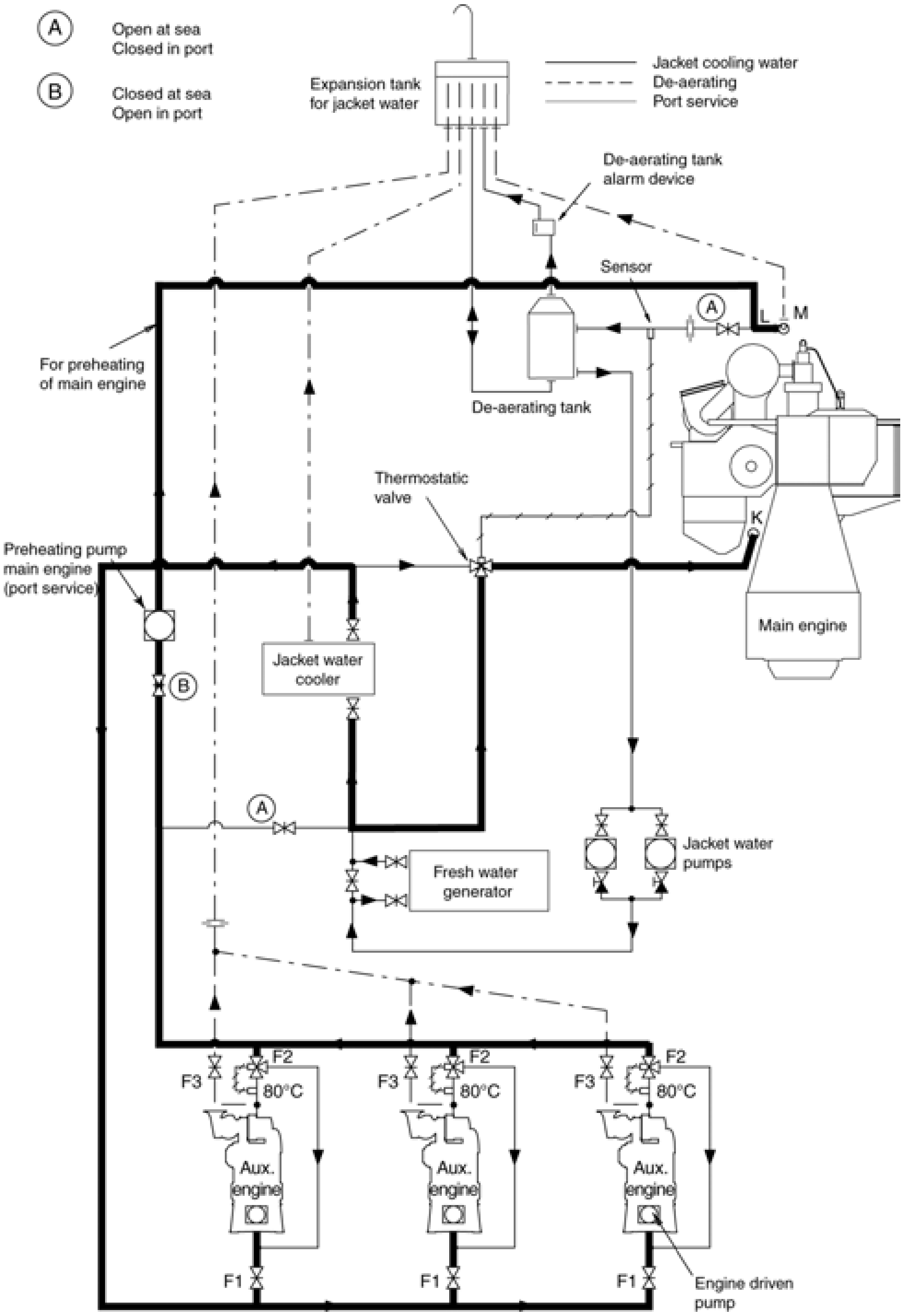

Figure 2: Operating in port.

Design features and working principle

This diagram describes the possibilities with regard to the design of a common auxiliary system for a two-stroke main engine of the MC-type and four-stroke GenSets from MAN Energy Solutions.

The jacket water cooling system controls the temperature of the engines proper.

The jacket water is to be inhibited to protect the surfaces of the cooling system against corrosion, corrosion fatigue, cavitation and the formation of scale.

Operation at sea

The jacket water pumps circulate hot cooling water from the engines to the fresh water generator and from there to the jacket water cooler. Here a thermostatically controlled 3-way valve mixes cooled and uncooled water to maintain an outlet temperature of 80-82°C from the main engine.

An integrated loop in the auxiliary engines ensures a constant temperature of 80°C at the outlet of the auxiliary engines.

There is one common expansion tank for the main engine and the auxiliary engines.

To prevent the accumulation of air in the jacket water system, a de-aeration tank is located at the outlet of the main engine. An alarm device is inserted between the de-aeration tank and the expansion tank so that the operating crew can be notified if excess air or gas is released, as this signals a malfunction of engine components.

Operation in port

The main engine is preheated by utilizing hot water from the auxiliary engine(s). Depending on the size of main engine and auxiliary engines, an extra preheater may be necessary. This preheating is activated by closing valve A and opening valve B.

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

As the temperature sensor for the valve in this operating mode is measuring in a non-flow, low temperature piping, the valve will lead most of the cooling water to the jacket water cooler.

The integrated loop in the auxiliary engines will ensure a constant temperature of 80°C at the auxiliary engine outlet, the main engine will be preheated, and auxiliary engines in stand-by can also be preheated by operating valves F3 and F1.

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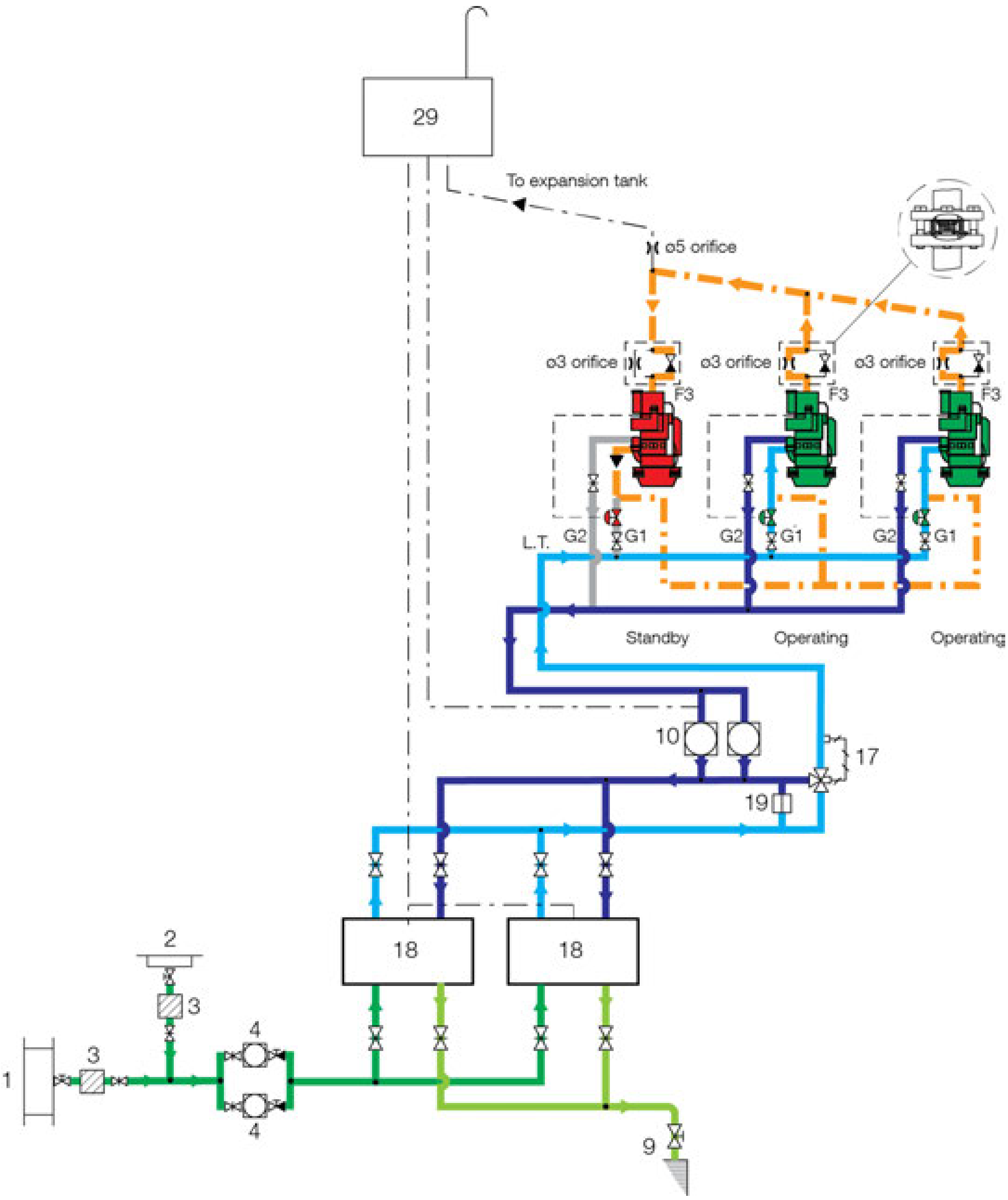
Cooling water system, 1-string

Diagram



1 Seachest low
2 Seachest high
3 Sea water filter
4 Sea water pump
9 Overboard discharge valve
10 LT pumps
17 LT thermostativ valve

18 Central cooler
19 MDO/MGO cooler
29 Expansion tank

G1 LT cooling water - inlet
G2 LT cooling water - outlet
F3 HT cooling water from expansion tank

Cooling water system

Layout of 1-string cooling water system is the simplest system for cooling the engine.

The engine is designed for freshwater cooling only. Therefore the cooling water system has to be arranged as a centralised or closed cooling water system. All recommendable types are described in the following.

The engine is equipped with built-on freshwater pump for high temperature cooling water systems.

Thermostatic valve elements, which control the high and low temperature cooling water system, are also integrated parts of the engine.

Velocity recommendations for freshwater and sea water pipes:

Freshwater	Suction pipe:	1.0 - 2.0 m/s
	Delivery pipe:	2.0 - 3.5 m/s
Sea water	Suction pipe:	1.0 - 1.5 m/s
	Delivery pipe:	1.5 - 2.5 m/s

Central cooling water system

Sea water filter, item 3

Design data:	
Capacity:	See sea water pump
Pressure drop across clean filter:	Max 0.05 bar
Pressure drop across dirty filter:	Max 0.1 bar
Mesh size:	ø3 - ø5 mm
Free filter hole area:	Min two times the normal pipe area

Sea water pumps, item 4

The pumps should always be installed below sea water level when the ship is unloaded.

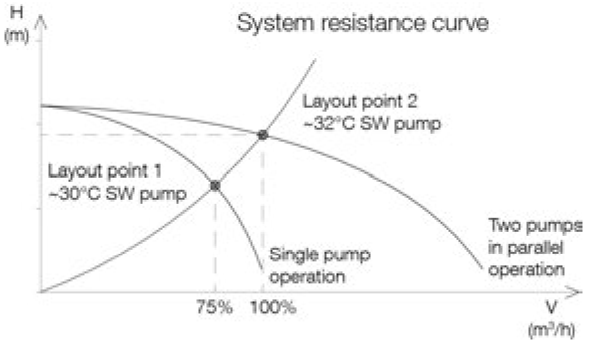


Figure 1: Pump characteristic

The pumps in parallel, layout point 2 (see fig 2), are as standard designed to fulfill:

Capacity:	Determined by the cooler manufacturer. Approx 100 - 175% of fresh water flow in the cooler, depending on the central cooler
Pressure:	1.8 - 2.0 bar
Sea water temperature:	Max 32ºC

The volume of sea water required to circulate through a known sized cooler to remove a known amount of heat, is very sensitive and dependent on the sea water temperature.

The relation between sea water temperature and the necessary water flow in the central cooler is shown in fig 2.

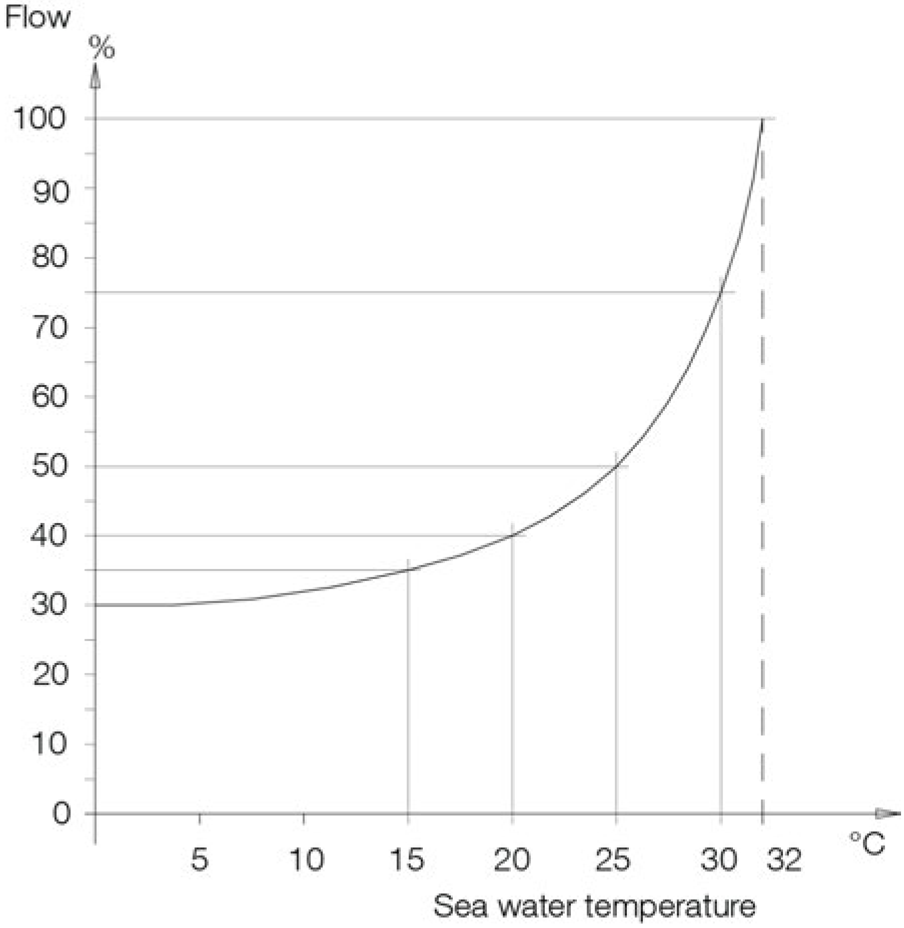


Figure 2: Necessary water flow

Depending on the actual characteristic of the system resistance curve and the pump characteristic curve, the sea water flow with only one pump in service will be approx 75%. This means that the cooling capacity can be obtained with only one pump until reaching a sea water temperature of approx 30°C.

The back pressure in single pump operation must be observed as a low back pressure may lead to unfavourable operation and cavitation of impeller. We are pleased to advise on more specific questions concerning the layout of pumps and location of orifices, etc.

Central cooler(s), item 18

If we are to supply the central cooler(s), it will be a plate cooler with titanium plates.

Design data:	
Heat transfer:	List of capacities
Pressure drop LT:	Max 0.5 bar
Pressure drop SW:	Max 0.5 bar standard Max 1.0 bar if HT cooler is in LT system

Expansion tanks, items 29

Separate expansion tanks for the LT and HT system should be installed to accommodate for changes of volume due to varying temperatures and possible leakage in the LT and HT systems. The separated HT and LT systems facilitates trouble shooting.

The minimum water level in the expansion tank should be approximately 8 m above the centre line of the crankshaft. This will ensure sufficient suction head to the fresh water pump and reduce the possibility of cavitation, as well as local “hot spots” in the engine.

The expansion tank should be equipped with a vent pipe and flange for filling the tank with water and inhibitors.

The vent pipe should be installed below the minimum water level to reduce oxidation of the cooling water due to splashing from the vent pipe.

Volume:	Min 15% of water volume, however, min 100 litres.

Preheating

As optional the engines can be equipped with electrical preheating. It is recommended to preheat engines operating on MGO/Gas due to the prolonged life time of the engines' wearing parts. The preheating is arranged for automatic operation, so that the preheating is disconnected when the engine is running, and connected when the engine is in stand-by position. The preheating is adjusted so that the temperature is ≥ 60°C at the top cover (see thermometer TI12), and approximately 25 to 45°C at outlet of the cylinders (see thermometer TI10).

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

Preheating of stand-by auxiliary engines during sea operation

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

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

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

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

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

Preheating element, build-in

See B 13 23 1.

Different arrangements of central cooling systems

There are many variations of centralised cooling systems and we are available to discuss various changes to suit an owner's or builder's specific wishes.

For each plant, special consideration should be given to the following design criteria: Sea water temperatures, pressure loss in coolers, valves and pipes, pump capacities etc, for which reason these components have not been specified in this guide.

Closed cooling systems

Several systems have been developed to avoid sea water. The benefits are:

- Minimising the use of expensive corrosion resistant pipes, valves and pumps
- Sea water pumps at reasonable costs
- No cleaning of plate type central heat exchangers

Such systems are advantageous in the following conditions:

- Sailing in shallow waters
- Sailing in very cold waters
- Sailing in corrosive waters (eg some harbours)
- Sailing in water with high contents of solids (dredging and some rivers)

A disadvantage of most closed cooling water systems is the poor heat transfer coefficient.

LT coolers with very small temperature differences between the cooling water and the sea or raw water, require a relatively large heat exchanger to enable sufficient heat transfer.

We are available to offer advice for specific cooler types, but the final responsibility for design, pressure losses, strength and system maintenance remains with the yard and the shipowner. We reserve the right not to accept proposed coolers, which seems to be insufficient for its purpose.

Also when using other types of closed cooling water systems the HT and LT cooling water systems have to be separated.

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Expansion tank

General

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

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

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

Volume

Engine type	Expansion volume litre*	Recommended tank volume m^3**
5L23/30H, 5L23/30H Mk2, 5L23/30S, 5L23/30DF	11	0.1
6L23/30H, 6L23/30H Mk2, 6L23/30S, 6L23/30DF	13	0.1
7L23/30H, 7L23/30H Mk2, 7L23/30S, 7L23/30DF	15	0.1
8L23/30H, 8L23/30H Mk2, 8L23/30S, 8L23/30DF	17	0.1
5L28/32H, 5L28/32S, 5L28/32DF	28	0.15
6L28/32H, 6L28/32S, 6L28/32DF	33	0.15
7L28/32H, 7L28/32S, 7L28/32DF	39	0.15
8L28/32H, 8L28/32S, 8L28/32DF	44	0.15
9L28/32H, 9L28/32S, 9L28/32DF	50	0.15
12V28/32S, 12V28/32S-DF, 12V28/32H	66	0.3
16V28/32S, 16V28/32S-DF, 16V28/32H	88	0.3
18V28/32S, 18V28/32S-DF, 18V28/32H	99	0.3
5L16/24, 5L16/24S	4	0.1
6L16/24, 6L16/24S	5	0.1
7L16/24, 7L16/24S	5	0.1
8L16/24, 8L16/24S	5	0.1
9L16/24, 9L16/24S	6	0.1
5L21/31, L21/31 Mk2, 5L21/31S	6	0.1
6L21/31, L21/31 Mk2, 6L21/31S	7	0.1
7L21/31, L21/31 Mk2, 7L21/31S	8	0.1
8L21/31, L21/31 Mk2, 8L21/31S	9	0.1
9L21/31, L21/31 Mk2, 9L21/31S	10	0.1
5L27/38, 5L27/38S	10	0.15
6L27/38, 6L27/38S	12	0.15
7L27/38, 7L27/38S	13	0.15
8L27/38, 8L27/38S	15	0.15
9L27/38, 9L27/38S	20	0.15
* Per engine ** Common expansion tank		

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

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Preheater arrangement in high temperature system

General

The built-on cooling water preheating arrangement consist of a thermostat-controlled el-preheating element built into the outlet pipe for the HT cooling water on the engine's front end. The pipe dimension has been increased in the piping section where the heating element is mounted.

Cyl. No.	Preheater 3x400V/3x440V kW
5	1 x 7.5
6	1 x 9.0
7	1 x 9.0
8	1 x 12.0

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

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

Operation

Engines starting on HFO and engines in stand-by position must be preheated. It is therefore rcommended that the preheater is arranged for automatic operation, so that the preheater is disconnected when the engine is running and connected when the engine is in stand-by position. The thermostat setpoint is adjusted to 70°C, that gives a temperature of app. 50°C at the top cover. *See also E 19 13 0, High Temperature Preheater Control Box.*

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Expansion tank pressurized

Description

Engine type	Expansion volume litre*	Recommended tank volume m³**
5L23/30H, 5L23/30H Mk2, 5L23/30H Mk3, 5L23/30S, 5L23/30DF	11	0.1
6L23/30H, 6L23/30H Mk2, 6L23/30H Mk3, 6L23/30S, 6L23/30DF	13	0.1
7L23/30H, 7L23/30H Mk2, 7L23/30H Mk3, 7L23/30S, 7L23/30DF	15	0.1
8L23/30H, 8L23/30H Mk2, 8L23/30H Mk3, 8L23/30S, 8L23/30DF	17	0.1
9L23/30H Mk3	-	-
5L28/32H, 5L28/32S, 5L28/32DF	28	0.15
6L28/32H, 6L28/32S, 6L28/32DF	33	0.15
7L28/32H, 7L28/32S, 7L28/32DF	39	0.15
8L28/32H, 8L28/32S, 8L28/32DF	44	0.15
9L28/32H, 9L28/32S, 9L28/32DF	50	0.15
12V28/32S, 12V28/32S-DF, 12V28/32H	66	0.3
16V28/32S, 16V28/32S-DF, 16V28/32H	88	0.3
18V28/32S, 18V28/32S-DF, 18V28/32H	99	0.3
5L16/24, 5L16/24S	4	0.1
6L16/24, 6L16/24S	5	0.1
7L16/24, 7L16/24S	5	0.1
8L16/24, 8L16/24S	5	0.1
9L16/24, 9L16/24S	6	0.1
5L21/31, 5L21/31 Mk2, 5L21/31S	6	0.1
6L21/31, 6L21/31 Mk2, 6L21/31S	7	0.1
7L21/31, 7L21/31 Mk2, 7L21/31S	8	0.1
8L21/31, 8L21/31 Mk2, 8L21/31S	9	0.1
9L21/31, 9L21/31 Mk2, 9L21/31S	10	0.1
5L27/38, 5L27/38S	10	0.15
6L27/38, 6L27/38S	12	0.15
7L27/38, 7L27/38S	13	0.15
8L27/38, 8L27/38S	15	0.15
9L27/38, 9L27/38S	20	0.15
* Per engine ** Common expansion tank		

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

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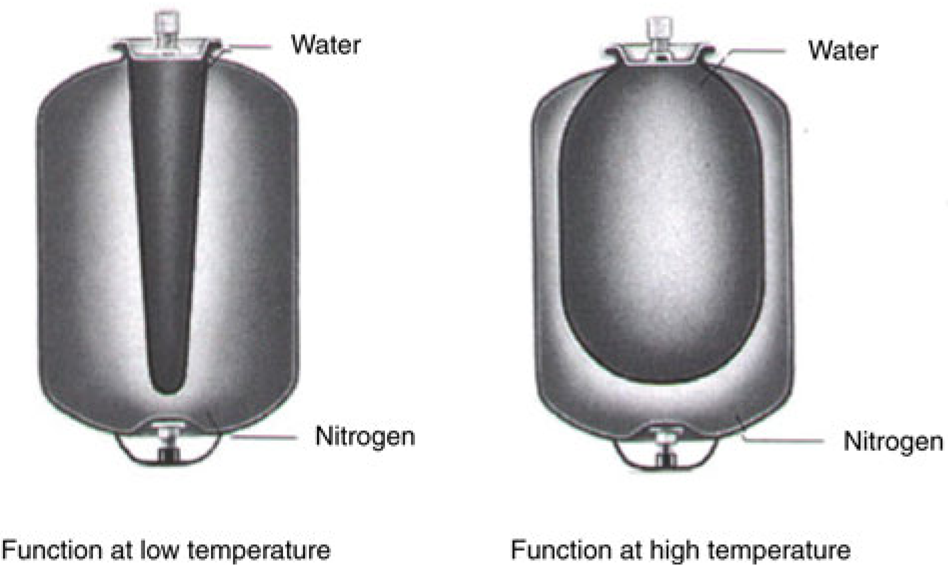


Figure 1: Function of expansion tank.

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

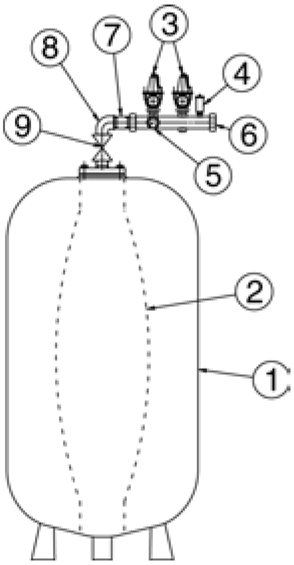
The expansion vessel should be connected to the system at a point close to the cooling water inlet connections (G1 / F1) in order to maintain positive pressures throughout the system and allow expansion of the water.

The safety valves are fitted on the manifold.

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

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

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



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

Figure 2: Expansion tank

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Compressed air system

Compressed air system

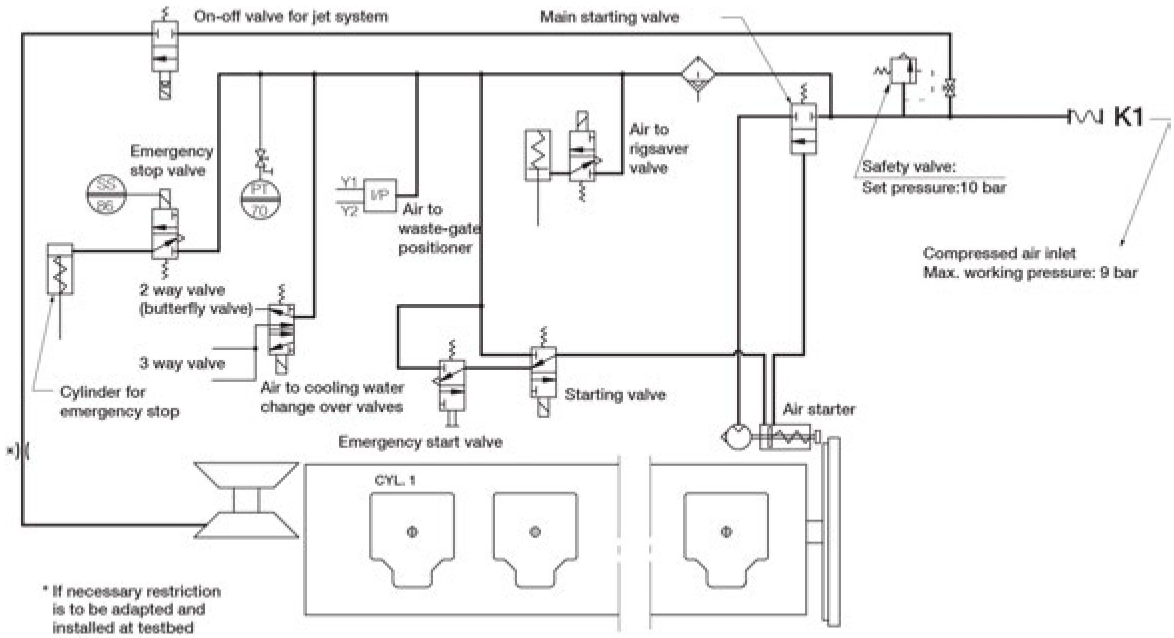

Figure 1: Diagram for compressed air system (for guidance only, please see the plant specific engine diagram)

Air supply!

⚠ WARNING **Air supply must not be interrupted when engine is running**

Pipe description

Pipe description		
K1	Compressed air inlet	DN 40

Table 1: Flange connections are standard according to DIN 2501

General

The compressed air system on the engine contains a starting system, starting control system and safety system. Further, the system supplies air to the jet system, the rigsaver valve, the waste gate valve and the change over valves for cooling water (low load operation).

The compressed air is supplied from the starting air receivers (30 bar) through an external reduction station, from where compressed air at 7-9 bar is supplied to the engine.

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

Starting system

The engine is started by means of a built-on air starter, which is a turbine motor with gear box, safety clutch and drive shaft with pinion. Further, there is a main starting valve.

Control system

The air starter is activated electrically with a pneumatic 3/2 way solenoid valve. The valve can be activated manually from the starting box on the engine, and it can be arranged for remote control, manual or automatic.

For remote activation, the starting spool is connected so that every starting signal to the starting spool goes through the safe start function, which is connected to the converter for engine rpm.

Further, the system is equipped with an emergency starting valve which makes it possible to activate the air starter manually in case of a power failure.

Safety system

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

As standard the engine is equipped with a electrical/mechanic stop cylinder, which starts to operate if the safety system is activated.

When the maximum permissible rpm is exceeded, the engine speed sensor will activate a pneumatically controlled stop cylinder, which will bring the fuel index to zero and stop the engine.

A microswitch will be activated too and give a stop signal to the safety system.

Pneumatic start sequence

When the starting valve is opened, air will be supplied to the drive shaft housing of the air starter.

The air supply will - by activating a piston - bring the drive pinion into engagement with the gear rim on the engine flywheel.

When the pinion is fully engaged, the pilot air will flow to, and open the main starting valve, whereby air will be led to the air starter, which will start to turn the engine.

When the rpm exceeds approx. 140, at which firing has taken place, the starting valve is closed whereby the air starter is disengaged.

Optionals

Besides the standard components, the following standard optionals can be built-on:

- Main stop valve, inlet engine

Pressure transmitting:

- PT 70 Compressed air inlet

Position switching, stop:

- ZS75 Microswitch on flywheel

Data

For air consumption pr. start, *see D 10 05 0 "List of Capacities".*

Operating levels and set points, *see B 19 00 0, "Operating Data and Set Points".*

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Specification of compressed air

General

For compressed air quality observe the ISO 8573-1. Compressed air must be free of solid particles and oil (acc. to the specification).

Requirements

Compressed air quality of starting air system

The starting air must fulfil at least the following quality requirements according to ISO 8573-1.

Purity regarding solid particles	Quality class 6
Particle size > 40µm	max. concentration < 5 mg/m^3
Purity regarding moisture	Quality class 7
Residual water content	< 0.5 g/m^3
Purity regarding oil	Quality class X

Additional requirements are:

- The air must not contain organic or inorganic silicon compounds.
- The layout of the starting air system must ensure that no corrosion may occur.
- The starting air system and the starting air receiver must be equipped with condensate drain devices.
- By means of devices provided in the starting air system and via maintenance of the system components, it must be ensured that any hazardous formation of an explosive compressed air/lube oil mixture is prevented in a safe manner.

Compressed air quality in the control air system

Please note that control air will be used for the activation of some safety functions on the engine – therefore, the compressed air quality in this system is very important.

Control air must meet at least the following quality requirements according to ISO 8573-1.

- Purity regarding solid particles — Quality class 5
- Purity regarding moisture — Quality class 4
- Purity regarding oil — Quality class 3

For catalysts

The following specifications are valid unless otherwise defined by any other relevant sources:

Compressed air quality for soot blowing

Compressed air for soot blowing must meet at least the following quality requirements according to ISO 8573-1.

- Purity regarding solid particles — Quality class 3
- Purity regarding moisture — Quality class 4
- Purity regarding oil — Quality class 2

Compressed air quality for reducing agent atomisation

Compressed air for atomisation of the reducing agent must fulfil at least the following quality requirements according to ISO 8573-1.

Specification of compressed air

- Purity regarding solid particles — Quality class 3
- Purity regarding moisture — Quality class 4
- Purity regarding oil — Quality class 2

NOTICE

Clogging of catalysts

To prevent clogging of catalysts and catalyst lifetime shortening, the compressed air specification must always be observed.

For gas valve unit control (GVU)

Compressed control air quality for the gas valve unit control (GVU)

Compressed air for the gas valve unit control (GVU) must meet at least the following quality requirements according to ISO 8573-1.

- Purity regarding solid particles — Quality class 2
- Purity regarding moisture — Quality class 3
- Purity regarding oil — Quality class 2

Compressed air system

Diagram

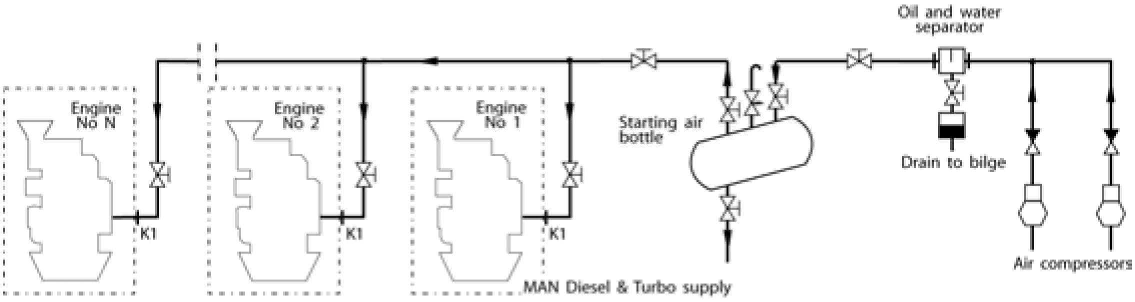

Figure 1: Diagram for compressed air system

Design of external system

The external compressed air system should be common for both propulsion engines and GenSet engines.

Separate tanks shall only be installed in turbine vessels, or if GenSets in engined vessels are installed far away from the propulsion plant.

The design of the air system for the plant in question should be according to the rules of the relevant classification society.

As regards the engine's internal compressed air system, please *see B 14 00 0 "Internal Compressed Air System".*

An oil and water separator should be mounted between the compressor and the air receivers, and the separator should be equipped with automatic drain facilities.

Each engine needs only one connection for compressed air, please *see diagram for the compressed air system.*

Installation

In order to protect the engine's starting and control equipment against condensation water, the following should be observed:

- The air receiver(s) should always be installed with good drainage facilities. Receiver(s) arranged in horizontal position must be installed with a slope downwards of min. 3°-5°.
- Pipes and components should always be treated with rust inhibitors.
- The starting air pipes should be mounted with a slope towards the receivers, preventing possible condensed water from running into the compressors.
- Drain valves should be mounted at the lowest position on the starting air pipes.

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Starting air system

Design features and working principle

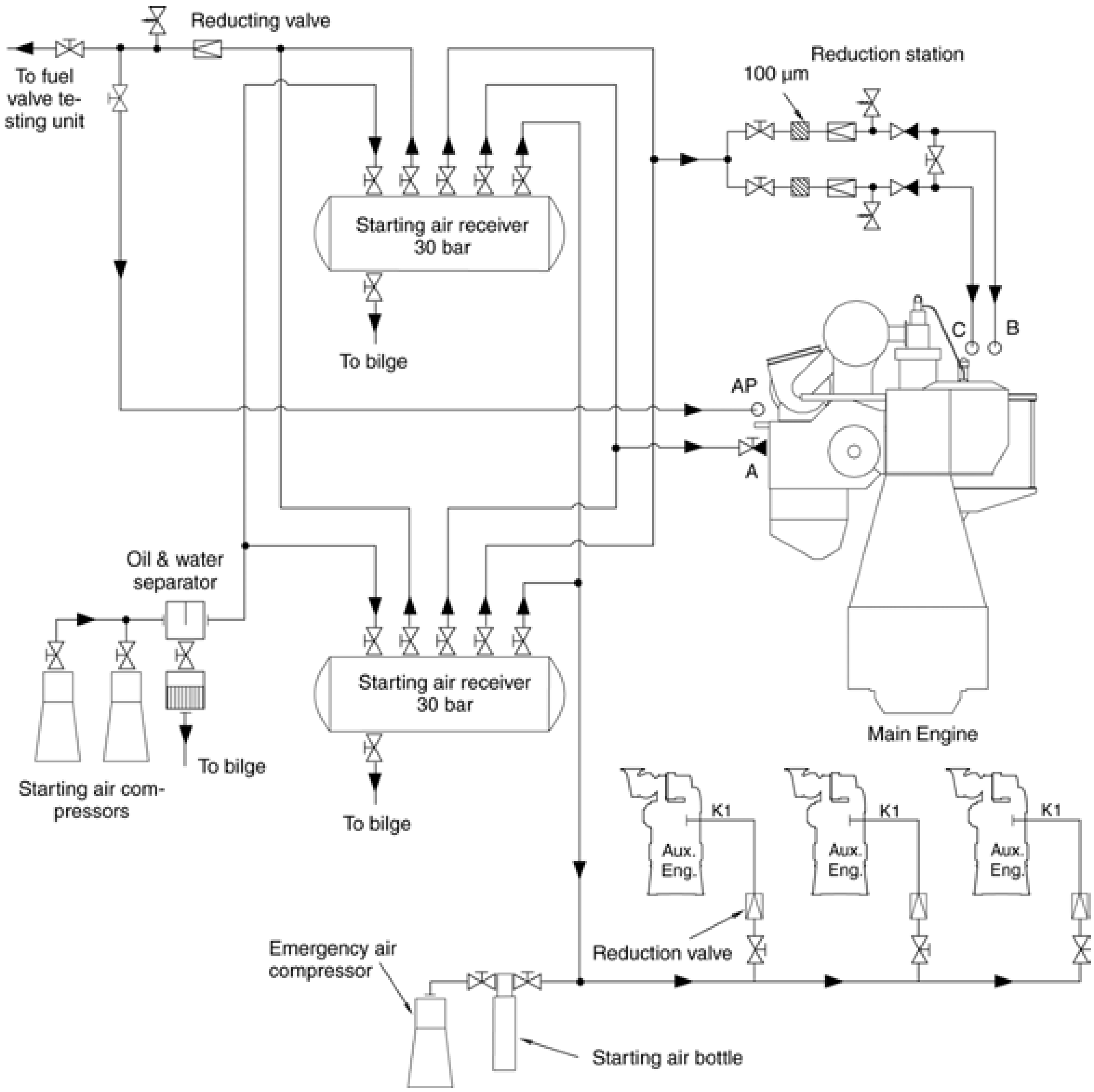

Figure 1: Starting air system

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This diagram describes the possibilities with regard to the design of a common auxiliary system for a two-stroke main engine of the MC-type and four-stroke GenSets from MAN Energy Solutions.

Two starting air compressors with automatic start and stop maintain a starting air pressure of 30 bar in the starting air receivers.

The main engine is supplied with 30 bar starting air directly from the starting air receivers. Through a pressure reduction station compressed air at 7 bar is supplied as control air for the engine manoeuvring system, and as safety air for the emergency system.

Starting air and control air for the auxiliary engine(s) is also supplied from the same starting air receivers, via reduction valves that lower the pressure to a value suited to the actual type of MAN Energy Solutions four-stroke auxiliary engines chosen. An emergency air compressor and a starting air bottle are installed for redundant emergency start of the auxiliary engines.

If high-humidity air is taken in by the air compressors, an oil and water separator will remove moisture drops present in the 30 bar compressed air. When the pressure is subsequently reduced to 7 bar, as for the main engine manoeuvring system, the humidity in the compressed air will be very slight. Consequently, further air drying is considered unnecessary.

From the starting air receivers a special air line leads to the valve testing equipment.

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Combustion air system

Combustion air system

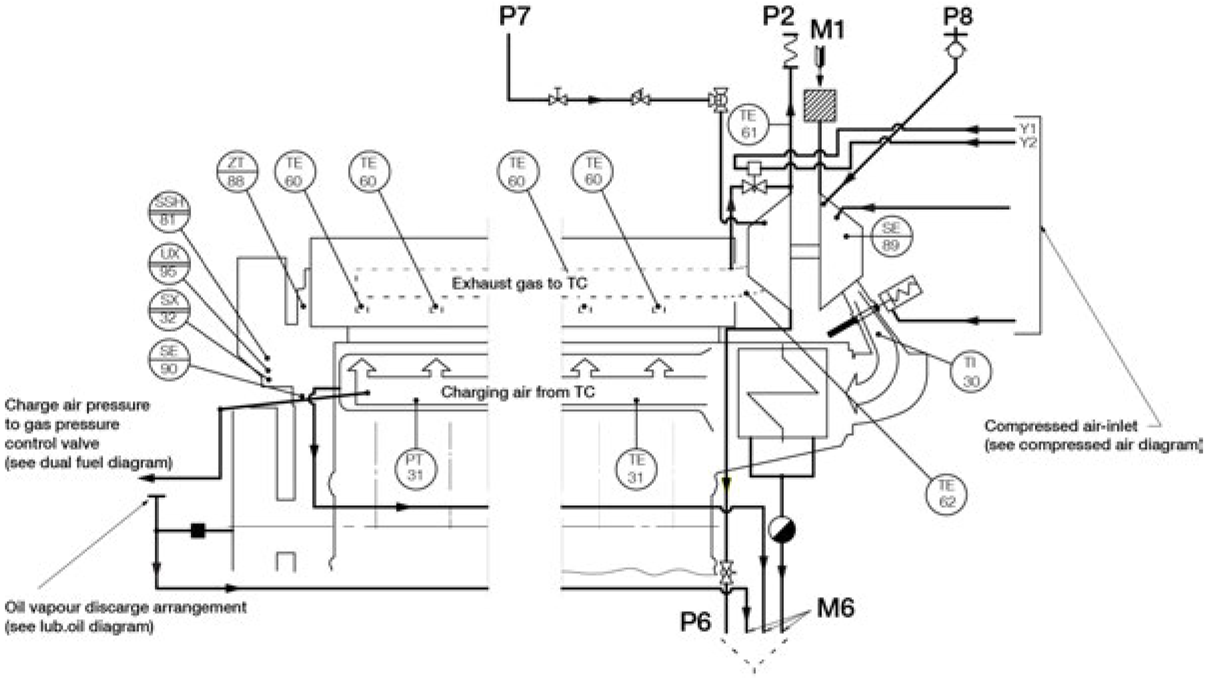

Figure 1: Diagram for combustion air system (for guidance only, please see the plant specific engine diagram)

Pipe description

Pipe description		
M1	Charge air inlet	
M6	Drain from charge air cooler, charge air receiver and oil vapour discharge - outlet	3/4"
P2	Exhaust gas outlet	**
P6	Drain from turbocharger outlet	22 x 2.5
P7	Water washing turbine side inlet (quick coupling)	1/2"
P8	Water washing, compressor side with quick coupling inlet	

Table 1: *Flange connections are standard according to DIN 2501. **See B 16 01 0 "Exhaust gas system" and B 16 02 0 "Position of gas outlet on turbocharger".

General

The air intake to the turbochargers takes place direct from the engine room through the intake silencer on the turbocharger.

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From the turbocharger the air is led via the charge air cooler and charge air receiver to the inlet valves of each cylinder.

The charge air cooler is a compact tube-type cooler with a large cooling surface.

The charge air receiver is integrated in the engine frame on the exhaust side.

It is recommended to blow ventilation air in the level of the top of the engine(s) close to the air inlet of the turbocharger, but not so close that sea water or vapour may be drawn in. It is further recommended that there always is a positive air pressure in the engine room.

Water mist catcher

At outlet charge air cooler the charge air is led through the water mist catcher. The water mist catcher prevents condensed water (one of the major causes of cylinder wear) from entering the combustion chamber.

Turbocharger

The engine is as standard equipped with a high-effeciency MAN Energy Solutions TCR turbocharger of the radial type, which is located on the front end of the engine, mounted on the top plate of the charging air cooler housing.

Cleaning of turbocharger

The turbocharger is fitted with an arrangement for cleaning of the turbine side, see B 16 01 3, and water washing of the compressor side, see B 15 05 1.

Charge air shut-off valve, "rig saver"

The valve is applicable for installations with risk of gas penetration such as dual fuel engines.

The principle of the valve is to activate in case of external gas leakage alarm in the safety system or in case of overspeed. In both cases the safety system will release the rig saver valve shortly after the shutdown signal. The reason for the slight delay is to get as much air out of the turbocharger as possible before the valve blocks for the air passage between the turbocharger and the engine.

Waste gate

For air-fuel ratio control, part of the exhaust gas bypasses the turbine via the waste gate valve. The air-fuel ratio control is only active in gas operating mode. In diesel operating mode, the waste gate valve is closed.

Optionals

Besides the standard components, the following standard optionals can be built-on:

Pressure transmitting

- PT 31 Charge air, outlet from cooler

Temperature alarm high

- TAH 31 Charge air, outlet from cooler
- TAL 31 Charge air, outlet from cooler

Temperature element

- TE 31 Charge air, outlet from cooler
- TE 60 Exhaust gas, outlet cylinder
- TE 61 Exhaust gas, outlet turbocharger
- TE 62 Exhaust gas, inlet turbocharger

Data

For charge air heat dissipation and exhaust gas data, *see D 10 05 0 "List of Capacities".*

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

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Specifications of intake air (combustion air)

General

The quality and condition of intake air (combustion air) have a significant effect on the engine output, wear and emissions of the engine. In this regard, not only are the atmospheric conditions extremely important, but also contamination by solid and gaseous foreign matter.

Mineral dust in the intake air increases wear. Chemicals and gases promote corrosion.

This is why effective cleaning of intake air (combustion air) and regular maintenance of the air filter are required.

When designing the intake air system, the maximum permissible overall pressure drop (filter, silencer, pipe line) of 20 mbar must be taken into consideration.

Exhaust turbochargers for marine engines are equipped with silencers and air filters as a standard.

Requirements

Liquid fuel engines: As minimum, inlet air (combustion air) must be cleaned by an ISO Coarse 45% class filter as per DIN EN ISO 16890, if the combustion air is drawn in from inside (e.g. from the machine room/engine room). If the combustion air is drawn in from outside, in the environment with a risk of higher inlet air contamination (e.g. due to sand storms, due to loading and unloading grain cargo vessels or in the surroundings of cement plants), additional measures must be taken. This includes the use of pre-separators, pulse filter systems and a higher grade of filter efficiency class at least up to ISO ePM10 50% according to DIN EN ISO 16890.

Gas engines and dual-fuel engines: As minimum, inlet air (combustion air) must be cleaned by an ISO COARSE 45% class filter as per DIN EN ISO 16890, if the combustion air is drawn in from inside (e.g. from machine room/engine room). Gas engines or dual-fuel engines must be equipped with a dry filter. Oil bath filters are not permitted because they enrich the inlet air with oil mist. This is not permissible for gas operated engines because this may result in engine knocking. If the combustion air is drawn in from outside, in the environment with a risk of higher inlet air contamination (e.g. due to sand storms, due to loading and unloading grain cargo vessels or in the surroundings of cement plants) additional measures must be taken. This includes the use of pre-separators, pulse filter systems and a higher grade of filter efficiency class at least up to ISO ePM10 50% according to DIN EN ISO 16890.

In general, the following applies:

The inlet air path from air filter to engine shall be designed and implemented airtight so that no false air may be drawn in from the outdoor.

The concentration downstream of the air filter and/or upstream of the turbocharger inlet must not exceed the following limit values.

The air must not contain organic or inorganic silicon compounds.

Properties	Limit	Unit [1]
Dust (sand, cement, CaO, Al_2O_3 etc.)	max. 5	mg/Nm^3

Specifications of intake air (combustion air)

Properties	Limit	Unit [1]
Chlorine	max. 1.5	
Sulphur dioxide (SO_2)	max. 1.25	
Hydrogen sulphide (H_2S)	max. 5	
Salt (NaCl)	max. 1	
[1] One Nm^3 corresponds to one cubic meter of gas at 0 °C and 101.32 kPa.		

Table 1: Typical values for intake air (combustion air) that must be complied with

⚠ WARNING

Explosion due to flammable intake air

Severe personal injury due to the explosion of flammable intake air.

- Intake air must not be explosive.
- Intake air must not contain flammable gases.
- Intake air must not be drawn in from ATEX zones.

Specifications of intake air (combustion air)

Engine room ventilation and combustion air

Combustion air requirements

- The combustion air must be free from water spray, dust, oil mist and exhaust gases. See D010.000.023-17.
- The air ventilation fans shoud be designed to maintain a positive air pressure of 50 Pa (5 mmWC) in the auxiliary engine room in all running conditions.

The combustion air is normally taken from the engine room through a filter mat on the turbocharger.

In tropical condition a sufficient volume of air must be supplied to the turbocharger(s) at outside air temperature. For this purpose there must be an air duct installed for each turbocharger, with the outlet of the duct facing the respective intake air silencer. No water of condensation from the air duct must be allowed to be drawn in by the turbocharger.

In arctic condition the air must be heated to at least 5°C or other measures must be taken in engine design specification. See B 15 00 0, "Combustion air system for arctic operation".

Ventilator capacity

The capacity of the air ventilators must be large enough to cover:

- The combustion air requirements of all consumers.
- The air required for carrying off the heat emission.
- Maintain an positive air pressure in engine room.

See "List of capacities" section D 10 05 0 for information about required combustion air quantity and heat emission.

For minimum requirements concerning engine room ventilation see applicable standards such as ISO 8861.

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Turbocharger - make MAN

Description

The engines are as standard equipped with a turbocharger of the radial type MAN NR/S and TCR.

The rotor, comprising compressor, turbine wheel and shaft, is supported in floating plain bearing bushes.

The turbine wheel is an integrated part of the shaft.

Gas admission casing with gas outlet diffusor matched to the exhaust pipe arrangement and a turbine nozzle ring made of a special wear resistant material.

Air intake silencer with filter, and compressor casing with one outlet.

Lubrication of the two plain bushes is an integrated part of the engine lubricating oil system.

The turbocharger has no water cooling.

Propulsion					
No. cyl.	**5**	**6**	**7**	**8**	**9**
L21/31 - 1000rpm	-	TCR16-42x	TCR18-42x	TCR18-42x	TCR18-42x
L27/38 - 800 rpm	-	TCR18-42x	TCR20-42x	TCR20-42x	TCR20-42x
28/32A	-	NR24/R	NR24/R	NR24/R	NR26/R

L16/24					
No. cyl.	**5**	**6**	**7**	**8**	**9**
1000 rpm	TCR12-42x	TCR12-41x	TCR12-41x	TCR14-41x	TCR14-41x
1200 rpm	TCR12-42x	TCR12-41x	TCR14-41x	TCR14-41x	TCR14-41x

L21/31					
No. cyl.	**5**	**6**	**7**	**8**	**9**
900 rpm	TCR16-42x	TCR16-42x	TCR18-42x	TCR18-42x	TCR18-42x
1000 rpm	TCR16-42x	TCR16-42x	TCR18-42x	TCR18-42x	TCR18-42x

L21/31 Mk2					
No. cyl.	**5**	**6**	**7**	**8**	**9**
900 rpm	TCR14-42x	TCR16-42x	TCR16-42x	TCR16-42x	TCR18-42x
1000 rpm	TCR14-42x	TCR16-42x	TCR16-42x	TCR18-42x	TCR18-42x

L27/38					
No. cyl.	**5**	**6**	**7**	**8**	**9**
330 kW @ 720 rpm	TCR18-42x	TCR18-42x	TCR20-42x	TCR20-42x	TCR20-42x
330 kW @ 750 rpm	TCR18-42x	TCR18-42x	TCR20-42x	TCR20-42x	TCR20-42x
350 kW @ 720 rpm	-	TCR18-42x	TCR20-42x	TCR20-42x	TCR20-42x
350 kW @ 750 rpm	-	TCR18-42x	TCR20-42x	TCR20-42x	TCR20-42x

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L23/30H + Mk2					
No. cyl	**5 ECR**	**5**	**6**	**7**	**8**
720 rpm	TCR14-42x	TCR14-41x	TCR14-41x	TCR16-41x	TCR16-41x
750 rpm	TCR14-42x	TCR14-41x	TCR14-41x	TCR16-41x	TCR16-41x
900 rpm	-	-	TCR16-41x	TCR16-41x	TCR16-41x

L23/30H Mk3					
No. cyl	**5**	**6**	**7**	**8**	**9**
720 rpm	TCR14-41x	TCR14-41x	TCR16-42x	TCR16-41x	TCR16-41x
750 rpm	TCR14-41x	TCR14-41x	TCR16-42x	TCR16-41x	TCR16-41x
900 rpm	-	TCR16-41x	TCR16-41x	TCR16-41x	TCR18-41x

L23/30DF				
No. cyl	**5**	**6**	**7**	**8**
720 rpm	TCR14-42x	TCR14-41x	TCR14-41x	TCR16-41x
750 rpm	TCR14-42x	TCR14-41x	TCR14-41x	TCR16-41x
900 rpm	-	TCR14-41x	TCR14-41x	TCR16-41x

L28/32DF					
No. cyl.	**5**	**6**	**7**	**8**	**9**
720 rpm	TCR14-41x	TCR16-41x	TCR16-41x	TCR18-41x	TCR18-41x
750 rpm	TCR14-41x	TCR16-41x	TCR16-41x	TCR18-41x	TCR18-41x

L28/32H (update to TCR are in progress)					
No. cyl.	**5**	**6**	**7**	**8**	**9**
720 rpm	NR20/R	NR20/R	TCR18-41x	TCR18-41x	NR24/S
750 rpm	NR20/R	NR20/R	NR24/R	NR24/R	NR24/S

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Water washing of turbocharger - compressor

Description

During operation the compressor will gradually be fouled due to the presence of oil mist and dust in the inlet air.

The fouling reduces the efficiency of the turbocharger which will result in reduced engine performance.

Therefore manual cleaning of the compressor components is necessary in connection with overhauls. This situation requires dismantling of the turbocharger.

However, regular cleaning by injecting water into the compressor during normal operation of the engine has proved to reduce the fouling rate to such an extent that good performance can be maintained in the period between major overhauls of the turbocharger.

The cleaning effect of injecting pure fresh water is mainly based upon the mechanical effect arising, when the water droplets impinge the deposit layer on the compressor components.

The water is injected in a measured amount and within a measured period of time by means of the water washing equipment.

The water washing equipment, see fig 1, comprises two major parts. The transportable container (6) including a hand valve with handle (5) and a plug-in coupling (4) at the end of a lance.

Installed on the engine there is the injection tube (1), connected to a pipe (2) and a snap coupling (3).

The cleaning procedure is:

1) Fill the container (6) with a measured amount of fresh water. Blow air into the container by means of a blow gun, until the prescribed operation pressure is reached.
2) Connect the plug-in coupling of the lance to the snap coupling on the pipe, and depress the handle on the hand valve.
3) The water is then injected into the compressor.

The washing procedure is executed with the engine running at normal operating temperature and with the engine load as high as possible, i.e. at a high compressor speed.

The frequency of water washing should be matched to the degree of fouling in each individual plant.

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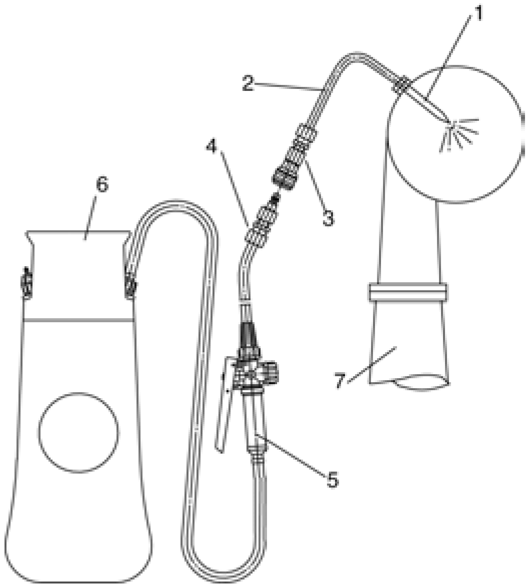

1 Injection tube
2 Pipe
3 Snap coupling
4 Plug-in coupling
5 Hand valve with handle
6 Container
7 Charge air line

Figure 1: Water washing equipment.

Exhaust gas system

Internal exhaust gas system

From the exhaust valves, the gas is led to the exhaust gas receiver where the fluctuating pressure from the individual cylinders is equalized and the total volume of gas led further on to the turbocharger, at a constant pressure. After the turbocharger, the gas is led to the exhaust pipe system.

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

After each cylinder a thermosensor for reading the exhaust gas temperature is fitted.

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

External exhaust gas system

The exhaust back-pressure should be kept as low as possible.

It is therefore of the utmost importance that the exhaust piping is made as short as possible and with few and soft bends.

Long, curved, and narrow exhaust pipes result in higher back-pressure which will affect the engine combustion. Exhaust back-pressure is a loss of energy and will cause higher fuel comsumption.

The exhaust back-pressure should not exceed 30 mbar at MCR. An exhaust gas velocity through the pipe of maximum 35 m/sec is often suitable, but depends on the actual piping.

During commissioning and maintenance work, checking of the exhaust gas back pressure by means of a temporarily connected measuring device may become necessary. For this purpose, a measuring socket must be provided approx. 1-2 m after the exhaust gas outlet of the turbocharger at an easily accessible place. Usual pressure measuring devices require a measuring socket size of ½". This measuring socket must be provided to ensure utilisation without any damage to the exhaust gas pipe insulation.

MAN Energy Solutions will be pleased to assist in making a calculation of the exhaust back-pressure.

The gas outlet of turbocharger, the expansion bellows, the exhaust pipe, and silencer, (in case of silencer with spark arrestor care must be taken that the cleaning parts are accessible), must be insulated with a suitable material.

The insulation should be shielded by a thin plating, and should comply with the requirements of the classification society and/or the local authorities.

Exhaust pipe dimensions

It should be noted that concerning the maximum exhaust gas velocity the pipe dimension after the expansion bellows should be increased for some of the engines.

The wall thickness of the external exhaust pipe should be min. 3 mm.

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Exhaust pipe mounting

When the exhaust piping is mounted, the radiation of noise and heat must be taken into consideration.

Because of thermal fluctuations in the exhaust pipe, it is necessary to use flexible as well as rigid suspension points.

In order to compensate for thermal expansion in the longitudinal direction, expansion bellows must be inserted. The expansion bellows should preferably be placed at the rigid suspension points.

Note: The exhaust pipe must not exert any force against the gas outlet on the engine.

One sturdy fixed-point support must be provided for the expansion bellows on the turbocharger. It should be positioned, if possible, immediately above the expansion bellows in order to prevent the transmission of forces, resulting from the weight, thermal expansion or lateral displacement of the exhaust piping, to the turbocharger.

The exhaust piping should be mounted with a slope towards the gas outlet on the engine. It is recommended to have drain facilities in order to be able to remove condensate or rainwater.

Position of gas outlet on turbocharger

B 16 02 0 shows turning alternatives positions of the exhaust gas outlet. Before dispatch of the engine exhaust gas outlet will be turned to the wanted position.

The turbocharger is, as standard, mounted in the front end.

Exhaust gas boiler

To utilize the thermal energy from the exhaust, an exhaust gas boiler producing steam or hot water can be installed.

Each engine should have a separate exhaust gas boiler or, alternatively, a common boiler with separate gas ducts. Concerning exhaust gas quantities and temperature, *see "List of capacities" D 10 05 0,* and "*Engine performance" D 10 10 0.*

The discharge temperature from the exhaust gas boiler should not be lower than 180°C (in order to avoid sulphuric acid formation in the funnel).

The exhaust gas boilers should be installed with by-pass entering in function at low-load operation.

The back-pressure over the boiler must be included in the back-pressure calculation.

Expansion bellows

The expansion bellows, which is supplied separately, must be mounted directly on the exhaust gas outlet, *see also E 16 01 1-2.*

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Exhaust silencer

The position of the silencer in the exhaust gas piping is not decisive for the silencing effect. It would be useful, however, to fit the silencer as high as possible to reduce fouling. The necessary silencing depends on the loudness of the exhaust sound and the discharge from the gas outlet to the bridge wing.

The exhaust silencer, *see E 16 04 2-3-5-6,* is supplied loose with counterflange, gaskets and bolts.

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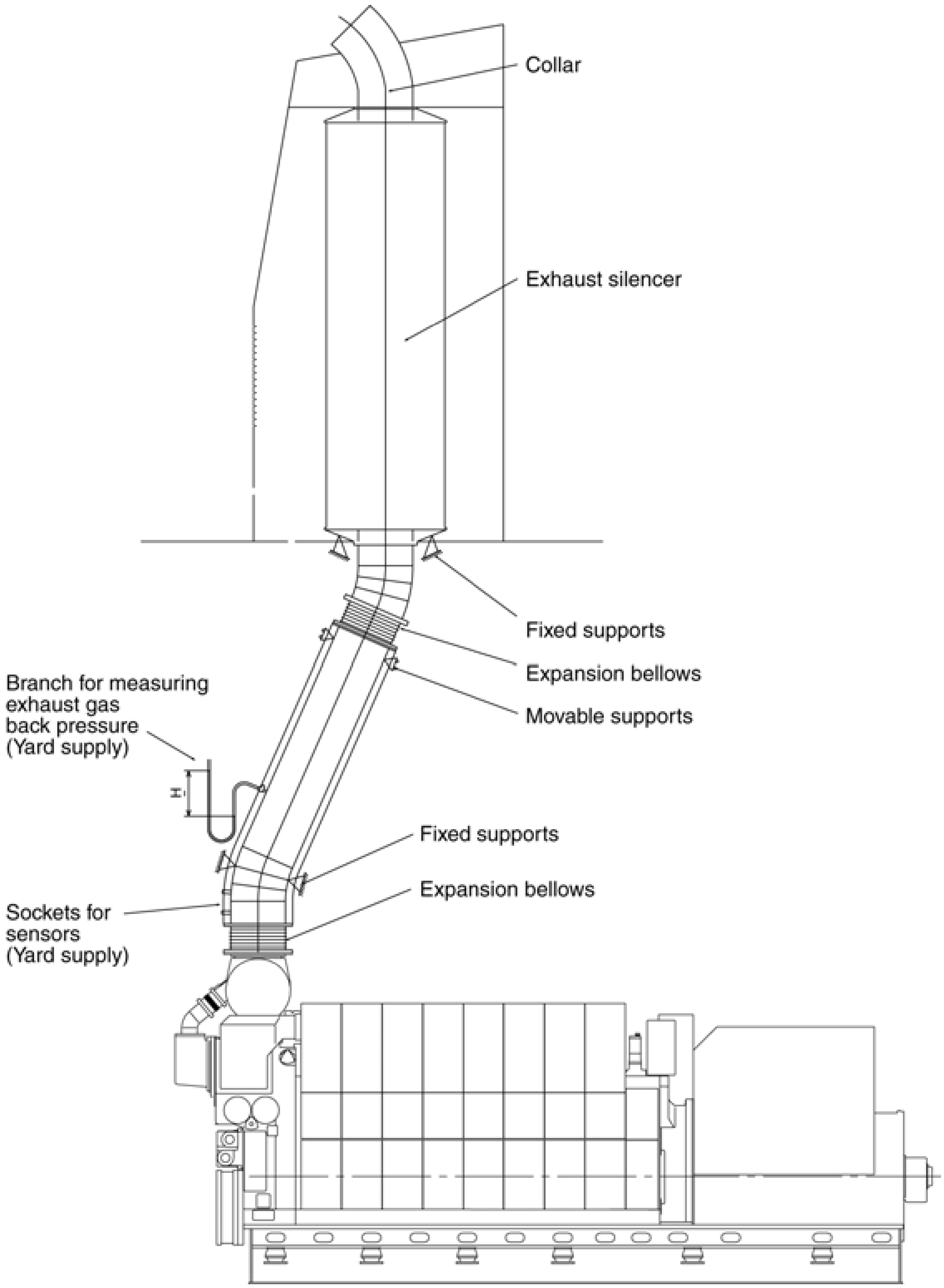
Collar
Exhaust silencer
Fixed supports
Expansion bellows
Movable supports
Branch for measuring
exhaust gas
back pressure
(Yard supply)
H
Fixed supports
Expansion bellows
Sockets for
sensors
(Yard supply)

Resulting installation demands

If the recommended exhaust gas back pressure cannot be kept due to exhaust gas after treatment installations. Following items need to be considered.

Exhaust gas back pressure after turbocharger	
Operating pressure Δp_{exh}, standard	0 ... 30 mbar
Operating pressure Δp_{exh}, range with increase of fuel consumption	30 ... 60 mbar
Operating pressure Δp_{exh}, where a customized engine matching is needed	> 60 mbar

Table 1: Exhaust gas back pressure after turbocharger

Intake air pressure turbocharger	
Operating pressure Δp_{intake}, standard	0 ... –20 mbar
Operating pressure Δp_{intake}, range with increase of fuel consumption	–20 ... –40 mbar
Operating pressure Δp_{intake}, where a customized engine matching is needed	< –40 mbar

Table 2: Intake air pressure turbocharger

Sum of the exhaust gas back pressure after turbocharger and the absolute value of the intake air pressure before turbocharger	
Operating pressure Δp_{exh} + Abs(Δp_{intake}), standard	0 ... 50 mbar
Operating pressure Δp_{exh} + Abs(Δp_{intake}), range with increase of fuel consumption	50 ... 100 mbar
Operating pressure Δp_{exh} + Abs(Δp_{intake}), where a customized engine matching is needed	> 100 mbar

Table 3: Sum of the exhaust gas back pressure after turbocharger and the absolute value of the intake air pressure before turbocharger

Maximum exhaust gas pressure drop – Layout

- Shipyard and supplier of equipment in exhaust gas line have to ensure that pressure drop Δp_{exh} over entire exhaust gas piping incl. pipe work, scrubber, boiler, silencer, etc. must stay below stated standard operating pressure at all operating conditions.
- It is recommended to consider an additional 10 mbar for consideration of aging and possible fouling/staining of the components over lifetime.
- Possible counter measures could be a proper dimensioning of the entire flow path including all installed components or even the installation of an exhaust gas blower if necessary.
- At the same time the pressure drop Δp_{intake} in the intake air path must be kept below stated standard operating pressure at all operating conditions and including aging over lifetime.

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Pressure drop in exhaust gas system

General

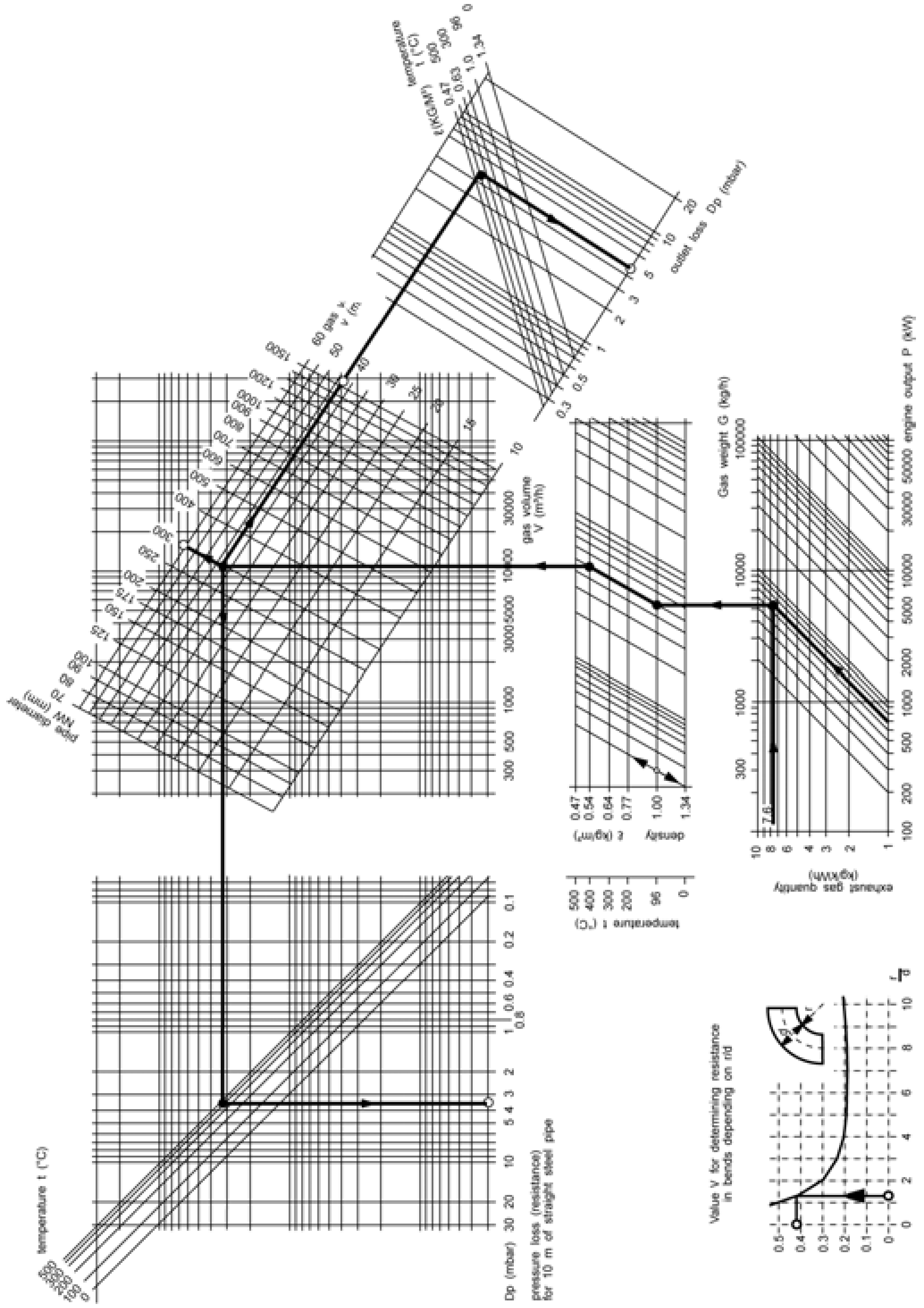

Figure 1: Nomogram for pressure drop in exhaust gas piping system.

Example

Where:	Engine rating	735 kW
	Exhaust gas quantity	7.6 kg/kWh
	Exhaust gas temperature **t** (under full-load conditions)	400°C
	Ambient air conditions	20°C, 980 mbar
	Density of air ρ_L	1.165 kg/m³
	Exhaust pipe system (pipes laid out without changes in section)	
	Straight runs of pipe horizontal	12 m (L_H)
	vertical	8 m (L_V)
	Three 90° pipe bends (with r/d = 1.3)	
	1 absorbtion silencer (35 dBA damping)	
Required:	Total pressure loss across exhaust gas system (static and dynamic) = flow resistance in pipes and silencer + outlet losses - up-draught	
From the diagram:	Density of exhaust gasses ρ_A	0.54 kg/m³
	Exhaust gas volume	10200 m³/h
	With a pipe diameter of 300 mm this gives:	
	Exhaust gas velocity	42 m/sec
	Resistance per 10 m of straight run of pipe (at 400°C)	3.6 mbar
	Outlet loss (at 400°C)	4.7 mbar ($\rho_A \times \frac{V^2}{2} \times 10^{-2}$)
	ζ value for pipe bend (at r/d = 1.3)	0.41
	Resistance of a 90° pipe bend (0.41 x 4.7)	1.9 mbar ($\zeta \times \rho_A \times \frac{V^2}{2} \times 10^{-2}$)
	Up-draught in vertical pipe	8 (1.165 - 0.54) x 9.81 = 50 Pa = 0.5 bar
Result:	The total pressure loss in the system is	
	Straight runs of pipe (12 + 8 = 20 m) = 2 x 3.6	7.2 mbar
	3 pipe bends of 1.9 mbar each	5.7 mbar
	Silencer (35 dB(A) without spark arrestor)	1.7 mbar
	(see product manual page E 16 04 3)	
	Outlet loss	4.7 mbar
		19.3 mbar
	Lift	- 0.5 mbar
		18.8 mbar

Permissible total resistance:
IMO Tier II: 30 mbar
IMO Tier III (SCR), scrubber and other aftertreatment: 50 mbar

Density of air

Density of air can be determined by following empiric, formula*:

$$\rho = \frac{348.3}{t + 273} \times P$$

ρ	=	density	kg/m³
P	=	air pressure	bar
t	=	temperature	°C

* This formula is only valid between -20° to 60°C.

Example

At ambient air conditions 20°C and pressure 0.98 bar, the density is:

$$\rho = \frac{348.3}{20 + 273} = 1.165 \text{ kg/m}^3$$

At 1.0132 bar:

t	-20	0	20	40	60
ρ	1.4	1.29	1.21	1.13	1.06

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Cleaning the turbocharger in service - turbine side

Description

High exhaust gas temperatures are often observed and claimed in service. High exhaust gas temperatures are normally caused by fouling on the turbine side of the turbocharger:

➢ Fouling turbine (coke deposit)

⇨ Lower turbocharger performance

⇨ Lower air flow / pressure through the engine

⇨ Increasing exhaust gas temperatures

⇨ Increasing fuel oil consumption

Fouling of the turbine and consequently higher exhaust gas temperature is influenced by: level of maintenance, condition of the fuel injection nozzles / fuel pumps, fuel oil quality and/or long-term low-load operation.

Smaller turbochargers are, due to area-relation in matching parts, more sensitive to coke deposit than larger turbochargers and consequently low power engines as L16/24 or L23/30H will need turbine cleaning more frequent than more powerful engines.

Turbine cleaning intervals must be expected to be following when operating on HFO:
“D-D” Dry-cleaning Daily Cleaning
“W-W” Wet-cleaning Weekly
Cleaning intervals can be shorter/longer based on operational experience. Regular performance observations will show the trend in charge air pressure, exhaust gas temperatures, and define the cleaning intervals for the turbine. However the turbine must be cleaned when exhaust gas temperature before turbine are about 20°C above the normal temperature (ISO corrected) (Sea trial).

Practical service experience have revealed that turbine side of turbocharger only can be sufficient cleaned by combination of nut-shell dry cleaning and water washing.

Dry cleaning of turbine side

This cleaning method employs cleaning agents consisting of dry solid bodies in the form of granules. A certain amount of these granules, depending on the turbocharger size, is, by means of compressed air, blown into the exhaust gas line before the gas inlet casing of the turbocharger.

The injection of granules is done by means of working air with a pressure of 5-7 bar.

On account of their hardness, particularly suited blasting agents such as nutshells, broken or artificially shaped activated charcoal with a grain size of 1.0 mm to max. 1.5 mm should be used as cleaning agents.

The solid bodies have a mechanical cleaning effect which removes any deposits on nozzle vanes and turbine blades.

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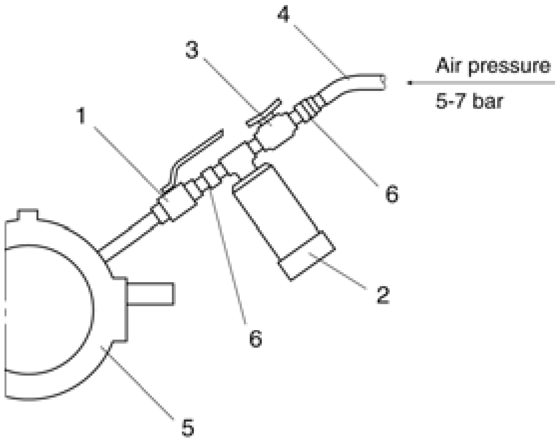
Dry cleaning can be executed at full engine load and does not require any subsequent operating period of the engine in order to dry out the exhaust system.

Cleaning system

The cleaning system consists of a cleaning agent container (2) with a capacity of approx. 0.5 liters and a removable cover. Furthermore the system consists of an air valve (3), a closing valve (1) and two snap on connectors.

The position numbers (2) and (3) indicate the system's "blow-gun". Only one "blow-gun" is used for each engine plant. The blow-gun is working according to the ejector principle with pressure air (working air) at 5-7 bar as driven medium. Injection time approx. 2 min. Air consumption approx. 5 Nm^3/2 min.



1	Closing valve	2	Container
3	Air valve	4	Working air inlet
5	Exhaust pipe	6	Snap coupling

Figure 1: Arrangement of dry cleaning of turbocharger - turbine

Suppliers of cleaning agents:

1. “Solf Blast Grit, Grade 14/25”

TURCO Produkten B.V.
Astronaut 36 3824 MJ Amersfoort - Netherlands

2. Designation unknown

Neptunes Vinke B.V.
Schuttevaerweg 24, 3044 BB Rotterdam
Potbus 11032 3004 E.A. Rotterdam, Holland

3. “Grade 16/10”

FA. Poul Auer GmbH
Strahltechnik
D-68309 Mainheim, Germany

4. “Granulated Nut Shells”

Eisenwerke Würth GmbH
D-74177 Bad Friederichshall, Germany

5. “Soft Blasting Grade 12/3a”

H.S. Hansen Eftf. Kattegatvej 2
2100 Copenhagen Ø, Denmark

6. “Crushed Nutshells”

Brigantine Services, Hong Kong

7. “Turbine Wash”

IHI Corporation
Toyosu IHI Building, Tokyo, Japan

8. "A-C Cleaner" (Activated Coal)

Mitsui Kozan Co. Ltd. (Fuel Dept.)
Tokyo, Japan

9. "OMT-701"

Marix KK
3-24-10, Nishi Shimbashi, Minato-ku, Tokyo, Japan

10. "OMT-701"

OMT Incorporated
2-8 Hatchobori
4-chome, Chuo-Ku, Tokyo 1040032, Japan

11. "Marine Grid No. 14" (Walnut)

Hikawa Marine Corporation
Japan

12. "Marine Grid No. 14"

Mashin Shokai
12-26 Hamamachi Mojiku, Kitakyushushi 801-0856 Japan

13. Granulate

MAN Energy Solutions
Teglholmsgade 41 2450 Copenhagen SV, Denmark

The list is for guidance only and must not be considered complete.
We undertake no responsibility that might be caused by these or other products.

Water washing of turbine side

The water flow must be so high that all of the water do not evaporate. Also the waterflow must not be so high that the turbine wheel is drowned and stops rotating. The exhaust gas temperature before turbine and turbine speed must be adjusted in accordance with the below table.

Carry out sequential washing so that exhaust gas temperature after turbine drops below 100°C and in the drying period increases to more than 100°C.

The necessary water flow is depending on exhaust gas flow and temperature. The flow needed depends on the turbocharger size.

For preadjustment of the washing tool, check that the water flow is in accordance with the value in the below table. Open the water supply and adjust the water flow at the valve at the tool. Check in a bucket that the water flow is in the correct range.

Type	Flow rate of washing water l/min
TCR10	3
TCR12	5
TCR14	7.5
TCR16	7.5
TCR18	10
TCR20	13.5
TCR22	20
The max. permissible cleaning conditions: u_2 = 300 m/s T_{vT} = 320°C anc $P_{water\ max.}$ = approx. 3 bar	
u_2 = peripheral speed of the turbine rotor T_{vT} = exhaust gas temperature upstream of turbine $P_{water\ max.}$ = water pressure	

Table 1: Quantity of washing water for turbine cleaning

Experience has shown, that washing at regular intervals is essential to successful cleaning, as excessive fouling is thus avoided. Washing at intervals of 150 hours is therefore recommended. Depending on the fuel quality these intervals can be shorter or longer. However, the turbine must be washed at the latest when the exhaust gas temperature upstream of the turbine has risen about 20° C above the normal temperature.

Heavily contaminated turbines, which where not cleaned periodically from the very beginning or after an overhaul, cannot be cleaned by this method.

If vibration in the turbocharger occur after waterwashing has been carried out, the washing should be repeated. If unbalance still exists, this is presumably due to heavy fouling, and the engine must be stopped and the turbocharger dismantled and manually cleaned.

The cleaning effect is based on the water solubility of the deposits and on the mechanical action of the impinging water droplets and the water flow rate.

The washing water should be taken from the fresh water system and not from the fresh cooling water system or salt water system. No cleaning agents and solvents need to be added to the water.

To avoid corrosion during standstill, the engine must, upon completing of water washing run for at least 1 hour before stop to insure that all parts are dry.

Water washing arrangement / tool

New engines are as standard delivered with "water washing gun" as a part of standard tools for engines. The tool can be seen in figure 2 and is using the same connecting as the dry cleaning connection.

Figure 2: Maneuvering valve

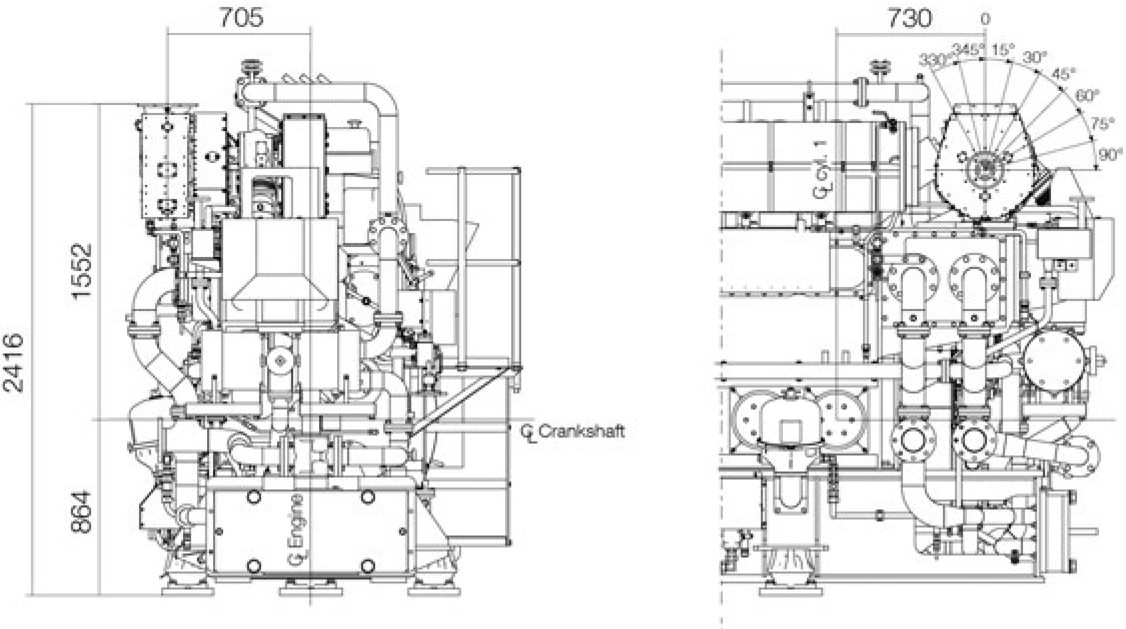
The water for washing the turbine, is supplied from the external fresh water system through a flexible hose with couplings. The flexible hose must be disconnected after water washing.

By activating the maneuvering valve and the regulating valve the water is sprayed into the exhaust gas pipe before the turbine side of the turbocharger. See specific work card for water washing of turbine side. The water that is not evaporated is led out through a drain pipe in the exhaust gas outlet.

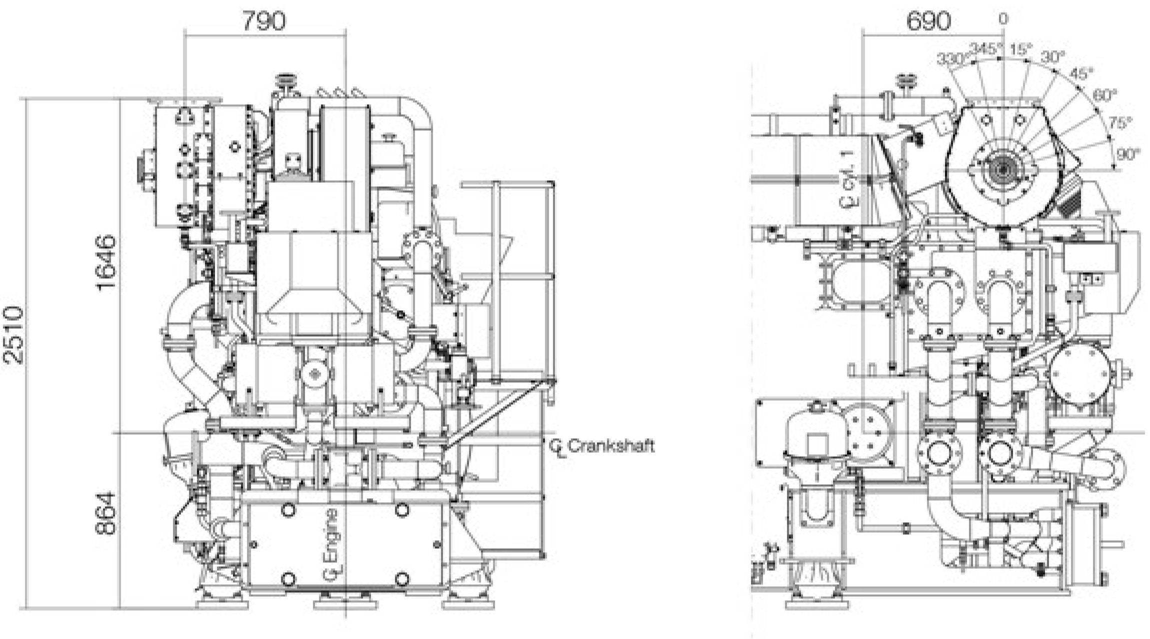
Position of gas outlet on turbocharger

Dimensions

5-6L23/30H Mk2 (720-750 rpm)



7-8L23/30H Mk2 (720-750 rpm)
and 6-7-8L23/30H Mk2 (900 rpm)



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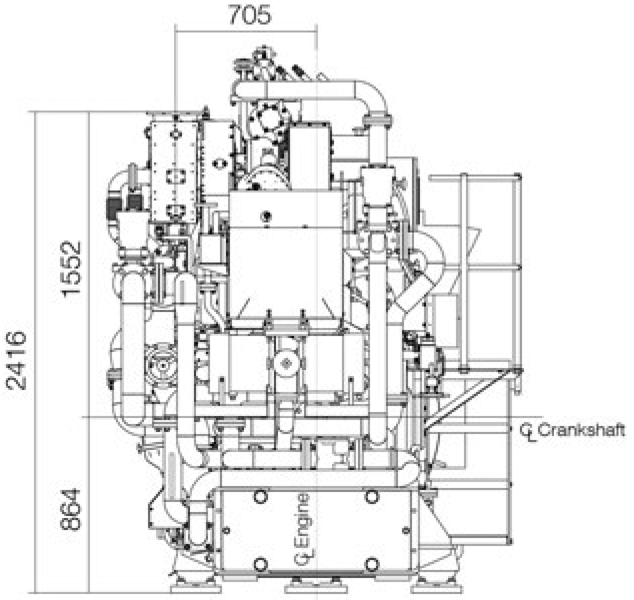
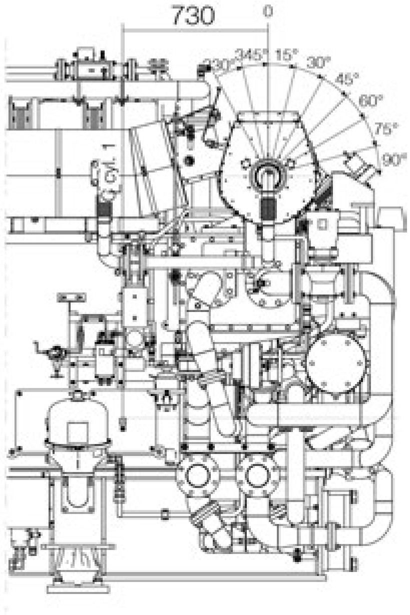
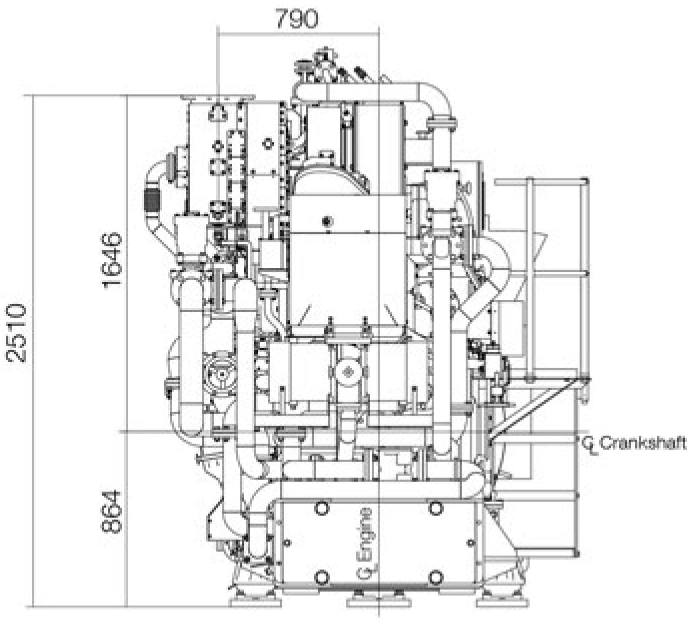
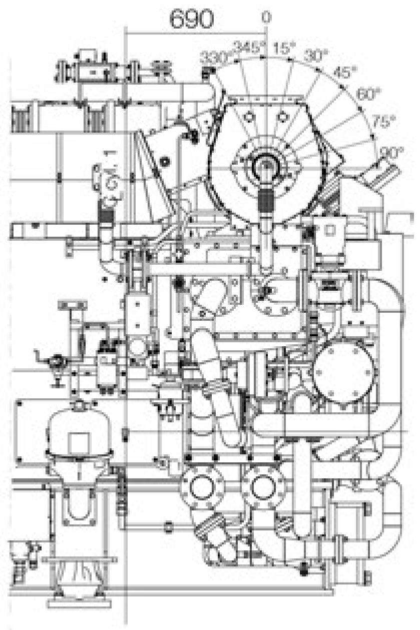
5-6L23/30DF (720-750 rpm)



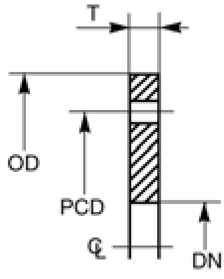


7-8L23/30DF (720-750 rpm)
and 6-7-8L23/30DF (900 rpm)





Flange



Exhaust flange D. mating dimensions						
Engine type	**DN (mm)**	**OD (mm)**	**T (mm)**	**PCD (mm)**	**Hole size (mm)**	**No of holes**
5L23/30H Mk2, 720/750 rpm 5L23/30DF, 720/750 rpm	350	490	16	445	22	12
6-7L23/30H Mk2, 720/750 rpm 6-7L23/30DF, 720/750 rpm	400	540	16	495	22	16
6-7L23/30H Mk2, 900 rpm 8L23/30H Mk2, 720/750 6-7L23/30DF, 900 rpm 8L23/30DF, 720/750	450	595	16	550	22	16
8L23/30H MK2, 900 rpm 8L23/30DF, 900 rpm	500	645	16	600	22	20

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Starting of engine

General

NOTICE

Dual Fuel engines can only be started on MGO.

The engine can be loaded according to the following procedure:

A: Normal start without pre-heated cooling water. Only on MDO/MGO.

B: Normal start with pre-heated cooling water. On MDO/MGO or HFO.

C: Stand-by engine. Emergency start, with pre-heated cooling water. On MDO/MGO or HFO pre-lubrication at intervals or continuous pre-lubrication.

The curves indicate the absolute shortest load-up time and we advise that loading up to 100% take some more minutes.

Starting on HFO

During shorter stops or if the engine is in a standby position on HFO, the engine must be pre-heated, and HFO viscosity must be in the range 12–18 cSt.

During pre-heating the jacket cooling water temperature must be kept as high as possible at least 60°C (± 5°C) either by cooling water from engines which are running or with a built-in pre-heater.

If the engine normally runs on HFO, pre-heated fuel must be circulated through the injection pumps while pre-heating the engine, although the engine just has run or has been flushed on MDO/MGO for a short period.

Starting on MDO/MGO

For starting on MDO/MGO, there are no restrictions except lubricating oil viscosity may not by higher than 1500 cSt. (5°C for SAE 30 or 10°C for SAE 40).

Initial ignition may be difficult if the engine and the ambient temperature are lower than 5°C and the cooling water temperature is lower than 15°C.

Prelubricating

The engine shall always be pre-lubricated 2 minutes prior to start if there is no pre-lubrication at intervals or continuous pre-lubrication installed.

Pre-lubrication at intervals is 2 minutes every 10 minutes.

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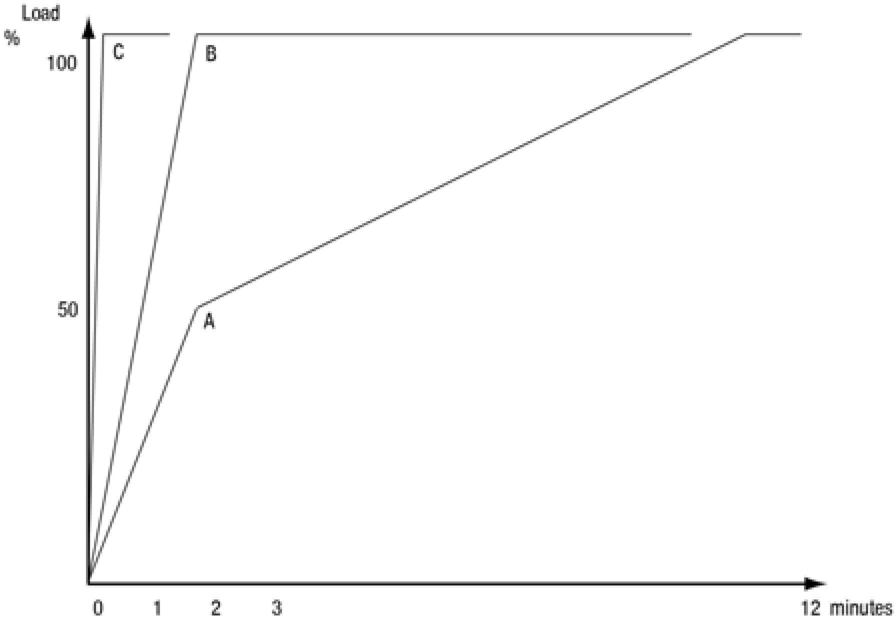
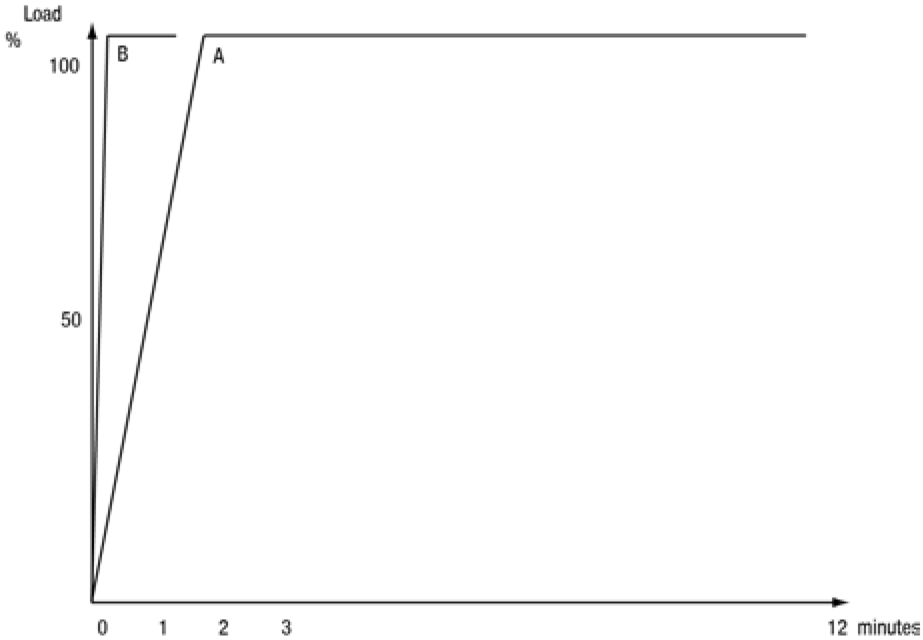


Loading chart for engines



Loading chart for Duel Fuel engines

Figure 1: Loading chart

Actuators

Actuator types

The engines can be equipped with an electro-hydraulic actuator, make Regulateurs Europa, type 2800. Speed Control is carried out via $SaCoS_{one}$ GENSET.

Actuator signal

	Actuator input signal
Regulateurs Europa, type 2800	0-1 A nominal operating range

Speed adjustment range

Speed adjustment range is adjustable in $SaCoS_{one}$.

Droop

Droop is adjustable in $SaCoS_{one}$.

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Safety concept - Dual fuel engines

Introduction

The aim of the safety concept is to demonstrate that dual fuel engines can be installed in ships fulfilling the requirements of the IGF Code and IGC Code (see section Abbreviations) and IACS classification requirements.

The dual fuel engines will be type approved by the individual IACS classes according to their rules. Therefore in this document the general and special requirements relating to dual fuel engines and gas fuel supply to the engine are mentioned only. The class approval in principle and safety concept should give confidence to the yard that dual fuel engines fulfil IACS class requirements as well as the IGF Code and IGC Code (see section Abbreviations) requirements. The gas fuel supply system is considered beginning with the shut-off valve upstream of the gas valve unit room. The engines are suitable as prime movers in mechanic propulsion or electric propulsion plants and as auxiliary engines. This safety concept is applicable for multi and single engine plants. The requirements stated in this safety concept for the installation of the dual fuel engine and the equipment are ’s recommendations. If the customer or yard make modifications on the arrangements and design principles, they are responsible for the approval of the deviations by the classification societies and the flag state administrations.

Basic standards

The following basic standards were used for this safety concept:

- IACS unified requirements
- IEC 60079-10: 2021-02
- IEC 60079-14: 2016-06
- IGF Code and IGC Code (each 2016 edition, see section Abbreviations)
- SOLAS IMO convention "Safety of Life at Sea"
- EC directive 2014/34/EU European Commission directive (ATEX) regarding devices and protecting systems used in explosion hazardous areas
- European pressure equipment directive 2014/68/EU

Note:
Relevant classification rules have to be considered project specific.

Abbreviations and definitions

Abbreviations

Abbreviation	Explanation
ACO	Automatic change over
AL	Alarm level (acc. IEC 60050-426)
API	American Petroleum Institute

Abbreviation	Explanation
ATEX	European Commission Directive regarding devices and protecting systems used in explosion hazardous areas (ATEX 2014/34/EU)
DF engine	Dual fuel engine
EC Directive 2014/34/EU	European Commission Directive (ATEX) regarding devices and protecting systems used in explosion hazardous areas
EPL	Equipment protection level
FMEA	Failure mode and effect analysis
FS	Flow switch
GD	Gas detector
GVU	Gas valve unit
HP	High pressure
HT	High temperature
IACS	International Association of Classification Societies
IEC	International Electrotechnical Commission
IGC Code	IMO convention "International code for the construction and equipment of ships carrying liquefied gases in bulk"
IGF Code	IMO convention "International code of safety for ships using gases or other low-flashpoint fuels”
IMO	International Maritime Organization
LEL	Lower explosion level (acc. IEC 60050-426)
LT	Low temperature
MCR	Maximum continuous rating
PDT	Pressure difference transmitter
PREAL	Pre-alarm
PT	Pressure transmitter
QCO	Quick change over
SaCoSone	engine safety and control system
SOLAS	IMO convention “Safety of Life at Sea”, 1974 with amendments 2010
TE	Temperature transmitter
TI	Temperature indicator
UEL	Upper explosion level (acc. IEC 60050-426)

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Abbreviation	Explanation
VTA	Variable turbine area

Table 1: Abbreviations

Definitions

Double block and bleed valves

For gas carrier installations in accordance to IGC Code section 16, 16.4.5. For other gas-fuelled vessel applications in accordance to IGF Code section 9.4.4.

Dual fuel engine

Engines able to burn liquid fuel or gaseous fuel gases with liquid pilot fuel.

Engine room

See paragraph Machinery space.

Explosion proof design

Pressure related components are designed to withstand an internal explosion pressure without destroying the components and to make them untight. Plastic deformation is permissible, but the system has to be tight after the explosion that no contained media could be let to the surrounding atmosphere.

Gas high-pressure piping

Gas fuel piping with working pressure above 10 bar.

Gas safe areas

Zones or areas not being gas dangerous.

Gas dangerous zones

Zones or areas defined as gas dangerous zones Z0, Z1 or Z2, according to IEC 60079-10.

Gas mode

Operation with gas and pilot fuel as ignition source.

Gas sources

Any valves or detachable pipe joints in the fuel gas system. Also all seals of rotating components in which there is an overpressure to the surrounding environment regarded as gas sources.

GVU compartment

GVU compartment can be either the dedicated housing of a GVU or the room in which the GVU is placed.

High-pressure fuel oil pipe

Double walled piping with leakage monitoring according to SOLAS section II-2, regulation 4, 2.2.5.

Machinery space of category A

For gas carrier installations definition according to IGC Code section 1, 1.2.32. For other gas-fuelled vessel applications in accordance to the IGF Code section 11, 11.3.3.

Machinery space

For gas carrier installations definition according to IGC Code section 1, 1.2.33. For other gas-fuelled vessel applications in accordance to the IGF Code section 5, 5.4.

Shut-off valve/Master gas fuel valve

The shut-off valve is an automatic valve in the gas supply line to each engine room located upstream of the gas valve unit outside the machinery space. For gas carrier installations definition according to IGC Code section 1, 1.2.33. For other gas-fuelled vessel applications in accordance to the IGF Code section 9, 9.4.2.

Gas admission valve (SOGAV)

Engine mounted valve controlling gas amount into air inlet manifold.

Ambient reference conditions

The ambient reference conditions according to IACS URM28 are the regular machinery space room temperature 45 °C, ambient pressure 1,000 mbar absolute and air humidity 60 %.

Basics

Basic standards

The following basic standards were used for this safety concept:

- IACS unified requirements
- IEC 60079-10: 2021-02
- IEC 60079-14: 2016-06
- IGF Code and IGC Code (each 2016 edition, see section Abbreviations)
- SOLAS IMO convention "Safety of Life at Sea"
- EC directive 2014/34/EU European Commission directive (ATEX) regarding devices and protecting systems used in explosion hazardous areas
- European pressure equipment directive 2014/68/EU

Note:
Relevant classification rules have to be considered project specific.

Explosion danger

Note:
Explosive atmosphere (air/fuel mixture) and an effective ignition source are simultaneously present.

Purpose of this safety concept

- Prevention from formation of an explosive atmosphere, e.g. ventilation, operation of equipment over UEL or below LEL (gas detection and warning system) and inertisation.
- Exclusion of igniting sources by design measures (no surfaces at or over ignition temperature of critical substances, neither electrostatic nor electric ignition sources, no spark generation, no open flame).
- Limitation of the effect of explosion. Safety measures against dangerous overpressure (rupture discs, safety valves, explosion proof design (design pressure [abs] = max. explosion pressure [abs] x initial pressure [abs]), flame arresting piping equipment).

Gas feeding concept

Marine rule requirements

The basic requirement is the prevention from formation of an explosive atmosphere.

The design principle for explosion protection is the application of a double barrier between the fuel gas and the environment. The space between the first and the second barrier is defined as explosion hazardous zone. The space outside of the second barrier is defined as a gas safe area.

To realise this, there are the following two possibilities:

- Double walled piping or
- Single walled piping installed in a separate compartment

The space between the first and second barrier could be realised as follows:

- Gas monitoring and venting of the space or
- Gas tight space, monitored and filled with over pressurised inert gas (outside machinery spaces only permissible if accepted by administration)

Fuel gas concept

Based on the criteria in section Basics decided to select for the fuel gas supply of the DF engine a system with double walled pipes on the engine and upstream and downstream of the GVU compartment. The space in between the first and second barrier is monitored by gas and flow detection. The GVU is of single wall type and therefore it is installed in a separate and well vented GVU compartment with gas detection. The fuel gas system is designed to fulfil all requirements for a gas safe engine room.

General requirements on double wall fuel gas piping:

- Ventilation by suction in the outer pipe with an air change of 30 times per hour and control and monitoring of possible fuel gas concentration in the space between the inner and outer pipe (see figure Gas feeding system) or alternative inertisation media in the outer pipe, inert media pressure > operating pressure of flammable gas, control and monitoring of the inert gas media due to inertisation pressure and inert media leakages.

- Purging or inertisation of the gas pipe in case of gas leakage.

General requirements for ventilation of possible gas leakages:

- Air change min. 30 times per hour monitored by flow switch or transmitter (see figure Gas feeding system).
  - Switch over from gas fuel mode to diesel fuel mode in case of provided air changes < 30 air changes per hour.
- Control of leakage gas by gas detection sensors.
- Closing of shut-off valves.

Installation plan

Definition of explosion hazardous areas

The protection and certification requirements on components used in explosion hazardous areas are related to the explosion hazardous zones in which they are used. The definitions according to IEC 60079-10 are:

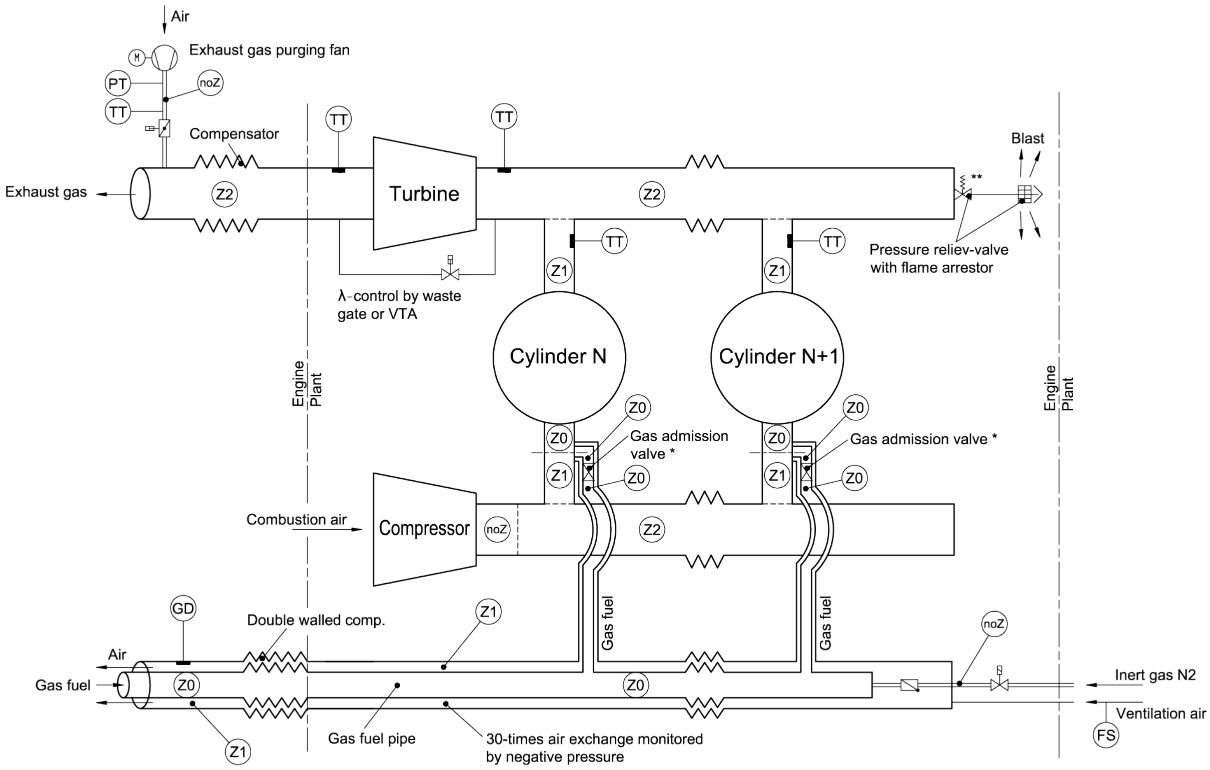
- Zone 0: Area in which an explosive gas atmosphere is present continuously or is present for long periods.
- Zone 1: Area in which an explosive gas atmosphere is likely to occur in normal operation.
- Zone 2: Area in which an explosive gas atmosphere is not likely to occur in normal operation and, if it does occur, is likely to do so only infrequently and will exist for a short period only.

Note:

- Z0: Explosion protection zone 0 (IEC 60079-10); class I, special division 1 (API 500, January 2014)
- Z1: Explosion protection zone 1 (IEC 60079-10); class I, division 1 (API 500, January 2014)
- Z2: Explosion protection zone 2 (IEC 60079-10); class I, division 2 (API 500, January 2014)

Plan of explosion hazardous areas

Engine related hazardous areas



* Hazardous area zone 0 within the inner gas pipe according to charpter 12.5.1 of the IGF code MSC.391(95). A risk assessment in accordance with MSC.1/Circ.1605 Annex Pt. 2 was carried out for the gas admission valves. Based on the risk assessment the hazardous area zone for the gas admission valves is defined as Zone 2.

** Pressure relieve arrangement differs depending on engines type

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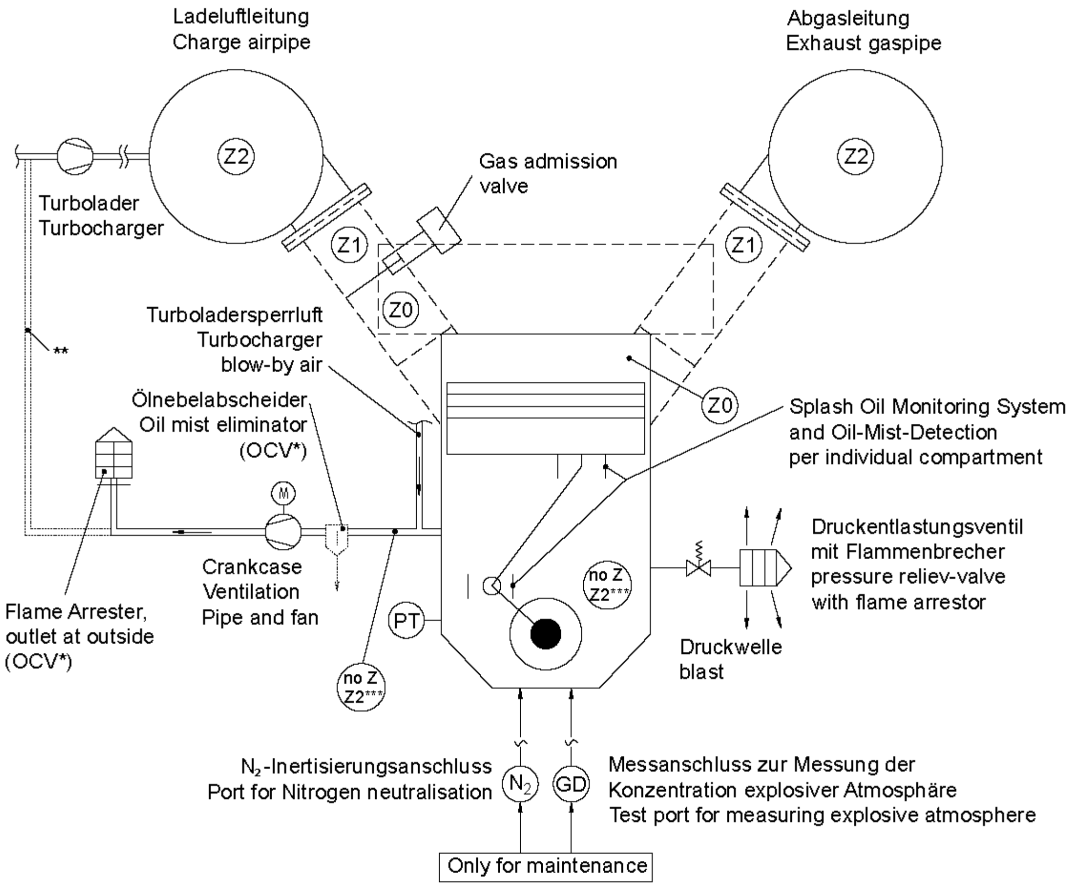
Figure 1: Engine related hazardous areas 1



--- Optionale Komponenten und Verrohrung für CCV Installation
Opitonal components and piping for CCV installation

*CCV = Geschlossene Triebraumabsaugung / Closed crankcase ventilation
OCV = Offene Triebraumabsaugung / Open crankcase ventilation

** If the crankcase is defined as Zone 2, no closed crankcase ventilation is available in MAN ES standard
*** No Zone according to MAN ES risk assesment. Zone 2 must be assumed, depending on the classification society

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Figure 2: Engine related hazardous areas 2

External engine systems

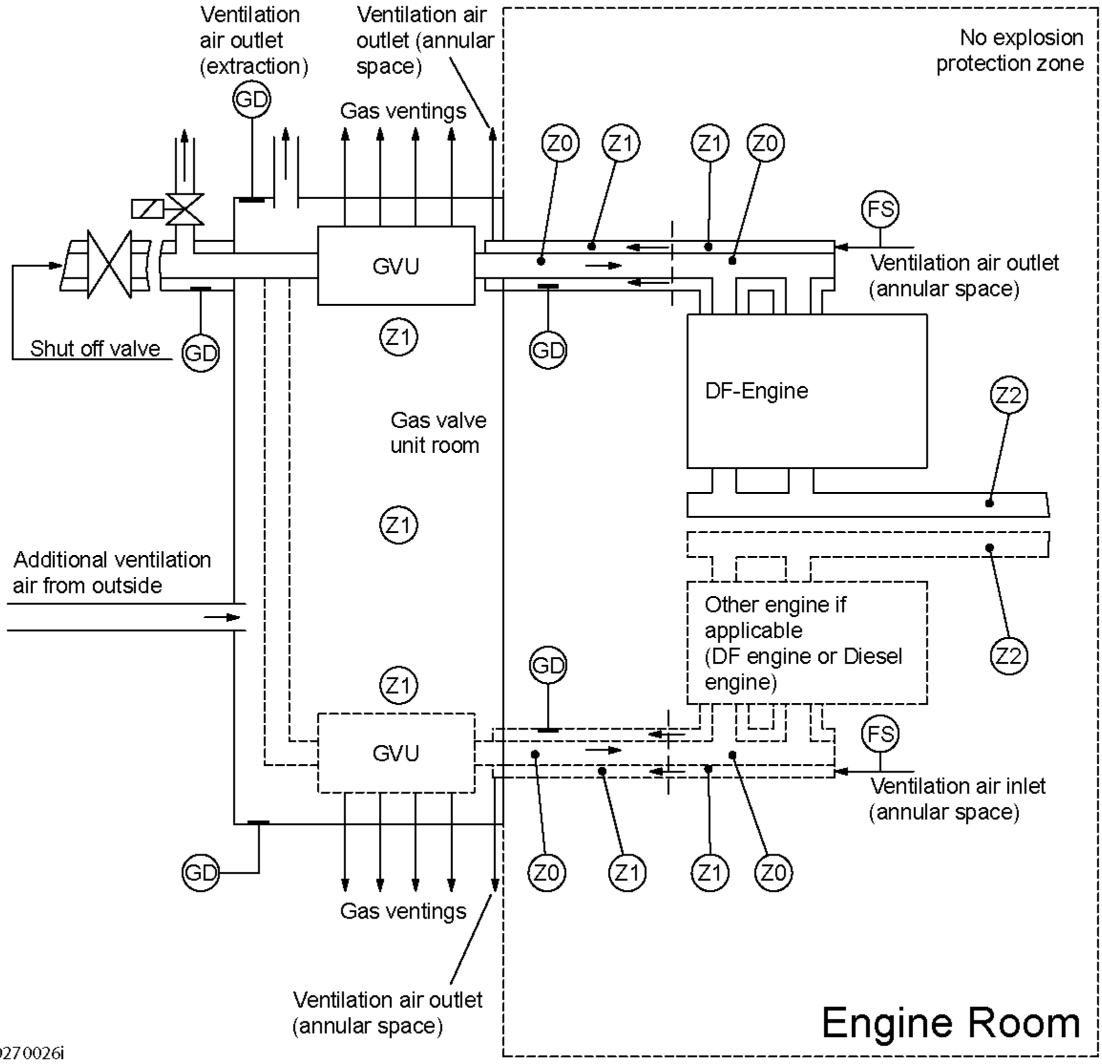

Figure 3: Plant related hazardous areas

Further system components – Plant related

System	Explosion zone	Remark
Lube oil system	No zone	Description, see section Lube oil (LO) system
HT cooling water system	Zone 2	Description, see section High temperature cooling water system
LT cooling water system	Zone 2	Description, see section Low temperature cooling water system
Shipboard exhaust gas system	Zone 2	Description, see section Exhaust gas system (external)
Venting pipe for engine crankcase	No zone/Zone 2*	Description, see section Crankcase
Venting pipes in general/ other venting	Zone depending on vented area (zone entrainment)	-
* No zone according to MAN risk assessment. Zone 2 must be assumed, depending on the classification society.		

Table 2: Plant related hazardous areas

Explosion protection requirements on components

Engine

Functional description

The engine is a dual fuel type. The engine could either operate on liquid fuel or on fuel gas.

Operation modes

- Gas mode: Gaseous fuel with pilot fuel oil ignition

  The ignition of the lean gas mixture is provided by a small amount of diesel fuel, which ignites the gas-air mixture. The operating principle in gas mode is the lean-burn concept. A lean mixture of fuel gas and charge air will be provided to the combustion chamber of each cylinder by individually controlled gas admission valves, see also section Dual fuel engine operation modes.
- Diesel mode: Main fuel oil and pilot fuel oil

  In diesel mode, liquid fuel oil is provided by the main injection system and the pilot fuel system to be burned inside the combustion chamber, see also section Dual fuel engine operation modes.
- Back-up mode: Main fuel oil only

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In back-up mode, liquid fuel oil is provided by the main fuel oil injection system and burned inside the combustion chamber, see also section Dual fuel engine operation modes.

Fuel system

Gas fuel system

The general arrangement of the gas fuel system is shown in figure Gas feeding system. Explanation of the different systems is given in the following sections.

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Safety concept - Dual fuel engines

Description

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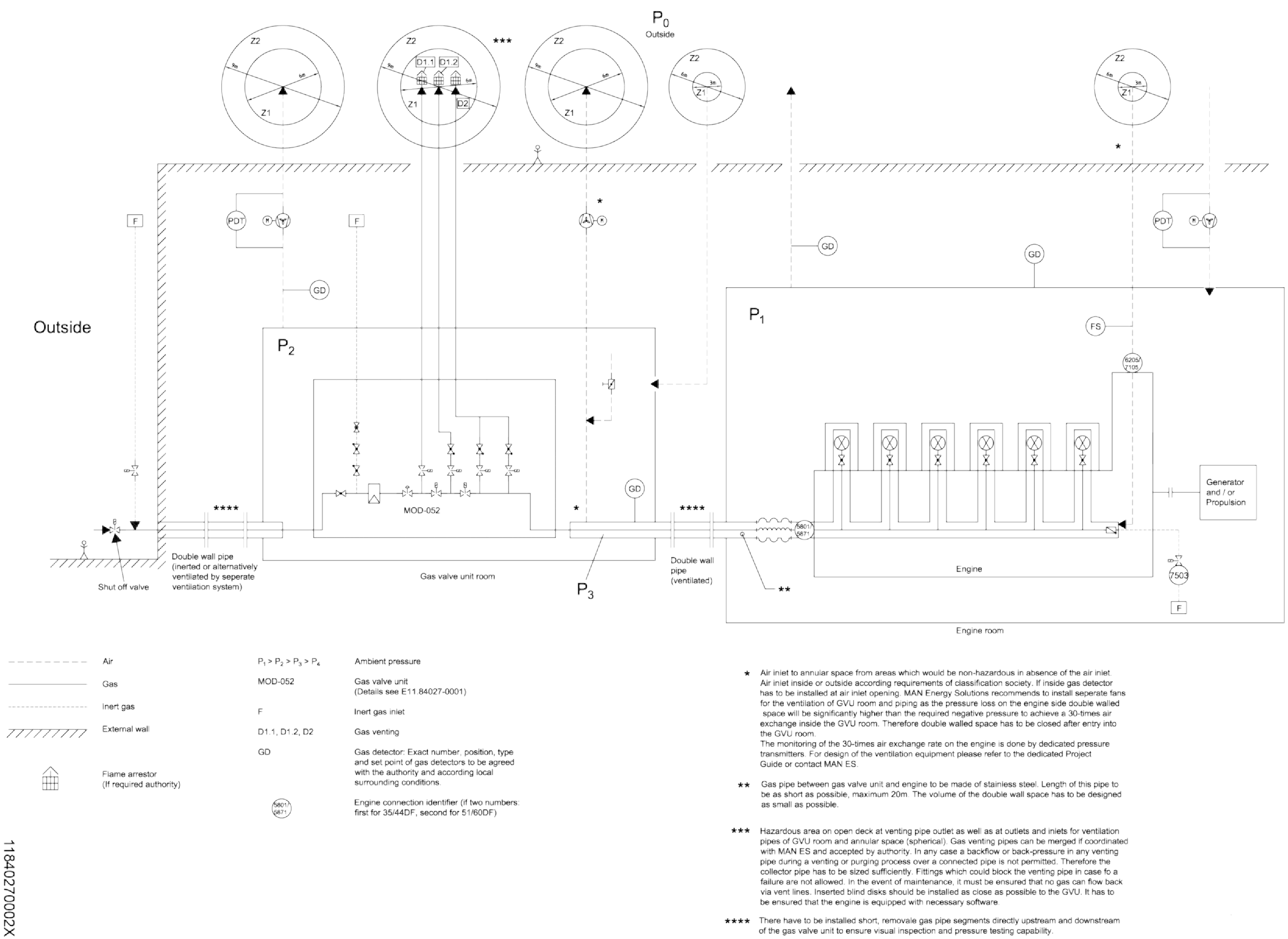

Figure 4: Gas feeding system

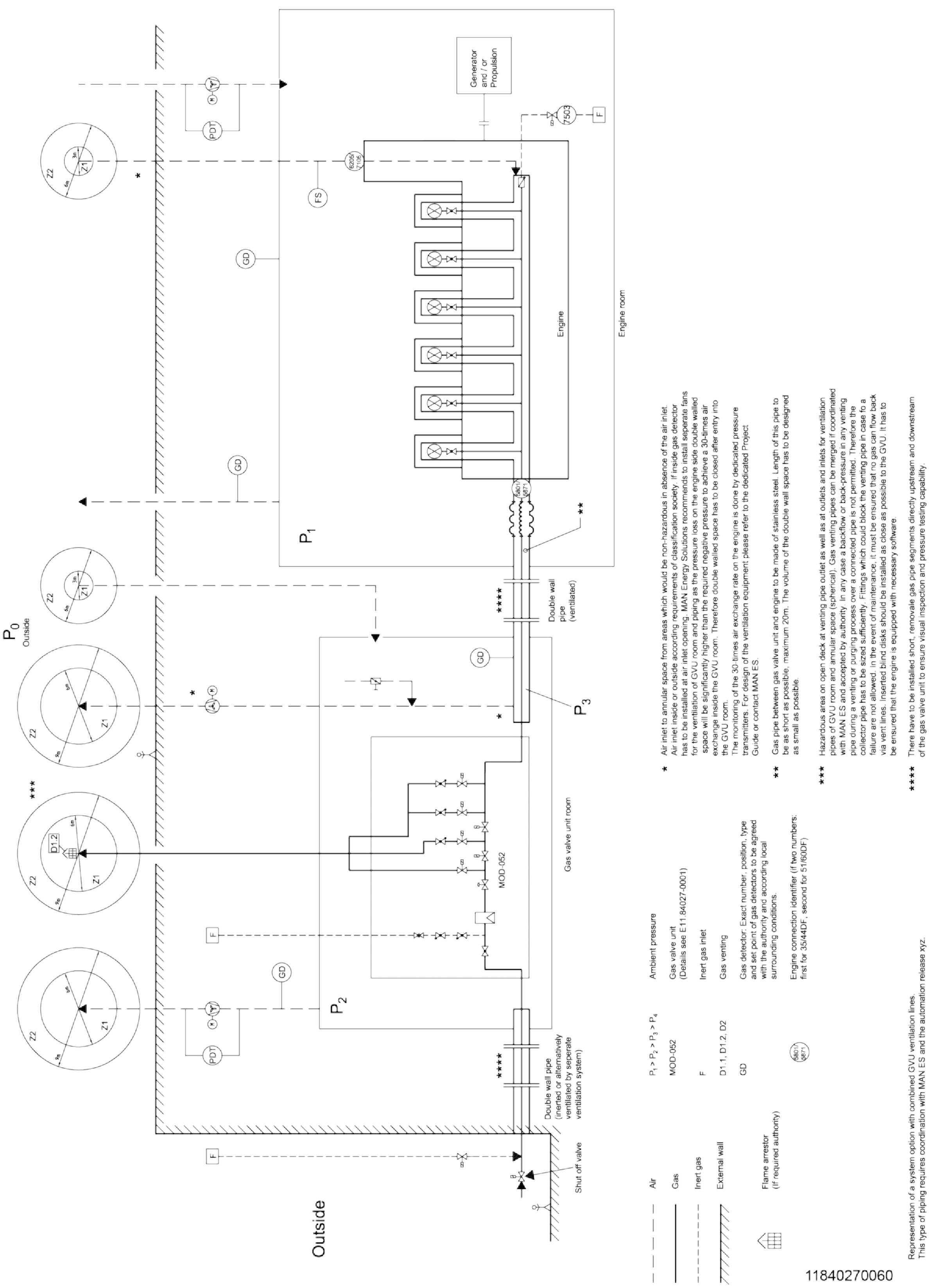

Figure 5: Gas feeding system - optional arrangement with merged vent lines

Gas fuel piping on the engine

The fuel gas supplied to the engine is provided to the cylinders individually through the gas admission valves mounted in the air inlet manifold of each cylinder. The gas admission valves are controlled individually by the speed governor in order to regulate the engine power and speed through controlling the amount of fuel gas fed to each cylinder.

The design of the gas admission valves and piping ensures that under normal conditions, only air and not fuel gas is contained in the charge air manifold. The gas admission valves are actuated (opened) through solenoids and are closed through springs (normally closed type).

All engine mounted fuel gas pipes upstream of the cylinder heads are of double walled pipe design, including the sections around the gas admission valves. The space in between the inner and outer pipe of the double walled piping is continuously ventilated by 30 air changes per hour. The proper ventilation rate shall be monitored by flow detection at the air inlet of the engine. Furthermore an intrinsically safe certified gas sensor shall be mounted at the entrance of the GVU compartment to detect a minimal amount of fuel gas immediately (see next paragraph Gas fuel piping between gas valve unit room and engine). For an example on the ventilation flow monitoring refer to figure Gas feeding system.

After switch over from gas mode to diesel mode charge air can flow into the gas pipe. The amount depends on load of the engine. Without further measures this results in a present continuously explosive atmosphere (zone 0). To avoid this explosive atmosphere within the gas pipe during normal operation the gas pipes on DF engines will be purged by inert gas before and after operating in gas mode. The necessary functionality of the purging system is monitored by pressure sensors. In case of a failure on the inert gas purging system two cases are differed:

- If the inert gas purging system should not be available before switch over into gas mode the engine remains in diesel mode and the gas mode will be blocked (no fuel gas inside the engine-side gas system).
- If the loss of the inert gas system during gas operation is detected, after the switch over from gas to diesel mode the fuel gas will be purged out with charge air by gas admission valves. Alternatively if a gas pressure control valve is installed directly on a dual fuel engine, this will be closed preventing explosive air mixture in the gas line from GVU to engine.

Due to the applied measures the presence of an explosive atmosphere during normal operation will be avoided.

Only the black out of the inert gas purging system during gas operation leads to an explosive atmosphere after the switch over from gas to diesel mode by controlled entry of charge air. According to section 12.5.1 of the IGF Code MSC.391(95) the inner gas pipe is defined as an hazardous area zone 0. A risk assessment in accordance with MSC.1/Circ.1605 Annex Pt. 2 was carried out for the gas admission valves. Based on the risk assessment the hazardous area zone for the gas admission valves is defined as zone 2. Hence the use of electrical equipment (gas admission valves) according EPL Gc is adequate.

As the risk of homogeneous ignitable mixture present in the fuel gas pipe is very low, it is not required to install a flame arrester inside the gas pipe.

Features:

- Gas admission valve for each cylinder.
- Redundant depressurisation of gas fuel pipe after gas operation.

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- Evacuation of gas fuel pipe after depressurisation.
- Gas supply on the engine by double walled distribution pipe.
- Complete double walled piping system including gas admission valves and compensators.
- The space in between the inner and outer pipe of the double walled piping is in depression and ventilated by at least 30 air changes per hour. This function is monitored by flow detection.
- The space in between the inner and outer pipe of the double walled pipe is controlled by intrinsically safe and certified gas detectors (to be installed in the pipe section between the engine and gas valve unit room, see next paragraph Gas fuel piping between gas valve unit room and engine).

Gas fuel piping between gas valve unit room and engine

The pipe between the gas valve unit room and the engine is a double walled pipe, also the compensator used to connect the engine is double walled. The space in between the inner and outer pipe of the double walled pipe is continuously ventilated by 30 air changes per hour. The ventilation is monitored by flow detection at the air inlet of the engine (see figure Engine related hazardous areas 1) and by at least 1 intrinsically safe certified gas sensor (exact number of gas detectors to be agreed with the authority). When reaching PREAL see table Automatic safety actions the detectors will cause an alarm. When no manual action is taken and the gas concentration inside double wall piping is still rising and reaching AL-level the ship safety system will cause an external QCO what means the engine will automatically change the gas fuel mode to diesel mode. In this case, the gas supply line will be shut off by closing the shut-off valve upstream of the GVU and the block and bleed valve in the GVU. In addition, the whole pipe down to the GVU will be depressurised and purged by nitrogen. No additional flammable gas can be supplied to defect components.

It is not required to install a flame arrestor in the fuel gas pipe as there is no homogeneous ignitable mixture of gas present.

Installation:

- Gas lines passing through the engine room, or other enclosed spaces with exception of the gas valve unit compartment, are to be of double walled type with controlled ventilation in depression.
- The space in between the inner and outer pipe is monitored by intrinsically safe and certified gas detectors (installed between the engine and gas valve unit room, exact number of gas detectors to be agreed with the authority).
- Double walled compensator.
- Inner pipe to be made of stainless steel.

The space between inner gas pipe and outer barrier to the machinery space is ventilated with 30-times air changes per hour. According IGF Code this space is defined as a hazardous zone 1 due to possible gas leakages in case of damage at the inner pipe.

During commissioning, or after maintenance works, appropriate flow measurements have to be carried out by the shipyard to ensure a 30-times air exchange of the double walled space from engine to GVU compartment.

The functionality of the ventilation system has to be monitored by flow detection at the air inlet of the engine, as well as, by negative pressure monitoring in the GVU compartment. If the air flow over the engine falls below a project-specific set-point, or the negative pressure in the GVU compartment is out of range, the engine has to be automatically switched to diesel mode. An external QCO has to be initiated by the ship automation/safety system. The set-points of the negative pressure range in the GVU compartment have to be defined according the pressure losses over the double walled piping from engine to GVU, the pressure losses over the engine and the pressure losses over the air suction line. For the pressure losses over the engine in relation to the plant-side installed double walled space refer to the engine specific Project Guide.

Furthermore an excessive gas concentration due to gas leakage on the inner gas pipe can be monitored by the gas detection equipment at the entrance of the double walled space into the GVU compartment.

Only the failure of the ventilation system in combination with a failure of the monitoring equipment can lead to an explosive atmosphere for a short period inside space between inner and outer pipe. This justifies the use of electrical equipment according EPL Gc inside this space.

Gas valve unit

The fuel gas pressure supplied to the dual fuel engine is regulated and controlled individually by one gas valve unit (GVU) for each dual fuel engine. The piping scheme is shown in figure Gas valve unit (GVU) P&ID and figure Gas valve unit (GVU) measuring devices diagram.

The gas valve unit has the following functions:

- Gas leakage test through engine control systems before change over to DF operation or gas start where applicable (see table Gas leakage test, procedure).
- Control of gas feed pressure to dual fuel engine (depending on engine type).
- At the end of gas operation, the unit shuts off the gas supply.
- Shut-off of the fuel gas supply in case of emergency stop.
- Automatic purging of gas distribution after DF operation incl. emergency stop with inert gas.
- Manual purging of GVU for maintenance reasons with inert gas (depending on engine type).
- Shut-off of the fuel gas supply in case of pressure downstream pressure controller is exceeding the design pressure of the engine (by pressure monitoring and block & bleed valves).

The unit is controlled by an engine control sequence of SaCoSone.

If the engine is not in operation, the manual gas shut-off valve (V-003) at the inlet of the GVU, or another shut-off valve nearby upstream of the GVU, has to be closed. There must not be any gas present downstream of the manual shut-off valve of the GVU if the engine is not in operation for a longer period.

Installation of GVU:

- Installation of gas valve unit in dedicated compartment (GVU room) with gas-tight walls. Alternatively encased GVU with gas-tight housing.
- Single wall gas pipes and instrumentation in the gas valve unit compartment.
- The gas valve unit compartment has to be ventilated by 30 air changes per hour. The ventilation system of the GVU compartment consists of exhaust ventilators installed in a dedicated exhaust air duct. Ventilation air for the GVU compartment will be sucked in from outside and will also come from the engine room via the double wall pipe. The air pressure in

the GVU compartment has to be constantly lower than the air pressure in the engine room and outside. The adjustment of the negative pressure inside the GVU compartment can be realised by a throttle valve installed in the separate ventilation pipe to the GVU compartment or by a frequency controlled extraction fan. The negative pressure inside the GVU compartment has to be monitored.

- The volume of the gas valve unit compartment has to be as small as possible. Maintenance work must be possible.
- The GVU compartment has to be monitored by at least one intrinsically safe certified gas sensor. The exact number of gas sensors to be agreed with the authority and according to the compartment geometry.
- If the supply pressure of the fuel gas supply system can exceed the design pressure of the engine an appropriate pressure reducing device including a gas over pressure safety shut-off or blow-off valve has to be installed upstream of the GVU. It is recommended to install these devices within the common gas supply line for all engines of the plant.
- Three NRVs to avoid any back flow from the vent lines into the GVU (depending on engine type).

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Safety concept - Dual fuel engines

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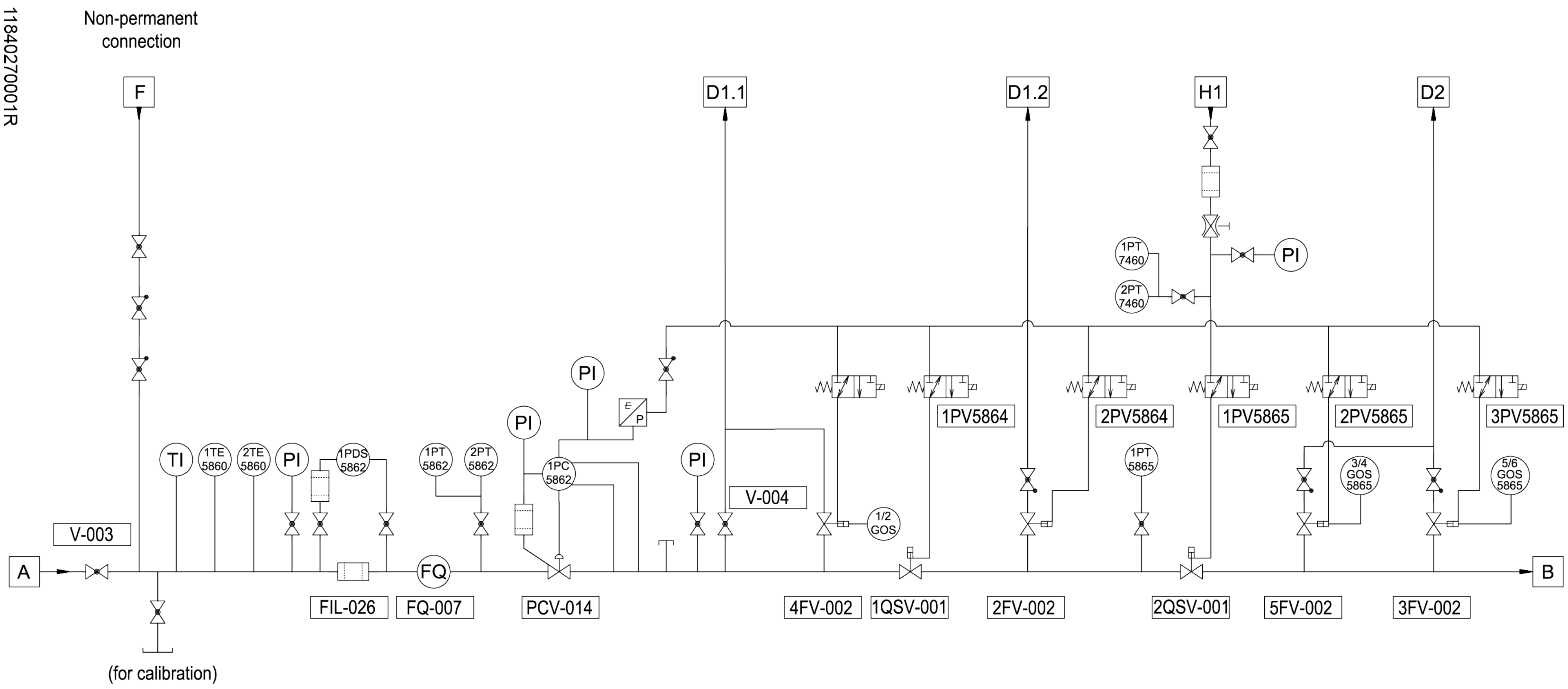
Description



A	Gas inlet
B	Gas outlet
F	Inert gas
D1.1 D1.2 D2	Gas venting
H1	Compressed air

FIL-026	Gas filter
2,3,5 FV-002	Automatic venting valve (NO)
4 FV-002	Automatic venting valve (controlled by shipyard; NC)
MOD-052	Gas valve unit (GVU)
PCV-014	Gas pressure control valve (constantly open due to offset)
1,2 QSV-001	Quick action stop valve (NC)
V-003	Gas shut-off valve, manual
FQ 007	Gas flow meter

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Figure 6: Gas valve unit (GVU) P&ID

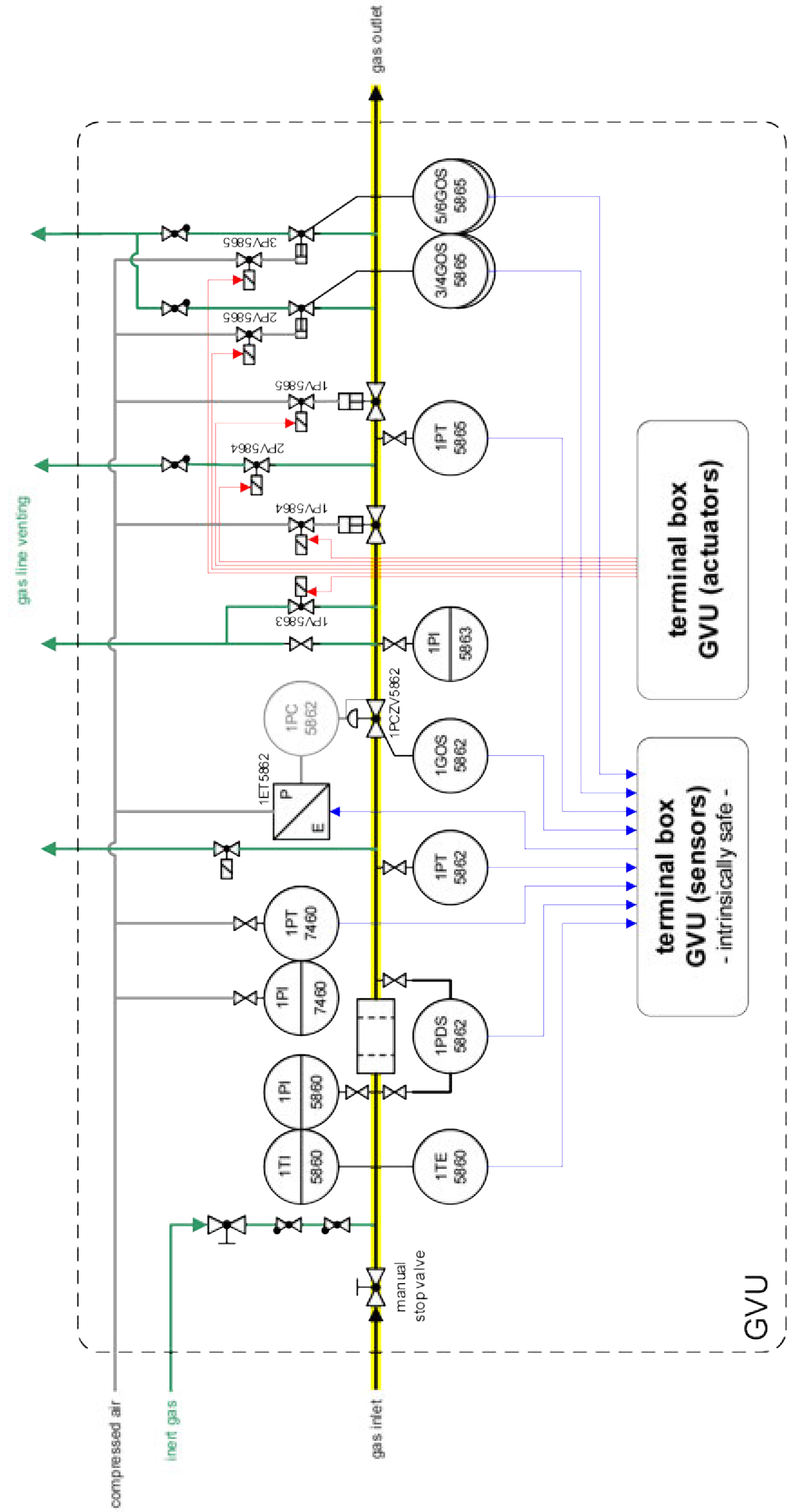

Figure 7: Gas valve unit (GVU) measuring devices diagram

The gas valve unit (GVU), see figure Gas valve unit (GVU) P&ID is a regulating and safety device, allowing the engine to be safely operated in gas mode. The control unit is equipped with double block and bleed valves (quick-acting stop valves and venting valves) and a gas pressure regulating device.

In order to keep impurities away from the downstream control and safety equipment, a gas filter (FIL-026) is installed after the manual-stop valve (V-003). The pressure loss of the filter is optionally monitored by a differential pressure gauge of the DF engine.

The gas pressure control device (PCV-014) adjusts the pressure of the gas fed into the engine. The control devices include a regulating valve with pressure regulator and an IP transducer.

For MAN L23/30DF and MAN L28/32DF the pressure regulating valve at the GVU has only the purpose to stabilise the pressure downstream the GVU. Main gas pressure control valve is on the engine.

In accordance with the engine load, the pressure control device maintains a differential gas overpressure to the charge air pressure. This ensures that the gas feed pressure is correct at all operating points of the DF engine.

At the outlet of the gas valve line, quick-acting stop valves (1,2QSV-001, 1PV5864, 1PV5865) and automatic venting valves (1,2,3,5FV-002 = 1PV5863, 2PV5864, 2PV5865, 3PV5865) are mounted. The quick-acting stop valves will interrupt on the request the gas supply to the engine. The automatic venting valve (2FV-002) relieves the pressurised gas trapped between the two closed quick-acting stop valves (1,2QSV-001). The automatic venting valves (3FV-002 and in parallel for redundancy 5FV-002) relieves the pressurised gas trapped between the last quick-acting stop valve (2QSV-001) and the engine and is used to depressurise the gas distribution system and purge with nitrogen in inverse direction. An optional valve, 4FV-002, can be installed on the GVU for venting and purging of the gas supply line upstream of the GVU (controlled by ship- or fuel gas supply system automation).

For safety reasons, the working principle of the quick-acting stop valves (1,2QSV-001) ensures that the valves are normally closed (closed in case there is no signal or no control media, i.e. compressed air) while the venting valves (2,3,5FV-002) are normally open. The gas valve unit includes pressure transmitters/gauges and a temperature transmitter. The output of these sensors is transmitted to the engine management system. The control logic meets requirements and controls the opening and closing of the block and bleed valves as well as the gas valve line leak test.

At the gas input connection (A) of the gas valve unit, all gas parameters as specified for the engine are to be observed (for further informations contact , as for example the natural gas specifications).

Gas leakage test of the gas valve unit

Step	Action
Initial	Valves 1QSV-001 (1PV5864), 2QSV-001 (1PV5865), 5FV-002 (2PV5865) and 3FV-002 (3PV5865) are closed, while 2FV-002 (2PV5864) is open.

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Step	Action
1	Valves 5FV-002 (2PV5865) and 3FV-002 (3PV5865) will be opened, while 2FV-002 (2PV5864) will be closed. The gas pressure rises up to certain value within a certain time (measures by pressure transmitter 1PT5865). This indicates a leaking valve 1QSV-001 (1PV5864). Reaction: Alarm and shut-off sequence. Purging with inert gas. No alarm: Step 2
2	Valve 1QSV-001 (1PV5864) will be opened. Valve 5FV-002 (2PV5865) and 3FV-002 (3PV5865) remains open. If there is no pressure rise measured by pressure transmitter, it indicates that there is either a defect pressure transducer 1PT5865 or the valves 1QSV-001 (1PV5864), 2QSV-001 (1PV5865) or 2FV-002 (2PV5864) are defect. Reaction: Alarm and shut-off sequence. Purging with inert gas. No alarm: Step 3
3	Valve 1QSV-001 (1PV5864) will be closed. Valve 5FV-002 (2PV5865) and 3FV-002 (3PV5865) remains still open. Pressure drop at transducer 1PT5865 within a certain time indicates leaking valves 2FV-002 (2PV5864) or 2QSV-001 (1PV5865). Reaction: Alarm and shut-off sequence. Purging with inert gas. No alarm: Step 4
4	Gas leakage sequence complete. Gas supply for gas engines will be opened.

Table 3: Gas leakage test, procedure

See also figure Gas valve unit (GVU) P&ID and figure Gas valve unit (GVU) measuring devices diagram for control unit and valve arrangements.

Gas start capability

The MAN 51/60DF and the MAN 35/44DF engines have the ability to start with fuel gas and pilot oil injection only.

The gas start capability will meet the following criteria:

- Full gas operation at the very first cycle; thus no main injection necessary.
- Engine start mode: Optionally available in either diesel or gas.
- Stand-by: The engine is capable of starting from stand-by either in gas or diesel operation.
- Gas operation under low load conditions: Operation in gas mode w/o time limit for loads ≥ 10 % – 100 % MCR.
- Transfer to diesel operation w/o loss of power/speed.
- Overload capability of 10 % for regulating purposes.

Following sequences are necessary for a reliable and safe engine start in gas mode beside engine preheated and prelubricated:

- Gas leakage test of the gas valve unit (GVU)

  For a safe gas operation the functionality of the double block and bleed valves is tested.
- Gas valve functional test

With the gas admission valves the amount of gas in the combustion air ratio is controlled. So correct working gas admission valves are necessary to ensure an appropriate combustion air ratio. Therefore a functional test of the solenoid gas valves is done before the engine is started.

- Pilot injector functional test

  Beside an appropriate combustion air ratio also an ignition source is necessary for a successful combustion. So a correct functionality of the pilot injectors has to be confirmed before starting the engine. Therefore a functional test of the pilot injectors is done before the engine is started.

- Exhaust venting

  Activation of the exhaust gas blower. The exhaust gas blower dilutes the exhaust gas in case of an incomplete or not occurred combustion during the engine is running up to nominal speed. During the gas start sequence the correct functionality of the blower and the exhaust flap is checked.

- Purging and gas line leakage test

  The entire gas system is purged and filled up with nitrogen to ensure defined conditions in the gas system. Consecutively the leakage test of the gas line between GVU and engine will be performed. This test ensures that the leakage rates of all main gas valves are in proper manner.

- Pre start gas line filling

  Initial filling of the gas line with fuel gas without having compressed gas in front of the main gas valves.

If all start preparation steps are successfully done, the engine start is finished. If one of the start preparation steps fails, the engine start gets aborted.

Black start and emergency start operation is not possible in gas mode.

Shut-off sequence during change over from gas to diesel mode

Step	Action
1	Valves 1QSV-001 (1PV5864) and 2QSV-001 (1PV5865) will be immediately closed.
2	Valves 2FV-002 (2PV5864), 5FV-002 (2PV5865) and 3FV-002 (3PV5865) will be opened with an individual delay time.
3	In case of safety shut-off valve is installed valve 6FV-002 (1PV5863) opens for a short period of time to depressurise the gas after the pressure regulating valve. After depressurising, valve 6FV-002 (1PV5863) remains closed.
4	Valve 5FV-002 (2PV5865) and in parallel 3FV-002 (3PV5865) will be closed after purge time.

Table 4: Shut-off sequence during change over from gas to diesel mode

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Purging with inert gas

To secure a gas supply line free of explosive atmosphere on the DF engine up to the block valve 2QSV-001 (1PV5865) of the GVU at any time, the piping will be automatically purged with inert gas after each normal or quick change over from gas mode to liquid fuel mode, before each switch-over from liquid fuel mode to gas mode and after each emergency shutdown from gas mode. Therefore an inert gas purge valve 1FSV5888 will be installed on the DF engine (see figure Gas fuel system, measuring device diagram (MAN 51/60DF).

During purge mode first the venting valves 5FV-002 (2PV5865) and 3FV-002 (3PV5865) will be opened to depressurise the piping. Afterwards the purge valve will be opened for a defined time and inert gas can purge the remaining gas upstream over the valves 5FV-002 (2PV5865) and 3FV-002 (3PV5865) out to the gas venting installation. After the purge time (depending on the length of the gas piping from GVU to DF engine manifold), 5FV-002 (2PV5865), 3FV-002 (3PV5865) and 1FSV5888 will be closed. During preparation to gas mode, the purge mode has to start once again to secure an air-free gas piping.

In case depressurising of the gas pipe between GVU and engine is not possible due to a malfunction (e.g. sticking venting valve), the limited fuel gas volume trapped in the pipe can slowly pass through the not completely tight gas admission valves and can reach the charge air manifold. If the engine is not in operation, following the gas can reach the engine room or through open cylinder inlet and outlet valves, the exhaust gas system. To minimise this risk, redundant venting valves 5FV-002 (2PV5865) and in parallel 3FV-002 (3PV5865) are installed on the GVU.

In case the nitrogen purging system fails, the gas pipe is once purged with charge air and a gas blocking is set. Thus an explosive atmosphere can only occur seldom and for short periods. Operation in gas mode is only possible if nitrogen pressure is available and gas blocking alarm has been reset by operator.

Gas fuel piping between shut-off valve and gas valve unit room

The pipe between the shut-off valve and the gas valve unit room must be double walled if passing through enclosed areas (in frequent cases this pipe can pass directly from the exterior to the gas valve unit room without passing in other enclosed areas, then a double walled pipe is not required). The space in between the inner and outer pipe of the double walled pipe is continuously ventilated by 30 air changes per hour or alternatively inerted with higher pressure than the maximum working pressure of the inner pipe. The ventilation flow is monitored by differential pressure or flow detection. Inerted ducting shall be pressure monitored. Gas detection by at least one intrinsically safe certified gas sensor is required (exact number and type of the gas sensor to be agreed with the authority). By detection of AL (see table Automatic safety actions) the gas fuel mode will be automatically changed to diesel fuel mode. In that case, the shut-off valve will be closed and the external venting valve will be opened. No additional flammable gas can be supplied to the possible defect component and therefore cannot be a source of danger for a fuel gas related explosion.

Installations:

- Shut-off valve installed at the exterior upstream of the GVU room in accordance to IGF Code and IGC Code. Pipe venting valve to be installed. For each separate engine room, we recommend to provide one separate shut-off and venting valve. Inertisation of the pipe with inert gas.
- Gas fuel piping should not pass through accommodation spaces. Gas lines passing through enclosed spaces, with exception of the gas valve control room, are to be of double walled type with controlled ventilation in depression, or controlled overpressure of inert gas in the outer pipe space (no automatic refilling of inert gas in case of a leak).

- The space in between the inner and outer pipe of the double wall pipe is controlled by at least one intrinsically safe and certified gas detector (installed between the exterior and the gas valve unit room, exact number of gas detectors to be agreed with the authority).

Fuel oil systems

Pilot fuel oil system

The pilot fuel oil system of common rail type is built according actual classification rules in force. It consists of a high-pressure fuel pump with double wall pipes and solenoid injection nozzles for each cylinder. Fuel gas can not enter in the fuel oil system as the injection pressure of the pilot fuel oil is a few times higher than the fuel gas or ignition pressure of the cylinder. In case of a failure in the pilot fuel oil system (supervision of pilot fuel pressure), there is an automatic change-over to diesel fuel mode with back-up fuel. dual fuel engines, which have no separate pilot fuel oil system, will inject the necessary amount of liquid fuel for igniting the gas-/air-mixture by the main injection system.

Main fuel oil system

Conventional fuel system

Conventional diesel engine fuel oil system, with one engine driven injection pump for each cylinder which actuates the injection valve by double wall and leakage monitored high-pressure pipes. The system is built according to the actual classification rules in force. The fuel gas mixture in the cylinder can not enter in any case of failure into the main fuel oil injection system. The injection pressure is higher than the ignition pressure and there is a non-return valve installed on the injection pump which protects the low-pressure fuel system against gas flow in case of an untight injection nozzle.

Common rail fuel system

The main common rail injection system is based on the following principle: High-pressure pumps compress the fuel to the required pressure and deliver it to the in-line accumulator units. At the accumulator units, there are connections for the injection valves and also the components for the fuel distribution and injection control.

The system is designed according to the actual classification rules in face with following safety concept:

- Double walled high-pressure pipes
- Flow limiting valve at each cylinder
- Redundant HP pumps
- Twin type HP sensors and speed sensors

Crankcase

Crankcase safety valves are used for every crankcase compartment. The certified safety valves are used in gas dangerous zones to protect components. The certification is usually according to the ATEX EC directive 2014/34/EU and IMO rules.

As inside the crankcase ventilation pipe no hazardous area related to explosion is present, the outlet can be led to a non-hazardous location on open deck. Regarding fire protection the end of the ventilation pipe shall be equipped with a flame arrester. The ventilation pipe has to be built steadily ascending to avoid any accumulation of oil.

To improve the ventilation of the crankcase, an extraction fan is installed in the venting pipe. The speed of the extraction fan is controlled to not exceed a negative pressure of −2.5 mbarg in the crankcase. In case of a malfunction of the fan, the engine will automatically switch over to diesel mode or will prevent the switch over from diesel mode to gas mode in case it was in diesel mode when the malfunction of the fan is detected. Operation in diesel mode is possible at any time even if the fan is not running or is showing a malfunction. In this case, the oil mist will pass through the not operated fan by natural ventilation.

By controlling the negative pressure inside the crankcase by software monitored crankcase ventilation system, the gas/air-mixture is safely kept below 100 % LEL. Only in case of rare disturbances like a damaged piston ring on one cylinder or mechanical atomisation and subsequent evaporation of lube oil in the area of hot locations, an explosive atmosphere can be formed locally. Since rare engine disturbances do not imply explosive zoning, the crankcase remains without the definition of an explosive zone when applying active crankcase ventilation. In case classification society requires zone 2 for crankcase, the ventilation pipe has to be defined as zone 2. The outlet of the ventilation has to be guided to the outside of the ship. Around the ventilation openings an explosion hazardous zone 2 with a radius of 1.5 m has to be specified. Due to dilution with turbocharger blow-by air there is no explosion protection zone inside the ventilation pipes at any time.

As an option a closed crankcase ventilation can be installed. With it the crankcase atmosphere is freed from oil by an oil mist eliminator and led back to the compressor inlet-side of the turbocharger. The classification of the hazardous areas related to the crankcase and its ventilation stays untouched by applying a closed crankcase ventilation.

If no active crankcase ventilation is installed on dual fuel engines from an explosion hazardous area zone 0 will be present inside the crankcase. Therefore the electrical equipment inside the crankcase has to be of an appropriate type for the use in this atmosphere.

The maximum explosion pressures in the (closed) crankcase of dual fuel engines and normal diesel engines are comparable (explosion pressure of lube oil mist 8 bar). The ignition sources (see figure Engine related hazardous areas 2) are monitored and alarmed by two redundant and diverse systems, splash-oil-monitoring-system with main bearing temperature monitoring and a class approved oil-mist-detection system.

For maintenance work, the crankcase is provided with a manual gas detection connection and an inert gas connection.

If required by classification societies or IGC Code has to be applied, the shipyard shall install a gas detection device (methane) in the crankcase ventilation pipe after the flange at the crankcase.

Charge air system

If the combustion air is sucked from the machinery room, no additional requirements are necessary, as the machinery room is a gas safe area which is additionally monitored and supervised by approved gas detection sensors.

In case the combustion air is taken directly from the free atmosphere, the air has to be taken from a gas safe area via ducting. The air inlet ducting has to be protected by a shut-off device and must be monitored by at least two independent approved gas detectors. In case of fuel gas flow in, the shut-off device has to close the combustion air intake of the engine.

MAN 51/60DF: The combustion air shut-off device has to be installed by the yard in the combustion air pipe upstream of the compressor inlet.

MAN 35/44DF: The combustion air shut-off device can be installed on the engine in the charge air pipe downstream of the compressor outlet.

MAN L23/30DF and MAN L28/32DF: The combustion air shut-off device is mounted on the engine.

Exhaust gas system

Exhaust gas system (on engine)

Gas can only enter into the exhaust gas system in case of an incomplete combustion or misfiring of one or more cylinders. Misfiring will be detected by the combustion monitoring. The material used for the piping and its components are ductile. The design is as thus, that there are no pockets where unburned gas can be accumulated.

Nevertheless, when operating the engine on variable speed, for a short time, a certain amount of unburned gas mixed with exhaust gas and residual air cannot be avoided in the exhaust gas system during incomplete combustion or misfiring due to a open stucked gas admission valve. Therefore, a pressure relief valve with flame arrester protects the piping system on the engine. The discharged overpressure and the discharged media are led to a safe place, which is not permissible to be entered during engine operation in gas mode. When operating the engine only on constant (nominal) speed the fuel gas will be fired inside the cylinder even in case of a open stucked gas admission valve and no critical amount of residual gas can enter the exhaust gas system.

Exhaust gas system (external)

DF engine exhaust gas pipes after outlet turbocharger shall not be connected to other exhaust gas pipes from any other engine or systems. The exhaust ducts have to be built steadily ascending to avoid any accumulation of explosive gas concentration.

During abnormal operation conditions due to incomplete combustion or misfiring, gas mixture could enter the exhaust system (see section Exhaust gas system (on engine)). Piping or spaces in which explosive atmosphere could enter or accumulate must be protected against dangerous overpressure which could destroy them or will cause injury to person or equipment. Rupture discs or other pressure relief valves must reliably discharge the overpressure to a safe place and be suitable to be used in gas dangerous, explosive atmosphere.

The rupture discs or other pressure relief valves have to be monitored. An alarm is provided in cases where the exhaust system has opened so exhaust gas can be released. The following options are possible:

- In cases where the exhaust gas is released through the rupture disc or other pressure relief valves without detrimental effect, the engine can be operated in diesel mode or backup mode for emergency reasons.
- In case of multi-engine propulsion, an alarm is to be provided and the shut-off of the engine is to be activated in cases where safe engine operation with release of exhaust gas through the rupture disc or other safety devices is not guaranteed. However, in case pressure relief valves (self closing types) have been implemented instead of the standard rupture discs, an alarm is released that causes a changeover from gas operation to diesel operation.
- In case of single-engine propulsion or special applications (e.g. dredger, dynamic positioning, etc.), pressure relief valves are required (self closing types) and an alarm is released that causes a changeover from gas oper-

ation mode to diesel operation. The pressure relief valve has to be checked regarding tightness after it has opened due to an overpressure inside the exhaust gas piping.

During the design stage it has to be decided which option will be followed. The system has to be designed accordingly. The respective alarms and signals will be included in the engine control system.

In common, the rupture discs or pressure relief valves shall be positioned as near as possible to the ignition source to keep the effective maximum explosion pressure as low as possible. In addition, the axis of the rupture disc or pressure relief valve shall be in flow direction of a possible explosion to have the most effective pressure relief.

The exact amount and the position of the explosion relief equipment are heavily depending on the geometry of the exhaust gas system and the installed equipment as e.g. boiler, silencer, catalysts etc. Pressure release installation for each equipment shall be installed in front of the related equipment.

The exact engine type, the number of cylinders and the load cases have high influence on the ignitability of the gas mixture. Furthermore, specific rules depending on the classification societies forbid to release the exhaust into the engine room.

Therefore project specific investigations have to be taken where all parameters are reflected and defined.

Even with explosion relief equipment it can not be ensured that all components of the exhaust gas system are free of damages after an explosion event. Thus the components of the exhaust gas system have to be checked after an explosion event in any case before engine is operated again.

During the unlikely case of an explosion inside the exhaust gas system persons could be injured near installed rupture discs or explosion relief valves. As is not responsible for the surrounding area, it must be ensured by the builder and/or operator that opening rupture discs or explosion relief valves, will not lead to threating of persons by flames or pressure increase in closed rooms. Suitable technical solutions, e.g. leading away the relieved explosion product to a safe area or installing flame arrestors on the rupture discs, have to be taken.

In case of an emergency stop or at a regular stop of the engine (for checking the correct functioning of the exhaust gas ventilation unit and for soot-freeing of the butterfly valve), the external exhaust gas installation, as duct, silencers, boiler and stack (see figure Example for exhaust gas ducting arrangement), will be ventilated by an additional exhaust gas vent. The purging is done sufficiently by an air volume equal to min. 3 times of the total volume of the exhaust gas system. If exhaust gas system is not purged sufficiently after an emergency stop in gas mode, the engine can not be started. A valve is protecting the exhaust gas ventilation unit against exhaust gas inflow. The butterfly valve opens as soon as a pressure of 35 mbar has been formed by the fan. In case of missing control air or power the valve will close automatically (fail-to-close). The fan is able to generate a pressure which is higher than the exhaust gas back-pressure (40 mbar for plants w/o SCR, 60 mbar for plant with SCR). The tightness of the butterfly valve will be monitored by redundant temperature sensors.

For multi-engine plants an alarm will be generated and the engine will be shut down in case of excessive temperature which indicates a non-tight butterfly valve. Furthermore an alarm is generated if the valve is not completely closed and the engine shall not be started if not urgently necessary.

If engine is started in gas mode the exhaust gas ventilation unit will be operated to dilute a possible explosive mixture in case of a failure on one gas admission valve. For electric propulsion applications with constant speed the exhaust gas ventilation unit will be operated until reaching nominal engine speed. For mechanic propulsion applications the exhaust gas ventilation unit will be operated until reaching a certain speed/load ratio.

For single-engine plants there is no automatic engine shutdown and the fan can be started after the alarm to operate against the exhaust-gas pressure. Thus the engine can be operated in diesel mode.

From the exhaust gas piping a hazardous area zone 2 propagates up to the butterfly valve. After the butterfly valve there is no hazardous area present as a two-failure scenario is necessary so an explosive atmosphere can reach the exhaust gas purging fan.

The ventilation air inlet has to be as near as possible to the turbocharger outlet. The connected ventilation air piping shall be steadily ascending and as short as possible (recommendation max. 5 m). The piping shall be insulated to avoid the forming of condensate. The temperature loss between inlet to the exhaust gas system and the butterfly valve shall be max. 10 K. If a steady ascending pipe can not be realised a condensate trap shall be installed on the deepest point of the piping.

The exhaust gas purging fan module can be either controlled and delivered by or by shipyard according specifications from . This has to be evaluated project specific.

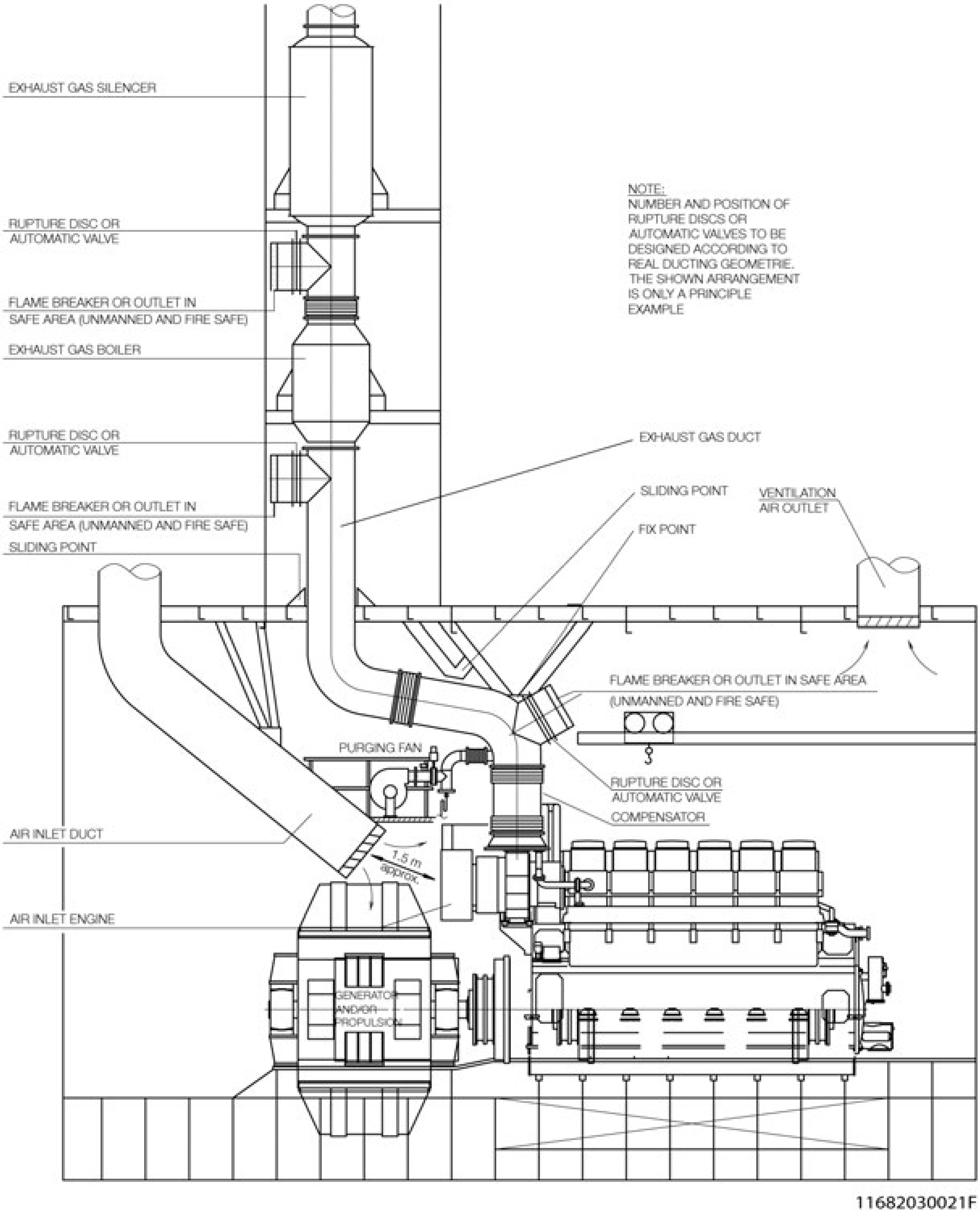

Figure 8: Example for exhaust gas ducting arrangement

Lube oil (LO) system

There are two different arrangements of the lube oil tank:

- Lube oil service tank
  This tank is installed separately from the engine. The lube oil sump of the engine is of dry type. Oil returns by return pipes from the dry lube oil sump to the lube oil service tank.
- Engine frame tank
  This tank is directly open to the crankcase and it is part of the engine frame. The lube oil sump is of wet type.

Due to the forced ventilation of the crankcase, the main amount of possible explosive atmosphere coming from the cylinder and turbocharger blow-by is removed. In general, the atmosphere in the engine frame and also inside the lube oil service tank is the same one as in the crankcase. The engine frame tank anyway is ventilated with the crankcase but can also see oil mist. Following hazardous area 2 is defined for the engine frame tank.

In the lube oil returning from the engine, gas filled bubbles and solved gas are contained. The returning oil normally outgases inside the crankcase and engine frame or lube oil tank on the calm liquid surface. The amount of gas coming from the degassed oil is very small and coheres with the gas atmosphere inside the crankcase, which is safely below 100 % LEL due to the ventilation in gas operation. In combination with a separate venting pipe of the lube oil service tank to a safe location on the open deck, remote from any source of ignition, no hazardous zone has to be defined for the lube oil service tank, the venting pipe and the venting pipe outlet. The venting pipe has to be built steadily ascending to avoid any accumulation of gas. The free end of the venting pipe is protected by a flame arrester. The venting pipe must not be connected to venting pipes of other systems.

Lube oil service tank

The lube oil return pipe from the crankcase to the separate lube oil service tank must be installed such that the lower pipe end discharges adequate below the lowest possible oil level surface (immerged return pipe), considering also max. ship inclinations according to the class society. This is to ensure that there is no direct communication between the crankcase and the gas area (upper area) of the lube oil service tank possible. Following a possible oil mist crankcase explosion cannot propagate to the lube oil service tank.

The level of the oil surface is monitored by a level indicator, which will give an alarm in case of low level lube oil in lube oil service tank.

A principal arrangement of a lube oil service tank for a DF engine is shown in figure Lube oil service tank arrangement 1 and figure Lube oil service tank arrangement 2.

Engine frame tank

Tank venting is combined with crankcase venting. Therefore the same hazardous area as for the crankcase has to be applied for the engine frame tank. See section Crankcase.

The manual gas detection connection and the inert gas connection of the crankcase is used.

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Lube oil filters, strainers and centrifugal separators are supplied with lube oil from the lube oil service tank or engine frame tank. The oil in the service tank or engine frame tank is degassed during the dwell period. Oil sucked from the service tank bottom is pumped to the separators and filters, where only well degassed lube oil is treated. Any open end of pipes, returning oil from external plant installed systems and components in the lube oil service tank or engine frame tank, are to be immerged min. 100 mm below the oil surface (also considering sea motion) to avoid that atmosphere from the tank can enter into the piping system. Alternatively, where this is not possible, siphons are to be installed in the return pipes or the piping has to be immerged on the connected tank. Therefore in this equipment, no considerable amount of fuel gas is present which could accumulate to an explosion hazardous atmosphere. No special explosion protection precautions have to be taken. Nevertheless, in all tanks filled with used lube oil, unburned fuel gas can be present. Due regard has been paid therefore for the used equipment on that tanks and the related piping. That means that all tanks for used lube oil need vent pipes led to a safe location on the open deck, remote from any source of ignition.

Cooling water system

Note:
For cooling water diagrams refer to the actual dual fuel engine Project Guides or contact .

High temperature cooling water system

The high temperature cooling water system is an open system.

During normal operation, there would not be any accumulation of unburned fuel gas in the HT cooling system. Only in case of a damage, an important amount of fuel gas could enter the HT cooling water system. This leaked unburned fuel gas is lighter than air and is constantly naturally vented through the venting pipe from the HT expansion tank to a safe location on the open deck, remote from any source of ignition. The venting pipe has to be built steadily ascending to avoid any accumulation of explosive gas concentration. The free end of the venting pipe is protected by a flame arrester. The inner space of the HT expansion tank is related to explosion protection zone 2. All electrical equipment has to be certified for that use.

For safe maintenance, the HT expansion tank has to be equipped with a manual gas detection connection and an inert gas connection to prove that there is no explosive atmosphere contained before starting any maintenance works.

In case gas has been measured inside the HT expansion tank, the HT-system and it´s components have to be checked for possible accumulation of gas e.g. in heat exchangers or piping sections. In case accumulation is possible, the components have to be marked with a warning label. During venting of the components air ventilation has to be ensured and no ignition sources are permissible near the venting points.

If in the HT cooling water system a drain tank or other cooling water tanks are installed, the same zone as for the HT expansion tank is applied.

Low temperature cooling water system

The low temperature cooling water system is an open system.

During normal operation, there would not be any accumulation of unburned fuel gas in the LT cooling system. Only in case of a damage in the HT cooling water system and only if the HT system is connected with the LT system, an important amount of fuel gas could enter into the LT cooling system and the following measures become necessary. The leaked fuel gas is lighter than air and is constantly naturally vented through a venting pipe from the LT expansion tank to a safe location on the open deck, remote from any source of ignition. The venting pipe has to be built steadily ascending to avoid any accumulation of explosive gas concentration. The free end of the venting pipe is protected by a flame arrester (all this is only required in case that the HT system is connected to LT system). The inner space of the tank is related to explosion protection zone 2. All electrical equipment has to be certified for that use.

For safe maintenance work, the LT expansion tank has to be equipped with a manual gas detection connection and an inert gas connection to prove that there is no explosive atmosphere contained before starting any maintenance works.

In case gas has been measured inside the LT expansion tank, the LT-system and it´s components have to be checked for possible accumulation of gas e.g. in heat exchangers or piping sections. In case accumulation is possible, the components have to be marked with a warning label. During venting of the components air ventilation has to be ensured and no ignition sources are permissible near the venting points.

If in the LT cooling water system a drain tank or other cooling water tanks are installed, the same zone as for the LT expansion tank is applied.

Gas venting pipes

Gas venting pipes open to the atmosphere are to be designed to resist the maximum operating pressure of the vented section. Venting pipes are to be placed continuously ascending to avoid the formation of gas pockets inside. A flame breaker is to be installed close to the outlet, if required by classification society. Water ingress in any form (e.g. rain or spray water) to venting and/or ventilation openings shall be avoided at any time.

offers a gas valve unit with dedicated venting line connections.

Gas venting pipes can be merged if coordinated with and accepted by authority. offers at least three dedicated venting line connections at the gas value unit. To ensure safe operation under all circumstances, additional safety measures have been implemented. These measures are provided for gas valve units delivered at 2022 and requires a corresponding SaCoS release. The measures are not backward compatible. Independent of the measures provided, venting lines - independent if they are merged or not - shall be designed to limit back flow or back pressure to a minimum and to offer sufficient depressurization.

Electrical systems

To avoid ignition sources within gas explosive areas, the electrical equipment is to be designed according to ATEX guidelines RL 2014/34/EU for manufacturer and RL 1999/92/EG for operators. Furthermore, the appropriate standard IEC 60079 has to be considered.

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This design description is valid for the vicinity of engine room and the gas valve unit compartment.

The cable connection to and between the gas hazardous areas has to be carried out with approved gasket sets for cables.

The assortment of the electrical devices has to be done according to the defined explosion zones in section Definition of explosion hazardous areas. The verification of suitability of each electrical equipment for the corresponding explosion zone is necessary according to IEC 60079-14.

The flooring in rooms within gas hazardous areas has to be equipped with an anti-static surface.

Electrical equipment in hazardous areas

According to IEC 60079-14. The following equipment may be considered for the associated zones:

Zone 0

- certified intrinsically-safe apparatus of category "ia",
- simple electrical apparatus and components (for example thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically-safe circuits of category "ia", not capable of storing or generating electrical power energy in excess of the limits given in IEC 60079-14 and acceptable to the appropriate authority,
- or additional parts according to IEC 60079-14.

Zone 1

- any type that may be considered for zone 0,
- certified intrinsically-safe apparatus of category "ib",
- or additional parts according to IEC 60079-14.

Zone 2

- any type that may be considered for zone 1,
- tested specially for zone 2 (for example type "n" protection),
- or additional parts according to IEC 60079-14.

Control cabinets/terminal boxes on engine

The control cabinets of SaCoSone and the terminal boxes on engine are installed in a non-gas-hazardous area. The engine room is defined as a non-gas-hazardous area because of double-wall fuel gas piping and a permanent ventilation.

Moreover, in the unlikely case of leakage, the gas mixture ascends. This avoids the development of an explosive atmosphere in the control cabinets or terminal boxes.

For the protection degree (IP code), IP 54 is required at minimum.

Grounding/potential equalisation

In general, all electrical devices and the engine (via ground straps) are to connect to the potential equalisation.

In case of earthing of inherently safe circuit, there are differences between potentials possible. This fact should be taken into consideration.

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It is possible to isolate inherently safe circuits. The risk of electrostatic charge is to be considered. The connection with the ground via a resistor of maximum R = 0.2 – 1 megohm for dissipation of electrostatic charges applies not as a grounding measurement.

An inherently safe circuit can be connected to the potential equalisation system, if this is done at one location only and this circuit is galvanic isolated. This requirement is fulfilled if a galvanic isolator is used.

In case of a functional caused earthing of a sensor/actuator, the earthing can be done outside zone 0 only.

For the conductor of the potential equalisation, a cross section of 16 mm^2 is required at minimum.

Exemption: Diameter of engines grounding cables according to section "Earthing of diesel engines and bearing insulation on generators" in the marine Project Guides.

For any piping connections it has to be ensured that the electrical potential between the piping is equalised (e.g. by direct metal contact or connecting wire).

Insulation

Accumulation of dangerous gas concentration

Gas pipes are of double wall design and are not isolated.

Hot exhaust gas pipes and components containing exhaust gas are of single wall design and are isolated. Due to the lean burn concept and the rapid detection of misfiring with consequential change from gas fuel mode to diesel fuel mode, the risk of leakage from a noteworthy gas volume through untight flange connections into the insulation is not very probable. Therefore, no special consideration is paid for that reason to the design and evaluation of the insulation material.

Turbocharger

Explosion protection turbine side

The exhaust pipe on the engine to the turbocharger turbine inlet is protected by approved explosion pressure relief valves with flame arrestor and the opening pressure set point is approximately 5.0 barg overpressure. The certification is usually according to the ATEX EC directive 2014/34/EU. All pressure related parts are designed to withstand at least an overpressure of 8 bar. The used materials are to be ductile. Spheroidal casted iron is to be of the minimum quality "RT18" according to EN 1563.

Explosion protection compressor side

During engine operation the pressure at the compressor delivery side is higher than on the compressor suction side. Therefore no fuel gas could reach the suction side of the compressor wheel. In case of stopping the engine, the engine is switched over from the gas fuel mode to diesel fuel mode by shutdown of the fuel gas supply including venting and purging of the fuel gas supply piping. Therefore no fuel gas could pass through the compressor wheel outside the turbocharger.

Safety and control system SaCoSone

Components of SaCoSone

The safety and control system for the dual fuel (DF) engine serves for full monitoring and control of an engine (see figure System overview – Block diagram and figure Schematic drawing of SaCoSone system (optional VTA).

SaCoSone comprises

Two units directly mounted on the engine, one containing two independent modules for safety and engine control/alarm initiation, the other containing the injection module(s) (the number of injection modules is dependent on the engine's number of cylinders).

For large bore engines also:

- An interface cabinet, which provides power supply and connection to the ship's systems via the gateway module.
- An auxiliary cabinet containing drives for pumps and other auxiliary systems as well as additional sensors.
- The local operating panel directly mounted on the engine and the remote operating panel in the engine control room.

The two subsystems, safety system and engine control/alarm system, are independent from each other. However, exchange of information is effected via a common system bus. Each of the subsystems is connected with its appertaining signal processing modules, which are directly installed in the engine's terminal box, via separate field bus systems. The SaCoSone interface cabinet contains all interfaces to the other system components and to external systems, i.e.:

- Generator protection
- Load management
- Alarm system/remote control
- Pump control
- Gas alarm system

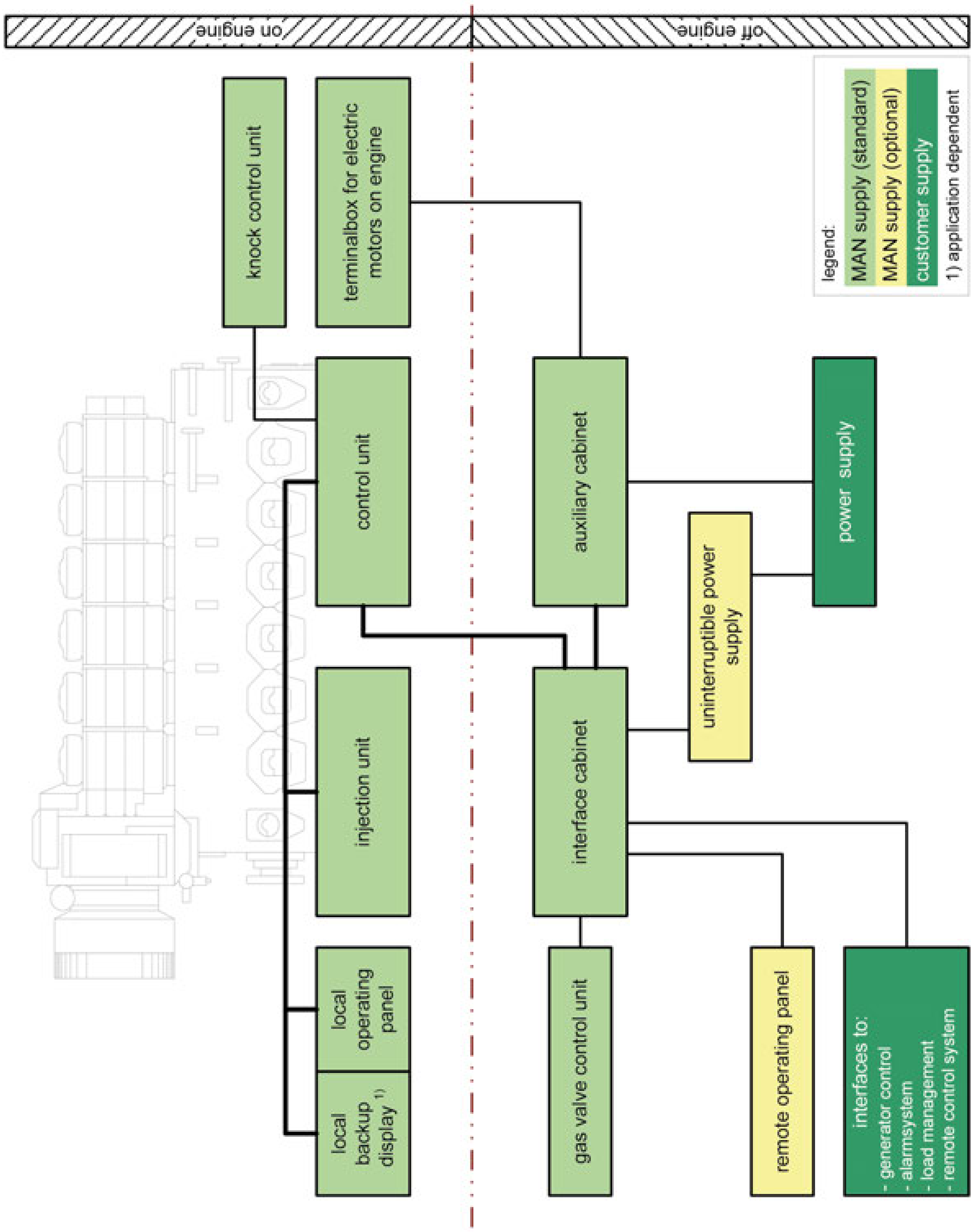

Figure 9: System overview – Block diagram

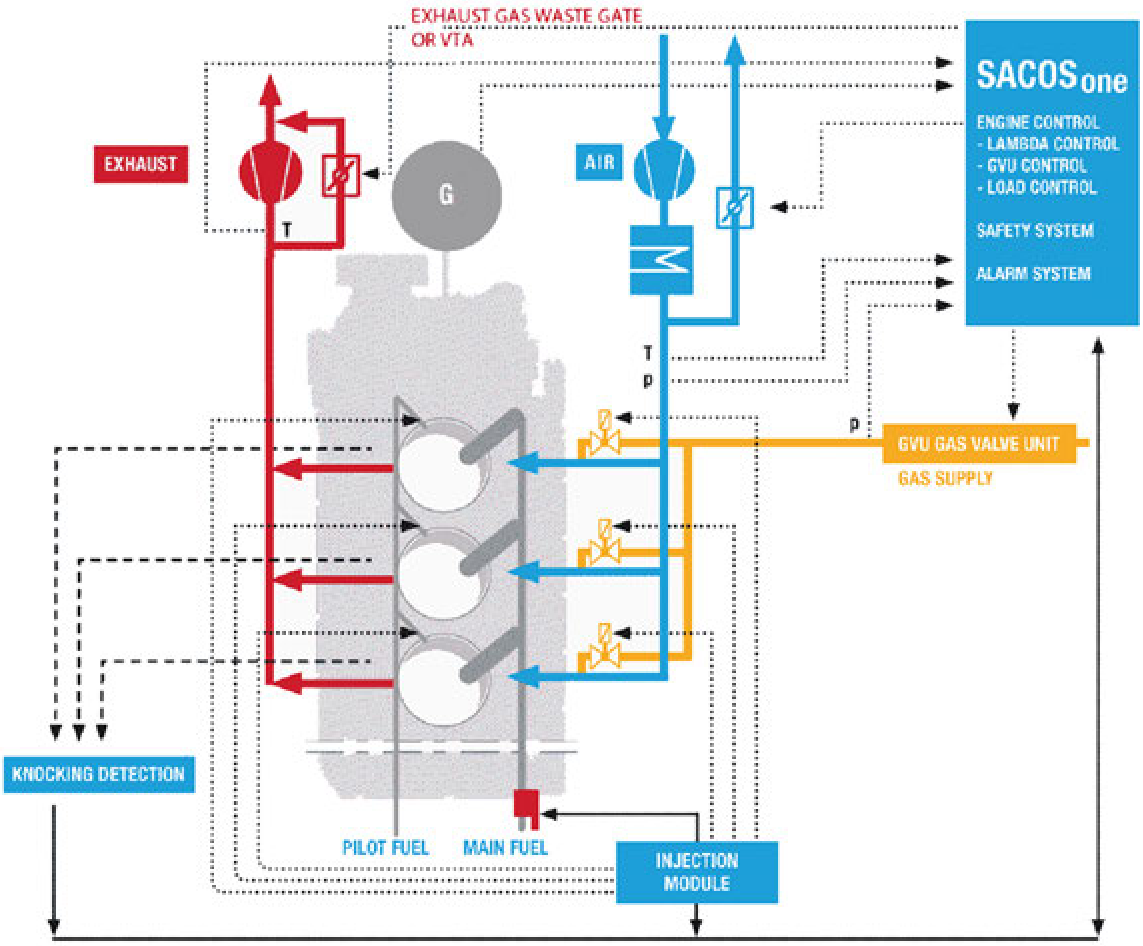

Figure 10: Schematic drawing of SaCoSone system (optional VTA)

Safety system

The safety system monitors all operating data of the engine and initiates the required actions, i.e. load reduction, change over or engine shutdown, in case the limit values are exceeded. The system is designed to ensure that the functions are achieved in accordance with the classification societies' requirements for marine propulsion engines. In addition to the provisions made to permit the internal initiation of demands, binary and analogue channels have been provided for the initiation of safety functions by external systems:

- Auto shutdown by the generator protection
- Auto shutdown by the load management
- Auto shutdown by the heat recovery boiler
- Auto shutdown by the mechanical driven propeller system
- Auto shutdown by engine protection
- Emergency stop by manual emergency shutdown device (emergency stop push button)
- Monitoring of generator bearings and lubrication
- Monitoring of the generator windings

Load reduction

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The safety system issues a load reduction request to the superior system. In special cases a switch over to diesel mode is initiated.

Auto shutdown

Auto shutdown is an engine shutdown initiated by any automatic supervision of either engine internal parameters or mentioned above external control systems.

Emergency stop

Emergency stop is an engine shutdown initiated manually by an operator.

Engine shutdown

If an engine shutdown is triggered by auto shutdown, emergency stop or engine shutdown the signal has an immediate effect on the emergency shutdown device, the speed control and the gas valve unit. At the same time the shutdown is triggered, SaCoSone issues a signal resulting in the generator switch to be opened.

Override

Only during operation in the diesel mode, safety actions can be suppressed by the override function for various parameters. In gas operating mode by selecting the override function, automatic changeover to liquid fuel mode is carried out. The override has to be selected before a safety action is actuated. The scope of parameters prepared for override are different and depend to the chosen classification society.

Engine control/alarm initiation

The subsystem engine control/alarm initiation works independently from the safety system. It monitors all operating parameters and signals alarms in case impermissible deviations occur.

Following functions are included:

Start/stop sequences

- Demands regarding lube oil and cooling water pumps
- Monitoring of the prelubrication and post-cooling period
- Monitoring of the acceleration period

Fuel change over

- Release of the gas operating mode
- Control of the switch over from one type of fuel to another
- Fuel injection flow is controlled by the speed governor

Control station switch over

Switch over from local operation in the engine room to remote control from the engine control room or external control from power management system.

Fast switch over to diesel mode at gas alarm

The external gas warning system monitors the engine room and, in the case of a gas alarm, issues an emergency switch over demand to diesel mode to SaCoSone. SaCoSone will execute a quick change over (QCO) to diesel mode.

Knock control

For the purpose of knock recognition, a special evaluation unit is fitted to the engine and connected with the engine control via the field bus.

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Lambda control

There are two possibilities for lambda control. The first is to control the exhaust gas temperature upstream of the turbine in combination with characteristic fields stored in the engine control. The second one is by controlling the charge air pressure and the coherent amount of air flow to the cylinders.

The air fuel ratio control is only active in the gas operating mode. There are two possibilities:

- Air fuel ratio control by continuously regulating waste gate (by-pass across the exhaust gas turbine).
- Air fuel ration control by variable turbine geometry (VTA).

Control of the gas valve unit

The gas pressure at the engine inlet is specified by the engine control and regulated by the gas valve unit. The pressure control device is activated by the engine control system. Prior to every switch over to the operating mode the block and bleed valves are checked for tightness (see also section Fuel system).

Jet assist

To improve the response of the engine in case of fast increasing load, starting air is supplied to the turbocharger via a valve.

Pump control

The demands regarding the electric pumps for lube oil and cooling water are issued by SaCoSone. SaCoSone also supplies the requested signals for stand-by start of the lube oil and HT cooling water pumps. The stand-by and pump logics are to be realised in an external pump control system.

Alarm initiation

All impermissible deviations from operating parameters as well as malfunctions cause alarm signals to be issued and transmitted to the alarm systems via an serial bus interface.

Temperature control

Temperature controllers for various operating media are integrated in SaCoSone. For more details refer to the temperature control of the respective subsystems.

Electronic speed control

The electronic speed governing system is part of the injection module(s) and includes the control and regulating devices for activating all of the engine's fuel control valves.

It comprises:

- Speed control
- Common rail control system for pilot fuel
- Gas admission valve control
- Conventional fuel system
  Driver unit for operation on diesel oil (main fuel system), in case of single engine plant: Additional electric/mechanical backup for speed governor
- Common rail fuel system
  Common rail control system for operation on diesel oil (main fuel system), in case of single engine plant: Redundant electronic speed governor

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The speed governing system effects the exchange of all data required for safe and reliable operation with the safety and control system. This data exchange takes place via bus and hardware connections.

Speed alteration

An influence on speed is exerted by SaCoSone. In the case of remote control, a set point input by the plant-specific control system is possible either by means of binary contacts (e.g. for synchronisation) or, alternatively, by an active 4 – 20 mA analogue signal via SaCoSone. In the case of local control, speed alteration is only possible at the local operating panel.

Operating modes

The following operating modes are available:

- Isochronous (optional)
- Droop (with a 5 % speed increase when reducing load from nominal load to no load, as a standard)

Load sharing

In the case of multi-engine plants, load sharing is effected by a droop function.

Autobalancing

For autobalancing a load control for each single cylinder is implemented in the modules "engine control" and "speed governing" of SaCoSone.

Interfaces

The speed governing system is supplied with electric power of the required voltage from the interface cabinet.

The connection of the speed control cabinet to the actuators on the engine is to be carried out by the yard. The restrictions with regard to the length of these connecting lines, mentioned in section "Installation requirements" in the marine Project Guides, are to be observed.

Operation

Local operation

Local operation takes place via an operating panel which is directly fitted to the engine.

An integrated display/touchscreen permits the visualisation of all operating data as well as status and fault indications available via SaCoSone.

The following operational functions are possible:

- Starting
- Stopping
- Adjustment of the desired speed value
- Local control/remote control switch over
- Reset for stops and alarms
- Engine emergency stop

Remote operation (if applicable)

An operating panel to be installed in the control console in the engine control room can be delivered for remote control as an option.

The panel is equipped with an interactive display/touchscreen for visualisation of all engine parameters, status and fault indications.

The following operational functions are possible:

- Starting
- Stopping
- Control station switch over (local/remote control) to load management
- Reset for stops and alarms
- Engine emergency stop

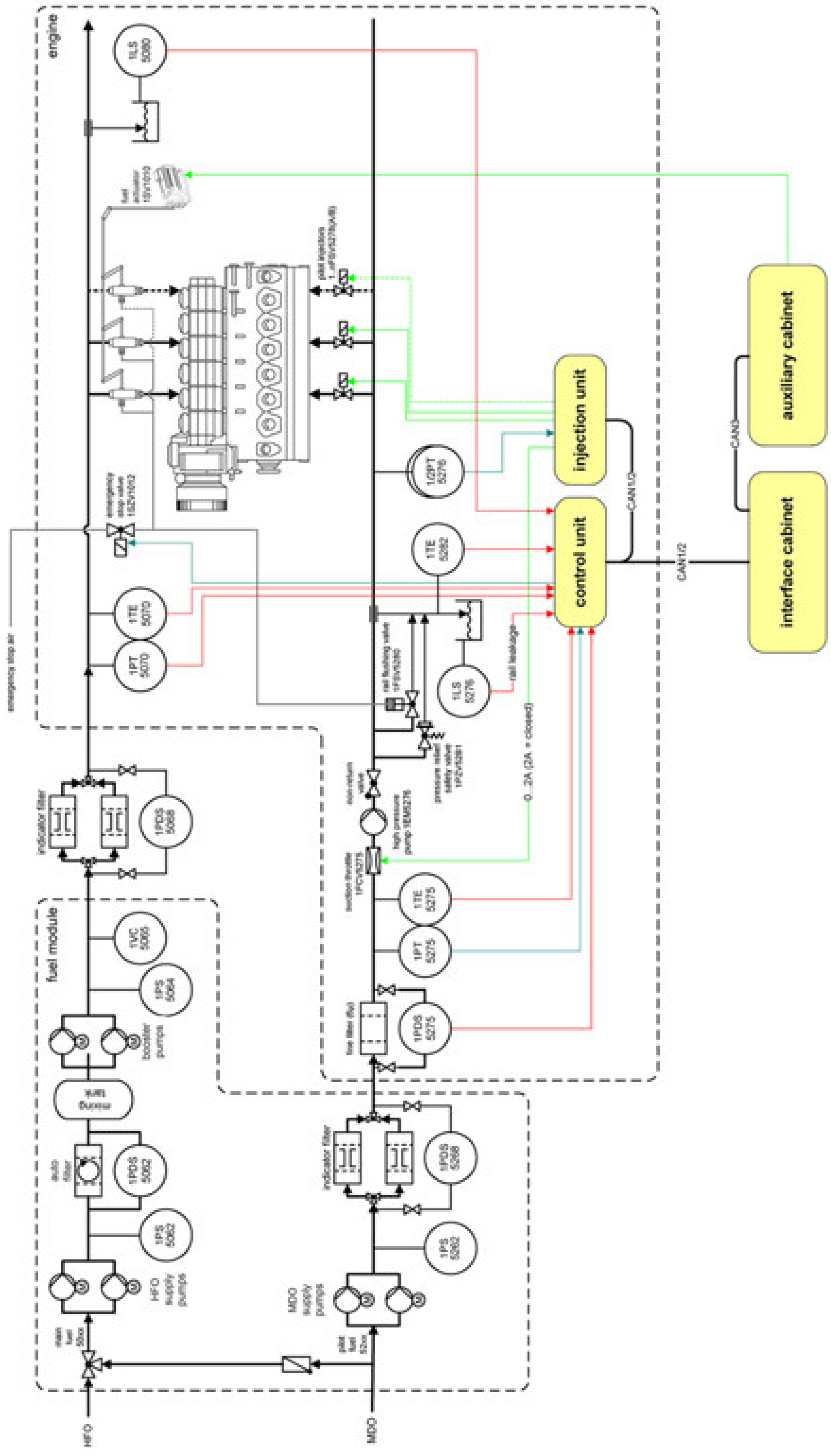

Figure 11: Diesel fuel system, measuring device diagram (MAN 51/60DF)

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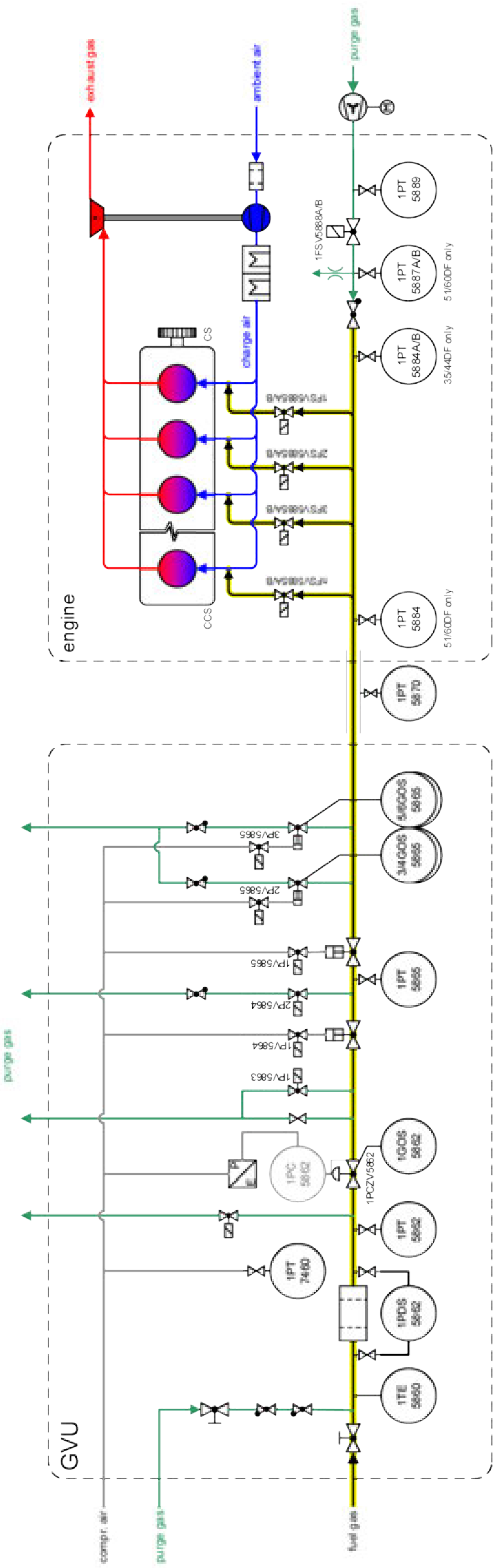

Figure 12: Gas fuel system, measuring device diagram (MAN 51/60DF)

Dual fuel engine operation modes

The control system performs three modes of operation. The gas mode, the diesel mode and the backup mode. The desired operating mode can be selected via the operating devices or the interfaces to the remote control. For detail information about ventilation and gas detection, see the sections Ventilation and Gas detection.

Gas mode

In gas mode the fuel mixture generation is done separately for each cylinder, by individual fuel gas admission valves directly in the cylinder head. The required amount of pilot fuel oil is made available by a common rail system and is directly injected by electromagnetic valves.

Diesel mode (liquid mode)

In diesel mode main fuel supply is realised by the main fuel injection system.

Flow control

Conventional fuel system:

Flow control takes place by means of an electric actuator, which is activated by the speed governor.

Common rail fuel system:

Flow control by the main common rail system.

The pilot fuel common rail system, which supplies the engine with the required amount of pilot fuel oil in gas mode, is also active in diesel mode.

Backup mode (only applicable with separate pilot fuel injection system)

Backup mode operation is active when the common rail pilot fuel oil system fails. During backup operation, only the main diesel oil system is active. The different operation modes and their availability are summarised in tables Fuel supply systems and operating modes active and Alarm settings and operating modes available.

	Backup mode	Diesel mode	Gas mode
Gas fuel system	not active	not active	active
Pilot fuel system	not active	active	active
Main diesel system	active	active	not active

Table 5: Fuel supply systems and operating modes active

Availability of operating modes			
	Backup mode	Diesel mode	Gas mode
Normal operation	not available	available	available
Gas pre alarm	not available	available	not available
Gas valve unit failure	not available	available	not available
Gas supply failure	not available	available	not available
Pilot oil system failure	available	not available	not available

Table 6: Alarm settings and operating modes available

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Fuel sharing (supply of gas, pilot fuel and main fuel symmetrically in all cylinders at the same time) is not an additional operation mode concerning gas safety aspects, it is considered as gas mode.

Engine control sequences[1]

- Engine start

  Engine can be started in diesel mode or in gas mode. Gas operation is possible between 0 % and 100 % load. The operator is free to select between the fuel gas mode and the liquid fuel oil mode.

- Engine stop

  If an engine stop is requested, the power management system has to reduce the engine load. Thereafter SaCoSone will stop the engine.

  Engine can be stopped in diesel mode. Engine stop in gas mode is possible if engine is gas start capable.

- Emergency shutdown

  Is an emergency shutdown triggered in liquid fuel oil mode, fuel injection will be stopped.

  Conventional fuel system: The main injection pumps will be pushed to zero filling, through a pneumatic emergency stop system.

  Common rail fuel system: The high-pressure fuel rail is depressurised by opening of a pneumatically driven valve.

  In case of an emergency shutdown in fuel gas mode, the double block and bleed valve of the GVU will be automatically closed. The gas injection through the main gas admission valves will be stopped. The pilot fuel system will be stopped depending on engine.

  Conventional fuel system: Immediate deactivation of the pilot fuel system.

  Common rail fuel system: Pilot fuel system is deactivated below 70 rpm or after a delay time of approximately 1 sec.

  The main fuel injection will be stopped as described above (emergency shutdown triggered in liquid fuel oil mode). The fuel gas pipe will be purged with inert gas in this case and the exhaust gas system will be ventilated by the exhaust gas purging fan.

- Switch over from liquid fuel oil mode to gas fuel mode

  The switch over from liquid fuel oil mode to fuel gas mode is carried out automatically. If the fuel gas mode is selected, a prior check of all important gas equipment is effected like, for example, the accomplishment of a leakage test of the GVU, as well as the review of all relevant alarms (see table Alarm list (example MAN 51/60DF)). If no failure or alarm is detected, the pre purge mode will be activated. In this purge mode the gas pipe will be filled with gas, so that gas is available on each main gas valve. After finishing the pre purge mode the switch over will be enabled. During the switch over procedure, the fuel admission to the main fuel oil injection is regulated reduced to zero. The injection module balances the decreasing main fuel oil amount, through a controlled increasing amount of fuel gas. During the switch over procedure the engine will be controlled and checked at any time by the SaCoSone system.

- Switch over from fuel gas mode to liquid fuel mode

  If no fuel gas operation is required, the operator can deselect this mode. Then the engine will be automatically transferred to the fuel oil mode by the SaCoSone system. If the engine operates on liquid fuel oil, the gas valves 1QSV-001 (1PV 5864) and 2QSV-001 (1PV 5865) will be immediately closed and the venting valve 5FV-002 (2PV 5865) and in parallel 3FV-002 (3PV 5865) will be opened. The after purge mode will be initiated, this will cause the flushing of the gas pipe. If a gas alarm occurs (see table Alarm list (example MAN 51/60DF)), a switch over to the liquid fuel oil mode is applied by the SaCoSone system.

- Quick change over (QCO)

  A quick change over from gas fuel mode to liquid fuel oil mode is only released, if relevant alarms (see table Alarm list (example MAN 51/60DF)) occur. In this case it will be changed to liquid fuel oil mode without a delay and the gas valves 1QSV-001 (1PV 5864) and 2QSV-001 (1PV 5865) will be closed. The shut-off sequence will be initiated and the gas pipe will be purged with inert gas.

[1] For min. gas load, detailed load application and operating ranges refer to Project Guide of the specific engine type.

Gas alarm list

Alarm levels for gas detection

PREAL

On this alarm level a visual and audible alarm is generated in the affected space and the control room. No automatic safety actions.

- According IGF = 20 % LEL (or 30 % inside duct)
- According IGC = 30 % LEL

AL

On this alarm level a visual and audible alarm is generated in the affected space and the control room. Automatic safety actions are executed according table Automatic safety actions.

- According IGF = 40 % LEL (or 60 % inside duct)
- According IGC = 60 % LEL

For a valid AL the detection always has to be on two independent detectors located close to each other or on one self-monitored type of gas detector.

Parameter		**Automatic safety actions**[1)]			**External signal from plant/ship required**
Gas detection	**Level**	**Activation of the block and bleed valves on the GVU**	**Activation of the master shut-off valve of dedicated engine room**	**Switch over to diesel mode (QCO)**	
Duct of gas fuel piping on the engine, duct of gas fuel piping between engine and GVU compartment	AL	X	X	X	X
Duct of gas fuel piping between master shut-off valve and GVU compartment	AL	X	X	X	X
Ventilation air duct GVU compartment, outside	AL	X	X	X	X
Ventilation air duct engine room, outside	AL	X	X	X	X
GVU compartment	AL	X	X	X	X
Engine room	AL	X	X	X	X

Parameter		Automatic safety actions[1]			External signal from plant/ship required
Gas detection	**Level**	**Activation of the block and bleed valves on the GVU**	**Activation of the master shut-off valve of dedicated engine room**	**Switch over to diesel mode (QCO)**	
General external gas alarm (e.g. in tank or cargo area)	AL	X	X	X	X
Ventilation					
Engine air flow	Low	X	X	X	X
GVU compartment differential pressure	Low	X	X	X	X
Engine room supply fan differential pressure	Low	X	X	X	X
GVU compartment extraction fan differential pressure	Low	X	X	X	X
Gas parameters at GVU inlet (A)					
Gas pressure	High/low	X	-	X	-
Gas temperature	High/low	X	-	X	-
Fire alarm					
GVU compartment	-	X	X	X	X
Engine room	-	X	X	X	X

[1] Automatic safety actions released by:

- SaCoSone: Activation of the block and bleed valves, switch over to diesel mode, engine shutdown, engine related alarm generation.
- External safety systems: Activation of the master shut-off valve, plant related alarm generation.
- The alarm to be generated and the automatic safety action itself have to be initiated by separate or redundant sensors.

Table 7: Automatic safety actions

For more information about gas detection, see section Gas detection.

Alarm list for SaCoSone control system (additional alarm list for DF engines)

	Alarm	ACO to diesel	QCO to diesel	Auto shutdown	Emergency stop	Start blocking	Gas blocking	Gas start blocking	Gas start failure	Load reduction request	Pilot off
ACO active	-	-	-	-	-	-	-	X	-	-	-
ACO from external	-	X	-	-	-	-	-	-	-	-	-
Auto shutdown from external	-	-	-	X	-	-	-	-	-	-	-
Change-over to gas mode failure active	-	-	-	-	-	-	X	-	-	-	-
Charge air pressure total loss of signals	-	-	X	-	-	-	X	X	X	-	-

	Alarm	ACO to diesel	QCO to diesel	Auto shut-down	Emer-gency stop	Start block-ing	Gas block-ing	Gas start block-ing	Gas start failure	Load re-duction request	Pilot off
Charge air temperature high	X	-	-	-	-	-	-	-	-	-	-
Charge air temperature low	X	-	-	-	-	-	-	-	-	-	-
Charge air temperature total loss of signals	-	-	-	-	-	-	X	X	X	-	-
Control air pressure GVU high	X	X	-	-	-	-	X	X	X	-	-
Control air pressure GVU low	X	-	X	-	-	-	X	X	X	-	-
Control air pressure GVU total loss of signals	-	X	-	-	-	-	X	X	X	-	-
Crankcase pressure high	X	-	X	-	-	-	X	-	-	-	-
Crankcase pressure low	X	X	-	-	-	-	X	-	-	-	-
Crankcase pressure total loss of signals	-	X	-	-	-	-	X	X	X	-	-
Crankcase ventilation module failure	-	X	-	-	-	-	X	-	X	-	-
Emergency stop active	-	-	-	-	-	X	-	-	-	-	-
Engine load high	X	-	-	-	-	-	X	-	-	-	-
Engine load low	X	-	-	-	-	-	X	-	-	-	-
Engine load total loss of signals	-	-	-	-	-	-	X	X	X	-	-
Engine speed undershoot	-	-	X	-	-	-	-	-	-	-	-
Exhaust gas temperature after cylinder high	X	-	X	-	-	-	-	-	-	X	-
Exhaust gas temperature after cylinder low	X	-	X	-	-	-	-	-	-	-	-
Exhaust gas temperat-ure after cylinder total loss of signals	-	-	X	-	-	-	X	X	X	-	-
Exhaust gas temperat-ure mean value deviation	X	X	-	-	-	-	-	-	-	-	-

	Alarm	ACO to diesel	QCO to diesel	Auto shut-down	Emer-gency stop	Start block-ing	Gas block-ing	Gas start block-ing	Gas start failure	Load re-duction request	Pilot off
Exhaust gas temperature turbocharger inlet high	X	X	-	-	-	-	X	-	-	-	-
Exhaust gas temperature turbocharger inlet total loss of signals	-	-	X	-	-	-	X	X	X	-	-
External start interlocked	-	-	-	-	-	X	-	-	-	-	-
External-internal load deviation	-	-	X	-	-	-	X	-	-	-	-
External alarm from gas warning unit	-	-	X	-	-	-	X	X	X	-	-
External alarm from ventilation control	-	-	X	-	-	-	X	X	X	-	-
Fuel oil injection active during gas start	-	-	-	-	-	-	-	-	X	-	-
Fuel oil pressure engine inlet low	X	-	X	-	-	-	X	-	-	-	-
Fuel sharing distance between curves high	X	X	-	-	-	-	-	-	-	-	-
Fuel sharing operating point close to limit	X	-	-	-	-	-	-	-	-	-	-
Fuel sharing outer curve no steady increase	X	X	-	-	-	-	-	-	-	-	-
Fuel sharing relative engine power limit exceeded	-	-	-	-	-	-	-	-	-	-	-
Fuel sharing relative engine power low	-	X	-	-	-	-	-	-	-	-	-
Fuel sharing setpoint out of range	X	-	-	-	-	-	-	-	-	-	-
Gas differential pressure GVU filter high	X	-	-	-	-	-	-	-	-	-	-
Gas energy split fraction setpoint deviation high	-	X	-	-	-	-	-	-	-	-	-
Gas energy split fraction setpoint not available	-	X	-	-	-	-	-	-	-	-	-
Gas line purge gas supply pressure low	X	-	-	-	-	-	-	-	-	-	-

	Alarm	ACO to diesel	QCO to diesel	Auto shut-down	Emer-gency stop	Start block-ing	Gas block-ing	Gas start block-ing	Gas start failure	Load re-duction request	Pilot off
Gas line purge system failure	-	-	-	-	-	-	-	X	-	-	-
Gas line purging failure	X	X	-	-	-	-	X	-	-	-	-
Gas line venting valve 2PV5865 failure	-	-	-	-	-	-	X	X	X	-	-
Gas line venting valve 3PV5865 failure	-	-	-	-	-	-	X	X	X	-	-
Gas pressure setpoint offset GVU inlet low	X	-	X	-	-	-	-	X	X	-	-
Gas temperature GVU inlet high	X	X	-	-	-	-	-	X	X	-	-
Gas temperature GVU inlet low	X	X	-	-	-	-	-	X	X	-	-
Gas temperature GVU inlet total loss of signals	-	X	-	-	-	-	X	X	X	-	-
GVU CAN3 communication failure	-	-	X	-	-	-	X	X	X	-	-
GVU power supply control failure	-	-	-	-	-	-	X	X	X	-	-
Heavy knocking	-	-	X	-	-	-	-	-	-	-	-
IM/Gas-A CAN1/2 communication failure	-	-	X	-	-	-	-	-	-	-	-
IM/Gas-A major alarm	-	-	X	X	-	X	X	X	X	-	-
Knock control CAN3 communication failure	-	-	X	-	-	-	X	-	X	-	-
Knock control device failure	-	-	X	-	-	-	X	X	X	-	-
Knock control sensor failure	-	-	X	-	-	-	-	-	-	-	-
Knocking value high	X	-	X	-	-	-	-	-	-	-	-
Lambda control disturbed	-	X	-	-	-	-	-	-	-	-	-
Lambda control setpoint deviation	X	-	X	-	-	-	-	-	-	-	-
Lube oil level service tank low	X	X	-	-	-	-	X	X	X	-	-
Lube oil level service tank total loss of signals	-	X	-	-	-	-	X	X	X	-	-

	Alarm	ACO to diesel	QCO to diesel	Auto shut-down	Emer-gency stop	Start block-ing	Gas block-ing	Gas start block-ing	Gas start failure	Load re-duction request	Pilot off
Lube oil pressure engine inlet low	-	-	X	-	-	-	-	-	X	-	X
Main bearing temperature high	X	X	-	X	-	-	X	-	-	-	-
Main bearing temperature total loss of signals	-	X	-	-	-	-	X	X	X	-	-
Main gas differential pressure to charge air low	X	-	X	-	-	-	-	-	-	-	-
Main gas injection duration high	X	-	X	-	-	-	-	-	-	-	-
Main gas injection valve error	-	-	X	-	-	-	-	-	X	-	-
Main gas line safety shut-off valve closed	-	-	X	-	-	-	X	X	X	-	-
Main gas lock valves monitoring	-	-	-	X	-	-	X	-	-	-	-
Main gas pressure engine inlet total loss of signals	-	-	-	-	-	-	X	X	X	-	-
Main gas pressure GVU inlet high	X	-	-	-	-	-	-	-	-	-	-
Main gas pressure GVU inlet low	-	-	-	-	-	-	X	-	-	-	-
Main gas pressure GVU total loss of signals	-	-	X	-	-	-	X	X	X	-	-
Main gas pressure GVU outlet total loss of signals	-	-	-	-	-	-	X	X	X	-	-
Main gas to charge air differential pressure high	X	-	X	-	-	-	-	-	-	-	-
Main gas to charge air differential pressure low	X	-	X	-	-	-	-	-	-	-	-
Manual emergency stop from external	-	-	-	-	X	-	-	-	-	-	-
Manual QCO	-	-	X	-	-	-	-	-	-	-	-
Oil-mist concentration crankcase high	-	X	-	-	-	-	X	X	X	-	-

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	Alarm	ACO to diesel	QCO to diesel	Auto shut-down	Emer-gency stop	Start block-ing	Gas block-ing	Gas start block-ing	Gas start failure	Load re-duction request	Pilot off
Oil-mist detector fail-ure	-	X	-	-	-	-	X	X	X	-	-
Opened rupture disk	X	-	-	X	-	X	-	-	-	-	-
Override active	-	-	X	-	-	-	X	X	-	-	-
Pilot fuel oil differential pressure fine filter high	X	-	-	-	-	-	-	-	-	-	-
Pilot fuel oil high-pressure pump off	-	-	X	-	-	-	X	X	X	-	-
Pilot fuel oil injection valve error	-	-	X	-	-	-	-	-	X	-	-
Pilot fuel oil leakage high-pressure pump high	X	-	-	-	-	-	-	-	-	-	-
Pilot fuel oil rail pressure high	X	X	-	-	-	-	X	X	X	-	-
Pilot fuel oil rail pressure low	X	-	X	-	-	-	X	-	X	-	X
Pilot fuel oil rail pressure total loss of signals	-	-	X	-	-	-	X	X	X	-	-
Pilot fuel oil supply and rail pressure total loss of signals	-	-	-	-	-	-	-	-	-	-	X
Pilot fuel oil supply pressure low	X	-	X	-	-	-	-	X	X	-	X
Pilot fuel oil supply pressure total loss of signals	-	-	-	-	-	-	-	X	-	-	-
Pilot fuel oil temperature high	X	-	-	-	-	-	-	-	-	-	-
QCO active	-	-	-	-	-	-	X	-	-	-	-
QCO from external	-	-	X	-	-	-	-	-	-	-	-
QCO/ACO from external active	-	-	-	-	-	-	X	X	X	-	-
Splash-oil temperature high	X	X	-	-	-	-	X	-	-	-	-
Splash-oil temperature total loss of signals	-	X	-	-	-	-	X	X	X	-	-
VVT position collective error	-	-	X	-	-	-	X	X	X	-	-

Table 8: Alarm list (example MAN 51/60DF)

Air pressure systems

Starting air system

engines can be either started in diesel or in gas mode (for MAN 23/30DF and MAN 28/32DF only diesel start available). As commonly for engines the starting air system overpressure in the air receivers is at max. 30 bar and max. 50 °C temperature.

Cylinder starter: The engine is started by cylinder starter. Air is released by camshaft for each individual cylinder and blown in on the upper dead point of the piston. If pressure inside the cylinder is higher than the air supply pressure to the cylinder the individual starting air valve cannot open. Following an ingress of non-burned air-/gas mixture into the starting air system will be avoided. Furthermore, every cylinder is equipped with a flame arrester to avoid any flame to strike back into the starting air pipe.

Flywheel starter: The engine is started by use of pneumatically driven starting motor(s) acting by a gear on the flywheel. Air pressure is reduced from 30 bar to approximately 8 – 10 bar before reaching the pneumatically driven starting motor. There is no connection between the cylinders and the starting air system (no cylinder starter), it is not possible that fuel gas from the engine can enter into the starting air system.

Control air

There is no connection on the engine through which any fuel gas could ingress into the control air system.

Inert gas system

It is to be build according to the yards specification and IGF Code and IGC Code. Inert gas consumption according to purged volumes. Inert gas is used for automatic gas pipe purging and for manual inertisation of the crankcase if required (e.g. after emergency stop from gas mode). Inert gas to the engine for automatic purging of the gas pipe in between GVU and engine is closed with an automatic valve and secured by a non-return valve against fuel gas return in the inert gas system. The tightness of the non-return valve is monitored. Anyway it is recommended to install double block and bleed valves to the inert gas supply line (mandatory if IGF Code applied). The double block and bleed valves shall be located outside of non-hazardous areas (e.g. GVU room, bunkering station, tank connection space, etc.). If inert gas is not available the engine cannot be operated in gas mode. Inert gas for manual purging (in case of maintenance, e.g. crankcase, lube oil service tank, etc.) is not connected permanently to the inert gas system of the ship. In case of manual purging a flexible hose or a short pipe has to be installed temporarily. If the inert gas producer is not installed inside the engine room it has to be ensured that the seperate compartment is well ventilated and oxygen monitored according the requirements from IGC and IGF Code.

If the inert gas supply line to the GVU is non-permanent, the two installed non return valves substitute the double block and bleed requirement for this line (see IGF Code 6.13.3).

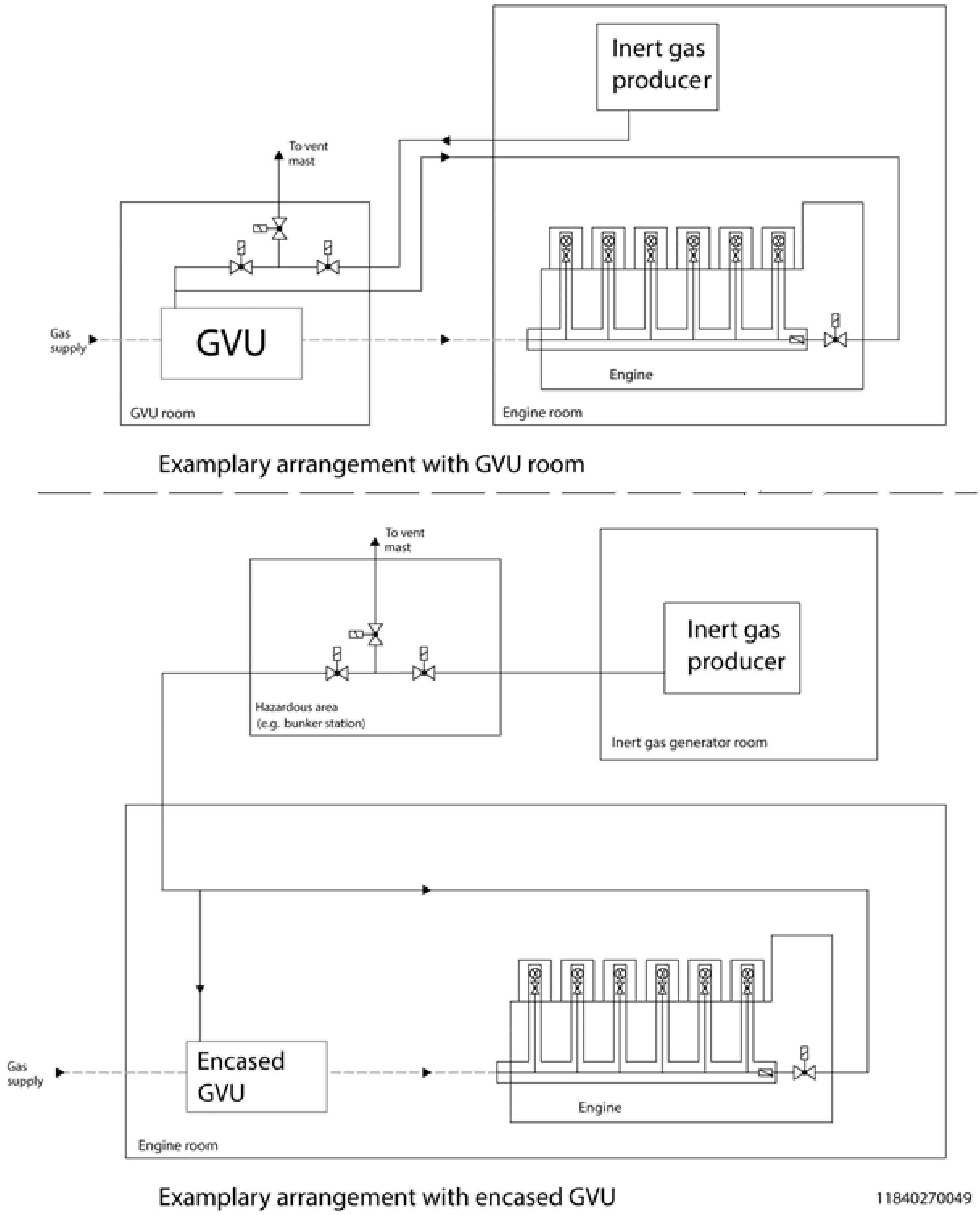

Figure 13: Examples for inert gas supply installations

Plant

General

To keep the complexity and costs on a reasonable level, the components of the plant are installed in special, functionality related, machinery spaces.

Due to the double wall concept of the fuel gas pipes, dual fuel engines can be installed in engine rooms, with substantially similar requirements as engine rooms for normal diesel engines. Nevertheless, for the engine room same special provisions are to be observed and recommended.

The complete arrangement drawings and design proposal for a new building with dual fuel engines have to be in accordance with applicable marine rules (IGF Code, IGC Code, IACS unified requirements etc.) and approved by the marine classification society.

For the proposal, see section Appendix.

Gas valve unit room

The GVU room is a separate compartment with gastight walls. It is a gas hazardous area, related to explosion hazardous area, zone 1.

Usually in the GVU room are installed:

- Gas valve unit
- Gas and fire detection systems
- Fire fighting system
- Room ventilation system
- Lighting

For redundancy reasons it is recommended to distribute the gas valve units in separate GVU rooms. In this way not all main engines are involved, if a gas or fire alarm happens in one of the gas valve unit rooms.

For single engine plants only one GVU room is necessary. The ambient air pressure in the GVU room is in depression related to the engine room and related to the exterior. In this way the space between the double walls of the fuel gas pipes leading to the GVU room and leading from the GVU room to the engine, are ventilated in direction to the GVU room. The depression in the GVU room is monitored and verified by differential pressure switches. In case of abnormal differential pressures, the shut-off valve (upstream of the GVU room) is closed and the engines are switched over to liquid fuel mode. In accordance with IEC 60079-10 and considering that the outside of the GVU room is a non-hazardous area, the GVU room is to be equipped with a double door system forming an air-lock. Alternatively a single door system can be considered if the ventilation of the GVU room is capable to ensure the min. required underpressure in the GVU room (only to be applied if accepted by classification society and administration, not permissible for IGF code relevant installations). The doors must be self closing giving an alarm when the doors remain open for longer than 60 seconds. If the ship layout of the yard leads to another area classification of the outside of the GVU room, other door arrangements might be possible according to IEC 60079-10. In case persons are in the gas valve unit room, the automatic fire fighting system has to be disabled (only in case that personnel could be endangered). In that case other fire protection measurements have to be organised.

All installed electrical equipment has to be of certified safe type for zone 1.

In case of a gas PREAL (see table Automatic safety actions) in the GVU room or inside double wall piping, only an alarm is generated.

In case of a main gas alarm (AL) in the GVU room or inside double wall piping, the shut-off valve is closed automatically and the engine is switched over to liquid fuel mode. The ventilating system will remain in operation to remove the fuel gas from the GVU room. This alarm has to be visual and audible indicated also locally at the entrance of the GVU room.

In case of fire alarm in the GVU room the shut-off valve is closed automatically, the engine is shifted to liquid mode, the ventilation of the GVU room is stopped, louvers in the ventilating system are closed to avoid air or oxygen admission from the exterior and fire extinguishing agent is injected in the gas valve unit room.

The requirements on gas detection, ventilation and electrical equipment are mentioned in the following sections Ventilation, Gas detection and Safety of electrical equipment.

Gas valve unit with encasement

As an alternative for an installation in a GVU room the GVU can be equipped with a dedicated enclosure/housing. In this way the GVU can be installed directly in the machinery space. The safety and operation principal is analog to the GVU room installation see section Gas valve unit room.

The enclosure represents the double wall barrier against non-hazardous spaces and is designed as a gas tight pressure vessel with a design pressure of 10 barg. Inside the enclosure the piping is single walled. The gas pipe connections to the enclosure unit are per double wall pipes. Inside the enclosure an explosion hazardous zone 1 is specified. Thus all electrical equipment inside the enclosure has to be certified for use in zone 1.

The housing has to be ventilated 30 air changes per hour. Ventilation inlet and outlet connections have to be foreseen at the housing. The inlet air has to be taken from a safe area outside of the ship. The outlet of the ventilation has also to be guided to the outside of the ship. Around the ventilation openings an explosion hazardous zone 1 or 2 (in different radiuses) has to be specified. At the ventilation outlet an inherently safe gas detector has to be installed. Additionally gas detectors can be installed inside enclosure and at the ventilation inlet.

Operation in gas mode is only permitted when the housing is closed and tight as well as the ventilation system is active. A certain negative pressure must be existent inside the enclosure (measured by a dedicated pressure transmitter). It depends on length of inlet and outlet jacket volume from double walled gas pipes as well as on the volume of the enclosure itself.

It has to be ensured that maintenance work on the GVU is possible. Therefore the housing must have an appropriate design (e.g. half shells with lifting points or hydraulic cylinders). Opening of the enclosure is only permissible when gas supply system is shut down and gas valve unit is free of natural gas (purged by nitrogen).

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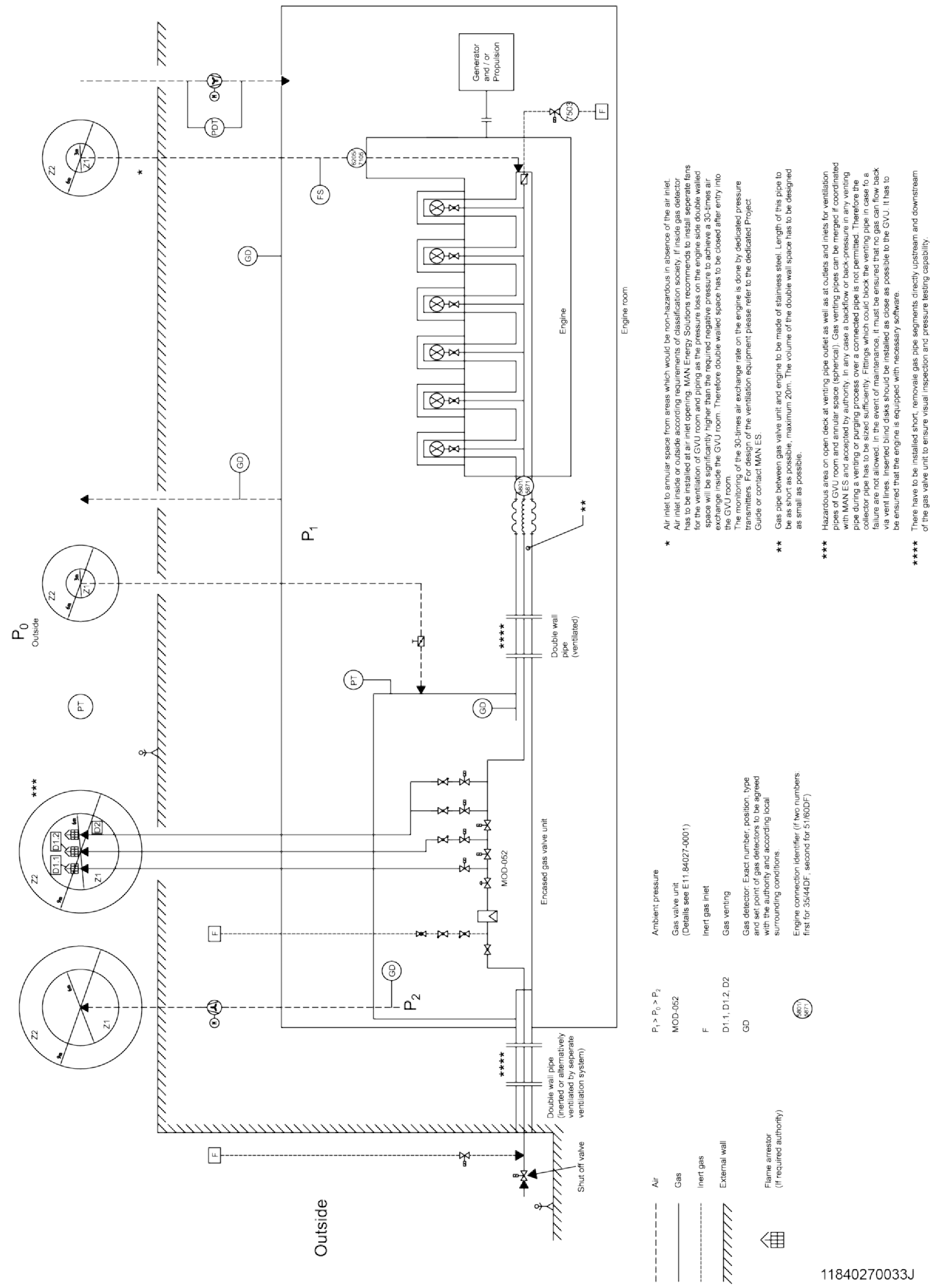

Figure 14: Gas valve unit with encasement

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Safety concept - Dual fuel engines

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Description

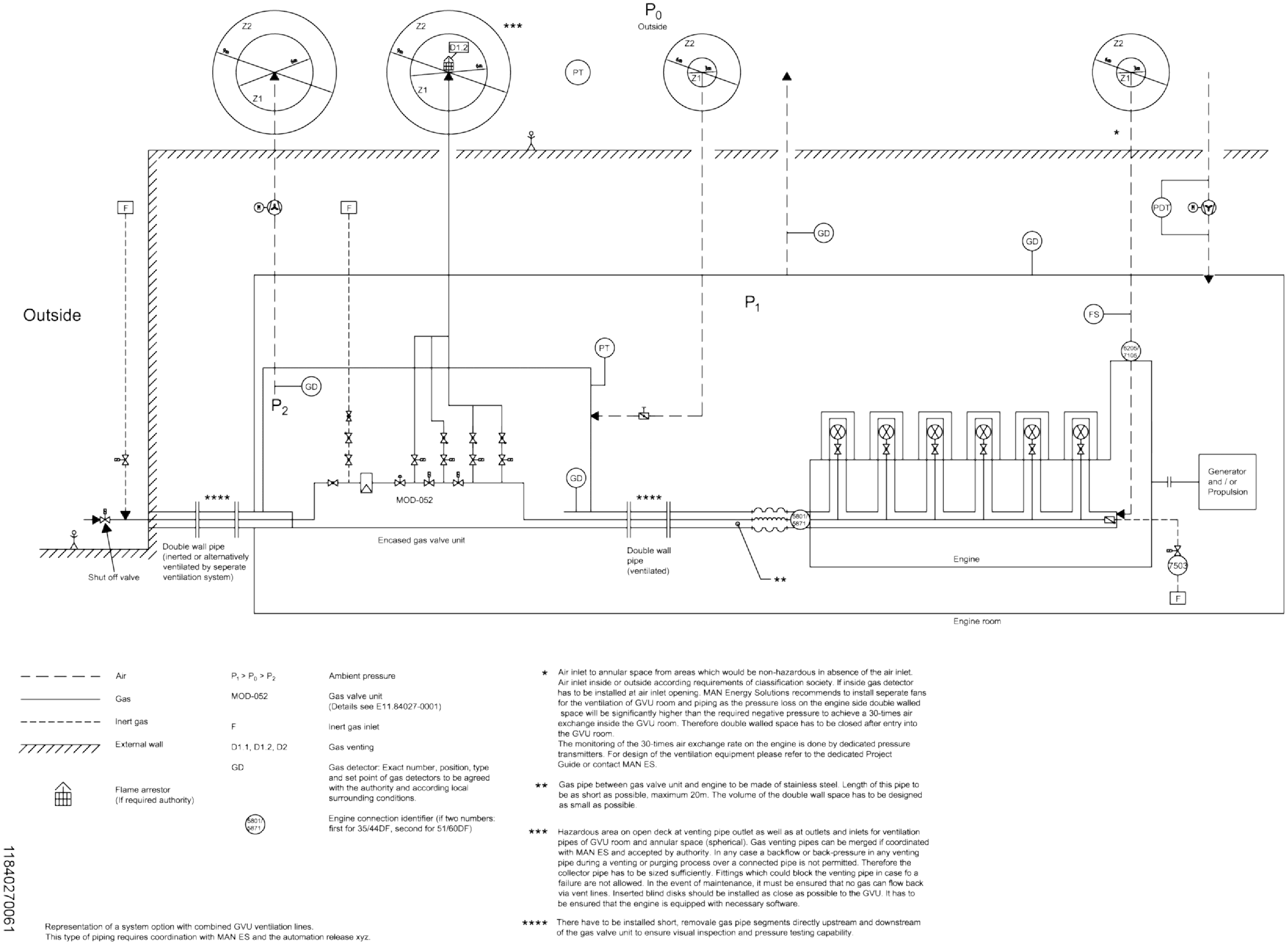

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Figure 15: Gas valve unit with encasement - optional arrangement with merged vent lines

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Engine room

The engine room is considered as a gas safe area due to the complete double wall fuel gas piping system on the engine and in the engine room. Additionally each engine room must be equipped with at least two intrinsically safe certified gas sensors of continuous monitoring type. One intrinsically safe certified gas sensor in the ventilation outlet and one intrinsically safe certified gas sensor above each DF engine. The detection equipment shall be located where gas may accumulate. The number of detectors could depend on size, layout and ventilation of the engine room, and has to be agreed by the classification society.

Usually in the engine room are installed:

- Dual fuel engines
- Alternators
- Gear box
- Propeller system
- Gas and fire detection systems
- Fire fighting system
- Inlets and outlets of the engine room ventilation system
- Lighting
- Lube oil pumps, lube oil service tank and lube oil system
- Liquid fuel pumps and liquid fuel system
- Cooling water pumps and parts of the cooling water system
- Different components of auxiliary engine systems

For redundancy reasons it is recommended to distribute the main engines in at least two separate engine rooms (not for single engine plants).

In case of gas PREAL (see table Automatic safety actions) at a gas detector in the engine room an audible and visible alarm is given.

In case of a main gas alarm AL (see table Automatic safety actions) at a gas detector in the engine room, the shut-off valve of the affected engine room is closed automatically and all engines installed in the affected engine room are switching over to diesel mode (QCO). The engine room ventilation system will remain in operation to remove the fuel gas from the engine room.

The setting of the alarms ensures that the engine room is protected against a major inrush of gas as the gas supply lines would be shut off and purged with inert gas in the case that the level of AL (see table Automatic safety actions) is reached and detected by at least two gas detectors or one self monitored gas detector (exact number and type of gas detectors to be agreed with the authority and according to room geometry). A sudden, strong gas release which would lead to fast increasing gas concentrations would be detected by the engine monitoring system, by the gas pressure monitoring and by the gas detectors within the double piping system. However it is possible that gas could be sucked into the engine room from external sources (e.g. offshore applications). Therefore a gas alarm for the engine room should be established to have the information and start the necessary countermeasures. For safety reasons no automatic shutdown of the engine is planned as this last decision is to be made by the crew appropriate to the ships situation.

In case of fire alarm in the engine room the shut-off valve of the affected engine room is closed automatically and all engines installed in the affected engine room are switching over to diesel mode (QCO). For further information, see section Fire detection and fire fighting system.

The fuel gas content in the combustion air has to be monitored by a gas detection system. In case of combustion air taken from the engine room this will be done by the gas detection system of the engine room. In case that the combustion air is taken directly from the exterior gas detectors have to be installed within the air admission system.

The requirements on gas detection, ventilation and electrical equipment are mentioned in the following sections Ventilation, Gas detection and Safety of electrical equipment.

Ventilation

Rooms and spaces to be ventilated for gas leakage fighting reasons:

- GVU compartment
- Space between the double wall gas pipes

Technical requirements of the ventilation:

The complete design of the ventilation system for a gas engine driven new building has to be in accordance with applicable marine rules (IGF Code and IGC Code etc.) and approved by the marine classification society. The design of the ventilation is in general a mechanical forced ventilation system. The complete ventilation system has to be optimised in the engine room and GVU compartment, that no "dead" edges or spaces with no or less efficient ventilation will occur. The efficiency of the ventilation system has to be shown with simulation methods or practical testing on the vessel.

The ventilation air is taken from free atmosphere and gas safe area via ducting. Ventilation inlet and outlet duct have to be equipped with automatically closing fire louvres and are mechanically protected by screens with not more than 13 mm square mesh. Ventilation capacity for hazardous areas is min. 30 air changes per hour. Monitoring of the suction with alarm below 30 air changes per hour. Indication and alarming of loss of ventilation capacity have to be carried out by ship automation system in engine control room.

The ventilation system has to be independent from other ventilation systems. Independent systems have to be installed for each engine room. Each GVU will be forced exhaust ventilated.

The ventilation is in operation even under shutdown conditions to avoid accumulation of dangerous gases like fuel or inert gas due to possible leakages. Before opening or entering the GVU compartment, measurements have to be executed to exclude the occurrence of fuel gas and ensure sufficient oxygen is present.

Ventilation fans have to be approved for ventilating explosive atmosphere.

The ventilation air for the GVU compartment taken from the engine is equipped with gas detection with alarm points set at PREAL (see table Automatic safety actions).

The ventilation air outlet has to be kept away from ignition sources. Electric fan motors are not permissible to be installed in ventilation ducts or piping. The ventilation air outlets have to be discharged upwards in locations at least

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10 m in the horizontal direction from ventilation intakes and openings for gas safe spaces. Inlet and outlet equipped with closing arrangement (louvres) in case of fire in engine or GVU compartment.

Gas detection

The project related requirements have to be in accordance with applicable marine rules (IGF Code and IGC Code etc.) and approved by the marine classification society.

Each engine room must be equipped with at least two intrinsically safe certified gas sensors of continuous monitoring type. One intrinsically safe certified gas sensor in ventilation outlet and one intrinsically safe certified gas sensor above each DF engine, where gas may accumulate.

The GVU room ventilation outlet must be monitored at least by additional one intrinsically safe certified gas sensor. Gas sensors are to be connected to a common alarm system with audible and visible alarms. Furthermore they have to be of intrinsically-safe and certified type and have to be type approved by IACS classification societies.

Instead of intrinsic safety a different type of ignition protection can be applied to the gas detectors. The applied protection type has to be appropriate for the hazardous area in which the gas sensors are installed.

Two independent, continuous working self monitoring, fixed gas monitoring systems have to be in operation when gas fuel is in piping or during purging. A malfunction shall not lead to false emergency shutdown of the engine. Functional redundancy shall be given when either one of the systems fails.

For alarm levels, see table Automatic safety actions.

Safety of electrical equipment

Kindly note the requirements of section Electrical systems for electrical equipment.

Furthermore consider that electrical equipment shall be of intrinsically-safe type and equipment inside GVU compartment like fire and gas detectors, fire and gas alarm equipment, lightning, ventilation fans and other installed equipment is certified safe for zone 1.

Fire detection and fire fighting system

The complete design of the fire detection and fire fighting system for a gas engine driven new building has to be in accordance with applicable marine rules (IGF Code and IGC Code etc.) and approved by the marine classification society.

The fire detection and fire fighting system is to be approved by the IACS Classification Societies according SOLAS Ch II-2 and IGF Code and IGC Code and the relevant classification rules.

Appendix

Fuel system, small bore

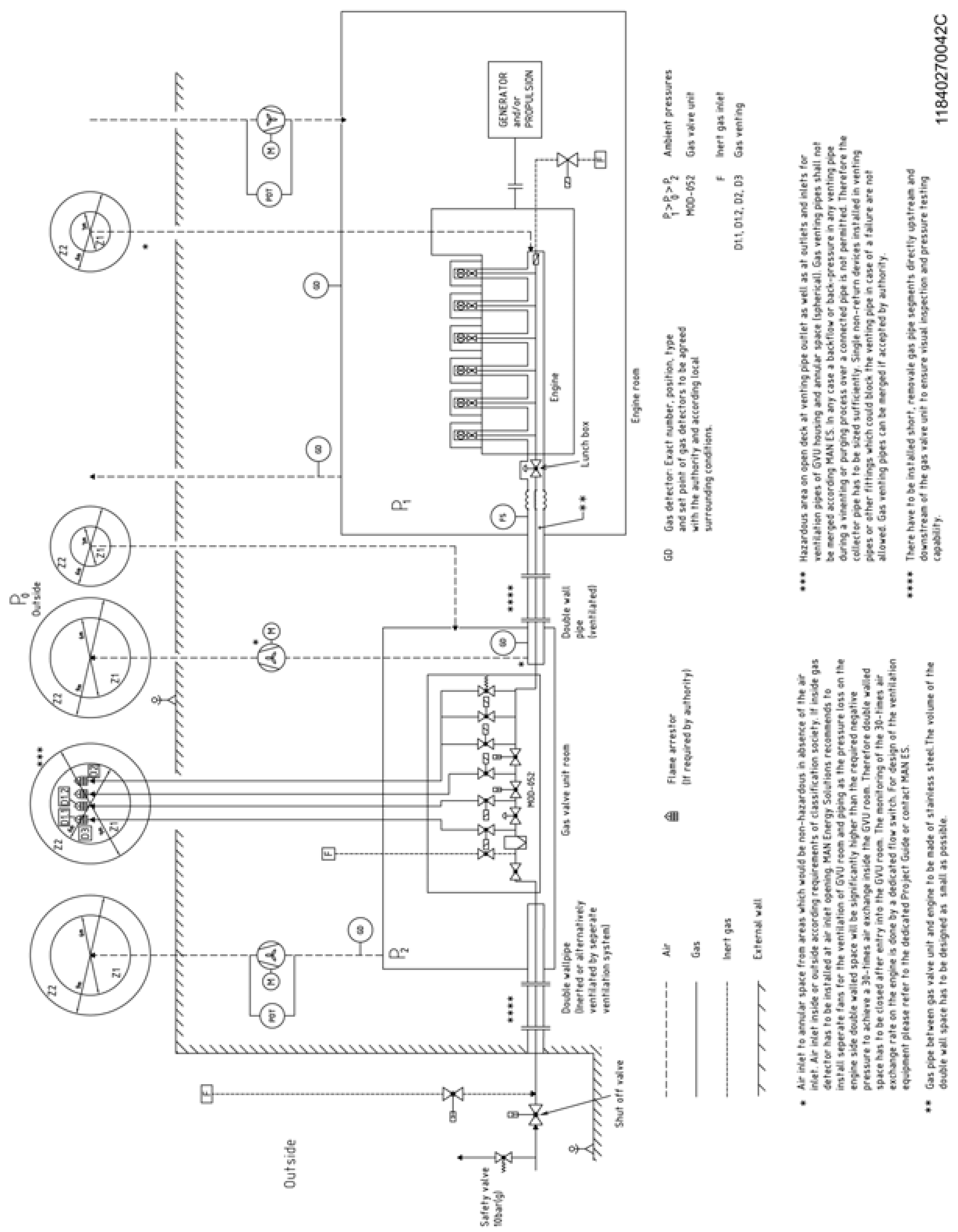

Figure 16: Gas feeding system, small bore

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Lube oil service tank arrangement

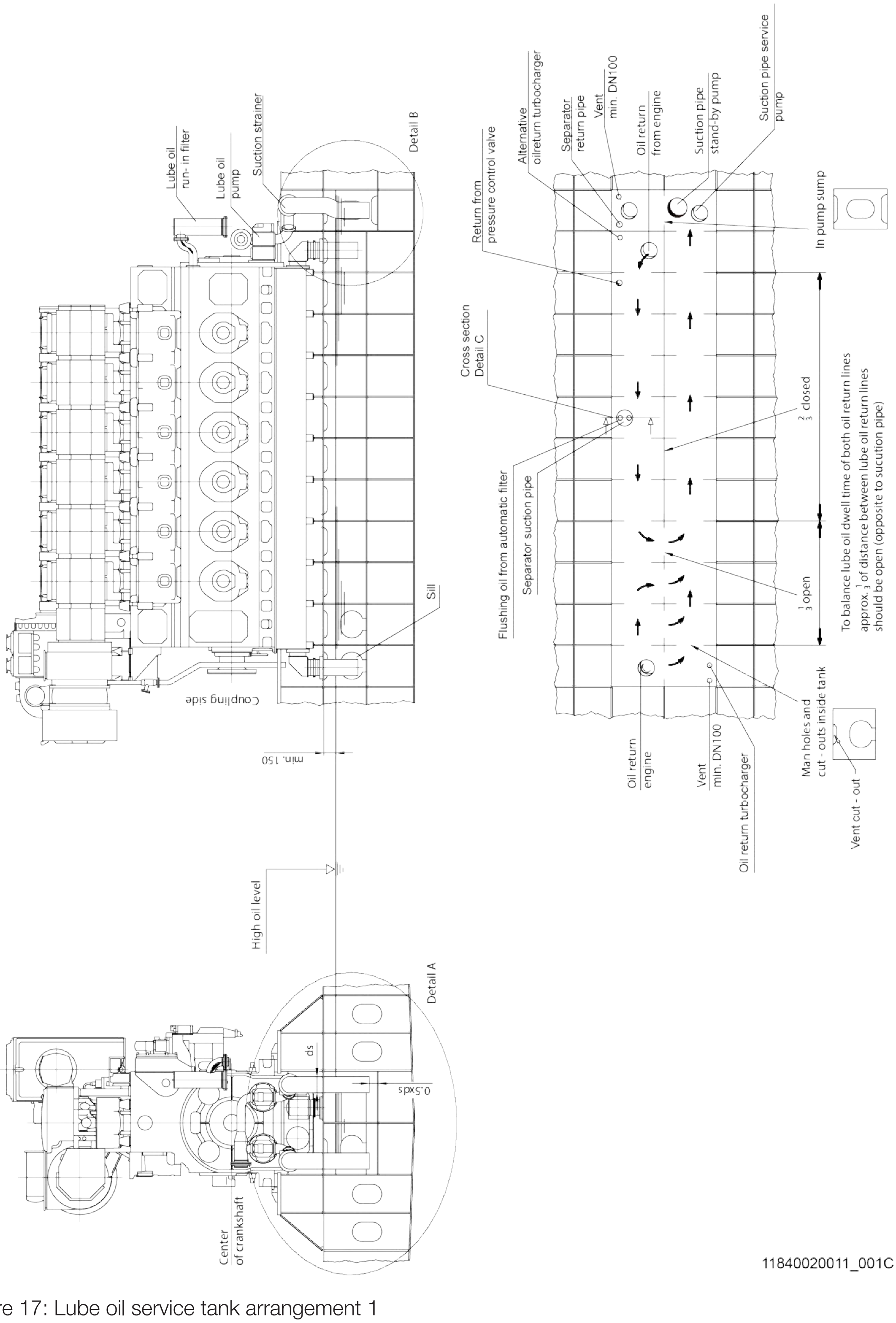

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Figure 17: Lube oil service tank arrangement 1

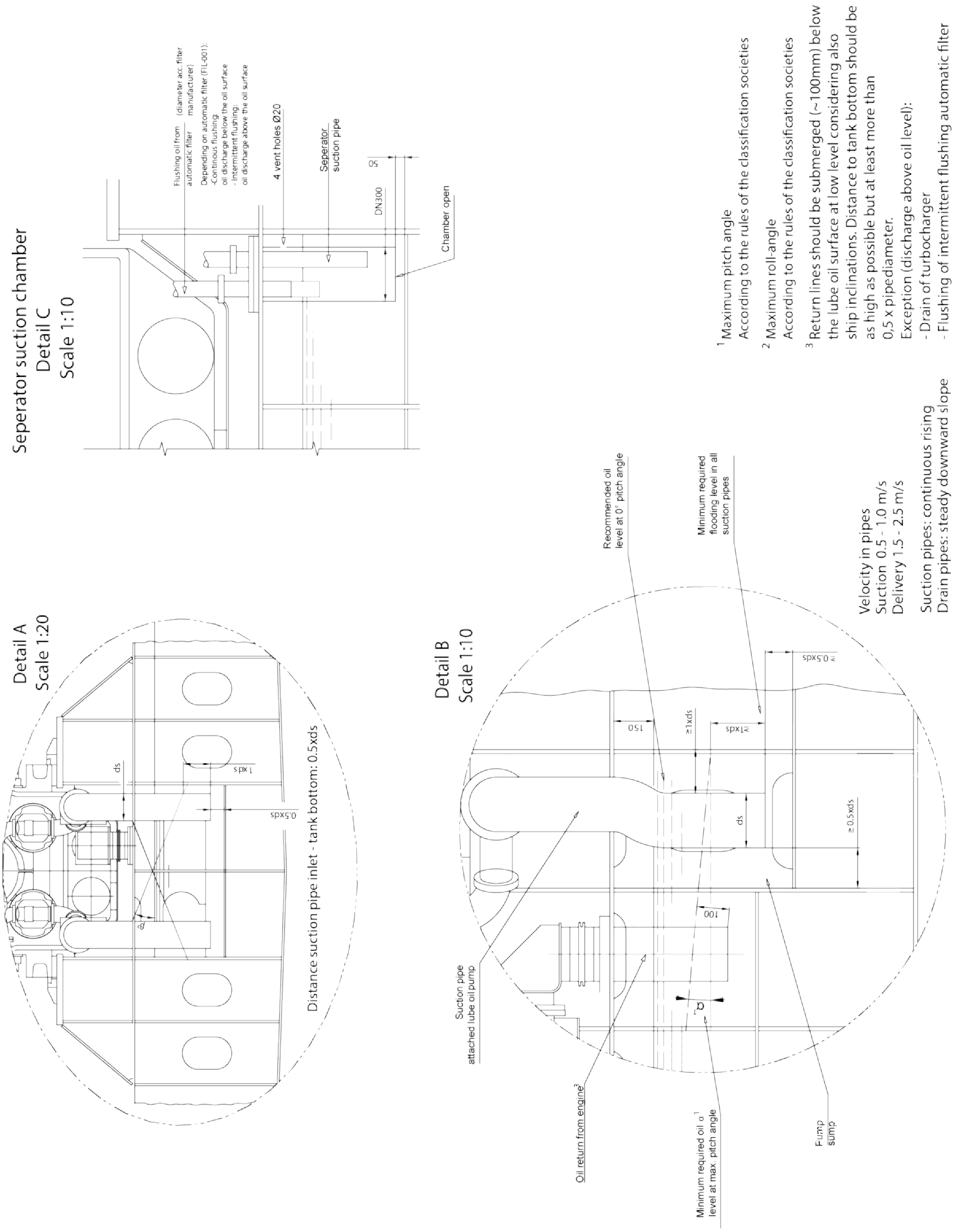

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Figure 18: Lube oil service tank arrangement 2

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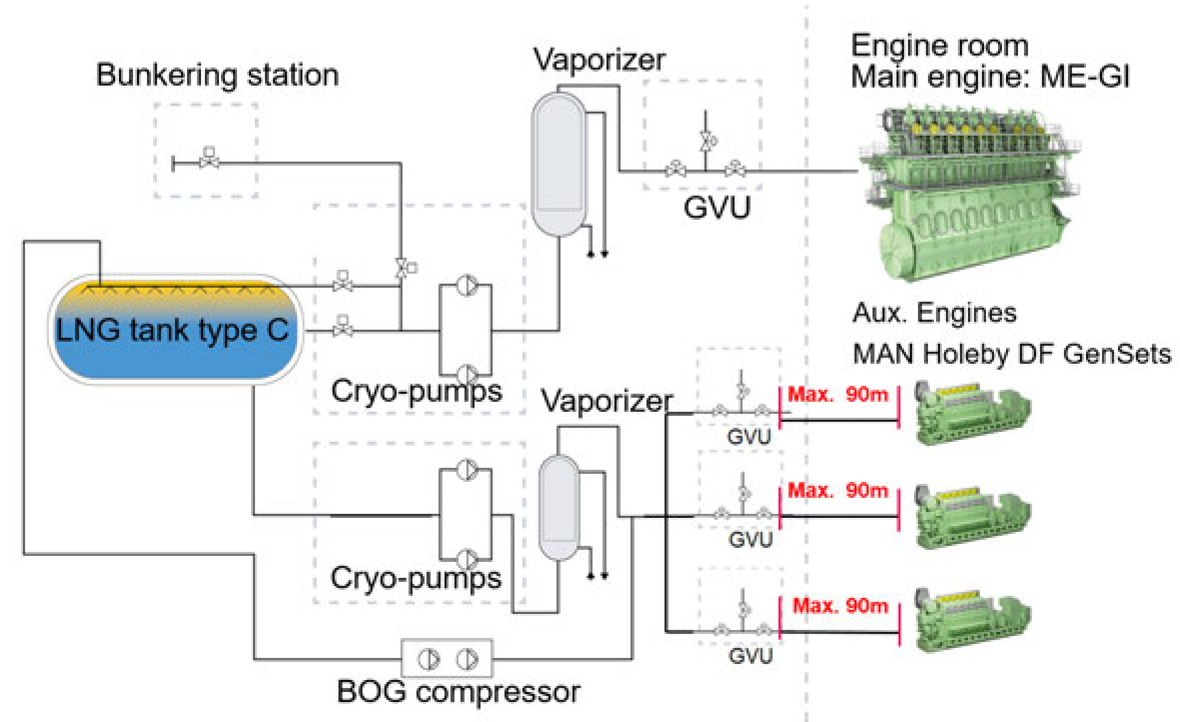
System description - Dual-fuel

Principal installation diagram for main engine and GenSet:

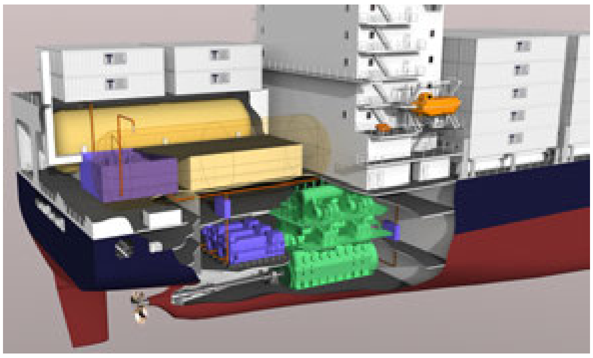


Distance from GVU to GenSet : max. 90 meters

GenSet-GVU can be delivered in two design variants

Encapsulated GVU in engine room

Combine all GVU (normally 3xGVU) without encapsulation in a “GVU-room” together with Main Engine GVU, FGSS, or other gas installation where best applicable for ship design.



It is important to consider ventilation plan for a gas installation in engine room. Each GVU have 3-4 venting lines that separately need to be led to safe location on deck or in vent mast. Encapsulated GVU have large volume that need to ventilate 30 times and requires rather large ventilation capacity. Double-wall GVU have smaller ventilation volume. With design of GVU-room on ship deck will venting for all GenSet-GVU be combined into one ventilator on wall side of the GVU-room.

Longer distance from GVU to GenSet will require higher capacity of inert gas (nitrogen)

Gas pressure in the GenSet string (normal values)

Before GVU	Gas pressure 6-9 bar (abs)
Before GenSet	Gas pressure 4-6 bar (abs) (Load depending)

Gas fuel is compressible (Liquid fuel is incompressible) meaning normal fuel calculation programs are not suitable for DF pipe installation. Mass flow [kg/h] is constant and depending on load.

- For every gas pressure = new density = new volume = new flow velocity
- For every gas temperature = new density = new volume = new flow velocity

Recommendable maximum limit on flow velocity is 25 m/s.

Our recommendation is to use pipe with DN80 pipe dimension.

Boil-Off-Gas (BOG)

GenSet running on Boil-Off-Gas (BOG) - Design for low pressure

BOG normally require low gas pressure. Or a very expensive BOG-compressor to achieve the requested pressure.

- All GenSet/GVU applications are able to run lower load on lower gas pressure. Then use FGSS higher gas pressure only for high load.
- By ordering special Tank/FGSS/GenSet/GVU application for BOG, a minimum pressure loss can achieved in the gas string for GenSet, consequently higher flexibility for using BOG in a larger load range.

Contact MAN Energy Solution for further information.

Interface description - dual fuel engines

General

Validity	This document describes the interfaces between $SaCoS_{one}$ GenSet DF and externals systems. This description is valid for engines L23/30DF, and L28/32DF equipped with $SaCoS_{one}$ GenSet Hardware Version V 1.2.0 and higher (see type plate).
Signals	All analogue inputs have to be electrically isolated by signal supplier. All digital inputs are designed as passive switching contacts. All digital outputs (DOs) are designed as relay outputs switching of at a maximum 250 VAC / 2A or 30 VDC / 2A.
Terminal bars	Terminal bars are split depending on different signal types. The power supplies must be connected to terminal bar –X12. Terminal bar –X14 is reserved to binary signals. Analogue signals must be connected to terminal bar –X15. The MODBUS is connected to terminal bar –X36 and speed sensors for injection module and knocking module is connected to –X18.

Power supply requirements

Redundant and controlled power supply for $SaCoS_{one}$ GenSet

Power supply 1 is 24V DC, 0,72kW, with a 30A pre-fuse. Power supply 2 (UPS buffered) is 24V DC, 0,72kW, with a 30A pre-fuse.

Detailed signal description

Signals between $SaCoS_{one}$ GenSet and ship alarm system

Stop from engine (Engine is stopping)	This binary signal can be used by the ship alarm system to indicate that the engine stop sequence is in progress (closed contact).
Remote shutdown	This input to $SaCoS_{one}$ GenSet can be used for a remote shutdown from the ship alarm system. The contact in the ship alarm system has to be bridged with a wire break resistor (24kΩ, 1%, 0,6W).
Common alarm	Open contact indicates that an alarm (system alarms and pre-alarms) has occurred at the GenSet. If a new alarm occurs, the contact is closed again for 1 second and then reopened again.
Ready to start	The closed contact indicates that no start blockings are active. The engine can only be remote started if this contact is closed. If start sequence is aborted due to start failure, this contact is opened again. The start failure has to be fixed and afterwards acknowledged and reset. If the engine is in local control, the signal is not used.
Engine running	Signal is used for to release the synchronisation of the generator. Contact is closed if engine speed reaches synchronisation speed (above 90% of nominal speed).
Start prelubrication oil pump	Closed contact requests the start of the prelubrication oil pump. The contact stays closed as long as prelubrication is required.
Start preheater control	Closed contact requests the start of the HTCW preheating. The contact stays closed as long as preheating is required.
Start failure	Open contact indicates a start failure. The signal is 5 seconds active.

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Common shutdown	This closed contact indicates the following events: ▪ automatic shutdown by the safety system and the alarm system ▪ remote shutdown by external control system ▪ automatic shutdown by Crankcase Monitoring ▪ an emergency stop pushbutton is pressed

Signal between SaCoS$_{one}$ GenSet and load sharing control device

Speed setpoint analog	The 4-20mA-signal is used for the regulation of the engine load setpoint. The signal has to be adjusted during commissioning. System will read in information, if digital signal “Speed setpoint analog” is set – means contact is closed.

Signals between SaCoS$_{one}$ GenSet and PMS

Remote stop	If this contact is closed, an engine stop is initiated (only while in remote control). The contact has to be bridged with a resistor (24kΩ, 1%, 0,6W).
Remote start	Start request by remote system (closed contact), available when contacts “ready to start” and “remote control” are closed. If contact “engine ready to start” is active, the PMS can close this contact to start the start sequence of the GenSet. The contact has to be bridged with a resistor (24kΩ, 1%, 0,6W).
Remote reset of alarms	Closing of this contact will reset all actual faults (alarms, start failures) if remote control is enabled. It is a pulse contact. Shutdowns can only be reset from the Control Unit. The contact has to be bridged with a resistor (24kΩ, 1%, 0,6W).
Selector switch local/remote (Remote control indication)	This signal is used for remote control indication. The closed contact indicates that remote control is enabled.
Remote lower speed	For generator synchronisation, the synchronisation unit requests engine speed decrease via this signal (closing of the contact). The contact has to be bridged with a resistor (24kΩ, 1%, 0,6W).
Remote raise speed	For generator synchronisation, the synchronisation unit requests engine speed increase via this signal (closing of the contact). The contact has to be bridged with a resistor (24kΩ, 1%, 0,6W).
Speed setpoint analog	Signal is used to enable analogue set-point control (closing of the contact). Otherwise speed will be controlled digital with the Lower- / Raise Speed signal. The contact has to be bridged with a resistor (24kΩ, 1%, 0,6W).

Signals between SaCoS$_{one}$ GenSet and crankcase monitoring unit

Crankcase Monitoring Unit (CCM) is separate stand alone unit with hard wired interface to the engine control system.

Engine running	Hardwired digital engine speed signal from engine control is signaling to CCM that engine is running.
Crankcase monitoring pre-alarm	Open contact indicates that a pre-alarm occurred at the Crankcase Monitoring Unit. The contact has to be bridged with a resistor (24kΩ, 1%, 0,6W). Crankcase monitoring pre-alarm will cause change over to diesel mode.
Automatic shut down Crankcase monitoring	This closed contact indicates an automatic shutdown is triggered by the CMU. The contact in the Crankcase Monitoring Unit has to be bridged with a resistor (24kΩ, 1%, 0,6W).
Bearing sensors	All main and rod bearing sensors are RTD type PT100.

Crankcase monitoring	Open contact indicates that a system failure occurred at the Crankcase Monitoring Unit. The contact has to be bridged with a resistor (24kΩ, 1%, 0,6W). Crankcase monitoring system failure will cause change over to diesel mode.

Signals between SaCoS$_{one}$ GenSet and engine room

Ambient air temperature	A PT1000 resistance thermometer transmits the temperature of the engine room. This signal is used for calculations in EDS. Signal can be used and is available, if Signal TC Lube Oil Temperature is not needed in case of diesel electric propulsion application. Please see Signal Cooling Air Alternator also.
Ambient air pressure	A pressures transmitter provides the ambient air pressure of the engine room. This signal is used for calculations in EDS.

Signals between SaCoS$_{one}$ GenSet and alternator

Alternator cooling water leakage alarm	Closed contact indicates that a leakage occurred at the alternator's cooling water supply. The contact has to be bridged with a resistor (24kΩ, 1%, 0,6W).
Alternator front bearing temperature	A PT1000 resistance thermometer transmits the temperature of the alternator front bearing.
Alternator rear bearing temperature	A PT1000 resistance thermometer transmits the temperature of the alternator rear bearing.
Alternator winding temperature L1	A PT1000 resistance thermometer transmits the temperature of the alternator winding L1. This signal has to be connected to Control Unit.
Alternator winding temperature L2	A PT1000 resistance thermometer transmits the temperature of the alternator winding L2. This signal has to be connected to Control Unit.
Alternator winding temperature L3	A PT1000 resistance thermometer transmits the temperature of the alternator winding L3. This signal has to be connected to Control Unit.
Cooling Air Alternator	A PT1000 resistance thermometer transmits the temperature of the cooling air of the alternator. This signal has to be connected to Connection Box.

Signals between SaCoS$_{one}$ GenSet and main switch board

Generator load	Analogue 4 ... 20mA used for engine control.

Signals between SaCoS$_{one}$ GenSet and EDS

CoCoS-EDS can be connected to engine control system. This requires additional gateway module (GM).

Signals between SaCoS$_{one}$ GenSet and actuator

Actuator healthy	The MA1.031-1 actuator provides this signal to the system. Closed contact indicates that the actuator is healthy.

Signals between SaCoSone GenSet and alarm system

Quick change over (QCO): External QCO is a common signal from alarm system. QCO shall be generated of following signals

- Manual External Quick Change Over switch
- Gas Leakage in engine relevant areas
- Fire alarm
- External gas blockings

External gas plant shutdown

External gas plant shutdown is a common signal sent parallel to all GCU controls to shutdown DF mode. Inert sequences will be conducted by all GVU's on their respective engines in order to remove all gas from the systems. Furthermore, there is possibility that the controls are able to also inert te incoming gas line upstream the GVU's. However, for this operation following signals are required:

- Close main gas supply valve
- Inert valve gas supply side
- Position feedback switches on main gas supply valve
- Position feedback switches on inert valve supply side

It is also possible for the FGSS or alarm system to control this function and the GVU's will then only inert the system downstream the GVU's.

External gas plant shutdown is to be given if the complete gas system must be shutdown. This should be as minimum:

- Emergency stop of gas plant
- Fire
- Gas leakage in GVU room
- Pipe rupture in gas supply line
- Ventilation GVU room

Signals between GVU control cabinet and all equipment

Numbering for all interfaces are connected for one engine GVU control cabinet.
If multiple engines are connected one common GVU cabinet cable and wire numbers will be different for other engines than the first.

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Interface list

Power supply

		SaCoSone GenSet connection box				Power supply			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
1	Power supply 1	24V DC		-X12:5	-W1/1				
				-X12:6	-W1/2				
2	Power supply 2	24V DC		-X12:7	-W2/1				
				-X12:8	-W2/2				

Ship alarm system

		SaCoSone GenSet connection box				Ship alarm system			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
1a	Modbus / RS422	RS422	T x H	-X36:11	-W513/1				Terminating resistor (last Bus Device)
			T x L	-X36:111	-W513/2				
			T x H	-X36:12	-W513/3				
			T x L	-X36:112	-W513/4				
				EMC-Gland	-W513/S				
1b	Modbus / RS485	RS485	T x H	-X36:11	-W514/1				Terminating resistor (last Bus Device)
			T x L	-X36:111	-W514/2				
				EMC-Gland	-W514/S				
2	Stop from engine	DO max. 200mA	NO	-X14:1	-W10/1				External supply max. 250VAC/2A max. 30VDC/2A
				-X14:101					
				EMC-Gland	-W10/2				
					-W10/S				
3	Remote shutdown (option)	DI	200 mA +24 V 0 V	-X14:2	-W11/1		24kΩ	No	
				-X14:102	-W11/2				
				EMC-Gland	-W11/S				
4	Common alarm (option)	DO max. 200mA	NO	-X14:12	-W12/1				External supply max. 250VAC/2A max. 30VDC/2A
				-X14:112	-W12/2				
5	Ready to start	DO max. 200mA	NO	-X14:13	-W12/3				External supply max. 250VAC/2A max. 30VDC/2A
				-X14:113	-W12/4				

		SaCoSone GenSet connection box				Ship alarm system			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
6	Engine is running	DO max. 200mA	NO	-X14:14	-W12/5				External supply max. 250VAC/2A max. 30VDC/2A
				-X14:114	-W12/6				
				EMC-Gland	-W12/S				
7	Start pre-lubrication oil pump	DO max. 200mA	NO	-X14:15	-W13/1				External supply max. 250VAC/2A max. 30VDC/2A
				-X14:115	-W13/2				
				EMC-Gland	-W13/S				
8	Start pre-heater control	DO max. 200mA	NO	-X14:17	-W14/1				External supply max. 250VAC/2A max. 30VDC/2A
				-X14:117	-W14/2				
				EMC-Gland	-W14/S				
9	Start failure	DO max. 200mA	NO	-X14:18	-W15/1				External supply max. 250VAC/2A max. 30VDC/2A
				-X14:118	-W15/2				
				EMC-Gland	-W15/S				
10	Common shutdown	DO max. 200mA	NO	-X14:19	-W16/1				External supply max. 250VAC/2A max. 30VDC/2A
				-X14:119	-W16/2				
				EMC-Gland	-W16/S				
11	Quick change over	DI		-X14:31	-W475/1		24kΩ	No	
				-X14:131	-W475/2				
				EMC-Gland	-W475/S				

Load sharing control device

		SaCoSone GenSet connection box				Load sharing control device			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
11	Speed set point analog	AI	24 V 4-20 mA	-X15:6	-W20/1		Supply Signal	Analogue	used for load sharing Calibration: 4mA = 0 rpm 20mA = max. rpm of engine
				-X15:106	-W20/2				
				EMC-Gland	-W20/S				

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Power management system

		SaCoSone GenSet connection box				Power management system			Remarks
No.	**Signal de-scription**	**Signal type**	**Symbol**	**Terminal**	**Cable/core**	**Terminal**	**Symbol**	**Signal type**	
1	Remote stop	DI		-X14:6	-W30/1			No	
				-X14:106	-W30/2				
2	Remote start	DI		-X14:7	-W30/3			No	
				-X14:107	-W30/4				
				EMC-Gland	-W30/S				
3	Remote re-set of alarms (option)	DI		-X14:8	-W31/1			No	
				-X14:108	-W31/2				
				EMC-Gland	-W31/S				
4	Selector switch local/ remote (Re-mote control indication)	DI		-X14:9	-W32/1			No	
				-X14:109	-W32/2				
5	Remote - lower speed setpoint	DI		-X14:10	-W32/3			No	
				-X14:110	-W32/4				
6	Remote - raise speed setpoint	DI		-X14:11	-W32/5			No	
				-X14:111	-W32/6				
				EMC-Gland	-W32/S				
7	Speed set-point analog	DI		-X14:22	-W43/1			No	Has been changed. See document SW_1.2.0_Release-Note - Digital input for selecting digital (open contact) or analogue (closed contact) speed set-ting
				-X14:122	-W43/2				
				EMC-Gland	-W43/S				

Crankcase monitoring unit

		SaCoSone GenSet connection box				Crankcase monitoring unit			Remarks
No.	**Signal de-scription**	**Signal type**	**Symbol**	**Terminal**	**Cable/core**	**Terminal**	**Symbol**	**Signal type**	
1	Crankcase monitoring pre-alarm	DI		-X14:3	-W25/BK			No	Instead of OMD monitoring CCM can be used. CCM
				-X14:103	-W25/BU				

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		SaCoSone GenSet connection box				Crankcase monitoring unit			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
									is using same DIs as OMD monitoring
2	Crankcase monitoring shutdown	DI	200 mA +24 V 0 V	-X14:4	-W25/BN		24kΩ	No	Instead of OMD monitoring CCM can be used. CCM is using same DIs as OMD monitoring
				-X14:104	-W25/GN				
3	Crankcase monitoring system failure	DI	200 mA +24 V 0 V	-X14:5	-W25/TR		24kΩ	No	Instead of OMD monitoring CCM can be used. CCM is using same DIs as OMD monitoring
				-X14:105	-W25/WH				
4	Engine running	DO	NO	-X14:26	-W25/RD				
				-X14:126	-W25/GY				
				EMC-Gland	-W25/S				

		Engine room				Crankcase monitoring cabinet			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
5	Jacket pipe pressure	AI	4-20 mA			-X7:12	4-20 mA	Analogue	Calibration: 4...20 mA -10...3 mbar
						-X7:13			
				EMC-Gland		EMC-Gland			

		Crankcase monitoring cabinet				GVU cabinet			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
6	Jacket pipe pressure	AI	4-20 mA	-X7:14	-W117/1	-X11:10	4-20 mA	Analogue	Calibration: 4...20 mA -10...3 mbar
				-X7:15	-W117/2	-X11:110			
				EMC-Gland	-W117/S	EMC-Gland			

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Engine room

		SaCoSone GenSet connection box				Engine room			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
1	Ambient air temperature	TI		-X15:2	-W50/1			PT1000	Optional available, if TC lube oil temperature is not needed for classification approval for diesel electric propulsion application. See signal cooling air alternator also.
				-X15:102	-W50/2				
				EMC-Gland	-W50/S				
2	Ambient air pressure (option)	AI		-X15:10	-W76/BK			Analogue	
				-X15:110	-W76/BU				
				EMC-Gland	-W76/S				
3	Remote start blocking	DI		-X14:16	-W34/1			No	Feedback from exhaust gas fan control
				-X14:116	-W34/2				
				EMC-Gland	-W34/S				

Alternator

		SaCoSone GenSet connection box				Alternator			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
1	Alternator cooling water leakage alarm	DI		-X14:21	-W40/1			No	
				-X14:121	-W40/2				
				EMC-Gland	-W40/S				
2	Alternator front bearing temperature	TI		-X35:31	-W41/1			PT1000	
				-X35:131	-W41/2				
3	Alternator rear bearing temperature	TI		-X35:32	-W41/3			PT1000	
				-X35:132	-W41/4				
				EMC-Gland	-W41/S				
4	Alternator winding temperature L1	TI		-X35:28	-W42/1			PT1000	
				-X35:128	-W42/2				
5	Alternator winding temperature L2	TI		-X35:29	-W42/3			PT1000	
				-X35:129	-W42/4				

		SaCoSone GenSet connection box				Alternator			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
6	Alternator winding temperature L3	TI		-X35:30	-W42/5			PT1000	
				-X35:130	-W42/6				
				EMC-Gland	-W42/S				
7	Cooling air alternator	TI		-X15:8	-W52/1			PT1000	Optional available, if TC lube oil temperature is not needed for classification approval for diesel electric propulsion application. See signal ambient air temperature also.
				-X15:108	-W52/2				
				EMC-Gland	-W52/S				

Main switch board

		SaCoSone GenSet connection box				Main switch board			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
1	Generator load	AI	4-20 mA	-X15:12	-W114E /BK			Analogue	Calibration: 4mA = 0 kW 20mA = depending on generator
				-X15:112	-W114 /BU				
				EMC-Gland	-W114/S				
2	Circuit breaker closed	DI	200 mA +24 V 0 V	-X14:32	-W477/1		24kΩ	No	
				-X14:132	-W477/2				
				EMC-Gland	-W477/S				

Actuator

		SaCoSone GenSet connection box				Actuator MA1.031-1			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
1	Major alarm actuator	DI	200 mA +24 V 0 V	-X15:9	-W116E /BK		24kΩ	No	Signal is only available with MA1.031-1
				-X15:109	-W116E /BU				
				EMC-Gland	-W116E /S				

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Signal between SaCoSone and GVU cabinet

		SaCoSone GenSet connection box				Gas valve unit control cabinet			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
1	Power supply	24VDC 5A		-F7:2		-X13:14			Numbering may differ on application
				-F7:3		-X13:15			
				-X11:PE		-X13:PE			
				EMC-Gland		EMC-Gland			
2	Common shutdown	DO max. 200mA	NO	-X14:27	-W17/1	-X11:6		No	
				-X14:127	-W17/2	-X11:106			
				EMC-Gland	-W17/S	EMC-Gland			
3	Inert valve	DI	200 mA +24 V 0 V	-X14:28	-W124/1	-X12:7			Numbering may differ on application
				-X14:128	-W124/2	-X12:107			
				-X14:PE		-X12:207 (PE)			
				EMC-Gland		EMC-Gland			
4	Inert valve Open Position	DI	200 mA +24 V 0 V	-X12:20	-W131/1		24kΩ	No	Position switch Optional
				-X12:120	-W131/2				
5	Inert valve Closed position	DI	200 mA +24 V 0 V	-X12:21	-W131/3		24kΩ	No	Position switch Optional
				-X12:121	-W131/4				
				-X12:PE	-W131/5				
				EMC-Gland	-W131/S				

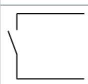
Signals between GVU cabinet and external control

		Gas valve unit control cabinet				External control			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
1	Power supply	24VDC 5A		-F7:0					From UPS back-up power supply
				-F7:0					
				-X0:PE					
				EMC-Gland					
2	Gas operation select	DI	200 mA +24 V 0 V	-X11:2	-W111/3		24kΩ	No	
				-X11:102	-W111/4				

		Gas valve unit control cabinet				External control			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
				EMC-Gland	-W111/S				
3	External gas plant shut-down	DI	200 mA +24 V 0 V	-X11:1	-W111/1		24kΩ	No	Numbering may differ on application
				-X11:101	-W111/2				
4	Master gas valve Closed position	DI	200 mA +24 V 0 V	-X0:1			24kΩ	No	Position switch Optional
				-X0:101					
5	Master gas valve Open position	DI	200 mA +24 V 0 V	-X0:2			24kΩ	No	Position switch Optional
				-X0:102					
6	External inert valve Closed position	DI	200 mA +24 V 0 V	-X0:3			24kΩ	No	
				-X0:103					
7	External inert valve Open position	DI	200 mA +24 V 0 V	-X0:4			24kΩ	No	
				-X0:104					
8	External inert valve	DO	NO	-X0:5				No	
				-X0:105					
				-X0:PE					
				EMC-Gland					
9	Exhaust gas fan	DO	NO	-X11:8	-W115/1			No	Signal high for 3 sec. as start signal
				-X11:108	-W115/2				
				EMC-Gland	-W115/S				
10	GVU enclosure pressure switch	DI	200 mA +24 V 0 V	-X14:24	-W123/1			No	
				-X14:124	-W123/2				
				EMC-Gland	-W123/S				

Signals between GVU control cabinet and GVU

		Gas valve unit control cabinet				Gas valve unit			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
1	Block valve 1	24VDC		-X12:1	-W118/1	-1PV 5864:+			

		Gas valve unit control cabinet				Gas valve unit			Remarks
No.	**Signal description**	**Signal type**	**Symbol**	**Terminal**	**Cable/core**	**Terminal**	**Symbol**	**Signal type**	
				-X12:101	-W118/2	-1PV 5864:-			
				-X12:PE	-W118 /PE	-1PV 5864:PE			
				EMC-Gland	-W118/S	EMC-Gland			
2	Block valve 2	24VDC		-X12:2	-W119/1	-1PV 5865:+			
				-X12:102	-W119/2	-1PV 5865:-			
				-X12:202 (PE)	-W119 /PE	-1PV 5865:PE			
				EMC-Gland	-W119/S	EMC-Gland			
3	Venting valve 1	24VDC		-X12:3	-W120/1	-1PV 5863:+			
				-X12:103	-W120/2	-1PV 5863:-			
				-X12:203 (PE)	-W120 /PE	-1PV 5863:PE			
				EMC-Gland	-W120/S	EMC-Gland			
4	Bleed valve	24VDC		-X12:4	-W121/1	-2PV 5864:+			
				-X12:104	-W121/2	-2PV 5864:-			
				-X12:204 (PE)	-W121 /PE	-2PV 5864:PE			
				EMC-Gland	-W121/S	EMC-Gland			
5	Venting valve 3	24VDC		-X12:5	-W122/1	-2PV 5865:+			
				-X12:105	-W122/2	-2PV 5865:-			
				-X12:205 (PE)	-W122 /PE	-2PV 5865:PE			
				EMC-Gland	-W122/S	EMC-Gland			
6	Block valve 1 open position	DI		-X12:8	-W125/1	-2GOS 5864:7		No	Optional

		Gas valve unit control cabinet				Gas valve unit			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
				-X12:108	-W125/2	-2GOS 5864:8			
7	Block valve 1 closed position	DI	200 mA +24 V 0 V	-X12:9	-W125/3	-1GOS 5864:6		No	Optional
				-X12:109	-W125/4	-1GOS 5864:5			
				-X12:209 (PE)	-W125 /PE				
				EMC-Gland	-W125/S	EMC-Gland			
8	Block valve 2 open position	DI	200 mA +24 V 0 V	-X12:10	-W126/1	-2GOS 5865:7		No	Optional
				-X12:110	-W126/2	-2GOS 5865:8			
9	Block valve 2 closed position	DI	200 mA +24 V 0 V	-X12:11	-W126/3	-1GOS 5865:6		No	Optional
				-X12:111	-W126/4	-1GOS 5865:5			
				-X12:211 (PE)	-W126 /PE				
				EMC-Gland	-W126/S	EMC-Gland			
10	Venting valve 1 open position	DI	200 mA +24 V 0 V	-X12:12	-W127/1	-2GOS 5863:7		No	Optional
				-X12:112	-W127/2	-2GOS 5863:8			
11	Venting valve 1 closed position	DI	200 mA +24 V 0 V	-X12:13	-W127/3	-1GOS 5863:6		No	Optional
				-X12:113	-W127/4	-1GOS 5863:5			
				-X12:213 (PE)	-W127 /PE				
				EMC-Gland	-W127/S	EMC-Gland			
12	Bleed valve open position	DI	200 mA +24 V 0 V	-X12:14	-W128/1	-4GOS 5864:7		No	Optional
				-X12:114	-W128/2	-4GOS 5864:8			
13	Bleed valve closed position	DI	200 mA +24 V 0 V	-X12:15	-W128/3	-3GOS 5864:6		No	Optional

		Gas valve unit control cabinet				Gas valve unit			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
				-X12:115	-W128/4	-3GOS 5864:5			
				-X12:215 (PE)	-W128 /PE				
				EMC-Gland	-W128/S	EMC-Gland			
14	Venting valve 3 open position	DI	200 mA +24 V 0 V	-X12:16	-W129/1	-4GOS 5865:7		No	Optional
				-X12:116	-W129/2	-4GOS 5865:8			
15	Venting valve 3 closed position	DI	200 mA +24 V 0 V	-X12:17	-W129/3	-3GOS 5865:6		No	Optional
				-X12:117	-W129/4	-3GOS 5865:5			
				-X12:217 (PE)	-W129 /PE				
				EMC-Gland	-W129/S	EMC-Gland			
16	control air pressure	AI	4-20 mA	-X13:3	-W140/1	-1PT 7460:+		Analogue	Calibration: 4...20 mA 0...16 bar
				-X13:103	-W140/2	-1PT 7460:-			
				EMC-Gland	-W140/S				
17	Gas pressure GVU inlet	AI	4-20 mA	-X13:4	-W141/1	-1PT 5860:+		Analogue	Calibration: 4...20 mA 0...16 bar
				-X13:104	-W141/2	-1PT 5860:-			
				EMC-Gland	-W141/S	EMC-Gland			
18	Gas pressure in GVU	AI	4-20 mA	-X13:5	-W142/1	-1PT 5865:+		Analogue	Calibration: 4...20 mA 0...16 bar
				-X13:105	-W142/2	-1PT 5865:-			
				EMC-Gland	-W142/S	EMC-Gland			
19	Gas flow	AI	4-20 mA	-X13:6	-W143/1	-1FQ 5870:26		Analogue	Calibration: 4...20 mA 0...400 kg/h
				-X13:106	-W143/2	-1FQ 5870:27			

		Gas valve unit control cabinet				Gas valve unit			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
				EMC-Gland	-W143/S	EMC-Gland			
20	Gas flow power supply	24VDC		-X11:5		-1FQ 5870:1		Power supply	
				-X11:105		-1FQ 5870:2			
				-X11:205 (PE)		-1FQ 5870:PE			
				EMC-Gland		EMC-Gland			
21	Gas temperature inlet GVU	TI		-X13:7	-W144/1	-1TE 5860:1		RTD	Calibration: PT1000 -100...400° C
				-X13:107	-W144/2	-1TE 5860:2			
				EMC-Gland	-W144/S	EMC-Gland			

Signals between engine - A10 box and crankcase monitoring cabinet

		Engine - W10 box				Crankcase monitoring cabinet			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
1	Rod bearing cyl. 1	TI		-A10:1		-1A15:1		RTD	
				-A10:101		-1A15:3			
				-A10:201		-1A15:4			
2	Rod bearing cyl. 2	TI		-A10:2		-1A16:1		RTD	
				-A10:102		-1A16:3			
				-A10:202		-1A16:4			
3	Rod bearing cyl. 3	TI		-A10:3		-1A17:1		RTD	
				-A10:103		-1A17:3			
				-A10:203		-1A17:4			
4	Rod bearing cyl. 4	TI		-A10:4		-1A18:1		RTD	
				-A10:104		-1A18:3			
				-A10:204		-1A18:4			
5	Rod bearing cyl. 5	TI		-A10:5		-1A19:1		RTD	
				-A10:105		-1A19:3			
				-A10:205		-1A19:4			
6	Rod bearing cyl. 6	TI		-A10:6		-1A20:1		RTD	
				-A10:106		-1A20:3			

		Engine - W10 box				Crankcase monitoring cabinet			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
				-A10:206		-1A20:4			
7	Rod bearing cyl. 7	TI		-A10:7		-1A21:1		RTD	
				-A10:107		-1A21:3			
				-A10:207		-1A21:4			
8	Rod bearing cyl. 8	TI		-A10:8		-1A22:1		RTD	
				-A10:108		-1A22:3			
				-A10:208		-1A22:4			
9	Rod bearing cyl. 9	TI		-A10:9		-1A23:1		RTD	
				-A10:109		-1A23:3			
				-A10:209		-1A23:4			
				EMC-Gland		EMC-Gland			
01	Main bearing cyl. 01	TI		-A10:10		-1A14:1		RTD	
				-A10:110		-1A14:3			
				-A10:210		-1A14:4			
1	Main bearing cyl. 1	TI		-A10:11		-1A14:5		RTD	
				-A10:111		-1A14:7			
				-A10:211		-1A14:8			
2	Main bearing cyl. 2	TI		-A10:12		-1A15:5		RTD	
				-A10:112		-1A15:7			
				-A10:212		-1A15:8			
3	Main bearing cyl. 3	TI		-A10:13		-1A16:5		RTD	
				-A10:113		-1A16:7			
				-A10:213		-1A16:8			
4	Main bearing cyl. 4	TI		-A10:14		-1A17:5		RTD	
				-A10:114		-1A17:7			
				-A10:214		-1A17:8			
5	Main bearing cyl. 5	TI		-A10:15		-1A18:5		RTD	
				-A10:115		-1A18:7			
				-A10:215		-1A18:8			
6	Main bearing cyl. 6	TI		-A10:16		-1A19:5		RTD	
				-A10:116		-1A19:7			
				-A10:216		-1A19:8			
7	Main bearing cyl. 7	TI		-A10:17		-1A20:5		RTD	
				-A10:117		-1A20:7			

		Engine - W10 box				Crankcase monitoring cabinet			Remarks
No.	Signal description	Signal type	Symbol	Terminal	Cable/core	Terminal	Symbol	Signal type	
				-A10:217		-1A20:8			
8	Main bearing cyl. 8	TI		-A10:18		-1A21:5		RTD	
				-A10:118		-1A21:7			
				-A10:218		-1A21:8			
9	Main bearing cyl. 9	TI		-A10:19		-1A22:5		RTD	
				-A10:119		-1A22:7			
				-A10:219		-1A22:8			

Nitrogen supply system

General

The dual fuel engine and the fuel gas supply system (FGSS) requires nitrogen gas for purging, which can either be supplied from a common nitrogen gas system, or a separate stand-alone system. This will depend on the individual installation.

The nitrogen system must have a sufficient quantity of nitrogen gas available on board prior to gas operation.

General data for the nitrogen system

Medium: N2
Quality: minimum 95% N2
Purging pressure: minimum 7 bar
Purging temperature: ambient temperature

To secure the gas supply line on the DF engine from an explosive atmosphere up to the block valve of the GVU, the piping will be automatically purged with inert gas after each normal or quick change over from gas mode to liquid fuel mode and each emergency shutdown from gas mode. Therefore an inert gas purge valve is installed on the DF engine.

Purging volume

The purging storage volume must be designed for a number of consecutive gas starts, each including a number of purge sequences, as well as for purging prior and after engine gas operation.

The following formula can be used to determine the required nitrogen amount to be available onboard.

$$V_{N2} = 2 \times N_{SO} \times N_{EX} \times (V_{engine} + V_{plant})$$

V_{N2}	Nitrogen volume in Nm^3 per engine
$_{Factor}$ 2	Post- and pre-purging operation
N_{SO}	Number of switch-over operations to be operated without waiting time in between
N_{EX}	Number of volume exchanges in piping (3 to 5 is recommended)
V_{engine}	Volume of inner engine piping
V_{plant}	Volume of inner plant piping between GVU and engine

Factors		
Post- / pre-purging factor		2
Number of change-over	N_{SO}	2
Number of volume exchange	N_{EX}	3
Factor to be used in the calculation		12

In order to calculate the purging volume, the total volume of piping and equipment used during the purging sequence must be calculated.

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Volume of the gas system at the engine can be found in the below table.

Gas pipe volume at engine			
L23/30DF	Liters	L28/32DF	Liters
5	26	5	28
6	28	6	30
7	30	7	33
8	32	8	35
-	-	9	38
The dimension of the gas supply pipes are DN80 equal to a volume of 5.35 liters/meter.			

Formula for calculation of needed nitrogen volume for one engine

$$\text{Nitrogen volume} = \text{Factor} \times \frac{\text{Gas pipe volume at engine}}{1000} + \frac{\text{Pipe volume}}{1000}$$

Example: 6L28/32DF with 27 meter gas supply pipe between engine and gas valve unit (GVU)

$$12 \times \frac{30}{1000} + \frac{27 \times 5.35}{1000} = 2.09\ Nm^3$$

It should also be noted that the purging volume calculation is made under atmospheric conditions, and calculation of actual tank volume should correct for the tank pressure when sizing the tank.
If a common nitrogen gas system is used to purge the FGSS, then the volume of this system must also be added to the purging volume, according to FGSS specifications.

The design of the nitrogen equipment e.g. a nitrogen generator is depending on the required filling time of the pressurized nitrogen vessel in front of the engine and other nitrogen consumers.

Double wall ventilation capacity

General

All engine mounted fuel gas pipes upstream of the cylinder heads are double walled pipe design and that includes the sections around the gas admission valves. The space in between the inner and outer pipe of the double walled piping is continuously ventilated by 30 air changes per hour.

The venting air for the engine are supplied through the R1 connection at the engine and the dimension of the R1 connection are only intended to feed the ventilation of the engine and some 20-30 meter of double wall pipe before the engine, not the complete gas installation.

Gas lines passing through the engine room, or other enclosed spaces with exception of the gas valve unit compartment, have to be double walled type with controlled ventilation in depression.
The space in between the inner and outer pipe is monitored by intrinsically safe and certified gas detectors.

Each engine need its own separate piping and ventilation system.

In order to verify the needed capacity of the ventilators for the double wall space the total volume of the ventilated area must be determined.

Volume of the double wall pipe at the engine mounted gas pipes can be found in the table below.

Double wall pipe volume at engine			
L23/30DF	Liters	L28/32DF	Liters
5	93	5	98
6	97	6	104
7	101	7	110
8	105	8	115
		9	121

The volume of the double wall space in the DN80 gas supply pipes is 8,4 liters/meter.

Formula for calculation of ventilated volume for piping and engine.

Volume of double wall at engine + Volume of double wall space in piping = volume of ventilated area.

Example: 6L28/32DF with 27 meter gas supply pipe between engine and gas valve unit (GVU)

104 + (27 x 8.4) = 330 liters

In case an encapsulated GVU is included in the vented area this has to be added to the ventilated area. The actual size must be drawn from the documentation of the applied GVU.

In this example we apply an encapsulated GVU a volume of 750 liters. This volume must be added to the piping volume.

Total ventilated volume is following: 330 + 750 = 1080 liters.

From the total ventilated volume it is able to determine the needed capacity of the double wall ventilator in the table below.

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Total volumen - Liter	Ventilator capacity - m^3/h
800	24
850	26
900	27
950	29
1000	30
1050	32
1100	33
1150	35
1200	36
1250	38
1300	39
1350	41
1400	42
1450	44
1500	45
1550	47
1600	48
1650	50
1700	51

In this case a ventilator with a minimum capacity of 33 Nm^3/h should be applied.

The negative pressure in the double walled piping are monitored by the engine control system. In case the pressure is not within the specification an alarm will occur and the engine will not be able to operate in gas mode. During the commissioning, the negative pressure in the double wall piping is to be adjusted.
In general the sufficient flow is obtained by adjusting the negative pressure just after the engine to a level of 9 -11 mbar, however it is depending on the position of the measuring point.

The example below shows the pressure adjusted by means of the throttle valve in the venting line connected to the gas valve unit. The adjustment can also be done by application of an orifice adapted to maintain the required negative system pressure.

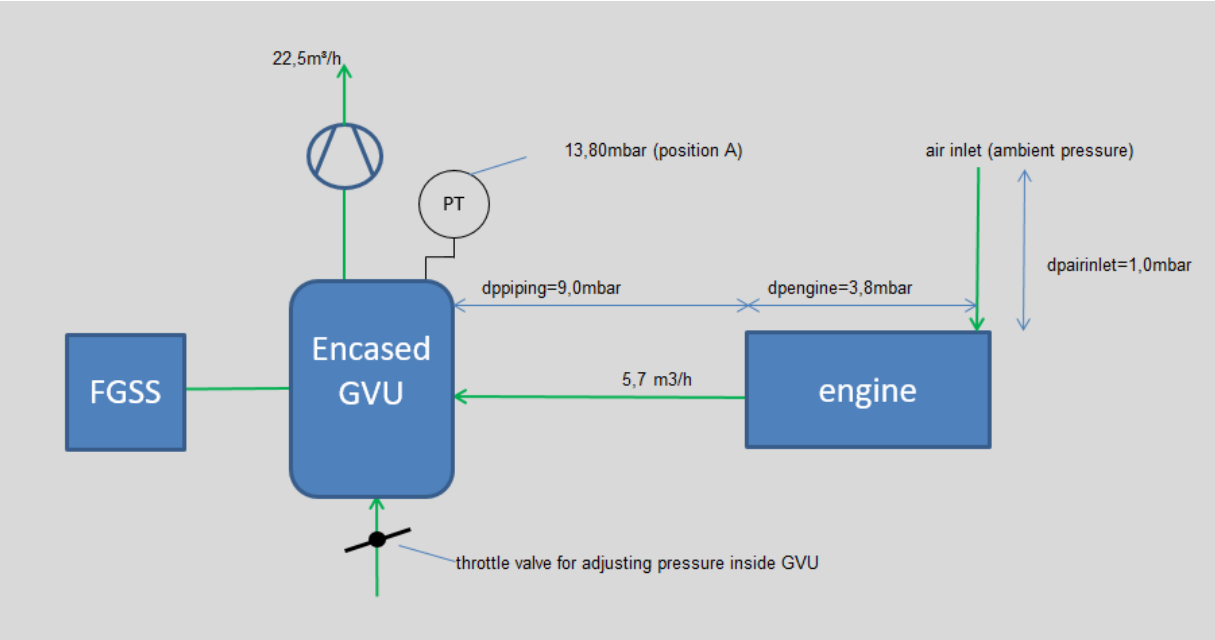
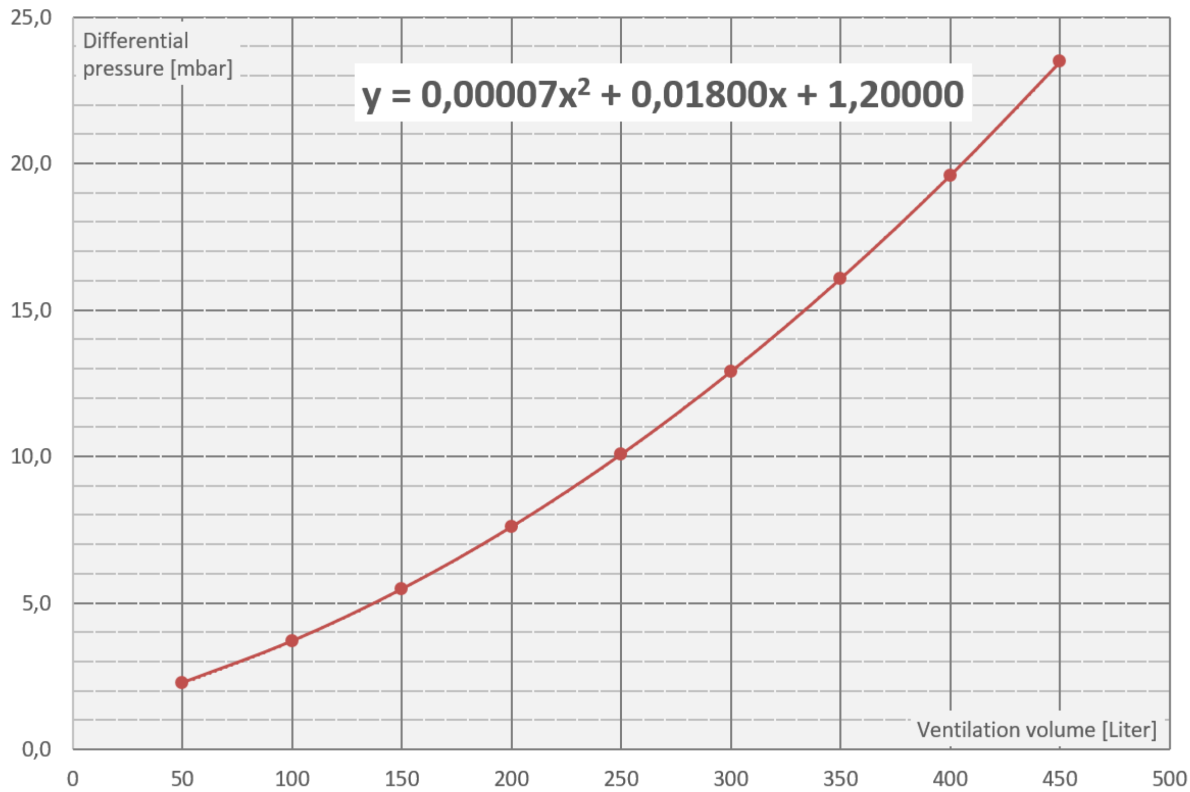
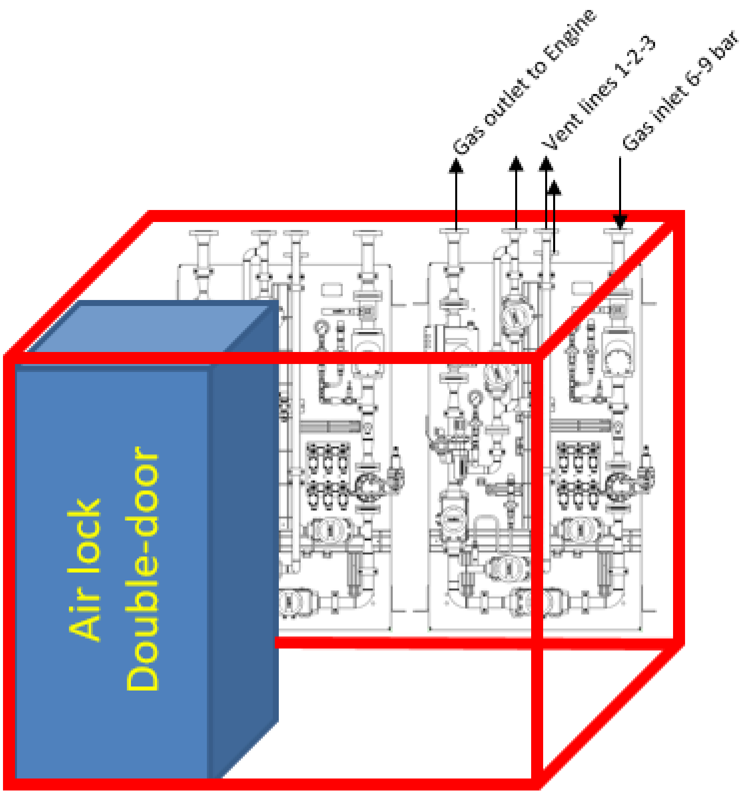


Figure 1: Differential pressure calculation for the piping between engine and GVU.



In case of GVU(S) are placed in a separate GVU room the ventilators for the double wall piping is positioned in this. In such case, it must be ensured that the venting of GVU room are sufficient to exchange the air 30 times / hour. The venting line from the GVU room must be led to the vent mast and the GVU room are regarded as an ATEX zone.


Gas outlet to Engine
Vent lines 1-2-3
Gas inlet 6-9 bar
Air lock
Double-door

Combined box with prelubricating oil pump, preheater and el turning device

Description

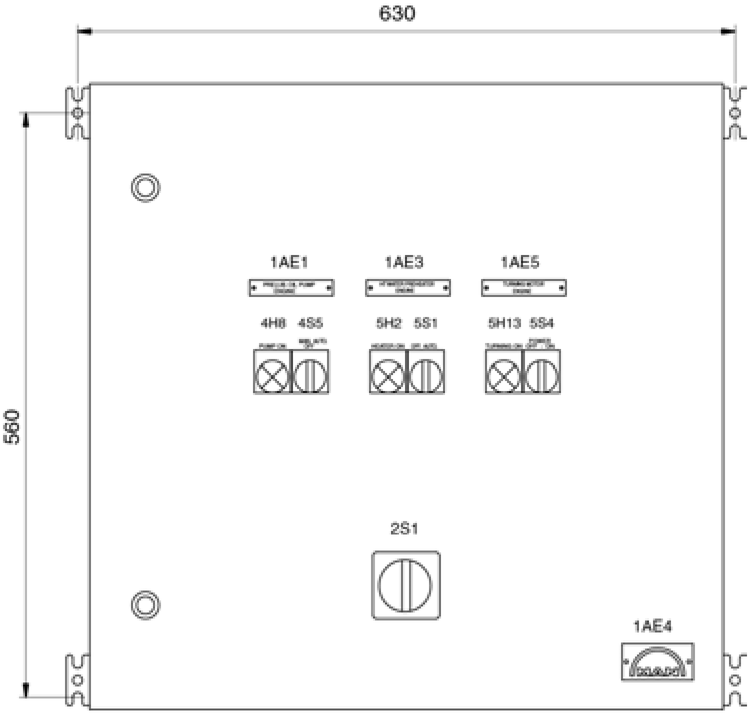


Figure 1: Dimensions

The box is a combined box with starters for prelubricating oil pump, preheater and el turning device.

The starter for prelubricating oil pump is for automatic controlling start/stop of the prelubricating oil pump built onto the engine.

Common for both pump starters in the cabinet is overload protection and automatic control system. On the front of the cabinet there is a lamp for "pump on", a change-over switch for manual start and automatic start of the pump; furthermore there is a common main cut-off switch.

The pump starter can be arranged for continuous or intermittent running. (For engine types L16/24, L21/31 & L27/38 only continuous running is accepted). *See also B 12 07 0, Prelubricating Pump.*

The preheater control is for controlling the electric heater built onto the engine for preheating of the engines jacket cooling water during stand-still.

On the front of the cabinet there is a lamp for "heater on" and a off/auto switch. Furthermore there is overload protection for the heater element.

The temperature is controlled by means of an on/off thermostat mounted in the common HT-outlet pipe. Furthermore the control system secures that the heater is activated only when the engine is in stand-still.

The box also include the control of el turning device. There is a "running" indication lamp and a on/off power switch on the front. The control for the turning gear is prepared with to contactors for forward and reverse control. The turning gear control has also overload protection.

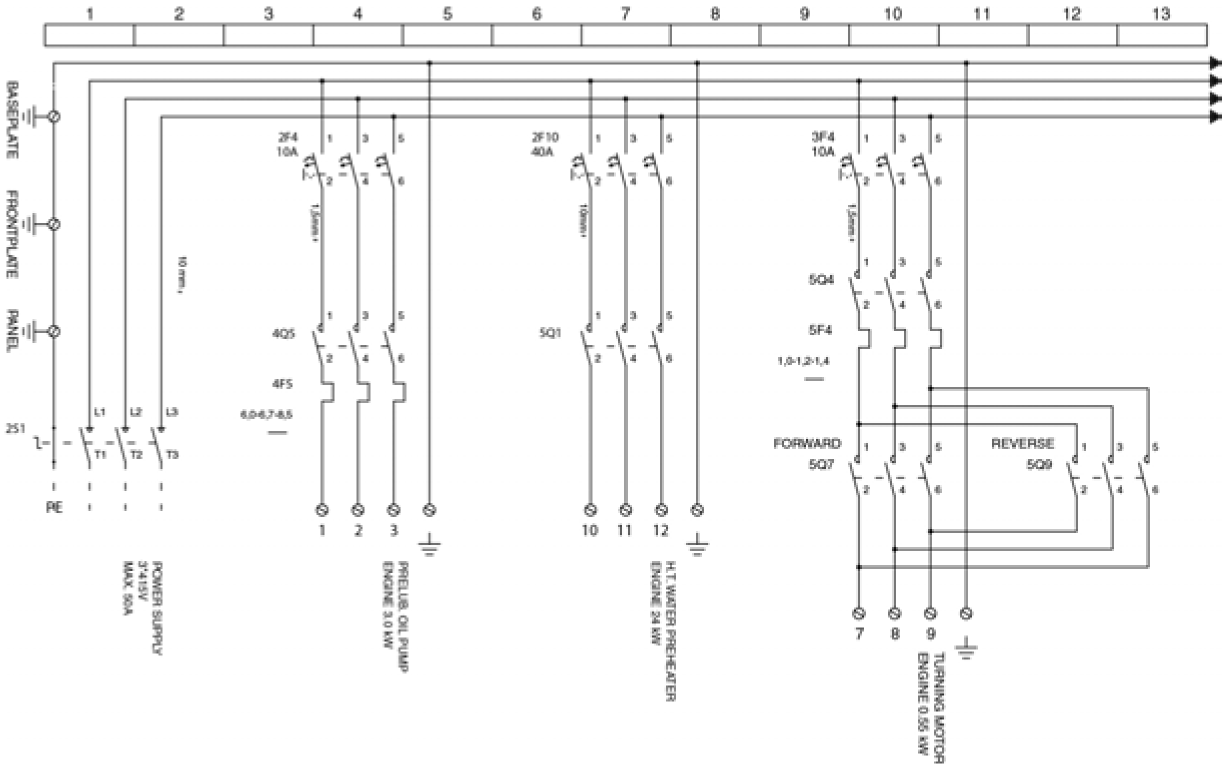


Figure 2: Wiring diagram

Prelubricating oil pump starting box

Description

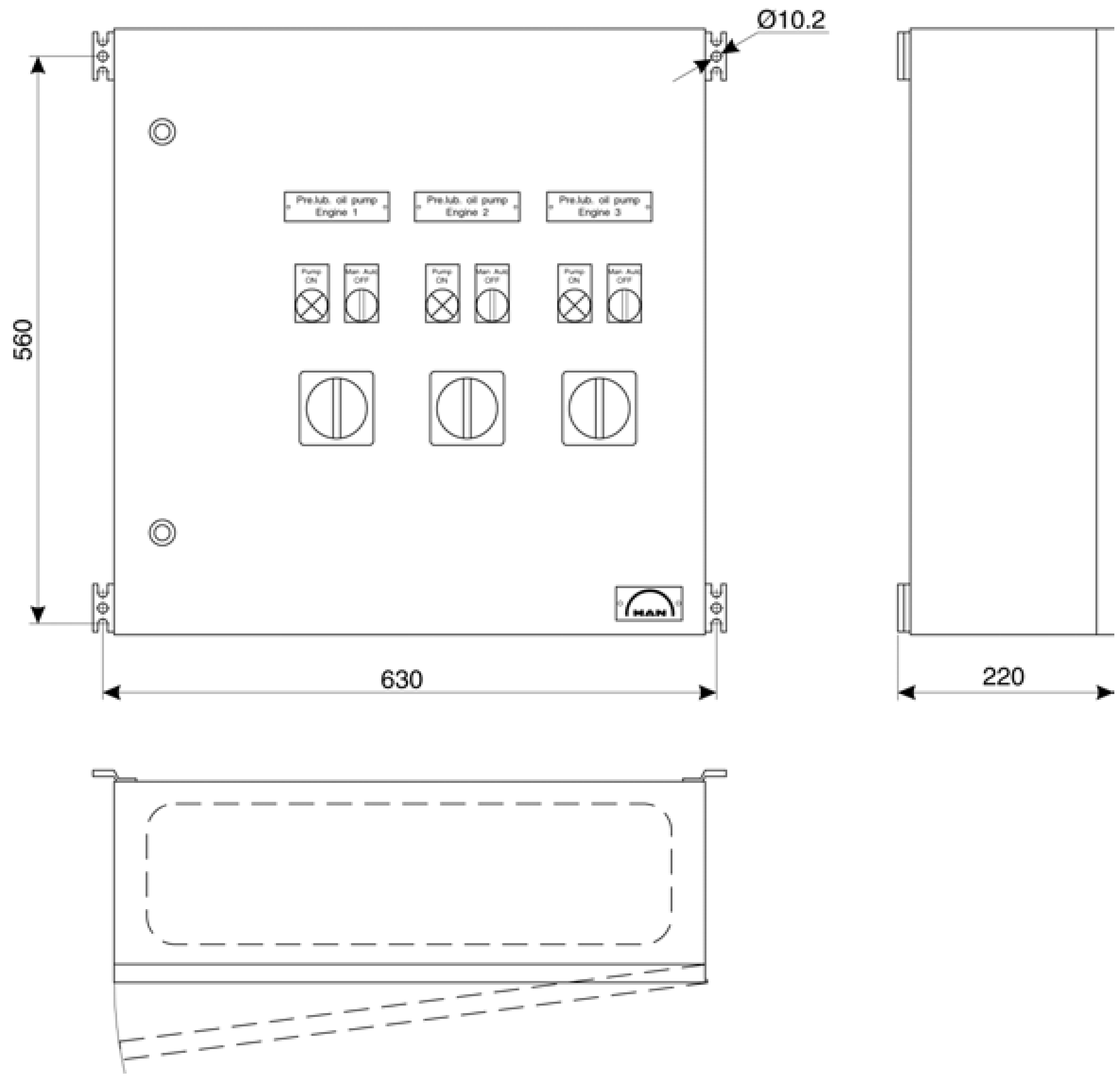


Figure 1: Dimensions.

The prelubricating oil pump box is for controlling the prelubricating oil pump built onto the engine.

The control box consists of a cabinet with starter, overload protection and control system. On the front of the cabinet there is a lamp for "pump on", a change-over switch for manual start and automatic start of the pump, furthermore there is a main switch.

The pump can be arranged for continuous or intermittent running. (For L16/24, L21/31 and L27/38 only continuous running is accepted).

Depending on the number of engines in the plant, the control box can be for one or several engines.

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The prelubricating oil pump starting box can be combined with the high temperature preheater control box. *See also B 12 07 0, Prelubricating Pump.*

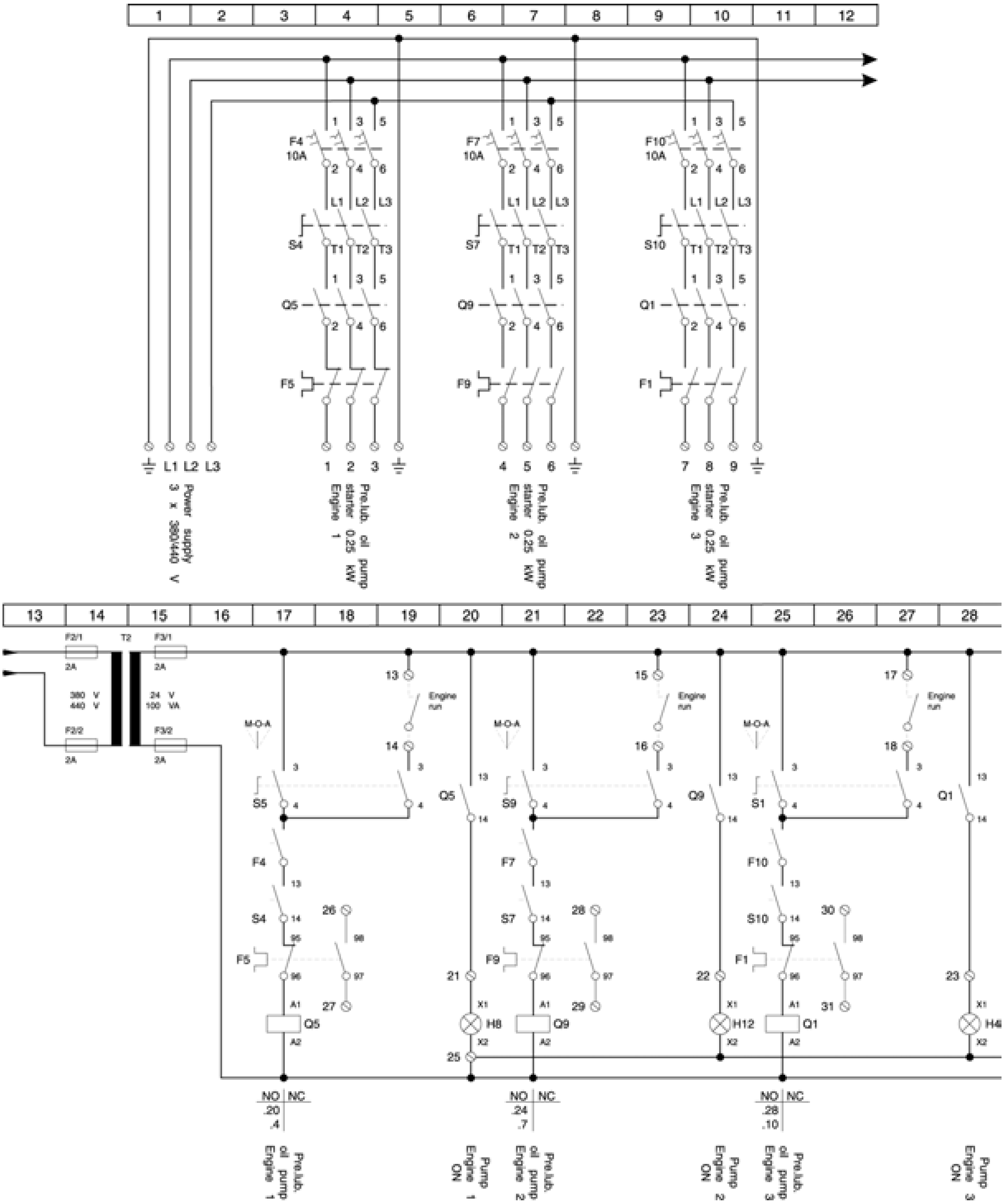

Figure 2: Wiring diagram.

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High temperature preheater control box

Description

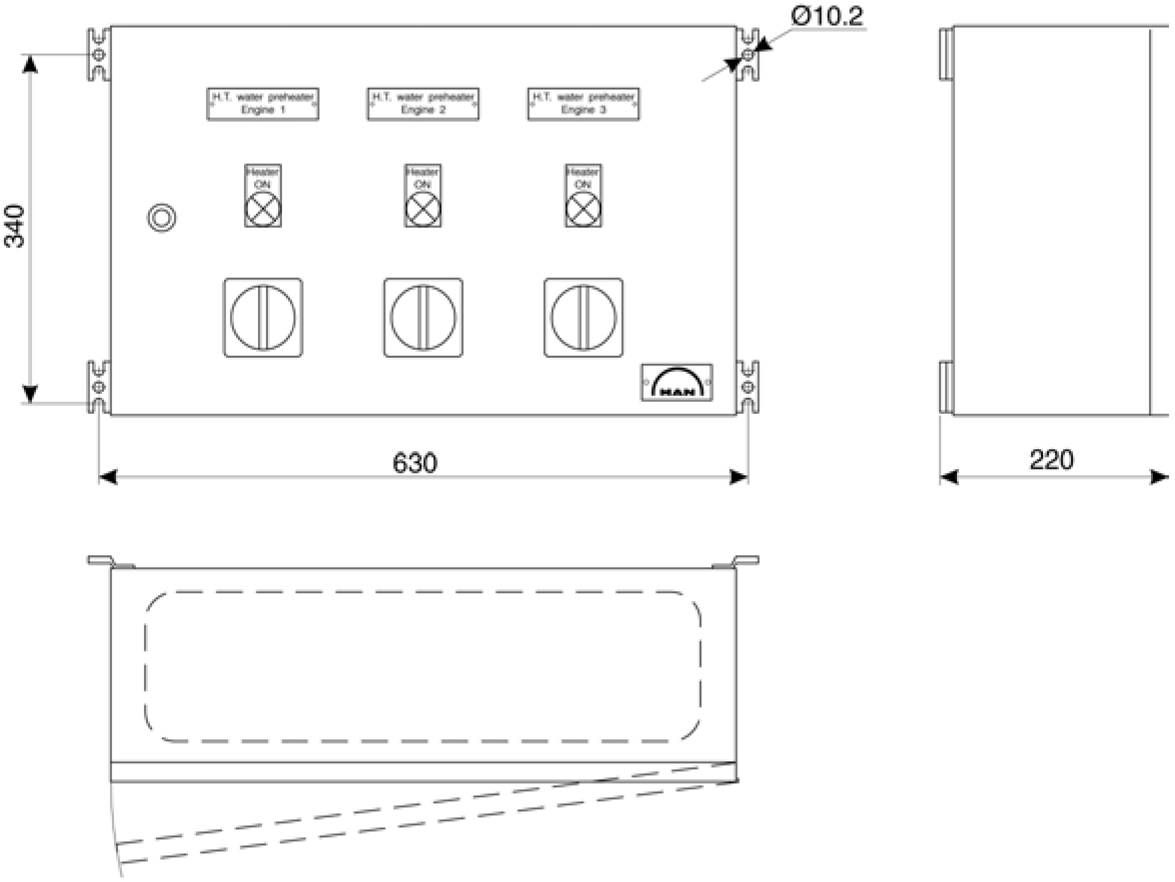

Figure 1: Dimensions of the control cabinet.

The preheater control box is for controlling the electric heater built onto the engine for preheating of the engines jacket cooling water during stand-still.

The control box consists of a cabinet with contactor and control system. On the front of the cabinet there is a lamp for "heater on" and a main switch for activating the system. Furthermore there is overload protection for the heater element.

The temperature is controlled by means of an on/off thermostat mounted in the common HT-outlet pipe. Furthermore the system secures that the heater is activated only when the engine is in stand-still.

Depending on the numbers of engines in the plant, the control box can be for one or several engines, however the dimensions of the cabinet will be the same. fig 1 illustrates a front for 3 engines.

The high temperature preheater control box can be combined with the pre-lubricating oil pump control box.

See also B 13 23 1 Preheating arrangement in high temperature system.

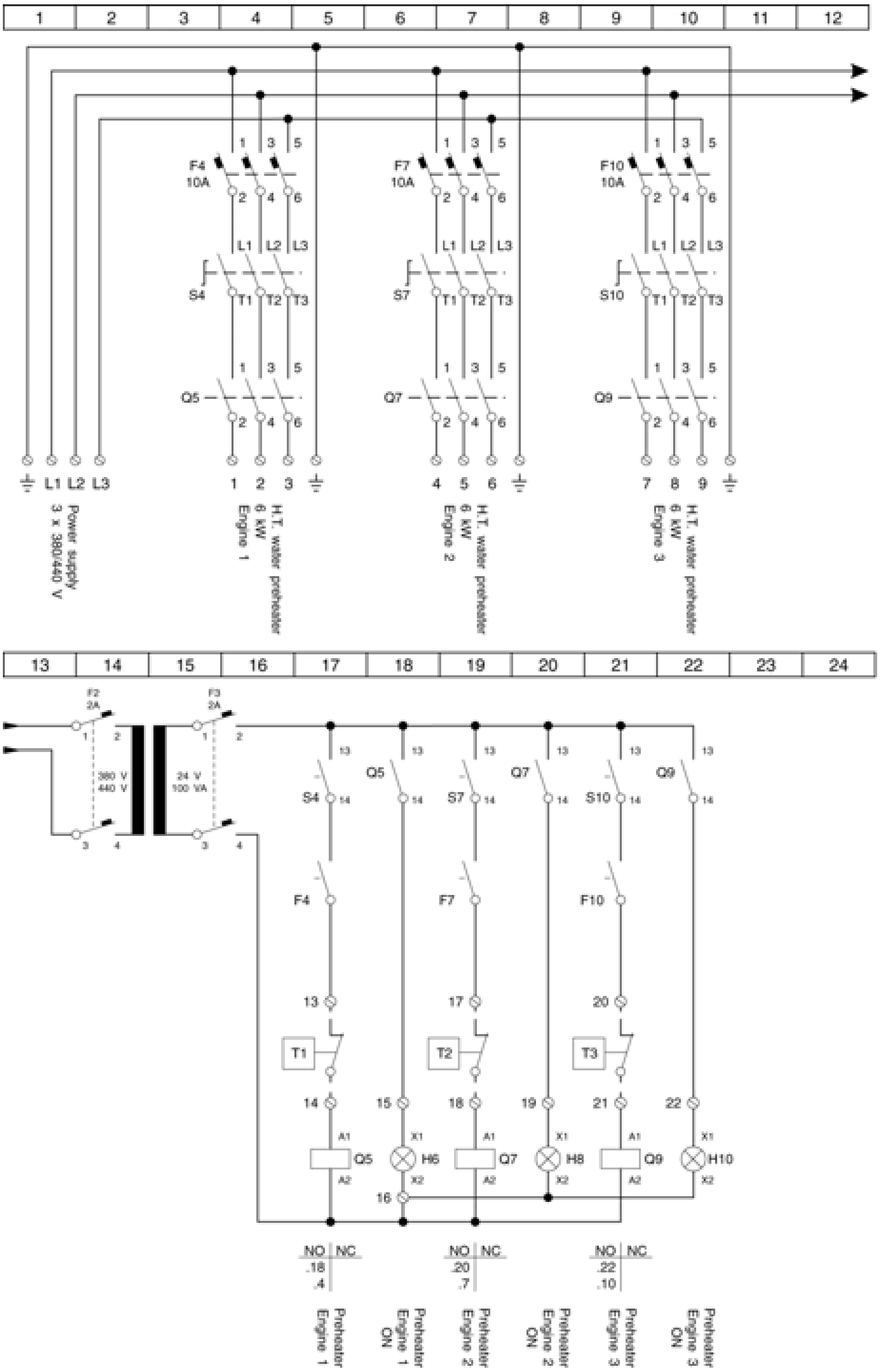

Figure 2: Wiring diagram.

Recommendations concerning steel foundations for resilient mounted GenSet

Foundation recommendations

Three point support (standard)

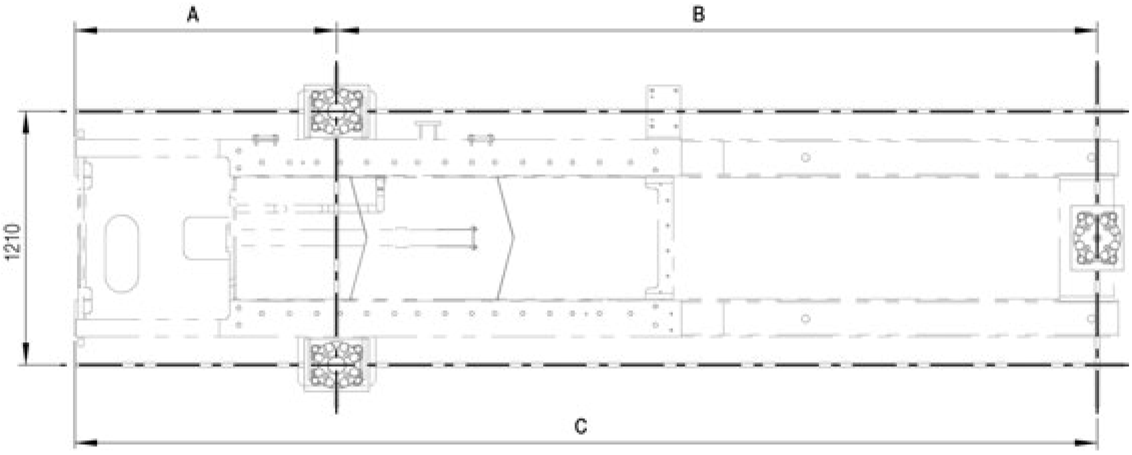

Figure 1: Resilient support

Engine	Front edge of base frame to first conical pair (A)	First conical pair to alternator conical (B)	Front edge of base frame to alternator conical (C)
5 cyl.	1246	3623	4869
6 cyl	1246	3993	5239
7 cyl	1246	4363	5609
8 cyl	1246	4733	5979

Table 1: Dimensions and distance between conicals

The strength and the stiffness of the deck structure must be based on the actual deck load, i.e. weight of machinery, tanks etc. and furthermore, resonance with the free forces and moments.

Each of the three supports carries approximately one third of the total weight of the GenSet.
An example of Standard GenSet weights can be found in MAN 'Marine Engine programme'
The loads for a specific GenSet /Alternator combination & situation can be calculated by MAN on request.

When the generating sets are installed on a transverse stiffened deck structure, it is generally recommended to strengthen the deck by a longitudinal stiffener in line with the resilient supports, see fig 1.

For longitudinal stiffened decks it is recommended to add transverse stiffening below the resilient supports. It is a general recommendation that the steel foundations are in line with both the supporting transverse and longitudinal deck structure.

Stiffness for foundation has to be minimum the following:

* Z-direction, stiffness for foundation has to be minimum 20 times the conical stiffness
* Y-direction, stiffness for foundation has to be minimum 10 times the conical stiffness

Example for conical stiffness:

* RD214-45 shore A to 65 shore A - stiffness 5.100 kN/m to 11.620 kN/m (preload 30 kN - 20 deg. C)

Four point support (optional)

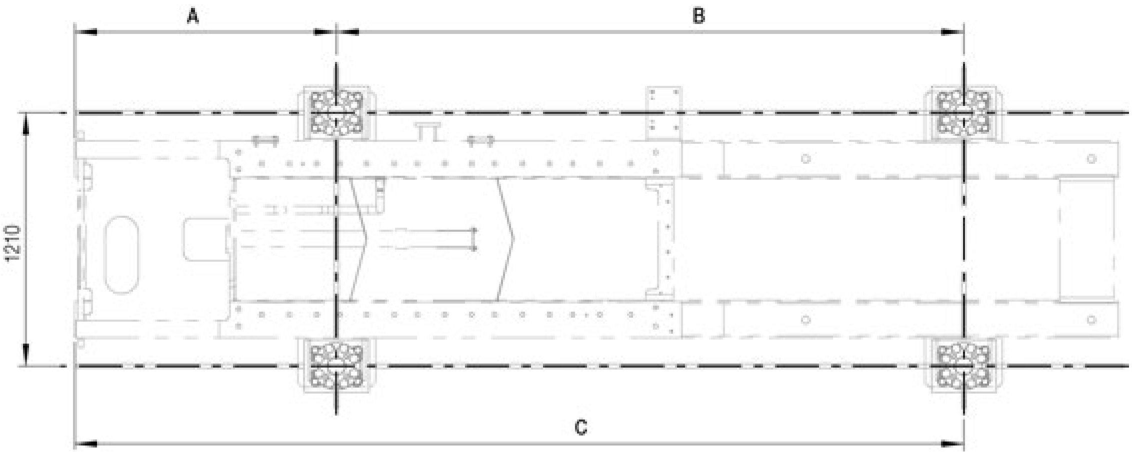

Figure 2: Resilient support

Engine	Front edge of base frame to first conical pair (A)	First conical pair to alternator conical pair (B)	Front edge of base frame to alternator conical pair (C)
5 cyl.	1241	2860	4101
6 cyl	1241	3230	4471
7 cyl	1241	3600	4841
8 cyl	1241	3970	5211

Table 2: Dimensions and distance between conicals

The same general considerations as for the three point supports apply for the four point support variant: The strength and the stiffness of the deck structure must be based on the actual deck load.

Each of the four supports carries approximately one quarter of the total weight of the GenSet.
An example of Standard GenSet weights can be found in MAN ‘Marine Engine programme’,
The loads for a specific GenSet /Alternator combination & situation can be calculated by MAN on request.

As for the three point support, additional stiffeners in the deck structure are generally recommended below the resilient supports, additional transvers stiffeners on a longitudinally stiffened deck & additional longitudinal stiffeners on a transversely stiffened deck.

A GenSet with four point support will require levelling, so that the resilient supports are evenly loaded. See B 20 01 3.

Note! The more flat & level the deck supports structure is the easier the levelling process will be.

Stiffness for foundation has to be minimum the following:

* Z-direction, stiffness for foundation has to be minimum 20 times the conical stiffness
* Y-direction, stiffness for foundation has to be minimum 10 times the conical stiffness

Example for conical stiffness:

* RD214-45 shore A to 65 shore A - stiffness 5.100 kN/m to 11.620 kN/m (preload 30 kN - 20 deg. C)

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Resilient mounting of generating sets

General

On resilient mounted generating sets, the diesel engine and the generator are placed on a common rigid base frame mounted on the ship's/erection hall's foundation by means of resilient supports.

All connections from the generating set to the external systems should be equipped with flexible connections, and pipes, gangway etc. must not be welded to the external part of the installation.

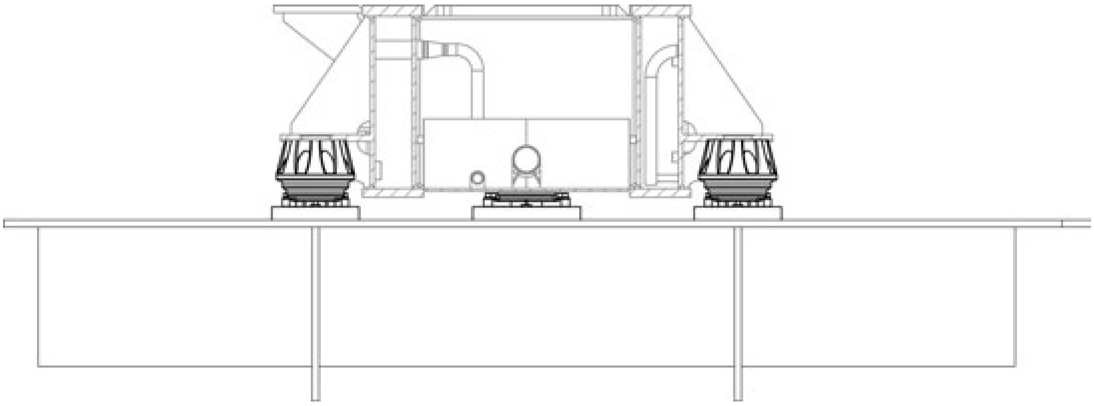

Figure 1: Support of conical

Resilient support

A resilient mounting of the ‘monocoque’ generating set is made with three conical mountings (optionally Four). Their placement depends on the size of the engine (number of cylinders).

These conical mountings are bolted to brackets on the base frame & bolted to ‘shim’ plates which can be welded to the deck. (see fig 1).
The conicals will yield elastically under load, this setting from unloaded to loaded condition is normally between 5-15 mm for the conical mounting. The exact setting can be determined by a calculation of the conical mountings for the plant in question.

After first loading the conicals will further settle over time (plastic deformation) the majority of this settling will take place in the first 48 hours of loading. We recommend that alignment & fitting is first finalized after 48 hours of load application to ensure that this settling has taken place.

For the ‘monocoque’ GenSet the support of the individual conical mounting is simplified compared to other MAN GenSets

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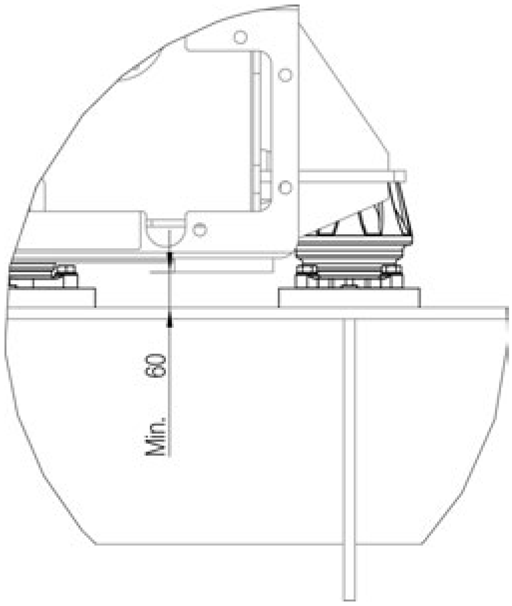

Figure 2: Resilient mounting of generating sets

The ‘monocoque’ GenSet can be placed directly on a flat deck, - if this is dimensioned to carry the load of the GenSet, - No extra support structure is required. The conicals can adjust to local small deflections (<5°) in the deck surface, and the three point support is self-levelling.
(The four point mounting will require levelling of the GenSet, so that all conicals are evenly loaded)

The support between the bottom flange of the conical and the foundation of the conical mounting is made with a loose steel shim. This steel shim is typically supplied already mounted on the conical, and the GenSet may be placed directly and the shim welded to the deck. If the GenSet must later be moved, or if the conical shall be replaced then it can then simply be unbolted from this shim, so that the mounting position is retained.

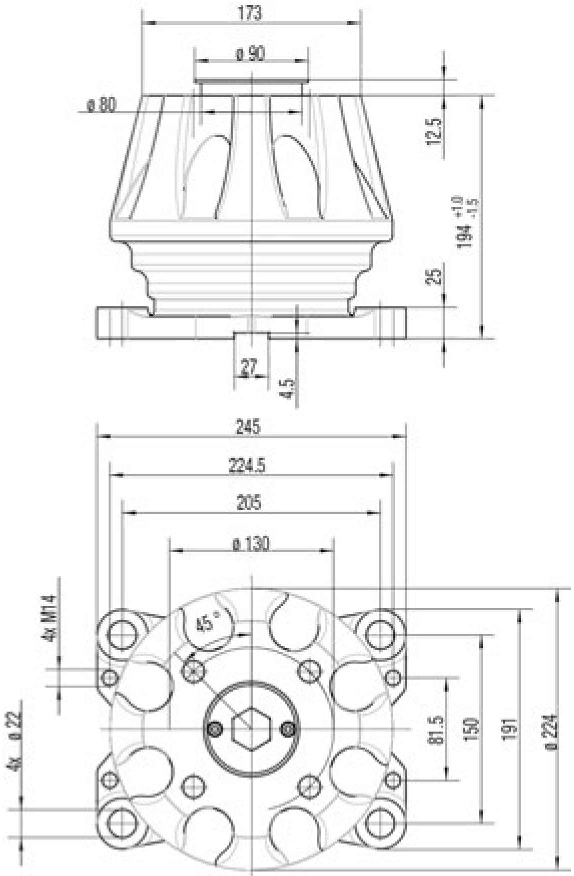

Figure 3: Conical mounting

Check of Crankshaft Deflection

The resiliently mounted generating set is normally delivered from the factory with engine and alternator mounted on the common base frame.
Even though engine and alternator have been adjusted by the engine builder, with the alternator rotor placed correctly in the stator and the crankshaft deflection of the engine (autolog) within the prescribed tolerances, it is recommended to check the crankshaft deflection (autolog) before starting up the GenSet.

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Shop test programme for marine GenSets

Requirement of the classification societies

Requirement of the classification societies	ABS	BV	DNV	GL	LR	RINA	NK	IACS	MAN ES programme
1) Starting attempts	X	X	-	X	X	X	X	X	X
2) Governor test (see page 2)	X	X	X	X	X	X	X	X	X
3) Test of safety and monitoring system	X	X	-	X	X	X	X	X	X
4) Load acceptance test (value in minutes)									

2020-07-01 - en

Engines driving alternators	Continuous rating (MCR)	Constant speed								
	100% 1*	60	60	M	60	60	60	120 2*	60	60
	110%	30	45	M	45	45	45	45 3*	30	45
	75%	M	M	M	M	M	M	30	M	30
	50%	M	M	M	M	M	M	30	M	30
	25%	M	M	-	M	M	M	-	M	30
	Idling = 0%	M	M	-	M	M	M	-	M	30
Engines driving alternators for electric propulsion	Continuous rating (MCR)	Constant speed								
	100% 1*	60	60	M	60	60	60	120 2*	60	60
	110%	30	45	M	45	45	45	45 3*	30	45
	90%	-	-	M	-	-	-	-	-	30
	75%	M	M	M	M	M	M	30	M	30
	50%	M	M	M	M	M	M	30	M	30
	25%	M	M	-	M	M	M	-	M	30
	Idling = 0%	M	M	-	M	M	M	-	M	30
5)	Verification of GenSet parallel running, if possible (cos Φ = 1, unless otherwise stated)									
6a)	Crankshaft deflection measurement of engines with rigid coupling in both cold and warm condition									
6b)	Crankshaft deflection measurement of engines with flexible coupling only in cold condition									
7)	Inspection of lubricating oil filter cartridges of each engine									
8)	General inspection									

1*	Two service recordings at an interval of 30 minutes.
2*	According to agreement with NK the running time can be reduced to 60 minutes.
3*	According to agreement with NK the running time can be reduced to 30 minutes.
M	Measurement at steady state condition of all engine parameters.
IACS	International Association of Classification Societies.

The operating values to be measured and recorded during the acceptance test have been specified in accordance with ISO 3046-1:2002 and with the rules of the classification societies.

The operation values are to be confirmed by the customer or his representative and the person responsible for the acceptance test by their signature on the test report. After the acceptance test components will be checked so far it is possible without dismantling. Dismantling of components is carried out on the customer's or his representative's request.

GenSet load responce
Load application for ship electrical systems

In the age of highly turbocharged diesel engines, building rules of classification societies regarding load application (e.g. 0 % => 50 % => 100 %) cannot be complied with, in all cases. However the requirements of the International Association of Classification Societies (IACS) and ISO 8528-5 are realistic. In the case of ship´s engines the application of IACS requirements has to be clarified with the respective classification society as well as with the shipyard and the owner. Therefore the IACS requirements has been established as generel rule.

For applications from 0 % to 100 % continuous rating, according to IACS and ISO 8528-5, the following diagram is applied:

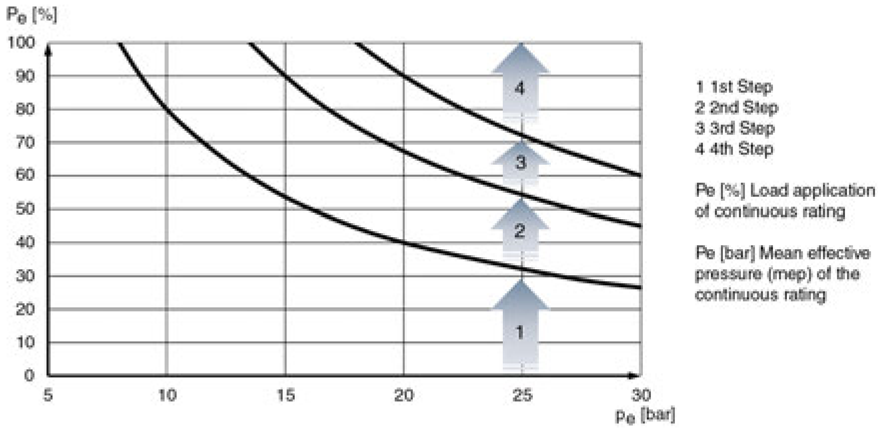


Fig. 1 Load application in steps as per IACS and ISO 8528-5.

According to the diagram in Fig. 1 the maximum allowable load application steps are defined in the table below. (24.4 bar mean effective pressure has been determined as a mean value for the listed engine types.)

Note: Our small bore GenSets has normally a better load responce than required by IACS and therefore a standard load responce test where three load steps (3 x 33%) is applied will be demostrated at factory acceptance test.

Minimum requirements concerning dynamic speed drop, remaining speed variation and recovery time during load application are listed below.

In case of a load drop of 100 % nominal engine power, the dynamical speed variation must not exceed 10 % of the nominal speed and the remaining speed variation must not surpass 5 % of the nominal speed.

Engine	bmep (bar) *	1 st step	2nd step	3th step	4th step
L23/30DF, Diesel	18.2 - 18.1 - 17.9	IACS 33% MDT 34%	IACS 23% MDT 33%	IACS 18% MDT 33%	IACS 26%
L28/32DF, Diesel	17.8 - 17.9				
L23/30DF, Gas	15	0-25%	25-50%	50-75%	75-100%
L28/32DF, Gas					
* see project guide B 10 01 1 'main particulars', for actual bmep at nominel rpm.					

Fig. 2. maximum allowable load application steps (higher load steps than listed are not possible as a standard)

Regulating test and load responce performance in Dual Fuel mode

Load step on MAN Energy Solutions GenSets is to be tested according to following procedure.

Classification society in Diesel mode	Dynamic speed drop in % of the nominal speed	Remaining speed variation in % of the nominal speed	Recovery time until reaching the tolerance band ±1 % of nominal speed
Germanischer Lloyd	≤ 10 %	≤ 5 %	≤ 5 sec.
RINA			
Lloyd´s Register			
American Bureau of Shipping			
Bureau Veritas			
Det Norske Veritas			
ISO 8528-5			

Fig. 3a Minimum requirements of the classification societies plus ISO rule.

Momentum speed variation (m) must not vary more than 10% max. deviation from steady speed 1 %. Permanent speed variation (p) must not be higher than 5%.

Classification society	Dynamic speed drop in % of the nominal speed	Remaining speed variation in % of the nominal speed	Recovery time until reaching the tolerance band ±1½ % of nominal speed
In Dual Fuel mode	≤ 10 %	≤ 5 %	10 sec.

Fig. 3b Minimum requirements of the classification societies plus ISO rule.

Momentum speed variation (m) must not vary more than 10% max. deviation from steady speed. Permanent speed variation (p) must not be higher than 5%. Recovery time not to exceed 10 sec. until speed reached 1½ % of static speed.

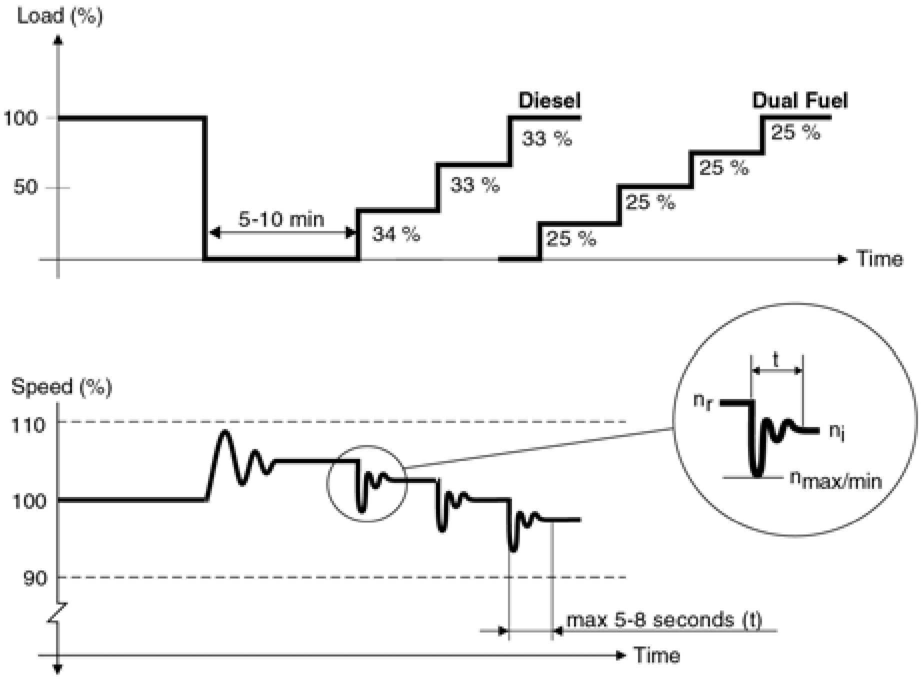


Fig. 4 Minimum requirements of the classification societies plus ISO rule.

bmep: Must be found in product guide. For most classification sociaties 3 x 33% load application will be accepted. *Actual classification society rules must be observed.*

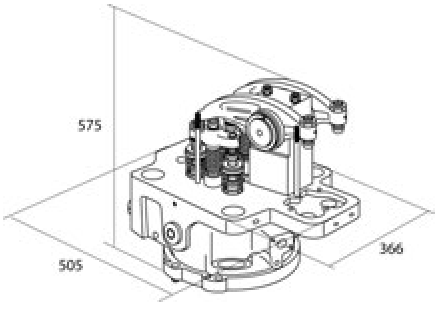
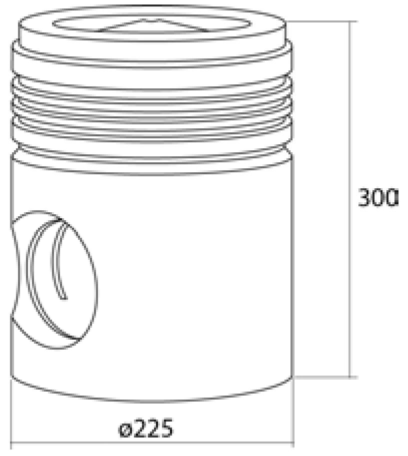
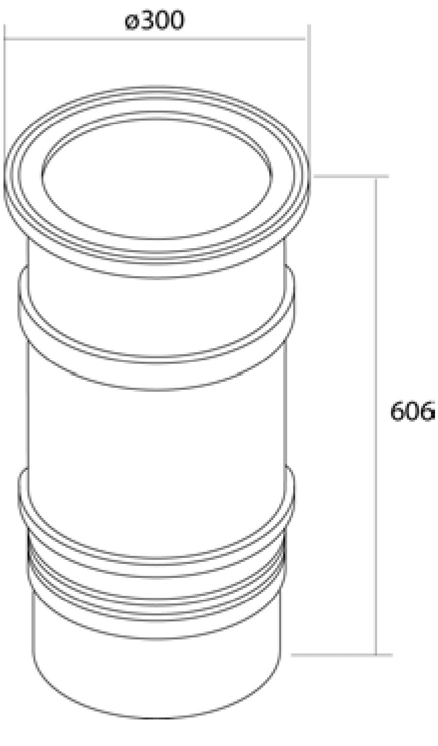
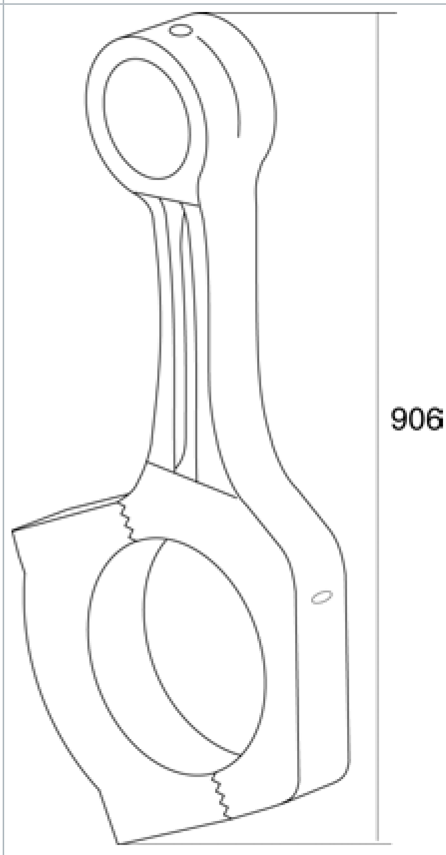
Speed droop: _____, Needle valve open: ______°

$$m = \frac{n_{max/min} - n_r}{n_r} \times 100 \qquad p = \frac{n_i - n_r}{n_r} \times 100$$

Load (%)	(n_r) Rated speed [Hz]	($n_{max/min}$) Momentum speed [Hz]	(n_i) Permanent speed [Hz]	(m) Momentum speed variation [%]	(p) Permanent speed variation [%]	(t) Time to steady speed [sec]
Diesel						
0 - 34						
34 - 67						
67 - 100						
Dual Fuel *0-25 Dual fuel mode covered by 0-34 mode.*						
25-50						
50-75						
75-100						

According to IACS requirements and ISO 8528-5.

Weight and dimensions of principal parts

	
Cylinder head approx.130 kg Cylinder head incl. rocker arms approx. 180 kg	Piston approx. 23 kg
	
Cylinder liner approx. 75 kg	Connecting rod approx. 41 kg

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Spare parts for unrestricted service

General

Spare parts for unrestricted service, according to the classification societies requirements/recommendations and/or MAN Energy Solutions standard.

Cylinder head

Description	Plates	Item	Qty.
Gasket Sealing ring inlet bend - Non glued Valve seat ring, inlet Valve seat ring, exhaust O-ring for cooling water connection O-ring O-ring	P50501	003 004 064 076 184 351 338	1 1 2 4 2 6 2
Conical ring in 2/2 Rotocap, complete Spring, inner Spring, outer Valve spindles, inlet Valve spindles, exhaust	P50502	465 477 489 490 512 597	6 4 6 6 2 4
Gasket, top cover	P50510	075	1

Piston, connecting rod and cylinder liner

Description	Plates	Item	Qty.
Piston pin Retaining ring	P50602	002 004	1 2
Bush for connecting rod Screw for connecting rod Nut	P50603	104 141 153	1 2 2
Connecting rod bearing	P50604	003	1
Piston ring Piston ring Piston ring Oil scraper ring	P50605	093 103 115 127	1 1 1 1
Sealing ring O-ring cylinder liner	P50610	031 043	1 2

Operating gear for valves and fuel injection pumps

Description	Plates	Item	Qty.
Sealing ring	P50801	185	4

Engine frame and base frame

Description	Plates	Item	Qty.
Main bearing shells Thrust washer Stud Nut	P51101	157 253 169 170	1 2 2 2
O-ring (safety valve) O-ring	P51106	740 058	2 2

Turbocharger system

Description	Plates	Item	Qty.
Gasket O-ring Gasket	P51202	002 110 111	1 2 1

Fuel oil system and injection equipment

Description	Plates	Item	Qty.
Fuel injection pump	P51401	057	1
Fuel injection valve	P51402	177	4
Fuel oil high-pressure pipe	P51404	010	1
Gasket, coaming Gas injection valve O-ring O-ring	P51480	003 007 074 075	1 4 4 8

Notice

Scope of this list are subject to change and therefore the latest version of this document should always be used, please see MAN Energy Solutions homepage or Extranet.
Spare parts listed may also vary if optional components are selected.

NOTICE

Please notice that the content of spare parts for specific projects may vary from the list of standard spare parts.

Introduction to spare part plates for tools

Description

For our GenSets the following three tool packages are available:

Standard tool for normal maintenance
This package is delivered as standard, this tool package do consist of a mix of special designed tools as well as ordinary available tools needed in connection with the operation of the engine and to perform daily engine maintenance. The tool do as well consists of tools to perform emergency repair as required by the various classification societies.

Additional tools
This tool package can only be ordered as single parts from the list in addition to the standard tool package. The tool package consists of special tools needed in addition to the standard tool in case a major overhaul or a part of this is to be carried out.

Hand Tools
This tool package can be ordered as a whole or partly in addition to the standard tool package. The tool package consists of ordinary hand tools needed in addition to the delivered standard tool for normal maintenance, in connection with the daily maintenance as well as major overhauls.

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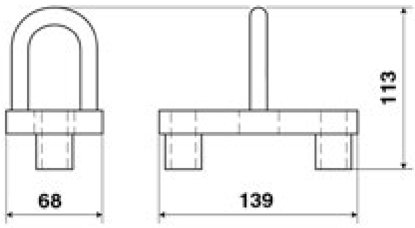
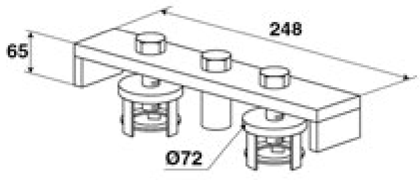
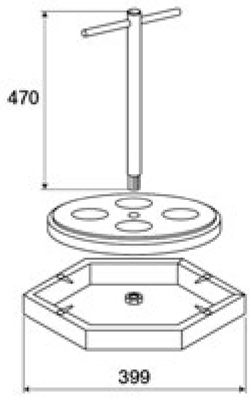
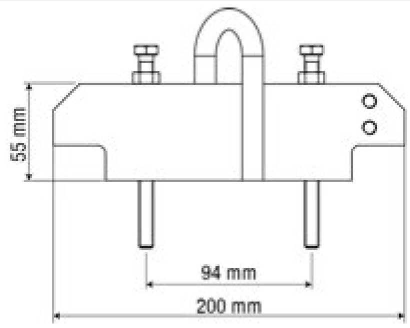
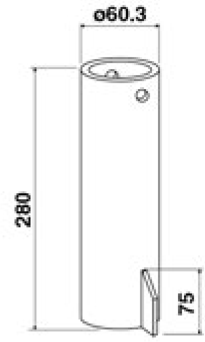
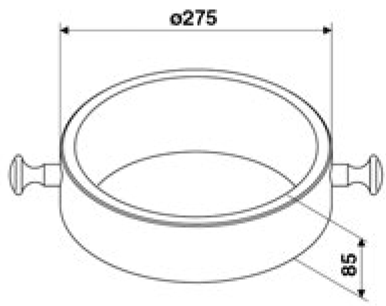
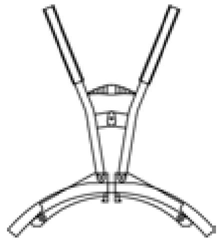
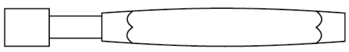
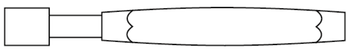
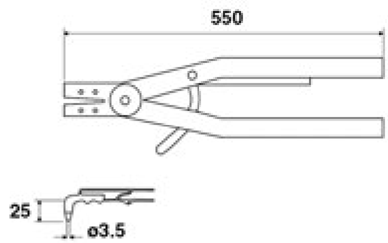
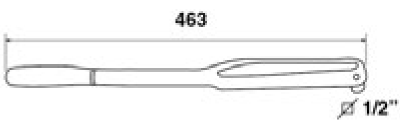
Standard tools for normal maintenance

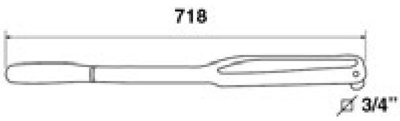
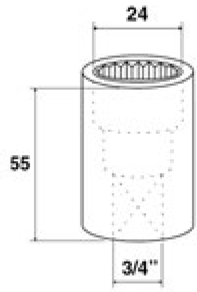
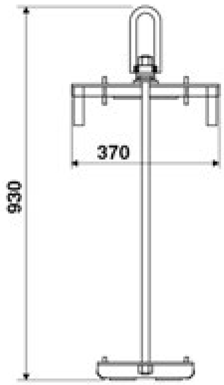
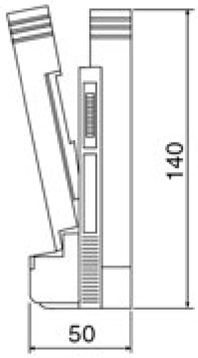
Cylinder head

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Lifting tool for cylinder head, complete			1	014
Mounting tool for valves, complete			1	051
Grinding tool for cylinder head and cylinder liner			1	205

Piston, connecting rod and cylinder liner

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Suspension tool for piston			1	024

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Back stop for cylinder liner, 2 pcs			1	094
Guide ring for mounting of piston			1	117
Piston ring opener			1	141
Testing mandrel for piston ring grooves, 4.43 mm			1	153
Testing mandrel for scraper ring grooves, 7.43 mm			1	165
Plier for piston pin lock ring			1	200
Torque spanner, 20-120 Nm			1	261

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Torque spanner, 80-360 Nm			1	273
Socket			1	381
Lifting tool for cylinder liner			1	452
Magnifier (30x)			1	559

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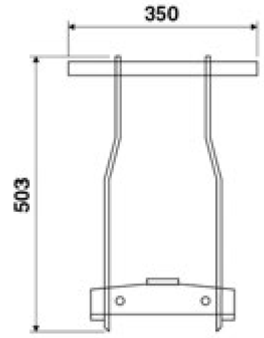
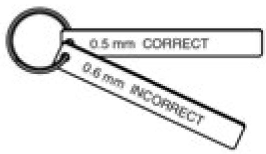
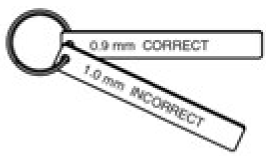
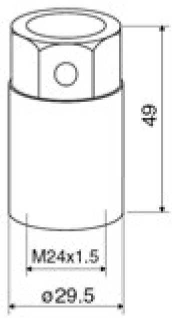
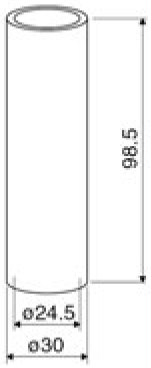
Standard tools for normal maintenance

Description

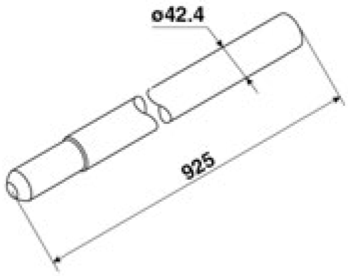
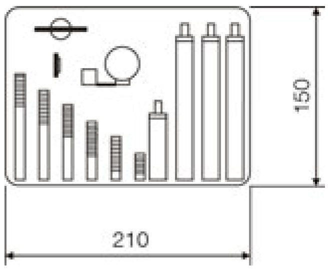
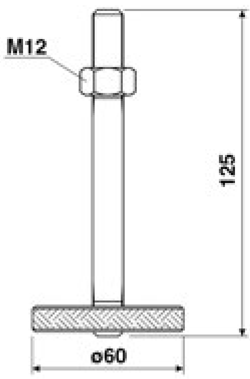
Name	Sketch	Supply per ship		Item no
		Working	Spare	
Grinding tool for cylinder liner			1	655

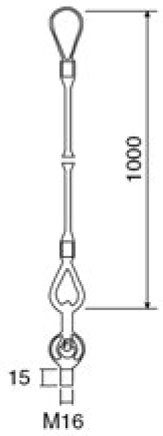
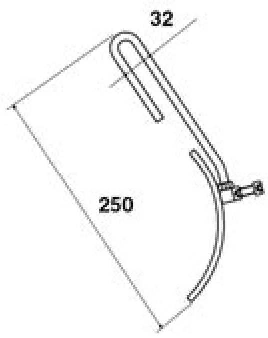
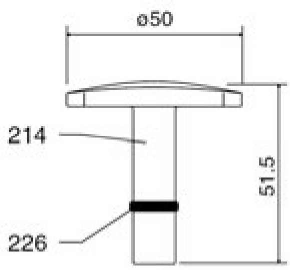
Operating gear for inlet valves, exhaust valves and fuel injection pumps

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Feeler gauge for inlet valves (2 pcs)			1	010
Feeler gauge for exhaust valves (2 pcs)			1	022
Extractor for thrust piece on roller guide for fuel pump			1	058

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Distance piece			1	071

Crankshaft and main bearing

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Turning rod			1	012
Crankshaft alignment gauge (autolog)			1	059
Dismantling tool for main bearing, 2 pieces			1	106

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Lifting straps for main and guide bearing cap, 2 pieces			1	156
Dismantling tool for guide bear-ing shells			1	220
Tool for upper main bearing O-ring			1 1	214 226

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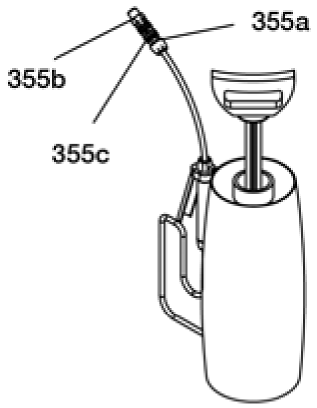
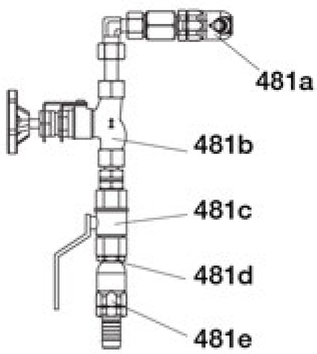
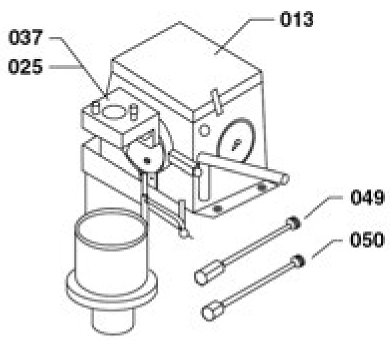
Turbocharger system

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Container complete for water washing of compressor side Reducing piece Fitting Fitting			1	355 355a 355b 355c
Water washing of turbine side, complete Snap coupling Regulating valve Ball valve Snap coupling Snap coupling			1	481 481a 481b 481c 481d 481e

Fuel oil system and injection equipment

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Pressure testing pump, complete Clamping bracket for fuel injector Clamping bracket for fuel injection pump Fuel pipe Fuel pipe			1 1 1 1 1	013 025 037 049 050

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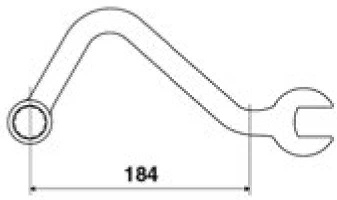
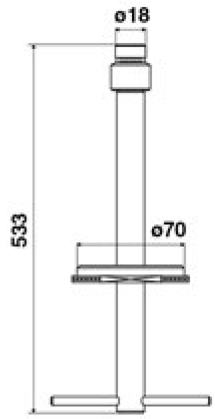
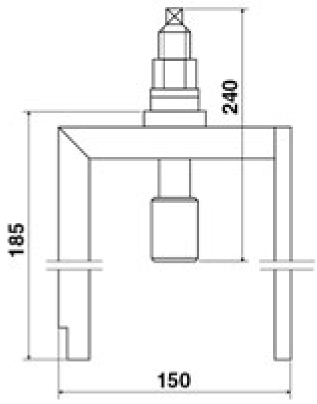
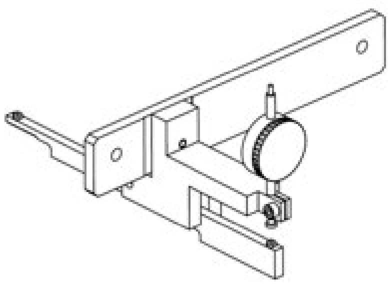
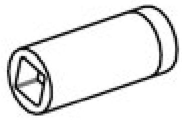
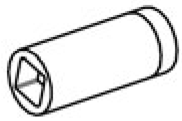
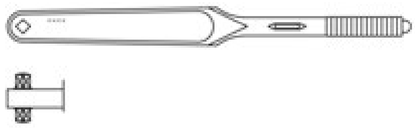
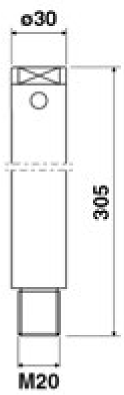
Standard tools for normal maintenance

Description

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Spanner for fuel injection pump			1	204
Grinding tool for seat for fuel injection valve			1	361
Extractor for fuel injector valve			1	407
Measuring device for plunger lift			1	420
Wrench 1/2" for high pressure pipe 24 mm 27 mm			 1 1	 838a 838b

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Long socket spanner 1/2" 24 mm				843
Long socket spanner 1/2" 27 mm				855
Torque spanner 1/2" 50-300 Nm				902

Lubricating oil system

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Guide bar for dismantling of lubricating oil cooler			1	019

Hydraulic tools

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Hydraulic tools complete consisting of the following boxes:				806

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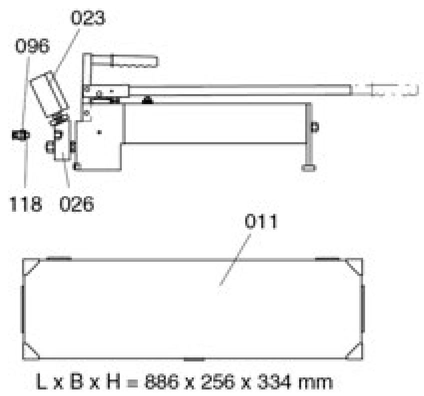
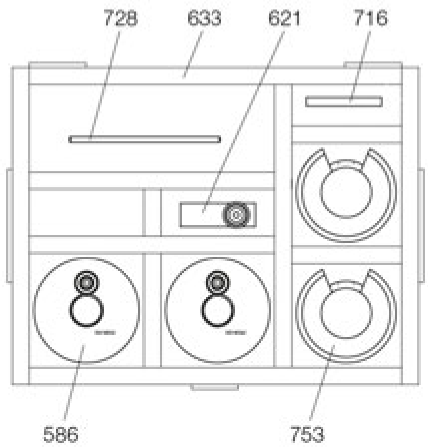
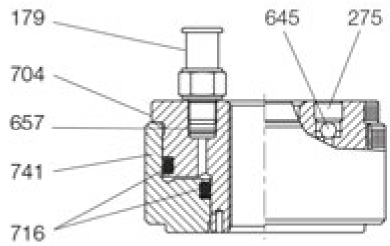
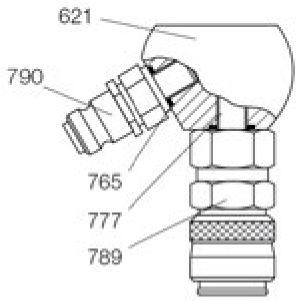
Standard tools for normal maintenance

Description

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Pressure pump, complete with wooden box, incl item 023, 118, 096, 026			1	011
Manometer			1	023
Gasket for item 096			1	118
Quick coupling			1	096
Distributor			1	026
Hydraulic tools for connecting rod with wooden box, complete			1	633
Quick coupling			1	179
Venting screw			1	275
Ball			1	645
Disc			1	657
Piston for hydraulic jack			1	704
Set of O-rings with back-up ring			2	716
Adjusting rod			1	728
Cylinder for hydraulic jack			1	741
Hydraulic jack as item nos 179, 275, 645, 657, 704, 716, 728, 741, 753			2	586
Spacer piece			2	753
Angle piece complete, incl item 765, 777, 789, 790			2	621
O-ring			1	765
Adapter			1	777
Coupling socket			1	789
Quick coupling			1	790

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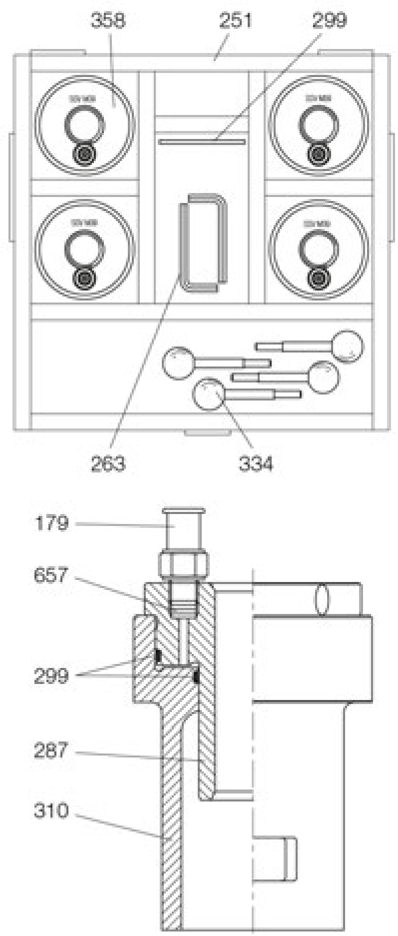
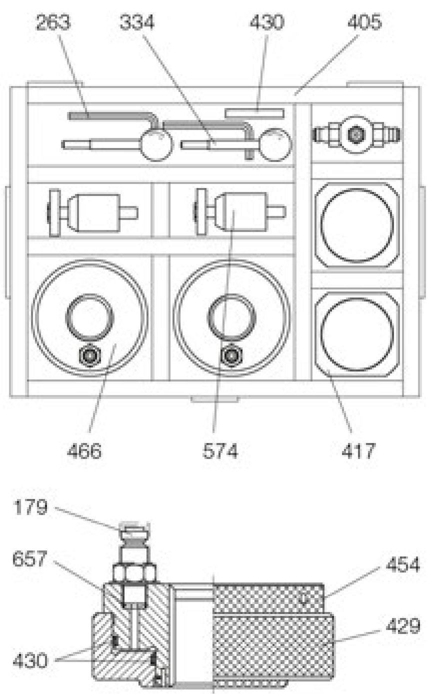
Name	Sketch	Supply per ship		Item no
		Working	Spare	
Hydraulic tools for cylinder head with wooden box, complete			1	251
Quick coupling			1	179
Allen key, 7 mm			2	263
Venting screw			1	275
Ball			1	645
Piston for hydraulic jack			1	287
Set of O-rings with back-up ring			2	299
Cylinder for hydraulic jack			1	310
Tommy bar			4	334
Hydraulic jack as item nos 179, 275, 287, 299, 309, 310, 645, 657, 812			4	358
Disc			1	657
Hydraulic tools for main bearings with wooden box, complete			1	405
Quick coupling			1	179
Allen key, 7 mm			2	263
Venting screw			1	275
Tommy bar			2	334
Ball			1	645
Disc			1	657
Spacer piece			2	417
Cylinder for hydraulic jack			1	429
Set of O-ring with back-up ring			1	430
Piston for hydraulic jack			1	454
Hydraulic jack as item 179, 275, 429, 430, 454, 645, 657, 824			1	466
Guide			1	574

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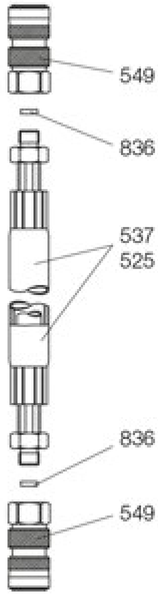
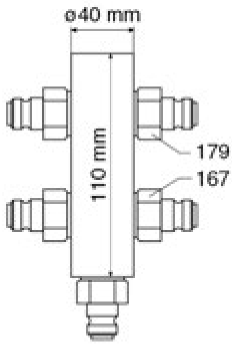
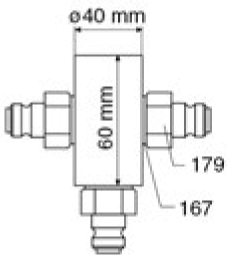
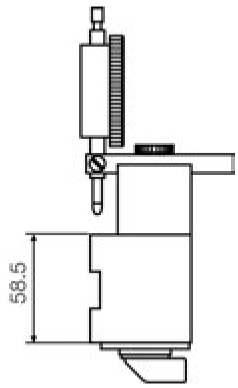
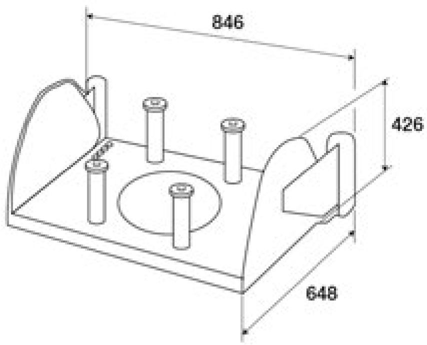
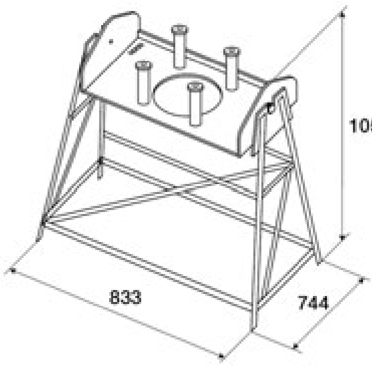
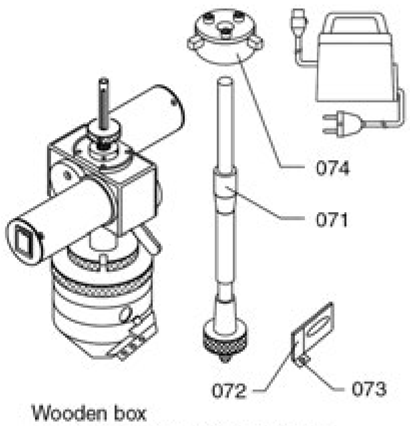
Name	Sketch	Supply per ship		Item no
		Working	Spare	
Hose for hydraulic tools complete (1000 mm), 4 pieces			4	501
Hose for hydraulic tools complete (3000 mm), 1 piece			1	513
Hose (3000 mm)			1	537
Quick coupling with protecting cap			1	549
Hose (1000 mm)			1	525
Disc			1	836
Distributing piece for cylinder head, complete			1	155
Gasket			1	167
Quick coupling			1	179
Distributing piece for main bearing, complete			1	202
Gasket			1	167
Quick coupling			1	179
Measuring device (not a part of Hydraulic tools complete, to be ordered separately)			2	533

Additional tools

Cylinder head

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Grinding table for cylinder head with bracket for wall mounting, complete			1	254
Grinding table for cylinder head with frame for floor mounting, complete			1	301
Grinding machine for valve seat rings Mandrel Cutting tool Carbide cutting insert Supporting spider			1 1 1 1 1	070 071 072 073 074

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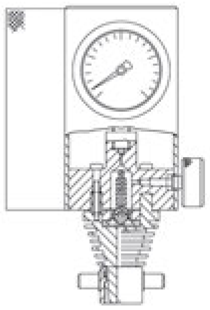
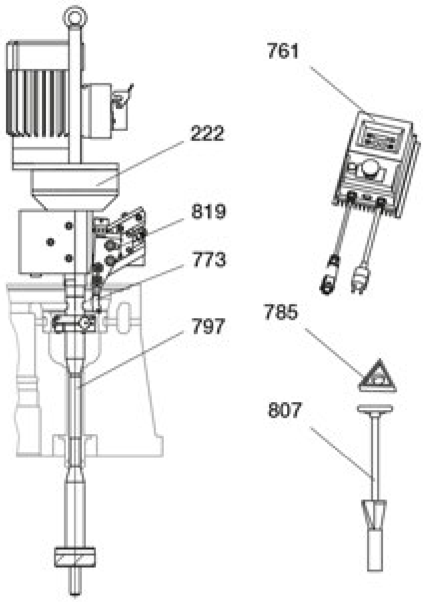
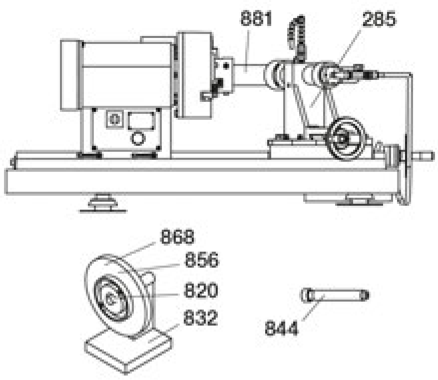
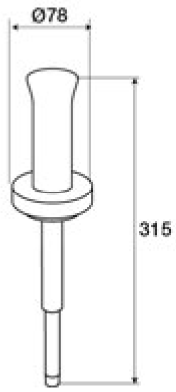
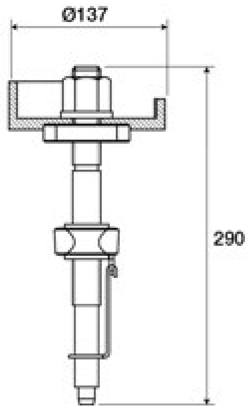
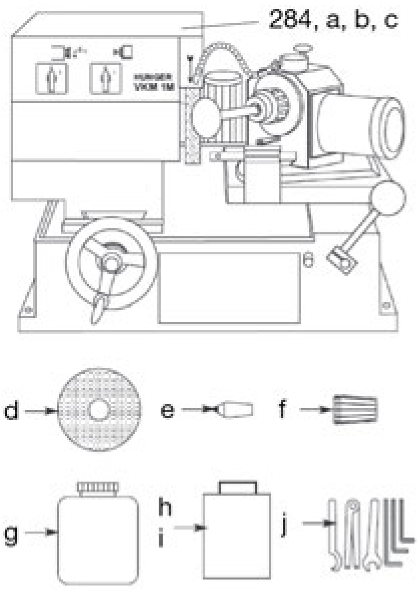
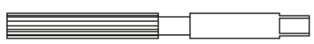
Name	Sketch	Supply per ship		Item no
		Working	Spare	
Max. pressure indicator			1	109
Grinding machine for valve seat rings Frequence converter Tool holder Turning bit Pilot spindle incl. stabilizer Cleaning tool Tool holder bracket			1 1 1 1 1 1 1	222 761 773 785 797 807 819
Grinding machine for valve spindle, complete Grinding wheel hub Balancing apparatus Grinding wheel dresser Grinding wheel, grain size 46 Grinding wheel, grain size 80 Stabilizer (valve stem ø10-18 mm)			1 1 1 1 1 1 1	285 820 832 844 856 868 881

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Mounting tool for valve seat ring, complete			1	457
Extractor for valve seat ring, complete			1	504
Mandrel for dismounting of valve guide			1	060
Grinding tool for valves				
230V 3P			1	284
400V 3P			1	284a
480V 3P			1	284b
690V 3P			1	284c
Grinding wheel			1	284d
Diamond dresser			1	284e
Collet R16			1	284f
Concentrated coolant			1	284g
Transformer				
480/400V			1	284h
690/400V			1	284i
Servicing tools			1	284j
Reamer for valve guide			1	748

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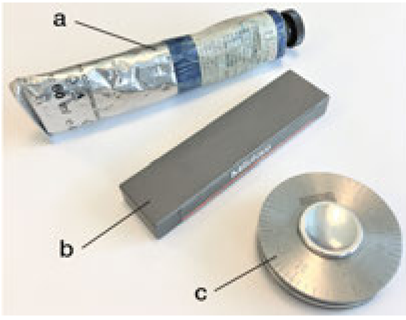
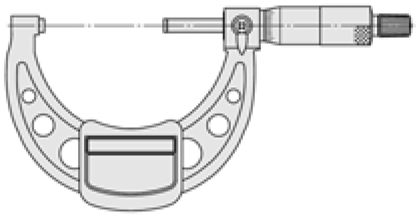
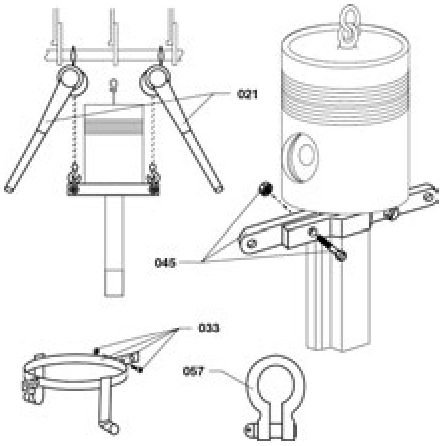
Piston, connecting rod and cylinder liner

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Ridge wear kit, complete Engineering blue Black stone Layer thickness gauge			1 1 1 1	018 018a 018b 018c
Outside micrometer			1	019
Tools for low overhaul height of piston, connecting rod and cyl-inder liner Pull lift Lifting tool for cylinder liner Collar for connecting rod Shackle			1 1 1 1 1	655 021 033 045 057
Pneumatic impact spanner			1	415
Inside micrometer (cylinder liner): measuring range 225-250 mm			1	618

Additional tools

Description

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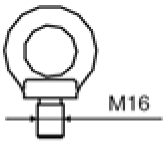
Name	Sketch	Supply per ship		Item no
		Working	Spare	
Inside micrometer (connecting rod): measuring range 175-200 mm			1	631

Crankshaft and main bearings

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Eye screw for lifting of tuning wheel			1	667

Turbocharger system

Name	Sketch	Supply per ship Working	Spare	Item no
Differential pressure tools complete Hose Nipple Nipple			1 1 2 2	915 915a 915b 915c

Compressed air system

Name	Sketch	Supply per ship Working	Spare	Item no
Set of tools, TDI air starter T50			1	928

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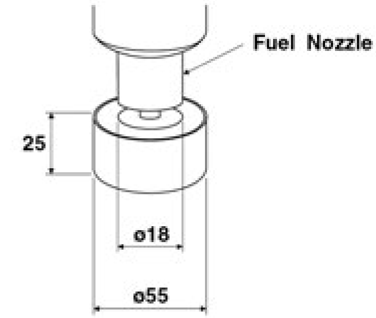
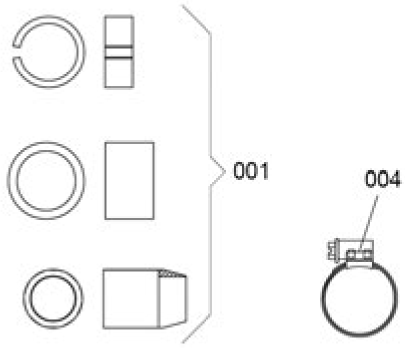
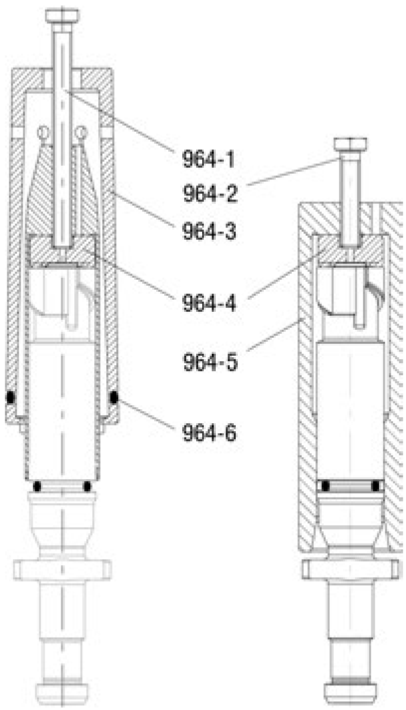
Fuel oil system and injection equipment

Name	Sketch	Supply per ship Working	Spare	Item no
Grinding tool for fuel injection valve			1	300
Tools for fuel injection pump, complete consisting of the following: Calibration ring, pushing device, guide device Hose clamps			1	037 001 004
Mounting tool for seals, plunger complete (only sealed plunger/ barrel) Screw Screw Mounting tool Mounting tool Mounting tool O-ring			1	964 964-1 964-2 964-3 964-4 964-5 964-6

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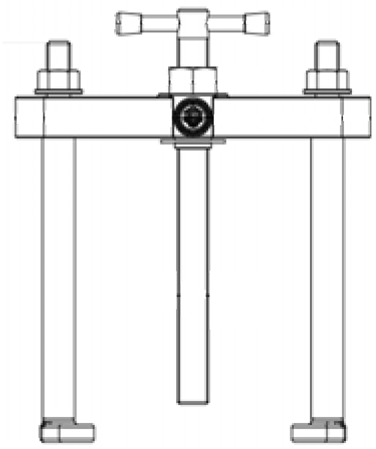
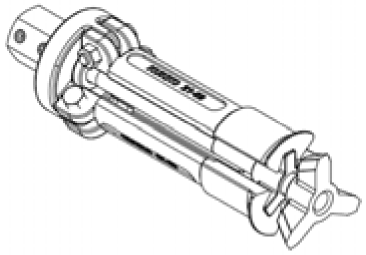
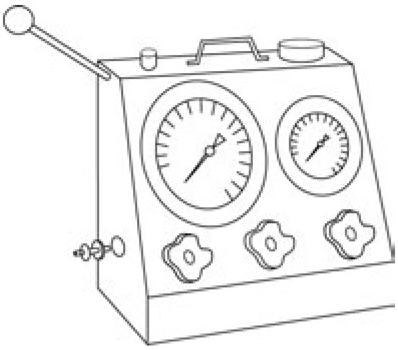
Additional tools

Description

Name	Sketch	Supply per ship Working	Spare	Item no
Extractor for bush, sogav valve			1	976
Extractor for bush, sogav valve			1	977

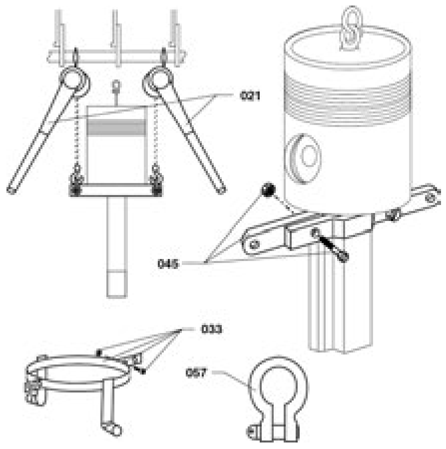
Hydraulic tools

Name	Sketch	Supply per ship Working	Spare	Item no
Air driven high pressure pump for hydraulic tools			1	608

Name	Sketch	Supply per ship Working	Spare	Item no
Remote controlled unit for hydraulic bolt tensioning			1	939

Extra tools for low dismantling height

Description

Name	Sketch	Qty	Plate	Item no
Tools for low overhaul height of piston, connecting rod and cylinder liner		1	P52002	655
Pull lift		1	P52002	021
Lifting tool for cylinder liner		1	P52002	033
Collar for connecting rod		1	P52002	045
Shackle		1	P52002	057

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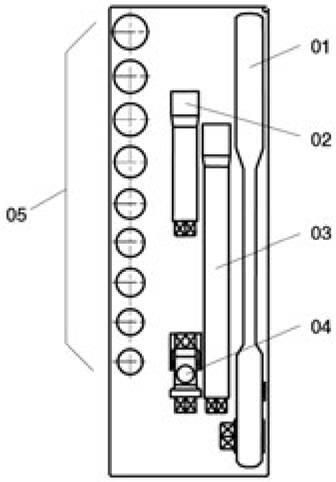
Hand tools

Hand tools

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Set of tools, consists of: Item 01 Ratchet Item 02 Extension, 125 mm Item 03 Extension, 250 mm Item 04 Universal Item 05, Sockets double hexagon, 10 mm double hexagon, 13 mm double hexagon, 17 mm double hexagon, 19 mm double hexagon, 22 mm internal hexagon, 5 mm internal hexagon, 6 mm internal hexagon, 7 mm internal hexagon, 8 mm internal hexagon, 10 mm internal hexagon, 12 mm screw driver, 1.6x10 mm cross head screw, 2 mm cross head screw, 3 mm cross head screw, 4 mm			1	019	
Combination spanner, 10 mm			1	032	
Combination spanner, 12 mm			1	044	
Combination spanner, 13 mm			1	056	
Combination spanner, 14 mm			1	068	
Combination spanner, 17 mm			1	081	
Combination spanner, 19 mm			1	093	
Combination spanner, 22 mm			1	103	
Combination spanner, 24 mm			1	115	
Combination spanner, 30 mm			1	127	
Combination spanner, 16 mm			1	223	

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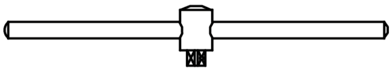
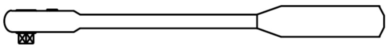
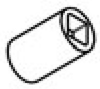
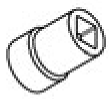
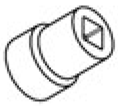
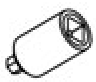
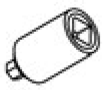
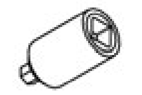
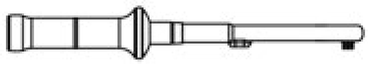
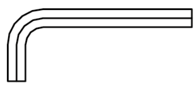
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Combination spanner, 18 mm			1	235	
Combination spanner, 27 mm			1	402	
Combination spanner, 32 mm			1	414	
Combination spanner, 36 mm			1	426	
Combination spanner, 41 mm			1	438	
Combination spanner, 46 mm			1	451	
Tee handle 1/2" square drive			1	139	
Ratchet, 20 mm			1	140	
Extension bar			1	152	
Socket spanner, square drive, size 24			1	164	
Socket spanner, square drive, size 30			1	176	
Socket spanner, square drive, size 36			1	188	
Bit, hexagon socket screw, square drive, size 8			1	247	
Bit, hexagon socket screw, square drive, size 10			1	259	

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Bit, hexagon socket screw, square drive, size 12			1	260	
Torque spanner, 20-120 Nm - 1/2"			1	272	
Torque spanner, 40-200 Nm - 1/2"			1	284	
Torque spanner, 60-320 Nm - 1/2"			1	296	
Hexagon key 7 mm			1	331	
Hexagon key 8 mm			1	343	
Hexagon key 10 mm			1	355	
Hexagon key 12 mm			1	367	
Hexagon key 14 mm			1	379	
Hexagon key 17 mm			1	380	
Hexagon key 19 mm			1	392	

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Information from the alternator supplier

Installation aspects

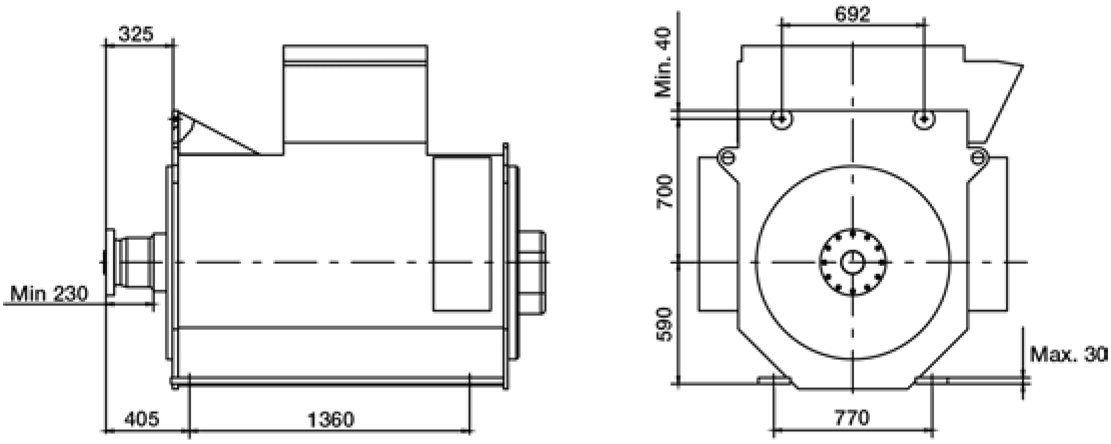

Figure 1: Outline drawing of alternator

The following information and documentation must, as minimum be included in the material supplied to MAN Energy Solutions in order to permit design/ preparation of drawings of the base frame and the general arrangement of the GenSet & torsional and linear vibration calculations for the complete GenSet.

For the mechanical design: Outline drawing of the alternator, including alternator type and total weight, position of centre of gravity, indication of direction of rotation, all dimensions for installation on base frame, external connections, covers for inspection, terminal box, vent openings, overall dimensions, minimum overhaul space for rotor, cooler, filter etc.

A: Air-cooled alternators:

- Maximum permissible ambient (inlet) temperature.

B: Water-cooled alternators:

- Cooling water capacity required (m3/h).
- Maximum water velocity (m3/sec).
- Pressure loss across heat exchanger (bar).
- Amount of water in alternator cooling system (litres).
- Dimension/placement of external connections (mm/standard).
- Drawing of rotor with sufficient information for calculation of torsional vibrations, such as moment of inertia –kgm2 for all rotating parts. The drawing must show all dimensions of the rotor shaft's length and diameter as well as rotor weight (kg).

C: For alternators with external lubricating of bearing(s) following information is required:

- Position of connections
- Dimension of connections

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- Dimensions of flange connections
- Required lub. oil flow
- Required lub. oil pressure
- Pressure regulator (if required/delivered)
- Oil sight glas (if required/delivered)

If the alternator is unknown to MAN Energy Solutions the following information has to be forwarded for carrying out finite element calculations for the complete GenSet. Drawings including dimensions and weight for:

- Fan wheel housing
- Aft end cover
- Stator housing
- Stator
- Shaft and rotor

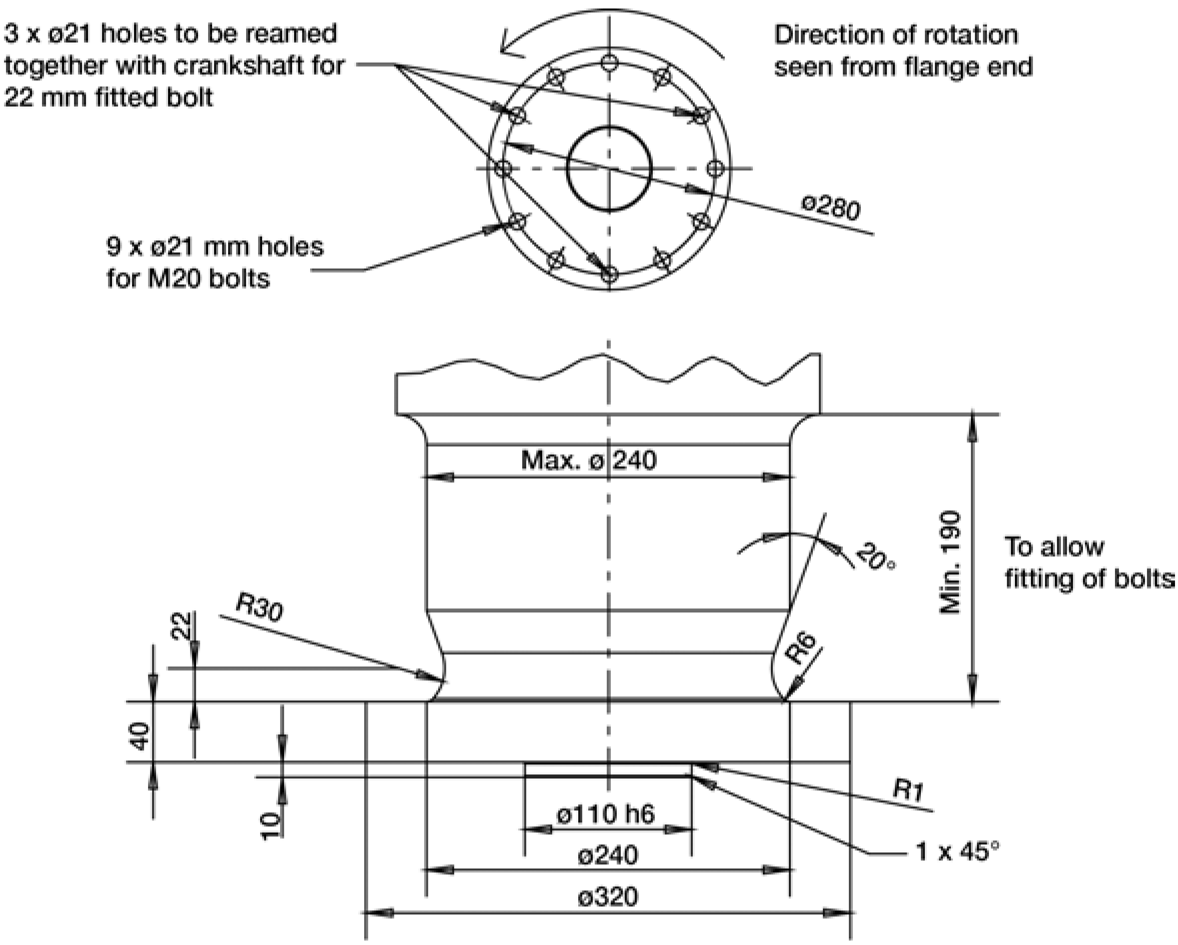

Figure 2: Shaft dimension for alternator

For the electrical design

- Electrical wiring diagram.
- Load efficiency in % of loads 25%, 50%, 75%, 100%, 110% for cos 0.8 and 1.0.
- Power consumption of anti-condensation standstill heater.
- Full load and no load short circuit ration.
- Direct axis synchronous reactance, Xd.
- Direct axis transient reactance, Xd'.
- Direct axis sub-transient reactance, Xd''.
- Open circuit time constant, Tdo''.
- Transient time constant. Td'.
- Sub-transient time constant, td''.

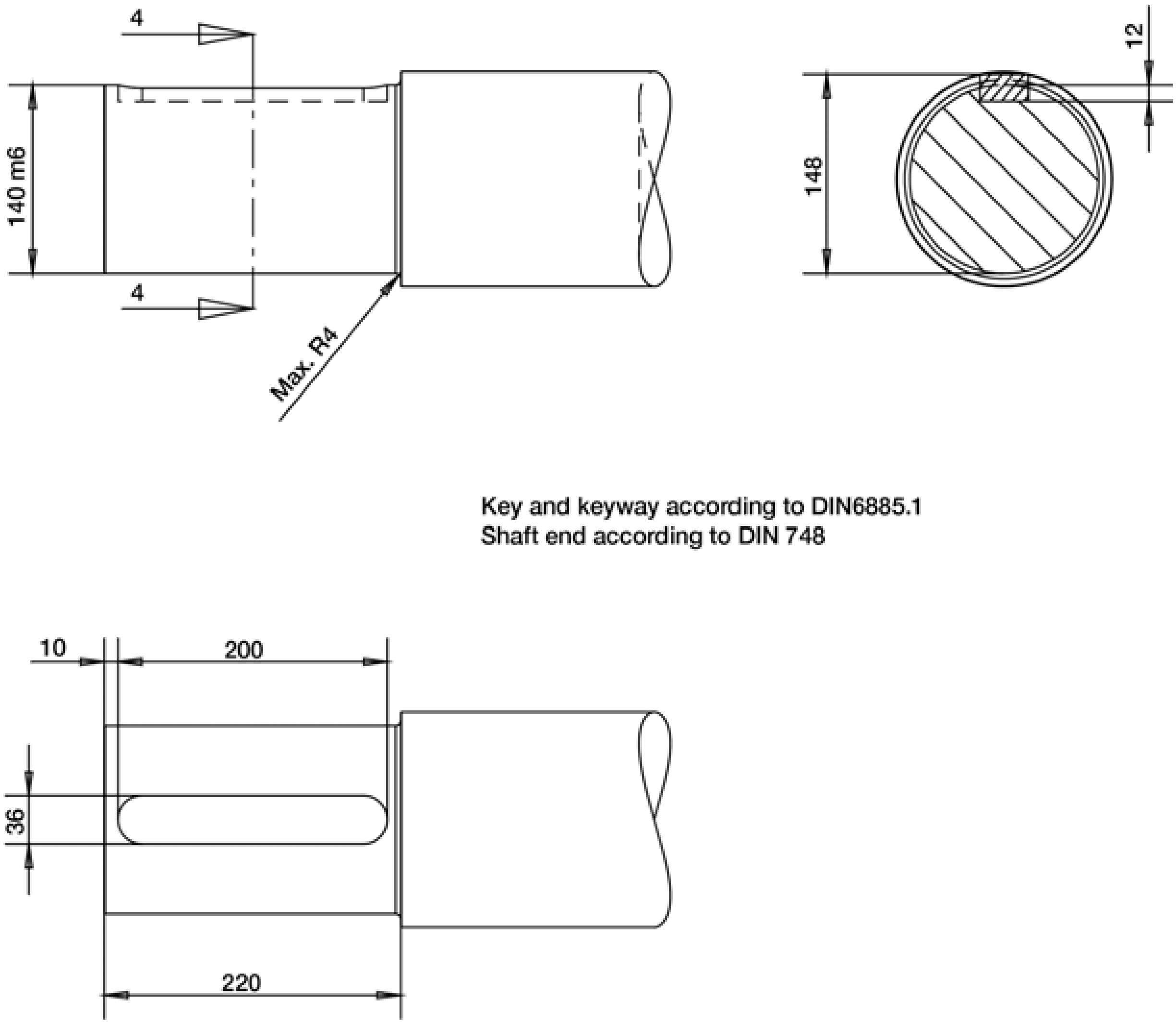

Figure 3: Shaft dimensions for alternator, 2 bearings

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Engine/Alternator type

General

Engine speed 720/750/900 RPM				
Cylinder	Standard		Alternative option	
	Alternator type	Requirements	Alternator type	Requirements
5 Cyl. 720/750 rpm	B 16	None	B 20	Elastic coupling
6 Cyl. 720/750/900 rpm	B 16	None	B 20	Elastic coupling
7 Cyl. 720/750 rpm	B 16	None	B 20	Elastic coupling
7 Cyl. 900 rpm	B 20	Elastic coupling	-	-
8 Cyl. 720/750/900 rpm	B 16	None	B 20	Elastic coupling

Alternator type B 16

One bearing type, shaft end with flange.

Alternator type B 20

Two bearing types, shaft end with keyway.

One bearing shall be of the guide bearing type.

Note for Re-engineering

In case of using an existing alternator, calculation for torsional vibrations has to be carried out before determination concerning intermediate bearing and elastic coupling can be established.

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Alternator cable installation

Description

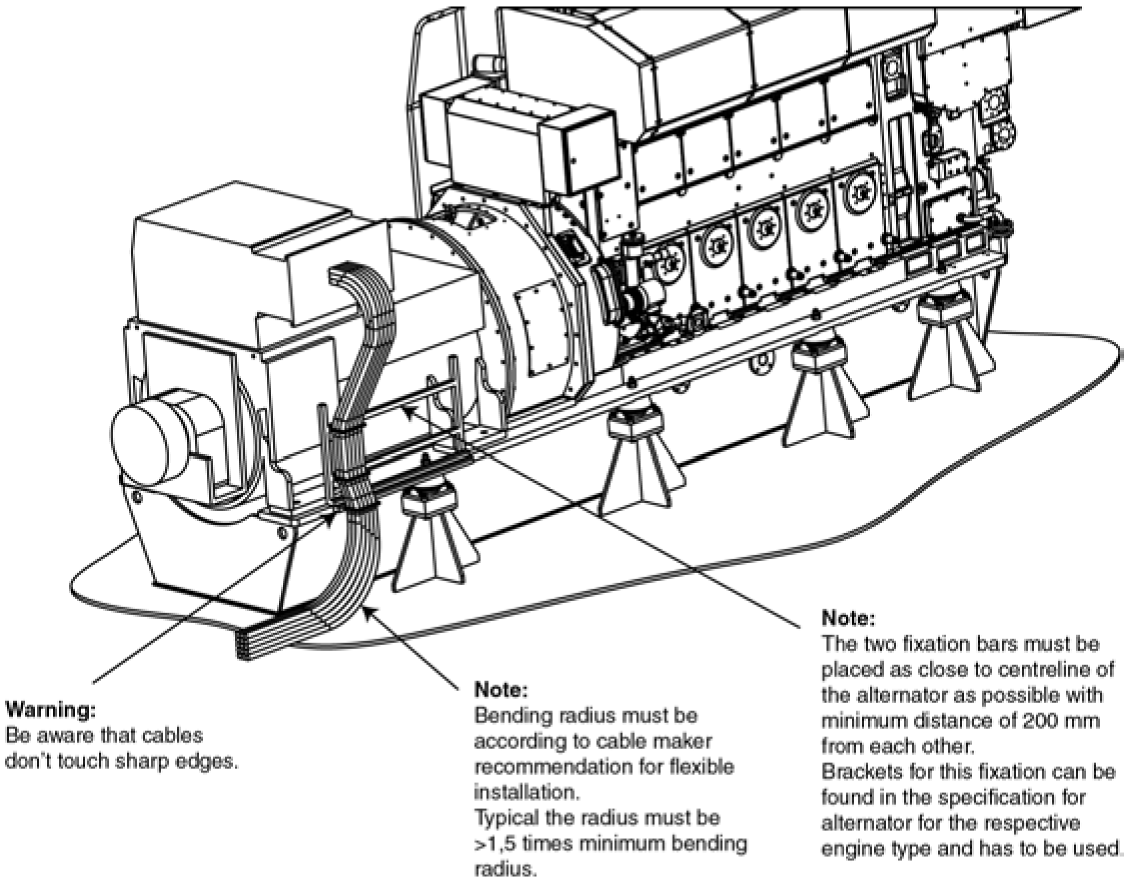

Figure 1: Connection of cables (example)

Main cables

The resilient installation of the GenSet must be considered when fixing the alternator cables.

The cables must be installed so that no forces have any effect on the terminal box of the alternator.

A support bracket can be welded on the engine base frame. If this solution is chosen, the flexibility in the cables must be between the cable tray and the support bracket.

The free cable length from the cable tray to the attachment on the alternator must be appropriate to compensate for the relative movements between the GenSet and the foundation.

The following can be used as a guideline:
The fix point of the alternator cables must be as close as possible to the centre line of the rotor.

Bending of the cables must follow the recommendations of the cable supplier regarding minimum bending radius for movable cables.

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If questions arise concerning the above, please do not hesitate to contact MAN Energy Solutions.

Note: The responsibility for alternator cable installation lies with the Installation Contractor. The Installation Contractor has to define the dimension of the cables with due respect to heat conditions at site, cable routing (nearby cables), number of single wires per phase, cable material and cable type.

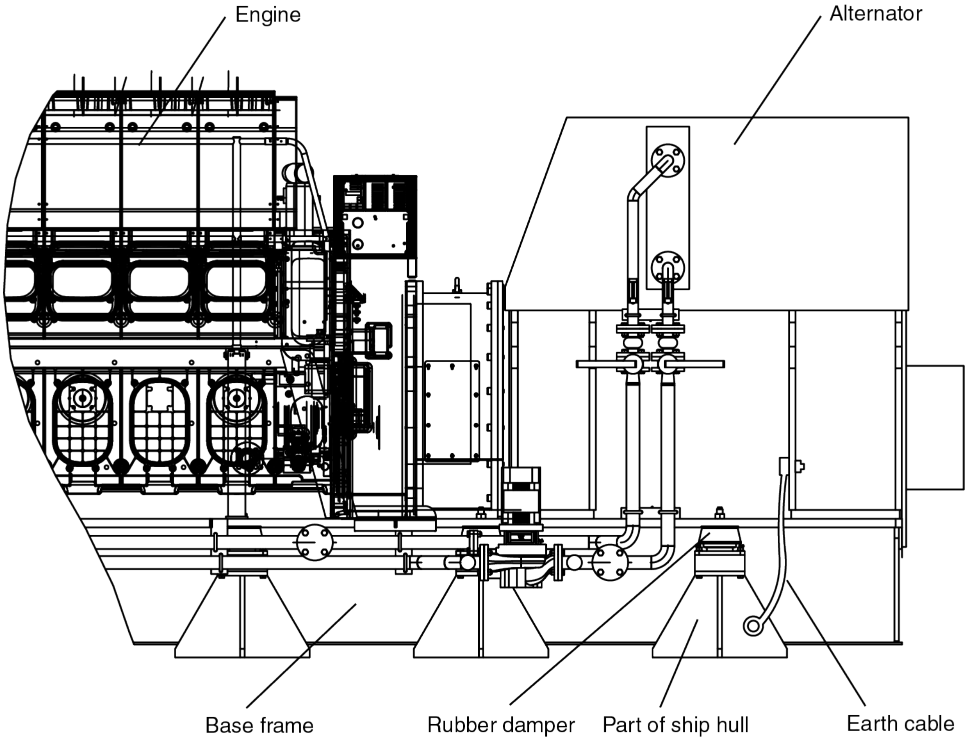

Figure 2: Marine operation (example)

Binding radius has to be observed, and furthermore binding radius for cables used for resilient installed engines must be observed.

Earth cable connection

It is important to establish an electrical connecting across the rubber dampers. The earth cable must be installed as a connection between alternator and ship hull for marine operation, and as a connection between alternator and foundation for stationary operation.

For stationary operation, the Contractor must ensure that the foundation is grounded according to local legislation.

Engine, base frame and alternator have internal metallic contact to ensure earth connection. The size of the earth cable is to be calculated on the basis of output and safety conditions in each specific case; or must as a minimum have the same size as the main cables.

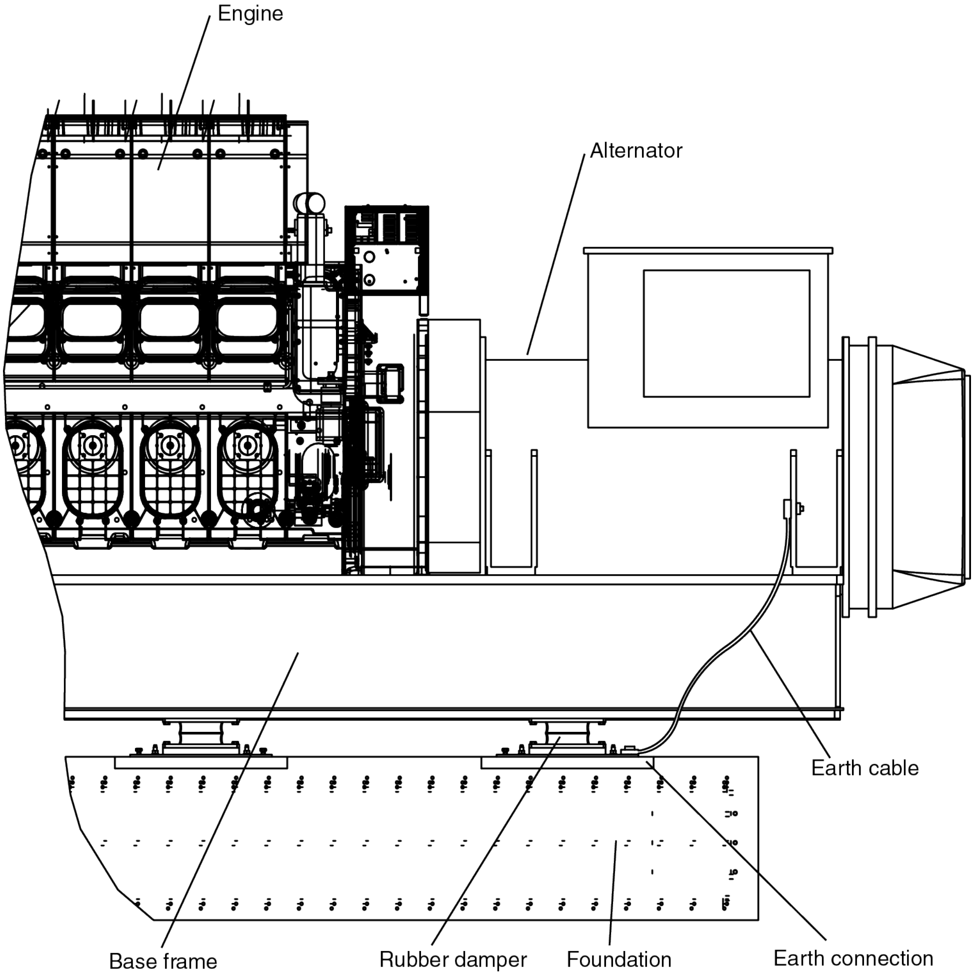

Figure 3: Stationary operation (example)

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Combinations of engine- and alternator layout

L23/30H Mk1 L23/30S Mk 1 L23/30H Mk1, Monocoque	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 720 RPM	• 2)	1)	2)	1)
5 Cyl. 750 RPM	• 2)	1)	2)	1)
6 Cyl. 720 RPM	•	#	#	#
6 Cyl. 750 RPM	•	#	#	#
6 Cyl. 900 RPM	•	#	#	#
7 Cyl. 720 RPM	•	#	#	#
7 Cyl. 750 RPM	•	#	#	#
7 Cyl. 900 RPM	•	#	#	#
8 Cyl. 720 RPM	•	#	#	#
8 Cyl. 750 RPM	•	#	#	#
8 Cyl. 900 RPM	•	#	#	#

L28/32H L28/32DF L28/32S	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 720 RPM	•	#	#	#
5 Cyl. 750 RPM	•	#	#	#
6 Cyl. 720 RPM	•	#	#	#
6 Cyl. 750 RPM	•	#	#	#
7 Cyl. 720 RPM	X	X	•	#
7 Cyl. 750 RPM	X	X	•	#
8 Cyl. 720 RPM	X	X	•	#
8 Cyl. 750 RPM	X	X	•	#
9 Cyl. 720 RPM	•	#	#	#
9 Cyl. 750 RPM	•	#	#	#

L23/30H Mk 2 L23/30S Mk 2	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 720 RPM	• 2)	1)	2)	1)
5 Cyl. 750 RPM	• 2)	1)	2)	1)
6 Cyl. 720 RPM	•	#	#	#
6 Cyl. 750 RPM	•	#	#	#
6 Cyl. 900 RPM	•	#	#	#
7 Cyl. 720 RPM	•	#	#	#
7 Cyl. 750 RPM	•	#	#	#
7 Cyl. 900 RPM	X	X	•	#
8 Cyl. 720 RPM	•	#	#	#
8 Cyl. 750 RPM	•	#	#	#
8 Cyl. 900 RPM	•	#	#	#

Monocoque: L23/30H Mk 2 L23/30DF	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 720 RPM	•	#	#	#
5 Cyl. 750 RPM	•	#	#	#
6 Cyl. 720 RPM	•	#	#	#
6 Cyl. 750 RPM	•	#	#	#
6 Cyl. 900 RPM	•	#	#	#
7 Cyl. 720 RPM	•	#	#	#
7 Cyl. 750 RPM	•	#	#	#
7 Cyl. 900 RPM	X	X	•	#
8 Cyl. 720 RPM	•	#	#	#
8 Cyl. 750 RPM	•	#	#	#
8 Cyl. 900 RPM	•	#	#	#

For a GenSet the engine and alternator are fixed on a common base frame, which is flexibly installed. This is to isolate the GenSet vibration-wise from the environment. As part of the GenSet design a full FEM calculation has been done and due to this and our experience some combinations of engine type and alternator type concerning one - or two bearings must be avoided. In the below list all combinations can be found.

Comments to possible combinations:

• : Standard
: Option
X : Not recommended
1) : Only in combination with "top bracing" between engine crankcase and alternator frame
2) : Need for 'topbracing' to be evaluated case by case

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Monocoque: L23/30H Mk 3	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 720 RPM	•	#	#	#
5 Cyl. 750 RPM	•	#	#	#
6 Cyl. 720 RPM	•	#	#	#
6 Cyl. 750 RPM	•	#	#	#
6 Cyl. 900 RPM	•	#	#	#
7 Cyl. 720 RPM	•	#	#	#
7 Cyl. 750 RPM	•	#	#	#
7 Cyl. 900 RPM	•	#	#	#
8 Cyl. 720 RPM	•	#	#	#
8 Cyl. 750 RPM	•	#	#	#
8 Cyl. 900 RPM	•	#	#	#
9 Cyl. 720 RPM	•	#	#	#
9 Cyl. 750 RPM	•	#	#	#
9 Cyl. 900 RPM	•	#	#	#

L16/24 L16/24S	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 1000 RPM	•	#	#	#
5 Cyl. 1200 RPM	•	#	#	#
6 Cyl. 1000 RPM	•	#	#	#
6 Cyl. 1200 RPM	•	#	#	#
7 Cyl. 1000 RPM	•	#	#	#
7 Cyl. 1200 RPM	•	#	#	#
8 Cyl. 1000 RPM	•	#	#	#
8 Cyl. 1200 RPM	•	#	#	#
9 Cyl. 1000 RPM	•	#	#	#
9 Cyl. 1200 RPM	•	#	#	#

L21/31 L21/31S L21/31 Mk2	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 900 RPM	•	#	#	#
5 Cyl. 1000 RPM	•	#	#	#
6 Cyl. 900 RPM	•	#	#	#
6 Cyl. 1000 RPM	•	#	#	#
7 Cyl. 900 RPM	•	#	#	#
7 Cyl. 1000 RPM	•	#	#	#
8 Cyl. 900 RPM	X	X	•	#
8 Cyl. 1000 RPM	X	X	•	#
9 Cyl. 900 RPM	X	X	•	#
9 Cyl. 1000 RPM	X	X	•	#

L27/38 L27/38S	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 720 RPM	•	#	#	#
5 Cyl. 750 RPM	•	#	#	#
6 Cyl. 720 RPM	•	#	#	#
6 Cyl. 750 RPM	•	#	#	#
7 Cyl. 720 RPM	•	#	#	#
7 Cyl. 750 RPM	•	#	#	#
8 Cyl. 720 RPM	X	X	•	#
8 Cyl. 750 RPM	X	X	•	#
9 Cyl. 720 RPM	X	X	•	#
9 Cyl. 750 RPM	X	X	•	#

V28/32S	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
12 Cyl. 720 RPM	X	X	•	1)
12 Cyl. 750 RPM	X	X	•	1)
16 Cyl. 720 RPM	X	X	•	1)
16 Cyl. 750 RPM	X	X	•	1)
18 Cyl. 720 RPM	X	X	•	1)
18 Cyl. 750 RPM	X	X	•	1)

Lifting instruction

Lifting of CompleteG generating Sets

The generating sets should only be lifted in the two wire straps. Normally, the lifting tools and the wire straps are mounted by the factory. If not, it must be observed that the fixing points for the lifting tools are placed differently depending on the number of cylinders.

After installation the lifting tools are to be removed.

Remove cover and remount compensator and brackets.

Lifting tool

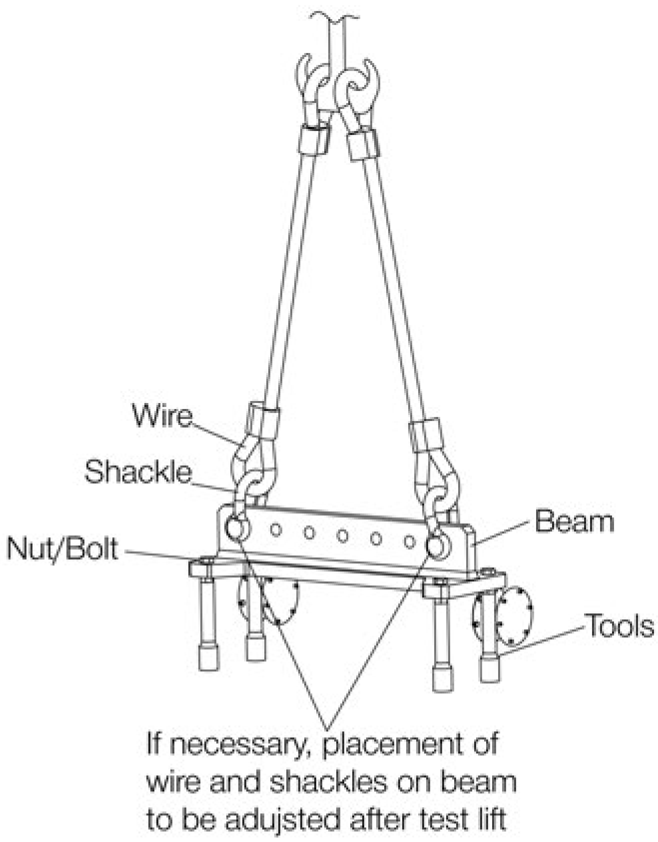

Figure 1: Lifting tool

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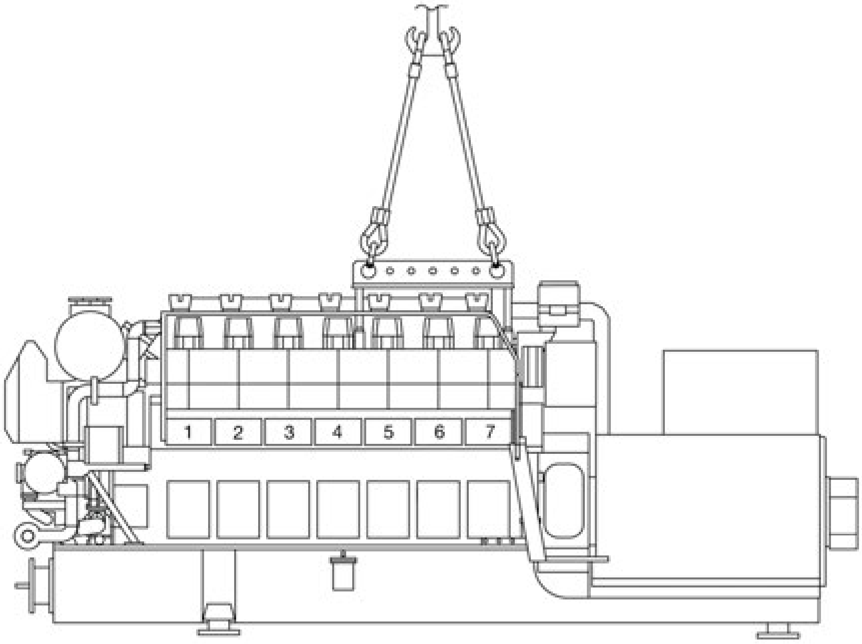

Figure 2: Lifting tools' and wires placing on engine.

Engine type	4xLifting tool to be mounted on cyl. bolt No from front	
5L23/30DF	4	10
6L23/30DF	6	12
7L23/30DF	8	14
8L23/30DF	8	14

Based on MAN Energy Solutions standard alternator.