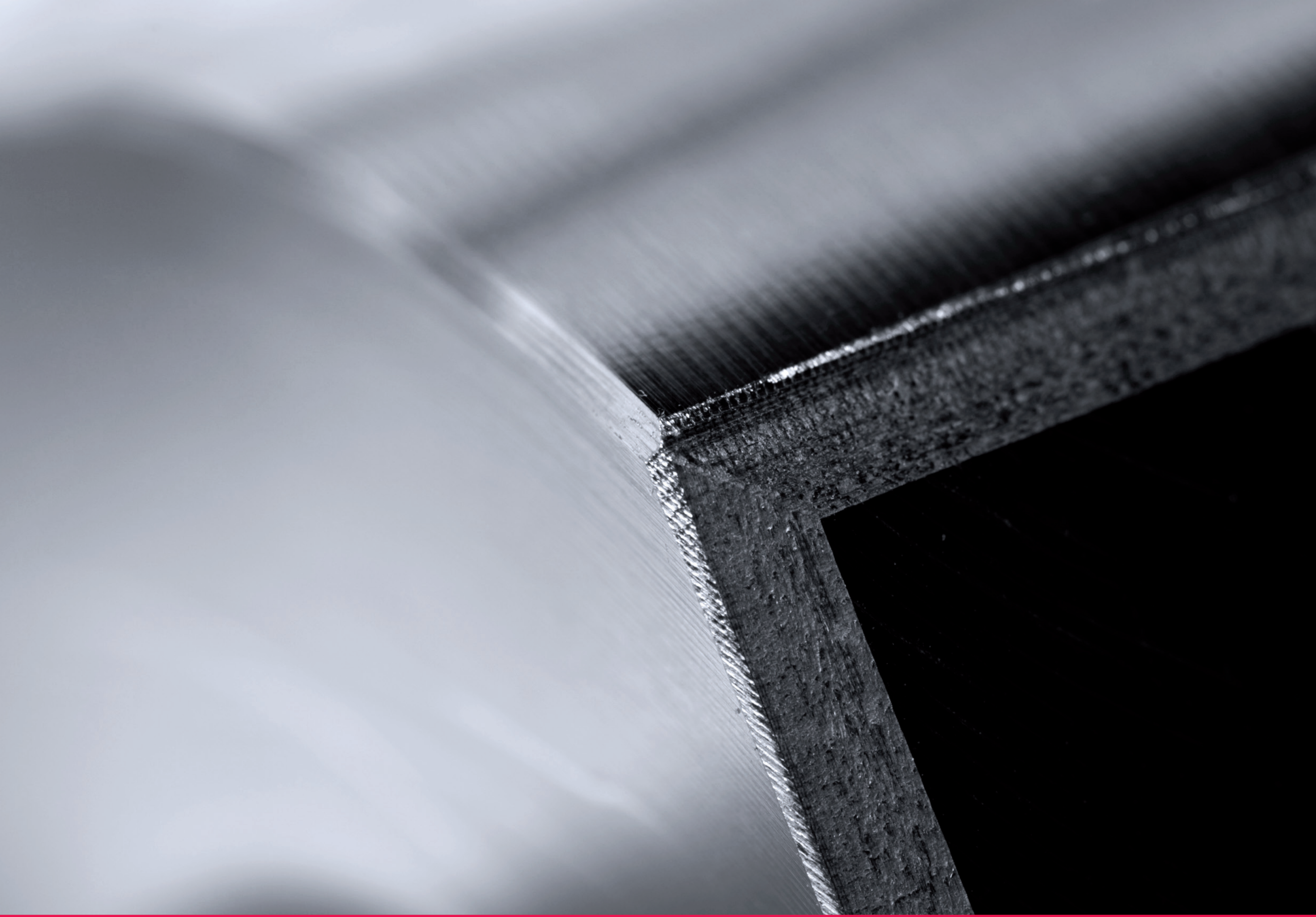

L16/24
Project Guide - Marine

Four-stroke GenSet
compliant with IMO Tier II

Engineering the Future – since 1758.

MAN Diesel & Turbo

Table of contents

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2019-03-22

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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

Identification No.	X	XX	XX	X
Code letter	X			
Function/system		XX		
Sub-function			XX	
Choice number				X

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.

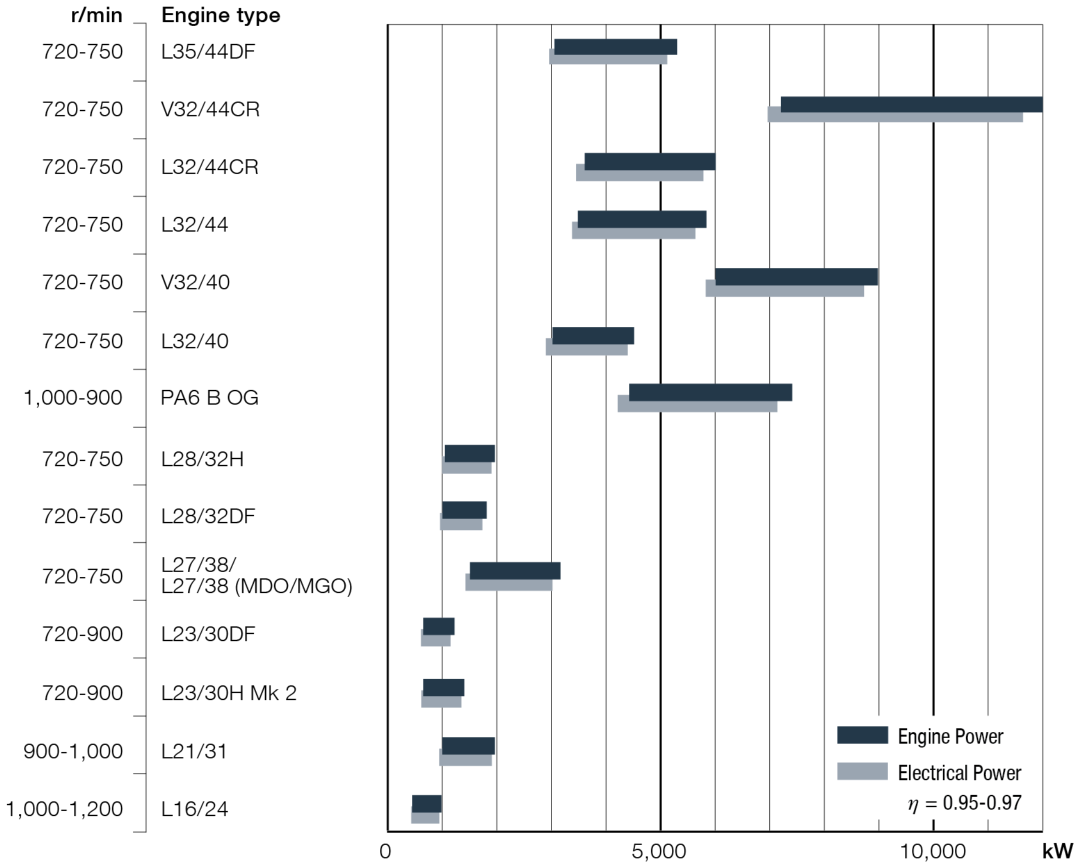
NOTICE

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

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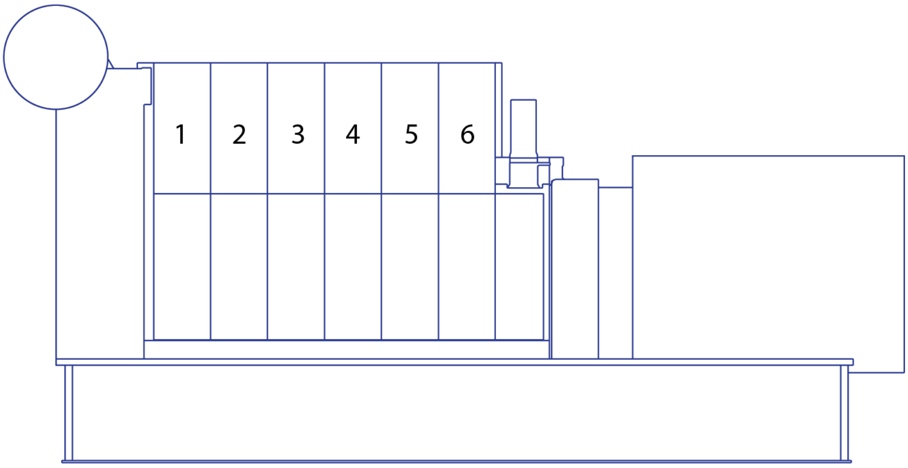
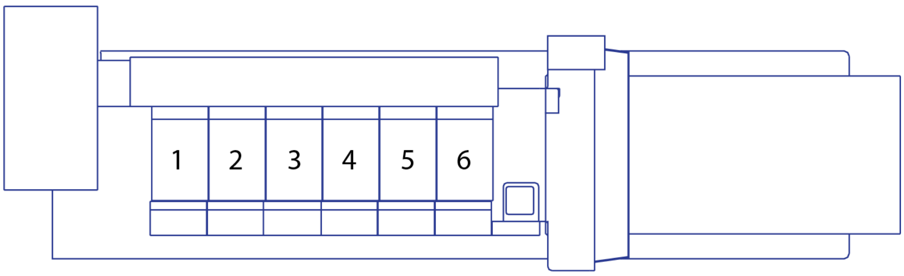
Designation of cylinders

General

Front end Flywheel end



Exhaust side / Right side



Service side / Fuel Pump side / Left side

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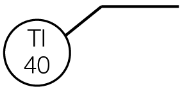
Code identification for instruments

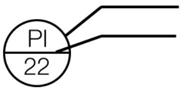
Explanation of symbols

Temperature **I**ndicator
No. 40 *



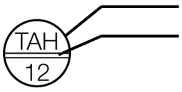
Measuring device
Local reading

Pressure **I**ndicator
No. 22 *



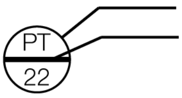
Measuring device
Sensor mounted on engine/unit
Reading/identification mounted in a panel on the engine /unit

Temperature **A**larm **H**igh
No. 12 *



Measuring device
Sensor mounted on engine/unit
Reading/identification outside the engine/unit

Pressure **T**ransmitting
No. 22 *



Measuring device
Sensor mounted on engine/unit
Reading/identification in a panel on the engine/unit
and reading outside the engine/unit

* 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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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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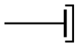
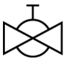
Symbols for piping

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

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

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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 ad-ded)	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	

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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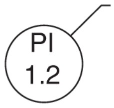
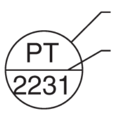
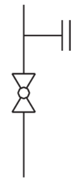


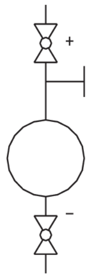
Measuring device
Local reading
Pressure **I**ndication
no 1.2 (refer to list of instruments)



Measuring device
Remote reading
Pressure **T**ransmitter
ID-no 2231 (refer to list of alarms)



Shut off cock
with test flange



Before unit - pressure high

Measuring pressure difference

After unit - pressure low

Plugged connection
for additional device

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

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	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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	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 ele-ment	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

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List of capacities

Capacities

5L:90 kW/cyl., 6L-9L: 95 kW/cyl. at 1000 rpm		5	6	7	8	9
Engine output	kW	450	570	665	760	855
Speed	rpm	1000	1000	1000	1000	1000
Heat to be dissipated 3)						
Cooling water cylinder	kW	107	135	158	181	203
Charge air cooler; cooling water HT	kW	138	169	192	213	234
Charge air cooler; cooling water LT	kW	56	69	80	91	102
Lubricating oil cooler	kW	98	124	145	166	187
Heat radiation engine	kW	15	19	23	26	29
Flow rates 4)						
Internal (inside engine)						
HT circuit (cylinder + charge air cooler HT stage)	m^3/h	10.9	12.7	14.5	16.3	18.1
LT circuit (lub. oil + charge air cooler LT stage)	m^3/h	15.7	18.9	22	25.1	28.3
Lubrication oil	m^3/h	18	18	30	30	30
External (from engine to system)						
HT water flow (at 40°C inlet)	m^3/h	5.2	6.4	7.4	8.3	9.2
LT water flow (at 38°C inlet)	m^3/h	15.7	18.9	22	25.1	28.3
Air data						
Temperature of charge air at charge air cooler outlet	°C	49	51	52	54	55
Air flow rate	m^3/h 5)	2721	3446	4021	4595	5169
	kg/kWh	6.62	6.62	6.62	6.62	6.62
Charge air pressure	bar	4.13	4.13	4.13	4.13	4.13
Air required to dissipate heat radiation (eng.) (t_2-t_1= 10°C)	m^3/h	4860	6157	7453	8425	9397
Exhaust gas data 6)						
Volume flow (temperature turbocharger outlet)	m^3/h 7)	5710	7233	8438	9644	10849
Mass flow	t/h	3.1	3.9	4.5	5.2	5.8
Temperature at turbine outlet	°C	375	375	375	375	375
Heat content (190°C)	kW	170	216	252	288	324
Permissible exhaust back pressure	mbar	< 30	< 30	< 30	< 30	< 30
Permissible exhaust back pressure (SCR)	mbar	< 50	< 50	< 50	< 50	< 50
Pumps						
External pumps 8)						
Diesel oil pump (5 bar at fuel oil inlet A1)	m^3/h	0.32	0.40	0.47	0.54	0.60
Fuel oil supply pump (4 bar discharge pressure)	m^3/h	0.15	0.19	0.23	0.26	0.29
Fuel oil circulating pump 9) (8 bar at fuel oil inlet A1)	m^3/h	0.32	0.40	0.47	0.54	0.60
Starting air data						
Air consumption per start, incl. air for jet assist (IR/TDI)	Nm^3	0.47	0.56	0.65	0.75	0.84
Air consumption per start, incl. air for jet assist (Gali)	Nm^3	0.80	0.96	1.12	1.28	1.44

Conditions

Reference condition : Tropic		
Air temperature	°C	45
LT water temperature inlet engine (from system)	°C	38
Air pressure	bar	1
Relative humidity	%	50
Temperature basis:		
Set point HT cooling water engine outlet [1]	°C	79°C nominal *(Range of mech. thermostatic element 77-85°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.
2) LT cooling water flows first through LT stage charge air cooler, then through lube oil cooler, water temperature outlet engine regulated by mechanical thermostat.
3) Tolerance: + 10% for rating coolers, - 15% for heat recovery.
4) Basic values for layout of the coolers.
5) Under above mentioned reference conditions.
6) Tolerance: quantity +/- 5%, temperature +/- 20°C.
7) Under below mentioned temperature at turbine outlet and pressure according above mentioned reference conditions.
8) Tolerance of the pumps' delivery capacities must be considered by the manufactures.
9) In order to ensure sufficient flow through the engine fuel system the capacity of the fuel oil circulation pumps must be minimum 3 times the full load consumption of the installed engines

NOTICE

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

List of capacities

Capacities

5L:100 kW/cyl., 6L-9L: 110 kW/cyl. at 1200 rpm			5	6	7	8	9
Engine output		kW	500	660	770	880	990
Speed		rpm	1200	1200	1200	1200	1200
Heat to be dissipated [3]							
Cooling water cylinder		kW	100	132	154	177	199
Charge air cooler; cooling water HT		kW	149	187	211	234	255
Charge air cooler; cooling water LT		kW	66	83	96	109	122
Lubricating oil cooler		kW	113	149	174	199	224
Heat radiation engine		kW	17	23	26	30	34
Flow rates [4]							
Internal (inside engine)							
HT circuit (cylinder + charge air cooler HT stage)		m^3/h	13.1	15.2	17.4	19.5	21.6
LT circuit (lube oil + charge air cooler LT stage)		m^3/h	19.3	20.7	24.2	27.7	31.1
Lubrication oil		m^3/h	21	21	35	35	35
External (from engine to system)							
HT water flow (at 40°C inlet)		m^3/h	5.7	7.3	8.4	9.4	10.4
LT water flow (at 38°C inlet)		m^3/h	19.1	20.7	24.2	27.7	31.1
Air data							
Temperature of charge air at charge air cooler outlet		°C	51	53	55	56	57
Air flow rate		m^3/h [5]	3169	4183	4880	5578	6275
		kg/kWh	6.94	6.94	6.94	6.94	6.94
Charge air pressure		bar	3.92	3.92	3.92	3.92	3.92
Air required to dissipate heat radiation (eng.) (t_2-t_1= 10°C)		m^3/h	5509	7453	8425	9721	11017
Exhaust gas data [6]							
Volume flow (temperature turbocharger outlet)		m^3/h [7]	6448	8511	9929	11348	12766
Mass flow		t/h	3.6	4.7	5.5	6.3	7.1
Temperature at turbine outlet		°C	356	356	356	356	356
Heat content (190°C)		kW	178	235	274	313	352
Permissible exhaust back pressure		mbar	< 30	< 30	< 30	< 30	< 30
Permissible exhaust back pressure (SCR)		mbar	< 50	< 50	< 50	< 50	< 50
Pumps							
External pumps [8]							
Diesel oil pump	(5 bar at fuel oil inlet A1)	m^3/h	0.35	0.47	0.54	0.62	0.70
Fuel oil supply pump	(4 bar discharge pressure)	m^3/h	0.17	0.22	0.26	0.30	0.34
Fuel oil circulating pump [9]	(8 bar at fuel oil inlet A1)	m^3/h	0.35	0.47	0.54	0.62	0.70
Starting air data							
Air consumption per start, incl. air for jet assist (IR/TDI)		Nm^3	0.47	0.56	0.65	0.75	0.84
Air consumption per start, incl. air for jet assist (Gali)		Nm^3	0.80	0.96	1.12	1.28	1.44

Conditions

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

Remarks to capacities

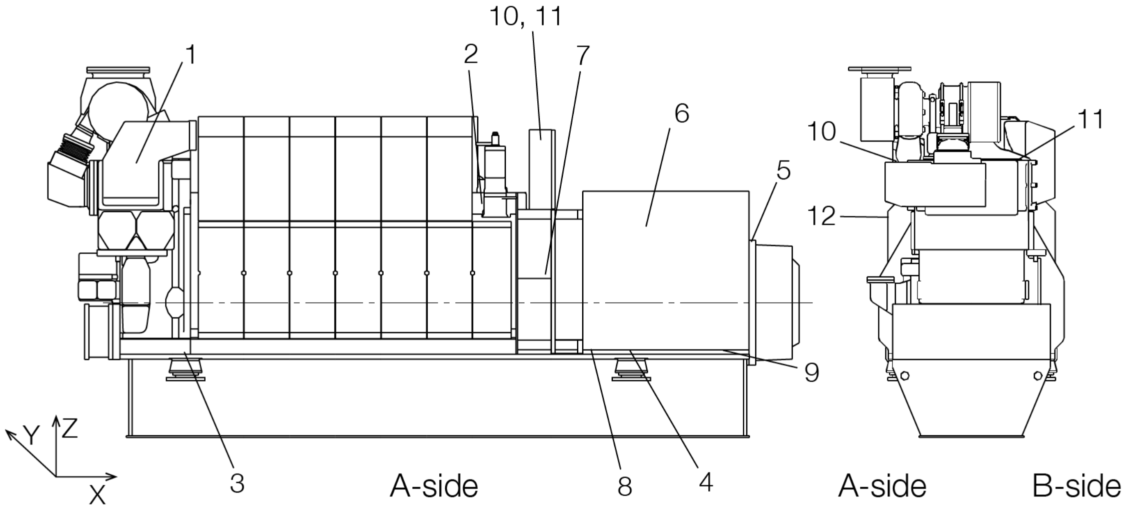
1) HT cooling water flows first through HT stage charge air cooler, then through water jacket and cylinder head, water temperature outlet engine regulated by mechanical thermostat.
2) LT cooling water flows first through LT stage charge air cooler, then through lube oil cooler, water temperature outlet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

NOTICE

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

Vibration limits and measurements

GenSet



Meas-ure-ment point	Descrip-tion	Limit	Meas-ure-ment point	Descrip-tion	Limit	Meas-ure-ment point	Descrip-tion	Limit
1	TC fore	18	5	Aft altern-ator bear-ing	18	9	Alternator foot	See be-low *
2	Governor/ TC aft	18	6	Alternator cooler	25	10	Automa-tion box A-side	25
3	Front sup-port	18	7	Intermedi-ate bear-ing	18	11	Automa-tion box B-side	25
4	Aft sup-port	18	8	Alternator foot	See be-low *	12	T&P panel	25

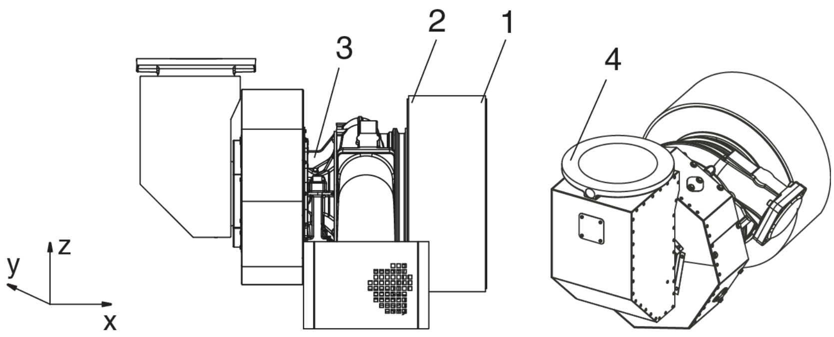
Engine: VDI 2063T
Alternator: ISO 8528-9, DIN 6280-11
Note: All measurements are specified as mm/s r.m.s.

* 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	5	6	7	8	9	10	11	12
Shop test		100												
			Crosswise (y) (Turbocharger oriented)											
		100												
			Longitudinal (x) (Turbocharger oriented)											
		100												

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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 Diesel & Turbo's test bed facilities.

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

Sound Power is normally determined from Sound Pressure measurements.

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

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

Sound measuring "on-site"

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

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

Standards

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

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

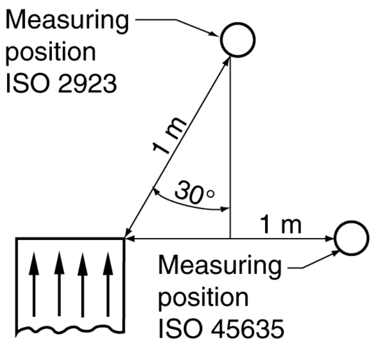

Figure 1: .

Description of structure-borne noise

Introduction

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

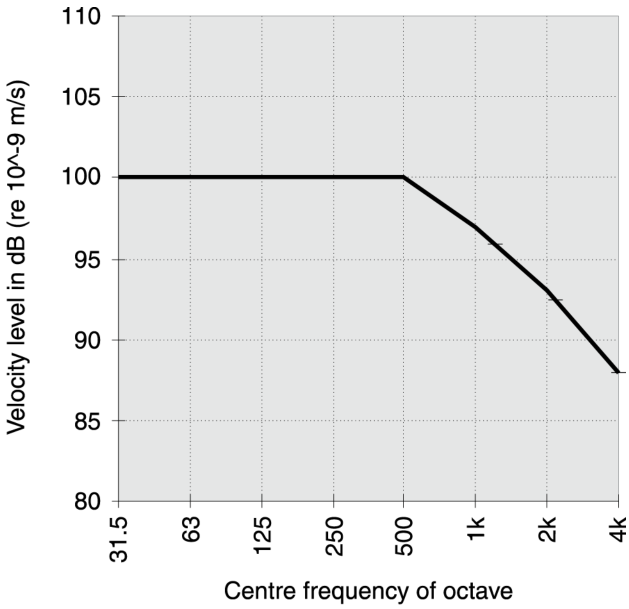

Figure 1: Structure-borne noise on resiliently mounted GenSets

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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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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 Diesel & Turbo 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 Diesel & Turbo 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 Diesel & Turbo fourstroke diesel engines is at a very low level.

Particulate matter PM

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

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

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

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

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

Moment of inertia

GenSet

Eng. type	Moments of inertia			Flywheel		
Number of cylinders	Continuous rating	Moments required total J_{min}	Engine + damper	Moments of inertia	Mass	Required moment of inertia after flywheel *)
	kW	kgm^2	kgm^2	kgm^2	kg	kgm^2
n = 1000 rpm						
5L16/24	450	82	12	54	419	16
6L16/24	540	99	16	54	419	29
7L16/24	630	115	18	67	480	30
8L16/24	720	131	19	67	480	45
9L16/24	810	148	21	67	480	60
n = 1200 rpm						
5L16/24	500	63	12	54	419	-
6L16/24	660	84	16	54	419	14
7L16/24	770	98	18	67	480	13
8L16/24	880	112	19	67	480	26
9L16/24	990	125	23	67	480	35

*) Required moment of inertia after flywheel is based on the most common flywheel for each number of cylinders.

The following flywheels are available:

J	=	47 kgm^2
J	=	54 kgm^2
J	=	67 kgm^2
J	=	75 kgm^2

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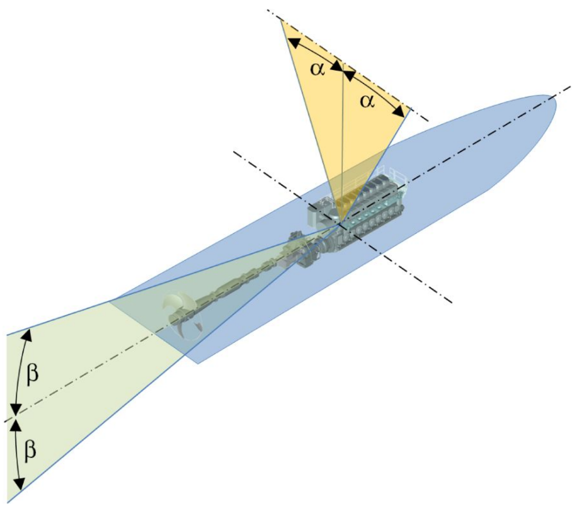
Inclination of engines

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.

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 Diesel & Turbo 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	96.000
Connecting rod	Inspection	32.000	64.000
Big-end bearing	Inspection Retightening *	32.000	64.000
Camshaft	Inspection of cams surface	8.000	64.000
Piston	Overhaul and measuring of ring grooves 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	96.000
Valve clearance	Checking and adjustment	2.000	
Fuel injection valve	Checking, cleaning and adjustment of opening pressure 3)	based on observation	8.000
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. Overhaul based on operational observations		32.000
Lub. Oil pump	Overhaul	32.000	48.000
Cooling water pumps	Overhaul	32.000	48.000
Air Cooler	Cleaning and pressure testing	16.000	64.000
Compr. air system	Check of compressed air system, air starter	16.000	
Autolog reading	Check last crank through	Once a year	
Lub. oil filter cartr.	Replacement based on observations of pressure drop		1.500
Regulating system	Function check of overspeed and shutdown devices. Check that the control rod of each individual fuel pump can easily go to "stop" position	quarterly	
Flexible mountings	Check anti-vibration mountings	quarterly	
Vibration damper	Check of condition and wear	28-30.000	
Turbocharger	Water washing of compressor side Water washing of turbine side Dry cleaning of turbine side Air filter cleaning	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 for GenSet, see Lub. Oil treatment, in section B 12 00 0 and Fuel oil specification in section B 11 00 0 and section 14 000 for Propulsion.

In the Instruction Manual for GenSet and L21/31 Propulsion, see Lub. Oil treatment and Fuel oil specification in section 504/604. For Propulsion L27/38, L23/30A, L28/32A see section 1.00.

1) Island mode, max. 75 % average load.

2) Parallel running with public grid, up to 100 % load.

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3) See working card for fuel injection valve in the instruction manual, section 514/614 for GenSet and section 1.20.

4) Time can be adjusted acc. to performance observations.

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

Overhaul recommendation, Maintenance and Expected life time

Component	Overhaul Recommendations, Maintenance and Expected Life Time	Time between overhauls (TBO) Hours **	Expected life time Hours
Main bearings	Inspection Retightening *	16.000	48.000
Connecting rod	Inspection	16.000	64.000
Big-end bearing	Inspection Retightening *	16.000	32.000
Camshaft	Inspection of cams surface	8.000	48.000
Piston	Overhaul and measuring of ring grooves	16.000	48.000
	Replacement of compression rings and scraper rings	16.000	16.000
Cylinder liner	Inspection, measuring and honing of running surface condition	16.000	32.000
Cylinder head		16.000	48.000
Valve clearance	Checking and adjustment	2.000	
Fuel injection valve	Checking and cleaning 3)	based on observation	8.000
Inlet and Exhaust valve	Overhaul and regrinding of spindle	16.000	32.000
Valve seat ring	Exchange and grinding	16.000	16.000
Rotorcap	Function check of rotation	2.000	32.000
Valve guide	Measuring of inside diameter	16.000	32.000
Cylinder head nuts	Retightening *		
Fuel pump	Fuel pump barrel/plunger assembly. Overhaul based on operational observations		16.000
Lub. Oil pump	Overhaul	16.000	48.000
Cooling water pumps	Overhaul	16.000	48.000
Air Cooler	Cleaning and pressure testing	16.000	64.000
Compr. air system	Check of compressed air system, air starter	16.000	
Autolog reading	Check last crank through	Once a year	
Lub. oil filter cartr.	Replacement based on observations of pressure drop		1.000
Regulating system	Function check of overspeed and shutdown devices. Check that the control rod of each individual fuel pump can easily go to "stop" position	quarterly	
Flexible mountings	Check anti-vibration mountings	quarterly	
Vibration damper	Check of condition and wear	28-30.000	
Turbocharger	Water washing of compressor side	based on observation	
	Water washing of turbine side	150 4)	
	Dry cleaning of turbine side	daily 4)	
	Air filter cleaning	based on observation	

* After starting up and before loading engine.

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

In the Project Guide for GenSet, see Lub. Oil treatment, in section B 12 00 0 and Fuel oil specification in section B 11 00 0 and section 14 000 for Propulsion.

In the Instruction Manual for GenSet and L21/31 Propulsion, see Lub. Oil treatment and Fuel oil specification in section 504/604. For Propulsion L27/38, L23/30A, L28/32A see section 1.00.

1) Island mode, max. 75 % average load.

2) Parallel running with public grid, up to 100 % load.

3) See working card for fuel injection valve in the instruction manual, section 514/614 for GenSet and section 1.20.

4) Time can be adjusted acc. to performance observations.

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

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Power, outputs, speed

Engine ratings

Engine type No of cylinders	1000 rpm		1200 rpm	
	1000 rpm	Available turning direction	1200 rpm	Available turning direction
	kW	CW [1]	kW	CW [1]
5L16/24	450	Yes	500	Yes
6L16/24	570	Yes	660	Yes
7L16/24	665	Yes	770	Yes
8L16/24	760	Yes	880	Yes
9L16/24	855	Yes	990	Yes
[1] CW clockwise				

Table 1: Engine ratings for emission standard - IMO Tier II

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

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

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

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

Table 3: Available outputs / related reference conditions.

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

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

De-rating

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

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

[1] Overpressure

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

1. 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 = $(-20mbar - p_{Air\ before\ compressor}\ [mbar]) \times 0.25K/mbar$

with U ≥ 0

O Increased exhaust gas back pressure after turbocharger leads to a de-rating, calculated as increased air temperature before turbocharger:

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

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]

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

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

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General description

General

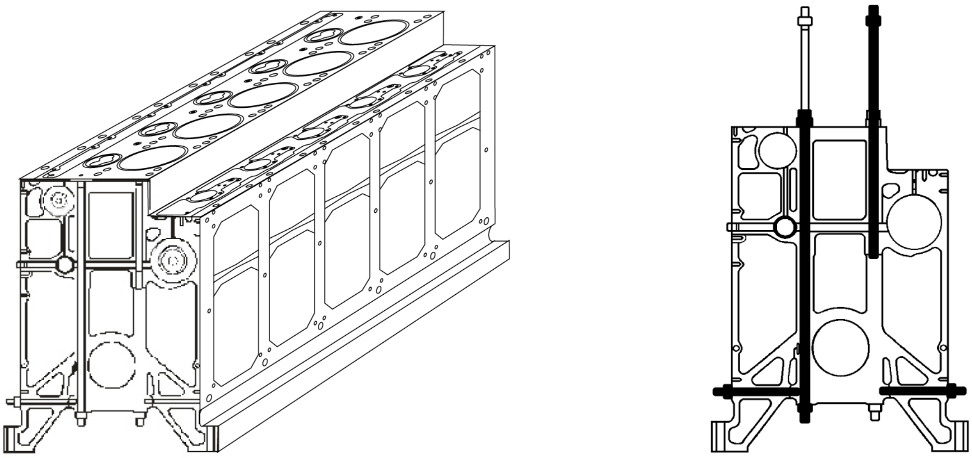

Figure 1: Engine frame.

The engine is a turbocharged, single-acting fourstroke diesel engine of the trunk type with a cylinder bore of 160 mm and a stroke of 240 mm. The crankshaft speed is 1000 or 1200 rpm.

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

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

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

Engine frame

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

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

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

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

Base frame

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

Cylinder liner

The cylinder liner is made of special centrifugal cast iron and fitted in a bore in the engine frame. The liner is clamped by the cylinder head and rests by its flange on the water jacket.

The liner can thus expand freely downwards when heated during the running of the engine.

Figure 2: Cylinder liner.

The liner is of the flange type and the height of the flange is identical with the water cooled area which gives a uniform temperature pattern over the entire liner surface.

The lower part of the liner is uncooled to secure a sufficient margin for cold corrosion in the bottom end. There is no water in the crankcase area.

The gas sealing between liner and cylinder head consists of an iron ring.

To reduce bore polishing and lube oil consumption a slip-fit-type flame ring is arranged on the top side of the liner.

Cylinder head

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

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

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

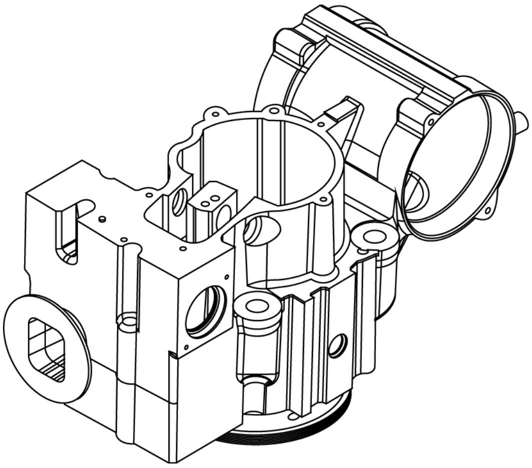

Figure 3: Cylinder head.

Air inlet and exhaust valves

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

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

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

Valve actuating gear

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

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

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

Fuel injection system

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

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

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

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

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

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

Piston

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

Figure 4: Piston.

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

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

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

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

Connecting rod

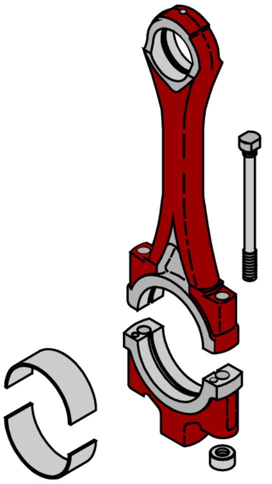

Figure 5: Connecting rod.

The connecting rod is die-forged. The big-end has a horizontal split. The connecting rod and piston are disassembled together with the cylinder liner, thus ensuring a large bearing diameter and a low bearing pressure.

The connecting rod has bored channels for supplying 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 the trimetal type and is pressed into the connecting rod. The bush is equipped with an inner circumferential groove, and a pocket for distribution of oil in the bush itself and for the supply of oil to the pin bosses.

Crankshaft and main bearings

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

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

Also fitted here is a flexible disc for the connection of an alternator. At the opposite end (front end) there is a gear wheel connection for lube 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 thence 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 two camshafts.

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

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

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

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

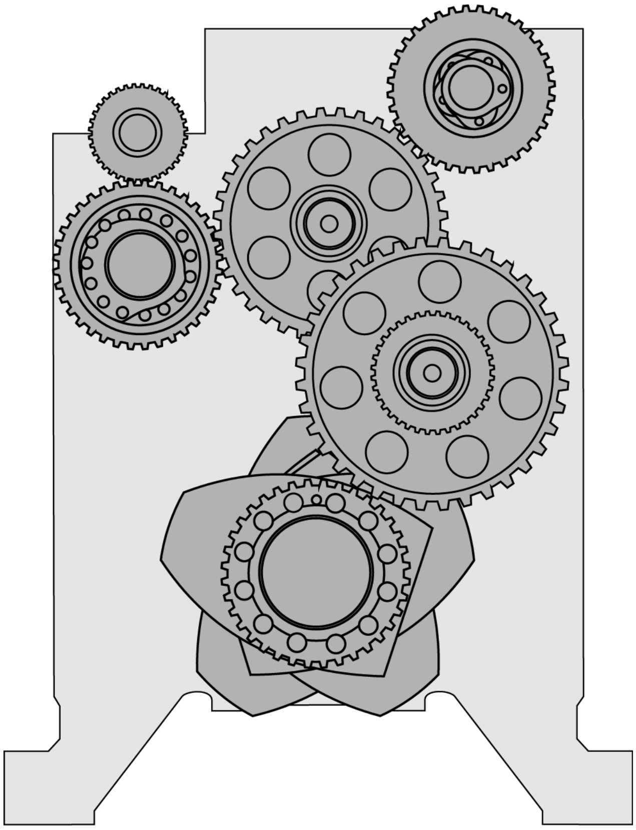

Figure 6: Twin camshafts.

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

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

Front-end box

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

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

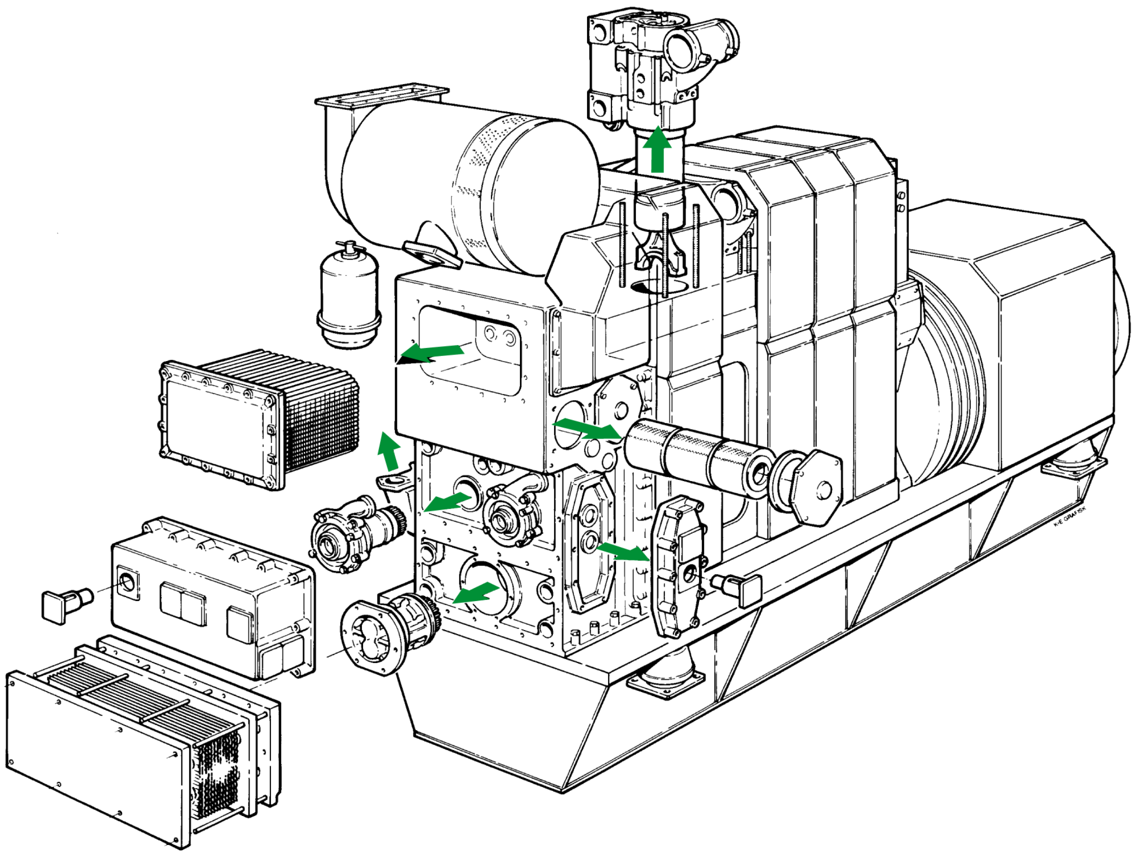

Figure 7: Front-end box.

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Governor

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

Safety and control system

The engine is equipped with MAN Diesel & Turbo’s own design of safety and control system called SaCoS$_{one}$. *See “B 19 00 0 Safety, control and monitoring system” and “B 19 00 0 Communication from the GenSet”.*

Turbocharger system

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

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

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

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

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

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

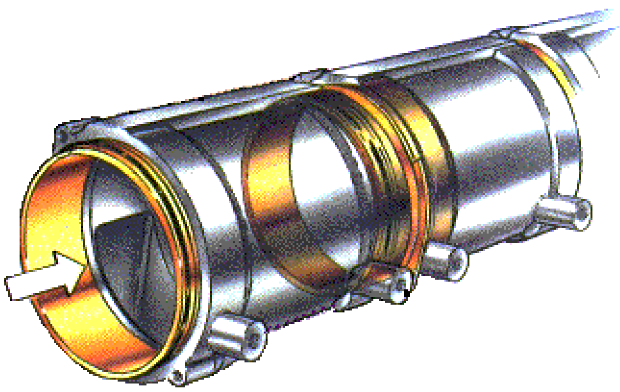


Figure 8: Constant pressure turbocharger system.

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

Compressed air system

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

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

Fuel oil system

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

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

Lubricating oil system

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

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

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

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

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

Cooling water system

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

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

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

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

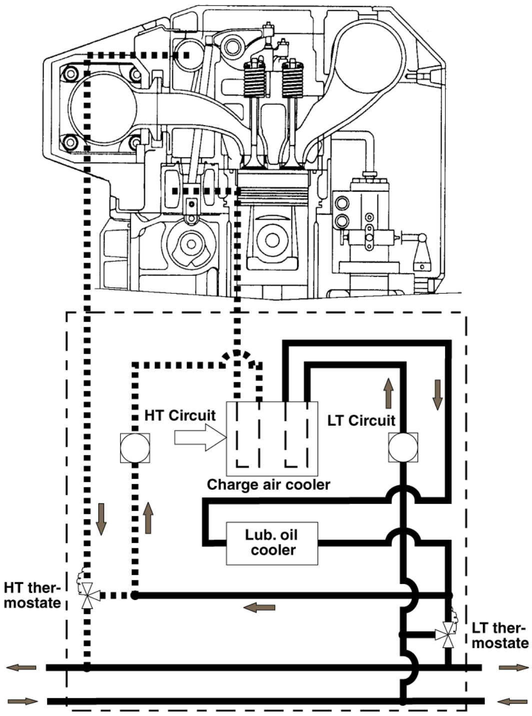


Figure 9: Internal cooling water system.

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

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

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

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

Tools

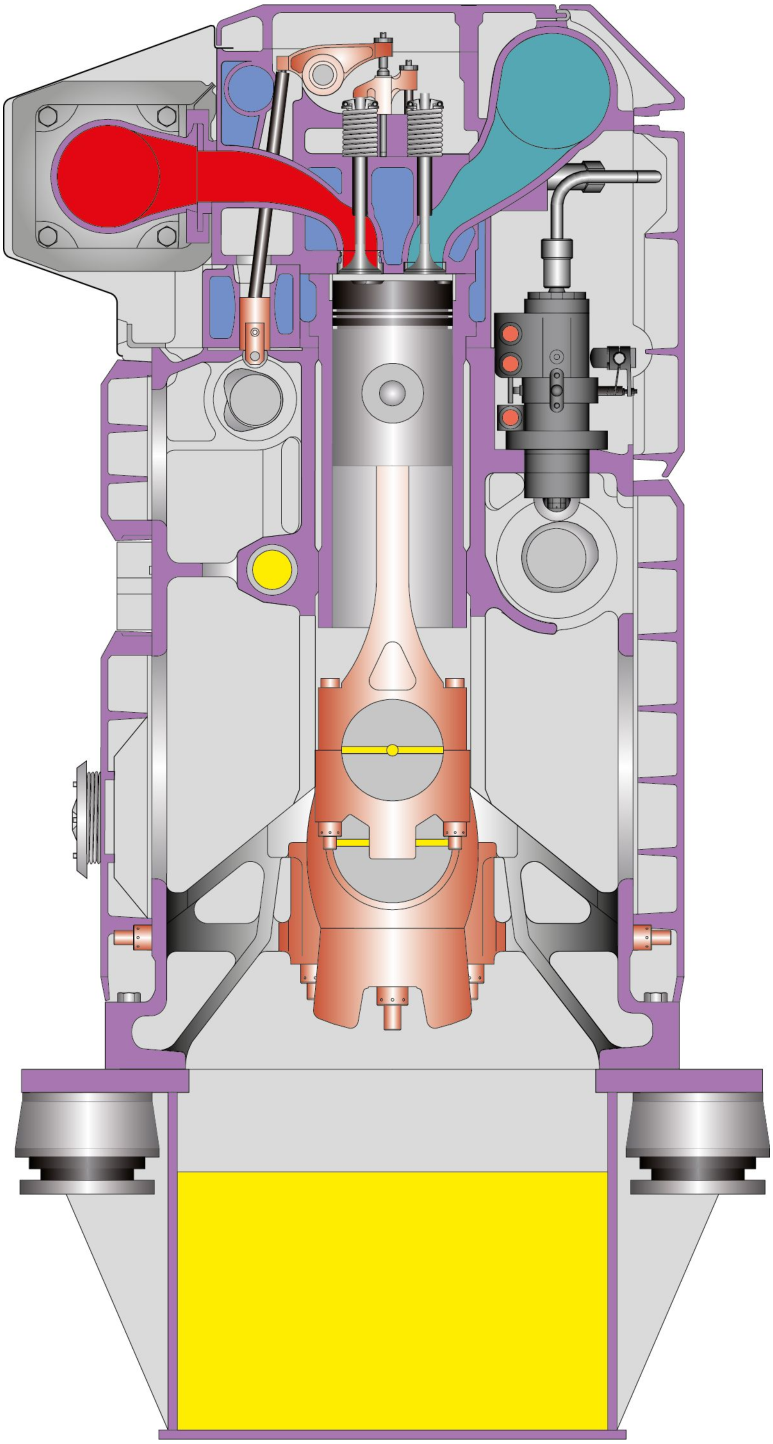
The engine can be delivered with all necessary tools for the overhaul of each specific plant. Most of the tools can be arranged on steel plate panels.

Turning

The engine is equipped with a manual turning device.

Cross section

Cross section



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Main particulars

Main Particulars

Cycle	:	4-stroke
Configuration	:	In-line
Cyl. nos available	:	5 - 6 - 7 - 8 - 9
Power range	:	450 - 990 kW
Speed	:	1000 / 1200 rpm
Bore	:	160 mm
Stroke	:	240 mm
Stroke/bore ratio	:	1.5 : 1
Piston area per cyl.	:	201 cm^2
swept volume per cyl.	:	4.8 ltr
Compression ratio	:	16.2 : 1
Turbocharging principle	:	Constant pressure system and intercooling
Fuel quality acceptance	:	HFO (up to 700 cSt/50º C, RMK700) MDO (DMB) - MGO (DMA, DMZ) according ISO8217-2010

Power lay-out		**MCR version**	
Speed	rpm	1000	1200
Mean piston speed	m/sec.	8	9.6
Mean effective pressure 5 cyl. engine 6, 7, 8, 9 cyl. engine	 bar bar	 22.4 23.6	 20.7 22.8
Max. combustion pressure	bar	170	170
Power per cylinder 5 cyl. engine 6, 7, 8, 9 cyl. engine	 kW per cyl. kW per cyl.	 90 95	 100 110

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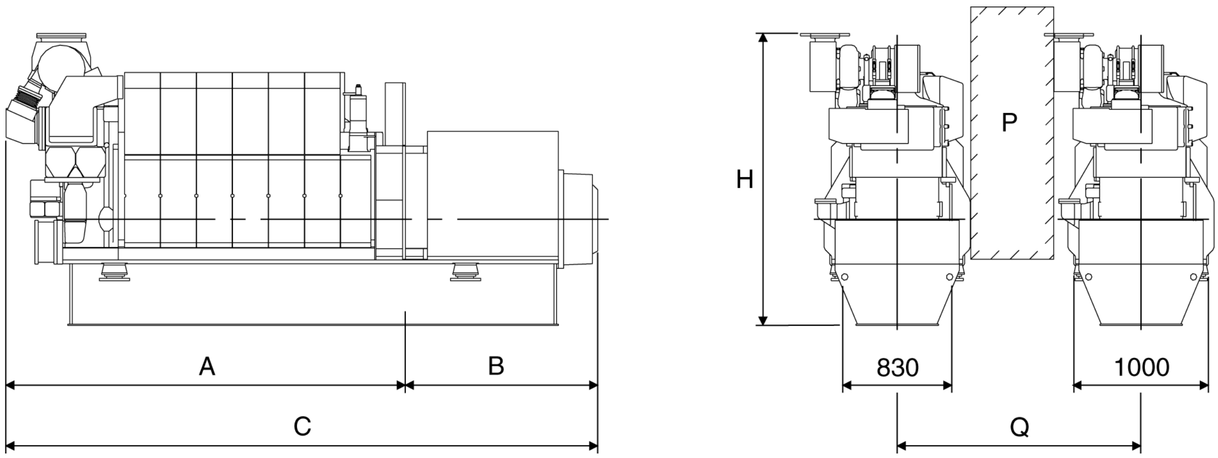
Dimensions and weights

General



Cyl. no	A (mm)	* B (mm)	* C (mm)	H (mm)	** Dry weight GenSet (t)
5 (1000 rpm)	2807	1400	4207	2337	9.5
5 (1200 rpm)	2807	1400	4207	2337	9.5
6 (1000 rpm)	3082	1490	4572	2337	10.5
6 (1200 rpm)	3082	1490	4572	2337	10.5
7 (1000 rpm)	3557	1585	5142	2337	11.4
7 (1200 rpm)	3557	1585	5142	2415	11.4
8 (1000 rpm)	3832	1680	5512	2415	12.4
8 (1200 rpm)	3832	1680	5512	2415	12.4
9 (1000 rpm)	4107	1680	5787	2415	13.1
9 (1200 rpm)	4107	1680	5787	2415	13.1

P Free passage between the engines, width 600 mm and height 2000 mm.
Q Min. distance between engines: 1800 mm.

* Depending on alternator
** Weight included a standard alternator

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

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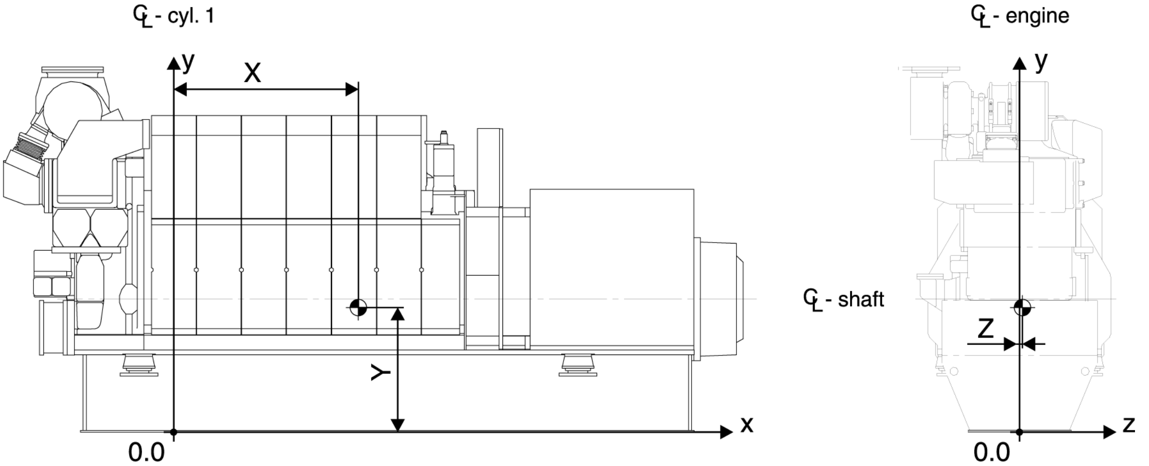
Centre of gravity

Description



Engine type	X - mm	Y - mm	Z - mm
5L16/24	923	755	0
6L16/24	1128	755	0
7L16/24	1315	750	0
8L16/24	1470	750	0
9L16/24	1595	755	0

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

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Overhaul areas

Dismantling height

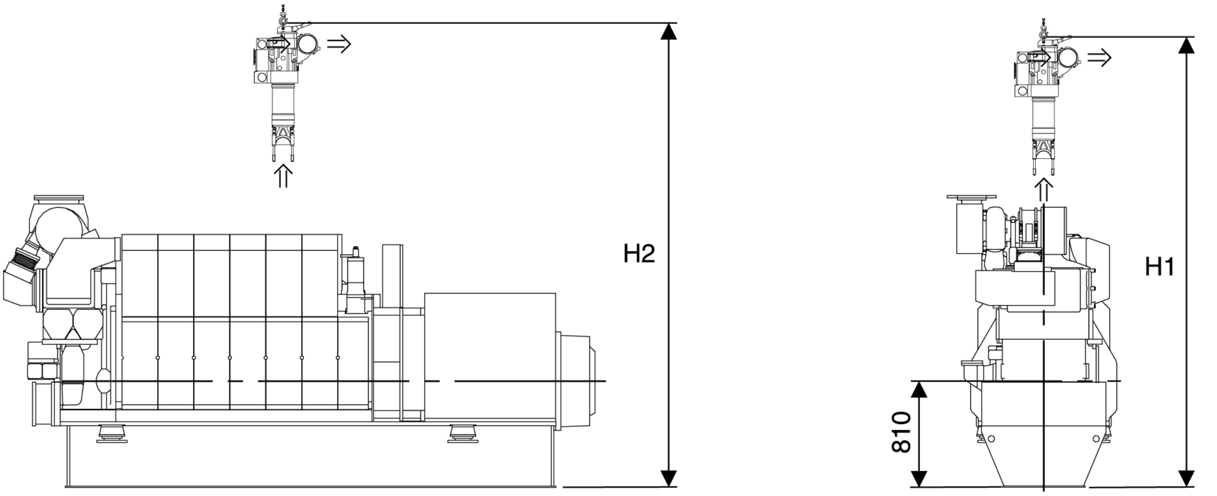


Figure 1: Dismantling height.

Engine type	H1 (mm)	H2 (mm)
Cylinder unit, complete:	2850	3180
Unit dismantled: Cylinder liner, water jacket, connecting rod and piston:	2530	2860

H1 : For dismantling at the service side.

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

Dismantling space

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

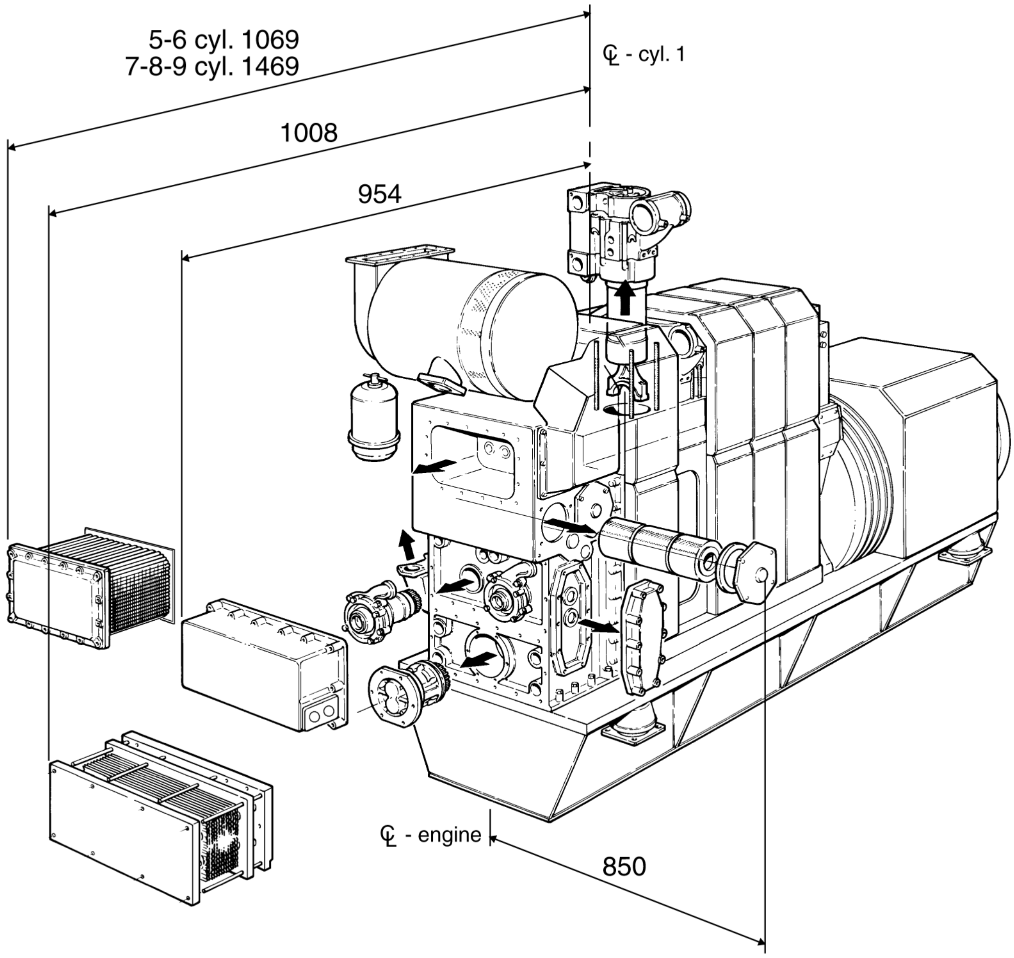
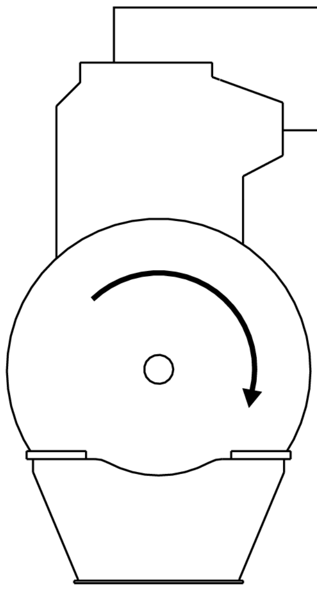


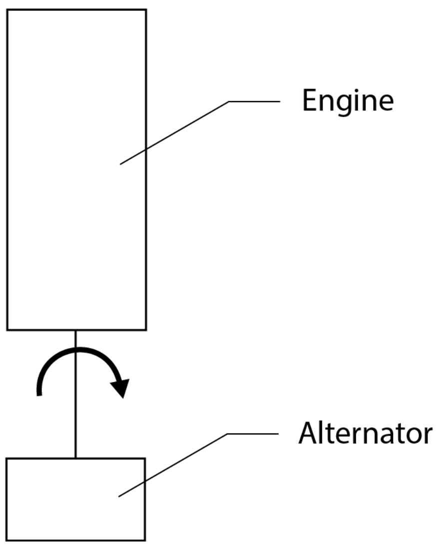
Figure 2: Overhaul areas for charge air cooler element, lub. oil cooler and lub. oil filter cartridge.

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 system

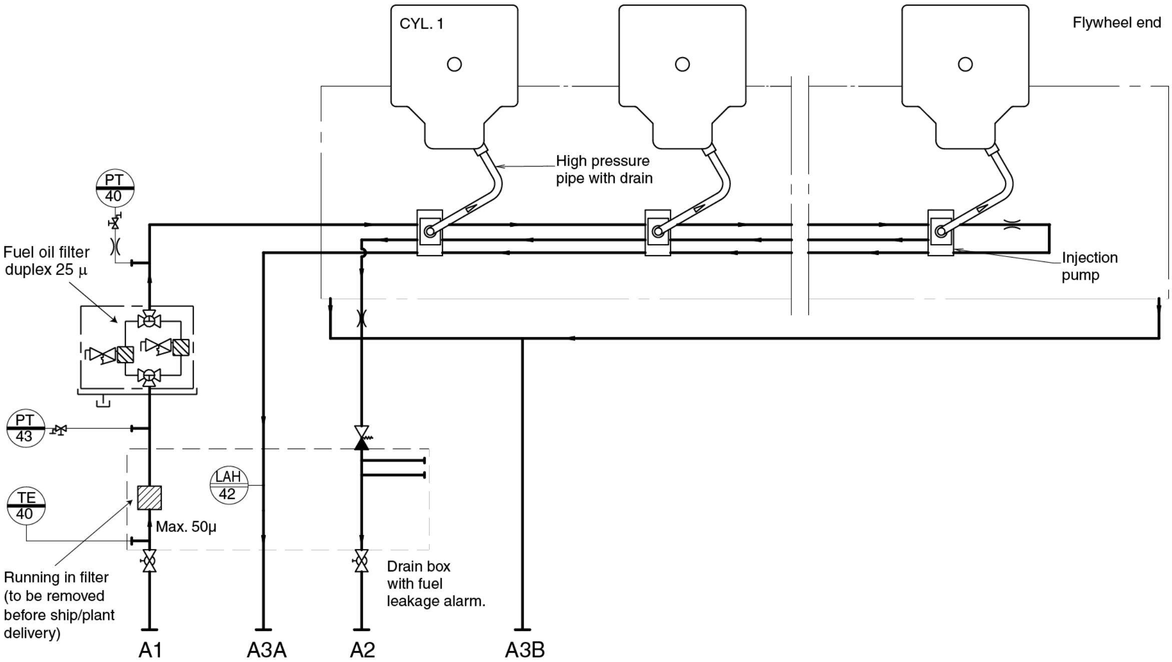

Figure 1: Diagram for fuel oil system (for guidance only, please see the plant specific engine diagram)

Pipe description		
A1	Fuel oil inlet	DN15
A2	Fuel oil outlet	DN15
A3A	Clean leak oil to service tank	DN15
A3B	Waste oil outlet to sludge tank	DN15

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
- the high-pressure injection equipment
- the waste oil system

Running-in filter

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

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

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

Fuel oil filter duplex (Safety filter)

GenSets with conventional fuel injection system or common rail fuel systems are equipped with a fuel oil filter duplex, with a fineness of max. 25 microns (sphere passing mesh) The fuel oil filter duplex is with star-pleated filter elements and allows change-over during operation without pressure-loss. The filter is compact and easy to maintain, requiring only manual cleaning when maximum allowable pressure drop is reached. When maximum pressure drop is reached the standby filter chamber is brought on line simultaneously as the dirty one is isolated by means of the change-over valve. After venting, the dirty element can be removed, cleaned and refilled to be the standby filter chamber.

Fuel injection equipment

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

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

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

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

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

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

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

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

Waste oil system

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

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

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

Clean leak fuel tank

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

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

Sludge tank

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

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

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

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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Setting the heavy fuel oil supply system

General information

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

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

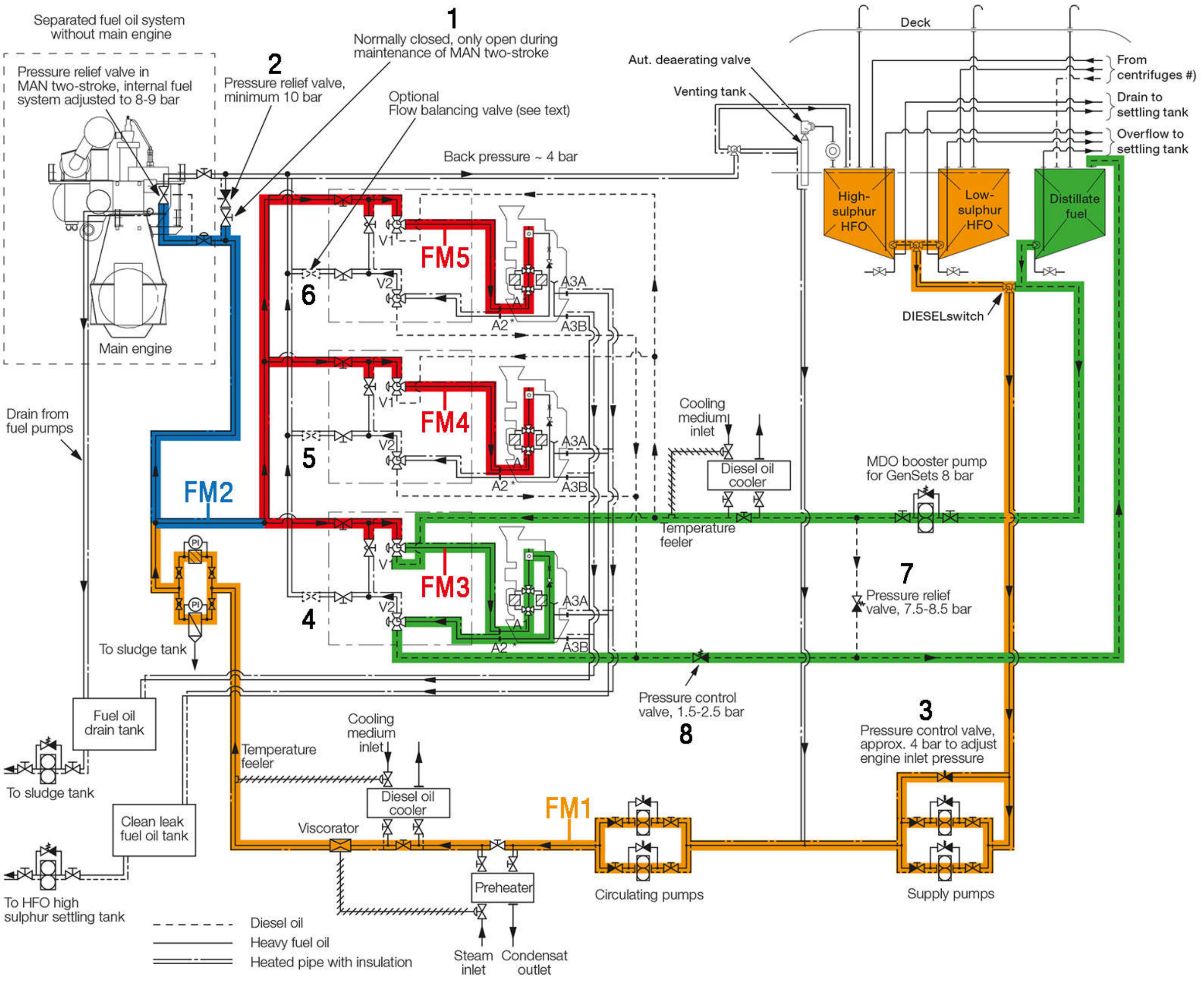
Based on the MAN Diesel & Turbo uni-fuel system, this guideline explains how the correct setting is performed and how each engine is supplied with its required fuel flow and pressure, as set out in the project specification for reliable operation. This guideline can also be applied to fuel systems for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

Preliminary work (precondition)

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

Setting procedure for the heavy oil system

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



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

Flow rate and pressure of circulating and supply pumps

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

Procedure

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

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

NOTICE

Safety valves

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

Flow distribution between main engine and GenSets

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

Applies to the Uni concept only.

Procedure

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

NOTICE

FO system without an MDT main engine

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

Flow distribution between GenSets

Aim: To achieve a sufficient flow for each GenSet

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

Preconditions for adjustment

- Installation of flow balancing valves downstream of each engine.

Procedure

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

- If the inlet pressure on a GenSet becomes too high during this procedure, open the pressure control valve (3) until the required pressure is reached again.

Setting procedure for the MDO fuel circuit

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

This circuit is intended for diesel operation.

Preconditions for adjustment

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

Procedure: Pressure adjustment

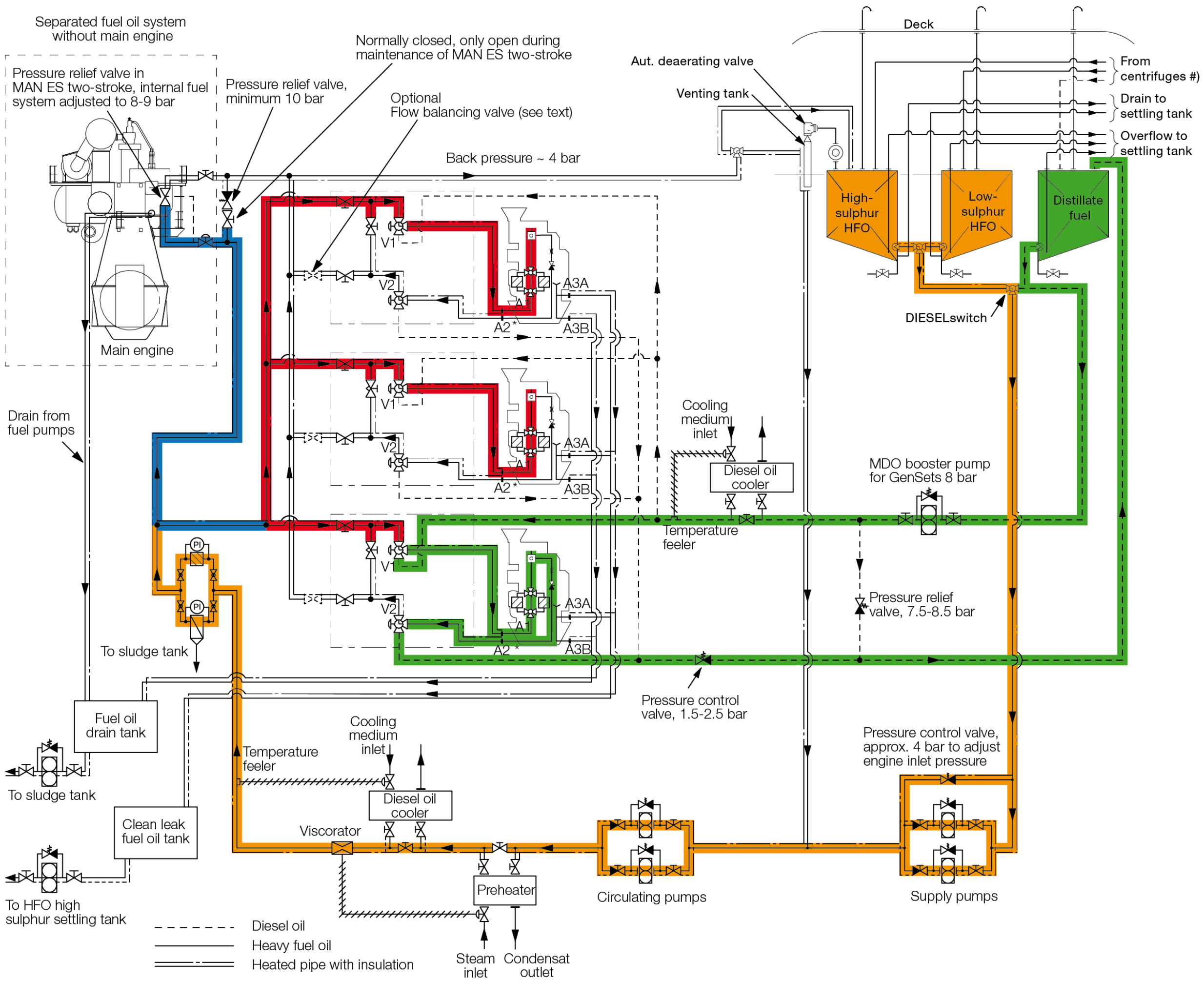
- If the pressure at the engine inlet is too low, close the pressure relief valve (7) connecting the inlet and outlet of the MDO circuit to one another until the required pressure is reached or the inlet pressure is no longer affected.
- If the required pressure cannot be reached by turning the pressure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

Procedure: Flow setting

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

Fuel oil diagram

Fuel oil diagram with drain split



UNI-fuel

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

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

Tank design

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

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

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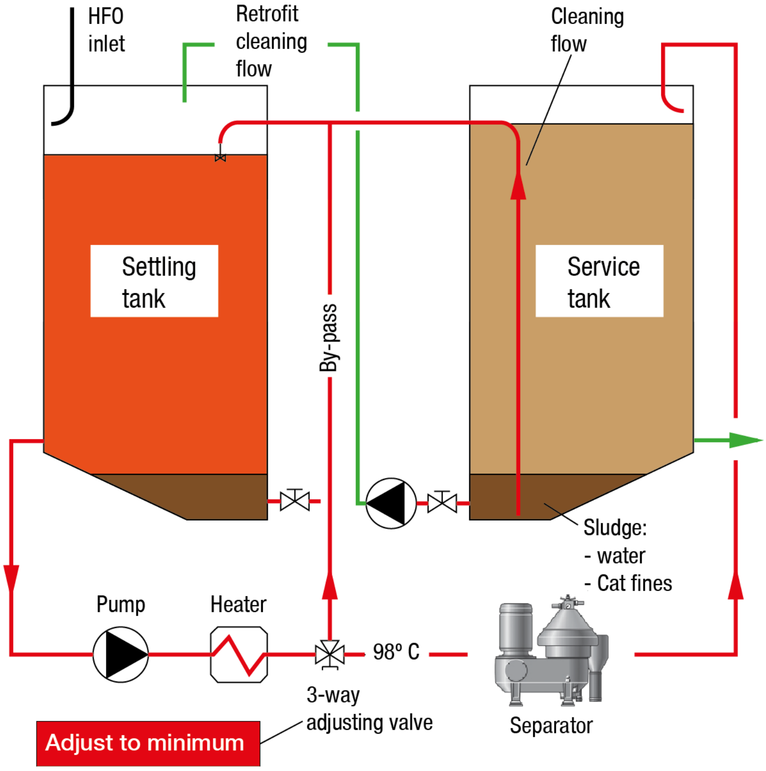
Tanks must be designed with a sloped bottom toward drainage outlet for easy collection of the settled particles. There must be drain valves in each tank for removing water and particles. Appropriate access should be provided for personnel to enable tank maintenance operations to be conducted safely.

The overflow pipe in the service tank must go to the bottom of the service tank to enable re-circulation; thus contributing to leading the highest particle concentration back to the settling tank. **Overflow as a simple hole from tank to tank is not permitted.**

Cat fines have a higher density than fuel oil and they tend to settle in the bottom of the service tanks. They might enter the engines in periodically high concentrations during rolling and pitching of the vessel in rough weather. Such a phenomenon can result in heavily cat fines attacks and engine damage.

Tank material and/or surface treatment have to be selected that it not will contaminate or change properties of fuel.



Fuel supply system

The common fuel supply system is a low pressurized system, consisting of “DIESELswitch”, HFO supply pumps with pressure control valves, venting tank and de-aerating valve.

Pump capacity is minimum fuel consumption for all engines in system running 100% load. *See “List of capacities” for each engine types*.

The fuel oil is led from one of the service tanks to one of the electrically driven supply pumps (*with redundancy*). It delivers the fuel oil with an adjusted pressure of approximately 4 bar to the fuel circulation system.

The venting pipe is connected to the service tank via an automatic de-aeration valve that will release any gases present.

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Fuel circulation system

From the low-pressure supply fuel system the fuel oil is poured with return fuel from engines and led to one of the electrically driven circulating pumps (*with redundancy*), through preheater, diesel cooler, and equipment for controlling the viscosity, (*e.g. "Viscorator"*).

Pump capacity is minimum 3 times fuel consumption for all engines in system running 100% load. *See "List of capacities" for each engine types*.

The circulating pumps will always be running; even if the propulsion engine and one or several of the GenSets are stopped. Circulation of heated heavy fuel oil through the fuel system on all the engine(s) keep them ready to start with preheated fuel injection pumps.

The surplus amount of fuel oil is re-circulated in the engine and back through the venting pipe. To have a constant fuel pressure to the fuel injection pumps during all engine loads a spring-loaded pressure relief valve is installed internally in the MAN ES 2-stroke propulsion fuel oil system.

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

Fuel oil pressure for GenSet must be minimum 8 bars and can be up to 16 bar. It is therefore recommended to distribute fuel to GenSet(s) before main engine.

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

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

Fuel preheater and diesel cooler should safely manage to control temperature. Clogging point, cloud and pour point of the bunkered fuel need to be considered in every operating areas and ambient temperatures.

Depending on system layout, viscosity, and volume in the external fuel oil system, unforeseen pressure fluctuations can be observed. In such cases it could be necessary to add pressure dampers to the fuel oil system. For further assistance, *please contact* MAN Energy Solutions.

Adjustment of fuel oil system

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

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

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

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

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

Fuel filtration and cleaning

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

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

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

The fuel oil separator should be installed and constantly circulating the fuel between settling tank and service tank. Separator must not be selected too small for the purpose. It is recommended to be approximately 4 times bigger than the requested capacity flow of the supply system to have optimum cleaning efficiency. Correct viscosity/temperature is also important for efficiency of separator.

The automatic back-flush filter with a change-over cock and bypass simplex filter and with integrated heating chamber has a mesh size of 10 microns (absolute/sphere passing mesh). The automatic back-flush filter permits a continuous operation even during back-flushing without any pressure drops or interruptions of flow. If the filter inserts are clogged, an automatic cleaning is started. The filter is equipped with a visual differential pressure indication and two differential pressure contacts to monitor the clogging of the filter. Back-flushing medium is discharged discontinuously to a sludge tank or back to the settling tank.

Automatic back-flush filter will also extend the cleaning intervals considerably of the filter elements in the fuel oil filter duplex (*safety filter*).

GenSets are equipped with a fuel oil filter duplex (safety filter) with a fineness of maximum 25 microns (absolute/sphere passing mesh). The filter is with star-pleated filter elements and allows change-over during operation without pressure loss. The filter is compact and easy to maintain, requiring only manual cleaning when maximum allowable pressure drop is reached. The filter is equipped with a visual differential pressure indication and two differential pressure contacts to monitor the clogging of the filter. When maximum pressure drop is reached, the standby filter chamber is brought on line simultaneously as the dirty one is isolated by means of the change-over valve. After venting, the dirty element can be removed, cleaned and refilled to be the standby filter chamber.

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

NOTICE

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

Operation on distillate

The distillate to the GenSets is recommended to be supplied by a separate pipeline from the service tank through a distillate booster pump. The capacity of the distillate booster pump must be minimum three times higher the amount of distillate consumed by the diesel engines at 100% load. *See list of capacities for each engine type*.

The system is designed in such a way that the fuel type for the GenSets can be changed independently of the fuel supply to the propulsion engine. As an option the GenSet plant can be delivered with the fuel changing system consisting of a set of remotely controlled, pneumatically actuated 3-way fuel changing valves “V1-V2” for each GenSet and a fuel changing valve control box common for all GenSets.

A separate fuel changing system for each GenSet gives the advantage of individually choosing distillate or HFO mode. Such a changeover may be necessary if the GenSets have to be:

- Entering SECA area
- Stopped for a prolonged period
- Stopped for major repair of the fuel system, etc.
- In case of a blackout / emergency start.

With the introduction of stricter fuel sulphur content regulations the propulsion engine as well as the GenSets increasingly have to be operated on distillate fuels, i.e. marine gas oil (MGO) and marine diesel oil (MDO). To maintain the required viscosity at the engine inlet, it is necessary to install a cooler in the fuel system. The lowest viscosity suitable for the main engine and the GenSets is 2 cSt at engine inlet.

Vessel that constantly will enter/exit SECA area, and has multiple GenSet installation, it is recommended not to change between fuels, but to select some GenSet for HFO and some GenSet for distillate fuels. The change-over procedure will then be starting/stopping GenSet and not changing between fuels.

Distillate pump capacity need to be minimum for one GenSet (see desription D 10 05 0 "List of capacities"). If 2 or more GenSets need to run distillate (ie. entering SECA) then distillate pump capacities must be adjusted accordingly.

If the fuel type for complete system both the propulsion engine and GenSets have to be changed from HFO to MDO/MGO/Distillate and vice versa, the 3-way valve (*“DIESELswitch”*) just after the service tanks has to be activated.

The change-over between HFO and MDO/MGO/Distillate needs to be done very thoroughly with high attention to temperature/viscosity. Incorrect handling can damage the engine.

An MDO separator must be installed upstream of the MDO service tank. Separation temperature must be in the range 40 – 50°C. Most solid particles (*sand, rust and catalyst particles*) and water can be removed, and the cleaning intervals of the filter elements can be extended considerably.

It is possible, however not our standard/recommendation, to install a common MGO/MDO back-flush filter for all GenSet.

Emergency start

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

1. Pneumatic driven MGO/MDO circulation pump with air supply from starting air bottles. Air consumption of the pump must be included in calculation of starting air consumption and sizes of starting air bottles according to classification rules in this regard.
2. Electrical driven MGO/MDO circulation pump connected to the emergency switchboard.
3. MGO gravity tank (*100 - 200 litres*) can be arranged above the GenSet. With no pumps available, it is possible to start up the GenSet if a gravity tank can be installed minimum 8 metres directly above the GenSet. However, only if the connection to the GenSet is as directly as possible, meaning change-over valve “V1-V2” should be placed as near as possible to the GenSet.

Sampling points

Points for taking fuel oil samples are recommended in following locations:

1. After the fuel oil service tank. Before any fuel change-over valve.
2. Before and after any fuel filters and/or separator to verify the filter effectiveness
3. Before each engine fuel inlet pipe.

Sampling points should be provided at locations within the fuel system that enable samples of fuel to be taken in a safe manner.

Position of a sampling point should be placed such that the fuel sample is representative of the oil fuel quality passing that location within the system.

The sampling points should be located in positions away from any heated surface or electrical equipment.

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Part-load optimisation - PLO

Description

MAN Diesel & Turbo is continuously adapting our engine programme to the changing market conditions.

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

Tuning method – part load optimisation

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

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

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

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

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

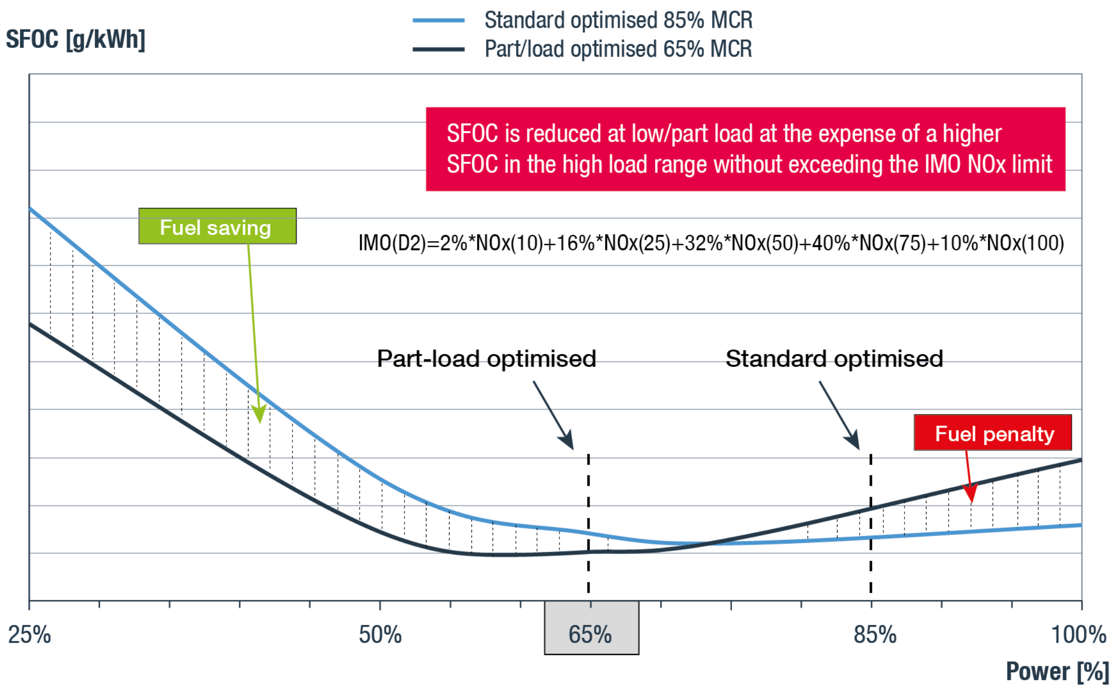

Figure 1: SFOC-curves from first delivery of PLO

Part-load optimisation - PLO

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

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

Design changes:

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

Specification of heavy fuel oil (HFO)

Prerequisites

MAN Energy Solutions four-stroke diesel engines can be operated with any heavy fuel oil obtained from crude oil that also satisfies the requirements in table The fuel specification and corresponding characteristics for heavy fuel oil providing the engine and fuel processing system have been designed accordingly. To ensure that the relationship between the fuel, spare parts and repair / maintenance costs remains favourable at all times, the following points should be observed.

Heavy fuel oil (HFO)

Origin/Refinery process

The quality of the heavy fuel oil largely depends on the quality of crude oil and on the refining process used. This is why the properties of heavy fuel oils with the same viscosity may vary considerably depending on the bunker positions. Heavy fuel oil is normally a mixture of residual oil and distillates. The components of the mixture are normally obtained from modern refinery processes, such as Catcracker or Visbreaker. These processes can adversely affect the stability of the fuel as well as its ignition and combustion properties. The processing of the heavy fuel oil and the operating result of the engine also depend heavily on these factors.

Bunker positions with standardised heavy fuel oil qualities should preferably be used. If oils need to be purchased from independent dealers, also ensure that these also comply with the international specifications. The engine operator is responsible for ensuring that suitable heavy fuel oils are chosen.

Specifications

Fuels intended for use in an engine must satisfy the specifications to ensure sufficient quality. The limit values for heavy fuel oils are specified in Table The fuel specification and corresponding characteristics for heavy fuel oil. The entries in the last column of this table provide important background information and must therefore be observed.

The relevant international specification is ISO 8217 in the respectively applicable version. All qualities in these specifications up to K700 can be used, provided the fuel system has been designed for these fuels. To use any fuels, which do not comply with these specifications (e.g. crude oil), consultation with Technical Service of MAN Energy Solutions in Augsburg is required. Heavy fuel oils with a maximum density of 1,010 kg/m3 may only be used if up-to-date separators are installed.

Important

Even though the fuel properties specified in the table entitled The fuel specification and corresponding properties for heavy fuel oil satisfy the above requirements, they probably do not adequately define the ignition and combustion properties and the stability of the fuel. This means that the operating behaviour of the engine can depend on properties that are not defined in the specification. This particularly applies to the oil property that causes formation of deposits in the combustion chamber, injection system, gas ducts and exhaust gas system. A number of fuels have a tendency towards incompatibility with lubricating oil which leads to deposits being formed in the fuel delivery pump that can block the pumps. It may therefore be necessary to exclude specific fuels that could cause problems.

Blends

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

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

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

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

Leak oil collector

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

Viscosity (at 50 °C)	mm^2/s (cSt)	max.	700	Viscosity/injection viscosity
Viscosity (at 100 °C)		max.	55	Viscosity/injection viscosity
Density (at 15 °C)	g/ml	max.	1.010	Heavy fuel oil preparation
Flash point	°C	min.	60	Flash point (ASTM D 93)
Pour point (summer)		max.	30	Low-temperature behaviour (ASTM D 97)
Pour point (winter)		max.	30	Low-temperature behaviour (ASTM D 97)
Coke residue (Conradson)	weight %	max.	20	Combustion properties
Sulphur content			5 or legal requirements	Sulphuric acid corrosion
Ash content			0.15	Heavy fuel oil preparation
Vanadium content	mg/kg		450	Heavy fuel oil preparation
Water content	Vol. %		0.5	Heavy fuel oil preparation
Sediment (potential)	weight %		0.1	–
Aluminium and silicon content (total)	mg/kg	max.	60	Heavy fuel oil preparation
Acid number	mg KOH/g		2.5	–
Hydrogen sulphide	mg/kg		2	–
Used lube oil (ULO) (calcium, zinc, phosphorus)	mg/kg		Calcium max. 30 mg/kg Zinc max. 15 mg/kg Phosphorus max. 15 mg/kg	The fuel must be free of lube oil (ULO – used lube oil). A fuel is considered contaminated with lube oil if the following concentrations occur: Ca > 30 ppm and Zn > 15 ppm or Ca > 30 ppm and P > 15 ppm.

Asphalt content	weight %		2/3 of coke residue (acc. to Conradson)	Combustion properties This requirement applies accordingly.
Sodium content	mg/kg		Sodium < 1/3 vanadium, sodium <100	Heavy fuel oil preparation
The fuel must be free of admixtures that have not been obtained from petroleum such as vegetable or coal tar oils, free of tar oil and lube oil (used oil), and free of chemical wastes, solvents or polymers.				

Table 1: The fuel specification and the corresponding properties for heavy fuel oil

ISO 8217-2012 HFO specification

Characteristic	Unit	Limit	Category ISO-F-											Test method
			RMA	RMB	RMD	RME	RMG				RMK			
			10[a]	30	80	180	180	380	500	700	380	500	700	
Kinematic viscosity at 50 °C[b]	mm^2/s	Max.	10.00	30.00	80.00	180.0	180.0	380.0	500.0	700.0	380.0	500.0	700.0	ISO 3104
Density at 15 °C	kg/m^3	Max.	920.0	960.0	975.0	991.0	991.0				1010.0			See 7.1 ISO 3675 or ISO 12185
CCAI	–	Max.	850	860	860	860	870				870			See 6.3 a)
Sulfur[c]	% (m/m)	Max.	Statutory requirements											See 7.2 ISO 8754 ISO 14596
Flash point	°C	Min.	60.0	60.0	60.0	60.0	60.0				60.0			See 7.3 ISO 2719
Hydrogen sulfide	mg/kg	Max.	2.00	2.00	2.00	2.00	2.00				2.00			See 7.11 IP 570
Acid number[d]	mg KOH/g	Max.	2.5	2.5	2.5	2.5	2.5				2.5			ASTM D664
Total sediment aged	% (m/m)	Max.	0.10	0.10	0.10	0.10	0.10				0.10			See 7.5 ISO 10307-2
Carbon residue: micro method	% (m/m)	Max.	2.50	10.00	14.00	15.00	18.00				20.00			ISO 10370

Quality guidelines (conventional and Common Rail engines)
General

Quality guidelines (conventional and Common Rail engines)

Characteristic	Unit	Limit	Category ISO-F-											Test method
			RMA	RMB	RMD	RME	RMG				RMK			
			10[a]	30	80	180	180	380	500	700	380	500	700	
Pour point (upper)[e] Winter quality	°C	Max.	0	0	30	30	30				30			ISO 3016
Summer quality	°C	Max.	6	6	30	30	30				30			ISO 3016
Water	% (V/V)	Max.	0.30	0.50	0.50	0.50	0.50				0.50			ISO 3733
Ash	% (m/m)	Max.	0.040	0.070	0.070	0.070	0.100				0.150			ISO 6245
Vanadium	mg/kg	Max.	50	150	150	150	350				450			see 7.7 IP 501, IP 470 or ISO 14597
Sodium	mg/kg	Max.	50	100	100	50	100				100			see 7.8 IP 501, IP 470
Aluminium plus silicon	mg/kg	Max.	25	40	40	50	60				60			see 7.9 IP 501, IP 470 or ISO 10478
Used lubricating oils (ULO):		–	The fuel shall be free from ULO. A fuel shall be considered to contain ULO when either one of the following conditions is met:											(see 7.10) IP 501 or
calcium and zinc or	mg/kg		calcium > 30 and zinc > 15											IP 470
calcium and phosphorus	mg/kg		or calcium > 30 and phosphorus > 15											IP 500

a	This category is based on a previously defined distillate DMC category that was described in ISO 8217:2005, Table 1. ISO 8217:2005 has been withdrawn.
b	$1 mm^2/s = 1 cSt$
c	The purchaser shall define the maximum sulfur content in accordance with relevant statutory limitations. See 0.3 and Annex C.
d	See Annex H.
e	Purchasers shall ensure that this pour point is suitable for the equipment on board, especially if the ship operates in cold climates.

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Additional information

The purpose of the following information is to show the relationship between the quality of heavy fuel oil, heavy fuel oil processing, the engine operation and operating results more clearly.

Selection of heavy fuel oil

Economical operation with heavy fuel oil within the limit values specified in the table entitled The fuel specification and corresponding properties for heavy fuel oil is possible under normal operating conditions, provided the system is working properly and regular maintenance is carried out. If these requirements are not satisfied, shorter maintenance intervals, higher wear and a greater need for spare parts is to be expected. The required maintenance intervals and operating results determine which quality of heavy fuel oil should be used.

It is an established fact that the price advantage decreases as viscosity increases. It is therefore not always economical to use the fuel with the highest viscosity as in many cases the quality of this fuel will not be the best.

Viscosity/injection viscosity

Heavy fuel oils with a high viscosity may be of an inferior quality. The maximum permissible viscosity depends on the preheating system installed and the capacity (flow rate) of the separator.

The prescribed injection viscosity of 12 – 14 mm²/s (for GenSets, L16/24, L21/31, L23/30H, L27/38, L28/32H: 12 – 18 cSt) and corresponding fuel temperature upstream of the engine must be observed. This is the only way to ensure efficient atomisation and mixture formation and therefore low-residue combustion. This also prevents mechanical overloading of the injection system. For the prescribed injection viscosity and/or the required fuel oil temperature upstream of the engine, refer to the viscosity temperature diagram.

Heavy fuel oil processing

Whether or not problems occur with the engine in operation depends on how carefully the heavy fuel oil has been processed. Particular care should be taken to ensure that highly-abrasive inorganic foreign matter (catalyst particles, rust, sand) are effectively removed. It has been shown in practice that wear as a result of abrasion in the engine increases considerably if the aluminum and silicium content is higher than 15 mg/kg.

Viscosity and density influence the cleaning effect. This must be taken into account when designing and making adjustments to the cleaning system.

Settling tank

The heavy fuel oil is pre-cleaned in the settling tank. This pre-cleaning is more effective the longer the fuel remains in the tank and the lower the viscosity of the heavy fuel oil (maximum preheating temperature 75 °C in order to prevent the formation of asphalt in the heavy fuel oil). One settling tank is suitable for heavy fuel oils with a viscosity below 380 mm²/s at 50 °C. If the heavy fuel oil has high concentrations of foreign material or if fuels according to ISO-F-RM, G/K380 or K700 are used, two settling tanks are necessary, one of which must be designed for operation over 24 hours. Before transferring the contents into the service tank, water and sludge must be drained from the settling tank.

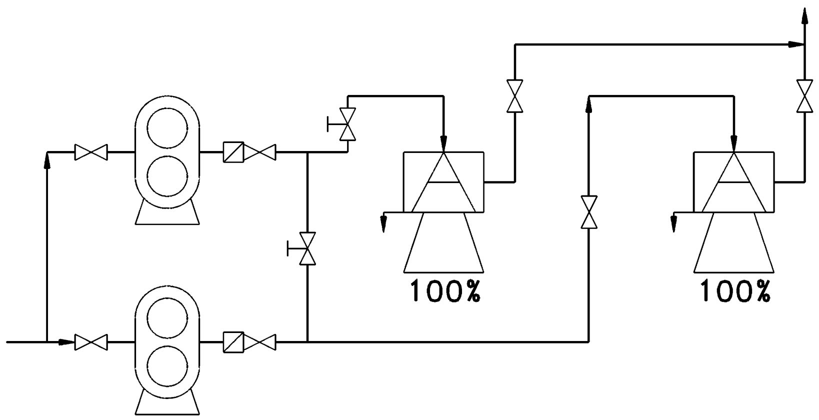
Separators

A separator is particularly suitable for separating material with a higher specific density – such as water, foreign matter and sludge. The separators must be self-cleaning (i.e. the cleaning intervals must be triggered automatically).

Only new generation separators should be used. They are extremely effective throughout a wide density range with no changeover required, and can separate water from heavy fuel oils with a density of up to 1.01 g/ml at 15 °C.

Table Achievable contents of foreign matter and water (after separation) shows the prerequisites that must be met by the separator. These limit values are used by manufacturers as the basis for dimensioning the separator and ensure compliance.

The manufacturer's specifications must be complied with to maximize the cleaning effect.



Application in ships and stationary use: parallel installation
One separator for 100% flow rate One separator (reserve) for 100% flow rate

Figure 1: Arrangement of heavy fuel oil cleaning equipment and/or separator

The separators must be arranged according to the manufacturers' current recommendations (Alfa Laval and Westphalia). The density and viscosity of the heavy fuel oil in particular must be taken into account. If separators by other manufacturers are used, MAN Energy Solutions should be consulted.

If the treatment is in accordance with the MAN Energy Solutions specifications and the correct separators are chosen, it may be assumed that the results stated in the table entitled Achievable contents of foreign matter and water for inorganic foreign matter and water in heavy fuel oil will be achieved at the engine inlet.

Results obtained during operation in practice show that the wear occurs as a result of abrasion in the injection system and the engine will remain within acceptable limits if these values are complied with. In addition, an optimum lube oil treatment process must be ensured.

Definition	**Particle size**	**Quantity**
Inorganic foreign matter including catalyst particles	< 5 µm	< 20 mg/kg
Al+Si content	–	< 15 mg/kg
Water content	–	< 0.2 vol.%

Table 2: Achievable contents of foreign matter and water (after separation)

Water

It is particularly important to ensure that the water separation process is as thorough as possible as the water takes the form of large droplets, and not a finely distributed emulsion. In this form, water also promotes corrosion and sludge formation in the fuel system and therefore impairs the supply, atomisation and combustion of the heavy fuel oil. If the water absorbed in the fuel is seawater, harmful sodium chloride and other salts dissolved in this water will enter the engine.

Water-containing sludge must be removed from the settling tank before the separation process starts, and must also be removed from the service tank at regular intervals. The tank's ventilation system must be designed in such a way that condensate cannot flow back into the tank.

Vanadium/Sodium

If the vanadium/sodium ratio is unfavourable, the melting point of the heavy fuel oil ash may fall in the operating area of the exhaust-gas valve which can lead to high-temperature corrosion. Most of the water and water-soluble sodium compounds it contains can be removed by pretreating the heavy fuel oil in the settling tank and in the separators.

The risk of high-temperature corrosion is low if the sodium content is one third of the vanadium content or less. It must also be ensured that sodium does not enter the engine in the form of seawater in the intake air.

If the sodium content is higher than 100 mg/kg, this is likely to result in a higher quantity of salt deposits in the combustion chamber and exhaust-gas system. This will impair the function of the engine (including the suction function of the turbocharger).

Under certain conditions, high-temperature corrosion can be prevented by using a fuel additive that increases the melting point of heavy fuel oil ash (also see Additives for heavy fuel oils).

Ash

Fuel ash consists for the greater part of vanadium oxide and nickel sulphate (see above section for more information). Heavy fuel oils containing a high proportion of ash in the form of foreign matter, e.g. sand, corrosion compounds and catalyst particles, accelerate the mechanical wear in the engine. Catalyst particles produced as a result of the catalytic cracking process may be present in the heavy fuel oils. In most cases, these catalyst particles are aluminium silicates causing a high degree of wear in the injection system and the engine. The aluminium content determined, multiplied by a factor of between 5 and 8 (depending on the catalytic bond), is roughly the same as the proportion of catalyst remnants in the heavy fuel oil.

Homogeniser

If a homogeniser is used, it must never be installed between the settling tank and separator as otherwise it will not be possible to ensure satisfactory separation of harmful contaminants, particularly seawater.

Flash point (ASTM D 93)

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

Low-temperature behaviour (ASTM D 97)

The pour point is the temperature at which the fuel is no longer flowable (pumpable). As the pour point of many low-viscosity heavy fuel oils is higher than 0 °C, the bunker facility must be preheated, unless fuel in accordance with RMA or RMB is used. The entire bunker facility must be designed in such a way that the heavy fuel oil can be preheated to around 10 °C above the pour point.

Pump characteristics

If the viscosity of the fuel is higher than 1000 mm^2/s (cSt), or the temperature is not at least 10 °C above the pour point, pump problems will occur. For more information, also refer to paragraph Low-temperature behaviour (ASTM D 97.

Combustion properties

If the proportion of asphalt is more than two thirds of the coke residue (Conradson), combustion may be delayed which in turn may increase the formation of combustion residues, leading to such as deposits on and in the injection nozzles, large amounts of smoke, low output, increased fuel consumption and a rapid rise in ignition pressure as well as combustion close to the cylinder wall (thermal overloading of lubricating oil film). If the ratio of asphalt to coke residues reaches the limit 0.66, and if the asphalt content exceeds 8%, the risk of deposits forming in the combustion chamber and injection system is higher. These problems can also occur when using unstable heavy fuel oils, or if incompatible heavy fuel oils are mixed. This would lead to an increased deposition of asphalt (see paragraph Compatibility).

Ignition quality

Nowadays, to achieve the prescribed reference viscosity, cracking-process products are used as the low viscosity ingredients of heavy fuel oils although the ignition characteristics of these oils may also be poor. The cetane number of these compounds should be > 35. If the proportion of aromatic hydrocarbons is high (more than 35 %), this also adversely affects the ignition quality.

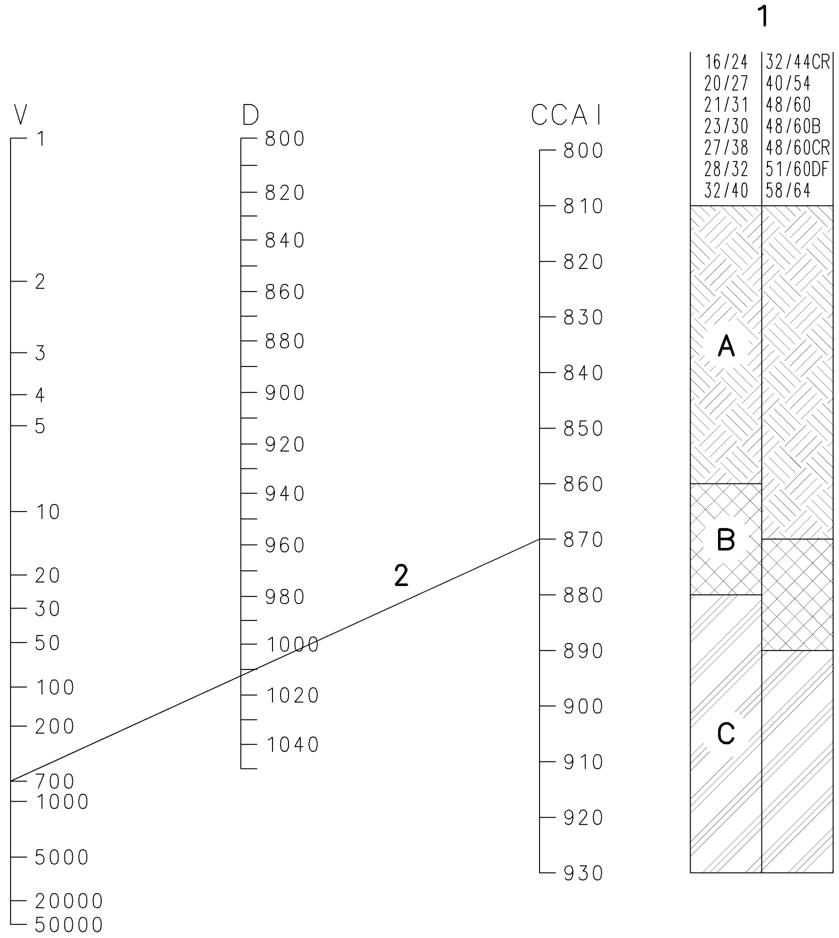
The ignition delay in heavy fuel oils with poor ignition characteristics is longer; the combustion is also delayed which can lead to thermal overloading of the oil film at the cylinder liner and also high cylinder pressures. The ignition delay and accompanying increase in pressure in the cylinder are also influenced by the end temperature and compression pressure, i.e. by the compression ratio, the charge-air pressure and charge-air temperature.

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

The ignition quality is one of the most important properties of the fuel. This value appears as CCAI in ISO 8217. This method is only applicable to "straight run" residual oils. The increasing complexity of refinery processes has the effect that the CCAI method does not correctly reflect the ignition behaviour for all residual oils.

A testing instrument has been developed based on the constant volume combustion method (fuel combustion analyser FCA), which is used in some fuel testing laboratories (FCA) in conformity with IP 541.
The instrument measures the ignition delay to determine the ignition quality of a fuel and this measurement is converted into an instrument-specific cetane number (ECN: Estimated Cetane Number). It has been determined that heavy fuel oils with a low ECN number cause operating problems and may even lead to damage to the engine. An ECN >20 can be considered acceptable.

As the liquid components of the heavy fuel oil decisively influence the ignition quality, flow properties and combustion quality, the bunker operator is responsible for ensuring that the quality of heavy fuel oil delivered is suitable for the diesel engine. Also see illustration entitled Nomogram for determining the CCAI – assigning the CCAI ranges to engine types.



V Viscosity in mm²/s (cSt) at 50° C

D Density [in kg/m³] at 15° C

CCAI Calculated Carbon Aromaticity Index

1 Engine type

A Normal operating conditions

B The ignition characteristics can be poor and require adapting the engine or the operating conditions.

C Problems identified may lead to engine damage, even after a short period of operation.

2 The CCAI is obtained from the straight line through the density and viscosity of the heavy fuel oils.

The CCAI can be calculated using the following formula:

CCAI = D - 141 log log (V+0.85) - 81

Figure 2: Nomogram for determining the CCAI and assigning the CCAI ranges to engine types

Sulphuric acid corrosion

The engine should be operated at the coolant temperatures prescribed in the operating handbook for the relevant load. If the temperature of the components that are exposed to acidic combustion products is below the acid dew point, acid corrosion can no longer be effectively prevented, even if alkaline lube oil is used.

The BN values specified in 010.005 Engine - Operating instructions 010.000.023-11 are sufficient, providing the quality of lubricating oil and the engine's cooling system satisfy the requirements.

Compatibility

The supplier must guarantee that the heavy fuel oil is homogeneous and remains stable, even after the standard storage period. If different bunker oils are mixed, this can lead to separation and the associated sludge formation in the fuel system during which large quantities of sludge accumulate in the separator that block filters, prevent atomisation and a large amount of residue as a result of combustion.

This is due to incompatibility or instability of the oils. Therefore heavy fuel oil as much as possible should be removed in the storage tank before bunkering again to prevent incompatibility.

Blending the heavy fuel oil

If heavy fuel oil for the main engine is blended with gas oil (MGO) or other residual fuels (e.g. LSFO or ULSFO) to obtain the required quality or viscosity of heavy fuel oil, it is extremely important that the components are compatible (see section Compatibility). The compatibility of the resulting mixture must be tested over the entire mixing range. A reduced long-term stability due to consumption of the stability reserve can be a result. A p-value > 1.5 as per ASTM D7060 is necessary.

Additives for heavy fuel oils

MAN Energy Solutions engines can be operated economically without additives. It is up to the customer to decide whether or not the use of additives is beneficial. The supplier of the additive must guarantee that the engine operation will not be impaired by using the product.

The use of heavy fuel oil additives during the warranty period must be avoided as a basic principle.

Additives that are currently used for diesel engines, as well as their probable effects on the engine's operation, are summarised in the table below Additives for heavy fuel oils and their effects on the engine operation.

Precombustion additives	▪ Dispersing agents/stabilisers ▪ Emulsion breakers ▪ Biocides
Combustion additives	▪ Combustion catalysts (fuel savings, emissions)
Post-combustion additives	▪ Ash modifiers (hot corrosion) ▪ Soot removers (exhaust-gas system)

Table 3: Additives for heavy fuel oils and their effects on the engine operation

Heavy fuel oils with low sulphur content

From the point of view of an engine manufacturer, a lower limit for the sulphur content of heavy fuel oils does not exist. We have not identified any problems with the low-sulphur heavy fuel oils currently available on the market that can be traced back to their sulphur content. This situation may change in future if new methods are used for the production of low-sulphur heavy fuel oil (desulphurisation, new blending components). MAN Energy Solutions will monitor developments and inform its customers if required.

If the engine is not always operated with low-sulphur heavy fuel oil, corresponding lubricating oil for the fuel with the highest sulphur content must be selected.

⚠ WARNING

Handling of operating fluids

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

- Observe safety data sheets of the operating fluid supplier.

Tests

Sampling

To check whether the specification provided and/or the necessary delivery conditions are complied with, we recommend you retain at least one sample of every bunker oil (at least for the duration of the engine's warranty period). To ensure that the samples taken are representative of the bunker oil, a sample should be taken from the transfer line when starting up, halfway through the operating period and at the end of the bunker period. "Sample Tec" by Mar-Tec in Hamburg is a suitable testing instrument which can be used to take samples on a regular basis during bunkering.

Analysis of samples

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

Analysis of HFO samples is very important for safe engine operation. We can analyse fuel for customers at MAN Energy Solutions laboratory PrimeServ-Lab.

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Specification of diesel oil (MDO)

Marine diesel oil

Other designations Marine diesel oil, marine diesel fuel.

Origin Marine diesel oil (MDO) is supplied as heavy distillate (designation ISO-F-DMB) exclusively for marine applications. MDO is manufactured from crude oil and must be free of organic acids and non-mineral oil products.

Specification

The suitability of a fuel depends on the engine design and the available cleaning options as well as compliance with the properties in the following table that refer to the as-delivered condition of the fuel.

The properties are essentially defined using the ISO 8217 standard in the current version as the basis. The properties have been specified using the stated test procedures.

Properties	Unit	Test procedure	Designation
ISO-F specification	–	–	DMB
Density at 15 °C	kg/m³	ISO 3675	< 900
Kinematic viscosity at 40 °C	mm²/s ≙ cSt	ISO 3104	> 2.0 < 11 [1)]
Pour point, winter grade	°C	ISO 3016	< 0
Pour point, summer grade	°C	ISO 3016	< 6
Flash point (Pensky Martens)	°C	ISO 2719	> 60
Total sediment content	weight %	ISO CD 10307	0.10
Water content	Vol. %	ISO 3733	< 0.3
Sulphur content	weight %	ISO 8754	< 2.0
Ash content	weight %	ISO 6245	< 0.01
Coke residue (MCR)	weight %	ISO CD 10370	< 0.30
Cetane index and cetane number	-	ISO 4264 ISO 5165	> 35
Hydrogen sulphide	mg/kg	IP 570	< 2
Acid number	mg KOH/g	ASTM D664	< 0.5
Oxidation stability	g/m³	ISO 12205	< 25
Lubricity (wear scar diameter)	µm	ISO 12156-1	< 520
Other specifications:			
ASTM D 975	–	–	2D
ASTM D 396	–	–	No. 2

Table 1: Properties of Marine Diesel Oil (MDO) to be maintained

[1)] For engines 27/38 with 350 resp. 365 kW/cyl the viscosity must not exceed 6 mm²/s @ 40 °C, as this would reduce the lifetime of the injection system.

Additional information

During reloading and transfer, MDO is treated like residual oil. It is possible that oil is mixed with high-viscosity fuel or heavy fuel oil, for example with residues of such fuels in the bunker vessel, which can markedly deteriorate the properties. Admixtures of biodiesel (FAME) are not permissible!

Lubricity

Normally, the lubricating ability of diesel oil is sufficient to operate the fuel injection pump. Desulphurisation of diesel fuels can reduce their lubricity. If the sulphur content is extremely low (< 500 ppm or 0.05%), the lubricity may no longer be sufficient. Before using diesel fuels with low sulphur content, you should therefore ensure that their lubricity is sufficient. This is the case if the lubricity as specified in ISO 12156-1 does not exceed 520 µm.

You can ensure that these conditions will be met by using motor vehicle diesel fuel in accordance with EN 590 as this characteristic value is an integral part of the specification.

The fuel must be free of lubricating oil (ULO – used lubricating oil, old oil). Fuel is considered as contaminated with lubricating oil when the following concentrations occur:

Ca > 30 ppm and Zn > 15 ppm or Ca > 30 ppm and P > 15 ppm.

The pour point specifies the temperature at which the oil no longer flows. The lowest temperature of the fuel in the system should be roughly 10 °C above the pour point to ensure that the required pumping characteristics are maintained.

A minimum viscosity must be observed to ensure sufficient lubrication in the fuel injection pumps. The temperature of the fuel must therefore not exceed 45 °C.

Seawater causes the fuel system to corrode and also leads to hot corrosion of the exhaust valves and turbocharger. Seawater also causes insufficient atomisation and therefore poor mixture formation accompanied by a high proportion of combustion residues.

Solid foreign matters increase mechanical wear and formation of ash in the cylinder space.

We recommend the installation of a separator upstream of the fuel filter. Separation temperature: 40 – 50°C. Most solid particles (sand, rust and catalyst particles) and water can be removed, and the cleaning intervals of the filter elements can be extended considerably.

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Analyses

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2018-09-06 - de

Specification of gas oil/diesel oil (MGO)

Diesel oil

Other designations

Gas oil, marine gas oil (MGO), diesel oil

Gas oil is a crude oil medium distillate and therefore must not contain any residual materials.

Military specification

Diesel fuels that satisfy the NATO F-75 or F-76 specifications may be used if they adhere to the minimum viscosity requirements.

Specification

The suitability of fuel depends on whether it has the properties defined in this specification (based on its composition in the as-delivered state).

The DIN EN 590 standard and the ISO 8217 standard (Class DMA or Class DMZ) in the current version have been extensively used as the basis when defining these properties. The properties correspond to the test procedures stated.

Properties	Unit	Test procedure	Typical value
Density at 15 °C	kg/m³	ISO 3675	≥ 820.0 ≤ 890.0
Kinematic viscosity at 40 °C	mm²/s (cSt)	ISO 3104	≥ 2 ≤ 6.0
Filtering capability [1)] in summer and in winter	 °C °C	 DIN EN 116 DIN EN 116	must be indicated
Flash point in enclosed crucible	°C	ISO 2719	≥ 60
Sediment content (extraction method)	weight %	ISO 3735	≤ 0.01
Water content	Vol. %	ISO 3733	≤ 0.05
Sulphur content	weight %	ISO 8754	≤ 1.5
Ash		ISO 6245	≤ 0.01
Coke residue (MCR)		ISO CD 10370	≤ 0.10
Hydrogen sulphide	mg/kg	IP 570	< 2
Acid number	mg KOH/g	ASTM D664	< 0.5
Oxidation stability	g/m³	ISO 12205	< 25
Lubricity (wear scar diameter)	µm	ISO 12156-1	< 520
Content of biodiesel (FAME)	% (v/v)	EN 14078	not permissible
Cetane index and cetane number	–	ISO 4264 ISO 5165	≥ 40
Other specifications:			
ASTM D 975	–	–	1D/2D
[1)] It must be ensured that the fuel can be used under the climatic conditions in the area of application.			

Table 1: Properties of Diesel Fuel (MGO) to be maintained

Additional information

Use of diesel oil

If distillate intended for use as heating oil is used with stationary engines instead of diesel oil (EL heating oil according to DIN 51603 or Fuel No. 1 or no. 2 according to ASTM D 396), the ignition behaviour, stability and behaviour at low temperatures must be ensured; in other words the requirements for the filterability and cetane number must be satisfied.

Viscosity

To ensure sufficient lubrication, a minimum viscosity must be ensured at the fuel pump. The maximum temperature required to ensure that a viscosity of more than 1.9 mm^2/s is maintained upstream of the fuel pump, depends on the fuel viscosity. In any case, the fuel temperature upstream of the injection pump must not exceed 45 °C.

The pour point indicates the temperature at which the oil stops flowing. To ensure the pumping properties, the lowest temperature acceptable to the fuel in the system should be about 10 ° C above the pour point.

Lubricity

Normally, the lubricating ability of diesel oil is sufficient to operate the fuel injection pump. Desulphurisation of diesel fuels can reduce their lubricity. If the sulphur content is extremely low (< 500 ppm or 0.05%), the lubricity may no longer be sufficient. Before using diesel fuels with low sulphur content, you should therefore ensure that their lubricity is sufficient. This is the case if the lubricity as specified in ISO 12156-1 does not exceed 520 µm.

You can ensure that these conditions will be met by using motor vehicle diesel fuel in accordance with EN 590 as this characteristic value is an integral part of the specification.

WARNING

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Analyses

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Specification of bio fuel

Biofuel

Other designations Biodiesel, FAME, vegetable oil, rapeseed oil, palm oil, frying fat.

Origin Biofuel is derived from oil plants or old cooking oil.

Provision

Transesterified and non-transesterified vegetable oils can be used.

Transesterified biofuels (biodiesel, FAME) must comply with the standard EN 14214.

Non-transesterified biofuels must comply with the specifications listed in table Specification of non-transesterified bio fuel.

These specifications are based on experience to date. As this experience is limited, these must be regarded as recommended specifications that can be adapted if necessary. If future experience shows that these specifications are too strict, or not strict enough, they can be modified accordingly to ensure safe and reliable operation.

When operating with bio-fuels, lubricating oil that would also be suitable for operation with diesel oil.

See 010.005 Engine - Operating Instructions section 010.000.023-07.

Properties/features	Properties/unit	Testing method
Density at 15 °C	900–930 kg/m^3	DIN EN ISO 3675, EN ISO 12185
Flash point	> 60 °C	DIN EN 22719
Lower calorific value	> 35 MJ/kg (typically: 37 MJ/kg)	DIN 51900-3
Viscosity/50 °C	< 40 cSt (corresponds to viscosity/40 °C< 60 cSt)	DIN EN ISO 3104 ASTM D7042
Estimated cetane number	> 40	IP 541
Coke residue	< 0.4%	DIN EN ISO 10370
Sediment content	< 200 ppm	DIN EN 12662
Oxidation resistance (110 °C)	> 5 h	EN ISO 6886, EN 14112
Monoglyceride content	< 0.70% (m/m)	EN14105
Diglyceride content	< 0.20% (m/m)	EN14105
Triglyceride content	< 0.20% (m/m)	EN14105
Free glycerol content	< 0.02% (m/m)	EN14105
Phosphorus content	< 15 ppm	ASTM D3231
Na and K content	< 15 ppm	DIN 51797-3
Ash content	< 0.01%	DIN EN ISO 6245
Water content	< 0.5%	EN ISO 12537
Iodine number	< 125g/100g	DIN EN 14111

Properties/features	Properties/unit	Testing method
TAN (total acid number)	< 5 mg KOH/g	DIN EN ISO 660
Cold filter plugging point	10 °C below the lowest temperature in the fuel system	EN 116

Table 1: Specifications for non-interesterified bio fuel

WARNING

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- Observe safety data sheets of the operating fluid supplier.

Analyses

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

2018-09-12 - de

Explanatory notes for biofuel

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 – not transesterified biofuel and pour point below 20°C

For example:

- Vegetable oil
- Rape-seed oil

Not 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 – not transesterified biofuel and pour point above 20° C

For example:

- Palm oil
- Stearin
- Animal fat
- Frying fat

CAUTION

Not 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 heattracing (not to be applied for biofuel category 1). Heattracing to be applied for biofuel category 2 outside covers of injection pump area and for biofuel category 3 also inside injection pump area.
- Inlet valve lubrication (L32/40)
- Nozzle cooling to be applied for biofuel category 2 and 3. (L32/40)
- 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%

Crude oil specification

Crude oil

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

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

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

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

Properties/Characteristics	Unit	Limit	Test method
Viscosity, before injection pumps, min.	cSt	3	
Viscosity, before injection pumps, max.	cSt	14 [1)]	
Viscosity @ 50°C, max.	cSt	700	ISO 3104
Density @ 15°C, max.	kg/m^3	1010.0	ISO 3675 or ISO 12185
CCAI, max.	–	870	ISO 8217
Water before engine, max.	% volume	0.2	ISO 3733
Sulphur, max.	% mass	4.5	ISO 8754 or ISO 14596
Ash, max.	% mass	0.15	ISO 6245
Vanadium, max.	mg/kg	600	ISO 14597 or IP 501 or IP 470
Sodium + Potassium before engine, max.	mg/kg	1/3 Vanadium content	ISO 10478
Aluminium + Silicon before engine, max.	mg/kg	15	ISO 10478 or IP 501 or IP 470
Carbon residue, max.	% mass	20	ISO 10370
Asphaltenes, max.	% mass	2/3 of carbon residue (according to Conradson)	ASTM D3279
Reid vapour pressure (RVP), max.	kPa @ 37.8°C	65	ASTM D323
Lubricity (wear scar diameter)	µm	< 520	ISO 12156-1
Pour point, max.	°C	30	ISO 3016
Cold filter plugging point	°C	[2)]	IP 309
Total sediment potential, max.	% mass	0.10	ISO 10307-2
Hydrogen sulphide, max.	mg/kg	2	IP 570
AN (acid number), max.	mg KOH/g	2.5	ASTM D664

Table 1: Crude oil - specifications.

[1] Viscosity, before injection pumps, max. 18 cSt for GenSets L23/30H, L28/32H and V28/32S
[2] Minimum 10°C below the lowest temperature in the entire fuel system

Viscosity-temperature diagram (VT diagram)

Explanations of viscosity-temperature diagram

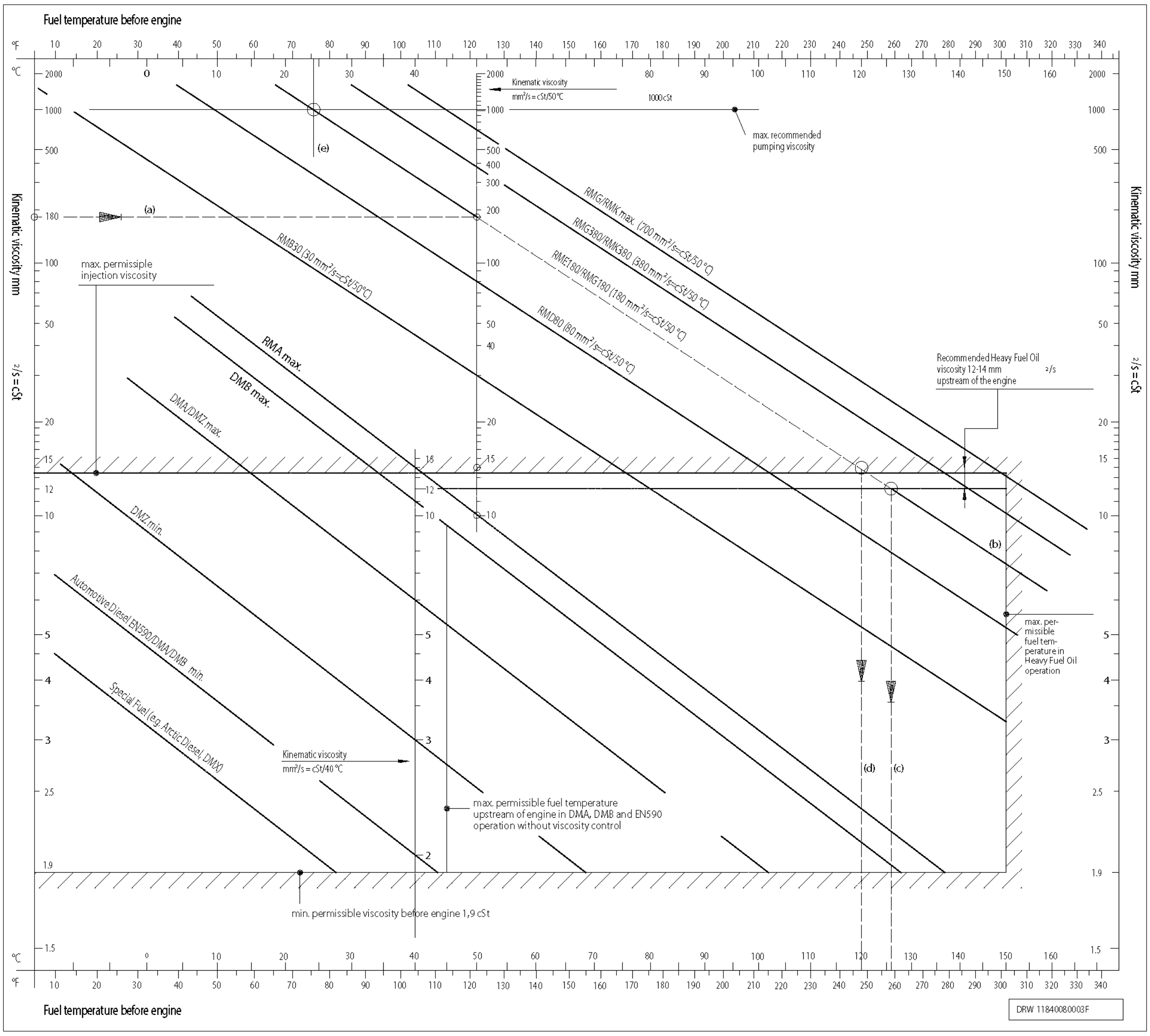

Figure 1: Viscosity-temperature diagram (VT diagram)

In the diagram, the fuel temperatures are shown on the horizontal axis and the viscosity is shown on the vertical axis.

The diagonal lines correspond to viscosity-temperature curves of fuels with different reference viscosities. The vertical viscosity axis in mm^2/s (cSt) applies for 40, 50 or 100 °C.

Determining the viscosity-temperature curve and the required preheating temperature

Example: Heavy fuel oil with 180 mm²/s at 50 °C

Prescribed injection viscosity in mm²/s	Required temperature of heavy fuel oil at engine inlet[1] in °C
≥ 12	126 (line c)
≤ 14	119 (line d)
[1] With these figures, the temperature drop between the last preheating device and the fuel injection pump is not taken into account.	

Table 1: Determining the viscosity-temperature curve and the required preheating temperature

A heavy fuel oil with a viscosity of 180 mm²/s at 50 °C can reach a viscosity of 1,000 mm²/s at 24 °C (line e) – this is the maximum permissible viscosity of fuel that the pump can deliver.

A heavy fuel oil discharge temperature of 152 °C is reached when using a recent state-of-the-art preheating device with 8 bar saturated steam. At higher temperatures there is a risk of residues forming in the preheating system – this leads to a reduction in heating output and thermal overloading of the heavy fuel oil. Asphalt is also formed in this case, i.e. quality deterioration.

The heavy fuel oil lines between the outlet of the last preheating system and the injection valve must be suitably insulated to limit the maximum drop in temperature to 4 °C. This is the only way to achieve the necessary injection viscosity of 14 mm²/s for heavy fuel oils with a reference viscosity of 700 mm²/s at 50 °C (the maximum viscosity as defined in the international specifications such as ISO CIMAC or British Standard). If heavy fuel oil with a low reference viscosity is used, the injection viscosity should ideally be 12 mm²/s in order to achieve more effective atomisation to reduce the combustion residue.

The delivery pump must be designed for heavy fuel oil with a viscosity of up to 1,000 mm²/s. The pour point also determines whether the pump is capable of transporting the heavy fuel oil. The bunker facility must be designed so as to allow the heavy fuel oil to be heated to roughly 10 °C above the pour point.

NOTICE

Viscosity

The viscosity of gas oil or diesel oil (marine diesel oil) upstream of the engine must be at least 1.9 mm²/s. If the viscosity is too low, this may cause seizing of the pump plunger or nozzle needle valves as a result of insufficient lubrication.

This can be avoided by monitoring the temperature of the fuel. Although the maximum permissible temperature depends on the viscosity of the fuel, it must never exceed the following values:

- 45 °C at the most with MGO (DMA) and MDO (DMB)

A fuel cooler must therefore be installed.

If the viscosity of the fuel is < 2 cSt at 40 °C, consult the technical service of MAN Energy Solutions in Augsburg.

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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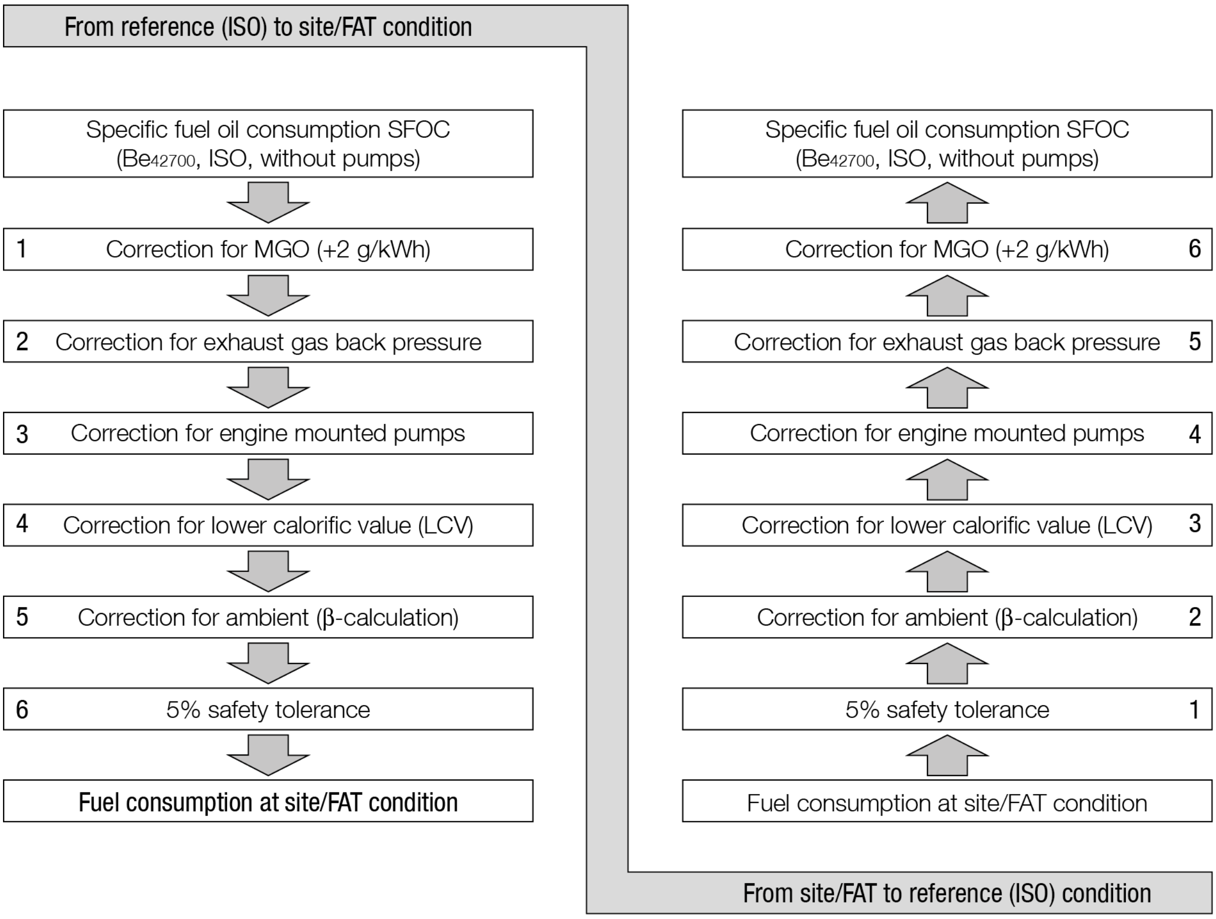
Calculation of specific fuel oil consumption (SFOC)

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%.

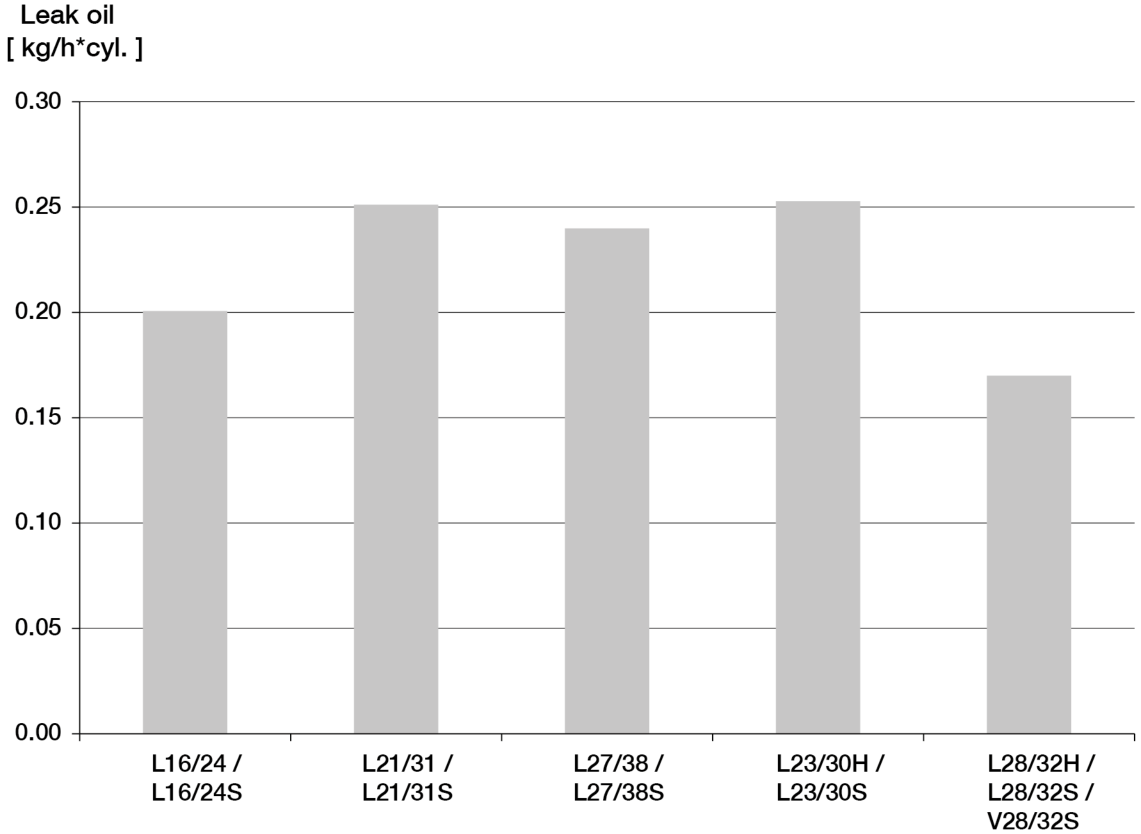


Figure 1: Leak oil on full load for MGO operation (for guidance only)

1) Safety tolerance 5%

Safety tolerance 5% is subtracted from fuel consumption

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

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:

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

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

$$Be2 = \frac{Be1}{ß}$$

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

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$b_x = ß \times b_r = 1.023 \times 200 = 204.6$ 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 L16/24/S, L21/31/S, L27/38/S

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

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

Engine type L23/30H/S/DF/S-DF, L28/32H/S/DF/S-DF, V28/32S/S-DF

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	$\times \left(\frac{110}{\text{load } \% + 10}\right) \%$

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

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:

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

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

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

L16/24 at 1000 rpm

5L16/24: 90 kW/cyl., 6-9L16/24: 95 kW/cyl.

% Load	100	85[1)]	75	50	25
Spec. fuel consumption (g/kWh) with HFO/ MDO without attached pumps [2) 3)]	195	195[1)]	194	202	223

[1)] Fuel consumption at 85% MCR
[2)] Tolerance +5%. Please note that the additions to fuel consumption must be considered before the tolerance is taken into account.
[3)] Based on reference, *see "Reference conditions"*

Table 1: Fuel oil consumption.

L16/24 at 1200 rpm

5L16/24: 100 kW/cyl., 6-9L16/24: 110 kW/cyl.

% Load	100	85[1)]	75	50	25
Spec. fuel consumption (g/kWh) with HFO/ MDO without attached pumps [2) 3)]	191	190[1)]	189	194	213

[1)] Fuel consumption at 85% MCR
[2)] Tolerance +5%. Please note that the additions to fuel consumption must be considered before the tolerance is taken into account.
[3)] Based on reference conditions, *see "Reference conditions"*

Table 2: Fuel oil consumption

No of cylinders	Fuel oil consumption at idle running (kg/h)				
	5L	6L	7L	8L	9L
Speed 1000/12000 rpm	12	14	16	18	20

Table 3: Fuel oil consumption at idle running

IMO Tier II requirements

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

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

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

For calculation of fuel consumption, *see "B 11 00 0 Recalculation of fuel oil consumption dependent on ambient conditions"*

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For operation with MGO SFOC will be increased by 2 g/kWh

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

Lub. oil main pump $1.2 \times \left(\frac{110}{\text{load \%} + 10}\right)$ %

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

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

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

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

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

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

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

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

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

Reference conditions

Reference conditions (according to ISO 3046-1: 2002; ISO 1550: 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	40
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)		

Table 4: Reference conditions.

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Fuel injection valve

Fuel injection valve

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

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

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

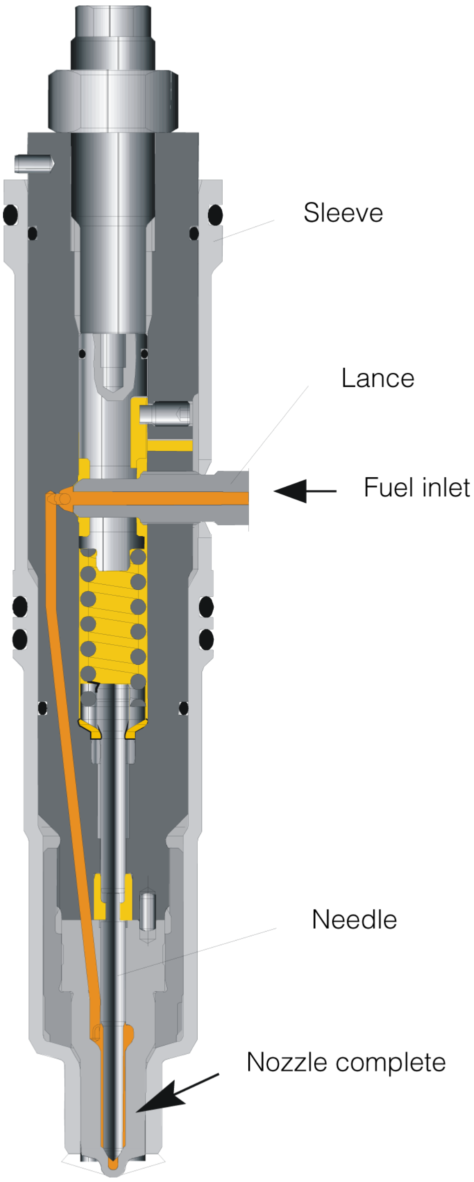

Figure 1: Fuel injection valve.

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Fuel injection pump

Fuel injection pump

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

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

At the same time it also gives the possibility to add sealing oil to minimize fuel contamination of the lubricating oil.

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

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

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

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

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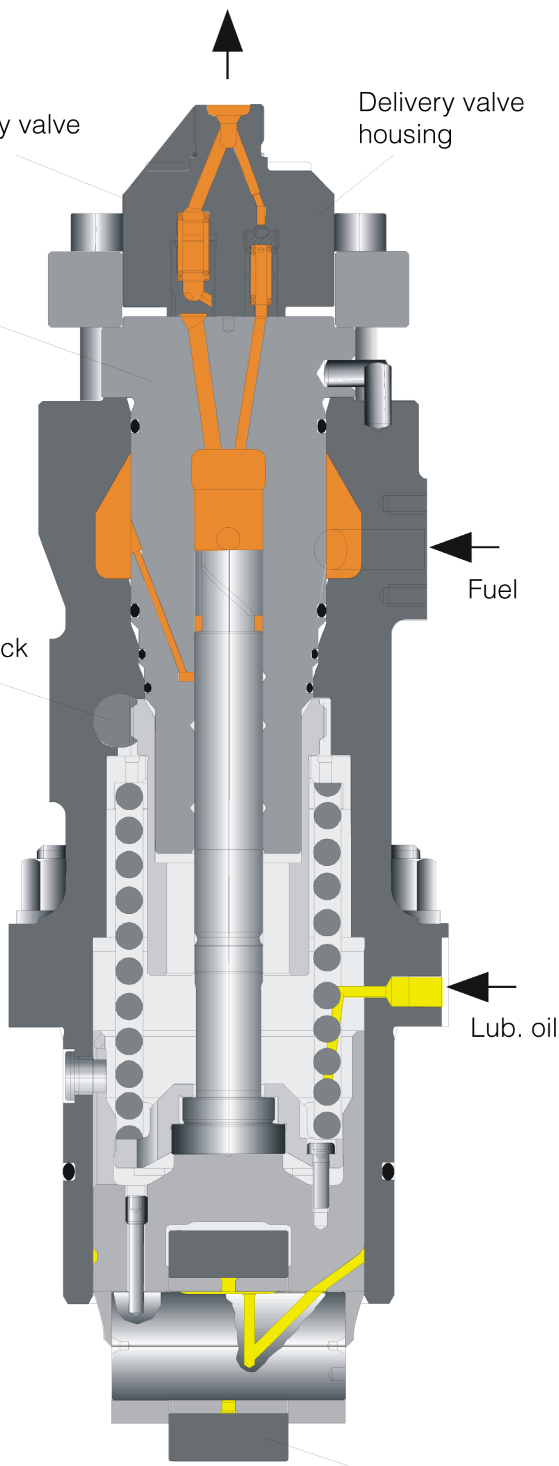

Figure 1: Fuel injection pump.

Fuel oil filter duplex

Fuel oil filter duplex

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

Table 1: Fuel oil filter duplex

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

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

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

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

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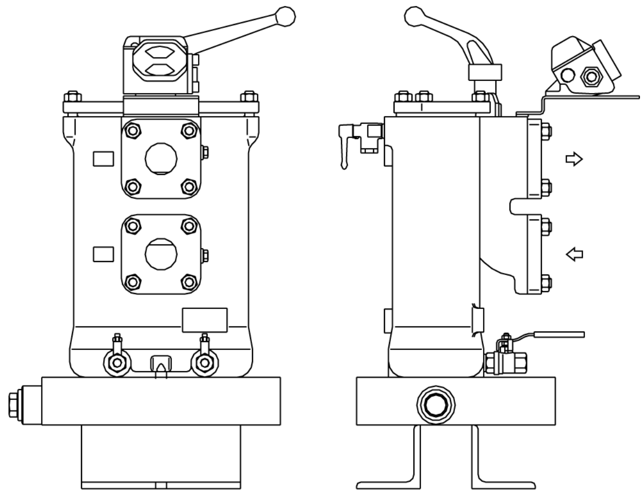
Figure 1: Fuel oil filter duplex.

MDO / MGO cooler

General

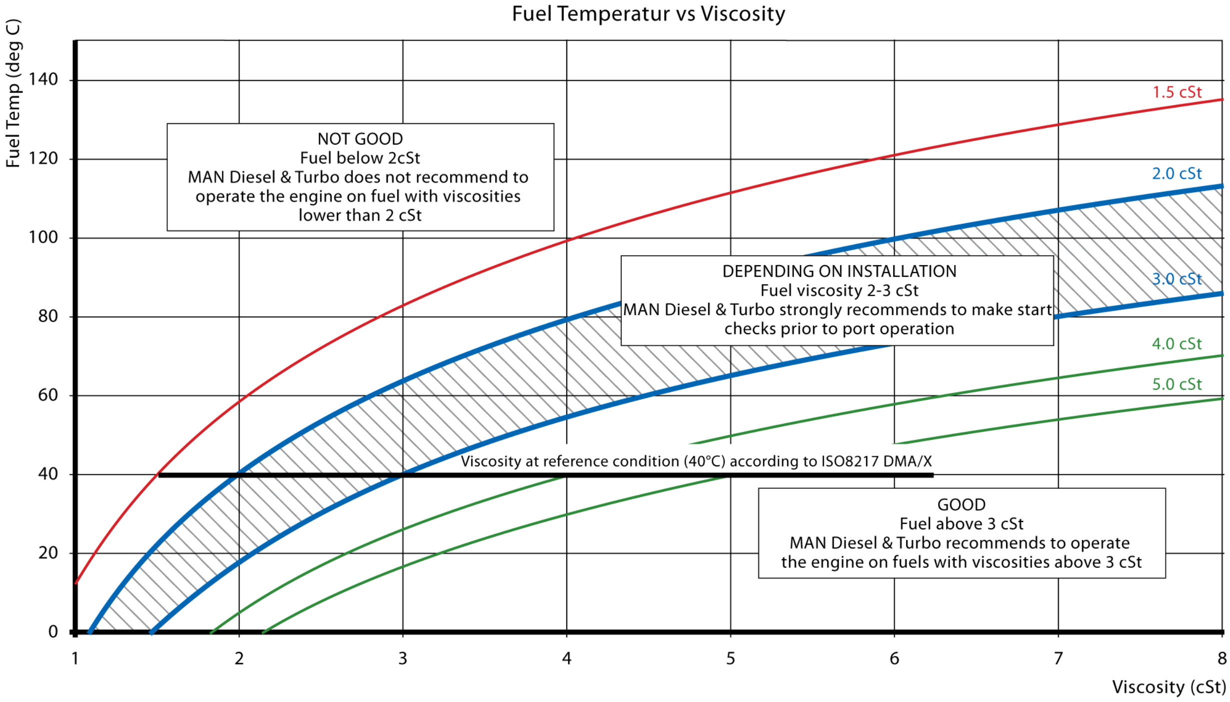

Figure 1: Fuel temperature versus viscosity.

In order to ensure a satisfactory hydrodynamic oil film between fuel injection pump plunger/barrel, thereby avoiding fuel injection pump seizures/sticking, MAN Diesel & Turbo 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	0.5
L21/31	1.0
L27/38	1.5
L32/40	2.0

Engine type	kW/cyl.
L23/30H	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).*

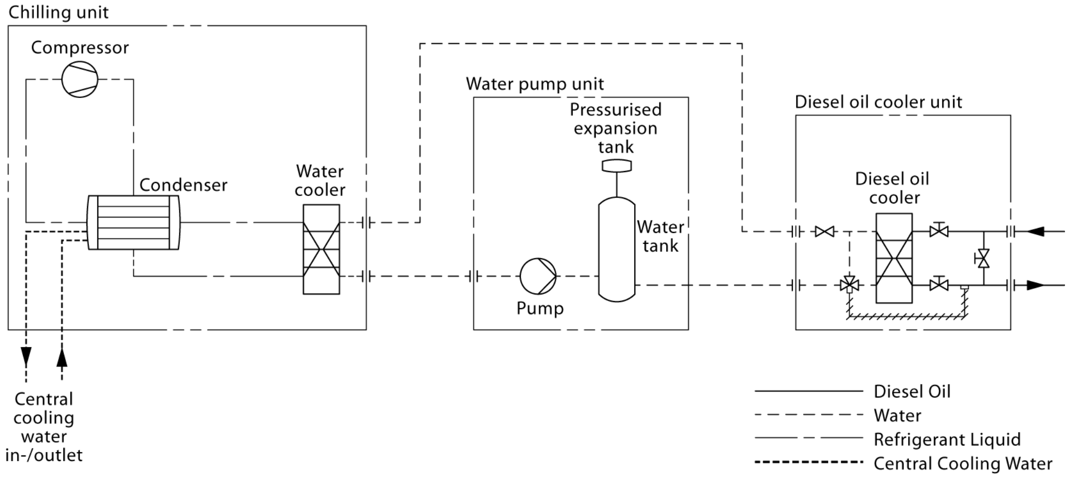

Figure 2: Chiller.

HFO/MDO changing valves (V1 and V2)

Description

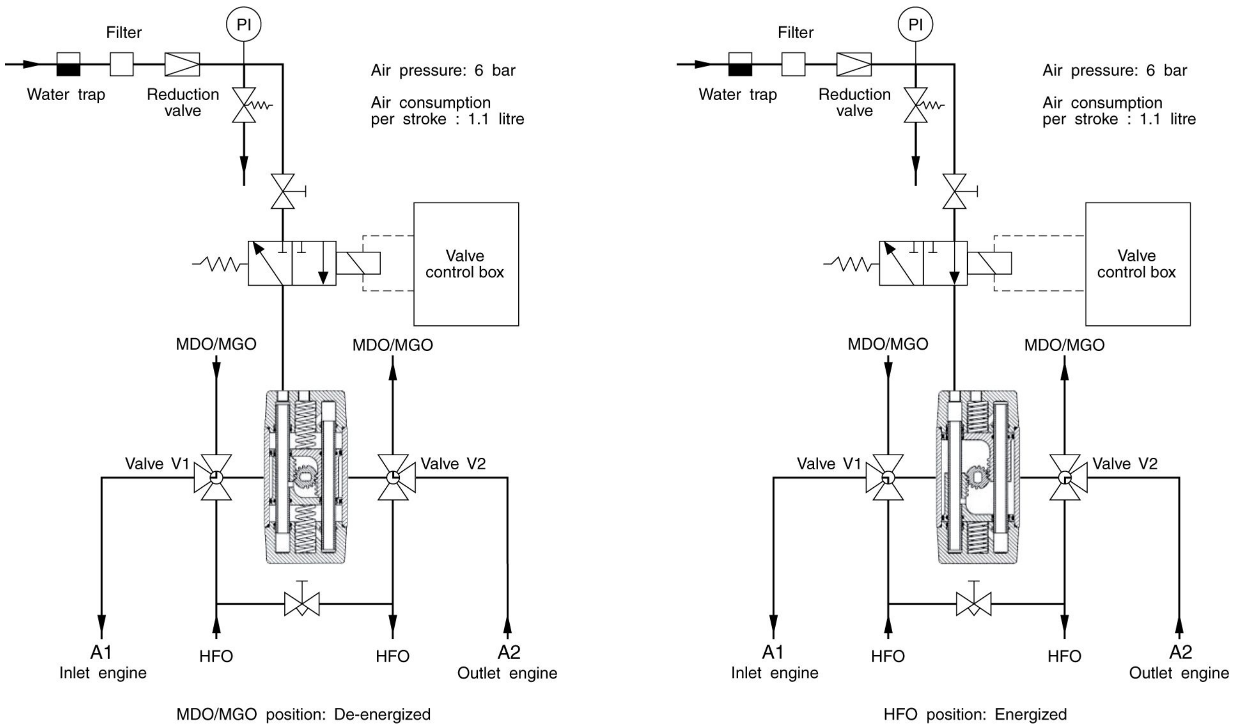

Figure 1: Pneumatic diagram for 3-way changing valves V1 & V2.

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

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

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

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

Valve control box

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

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

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

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

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

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Automatic back-flush filter

Automatic back-flush filter

To protect the GenSets from foreign particles in the fuel (cat fines attack), must a common automatic back-flush filter be installed in the circulation line, just before the branching to the individual GenSets.

The automatic back-flush filter with a change-over cock and by-pass simplex filter and with integrated heating chamber, has a mesh size of 10 microns (absolute/sphere passing mesh).

The automatic back-flush filter permits a continuous operation even during back flushing without any pressure drops or interruptions of flow. If the filter inserts are clogged, an automatic cleaning is started. The filter is equipped with a visual differential pressure indication and two differential pressure contacts to monitor the clogging of the filter. Back flushing medium is discharged discontinuous to a sludge tank or back to the settling tank.

Filter specification

Range of application	:	Heavy fuel oil 700 cSt @ 50°C
Max. operating pressure	:	16 bar
Test pressure	:	According to class rule
Max. operating temperature	:	160°C
Nominal width of connection flanges	:	DN40, DN65, DN80, DN100 or DN125
Grade of filtration	:	10 microns (absolute/sphere passing mesh)
Cleaning	:	Sequential reverse-flow back-flushing, assisted by compressed air
Back-flushing control	:	Differential pressure-dependent or time-dependent
Pressure drop at clean filter	:	≤ 0.2 bar
Filter to be cleaned at a pressure drop	:	0.38 bar ± 10%
Alarm contact switches at differential pressure	:	0.5 bar ± 10%
Compressed air	:	4-10 bar

Specification L16/24

1000 rpm	Booster circuit				
Qty. engines	5L16/24	6L16/24	7L16/24	8L16/24	9L16/24
1	DN40	DN40	DN40	DN40	DN40
2	DN40	DN40	DN40	DN40	DN40
3	DN40	DN40	DN40	DN65	DN65
4	DN40	DN65	DN65	DN65	DN65

1200 rpm	Booster circuit				
Qty. engines	5L16/24	6L16/24	7L16/24	8L16/24	9L16/24
1	DN40	DN40	DN40	DN40	DN40
2	DN40	DN40	DN40	DN40	DN40
3	DN40	DN40	DN65	DN65	DN65
4	DN40	DN65	DN65	DN65	DN65

Specification L21/31

900 rpm	Booster circuit				
Qty. engines	5L21/31	6L21/31	7L21/31	8L21/31	9L21/31
1	DN40	DN40	DN40	DN40	DN65
2	DN65	DN65	DN65	DN65	DN65
3	DN65	DN65	DN65	DN65	DN80
4	DN65	DN65	DN80	DN80	DN80

1000 rpm	Booster circuit				
Qty. engines	5L21/31	6L21/31	7L21/31	8L21/31	9L21/31
1	DN40	DN40	DN40	DN40	DN65
2	DN65	DN65	DN65	DN65	DN65
3	DN65	DN65	DN65	DN65	DN80
4	DN65	DN65	DN80	DN80	DN80

Specification L27/38

720 rpm	Booster circuit				
Qty. engines	5L27/38	6L27/38	7L27/38	8L27/38	9L27/38
1	DN40	DN40	DN65	DN65	DN65
2	DN65	DN65	DN65	DN65	DN65
3	DN65	DN65	DN65	DN80	DN80
4	DN65	DN80	DN80	DN80	DN100

750 rpm	Booster circuit				
Qty. engines	5L27/38	6L27/38	7L27/38	8L27/38	9L27/38
1	DN40	DN40	DN65	DN65	DN65
2	DN65	DN65	DN65	DN65	DN65
3	DN65	DN65	DN65	DN80	DN80
4	DN65	DN80	DN80	DN80	DN100

Specification L23/30H

720/750 rpm	Booster circuit			
Qty. engines	5L23/30H	6L23/30H	7L23/30H	8L23/30H
1	DN40	DN40	DN40	DN40
2	DN40	DN40	DN40	DN65
3	DN40	DN65	DN65	DN65
4	DN65	DN65	DN65	DN65

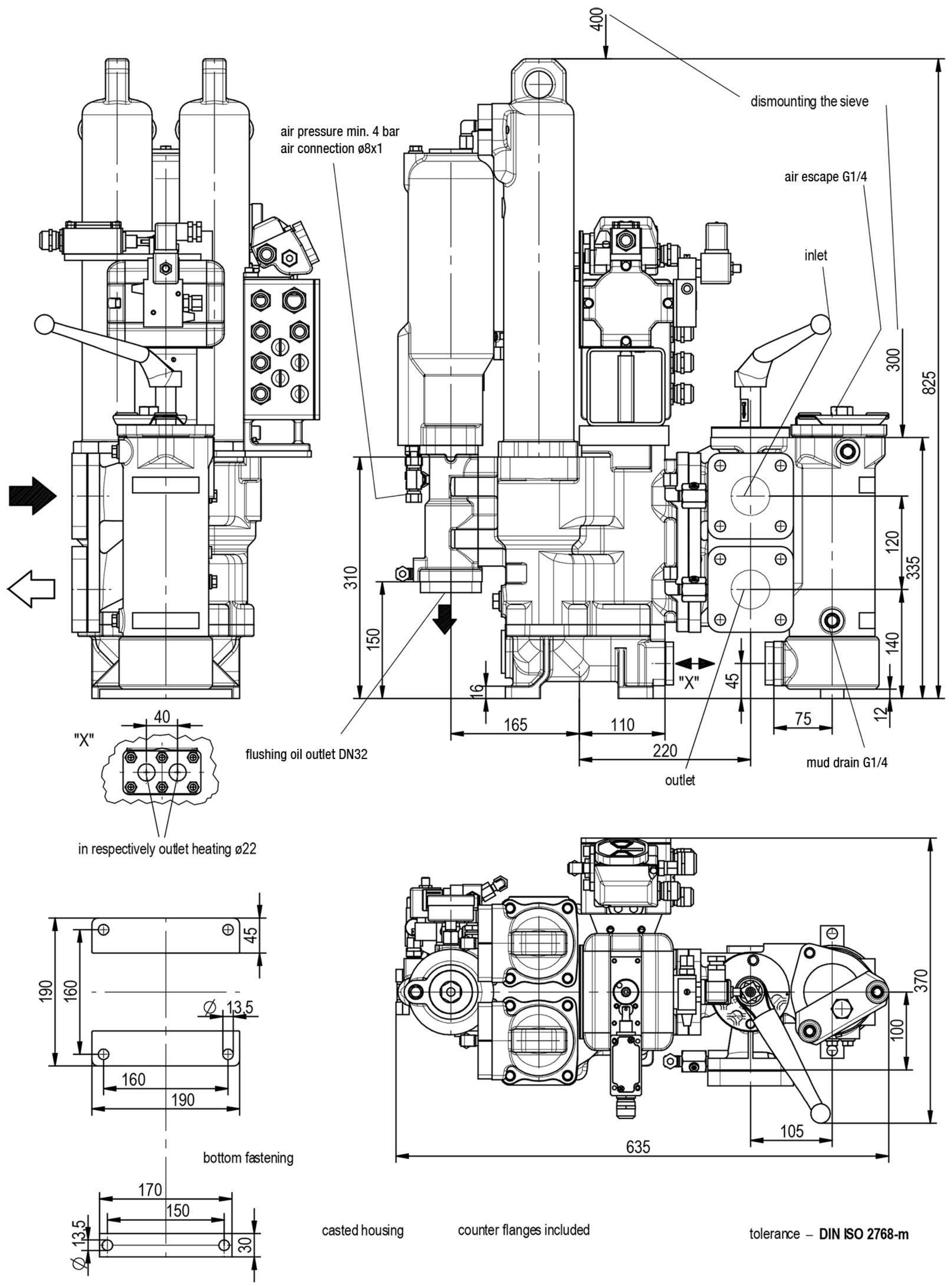
900 rpm	Booster circuit		
Qty. engines	6L23/30H	7L23/30H	8L23/30H
1	DN40	DN40	DN40
2	DN40	DN65	DN65
3	DN65	DN65	DN65
4	DN65	DN65	DN65

Specification L28/32H

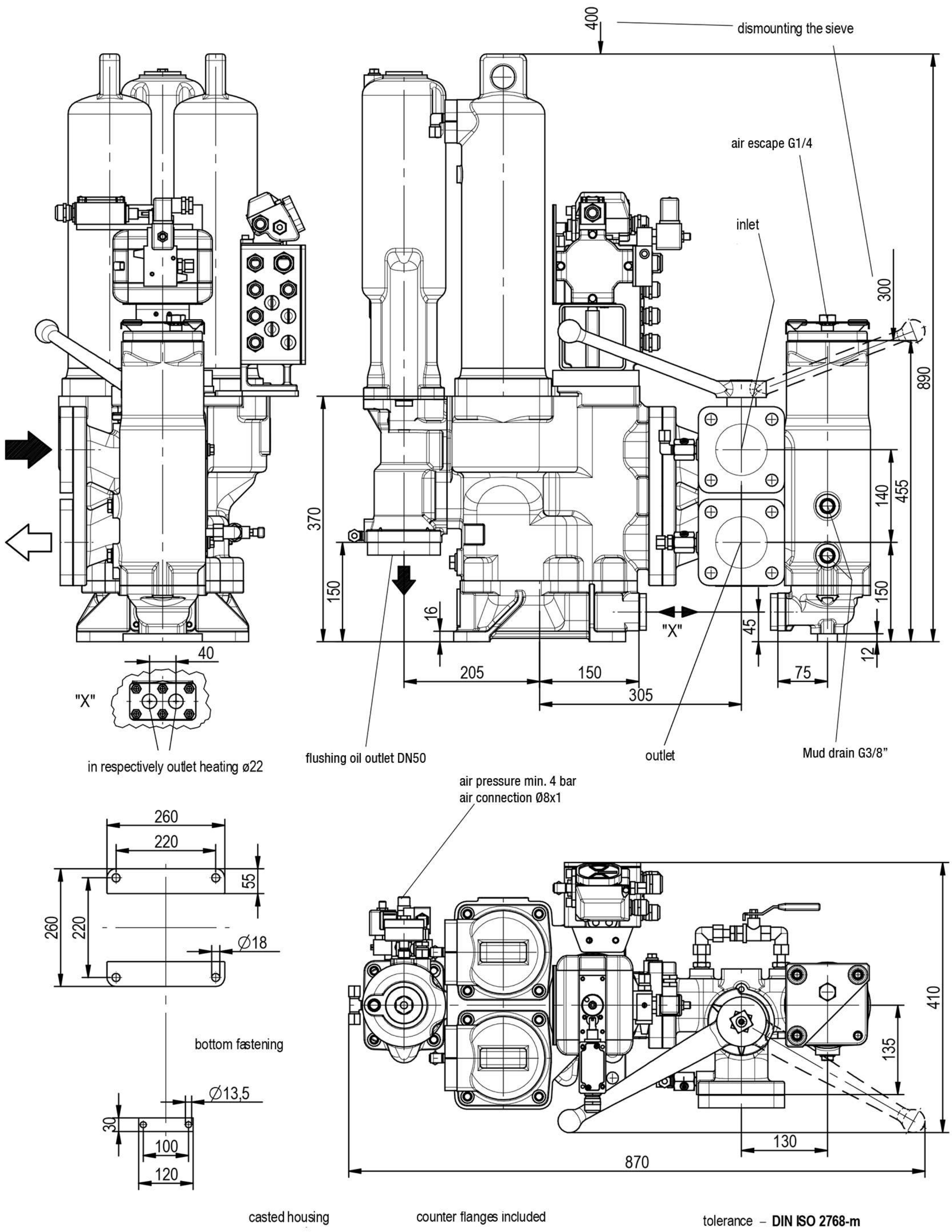
720 rpm	Booster circuit				
Qty. engines	5L28/32H	6L28/32H	7L28/32H	8L28/32H	9L28/32H
1	DN40	DN40	DN40	DN40	DN40
2	DN40	DN65	DN65	DN65	DN65
3	DN65	DN65	DN65	DN65	DN65
4	DN65	DN65	DN65	DN65	DN80

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

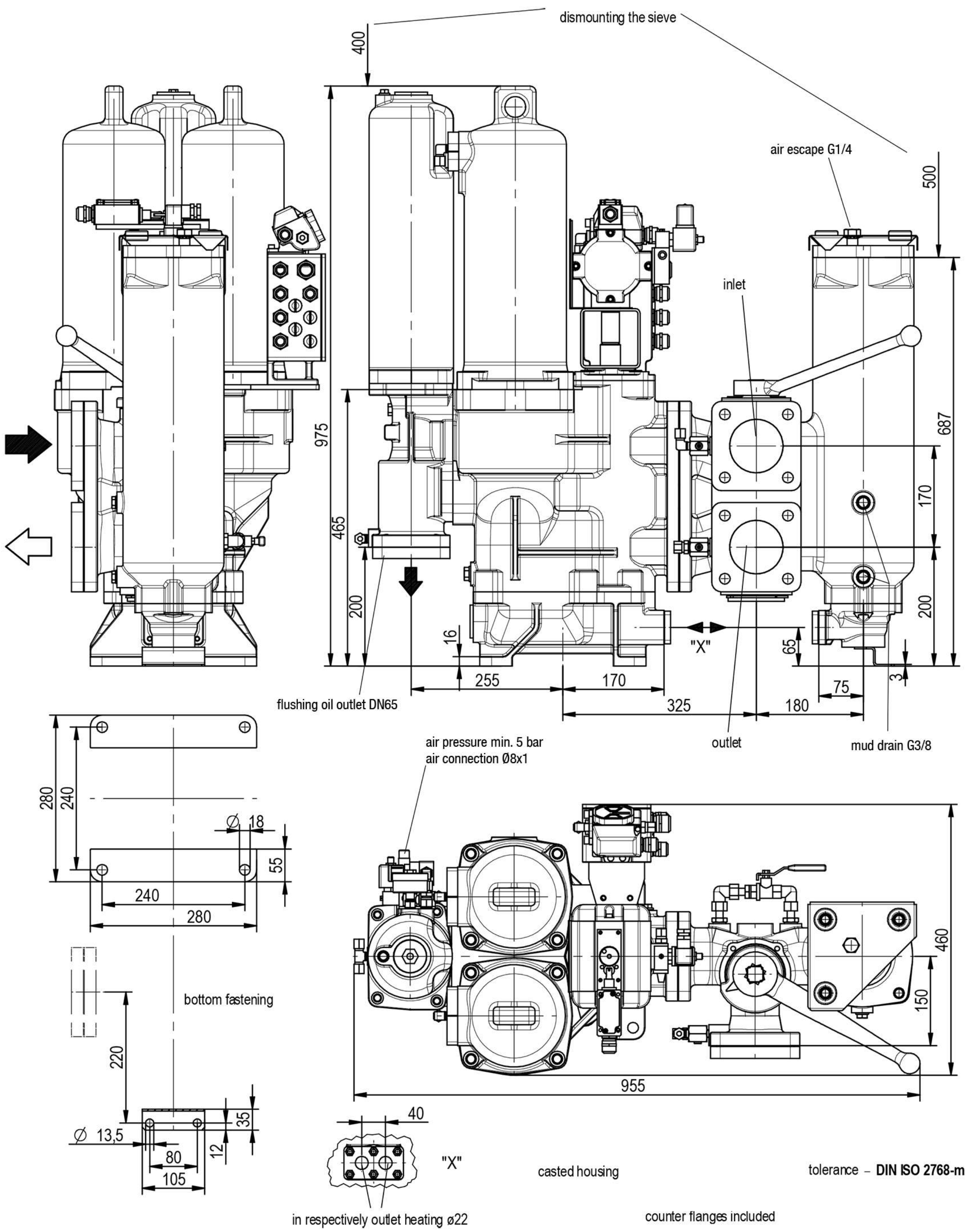
DN40 - Typ 6.72.1



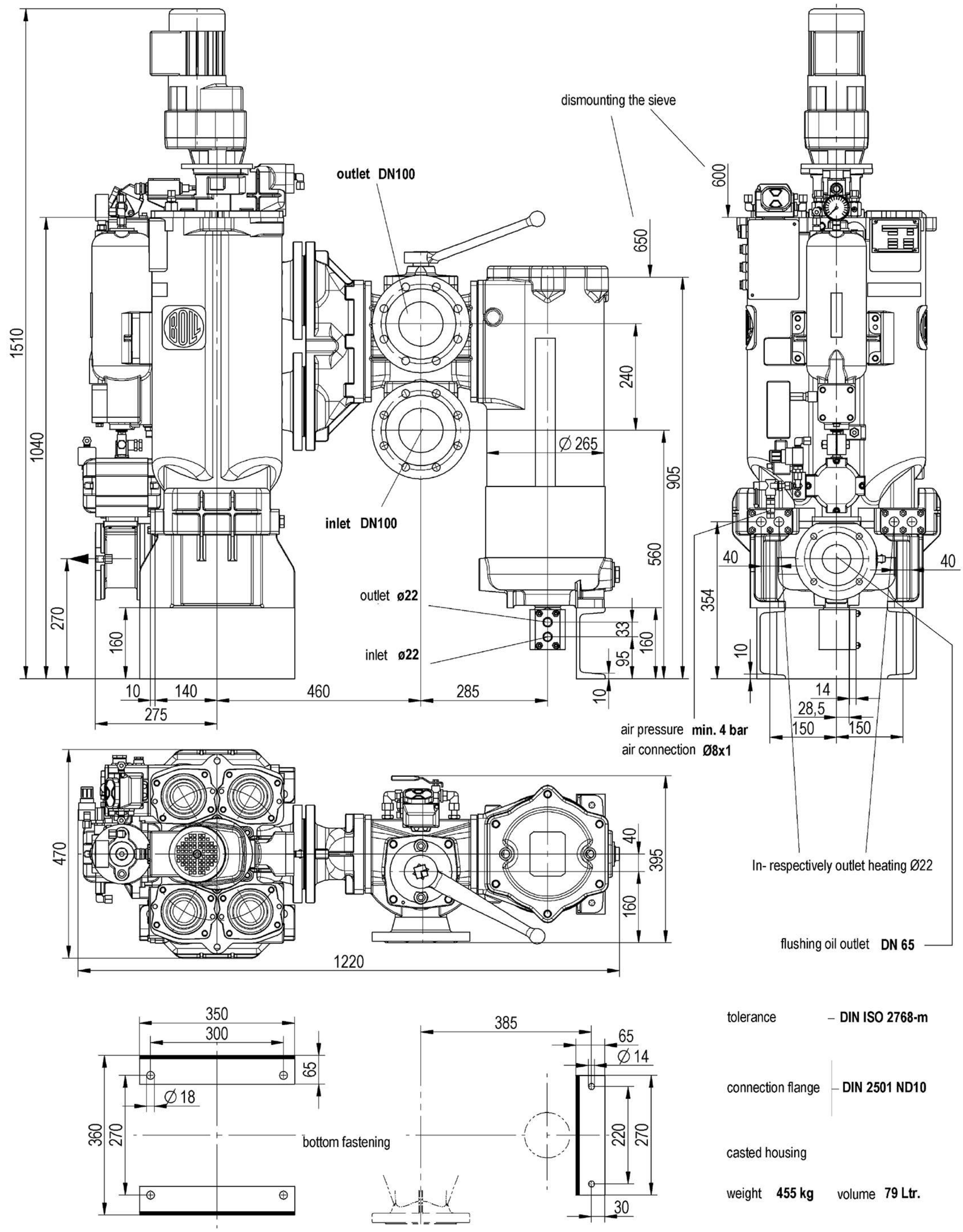
DN65 - Typ 6.72.1



DN80 - Typ 6.72.1



DN100 - Typ 6.64.1



Automatic back-flush filter

Automatic back-flush filter

To protect the GenSets from foreign particles in the fuel (cat fines attack), must a common automatic back-flush filter be installed in the circulation line, just before the branching to the individual GenSets.
The automatic back-flush filter with a change-over cock and by-pass simplex filter and with integrated heating chamber, has a mesh size of 10 microns (absolute/sphere passing mesh).
The automatic back-flush filter permits a continuous operation and is back-flushed continuously, without any interruptions of flow.

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

Filter specification

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

Specification L16/24

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

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

Specification L21/31

900 rpm		Booster circuit				
Qty. engines		5L21/31	6L21/31	7L21/31	8L21/31	9L21/31
1	Outlet flow	0.89	1.18	1.37	1.57	1.76
	Inlet flow	1.14	1.43	1.62	1.85	2.07
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 12/6 A01
2	Outlet flow	1.78	2.36	2.74	3.14	3.52
	Inlet flow	2.09	2.78	3.22	3.69	4.14
	Recommended filter size	FM-152-DE 12/6 A01	FM-152-DE 12/6 A01	FM-152-DE 16/8 A01	FM-152-DE 16/8 A01	FM-152-DE 24/12 A01
3	Outlet flow	2.67	3.54	4.11	4.71	5.28
	Inlet flow	3.14	4.16	4.84	5.54	6.21
	Recommended filter size	FM-152-DE 16/8 A01	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01	FM-152-DE 30/12 A01
4	Outlet flow	3.56	4.72	5.48	6.28	7.04
	Inlet flow	4.19	5.55	6.45	7.39	8.28
	Recommended filter size	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01	FM-152-DE 30/12 A01	FM-152-DE 60/24 A01	FM-152-DE 60/24 A01

1000 rpm		Booster circuit				
Qty. engines		5L21/31	6L21/31	7L21/31	8L21/31	9L21/31
1	Outlet flow	0.89	1.18	1.37	1.57	1.76
	Inlet flow	1.14	1.43	1.62	1.85	2.07
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 12/6 A01
2	Outlet flow	1.78	2.36	2.74	3.14	3.52
	Inlet flow	2.09	2.78	3.22	3.69	4.14
	Recommended filter size	FM-152-DE 12/6 A01	FM-152-DE 12/6 A01	FM-152-DE 16/8 A01	FM-152-DE 16/8 A01	FM-152-DE 24/12 A01
3	Outlet flow	2.67	3.54	4.11	4.71	5.28
	Inlet flow	3.14	4.16	4.84	5.54	6.21
	Recommended filter size	FM-152-DE 16/8 A01	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01	FM-152-DE 30/12 A01
4	Outlet flow	3.56	4.72	5.48	6.28	7.04
	Inlet flow	4.19	5.55	6.45	7.39	8.28
	Recommended filter size	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01	FM-152-DE 30/12 A01	FM-152-DE 60/24 A01	FM-152-DE 60/24 A01

Specification L23/30H

720/750 rpm		Booster circuit			
Qty. engines		5L23/30H	6L23/30H	7L23/30H	8L23/30H
1	Outlet flow	0.53	0.63	0.74	0.84
	Inlet flow	0.78	0.88	0.99	1.09
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01
2	Outlet flow	1.06	1.26	1.48	1.68
	Inlet flow	1.31	1.51	1.74	1.98
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 12/6 A01
3	Outlet flow	1.59	1.89	2.22	2.52
	Inlet flow	1.87	2.22	2.61	2.96
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 12/6 A01	FM-152-DE 12/6 A01	FM-152-DE 16/8 A01
4	Outlet flow	2.12	2.52	2.96	3.36
	Inlet flow	2.49	2.96	3.48	3.95
	Recommended filter size	FM-152-DE 12/6 A01	FM-152-DE 16/8 A01	FM-152-DE 16/8 A01	FM-152-DE 24/12 A01

900 rpm		Booster circuit		
Qty. engines		6L23/30H	7L23/30H	8L23/30H
1	Outlet flow	0.75	0.88	1.01
	Inlet flow	1.00	1.13	1.26
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01	FM-152-DE 8/4 A01
2	Outlet flow	1.5	1.76	2.02
	Inlet flow	1.76	2.07	2.38
	Recommended filter size	FM-152-DE 8/4 A01	FM-152-DE 12/6 A01	FM-152-DE 12/6 A01
3	Outlet flow	2.25	2.64	3.03
	Inlet flow	2.65	3.11	3.56
	Recommended filter size	'FM-152-DE 12/6 A01	FM-152-DE 16/8 A01	FM-152-DE 16/8 A01
4	Outlet flow	3	3.52	4.04
	Inlet flow	3.53	4.14	4.75
	Recommended filter size	FM-152-DE 16/8 A01	FM-152-DE 24/12 A01	FM-152-DE 24/12 A01

Specification L27/38

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

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

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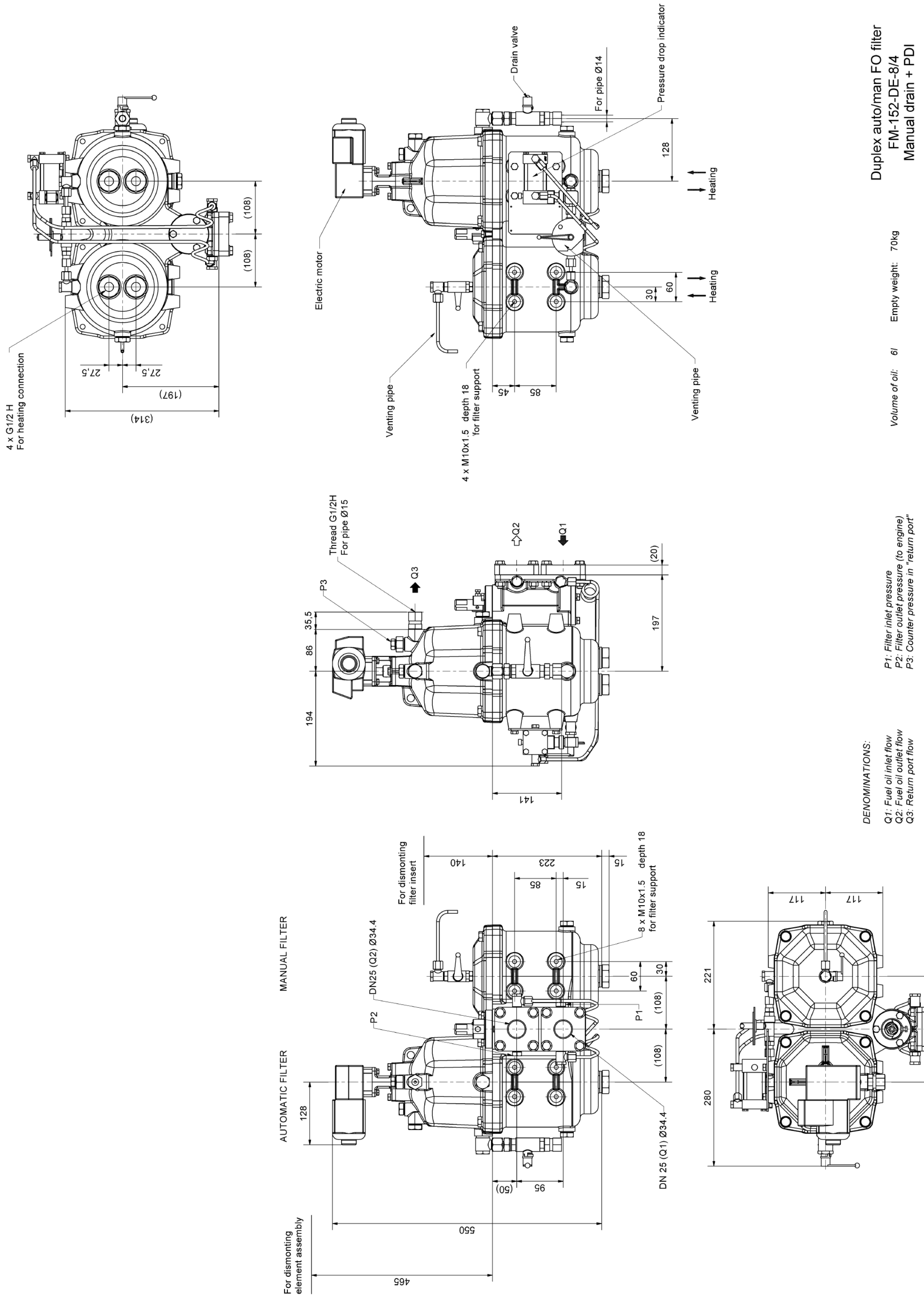
Specification L28/32H

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

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

FM-152-DE 8/4



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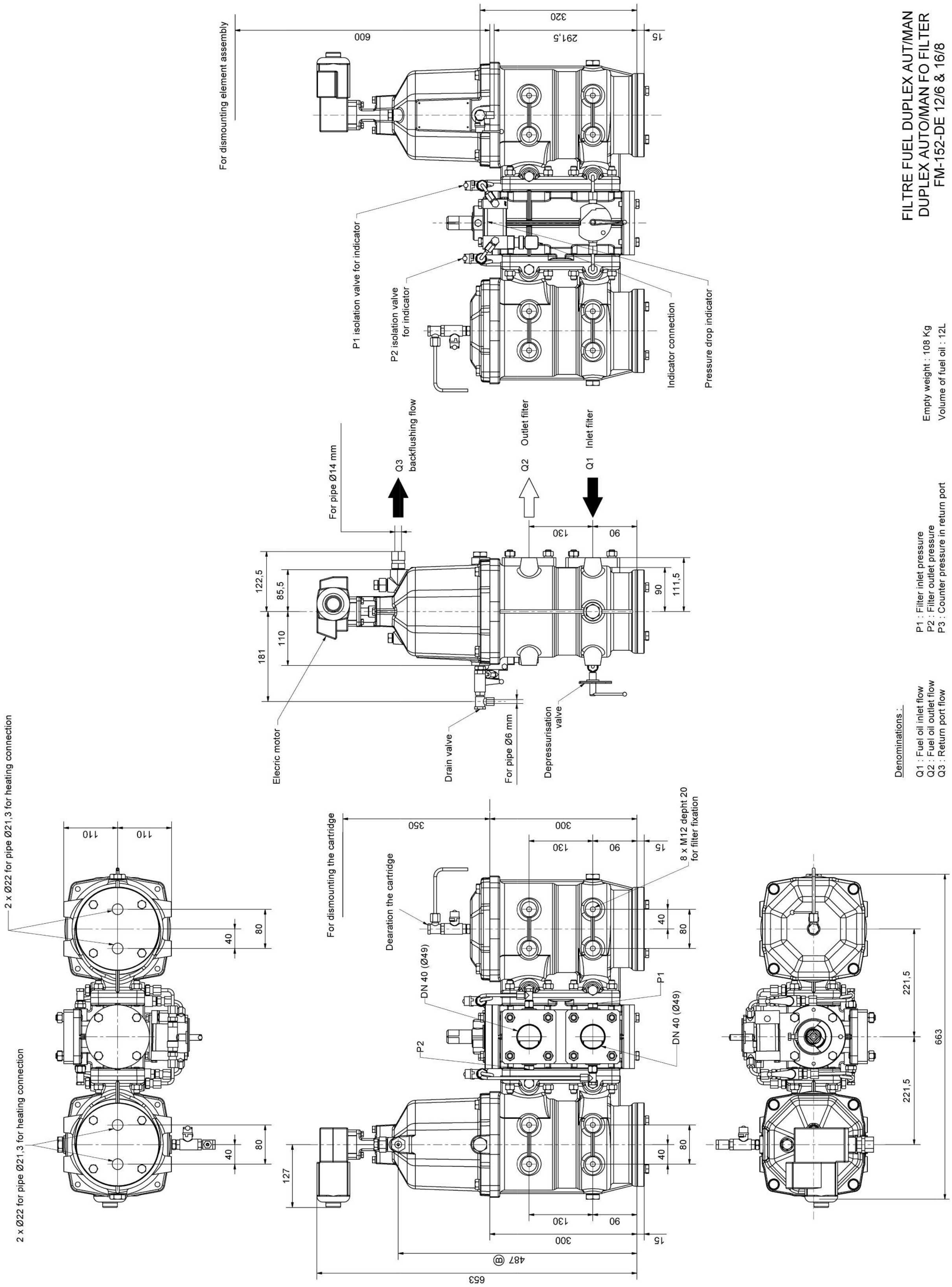
FM-152-DE 12/6 & 16/8



Automatic back-flush filter

Description
3700397-1.0

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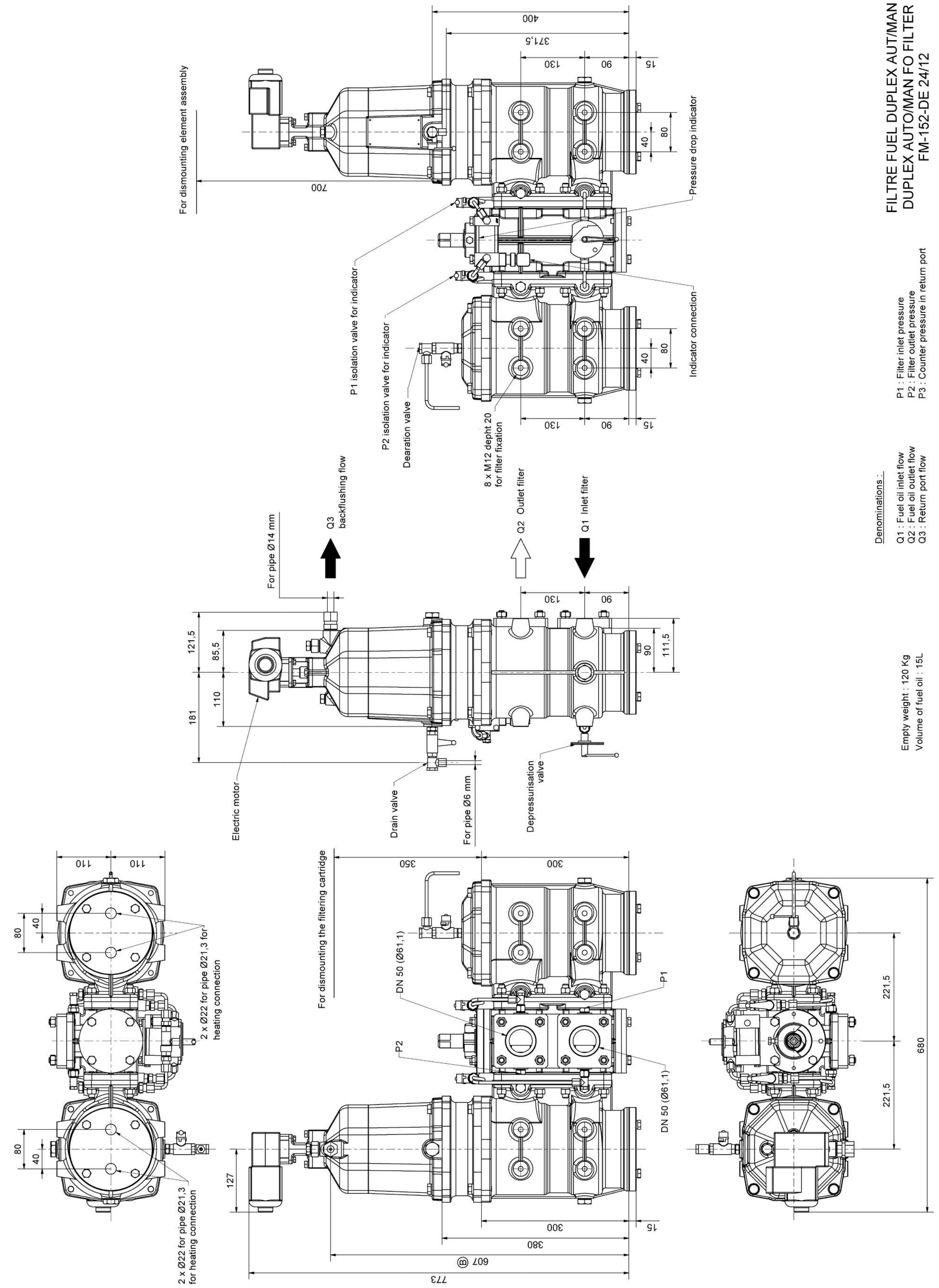
Automatic back-flush filter

Description
3700397-1.0

FM-152-DE 24/12



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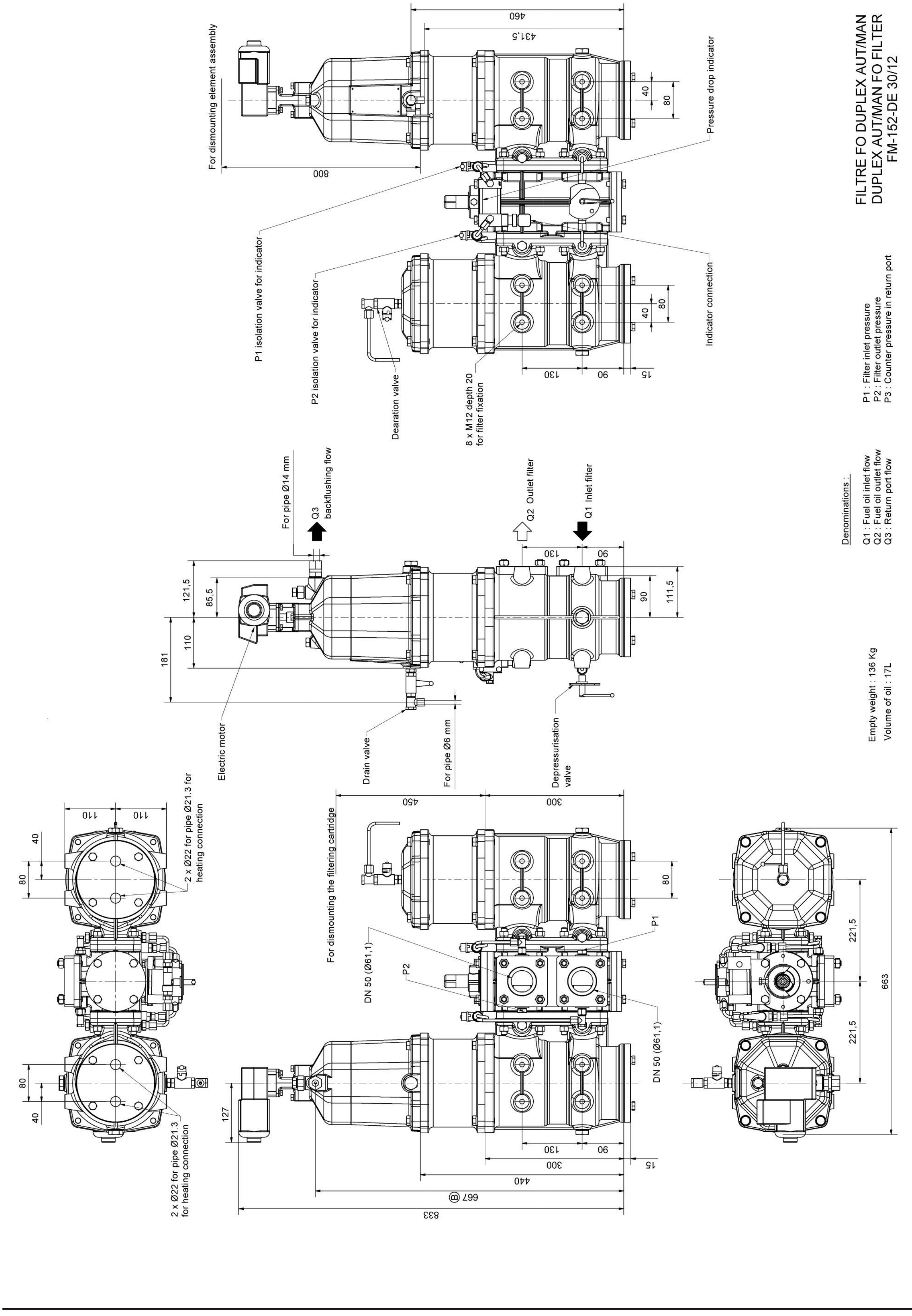
FM-152-DE 30/12



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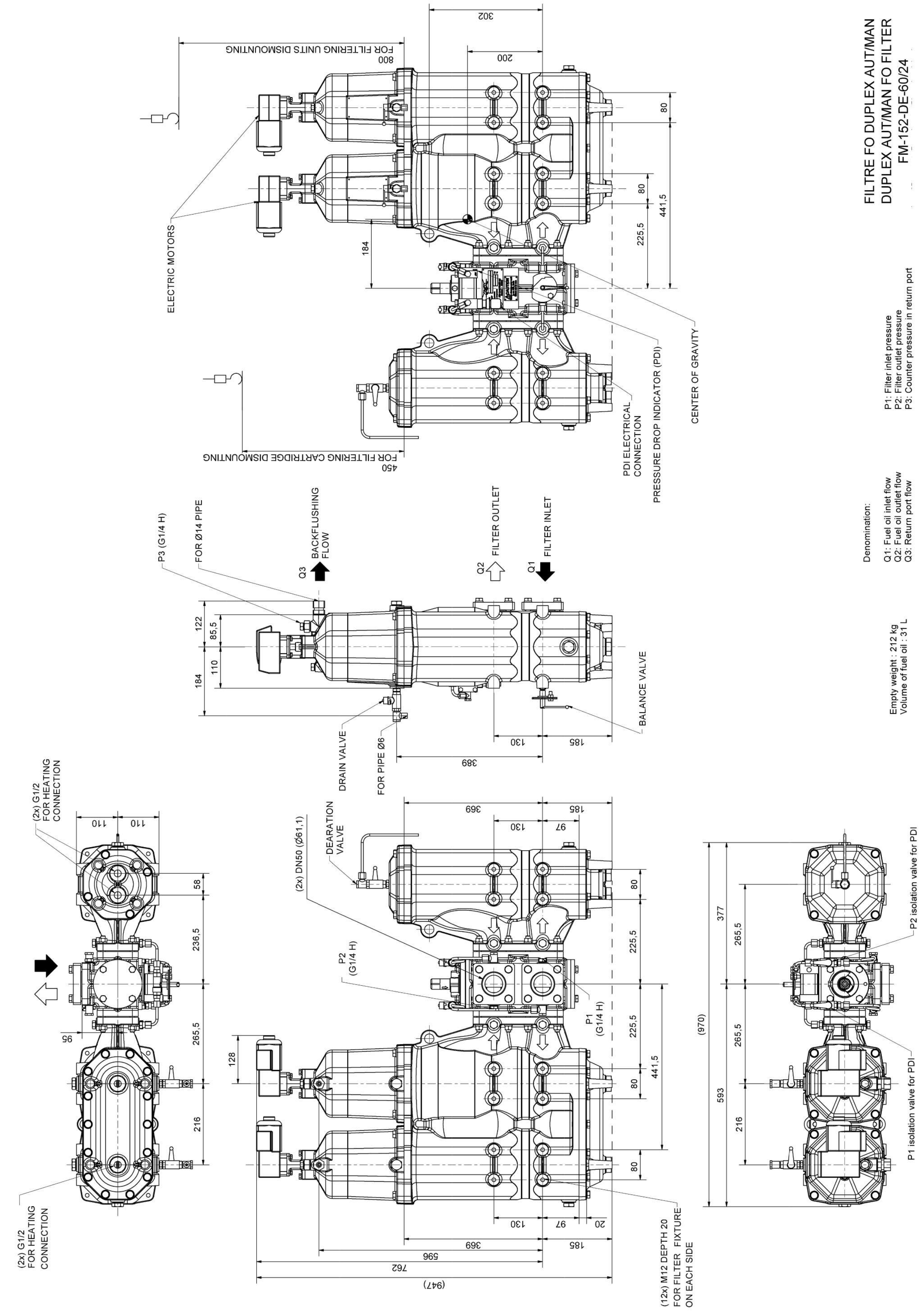
FM-152-DE 60/24



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Internal lubricating oil system

Internal lubricating oil system

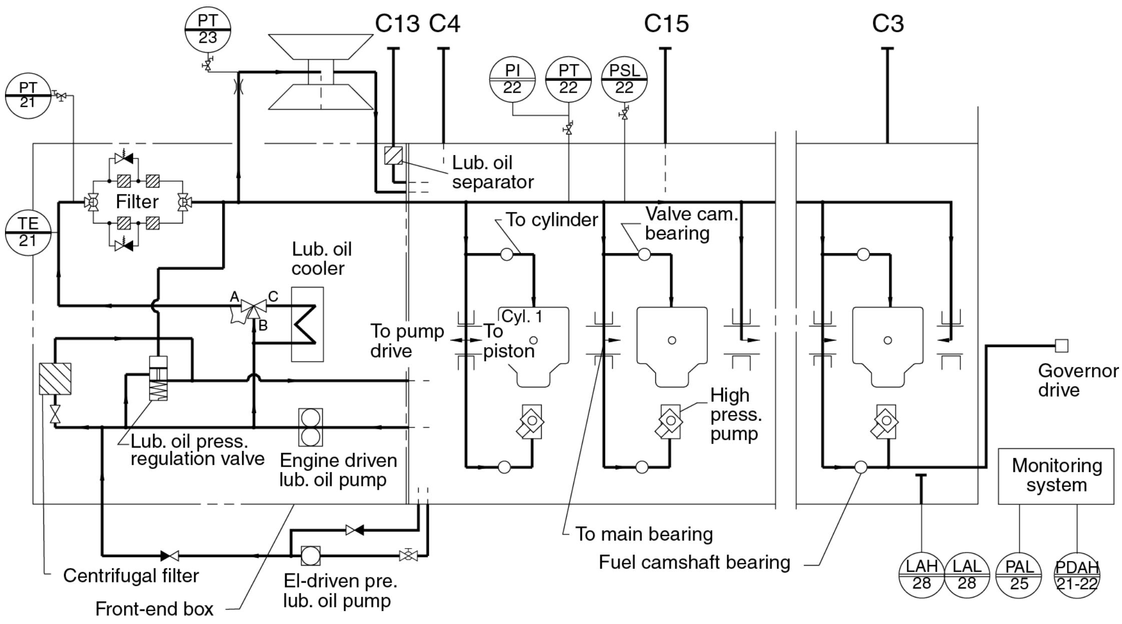

Figure 1: Diagram for internal lubricating oil system

Pipe description		
C3	Lubricating oil from separator	DN25
C4	Lubricating oil to separator	DN25
C13	Oil vapour discharge*	DN50
C15	Lubricating oil overflow	DN32

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

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

General

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

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

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

The standard engine is equipped with:

- Engine driven lubricating oil pump
- Lubricating oil cooler
- Lubricating oil thermostatic valve

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- 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 bore, from where the oil is distributed to the various lubricating points. From the lubricating points the oil returns by gravity to the oil sump. The oil pressure is controlled by an adjustable spring-loaded relief valve built in the system.

The main groups of components to be lubricated are:

1. Turbocharger
2. Main bearings, big-end bearing etc.
3. Camshaft drive
4. Governor drive
5. Rocker arms
6. Camshaft

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

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The inlet line to the turbocharger is equipped with an orifice in order to adjust the oil flow.

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

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

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

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

Lubricating oil pump

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

Lubricating oil cooler

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

Thermostatic valve

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

Built-on full-flow depth filter

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

Centrifugal by-pass filter

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

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

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

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

Pre-lubricating

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

Draining of the oil sump

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

Oil level switches

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

Data

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

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

Crankcase ventilation

Crankcase ventilation

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

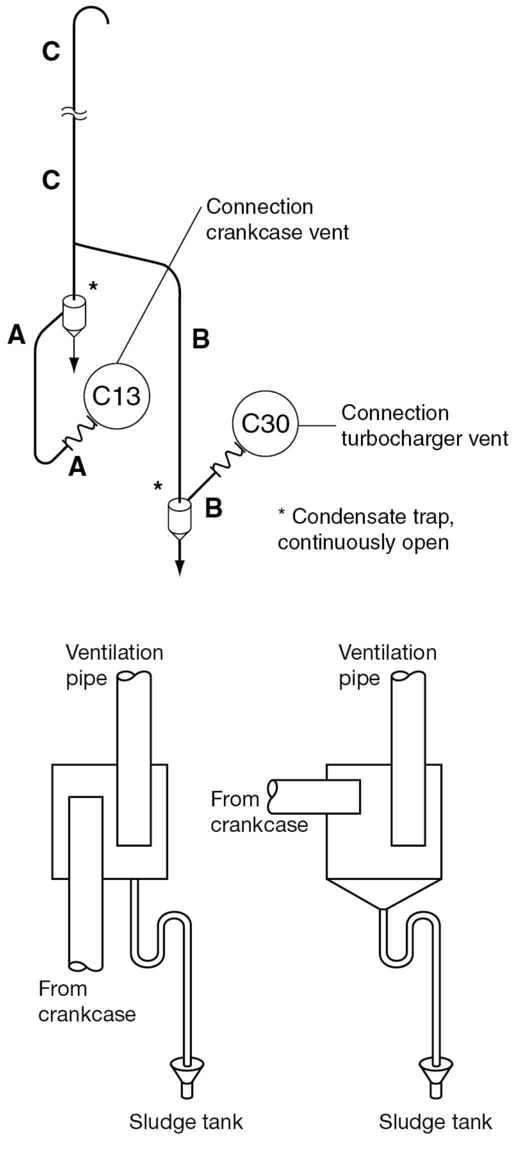

Figure 1: Crankcase ventilation

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

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

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

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

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

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

Table 1: Pipe diameters for crankcase ventilation

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

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

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

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

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

Example :

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

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

$$=5479\ [m^3/h]$$

The crankcase ventilation flow rate will then be in the range of 19.2 – 27.4 [m^3/h]

The maximum crankcase backpressure measured right after the engine at 100 % engine load must not exceed 3.0 [mbar] = 30 [mmWC].

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Prelubricating pump

General

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

The pump is self-priming.

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

The automatic control of prelubricating must be made by the customer or can be ordered fra MAN Diesel & Turbo.

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

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

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

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

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

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

Specification of lubricating oil (SAE 40) for heavy fuel operation (HFO)

General

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

Medium alkalinity lubricating oils have a proven track record as lubricants for the moving parts and turbocharger cylinder and for cooling the pistons. Lubricating oils of medium alkalinity contain additives that, in addition to other properties, ensure a higher neutralization reserve than with fully compounded engine oils (HD oils).

International specifications do not exist for medium alkalinity lubricating oils. A test operation is therefore necessary for a corresponding long period in accordance with the manufacturer's instructions.

Only lubricating oils that have been approved by MAN Energy Solutions may be used. See table Approved lubricating oils for HFO-operated MAN Energy Solutions four-stroke engines.

Specifications

Base oil

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

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

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

Medium alkalinity lubricating oil

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

Additives

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

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

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

Washing ability

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

Dispersion capability

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

Neutralisation capability

The 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.

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

Evaporation tendency

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

Additional requirements

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

Lubricating oil selection

Engine	SAE class
16/24, 21/31, 27/38, 28/32S, 32/40, 32/44, 35/44DF, 40/54, 45/60, 48/60, 58/64, 51/60DF	40

Table 2: Viscosity (SAE class) of lubricating oils

Neutralisation properties (BN)

Lubricating oils with medium alkalinity and a range of neutralization capabilities (BN) are available on the market. At the present level of knowledge, an interrelation between the expected operating conditions and the BN number can be established. However, the operating results are still the overriding factor in determining which BN number provides the most efficient engine operation.

Table Base number to be used for various operating conditions indicates the relationship between the anticipated operating conditions and the BN number.

Approx. BN of fresh oil (mg KOH/g oil)	Engines/Operating conditions
20	Marine diesel oil (MDO) of a lower quality and high sulphur content or heavy fuel oil with a sulphur content of less than 0.5 %.
30	generally 23/30H and 28/32H. 23/30A, 28/32A and 28/32S under normal operating conditions. For engines 16/24, 21/31, 27/38, 32/40, 32/44CR, 32/44K, 40/54, 48/60 as well as 58/64 and 51/60DF for exclusively HFO operation only with a sulphur content < 1.5 %.

Approx. BN of fresh oil (mg KOH/g oil)	Engines/Operating conditions
40	Under unfavourable operating conditions 23/30A, 28/32A and 28/32S, and where the corresponding requirements for the oil service life and washing ability exist. In general 16/24, 21/31, 27/38, 32/40, 32/44CR, 32/44K, 40/54, 48/60 as well as 58/64 and 51/60DF for exclusively HFO operation providing the sulphur content is over 1.5 %.
50	32/40, 32/44CR, 32/44K, 40/54, 48/60 and 58/64, if the oil service life or engine cleanliness is insufficient with a BN number of 40 (high sulphur content of fuel, extremely low lubricating oil consumption).

Table 3: Base number to be used for various operating conditions

Operation with low-sulphur fuel

To comply with the emissions regulations, the sulphur content of fuels used nowadays varies. Fuels with low-sulphur content must be used in environmentally-sensitive areas (e.g. SECA). Fuels with higher sulphur content may be used outside SECA zones. In this case, the BN number of the lube oil selected must satisfy the requirements for operation using fuel with high-sulphur content. A lube oil with low BN number may only be selected if fuel with a low sulphur content is used exclusively during operation.
However, the practical results demonstrate that the most efficient engine operation is the factor ultimately determining the permitted additive content.

Cylinder lubricating oil

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

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

Oil for mechanical/hydraulic speed governors

Multigrade oil 5W40 should ideally be used in mechanical-hydraulic controllers with a separate oil sump, unless the technical documentation for the speed governor specifies otherwise. If this oil is not available when filling, 15W40 oil may be used instead in exceptional cases. In this case, it makes no difference whether synthetic or mineral-based oils are used.

The military specification applied for these oils is NATO O-236.

Experience with the drive engine L27/38 has shown that the operating temperature of the Woodward controller UG10MAS and corresponding actuator for UG723+ can reach temperatures higher than 93 °C. In these cases, we recommend using synthetic oil such as Castrol Alphasyn HG150.

Hydraulic oil for engines with VVT controller

Hydraulic oil HLP 46 (DIN 51502) or ISO VG 46 (DIN 51519) must be used according to the specification DIN 51524-2. Mixing hydraulic oils from different manufacturers is not permitted.

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 of the oil can only be maintained if it is cleaned using suitable equipment (e.g. a separator or filter).

Temporary operation with gas oil

Due to current and future emission regulations, heavy fuel oil cannot be used in designated regions. Low-sulphur diesel fuel must be used in these regions instead.

If the engine is operated with low-sulphur diesel fuel for less than 1,000 h, a lubricating oil which is suitable for HFO operation (BN 30 – 55 mg KOH/g) can be used during this period.

If the engine is operated provisionally with low-sulphur diesel fuel for more than 1,000 h and is subsequently operated once again with HFO, a lubricating oil with a BN of 20 must be used. If the BN 20 lubricating oil from the same manufacturer as the lubricating oil is used for HFO operation with higher BN (40 or 50), an oil change will not be required when effecting the changeover. It will be sufficient to use BN 20 oil when replenishing the used lubricating oil.

If you wish to operate the engine with HFO once again, it will be necessary to change over in good time to lubricating oil with a higher BN (30 – 55). If the lubricating oil with higher BN is by the same manufacturer as the BN 20 lubricating oil, the changeover can also be effected without an oil change. In doing so, the lubricating oil with higher BN (30 – 55) must be used to replenish the used lubricating oil roughly 2 weeks prior to resuming HFO operation.

	Limit value	**Procedure**
Viscosity at 40 °C	110 – 220 mm²/s	ISO 3104 or ASTM D 445
Base number (BN)	at least 50 % of fresh oil	ISO 3771
Flash point (PM)	At least 185 °C	ISO 2719
Water content	max. 0.2 % (max. 0.5 % for brief periods)	ISO 3733 or ASTM D 1744
n-heptane insoluble	max. 1.5 %	DIN 51592 or IP 316
Metal content	depends on engine type and operating conditions	–
Guide value only Fe Cr Cu Pb Sn Al	 max. 50 ppm max. 10 ppm max. 15 ppm max. 20 ppm max. 10 ppm max. 20 ppm	–

Table 4: Limit values for used lubricating oil

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.

Manufacturer	Base Number (mgKOH/g)			
	20–25	30	40	50–55
AEGEAN	–	Alfamar 430	Alfamar 440	Alfamar 450
AVIN OIL S.A.	–	AVIN ARGO S 30 SAE 40	AVIN ARGO S 40 SAE 40	AVIN ARGO S 50 SAE 40
CASTROL	TLX Plus 204	TLX Plus 304	TLX Plus 404	TLX Plus 504
CEPSA	–	Troncoil 3040 Plus	Troncoil 4040 Plus	Troncoil 5040 Plus
CHEVRON (Texaco, Caltex)	Taro 20DP40 Taro 20DP40X	Taro 30DP40 Taro 30DP40X	Taro 40XL40 Taro 40XL40X	Taro 50XL40 Taro 50XL40X
EXXONMOBIL	Mobilgard M420	Mobilgard M430	Mobilgard M440	Mobilgard M50
Gulf Oil Marine Ltd.	GulfSea Power 4020 MDO Gulfgen Supreme 420	GulfSea Power 4030 Gulfgen Supreme 430	GulfSea Power 4040 Gulfgen Supreme 440	GulfSea Power 4055 Gulfgen Supreme 455
Idemitsu Kosan Co.,Ltd.	Daphne Marine Oil SW30/SW40/MV30/MV40	Daphne Marine Oil SA30/SA40	Daphne Marine Oil SH40	–
LPC S.A.	–	CYCLON POSEIDON HT 4030	CYCLON POSEIDON HT 4040	CYCLON POSEIDON HT 4050
LUKOIL	Navigo TPEO 20/40	Navigo TPEO 30/40	Navigo TPEO 40/40	Navigo TPEO 50/40 Navigo TPEO 55/40
Motor Oil Hellas S.A.	–	EMO ARGO S 30 SAE 40	EMO ARGO S 40 SAE 40	EMO ARGO S 50 SAE 40
PETROBRAS	Marbrax CCD-420	Marbrax CCD-430	Marbrax CCD-440	–
PT Pertamina (PERSERO)	Medripal 420	Medripal 430	Medripal 440	Medripal 450/455
REPSOL	Neptuno NT 2040	Neptuno NT 3040	Neptuno NT 4040	–
SHELL	Argina S 40 Argina S2 40	Argina T 40 Argina S3 40	Argina X 40 Argina S4 40	Argina XL 40 Argina S5 40
Sinopec	Sinopec TPEO 4020	Sinopec TPEO 4030	Sinopec TPEO 4040	Sinopec TPEO 4050
TOTAL LUBMAR-INE	Aurelia TI 4020	Aurelia TI 4030	Aurelia TI 4040	Aurelia TI 4055

Table 5: Approved lube oils for heavy fuel oil-operated MAN Energy Solutions four-stroke engines

The current releases are available at http://dieselturbo.man.eu/lubrication.

NOTICE

No liability assumed if these oils are used

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

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Specification of lubricating oil (SAE 40) for operation with MGO/MDO and biofuels

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

Engine	SAE class
16/24, 21/31, 27/38, 28/32S, 32/40, 32/44, 35/44DF, 40/54, 45/60, 48/60, 58/64, 51/60DF	40

Table 2: Viscosity (SAE class) of lubricating oils

Doped oil quality

We recommend doped lube oils (HD oils) according to the international specification MIL-L 2104 or API-CD with a base number of BN 10–16 mg KOH/g. Lube oils of military specification O-278 may be used if they are listed in the table Lube oils approved for use in MAN Energy Solutions four-stroke engines that run on gas oil and diesel fuel. Lube oils not listed here may only be used after consultation with MAN Energy Solutions.

The operating conditions of the engine and the quality of the fuel determine the additive content the lube oil should contain. If marine diesel oil is used, which has a high sulphur content of 1.5 up to 2.0 weight %, a base number (BN) of appr. 20 should be selected. However, the operating results that ensure the most efficient engine operation ultimately determine the additive content.

Cylinder lubricating oil

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

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

Oil for mechanical/hydraulic speed governors

Multigrade oil 5W40 should ideally be used in mechanical-hydraulic controllers with a separate oil sump, unless the technical documentation for the speed governor specifies otherwise. If this oil is not available when filling, 15W40 oil may be used instead in exceptional cases. In this case, it makes no difference whether synthetic or mineral-based oils are used.

The military specification applied for these oils is NATO O-236.

Experience with the drive engine L27/38 has shown that the operating temperature of the Woodward controller UG10MAS and corresponding actuator for UG723+ can reach temperatures higher than 93 °C. In these cases, we recommend using synthetic oil such as Castrol Alphasyn HG150.

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 of the oil can only be maintained if it is cleaned using suitable equipment (e.g. a separator or filter).

Temporary operation with gas oil

Due to current and future emission regulations, heavy fuel oil cannot be used in designated regions. Low-sulphur diesel fuel must be used in these regions instead.

If the engine is operated with low-sulphur diesel fuel for less than 1,000 h, a lubricating oil which is suitable for HFO operation (BN 30 – 55 mg KOH/g) can be used during this period.

If the engine is operated provisionally with low-sulphur diesel fuel for more than 1,000 h and is subsequently operated once again with HFO, a lubricating oil with a BN of 20 must be used. If the BN 20 lubricating oil from the same manufacturer as the lubricating oil is used for HFO operation with higher BN (40 or 50), an oil change will not be required when effecting the changeover. It will be sufficient to use BN 20 oil when replenishing the used lubricating oil.

If you wish to operate the engine with HFO once again, it will be necessary to change over in good time to lubricating oil with a higher BN (30 – 55). If the lubricating oil with higher BN is by the same manufacturer as the BN 20 lubricating oil, the changeover can also be effected without an oil change. In doing so, the lubricating oil with higher BN (30 – 55) must be used to replenish the used lubricating oil roughly 2 weeks prior to resuming HFO operation.

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.

Manufacturer	Base number (10) 12 – 16 (mgKOH/g)
CASTROL	Castrol MLC 40 / MHP 154
CHEVRON (Texaco, Caltex)	Delo 1000Marine 40 Delo SHP40
EXXONMOBIL	Mobilgard 412 / Mobilgard 1SHC Mobilgard ADL 40 [1)] Delvac 1640 [1)]
PETROBRAS	Marbrax CCD-410 Marbrax CCD-415
REPSOL	Neptuno NT 1540
SHELL	Gadinia 40 Gadinia AL40 Gadinia S3 Sirius X40 [1)]
STATOIL	MarWay 1040 [1)]
TOTAL Lubmarine	Caprano M40 Disola M4015
[1)] With sulphur content in the fuel of less than 1 %	

Table 3: Lube oils approved for use in MAN Energy Solutions four-stroke engines that run on gas oil and diesel fuel

The current releases are available at http://dieselturbo.man.eu/lubrication.

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	110 – 220 mm²/s	ISO 3104 or ASTM D445
Base number (BN)	at least 50 % of fresh oil	ISO 3771
Flash point (PM)	At least 185 °C	ISO 2719
Water content	max. 0.2 % (max. 0.5 % for brief periods)	ISO 3733 or ASTM D 1744
n-heptane insoluble	max. 1.5 %	DIN 51592 or IP 316
Metal content	depends on engine type and operating conditions	–
Guide value only Fe Cr Cu Pb Sn Al	. max. 50 ppm max. 10 ppm max. 15 ppm max. 20 ppm max. 10 ppm max. 20 ppm	–
When operating with biofuels: biofuel fraction	max. 12 %	FT-IR

Table 4: Limit values for used lubricating oil

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	2.3
L21/31, L21/31S	900/1000	0.4 - 0.8	4.7
L23/30H, L23/30S, L23/30H-Mk3, L23/30DF, L23/30S-DF	720/750	0.4 - 1.0	3.9
L23/30H, L23/30S, L23/30A, L23/30H-Mk3, L23/30DF, L23/30S-DF	900	0.4 - 1.0	4.7
L27/38, L27/38S (330/340 kW/cyl)	720/750/800	0.4 - 0.8	7.0
L27/38 (350/365 kW/cyl)	720/750/800	0.4 - 0.8	7.5
L28/32H, L28/32S, L28/32A, L28/32DF, L28/32S-DF	720/750/775	0.4 - 1.0	5.6
V28/32S (H)	720/750	0.4 - 0.8	5.2
[1] Max lubricating 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:

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

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:

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

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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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 504.04 "Criteria for Cleaning/Exchange of Lubricating Oil"*.

The moving parts in the engine are protected by the built-on duplex full-flow lubricating oil filter. The replaceable paper filter cartridges in each filter chamber has a fineness of 10-15 microns. The safety filter, at the centre of each filter chamber, is a basket filter element, with a fineness of 60 microns (sphere passing mesh).

The pressure drop across the replaceable paper filter cartridges is one parameter indicating the contamination level. The higher the dirt content in the oil, the shorter the periods between filter cartridge replacement and cleaning.

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.

Operation on Marine Diesel Oil (MDO) & Marine Gas Oil (MGO)

For engines exclusively operated on MDO/MGO we recommend to install a built-on centrifugal bypass filter as an additional filter to the built-on full flow depth filter.

It is advisable to run bypass separator units continuously for engines operated on MDO/MGO as separator units present the best cleaning solution. Mesh filters have the disadvantage that they cannot remove water and their elements clog quickly.

Operation on Heavy Fuel Oil (HFO)

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 full flow depth filter.

It is mandatory to run bypass separator units continuously for engines operated on HFO, 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 separator unit, 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 duplex full-flow lubricating oil filter as well.

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

The bypass cleaning equipment is operated

- 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
- Built-on centrifugal bypass filter (standard on MAN Diesel & Turbo, Holeby GenSets)
- 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.

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

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.

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 bypass 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 MDT's recommendation, on condition that the separator unit is operated according to MDT's 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 MDT's 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.

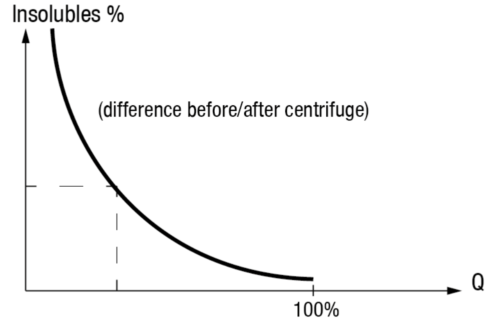


Figure 1: .

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).

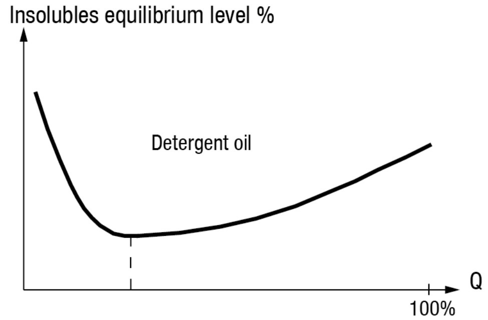


Figure 2: .

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:

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

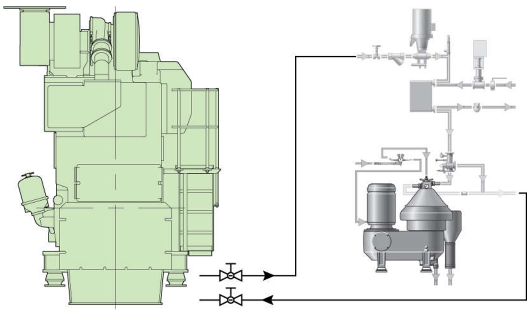


Figure 3: One separator per engine plant

Example 2

As an alternative, one common separator unit for max. 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.

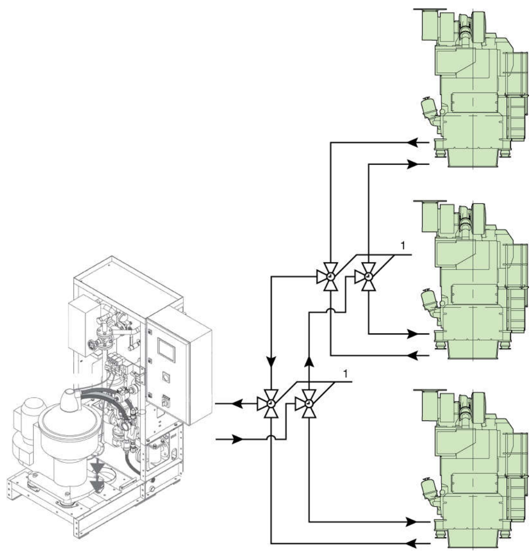
- Bulk carrier and tankers : ~1.3 times the power of one engine
- Container vessel : ~1.5 times the power of one engine

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:

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

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.



1 *Interconnected valves*

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

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.

Stokes' law

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

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

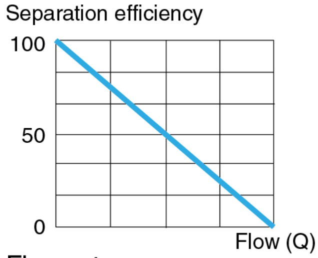
V	=	settling velocity [m/sec]
$r\omega^2$	=	acceleration in centrifugal field [m/sec^2]
d	=	diameter of particle [m]
ρ_p	=	density of particle [kg/m^3]
ρ_l	=	density of medium [kg/m^3]
μ	=	viscosity of medium [kg/m, sec.]

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

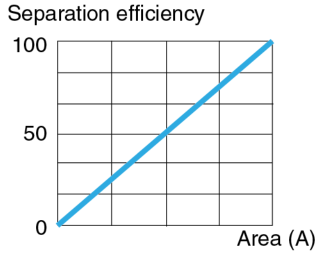
Density and viscosity are important parameters for efficient separation. The greater the difference in density between the particle and the lubricating oil, the higher the separation efficiency. The settling velocity increases in inverse proportion to viscosity. However, since both density and viscosity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

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

The separation efficiency is a function of:

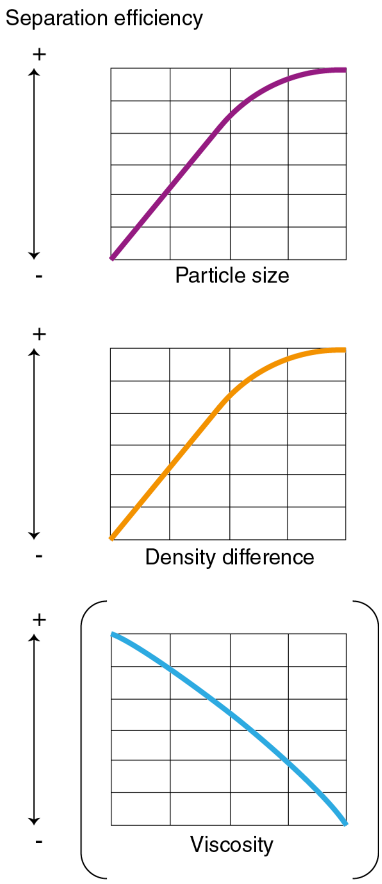


Flow rate



Settling area

Settling velocity



Operating parameters

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

Temperature of lubricating oil before separator unit

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

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

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

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

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

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

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

Flow rate

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

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

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

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

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

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

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

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

Maintenance

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

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. Engines running at HFO, will as standard be delivered with centrifugal by-pass filter mounted on engine. 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.

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Criteria for cleaning/exchange of lubricating oil

Replacement of lubricating oil

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

In order to evaluate the lubricating oil condition a sample should be drawn on regular basis at least once every three month or depending on the latest analysis result. The lubricating oil sample must be drawn before the filter at engine in operation. The sample bottle must be clean and dry, supplied with sufficient indentification 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 Diesel & Turbo 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 contaminated fuel oil, an engine cooling water leak or 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.

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 Chromium Copper Lead Tin Aluminium Silicon	Depend upon engine type and operating conditions	max. 50 ppm max. 10 ppm max. 15 ppm max. 20 ppm max. 10 ppm max. 20 ppm max. 20 ppm

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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 litre of water ≙ 17.9 mg $CaCO_3$/l

≙ 0.357 mval/l ≙ 0.179 mmol/l

[2] 1 mg/l ≙ 1 ppm

Testing equipment

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

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

Additional information

Distillate

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

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 MAN Diesel & Turbo 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

This additive is an emulsifiable mineral oil with additives for corrosion protection. A thin protective film of oil forms on the walls of the cooling system. This prevents corrosion without interfering with heat transfer, and also prevents limescale deposits on the walls of the cooling system.

Emulsifiable corrosion protection oils have lost importance. For reasons of environmental protection and due to occasional stability problems with emulsions, oil emulsions are scarcely used nowadays.

It is not permissible to use corrosion protection oils in the cooling water circuit of MAN Diesel & Turbo engines.

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

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

Antifreeze may only be added after approval by MAN Diesel & Turbo.

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

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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

Concentrations of chemical additives

The chemical additive concentrations shall not be less than the minimum concentrations indicated in the table *„Nitrite-containing chemical 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.

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.

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 MAN Diesel & Turbo 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

The MAN Diesel & Turbo can analyse antifreeze agent for their customers in the chemical laboratory PrimeServLab. A 0.5 l sample is required for the test.

Permitted coolant additives

Nitrite-containing chemical additives

Manufacturer	Product designation	Initial dosing for 1,000 litres	Minimum concentration ppm		
			Product	Nitrite (NO_2)	Na-Nitrite ($NaNO_2$)
Drew Marine	Liquidewt Maxigard	15 l 40 l	15,000 40,000	700 1,330	1,050 2,000
Wilhelmsen (Unitor)	Rocor NB Liquid Dieselguard	21.5 l 4.8 kg	21,500 4,800	2,400 2,400	3,600 3,600
Nalfleet Marine	Nalfleet EWT Liq (9-108) Nalfleet EWT 9-111 Nalcool 2000	3 l 10 l 30 l	3,000 10,000 30,000	1,000 1,000 1,000	1,500 1,500 1,500
Nalco	Nalcool 2000 TRAC 102 TRAC 118	30 l 30 l 3 l	30,000 30,000 3,000	1,000 1,000 1,000	1,500 1,500 1,500
Maritech AB	Marisol CW	12 l	12,000	2,000	3,000
Uniservice, Italy	N.C.L.T. Colorcooling	12 l 24 l	12,000 24,000	2,000 2,000	3,000 3,000
Marichem – Marigases	D.C.W.T. - Non-Chromate	48 l	48,000	2,400	-
Marine Care	Caretreat 2	16 l	16,000	4,000	6,000
Vecom	Cool Treat NCLT	16 l	16,000	4,000	6,000

Table 2: Nitrite-containing chemical additives

Nitrite-free additives (chemical additives)

Manufacturer	Product designation	Concentration range [Vol. %]
Chevron, Arteco	Havoline XLI	7.5 – 11
Total	WT Supra	7.5 – 11
Q8 Oils	Q8 Corrosion Inhibitor Long-Life	7.5 – 11

Table 3: Nitrite-free chemical additives

Antifreeze agents with slushing properties

<table>
<tr><th>Manufacturer</th><th>Product designation</th><th>Concentration range</th><th>Antifreeze agent range[1)]</th></tr>
<tr><td>BASF</td><td>Glysantin G 48
Glysantin 9313
Glysantin G 05</td><td rowspan="6">Min. 35 Vol. %
Max. 60 Vol. % [2)]</td><td rowspan="6">Min. –20 °C
Max. –50 °C</td></tr>
<tr><td>Castrol</td><td>Radicool NF, SF</td></tr>
<tr><td>Shell</td><td>Glycoshell</td></tr>
<tr><td>Mobil</td><td>Antifreeze agent 500</td></tr>
<tr><td>Arteco</td><td>Havoline XLC</td></tr>
<tr><td>Total</td><td>Glacelf Auto Supra
Total Organifreeze</td></tr>
</table>

Table 4: Antifreeze agents with slushing properties

[1)] Antifreeze agent acc. to ASTMD1177

35 Vol. % corresponds to approx. –20 °C

55 Vol. % corresponds to approx. –45 °C (manufacturer's instructions)

60 Vol. % corresponds to approx. –50 °C

[2)] Antifreeze agent concentrations higher than 55 vol. % are only permitted, if safe heat removal is ensured by a sufficient cooling rate.

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Coolant inspecting

Summary

Acquire and check typical values of the operating media to prevent or limit damage.

The fresh water used to fill the coolant circuits must satisfy the specifications. The coolant in the system must be checked regularly in accordance with the maintenance schedule.
The following work/steps is/are necessary:
Acquisition of typical values for the operating fluid,
evaluation of the operating fluid and checking the anticorrosive agent concentration.

Tools/equipment required

Equipment for checking the fresh water quality

The following equipment can be used:

- The MAN Diesel & Turbo 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 MAN Diesel & Turbo 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
= 17.9 mg/l $CaCO_3$
= 0.179 mmol/L

[2)] 1 mg/l = 1 ppm

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Testing the concentration of rust inhibitors

Short specification

Anticorrosive agent	Concentration
Chemical additives	in accordance with quality specification in Volume 010.005 Engine – operating manual 010.000.023-14
Anti-freeze agents	in accordance with quality specification in Volume 010.005 Engine – operating manual 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 slushing oils can only provide effective protection if the right concentration is precisely maintained. This is why the concentrations recommended by MAN Diesel & Turbo (quality specifications in Volume 010.005 Engine – operating manual 010.000.023-14) must be complied with in all cases. These recommended concentrations may be other than 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 MAN Diesel & Turbo.

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 MAN Diesel & Turbo laboratory PrimeServLab.

Coolant system cleaning

Summary

Remove contamination/residue from operating fluid systems, ensure/re-establish operating reliability.

Coolant systems containing deposits or contamination prevent effective cooling of parts. Contamination and deposits must be regularly eliminated.
This comprises the following:
Cleaning the system and, if required,
removal of limescale deposits,
flushing the system.

Cleaning

The coolant system must be checked for contamination at regular intervals. Cleaning is required if the degree of contamination is high. This work should ideally be carried out by a specialist who can provide the right cleaning agents for the type of deposits and materials in the cooling circuit. The cleaning should only be carried out by the engine operator if this cannot be done by a specialist.

Oil sludge

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

Manufacturer	Product	Concentration	Duration of cleaning procedure/temperature
Drew	HDE - 777	4 – 5%	4 h at 50 – 60 °C
Nalfleet	MaxiClean 2	2 – 5%	4 h at 60 °C
Unitor	Aquabreak	0.05 – 0.5%	4 h at ambient temperature
Vecom	Ultrasonic Multi Cleaner	4%	12 h at 50 – 60 °C

Table 1: Cleaning agents for removing oil sludge

Lime and rust deposits

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

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

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

NOTICE

Only carry out cleaning procedure with cooled engine

Only begin the cleaning procedure when the engine has cooled down. Hot engine parts may not come into contact with cold water. After refilling the cooling system, open the venting pipes. Blocked venting pipes prevent the air from escaping and may cause thermal overload of the engine.

⚠ WARNING

Danger of chemical burns

From cleaning agents poisonous gases and fumes can develop, which may cause light to severe person injuries.

- Wear protective clothing
- Provide adequate ventilation
- Do not inhale developed gases and fumes
- Observe Safety Data Sheets or Operating Instructions of the relevant manufacturer

The applicable instructions for disposing of cleaning agents or acids are to be observed.

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Specification of water for fuel-water emulsions

Prerequisites

The water used for the fuel-water emulsion is an operating fluid that must be carefully selected, processed (if necessary) and monitored. If this is not done, deposits, corrosion, erosion and cavitation may occur on the fuel system components that come into contact with the fuel-water emulsion.

Specifications

Limit values

The characteristic values of the water used must be within the following limit values:

Properties/ Characteristic	Characteristic value	Unit
Water type	Distillate or fresh water, free of foreign matter.	-
Total hardness	max. 10	°dH*
pH value	6.5 - 8	-
Chloride ion content	max. 50	mg/l

Table 1: Fuel-water emulsion - characteristic values to be observed

*) 1° dH (German hardness)	≙ 10 mg CaO in 1 litre of water	≙ 17.9 mg $CaCO_3$/l
	≙ 0.357 mval/l	≙ 0.179 mmol/l

Testing instruments

The MAN Diesel water testing kit contains instruments that allow the water characteristics referred to above (and others) to be easily determined.

Additional information

Distillate

If distillate (e.g. from the fresh water generator) or fully desalinated water (ion exchanger) is available, this should ideally be used for the fuel-water emulsion. These types of water are free of lime and salts.

Hardness

The total hardness of the water is the combined effect of the temporary and permanent hardness. It is largely determined by the calcium and magnesium salts. The temporary hardness depends on the hydrocarbonate content in the calcium and magnesium salts. The lasting (permanent) hardness is determined by the remaining calcium and magnesium salts (sulphates).

Water with hardness greater than 10°dH (German total hardness) must be blended or softened with distillate. It is not necessary to increase the hardness of extremely soft water.

NOTICE

Treatment with anticorrosive agents not required
Treatment with anticorrosive agents is not required and must be omitted.

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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 and lubricating oil cooling.

High temperature cooling water system

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

The engine outlet temperature ensures an optimal 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 cooling water temperature of ≥ 60°C – either by means of cooling water from running engines or by means of a separate pre-heating system.

System lay-out

MAN Diesel's standard for the internal cooling water system is shown on our Basic Diagram.

Temperature regulation in the HT and LT systems takes place in the internal system where also the pumps are situated. This means that it is only nessesary with two main pipes for cooling of the engine. The only demand is that the FW inlet temperature is between 10 and 40°C.

To be able to match every kind of external systems, the internal system can as optional be arranged with a FW cooler for an external SW system.

HT- and LT-circulating pumps

The circulating pumps which are of the centrifugal type are mounted in the front-end box of the engine and are driven by the crankshaft through gear transmissions.

Technical data: *See "list of capacities" D 10 05 0*

Thermostatic valves

The thermostatic valves are fully automatic three-way valves with thermostatic elements set at fixed temperatures.

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Preheating arrangement

In connection with plants where all engines are stopped for a certain period of time it is possible to install an electric heat exchanger in the external system.

In connection with plants with more than one engine the stand-by engines can be automatically preheated by the operating engines by means of the pipe connections leading to the expansion system and the HT-circulation pumps.

Internal cooling water system

Internal cooling water system

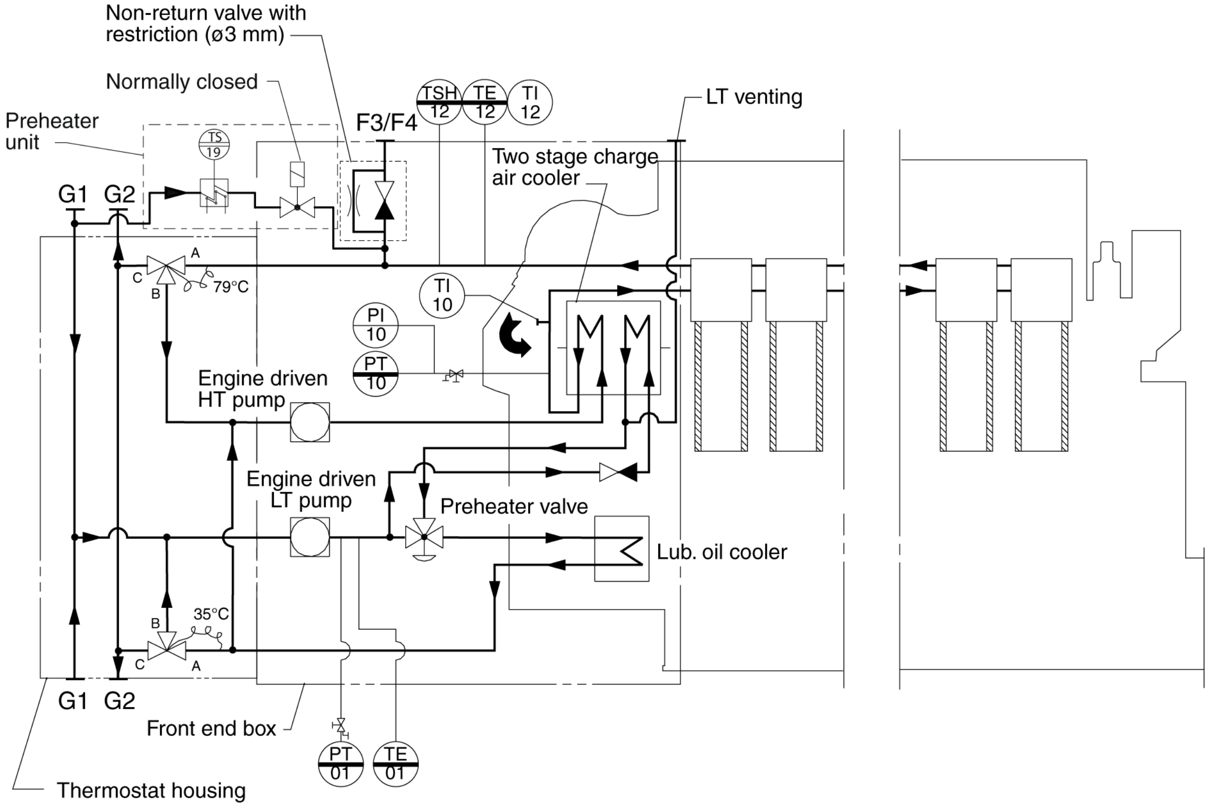

Figure 1: Diagram for internal cooling water system with internal preheater unit (for guidance only, please see the plant specific engine diagram)

Pipe description

F3	Venting to expansion tank	DN 20
F4	HT fresh water from preheater	DN 20
G1	LT fresh water inlet	DN 65
G2	LT fresh water outlet	DN 65

Table 1: Flange connections are standard according to DIN 2501

2015-04-22 - en

Description

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

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

Low temperature circuit

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

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

Preheating of charge air

Below approx. 40% load water is bypassed for LT-side of charge air cooler and led directly to lub. oil cooler. This is done to raise charge air temperature and improve combustion. At the connection F3/F4 for the expansion tank there is a non-return valve with ø3 mm hole. This is for the internal connections of the engine to improve preheating of the engine at stand-by.

High temperature circuit

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

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

Data

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

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

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

Internal cooling water system

Internal cooling water system

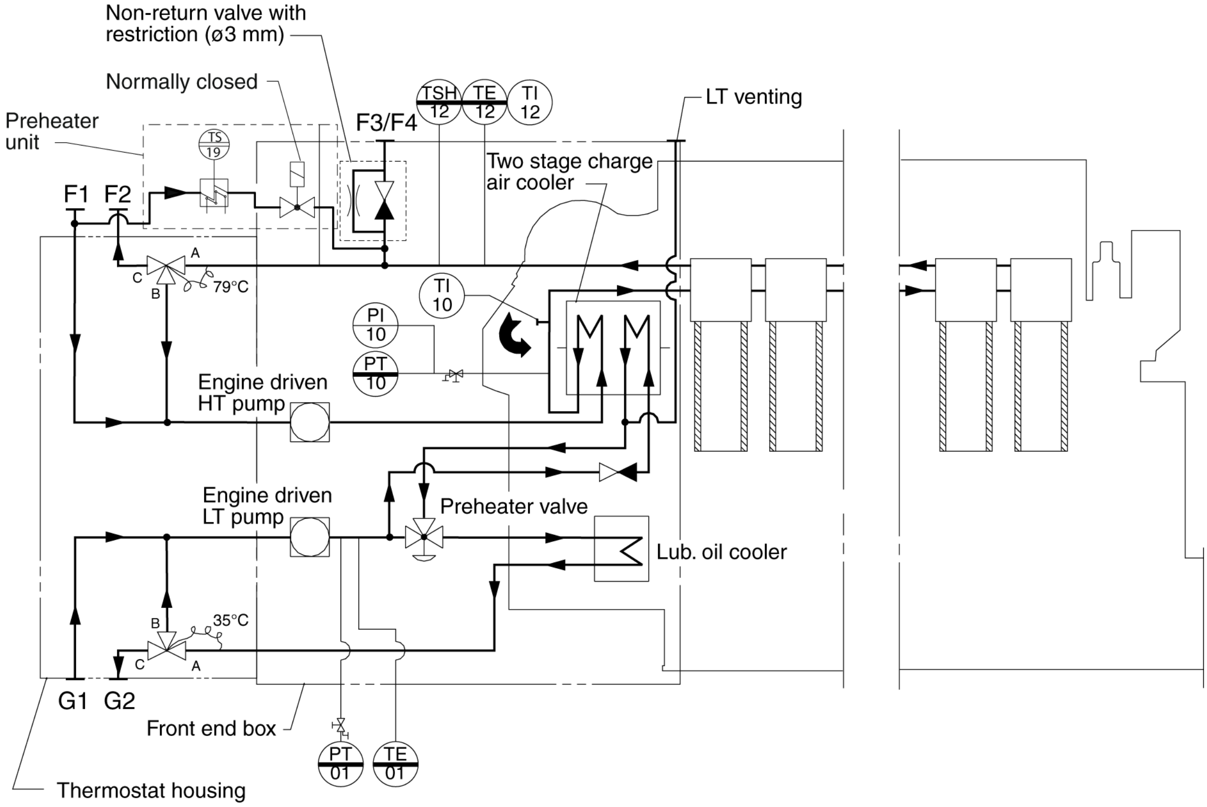

Figure 1: Diagram for internal cooling water system with internal preheater unit (for guidance only, please see the plant specific engine diagram)

Pipe description

F1	HT fresh water inlet	DN 65
F2	HT fresh water outlet	DN 65
F3	Venting to expansion tank	DN 20
F4	HT fresh water for preheating	DN 20
G1	LT fresh water inlet	DN 65
G2	LT fresh water outlet	DN 65

Table 1: Flange connections are standard according to DIN 2501

Description

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

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

Low temperature circuit

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

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

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

Preheating of charge air

Below approx. 40% load water is bypassed for LT-side of charge air cooler and led directly to lub. oil cooler. This is done to raise charge air temperature and improve combustion. At the connection F3/F4 for the expansion tank there is a non-return valve with ø3 mm hole. This is for the internal connections of the engine to improve preheating of the engine at stand-by.

High temperature circuit

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

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

Data

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

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

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

Internal cooling water system

Internal cooling water system

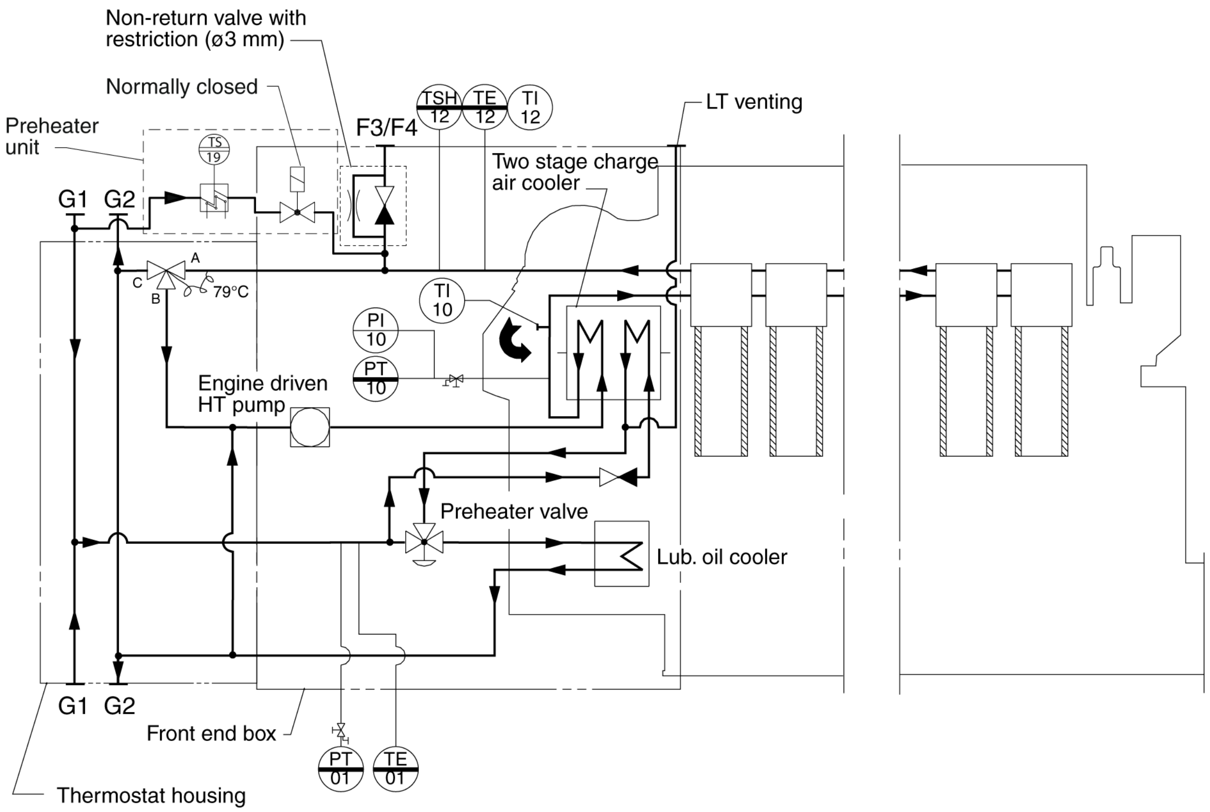

Figure 1: Diagram for internal cooling water system with internal preheater unit and without LT-regulation (for guidance only, please see the plant specific engine diagram)

Pipe description

F3	Venting to expansion tank	DN 20
F4	HT fresh water from preheater	DN 20
G1	LT fresh water inlet	DN 65
G2	LT fresh water outlet	DN 65

Table 1: Flange connections are standard according to DIN 2501

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Description

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

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

Low temperature circuit

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

The charge air cooler and the lubricating oil cooler are situated in serial order. After the LT water has passed the lubricating oil cooler, it is led to the external system.

Preheating of charge air

Below approx. 40% load water is bypassed for LT-side of charge air cooler and led directly to lub. oil cooler. This is done to raise charge air temperature and improve combustion. At the connection F3/F4 for the expansion tank there is a non-return valve with ø3 mm hole. This is for the internal connections of the engine to improve preheating of the engine at stand-by.

High temperature circuit

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

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

Data

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

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

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

Internal cooling water system

Internal cooling water system

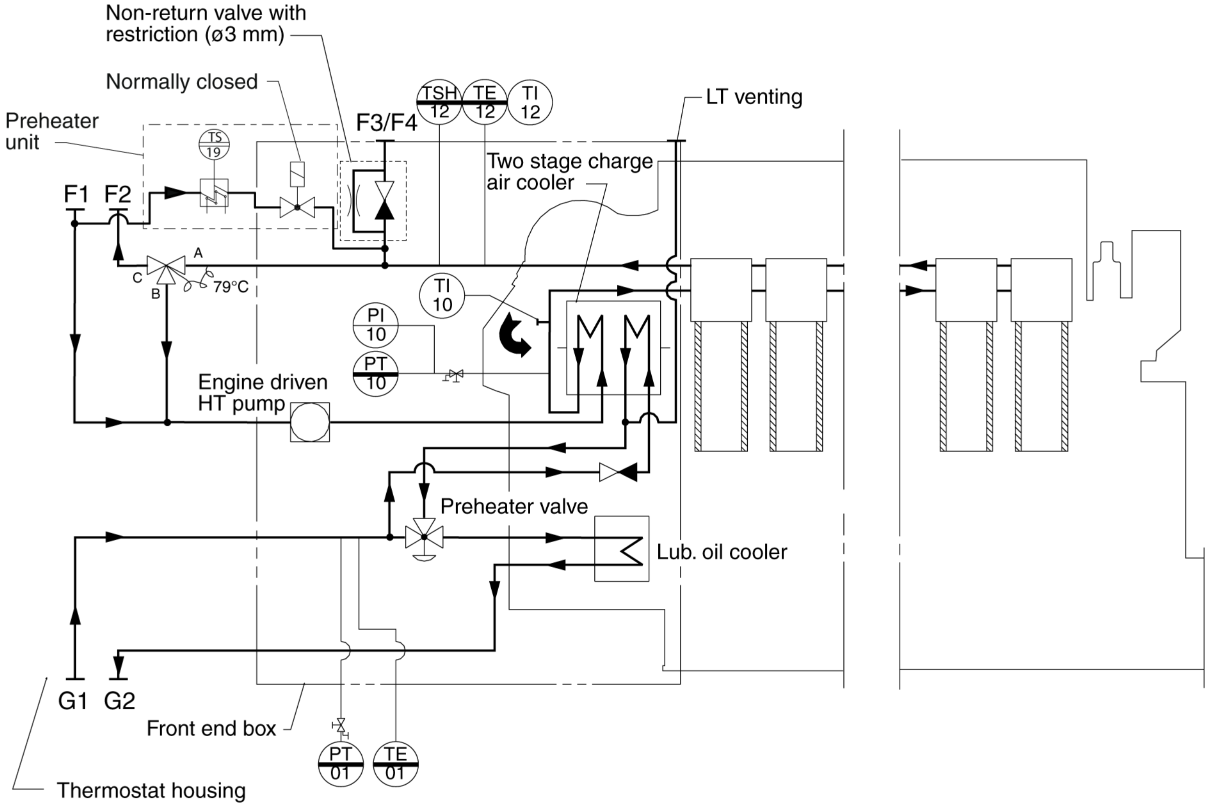

Figure 1: Diagram for internal cooling water system with internal preheater unit and without LT-regulation (for guidance only, please see the plant specific engine diagram)

Pipe description

F1	HT fresh water inlet	DN 65
F2	HT fresh water outlet	DN 65
F3	Venting to expansion tank	DN 20
F4	HT fresh water for preheating	DN 20
G1	LT fresh water inlet	DN 65
G2	LT fresh water outlet	DN 65

Table 1: Flange connections are standard according to DIN 2501

Description

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

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

Low temperature circuit

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

The charge air cooler and the lubricating oil cooler are situated in serial order. After the LT water has passed the lubricating oil cooler, it is led to the external system.

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

Preheating of charge air

Below approx. 40% load water is bypassed for LT-side of charge air cooler and led directly to lub. oil cooler. This is done to raise charge air temperature and improve combustion. At the connection F3/F4 for the expansion tank there is a non-return valve with ø3 mm hole. This is for the internal connections of the engine to improve preheating of the engine at stand-by.

High temperature circuit

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

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

Data

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

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

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

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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 L16/24 type engine(s).The stated data are for one engine only and are specified at MCR.

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

Note: Make sure that this pipeline always is open for this function.

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

Cooling water pressure

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

External pipe velocitiy

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

Fresh water : 3.0 m/s

Pressure drop across engine

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

Expansion tank

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

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

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

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

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

$V = 0.1 + (\text{exp. vol. per extra eng.})\ [m^3]$

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

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

Data for external preheating system

The capacity of the external preheater should be 1.0-1.3 kW/cyl. The flow through the engine should for each cylinder be approx. 1.2 l/min with flow from top and downwards and 8 l/min with flow from bottom and upwards. *See also table 1 below.*

Cyl. No	**5**	**6**	**7**	**8**	**9**
Quantity of water in eng: HT and LT system (litre)	75	81	87	94	100
Expansion vol. (litre)	4	5	5	5	6
Preheating data: Radiation area (m^2) Thermal coeff. (kJ/°C)	9.3 1627	10.3 1915	11.3 2205	12.3 2460	14.3 2783

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

External cooling water system

Design of external cooling water system

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

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

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

1. Simplicity.
2. Preheating with surplus heat.
3. Preheating in engine top, downwards.
4. As few change-over valves as possible.

Ad 1) Cooling water systems have a tendency to be unnecessarily complicated and thus uneconomic in installation and operation. Therfore, 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) 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 3) 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 4) The systems have been designed in such a way that the change-over from sea operation to harbour operation/stand-by with preheating can be made with a minimum of manual or automatic interference.

Fresh water treatment

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

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

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

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

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1 string central cooling water system

1 string central cooling water system

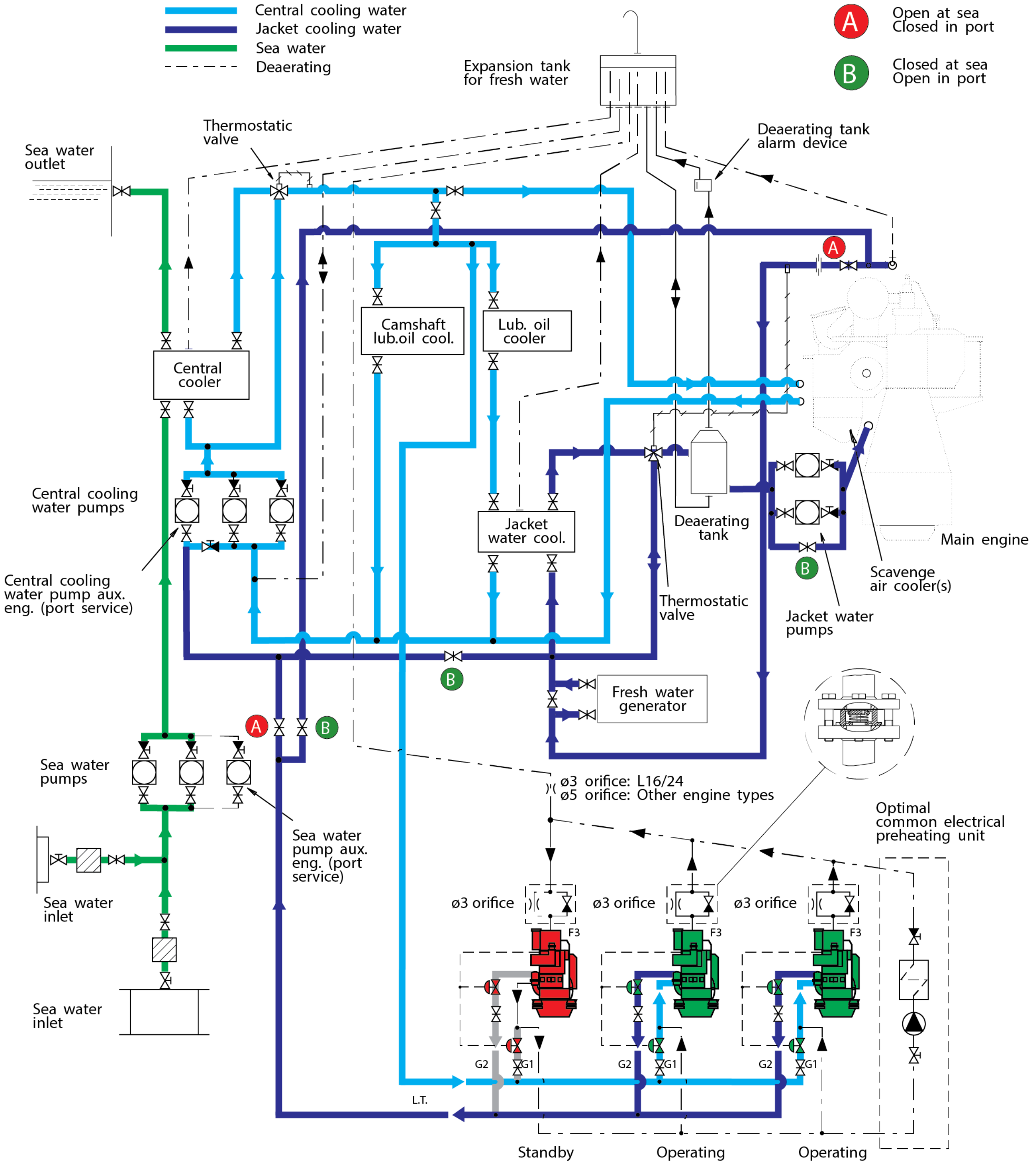

Figure 1: Central cooling system.

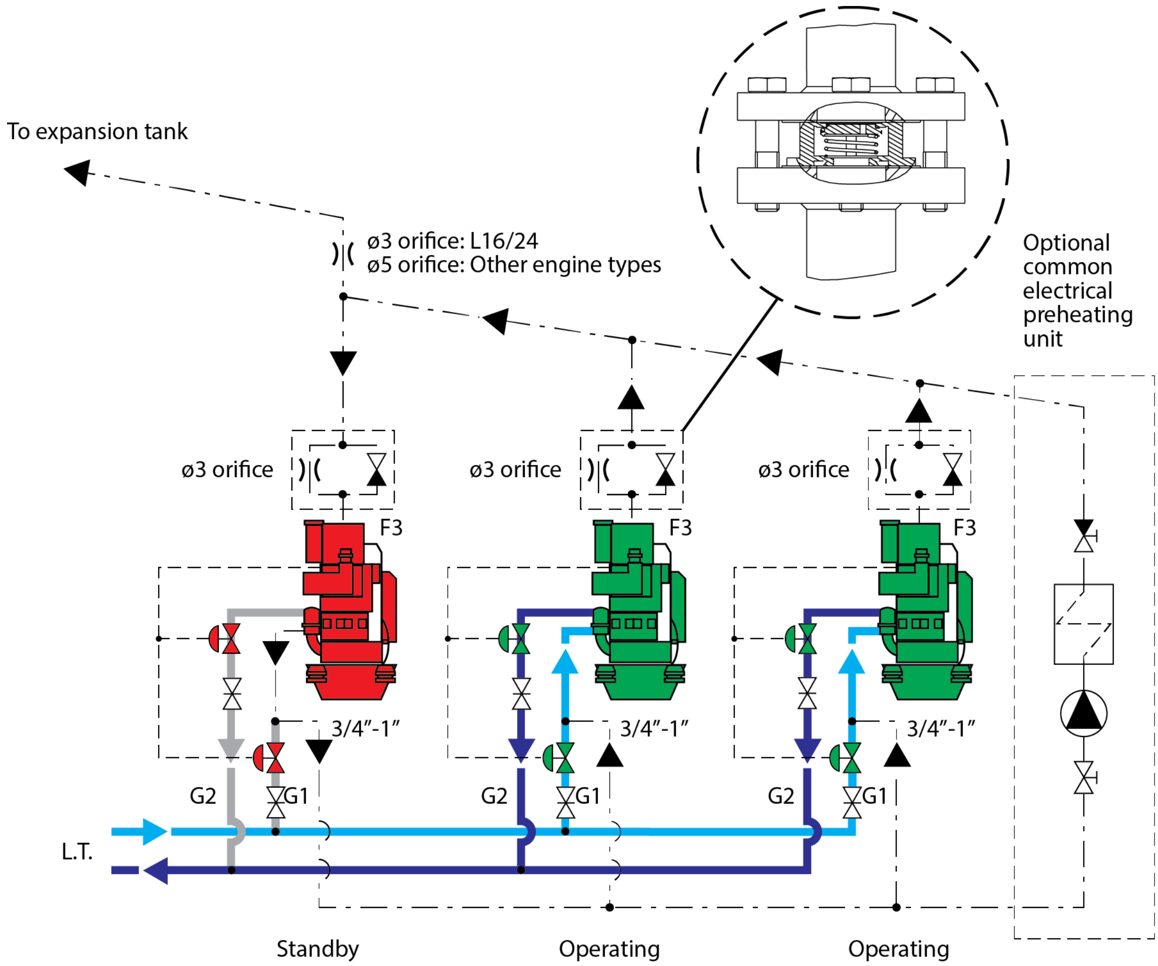

Figure 2: Preheating.

System design

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

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

Preheating

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

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

Preheating of stand-by auxiliary engines during sea operation

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

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

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

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

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

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

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

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

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

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

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

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1.5 string central cooling water system

1.5 string central cooling water system

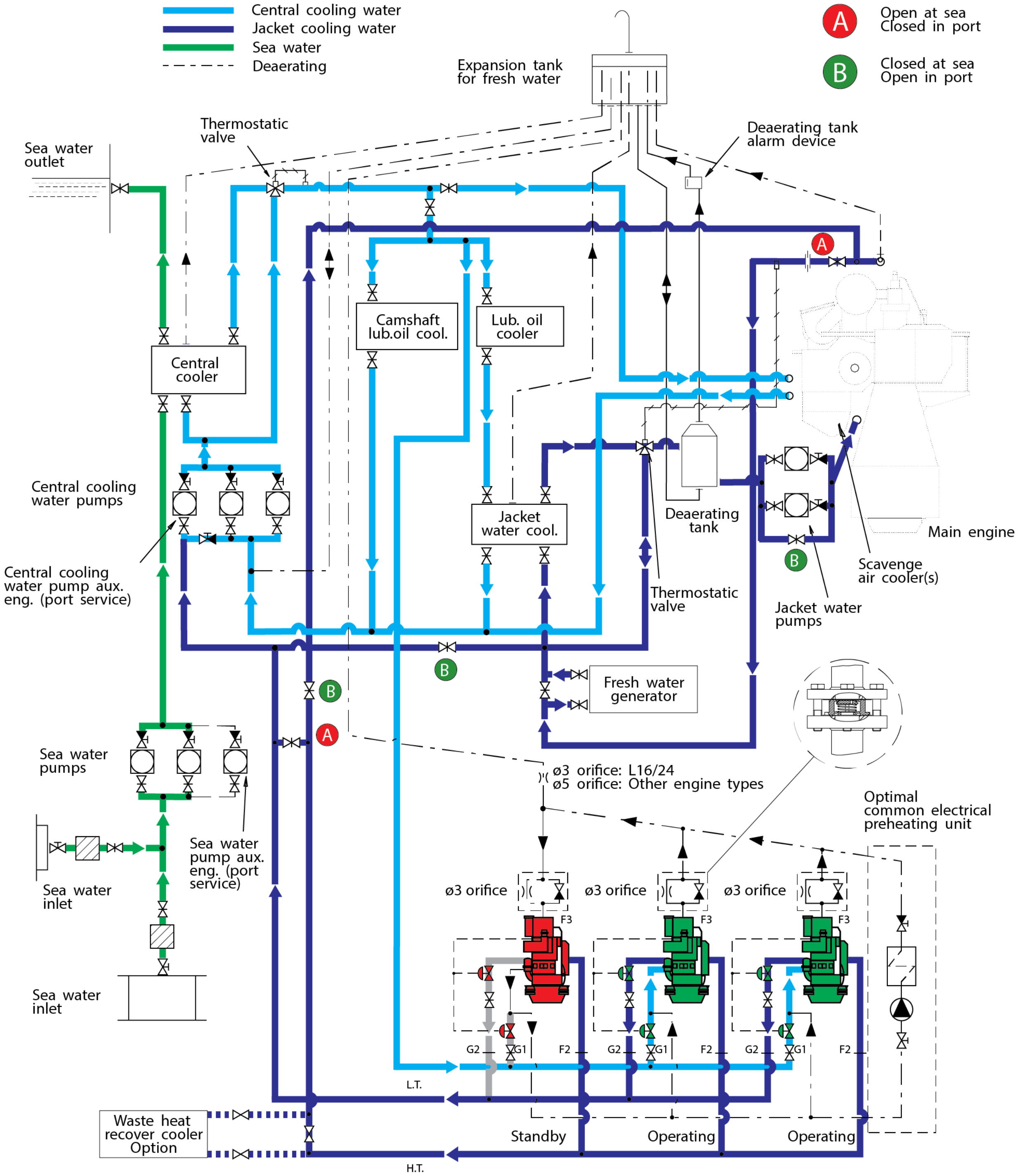

Figure 1: Central cooling system

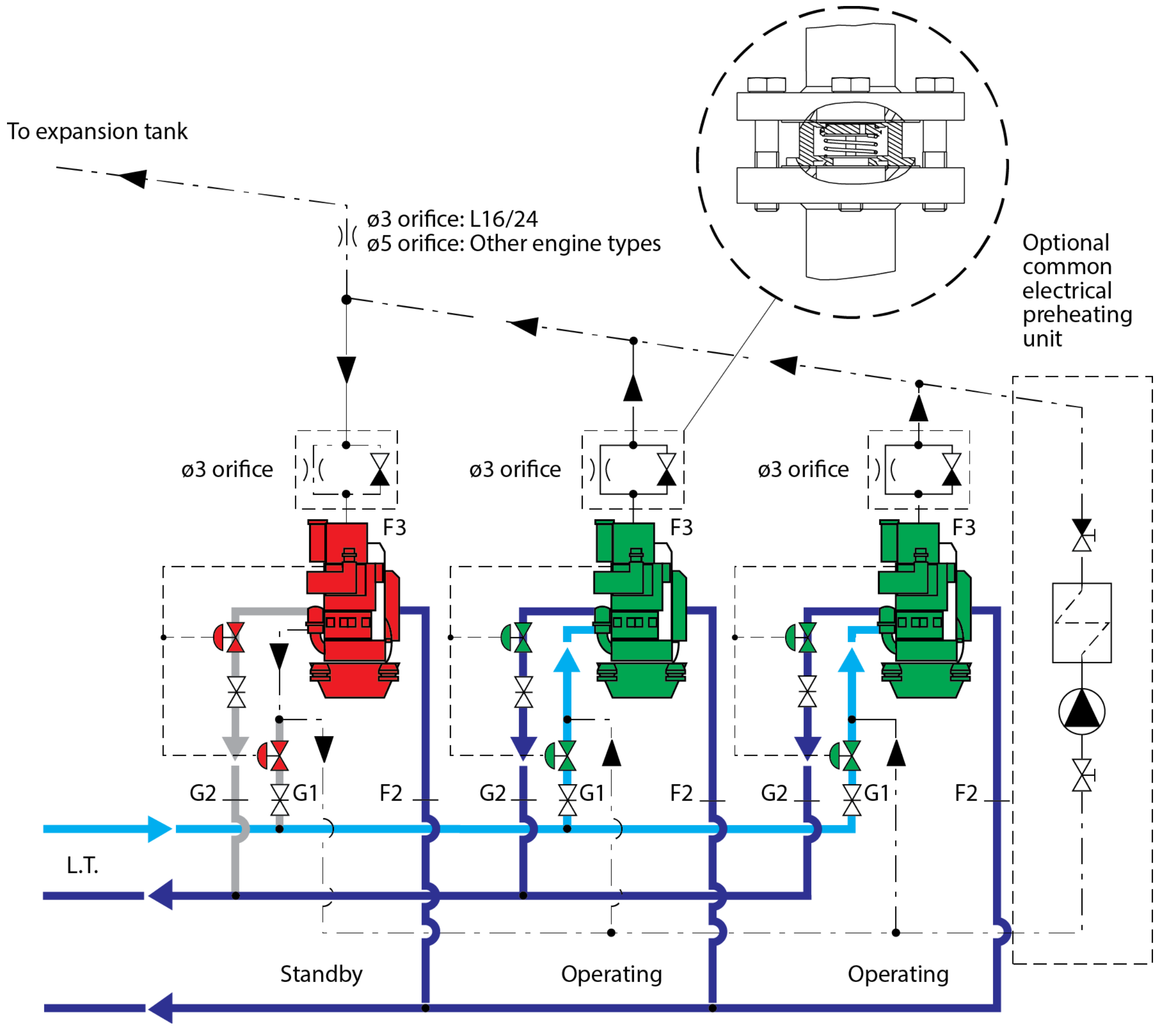

Figure 2: Preheating

System design

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

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

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

Preheating

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

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

Preheating of stand-by auxiliary engines during sea operation

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

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

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

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

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

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

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

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

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

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

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

2 string central cooling water system

2 string central cooling water system

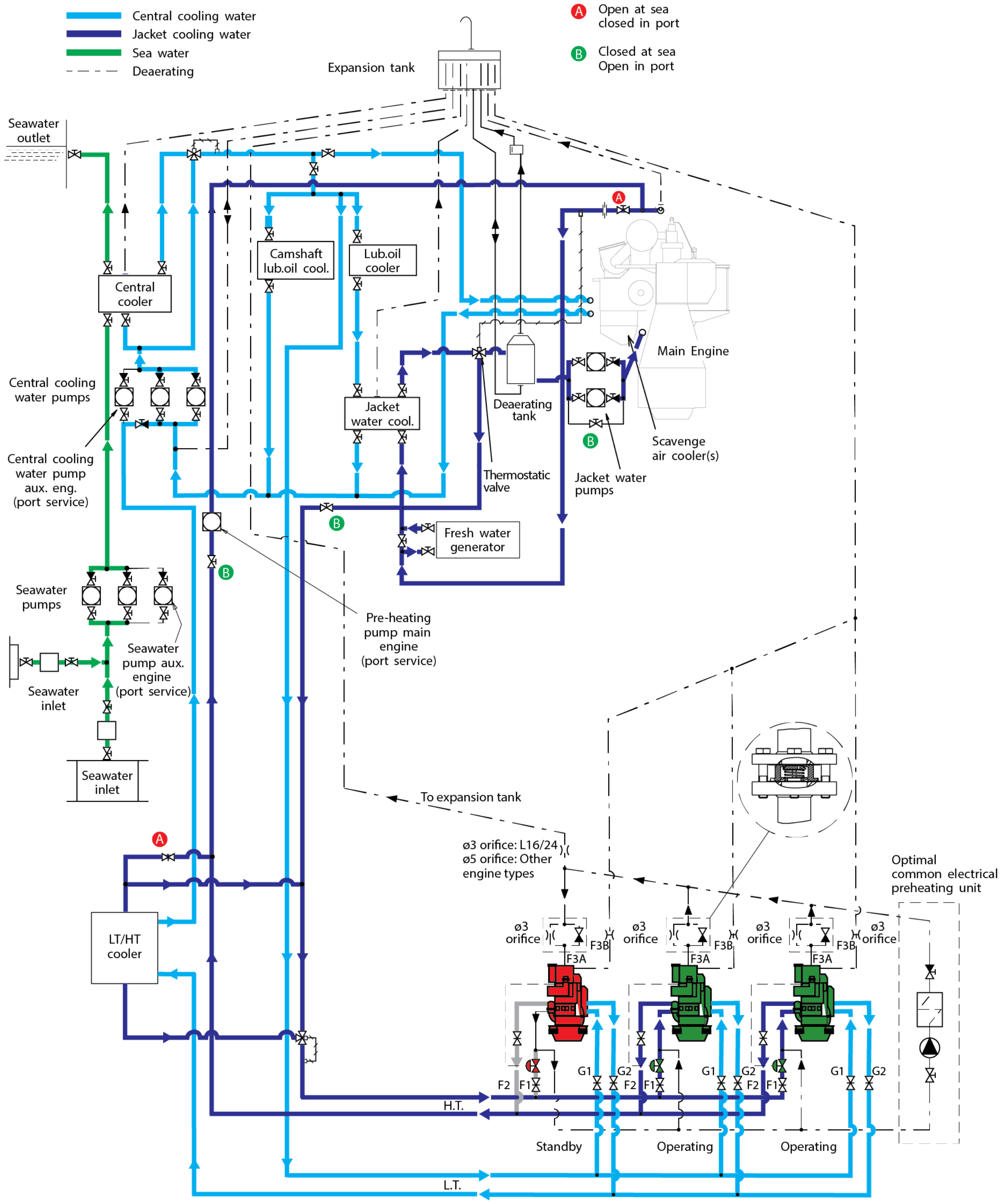

Figure 1: Operating at sea

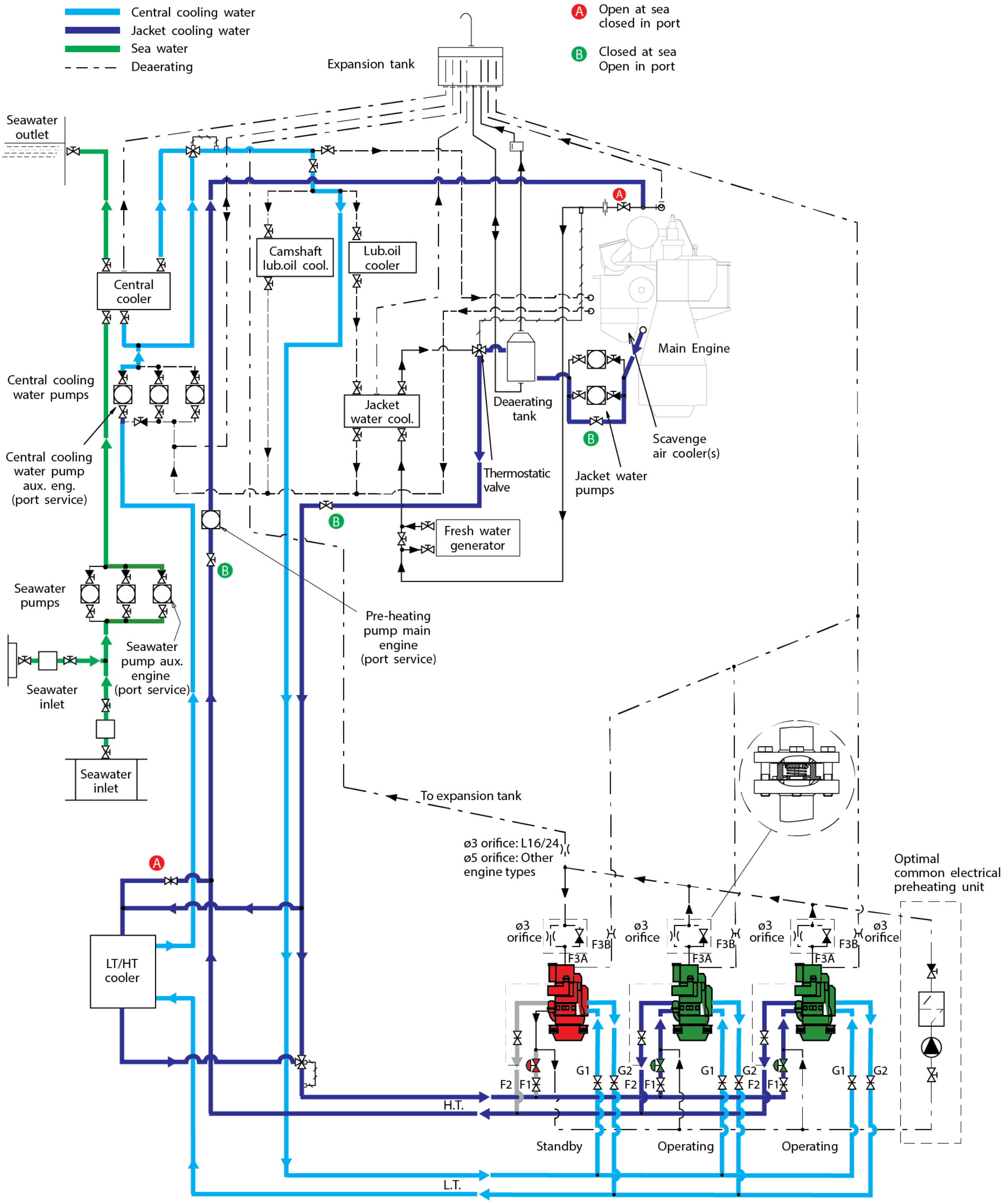

Figure 2: Operating in port

System design

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

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

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

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

Preheating

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

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

Preheating of stand-by auxiliary engines during sea operation

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

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

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

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

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

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

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

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

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

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

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

Optional preheating solutions

Optionally engines can be delivered with internal preheating.

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

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

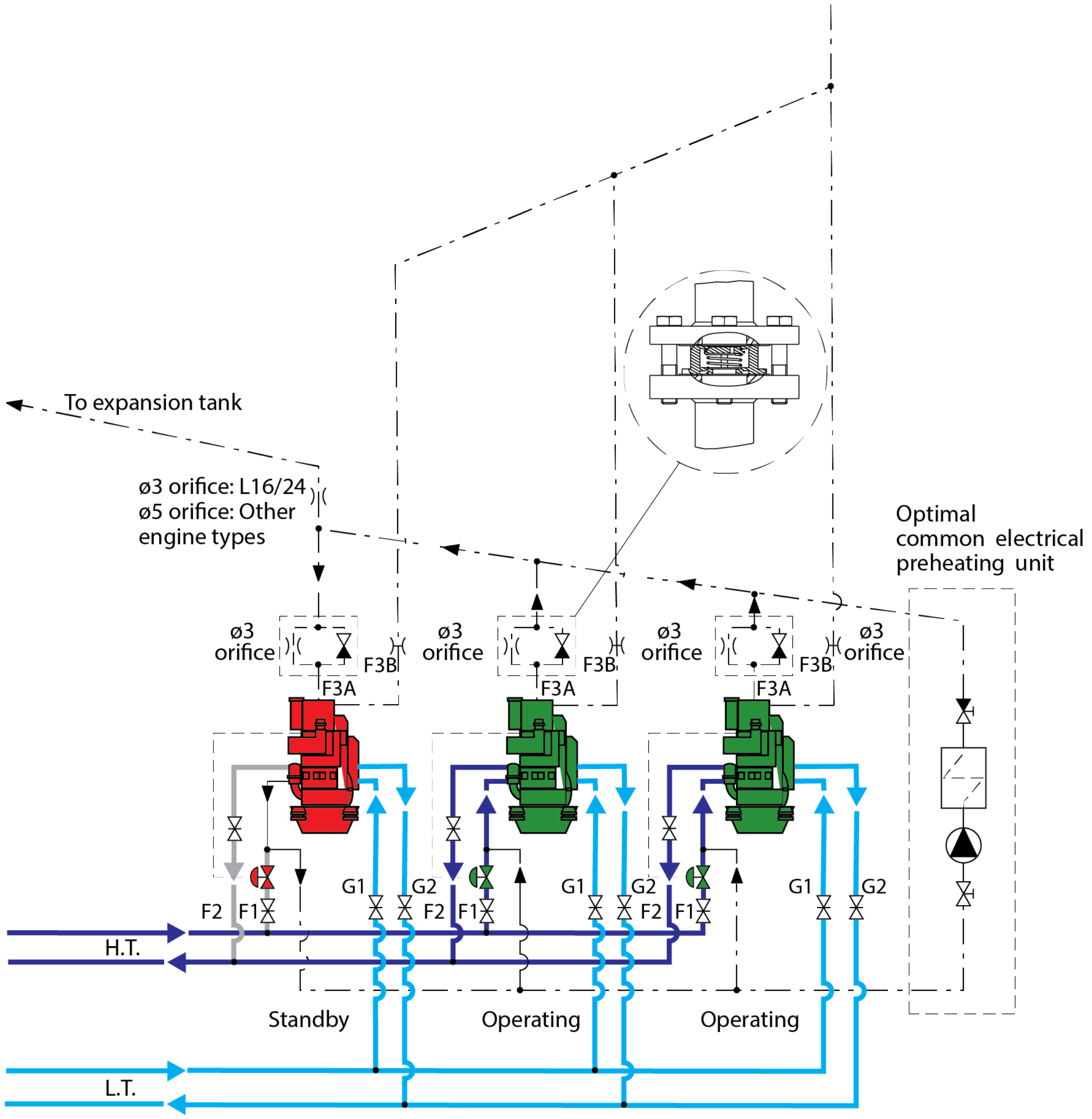

Figure 3: Preheating

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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 6L23/30H, 6L23/30H Mk2, 6L23/30S, 6L23/30DF 7L23/30H, 7L23/30H Mk2, 7L23/30S, 7L23/30DF 8L23/30H, 8L23/30H Mk2, 8L23/30S, 8L23/30DF	11 13 15 17	0.1 0.1 0.1 0.1
5L28/32H, 5L28/32S, 5L28/32DF 6L28/32H, 6L28/32S, 6L28/32DF 7L28/32H, 7L28/32S, 7L28/32DF 8L28/32H, 8L28/32S, 8L28/32DF 9L28/32H, 9L28/32S, 9L28/32DF	28 33 39 44 50	0.15 0.15 0.15 0.15 0.15
12V28/32S, 12V28/32S-DF, 12V28/32H 16V28/32S, 16V28/32S-DF, 16V28/32H 18V28/32S, 18V28/32S-DF, 18V28/32H	66 88 99	0.3 0.3 0.3
5L16/24, 5L16/24S 6L16/24, 6L16/24S 7L16/24, 7L16/24S 8L16/24, 8L16/24S 9L16/24, 9L16/24S	4 5 5 5 6	0.1 0.1 0.1 0.1 0.1
5L21/31, 5L21/31S 6L21/31, 6L21/31S 7L21/31, 7L21/31S 8L21/31, 8L21/31S 9L21/31, 9L21/31S	6 7 8 9 10	0.1 0.1 0.1 0.1 0.1

Engine type	Expansion volume litre*	Recommended tank volume m³**
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
6L32/40	13	0.5
7L32/40	15	0.5
8L32/40	18	0.5
9L32/40	20	0.5

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

* Per engine
** Common expansion tank

Preheater arrangement in high temperature system

General

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

Cyl. No.	Preheater 3x400V/3x440V kW
5-9	1 x 9.0

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

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Expansion tank pressurized

Description

Engine type	Expansion volume litre*	Recommended tank volume m³**
5L23/30H, 5L23/30H Mk2, 5L23/30S, 5L23/30DF 6L23/30H, 6L23/30H Mk2, 6L23/30S, 6L23/30DF 7L23/30H, 7L23/30H Mk2, 7L23/30S, 7L23/30DF 8L23/30H, 8L23/30H Mk2, 8L23/30S, 8L23/30DF	11 13 15 17	0.1 0.1 0.1 0.1
5L28/32H, 5L28/32S, 5L28/32DF 6L28/32H, 6L28/32S, 6L28/32DF 7L28/32H, 7L28/32S, 7L28/32DF 8L28/32H, 8L28/32S, 8L28/32DF 9L28/32H, 9L28/32S, 9L28/32DF	28 33 39 44 50	0.15 0.15 0.15 0.15 0.15
12V28/32S, 12V28/32S-DF, 12V28/32H 16V28/32S, 16V28/32S-DF, 16V28/32H 18V28/32S, 18V28/32S-DF, 18V28/32H	66 88 99	0.3 0.3 0.3
5L16/24, 5L16/24S 6L16/24, 6L16/24S 7L16/24, 7L16/24S 8L16/24, 8L16/24S 9L16/24, 9L16/24S	4 5 5 5 6	0.1 0.1 0.1 0.1 0.1
5L21/31, 5L21/31S 6L21/31, 6L21/31S 7L21/31, 7L21/31S 8L21/31, 8L21/31S 9L21/31, 9L21/31S	6 7 8 9 10	0.1 0.1 0.1 0.1 0.1
5L27/38, 5L27/38S 6L27/38, 6L27/38S 7L27/38, 7L27/38S 8L27/38, 8L27/38S 9L27/38, 9L27/38S	10 12 13 15 20	0.15 0.15 0.15 0.15 0.15
6L32/40 7L32/40 8L32/40 9L32/40	13 15 18 20	0.5 0.5 0.5 0.5
* Per engine ** Common expansion tank		

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

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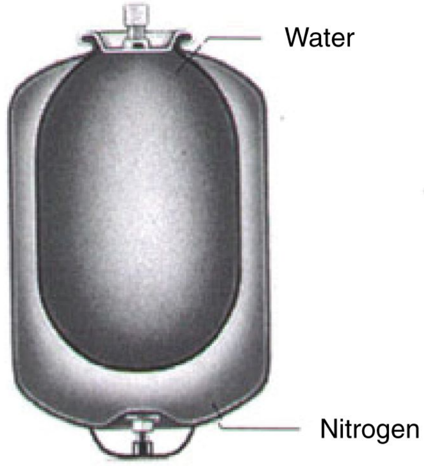


Figure 1: Function of expansion tank.

- 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.

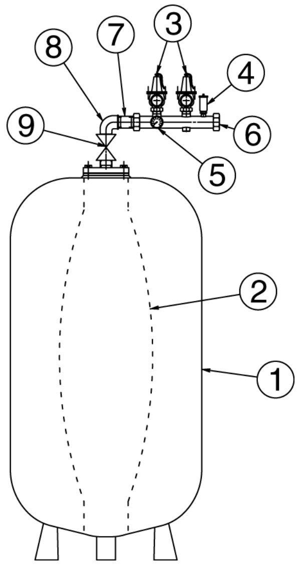
The expansion vessel should be connected to the system at a point close to the cooling water inlet connections (G1 / F1) in order to maintain positive pressures throughout the system and allow expansion of the water.

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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Specification of compressed air

General

For compressed air quality observe the ISO 8573-1:2010. 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 8573-1:2010.

Purity regarding solid particles	Quality class 6
Particle size > 40µm	max. concentration < 5 mg/m³
Purity regarding moisture	Quality class 7
Residual water content	< 0.5 g/m³
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 8573-1:2010.

- 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 8573-1:2010.

- 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 8573-1:2010.

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▪ 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 8573-1:2010.

▪ Purity regarding solid particles	Quality class 2
▪ Purity regarding moisture	Quality class 3
▪ Purity regarding oil	Quality class 2

Compressed air system

Compressed air system

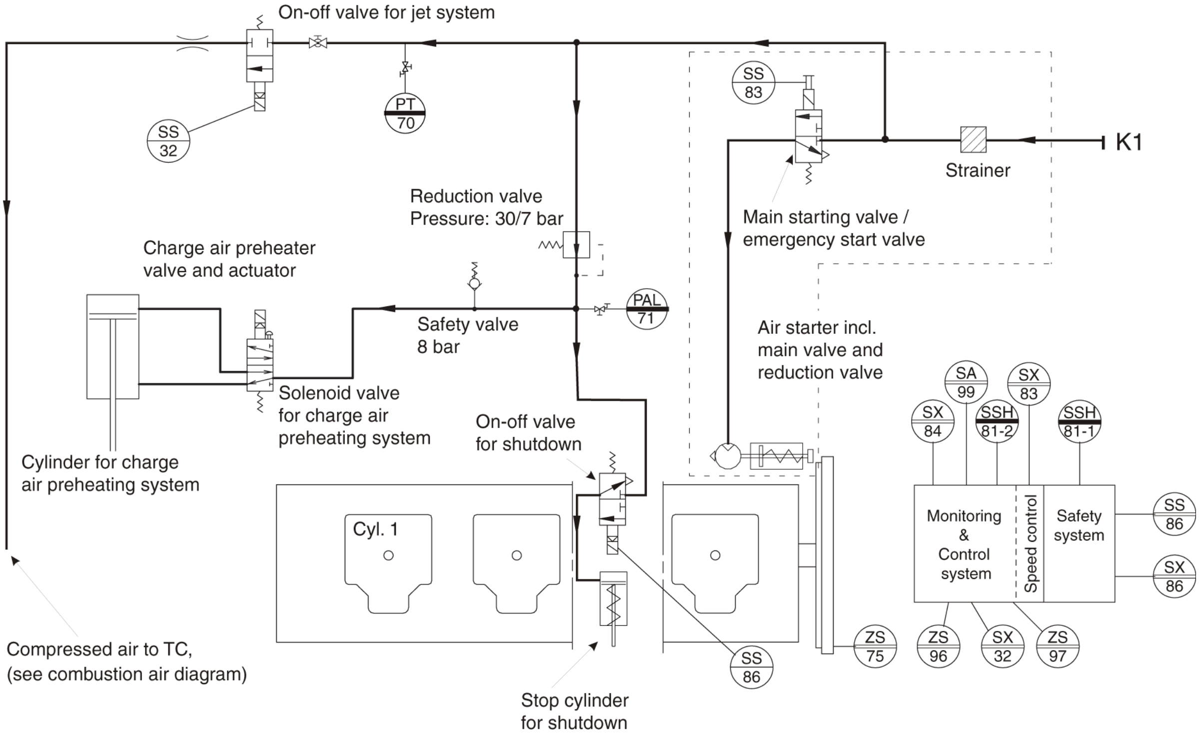

Figure 1: Diagram for 30 bar compressed air system (for guidance only, please see the plant specific engine diagram)

Air supply!

WARNING

Air supply must not be interrupted when engine is running

Pipe description

Pipe description		
K1	Compressed air inlet	DN 25

Table 1: Flange connections are standard according to DIN 2501

General

The compressed air system on the engine consists of a starting system, starting control system and safety system. Further, the system supplies air to the jet assist system.

The compressed air is supplied from the starting air receivers (16-30 bar) through a reduction station, from where compressed air 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 gear rotor 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 controlled start the starting coil is connected so that every starting signal to the starting coil goes through the control module mounted on the engine.

Further, the starting valve also acts as an emergency starting valve which makes it possible to activate the air starter manually in case of power failure. As shown in *fig. 2.*

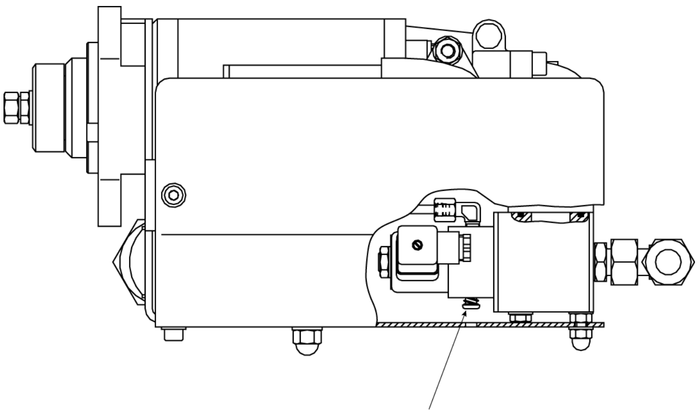

Figure 2: Emergency start.

Safety system

As standard the engine is equipped with a pneumatic/mechanic stop cylinder, which starts to operate if the safety system is activated. The system is activated electrically or mechanically by a 3/2-way valve on top of the engine, behind the regulator.

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

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Pneumatic start sequence

When the starting valve is opened, air will be supplied to the drive shaft housing of the air starter.

The air supply will - by activating a piston - bring the drive pinion into engagement with the gear rim on the engine flywheel.

When the pinion is fully engaged, the pilot air will flow to, and open the main starting valve, whereby air will be led to the air starter, which will start to turn the engine.

When the RPM exceeds approx. 158, at which firing has taken place, the starting valve is closed whereby the air starter is disengaged.

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Compressed air system

Compressed air system

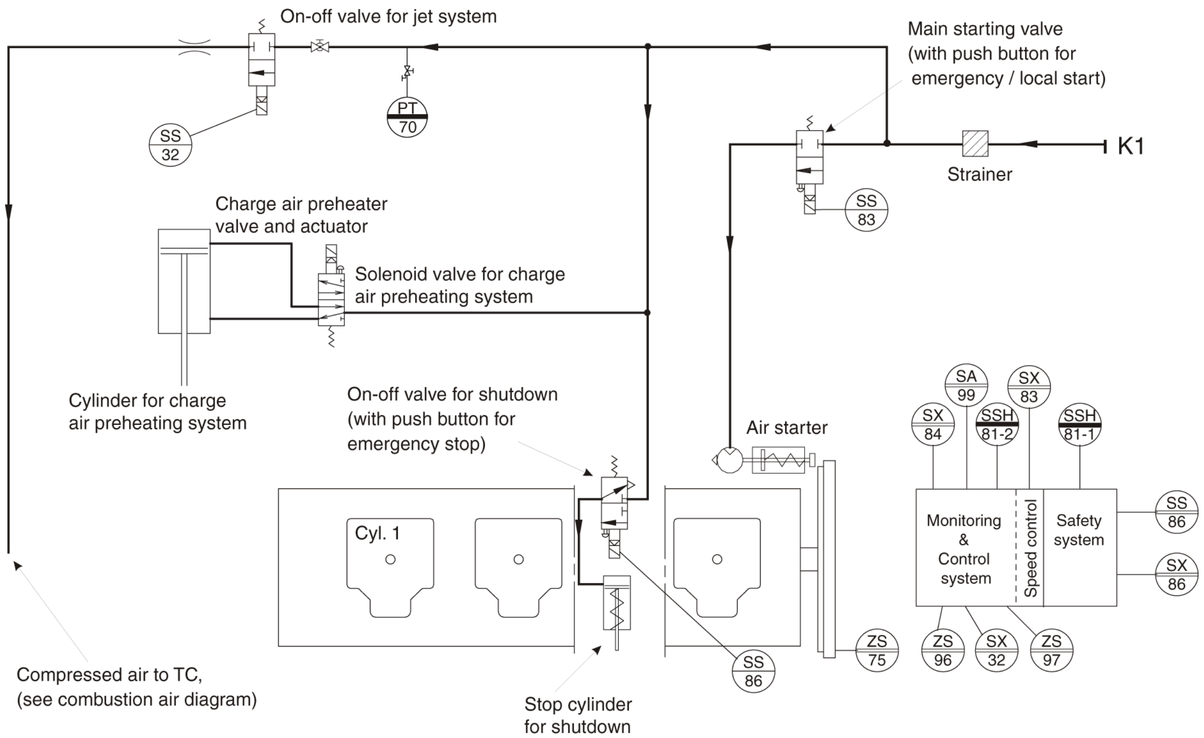

Figure 1: Diagram for 10 bar compressed air system (for guidance only, please see the plant specific engine diagram)

Pipe description

Pipe description		
K1	Compressed air inlet	DN 25

Table 1: Flange connections are standard according to DIN 2501

General

The compressed air system on the engine consists of a starting system, starting control system and safety system. Further, the system supplies air to the jet assist system.

The compressed air is supplied from the starting air receivers, through a reduction station, from where compressed air is supplied to the engine (max. 10 bar).

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

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Starting system

The engine is started by means of a built-on air starter, which is a turbine motor with 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 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 controlled start the starting coil is connected so that every starting signal to the starting coil goes through the control module mounted on the engine.

Further, the starting valve also acts as an emergency starting valve which makes it possible to activate the air starter manually in case of power failure. As shown in fig. 2.

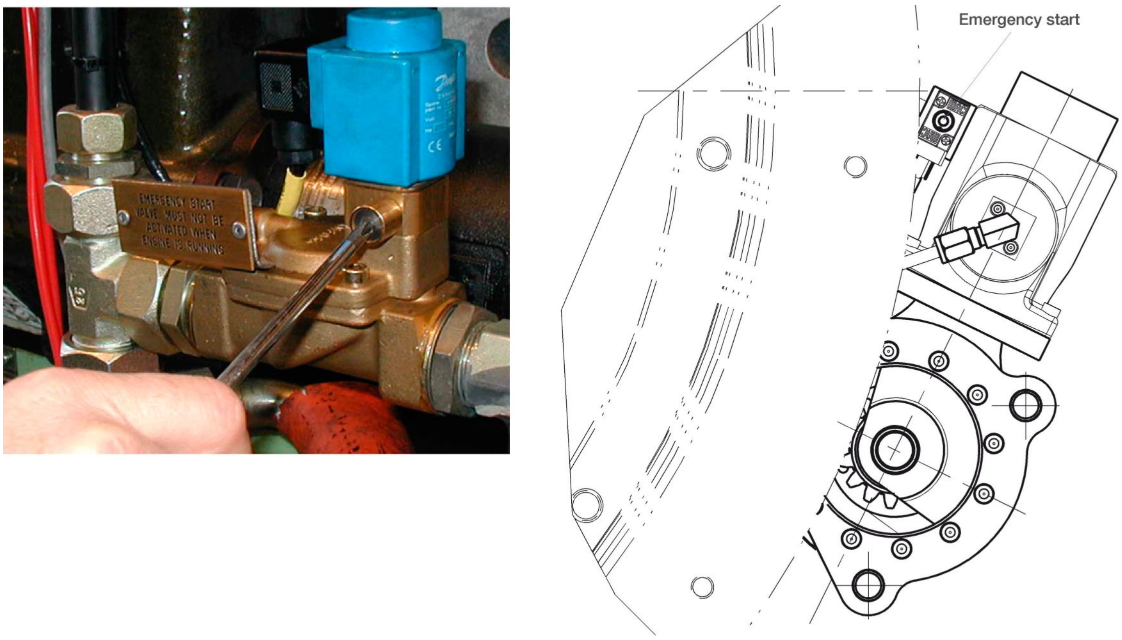

Figure 2: Emergency start (IR and TDI).

Safety system

As standard the engine is equipped with a pneumatic/mechanic stop cylinder, which starts to operate if the safety system is activated. The system is activated electrically or mechanically by a 3/2-way valve on top of the engine, behind the regulator.

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

Pneumatic start sequence

When the starting valve is opened, air will be supplied to the drive shaft housing of the air starter.

In the same sequence a signal is given to a solenoid valve which provide the governor booster and the index limiter with air.

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.

Simultaneously with air supply for the air starter, air will be supplied to the fuel limitating cylinder, thus limiting the fuel supply during the start sequence.

When the rpm exceeds approximately 110, at which firing has taken place, the starting valve is closed whereby the air starter is disengaged.

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Compressed air system

Diagram

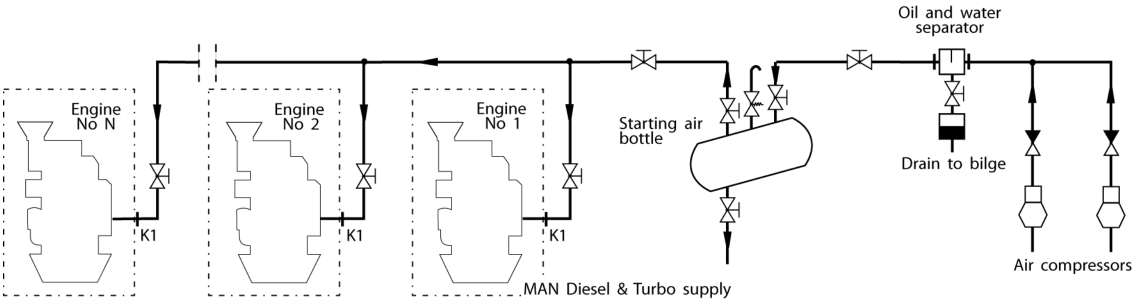

Figure 1: Diagram for compressed air system

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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Combustion air system

General

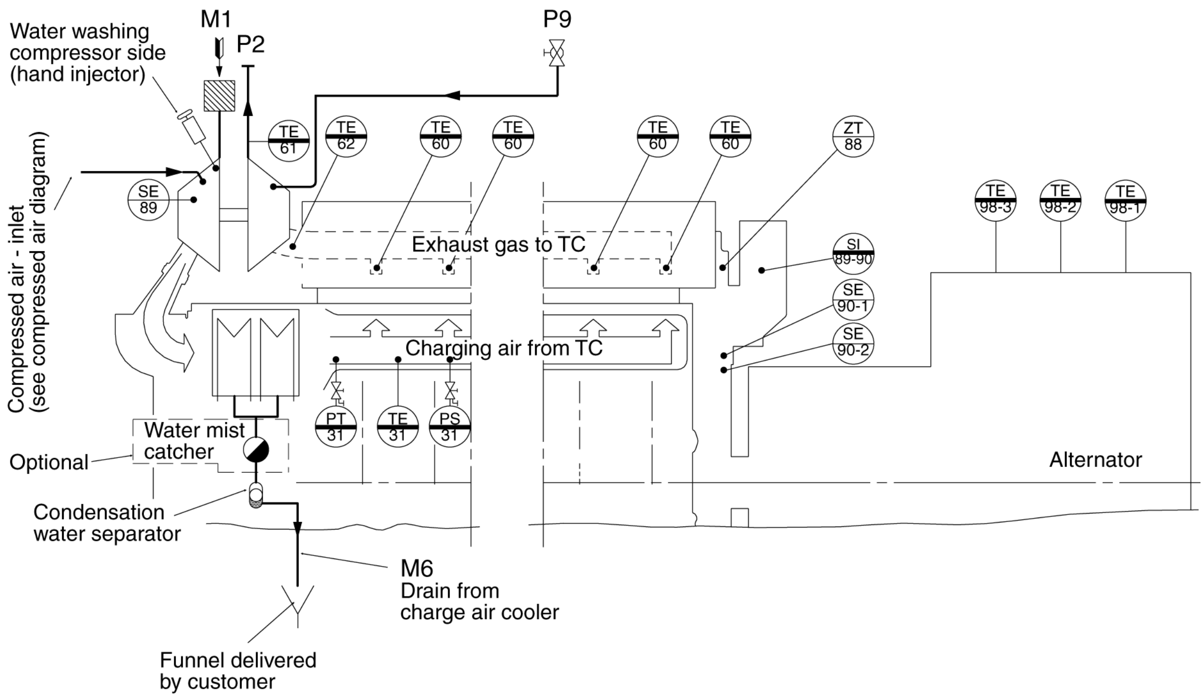

Figure 1: Diagram for combustion air system.

Pipe description		
M1	Charge air inlet	
P2	Exhaust gas outlet: 5 cyl. (1000/1200 rpm) 6 cyl. (1000/1200 rpm) 7 cyl. (1000 rpm)	 DN 300
	7 cyl. (1200 rpm) 8 cyl. (1000/1200 rpm) 9 cyl. (1000/1200 rpm)	DN 400
P6	Drain from turbocharger - outlet	
P9	Working air, dry cleaning turbine side with quick coupling - inlet	

Table 1: P2 flange connections are standard according to DIN 86 044. Other flange connections are standard according to DIN 2501.

The air intake to the turbochargers takes place directly from the engine room through the intake silencer on the turbocharger.

From the turbocharger the air is led via the charge air cooler and charge air receiver to the inlet valves of each cylinder.

The charge air cooler is a compact two-stage tubetype cooler with a large cooling surface.

The charge air cooler is mounted in the engine's front end box.

It is recommended to blow ventilation air in the level of the top of the engine(s) close to the air inlet of the turbocharger, but not so close that sea water or vapour may be drawn-in. It is further recommended that there always is a positive air pressure in the engine room.

Turbocharger

The engine is as standard equipped with a high-efficient MAN Diesel & Turbo TCR turbocharger of the radial type, which is located on the top of the front end box.

Cleaning of Turbocharger

The turbocharger is fitted with an arrangement for dry cleaning of the turbine side, and water washing of the compressor side.

Lambda controller

The purpose of the lambda controller is to prevent injection of more fuel in the combustion chamber than can be burned during a momentary load in-crease. This is carried out by controlling the relation between the fuel index and the charge air pressure. The lambda controller has the following advantages:

- Reduction of visible smoke in case of sudden momentary load increases.
- Improved load ability.
- Less fouling of the engine's exhaust gas ways.
- Limitation of fuel oil index during starting procedure.
- Emergency stop of engine.

The above states that the working conditions are improved under difficult circumstances and that the maintenance costs for an engine, working with many and major load changes, will be reduced.

Data

For charge air heat dissipation and exhaust gas data, *see D 10 05 0 "List of Capacities".*

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

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/cleaning 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 enclosed by a filter mat as a standard. The quality class (filter class) of the filter mat corresponds to the G3 quality in accordance with EN 779.

Requirements

Liquid fuel engines: As minimum, inlet air (combustion air) must be cleaned by a G3 class filter as per EN779, 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 M5 according to EN 779.

Gas engines and dual-fuel engines: As minimum, inlet air (combustion air) must be cleaned by a G3 class filter as per EN779, 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 M5 according to EN 779.

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]
Particle size < 5 µm: minimum 90% of the particle number		
Particle size < 10 µm: minimum 98% of the particle number		

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Properties	**Limit**	**Unit** [1]
Dust (sand, cement, CaO, Al_2O_3 etc.)	max. 5	mg/Nm³
Chlorine	max. 1.5	
Sulphur dioxide (SO_2)	max. 1.25	
Hydrogen sulphide (H_2S)	max. 5	
Salt (NaCl)	max. 1	
[1] One Nm³ 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 caused by flammable intake air

Explosion caused by flammable intake air can result in severe injuries and damage.

- Intake air must not contain any flammable gases.
- Intake air is not explosive.
- Intake air is not drawn in from the ATEX Zone.

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.

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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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.

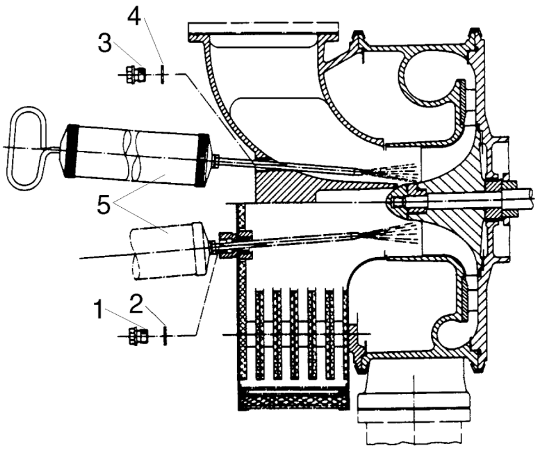
The water is injected in a measured amount and within a measured period of time by means of the water washing equipment.

Sequence of operation

1. Run the engine with as high a load as possible (80 - 100%).
2. Unscrew the screw plug (1) together with seal ring (2) from silencer, or unscrew the screw plug (3) together with seal ring (4) from the air-intake casing.
3. Fill the syringe (5) with clean, fresh water, and insert it through the screw-plug opening.
4. Inject the complete content of the syringe within a period of 4 - 10 seconds.
5. Run the engine for another 10 minutes at the same load.
6. Make comparative measurements of the operating data (engine power and charge-air pressure). These measurements will indicate the success or not of the washing procedure. If necessary, carry out the washing again.
7. Screw in the screw plug (1) together with the seal ring (2) at the silencer, or screw the screw plug (3) together with the seal ring (4) into the air-intake casing.

The washing procedure is executed with the engine running at normal operating temperature and with the engine load as high as possible, i.e. at a high compressor speed.

The frequency of water washing should be matched to the degree of fouling in each individual plant.



1 Screw plug
2 Seal ring
3 Screw plug
4 Seal ring
5 Syringe

Figure 1: Water washing equipment.

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Exhaust gas system

Internal exhaust gas system

From the exhaust valves, the gas is led to the exhaust gas receiver where the fluctuating pressure from the individual cylinders is equalized and the total volume of gas led further on to the turbocharger, at a constant pressure. After the turbocharger, the gas is led to the exhaust pipe system.

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

After each cylinder a thermosensor for reading the exhaust gas temperature is fitted.

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

External exhaust gas system

The exhaust back-pressure should be kept as low as possible.

It is therefore of the utmost importance that the exhaust piping is made as short as possible and with few and soft bends.

Long, curved, and narrow exhaust pipes result in higher back-pressure which will affect the engine combustion. Exhaust back-pressure is a loss of energy and will cause higher fuel comsumption.

The exhaust back-pressure should not exceed 30 mbar at MCR. An exhaust gas velocity through the pipe of maximum 35 m/sec is often suitable, but depends on the actual piping.

During commissioning and maintenance work, checking of the exhaust gas back pressure by means of a temporarily connected measuring device may become necessary. For this purpose, a measuring socket must be provided approx. 1-2 m after the exhaust gas outlet of the turbocharger at an easily accessible place. Usual pressure measuring devices require a measuring socket size of ½". This measuring socket must be provided to ensure utilisation without any damage to the exhaust gas pipe insulation.

MAN Diesel & Turbo 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.

Exhaust pipe mounting

When the exhaust piping is mounted, the radiation of noise and heat must be taken into consideration.

Because of thermal fluctuations in the exhaust pipe, it is necessary to use flexible as well as rigid suspension points.

In order to compensate for thermal expansion in the longitudinal direction, expansion bellows must be inserted. The expansion bellows should preferably be placed at the rigid suspension points.

Note: The exhaust pipe must not exert any force against the gas outlet on the engine.

One sturdy fixed-point support must be provided for the expansion bellows on the turbocharger. It should be positioned, if possible, immediately above the expansion bellows in order to prevent the transmission of forces, resulting from the weight, thermal expansion or lateral displacement of the exhaust piping, to the turbocharger.

The exhaust piping should be mounted with a slope towards the gas outlet on the engine. It is recommended to have drain facilities in order to be able to remove condensate or rainwater.

Position of gas outlet on turbocharger

B 16 02 0 shows turning alternatives positions of the exhaust gas outlet. Before dispatch of the engine exhaust gas outlet will be turned to the wanted position.

The turbocharger is, as standard, mounted in the front end.

Exhaust gas boiler

To utilize the thermal energy from the exhaust, an exhaust gas boiler producing steam or hot water can be installed.

Each engine should have a separate exhaust gas boiler or, alternatively, a common boiler with separate gas ducts. Concerning exhaust gas quantities and temperature, *see "List of capacities" D 10 05 0,* and *"Engine performance" D 10 10 0.*

The discharge temperature from the exhaust gas boiler should not be lower than 180°C (in order to avoid sulphuric acid formation in the funnel).

The exhaust gas boilers should be installed with by-pass entering in function at low-load operation.

The back-pressure over the boiler must be included in the back-pressure calculation.

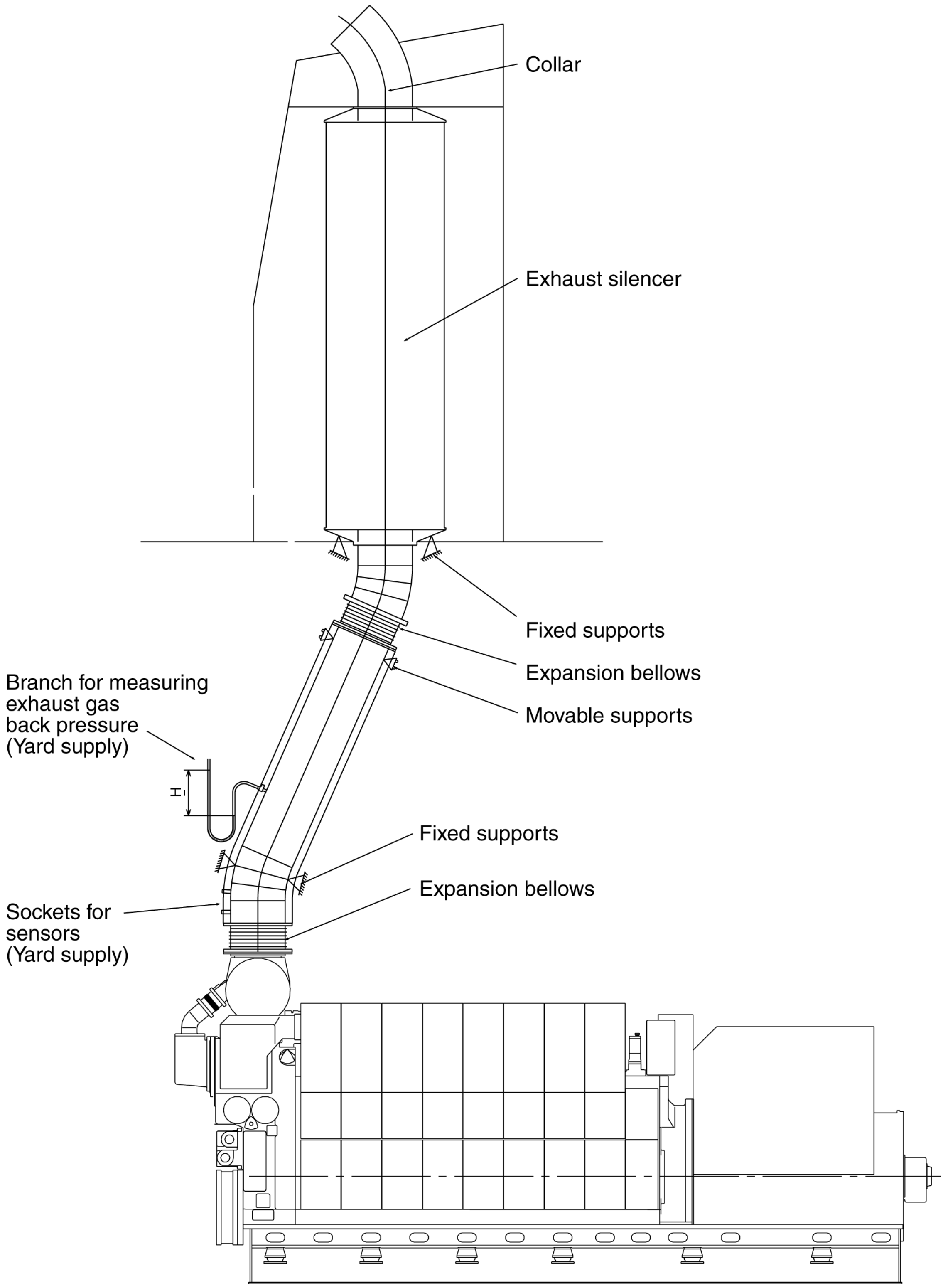
Expansion bellows

The expansion bellows, which is supplied separately, must be mounted directly on the exhaust gas outlet, *see also E 16 01 1-2.*

Exhaust silencer

The position of the silencer in the exhaust gas piping is not decisive for the silencing effect. It would be useful, however, to fit the silencer as high as possible to reduce fouling. The necessary silencing depends on the loudness of the exhaust sound and the discharge from the gas outlet to the bridge wing.

The exhaust silencer, *see E 16 04 2-3-5-6,* is supplied loose with counter-flange, gaskets and bolts.


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 droop in exhaust gas system

General

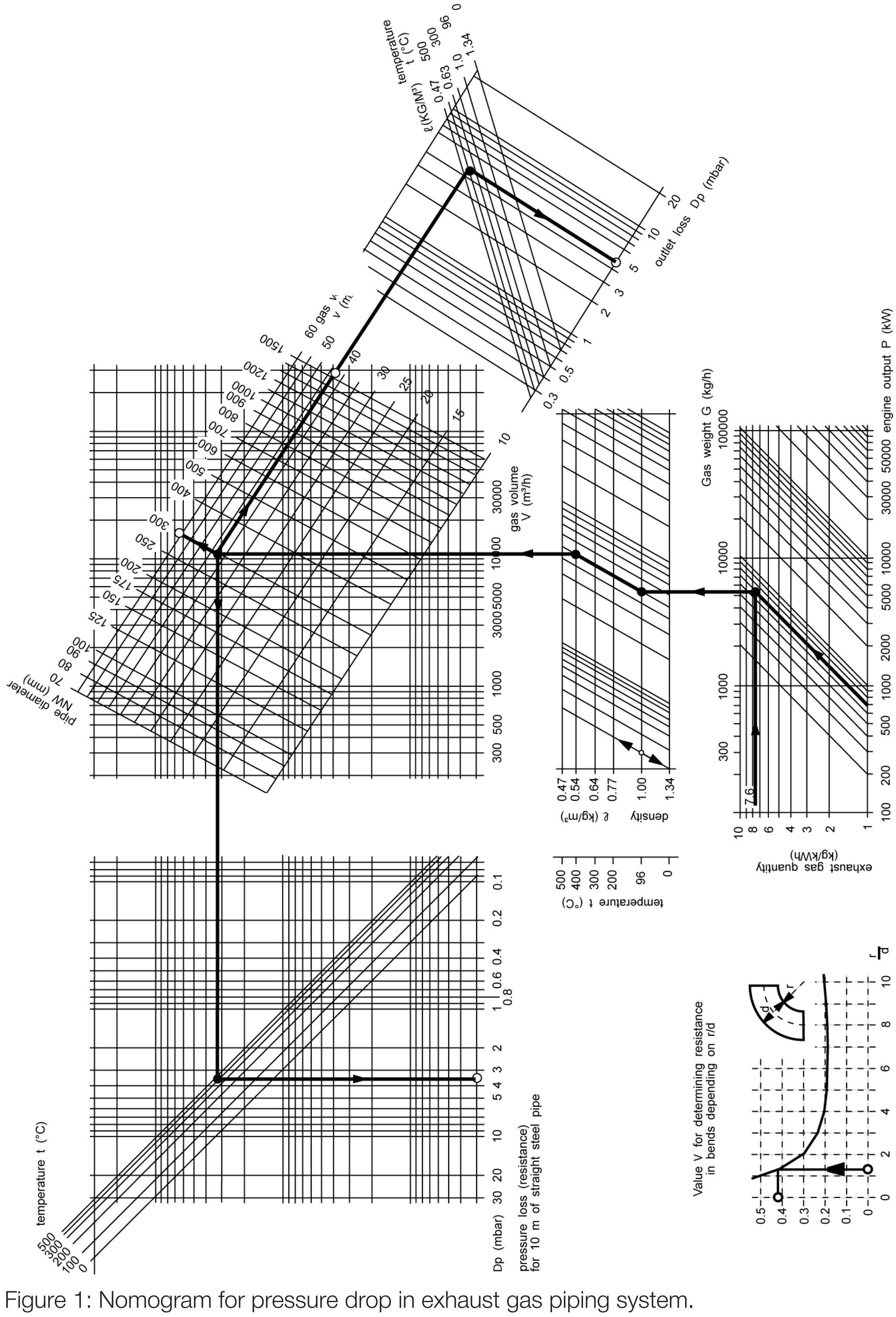

Figure 1: Nomogram for pressure drop in exhaust gas piping system.

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Example

Where:	Engine rating	735 kW
	Exhaust gas quantity	7.6 kg/kWh
	Exhaust gas temperature **t** (under full-load conditions)	400°C
	Ambient air conditions	20°C, 980 mbar
	Density of air ρ_L	1.165 kg/m³
	Exhaust pipe system (pipes laid out without changes in section)	
	Straight runs of pipe horizontal	12 m (L_H)
	vertical	8 m (L_V)
	Three 90° pipe bends (with r/d = 1.3)	
	1 absorbtion silencer (35 dBA damping)	
Required:	Total pressure loss across exhaust gas system (static and dynamic)	
	= flow resistance in pipes and silencer + outlet losses - up-draught	
From the diagram:	Density of exhaust gasses ρ_A	0.54 kg/m³
	Exhaust gas volume	10200 m³/h
	With a pipe diameter of 300 mm this gives:	
	Exhaust gas velocity	42 m/sec
	Resistance per 10 m of straight run of pipe (at 400°C)	3.6 mbar
	Outlet loss (at 400°C)	4.7 mbar ($\rho_A \times \frac{V^2}{2} \times 10^{-2}$)
	ζ value for pipe bend (at r/d = 1.3)	0.41
	Resistance of a 90° pipe bend (0.41 x 4.7)	1.9 mbar ($\zeta \times \rho_A \times \frac{V^2}{2} \times 10^{-2}$)
	Up-draught in vertical pipe	8 (1.165 - 0.54) x 9.81 = 50 Pa = 0.5 bar
Result:	The total pressure loss in the system is	
	Straight runs of pipe (12 + 8 = 20 m) = 2 x 3.6	7.2 mbar
	3 pipe bends of 1.9 mbar each	5.7 mbar
	Silencer (35 dB(A) without spark arrestor) (see product manual page E 16 04 3)	1.7 mbar
	Outlet loss	4.7 mbar
		19.3 mbar
	Lift	- 0.5 mbar
		18.8 mbar

The exhaust system is correctly designed since the permissible total resistance of 30 mbar is not exceeded.

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:

$$\rho = \frac{348.3}{20 + 273} = 1.165\ kg/m^3$$

At 1.0132 bar:

t	-20	0	20	40	60
ρ	1.4	1.29	1.21	1.13	1.06

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Equipment to optimize performance

Overview

MAN Energy Solutions four-stroke Diesel engines and turbochargers are designed in accordance with specifications so that optimum results, e.g. fuel consumption and emissions performance, are obtained through the services normally provided. However, it is possible that specific operating situations could be managed more effectively using additional or alternative equipment.

Equipment used to adapt the engine to specific operating conditions or to optimise its performance is listed in Table 1. The ideal areas of application are also stated in this table. The purpose of table is to provide you with an overview of the options available and the circumstances in which they should be used.

Equipment/Measure	Propulsion	GenSet
Blow off charge air	X	X
Bypass charge air	X	
Charge air preheating – via HT/LT switch-over (2-stage charge air cooler)	X	X
Control the charge air temperature (CHATCO)	X	X
Blow off exhaust gas (Waste Gate)	X	X
Accelerate turbocharger (Jet Assist)	X	X

Table 1: Equipment for optimising the operating behaviour

X = Availability

Brief description

Device for blowing off charge air

- Blow-off charge air pressure used for:
- Reduction of charge air pressure/max. pressure at cold ambient conditions.
- Prevent surging at cold ambient conditions.
- Control of max. pressure at Part Load Optimised operation.
- Control of exhaust gas temperature for SCR operation.

When operating engines under full load at a low intake temperature (≤ 5°C) there is a danger, due to the high air density, that the charge pressure, and therefore the ignition pressure, increases excessively. In order to avoid such conditions, excess charge air in front of or after the charge air cooler is removed and released. In the first case, the charge air is blown off into the engine room and in the second case, when charge air released from the charge air cooler is hot, the charge air is blown off into atmosphere to prevent danger to persons and equipment. Alternatively, this hot charge air may be also used for inlet air preheating. This blowing off is achieved by means of an electro-pneumatic or spring-loaded valve.

Device for bypassing charge air

- Charge Air By-pass used for:
- For Fixed Pitch Propeller operation on part load.
- Increaseds charge air pressure and airflow.
- Decreases exhaust gas temperatures.
- Decreases smoke emission.

The charge air pipe is connected via a pipe with a smaller diameter and a by-pass flap to the exhaust pipe. The flap is closed in normal operation. In the case of propeller operation (diesel-mechanical) at engine loads between 20% and 60% and at rated or reduced speed, the flap is opened to direct a part of the charge air into the exhaust pipe upstream of the turbine. The increased air flow of the turbine results in a higher charge air pressure of the compressor and consequently in improved operating behaviour of the engine. Additionally this flap may be used to prevent turbocharger pumping.

The throttle flap is controlled by a pneumatic actuator cylinder depending on the engine speed and the filling setting of the fuel delivery pumps.

Charge air preheating – via LT - cut-out (2-stage charge air cooler)

- Charge Air Preheating:
- For HFO low load operation (improves ignition delay).
- Increases charge air temperatur (compression temperature).
- Decreases smoke emission.

Charge air preheating – via LT (low temperature) cut-out is used in the partial load range from 0 % to 40 % of engine load, to achieve the higher charge air temperature. Thereby an improved combustion is ensured and thus - conditionally reduced exhaust smoke. In contrast to the charge air preheating via CHATCO control valve, there is no time delay in this case.

Control of the charge air temperature (CHATCO)

- CHATCO
- To prevent water condensation in charge air.
- Controlled charging air temperature by LT cooling water by-pass valve.
- Increases charge air temperature above the dew point.

The charge air temperature control CHATCO reduces the amount of condensed water that accumulates during engine operation under tropical conditions. In this case, the charge air temperature is controlled depending on the relative humidity measured directly in the charge air receiver, so that the temperature in the charge air pipe does not drop below the condensation temperature. The CHATCO functionality includes integrated charge air preheating on low load by passing the low temperature air cooler stage (LT).

Device for accelerating the turbocharger (jet assist)

This equipment is used where special demands exist for rapid acceleration and/or load application. In such cases, the compressed air from the starting air cylinders is reduced to 4 bars (relative), directed to the compressor casing of the turbocharger and blown to the compressor wheel. In this way, additional air is supplied to the compressor which, in turn, is accelerated, thus increasing the charge air pressure. Operation of the accelerating system is activated by the control system, during start-up and load steps.

Releasing the exhaust gas (Waste gate)

- Exhaust gas waste gate used for:
- Control of max. pressure at Part Load Optimised operation.
- Control of exhaust gas temperature for SCR operation.

By blowing-off exhaust gas before the turbine, and its return to the exhaust pipe behind the turbine, exhaust gas pressure reduction at the turbocharger takes place, or there is a turbine speed reduction at full load. This measure is necessary when the turbocharger is designed for an optimised partial-load operation.

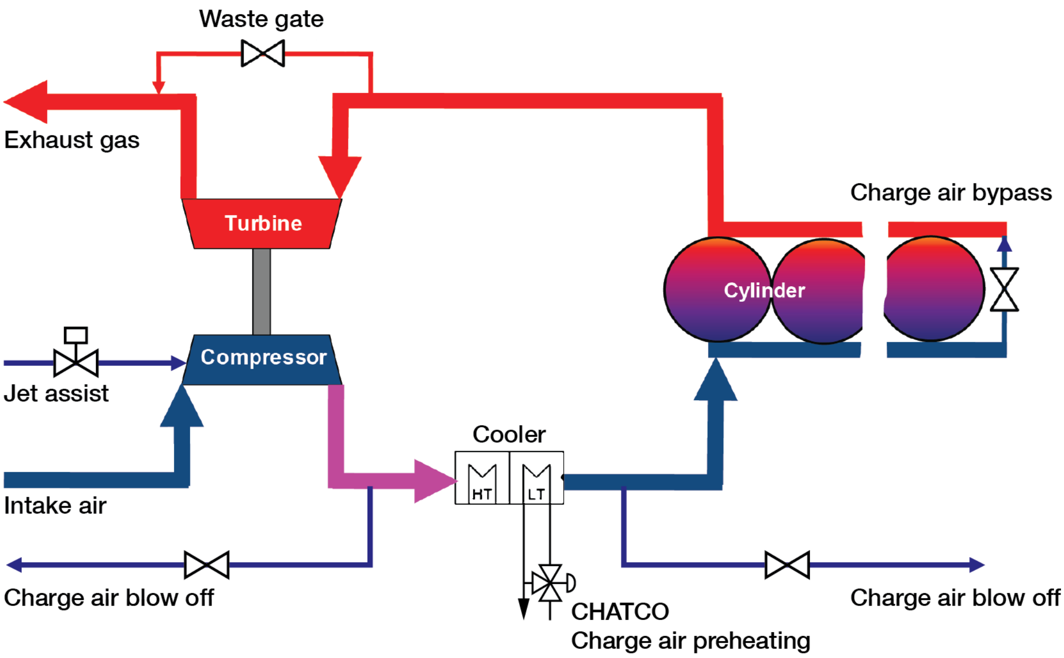

Figure 1: Overview of flaps

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Exhaust gas velocity

Velocities

Engine type	Exhaust gas flow	Exhaust gas temp.	DN Nominal diameter	Exhaust gas velocity
	kg/h	°C	mm	m/sec.
5L23/30H, 720/750 rpm	5100	342	350	27.7
6L23/30H, 720/750 rpm	6100	342	350	33.3
6L23/30H, 900 rpm	7600	371	400	32.7
7L23/30H, 720/750 rpm	7200	342	400	29.6
7L23/30H, 900 rpm	8800	371	450	30.2
8L23/30H, 720/750 rpm	8200	342	400	33.9
8L23/30H, 900 rpm	10100	371	450	34.5
5L23/30DF, 720/750 rpm	5100	342	350	27.7
6L23/30DF, 720/750 rpm	6100	342	350	33.3
6L23/30DF, 900 rpm	7600	371	400	32.7
7L23/30DF, 720/750 rpm	7200	342	400	29.6
7L23/30DF, 900 rpm	8800	371	450	30.2
8L23/30DF, 720/750 rpm	8200	342	400	33.9
8L23/30DF, 900 rpm	10100	371	450	34.5
5L23/30H Mk2, 720 rpm	5400	342	350	29.2
6L23/30H Mk2, 720 rpm	6500	342	400	26.7
7L23/30H Mk2, 720 rpm	7500	342	400	31.2
8L23/30H Mk2, 720 rpm	8600	342	450	28.2
5L23/30H Mk2, 750 rpm	5600	342	350	30.4
6L23/30H Mk2, 750 rpm	6700	342	400	27.9
7L23/30H Mk2, 750 rpm	7900	342	400	32.5
8L23/30H Mk2, 750 rpm	9000	342	450	29.4

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Engine type	Exhaust gas flow	Exhaust gas temp.	DN Nominal diameter	Exhaust gas velocity
	kg/h	°C	mm	m/sec.
6L23/30H Mk2, 900 rpm	8300	371	450	28.3
7L23/30H Mk2, 900 rpm	9600	371	450	33.0
8L23/30H Mk2, 900 rpm	11000	371	500	30.5

Density of exhaust gasses $\rho_A \sim 0.6$ kg/m^3

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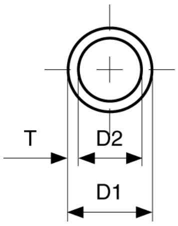
Engine type	Exhaust gas flow	Exhaust gas temp.	DN Nominal diameter	Exhaust gas velocity
	kg/h	°C	mm	m/sec.
5L28/32H, 720/750 rpm	8800	342	450	28.8
6L28/32H, 720/750 rpm	10500	342	450	34.5
7L28/32H, 720/750 rpm	12300	342	500	32.6
8L28/32H, 720/750 rpm	14100	342	550	30.9
9L 28/32H, 720/750 rpm	15800	342	550	34.6
5L28/32DF, 720/750 rpm	8800	342	450	28.8
6L28/32DF, 720/750 rpm	10500	342	450	34.5
7L28/32DF, 720/750 rpm	12300	342	500	32.6
8L28/32DF, 720/750 rpm	14100	342	550	30.9
9L 28/32DF, 720/750 rpm	15800	342	550	34.6
5L16/24, 1000 rpm (90 kW)	3100	375	300	21.1
6L 16/24, 1000 rpm (95 kW)	3900	375	300	26.9
7L16/24, 1000 rpm (95 kW)	4500	375	300	31.1
8L16/24, 1000 rpm (95 kW)	5200	375	400	22.6
9L16/24, 1000 rpm (95 kW)	5800	375	400	25.4
5L16/24, 1200 rpm (100 kW)	3600	356	300	23.8
6L16/24, 1200 rpm (110 kW)	4700	356	300	31.4
7L16/24, 1200 rpm (110 kW)	5500	356	400	23.2
8L16/24, 1200 rpm (110 kW)	6300	356	400	26.6
9L16/24, 1200 rpm (110 kW)	7100	356	400	29.9
5L27/38, 720 rpm (300 kW)	10300	376	500	28.8
6L27/38, 720 rpm (330 kW)	13600	376	550	31.4
7L27/38, 720 rpm (330 kW)	15900	376	600	30.6
8L27/38, 720 rpm (330 kW)	18100	376	600	35.0
9L27/38, 720 rpm (330 kW)	20400	376	650	31.8

Density of exhaust gasses ρ_A ~ 0.6 kg/m^3

Engine type	Exhaust gas flow	Exhaust gas temp.	DN Nominal diameter	Exhaust gas velocity
	kg/h	°C	mm	m/sec.
5L27/38, 750 rpm (320 kW)	11200	365	500	30.8
6L27/38, 750 rpm (330 kW)	13900	365	550	31.6
7L27/38, 750 rpm (330 kW)	16200	365	600	30.7
8L27/38, 750 rpm (330 kW)	18500	365	600	35.1
9L27/38, 750 rpm (330 kW)	20800	365	650	31.9
6L27/38, 720 rpm (350kW)	14400	388	550	33.9
7L27/38, 720 rpm (350 kW)	16800	388	600	33.0
8L27/38, 720 rpm (350 kW)	19200	388	650	30.5
9L27/38, 720 rpm (350 kW)	21600	388	650	34.3
6L27/38, 750 rpm (350kW)	14700	382	550	34.3
7L27/38, 750 rpm (350 kW)	17100	382	600	33.2
8L27/38, 750 rpm (350 kW)	19500	382	650	30.7
9L27/38, 750 rpm (350 kW)	22000	382	650	34.6
5L21/31, 900 rpm (200 kW)	7400	334	400	30.2
6L21/31, 900 rpm (220 kW)	9800	334	450	31.7
7L21/31, 900 rpm (220 kW)	11400	334	500	29.8
8L21/31, 900 rpm (220 kW)	13000	334	500	34.0
9L21/31, 900 rpm (220 kW)	14600	334	550	31.6
5L21/31, 1000 rpm (200 kW)	7400	349	400	30.8
6L21/31, 1000 rpm (220 kW)	9700	349	450	32.1
7L21/31, 1000 rpm (220 kW)	11400	349	500	30.5
8L21/31, 1000 rpm (220 kW)	13000	349	500	34.8
9L21/31, 1000 rpm (220 kW)	14600	349	550	32.4

Density of exhaust gasses ρ_A ~ 0.6 kg/m^3

The exhaust gas velocities are based on the pipe dimensions in the table below



DN Nominal diameter	D1 mm	D2 mm	T mm	Flow area A 10^{-3} m^2
300	323.9	309.7	7.1	75.331
350	355.6	339.6	8.0	90.579
400	406.4	388.8	8.8	118.725
450	457.0	437.0	10.0	149.987
500	508.0	486.0	11.0	185.508
550	559.0	534.0	12.5	223.961
600	610.0	585.0	12.5	268.783
650	660.0	650.0	5.0	331.830

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 a gents.

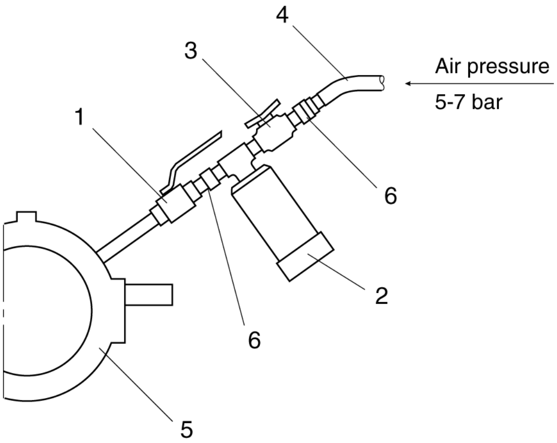
The solid bodies have a mechanical cleaning effect which removes any deposits on nozzle vanes and turbine blades.

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 Diesel & Turbo
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 necessary water flow is depending on exhaust gas flow and temperature. E.g. the flow needed for L16/24 is from 2 - 5 litres per minute for 5 and 9 cylinder engines. 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 washing sequence should be in accordance with the turbocharger manual. Engine load, exhaust gas temperature before turbine and turbine speed must be according to turbocharger manual. 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. For preadjustment of the washing tool, install the correct orifice for the actual engine size, check that the water flow is in accordance with the table by adjusting the water pressure. Check in a bucket that the water flow is in the correct range.

	Water flow l/min	**Diameter orifice mm**
5-9L16/24+5-9L16/24S	2-5	2.5
5-9L21/31+5-9L21/31S	5-10	3.5
5L27/38 (NR20/S) +5L27/38S (NR20/S) 5-6L27/38 (TCR18) +5-6L27/38S (TCR18)	7-11	3.5
6-8L27/38 (NR24/S) +6-8L27/38S (NR24/S) 7-9L27/38 (TCR20) +7-9L27/38S (TCR20)	10-15	4.5
5-6L23/30H+5-6L23/30S 5-6L23/30H Mk2	2-5	2.5
7-8L23/30H+7-8L23/30S 7-8L23/30H Mk2	4-7	3.5
5-6L28/32S+5-6L28/32H	5-10	3.5
7-9L28/32S+7-9L28/32H	7-11	3.5
12V28/32S	5-10	3.5
16-18V28/32S	7-11	3.5

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

Some customized engines are delivered with water washing arrangement consisting of a pipe system with a regulating valve, a manoeuvring valve, a 3-way cock and a drain pipe with a drain valve from the gas outlet, see illustration on work card 512-15.00/612-15.00.

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: .

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.

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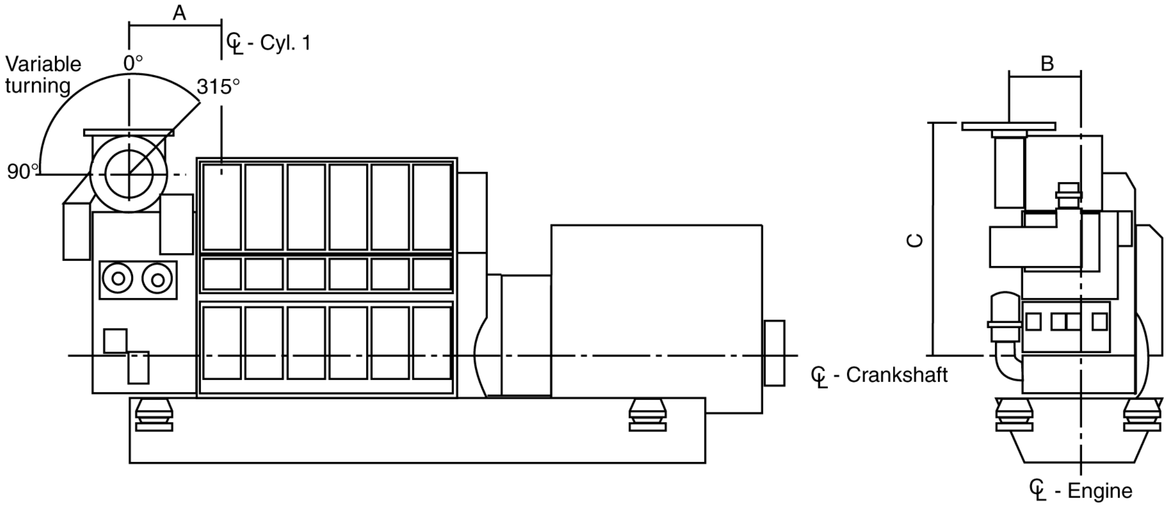
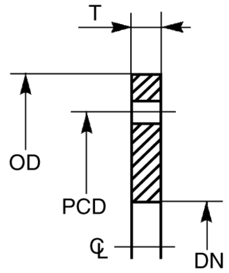
Position of gas outlet on turbocharger

5-9 cyl. (1000/1200 rpm)



Exhaust flange D. mating dimensions									
Engine type	**A (mm)**	**B (mm)**	**C (mm)**	**DN (mm)**	**OD (mm)**	**T (mm)**	**PCD (mm)**	**Hole size (mm)**	**No of holes**
5L16/24, 1000 rpm	618	545	1504	300	440	23	395	M20	12
5L16/24, 1200 rpm	618	545	1504	300	440	23	395	M20	12
6L16/24, 1000 rpm	618	545	1504	300	440	23	395	M20	12
6L16/24, 1200 rpm	618	545	1504	300	440	23	395	M20	12
7L16/24, 1000 rpm	618	545	1504	300	440	23	395	M20	12
7L16/24, 1200 rpm	618	682	1582	400	540	23	495	M20	16
8 L16/24, 1000 rpm	618	682	1582	400	540	23	495	M20	16
8L16/24, 1200 rpm	618	682	1582	400	540	23	495	M20	16
9L16/24, 1000 rpm	618	682	1582	400	540	23	495	M20	16
9L16/24, 1200 rpm	618	682	1582	400	540	23	495	M20	16

Flange



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Position of gas outlet on turbocharger

Description

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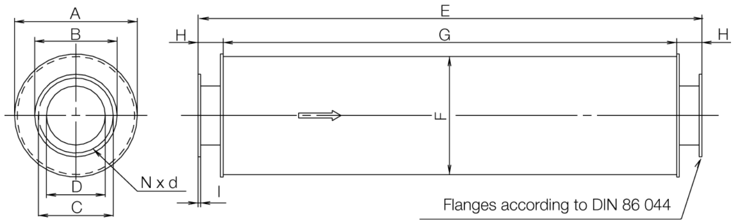
Silencer without spark arrestor, damping 35 dB (A)

Design

The operating of the silencer is based on the absorption system. The gasflow passes straight through a perforated tube, surrounded by highly effecient sound absorbing material, thus giving an excellent attenuation over a wide frequency range.

The silencer is delivered without insulation and fastening fittings.



Silencer type (A)

Damping dB (A)	Cyl. no (rpm)	DN	A	B	C	D	E	F	G	H	I	Nxd	Weight kg
35	5 (1000/1200) 6 (1000/1200) 7 (1000)	300	740	440	395	327	3300	700	3000	150	16	12 x ø22	400
35	7 (1200) 8 (1000/1200) 9 (1000/1200)	400	990	540	495	410	4000	950	3700	150	16	16x ø 22	700

Silencer type (B)

Damping dB (A)	Cyl. no (rpm)	DN	A	B	C	D	E	F	G	H	I	Nxd	Weight kg
35	5 (1000/1200) 6 (1000/1200) 7 (1000)	300	780	440	395	327	3200	750	3000	100	16	12 x ø22	421
35	7 (1200) 8 (1000/1200) 9 (1000/1200)	400	980	540	495	410	4000	950	3700	150	16	16x ø 22	730

Dimension for flanges for exhaust pipes is according to DIN 86 044

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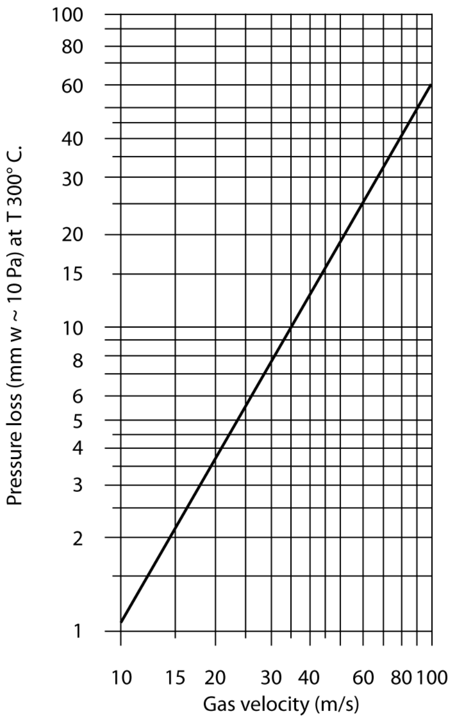
Installation

The silencer may be installed, vertically, horizontally or in any position close to the end of the piping.

Pressure loss

The pressure loss will not be more than in a straight tube having the same length and bore as the silencer. Graphic shows pressure loss in relation to velocity.



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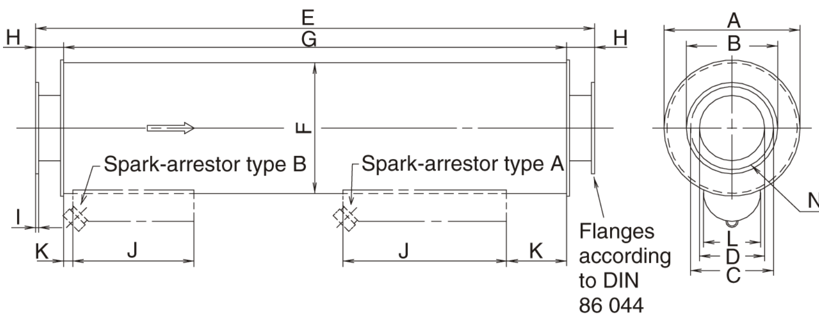
Silencer with spark arrestor, damping 35 dB (A)

Design



Silencer type (A)

Damping dB (A)	Cyl. no (rpm)	DN	A	B	C	D	E	F	G	H	I	J	K	L	Nxd	Weight kg
35	5 (1000/1200) 6 (1000/1200) 7 (1000)	300	740	440	395	327	3600	700	3300	150	16	450	80	220	12xø22	400
35	7 (1200) 8 (1000/1200) 9 (1000/1200)	400	990	540	495	410	4400	950	4100	150	16	750	100	290	16xø22	800

Silencer type (B)

Damping dB (A)	Cyl. no (rpm)	DN	A	B	C	D	E	F	G	H	I	J	K	L	Nxd	Weight kg
35	5 (1000/1200) 6 (1000/1200) 7 (1000)	300	780	440	395	327	3500	750	3300	100	16	550	50	250	12xø22	460
35	7 (1200) 8 (1000/1200) 9 (1000/1200)	400	980	540	495	410	4400	950	4100	150	16	700	100	300	16xø22	885

Dimension for flanges for exhaust pipes is according to DIN 86 044

The operating of the silencer is based on the absorption system. The gasflow passes straight through a perforated tube, surrounded by highly effecient sound absorbing material, thus giving an excellent attenuation over a wide frequency range.

The operation of the spark arrestor is based on the centrifugal system. The gases are forced into a rotary movement by means of a number of fixed blades. The solid particles in the gases are thrown against the wall of the spark arrestor and collected in the soot box. (Pressure loss, *see graphic.)*

The silencer is delivered without insulation and fastening fittings.

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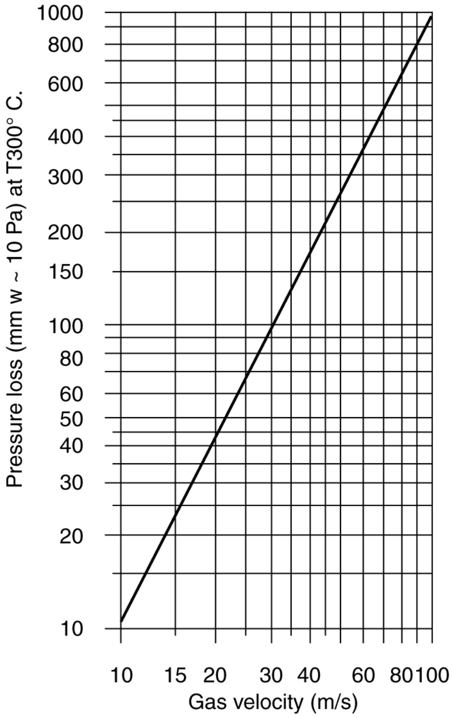
Installation

The silencer/spark arrestor has to be installed as close to the end of the exhaust pipe as possible.



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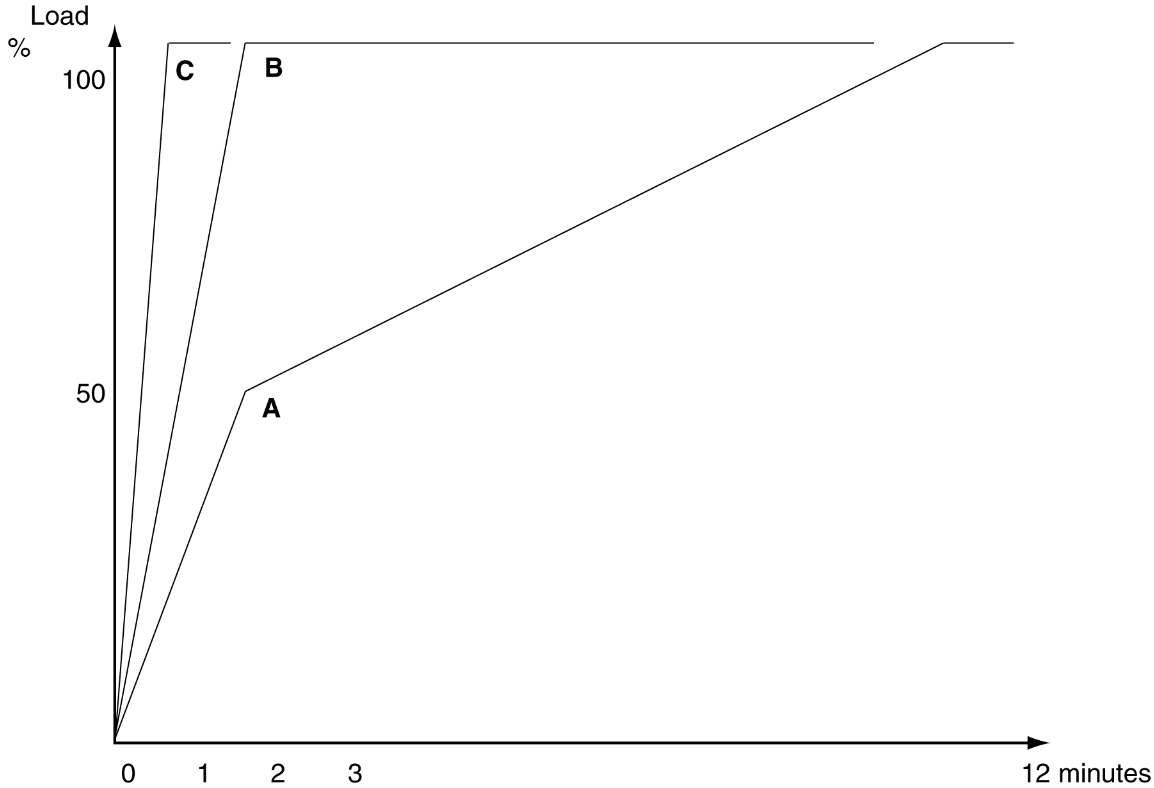
Starting of engine

General



The engine can be loaded according to the following procedure:

A) Normal start without preheated cooling water. Only on MDO. Continuous lubricating.

B) Normal start with preheated cooling water. On MDO or HFO. Continuous lubricating.

C) Stand-by engine. Emergency start, with pre-heated cooling water, continuous prelubricating. On MDO or HFO.

Above curves indicates the absolute shortes time and we advise that loading to 100% takes some more minutes.

Starting on HFO

During shorter stops or if the engine is in a standby position on HFO, the engine must be preheated and HFO viscosity must be in the range 12-18 cSt.

If the engine normally runs on HFO, preheated fuel must be circulated through the engine while preheating, although the engine has run or has been flushed on MDO for a short period.

Starting on MDO

For starting on MDO there are no restrictions except for the lub. oil viscosity which may not be higher than 1500 cSt (10°C SAE 40).

Initial ignition may be difficult if the engine and the ambient temperature are lower than 5°C and the cooling water temperature is lower than 15°C.

Prelubricating

Continuous prelubricating is standard. Intermittent prelubricating is not allowed for stand-by engines.

If the prelubrication has been switch-off for more than 20 minutes the start valve will be blocked.

Power Management - Alternator protection

Description

The Power Management System and the Alternator Protection System will not be delivered within the scope of MAN Diesel & Turbo.

But in order to advise and give our customers the best possible background to make some investigations regarding their Power Management System / Alternator Protection System MAN Diesel & Turbo will in the following give some guidelines and recommendations.

It is only our recommendation and it is the customer's responsibility to specify source and to set the different protection values together with the PMS system maker.

The customer must be aware that local regulations and requirements from authorities must also be taken into considerations during thespecification and design phase of these systems.

Overcurrent protection Node

ANSI – Code: 50+51

Application: Two stage. Overcurrent/ time and short Circuit/time. It shall be an independent time overcurrent relay, with inverse overcurrent time adjustments, with selectable characteristics, and determination of fault direction.

Function: Protecting generator, mains decoupling, Radial feeder, Overhead lines and cables by tripping the generator circuit breaker.

Thermal overload

ANSI-Code:49

Protection of thermal damage caused by overload . The thermal capacity used is calculated according to a model, which takes into account:

Current RMS values, ambient temperature, negative sequence current.

AC voltage protection

ANSI-Code: 27+59

Application : Voltage supervision of 1-phase og 3 –phase systems, two stage over- and under voltage protection of the alternator against abnormally low net voltage, which trigger load transfer in to the machine.

It is protecting of the generator against abnormally high net voltage, works with phase to phase and phase to neutral voltage, each voltage is monitored separately. Min volt. 95%, max volt 105%, volt to ground 5% 200msec.

Function: Protecting generator, mains decoupling, Radial feeder, Overhead lines, and cables by tripping the alternator circuit breaker.

Earth fault current protection

ANSI-Code: 50+51N

Application: Independent time over current relay, inverse overcurrent with selectable characteristic. The directional earth fault determination is based on the active and the reactive current flow and the zero sequence system.

Insulated or compensated as solid state earthed/ resistance-earth, neutral point systems, is the criterion for earth fault detection depending on the neutral point connection method.

Function : Protecting generator, by tripping the alternator circuit breaker.

Mains decoupling (vector surge)

ANSI-code: 78

Application: The mains decoupling relay is protecting parallel running generators against short time voltage interruptions. Whit this it is possible to get a protection against damaging asynchronous synchronisation. An interruption of 300 msec is damaging.

Function : Protecting generator, by tripping the alternator circuit breaker.

Frequency protection

ANSI-code: 81

Application: Frequency protection is protecting the alternator and consumers against over and under frequency continuous and fluctuating.

Function: Protecting generator, by tripping the alternator circuit breaker.

Directional power protection

ANSI-code: 32

Application: To control the power flow, between to two more power producing plants. The plants are not allowed to fed or heat each other.

Function 1: adjust the power flow or decoupling the plants. If it is over the limit.

Function 2: Protecting generator, by tripping the alternator circuit breaker.

Negative sequence

ANSI-code: 46

Application: to protect the alternator against imbalance loading of the phases or loss of phase. If there is a difference between the phases, this will create a negative rotating vector system in the alternator, which will produce harmonics and course heating of the rotor.

Function: Protecting generator, by tripping the generator circuit breaker.

Field failure protection

ANSI-code: 40

Application: To protect the synchronous generator against operation outside the stable operation area due to loss of excitation. When partial or complete loss of excitation occurs on a synchronous machine it obtaining reactive power,

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it flows from the system into the machine and the apparent impedance as viewed from the machine terminals, goes into the negative X region in the R-X diagram.

The Field failure system detects the low or under impedance condition. Max. 15% 2sec

Function: Protecting generator, by tripping the alternator circuit breaker.

Alternator differential protection

ANSI-code: 87G

Differential protection of alternator compares current in two measuring points, the star point with the current at the bus bar; it is a fast and selective form of protection. Faults lying within the protected zone are clearly and rapidly detected and reacted by switching the alternator of to limit the fault damage.

The type of faults which occurring is insulation failure.

Faults between stator and windings

Stator earth faults.

Ground faults and faults between phases outside the alternator but within the protected zone, at the terminal or on external connections.

Function: Protecting alternator, by tripping the alternator circuit breaker.

Temperature monitoring

IEC/EN 60751

Protection that detects abnormal temperature build up inside the alternator windings. The measurement is done by sensors placed inside the stator winding in the slots. There at two types

PT 100 Ohm normal 2 x 3 pcs with three Leeds pr. Sensor. (Base Module)

PT1000 Ohm normal 2 x 3 pcs with three Leeds pr. Sensor (SaCos One)

Thermistors or thermocouples 2 x 3 pcs. whit two leads for each sensor.

Alternator bearing protection can also be done by a PT100 / PT1000 Sensor

Synchronising protection

ANSI-code: 79

The synchronising protection is to protect the generator set when synchronising with the grid or other rotating GenSets. To do this it is necessary to detect the Phase angel position and acceleration, the phase angel must not be more than 2 deg.

Voltage difference, max 2%

Frequency difference, max 100mHz, min 98%, max 102%

To determine the max. acceptable tolerance, where the switching can be done safely.

Function: Protecting alternator, by blocking the switching on of the alternator circuit breaker.

Surge arrestors

IEC 60871-1, IEEE18, NEMA CP-1, VDE 0560 part 410, CIGRE 13.02

Is installed to protect the alternator insulation and electronics against lightning and bad synchronisation, and in rush peaks from transformers and large consumers. To do this, it is necessary to mount the arrestors direct at or near to the alternator (within a few meters from the terminals), the earth connection of the surge arrestors is not allowed to use the common earth connection of the plant, it shall have its own earth.

Function: Protecting alternator, it is not doing any action, which is interfering with the duty, it is necessary to have a counter, where it is possible to see how many hits it has taken.

Automatic Voltage Regulator AVR

The AVR can be delivered in two versions:

- Analogue
- Digital

If the analogue AVR is selected, it is necessary to consider, which type of AVR is used in the existing generator sets to secure the correct reactive load shearing.

If the digital AVR is selected, it is necessary to consider it is supplied with the power-factor measurement module.

Stand alone

Is the GenSet running as a “Stand Alone” Type which means there is the only running a single GenSet, the AVR has to be adjusted for Constant voltage.

Parallel running

The GenSet are running in parallel with other GenSets or the grid.

The AVR has to be equipped with a voltage drop, compensation lines power-factor regulator.

Parallel running with voltage droop

The AVR has to be equipped with a voltage droop function; this means the generator AVR is adjusting (Decreasing the voltage linear) the voltage by increasing load, the AVR are dropping the voltage from rated voltage by no-load to max – 2,5% droop at full load.

Parallel running with the grid by Power factor (Cos phi)

The AVR has to be equipped with a power factor regulator; this means the generator is adjusting the voltage after the Grid voltage and keeping the “Power factor” from the GenSet constant.

This system can be used in ships or smaller power plants, in the simple standard version, if the new GenSet I relation to the total installed power (30%), and the existing alternators have very old AVR’s .

Parallel running with other GenSets with Compensation Lines

Older alternators are using compensations lines, the AVR have to be selected specially for this.

It is not possible to run a standard analogue AVR with voltage droop in parallel with GenSet plants using compensations lines.

It is also possible to use digital regulators, they are then using a power factor mode.

Digital regulators (AVR)

Digital Regulators are equipped with many protection features to protect the alternator.

But they are not activated automatically. It is necessary to state it in the contract:

Who is responsible for the adjustment: the people who have the best information about how much the generator can withstand is the generator manufacturer. They shall be forced to make the adjustments and control the functions before the generator is leaving the test bench in the generator factory.

The functions from the protection features can be allocated to some configurable relay outputs (1,2 or 3 pcs with priority) in the alternator AVR, which can give signals to the supervision system in the Switchboard.

It has to be decided by the manufacturer, if the outputs have to result in an alarm, switch of the main circuit breaker, or switch of the main circuit breaker and stop of the GenSet.

The following has to be stated from the generator buyer by order:

It is recommended to use the protection features in the alternator AVR and following alarms can be generated on configurable relay outputs.

- Rated voltage UmN (Volt)
- Rated current ImN (amp)
- Largest inrush current and accepted voltage drop (amp), (Volt)
- Power factor PFmN (pu)
- Apperent power SmN (kVA)
- Active power PmN (kW)
- Frequency FmN (Hz)
- Pole number (RPM)
- Field overvoltage
- Field overcurrent
- Alternator overvoltage
- Alternator undervoltage
- Watchdog
- Loss of sensing
- Exciter diode monitoring
- Loss of field

Please note that not all Digital regulators may have all of above mentioned protection features

The alternator will be delivered with the alternator supplier standard AVR settings and all protection features are NOT enabled.

The alternator supplier can be requested from the customer or MAN Diesel & Turbo to put other settings in the AVR. Such customize settings must be informed to MAN Diesel & Turbo one month before the FAT-Test of the Genset.

The reactances of the alternator have to be stated from the alternator supplier by order confirmation. It is the basic information for ordering the Switchboard with power managament.

The alternator manufacturer has to state which signal contacts in the AVR is used for: Alarms / Switch off and which for Stop of plant.

Following values must be given in the alternator data sheet:

Generator reaktanses		
Rated voltage UmN (Volt) 80%	Min Voltage (Volt)120%	Max Voltage (Volt)
Rated current ImN (amp) 115%	Max Current (amp)50	Time (sec)

Power factor PFmN (pu)		
Apperent El-power SmN (KVA)110%	Max Power (KVA)60	Time (Minutes)
Aktive power El-PmN (KW) 110%	Max Power (KW)60	Time (Minutes)

Efficiency n (%)		
Mechanical M-Power (KW)		
Frequency FmN (Hz) 110%	Max Frequency (Hz) 90%	Min Freq.(Minutes)

Pole number
Gen. Sens Pt Pri. Voltage (Volt)
Gen. Sens Pt Sec. Voltage (Volt)
Gen. Sens Ct Pri. Current (amp)
Gen. Sens Ct Sec. Current (amp)
AVR CT Input terminal (amp)
Gen. Differential protection CT. Pri. Current (amp)
Gen. Differential protection CT. Sec. Current (amp)
Excitation current open Ieo (amp) Rippel 5% delay 2 sec
Excitation current Short IeK (amp) Rippel 10% delay 2 sec
Excitation Current Rated IeN (amp)
Excitation Resistance Re (ohms)
Excitation voltage Rated UeN (Volt) Max. Excitation voltage (volt) Time (sec)
Excitation pole Number

The alternator manufacturer has to adjust the AVR, and state the adjustments done by the test-run.

The alternator manufacturer has to state if there is any alteration in the statement by the order confirmation.

Cabling for Alternator Connections

The cabling for connecting the alternator has to be dimensioned after the local rules / regulations or classification societies' demands and the type of cable you want to use.

Because of the vibration of the generator which is put to a max of 22 mm/sec the installation have to be done in such a way that the cable can take these constant movements.

The cables have to be of Class5 which gives the flexibility of the cable.

The cable has to be hanging in a U from the fixed point in the installation to the terminal box.

The length of the U shall min. be 1 meter the cable manufacturer can have prescriptions for the min bending diameters. Se also installation manual chapter B/G 50 00 0: Alternator cable installation

Dimentioning of the Alternator

Before buying the alternator it has to be decided which DIN norm has to be fulfilled.

The most normal is DIN6270A (popular said, 12 hours 100%+1hour 110%) at rated surrounding temperature, for industry air 40 deg C and cooling medium at rated temp.

If it is an water cooled Generator it is 32 deg C

Insulation class and the construction lifetime has to be decided.

The insulation can be H=165 deg.C, F=145 deg.C, B=120 deg.C. in respect of IEC 34

F used as F theoretical lifetime 30 years. The most common for high voltage machines.

150% lifetime-dimension if the machine is running with an under temperature for 7 deg.C

200% lifetime-dimension the machine is running one class lower as insulation F used as B.

Power reductions factors for marine generators

Classification	Cooling air	Temp. enc.	Red. fact.
H insulation			
VDE	40	125	1
GL	45	120	0,96
RINA	50	115	0,93
LR	45	110	0,9
NKK	45	110	0,9

Classification	Cooling air	Temp. enc.	Red. fact.
DNV	45	115	0,93
BV	50	110	0,9
ABS	50	115	0,93
MRS	45	120	0,96

Classification	Cooling air	Temp. enc.	Red. fact.
F insulation			
VDE	40	105	0,93
GL	45	100	0,89
RINA	50	90	0,86
LR	45	90	0,86
NKK	45	90	0,86
DNV	45	90	0,86
BV	50	90	0,86
ABS	50	95	0,89
MRS	45	100	0,89

Classification	Cooling air	Temp. enc.	Red. fact.
B insulation			
VDE	40	80	0,79
GL	45	75	0,76
RINA	50	70	0,73
LR	45	70	0,73
NKK	45	70	0,73
DNV	45	70	0,73
BV	50	70	0,73
ABS	50	70	0,73
MRS	45	75	0,76

Alternator Protection

- Alternator protection settings below are all standard values.
- For each individual plant the settings can be adjusted to the site condition.
- Further to below we also recommend implementing Start blocking of the diesel engine in case of MSB earthing
- In case of Differential protection we recommend to implement trip of excitation.
- For Earth fault protection special consideration must be made due to Island operation, Grid operation and type of earthing system.

Alternator protection settings	Required by MAN Diesel	Nice to have
Short Circuit phase L1 – set _250_% of In. trip time_300_ms.	x	
Short Circuit phase L2 – set _250_% of In. trip time_300_ms.	x	
Short Circuit phase L3 – set _250_% of In. trip time_300_ms.	x	
Earth fault trip – set_20__% of In. trip time¬¬_8__s.	x	
Over voltage - set_110% of Un. trip time_5__s.	x	
Under voltage - set _90_% of Un. trip time_5__s.	x	
Over frequency - set_105_% of Hzn. trip time_10__s.	x	
Under frequency - set_ 95_% of Hzn. trip time__5_s.	x	
Reverse power (-P<) - set_8__% of Pn. trip time__10_s.	x	
Overload (P>) - set_110_% of Pn. trip time_20_s.	x	
Over current (I>) – set__130 % of In. trip time_4_s.	x	
Winding temp. Phase L1 – set 130 °C Alarm time__3__s.	x	
Winding temp. Phase L2 – set 130 °C Alarm time__3__s.	x	
Winding temp. Phase L3 - set 130 °C Alarm time__3__s.	x	
Bearing temp. – set 85° C Alarm time___3_s.		x

Generator differential protection settings	Required by MAN Diesel	Nice to have
Generator phase L1 – Set _10_% of In Shutdown time_<50_ms.		P>2500kW
Generator phase L2 Set _10_% of In Shutdown time_<50_ms.		P>2500kW
Generator phase L3 Set _10_% of In Shutdown time_<50_ms.		P>2500kW
Switchgear phase L1 Set _10_% of In Shutdown time_<50_ms.		P>2500kW
Switchgear phase L2 Set _10_% of In Shutdown time_<50_ms.		P>2500kW
Switchgear phase L3 Set _10_% of In Shutdown time_<50_ms.		P>2500kW

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Load curves for diesel electric propulsion

Running the GenSet as diesel electric propulsion

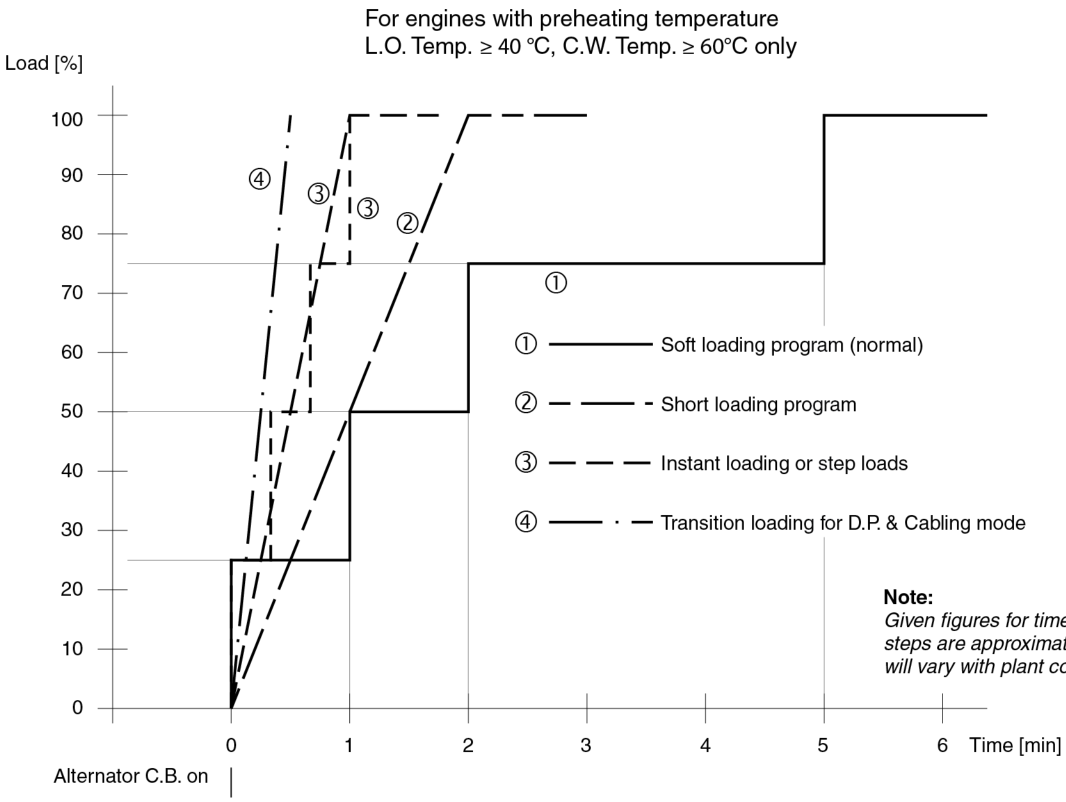

Figure 1: .

When using the GenSet as diesel electric propulsion the curves in fig. 1 is to be followed.

During Diesel Electrical Propulsion normally the Generators are running in isochronous load sharing to improve load sharing during high load transients.

A proper load curve is to be set in the propulsion system to get as smooth load sharing and engine performance as possible.

Isochronous load sharing is done on two possible ways.

1. Using the standard system where the engine control system is working as speed governor. For load sharing a load sharing devise is used for fast and proper load sharing.
2. An external speed governor is used for speed control and proper load control.

Both systems requires additional interface to the power management system and the main switchboard.

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Windmilling protection

If no loaded engines (fuel admission at zero) are being driven by the propeller, this is called "windmilling". The permissible period for windmilling is short, as windmilling may result in opening circuit breaker due to reverse power. The vessels total hotel consumption might very well be lower that the reverse power set point for the connected GenSets.

Please be aware that fuel admission below “0” cannot be controlled by the governors or load sharing device.

Engine operation under arctic conditions

Engine operation under arctic conditions

Arctic condition is defined as:

Ambient air temperature below +5°C

If engines operate under arctic conditions (intermittently or permanently), the engine equipment and plant installation have to meet special design features and requirements. They depend on the possible minimum air intake temperature of the engine and the specification of the fuel used.

Special engine design requirements

If arctic fuel oil (with very low lubricating properties) is used, the following actions are required:

Fuel injection pump:

- The maximum allowable fuel temperatures have to be kept.
- Only in case of conventional injection system, dependent on engine type installation and activation of sealing oil system may be necessary, because low viscosity of the fuel can cause an increased leakage and the lube oil will possibly being contaminated.

Engine equipment

Engine control

Engine control equipment is suitable to be stored at minimum ambient temperatures of -15°C.

In case these conditions cannot be met. Protective measures against climatic influences have to be taken for some electronic components.

Electronic components have to be stored at places, where the temperature is above –15°C.

- A minimum operating temperature of ≥ +5°C has to be ensured. That's why an optional electric heating has to be used.

Alternators

Alternator operation is possible according to suppliers specification.

Plant installation

Intake air conditioning

- Air intake of the engine and power house/ engine room ventilation have to be two different systems to ensure that the power house/ engine room temperature is not too low caused by the ambient air temperature.
- It is necessary to ensure that the charge air cooler cannot freeze when the engine is out of operation (and the cold air is at the air inlet side).

An air intake temperature of the engine ≥ 5°C has to be ensured by preheating.

Ventilation of power house/engine room:

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- The air of the power house/engine room ventilation must not be too cold (preheating is necessary) to avoid the freezing of the liquids in the power house/engine room) systems.
- Minimum powerhouse/engine room temperature for design ≥ +5°C

Coolant and lube oil systems:

- HT and lube oil system has to be preheated as specified in the relevant chapters of the project guide for each individual engine.
- If a concentration of anti-freezing agents of > 50 % is needed, please contact MAN Diesel & Turbo for approval.
- For information regarding engine cooling water please see chapter "Cooling water system".

Insulation:

- The design of the insulation of the piping systems and other plant parts (tanks, heat exchanger etc.) has to be modified and designed for the special requirements of arctic conditions.

Heat tracing:

- To support the restart procedures in cold condition (e.g. after unmanned survival mode during winter), it is recommended to install a heat tracing system in the piping to the engine.

Note!
A preheating of the lube oil has to be ensured. If the plant is not equipped with a lube oil separator (e.g. plants only operation on MGO) alternative equipment for preheating of the lube oil to be provided. For plants taken out of operation and cooled down below temperatures of +5°C additional special measures are needed – in this case please contact MAN Diesel & Turbo.

Actuators

Actuator types

As standard, the engines are equipped with an electro-hydraulic actuator, make Regulateurs Europa, type 2800; or make Woodward, type UG25+. Speed Control is carried out via $SaCoS_{one}$ GENSET.

Actuator signal

	Actuator input signal
Regulateurs Europa, type 2800	0-1 A nominal operating range
Woodward, type UG25+	4-20mA nominal operating range

Speed adjustment range

Speed adjustment range is adjustable in $SaCoS_{one}$.

Droop

Droop is adjustable in $SaCoS_{one}$.

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Actuators

Actuator types

The engines can be equipped with an electro-hydraulic actuator, make Regulateurs Europa, type 2800. Speed Control is carried out via $\mathrm{SaCoS}_{\mathrm{one}}$ 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 $\mathrm{SaCoS}_{\mathrm{one}}$.

Droop

Droop is adjustable in $\mathrm{SaCoS}_{\mathrm{one}}$.

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Actuators

Actuator type

As optional, the engines are equipped with an electro-hydraulic actuator, make Woodward, type UG25+. Speed Control is carried out via $\text{SaCoS}_{\text{one}}$ GENSET.

Actuator signal

	Actuator input signal
Woodward, type UG25+	4-20mA nominal operating range

Speed adjustment range

Speed adjustment range is adjustable in $\text{SaCoS}_{\text{one}}$.

Droop

Droop is adjustable in $\text{SaCoS}_{\text{one}}$.

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Operation data and set points

Engine load @ MCR

Description		Normal value at full load at ISO conditions		Acc. value *	Alarm set point 100 % load		Delay sec.	Auto stop of engine	
Lubricating oil system									
Temperature after cooler (inlet engine)	°C	TI 21	68-73	<73	TAH 21	82	3		
Pressure after filter (inlet engine)	bar	PI 22	4.2-5.0	>4.5	PAL 22	3.5	3	PSL 22 PSL 22	3.0 3.0 (D)
Pressure drop across filter	bar	PDAH 21-22	0.1-1	<0.5	PDAH 21-22	1.5	3		
Prelubricating pressure	bar	(PI 22)	0.1-1.5	<1.0	PAL 25	0.1 (H)	60		
Pressure inlet turbocharger	bar	PI 23	1.3-2.2 (C)	>1.3	PAL 23	1.0	3		
Lubrication oil level in base frame					LAL 28 LAH 28	low high	30 30		
Pressure before filter	bar	PI 21	4.5-5.5						
Crankcase protection (M)	°C				LAH 92 TAH 58 TDAH 58	high 100 4	3 3 3	LSH 92 TSH 58 TDSH 58	high 105 5
Temperature main bearing	°C	TI 29	80-95		TAH 29	100	3	TSH 29	105
Fuel oil system									
Pressure after filter - MDO	bar	PI 40	3-6		PAL 40	2	5		
Pressure after filter - HFO	bar	PI 40	8-10 (A)		PAL 40	4-6 (E)	5		
Leaking oil					LAH 42	high	5		
Temperature inlet engine - MDO	°C	TI 40	30-40						
Temperature inlet engine - HFO	°C	TI 40	110-150						
Cooling water system									
Pressure LT system, inlet engine	bar	PI 01	2.4-4.5	>1.8	PAL 01	0.4 + (B)	3		
Pressure HT system, inlet engine	bar	PI 10	2.0-5.0	>1.8-<6	PAL 10	0.4 + (B)	3		

Description		Normal value at full load at ISO conditions		Acc. value *	Alarm set point 100 % load		Delay sec.	Auto stop of engine	
Temperature HT system, outlet engine	°C	TI 12	75-85	<85	TAH 12	90	3	TSH 12 TSH 12	95 95 (D)
Temperature LT system, inlet engine	°C	TI 01	30-40						
Exhaust gas and charge air									
Exhaust gas temperature inlet TC	°C	TI 62	500-550		TAH 62	600 (N)	30		
Exhaust gas temperature outlet cyl 5 cyl. engine 6-9 cyl. engine	 °C °C	 TI 60 TI 60	 325-450 275-375		 TAH 60 TAH 60	 480 (N) 480 (N)	 30 30		
Difference between individual cyl.	°C			average ±25	TAD 60	average (K) ±50 (N) ±100 (N)	120		
Exhaust gas temperature outlet TC	°C	TI 61	325-375		TAH 61	450 (N)	30		
Charge air pressure after cooler	bar	PI 31	2.7-3.1						
Charge air temperature after cooler	°C	TI 31	35-55	<55					
Compressed air system									
Pressure inlet engine TDI Gali	bar	PI 70	 7-8 (max 10) < 30	 >7-<8 16-30	 PAL 70 PAL 70	 6.5 15	 15 15		
Speed control system									
Engine speed electrical 1200 rpm 1000 rpm	rpm	SI 90			 SAH 81 SAH 81	 1356 1130	 0 0	 SSH 81 SSH 81	 1380 (D) 1150 (D)
Turbocharger speed		SI 89	(L)		SAH 89	(J)	3		
Alternator									
Cooling water leakage		LAH 98			LAH 98	switch	3		
Winding temperature	°C	TI 98	100		TAH 98	130	3		
Miscellaneous									
Start failure	sec		< 10		SX 83	switch (G)	10		

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Description		Normal value at full load at ISO conditions		Acc. value *	Alarm set point 100 % load		Delay sec.	Auto stop of engine	
Stop signal					SS 84	switch (F)	0		
Stop failure	sec		< 30		SX 84	switch	30		
Engine run 1200/1000 rpm		SI 90			SS 90A	(I)			
Ready to start					SS 87	switch	0		
* Acceptable value at shop test or after repair									

Soft shut down

For the following alarms we recommend to implement soft shut down in the power management system:

PAL 22	Lubricating oil pressure inlet engine
TAH 12	HT cooling water temperature - high
TAH 60	Exhaust temperature deviation - high

If applicant:

LAH 92	High oil mist level
TAH 58	Splash oil temperature - high
TDAH 58	Splash oil temperature deviation alarm - high
TAH 29	Main bearing temperature - high

By soft shut down the ships power management system must start the next standby engine and transfer the load to this, following the engine with alarm is shutting down.

Remarks to individual parameters

A. Fuel oil pressure, HFO operation

When operating on HFO, the system pressure must be sufficient to depress any tendency to gasification of the hot fuel.

The system pressure has to be adjusted according to the fuel oil preheating temperature.

B. Cooling water pressure, alarm set points

As the system pressure in case of pump failure will depend on the height of the expansion tank above the engine, the alarm set point has to be adjusted to 0.4 bar plus the static pressure. The static pressure set point can be adjusted in the display module.

C. Lubricating oil pressure, offset adjustment

At charge air pressure below 1.0 bar the lub. oil pressure to turbocharger is normal at 0.6 ±0.1 bar.

The read outs of lubricating oil pressure has an offset adjustment because of the transmitter placement. This has to be taken into account in case of test and calibration of the transmitter.

D. Software created signal

Software created signal from PI 22, TI 12, SI 90.

SAH 81 is always activated together with SSH 81.

E. Set points depending on fuel temperature

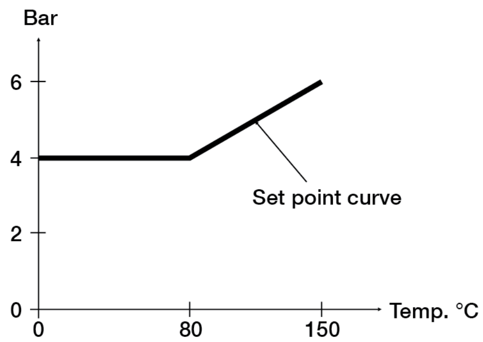

Figure 1: Set point curve

F. Start interlock

The following signals are used for start interlock/blocking:

1. Turning must not be engaged
2. Engine must not be running
3. "Remote" must be activated
4. No shutdowns must be activated.
5. The prelub. oil pressure must be OK, 20 min. after stop.
6. "Stop" signal must not be activated

G. Start failure

If remote start is activated and the engine is in blocking or local mode or turning is engaged the alarm time delay is 2 sec.

Start failure will be activated if revolutions are below 50 rpm within 5 sec. from start or revolutions are below 210 rpm 10 sec. from start.

Start failure alarm will automatically be released after 30 sec. of activation.

H. Alarm hysterese

On all alarm points (except prelub. oil pressure) a hysterese of 0.5% of full scale are present. On prelub. oil pressure alarm the hysterese is 0.2%.

I. Engine run signal

The engine run signal is activated when engine rpm >930 (L16/24-1000 rpm) / 1130 (L16/24-1200 rpm) or lube oil pressure >3.0 bar or TC rpm >5000 rpm.

If engine rpm is above 210 rpm but below 930 rpm (L16/24-1000 rpm) / 1130 rpm (L16/24-1200 rpm) within 30 sec. the engine run signal will be activated.

J. Limits for turbocharger overspeed alarm (SAH 89)

TC overspeed alarm		
Matching	**41XXX**	**42XXX**
TCR12	65300	68800
TCR14	54100	57000
TCR16	45000	47400
TCR18	37100	39000
TCR20	30800	32400

K. Exhaust gas temperatures

The exhaust gas temperature deviation alarm is normally ±50° C with a delay of 1 min., but at start-up the delay is 5 min. Furthermore the deviation limit is ±100° C if the average temperature is below 200° C.

L. Turbocharger speed

Normal value at full load of the turbocharger is dependent on engine type (cyl. no) and engine rpm. The value given is just a guide line. Actual values can be found in the acceptance test protocol or name plate on turbocharger.

M. Crankcase protection

For engines above 2250 kW or bore > 300 mm, crankcase protection is standard for marine application. The system is optional for smaller engines.

This will be done by an oil mist detector (LAH/LSH 92) as standard or with a splash oil/crankcase protection system (TAH/TSH/TDAH/TDSH 58 + TAH/ TSH 29) as option.

N. Alarm at 110% load

During shop test of 110% load it can occur that there is exhaust gas temperature alarm, this can be caused to high air temperature before compressor combined with low ambient air pressure.

10° C change in ambient temperature correspond to approx. 15° C exhaust gas temperature change.

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ENGINE AUTOMATION

MAN Diesel &Turbo SE

SaCoS$_{one}$ GENSET System description

Revision 1.5

Revision History

Revision	Date	Name	Comments
0.1	03.08.2009	Karger	First issue
0.2	04.08.2009	Karger	Interface overview added
0.3	07.08.2009	Brendle	Formal modifications
0.4	11.08.2009	Karger	Interface overview and description corrected
0.5	14.08.2009	Karger	Modbus list added, measurements of the units added, interface overview modified and corrected, power supply scheme added
0.6	23.09.2009	Brendle	Speed governing signals modified
0.7	04.11.2009	Karger	Interface overview modified, detailed interface description added, Modbus ASCII description added
0.8	12.11.2009	Karger	Interface overview modified, GenSet picture corrected
0.9	13.01.2010	Karger	Updated due to comments from Mr. Bojtas
0.10	11.02.2010	Karger	Interface description outsourced to independent document
1.0	18.02.2010	Karger	Measurements, weight and serial interface added
1.1	20.02.2010	Karger	Updated due to comments from H. Cevik
1.2	09.03.2010	Karger	Interface description for Crankcase Monitoring Unit added
1.3	28.05.2010	Karger	Chapter “2.3 Speed control system” modified
1.4	14.06.2010	Karger	Chapter “2.3 Speed control system” and power supply modified
1.5	16.08.2010	Karger	Chapter 3.8.: corrected power supply for safety system

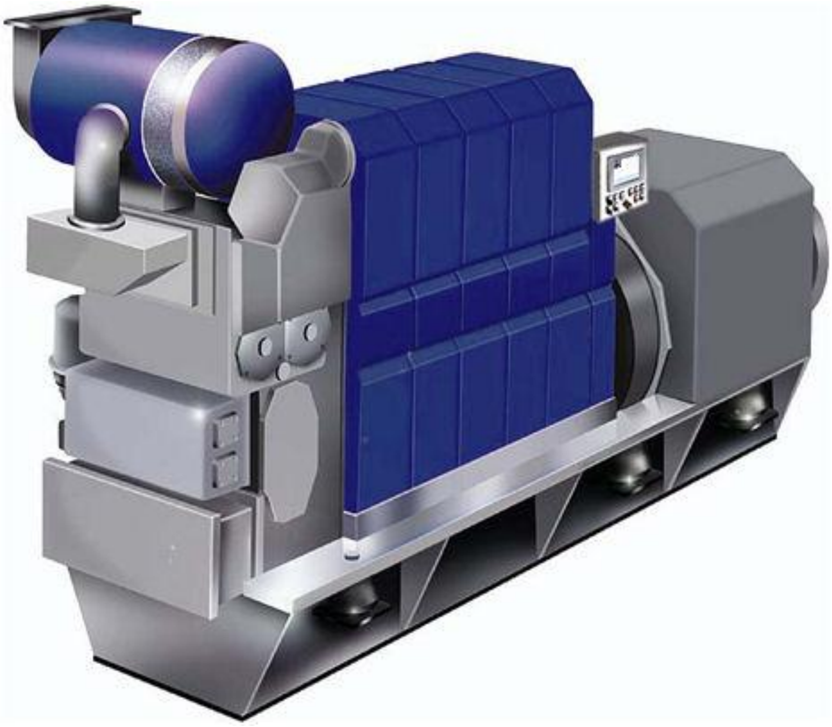
Table of Contents

1 General information

This document is valid for the following engine types:

- L16/24
- L21/31
- L27/38

The monitoring and safety system SaCoS$_{one}$ GENSET serves for complete engine operation, control, monitoring and safety of GenSets. All sensors and operating devices are wired to the engine-attached units.
The SaCoS$_{one}$ design is based on high reliable and approved components as well as modules specially designed for installation on medium speed engines. The used components are harmonised to a homogenously system. The whole system is attached to the engine cushioned against vibration.



SaCoS$_{one}$ GENSET mounted on a L16/24 GenSet (Probable Layout)

1.1 Control Unit

The Control Unit includes a highly integrated Control Module for engine control, monitoring and alarm system (alarm limits and delay). The module collects engines measuring data and transfers most measurements and data to the ship alarm system via Modbus.
Furthermore, the Control Unit is equipped with a Display Module. This module consists of a touchscreen and an integrated PLC for the safety system. The Display Module also acts as safety system for over speed, low lubrication oil pressure and high cooling water temperature.

The Display Module provides the following functions:

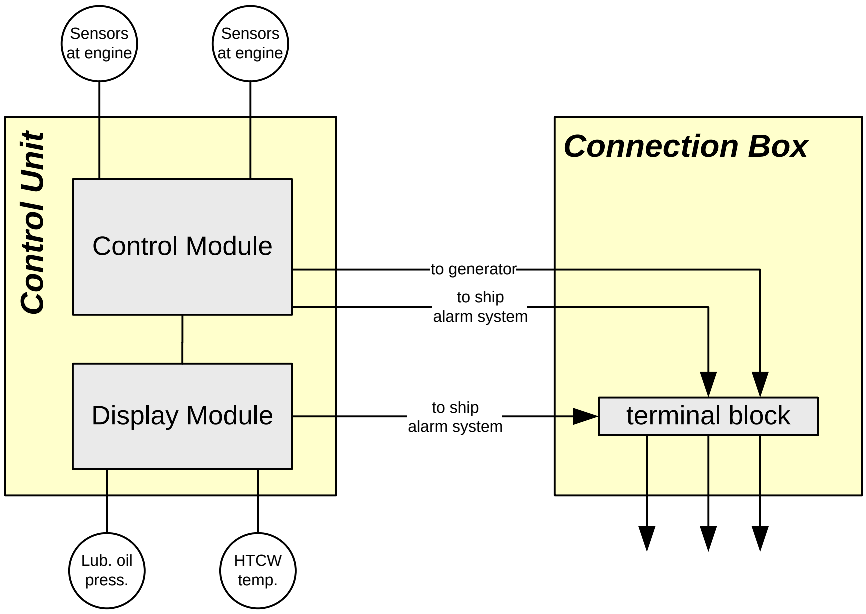
- safety system
- visualisation of measured values and operating values on a touchscreen
- engine operation via touchscreen

The safety system is electrically separated from the control system due to requirements of the classification societies.
For engine operation, additional hardwired switches are available for relevant functions.
The system configuration can be edited via an Ethernet interface at the Display Module.

Prototype of the SaCoS$_{one}$ GENSET

1.2 Connection Box

The Connection Box is the central connecting and distribution point for the 24 VDC power supply of the whole system.
Furthermore it connects the Control Unit with the GenSet, the ship alarm system and the optional crankcase monitoring.

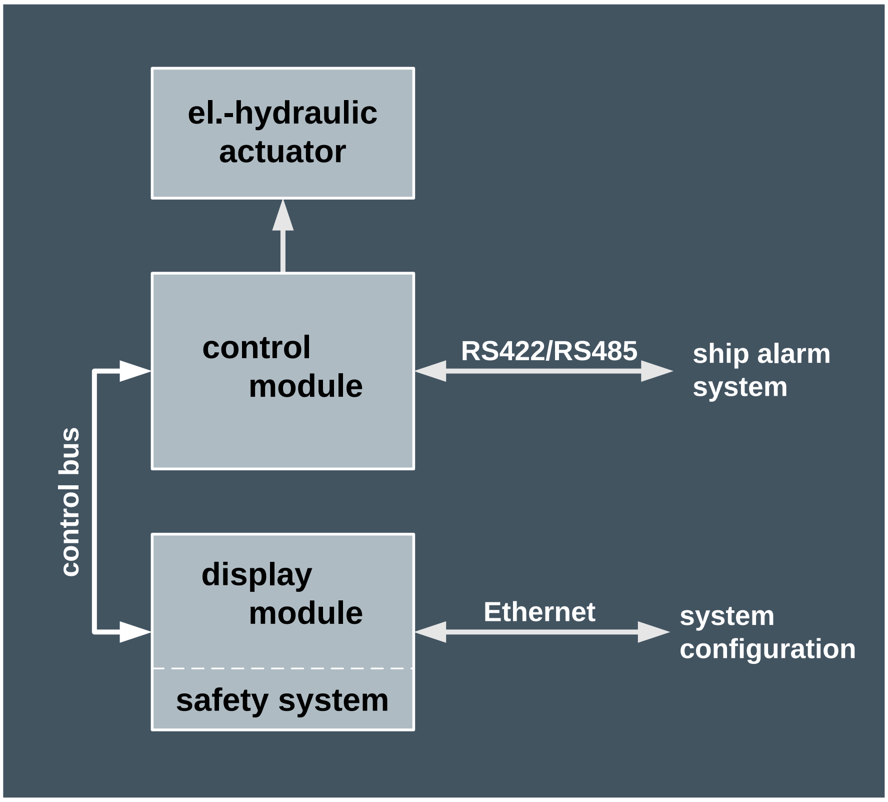


1.3 System bus

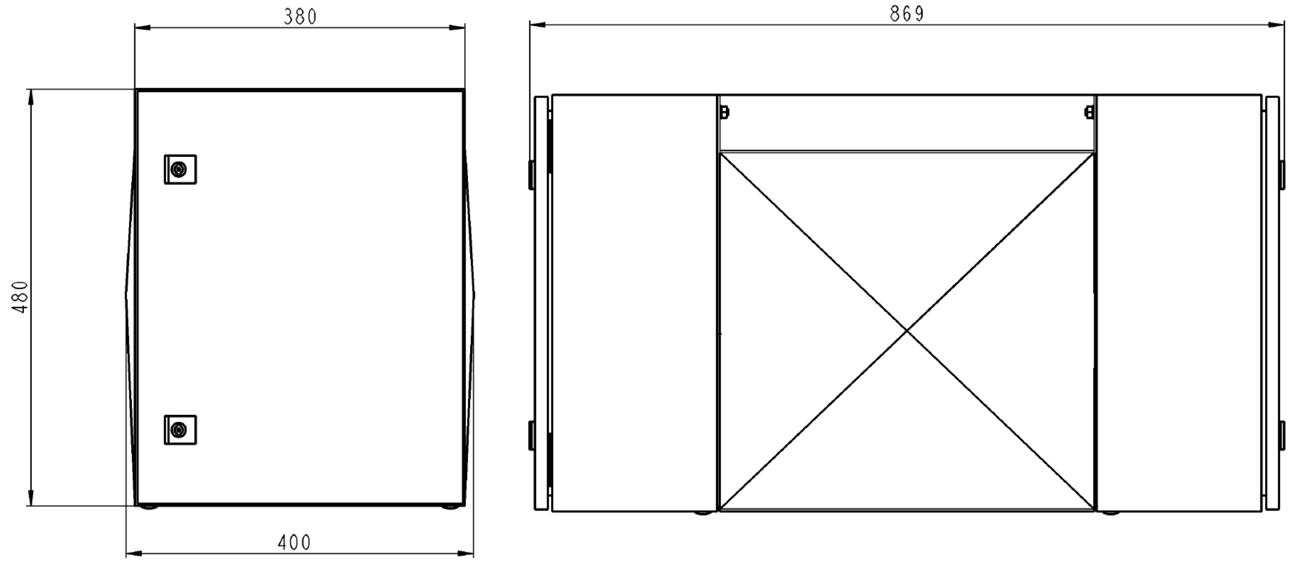
The SaCoS$_{one}$ system is equipped with a redundant bus based on CAN. The bus connects all system modules. This redundant bus system provides the basis data exchange between the modules. The control module operates directly with electro-hydraulic actuator.

- **engine control**
- **speed control**
- **alarm system**

- **display**
- **operation**
- **safety system**



1.4 Technical data



Example shows the dimensions of L16/24

	L16/24	L21/31	L27/38
Width	400 mm	400 mm	400 mm
Height	480 mm	565 mm	480 mm
Length	869 mm	1168 mm	1323 mm
Length overall	902 mm	1201 mm	1356 mm
Weight	60 kg	60 kg	65 kg

2 System description

2.1 Safety system

Safety functions

The safety system monitors all operating data of the engine and initiates the required actions, i.e. engine shut-down, in case the limit values are exceeded. The safety system is integrated the Display Module.
The safety system directly actuates the emergency shut-down device and the stop facility of the speed governor.

Auto shutdown

Auto shutdown is an engine shutdown initiated by any automatic supervision of engine internal parameters.

Emergency stop

Emergency stop is an engine shutdown initiated by an operator manual action like pressing an emergency stop button. An emergency stop button is placed at the Control Unit on engine. For connection of an external emergency stop button there is one input channel at the Connection Box.

Engine shutdown

If an engine shutdown is triggered by the safety system, the emergency stop signal has an immediate effect on the emergency shut-down device and the speed control. At the same time the emergency stop is triggered, SaCoS$_{one}$ issues a signal resulting in the generator switch to be opened.

Shutdown criteria

- Engine overspeed
- Failure of both engine speed sensors
- Lube oil pressure at engine inlet low
- HT cooling water temperature outlet too high
- High bearing temperature/deviation from Crankcase Monitoring System. (optional)
- High oilmist concentration in crankcase. (optional)
- Remote Shutdown. (optional)
  - Differential protection (optional)
  - Earth connector closed (optional)
  - Gas leakage (optional)

2.2 Alarm/monitoring system

Alarming

The alarm function of SaCoS*one* supervises all necessary parameters and generates alarms to indicate discrepancies when required. The alarms will be transferred to ship alarm system via Modbus data communication.

Self-monitoring

SaCoS*one* carries out independent self-monitoring functions. Thus, for example the connected sensors are checked constantly for function and wire break. In case of a fault SaCoS*one* reports the occurred malfunctions in single system components via system alarms.

Control

SaCoS*one* controls all engine-internal functions as well as external components, for example:

- Start/stop sequences:
  - Local and remote start/stop sequence for the GenSet.
  - Activation of start device. Control (auto start/stop signal) regarding prelubrication oil pump.
  - Monitoring and control of the acceleration period.

- Jet system:
  - For air fuel ratio control purposes, compressed air is lead to the turbocharger at start and at load steps.

- Control signals for external functions:
  - Nozzle cooling water pump (only engine type 32/40)
  - HT cooling water preheating unit
  - Prelubrication oil pump control
- Redundant shutdown functions:
  - Engine overspeed
  - Low lub. oil pressure inlet engine
  - High cooling water temperature outlet engine

2.3 Speed Control System

Governor

The engine electronic speed control is realized by the Control Module. As standard, the engine is equipped with an electro-hydraulic actuator.

Speed adjustment

Local, manual speed setting is possible at the Control Unit with a turn switch.

Remote speed setting is either possible via 4-20mA signal or by using hardwired lower/raise commands.

Speed adjustment range

Between -5% and +10% of the nominal speed at idle running.

Droop

Adjustable by parameterisation tool from 0-5% droop.

Load distribution

By droop setting.

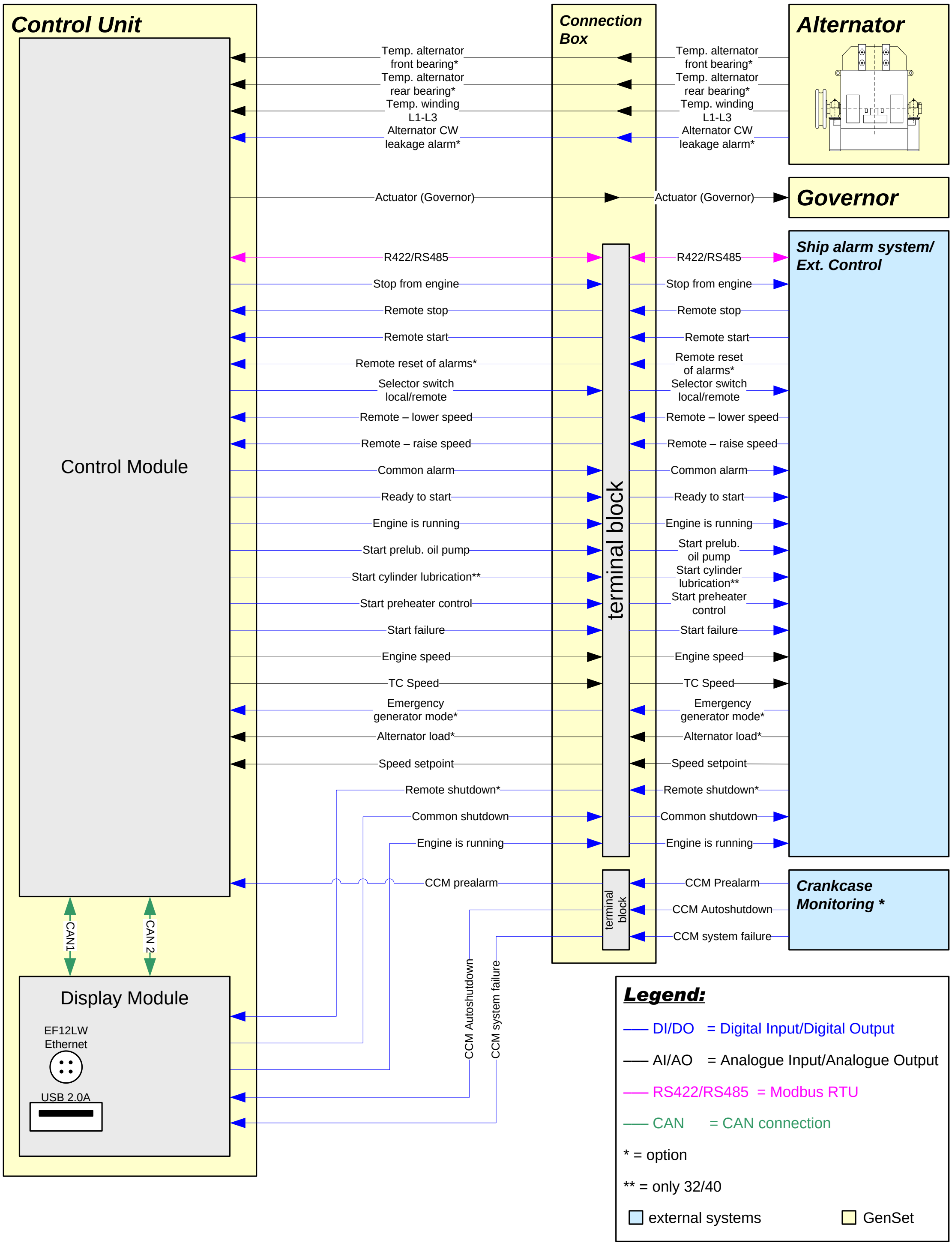
Engine stop

Engine stop can be initiated local at the display module and remote via a hardware channel or the bus interface.

3 Interfaces to external systems

3.1 Overview

A detailed signal description is available on the GS Product page in the document "*SaCoSone.GenSet.Interface_description_Vx.x.docx*". (Available as PDF)



3.2 Data Machinery Interface

This interface serves for data exchange to ship alarm systems or integrated automation systems (IAS).
The status messages, alarms and safety actions, which are generated in the system, can be transferred. All measuring values and alarms acquired by SaCoS$_{one}$ GENSET are available for transfer.

The following MODBUS protocols are available:

- MODBUS RTU (Standard)
- MODBUS ASCII (for retrofits)

For a detailed description of these protocols see the document “SaCoS$_{one}$ GENSET, Communication from the GenSet”.

3.3 Generator Control

SaCoS$_{one}$ provides inputs for all temperature signals for the temperatures of the generator bearings and generator windings.

3.4 Power Management

Hardwired interface for remote start/stop, speed setting, alternator circuit breaker trip etc.

3.5 Remote control

For remote control several digital inputs are available.

3.6 Ethernet interface

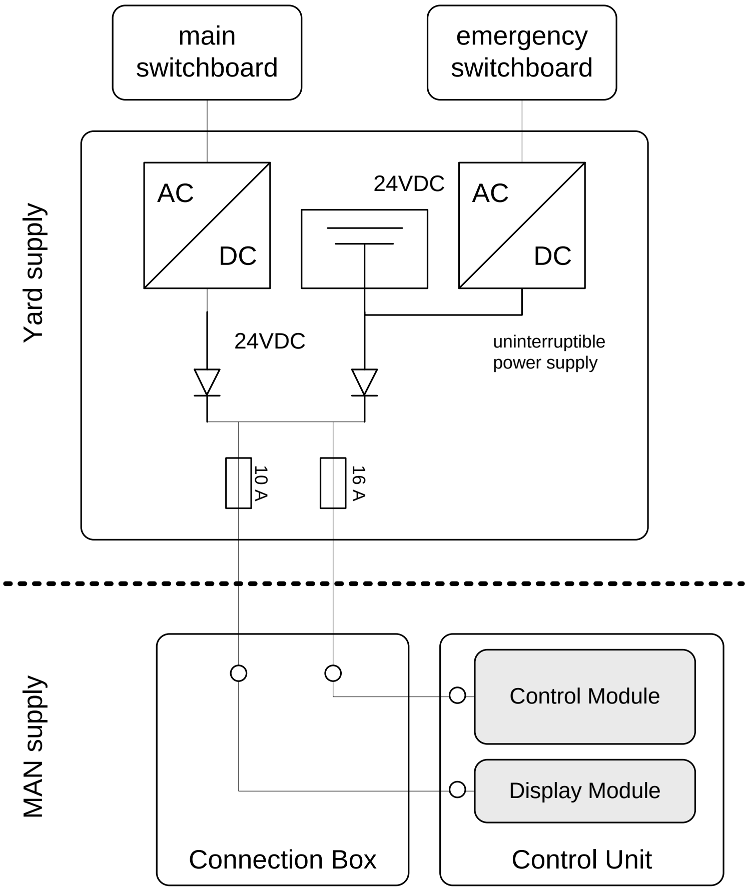
The Ethernet interface at the Display Module can be used for the connection of SaCoS$_{one}$ EXPERT.

3.7 Serial interface

CoCoS-EDS can be connected to a serial RS485 interface.

3.8 Power supply

The plant has to provide electric power for the automation and monitoring system. In general a redundant, uninterrupted 24V DC (+20% -30% and max ripple 10%) power supply is required for SaCoS$_{one}$.
The alarm system requires a 24V DC, 12,5 A uninterrupted power supply with a 16 A pre-fuse.
The safety system requires a 24V DC, 8,5 A uninterrupted power supply with a 10 A pre-fuse.



3.9 Crankcase Monitoring Unit (optional)

SaCoS$_{one}$ GENSET provides an interface to an optional Crankcase Monitoring Unit. This unit is not part of SaCoS$_{one}$ GENSET and is not scope of supply. If applied, it is delivered as stand-alone system in an extra control cabinet.

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SaCoS*one* GENSET
Communication from GenSet

Revision **1.7**

Revision history

Rev.	Description	Date	Department
0.1	First issue	11.01.2010	ESPP
0.2	Block 4 of Modbus ASCII removed, class information removed	02.03.2010	ESPP
1.0	Modbus TCP list updated	16.03.2010	ESPP
1.1	Modbus list updated	27.05.2010	ESPP
1.2	Modbus ASCII is available for all engines	10.06.2010	ESPP
1.3	Modbus ASCII block addresses deleted, Modbus list is now a separate document	02.08.2010	ESPP
1.4	Chapter 1: possibility of Modbus TCP for CoCoS-EDS communication added Chapter 2: Added notice about which module allows the use which Modbus protocol Chapter 2.4.2: Live Bit: live bit alternates every 4 seconds.	17.05.2011	ESPP
1.5	Chapter 2.4.2: Live Bit: Modbus address removed from description. For details see Modbus List	09.08.2011	ESPP
1.6	Chapter 3.3: Data format description corrected Document layout changed	16.12.2011	ESPP
1.7	Chapter 4: Information added about extended operation hour counter	23.11.2012	EESPD

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1 Data Bus Interface (Machinery Alarm System)

This interface serves for data exchange to ship alarm systems or integrated automation systems (IAS).

The status messages, alarms and safety actions, which are generated in the system, can be transferred. All measuring values and alarms acquired by SaCoS$_{one}$ GENSET are available for transfer.

The following Modbus protocols are available:

- Modbus RTU (Standard)
- Modbus ASCII
- Modbus TCP (only for CoCoS-EDS)

The Modbus RTU protocol is the standard protocol used for the communication from the GenSet. For the integration in older automation system, Modbus ASCII is also available. Modbus TCP is only available for the connection of CoCoS-EDS via Gateway Module.

2 Modbus RTU protocol

The Modbus RTU protocol is the standard protocol used for the communication from the GenSet.

The bus interface provides a serial connection. The protocol is implemented according to the following definitions:

- Modbus application protocol specification, Modbus over serial line specification and implementation guide,

NOTICE

Important

For serial Modbus communication the following hardware requirements must be observed:

- Control Module S: Modbus RTU and Modbus ASCII possible
- Gateway Module: only Modbus RTU available

There are two serial interface standards available:

- RS422 – Standard, 4 + 2 wire (cable length <= 100m), cable type as specified by the circuit diagram, line termination: 120 Ohms
- RS485 – Standard, 2 + 2 wire (cable length <= 100m), cable type as specified by the circuit diagram, line termination: 120 Ohms

2.1 Settings

The communication parameters are set as follows:

Modbus Slave	SaCoS
Modbus Master	Machinery alarm system
Slave ID (default)	1
Data rate (default)	57600 baud
Data rate (optionally available)	4800 baud 9600 baud 19200 baud 38400 baud 115200 baud
Data bits	8
Stop bits	1
Parity	None
Transmission mode	Modbus RTU

2.2 Function Codes

The following function codes are available to gather data from the SaCoS$_{one}$ controllers:

Function Code	Function Code (hexadecimal)	Description
1	0x01	read coils
3	0x03	read holding registers
5	0x05	write coil
6	0x06	write single register
15	0x0F	write multiple coils
16	0x10	write multiple registers

Function Code	Function Code (hexadecimal)	Description
22	0x16	mask write register
23	0x17	read write multiple registers

2.3 Message Frame Separation

Message frames shall be separated by a silent interval of at least 4 character times.

2.4 Provided Data

Provided data includes measured values and alarm or state information of the engine.

Measured values are digitized analogue values of sensors, which are stored in a fixed register of the Control Module Small. Measured values include media values (pressures, temperatures) where, according to the rules of classification, monitoring has to be done by the machinery alarm system. The data type used is signed integer of size 16 bit. Measured values are scaled by a constant factor in order to provide decimals of the measured.

Pre-alarms, shutdowns and state information from the SaCoS$_{one}$ system are available as single bits in fixed registers. The data type used is unsigned of size 16 bit. The corresponding bits of alarm or state information are set to the binary value „1“, if the event is active.

2.4.1 Contents of List of Signals

For detailed information about the transferred data, please refer to the ”list of signals“ of the engine’s documentation set. This list contains the following information:

Field	Description
Address	The address (e.g.: MW15488) is the software address used in the Control Module Small.
HEX	The hexadecimal value (e.g.: 3C80) of the software address that has to be used by the Modbus master when collecting the specific data.
Bit	Information of alarms, reduce load, shutdown, etc. are available as single bits. Bits in each register are counted 0 to 15.
Meas. Point	The dedicated denomination of the measuring point or limit value as listed in the „list of measuring and control devices“.
Description	A short description of the measuring point or limit value.
Unit	Information about how the value of the data has to be evaluated by the Modbus master (e.g. „°C/100“ means: reading a data value of „4156“ corresponds to 41,56 °C).
Origin	Name of the system where the specific sensor is connected to, or the alarm is generated.
Signal range	The range of measured value.

2.4.2 Live Bit

In order to enable the alarm system to check whether the communication with SaCoS is working, a live bit is provided in the list of signals. This Bit is alternated every 4 seconds by SaCoS. Thus, if it remains unchanged for more than 4 seconds, the communication is down.

3 Modbus ASCII protocol

3.1 General

The communication setup is: 9600 baud, 8 databits, 1 stopbit, no parity.

The Modbus protocol accepts one command (Function Code 03) for reading analogue and digital input values one at a time, or as a block of up to 32 inputs.

The following chapter describes the commands in the Modbus protocol, which are implemented, and how they work.

3.2 Protocol Description

The ASCII and RTU version of the Modbus protocol is used, where the CMS/DM works as Modbus slave.

All data bytes will be converted to 2-ASCII characters (hex-values). Thus, when below is referred to “bytes“ or “words“, these will fill out 2 or 4 characters, respectively in the protocol. The general “message frame format“ has the following outlook:

[:] [SLAVE] [FCT] [DATA] [CHECKSUM] [CR] [LF]

– [:]	1 char. Begin of frame
– [SLAVE]	2 char. Modbus slave address (Selected on DIP-switch at Display Module)
– [FCT]	2 char. Function code
– [DATA]	n X 2 chars data.
– [CHECKSUM]	2 char checksum (LRC)
– [CR]	1 char CR
– [LF]	1 char LF (end of frame)

The following function codes (FCT) is accepted:

- – 03H: Read n words at specific address.
- – 10H: Write n words at specific address.

In response to the message frame, the slave (CMS) must answer with appropriate data. If this is not possible, a package with the most important bit in FCT set to 1 will be returned, followed by an exception code, where the following is supported:

– 01: Illegal function

– 02: Illegal data address

– 03: Illegal data value

– 06: BUSY. Message rejected

FCT = 03H: Read n words

The master transmits an inquiry to the slave (CMS) to read a number (n) of datawords from a given address. The slave (CMS) replies with the required number (n) of datawords. To read a single register (n) must be set to 1. To read block type register (n)

must be in the range 1...32.

Request (master):

[DATA] = [ADR][n]

[ADR]=Word stating the address in HEX.

[n]=Word stating the number of words to be read.

Answer (slave-CMS):

[DATA] = [bb][1. word][2. word]....[n. word]

[bb]=Byte, stating number of subsequent bytes.

[1. word]=1. dataword

[2. word]=2. dataword

[n. word]=No n. dataword

FCT = 10H: Write n words

The master sends data to the slave (CMS/DM) starting from a particular address. The slave (CMS/DM) returns the written number of bytes, plus echoes the address.

Write data (master):

[DATA] = [ADR][n] [bb][1. word][2. word]....[n word]

[ADR] = Word that gives the address in HEX.

[n] = Word indicating number of words to be written.

[bb] = Byte that gives the number of bytes to follow (2*n)

Please note that 8bb9 is byte size!

[1. word]=1. dataword

[2. word]=2. dataword

[n. word]=No n. dataword

Answer (slave-CMS/DM):

[DATA] = [ADR][bb*2]

[ADR]= Word HEX that gives the address in HEX

[bb*2]=Number of words written.

[1. word]=1. dataword

[2. word]=2. dataword

[n. word]=No n. dataword

3.3 Data Format

Example for Modbus ASCII Data Format:

Extract from Modbus ASCII list

MW 113	71	0	F	Signal fault ZS82 : Emergency stop (pushbutton)	SF=1	CMS	binary
		1	F	Signal fault ZS75 : Turning gear disengaged	SF=1	CMS	binary
		2	F	Signal fault SS84 : Remote stop	SF=1	CMS	binary
		3	F	Signal fault SS83 : Remote start	SF=1	CMS	binary
		4	F	Signal fault LAH28 : Lube oil level high	SF=1	CMS	binary
		5	F	Signal fault LAL28 : Lube oil level low	SF=1	CMS	binary
		6	F	Signal fault LAH42 : Fuel oil leakage high	SF=1	CMS	binary
		7	F	Signal fault ZS97 : Remote switch	SF=1	CMS	binary
		8	F	Signal fault LAH92 : OMD alarm	SF=1	CMS	binary
		9	F	Signal fault TAH 29-27 : CCMON alarm	SF=1	CMS	binary
		10	F	Signal fault : Remote reset	SF=1	CMS	binary
		11	F	Signal fault LAH98 : Alternator cooling water leakage alarm	SF=1	CMS	binary
		12	F	Signal fault : Emergency generator mode	SF=1	CMS	binary
		13	F	Signal fault : Speed raise	SF=1	CMS	binary
		14	F	Signal fault : Speed lower	SF=1	CMS	binary
		15	F	Signal fault : Switch isochronous / droop mode	SF=1	CMS	binary

For this example we assume that the following alarms have been triggered:

Signal fault SS83 : Remote start,
Signal fault LAL28 : Lube oil level low,
Signal fault ZS97 : Remote switch,
Signal fault LAH92 : OMD alarm,
Signal fault TAH 29-27 : CCMON alarm,
Signal fault : Emergency generator mode,
Signal fault : Switch isochronous / droop mode

The Bit-sample of MW 113:

Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Value	0	0	0	1	0	1	0	1	1	1	0	0	1	0	0	1

In Modbus ASCII these 16 Bits are grouped in 4 groups each containing 4 Bits and then translated from binary format to hexadecimal format (0-9, A-F)

	Binary	Hex
Bit 0-3	0001	1
Bit 4-7	0101	5
Bit 8-11	1100	C
Bit 12-15	1001	9

In the next step these Hexadecimal values are interpreted as ASCII-signs (extract from ASCII table):

Hexadecimal	ASCII
30	0
31	1
32	2
33	3
34	4
35	5
36	6
37	7
38	8
39	9
41	A
42	B
43	C
44	D
45	E
45	F

In this example the letter (ASCII letter) 1 will be translated hexadecimal value 31 and so on:

1 --> 31

5 --> 35

C --> 43

9 --> 39

When the ship alarm system recalls MW113, it receives the following data embedded in the Modbus message: 31 35 43 39

4 Extended operating hour counters via MODBUS

The operating hour counter and the overload hour counter are available via the Modbus Interface. The maximum range was extended to 1,193,046 hours in CM-Software version 1.2.1.

At the Modbus register addresses MW124 and MW125 the existing operating hour counters are still available to ensure compatibility. These operating hour counters are showing up to 65,535 hours.

Register addresses

The new register addresses for the extended operating hour counter:

- Low word: MW 130
- High word: MW 131

The new register addresses for the extended overload hour counter:

- Low word: MW 132
- High word: MW 133

Data type

The data type used at these registers is **unsigned integer** of size **16 bit**.

To use the extended operating hour counter, connected systems must concatenate two Modbus register addresses in the following way:

MW 130 $\boxed{\text{LW}}$

MW 131 $\boxed{\text{HW}}$

$$\text{OpHour [h]} = ((\boxed{\text{HW}} \times 65536) + \boxed{\text{LW}}) / 3600$$

This procedure is also applicable for the overload hour counter:

MW 132 $\boxed{\text{LW}}$

MW 133 $\boxed{\text{HW}}$

$$\text{OverloadHour [h]} = ((\boxed{\text{HW}} \times 65536) + \boxed{\text{LW}}) / 3600$$

5 Modbus list

The Modbus list is valid for Modbus ASCII and Modbus RTU. The list can be found in the document “SaCoS-one.GENSET_SignListMan_MP_EN_xx.xx.pdf” where “xx.xx” means the actual revision.

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Cabling guideline

Revision 1.1

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Table of contents

1 Scope

This document serves as guideline regarding cabling of engines and control systems. Hereby, an invariant proceeding and quality of cabling should be guaranteed. In addition to that, the normative standards of electrical engineering and requirements of the shipping classification societies must be applied and taken into consideration in reference to cabling.

This guideline contains the following topics:

- General information
- Cutting cables to length and terminating them
- Cable routing
- Cabling of units on engine and control cabinets
- Labelling of cables and component parts.

2 General Principals

- Wiring of sensors, actuators and units on engine have to be carried out according to the wiring diagram.
- The cable insulations must not be damaged.
- By means of the cable routing, it must be guaranteed that there is no damage of cables possible during operation considering the existing operating conditions. These cable routes must be used which are mounted on the engine. The cabling is to be fixed according to this guideline in order to prevent damages caused by vibrations and mechanical influences.
- For cabling, either the listed cables in the parts lists must be used or cables which met the same specifications. Be aware that an altered cable diameter may result in altered cable gland sizes.
- The minimum cross section of the used cables is 0.75mm².
- Only halogen-free cables are to be used.
- Generally, foil shields do have a worse shielding effectiveness than braided shields. When it comes to selecting of cables, those with braided shields must be preferred.

3 Cutting to Length and Terminating Cables

3.1 Stripping the Insulation

- Cables must always be stripped with appropriate tools (insulation stripper, etc.). Hereby, neither the shield nor its coating must be damaged.
- Knives (pocket knives or carpet cutter, among other things) are not suitable for stripping.

3.2 Handling of Shield

3.2.1 General Introduction

- The shield must be continuously unbroken.
- The contacting of the shield must not be carried out by means of plug contacts. EMC-compatible connectors should be used instead.
- Electrical contact of shields should always be carried out using a planar connection. However, the shield must be protected by a heat shrink.

3.2.2 Proper Handling of the Shield

1. Twisting the shielding material according to figure 1.

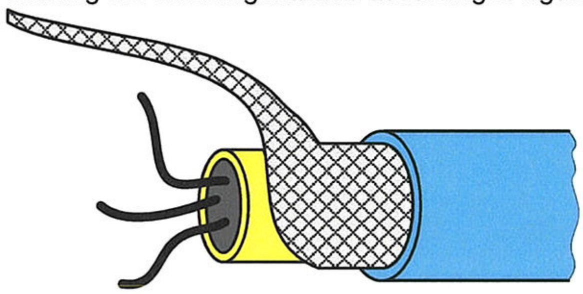

Fig. 1: Twisted shielding material

2. Applying a heat shrink (1) above the shielding material.
3. Applying another heat shrink (2) which reaches over the cable sheath and the first heat shrink and which encloses completely the so far exposed shielding material.

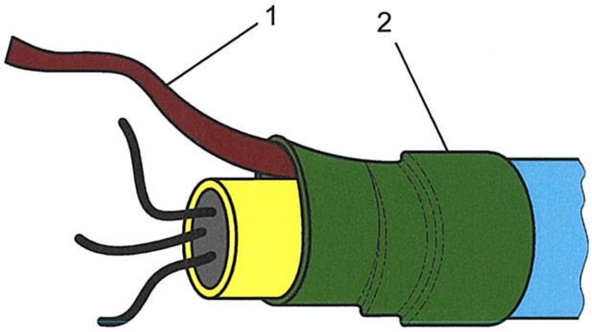

Fig. 2: Applying of heat shrinks

4. Crimping the necessary ferrule on top of the heat shrink.

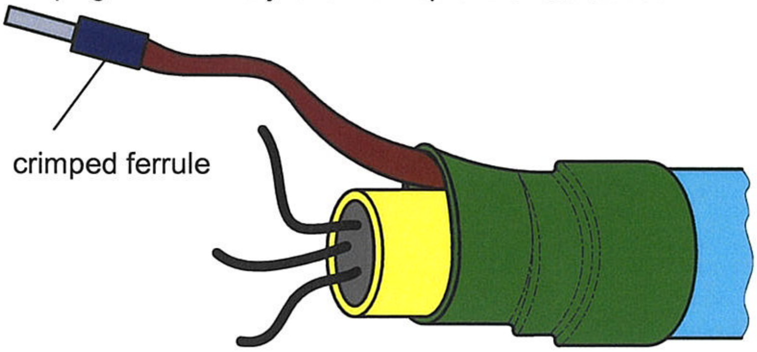

Fig. 3: Correct shielding

If the shielding connection (brown) and wires (black) are longer than the shielded area (light blue), twisted wires must be used instead.
The unshielded areas of the cable must be as short as possible.

The following examples show shieldings that were carried out incorrectly:

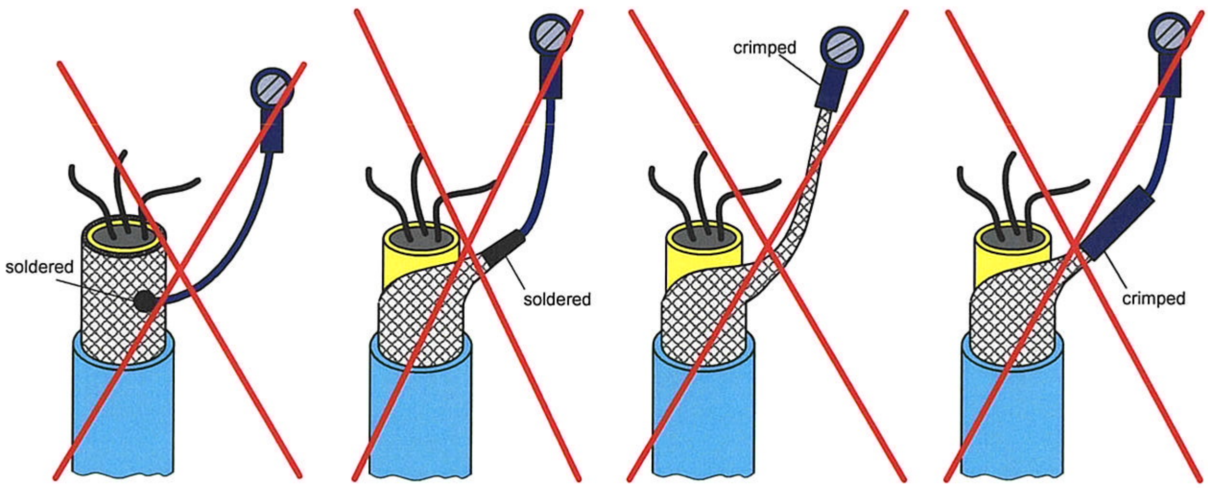

Fig. 4: Examples of incorrect shieldings

Example1 and 2 show a conductor as a shield connection which is soldered to the braid. In the first example the soldered joint is directly above the insulation. It is very likely that the insulation melts during soldering. In addition, there is the risk that the solder metal flows along the braided shielding and that this will stiffen when the metal solidifies. Due to vibrations it is then possible that the braid will break.
However, if the connection is carried out like in the example 3 or 4, the shielding connection will be almost ineffective when it comes to higher frequencies.

3.2.3 Single-sided and two-sided Connection of Shields

The circuit diagram reads, if a shield must be connected on one or both ends of the cable. The following figures show examples regarding single- and two-sided connections:

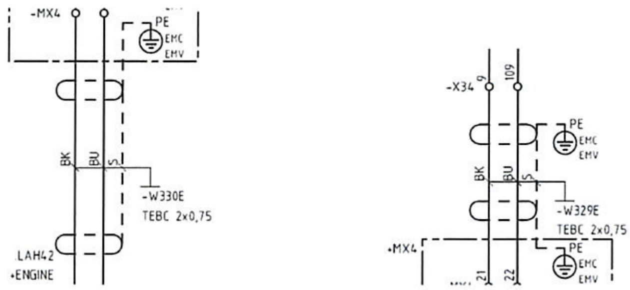

Fig. 5: Left side: single-sided connection; Right side: two-sided shield connection

3.2.4 Shielding of Data Cable and for Pulse Transmitter

Electrical contact of shields should always be carried out using a planar connection. In particular this procedure has to be taken into consideration with frequency converters.

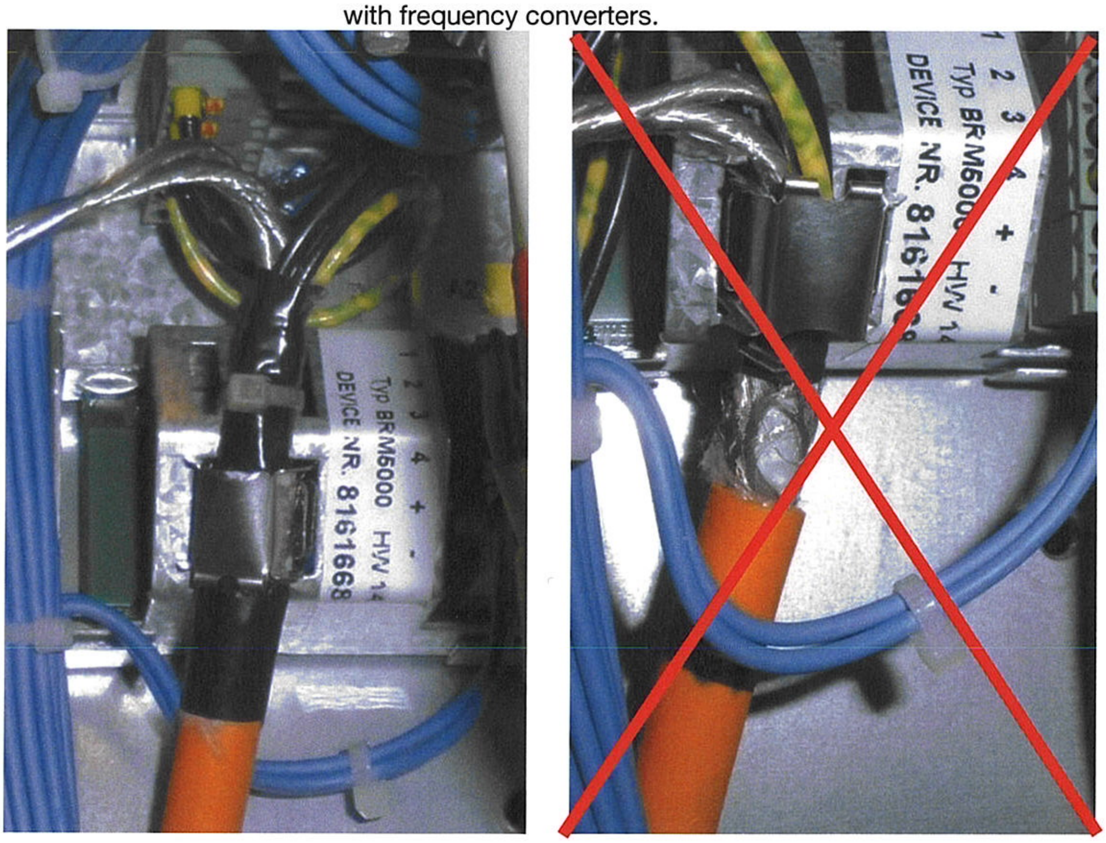

Fig. 6: Correct and incorrect connection of shields on shrouds of a Stöber – frequency converter.

The following figures show two ideal solutions:

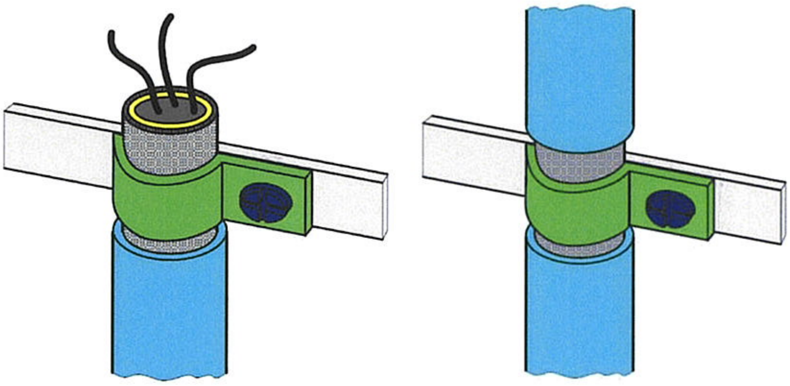

Fig. 7: Planar shielding of data cables with a cable clamp

With any power cables which are used in control cabinets (e.g. Power Stack, Auxiliary Cabinet, and so on) the shield must be applied like this. Hereby, the cable clamp is screwed directly onto the mounting plate.

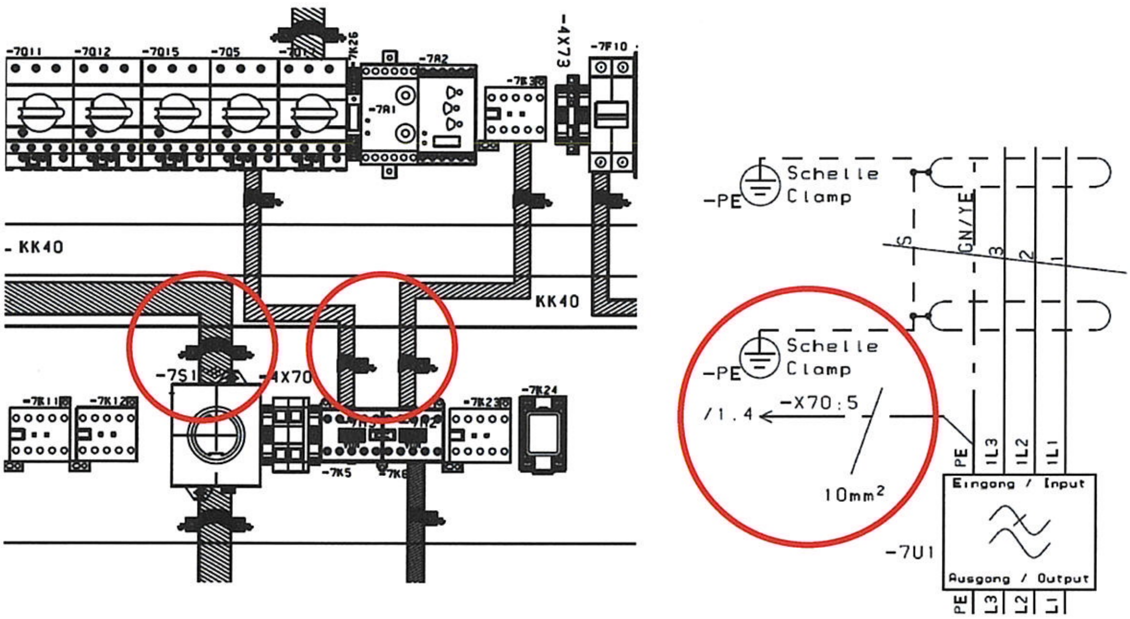

Fig. 8: Example taken from the assembly plan and the circuit diagram of an Auxiliary Cabinet.

3.2.5 Double-Shielded Cables

Regarding especially critical signals (e.g. pulse signals) double shielded cables are used.
Hereby, the outer shield is always connected in a two-sided way. Yet, the inner shield is connected on one end only.

3.3 Using Ferrules

- Clamped or screwed connections must be handled and secured that they cannot loose themselves due to operating influences (changes in temperature, vibrations)
- For screwed clamped connections corresponding ferrules on the receiving ends have to be used
- For spring type terminals, the single wires of the cables must be clamped without ferrules. An exception to this rule is the twin-ferrule. Those can be used with an adequate length (9-10 mm) with spring type terminals, too.
- If two single wires should be connected with one terminal, then corresponding twin-ferrules are to be used. It is not allowed to solder the receiving ends.

3.4 Crimping

3.4.1 General Information

The following aspects must be taken into consideration when you crimp:

- The appropriate crimping tool must be used for the corresponding connection element.
- The corresponding press force of the crimping tool.
- Correct length of the stripped area of the wires.

Hereby, the tool and the press force of the crimping tool must be adapted properly to the crimping connection.

By crimping, if it is carried out correctly, it comes to a gas-tight connection. By deforming of the crimp barrel and the finely stranded conductor, a structure is generated which is vastly separated from oxygen and is consequently protected from corrosion in its inside.

The following connections must be crimped:

- Ferrules must be crimped onto wires that are applied to screw terminals.
- The connector plugs on PT1000 sensors
- The connector plugs on speed control and actuators

When crimping plugs, the specific guidelines from their manufacturers must be met.

3.4.2 Crimping of Ferrules

When ferrules are used, it is particularly important that the wires are stripped at the correct length. Hereby, the wire must end flush with the ferrule. The stripping length varies depending on its ferrule. That is the reason why the length is specified by the manufacturer.

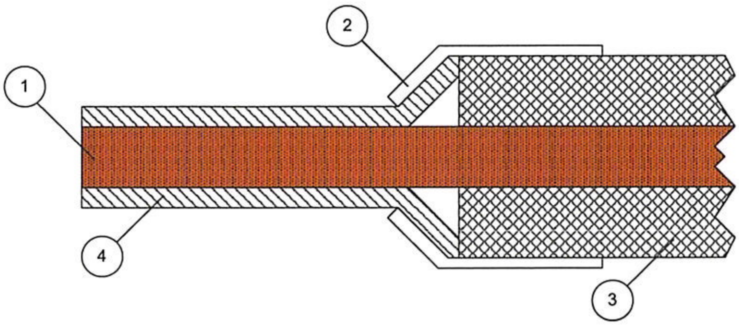

Fig. 9: Wire (1) ends flush with the ferrule (4)

If the stripping length is too short, wires and ferrules will not be properly connected to each other. This may lead to the result that the wires are pulled out of the ferrule.
If the stripping length is too long, there is the risk that the ferrule does not fit completely in the terminal and conductive parts lay bare.
Overlaying wires can be shortened with diagonal pliers.

4 Cable Routing

4.1 General Introduction

- The length of the cables must be sized in a way that operational temperature changes or
- Relative movement (vibrations) does not lead to loosening of cable connections or to operational deterioration. For this purpose it is possible to have a cable loop near the joint.
- When routing the cables, it must be taken into consideration that the cables must not be kinked or squeezed and that they do not twist around.
- If possible, cables must be laid vertically and horizontally.
- Cables must not be routed on sharp edges.
- Cables must be fixed at the attachment points that are especially assigned for that purpose by appropriate means (terminals, cable ties, cable clamp).
- If cable ties are used, they have to be tightened with an appropriate tool, for example with pliers which has got an adjustable tightening torque.
- If possible, signalling cable and power supply cable must be laid separately from each other. Special requirements, for example necessary shieldings must be taken categorically into consideration. Corresponding guidelines in the drawings are obligatory.
- Cables must not be laid without any fixing.
- When cable feedthroughs are done, it is to be taken into consideration that the cables are not to be laid on sharp edges because insulation and sheathings can be damaged. The consequence might be a short

circuit. Cables with damaged sheathings must not be used and have to be substituted.

- Cables must be laid in a way that they cannot have contact with any hot or moving parts. Corresponding safety distances must be maintained and as the case may be, appropriate shieldings or insulations must be provided.
- The damage of cables caused by aggressive media (oil, fuel, chemical substances) must be prevented by laying the cables appropriately or follow adequate safety precautions.

4.2 Bending radii

The following minimum bending radii apply:

- With single shielded cables the minimum bending radius is sixfold the size of the cross section of the cable.
- With double shielded cables the minimum bending radius is tenfold the size of the cross section of the cable.

4.3 Cable Trays

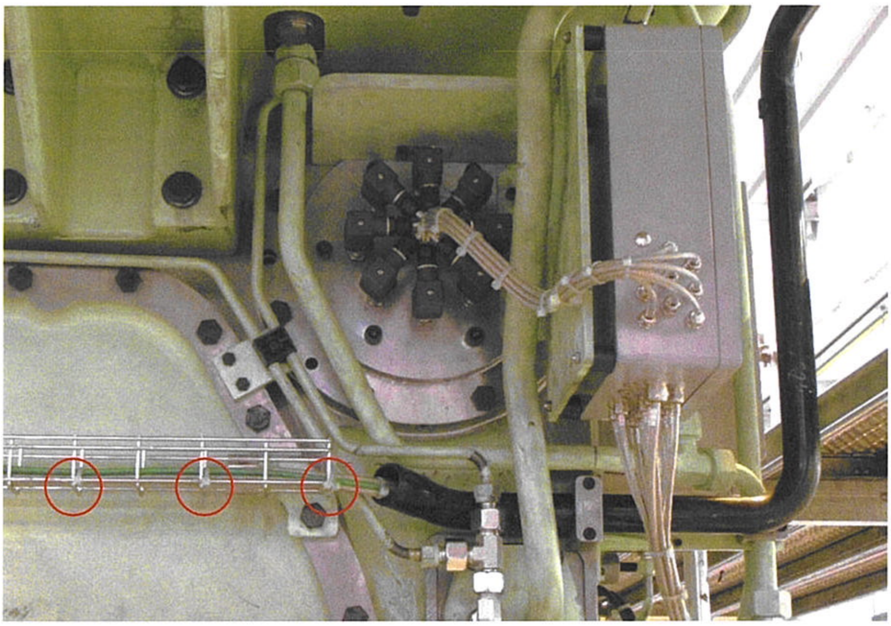

Fig. 10: Cable routing in cable trays and fixing by cable ties. (see red circles)

If cables are laid in cable trays, all cables must be fixed every 10 or 15 cm, or alternatively fixed on every second cross member with cable ties. These prevent that cables are rubbed through due to vibrations. It must be taken into consideration that the sheathing of the cable does not get damaged when the cable ties are tightened.

4.4 Pipes

With the cable conduits it is to be taken into consideration that there are no sharp edges on the ends, where cables can be rubbed through. Therefore, a holding plate with a pipe clamp is fixed. The cables must be fixed at the holding plate with cable ties (see Fig. 10 ducting and fixing cables in cable conduits).

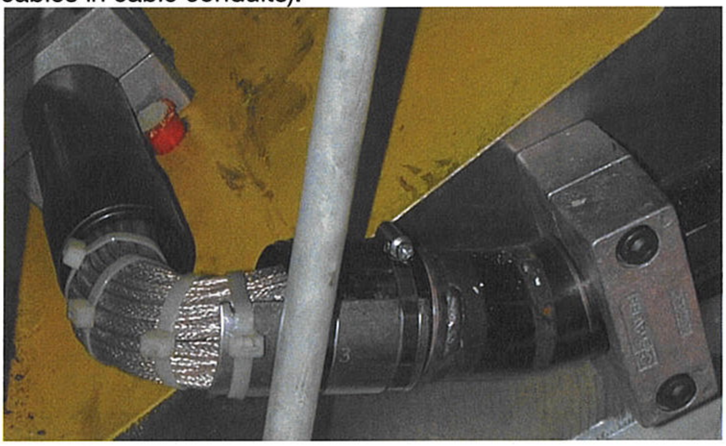

Fig. 11: Ducting and fixing cables in cable conduits

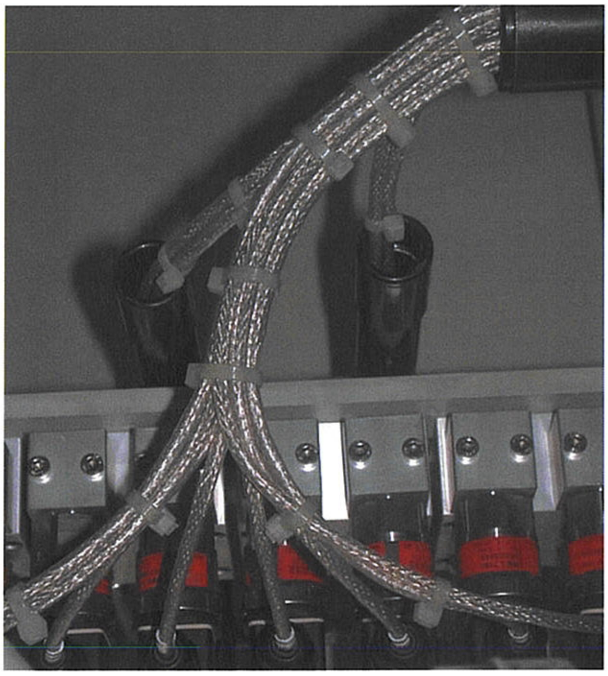

Fig. 12: Bringing together several cable harnesses and their fixing.

If single cables must be laid from the insight of the tube to the outside, the edges of the aperture must be provided with a grommet.

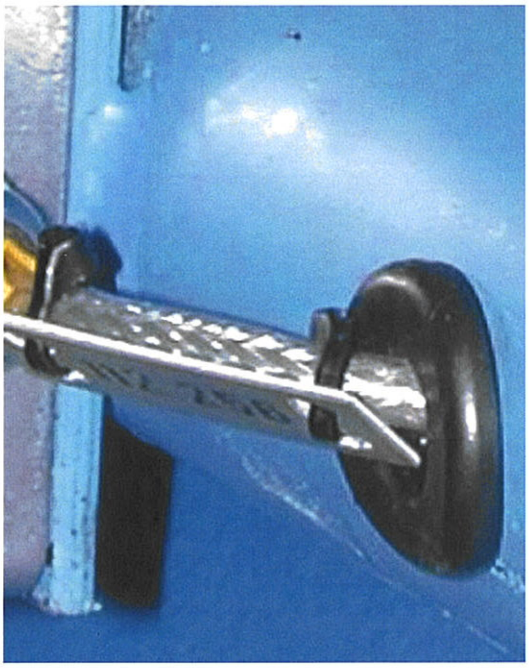

Fig. 13: Leading in a cable into a guide tube.

5 Cabling of Control Cabinets

5.1 Cable Inlets in Units on Engine

It is to be taken into consideration that with shielded cables the shield is mounted correctly within the cable glands and that, consequently, there is a working connection of the cable shield to the ground potential.

5.1.1 Standard Design

This design is made for binary signals. It can be used with analogue signals, too, if there is only a short distance between cable inlet and terminal point (app. <20cm).

1. Lock nut of the cable gland and grommet are moved over the cable end.
2. Strip the cable, reverting the shield in an appropriate length over the grommet.
3. Insert the grommet and cable in the body.
4. Tightening of the lock nut in a way that the necessary ingress protection is reached.

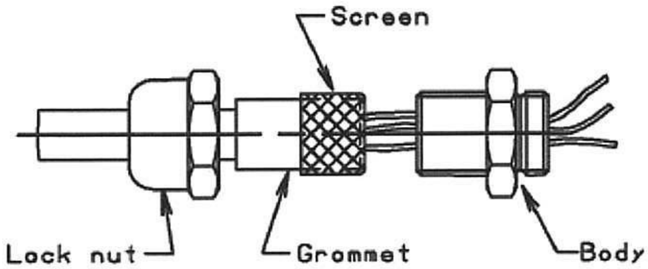

Fig. 14: Installation of the cable gland

5.1.2 Design for EMC-critical Signals

This design is applied for communication cables, frequency signals and analogue signals if the distance between cable inlet and terminal point exceeds 20cm.

The shield should remain unbroken until it reaches the terminal point at the end of the cable. Therefore, the cable end is insulated and the shield must be insulated with a heat shrink once it was led in the cable gland. If the cable gland admits this, the shield can be laid open in the area of the cable gland only, in order to have a proper shield contacting. The remaining outer insulation can then stay on the cable. The stripped insulation at the end of the cable must have a piece of heat shrink on top of the outer insulation.

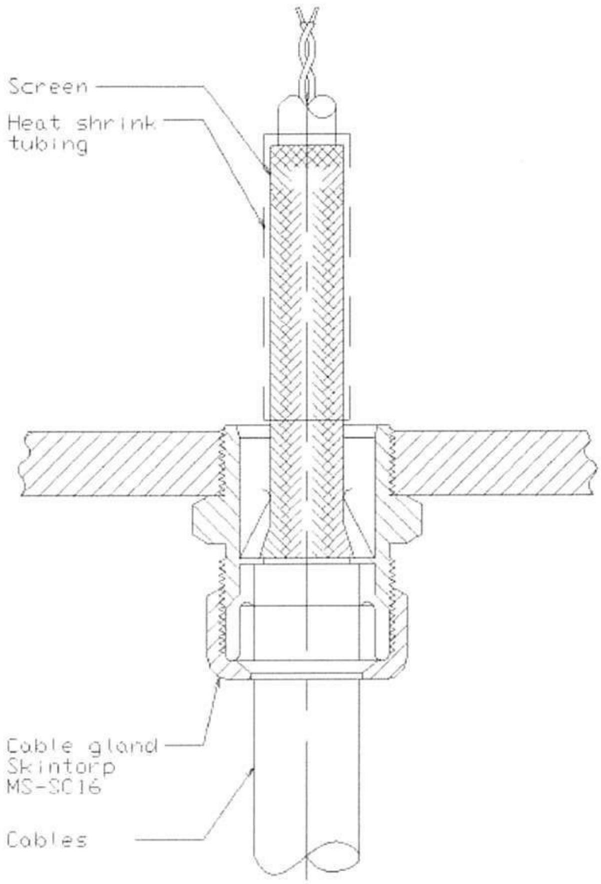

Fig. 15: Attachment of the cable gland with communication cables

5.1.3 Tightening Torques for Cable Glands

Cable glands are mounted onto the supplied flange plate of the control system by the engine manufacturer.
They are fixed on the flange plate with the following torques:

M12	=	4 ±0.5 Nm
M16	=	5 ±0.5 Nm
M20	=	8 ±1 Nm
M25	=	12 ±1 Nm

The gland at the cable must be tightened in a way that the tightening is dense and the degree of ingress protection IP55 is met.

5.2 Fixing and Bundling of Wires in Terminal Boxes

- The wires within the terminal box must be long enough to cover the length that there is no tensile load on single wires even after mounting of the connector plug and the following bundling to the cable harness.
- When the modules are connected by cables, it is to be taken into consideration that at first the wires for a connector plug must be

bundled with cable ties. Afterwards the cables of all connector plugs which are on the module at the same level are put together to one cable harness (see Fig. 15 wired control unit).

- The bundling of the wires must be carried out in a way that the rubbing through of single wires is not possible.
- Overlapping ends of the cable ties must be shortened.
- Wires that are directly connected to terminals must be ducted horizontally or vertically from the cable conduit to the terminal.
- It has to be taken into consideration that an adequate cable gland is used on the same level where the connecting point is in order to keep the cable run in the inside of the terminal box as short as possible.

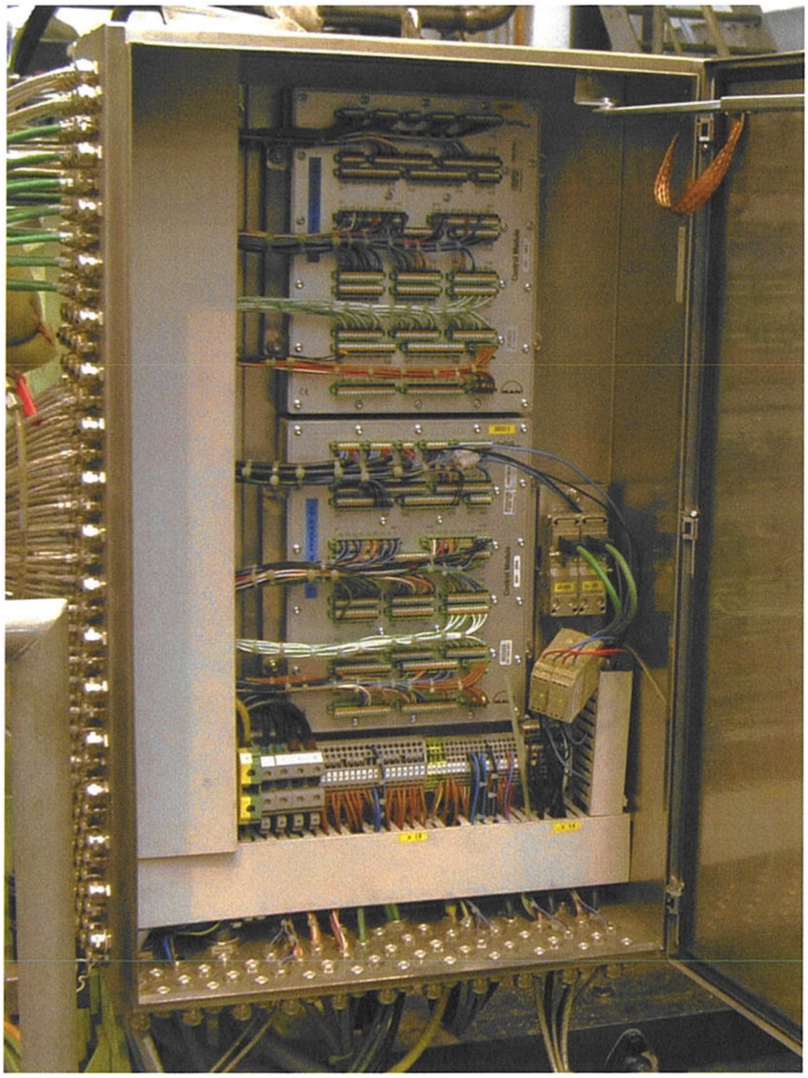

Fig. 16: Wired Control Unit

6 Labelling

6.1 General Instructions

6.1.1 Layout of Labelling

The lettering of adhesive labels and signs must be permanent and easily readable.
Possible damages caused by ambient conditions during the operation of the engine must be taken into consideration as well.

6.1.2 Mounting of Plates and Labels

As a matter of principle, the fixing of the labels and identification markings must be carried out in a way that the plates and labels do not get lost caused by conditions during engine operation.
Among other things, one must pay attention to the following points:

- Extreme temperatures (resistance to cold or heat of adhesives with labels and plates that are glued on)
- Damages caused by chemical materials (e.g. fuel, oil, solvent)
- Mechanical damages (vibrations, rubbing)

First of all, it must be guaranteed that warning notices and instructions are read and taken notice of before entering the danger zone or using operating and controlling devices. They must have the officially valid warning symbols.

6.1.3 Possible Ways of Mounting of Labels and Plates

Foils and plastic labels must be mounted according to their adhesives and material characteristics and the corresponding ambient conditions on their mounting location. Hereby, temperature and chemical resistance have to be taken into consideration especially. When the labels and plates are fixed by means of cable ties or wire loops, it has to be paid attention to the existing operational conditions (vibration) so that they do not change their position or get lost. The sheathing of the cables must not be damaged when the cables are fixed (risk of rubbing through!)

6.2 Inscription of Cables

When the cables are lettered, the following aspects must be taken into consideration:

- The fixing by means of cable ties must withstand permanently the operational conditions.
- The position must be kept and plates and labels must not get lost.
- Cable sheathings must not be damaged.

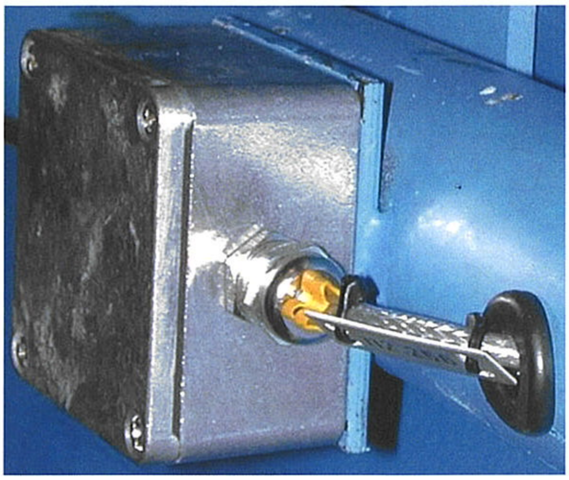

Fig. 17: Mounting of labels with cable ties

6.3 Inscription of Measuring Sensors

6.3.1 Adhesive Labels

If plates are glued on, the adhesive must be appropriate to the existing operational conditions in the engine room (temperature, vibrations). The following pictures show typical applications, how labels must be fixed and how the fixing of plates must be carried out:

Fig. 18: Sensors with glued on aluminium plate

6.3.2 Adhesive Foil

If sensors are labelled with adhesive foil, it has to be appropriate for the existing operational conditions in the engine room.

- Lettering that is permanently readable.
- Temperature - resistant
- Inured to chemical substances

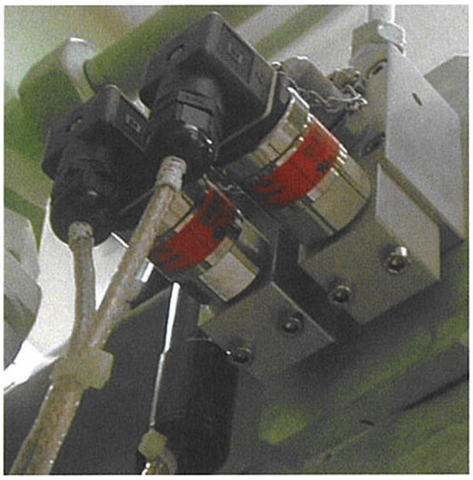

Fig. 19: Sensor with adhesive foil

6.4 Single Wire Numbering

In order to number single wires, marker carriers are put on the wires. Plastic plates which are inserted into the marker carriers afterwards have a permanently printed terminal description.

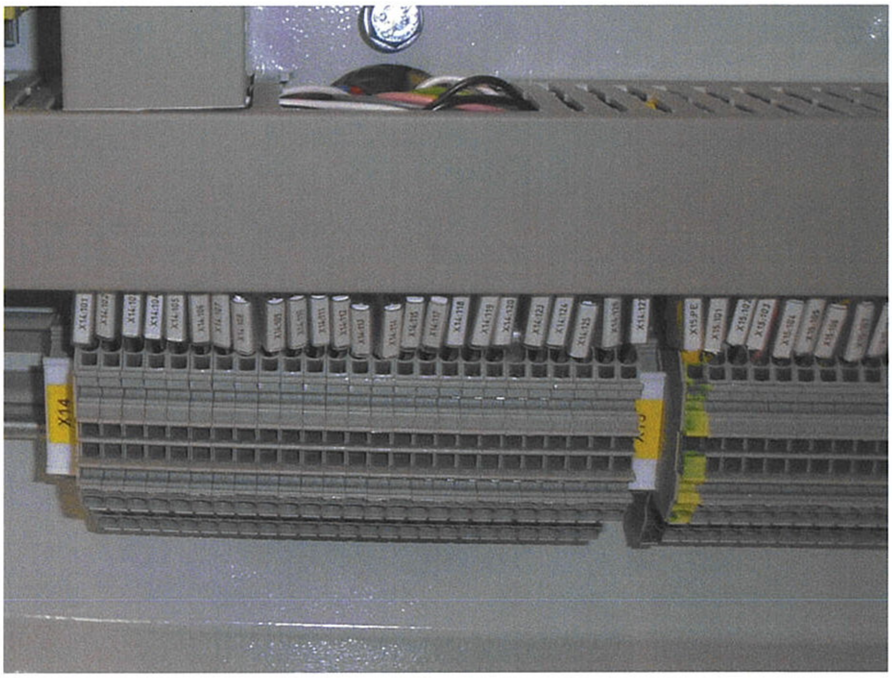

Fig. 20: Example of numbering single wires

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Modbus list

The Modbus list is valid for Modbus ASCII and Modbus RTU

Adress	Hex	Bit	Meas. Point	Description	Unit	Origin	Signal range
MW 0	0		TE60-1	Exhaust gas temperature cylinder A1	°C	CMS	0 - 700
MW 1	1		TE60-2	Exhaust gas temperature cylinder A2	°C	CMS	0 - 700
MW 2	2		TE60-3	Exhaust gas temperature cylinder A3	°C	CMS	0 - 700
MW 3	3		TE60-4	Exhaust gas temperature cylinder A4	°C	CMS	0 - 700
MW 4	4		TE60-5	Exhaust gas temperature cylinder A5	°C	CMS	0 - 700
MW 5	5		TE60-6	Exhaust gas temperature cylinder A6	°C	CMS	0 - 700
MW 6	6		TE60-7	Exhaust gas temperature cylinder A7	°C	CMS	0 - 700
MW 7	7		TE60-8	Exhaust gas temperature cylinder A8	°C	CMS	0 - 700
MW8	8		TE60-9	Exhaust gas temperature cylinder A9	°C	CMS	0 - 700
MW9	9		TE60-10	Exhaust gas temperature cylinder A10	°C	CMS	0 - 700
MW10	A		TE62	Exhaust gas temp. before turbocharger A	°C	CMS	0 - 700
MW11	B		TE61	Exhaust gas temp. after turbocharger A	°C	CMS	0 - 700
MW15	F			Exhaust gas temperature mean value	°C	CMS	0 - 700
MW 16	10	0		Sensor fault TE60-1: Exh. gas temp. cylinder A1	SF=1	CMS	binary
		1		Sensor fault TE60-2: Exh. gas temp. cylinder A2	SF=1	CMS	binary
		2		Sensor fault TE60-3: Exh. gas temp. cylinder A3	SF=1	CMS	binary
		3		Sensor fault TE60-4: Exh. gas temp. cylinder A4	SF=1	CMS	binary
		4		Sensor fault TE60-5: Exh. gas temp. cylinder A5	SF=1	CMS	binary
		5		Sensor fault TE60-6: Exh. gas temp. cylinder A6	SF=1	CMS	binary
		6		Sensor fault TE60-7: Exh. gas temp. cylinder A7	SF=1	CMS	binary
		7		Sensor fault TE60-8: Exh. gas temp. cylinder A8	SF=1	CMS	binary
		8		Sensor fault TE60-9: Exh. gas temp. cylinder A9	SF=1	CMS	binary
		9		Sensor fault TE60-10: Exh. gas temp. cylinder A10	SF=1	CMS	binary
		10		Sensor fault TE62: Exhaust gas temp. before TC A	SF=1	CMS	binary
		11		Sensor fault TE61: Exhaust gas temp. after TC A	SF=1	CMS	binary
MW 17	11	0	TAH60-1	Alarm: High exhaust gas temperature cylinder A1	active=1	CMS	binary
		1	TAH60-2	Alarm: High exhaust gas temperature cylinder A2	active=1	CMS	binary
		2	TAH60-3	Alarm: High exhaust gas temperature cylinder A3	active=1	CMS	binary
		3	TAH60-4	Alarm: High exhaust gas temperature cylinder A4	active=1	CMS	binary
		4	TAH60-5	Alarm: High exhaust gas temperature cylinder A5	active=1	CMS	binary
		5	TAH60-6	Alarm: High exhaust gas temperature cylinder A6	active=1	CMS	binary
		6	TAH60-7	Alarm: High exhaust gas temperature cylinder A7	active=1	CMS	binary
		7	TAH60-8	Alarm: High exhaust gas temperature cylinder A8	active=1	CMS	binary
		8	TAH60-9	Alarm: High exhaust gas temperature cylinder A9	active=1	CMS	binary
		9	TAH60-10	Alarm: High exhaust gas temperature cylinder A10	active=1	CMS	binary
		10	TAH62	Alarm: High exh. gas temp. before turbocharger A	active=1	CMS	binary
		11	TAH61	Alarm: High exhaust gas temp. after turbocharger A	active=1	CMS	binary

Adress	Hex	Bit	Meas. Point	Description	Unit	Origin	Signal range
MW 18	12	0	TAD60-1	Alarm: Mean value deviation exh. gas temp. cyl. A1		CMS	binary
		1	TAD60-2	Alarm: Mean value deviation exh. gas temp. cyl. A2		CMS	binary
		2	TAD60-3	Alarm: Mean value deviation exh. gas temp. cyl. A3		CMS	binary
		3	TAD60-4	Alarm: Mean value deviation exh. gas temp. cyl. A4		CMS	binary
		4	TAD60-5	Alarm: Mean value deviation exh. gas temp. cyl. A5		CMS	binary
		5	TAD60-6	Alarm: Mean value deviation exh. gas temp. cyl. A6		CMS	binary
		6	TAD60-7	Alarm: Mean value deviation exh. gas temp. cyl. A7		CMS	binary
		7	TAD60-8	Alarm: Mean value deviation exh. gas temp. cyl. A8		CMS	binary
		8	TAD60-9	Alarm: Mean value deviation exh. gas temp. cyl. A9		CMS	binary
		9	TAD60-10	Alarm: Mean value deviation exh. gas temp. cyl. A10		CMS	binary
MW 32	20		TE12	HT cooling water temperature engine outlet		CMS	0 - 200
MW 33	21		TE01	LT cooling water temperature air cooler inlet		CMS	0 - 200
MW 34	22		TE21	Lube oil temperature filter inlet		CMS	0 - 200
MW 35	23		TE40	Fuel oil temperature engine inlet		CMS	0 - 200
MW 36	24		TE31	Charge air temperature cooler outlet		CMS	0 - 200
MW 37	25		TE98-1	Alternator windwing temperature L1		CMS	0 - 200
MW 38	26		TE98-2	Alternator windwing temperature L2		CMS	0 - 200
MW 39	27		TE98-3	Alternator windwing temperature L3		CMS	0 - 200
MW 40	28		TE38	Ambient air temperature		CMS	0 - 200
MW 41	29		TE10	HT cooling water temperature engine inlet		CMS	0 - 200
MW 42	2A		TE27-1	Alternator front bearing temperature		CMS	0 - 200
MW 43	2B		TE27-2	Alternator rear bearing temperature		CMS	0 - 200
MW 48	30	0		Sensor fault TE12 : HT cool water temp. engine outlet		CMS	binary
		1		Sensor fault TE01 : LT cool water temp. air cooler inlet		CMS	binary
		2		Sensor fault TE21 : Lube oil temperature filter inlet		CMS	binary
		3		Sensor fault TE40 : Fuel oil temperature engine inlet		CMS	binary
		4		Sensor fault TE31 : Charge air temp. cooler outlet		CMS	binary
		5		Sensor fault TE98-1 : Alternator windwing temp. L1		CMS	binary
		6		Sensor fault TE98-2 : Alternator windwing temp. L2		CMS	binary
		7		Sensor fault TE98-3 : Alternator windwing temp. L3		CMS	binary
		8		Sensor fault TE38 : Ambient air temperature		CMS	binary
		9		Sensor fault TE10 : HT cool. water temp. engine inlet		CMS	binary
		10		Sensor fault TE27-1 : Alternator front bearing temp.		CMS	binary
		11		Sensor fault TE27-2 : Alternator rear bearing temp.		CMS	binary

Adress	Hex	Bit	Meas. Point	Description	Unit	Origin	Signal range
MW 64	40		PT10	HT cooling water pressure		CMS	
MW 65	41		PT01	LT cooling water pressure		CMS	
MW 66	42		PT21	Lube oil pressure filter inlet		CMS	
MW 67	43		PT22	Lube oil pressure filter outlet		CMS	
MW 68	44		PT23	Lube oil pressure TC		CMS	
MW 69	45		PT40	Fuel oil pressure engine inlet		CMS	
MW 70	46		PT31	Charge air pressure cooler outlet		CMS	
MW 71	47		PT70	Start air pressure		CMS	
MW 72	48		PT43	Fuel oil pressure filter inlet		CMS	
MW 73	49		ZT59	Alternator load		CMS	
MW 74	4A		ZT45	Fuel rack position		CMS	
MW 75	4B		PT38	Ambient air pressure		CMS	
MW 76	4C			Analog speed setpoint		CMS	
MW 80	50	0		Sensor fault PT10 : HT cooling water pressure		CMS	binary
		1		Sensor fault PT01 : LT cooling water pressure		CMS	binary
		2		Sensor fault PT21 : Lube oil pressure filter inlet		CMS	binary
		3		Sensor fault PT22 : Lube oil pressure filter outlet		CMS	binary
		4		Sensor fault PT23 : Lube oil pressure TC		CMS	binary
		5		Sensor fault PT40 : Fuel oil pressure engine inlet		CMS	binary
		6		Sensor fault PT31 : Charge air press. cooler outlet		CMS	binary
		7		Sensor fault PT70 : Start air pressure		CMS	binary
		8		Sensor fault PT43 : Fuel oil pressure filter inlet		CMS	binary
		9		Sensor fault ZT59 : Alternator load		CMS	binary
		10		Sensor fault ZT45 : Fuel rack position		CMS	binary
		11		Sensor fault PT38 : Ambient air pressure		CMS	binary
		12		Sensor fault : Analog speed setpoint		CMS	binary
MW 96	60		SE90	Engine speed		CMS	0..2000
MW 97	61		SE89	TC speed		CMS	0..70000
MW 112	70	0	SE90-1	Sensor fault engine speed pick up 1		CMS	binary
		1	SE90-2	Sensor fault engine speed pick up 2		CMS	binary
		2	SE90-1	Sensor fault engine speed pick up 1		DM	binary
		3	SE90-2	Sensor fault engine speed pick up 2		DM	binary
		4	SE89	Sensor fault TC speed pick up		CMS	binary
MW 113	71	0		Signal fault ZS82 : Emergency stop (pushbutton)		CMS	binary
		1		Signal fault ZS75 : Turning gear disengaged		CMS	binary
		2		Signal fault SS84 : Remote stop		CMS	binary
		3		Signal fault SS83 : Remote start		CMS	binary
		4		Signal fault LAH28 : Lube oil level high		CMS	binary
		5		Signal fault LAL28 : Lube oil level low		CMS	binary
		6		Signal fault LAH42 : Fuel oil leakage high		CMS	binary
		7		Signal fault ZS97 : Remote switch		CMS	binary
		8		Signal fault LAH92 : OMD alarm		CMS	binary
		9		Signal fault TAH 29-27 : CCMON alarm		CMS	binary
		10		Signal fault : Remote reset		CMS	binary
		11		Signal fault LAH98 : Altern. cool w. leakage alarm		CMS	binary
		12		Signal fault : Emergency generator mode		CMS	binary
		13		Signal fault : Speed raise		CMS	binary
		14		Signal fault : Speed lower		CMS	binary
		15		Signal fault : Switch droop / isochronous mode		CMS	binary

Adress	Hex	Bit	Meas. Point	Description	Unit	Origin	Signal range
MW 114	72	0 4 13 15		Spare Signal fault : Actuator signal Signal fault SS83 : Start solenoid valve Signal fault SS32 : Jet system valve		CMS CMS CMS CMS	binary binary binary binary
MW 115	73	0 2 3 4		Spare Signal fault ZS34-1 : Charge air blow off valve 1 Signal fault ZS34-2 : Charge air blow off valve 2 Signal fault: VIT feedback position		CMS CMS CMS CMS	binary binary binary binary
MW 116	74	0 1 2 3 4 5 6 7 9 10 11 12		Sensor fault TSH12 : HT cool water engine outlet termostate Sensor fault PSL22 : Lube oil eng. inlet pressostate Sensor fault ZS82 : Emergency stop (pushbutton) Sensor fault LSH92 : OMD shutdown Sensor fault TSH27-29 : CCMON shutdown Sensor fault ZX92 : OMD system failure Sensor fault ZX27-29 : CCMON system failure Sensor fault : Remote shutdown Sensor fault ZS30-2 : Charge air press. relief valve Sensor fault ZS30-1 : Charge air shut off flap Sensor fault SS86-1 : Emergency stop valve Signal fault ZS82 : Emergency stop (pushbutton)		DM DM DM DM DM DM DM DM DM DM DM DM	binary binary binary binary binary binary binary binary binary binary binary binary
MW 117	75	0 1 2 3 4 5		CAN-1 error CAN-2 error Communication error to CMS Backlight error Ethernet communication error Wirebrake supervision of remote signals disabled		DM DM DM DM DM DM	binary binary binary binary binary binary
MW 118	76	0 1 2 3 10 11 12 15		CAN-1 error CAN-2 error CAN-3 error Communication error to DM Emergency generator mode MDO used HFO used Live-Bit (status changes at least every 5 seconds)		CMS CMS CMS CMS CMS CMS CMS CMS	binary binary binary binary binary binary binary binary
MW 119	77	0 1 2 3 4 5 6 7		Shutdown : HT cool. water temp. engine outlet high Shutdown overridden : HT cool. water temp. engine outlet high Shutdown : Lube oil pressure filter outlet low Shutdown overridden : Lube oil press. filter outl. low Shutdown : Engine overspeed Shutdown : Actuator Error Shutdown : Double Pick-Up Error Shutdown : Stop failure		CMS CMS CMS CMS CMS CMS CMS CMS	binary binary binary binary binary binary binary binary

Adress	Hex	Bit	Meas. Point	Description	Unit	Origin	Signal range
MW 120	78	0 1 2 3 4 5 6 7 8 9 10		Shutdown : HT cool. water temp. engine outlet high Shutdown overridden : HT cool. water temp. eng. outlet high Shutdown : Lube oil pressure filter outlet low Shutdown overridden : Lube oil press. filter outl. low Shutdown : Engine overspeed Shutdown : OMD Shutdown overridden : OMD Shutdown : CCMON Shutdown overridden : CCMON Shutdown : Emergency stop active Shutdown : Remote Shutdown		DM DM DM DM DM DM DM DM DM DM/ CMS DM	binary binary binary binary binary binary binary binary binary binary binary
MW 121	79	0 1 2 3 4 5 6 7 8 9 11 12 13 14 15		Alarm : HT cooling water temp. engine outlet high Alarm : Lube oil pressure filter outlet low Alarm : Engine overspeed Alarm LAH28 : Lube oil level high Alarm LAL28 : Lube oil level low Alarm LAH42 : Fuel oil leakage Alarm FE94 : Cylinder lubrication no flow Alarm LAL98 : Alternator cooling water leakage Alarm : Start failure Alarm PAL25: Prelub. Oil pressure low Alarm : Startpreparation failure Alarm : Engine running error Alarm PAL01 : L.T. cooling water pressure low Alarm PAL10 : H.T. cooling water pressure low Alarm PDAH21-22 : Diff. pressure lube oil filter high		CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS	binary binary binary binary binary binary binary binary binary binary binary binary binary binary binary
MW 122	7A	0 1 2 3 4 5 6 7 8 9 10 11 12 14 15		Alarm TAH21 : Lube oil temperature filter inlet high Alarm PAL23 : Lube oil pressure TC low Alarm PDAH40-43 : Diff. pressure fuel oil filter high Alarm PAL40 : Fuel oil pressure engine inlet low Alarm PAL70 : Start air pressure low Alarm TAH98-1 : Alternator winding temp. L1 high Alarm TAH98-2 : Alternator winding temp. L2 high Alarm TAH98-3 : Alternator winding temp. L3 high Alarm TAH29-1 : Alternator front bearing temp. high Alarm TAH29-2 : Alternator rear bearing temp. high Alarm : OMD Alarm : CCMON Alarm : TC Overspeed Alarm: Cylinder Lubrication Error Alarm: Prelube pressure low		CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS CMS	binary binary binary binary binary binary binary binary binary binary binary binary binary binary binary

Adress	Hex	Bit	Meas. Point	Description	Unit	Origin	Signal range
MW 123 MW 124	7B 7C	0 1 2 3 5		Alarm ZX92 : OMD system failure Alarm ZX27-29 : CCMON system failure Alarm: VIT positioning Error Alarm: CAN 3 Error - VIT communication Error Alarm: Jet System Error Operating hour counter		DM DM DM DM DM CMS	binary binary binary binary binary 0..65535
MW 125	7D			Overload hour counter	h	CMS	0..65535
MW 126	7E	0 1		Load reduction request: VIT emergency mode error Load reduction request overridden : VIT emerg. mode error	active=1 active=1	DM DM	binary binary
MW 127	7F			Start of spare			
MW 1799	707			End of spare			

Oil mist detector

Description

The oil mist detector type Tufmon from company Dr. Horn is standard on the 7, 8 and 9L27/38 engine types and option for all other engine types.

The oil mist detector is based on direct measurement of the oil mist concentration in the natural flow from the crankcase to the atmosphere.

The detector is developed in close cooperation between the manufacturer Dr. Horn and us and it has been tested under realistic conditions at our testbed.

The oil mist sensor is mounted on the venting pipe together with the electronic board. At first the sensor will activate an alarm, and secondly the engine will be stopped, in case of critical oil mist concentration. Furthermore there is an alarm in case of sensor failure. To avoid false alarms direct heating of the optical sensor is implemented.

The installation is integrated on the engine. No extra piping/cabling is required.

Technical data

Power supply	: 24 V DC +30% / -25%
Power consumption	: 1 A
Operating temperature	: 0°C....+70°C

Enclosure according to DIN 40050:

Analyzer	: IP54
Speed fuel rack and optical sensors	: IP67
Supply box and connectors	: IP65

Figure 1: Oil mist detector.

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Combined box with prelubricating oil pump, preheater and el turning device

Description

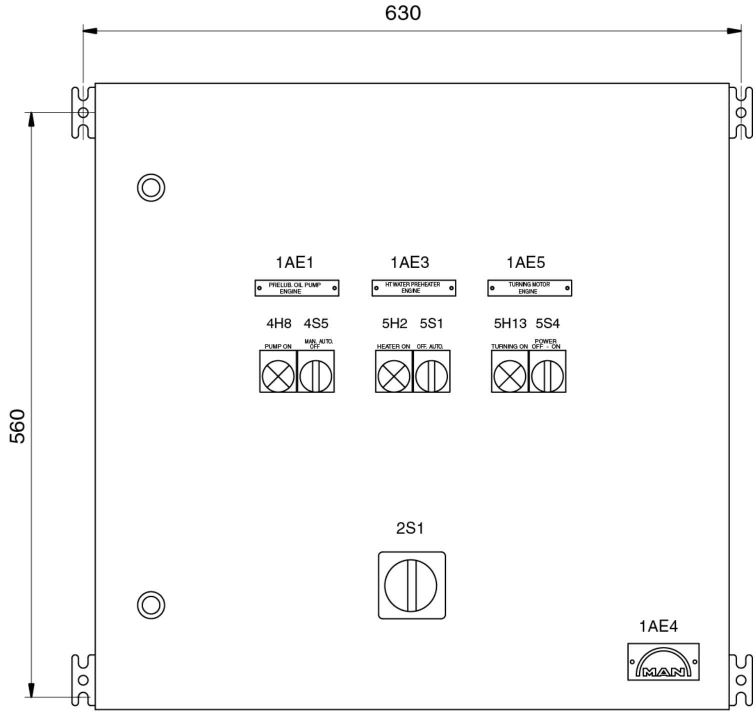

Figure 1: Dimensions

The box is a combined box with starters for prelubricating oil pump, preheater and el turning device.

The starter for prelubricating oil pump is for automatic controlling start/stop of the prelubricating oil pump built onto the engine.

Common for both pump starters in the cabinet is overload protection and automatic control system. On the front of the cabinet there is a lamp for "pump on", a change-over switch for manual start and automatic start of the pump; furthermore there is a common main cut-off switch.

The pump starter can be arranged for continuous or intermittent running. (For engine types L16/24, L21/31 & L27/38 only continuous running is accepted). *See also B 12 07 0, Prelubricating Pump.*

The preheater control is for controlling the electric heater built onto the engine for preheating of the engines jacket cooling water during stand-still.

On the front of the cabinet there is a lamp for "heater on" and a off/auto switch. Furthermore there is overload protection for the heater element.

The temperature is controlled by means of an on/off thermostat mounted in the common HT-outlet pipe. Furthermore the control system secures that the heater is activated only when the engine is in stand-still.

The box also include the control of el turning device. There is a "running" indication lamp and a on/off power switch on the front. The control for the turning gear is prepared with to contactors for forward and reverse control. The turning gear control has also overload protection.

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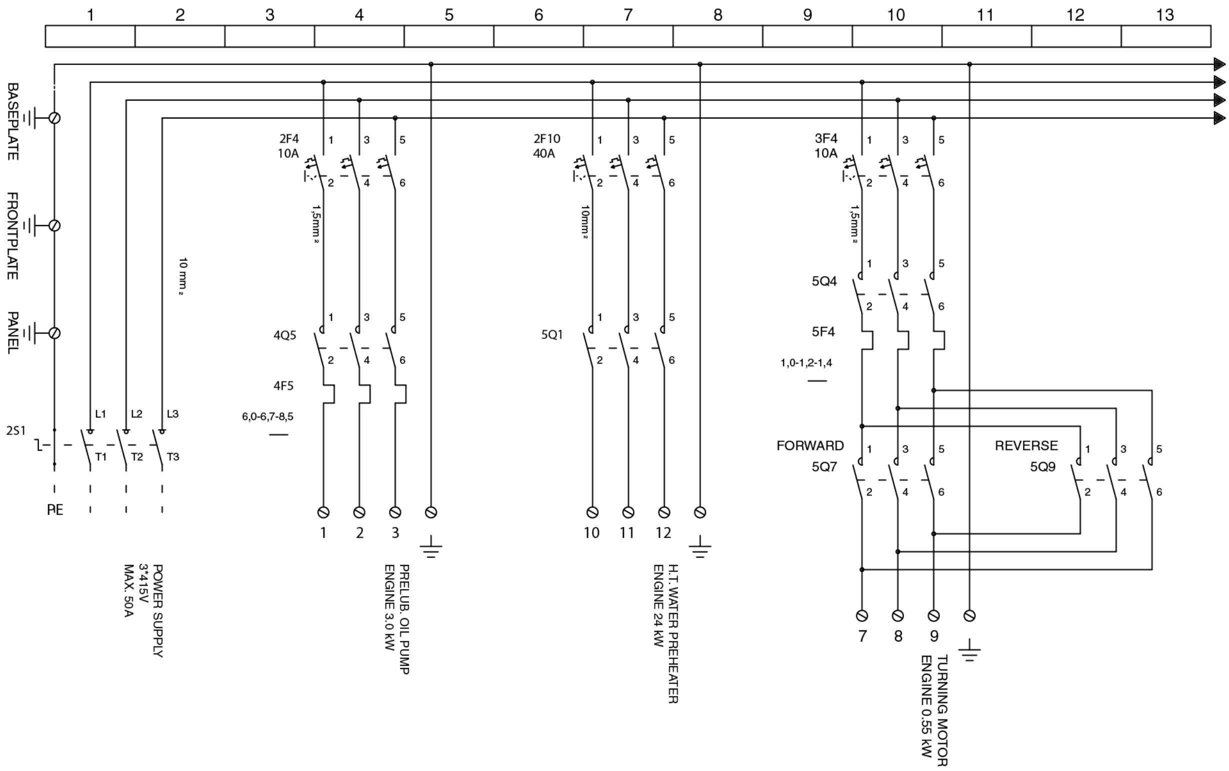

Figure 2: Wiring diagram

Prelubricating oil pump starting box

Description

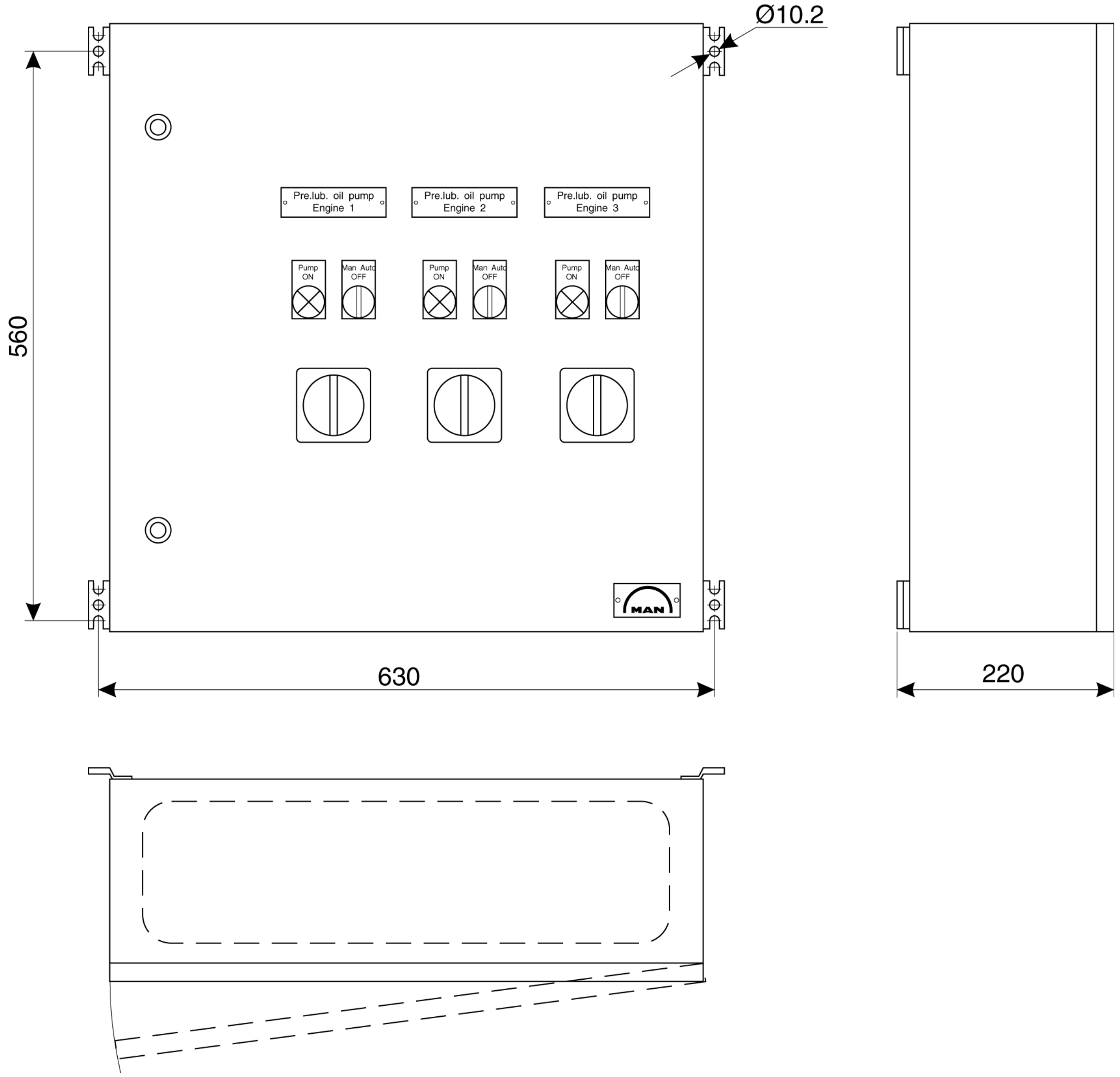

Figure 1: Dimensions.

The prelubricating oil pump box is for controlling the prelubricating oil pump built onto the engine.

The control box consists of a cabinet with starter, overload protection and control system. On the front of the cabinet there is a lamp for "pump on", a change-over switch for manual start and automatic start of the pump, furthermore there is a main switch.

The pump can be arranged for continuous or intermittent running. (For L16/24, L21/31 and L27/38 only continuous running is accepted).

Depending on the number of engines in the plant, the control box can be for one or several engines.

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The prelubricating oil pump starting box can be combined with the high temperature preheater control box. *See also B 12 07 0, Prelubricating Pump.*

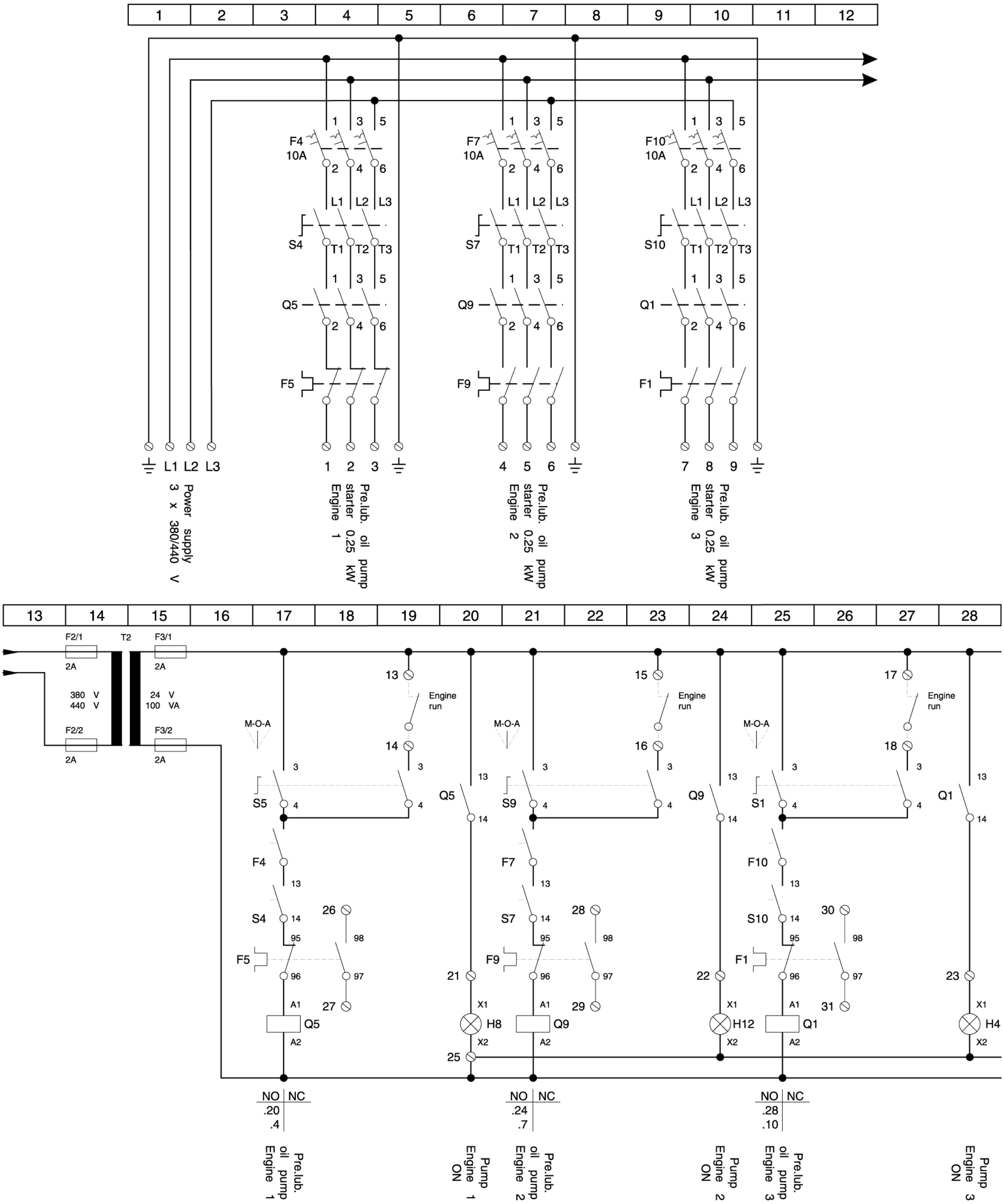

Figure 2: Wiring diagram.

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Recommendations concerning steel foundations for resilient mounted GenSets

Foundation recommendations

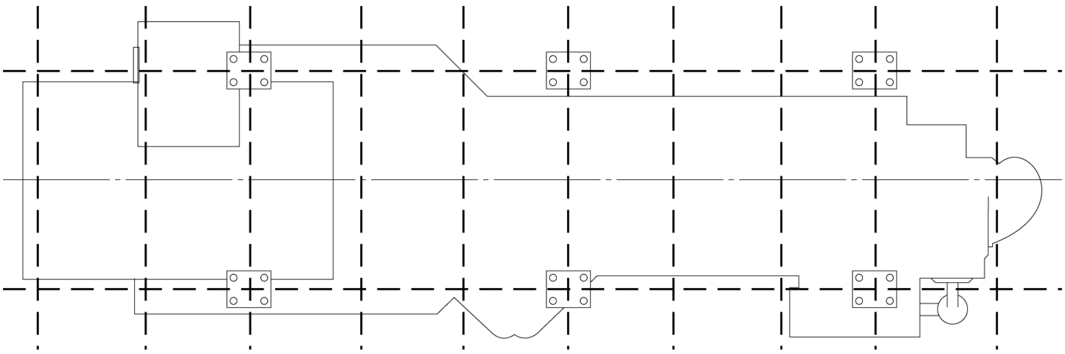

Figure 1: Resilient supports.

When the generating sets are installed on a transverse stiffened deck structure, it is generally recommended to strengthen the deck by a longitudinal stiffener in line with the resilient supports, *see fig 1.*

For longitudinal stiffened decks it is recommended to add transverse stiffening below the resilient supports.

It is a general recommendation that the steel foundations are in line with both the supporting transverse and longitudinal deck structure, *fig 2,* in order to obtain sufficient stiffness in the support of the resilient mounted generating sets.

The strength and the stiffness of the deck structure has to be based on the actual deck load, i.e. weight of machinery, tanks etc. and furthermore, resonance with the free forces and moments from especially the propulsion system have to be avoided.

Stiffness for foundation has to be minimum the following:

- Z-direction, stiffness for foundation has to be minimum 20 times the conical stiffness.
- Y-direction, stiffness for foundation has to be minimum 10 times the conical stiffness.
  (see fig 3)

Example for conical stiffness:

- RD314-45 Shore A to 65 Shore A - stiffness 4.865 kN/m to12.660 kN/m (Preload 30 kN - 20 deg. C)

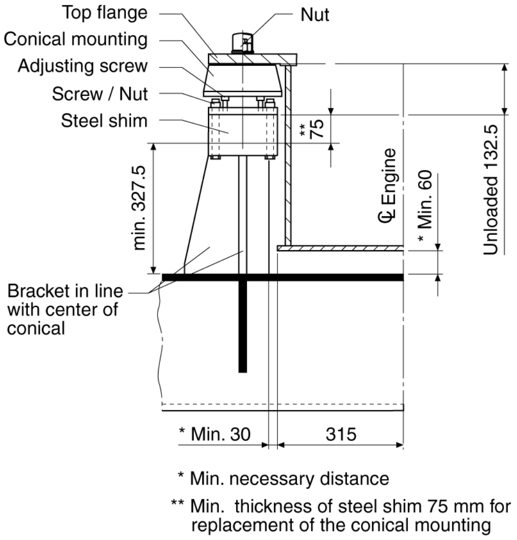

Figure 2: Transverse stiff deck structure.

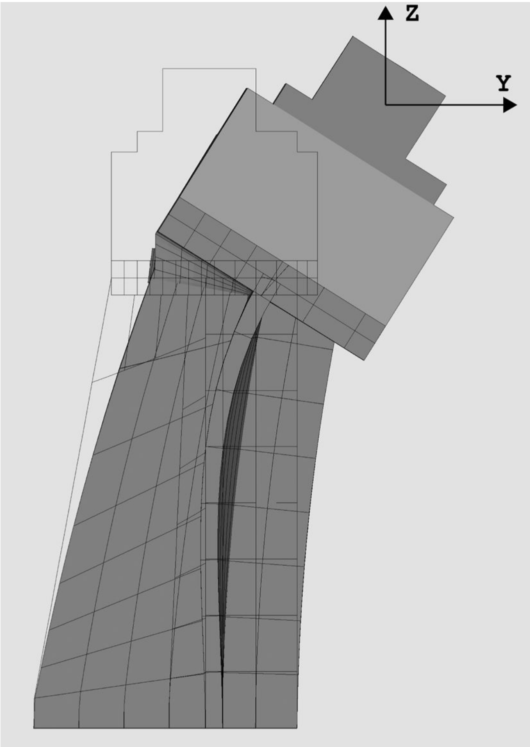

Figure 3: Stiffness for foundation

Resilient mounting of generating sets

Resilient Mounting of Generating Sets

On resiliently mounted generating sets, the diesel engine and the alternator are placed on a common rigid base frame mounted on the ship's/machine house's foundation by means of resilient supports, Conical type.

All connections from the generating set to the external systems should be equipped with flexible connections and pipes. Gangway etc. must not be welded to the external part of the installation.

Resilient support

A resilient mounting of the generating set is made with a number of conical mountings. The number and the distance between them depend on the size of the plant. These conical mountings are bolted to the top flange of the base frame (*see fig 1*).

The setting from unloaded to loaded condition is normally between 5-11 mm for the conical mounting.

The support of the individual conical mounting can be made in one of the following three ways:

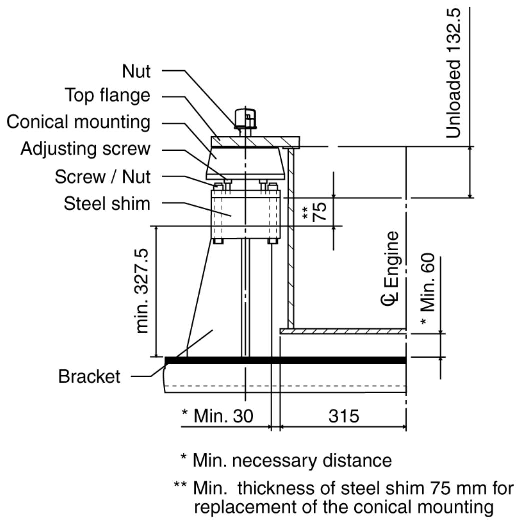

Figure 1: Resilient mounting of generating sets.

1. The support between the bottom flange of the conical mounting and the foundation is made with a loose steel shim. This steel shim is adjusted to an exact measurement (min. 75 mm) for each conical mounting.
2. The support can also be made by means of two steel shims, at the top a loose steel shim of at least 75 mm and below a steel shim of at least 10 mm which are adjusted for each conical mounting and then welded to the foundation.

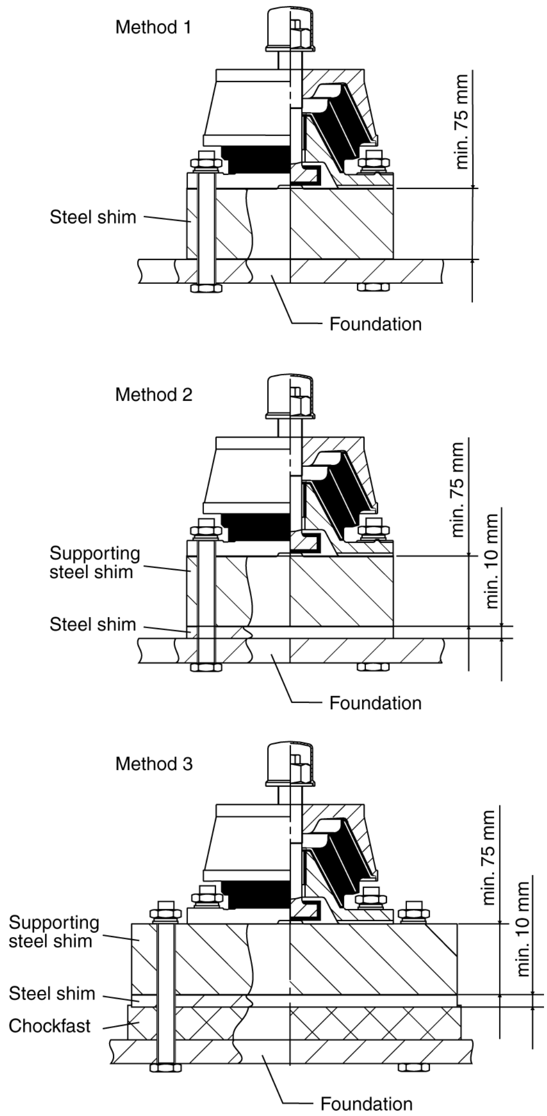

Figure 2: Support of conicals

1. Finally, the support can be made by means of chockfast. It is necessary to use two steel shims, the top steel shim should be loose and have a minimum thickness of 75 mm and the bottom steel shim should be cast in chockfast with a thickness of at least 10 mm.

Irrespective of the method of support, the 75 mm steel shim is necessary to facilitate a possible future replacement of the conical mountings, which are always replaced in pairs.

Check of Crankshaft Deflection (Optional)

The resiliently mounted generating set is normally delivered from the factory with engine and alternator mounted on the common base frame.
Eventhough engine and alternator have been adjusted by the engine builder, with the alternator rotor placed correctly in the stator and the crankshaft deflection of the engine (autolog) within the prescribed tolerances, it is recommended to check the crankshaft deflection (autolog) before starting up the GenSet.

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Shop test programme for marine GenSets

Requirement of the classification societies

Operating points	ABS	BV	DNV	GL	LR	RINA	NK	IACS	MAN Energy Solutions 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)									

2019-03-18 - 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:

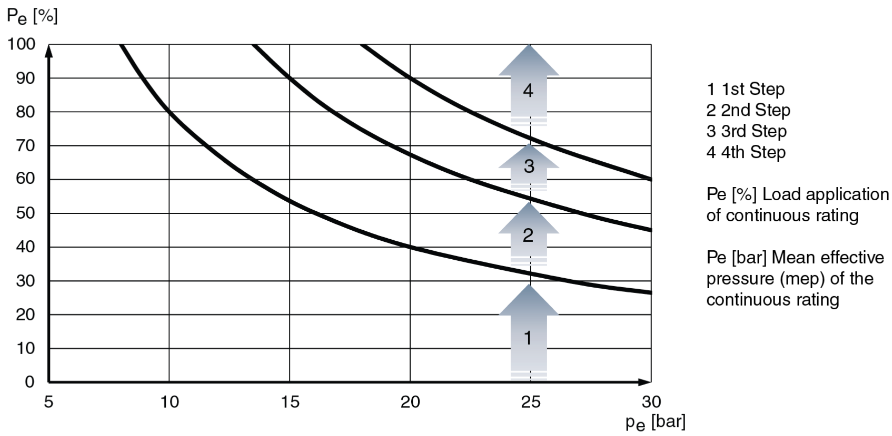

Fig. 1 Load application in steps as per IACS and ISO 8528-5.

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.

New Node

<table>
<tr><th>Engine</th><th>bmep (bar) *</th><th>1 st step</th><th>2nd step</th><th>3th step</th><th>4th step</th></tr>
<tr><td>L16/24</td><td>22.4/23.6
-20.7/22.8</td><td rowspan="5">IACS 33%
MDT 34%</td><td rowspan="5">IACS 23%
MDT 33%</td><td rowspan="5">IACS 18%
MDT 33%</td><td rowspan="5">IACS 26%</td></tr>
<tr><td>L23/30H</td><td>18.2 - 18.1 - 17.9</td></tr>
<tr><td>L21/31</td><td>24.9/27.3
-22.4/24.6</td></tr>
<tr><td>L27/38</td><td>23/25.3 -23.5/24.3</td></tr>
<tr><td>L28/32H</td><td>17.8 -17.9</td></tr>
<tr><td colspan="6">* see project guide B 10 01 1 'main particulars', for actual bmep at nominel rpm.</td></tr>
</table>

Fig. 2. maximum allowable load application steps (higher load steps than listed are not possible as a standard)

<table>
<tr><td>L23/30DF
Diesel</td><td rowspan="2">IACS
MDT</td><td rowspan="2">IACS
MDT</td><td rowspan="2">IACS
MDT</td><td rowspan="2">IACS
MDT</td></tr>
<tr><td>L28/32DF
Diesel</td></tr>
<tr><td>L23/30DF Gas</td><td rowspan="2">20%</td><td rowspan="2">20%</td><td rowspan="2">20%</td><td rowspan="2">20%</td></tr>
<tr><td>L28/32DF Gas</td></tr>
<tr><td colspan="5">0-20% load on diesel. Approximately 20% load switch over to gas</td></tr>
</table>

Regulating test and load responce performance

Load step on MAN Energy Solutions GenSets is to be tested according to following procedure.

<table>
<tr><th>Classification society</th><th>Dynamic speed drop in % of the nominal speed</th><th>Remaining speed variation in % of the nominal speed</th><th>Recovery time until reaching the tolerance band ±1 % of nominal speed</th></tr>
<tr><td>Germanischer Lloyd</td><td rowspan="7">≤ 10 %</td><td rowspan="7">≤ 5 %</td><td rowspan="7">≤ 5 sec.</td></tr>
<tr><td>RINA</td></tr>
<tr><td>Lloyd´s Register</td></tr>
<tr><td>American Bureau of Shipping</td></tr>
<tr><td>Bureau Veritas</td></tr>
<tr><td>Det Norske Veritas</td></tr>
<tr><td>ISO 8528-5</td></tr>
</table>

Fig. 3 Minimum requirements of the classification societies plus ISO rule.

Momentum speed variation (m) must not vary more than 10% max. deviation from steady speed 1 %. Permanent speed variation (p) must not be higher than 5%.

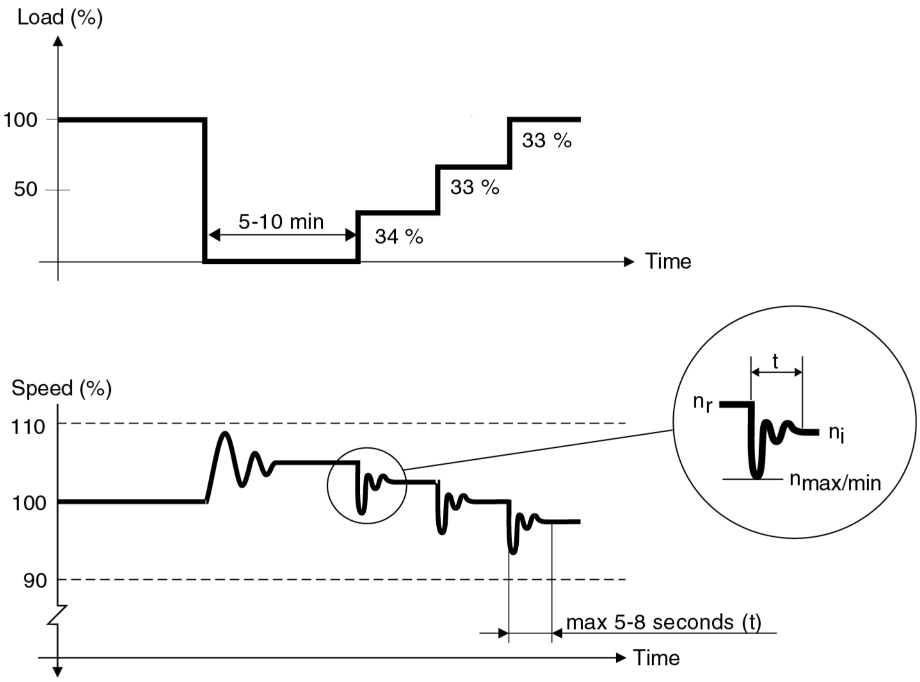

Fig. 4 Minimum requirements of the classification societies plus ISO rule.

bmep: Must be found in product guide. For most classification sociaties 3 x 33% load application will be accepted. *Actual classification society rules must be observed.*

Speed droop: _____, Needle valve open: ______°

$$m = \frac{n_{max/min} - n_r}{n_r} \times 100 \qquad p = \frac{n_i - n_r}{n_r} \times 100$$

Load (%)	(n_r) Rated speed [Hz]	($n_{max/min}$) Momentum speed [Hz]	(n_i) Permanent speed [Hz]	(m) Momentum speed variation [%]	(p) Permanent speed variation [%]	(t) Time to steady speed [sec]
0 - 34						
34 - 67						
67 - 100						

According to IACS requirements and ISO 8528-5.

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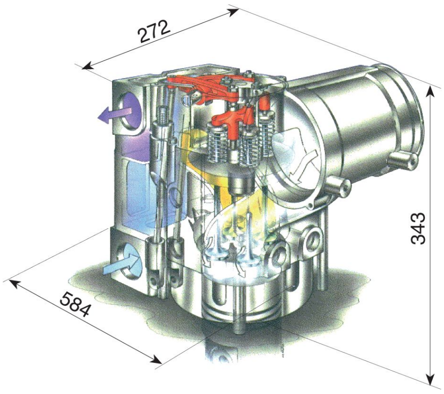
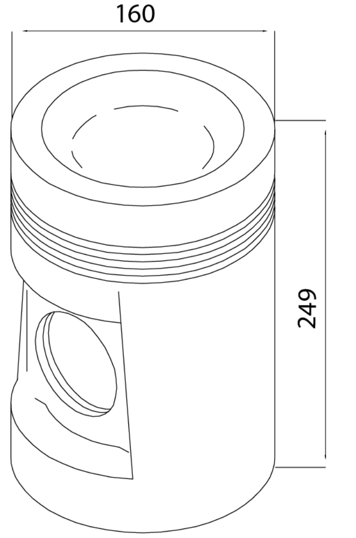
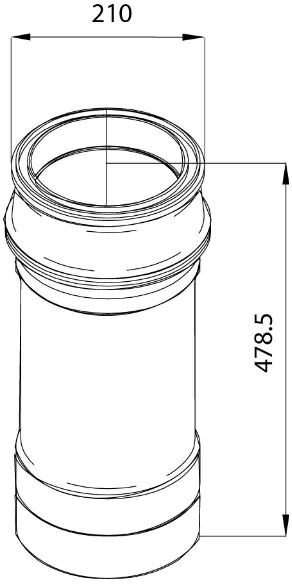
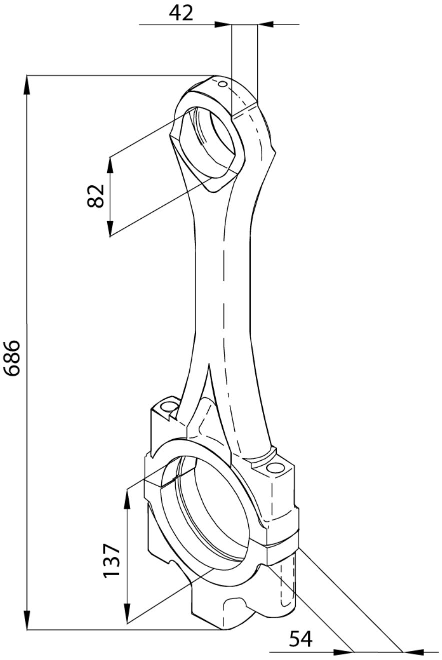
Weight and dimensions of principal parts

	
Cylinder head incl. rocker arms approx. 85 kg	Piston approx. 14 kg
	
Cylinder liner approx. 30 kg	Connecting rod approx. 20 kg

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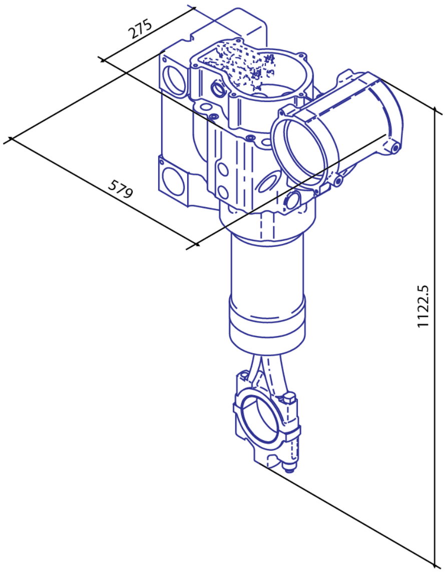
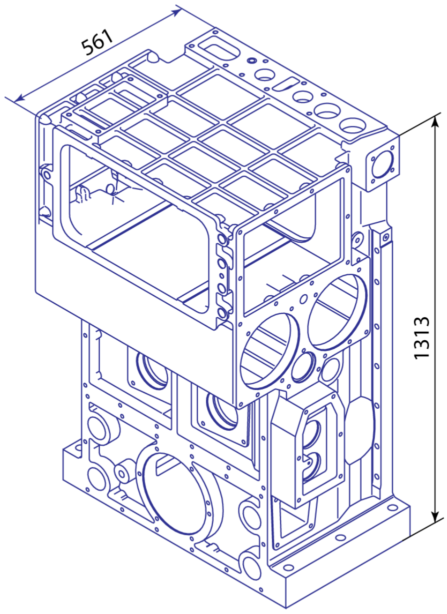
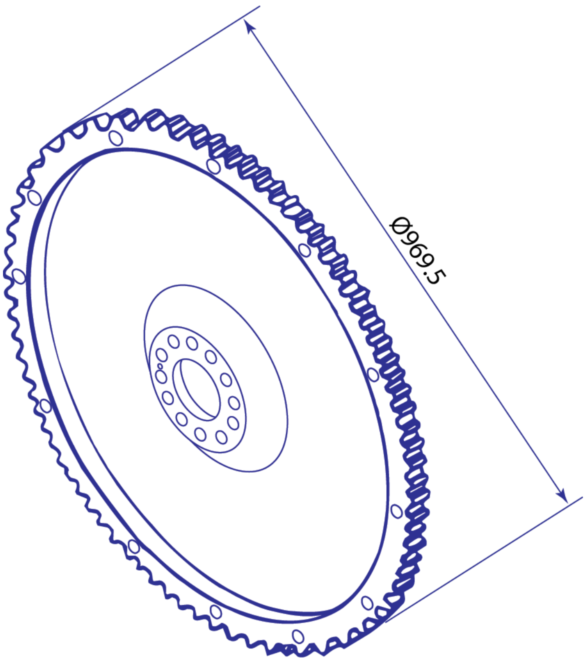
Weight and dimensions of principal parts

Description





Cylinder unit approx.187 kg	Front end box:	Tier II: 5-6 cylinder approx. 550 kg 7-8-9 cylinder approx. 620 kg Tier I: 5-6-7-8-9 cylinder approx. 550 kg



Flywheel with gear rim approx. 535 kg

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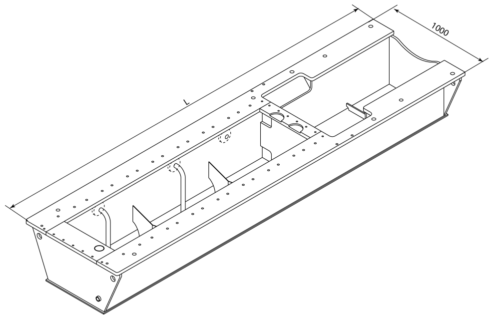
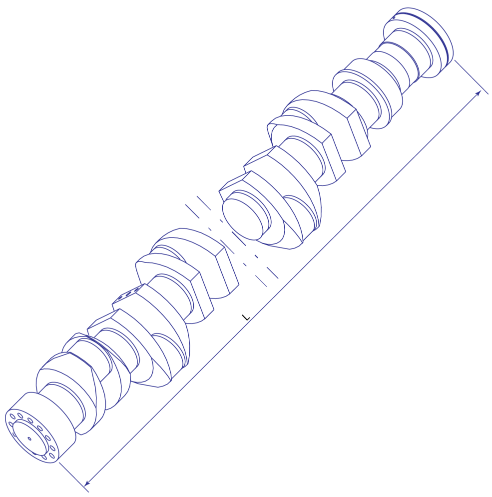
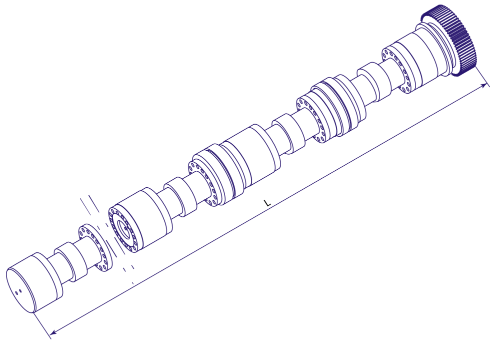


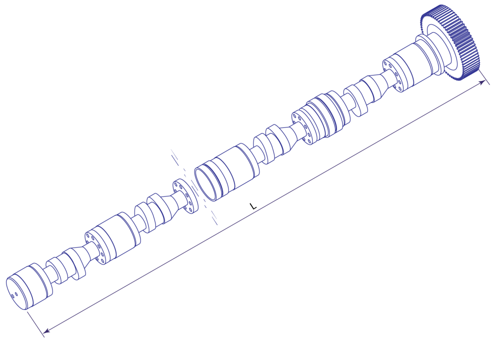
Base Frame	Length (L)	Weight
5 cyl.	3420	1129 kg
6 cyl.	3878	1191 kg
7 cyl.	4153	1283 kg
8 cyl.	4525	1372 kg
9 cyl.	4800	1443 kg



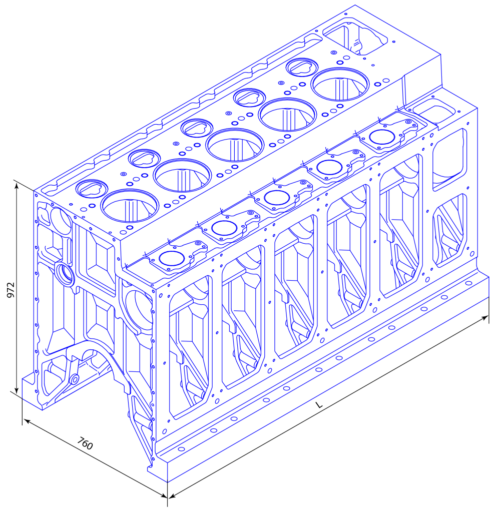
Crankshaft	Length (L)	Weight
5 cyl.	1835	1070 kg
6 cyl.	2110	1210 kg
7 cyl.	2385	1410 kg
8 cyl.	2660	1570 kg
9 cyl.	2935	1710 kg



Injection Camshaft	Length (L)	Weight
5 cyl.	1531	167 kg
6 cyl.	1806	194 kg
7 cyl.	2081	221 kg
8 cyl.	2356	248 kg
9 cyl.	2631	275 kg



Valve Cam-shaft	Length (L)	Weight
5 cyl.	1537	78 kg
6 cyl.	1812	88.7 kg
7 cyl.	2087	99.4 kg
8 cyl.	2362	110.1 kg
9 cyl.	2637	120.8 kg



Frame	Length (L)	Weight
5 cyl.	1681.5	1450 kg
6 cyl.	1956.5	1603 kg
7 cyl.	2231.5	1757 kg
8 cyl.	2506.5	1910 kg
9 cyl.	2781.5	2065 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.

Description	Plate [1)]	Item [1)]	Qty. [2)]
Cylinder Head			
Valve seat ring, inlet	50501	123	2
Valve seat ring, outlet	50501	184	4
Valve spindles and valve gear			
Conical ring	50502	178	6
Rotocap complete	50502	191	6
Spring	50502	201	6
Valve spindle, exhaust	50502	262	4
Valve spindle, inlet	50502	274	2
Piston and connecting rod			
Piston ring	50601	093	1
Piston ring	50601	103	1
Oil scraper ring	50601	127	1
Piston pin	50601	235	1
Retaining ring	50601	247	2
Bush for connecting rod	50601	056	1
Connecting rod bearing 2/2	50601	139	1
Screw for connecting rod	50601	152	2
Nut	50601	164	2
Frame with main bearings			
Main bearing shell, 2/2	51101	241	1
Thrust bearing ring	51101	253	1
Fuel injecting pump			
Fuel injecting pump, complete	51401	565	1
Round seal ring	51401	984	1
Fuel injection valve			
O-ring	51402	033	10
Fuel valve	51402	116	5
Fuel injection pipe			
Pressure piece	51404	010	1
Pressure pipe	51404	034	1
Gaskets			
Gasket kit for cylinder unit	51704	021	1

1. Plate No. and Item No. refer to the spare parts plates in the instruction book.
2. Quantity is in force per engine type per plant.

Notice:

Scope of this list are subject to change and therefore the latest version of this document should always be used, please see MAN Diesel & Turbo homepage or Extranet. Spare parts listed may also vary if optional components are selected.
Please notice that the content of spare parts for specific projects may vary from the list of standard spare parts.

Spare parts for unrestricted service

General

Spare parts for unrestricted service, according to the classification societies requirements/recommendations and/or MAN Energy Solutions standard.

Description	Plate [1)]	Item [1)]	Qty. [2)]
Cylinder Head			
Valve seat ring, inlet	50501	123	2
Valve seat ring, outlet	50501	184	4
Valve spindles and valve gear			
Conical ring	50502	178	6
Rotocap complete	50502	191	6
Spring	50502	201	6
Valve spindle, exhaust	50502	262	4
Valve spindle, inlet	50502	274	2
Piston and connecting rod			
Piston ring	50601	093	1
Piston ring	50601	103	1
Oil scraper ring	50601	127	1
Piston pin	50601	235	1
Retaining ring	50601	247	2
Bush for connecting rod	50601	056	1
Connecting rod bearing 2/2	50601	139	1
Screw for connecting rod	50601	152	2
Nut	50601	164	2
Frame with main bearings			
Main bearing shell, 2/2	51101	241	1
Thrust bearing ring	51101	253	1
Fuel injecting pump			
Fuel injecting pump, complete	51401	565	1
Round seal ring	51401	984	1
Fuel injection valve			
O-ring	51402	033	10
Fuel valve	51402	285	5
Fuel injection pipe			
Pressure piece	51404	010	1
Pressure pipe	51404	034	1
Gaskets			
Gasket kit for cylinder unit	51704	021	1

1. Plate No. and Item No. refer to the spare parts plates in the instruction book.
2. Quantity is in force per engine type per plant.

Notice:

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Spare parts for unrestricted service

General

Diesel electric system. Spare parts for unrestricted service, according to DNV and GL classification society
recommendation and/or MAN Energy Solutions standard.
For multi-engine installations spares are only necessary for one engine.

Description	Plate 1)	Item 1)	Qty.
Cylinder Unit			
Cylinder Unit	50515	011	1
Cylinder Head			
Valve seat ring, inlet	50501	123	2
O-ring	50501	172	4
Valve seat ring, exhaust	50501	184	4
Cylinder Valves			
Conical ring	50502	178	6
Rotocap complete	50502	191	6
Spring	50502	201	6
Valve spindle, exhaust	50502	262	4
Valve spindle, inlet	50502	274	2
Cylinder head, Top Cover			
O-ring	50510	014	1
Piston and connecting rod			
Bush for connecting rod	50601	056	1
Piston ring	50601	093	1
Piston ring	50601	103	1
Oil scraper ring	50601	127	1
Connecting rod bearing, 2/2	50601	139	1
Cylindrical pin	50601	140	4
Screw for connecting rod	50601	152	2
Nut	50601	164	2
Frame with main bearings			
Tie rod	51101	062	2
O-ring	51101	074	2
Nut	51101	086	4
Tie rod	51101	182	2
Crown nut	51101	194	2
Cylindrical pin	51101	204	1
Main bearing shell, 2/2	51101	241	1
Axial bearing	51101	253	2
Packing - Silicone paste	51101	265	1
Charge air pipe			
O-ring	51230	027	2
Fuel injecting pump			
O-ring	51401	457	1
Fuel injecting pump	51401	565	1
Round seal ring	51401	984	1
Fuel injection valve			
O-ring	51402	033	2/Cyl.
Fuel valve	51402	116	1/Cyl.

Description	Plate [1)]	Item [1)]	Qty.
Fuel injection pipe			
Pressure pipe, complete	51404	010	1
O-ring	51404	022	1
Delivery socket , complete	51404	034	1
O-ring	51404	046	1
Cooling water connections			
Intermediate piece	51630	153	1

1. Plate No. and Item No. refer to the spare parts plates in the instruction book.

Notice:

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Spare parts for unrestricted service

General

Diesel electric system. Spare parts for unrestricted service, according to DNV and GL classification society
recommendation and/or MAN Energy Solutions standard.
For multi-engine installations spares are only necessary for one engine.

Description	Plate [1)]	Item [1)]	Qty.
Cylinder Unit			
Cylinder Unit	50515	011	1
Cylinder Head			
Valve seat ring, inlet	50501	123	2
O-ring	50501	172	4
Valve seat ring, exhaust	50501	184	4
Cylinder Valves			
Conical ring	50502	178	6
Rotocap complete	50502	191	6
Spring	50502	201	6
Valve spindle, exhaust	50502	262	4
Valve spindle, inlet	50502	274	2
Cylinder head, Top Cover			
O-ring	50510	014	1
Piston and connecting rod			
Bush for connecting rod	50601	056	1
Piston ring	50601	093	1
Piston ring	50601	103	1
Oil scraper ring	50601	127	1
Connecting rod bearing, 2/2	50601	139	1
Cylindrical pin	50601	140	4
Screw for connecting rod	50601	152	2
Nut	50601	164	2
Frame with main bearings			
Tie rod	51101	062	2
O-ring	51101	074	2
Nut	51101	086	4
Tie rod	51101	182	2
Crown nut	51101	194	2
Cylindrical pin	51101	204	1
Main bearing shell, 2/2	51101	241	1
Axial bearing	51101	253	2
Packing - Silicone paste	51101	265	1
Charge air pipe			
O-ring	51230	027	2
Fuel injecting pump			
O-ring	51401	457	1
Fuel injecting pump	51401	565	1
Round seal ring	51401	984	1
Fuel injection valve			
O-ring	51402	033	1 /Cyl.
Fuel valve	51402	285	1 /Cyl.

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Description	Plate [1]	Item [1]	Qty.
Fuel injection pipe			
Pressure pipe, complete	51404	010	1
O-ring	51404	022	1
Delivery socket , complete	51404	034	1
O-ring	51404	046	1
Cooling water connections			
Intermediate piece	51630	153	1

1. Plate No. and Item No. refer to the spare parts plates in the instruction book.

Notice:

Scope of this list are subject to change and therefore the latest version of this document should always be used, please see MAN Diesel & Turbo homepage or Extranet. Spare parts listed may also vary if optional components are selected.
Please notice that the content of spare parts for specific projects may vary from the list of standard spare parts.

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Introduction to spare part plates for tools

Description

For our GenSets the following three tool packages are available:

Standard tool for normal maintenance
This package is delivered with the vessel 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 on board the vessel.

Hand Tools
This tool package can be ordered as a whole or partly in addition to the standard tool package. The tool package consists of ordinary hand tools needed in addition to the delivered standard tool for normal maintenance, in connection with the daily maintenance as well as major overhauls.

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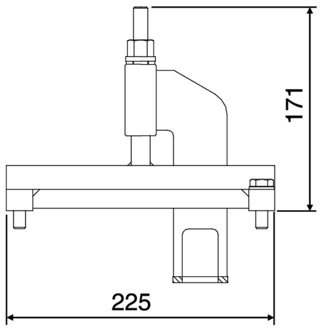
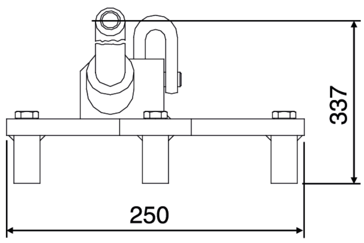
Standard tools for normal maintenance

Cylinder head

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Valve spring tightening device			1	014	
Lifting tool for cylinder unit			1	038	

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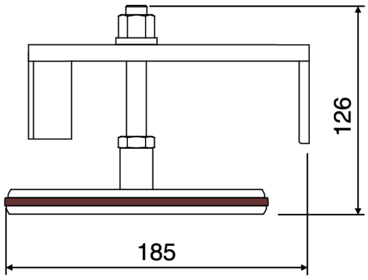
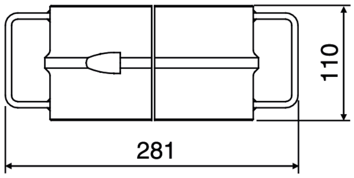
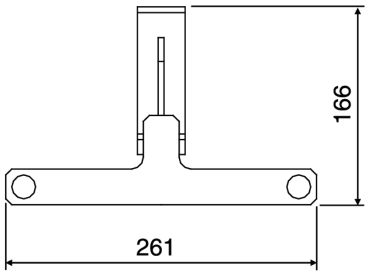
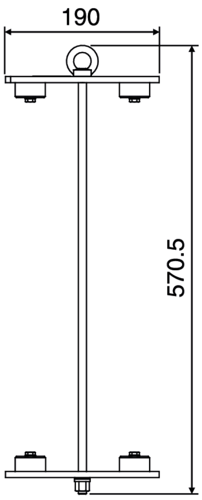
Piston, connecting rod and cylinder liner

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Removing device for flame ring			1	021	
Guide bush for piston			1	045	
Fit and removal device for connecting rod bearing, incl eye screws (2 pcs)			1	069	
Lifting device for cylinder liner			1	082	

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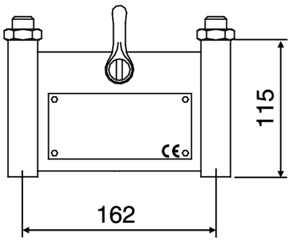
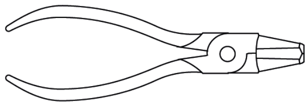
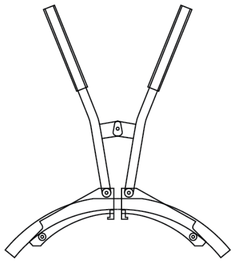
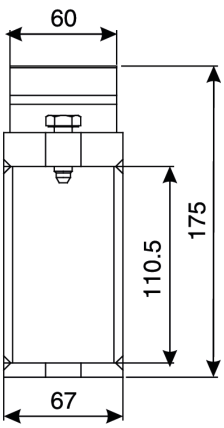
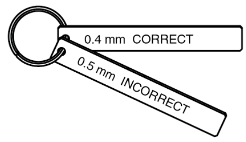
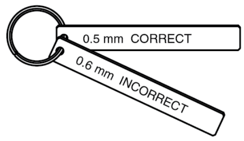
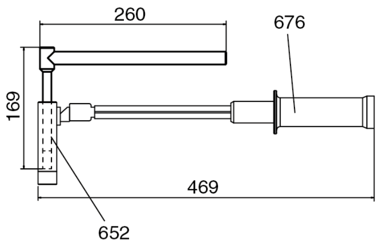
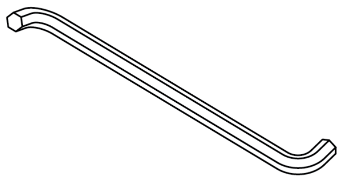
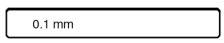
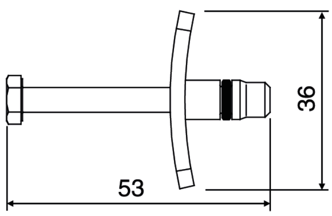
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Lifting device for piston and connecting rod			1	104	
Plier for piston pin lock ring			1	177	
Piston ring opener			1	190	
Supporting device for connecting rod and piston in the cylinder liner			1	212	

Operating gear for inlet and exhaust valves

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Feeler gauge, 0.4-0.5 mm (inlet valve)			1	010	
Feeler gauge, 05.-0.6 mm (exhaust valve)			1	034	
Setting device, complete incl item 652, 676 Torque spanner Socket wrench			1 1 1	664 676 652	
Socket screw key			1 1	831	
Feeler gauge for adjustment of roller guide			2	640	

Crankshaft and main bearings

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Dismantling tool for main bearing upper shell			1	035	

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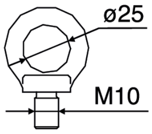
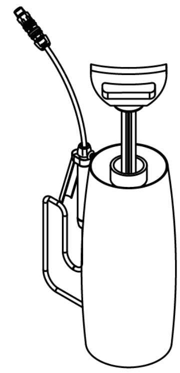
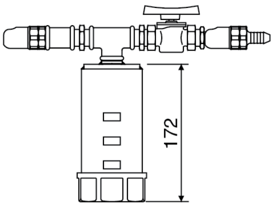
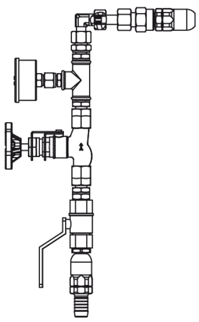
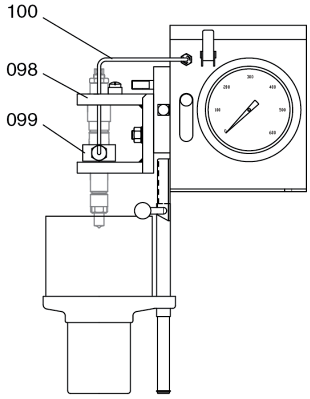
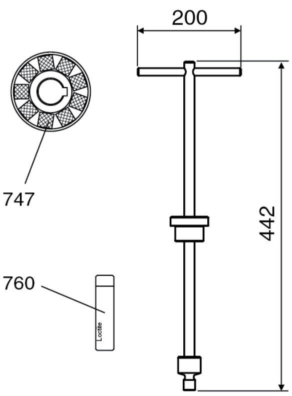
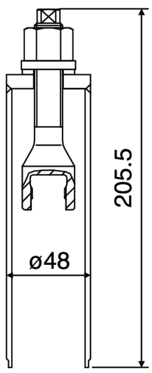
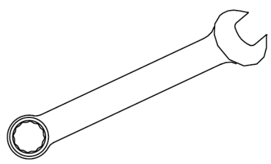
Turbocharger system

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Eye screw for lifting of charge air cooler/lubricating oil cooler			2	036	
Container complete for water washing of compressor side			1	355	
Blowgun for dry cleaning of turbocharger			1	136	
Water washing of turbine side, complete			1	481	

Fuel oil system

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Pressure testing tool, complete incl item 098, 099, 100 Bow Plate Pressure pipe			1 1 1 1	050 098 099 100	
Grinding device for nozzle seat, incl item 747, 760 Grinding paper Loctite			1 1 1	074 747 760	
Extractor device for injector valve			1	407	
Combination spanner, 32 mm			1	772	

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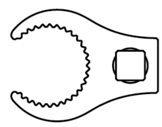
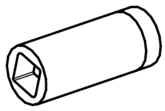
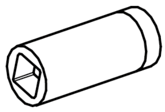
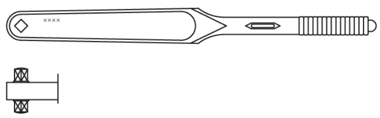
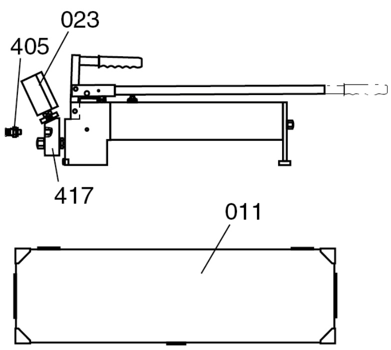
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Crow foot, 32 mm			1	784	
Long socket spanner 1/2" 27 mm			1	855	
Long socket spanner 1/2" 30 mm			1	867	
Torque spanner 1/2" 50-300 Nm			1	902	

Hydraulic tools

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Hydraulic tools complete consisting of the following:				806	
Pressure pump, complete Manometer Quick coupling Distributor	 L x B x H = 886 x 256 x 334 mm		1	011 023 405 417	

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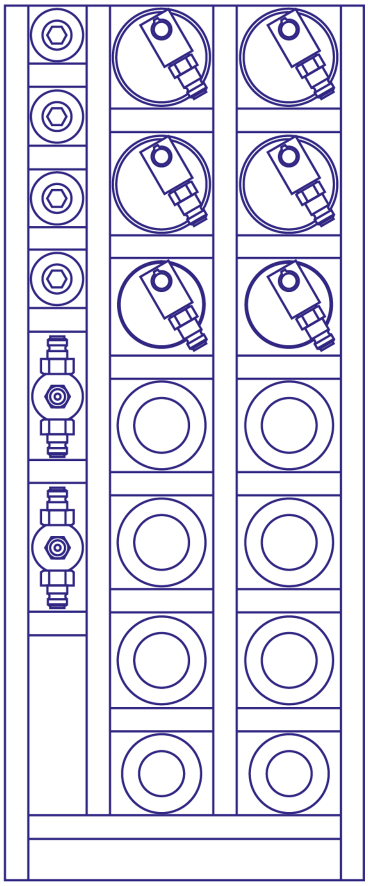
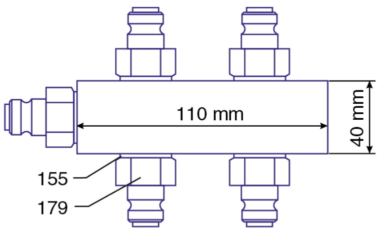
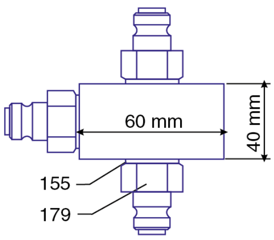
3700128-8.9

Standard tools for normal maintenance

Description

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Hydraulic tools complete, consisting of the following:	 L x B x H = 712 x 353 x 288 mm			633	
Distributing piece for cylinder head, complete Gasket Quick coupling			1	143 155 179	
Distributing piece for main bearing, complete Gasket Quick coupling			1	167 155 179	

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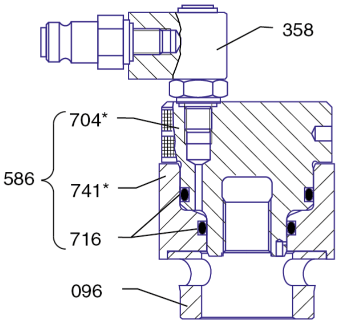
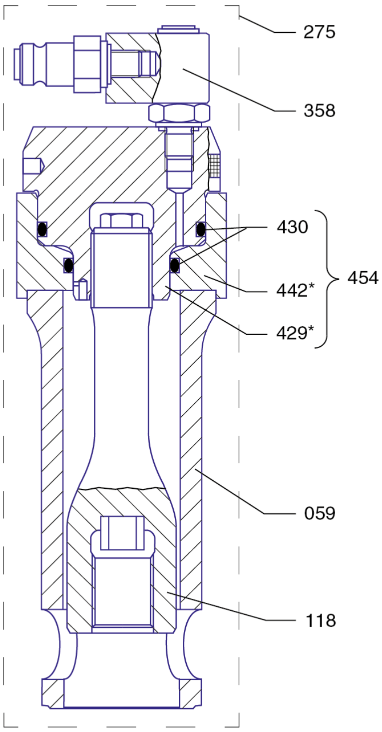
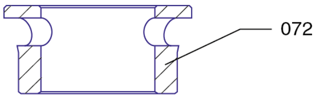
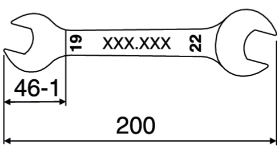
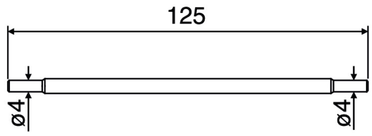
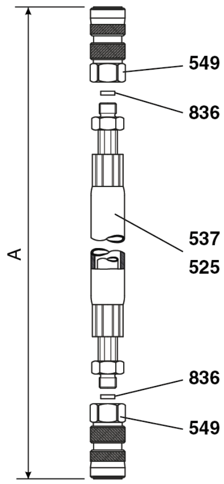
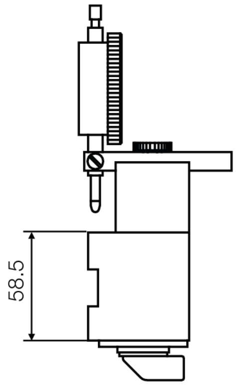
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Hydraulic tools for connecting rod, complete			1	299	
Piston for hydraulic jack*				704*	
Set of O-rings with back-up ring			1	716	
Cylinder for hydraulic jack*				741*	
Spacer piece			1	096	
Angle piece complete			1	358	
Hydraulic jack as item nos 704, 716, 741			1	586	
* not available as a single part					
Hydraulic tools for cylinder head, complete			1	275	
Piston for hydraulic jack*				429*	
Set of O-rings with back-up ring			1	430	
Cylinder for hydraulic jack*				442*	
Spacer piece, long				059	
Hydraulic jack as item nos 429, 430, 442			1	454	
Angle piece complete				358	
Tension screw				118	
Spacer piece, short			1	072	
Spare parts kit for angle piece			1	322	
* not available as a single part					
Spanner			1	310	

3700128-8.9

Standard tools for normal maintenance

Description

2019-03-19 - en

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Tommy bar			1	334	
Hose with unions for cylinder head complete, 1000 mm			4	180	
Hose with unions for connection of oil pump and distributing block complete, 3000 mm			1	202	
Hose, 3000 mm				537	
Quick coupling with protecting cap				549	
Hose, 1000 mm				525	
Disc				836	
Measuring device (not a part of Hydraulic tools complete, to be ordered separately)			2	533	

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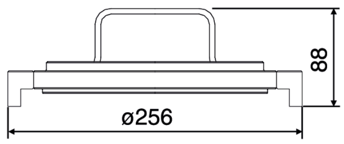
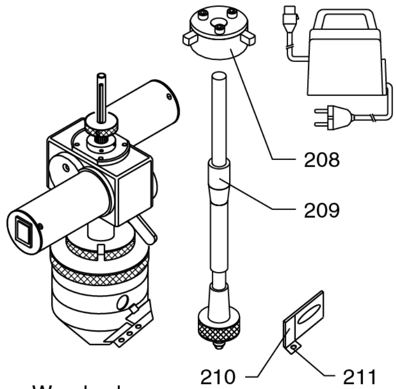
Additional tools

Cylinder head

<table>
<tr><th>Name</th><th>Sketch</th><th>Supply per ship
Working</th><th>
Spare</th><th>Drawing
Item no</th><th>Remarks</th></tr>
<tr><td>Grinding tool for cylinder head/liner</td><td>
</td><td></td><td>1</td><td>126</td><td></td></tr>
<tr><td>Grinding machine for valve seat ring
Supporting spider
Mandrel
Cutting tool
Carbide cutting insert</td><td>

Wooden box
L x B x H = 450 x 380 x 190 mm</td><td></td><td>1
1
1
1
1</td><td>199
208
209
210
211</td><td></td></tr>
<tr><td>Grinding tool for valves</td><td>
</td><td></td><td>1</td><td>283</td><td></td></tr>
</table>

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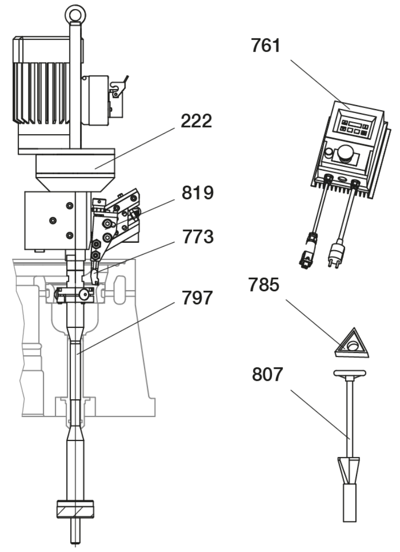
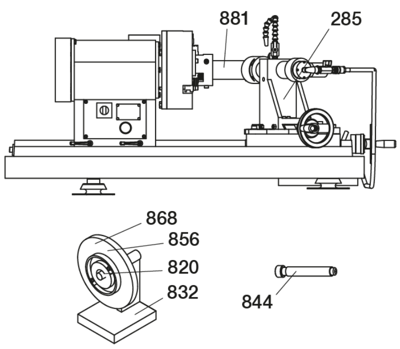
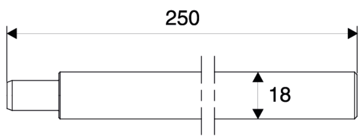
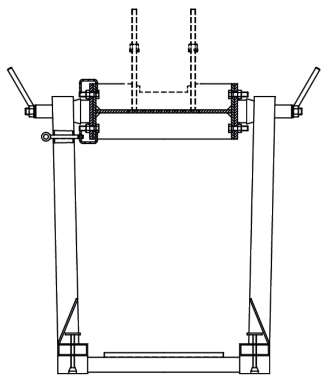
3700131-1.10

Additional tools

Description

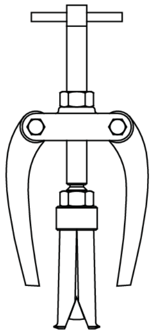
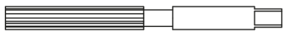
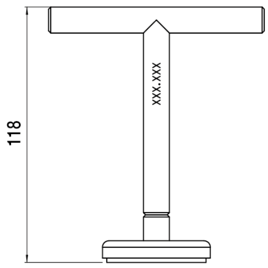
3700131-1.10

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Grinding machine for valve seat rings			1	222	
Frequence converter			1	761	
Tool holder			1	773	
Turning bit			1	785	
Pilot spindle incl. stabilizer			1	797	
Cleaning tool			1	807	
Tool holder bracket			1	819	
Grinding machine for valve spindle, complete			1	285	
Grinding wheel hub			1	820	
Balancing apparatus			1	832	
Grinding wheel dresser			1	844	
Grinding wheel, grain size 46			1	856	
Grinding wheel, grain size 80			1	868	
Stabilizer (valve stem ø10-18 mm)			1	881	
Mandrel for dismounting/ mounting of valve guide			1	258	
Turning device for cylinder unit			1	114	

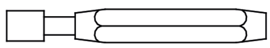
Additional tools

Description

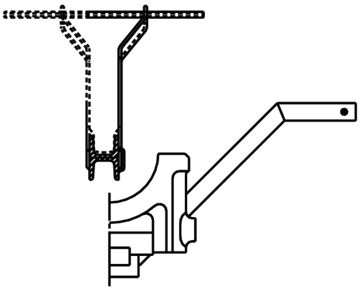
2018-06-20 - en

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Extractor for valve seat rings			1	329	
Reamer for valve guide			1	748	
Touching up device			1	893	

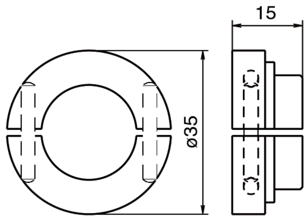
Piston, connecting rod and cylinder liner

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Testing mandrel for piston ring grooves, 5.38 mm			1	163	
Micrometer screw for cylinder liner 150-175 mm			1	425	
Micrometer screw for connecting rod 125-150 mm			1	665	

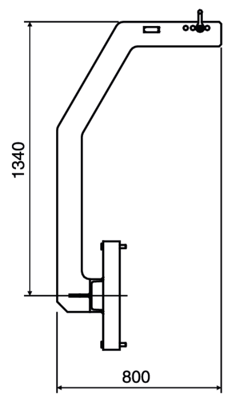
Crankshaft and main bearings

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Removal device for main bearing cap			1	641	

Engine frame and base frame

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Assembly sleeve			1	604	

Turbocharger system

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Lifting tool for charge air cooler			1	401	

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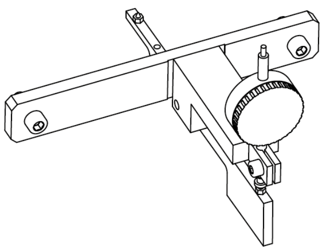
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Differential pressure tools, complete			1	915	

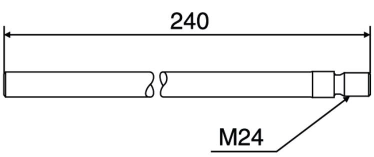
Compressed air system

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Set of tools, TDI air starter T30			1	927	

Fuel oil system

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Setting device for fuel injection pump, MAN & L'Orange			1	366	

Lubricating oil system

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Mandrel for lubricating oil cooler			1	508	

3700131-1.10

Additional tools

Description

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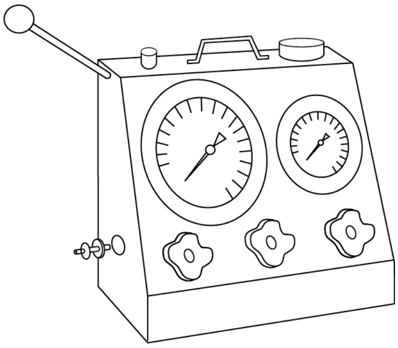
Hydraulic tools

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Air driven high pressure pump for hydraulic valve			1	653	
Remote controlled unit for hydraulic bolt tensioning			1	939	

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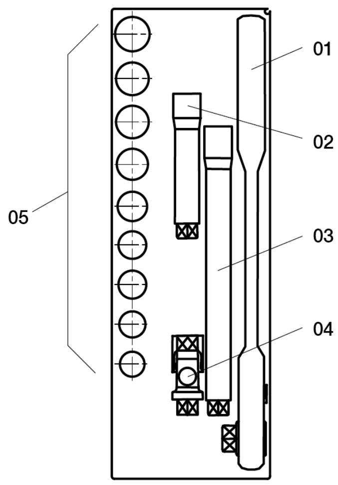
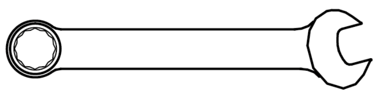
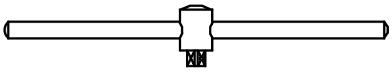
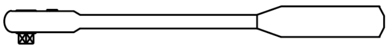
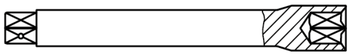
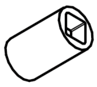
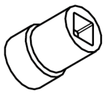
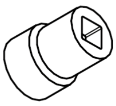
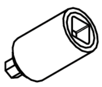
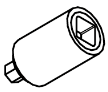
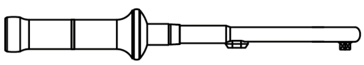
Hand tools

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	

3700414-0.0

Hand tools
Description

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Combination spanner, 18 mm			1	235	
Tee handle 1/2" square drive			1	139	
Ratchet, 20 mm			1	140	
Extension bar			1	152	
Socket spanner, square drive, size 24			1	164	
Socket spanner, square drive, size 30			1	176	
Socket spanner, square drive, size 36			1	188	
Bit, hexagon socket screw, square drive, size 8			1	247	
Bit, hexagon socket screw, square drive, size 10			1	259	
Bit, hexagon socket screw, square drive, size 12			1	260	
Torque spanner, 20-120 Nm - 1/2"			1	272	
Torque spanner, 40-200 Nm - 1/2"			1	284	
Torque spanner, 30-320 Nm - 1/2"			1	296	

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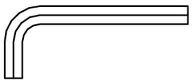
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Hexagon key 7 mm			1	331	
Hexagon key 8 mm			1	343	
Hexagon key 10 mm			1	355	
Hexagon key 12 mm			1	367	
Hexagon key 14 mm			1	379	
Hexagon key 17 mm			1	380	
Hexagon key 19 mm			1	392	

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Alternators for GenSets

GenSet

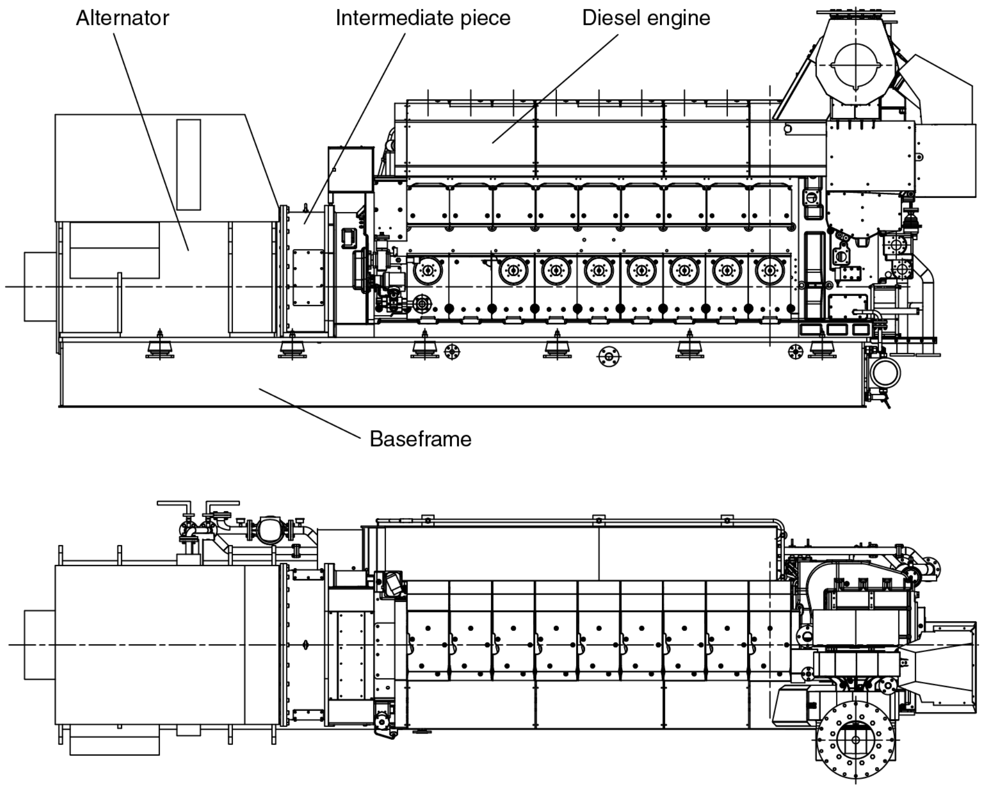

Figure 1: GenSet

A GenSet is a joined unit with a diesel engine, an alternator and a common base frame. The alternator has a stator housing with a front flange which is connected to the diesel engine with bolts. Similar to this the alternator has foot flanges with bolt connection to the base frame. The base frame is anchored to the foundation with a variable number of rubber dampers.

Mechanical alternator design

The rotor in the alternator is installed with either one or two bearings. On one-bearing alternators the rotor is connected to the flywheel of the diesel engine with a flex disc. The one-bearing alternator does not have a front bearing and in this case the rotor is carried by the crankshaft of the engine. On two-bearing alternators the connection is a flexible rubber coupling, and the rotor front is seated in the stator housing of the alternator.

In both cases the alternator stator housing is connected to the diesel engine with bolts, however, with two-bearing alternators an intermediate piece with bolt flanges is used which at the same time is shielding the flexible rubber coupling.

The bearing type can be ball bearing, roller bearing or sleeve bearing.

NOTICE

The engine types 8L21/31, 9L21/31, 8L27/38 and 9L27/38 only use two-bearing alternators to keep the load on the engine's rear crankshaft bearing on a low level.

The alternator can be delivered air-cooled with insulation class IP23 or water-cooled with insulation class IP44.

The air-cooled alternator takes air in through filters; leads the air through the alternator by means of a built-in ventilator and out of the alternator again.

The water-cooled alternator circulates air internally in the alternator by means of the ventilator. The airflow passes through a built-in water cooler, removing the heat from the alternator through the connected cooling water system.

The entrance to the electrical main cables can be placed on the right or left side of the alternator with a horizontal or vertical inlet.

Electrical alternator design

The alternator is a three-phase AC synchronous alternator – brushless with built-in exciter and automatic, electronic voltage regulator (AVR) with potentiometer for remote control. (The potentiometer for final adjustment of the voltage is included in the standard delivery and normally part of the control panel).

The alternator is intended for parallel running.

The insulation class for the windings can be H/H or lower. H/H corresponds to 180° C on the windings and 180° C operating temperature.

According to the GL classification rules the alternator must as maximum be used up to 155° C operating temperature – corresponding to insulation class F. It may also be a customer requirement to keep the efficiency below class H.

The windings have tropical resistance against high humidity.

The alternator is equipped with anti-condensate standstill heater.

For temperature surveillance in the windings, the alternator is equipped with 2x3 PT100 sensors (PT1000 sensors for engines with SaCoSone). PT100/PT1000 sensors are also installed for surveillance of the bearing temperature and for water cooled alternators for surveillance of cooling air temperature. Alternators may also be equipped with visual thermometers on bearings.

The alternator can be delivered for the voltages 380 VAC to 13.8 KVAC. The frequencies are 50 Hz or 60 Hz.

The alternator fulfils the requirements for electromagnetic compatibility protection EMC, is designed and tested according to IEC34 and fulfils the DIN EN 60034 / VDE0530 requirements.

Alternator cable installation

Description

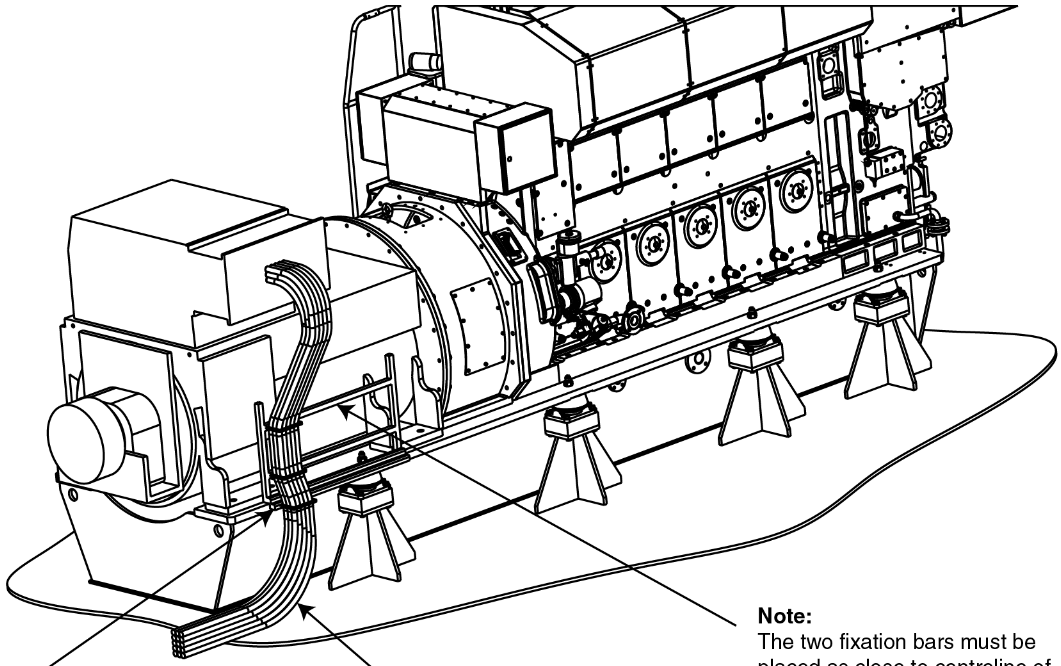

Figure 1: Connection of cables (example)

Main cables

The resilient installation of the GenSet must be considered when fixing the alternator cables.

The cables must be installed so that no forces have any effect on the terminal box of the alternator.

A support bracket can be welded on the engine base frame. If this solution is chosen, the flexibility in the cables must be between the cable tray and the support bracket.

The free cable length from the cable tray to the attachment on the alternator must be appropriate to compensate for the relative movements between the GenSet and the foundation.

The following can be used as a guideline:
The fix point of the alternator cables must be as close as possible to the centre line of the rotor.

Bending of the cables must follow the recommendations of the cable supplier regarding minimum bending radius for movable cables.

If questions arise concerning the above, please do not hesitate to contact MAN Diesel & Turbo.

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.

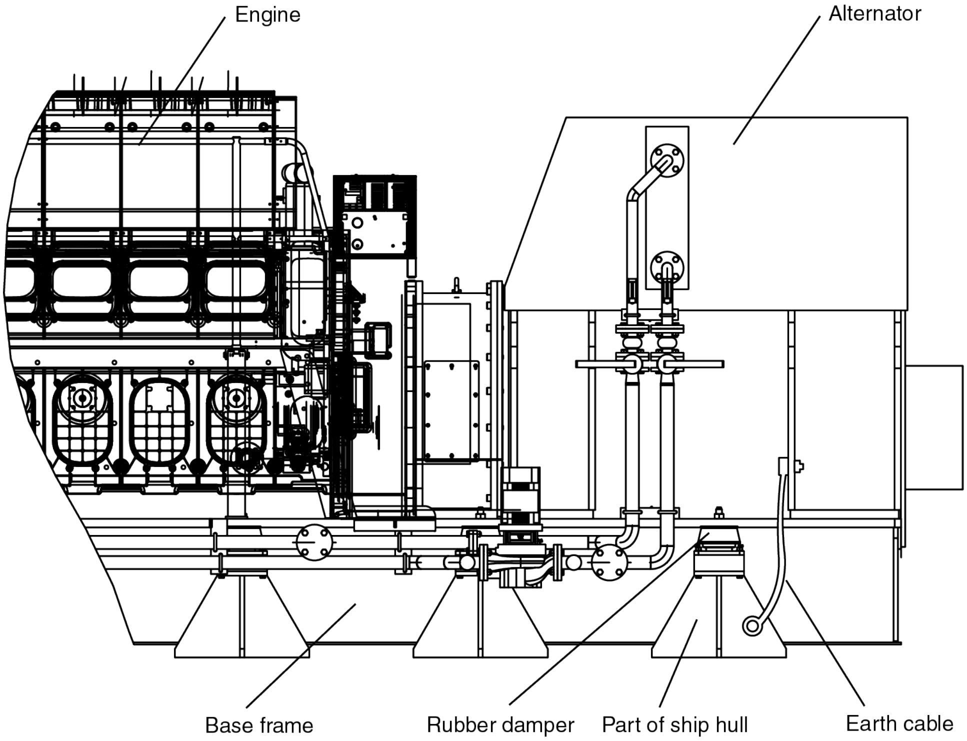

Figure 2: Marine operation (example)

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.

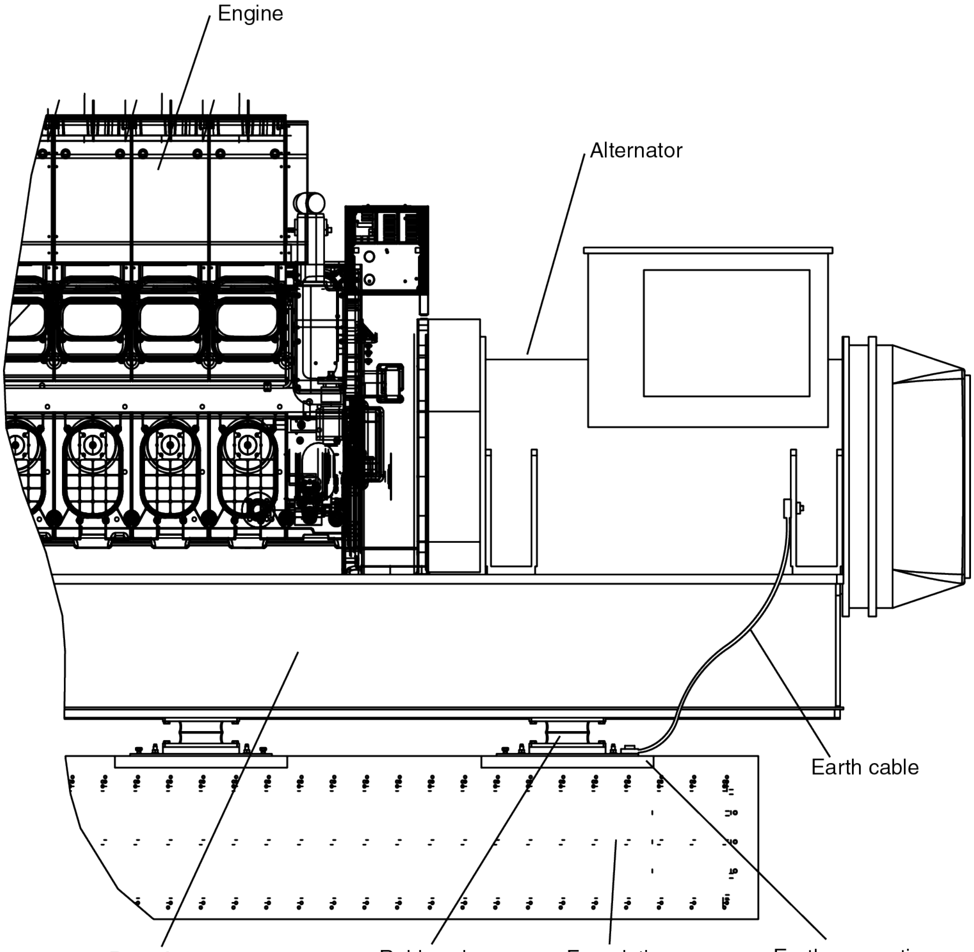

Figure 3: Stationary operation (example)

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Combinations of engine- and alternator layout

Combinations of engine- and alternator layout

Engine and alternator combinations

L23/30H Mk1 L23/30S Mk 1 L23/30H Mk1, Monocoque	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 720 RPM	• 2)	1)	2)	1)
5 Cyl. 750 RPM	• 2)	1)	2)	1)
6 Cyl. 720 RPM	•	#	#	#
6 Cyl. 750 RPM	•	#	#	#
6 Cyl. 900 RPM	•	#	#	#
7 Cyl. 720 RPM	•	#	#	#
7 Cyl. 750 RPM	•	#	#	#
7 Cyl. 900 RPM	•	#	#	#
8 Cyl. 720 RPM	•	#	#	#
8 Cyl. 750 RPM	•	#	#	#
8 Cyl. 900 RPM	•	#	#	#

L23/30H Mk 2 L23/30S Mk 2	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 720 RPM	• 2)	1)	2)	1)
5 Cyl. 750 RPM	• 2)	1)	2)	1)
6 Cyl. 720 RPM	•	#	#	#
6 Cyl. 750 RPM	•	#	#	#
6 Cyl. 900 RPM	•	#	#	#
7 Cyl. 720 RPM	•	#	#	#
7 Cyl. 750 RPM	•	#	#	#
7 Cyl. 900 RPM	X	X	•	#
8 Cyl. 720 RPM	•	#	#	#
8 Cyl. 750 RPM	•	#	#	#
8 Cyl. 900 RPM	•	#	#	#

L28/32H L28/32DF L28/32S	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 720 RPM	•	#	#	#
5 Cyl. 750 RPM	•	#	#	#
6 Cyl. 720 RPM	•	#	#	#
6 Cyl. 750 RPM	•	#	#	#
7 Cyl. 720 RPM	X	X	•	#
7 Cyl. 750 RPM	X	X	•	#
8 Cyl. 720 RPM	X	X	•	#
8 Cyl. 750 RPM	X	X	•	#
9 Cyl. 720 RPM	•	#	#	#
9 Cyl. 750 RPM	•	#	#	#

Monocoque: L23/30H Mk 2 L23/30DF	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 720 RPM	•	#	#	#
5 Cyl. 750 RPM	•	#	#	#
6 Cyl. 720 RPM	•	#	#	#
6 Cyl. 750 RPM	•	#	#	#
6 Cyl. 900 RPM	•	#	#	#
7 Cyl. 720 RPM	•	#	#	#
7 Cyl. 750 RPM	•	#	#	#
7 Cyl. 900 RPM	X	X	•	#
8 Cyl. 720 RPM	•	#	#	#
8 Cyl. 750 RPM	•	#	#	#
8 Cyl. 900 RPM	•	#	#	#

For a GenSet the engine and alternator are fixed on a common base frame, which is flexibly installed. This is to isolate the GenSet vibration-wise from the environment. As part of the GenSet design a full FEM calculation has been done and due to this and our experience some combinations of engine type and alternator type concerning one - or two bearings must be avoided. In the below list all combinations can be found.

Comments to possible combinations:

• : Standard
: Option
X : Not recommended

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1) : Only in combination with "top bracing" between engine crankcase and alternator frame
2) : Need for 'topbracing' to be evaluated case by case

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	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 900 RPM	•	#	#	#
5 Cyl. 1000 RPM	•	#	#	#
6 Cyl. 900 RPM	•	#	#	#
6 Cyl. 1000 RPM	•	#	#	#
7 Cyl. 900 RPM	•	#	#	#
7 Cyl. 1000 RPM	•	#	#	#
8 Cyl. 900 RPM	X	X	•	#
8 Cyl. 1000 RPM	X	X	•	#
9 Cyl. 900 RPM	X	X	•	#
9 Cyl. 1000 RPM	X	X	•	#

L27/38 L27/38S	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
5 Cyl. 720 RPM	•	#	#	#
5 Cyl. 750 RPM	•	#	#	#
6 Cyl. 720 RPM	•	#	#	#
6 Cyl. 750 RPM	•	#	#	#
7 Cyl. 720 RPM	•	#	#	#
7 Cyl. 750 RPM	•	#	#	#
8 Cyl. 720 RPM	X	X	•	#
8 Cyl. 750 RPM	X	X	•	#
9 Cyl. 720 RPM	X	X	•	#
9 Cyl. 750 RPM	X	X	•	#

V28/32S	1-bearing, air cooled	1-bearing, water cooled	2-bearing, air cooled	2-bearing, water cooled
12 Cyl. 720 RPM	X	X	•	1)
12 Cyl. 750 RPM	X	X	•	1)
16 Cyl. 720 RPM	X	X	•	1)
16 Cyl. 750 RPM	X	X	•	1)
18 Cyl. 720 RPM	X	X	•	1)
18 Cyl. 750 RPM	X	X	•	1)

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Lifting instruction

Lifting of Complete Generating Sets.

The generating sets should only be lifted in the two wire straps. Normally, the lifting tools and the wire straps are mounted by the factory. If not, it must be observed that the fixing points for the lifting tools are placed differently depending on the number of cylinders.

The lifting tools are to be removed after the installation, and the protective caps should be fitted.

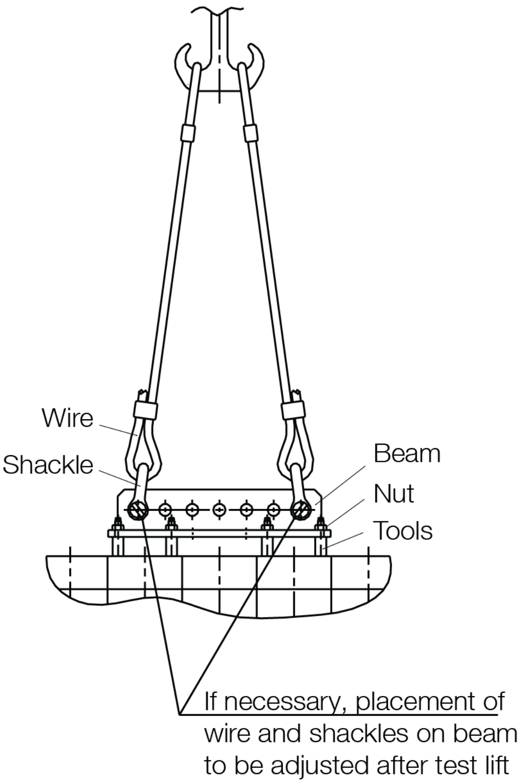

Figure 1: Lifting tools

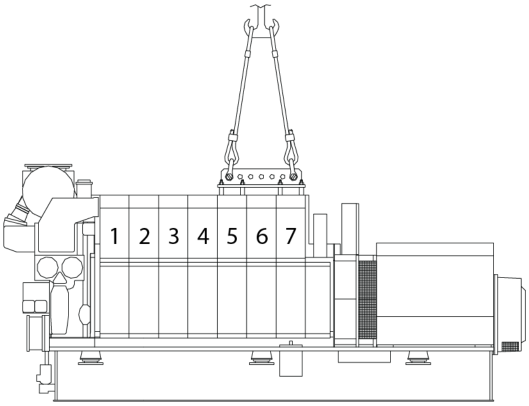

Figure 2: Lifting tools' and wires placing on engine.

Engine Type	2 X 4 bolt to be mounted over cover of cyl. no.	
5L16/24, 5L21/31	3 cyl.	5 cyl.
6L16/24, 6L21/31	4 cyl.	6 cyl.
7L16/24, 7L21/31	5 cyl.	7 cyl.
8L16/24, 8L21/31	5 cyl.	7 cyl.
9L16/24, 9L21/31	6 cyl.	8 cyl.

Note: Based on MAN Energy Solutions standard alternator

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