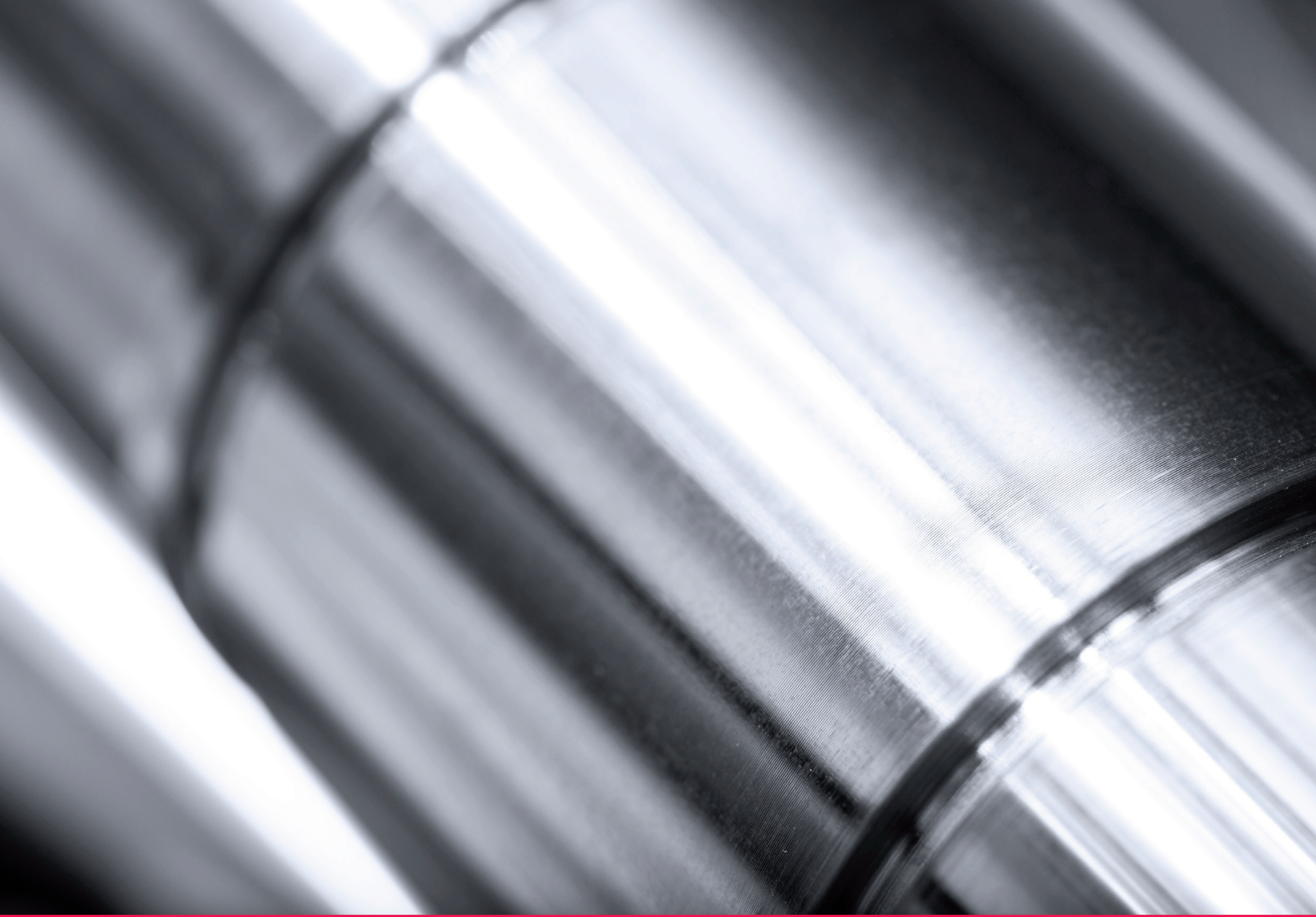

L28/32H
Project Guide - Marine

Four-stroke GenSet
compliant with IMO Tier II

Engineering the Future – since 1758.

MAN Diesel & Turbo

Table of contents

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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

Function/system

Sub-function

Choice number

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.

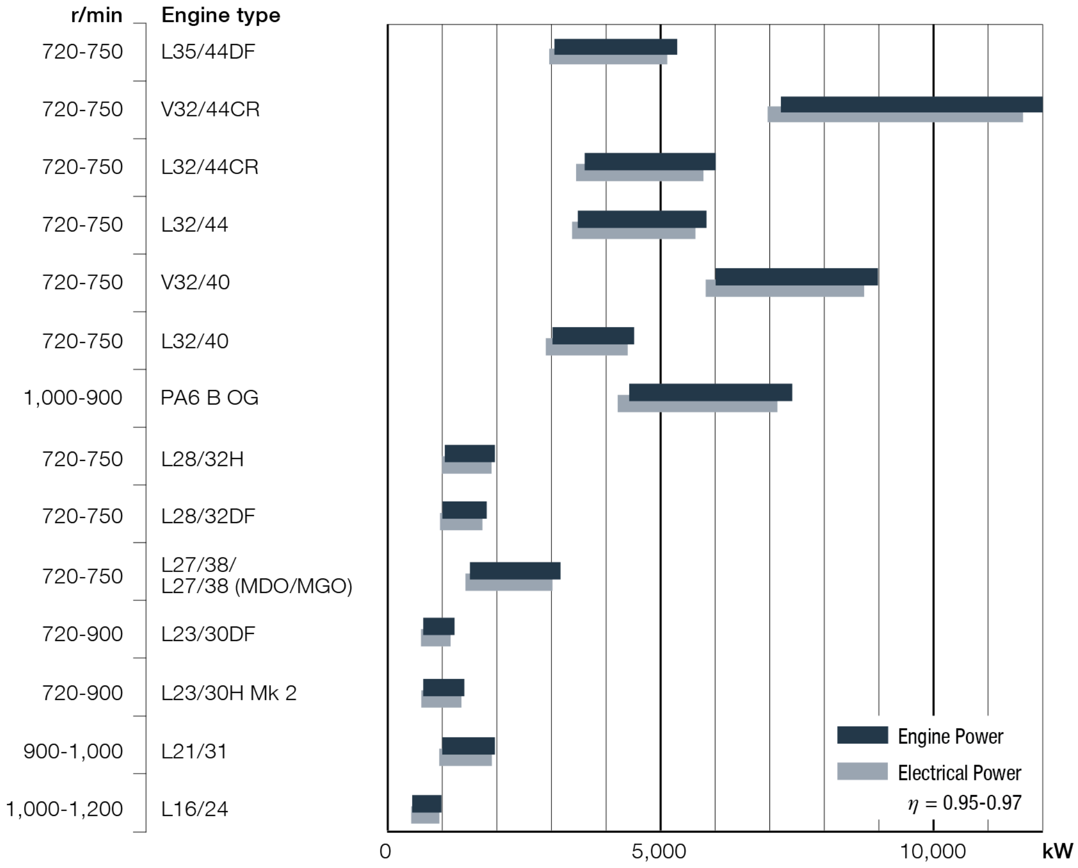
NOTICE

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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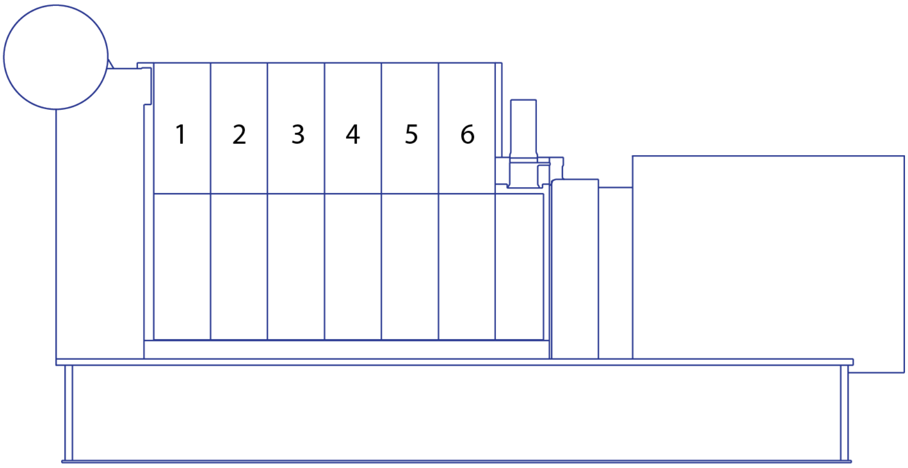
Designation of cylinders

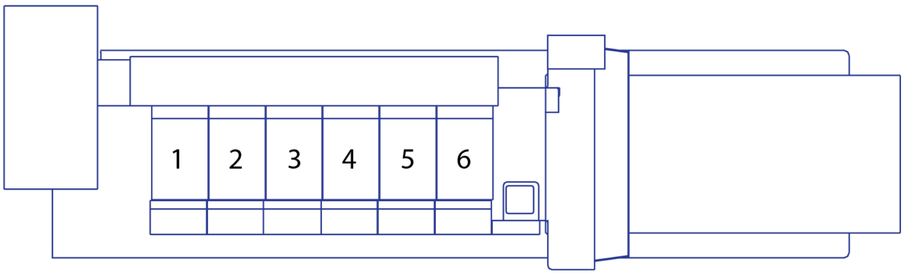
General

Front end

Flywheel end



Exhaust side / Right side



Service side / Fuel Pump side / Left side

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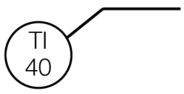
Code identification for instruments

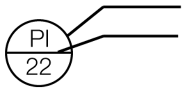
Explanation of symbols

Temperature **I**ndicator
No. 40 *



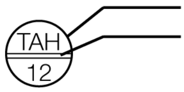
Measuring device
Local reading

Pressure **I**ndicator
No. 22 *



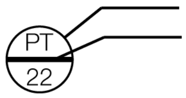
Measuring device
Sensor mounted on engine/unit
Reading/identification mounted in a panel on the engine /unit

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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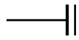
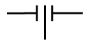
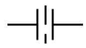
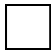
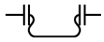
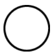
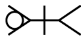
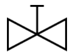
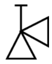
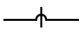
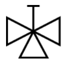
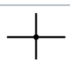
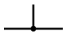
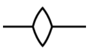
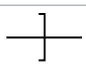
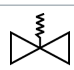
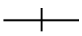
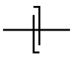
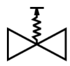
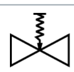
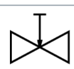
Symbols for piping

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

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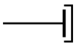
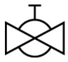
2.12		Cap nut	3.14		Ball valve (cock)

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

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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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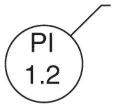
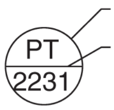
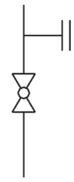
General



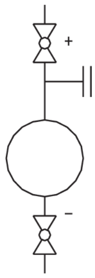
Measuring device
Local reading
Pressure **I**ndication
no 1.2 (refer to list of instruments)



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.	

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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 actuator										
2235	Hand operated										
	Basic Symbol										
	Valves	584	585	593	588	592	590	591	604	605	579

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

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		594	595	586	587	599	600	601	602	607	608	606
	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

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

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

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List of capacities

Capacities

5L-9L: 210 kW/Cyl. at 720 rpm			5	6	7	8	9
Engine output		kW	1050	1260	1470	1680	1890
Speed		rpm	720	720	720	720	720
Heat to be dissipated [3]							
Cooling water cylinder		kW	234	281	328	375	421
Charge air cooler; cooling water HT (Single stage charge air cooler)		kW	0	0	0	0	0
Charge air cooler; cooling water LT		kW	355	397	500	553	592
Lubricating oil cooler		kW	191	230	268	306	345
Heat radiation engine		kW	26	31	36	42	47
Flow rates [4]							
Internal (inside engine)							
HT cooling water cylinder		m^3/h	37	45	50	55	60
LT cooling water lube oil cooler		m^3/h	7.8	9.4	11	12.7	14.4
LT cooling water charge air cooler		m^3/h	37	45	55	65	75
Air data							
Temperature of charge air at charge air cooler outlet		°C	51	52	51	52	53
Air flow rate		m^3/h [5]	7355	8826	10297	11768	13239
		kg/kWh	7.67	7.67	7.67	7.67	7.67
Charge air pressure		bar	2.97	2.97	2.97	2.97	2.97
Air required to dissipate heat radiation (engine) (t_2-t_1= 10°C)		m^3/h	8425	10045	11665	13609	15230
Exhaust gas data [6]							
Volume flow (temperature turbocharger outlet)		m^3/h [7]	14711	17653	20595	23537	26479
Mass flow		t/h	8.3	9.9	11.6	13.2	14.9
Temperature at turbine outlet		°C	347	347	347	347	347
Heat content (190°C)		kW	389	467	545	623	701
Permissible exhaust back pressure		mbar	< 30	< 30	< 30	< 30	< 30
Permissible exhaust back pressure (SCR)		mbar	< 50	< 50	< 50	< 50	< 50
Pumps							
Engine driven pumps							
Fuel oil feed pump	(5.5-7.5 bar)	m^3/h	1.4	1.4	1.4	1.4	1.4
HT circuit cooling water	(1.0-2.5 bar)	m^3/h	45	45	60	60	60
LT circuit cooling water	(1.0-2.5 bar)	m^3/h	45	60	75	75	75
Lubrication oil	(3.0-5.0 bar)	m^3/h	24	24	34	34	34
External pumps [8]							
Diesel oil pump	(4 bar at fuel oil inlet A1)	m^3/h	0.74	0.89	1.04	1.19	1.34
Fuel oil supply pump	(4 bar discharge pressure)	m^3/h	0.36	0.43	0.50	0.57	0.64
Fuel oil circulating pump [9]	(8 bar at fuel oil inlet A1)	m^3/h	0.74	0.89	1.04	1.19	1.34
HT circuit cooling water	(1.0-2.5 bar)	m^3/h	37	45	50	55	60
LT circuit cooling water	(1.0-2.5 bar)	m^3/h	45	54	65	77	89
Lubrication oil	(3.0-5.0 bar)	m^3/h	22	23	25	27	28
Starting air system							
Air consumption per start		Nm^3	2.5	2.5	2.5	2.5	2.5

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]	°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-9L: 220 kW/Cyl. at 750 rpm			5	6	7	8	9
Engine output		kW	1100	1320	1540	1760	1980
Speed		rpm	750	750	750	750	750
Heat to be dissipated [3]							
Cooling water cylinder		kW	245	294	343	392	442
Charge air cooler; cooling water HT		kW	0	0	0	0	0
(Single stage charge air cooler)							
Charge air cooler; cooling water LT		kW	387	435	545	587	648
Lubricating oil cooler		kW	201	241	281	321	361
Heat radiation engine		kW	27	33	38	44	49
Flow rates [4]							
Internal (inside engine)							
HT cooling water cylinder		m^3/h	37	45	50	55	60
LT cooling water lube oil cooler		m^3/h	7.8	9.4	11	12.7	14.4
LT cooling water charge air cooler		m^3/h	37	45	55	65	75
Air data							
Temperature of charge air at charge air cooler outlet		°C	52	54	52	52	55
Air flow rate		m^3/h [5]	7826	9391	10956	12521	14087
		kg/kWh	7.79	7.79	7.79	7.79	7.79
Charge air pressure		bar	3.07	3.07	3.07	3.07	3.07
Air required to dissipate heat radiation (engine)		m^3/h	8749	10693	12313	14257	15878
(t_2-t_1= 10°C)							
Exhaust gas data [6]							
Volume flow (temperature turbocharger outlet)		m^3/h [7]	15520	18624	21728	24832	27936
Mass flow		t/h	8.8	10.5	12.3	14.1	15.8
Temperature at turbine outlet		°C	342	342	342	342	342
Heat content (190°C)		kW	401	481	561	641	721
Permissible exhaust back pressure		mbar	< 30	< 30	< 30	< 30	< 30
Permissible exhaust back pressure (SCR)		mbar	< 50	< 50	< 50	< 50	< 50
Starting air system							
Air consumption per start		Nm^3	2.5	2.5	2.5	2.5	2.5
Pumps							
Engine driven pumps							
Fuel oil feed pump	(5.5-7.5 bar)	m^3/h	1.4	1.4	1.4	1.4	1.4
HT circuit cooling water	(1.0-2.5 bar)	m^3/h	45	45	60	60	60
LT circuit cooling water	(1.0-2.5 bar)	m^3/h	45	60	75	75	75
Lubrication oil	(3.0-5.0 bar)	m^3/h	24	24	34	34	34
External pumps [8]							
Diesel oil pump	(4 bar at fuel oil inlet A1)	m^3/h	0.78	0.93	1.09	1.24	1.40
Fuel oil supply pump	(4 bar discharge pressure)	m^3/h	0.37	0.45	0.52	0.60	0.67
Fuel oil circulating pump [9]	(8 bar at fuel oil inlet A1)	m^3/h	0.78	0.93	1.09	1.24	1.40
HT circuit cooling water	(1.0-2.5 bar)	m^3/h	37	45	50	55	60
LT circuit cooling water	(1.0-2.5 bar)	m^3/h	45	54	65	77	89
Lubrication oil	(3.0-5.0 bar)	m^3/h	22	23	25	27	28

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

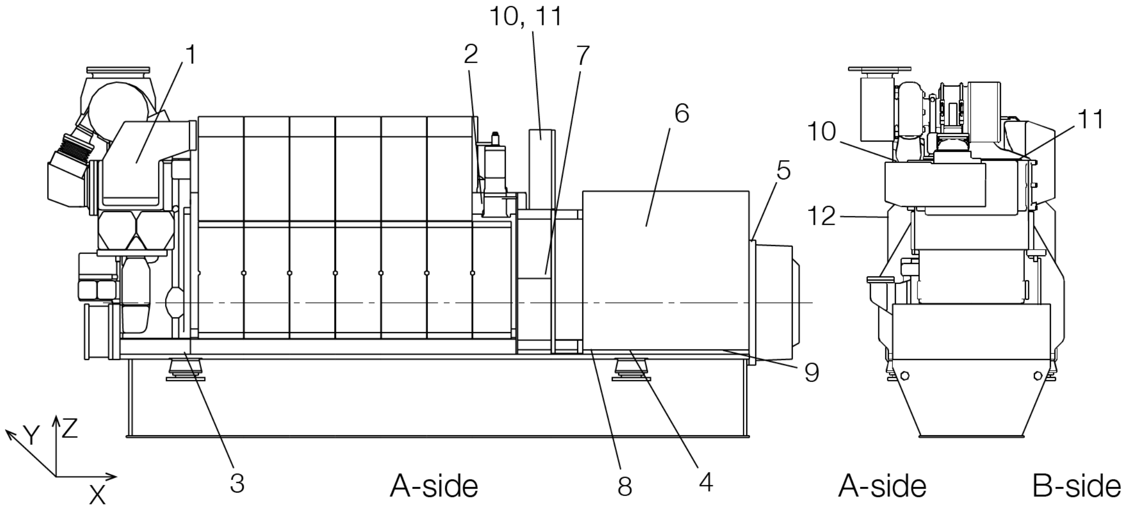
1) HT cooling water flows first through HT stage charge air cooler, then through water jacket and cylinder head, water temperature outlet engine regulated by mechanical thermostat.
2) LT cooling water flows first through LT stage charge air cooler, then through lube oil cooler, water temperature outlet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



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

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

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

Value 1 or 2 are depending on alternator make

3700395-8.4

Vibration limits and measurements

Description

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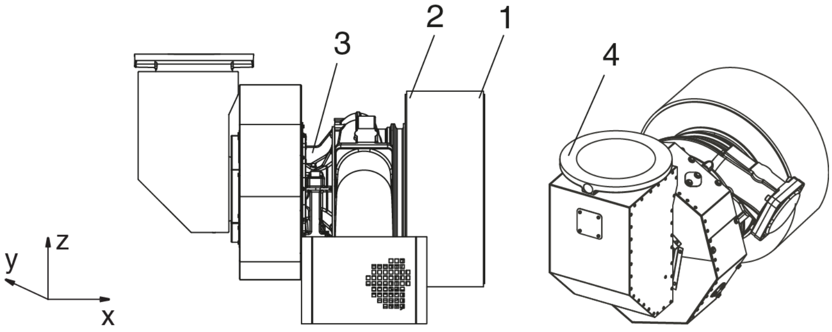
Date	Running Hours	Load %	Vertical (z) (Engine oriented)											
			1	2	3	4	5	6	7	8	9	10	11	12
		100												
			Crosswise (y) (Engine oriented)											
		100												
			Longitudinal (x) (Engine oriented)											
		100												

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

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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 microphone positions etc) and ISO 3746 (Accuracy due to criterion for suitability of test environment, K2>2 dB).

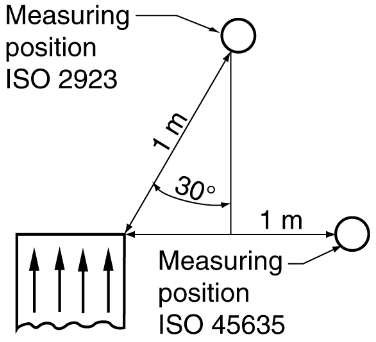

Figure 1: .

Description of structure-borne noise

Introduction

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

References

References and guidelines according to ISO 9611 and ISO 11689.

Operating condition

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

Frequency range

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

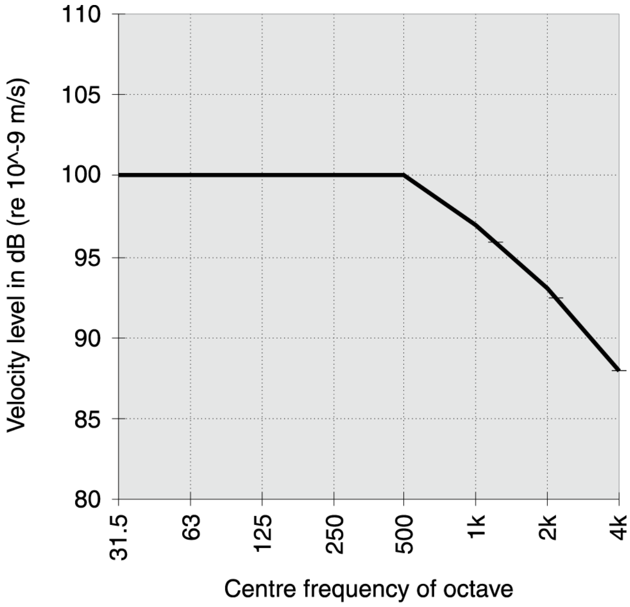

Figure 1: Structure-borne noise on resiliently mounted GenSets

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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 ≤ n ≤ 2000 → 44 x 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 ≤ n ≤ 2000 → 9 x 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.

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Moment of inertia

GenSet

No. of cyl.	Generator type*	Max. cont. rating kW	Speed rpm	Moment of inertia (J) Engine kgm²	Flywheel kgm²	Generator ** kgm²	Total kgm²
5	DIDBN 131i/10	1050	720	74.0	277	210	561.0
	DIDBN 131h/8	1100	750	74.0	277	160	511.0
6	DIDBN 131k/10	1260	720	146.9	277	240	663.9
	DIDBN 131i/8	1320	750	146.9	277	190	613.9
7	DIDBN 141k/10	1470	720	155.1	***267	380	802.1
	DIDBN 131k/8	1540	750	155.1	***267	215	637.1
8	DIDBN 141k/10	1680	720	123.3	***181	380	684.3
	DIDBN 131i/8	1760	750	123.3	***181	245	549.3
9	DIDBN 141i/10	1890	720	230.1	277	420	927.1
	DIDBN 141k/8	1980	750	230.1	277	330	837.1

* Standard generator, make A. van Kaick.

** If other generator is chosen the values will change.

*** Flywheel incl. flexible coupling.

Moment of intertia : $GD^2 = J \times 4$ (kgm^2)

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Moment of inertia
Description

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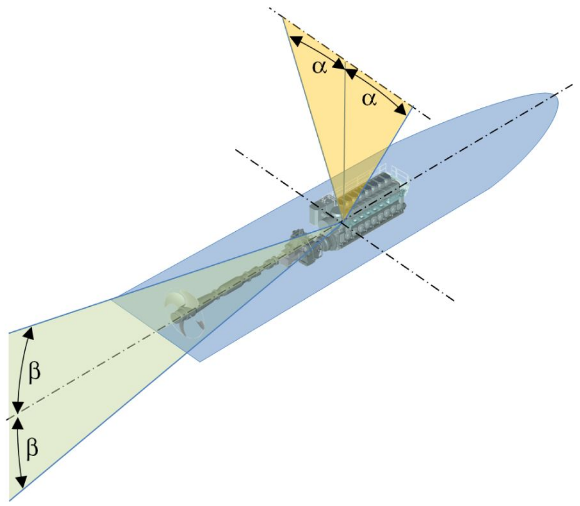
Inclination of engines

Description

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

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

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



α Athwartships β Fore and aft

Figure 1: Angle of inclination.

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 *	36.000	72.000
Connecting rod	Inspection	36.000	72.000
Big-end bearing	Inspection Retightening *	36.000	36.000
Camshaft	Inspection of cams surface	8.000	72.000
Piston	Overhaul and measuring of ring grooves	36.000	72.000
	Replacement of compression rings and scraper rings	36.000	36.000
Cylinder liner	Inspection, measuring and honing of running surface condition	36.000	72.000
Cylinder head		36.000	96.000
Valve clearance	Checking and adjustment	2.000	
Fuel injection valve	Checking, cleaning and adjustment of opening pressure 3)	based on observation	6.000 3)
Inlet and Exhaust valve	Overhaul and regrinding of spindle	36.000	72.000
Valve seat ring	Exchange and grinding	36.000	36.000
Rotorcap	Function check of rotation	2.000	36.000
Valve guide	Measuring of inside diameter	36.000	72.000
Cylinder head nuts	Retightening *		
Fuel pump	Fuel pump barrel/plunger assembly. Overhaul based on operational observations		36.000
Lub. Oil pump	Overhaul	36.000	72.000
Cooling water pumps	Overhaul	36.000	64.000
Air Cooler	Cleaning and pressure testing	18.000	64.000
Compr. air system	Check of compressed air system, air starter	18.000	
Autolog reading	Check once a year or in connection with disassembly/assembly with alternator and coupling	once a year	
Lub. oil filter cartr.	Replacement based on observations of pressure drop		1.500
Regulating system	Function check of overspeed and shutdown devices. Check that the control rod of each individual fuel pump can easily go to "stop" position	quarterly	
Flexible mountings	Check anti-vibration mountings	quarterly	
Vibration damper	Check of condition and wear	36.000	
Turbocharger	Water washing of compressor side	based on observation	
	Water washing of turbine side		
	Dry cleaning of turbine side	based on observation	
	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.

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 *	20.000	60.000
Connecting rod	Inspection	20.000	60.000
Big-end bearing	Inspection Retightening *	20.000	40.000
Camshaft	Inspection of cams surface	8.000	60.000
Piston	Overhaul and measuring of ring grooves	20.000	60.000
	Replacement of compression rings and scraper rings	20.000	20.000
Cylinder liner	Inspection, measuring and honing of running surface condition	20.000	60.000
Cylinder head		20.000	60.000
Valve clearance	Checking and adjustment	2.000	
Fuel injection valve	Checking, cleaning and adjustment of opening pressure 3)	based on observation	4.000 3)
Inlet and Exhaust valve	Overhaul and regrinding of spindle	20.000	40.000
Valve seat ring	Exchange and grinding	20.000	20.000
Rotorcap	Function check of rotation	2.000	20.000
Valve guide	Measuring of inside diameter	20.000	40.000
Cylinder head nuts	Retightening *		
Fuel pump	Fuel pump barrel/plunger assembly. Overhaul based on operational observations		20.000
Lub. Oil pump	Overhaul	20.000	60.000
Cooling water pumps	Overhaul	20.000	64.000
Air Cooler	Cleaning and pressure testing	20.000	64.000
Compr. air system	Check of compressed air system, air starter	20.000	
Autolog reading	Check once a year or in connection with disassembly/assembly with alternator and coupling	once a year	
Lub. oil filter cartr.	Replacement based on observations of pressure drop		1.000
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	36.000	
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.

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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.

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	720 rpm		750 rpm	
	720 rpm	Available turning direction	750 rpm	Available turning direction
	kW	CW [1]	kW	CW [1]
5L28/32H	1050	Yes	1100	Yes
6L28/32H	1260	Yes	1320	Yes
7L28/32H	1470	Yes	1540	Yes
8L28/32H	1680	Yes	1760	Yes
9L28/32H	1890	Yes	1980	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.

Available outputs

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

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

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

Table 3: Available outputs / related reference conditions.

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

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

De-rating

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

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

[1] Overpressure

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

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 $U \geq 0$
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 $O \geq 0$
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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Power take-off (PTO)

Description

The engine can be supplied with a power take-off (PTO) in several positions, as an adapted extension to the crankshaft or alternator shaft.

The PTO is dimensioned to transmit the full engine power.

Between PTO and driven equipment there need to be selected a highly flexible coupling to transmit full engine power and to accommodate and absorb any vibrations which may be present radially and axially.

The PTO-arrangement for the driven equipment may only cause minimal axial force to the engine crankshaft. Any temperature expansion shall be avoided.

Crankshaft deflection may cause the flexible coupling between the crankshaft and the driven equipment to create an additional axial force, which must be taken into consideration when the PTO-arrangement is being designed.

NOTICE

There need to be performed a full torsional vibration analysis for engine, PTO and driven equipment.

Please contact MAN Energy Solutions for support and assistance.

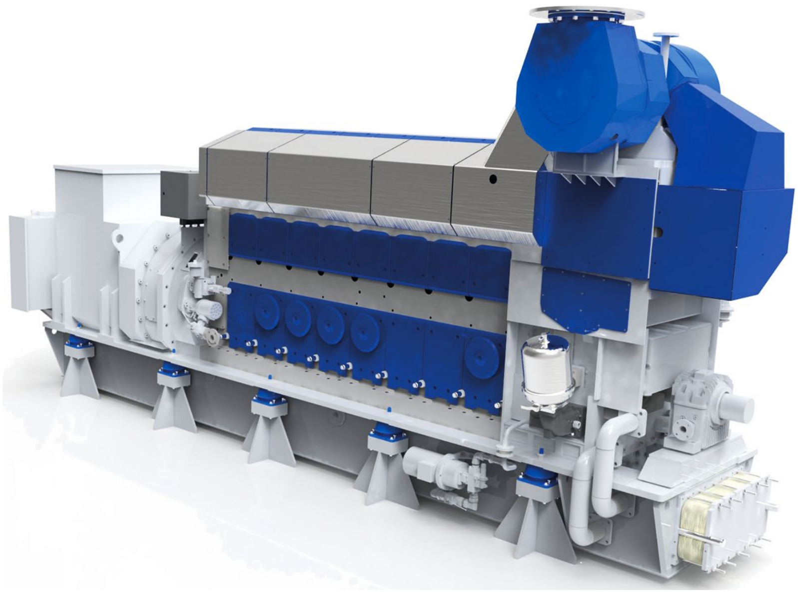

Figure 1: PTO on front end - external pump

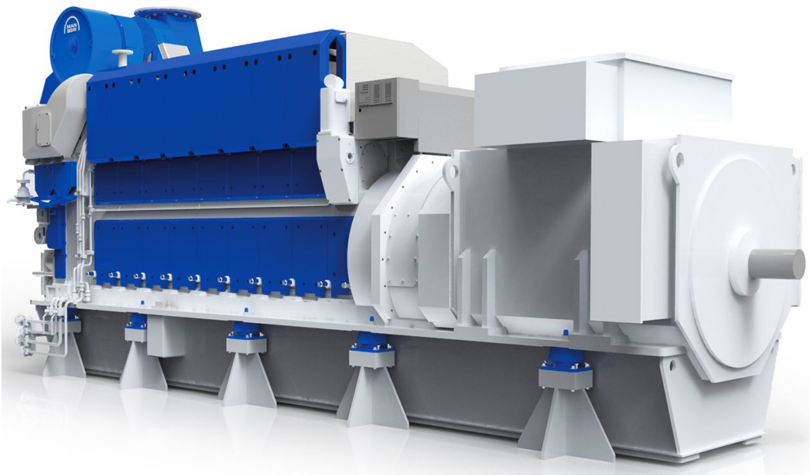

Figure 2: PTO on alternator - external pump

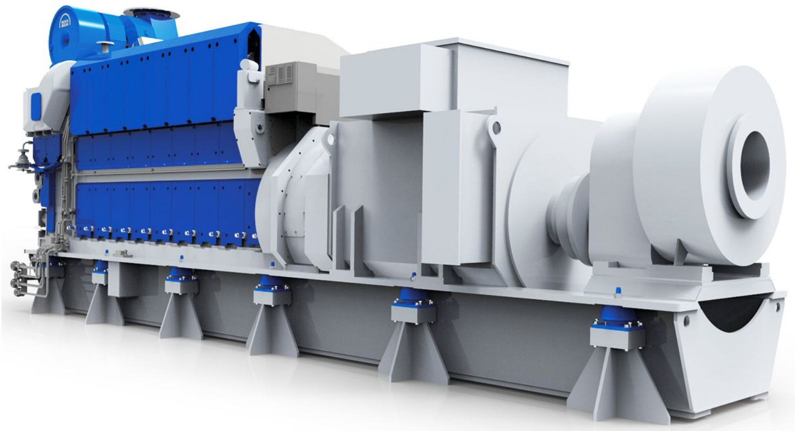

Figure 3: Pump on alternator - common base frame

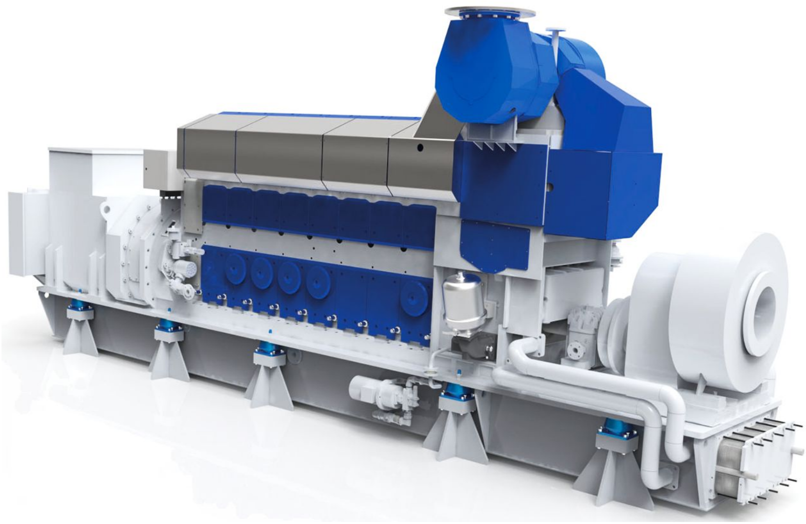

Figure 4: Pump on front end - common base frame

General description

General

The engine is a turbocharged, single-acting, fourstroke diesel engine of the trunk piston type with a cylinder bore of 280 mm and a stroke of 320 mm, the crankshaft speed is 720/750 rpm.

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

Engine frame

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

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

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

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

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

Base frame

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

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

Cylinder liner

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

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

Top land ring

The top land ring is made of heat resistant steel, and is used to protect the cylinder liner from the heat generated by the combustion.

This way the liner will have a smaller wear rate, and less deformation.

Cylinder head

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

The cylinder head is tightened by means of 6 nuts and 6 studs, which are screwed into the engine frame. The nuts are tightened by means of hydraulic jacks.

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

From the cooling water guide jacket, cooling water is led through radial bores in the bottom of the head. From the cooling water space and bores of the cylinder head, the cooling water is led to a common outlet.

Air inlet and exhaust valves

The inlet and exhaust valve spindles are identical.

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

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

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

The valve seat rings for inlet and exhaust valves are identical.

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

Valve actuating gear

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

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

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

Fuel injection system

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

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

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

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

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

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

Piston

The piston, which is oil-cooled and of the monobloc type made of nodular cast-iron, is equipped with 3 compression rings and 1 oil scraper ring.

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

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

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

The piston pin is fully floating and kept in position in axial direction by two circlips (seeger rings). The piston pin is equipped with channels and holes for supply of oil to lubrication of the pin bosses and for supply of cooling oil to the piston.

Connecting rod

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

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

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

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

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

Crankshaft and main bearings

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

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

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

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

Vibration damper

In special cases a vibration damper is mounted on the crankshaft to limit torsional vibrations. The damper consists essentially of a heavy flywheel totally enclosed in a light casing.

A small clearance is allowed between the casing and the flywheel, and this space is filled with a highly viscous fluid. The casing is rigidly connected to the front end of the engine crankshaft and the only connection between the crankshaft and the damper flywheel is through the fluid. Under conditions of no vibration, the casing and damper flywheel tend to rotate as one unit, since the force required to shear the viscous film is considerable. As the torsional vibration amplitudes increase, the casing follows the movement of the crankshaft but the flywheel tends to rotate uniformly by virtue of its inertia, and relative motion occurs between the flywheel and the casing. The viscous fluid film therefore undergoes a shearing action, and vibration energy is absorbed and appears as heat.

Camshaft and camshaft drive

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

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

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

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

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

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

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

Governor

The engine speed is controlled by a hydraulic or electric governor.

Monitoring and control system

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

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

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

Turbocharger system

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

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

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

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

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

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

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

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

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

Compressed air system

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

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

Fuel oil system

The built-on fuel oil system consists of the fuel oil filter and the fuel injection system. An engine-driven fuel oil feed pump can be mounted as optional.

The fuel oil feed pump, which is of the gear pump type, is mounted to the front end of the engine frame and driven by the camshaft through a splined shaft coupling. The pump housing is equipped with a spring-loaded adjustable by-pass valve.

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

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

Internal nozzle cooling system

The nozzles of the injection valves on HFO-engines are temperature controlled by means of a separate circuit containing diesel oil or thermal oil as media.

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

Lubricating oil system

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

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

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

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

Cooling water system

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

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

The low temperature system is normally cooled by fresh water.

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

Tools

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

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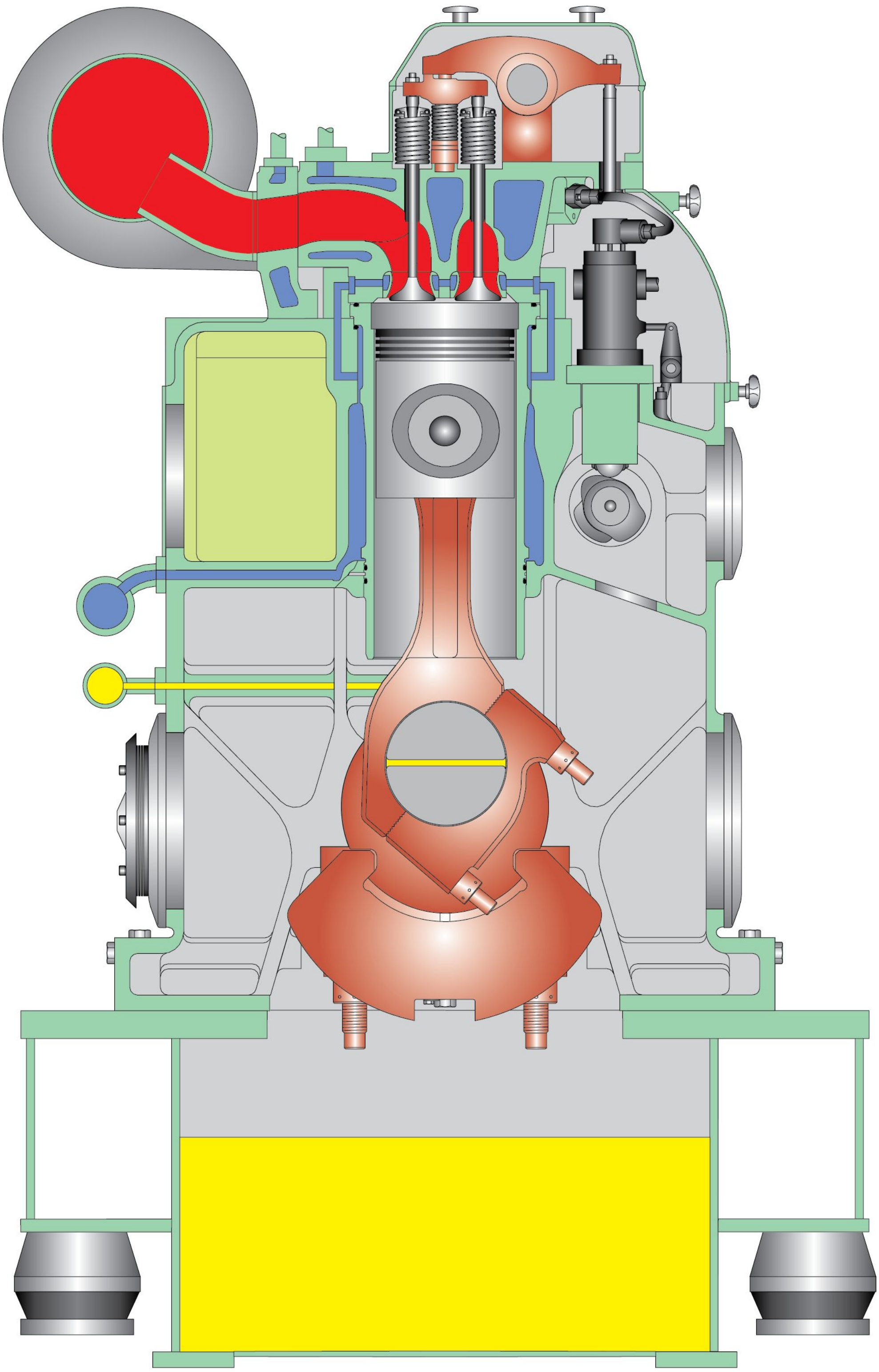
Cross section

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	:	1050 - 1980 kW
Speed	:	720 / 750 rpm
Bore	:	280 mm
Stroke	:	320 mm
Stroke/bore ratio	:	1.14 : 1
Piston area per cyl.	:	616 cm^2
swept volume per cyl.	:	19.7 ltr
Compression ratio	:	13.9 : 1
Max. combustion pressure	:	130 bar
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	720	750
Mean piston speed	m/sec.	7.7	8.0
Mean effective pressure	bar	17.8	17.9
Max. combustion pressure	bar	130	130
Power per cylinder	kW per cyl.	210	220

	Overload rating (up to 10 %) allowable in 1 hour for every 12 hours		
Power per cylinder	kW per cyl.	230	240

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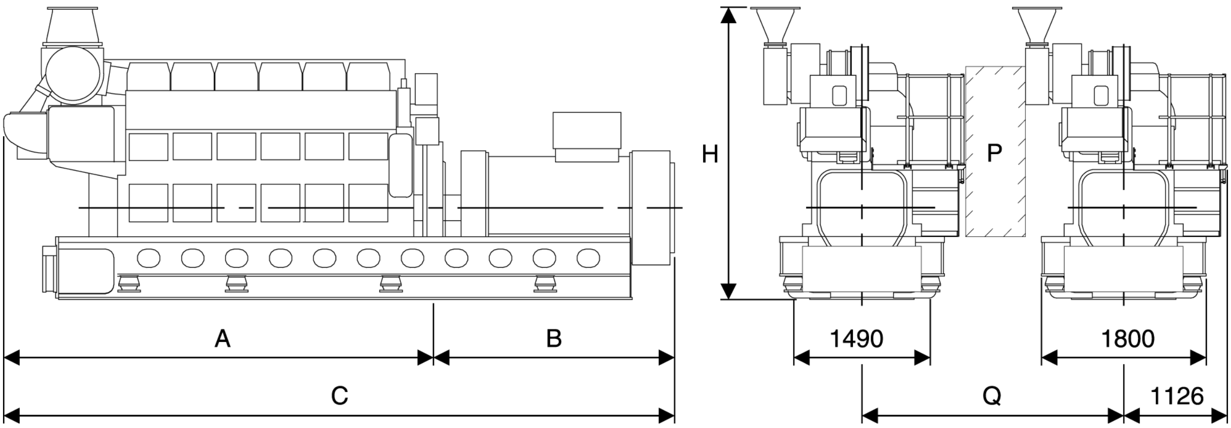
Dimensions and weights

General



Cyl. no	A (mm)	* B (mm)	* C (mm)	H (mm)	** Dry weight GenSet (t)
5 (720 rpm)	4279	2400	6679	3184	32.6
5 (750 rpm)	4279	2400	6679	3184	32.3
6 (720 rpm)	4759	2510	7269	3184	36.3
6 (750 rpm)	4759	2510	7269	3184	36.3
7 (720 rpm)	5499	2680	8179	3374	39.4
7 (750 rpm)	5499	2680	8179	3374	39.4
8 (720 rpm)	5979	2770	8749	3374	40.7
8 (750 rpm)	5979	2770	8749	3374	40.6
9 (720 rpm)	6199	2690	8889	3534	47.1
9 (750 rpm)	6199	2690	8889	3534	47.1

P Free passage between the engines, width 600 mm and height 2000 mm.
Q Min. distance between engines: 2655 mm (without gallery) and 2850 mm (with gallery).

* 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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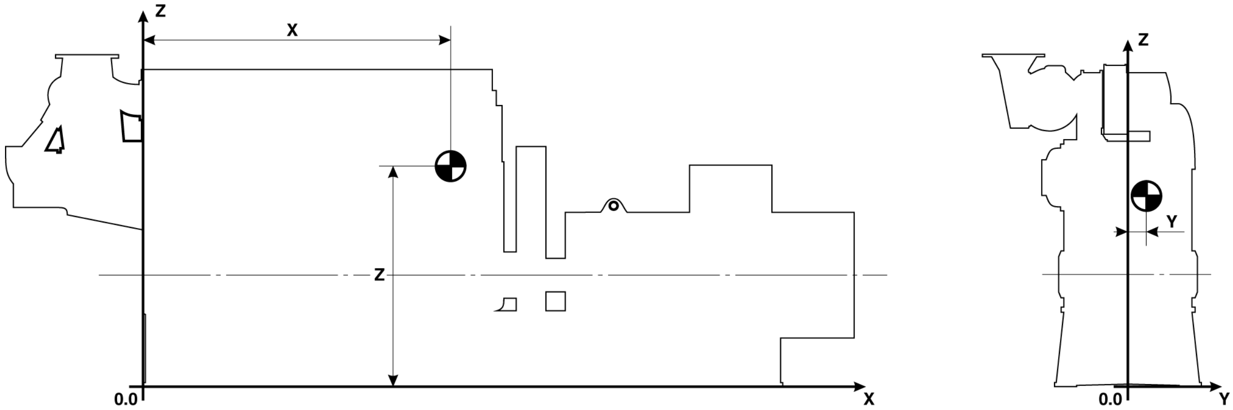
Centre of gravity

Description



Cyl. no	X - mm	Y - mm	Z - mm
5 (720/750 rpm)	2010	0	1060
6 (720/750 rpm)	2315	0	1060
7 (720/750 rpm)	2690	0	1060
8 (720/750 rpm)	3015	0	1060
9 (720/750 rpm)	3240	0	1060

The values are based on generator make A. van Kaick.
If other generator is chosen the values will change.

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Overhaul areas

Dismantling height for piston

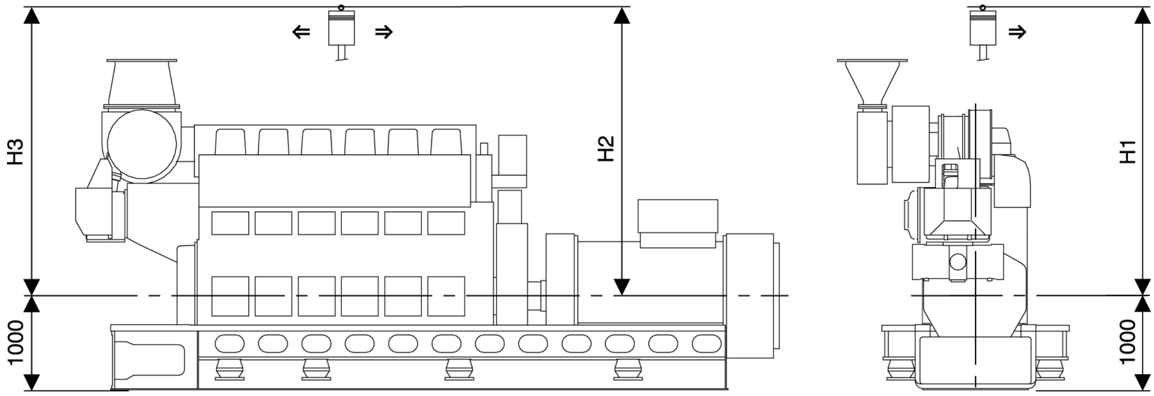

Figure 1: Dismantling height for piston

Cyl. no	Frame (H1)	Cylinder head (H2)	Turbocharger (H3)
5-6 (720/750 rpm)	2235	2710	2900
7-8 (720/750 rpm)	2235	2710	2990
9 (720/750 rpm)	2235	2710	3040

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

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

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

If lower dismantling height is required, special tools can be delivered

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Dismantling space

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

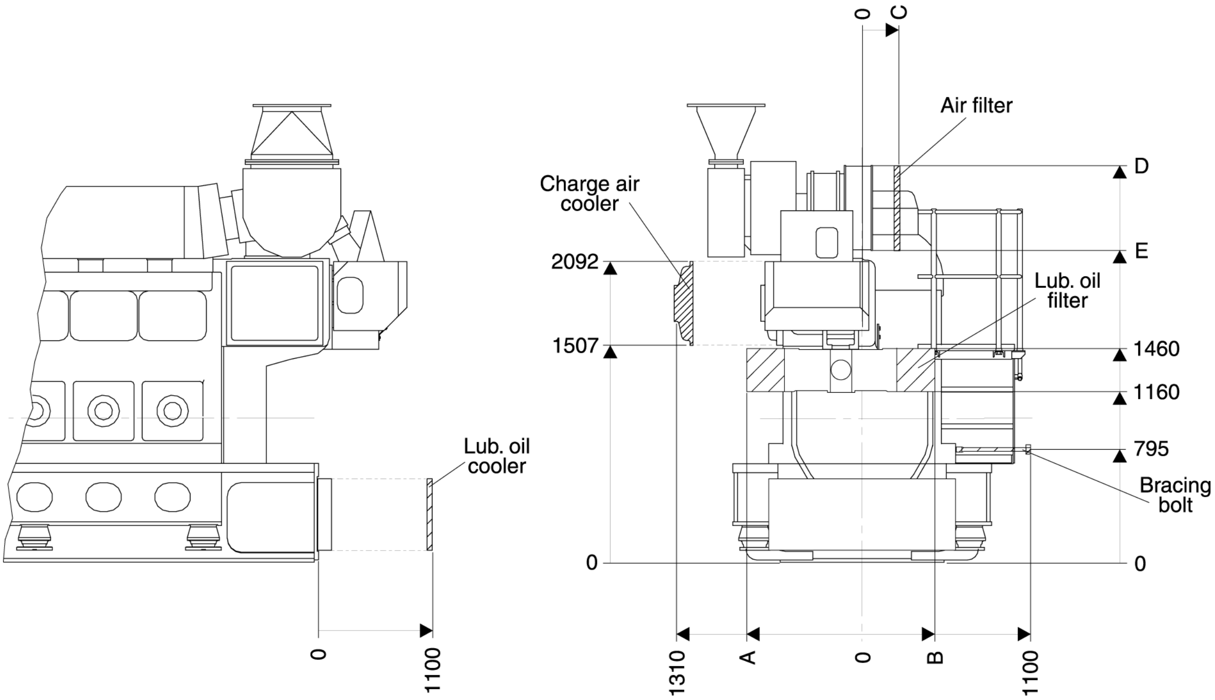

Figure 2: Overhaul areas for charge air cooler element, turbocharger filter element, lub. oil cooler, lub. oil filter cartridge and bracing bolt.

Cylinders	A	B	C	D	E
5	780	480	273	2757	2167
6	780	480	273	2757	2167
7	1130	830	345	2869	2154
8	1130	830	345	2869	2154
9	1130	830	445	2987	2157

Table 1: Definition of point of measurement in fig. 2.

Low dismantling height

Space requirements

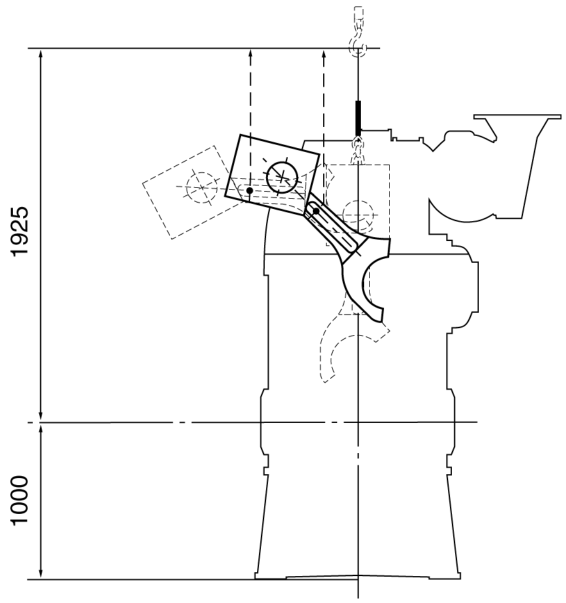

Figure 1: Minimum dismantling height of pistons only with special tools.

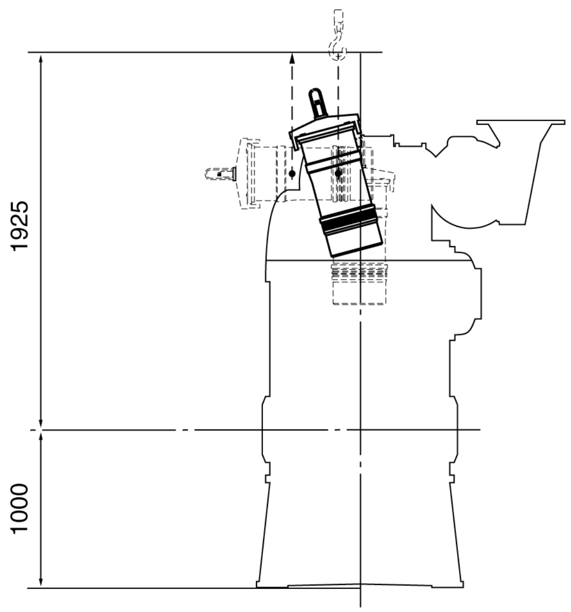

Figure 2: Minimum lifting height of cylinder liner only with special tools.

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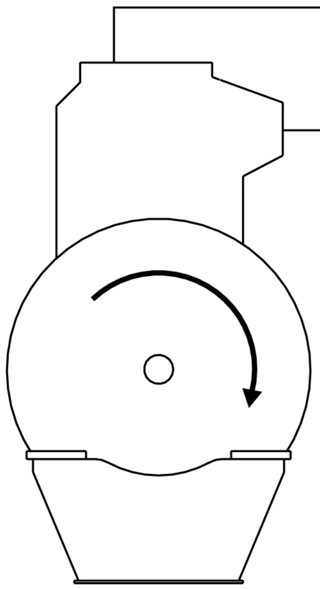
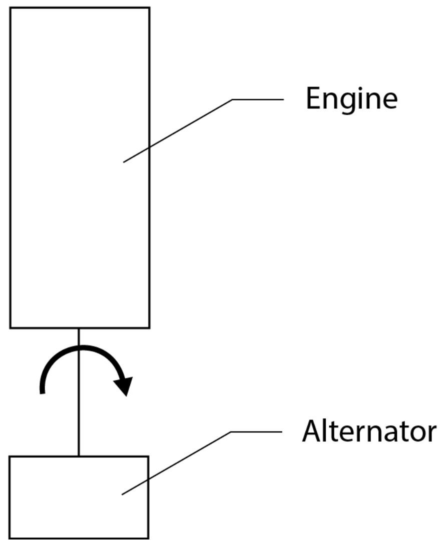
Engine rotation clockwise

Engine rotation clockwise



Direction of rotation seen from flywheel end "Clockwise"



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Internal fuel oil system

Internal fuel oil system

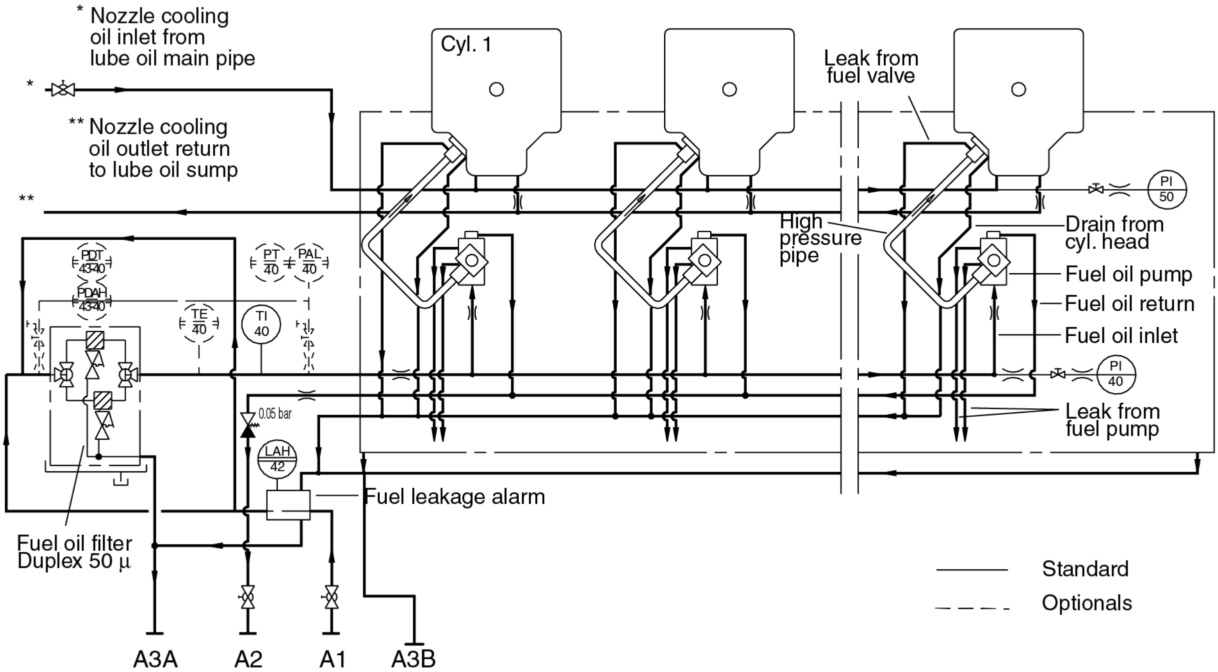


Figure 1: Diagram for fuel oil system (for guidance only, please see the plant specific engine diagram)

Pipe description		
A3A	Clean leak oil outlet to service tank	DN15
A3B	Waste oil outlet to drain tank	DN15
A1	Fuel oil inlet	DN25
A2	Fuel oil outlet	DN25

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

General

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

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

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, high-pressure pipe and injection valve.

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

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

Fuel oil injection pump

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

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

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

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

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

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

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

Fuel oil injection valve

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

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

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

Fuel oil high pressure pipe

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

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

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

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

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

Internal nozzle cooling system

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

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

Waste oil system

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

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

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

Clean leak fuel tank

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

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

Sludge tank

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

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

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

Optionals

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

- Pressure differential alarm high
  - PDAH 43-40 Fuel oil, inlet and outlet filter
- Pressure differential transmitting
  - PDT 43-40 Fuel oil, inlet and outlet filter
- Pressure alarm low
  - PAL 40 Fuel oil, inlet fuel oil pump
- Pressure transmitting
  - PT40 Fuel oil, inlet fuel oil pump
- Temperature element
  - TE40 Fuel oil, inlet fuel oil pump

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.

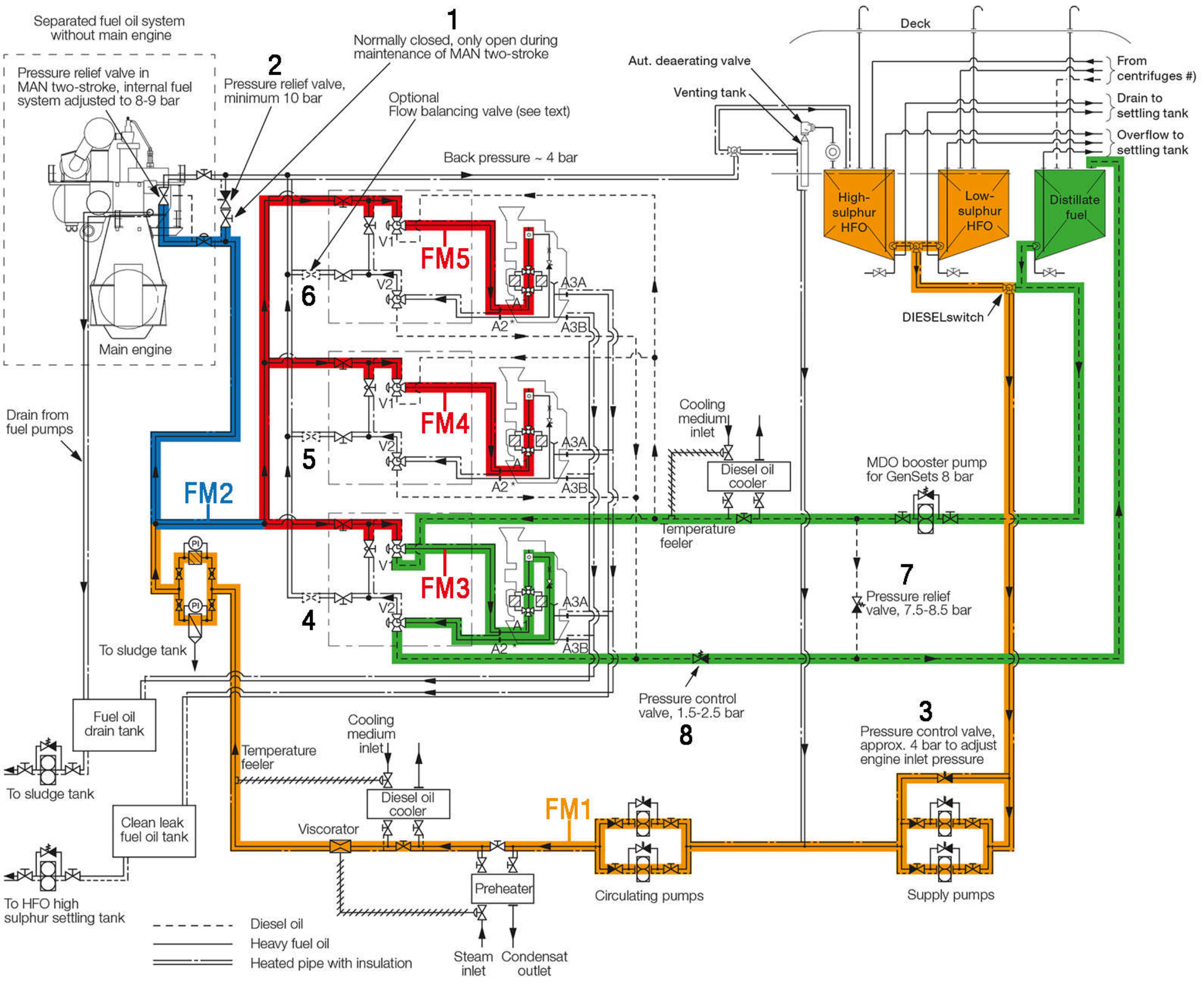
Based on the MAN Diesel & Turbo uni-fuel system, this guideline explains how the correct setting is performed and how each engine is supplied with its required fuel flow and pressure, as set out in the project specification for reliable operation. This guideline can also be applied to fuel systems for 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

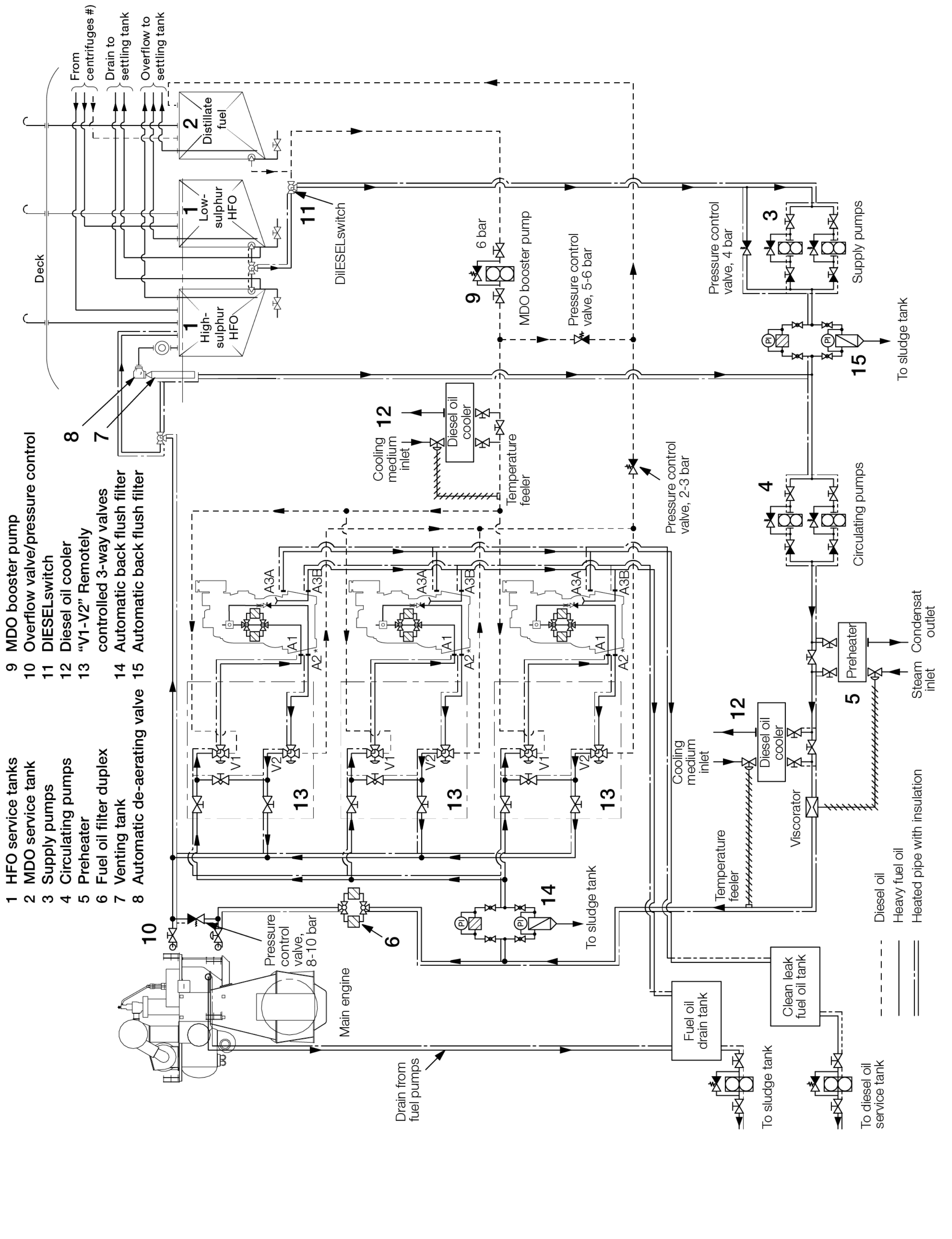
- If the pressure at the engine inlet is too low, close the pressure relief valve (7) connecting the inlet and outlet of the MDO circuit to one another until the required pressure is reached or the inlet pressure is no longer affected.
- If the required pressure cannot be reached by turning the pressure 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 system

Fuel oil system with drain split



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Fuel oil system

Description

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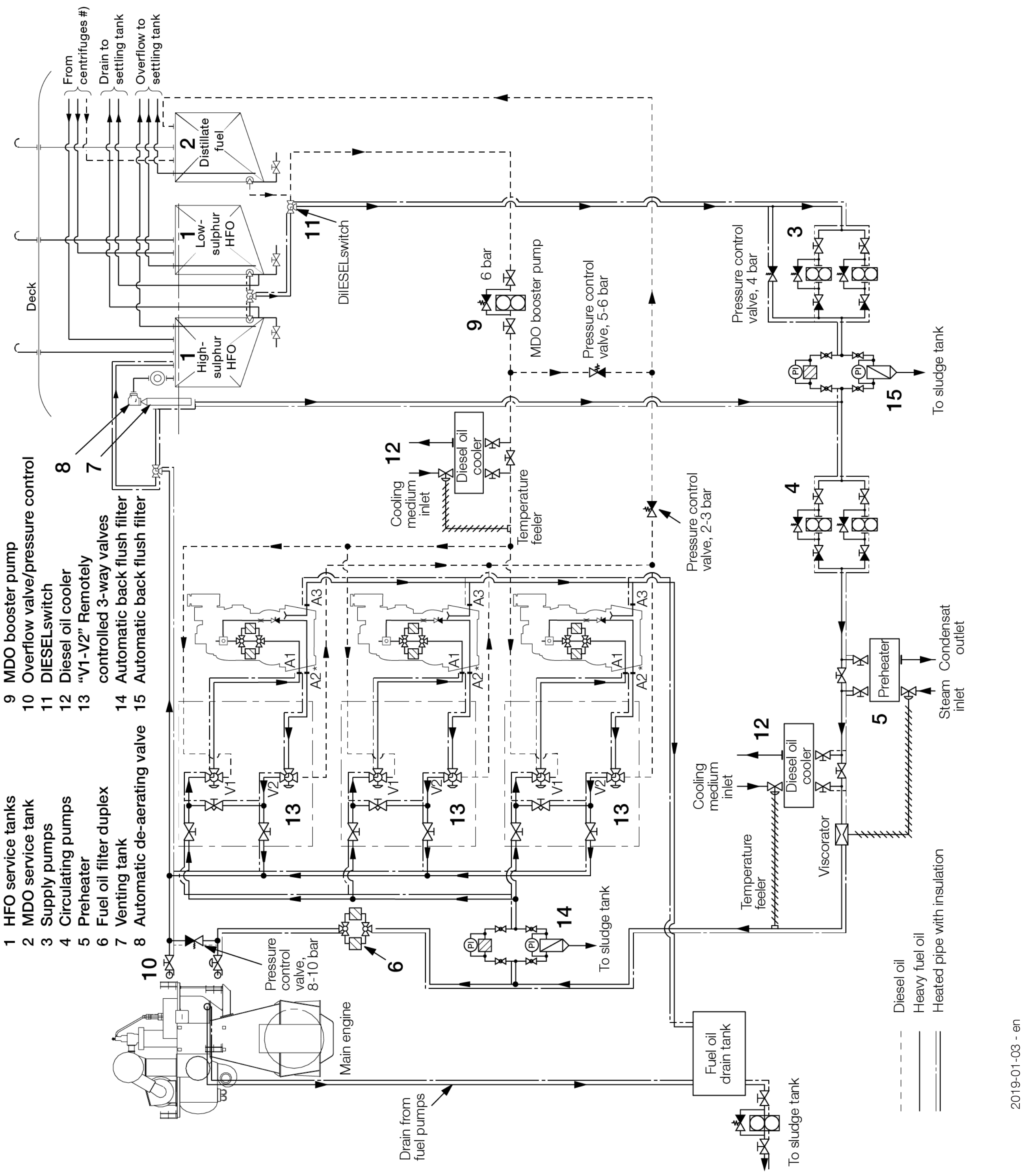
Fuel oil system without drain split



Design features and working principle

This diagram describes the uni-concept, i.e. the possibilities inherent to the design of a common auxiliary system for MAN Energy Solutions' two stroke low speed diesel engines and MAN Diesel & Turbo's four-stroke medium speed GenSets. The engines are designed to operate in accordance with the uni-fuel principle, meaning the same fuel for both main and auxiliary diesel engines.

The fuel oil system is a common, pressurized system using either heavy fuel oil or diesel oil. The primary purpose of pressurization is to avoid gasification and cavitation in the system. This may occur when the heavy fuel oil is heated to achieve a viscosity of 10-15 cSt required for injection.

Operation at sea

The fuel from the bunker tanks must be treated in centrifugal separators before entering the service tanks, see items 1 and 2. From the service tanks the fuel enters the supply system. The fuel is pumped by the supply pumps, item 3, into the circulating system at a pressure of 4 bars. The supply system may include an automatic back flush filter. The overflow from the supply pumps is recirculated in the bypass piping that incorporates the overflow valve to keep the pressure in the circulation loop constant, irrespective of the actual consumption. The pumps in the circulation loop, item 4, raise the pressure of the fuel oil from the supply system to a constant inlet pressure as specified in "*B 19 00 0, Operation data & set points*".

The inlet pressure is maintained at the specified level by a spring-loaded overflow valve located close to the main engine, see item 10. The temperature controlled or viscosity controlled pre-heater, item 5, heats the heavy fuel oil until it reaches the required viscosity.

To safeguard the injection system components on the main engine is it recommended to install a fuel oil filter duplex, item 6, with a fineness of max. 50 microns (*sphere passing mesh*) as close as possible to the main engine.

GenSets with conventional fuel injection systems are equipped with a fuel oil filter duplex (safety filter), with a fineness of max. 25 microns (*absolute/sphere passing mesh*) The fuel oil filter duplex (*safety 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.

To protect the GenSets from foreign particles in the fuel (*cat fines attack*), a common automatic back flush filter, item 14, must be installed in the circulation line, just before the branching to the individual GenSets. This will also extend the cleaning intervals of the filter elements in the aforementioned fuel oil filter duplex (*safety filter*) considerably.

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.

To protect both the propulsion engine and the Gen- Sets from foreign particles in the fuel (*cat fines attack*), it is recommended to install a common 10 microns (*absolute/sphere passing mesh*) automatic back-flush filter, item 15, in the feeder circle.

Excess fuel oil is re-circulated via the venting pipe, item 7, where gases, if any, are released by a de-aerating valve, item 8, to avoid cavitation in the system. The flexibility of the system makes it possible, if necessary, to operate the auxiliary engines on either diesel oil or heavy fuel oil simultaneously by means of remotely controlled and interconnected 3- way valves, item 13, which are installed immediately before each auxiliary engine.

A separate diesel booster pump, item 9, supplies diesel oil from the service tank, item 2, to the auxiliary engines and returns any excess oil to the service tank. To ensure operation in case of a blackout the booster pump must have an immediate possibility of being powered by compressed air or by power supplied from the emergency generator / emergency switchboard. If a blackout occurs, the remotely controlled and interconnected 3-way valve at each auxiliary engine will automatically change over to the MDO supply system. Within few seconds the internal piping on the auxiliary engines will then be flushed with MDO and be ready for start up.

Depending on system lay-out, 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.

Operation in territorial waters / in port

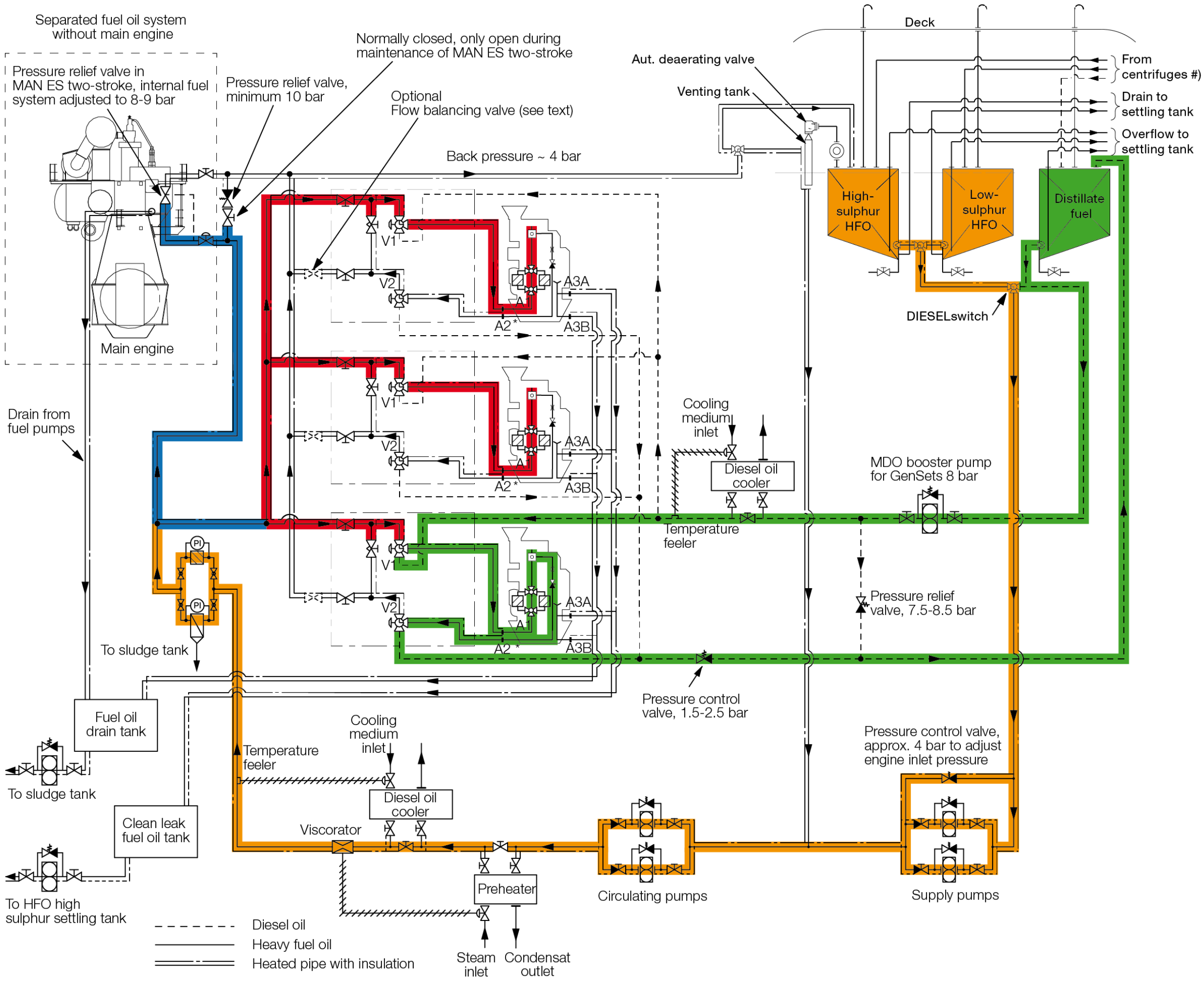
If the fuel type for both the main engine and the auxiliary engines have to be changed from HFO to MDO/MGO and vice versa, the 3-way valve, item 11, just after the service tanks (the DIESELswitch) has to be activated. With the introduction of stricter fuel sulphur content regulations the main engine as well as the auxiliary engines 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, item 12, in the fuel system. The lowest viscosity suitable for the main engine and the auxiliary engines is 2 cSt at engine inlet.

During operation in port when the main engine is stopped, but power from one or more auxiliary engines is still required, the supply pump, item 3, and the circulation pump, item 4, should be running.

The bypass line with overflow valve, item 10, between the inlet and outlet of the main engine serves the purpose of bypassing the main engine if, for instance, a major overhaul is required on the main engine fuel oil system. During this bypass the overflow valve takes over the function of the internal overflow valve of the main engine.

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.

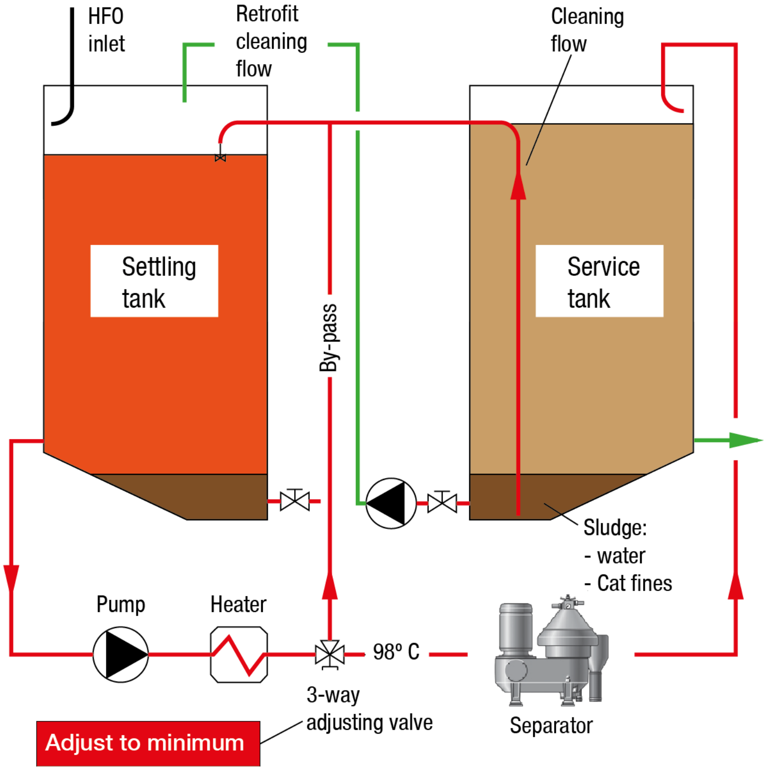
In all fluids a natural settling of particles, takes place. This results in a higher concentration of particles in the bottom of the tanks. Due to this phenomenon it is important that the various fuel tanks are designed and operated correctly.

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/cm^2 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.

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.

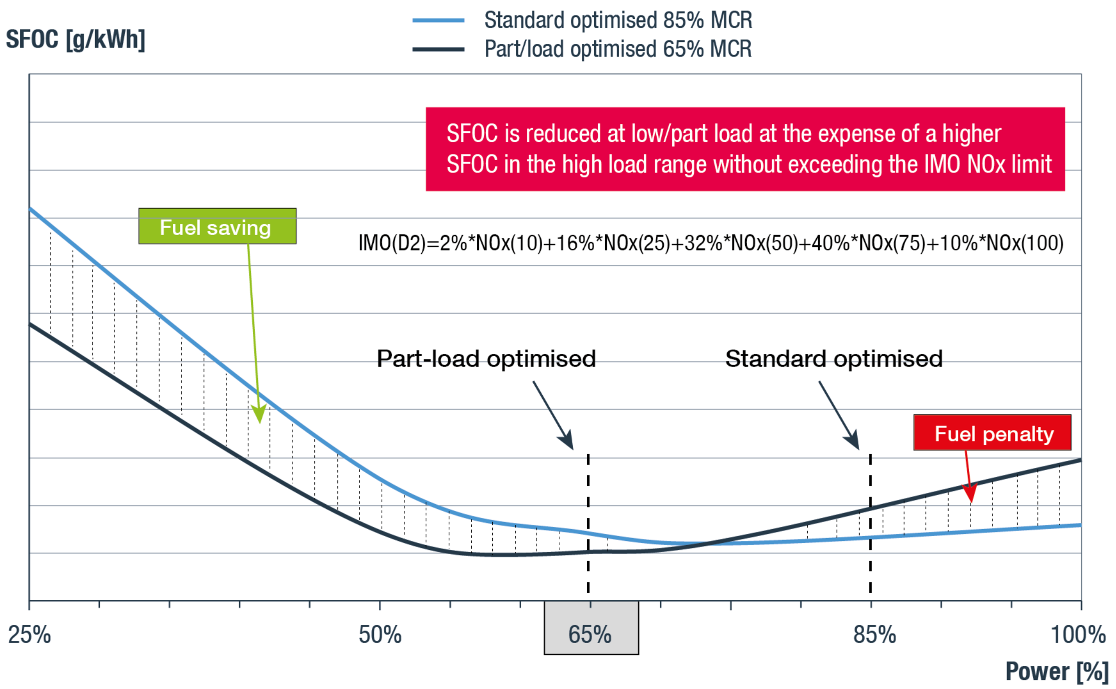

Figure 1: SFOC-curves from first delivery of PLO

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 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)	mm²/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.

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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

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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

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.

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 mm^2/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 mm^2/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.

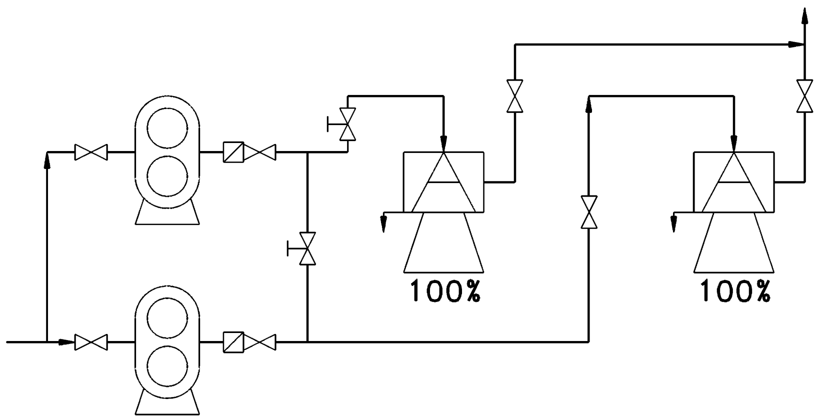
Separators

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.

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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.

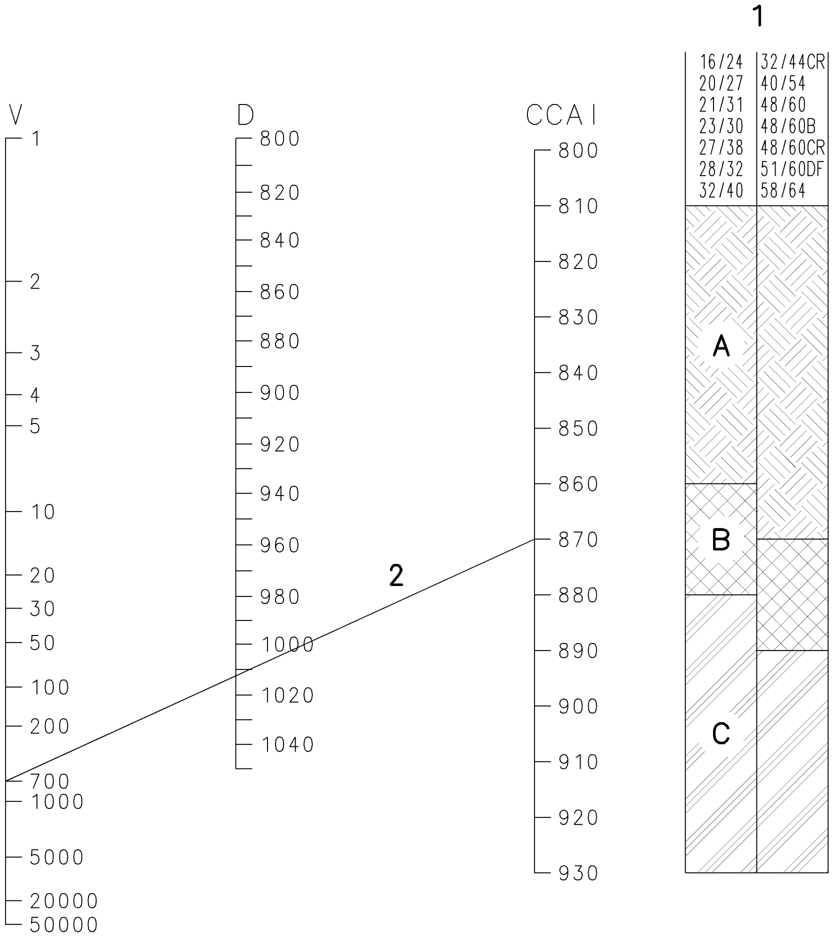
The ignition delay in heavy fuel oils with poor ignition characteristics is longer; the combustion is also delayed which can lead to thermal overloading of the oil film at the cylinder liner and also high cylinder pressures. The ignition delay and accompanying increase in pressure in the cylinder are 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

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- 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.

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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.

⚠ WARNING

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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.

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/m^3	ISO 3675	≥ 820.0 ≤ 890.0
Kinematic viscosity at 40 °C	mm^2/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		ISO 8754	≤ 1.5
Ash	weight %	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/m^3	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

Handling of operating fluids

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Analyses

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2018-09-06 - de

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

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.

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.

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%

2018-09-07 - en

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

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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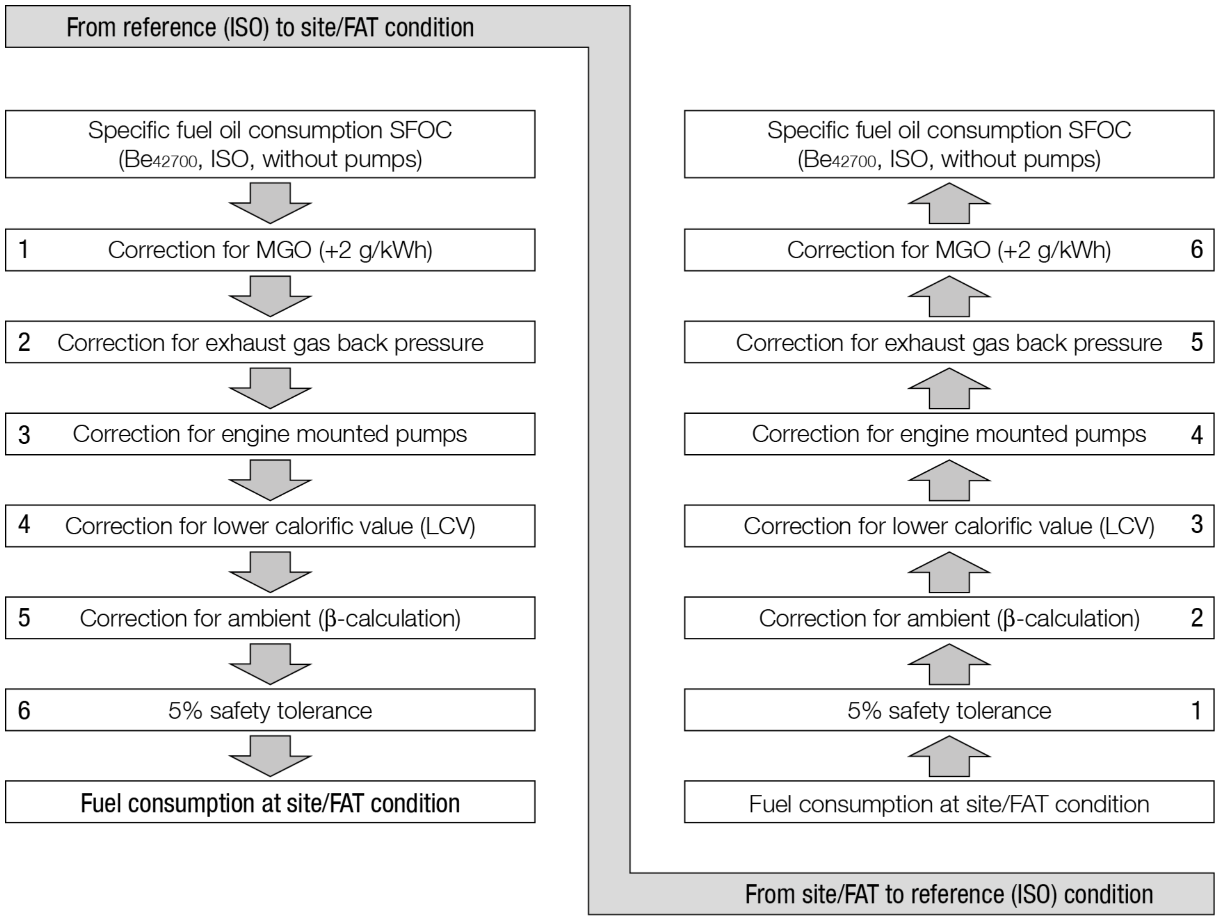
Calculation of specific fuel oil consumption (SFOC)

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.

2017-05-03 - en

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 = (*Fuel oil*) – (*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%.

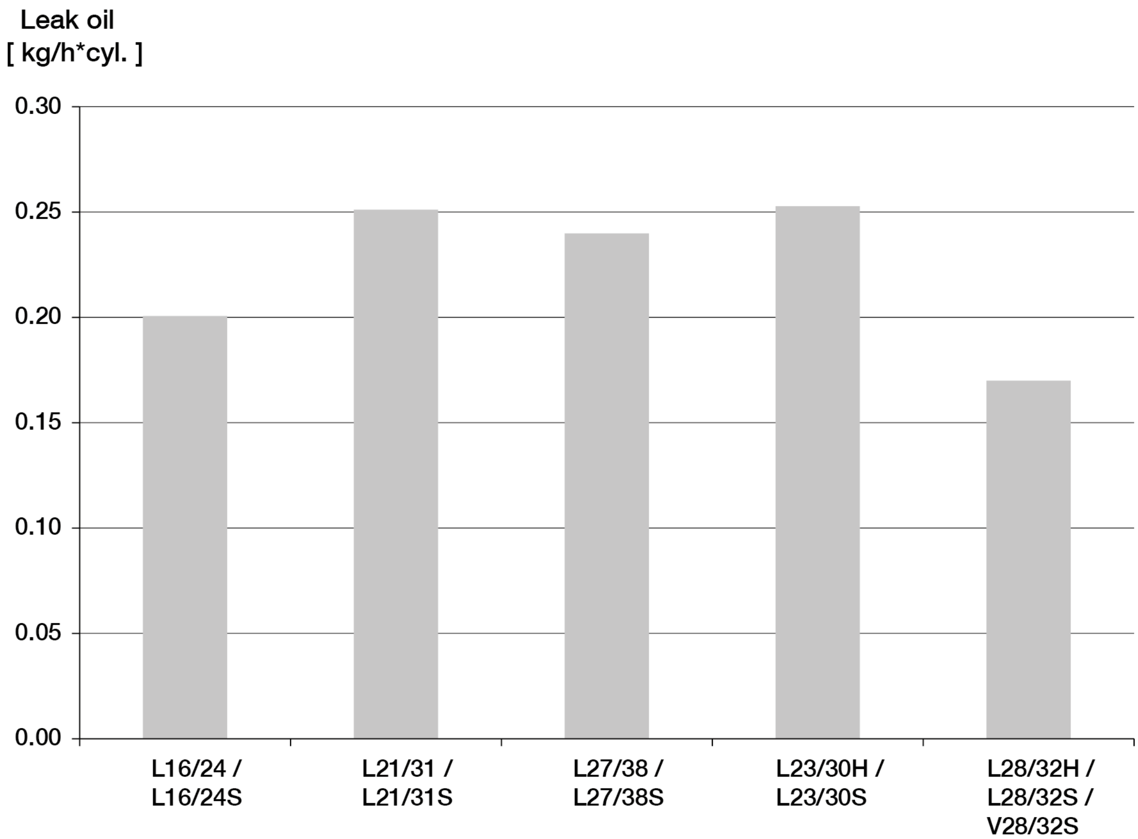


Figure 1: Leak oil on full load for MGO operation (for guidance only)

1) Safety tolerance 5%

Safety tolerance 5% is subtracted from fuel consumption

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

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

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

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

3) Correction for lower calorific value (LCV)

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

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

$$\text{Be3} = \text{Be2} * \text{LCV } f$$

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

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

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

5-9L28/32H: 210 kW/cyl. at 720 rpm

% Load	100	85[1)]	75	50	25
Spec. fuel consumption (g/kWh) with HFO/MDO without attached pumps [2) 3)]	190	190[1)]	190	198	219

[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 Table 4 "Reference conditions"*

Table 1: Fuel oil consumption.

5-9L28/32H: 220 kW/cyl. at 750 rpm

% Load	100	85[1)]	75	50	25
Spec. fuel consumption (g/kWh) with HFO/MDO without attached pumps [2) 3)]	191	191[1)]	192	198	221

[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 Table 4 "Reference conditions"*

Table 2: Fuel oil consumption.

No of cylinders	Fuel oil consumption at idle running (kg/h)				
	5L	6L	7L	8L	9L
Speed 720/750 rpm	-	-	-	-	-

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".*

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.

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

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

Net calorific value NVC rise 427 kJ/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.

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.

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MDO / MGO cooler

General

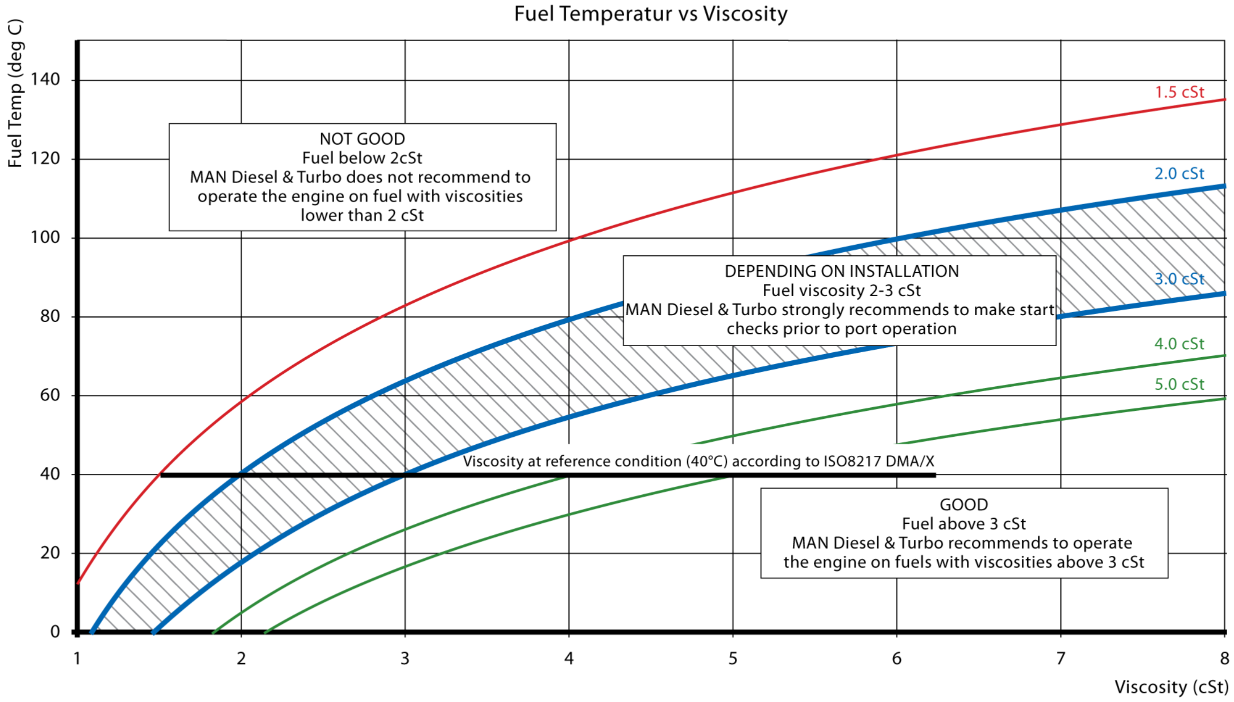

Figure 1: Fuel temperature versus viscosity.

In order to ensure a satisfactory hydrodynamic oil film between fuel injection pump plunger/barrel, thereby avoiding fuel injection pump seizures/sticking, MAN 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).*

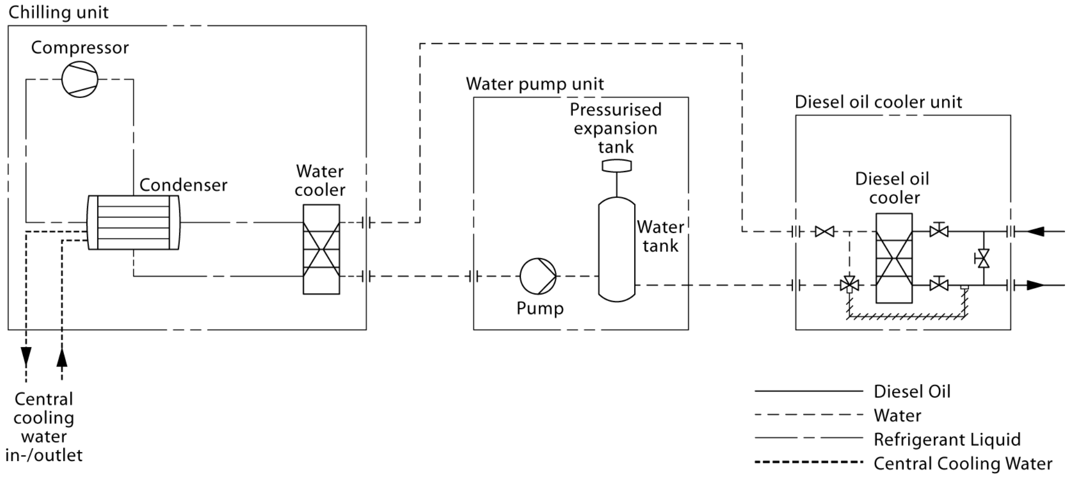

Figure 2: Chiller.

HFO/MDO changing valves (V1 and V2)

Description

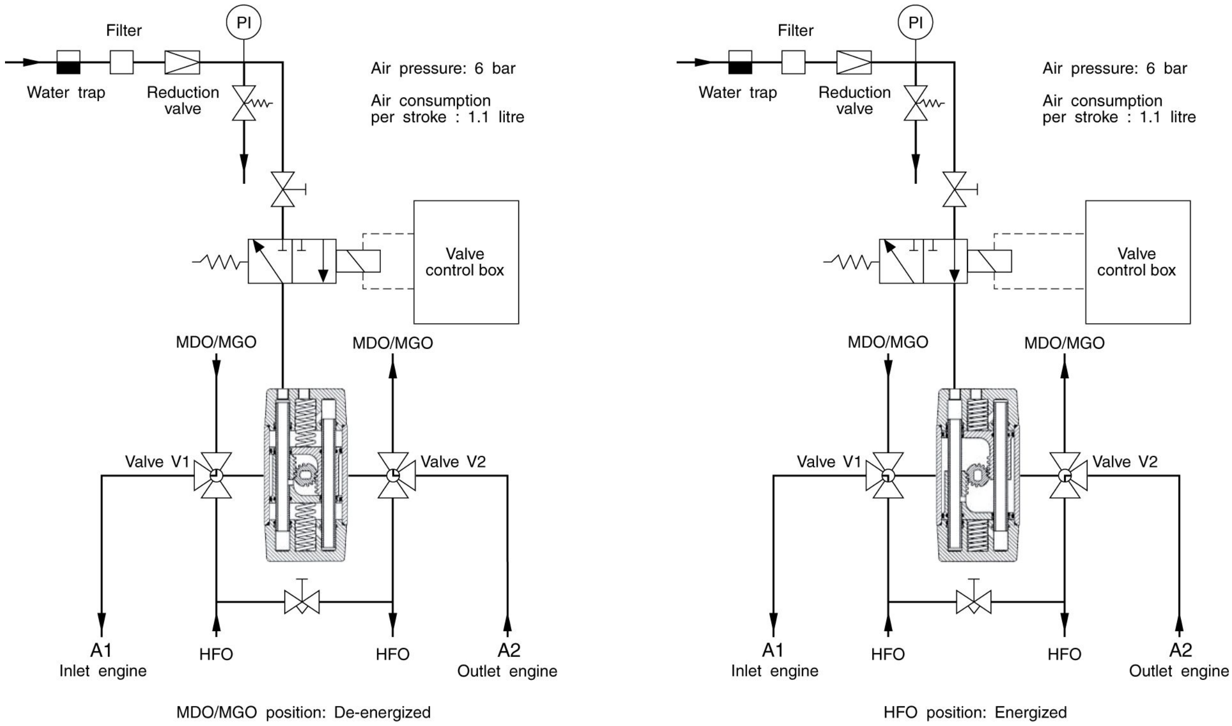

Figure 1: Pneumatic diagram for 3-way changing valves V1 & V2.

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.

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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

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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

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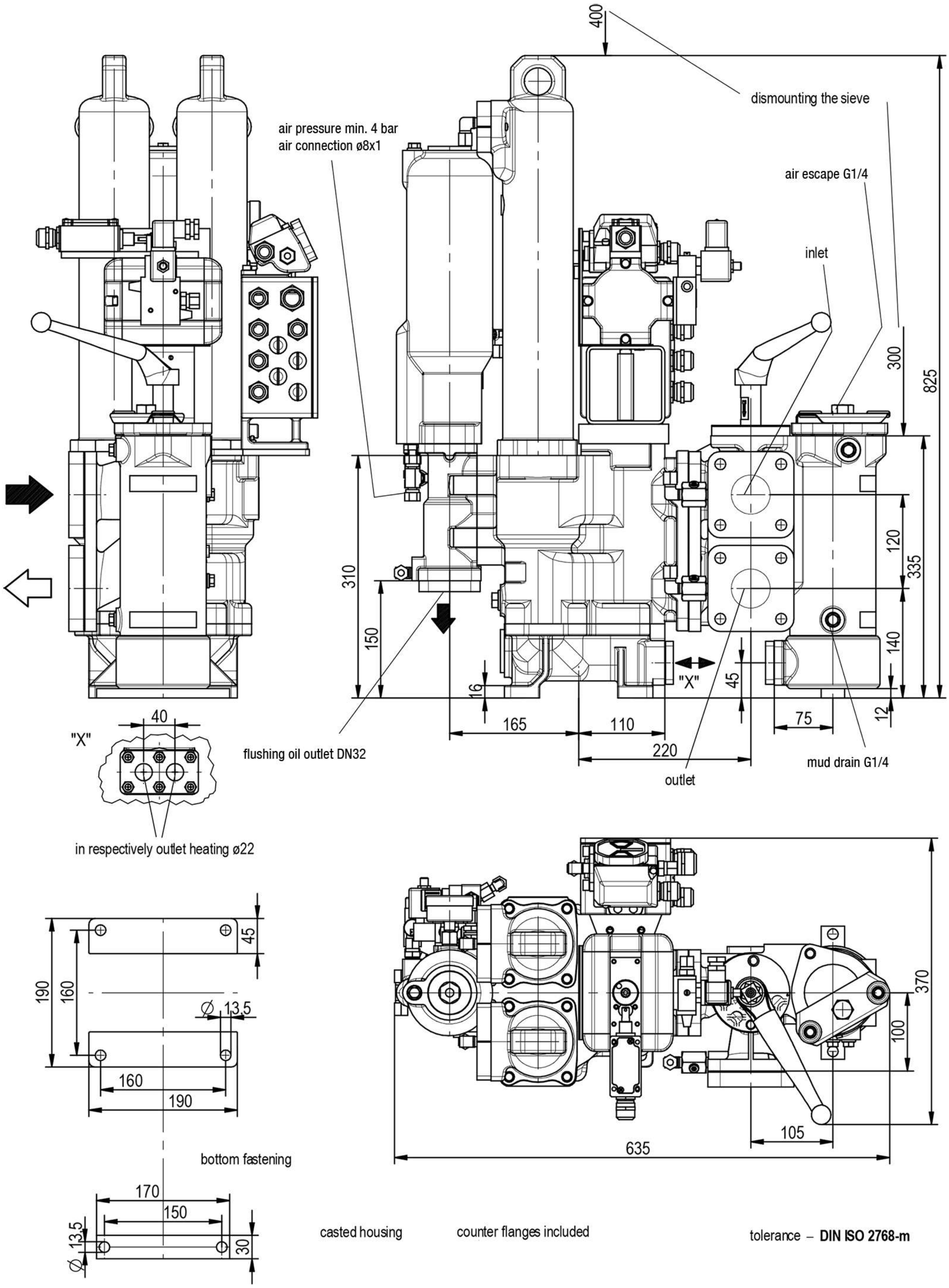
Specification L28/32H

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



casted housing

counter flanges included

tolerance – **DIN ISO 2768-m**

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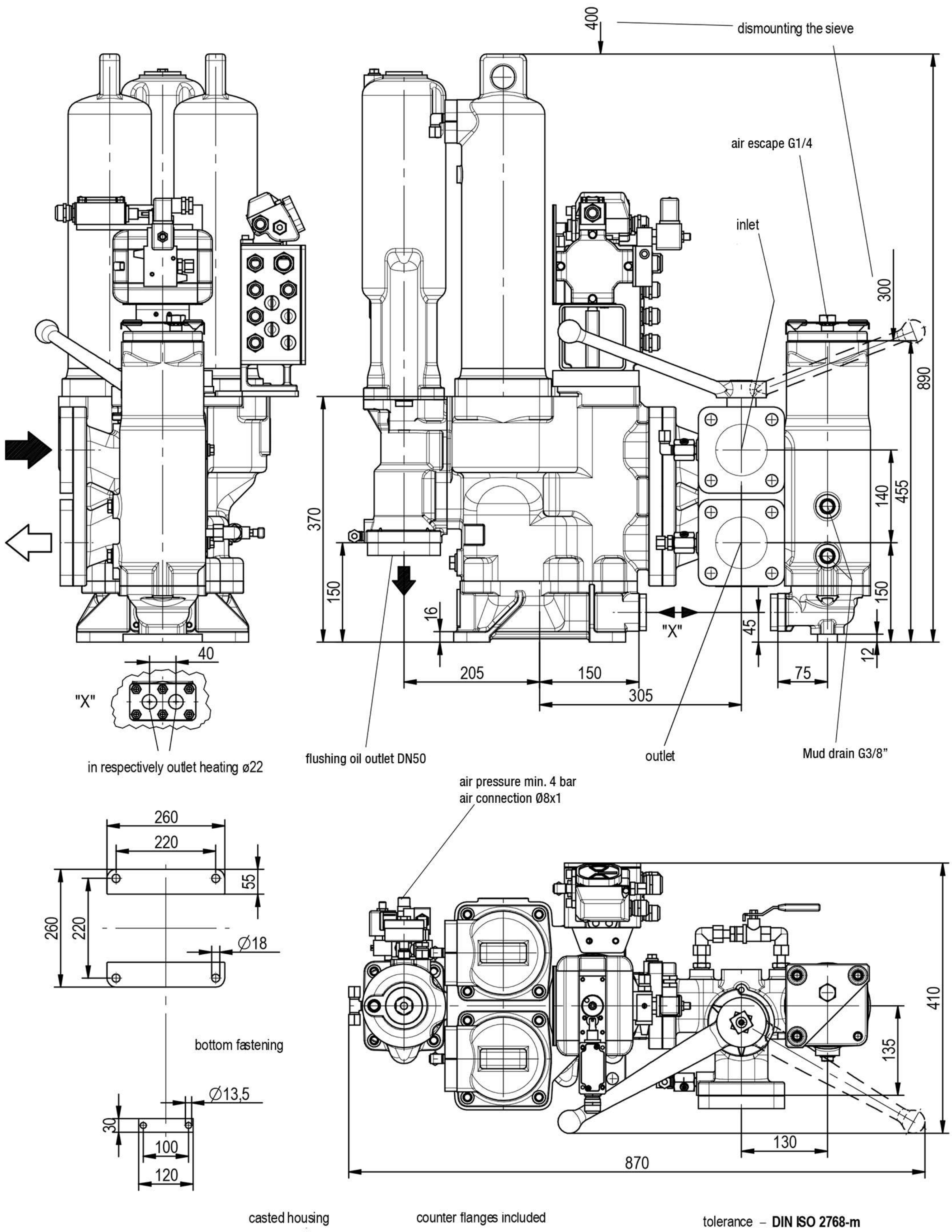
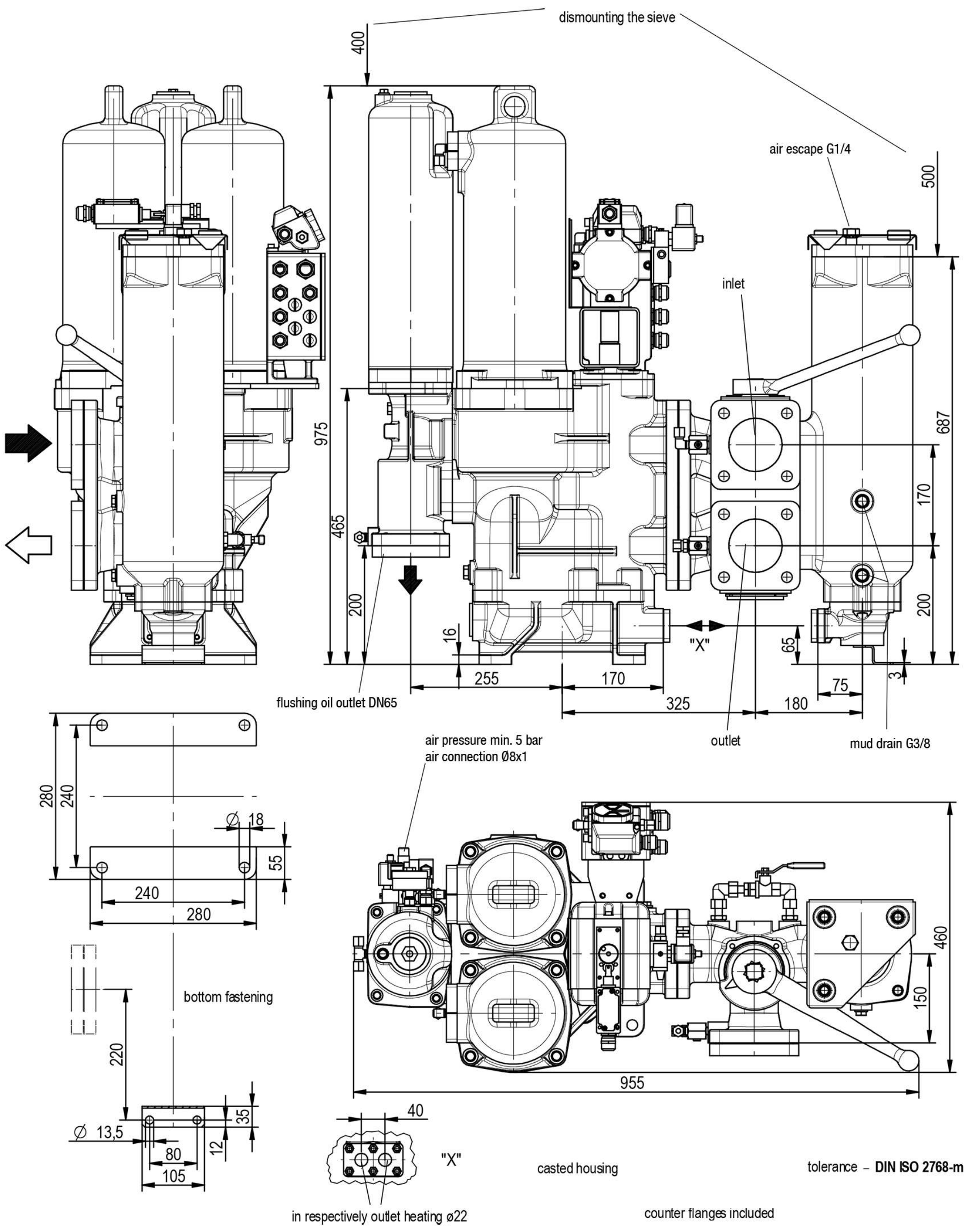
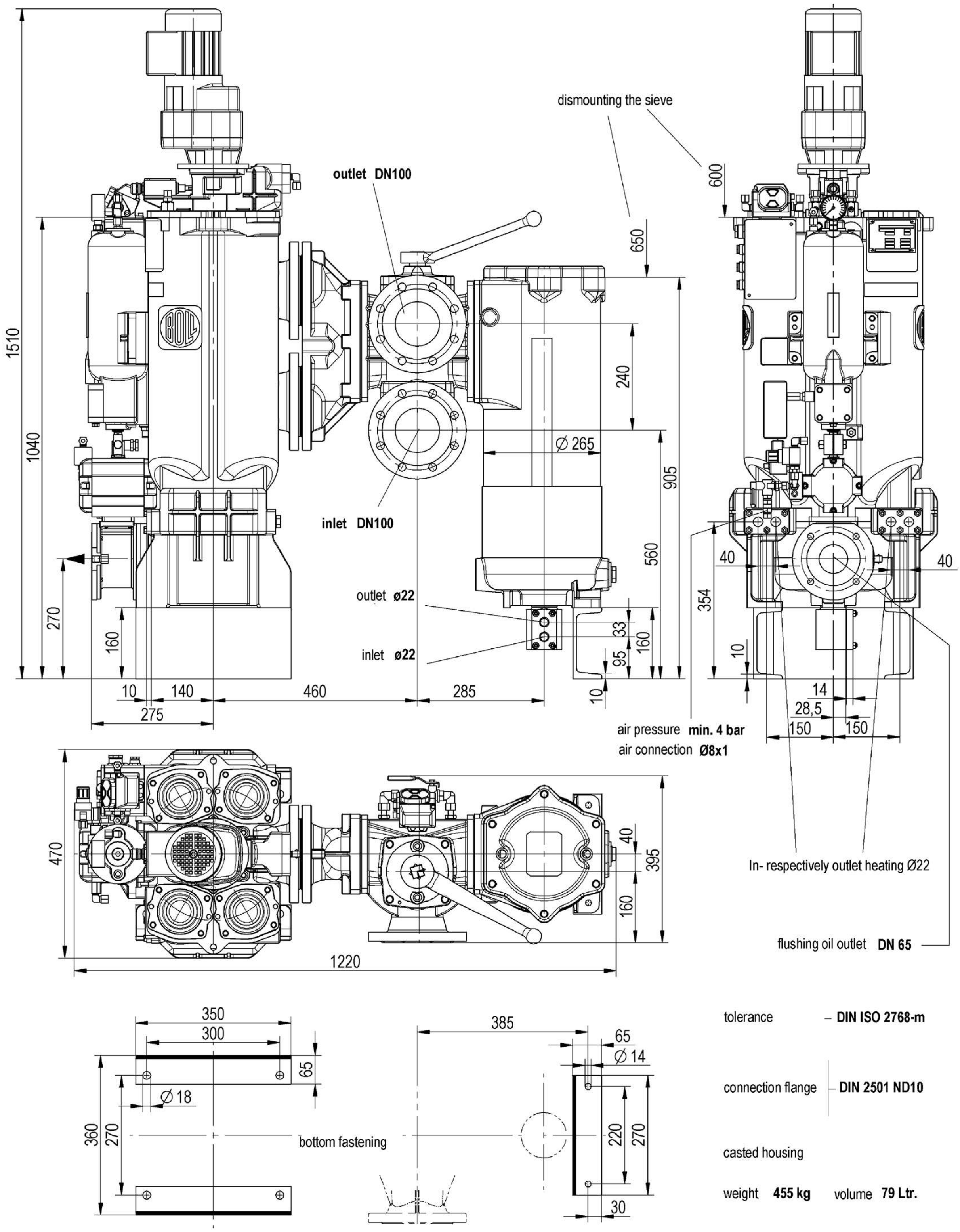
DN65 - Typ 6.72.1



DN80 - Typ 6.72.1



DN100 - Typ 6.64.1



tolerance – DIN ISO 2768-m

connection flange – DIN 2501 ND10

casted housing

weight 455 kg volume 79 Ltr.

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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 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

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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

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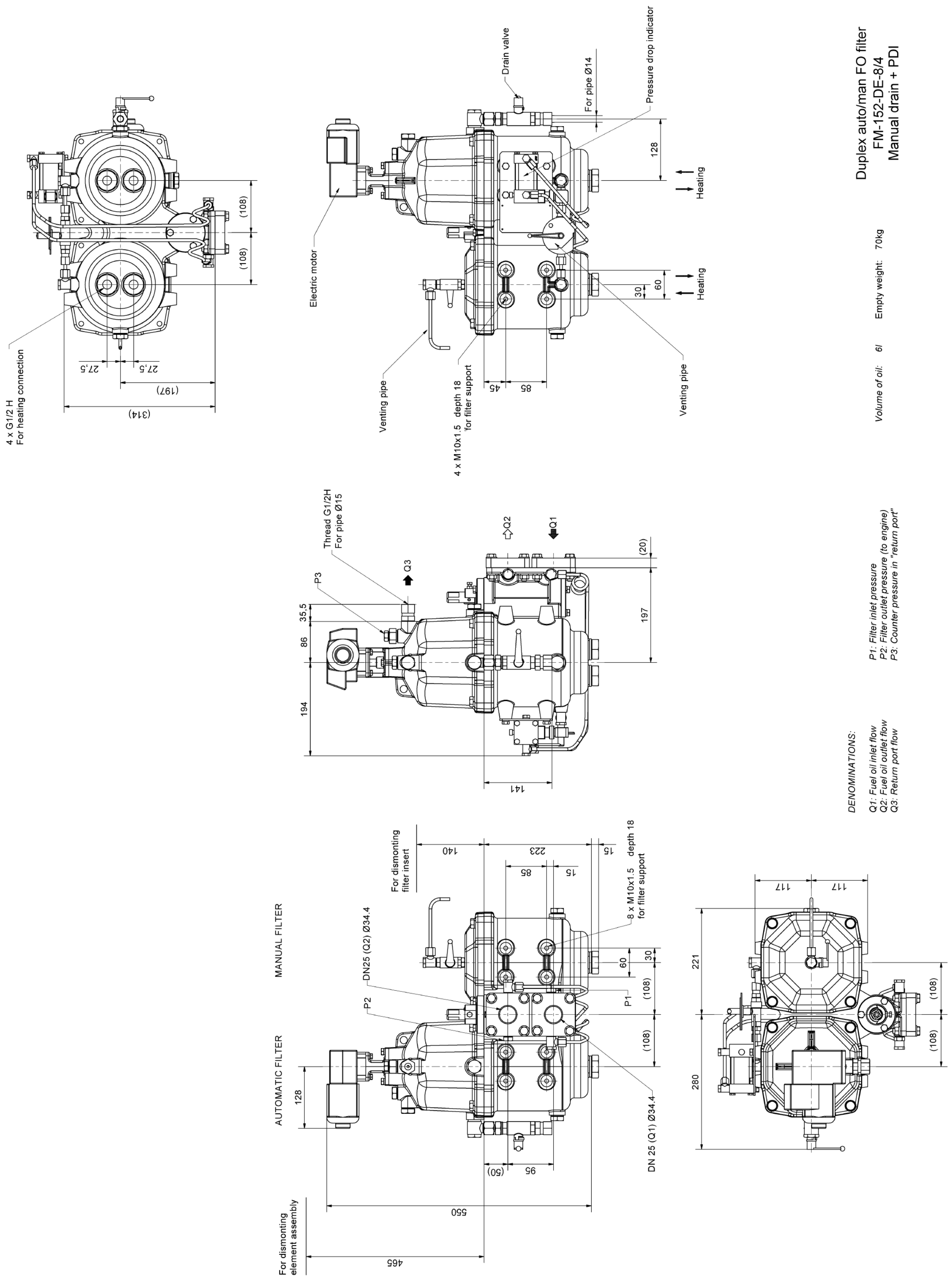
FM-152-DE 8/4



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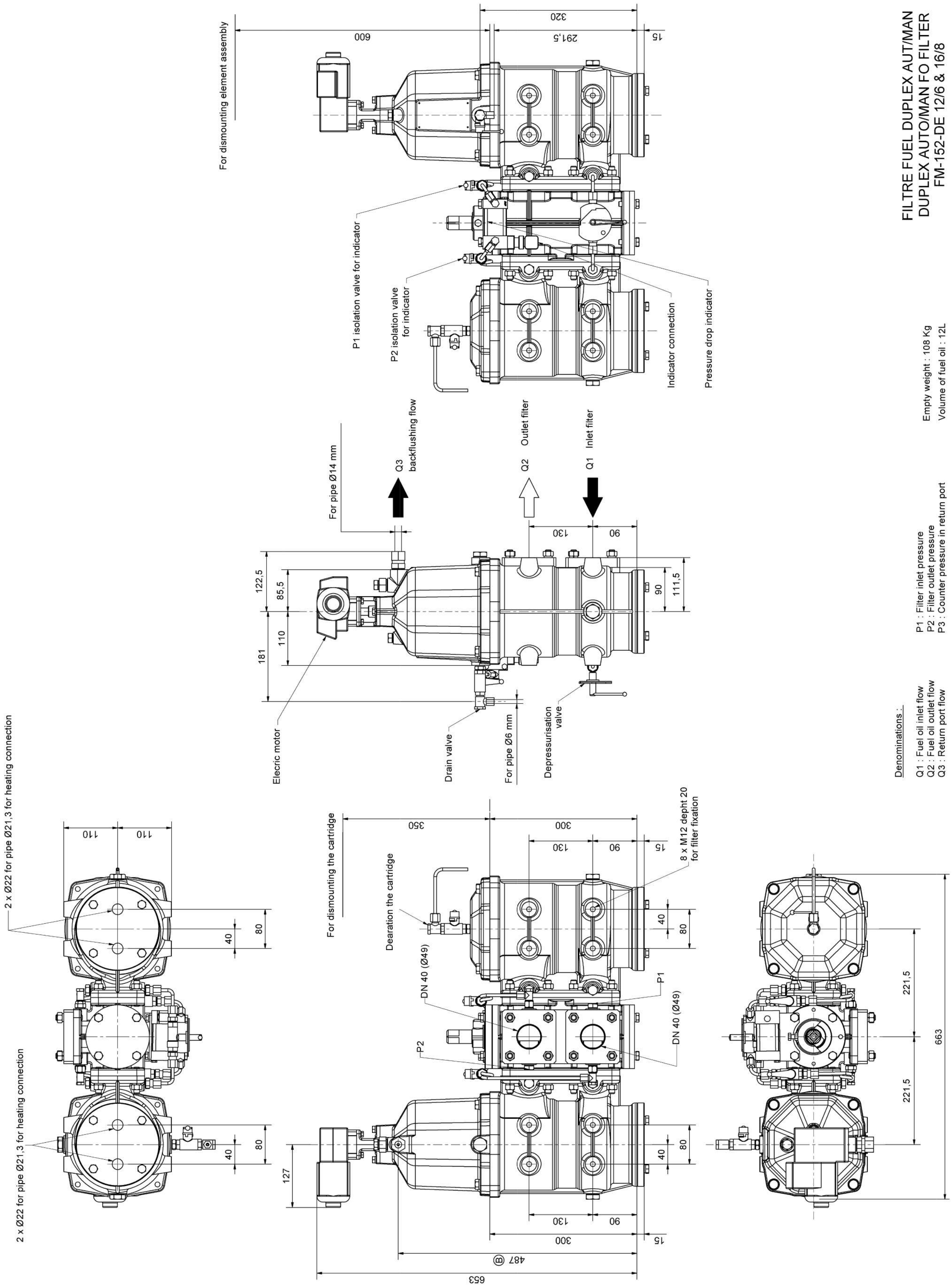
FM-152-DE 12/6 & 16/8



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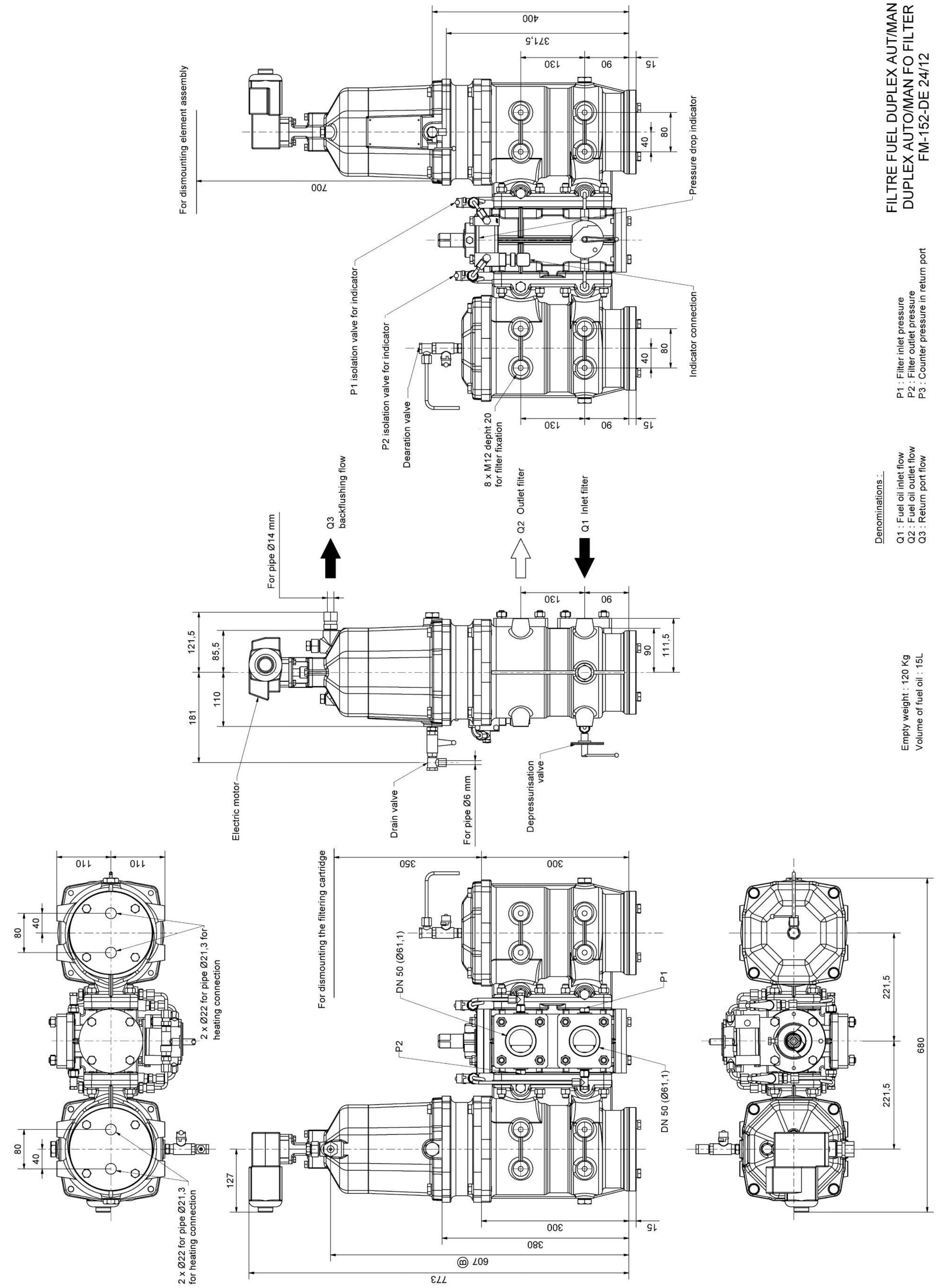
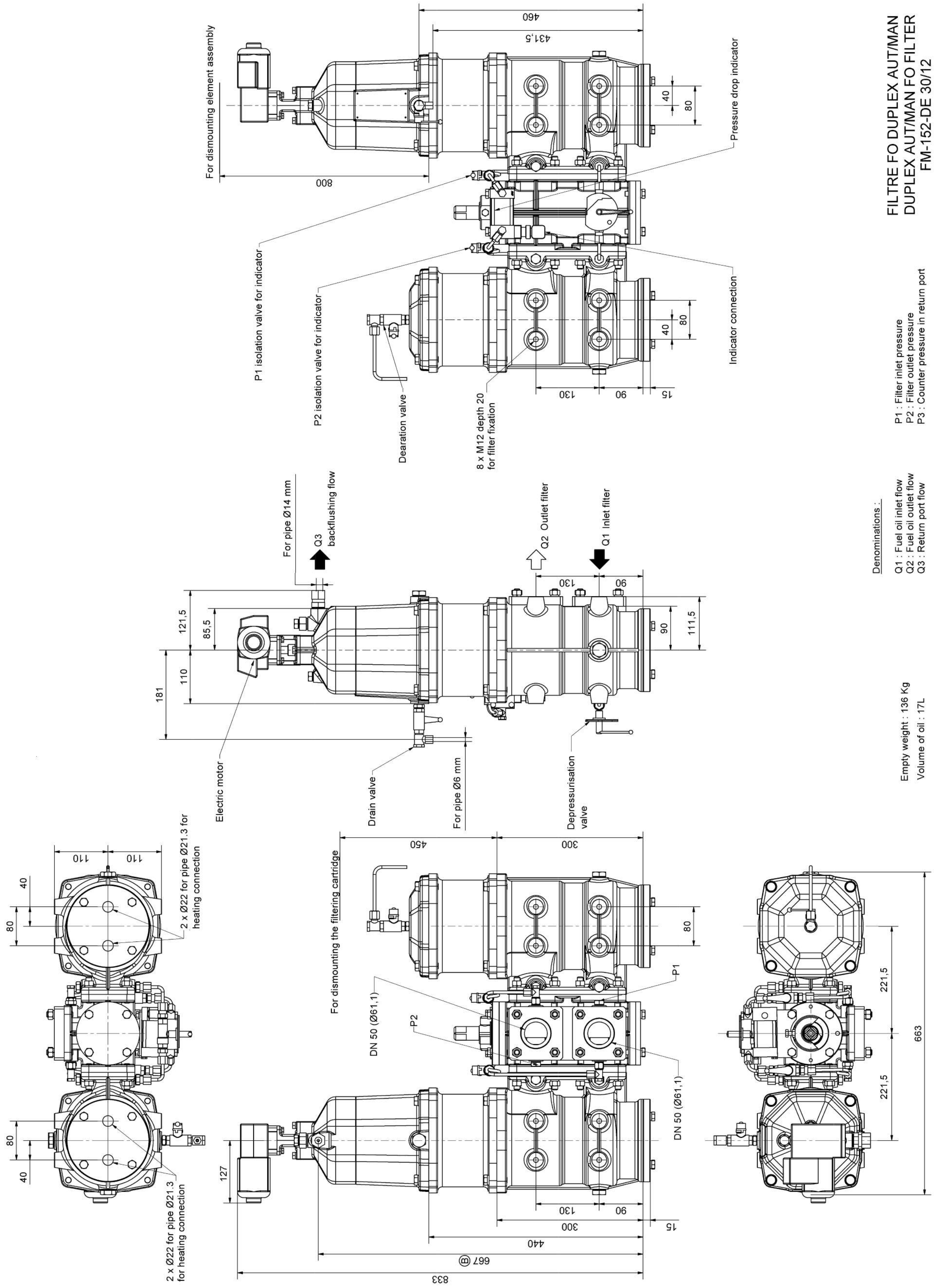


FM-152-DE 30/12



Automatic back-flush filter

Description
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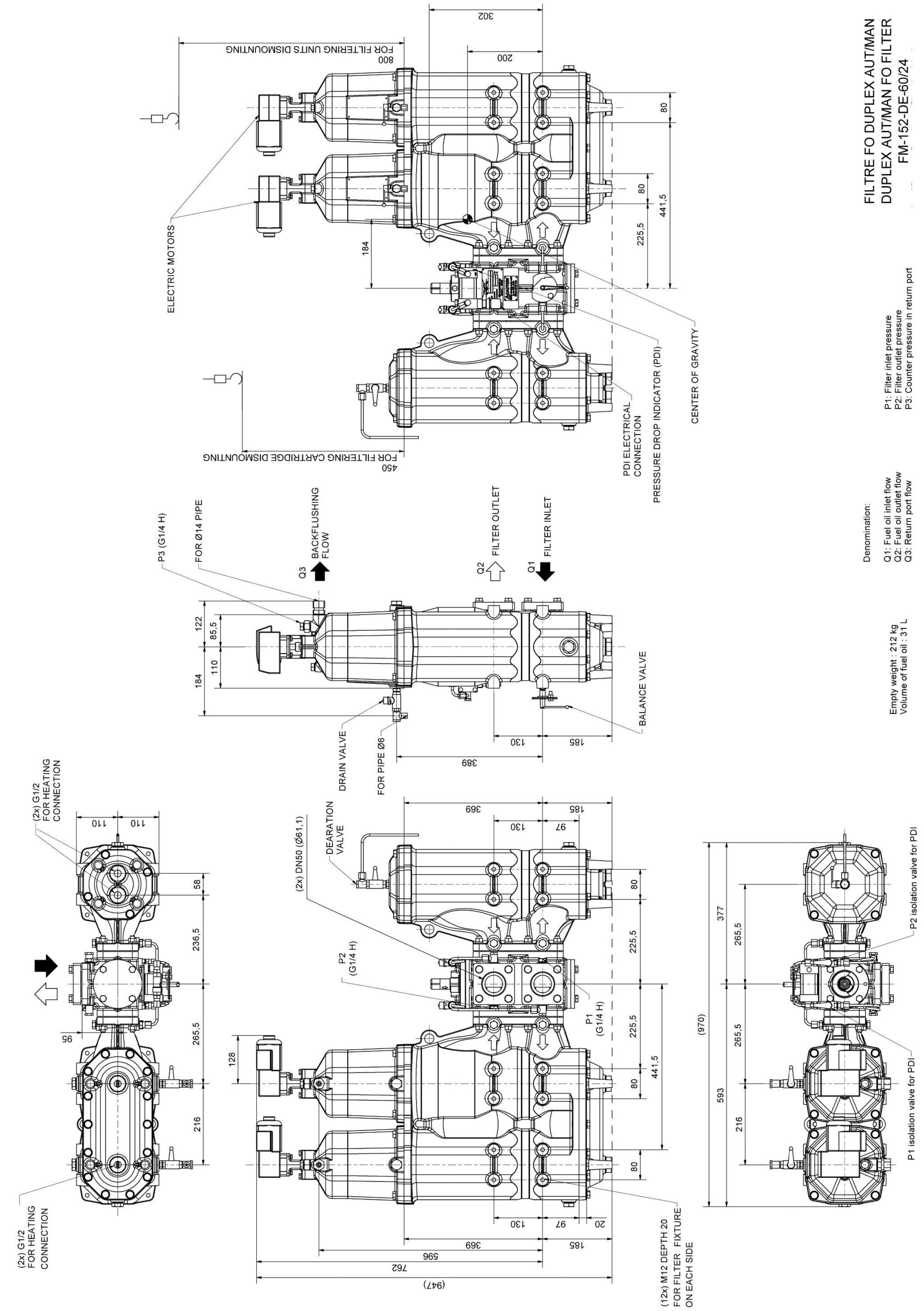
FM-152-DE 60/24



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Description
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Internal lubricating oil system

Internal lubricating oil system

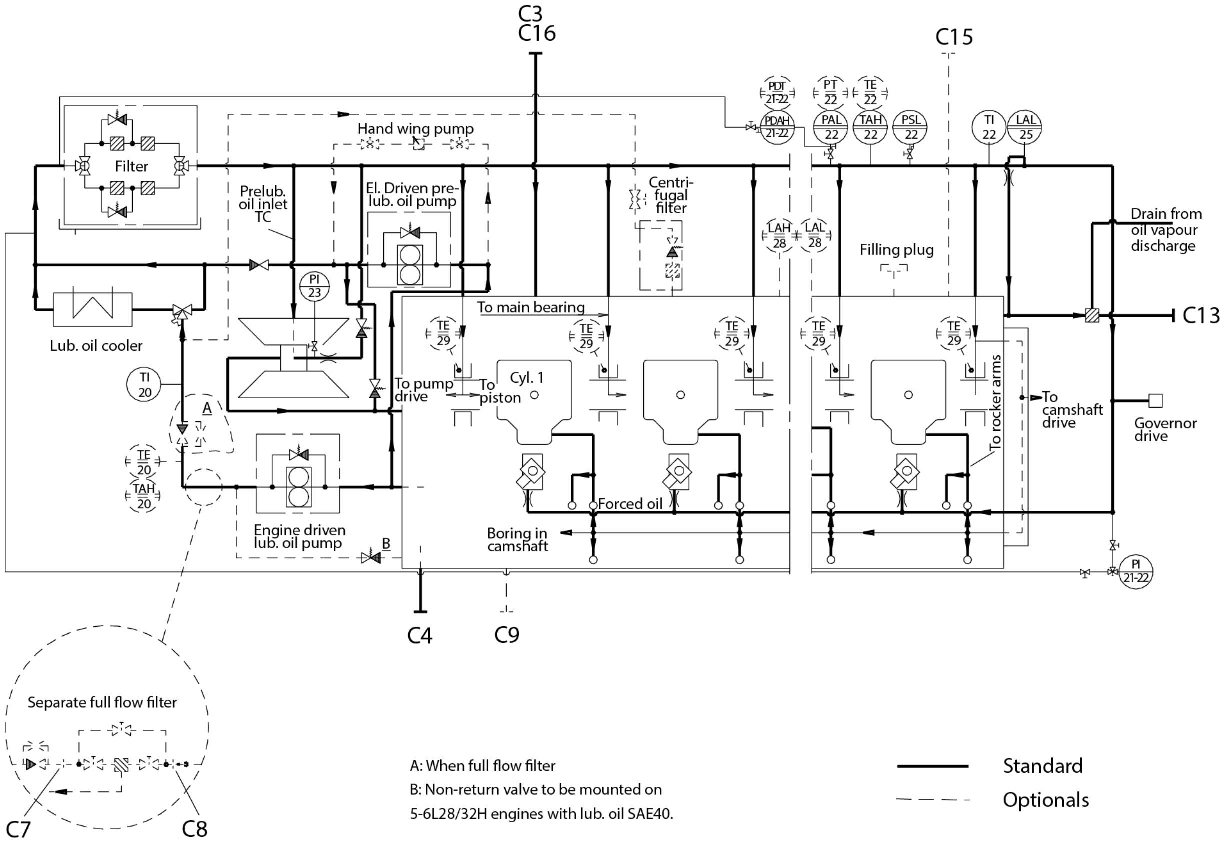

Figure 1: Diagram for internal lubricating oil system (for guidance only, please see the plant specific engine diagram).

Pipe description for connection at the engine		
C3	Lubricating oil from separator	DN25
C4	Lubricating oil to separator	DN25
C7	Lubricating oil from separate filter	DN80
C8	Lubricating oil to separate filter	DN80
C9	Back-flush from full-flow filter	DN20
C13	Oil vapour discharge*	DN50
C15	Lubricating oil overflow	DN50
C16	Lubricating oil supply	DN25

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

* For external pipe connection, please see Crankcase Ventilation, B 12 00 0/615.31.

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General

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

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

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

The standard engine is equipped with built-on:

- Engine driven lubricating oil pump
- Lubricating oil cooler
- Lubricating oil thermostatic valve
- Duplex full-flow depth filter
- Pre-lubricating oil pump

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 / 604.07"

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

Quality of oil

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

System flow

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

The main groups of components to be lubricated are:

1. Turbocharger
2. Main bearings, big-end bearing etc.
3. Camshaft drive

4. Governor drive
5. Rocker arms
6. Camshaft

7. For priming and during operation, the turbocharger is connected to the lubricating oil circuit of the engine, the oil serves for bearing lubrication and also for dissipation of heat.

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

   The non-return valve has back-pressure function requiring a pressure slightly above the priming pressure to open in normal flow direction. In this way overflooding of the turbocharger is prevented during stand-still periods, where the pre-lubricating pump is running.
8. Lubricating oil for the main bearings is supplied through holes drilled in the engine frame. From the main bearings it passes through bores in the crankshaft to the connecting rod big-end bearings.

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

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

Lubricating oil pump

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

Lubricating Oil Cooler

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

Thermostatic Valve

The thermostatic valve is a fully automatic threeway valve with thermostatic elements set of fixed temperature.

Built-on Full-flow Depth Filter

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

Pre-lubricating

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

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

Draining of the oil sump

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

Optionals

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

- Level switch for low/high level in oil sump (LAL/LAH 28)
- Centrifugal by-pass filter (standard for stationary engines)
- Hand wing pump

Pressure differential transmitting

- PDT 21-22 Lubricating oil inlet across filter

Temperature alarm high

- TAH 20 Lubricating oil inlet before cooler

Pressure transmitting

- PT 22 Lubricating oil inlet after cooler

Temperature element

- TE 20 Lubricating oil inlet before cooler

Temperature element

- TE 22 Lubricating oil inlet after cooler

Temperature element

- TE 29 Lubricating oil inlet main bearings

Branches for:

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- External fine filter
- External full/flow filter

Branches for separator is standard.

Data

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

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

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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.

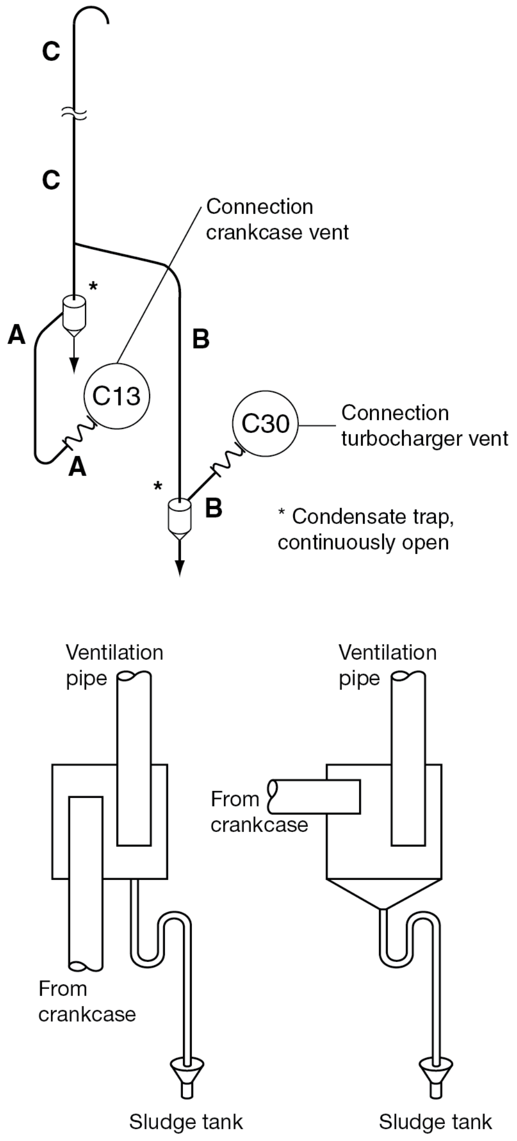

Figure 1: Crankcase ventilation

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.

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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) :

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

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

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

Engine type	No. of cyl.	Pump type	m^3/h	rpm	Electric motor 230/400 V, 50 Hz (IP 55)		
					kW	Start current Amp.	Full-load current Amp.
L23/30H (NR) L28/32H L28/32S L28/32DF	5-6-7-8 5-6-7-8-9 5-6-7-8-9 5-6-7-8-9	R25/12.5 FL-Z-DB-SO	2.09	2805	0.75	14.21	2.9
L23/30H (TCR) L23/30S (TCR) L23/30DF V28/32H	5-6-7-8 5-6-7-8 5-6-7-8 12-16-18	R35/25 FL-Z-DB-SO	4.25	2885	1.5	37.8	5.48
V28/32S V28/32S-DF	12-16-18 12-16-18	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 265/460 V, 60 Hz (IP 55)		
					kW	Start current Amp.	Full-load current Amp.
L23/30H (NR) L28/32H L28/32S L28/32DF	5-6-7-8 5-6-7-8-9 5-6-7-8-9 5-6-7-8-9	R25/12.5 FL-Z-DB-SO	2.54	3410	0.86	8.2	1.67
L23/30H (TCR) L23/30S (TCR) L23/30DF V28/32H	5-6-7-8 5-6-7-8 5-6-7-8 12-16-18	R35/25 FL-Z-DB-SO	5.12	3480	1.73	21.7	3.15
V28/32S V28/32S-DF	12-16-18 12-16-18	R35/40 FL-Z-DB-SO	8.3	3505	3.45	42.7	6.1

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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.

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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.

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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.

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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.

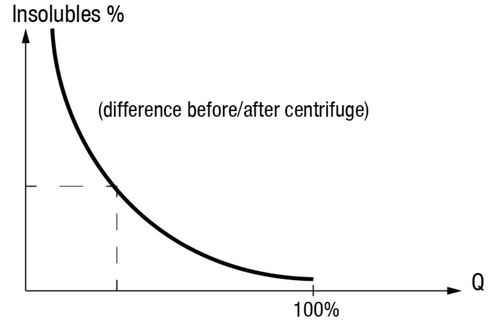


Figure 1: .

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).

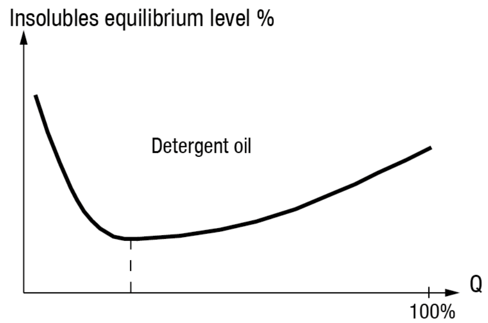


Figure 2: .

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:

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

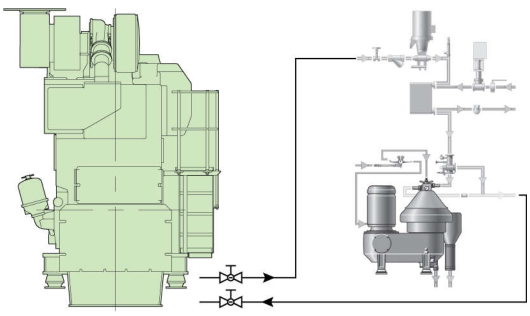


Figure 3: One separator per engine plant

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.

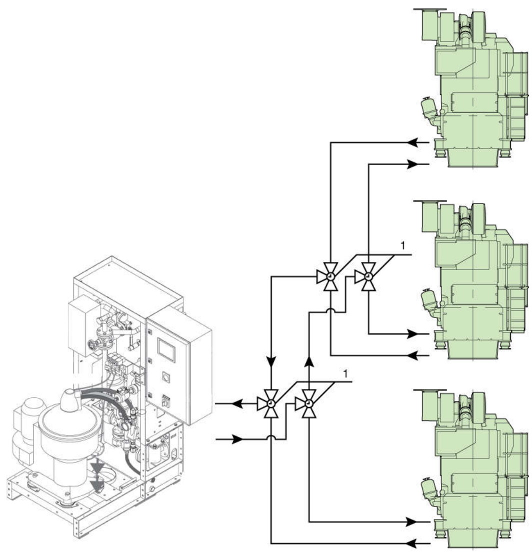
- Bulk carrier and tankers : ~1.3 times the power of one engine
- Container vessel : ~1.5 times the power of one engine

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:

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

Bulk carrier and tankers

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



1 *Interconnected valves*

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

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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:

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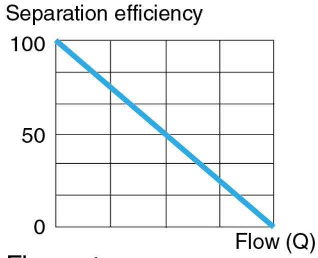
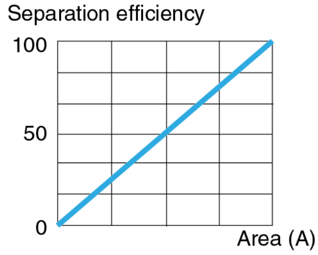
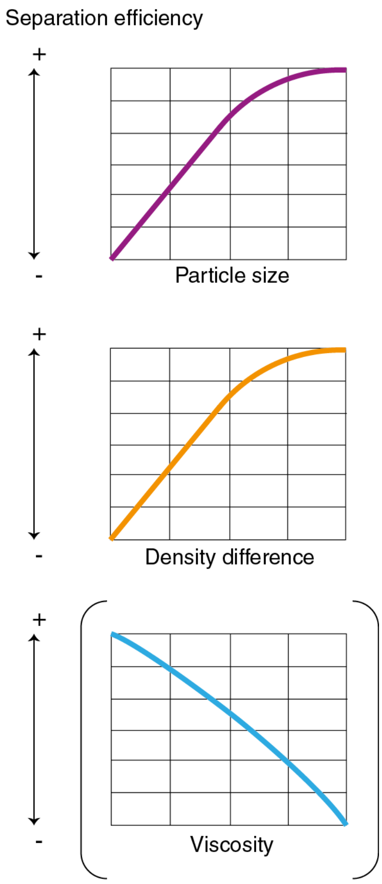


Flow rate



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.

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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.

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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.

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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

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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

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

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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Specification of engine coolant

General

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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 man-

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ufacturer's instructions for use must be strictly observed. Prior to cleaning, check whether the cleaning agent is suitable for the materials to be cleaned. The products listed in the table entitled Cleaning agents for removing limescale and rust deposits are also suitable for stainless steel.

Manufacturer	Product	Concentration	Duration of cleaning procedure/temperature
Drew	SAF-Acid Descale-IT Ferroclean	5 – 10 % 5 – 10 % 10 %	4 h at 60 – 70 °C 4 h at 60 – 70 °C 4 – 24 h at 60 – 70 °C
Nalfleet	Nalfleet 9 - 068	5 %	4 h at 60 – 75 °C
Unitor	Descalex	5 – 10 %	4 – 6 h at approx. 60 °C
Vecom	Descalant F	3 – 10 %	ca. 4 h at 50 – 60 °C

Table 2: Cleaning agents for removing lime scale and rust deposits

In emergencies only

Hydrochloric acid diluted in water or aminosulphonic acid may only be used in exceptional cases if a special cleaning agent that removes limescale deposits without causing problems is not available. Observe the following during application:

- Stainless steel heat exchangers must never be treated using diluted hydrochloric acid.
- Cooling systems containing non-ferrous metals (aluminium, red bronze, brass, etc.) must be treated with deactivated aminosulphonic acid. This acid should be added to water in a concentration of 3 – 5 %. The temperature of the solution should be 40 – 50 °C.
- Diluted hydrochloric acid may only be used to clean steel pipes. If hydrochloric acid is used as the cleaning agent, there is always a danger that acid will remain in the system, even when the system has been neutralised and flushed. This residual acid promotes pitting. We therefore recommend you have the cleaning carried out by a specialist.

The carbon dioxide bubbles that form when limescale deposits are dissolved can prevent the cleaning agent from reaching boiler scale. It is therefore absolutely necessary to circulate the water with the cleaning agent to flush away the gas bubbles and allow them to escape. The length of the cleaning process depends on the thickness and composition of the deposits. Values are provided for orientation in the table entitled Cleaning agents for removing limescale and rust deposits.

Following cleaning

The cooling system must be flushed several times once it has been cleaned using cleaning agents. Replace the water during this process. If acids are used to carry out the cleaning, neutralise the cooling system afterwards with suitable chemicals then flush. The system can then be refilled with water that has been prepared accordingly.

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

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

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

High temperature cooling water system

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

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

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

System lay-out

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

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

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

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

HT-circulating pump

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

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

Thermostatic valve

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

Technical data: *See B 13 15 1.*

Preheating arrangement

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

The system is based on thermo-syphon circulation.

For further information *see B 13 23 1.*

Internal cooling water system 1

Internal cooling water system 1

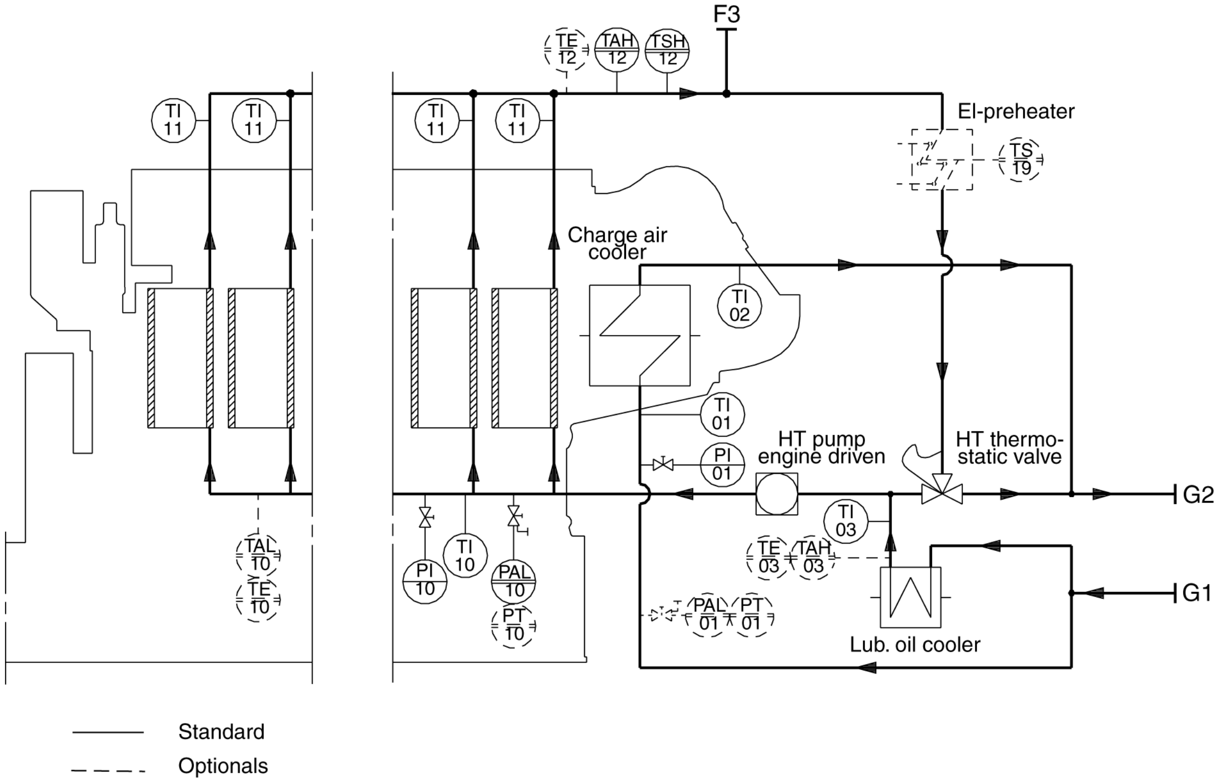

Figure 1: Diagram for internal cooling water system 1 (for guidance only, please see the plant specific engine diagram)

Pipe description

F3	Venting to expansion tank	DN 15
G1	LT fresh water inlet	DN 100
G2	LT fresh water outlet	DN 100

Table 1: Flange connections are standard according to DIN 2501

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Description

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

The engine is equipped with a self-controlling high temperature (HT) water circuit for cooling of cylinder liners and cylinder heads. Thus the engine on the cooling water side only requires one fresh water cooler and so the engine can be intergrated in the ships cooling water system as as a stand alone unit, in a simple way, with low installation costs, which 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 external system.

The charge air coolers and the lubricating oil cooler are situated parallelly in order to have the lowest possible cooling water inlet temperature for the coolers.

The HT-circuit is cooled by adjustment of water from the LT-circuit, taken from the lubricating oil cooler outlet. Thus the amount of cooling water through the cooling system is always adjusted to the engine load.

High temperature circuit

The built-on engine driven HT-circulating pump of the centrifugal type, pumps water through a distributing pipe to bottom of the cooling water space between the liner and the frame of each cylinder unit. The water is led out through bores in the top of the frame via the cooling water guide jacket to the bore cooled cylinder head for cooling of this and the valve seats.

From the cylinder heads the water is led through a common outlet pipe 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 be re-circulated.

Optionals

Alternatively the engine can be equipped with the following:

- Thermostatic valve on outlet LT-system
- Engine driven pump for LT-system
- Preheater arrangement in HT-system

Branches for:

- External preheating
- Alternator cooling

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

Data

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

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

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

Internal cooling water system 2

Internal cooling water system

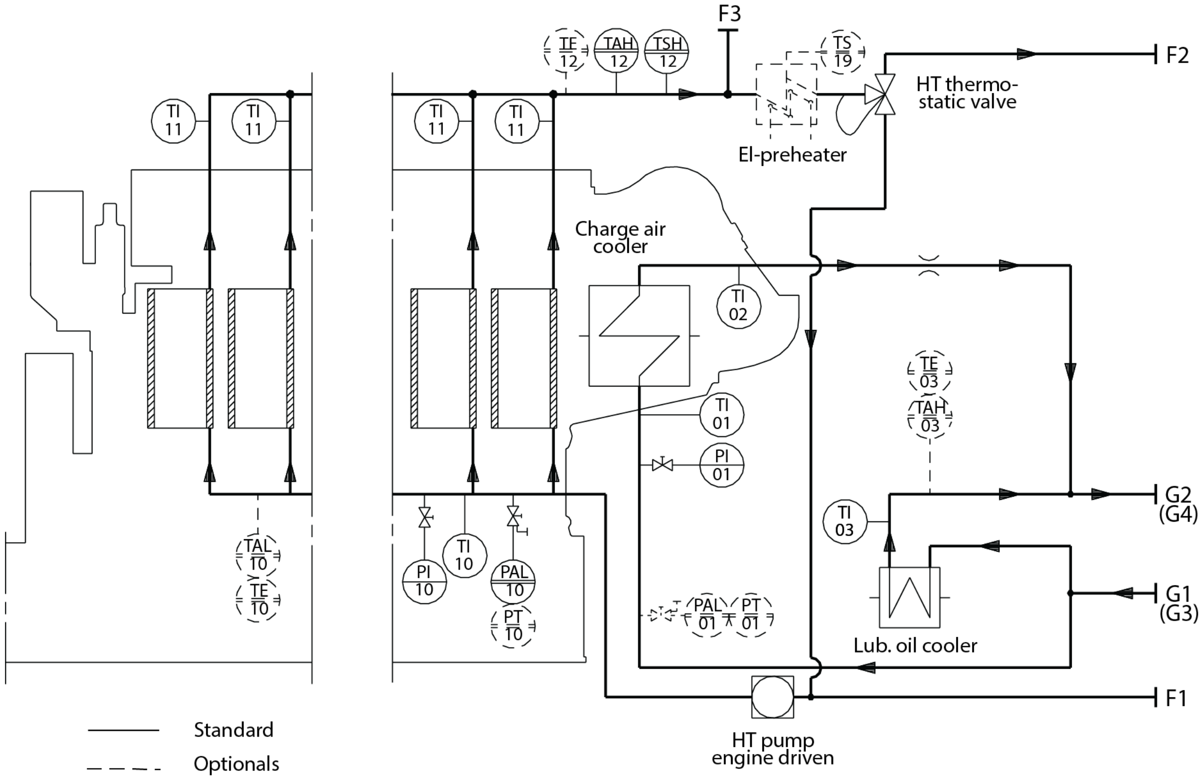

Figure 1: Diagram for internal cooling water system 2 (for guidance only, please see the plant specific engine diagram)

Pipe description

F1	HT fresh water inlet	DN 100
F2	HT fresh water outlet	DN 100
F3	Venting to expansion tank	DN 15
G1	LT fresh water inlet	DN 100
(G3)	LT sea water inlet	DN 100
G2	LT fresh water outlet	DN 100
(G4)	LT sea water outlet	DN 100

Table 1: Flange connections are standard according to DIN 2501

Description

The system is designed with separate LT- and HT-circuits and is fully integrated in the external system, which can be a conventional or a centralized cooling water system. With this system pumps and heat exchangers can be common for propulsion and alternator engines. It is however, recommended that the alternator engines have separate temperature regulation on the HT-circuit.

Low temperature circuit

As standard the system is prepared for fresh water in the LT-system, with pipes made of steel and the plates in the lub. oil cooler made of stainless steel.

High temperature circuit

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

From the cylinder heads the water is led through a common outlet pipe to the external system.

Optionals

Alternatively the engine can be equipped with the following:

- Thermostatic valve on outlet, LT-system
- Engine driven pump for LT-system
- Preheater arrangement in HT-system

Branches for:

- External preheating
- Alternator cooling

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

Data

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

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

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

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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 L28/32H type engine(s).The stated data are for one engine only and are specified at MCR.

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

External pipe velocities

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

Fresh water : 3.0 m/s
Sea water : 3.0 m/s

Pressure drop across engine

The pressure drop across the engines HT system, exclusive pump and thermostatic valve, is approx. 0.5 bar.

Lubricating oil cooler

The pressure drop of cooling water across the built-on lub. oil cooler is approx. 0.3 bar; the pressure drop may be different depending on the actual cooler design.

Thermostatic valve

The pressure drop across the built-on thermostatic valve is approx. 0.5 bar.

Charge air cooler

The pressure drop of cooling water across the charge air cooler is:

$\Delta P = V^2 \times K$ [Bar]

V = Cooling water flow in m^3/h

K = Constant, *see B 15 00 0, Charge Air Cooler*

Pumps

The cooling water pumps should be of the centrifugal type.

	FW	SW
Differential pressure	1-2.5 bar	1-2.5 bar
Working temperature	max. 90°C	max. 50°C

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Operating pressures

HT cooling water before cylinder (incl. built-on pumps):

Min. 2.0 bar
Max. 4.0 bar

Expansion tank

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

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

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

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

Minimum recommended tank volume: 0.15 m³.
For multiplants the tank volume should be min.:

V = 0.15 + (exp. vol. per ekstra eng.) [m³]

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 1.7-2.0 kW/cyl. The flow through the engine should for each cylinder be approx. 2.2 l/min with flow from top and downwards and 15 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-system (litre) LT-system (litre)	 500 89	 600 93	 700 97	 800 101	 900 105
Expansion vol. (litre)	28	33	39	44	50
Preheating data: Radiation area (m²) Thermal coeff. (kJ/°C)	 24.9 5460	 28.5 6552	 32.1 7644	 35.7 8736	 39.3 9828

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

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External cooling water system

Design of external cooling water system

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

The diagrams on the following pages are principal diagrams, and are MAN Energy Solutions' recommendation for the design of external cooling water systems.

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

1. Simplicity
2. Separate HT temperature regulation for propulsion and alternator engines.
3. HT temperature regulation on engine outlet.
4. Preheating with surplus heat.
5. Preheating in engine top, downwards.
6. As few change-over valves as possible.
7. Possibility for MAN Energy Solutions ICS-system.

Ad 1) Cooling water systems have a tendency to be unnecessarily complicated and thus uneconomic in installation and operation. Therefore, we have attached great importance to simple diagram design with optimal cooling of the engines and at the same time installation- and operation-friendly systems resulting in economic advantages.

Ad 2) Cooling of alternator engines should be independent of the propulsion engine load and vice versa. Therefore, there should be separate cooling water temperature regulation thus ensuring optimal running temperatures irrespective of load.

Ad 3) The HT FW thermostatic valve should be mounted on the engine's outlet side ensuring a constant cooling water temperature above the engine at all loads. If the thermostat valve is placed on the engine's inlet side, which is not to be recommended, the temperature on the engine depends on the load with the risk of overheating at full load.

Ad 4) It has been stressed on the diagrams that the alternator engines in stand-by position as well as the propulsion engine in stop position are preheated, optimally and simply, with surplus heat from the running engines.

Ad 5) If the engines are preheated with reverse cooling water direction, i.e. from the top and downwards, an optimal heat distribution is reached in the engine. This method is at the same time more economic since the need for heating is less and the water flow is reduced.

Ad 6) The systems have been designed in such a way that the change-over from sea operation to harbour operation/stand-by with preheating can be made with a minimum of manual or automatic interference.

Ad 7) If the actual running situations demand that one of the auxiliary engines should run on low-load, the systems have been designed so that one of the engines can be equipped with a cooling system for ICS-operation (Integrated Charge air System).

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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.

One string central cooling water system

One string central cooling water system

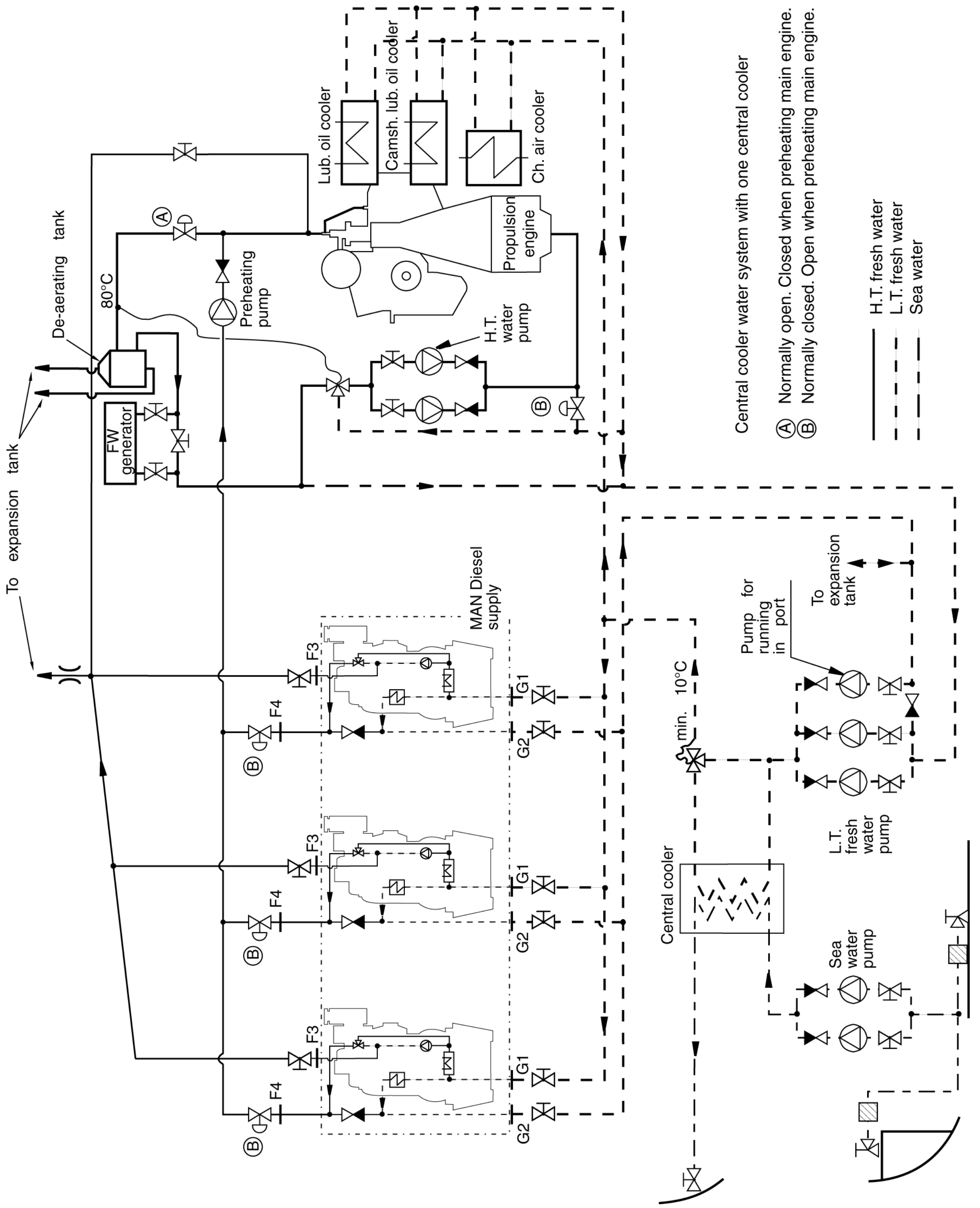

Figure 1: Diagram for one string central cooling water system.

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System design

The system is a central cooling water system of simple design with only one central cooler. Low temperature (LT) and fresh water (FW) pumps are common for all engines. In order to minimize the power consumption the LT FW pump installation consists of 3 pumps, two for sea operation and smaller one for harbour operation.

The GenSet engines are connected as a one string plant, with only one inlet- and outlet cooling water connection and with internal HT-circuit, see also B 13 00 0 “Internal cooling water system 1”, describing this system.

The propulsion engines' HT-circuit is built up acc. to the same principle, i.e. HT-water temperature is adjusted with LT-water mixing by means of the thermostatic valve.

The system is also remarkable for its preheating of stand-by GenSet engines and propulsion engine by running GenSets, without extra pumps and heaters.

Preheating of stand-by GenSets during sea operation

GenSets in stand-by position are preheated automatically via the venting pipe with water from the running engines. This is possible due to the pressure difference, which the running GenSet engines HT-pumps produce.

Preheating of stand-by GenSets and propulsion engine during harbour operation

During harbour stay the propulsion and GenSet engines are also preheated in stand-by position by the running GenSets. Valve (B) is open and valve (A) is closed. Thus the propulsion engine is heated from top and downwards, which is the most economic solution.

Central cooling system

Central cooling system

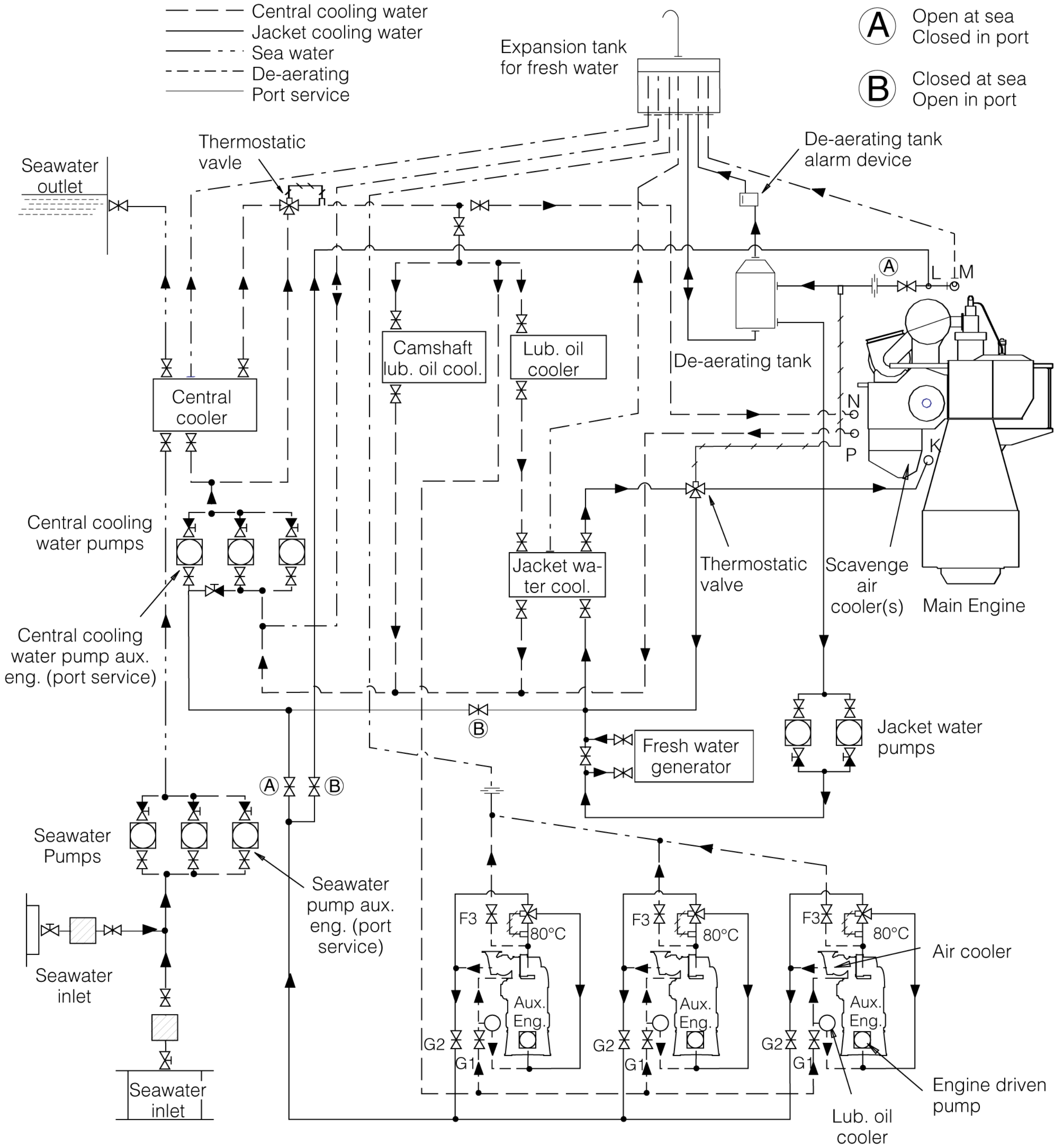

Figure 1: Diagram for central cooling system.

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Design features and working principle

This diagram describes the possibilities with regard to the design of a common auxiliary system for a two-stroke main engine of the MC-type and four-stroke GenSets fromMAN Energy Solutions.

The central cooling system is an alternative to the conventional seawater cooling system, based on the same design principles with regard to cooler locations, flow control and preheating, but with a central cooler and one additional set of pumps. The central cooler minimizes maintenance work by being the only component that is in contact with seawater. In all other parts of the system, inhibited fresh water is used in accordance with MAN Energy Solutions' specifications.

Operation at sea

The seawater cooling pumps, item 1, pump seawater from the sea chests through the central cooler, item 2, and overboard. Alternatively, some shipyards use a pumpless scoop system. On the freshwater side, the central cooling water pumps, item 3, circulate the low-temperature fresh water, in a cooling circuit, directly through the lubricating oil coolers, item 4, of the main engine, the auxiliary engines and the air coolers, item 5.

The jacket water cooling system for the auxiliary engines is equipped with engine-driven pumps and a by-pass system integrated in the low-temperature system, whereas the main engine jacket system has an independent pump circuit with jacket water pumps, item 6, circulating the cooling water through the fresh water generator, item 7, and the jacket water cooler, item 8, to the inlet of the engine.

A thermostatically controlled 3-way valve, item 9, at the jacket cooler outlet mixes cooled and uncooled water to maintain an outlet water temperature of 80-82°C from the main engine.

As all fresh cooling water is inhibited and common for the central cooling system, only one common expansion tank, item 10, is necessary, for de-aeration of both the low and high temperature cooling systems. This tank accommodates the difference in the water volume caused by changes in the temperature.

To prevent the accumulation of air in the cooling water system, a de-aeration tank, item 11, is located below the expansion tank. An alarm device is inserted between the de-aeration tank and the expansion tank so that the operating crew can be notified if excess air or gas is released, as this signals a malfunction of engine components.

Operation in port

During operation in port, when the main engine is stopped but one or more auxiliary engines are running, the valve, item A, is closed and the valve, item B, is open. A small central water pump, item 3, will circulate the necessary flow of water for the air cooler, the lubricating oil cooler, and the jacket cooler of the auxiliary engines. The auxiliary engine-driven pumps and the integrated loop mentioned above ensure a satisfactory jacket cooling water temperature at the auxiliary engine outlet.

The main engine is preheated as described for the jacket water system, fig. 1.

Sea water cooling system

Design features and working principle

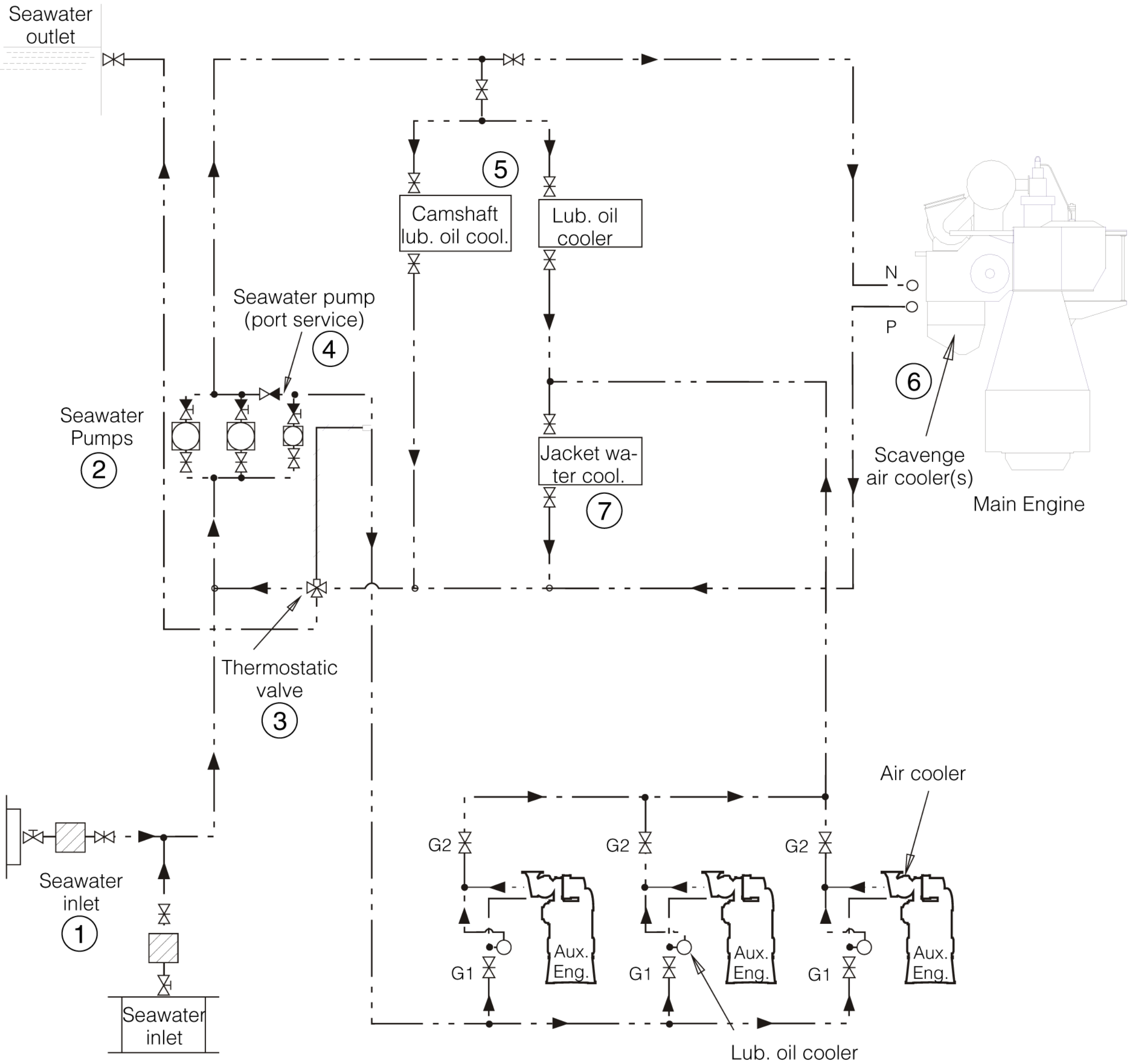

Figure 1: Sea water cooling system.

This diagram describes the possibilities with regard to the design of a common auxiliary system for a two-stroke main engine of the MC-type and four-stroke GenSets from MAN Energy Solutions.

The sea water cooling system is a low-temperature system. However, to be sure that the lubricating oil is kept at a viscosity level suitable for heat transfer, a recirculation arrangement, controlled by the thermostatic valve, item 3, ensures that the inlet temperature of the cooling water does not fall below 10°C.

Operation at sea

Through two separate inlets or "sea chests", item 1, sea water is drawn by the seawater pumps, item 2, and pumped through the various coolers for both the main engine and the auxiliary engines.

The coolers incorporated in the system are the lubricating oil coolers, item 5, the scavenge air cooler(s), item 6, and a common jacket water cooler, item 7.

The air cooler(s) are supplied directly by the pumps and are therefore cooled by the coldest water available in the system. This ensures the lowest possible scavenge air temperature, and thus optimum cooling is obtained with a view to the highest possible thermal efficiency of the engines.

Since the system is sea water cooled, all components are to be made of sea water resistant materials to reduce maintenance work.

With both the main engine and one or more auxiliary engines in service, the sea water pump, item 2, supplies cooling water to all the coolers shown, and the pump, item 4, is inactive.

Operation in port

During operation in port, when the main engine is stopped but one or more auxiliary engines are running, a small sea water pump, item 4, is started up, instead of the large pumps, item 2. The sea water is led from the pump to the auxiliary engine(s), through the common jacket water cooler, item 7, and from there to the sea.

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Jacket water cooling system

Jacket water cooling system

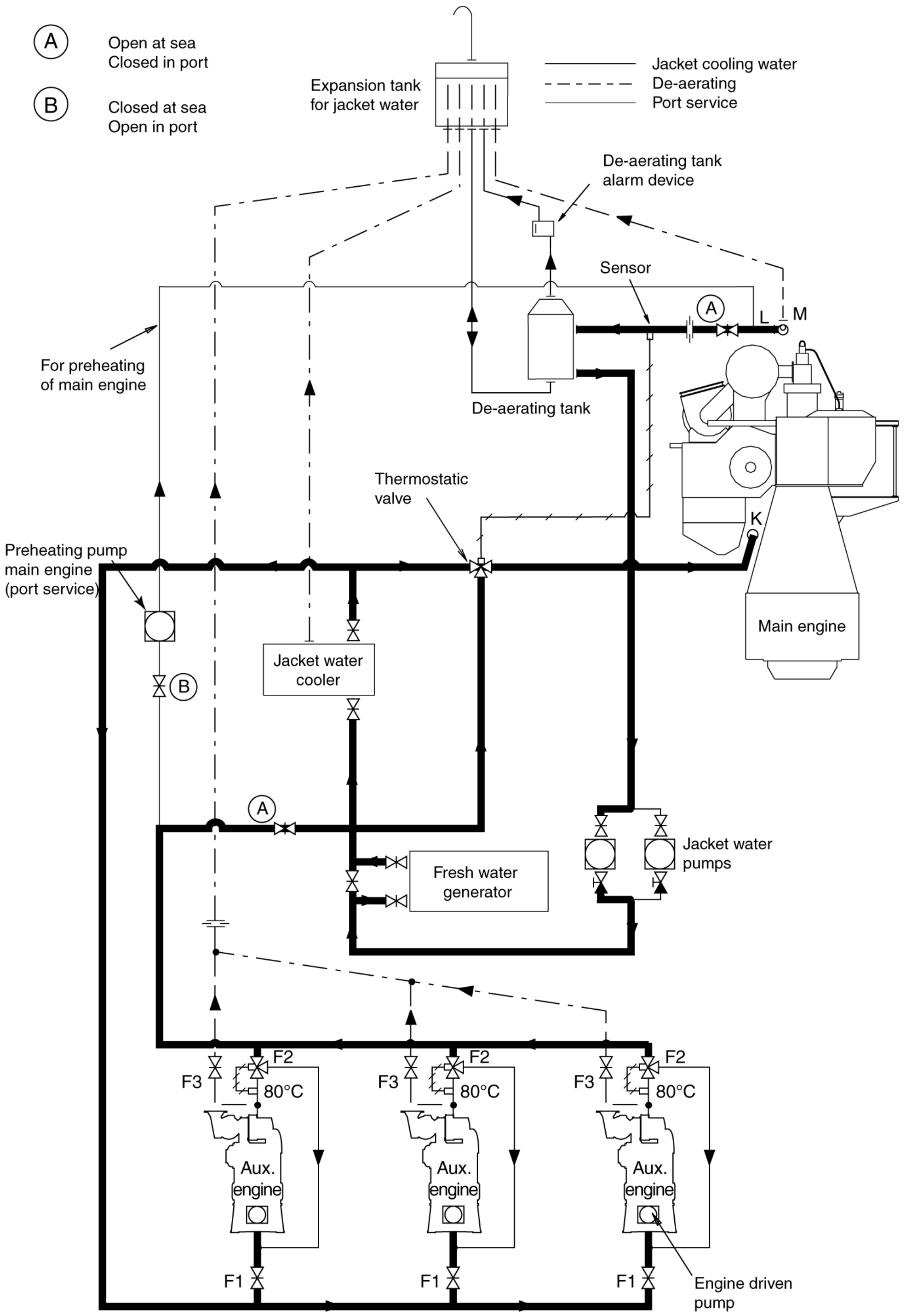

Figure 1: Operating at sea.

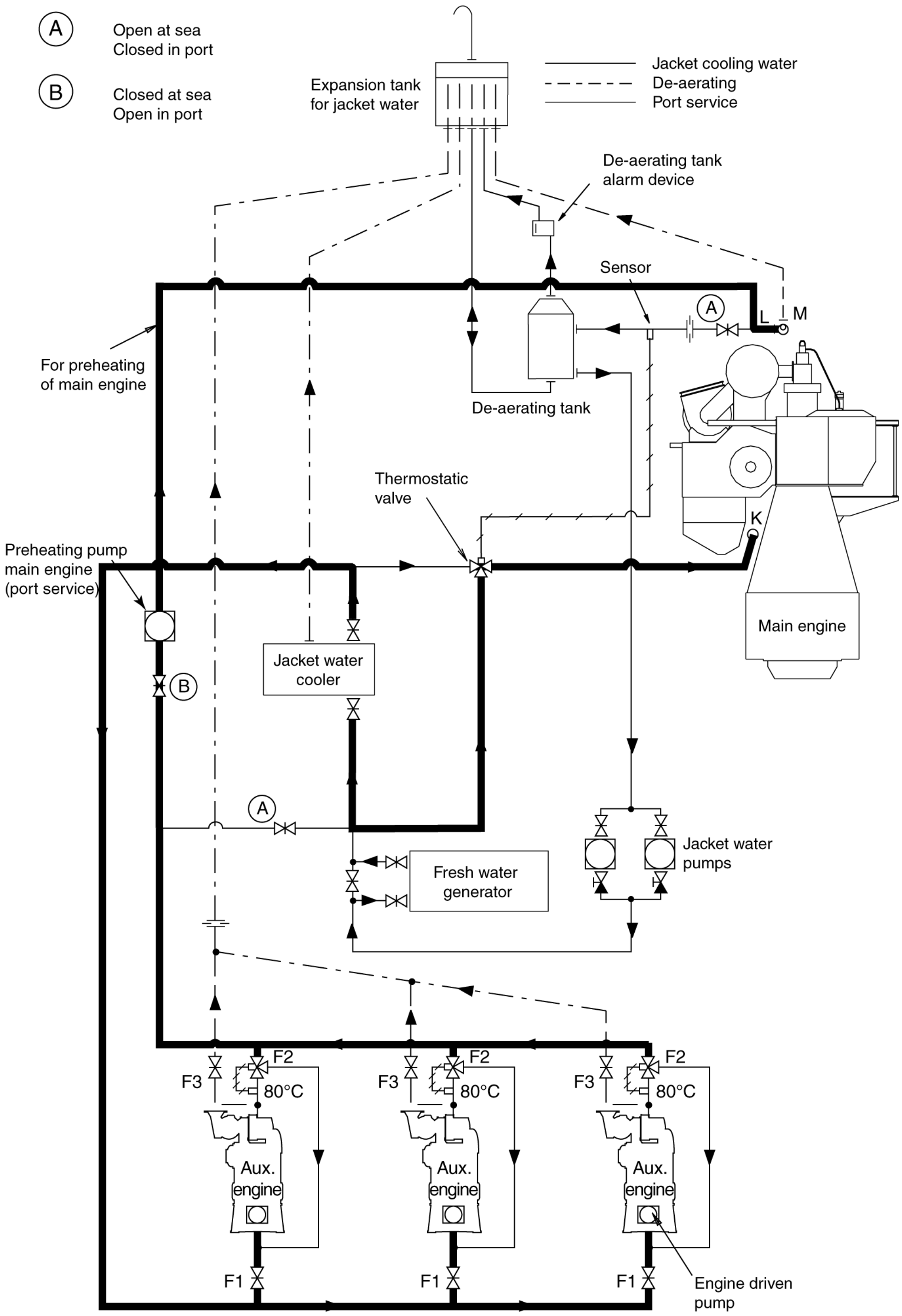

Figure 2: Operating in port.

Design features and working principle

This diagram describes the possibilities with regard to the design of a common auxiliary system for a two-stroke main engine of the MC-type and four-stroke GenSets from MAN Energy Solutions.

The jacket water cooling system controls the temperature of the engines proper.

The jacket water is to be inhibited to protect the surfaces of the cooling system against corrosion, corrosion fatigue, cavitation and the formation of scale.

Operation at sea

The jacket water pumps circulate hot cooling water from the engines to the fresh water generator and from there to the jacket water cooler. Here a thermostatically controlled 3-way valve mixes cooled and uncooled water to maintain an outlet temperature of 80-82°C from the main engine.

An integrated loop in the auxiliary engines ensures a constant temperature of 80°C at the outlet of the auxiliary engines.

There is one common expansion tank for the main engine and the auxiliary engines.

To prevent the accumulation of air in the jacket water system, a de-aeration tank is located at the outlet of the main engine. An alarm device is inserted between the de-aeration tank and the expansion tank so that the operating crew can be notified if excess air or gas is released, as this signals a malfunction of engine components.

Operation in port

The main engine is preheated by utilizing hot water from the auxiliary engine(s). Depending on the size of main engine and auxiliary engines, an extra preheater may be necessary. This preheating is activated by closing valve A and opening valve B.

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

As the temperature sensor for the valve in this operating mode is measuring in a non-flow, low temperature piping, the valve will lead most of the cooling water to the jacket water cooler.

The integrated loop in the auxiliary engines will ensure a constant temperature of 80°C at the auxiliary engine outlet, the main engine will be preheated, and auxiliary engines in stand-by can also be preheated by operating valves F3 and F1.

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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

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Engine type	Expansion volume litre*	Recommended tank volume m^3**
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 arrangement consist of a thermostat-controlled el-preheating element built into the outlet pipe for the HT cooling water on the engine's front end. The pipe dimension has been increased in the piping section where the heating element is mounted.

Cyl. No.	Preheater 3x400V/3x440V kW
5	1 x 12.0
6	1 x 12.0
7	1 x 15.0
8	1 x 15.0
9	1 x 15.0

The system is based on thermo-syphon cooling and reverse water direction, i.e. from top and downward, and an optimal heat distribution in the engine is thus reached.

When the engine is in standstill, an extern valve must shut off the cooling water inlet.

Operation

Engines starting on HFO and engines in stand-by position must be preheated. It is therefore rcommended that the preheater is arranged for automatic operation, so that the preheater is disconnected when the engine is running and connected when the engine is in stand-by position. The thermostat setpoint is adjusted to 70°C, that gives a temperature of app. 50°C at the top cover. *See also E 19 13 0, High Temperature Preheater Control Box.*

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Expansion tank pressurized

Description

Engine type	Expansion volume litre*	Recommended tank volume 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
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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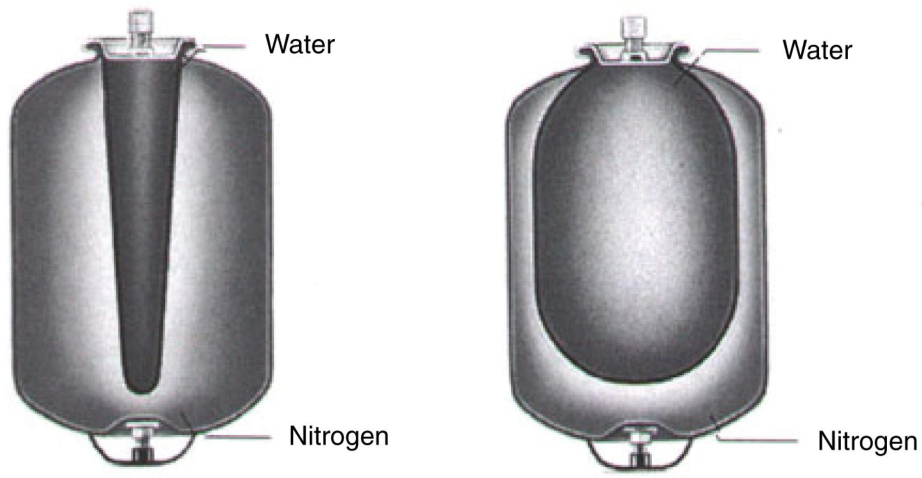

Function at low temperature

Function at high temperature

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.

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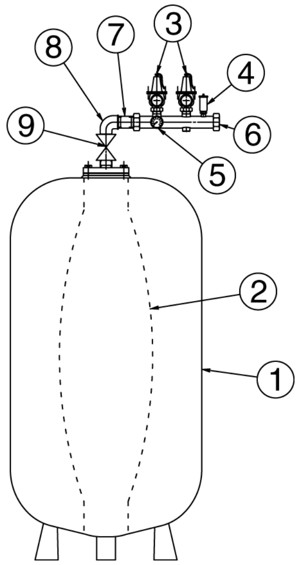

1	Pressure vessel	2	Exchangeable rubber bag
3	Safety valves	4	Automatic air venting valve
5	Pressure gauge	6	Manifold
7	Threaded pipe	8	Elbow
9	Shutt-off valve		

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/m^3
Purity regarding moisture	Quality class 7
Residual water content	< 0.5 g/m^3
Purity regarding oil	Quality class X

Additional requirements are:

- The air must not contain organic or inorganic silicon compounds.
- The layout of the starting air system must ensure that no corrosion may occur.
- The starting air system and the starting air receiver must be equipped with condensate drain devices.
- By means of devices provided in the starting air system and via maintenance of the system components, it must be ensured that any hazardous formation of an explosive compressed air/lube oil mixture is prevented in a safe manner.

Compressed air quality in the control air system

Please note that control air will be used for the activation of some safety functions on the engine – therefore, the compressed air quality in this system is very important.

Control air must meet at least the following quality requirements according to ISO 8573-1:2010.

- 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.

- 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

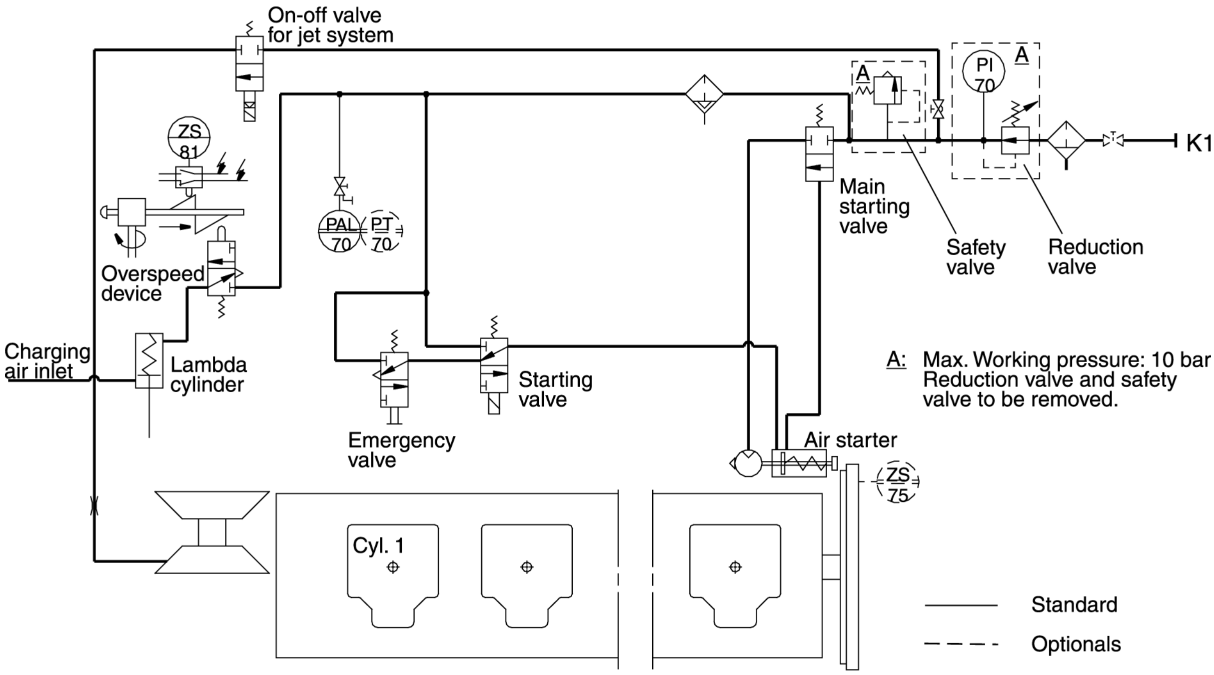

Figure 1: Diagram for compressed air system (for guidance only, please see the plant specific engine diagram)

Air supply!

WARNING

Air supply must not be interrupted when engine is running

Pipe description

Pipe description		
K1	Compressed air inlet	DN 40

Table 1: Flange connections are standard according to DIN 2501

General

The compressed air system on the engine contains a starting system, starting control system and safety system. Further, the system supplies air to the jet system.

The compressed air is supplied from the starting air receivers (30 bar) through a reduction station, from where compressed air at 7-9 bar is supplied to the engine.

To avoid dirt particles in the internal system, a strainer is mounted in the inlet line to the engine.

Starting system

The engine is started by means of a built-on air starter, which is a turbine motor with gear box, safety clutch and drive shaft with pinion. Further, there is a main starting valve.

Control system

The air starter is activated electrically with a pneumatic 3/2 way solenoid valve. The valve can be activated manually from the starting box on the engine, and it can be arranged for remote control, manual or automatic.

For remote activation, the starting spool is connected so that every starting signal to the starting spool goes through the safe start function, which is connected to the converter for engine rpm.

Further, the system is equipped with an emergency starting valve which makes it possible to activate the air starter manually in case of a power failure.

Safety system

As standard the engine is equipped with a pneumatic/mechanical overspeed device, which starts to operate if the maximum permissible rpm is exceeded. This device is fitted to the end cover of the engine driven lubricating pump and is driven from the pump through a resilient coupling.

When the maximum permissible rpm is exceeded, the overspeed device will activate a pneumatically controlled stop cylinder, which will bring the fuel index to zero and stop the engine.

A microswitch will be activated too and give a stop signal to the safety system.

Pneumatic start sequence

When the starting valve is opened, air will be supplied to the drive shaft housing of the air starter.

The air supply will - by activating a piston - bring the drive pinion into engagement with the gear rim on the engine flywheel.

When the pinion is fully engaged, the pilot air will flow to, and open the main starting valve, whereby air will be led to the air starter, which will start to turn the engine.

When the rpm exceeds approx. 140, at which firing has taken place, the starting valve is closed whereby the air starter is disengaged.

Optionals

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

- Main stop valve, inlet engine

Pressure transmitting:

- PT 70 Compressed air inlet

Position switching, stop:

- ZS75 Microswitch on flywheel

Data

For air consumption pr. start, *see D 10 05 0 "List of Capacities".*

Operating levels and set points, *see B 19 00 0, "Operating Data and Set Points".*

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Compressed air system

Diagram

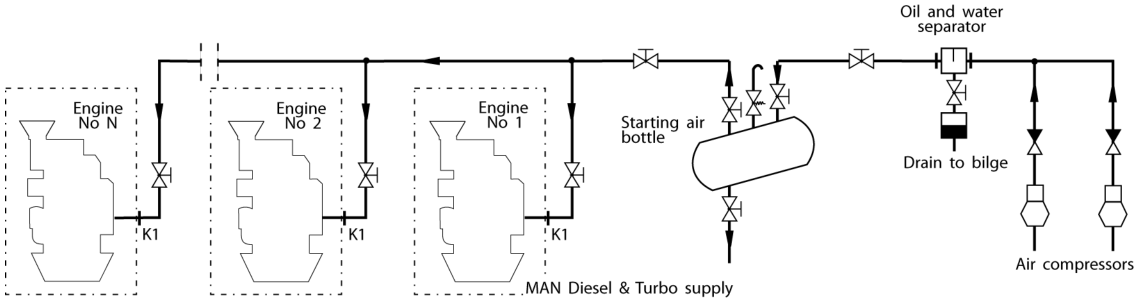

Figure 1: Diagram for compressed air system

Design of external system

The external compressed air system should be common for both propulsion engines and GenSet engines.

Separate tanks shall only be installed in turbine vessels, or if GenSets in engined vessels are installed far away from the propulsion plant.

The design of the air system for the plant in question should be according to the rules of the relevant classification society.

As regards the engine's internal compressed air system, please *see B 14 00 0 "Internal Compressed Air System".*

An oil and water separator should be mounted between the compressor and the air receivers, and the separator should be equipped with automatic drain facilities.

Each engine needs only one connection for compressed air, please *see diagram for the compressed air system.*

Installation

In order to protect the engine's starting and control equipment against condensation water, the following should be observed:

- The air receiver(s) should always be installed with good drainage facilities. Receiver(s) arranged in horizontal position must be installed with a slope downwards of min. 3°-5°.
- Pipes and components should always be treated with rust inhibitors.
- The starting air pipes should be mounted with a slope towards the receivers, preventing possible condensed water from running into the compressors.
- Drain valves should be mounted at the lowest position on the starting air pipes.

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Starting air system

Design features and working principle

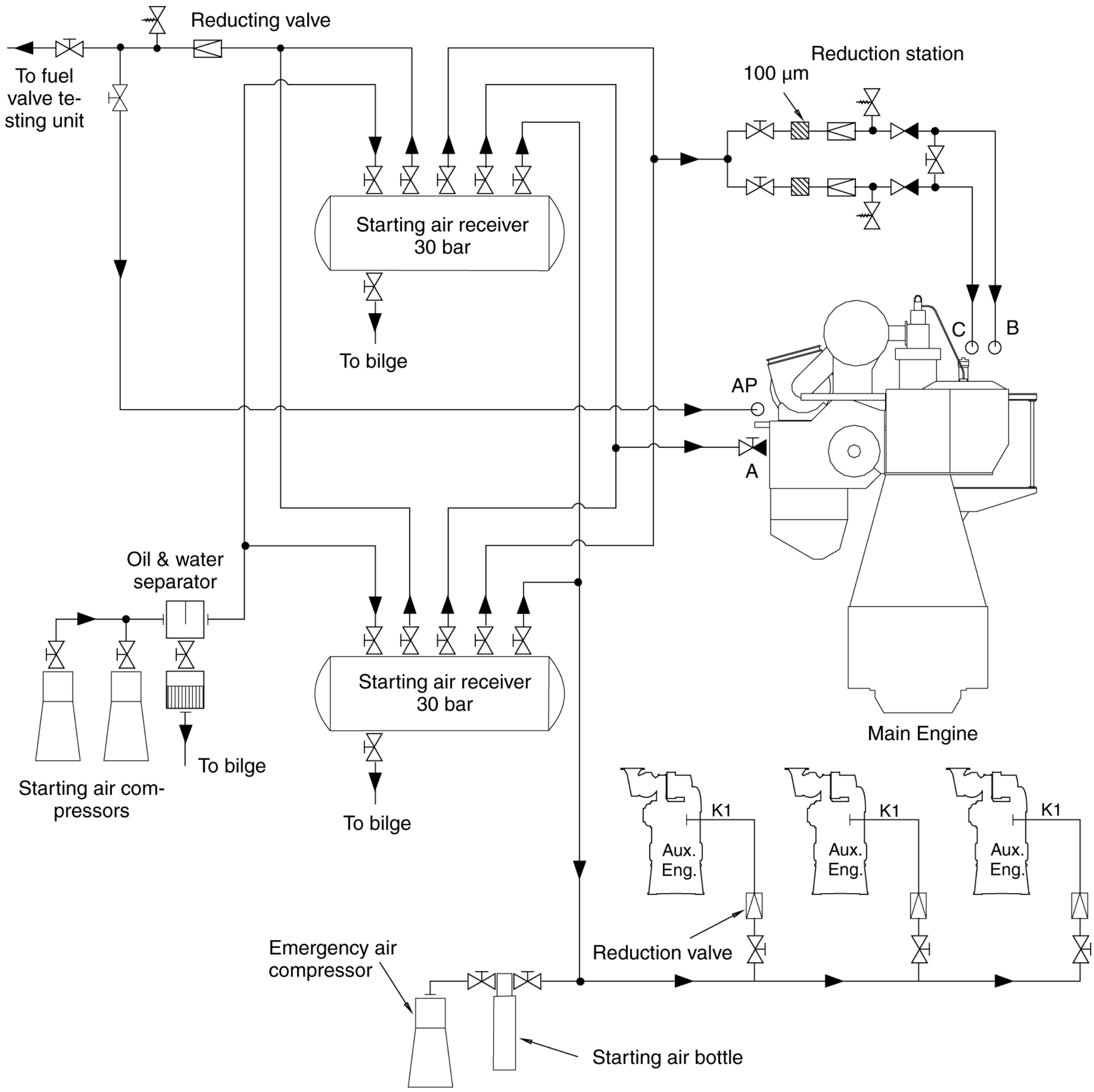

Figure 1: Starting air system

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This diagram describes the possibilities with regard to the design of a common auxiliary system for a two-stroke main engine of the MC-type and four-stroke GenSets from MAN Energy Solutions.

Two starting air compressors with automatic start and stop maintain a starting air pressure of 30 bar in the starting air receivers.

The main engine is supplied with 30 bar starting air directly from the starting air receivers. Through a pressure reduction station compressed air at 7 bar is supplied as control air for the engine manoeuvring system, and as safety air for the emergency system.

Starting air and control air for the auxiliary engine(s) is also supplied from the same starting air receivers, via reduction valves that lower the pressure to a value suited to the actual type of MAN Energy Solutions four-stroke auxiliary engines chosen. An emergency air compressor and a starting air bottle are installed for redundant emergency start of the auxiliary engines.

If high-humidity air is taken in by the air compressors, an oil and water separator will remove moisture drops present in the 30 bar compressed air. When the pressure is subsequently reduced to 7 bar, as for the main engine manoeuvring system, the humidity in the compressed air will be very slight. Consequently, further air drying is considered unnecessary.

From the starting air receivers a special air line leads to the valve testing equipment.

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Combustion air system

General

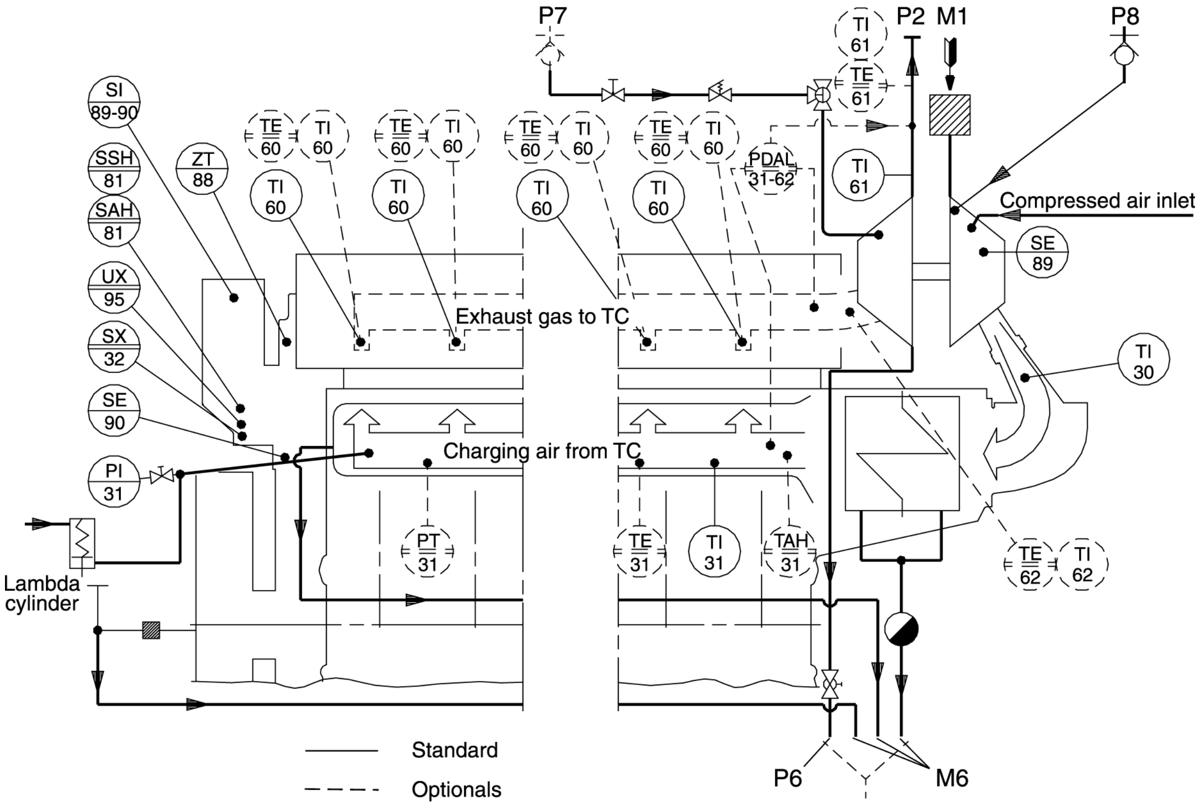

Figure 1: Diagram for combustion air system.

Pipe description		
M1	Charge air inlet	
M6	Drain from charge air cooler outlet	DN 15*
P2	Exhaust gas outlet	**
P6	Drain from turbocharger outlet	DN 15*
P7	Water washing turbine side inlet (Optional quick coupling)	1/2"
P8	Water washing, compressor side with quick coupling inlet	1/4"

Table 1: *Flange connections are standard according to DIN 2501. **See B 16 01 0 "Exhaust gas system" and B 16 02 0 "Position of gas outlet on turbocharger".

The air intake to the turbochargers takes place direct 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.

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Combustion air system
Description

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The charge air cooler is a compact tube-type cooler with a large cooling surface.

The charge air receiver is integrated in the engine frame on the exhaust side.

It is recommended to blow ventilation air in the level of the top of the engine(s) close to the air inlet of the turbocharger, but not so close that sea water or vapour may be drawn in. It is further recommended that there always is a positive air pressure in the engine room.

Water mist catcher

At outlet charge air cooler the charge air is led through the water mist catcher. The water mist catcher prevents condensed water (one of the major causes of cylinder wear) from entering the combustion chamber.

Turbocharger

The engine is as standard equipped with a high-effeciency MAN Energy Solutions NR/R turbocharger of the radial type, which is located on the front end of the engine, mounted on the top plate of the charging air cooler housing.

Cleaning of Turbocharger

The turbocharger is fitted with an arrangement for water washing of the turbine side, *see B 16 01 1,* and water washing of the compressor side, *see B 15 05 1.* Soft blast cleaning on the turbine side can be fitted as optional, *see B 16 01 2.*

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.

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.

Optionals

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

Pressure alarm low

- PAL 35 Charge air, surplus air inlet

Pressure differential alarm low

- PDAL 31-62, charge air and exhaust gas

Pressure transmitting

- PT 31 Charge air, outlet from cooler

Temperature alarm high

- TAH 31 Charge air, outlet from cooler

Temperature element

- TE 31 Charge air, outlet from cooler
- TE 60 Exhaust gas, outlet cylinder
- TE 61 Exhaust gas, outlet turbocharger
- TE 62 Exhaust gas, inlet turbocharger

Temperature indicating

- TI 60 Exhaust gas, outlet cylinder
- TI 61 Exhaust gas, outlet turbocharger
- TI 62 Exhaust gas, inlet turbocharger

Data

For charge air heat dissipation and exhaust gas data, *see D 10 05 0 "List of Capacities".*

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

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Specifications of intake air (combustion air)

General

The quality and condition of intake air (combustion air) have a significant effect on the engine output, wear and emissions of the engine. In this regard, not only are the atmospheric conditions extremely important, but also contamination by solid and gaseous foreign matter.

Mineral dust in the intake air increases wear. Chemicals and gases promote corrosion.

This is why effective cleaning of intake air (combustion air) and regular maintenance/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		

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.

The water washing equipment, see fig 1, comprises two major parts. The transportable container (6) including a hand valve with handle (5) and a plug-in coupling (4) at the end of a lance.

Installed on the engine there is the injection tube (1), connected to a pipe (2) and a snap coupling (3).

The cleaning procedure is:

1. Fill the container (6) with a measured amount of fresh water. Blow air into the container by means of a blow gun, until the prescribed operation pressure is reached.
2. Connect the plug-in coupling of the lance to the snap coupling on the pipe, and depress the handle on the hand valve.
3. The water is then injected into the compressor.

The washing procedure is executed with the engine running at normal operating temperature and with the engine load as high as possible, i.e. at a high compressor speed.

The frequency of water washing should be matched to the degree of fouling in each individual plant.

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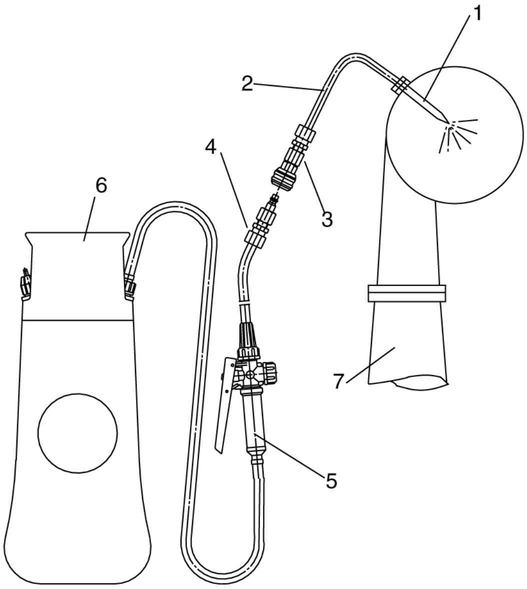

1 Injection tube
2 Pipe
3 Snap coupling
4 Plug-in coupling
5 Hand valve with handle
6 Container
7 Charge air line

Figure 1: Water washing equipment.

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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.

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Exhaust pipe mounting

When the exhaust piping is mounted, the radiation of noise and heat must be taken into consideration.

Because of thermal fluctuations in the exhaust pipe, it is necessary to use flexible as well as rigid suspension points.

In order to compensate for thermal expansion in the longitudinal direction, expansion bellows must be inserted. The expansion bellows should preferably be placed at the rigid suspension points.

Note: The exhaust pipe must not exert any force against the gas outlet on the engine.

One sturdy fixed-point support must be provided for the expansion bellows on the turbocharger. It should be positioned, if possible, immediately above the expansion bellows in order to prevent the transmission of forces, resulting from the weight, thermal expansion or lateral displacement of the exhaust piping, to the turbocharger.

The exhaust piping should be mounted with a slope towards the gas outlet on the engine. It is recommended to have drain facilities in order to be able to remove condensate or rainwater.

Position of gas outlet on turbocharger

B 16 02 0 shows turning alternatives positions of the exhaust gas outlet. Before dispatch of the engine exhaust gas outlet will be turned to the wanted position.

The turbocharger is, as standard, mounted in the front end.

Exhaust gas boiler

To utilize the thermal energy from the exhaust, an exhaust gas boiler producing steam or hot water can be installed.

Each engine should have a separate exhaust gas boiler or, alternatively, a common boiler with separate gas ducts. Concerning exhaust gas quantities and temperature, *see "List of capacities" D 10 05 0,* and *"Engine performance" D 10 10 0.*

The discharge temperature from the exhaust gas boiler should not be lower than 180°C (in order to avoid sulphuric acid formation in the funnel).

The exhaust gas boilers should be installed with by-pass entering in function at low-load operation.

The back-pressure over the boiler must be included in the back-pressure calculation.

Expansion bellows

The expansion bellows, which is supplied separately, must be mounted directly on the exhaust gas outlet, *see also E 16 01 1-2.*

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Exhaust silencer

The position of the silencer in the exhaust gas piping is not decisive for the silencing effect. It would be useful, however, to fit the silencer as high as possible to reduce fouling. The necessary silencing depends on the loudness of the exhaust sound and the discharge from the gas outlet to the bridge wing.

The exhaust silencer, *see E 16 04 2-3-5-6,* is supplied loose with counter-flange, gaskets and bolts.

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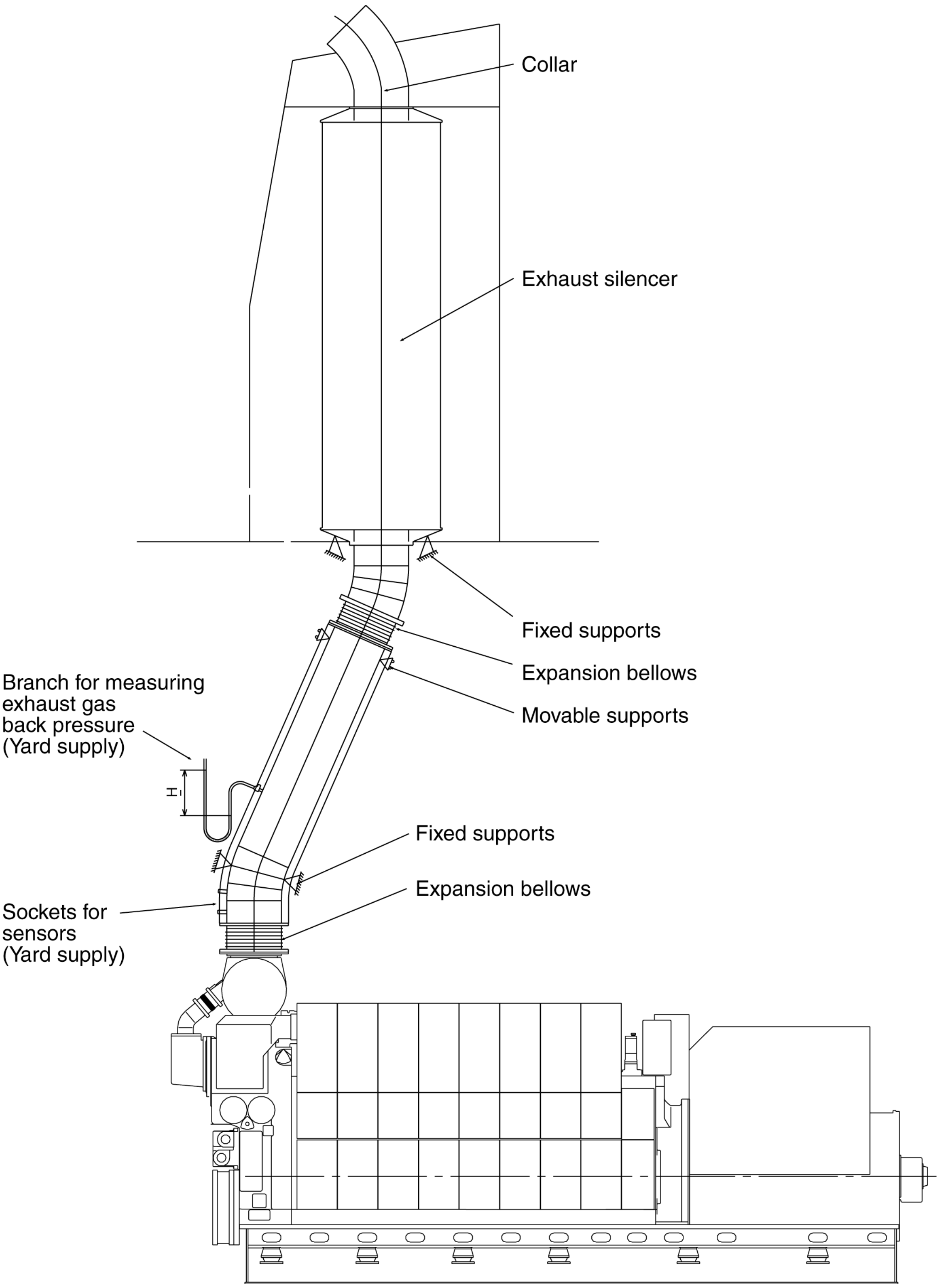
Collar
Exhaust silencer
Fixed supports
Expansion bellows
Movable supports
Branch for measuring exhaust gas back pressure (Yard supply)
H
Fixed supports
Expansion bellows
Sockets for sensors (Yard supply)

Resulting installation demands

If the recommended exhaust gas back pressure cannot be kept due to exhaust gas after treatment installations. Following items need to be considered.

Exhaust gas back pressure after turbocharger	
Operating pressure Δp_{exh}, standard	0 ... 30 mbar
Operating pressure Δp_{exh}, range with increase of fuel consumption	30 ... 60 mbar
Operating pressure Δp_{exh}, where a customized engine matching is needed	> 60 mbar

Table 1: Exhaust gas back pressure after turbocharger

Intake air pressure turbocharger	
Operating pressure Δp_{intake}, standard	0 ... –20 mbar
Operating pressure Δp_{intake}, range with increase of fuel consumption	–20 ... –40 mbar
Operating pressure Δp_{intake}, where a customized engine matching is needed	< –40 mbar

Table 2: Intake air pressure turbocharger

Sum of the exhaust gas back pressure after turbocharger and the absolute value of the intake air pressure before turbocharger	
Operating pressure Δp_{exh} + Abs(Δp_{intake}), standard	0 ... 50 mbar
Operating pressure Δp_{exh} + Abs(Δp_{intake}), range with increase of fuel consumption	50 ... 100 mbar
Operating pressure Δp_{exh} + Abs(Δp_{intake}), where a customized engine matching is needed	> 100 mbar

Table 3: Sum of the exhaust gas back pressure after turbocharger and the absolute value of the intake air pressure before turbocharger

Maximum exhaust gas pressure drop – Layout

- Shipyard and supplier of equipment in exhaust gas line have to ensure that pressure drop Δp_{exh} over entire exhaust gas piping incl. pipe work, scrubber, boiler, silencer, etc. must stay below stated standard operating pressure at all operating conditions.
- It is recommended to consider an additional 10 mbar for consideration of aging and possible fouling/staining of the components over lifetime.
- Possible counter measures could be a proper dimensioning of the entire flow path including all installed components or even the installation of an exhaust gas blower if necessary.
- At the same time the pressure drop Δp_{intake} in the intake air path must be kept below stated standard operating pressure at all operating conditions and including aging over lifetime.

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Pressure droop in exhaust gas system

General

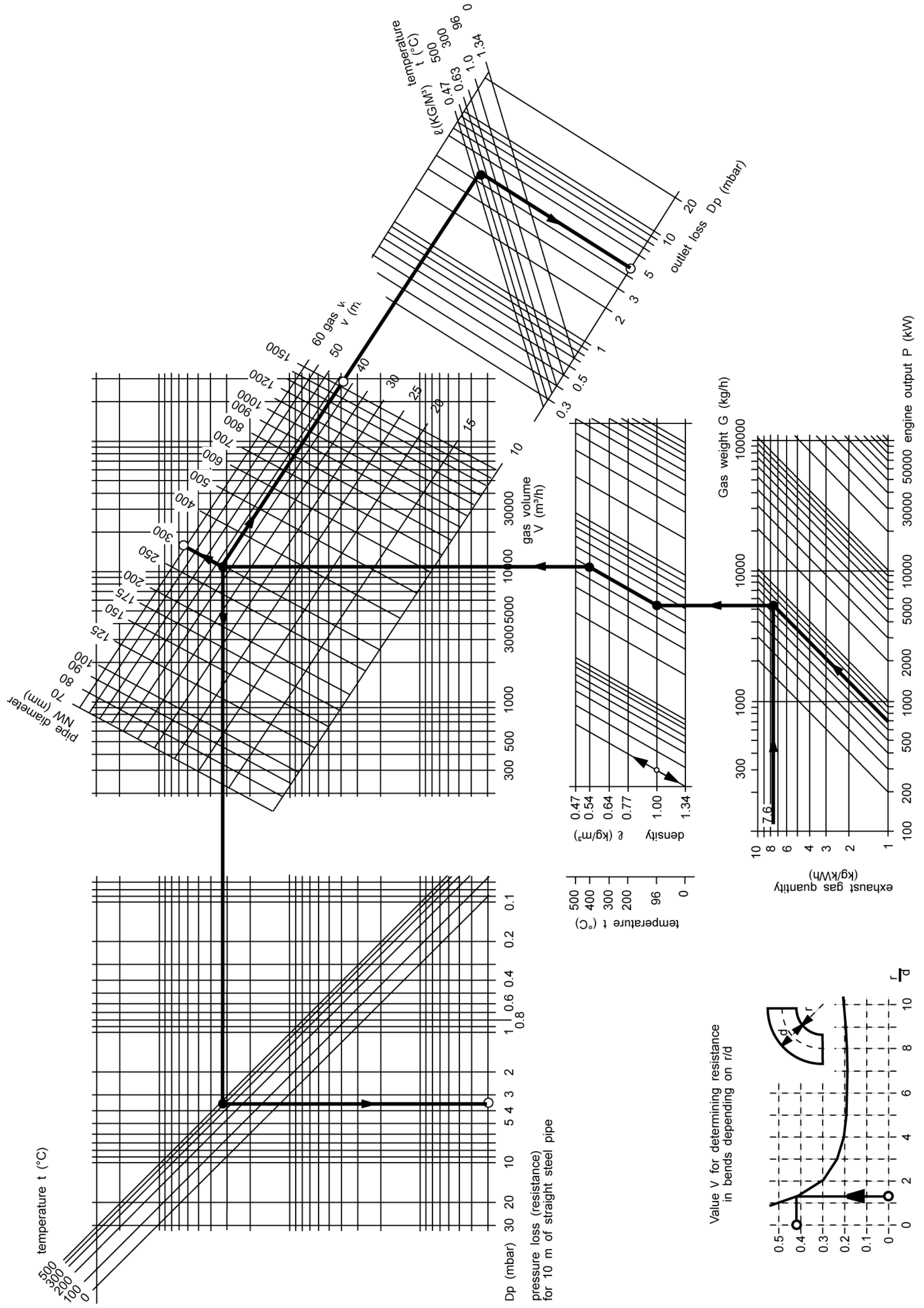

Figure 1: Nomogram for pressure drop in exhaust gas piping system.

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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

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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.

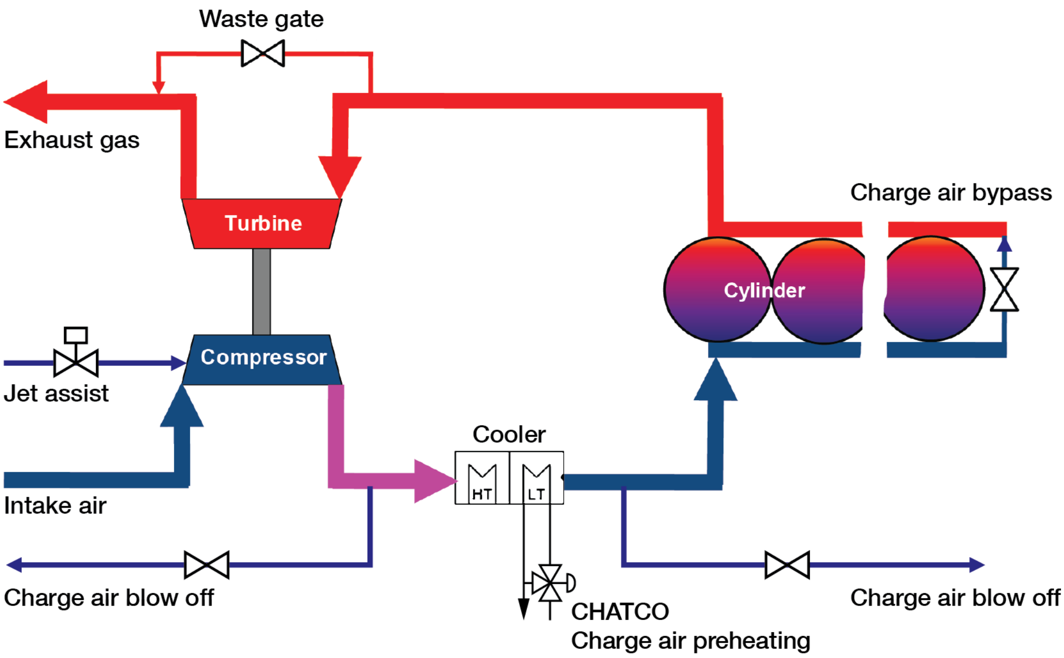

Figure 1: Overview of flaps

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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 ρ_A ~ 0.6 kg/m^3

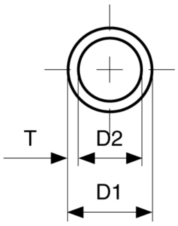
Engine type	Exhaust gas flow	Exhaust gas temp.	DN Nominal diameter	Exhaust gas velocity
	kg/h	°C	mm	m/sec.
5L28/32H, 720/750 rpm	8800	342	450	28.8
6L28/32H, 720/750 rpm	10500	342	450	34.5
7L28/32H, 720/750 rpm	12300	342	500	32.6
8L28/32H, 720/750 rpm	14100	342	550	30.9
9L 28/32H, 720/750 rpm	15800	342	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 $\rho_A \sim 0.6\ kg/m^3$

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.

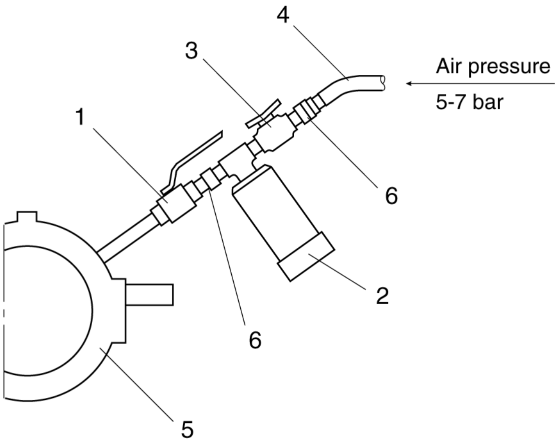
The solid bodies have a mechanical cleaning effect which removes any deposits on nozzle vanes and turbine blades.

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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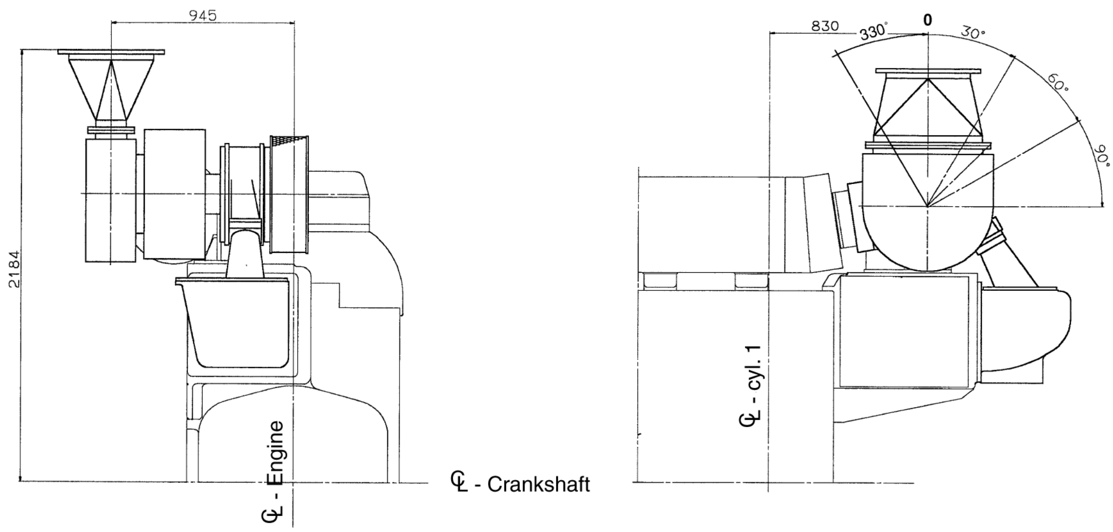
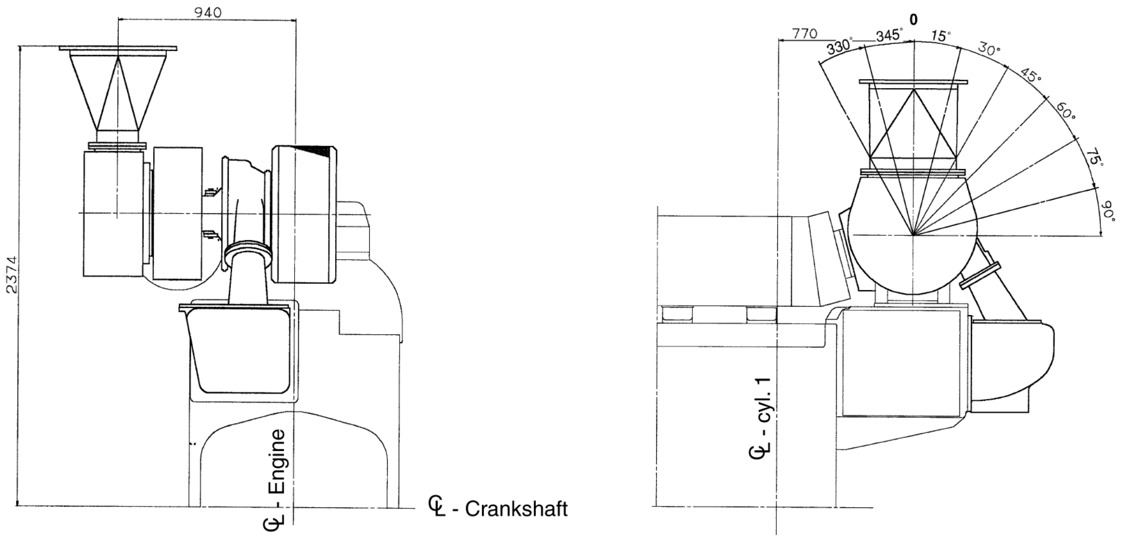
Position of gas outlet on turbocharger

Dimensions

5-6L28/32H

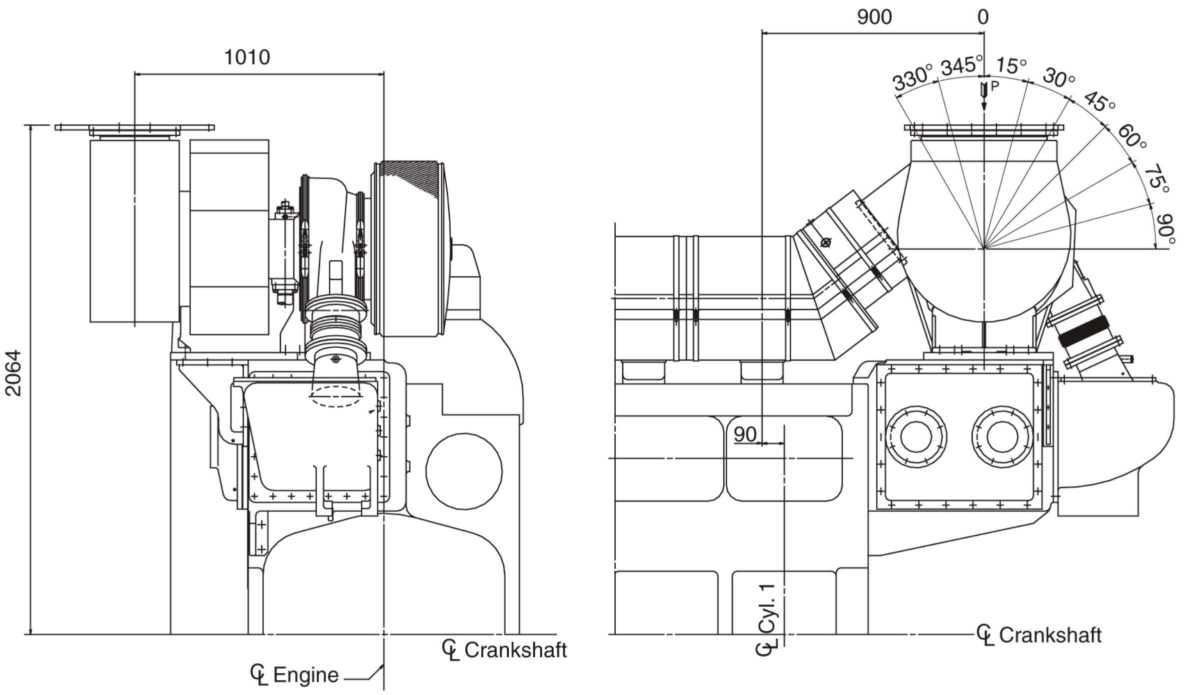


7-8L28/32H

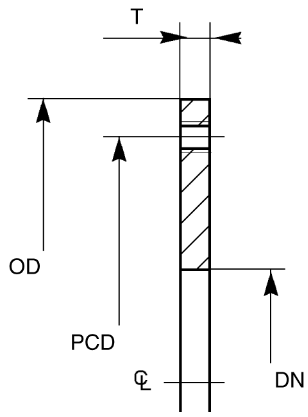


Exhaust flange D. mating dimensions						
Engine type	DN (mm)	OD (mm)	T (mm)	PCD (mm)	Hole size (mm)	No of holes
5-6L28/32H, 720/750 rpm	450	595	16	550	22	16
7L28/32H, 720/750 rpm	500	645	16	600	22	20
8L28/32H, 720/750 rpm	550	703	20	650	22	20

9L28/32H with NR24/S turbocharger



Flange



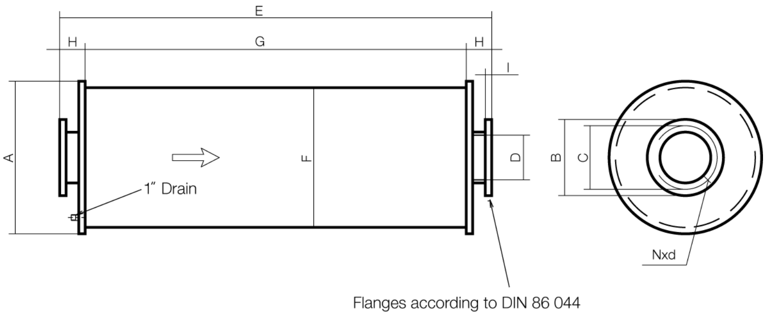
Exhaust flange D. mating dimensions						
Engine type	**DN (mm)**	**OD (mm)**	**T (mm)**	**PCD (mm)**	**Hole size (mm)**	**No of holes**
9L28/32H	550	703	20	650	22	20

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. type	DN	A	B	C	E	F	G	H	I	Nxd	Weight kg
35	5+6 (720/750 rpm)	450	1040	595	550	4300	1000	4000	150	16	16xø22	900
35	7 (720/750 rpm)	500	1140	645	600	4500	1100	4200	150	16	20xø22	1100
35	8+9 (720/750 rpm)	550	1240	703	650	4700	1200	4400	150	20	20xø22	1350

Silencer type (B)

Damping dB (A)	Cyl. type	DN	A	B	C	E	F	G	H	I	Nxd	Weight kg
35	5+6 (720/750 rpm)	450	1080	595	550	4200	1050	3900	150	16	16xø22	1015
35	7 (720/750 rpm)	500	1130	645	600	4200	1100	3900	150	16	20xø22	1093
35	8+9 (720/750 rpm)	550	1230	703	650	4400	1200	4100	150	20	20xø22	1276

All dimensions are in mm.
Dimension for flanges for exhaust pipes is according to DIN 86 044

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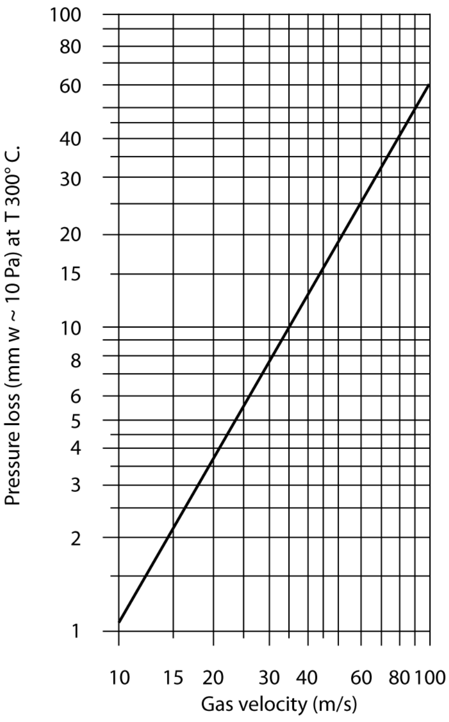
Installation

The silencer may be installed, vertically, horizontally or in any position close to the end of the piping.

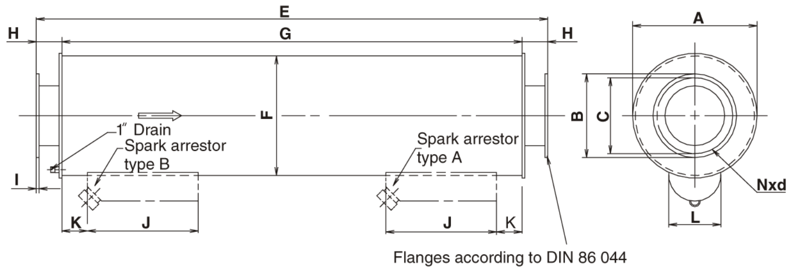
Pressure loss

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.



Silencer with spark arrestor, damping 35 dB (A)

Design



Silencer type (A)

Damping dB (A)	Cyl. No (rpm)	DN	A	B	C	E	F	G	H	I	Nxd	J	K	L	Weight kg
35	5+6 (720/750)	450	1040	595	550	4700	1000	4400	150	16	16xø22	1000	100	300	1000
35	7 (720/750)	500	1140	645	600	5000	1100	4700	150	16	20xø22	1000	150	310	1250
35	8+9 (720/750)	550	1240	703	650	5200	1200	4900	150	20	20xø22	1100	150	350	1500

Silencer type (B)

Damping dB (A)	Cyl. No (rpm)	DN	A	B	C	E	F	G	H	I	Nxd	J	K	L	Weight kg
35	5+6 (720/750)	450	1080	595	550	4650	1050	4350	150	16	16xø22	800	100	350	1140
35	7 (720/750)	500	1130	645	600	4700	1100	4400	150	16	20xø22	900	100	350	1204
35	8+9 (720/750)	550	1230	703	650	4950	1200	4650	150	20	20xø22	1000	100	350	1411

All dimensions are in mm.
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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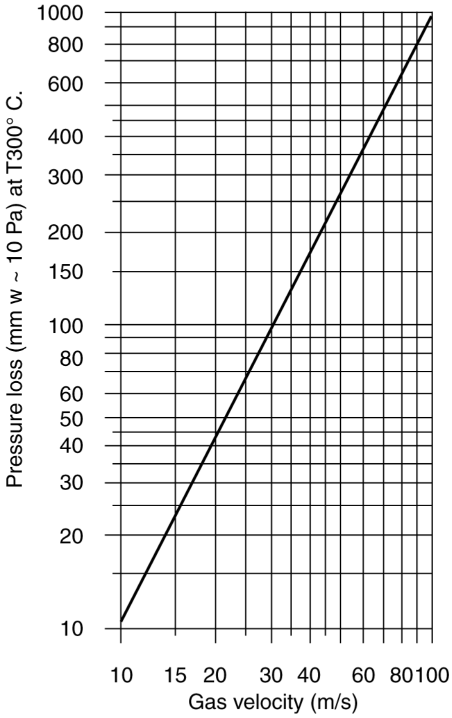
Installation

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

NOTICE

Dual Fuel engines can only be started on MGO.

The engine may be loaded according to the following procedure:

A: Normal start without preheated cooling water. Only on MDO.

B: Normal start with preheated cooling water. MDO or HFO.

C: Stand-by engine. Emergency start, with pre-heated cooling water, intermediate prelubri- cating or continuos prelubricating. MDO or HFO.

Starting on HFO

During shorter stops or if the engine is in stand-by on HFO the engine must be preheated.

During preheating the cooling water outlet temperature should be kept as high as possible at least 60°C (± 5°C) -either by means of cooling water from engines which are running or by means of a built-in preheater.

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 exept lub. oil viscosity may not by higher than 1500 cSt. (5°C for lub. oil SAE 30, or 10°C for SAE 40).

Initial ignition may be difficult if the engine and ambient temp. are lower than 5°C, and the cooling water temperature is lower than 15°C.

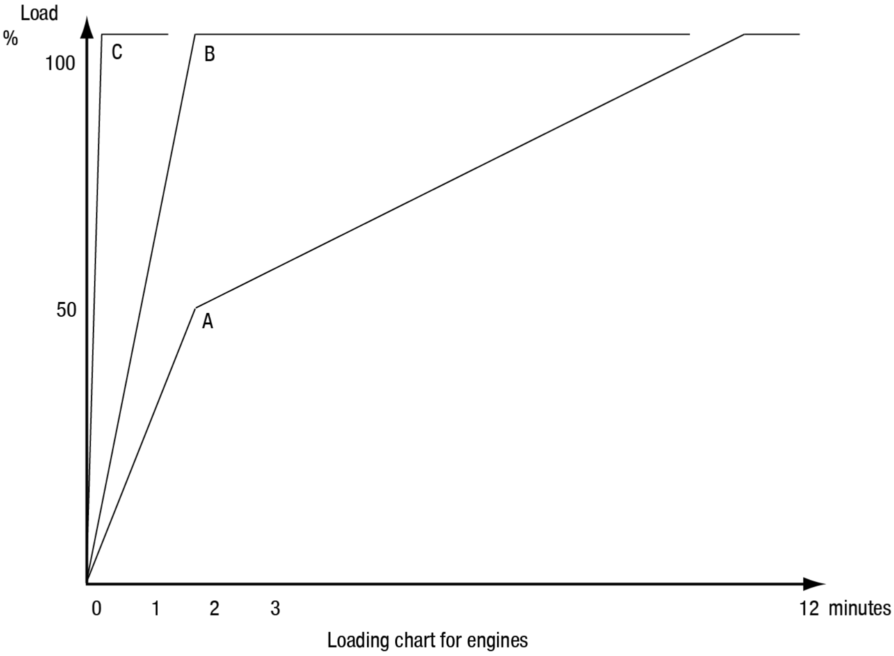
Starting on MGO

For starting on MGO there are no restrictions except that lubricating oil viscosity may not be higher than 1500 cSt (10°C SAE 40).

Initial ignition may be difficult if the engine and ambient temperatures are lower than 25°C and 65°C cooling water temperature.

Prelubricating

The engine shall always be prelubricated 2 minutes prior to start if there is not intermittent or continuos prelubricating installed. Intermittent prelub. is 2 min. every 10 minutes.



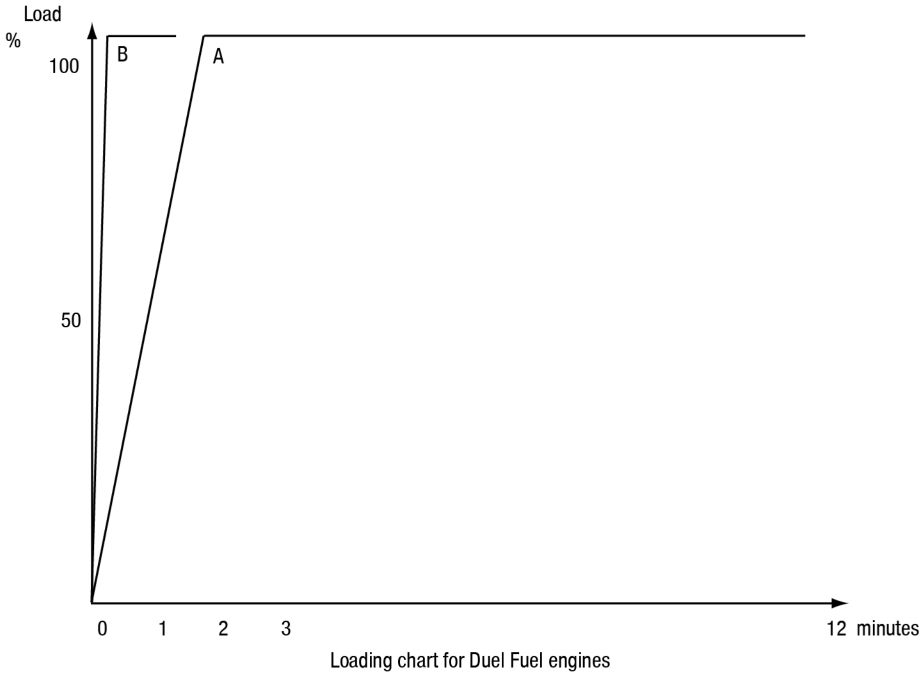


Figure 1: Loading chart

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

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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, 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 .

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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

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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.

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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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Governor

Governor type

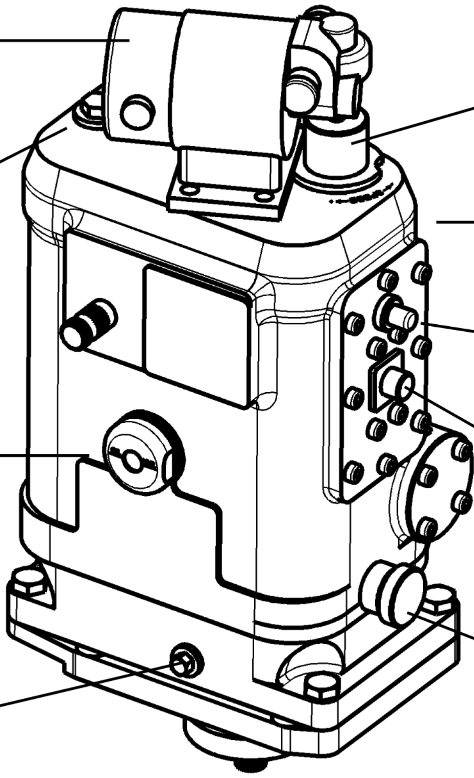

Figure 1: Regulateurs Europa governor.

The engines can be equipped with a hydraulic-mechanical governor, make Regulateurs Europa, type 1102.

Speed adjustment

Manual and electric.

Manual operated : Speed setting controlled by handwheel.

Electric motor : Permanent magnet synchronizing motor: 24V DC for raise and lower the speed.

Speed adjustment range

Between -5% and +10% of the nominal speed at idle running.

Droop

Adjustable by dial type lockable control from 0-10% droop.

Load distribution

By the droop setting.

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Shutdown/Stop

Solenoid energised to "stop".

Manually operated shutdown button fitted on governor energised to "stop" only.

Stop Solenoid voltages: 24V DC.

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Standard instrumentation

Description

One instrument panel consisting of:

Type	Code	Function
Pressure gauge	PI 01	LT Fresh water – inlet to air-cooler
Pressure gauge	PI 10	HT Fresh water – inlet engine
Pressure gauge	PI 21	Lubricating oil – inlet to filter
Pressure gauge	PI 22	Lubricating oil – outlet from filter
Pressure gauge	PI 23	Lubricating oil – inlet to turbocharger
Pressure gauge	PI 31	Charging air – outlet from cooler
Pressure gauge	PI 40	Fuel oil – inlet to engine
Pressure gauge	PI 50	Nozzle cooling oil – inlet to fuel valves

Instruments placed in start box:

Tachometer	SI 89/90	Turbocharger/engine – rpm

Switch for turbocharger/engine rpm

Instrumentation mounted local on engine:

Thermometer	TI 01	LT water – inlet from air cooler
Thermometer	TI 02	LT water – outlet from air cooler
Thermometer	TI 03	LT water – oulet from lub. oil cooler
Thermometer	TI 10	HT fresh water – inlet to engine
Thermometer	TI 11	HT fresh water – outlet each cylinder
Thermometer	TI 20	Lubricating oil – inlet to cooler
Thermometer	TI 22	Lubricating oil – outlet from filter
Thermometer	TI 30	Charge air – inlet to cooler
Thermometer	TI 31	Charge air – outlet from cooler
Thermometer	TI 40	Fuel oil – inlet to engine
Thermometer (*)	TI 51	Nozz. cool. oil – outlet from fuel valves

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Thermometer	TI 60	Exhaust gas – outlet each cylinder
Thermometer	TI 61	Exhaust gas – outlet turbocharger

(*) If nozzle cooiling oil is applied only.

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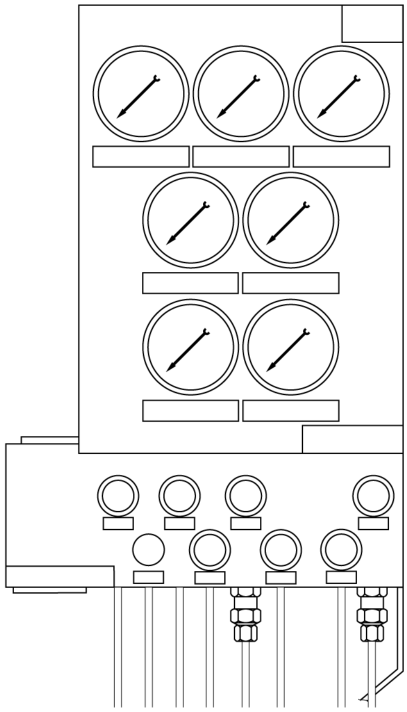
Standard instrument panel

Main instrument panel

As standard the engine is equipped with an instrument panel, comprising instruments for visual indication of the most essential pressures. Illustrated on *fig. 1.*



As standard an instrument panel is mounted on the engine.

The following incorporating pressure gauges for the most essential pressures.

Pressure gauge for:

PI 01 LT fresh water, inlet to air cooler
PI 10 HT fresh water, inlet engine
PI 21/22 Lubricating oil, inlet/outlet to filter
PI 23 Lub. oil, inlet to turbocharger
PI 31 Charge air, outlet from cooler
PI 40 Fuel oil, inlet to engine
PI 50 Nozz. cool. oil, inlet to fuel valves
Switch for PI 21/22

Figure 1: Lay-out of instrument panel.

The instrument panel is mounted flexibly on rubber elements and all manometer connections are connected to the panel by means of flexible hoses, as shown on *fig. 2.*

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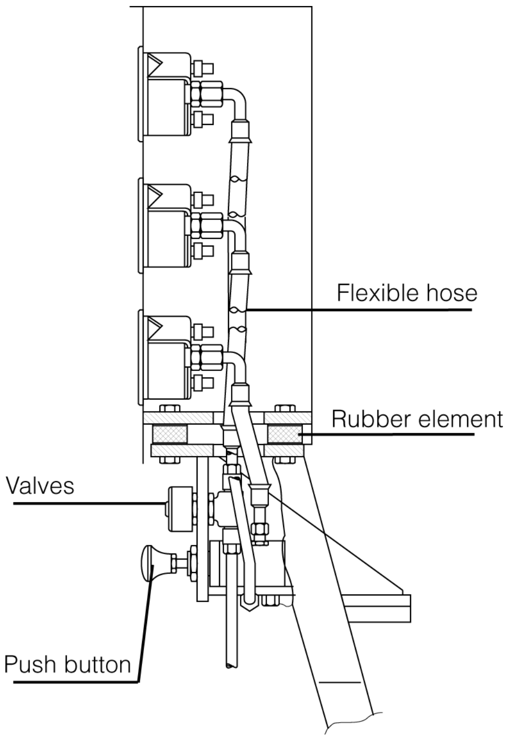

Figure 2: Cross section of instrument panel.

The connecting pipes to the manometers are equipped with valves which make it possible to replace the manometers during operation.

In the charging air and nozzle oil piping damping filters are inserted for levelling out pressure fluctuations.

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	Normal Value at Full load at ISO conditions		Acceptable value at shop test or after repair	Alarm Set point		Autostop of engine	
Lubricating Oil System							
Temp. before cooler SAE 30 (outlet engine) SAE 40	TI 20 TI 20	60-75° C 65-82° C	<75° C <82° C	TAH 20 TAH 20	90° C 100° C		
Temp. after cooler SAE 30 (inlet engine) SAE 40	TI 22 TI 22	45-65° C 50-72° C	<65° C <72° C	TAH 22 TAH 22	75° C 85° C	TSH 22 TSH 22	85° C 95° C
Pressure after filter (inlet eng)	PI 22	4-5 bar	>4.5 bar	PAL 22	3.5 bar	PSL 22	3.0 bar
Pressure drop across filter	PDAH 21-22	0.5-1 bar	<0.5 bar	PDAH 21-22	1.5 bar		
Prelubricating pressure Pressure inlet turbocharger	 PI 23	 1.5 ±0.2 bar	 >1.5 bar	LAL 25	level switch		
Lub. oil, level in base frame				LAL 28/ LAH 28	low/high level		
Temp. main bearings	TE 29	75-85° C	<85° C	TAH 29	95° C		
Fuel Oil System							
Pressure after filter MDO HFO	PI 40 PI 40	5-8 bar 5-16 bar (A)		PAL 40 PAL 40	4 bar 4 bar		
Leaking oil				LAH 42	leakage		
Cooling Water System							
Press. LT-system, inlet engine	PI 01	1-2.5 bar (D)	>1.3 bar	PAL 01	0.4 bar + (C)		
Press. HT-system, inlet engine	PI 10	1.5-4.6 bar	>1.8-<6 bar	PAL 10	0.4 bar + (C)		
Temp. HT-system, inlet engine	TI 10	60-75° C					
Temp. HT-system, outl. cyl.units	TI 11	70-85° C	<85° C				
Temp. HT-system, outlet engine				TAH 12 TAH 12-2	90° C 93° C		
Temp. raise across cyl. units		max. 10° C				TSH 12	95° C
Exhaust Gas and Charge Air							
Exh. gas temp. before TC	TI 62	425-475° C		TAH 62 TAH 62-2	550° C 600° C		
Exh. gas temp. outlet cyl. Diff. between individual cyl.	TI 60	270-380° C	 average ±25° C	TAH 60 TAD 60	410° C average (F) ±50° C		
Exh. gas temp. after TC	TI 61	275-350° C		TAH 61	500° C		
Ch. air press. after cooler Ch. air temp. after cooler	PI 31 TI 31	2-2.5 bar 35-55° C	 <55° C	 TAH 31	 65° C		
Compressed Air System							
Press. inlet engine	PI 70	7-9 bar	>7.5-<9 bar	PAL 70	7 bar		
Speed Control System Engine speed GenSets for 60 Hz Mechanical Elec.	SI 90	720 rpm	820 rpm	SAH 81	815 rpm	SSH 81 SSH 81	825 rpm 815 rpm

Specific plants will not comprise alarm equipment and autostop for all parameters listed above. For specific plants additional parameters can be included. For remarks to some parameters, see overleaf.

10° C change in ambient temperature correspond to approx. 15° C exhaust gas temperature change

Operation Data & Set Points

L28/32H, L28/32S

	Normal Value at Full load at ISO conditions		Acceptable value at shop test or after repair	Alarm Set point		Autostop of engine	
GenSets for 50 Hz Mechanical Elec.	SI 90	750 rpm	855 rpm	SAH 81	850 rpm	SSH 81 SSH 81	860 rpm 850 rpm
Turbocharger speed	SI 89	(G)		SAH 89	(E)		

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.

C. 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.

D. Press. LT -system, inlet engine (PI 01)

With two-string cooling water system the normal value can be higher, max. 4.0 bar.

E. Limits for Turbocharger Overspeed Alarm (SAH 89)

Engine type	720 rpm	750 rpm
5L28/32H	42,680	42,680
6L28/32H	42,680	42,680
7L28/32H	34,900	34,900
8L28/32H	34,900	34,900
9L28/32H	36,180	36,180

F. 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.

G. 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.

Mechanical overspeed

Mechanical overspeed

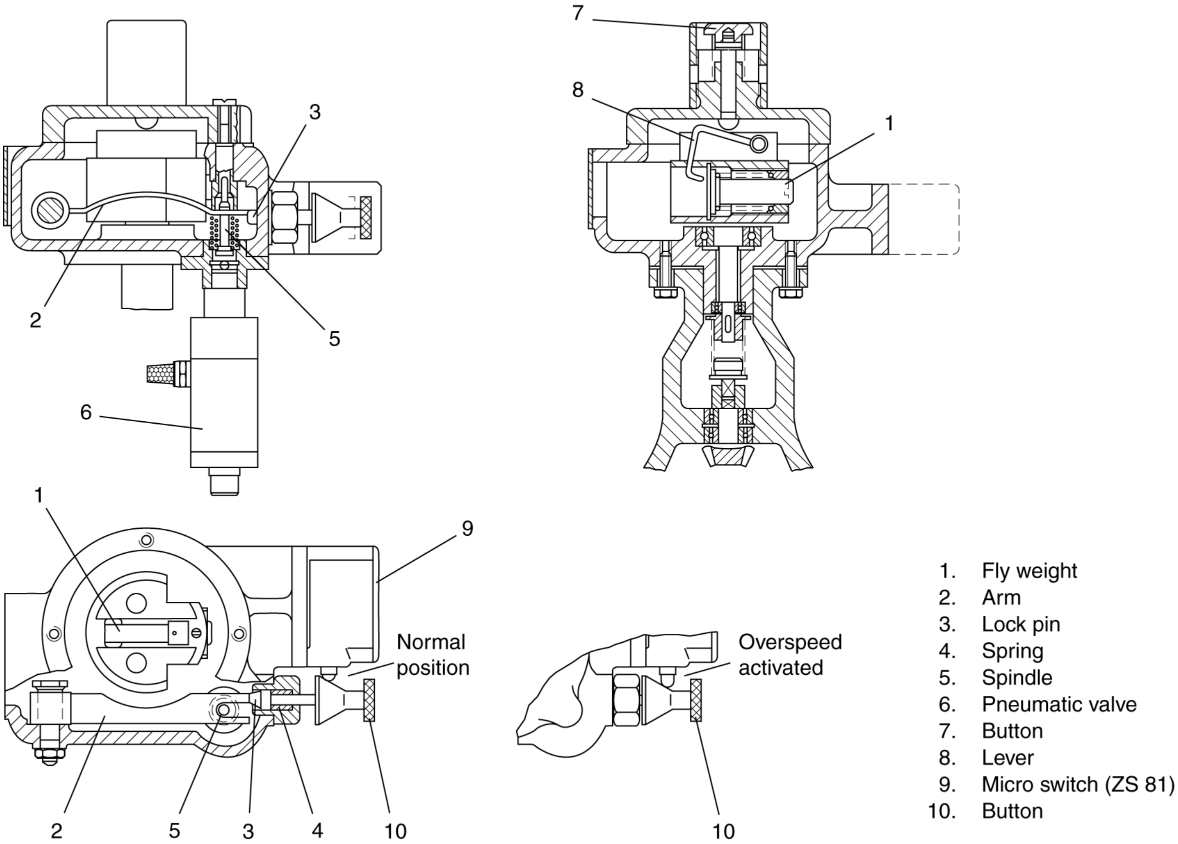

Figure 1: Mechanical overspeed.

The engine is protected against overspeeding in the event of, for instance, governor failure by means of an overspeed trip.

The engine is equipped with a stopping device which starts to operate if the maximum permissible revolution number is exceeded.

The overspeed tripping device is fitted to the end cover of the lubricating oil pump and is driven through this pump.

If the pre-set tripping speed is exceeded, the springloaded fly weight (1), *see fig 1,* will move outwards and press down the arm (2).

The arm is locked in its bottom position by the lock pin (3) which is pressed in by the spring (4).

At the same time the arm (2) presses down the spindle (5), and the pneumatic valve (6) opens, whereby compressed air will be led to the stop cylinder, *(see also B 17 30 1)* in which the piston is pressed forward and, through the arm, turns the fuel pump regulating shaft to STOP position. Thereby the engine stops, the spring-loaded pull rod connection to the governor being compressed.

The engine can be stopped manually by pressing down the button (7), which will activate the springloaded fly weight (1) through the lever (8).

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If the overspeed has been activated, the overspeed must be reset before the engine can be started. Reset is done by means of the button (10).

Overspeed alarm (SAH 81)

The overspeed alarm (SAH 81) is activated by means of the micro switch (9).

Local starting box - No 1

Description

The starting box is mounted on the engine's control side. On front of the box there are the following indications/pushbuttons:

- Indication of engine or turbocharger RPM
- Indication of electronic overspeed
- Pushbutton for "Manual Start"
- Pushbutton for "Manual Stop"
- Pushbutton for "Remote" *
- Pushbutton for "Local" *
- Pushbutton for "Blocking" *
- Pushbutton for change-over between engine and turbocharger RPM

* The function chosen is indicated in the pushbutton. See fig. 1.

Manual start

The engine can be started by means of the start button, but only if the button "Local" is activated.

The manual, local start is an electrical, pneumatic start, i.e. when activating the start button a solenoid valve opens for air to the air starter, thereby engaging the starter and starting the diesel engine. Throughout the starting cycle the start button must be activated.

The air starter is automatically disengaged when the diesel engine exceeds 110 RPM. If the start button is disengaged before the diesel engine has exceeded 110 RPM, further starting cycles are blocked, until 5 sec. after the engine is at standstill.

Remote start

Remote start can only take place if the pushbutton for "Remote" is activated.

Manual stop

The "Manual Stop" button is connected to the stop coil on the governor.

Blocking

If "Blocking" is activated, it is not possible to start the diesel engine.

Engine / turbocharger RPM

By activating the "Engine RPM/TC RPM" button, the indication is changed.

Engine RPM indication is green light-emitting diodes and turbocharger RPM indication is red light-emitting diodes.

External indications

There are output signals for engine RPM and turbocharger RPM.

Engine	0 -	1200 RPM ~ 4-20 mA
TC	0 -	60000 RPM ~ 4-20 mA

The pushbuttons for "Remote", "Local" and "Blocking" have potential free switches for external indication.

All components in the starting box are wired to the built-on terminal box.

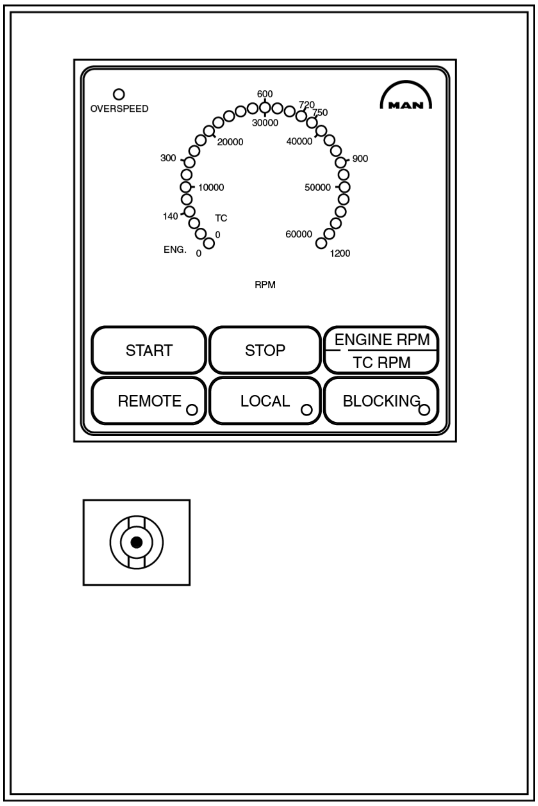

Figure 1: Starting box

Converter for engine RPM signal

Engine RPM signals

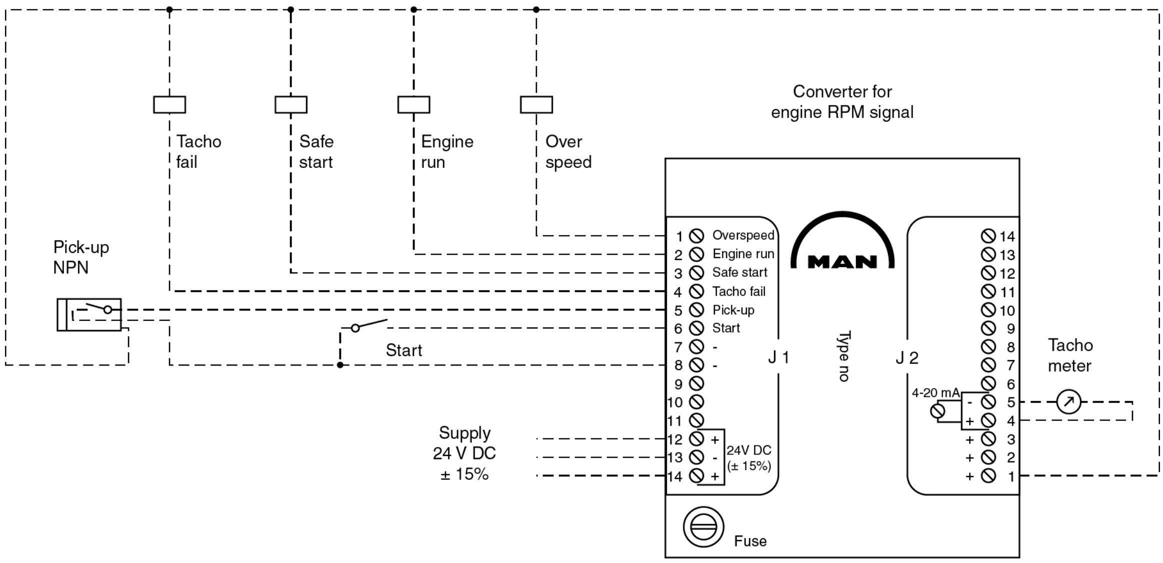

Figure 1: Converter for engine RPM

For measuring the engine's RPM, a pick-up mounted on the engine is used giving a frequency depending on the RPM. To be able to show the engine's RPM on an analogue tachometer, the frequency signal is sent through an f/I converter (frequency/current converter), where the signal is transformed into a proportional 4-20 mA ~ 0-1200 RPM.
Both tachometer on the engine and possibly external tachometers should be connected in the current loop.

Further, the converter has following signals :

- overspeed
- engine run
- safe start
- tacho fail

Overspeed

When the engine speed reach the set point for electronic overspeed the converter gives a shutdown signal and a alarm signal through a relay.

Engine run

When the engine speed reach 710 RPM the converter gives a "engine run" signal. The signal will also be given when the engine speed reach 200 RPM + 8 sec., (this is used for pump engines).

The engine run signal will be deactivated when the speed is 640 RPM. If the engine speed haven't been over 710 RPM the signal will be deactivated at 200 RPM.

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The "engine run" signals will be given through a relay. One for synchronizing and one for start/stop of pre. lub. oil pump or alarm blocking at start/stop.

Safe start

When the safe start signal is activated the engine can start. When the engine reach app. 140 RPM the air starter will be shut-off.

Further, the safe start signal is a blocking function for the air starter during rotation.

Tacho fail

The tacho fail signal will be on when everything is normal. If the pick-up or the converter failed the signal will be deactivated. E.g. if there is power supply failure.

The converter for engine RPM signal is mounted in the terminal box on the engine.

Pick-up

The pick-up is a NPN-type with LED-indication. The sensing distance is 0.5 to 1.2 mm.

All wiring to relay, pick-up and tachometer are made by MAN Energy Solutions.

Data

Operating data	:	24 V DC ± 15%
Power consumption	:	3 Watt
Ambient temperature	:	-20° C to 70° C
Output current	:	4-20mA ~ 0-1200 RPM

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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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Engine control box no 1

The safety system

From main switch board

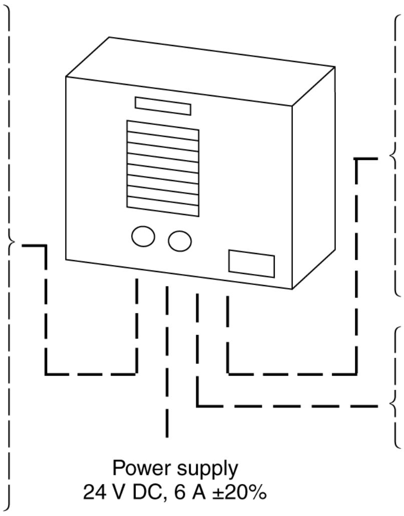
- Start signal
- Stop signal
- Emergency stop signal
- Reset signal

To main switch board

- Common shutdown
- Start failure
- Power failure
- Cable failure
- Alarm blocking
- Engine run

To pre.lub. oil pump starter

- Start/stop signal



Input from engine

- Engine run signal
- Pressurestate PSL 22 lub.oil pressure low - shut-down
- Thermostate TSH 12 cooling water - shut-down
- Microswitch SSH 81 speed high - Shut-down
- Stop
- Start interlock

Output to engine

- Power supply
- Stop signal - shut-down solenoid
- Start signal

Figure 1: External connections to/from the engine control box.

The engine control box is watching the most important safety operating functions of the diesel engine, i.e. low lub. oil pressure, high cooling water temperature, and overspeed.

If an unintended condition occurs to one of the above functions, the engine control box will release automatic stop of the engine (shutdown).

In order to avoid an unintended re-starting after release of a shutdown, there is a built-in reset function which has to be activated before the engine can be restarted. Remote reset is also possible.

Besides, there are built-in start/stop procedures for the engine. On *fig. 1* the possible external connections and input/output signals are shown.

On the front cover of the engine control box there is an indication panel.

There are indications for:

- Power
- Lub. oil shutdown
- High temp. fresh water shutdown
- Overspeed shutdown
- Start failure
- Wire break
- Start interlocks

There are push buttons for:

- Start
- Stop
- Reset
- Lamp test

Alarm blocking

The engine control box is provided with a relay output for alarm blocking. It is advisable to use in case of too low lub. oil pressure, so that alarm is avoided during starting and stopping of the engines.

Start/stop of the diesel engine

As the engine control box can give the diesel engine a signal of normal start/stop, it is possible to mount remote switches for these functions.

If the diesel engine does not start during a starting trial, a potential free switch will give the information that there is a starting failure.

When the diesel engine is running, two relay outputs are activated. One of these switches can be used for start/stop of the prelubricating pump.

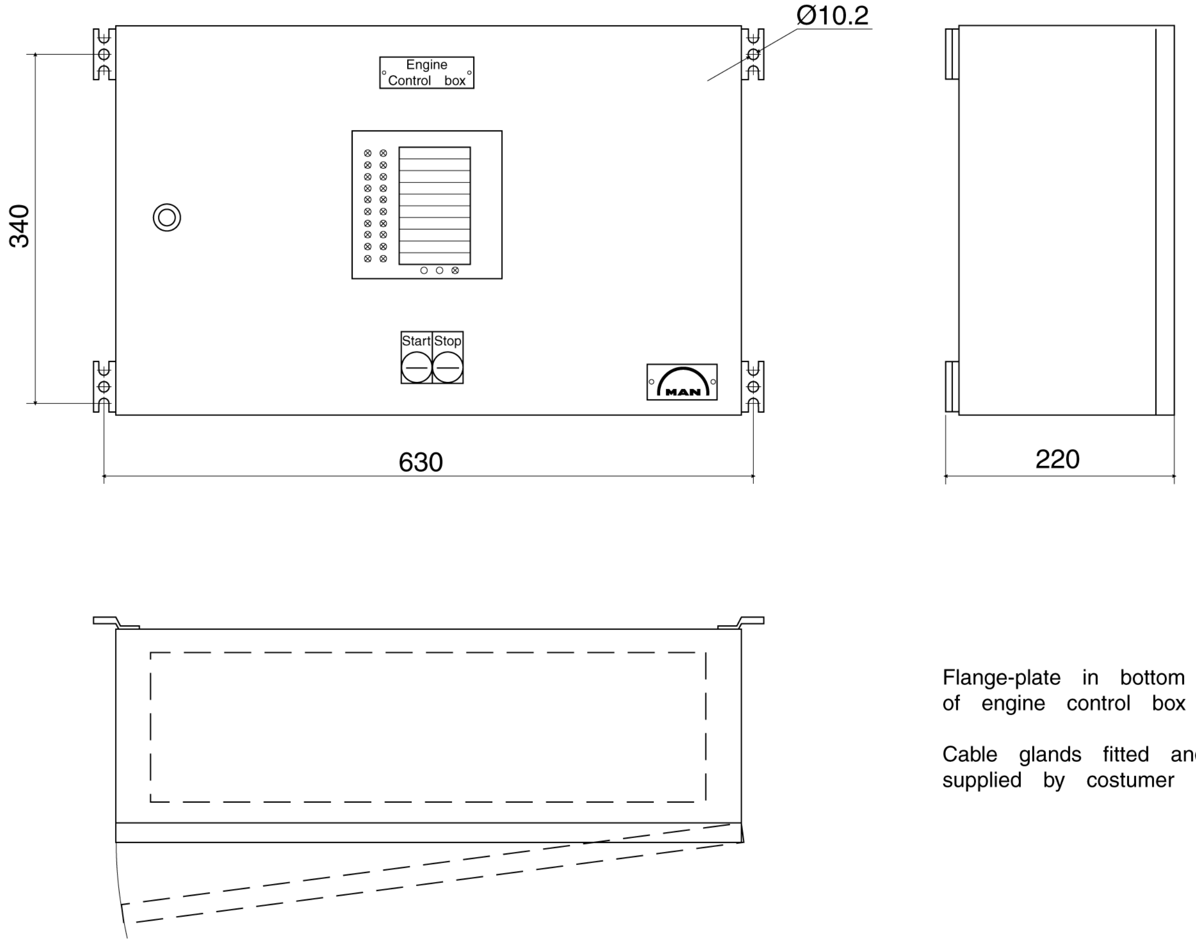
Engine control box cabinet

The engine control box cabinet can be installed in the engine room, near the engine, fig. 2 shows the dimensions of the cabinet. Enclosure: IP 55.

The engine control box can also be installed in the engine control room. It is possible to integrate the engine control box in the switch board.

The following is available as an option:

- One box for 3 engines
- Electronic overspeed
- Custom made solutions



Flange-plate in bottom of engine control box

Cable glands fitted and supplied by costumer

Figure 2: Engine control box.

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Engine control box no 2, safety- and alarm system

Alarm and safety system

The engine control box is watching all alarm and safety operating functions of the diesel engine.

In case of unintended conditions for the above functions, the engine control box will initiate:

- automatic stop of the engine (shutdown)

or

- a warning indication (alarm)

In order to avoid an unintended re-starting after release of a shutdown, there is a built-in reset function which has to be activated before the engine can be re-started. Remote reset is also possible.

Besides, there are built-in start/stop procedures for the engine.

On the front cover of the engine control box there are 3 indication panels. One for the safety system and two for the alarm system.

The engine control box will reflect the actual engine automation/instrumentation. The items below are general.

For the safety system there are indications for:

- Power on
- Engine run
- Lub. oil shutdown
- High temp. fresh water shutdown
- Overspeed shutdown
- Emergency shutdown
- Start failure
- Wire break
- Start interlock (blocking)
- Start interlock (local)
- Starting air

For the alarm system there are indications for:

- Lubricating oil inlet pressure
- Prelubricating oil pressure
- Fuel leakage
- Oil level base frame *
- Lub. oil filter
- Cooling water outlet temp.
- Lub. oil inlet temp.
- Cooling water press.
- Tacho failure
- Low supply voltage
- High supply voltage
- Alternator overheating

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- Lambda control failure
- Fuse failure
- Pre. lub pump failure
- Overspeed
- Spare x 4

Furthermore there are push buttons for:

- Start of engine
- Stop of engine
- Reset
- Lamp test
- Diesel oil (MDO) mode with indication *
- Heavy fuel oil (HFO) mode with indication *

* Options

Alarm blocking

The engine control box is provided with a relay for alarm blocking, so that alarm is avoided during starting and stopping of the engine.

Start/stop of the diesel engine

The diesel engine can be started and stopped by means of push buttons on the panel. Furthermore, it is possible to mount remote switches for these functions.

If the diesel engine does not start during a starting trial, a potential free switch will give the information that there is a starting failure.

When the diesel engine is running, three relay outputs are activated. One is used for start/stop of the prelubricating pump, one for the preheating start/stop, and one for the engine start/stop signal.

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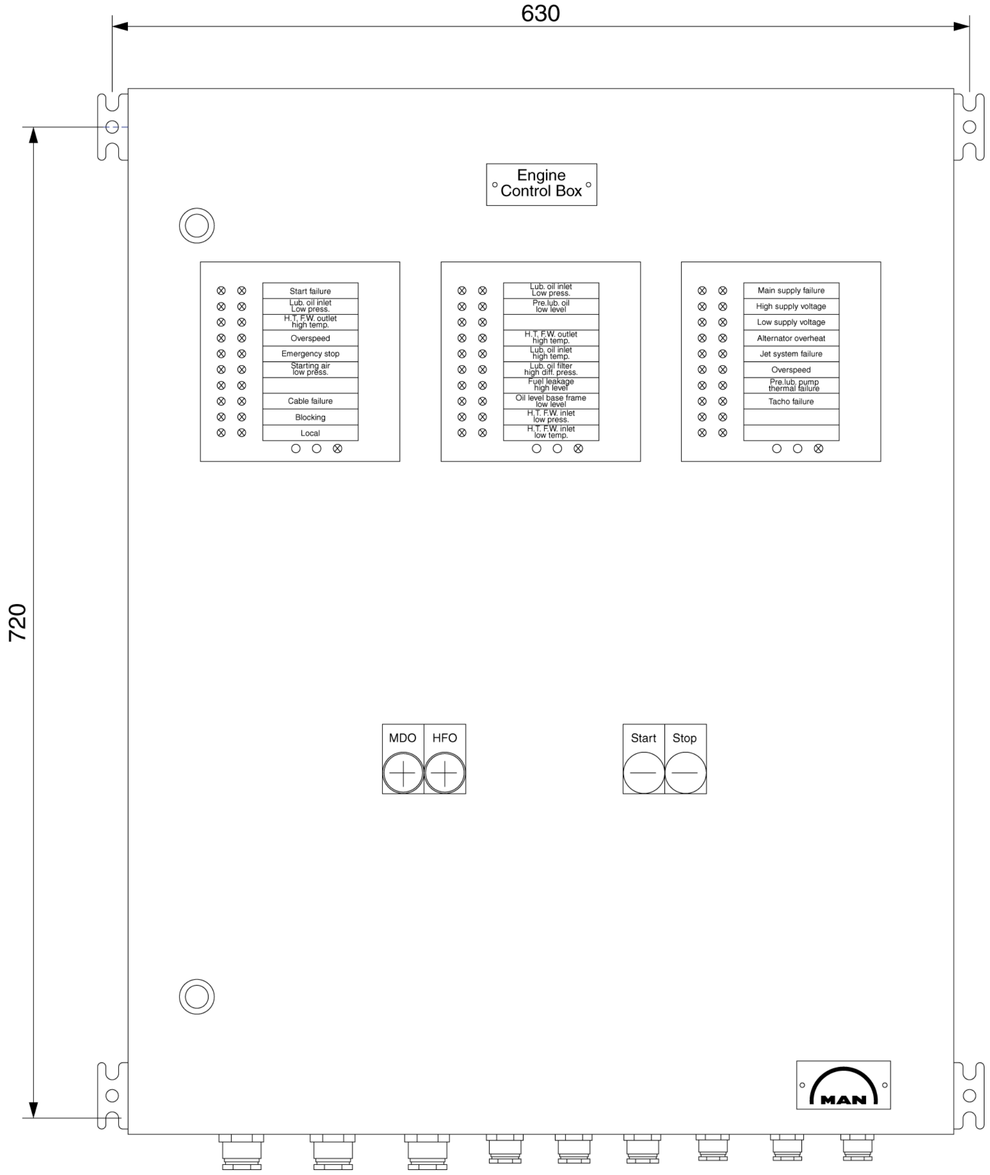

Figure 1: Engine control box.

Diesel oil / heavy fuel oil mode

The valve control for MDO or HFO running mode is incorporated in the engine control box. It is possible to change the valve position on the engine control panel or remote.

The push buttons for MDO and HFO are lighted push buttons to indicate the mode.

The valve control MDO/HFO is only used together with E 11 10 1.

Engine control box cabinet

The engine control box cabinet can be installed in the engine room, near the engine. *Fig 1* shows the dimensions of the cabinet.

Enclosure: IP 54.

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The engine control box can also be installed in the engine control room. It is possible to integrate the engine control box in the switchboard.

Combined box with prelubricating oil pump, preheater and el turning device

Description

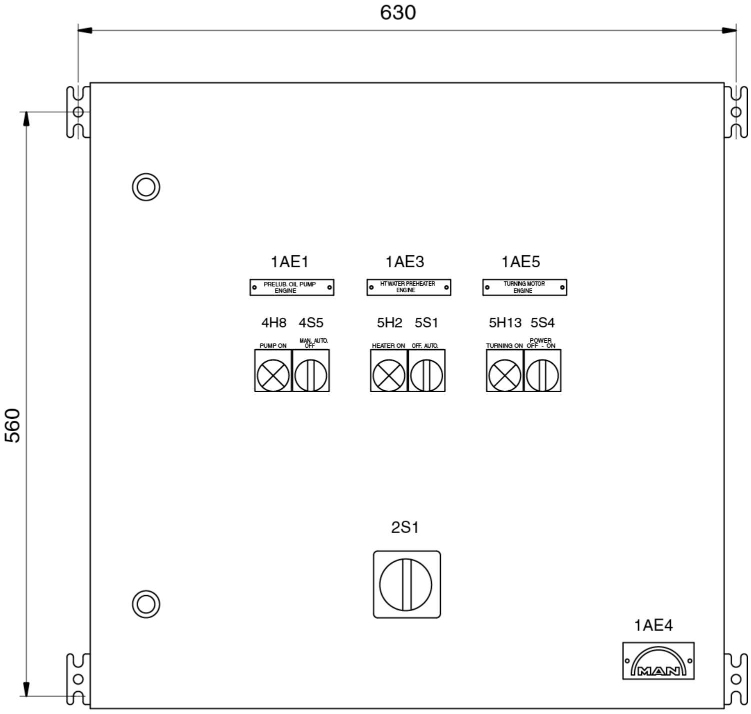

Figure 1: Dimensions

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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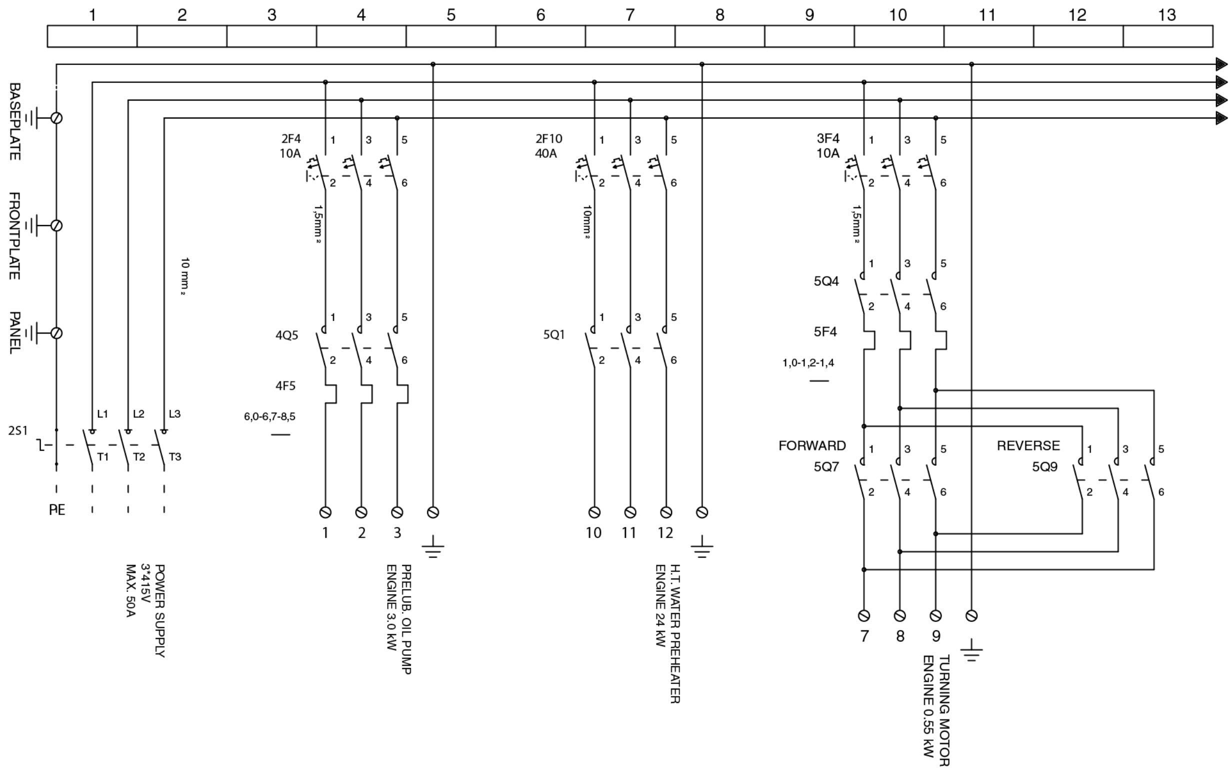

Figure 2: Wiring diagram

Prelubricating oil pump starting box

Description

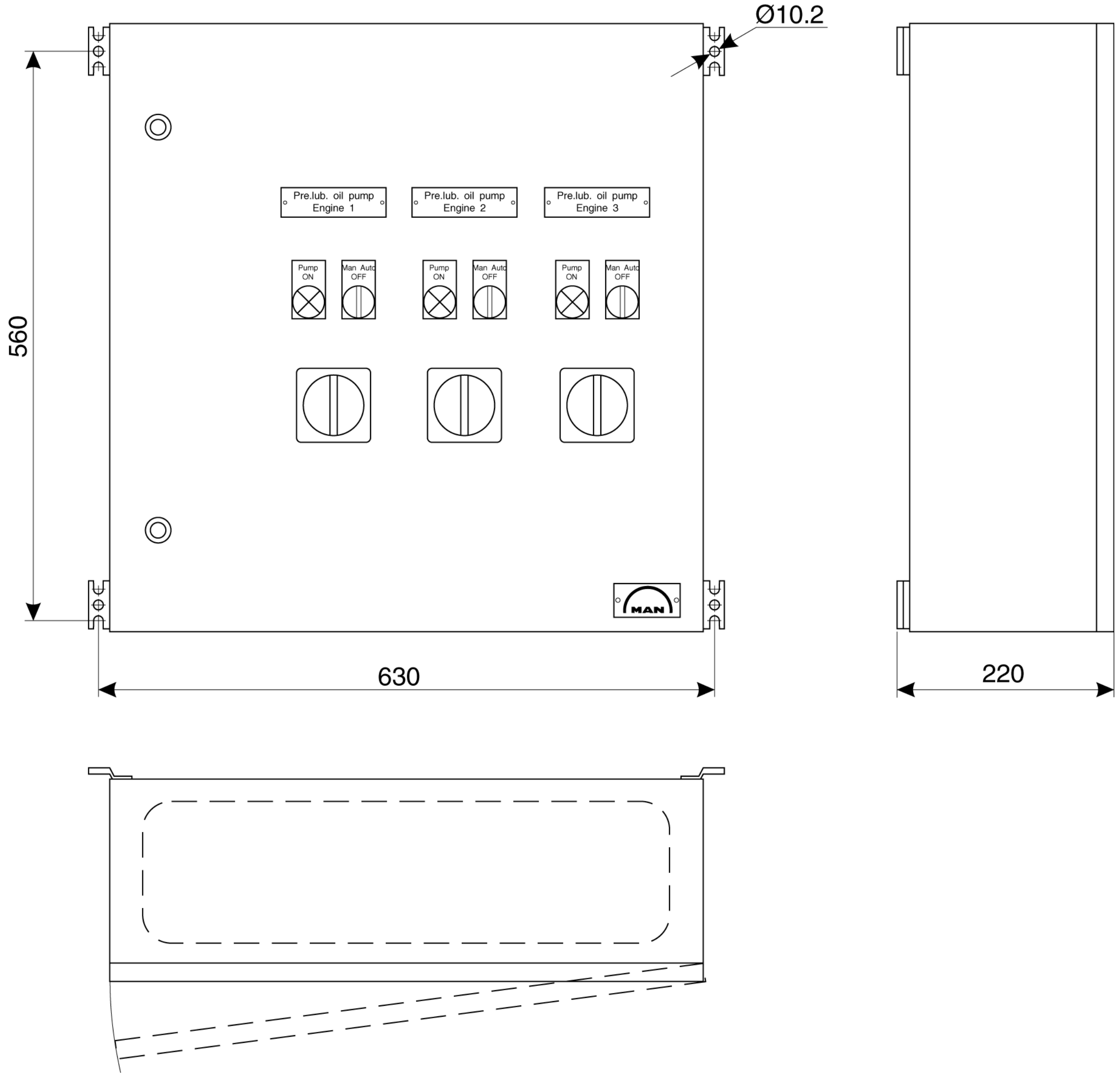

Figure 1: Dimensions.

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.*

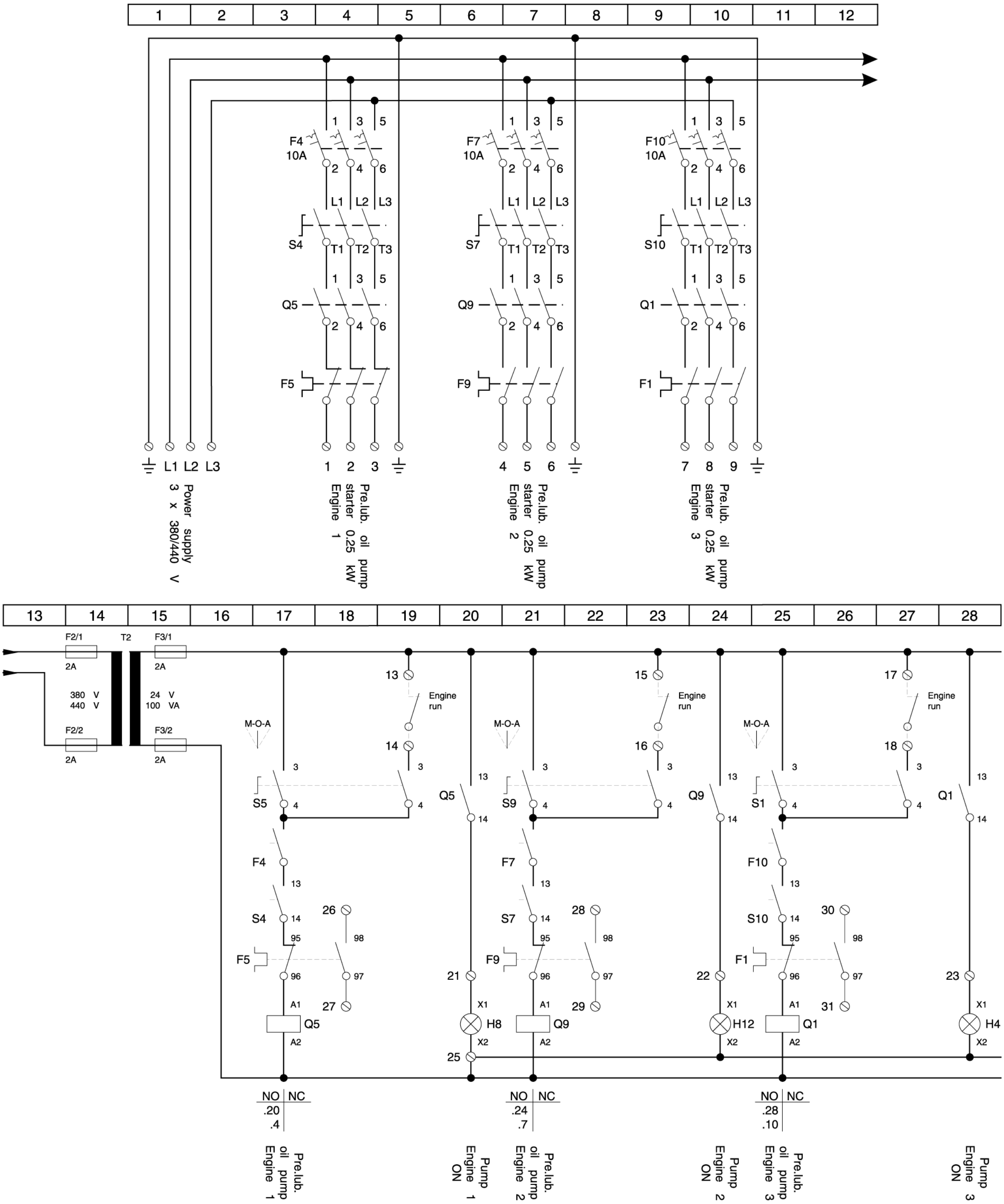

Figure 2: Wiring diagram.

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High temperature preheater control box

Description

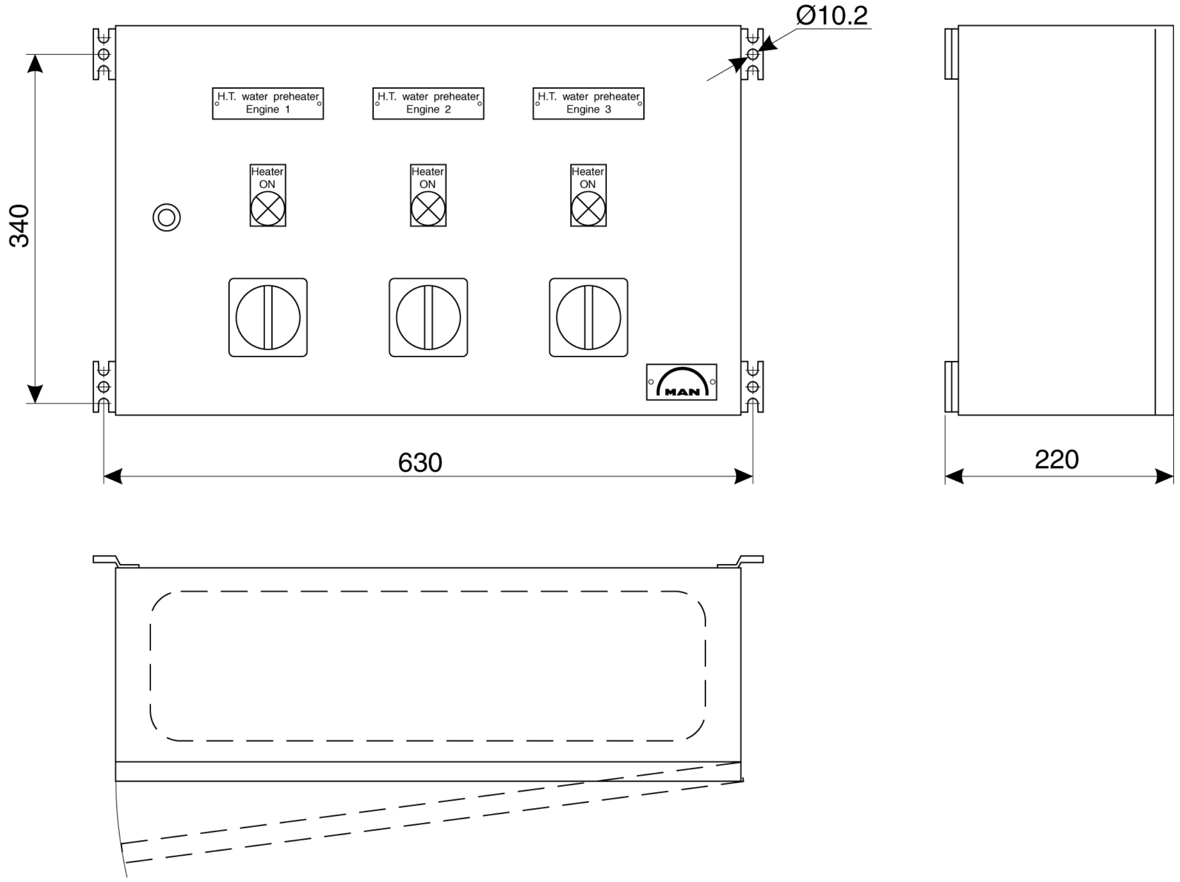

Figure 1: Dimensions of the control cabinet.

The preheater control box is for controlling the electric heater built onto the engine for preheating of the engines jacket cooling water during stand-still.

The control box consists of a cabinet with contactor and control system. On the front of the cabinet there is a lamp for "heater on" and a main switch for activating the system. Furthermore there is overload protection for the heater element.

The temperature is controlled by means of an on/off thermostat mounted in the common HT-outlet pipe. Furthermore the system secures that the heater is activated only when the engine is in stand-still.

Depending on the numbers of engines in the plant, the control box can be for one or several engines, however the dimensions of the cabinet will be the same. fig 1 illustrates a front for 3 engines.

The high temperature preheater control box can be combined with the prelubricating oil pump control box.

See also B 13 23 1 Preheating arrangement in high temperature system.

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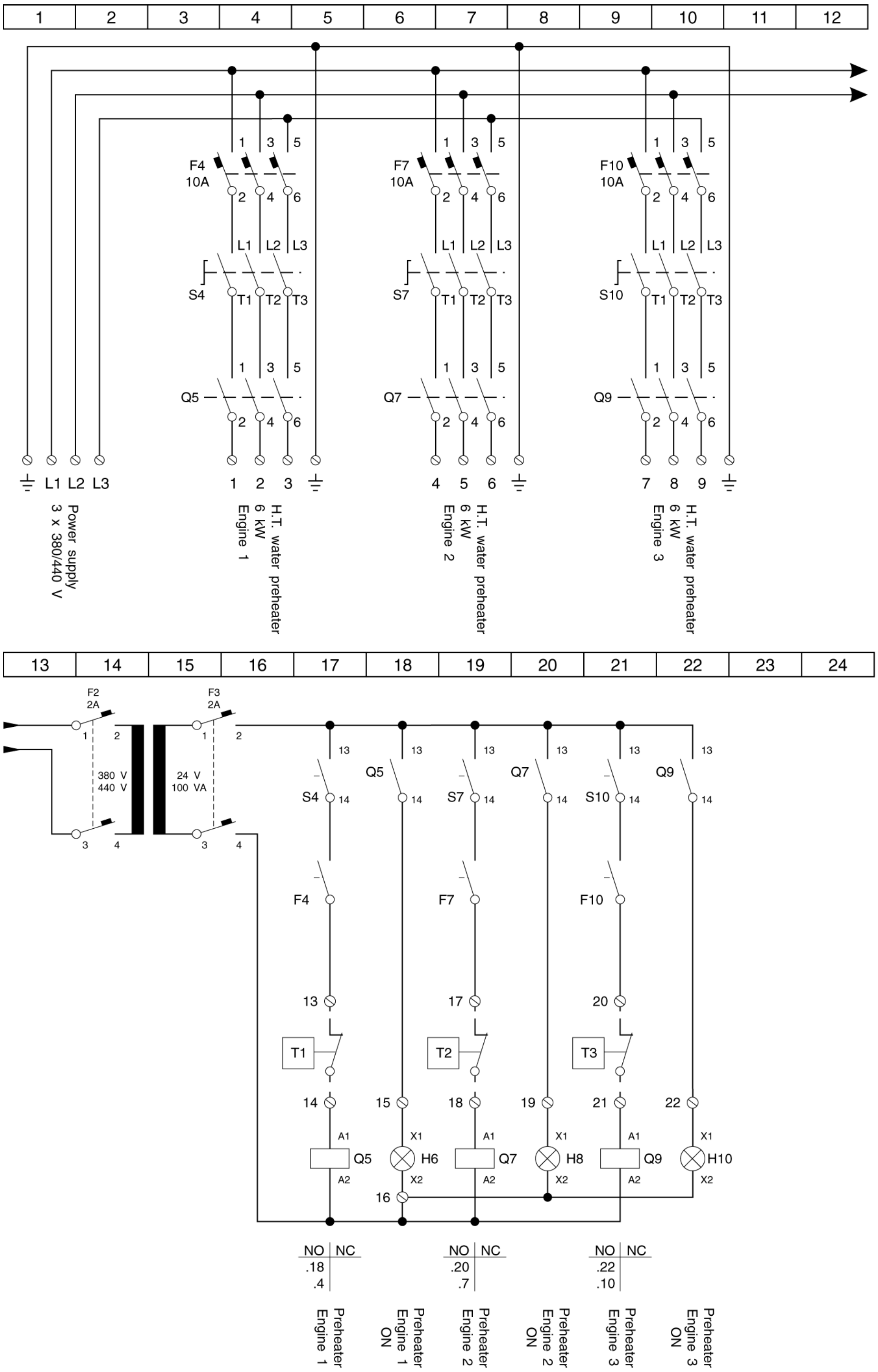

Figure 2: Wiring diagram.

2013-04-04 - en

13 B 20 Foundation

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Recommendations concerning steel foundations for resilient mounted GenSets

Foundation recommendations

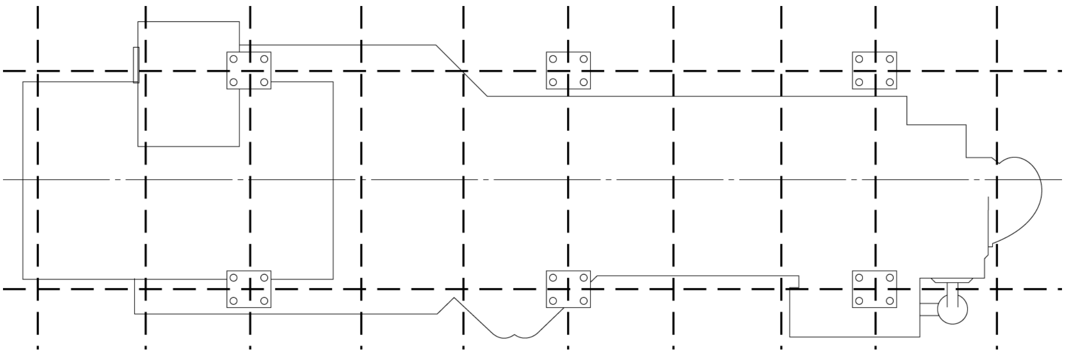

Figure 1: Resilient supports.

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:

- RD214-45 Shore A to 65 Shore A - stiffness 5.100 kN/m to11.620 kN/m (Preload 30 kN - 20 deg. C)

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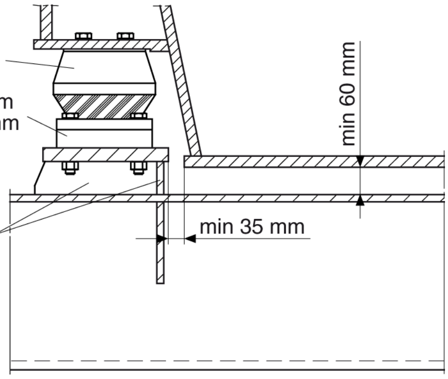

Figure 2: Transverse stiff deck structure.

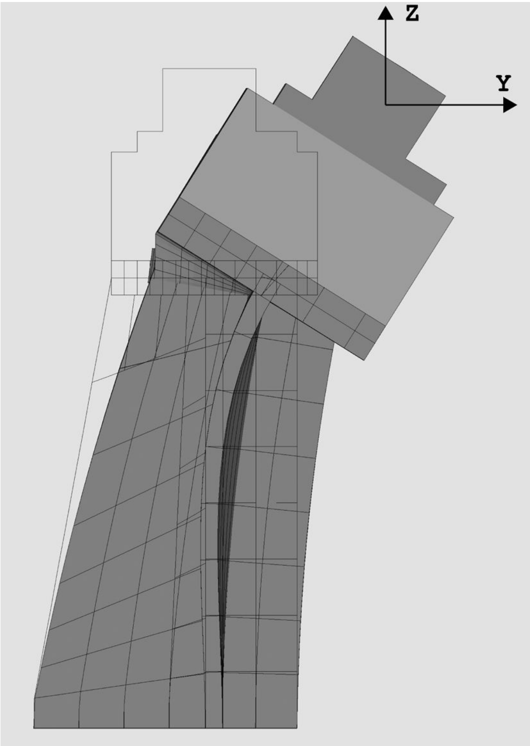

Figure 3: Stiffness for foundation

Resilient mounting of generating sets

Resilient mounting of generating sets

On resilient mounted generating sets, the diesel engine and the generator are placed on a common rigid base frame mounted on the ship's/erection hall's foundation by means of resilient supports, type Conical.

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 brackets on the base frame (see fig 1).

The setting from unloaded to loaded condition is normally between 5-11 mm for the conical mounting.

The exact setting can be found in the calculation of the conical mountings for the plant in question.

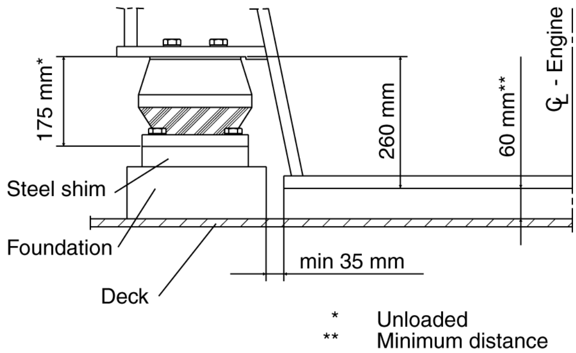

Figure 1: Resilient mounting of generating sets

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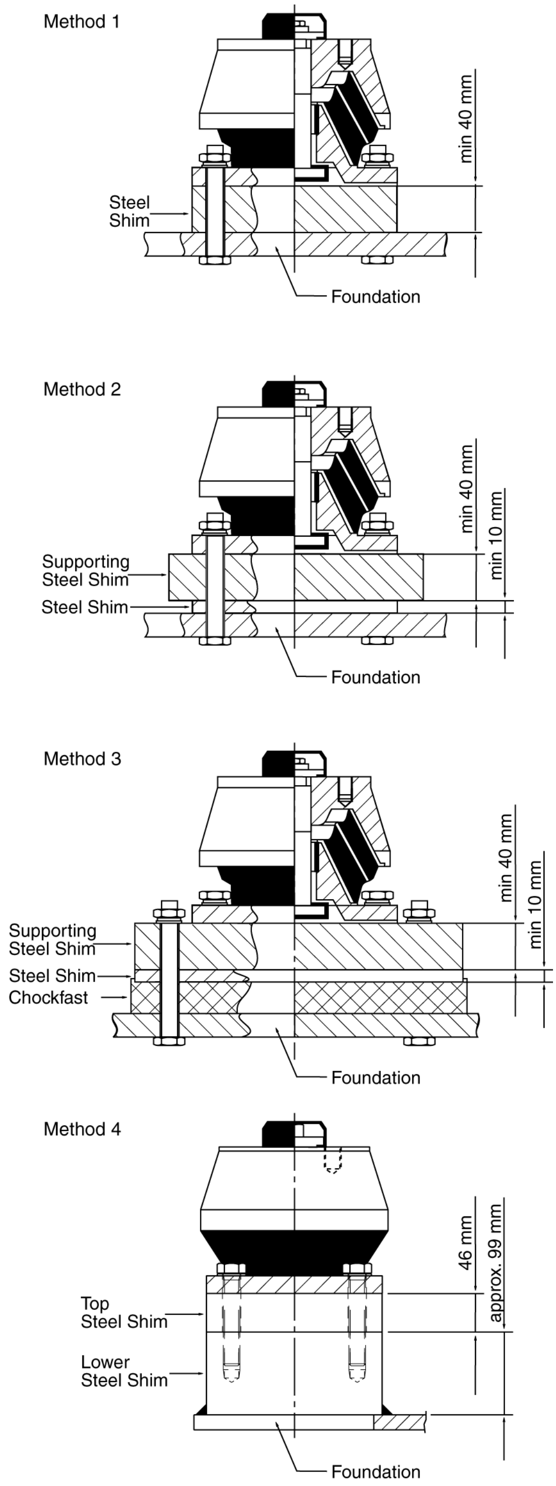

Figure 2: Support of conicals

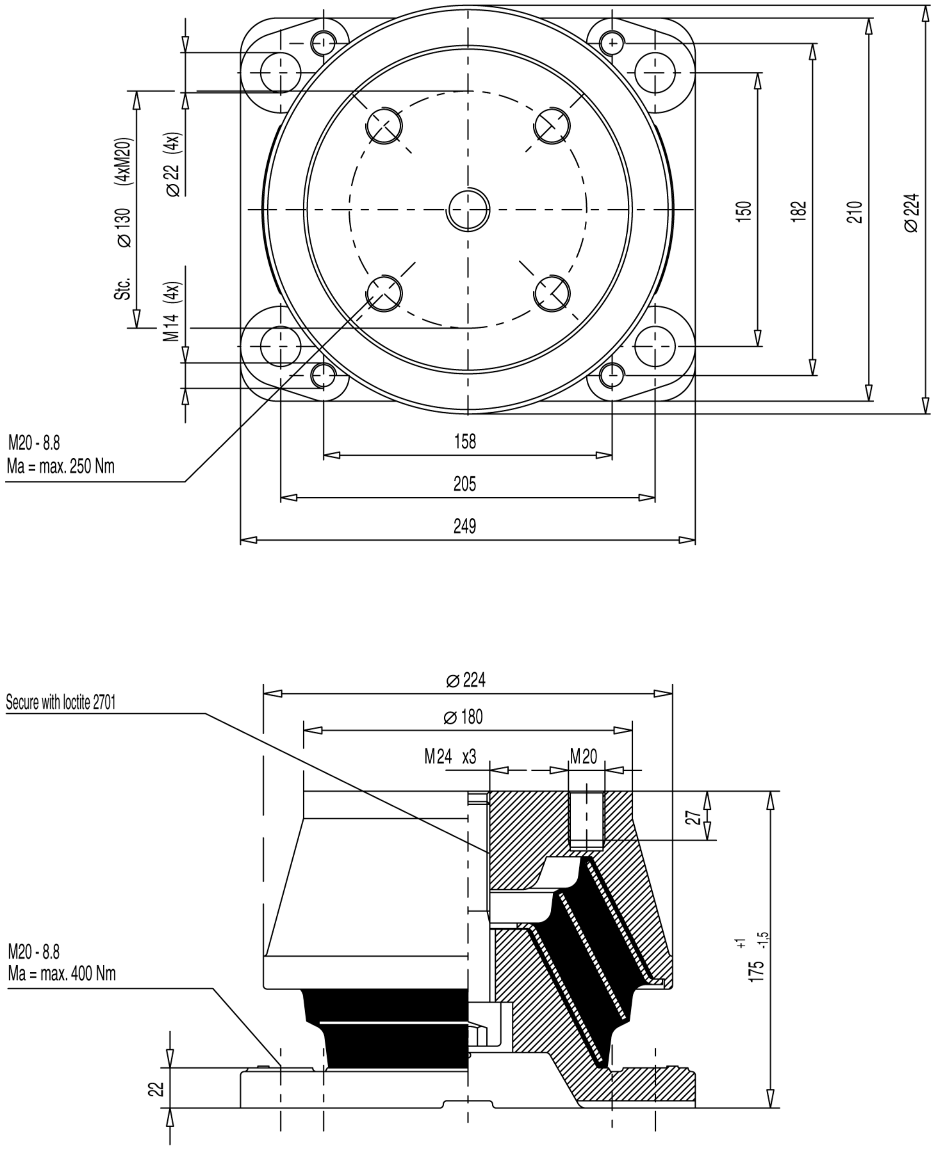

Figure 3: Conical mountings

The support of the individual conical mounting can be made in one of the following three ways:

1. The support between the bottom flange and the foundation of the conical mounting is made with a loose steel shim. This steel shim is adjusted to an exact measurement (min. 40 mm) for each conical mounting.
2. The support can also be made by means of two steel shims, at the top a loose shim of at least 40 mm and below a shim of approx. 10 mm which are adjusted for each conical mounting and then welded to the foundation.
3. The support can be made by means of chockfast. It is recommended to use two steel shims, the top shim should be loose and have a minimum thickness of 40 mm, the bottom shim should be cast in chockfast with a thickness of at least 10 mm.

Check the minimum permitted thickness of chockfast for the load surface of this application with chockfast supplier.

1. Finally, the support can be made by means of two steel shims, the top shim of 46 mm and below a shim of approx. 99 mm. the shims are then welded to the foundation. The top shims are then adjusted and tighten to the lower shim.

Irrespective of the method of support, it is recommended to use a loose steel shim to facilitate a possible future replacement of the conical mountings.

Check of Crankshaft Deflection

The resiliently mounted generating set is normally delivered from the factory with engine and alternator mounted on the common base frame.
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)									

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:

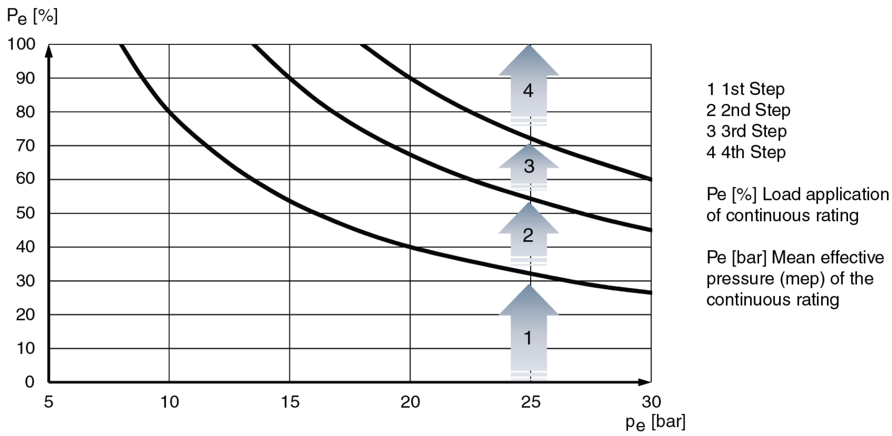

Fig. 1 Load application in steps as per IACS and ISO 8528-5.

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%.

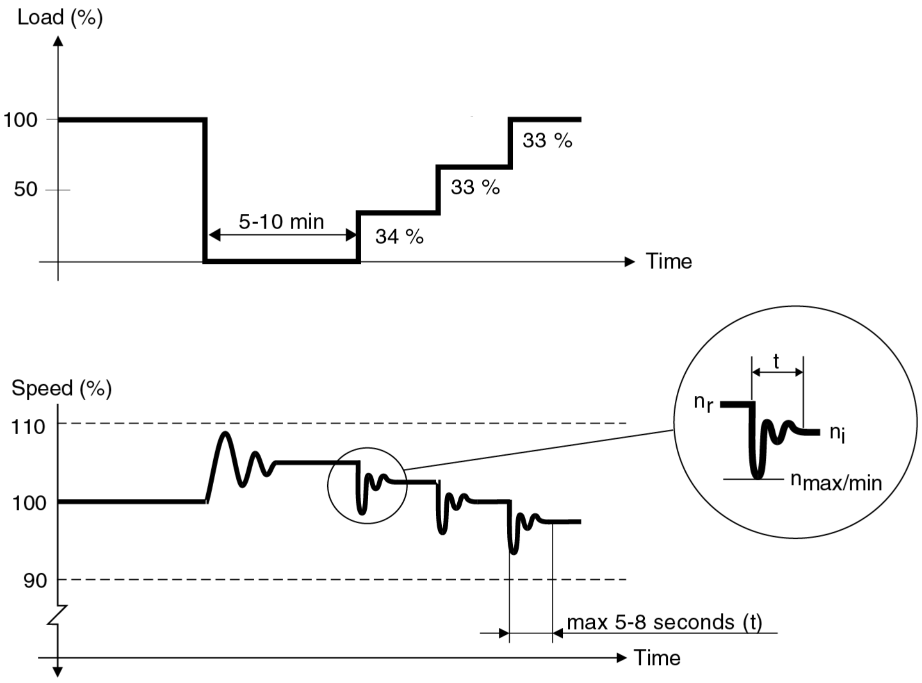

Fig. 4 Minimum requirements of the classification societies plus ISO rule.

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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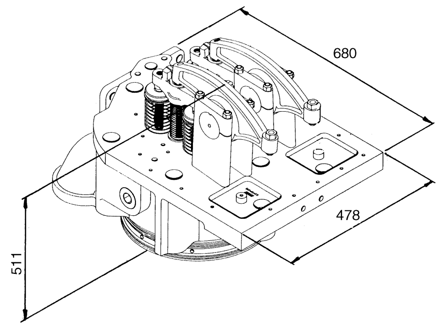
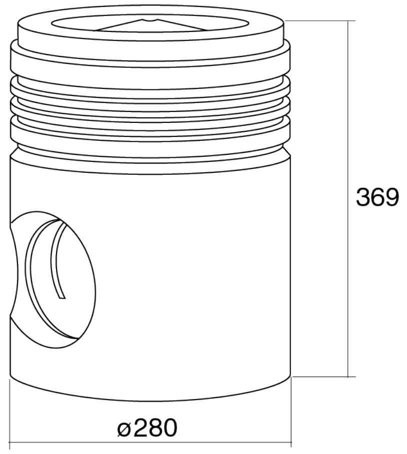
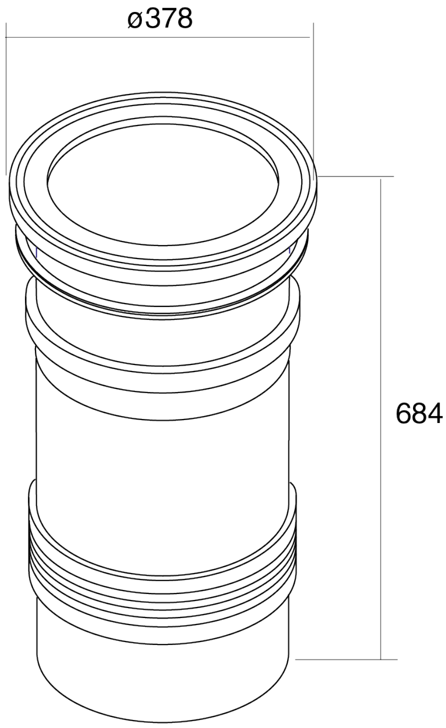
Weight and dimensions of principal parts



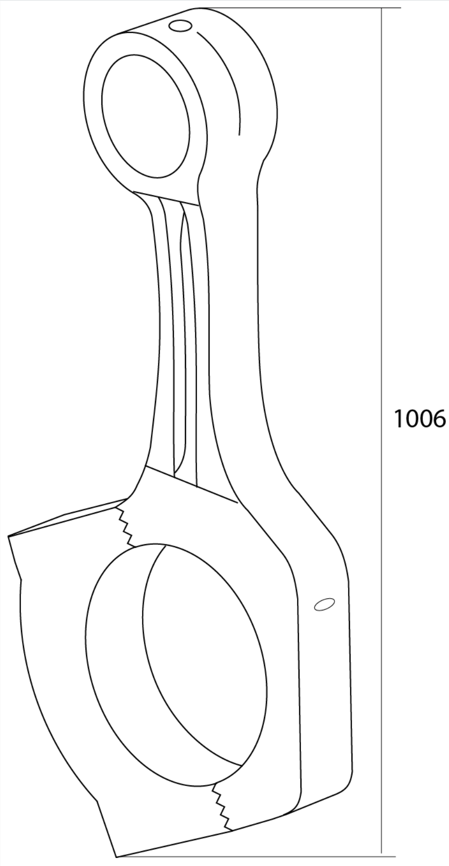
Cylinder head approx. 200 kg
Cylinder head incl. rocker arms approx. 255 kg



Piston approx. 40 kg



Cylinder liner approx. 119 kg



Connecting rod approx. 81 kg

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Standard spare parts

Extent according to the requirements of:	
For guidance	Demands
American Bureau of Shipping Bureau Veritas Lloyd's Register of Shipping Det Norske Veritas	Germanischer Lloyd Russian Maritime Register of Shipping Chinese Register Nippon Kaiji Kyokai Korean Register of Shipping Registro Italiano Navale

Description	Plates	Item	Qty.
Cylinder Head			
Valve spindle, inlet	60502	12	2
Valve spindle, exhaust	60502	12	4
Conical ring in 2/2	60502	08	6
Inner spring	60502	10	6
Outer spring	60502	11	6
Valve seat ring, inlet	60501	257	2
Valve seat ring, exhaust	60501	257	4
Safety valve	60508	13	1
Gasket, coaming	60510	11	1
Gasket, top cover	60510	08	1
O-ring, cylinder head	60501	269	2
Valve rotators	60502	09	4
Piston and Connecting Rod, Cylinder Liner			
Sealing ring	60610	08	1
Connecting rod bearing	60601	13	1
Connecting rod stud	60601	15	2
Connecting rod nut	60601	16	2
Bush for connecting rod	60601	05	1
Piston pin	60601	01-02	1
Retaining ring	60601	03	2
Piston ring	60601	09	1
Piston ring	60601	10	1
Piston ring	60601	11	1
Oil scraper ring	60601	12	1
O-ring, cylinder liner	60610	11	2
O-ring, inlet bend	60610	01	2
O-ring, inlet duct	60610	04	1
O-ring, cooling water connections	60610	07	12
Operating gear for valve and fuel injection pumps			
Sealing ring	60801	04	4
Engine Frame and Base Frame			
Main bearing shells	61101	13	1
Thrust washer	61101	20	2
Stud	61101	23	2
Nut	61101	24	2
O-ring	61106	13	2
Turbocharger System			
Gasket	61202	21	1
O-ring, cooling water connections	61202	34	1
O-ring, cooling water connections	61202	32	1

Description	Plates	Item	Qty.
Fuel Oil System and Injection Equipment			
Fuel injection valve	61402	02	*
Fuel oil injection pump	61401	02	1
Fuel oil high-pressure pipe	61404	01	1

* No of spare parts =C/2 (add up to equal number)
C = Number of cylinders for engine with max. cyl. no in plant.
ex. A plant consists of 2x5L28/32H and 2x7L28/32H.

Then the number of spare parts must be 7/2 = 3.5
~ add up to equal number = 4.

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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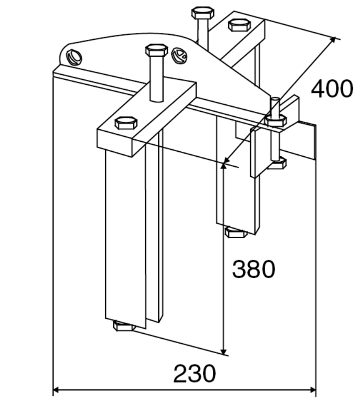
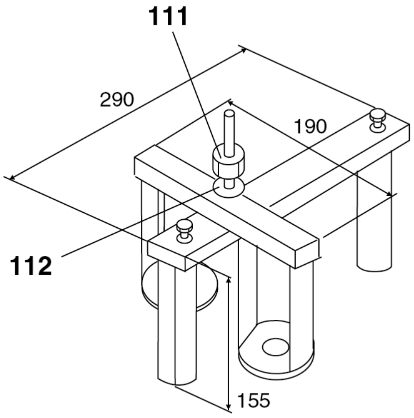
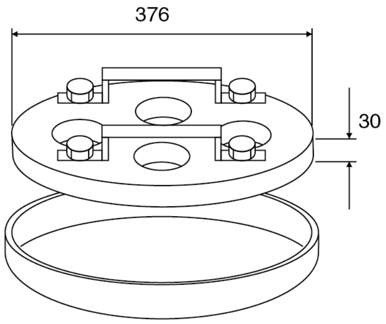
Standard tools for normal maintenance

Cylinder head

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Lifting tool for cylinder head			1	105
Mounting tool for valves Nut Thrust bearing			1	110 111 112
Grinding ring for cylinder head/ cylinder liner			1	115

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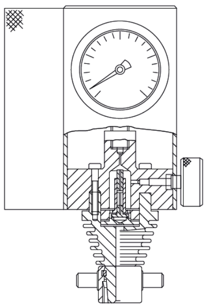
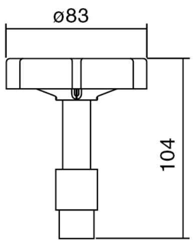
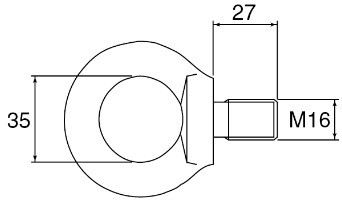
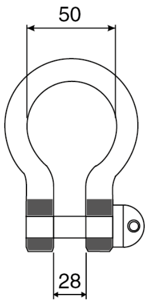
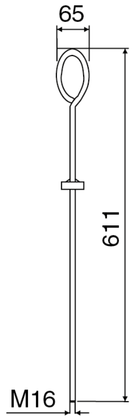
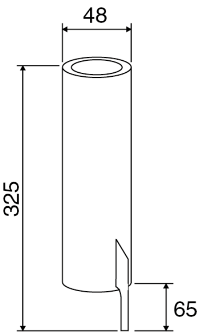
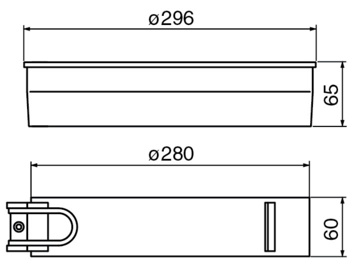
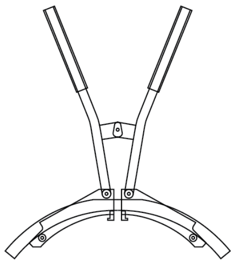
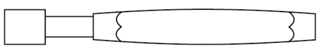
Name	Sketch	Supply per ship		Item no
		Working	Spare	
Max. pressure indicator			1	109
Handle for indicator valve			1	122

Piston, connecting rod and cylinder liner

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Eye screw for lifting of piston			1	125	
Shackle for lifting of piston			1	130	

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Eye screw for piston lift and check of connecting rod			1	135	
Back stop for cylinder liner (2 pcs)			1	140	
Guide for mounting of piston			1	145	
Piston ring opener			1	150	
Testing mandrel for piston ring 5.43 mm			1	155	
Testing mandrel for piston ring 6.43 mm			1	157	

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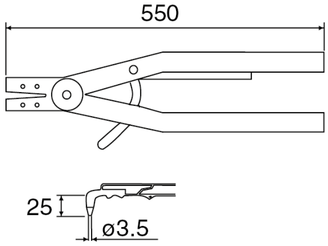
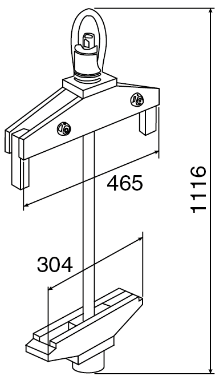
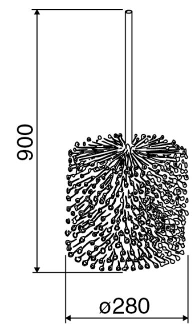
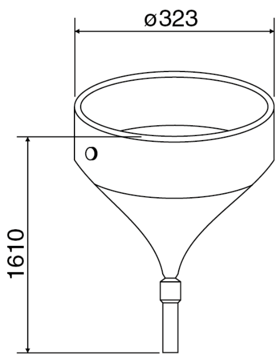
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Testing mandrel for scraper ring 8.43 mm			1	156	
Plier for piston pin lock ring			1	160	
Lifting tool for cylinder liner			1	165	
Honing tool			1	170	
Funnel for honing of cylin-der liner			1	175	

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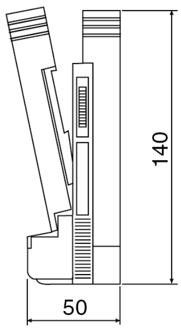
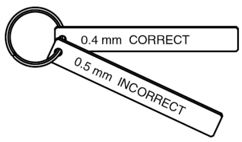
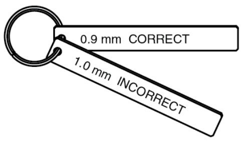
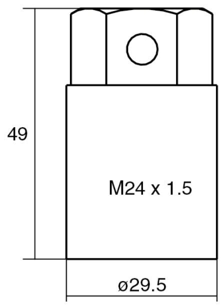
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Magnifier			1	180	

Operating gear for inlet and exhaust valves

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Feeler gauge for inlet valves 0.4-0.5 mm			1	185	
Feeler gauge for exhaust valves 0.9-1.0 mm			1	186	
Extractor for thrust piece on roller guide for fuel pump			1	190	

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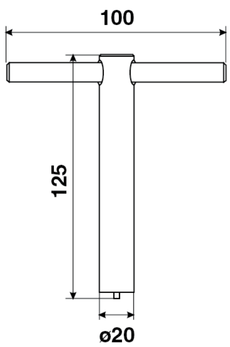
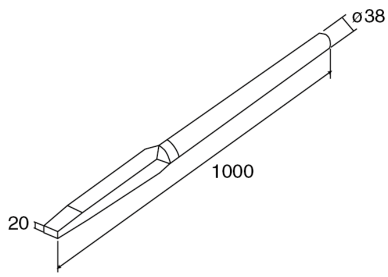
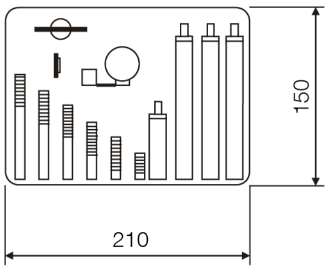
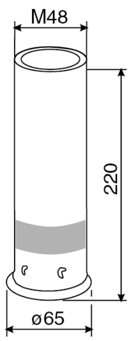
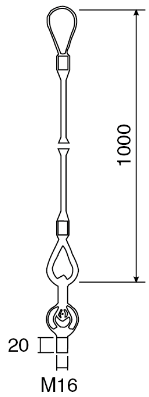
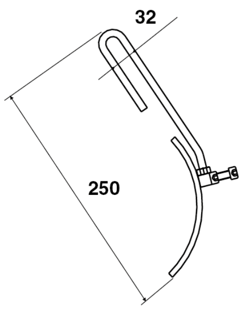
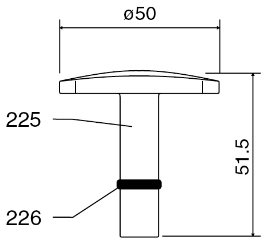
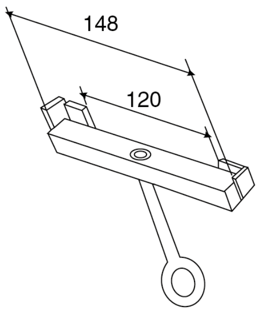
Control and safety systems - automatics and instruments

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Spanner for adjusting of over-speed stop			1	195

Crankshaft and main bearings

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Turning rod			1	200	
Crankshaft alignment gauge (autolog)			1	205	
Guide pipe for main bearing (2 pieces)			1	210	

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Lifting strap for main and guide bearing cap (2 pieces)			1	215	
Dismantling tool for guide bearing shells			1	220	
Tool for upper main bearing O-ring			1	225 226	
Guide tools for mounting of upper guide bearing shell			1	230	

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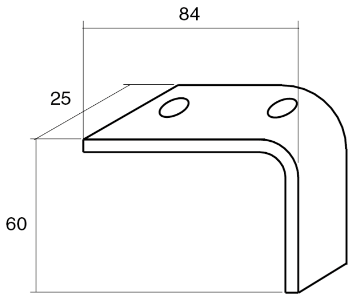
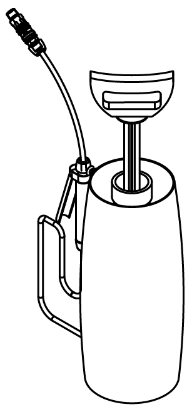
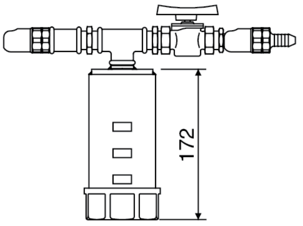
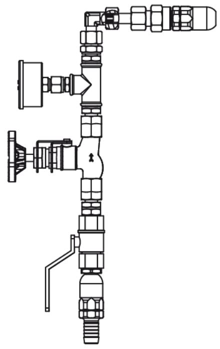
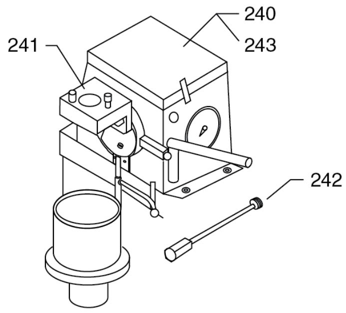
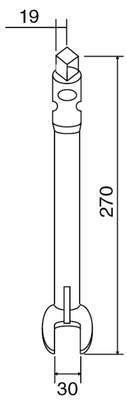
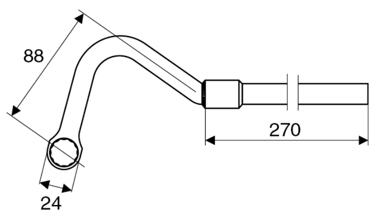
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Angle for mounting on crankweb without counter-weight			1	235	

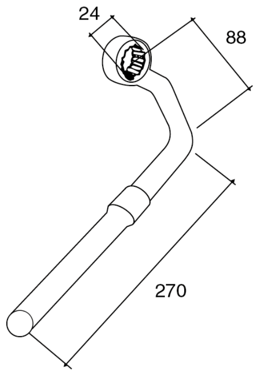
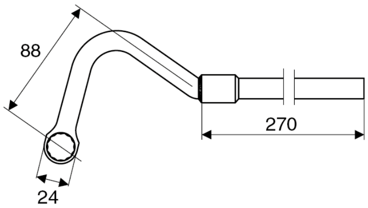
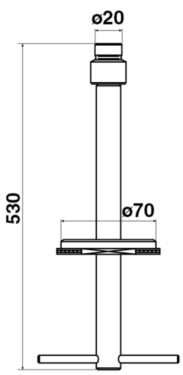
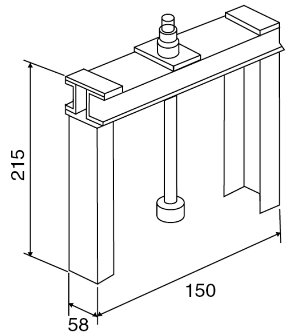
Turbocharger system

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Container complete for water washing of compressor side			1	355
Blowgun for dry cleaning of turbocharger			1	136

Name	Sketch	Supply per ship		Item no
		Working	Spare	
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, incl item 241, 242, 243 Clamping bracket for fuel injector Fuel pipe Pressure pump			1 1 1 1	240 241 242 243	
Spanner for high pressure pipe, 30 mm			1	250	
Spanner for fuel injection pump 24 mm (left side)			1	255	

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Spanner for fuel injection pump 24 mm (right side)			1	260	
Spanner for fuel injection pump 24 mm (right side)			1	265	
Grinding tool for seat for fuel valve			1	270	
Extractor for fuel injector valve			1	275	

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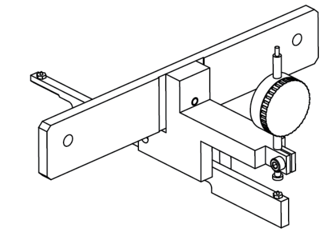
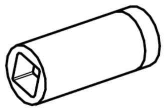
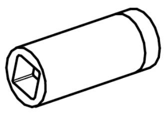
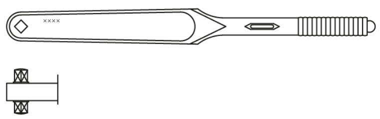
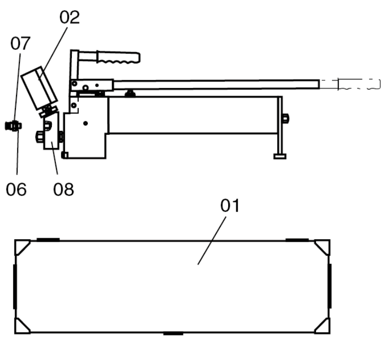
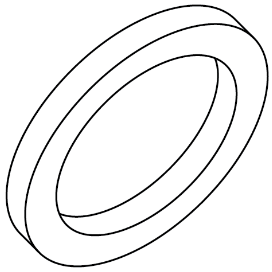
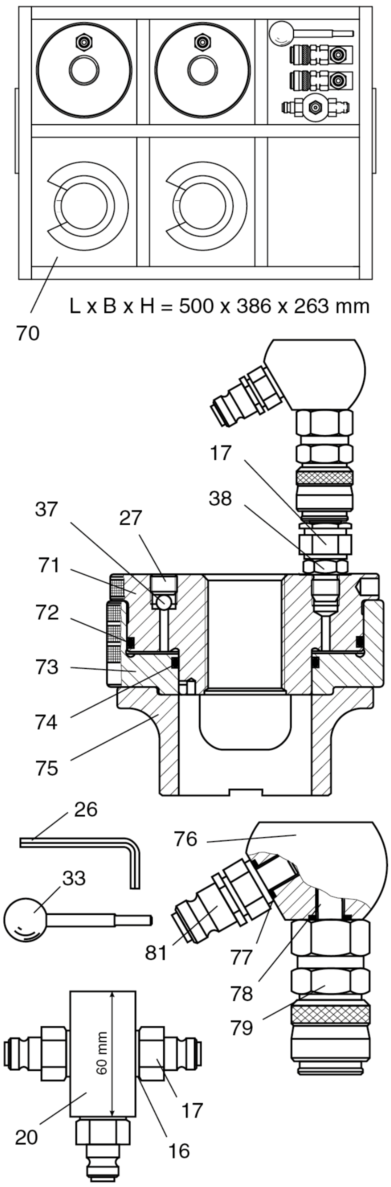
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Measuring device for plunger lift			1	280	
Long socket spanner 1/2" 24 mm			1	843	
Long socket spanner 1/2" 30 mm			1	867	
Torque spanner 1/2" 50-300 Nm			1	902	

Hydraulic tools

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Hydraulic tools complete consisting of the following boxes:				806	
Pressure pump, complete, with wooden box, incl item 02, 06, 07, 08	 L x B x H = 925 x 255 x 334 mm		1	01	
Manometer			1	02	
Gasket for item 07			1	06	
Quick coupling			1	07	
Distributor			1	08	

Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Spacer ring (only to be used if the vibration damper is to big for the hydraulic tools)			1	65	
Hydraulic tools for connecting rod complete, consists of the following items:			1	70	
Gasket			1	16	
Quick coupling			1	17	
Distributing piece for main bearing, incl item 16, 17			1	20	
Venting screw			1	27	
Tommy bar			1	33	
Ball			1	37	
Adapter			1	38	
Piston for hydraulic jack			1	71	
O-ring with back-up ring			1	72	
O-ring with back-up ring			1	74	
Cylinder for hydraulic jack			1	73	
Spacer piece			1	75	
Angle piece complete, incl item 77, 78, 79, 81			1	76	
O-ring			1	77	
Adapter			1	78	
Coupling socket			1	79	
Hydraulic jack as item nos 17, 27, 37, 38, 71, 72, 73, 74, 75			1	80	
Quick coupling			1	81	

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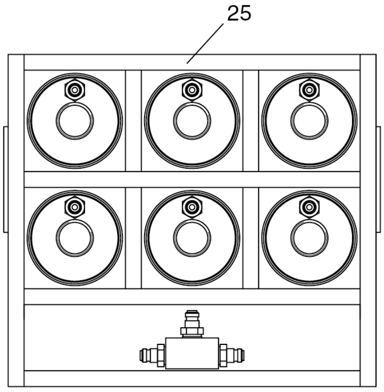
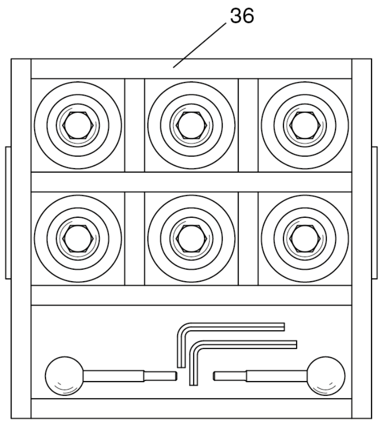
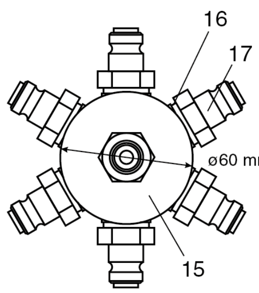
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Hydraulic tools for cylinder head complete, consisting of the following items:			1	25	
Venting screw			1	27	
Piston for hydraulic jack			1	28	
O-ring with back-up ring			1	29	
O-ring with back-up ring			1	30	
Cylinder for hydraulic jack			1	31	
Hydraulic jack as item nos 17, 27, 28, 29, 30, 31, 37, 38	L x B x H = 417 x 377 x 273 mm		1	35	
Ball			1	37	
Adapter			1	38	
Distributing piece for cylinder head complete, incl item 16, 17			1	15	
Gasket			1	16	
Quick coupling	L x B x H = 327 x 327 x 378 mm 		1	17	

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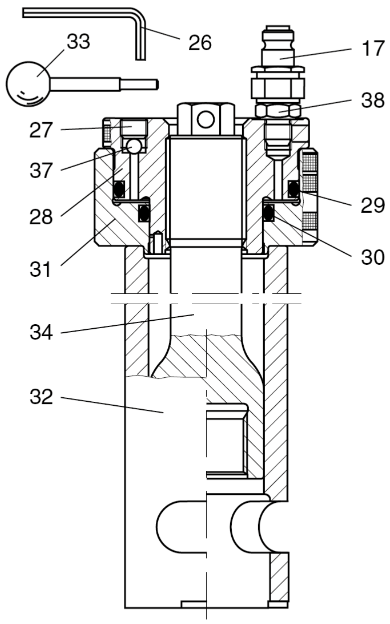
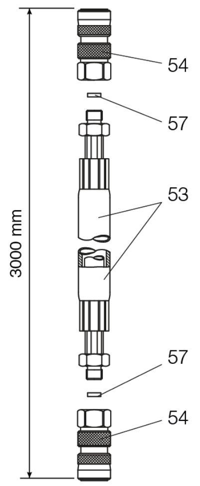
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Hydraulic tools for cylinder head with wooden box complete, consisting of the following items:	 		1	36	
Allen key, 7 mm			1	26	
Spacer piece			1	32	
Tommy bar			1	33	
Tension screw			1	34	
Hose as item 53, 54, 57 (1 piece)			1	51	
Hose			1	53	
Quick coupling with protecting cap			1	54	
Disc			1	57	

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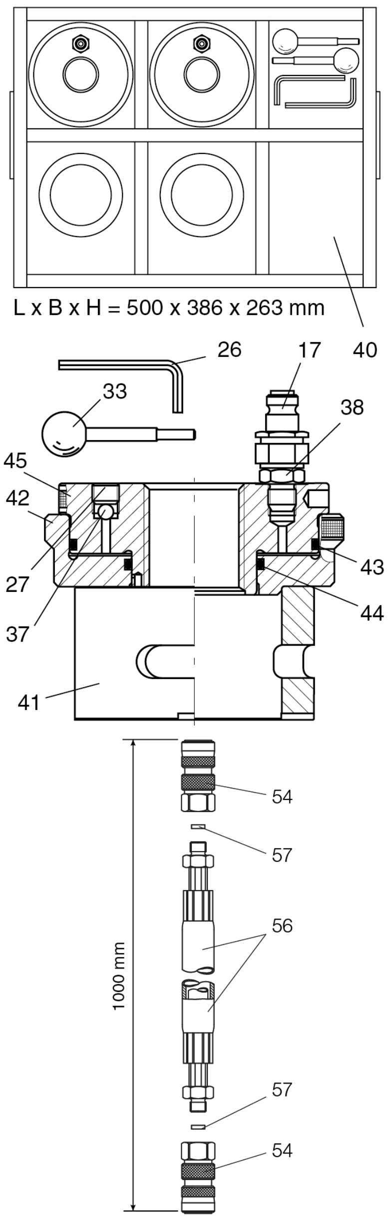
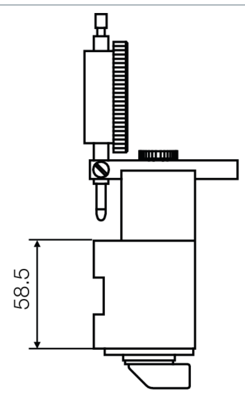
Name	Sketch	Supply per ship		Drawing	Remarks
		Working	Spare	Item no	
Hydraulic tools for main bearings with wooden box, complete consisting of the following items:			1	40	
Quick coupling			1	17	
Allen key, 7 mm			1	26	
Venting screw			1	27	
Tommy bar			1	33	
Ball			1	37	
Adapter			1	38	
Spacer piece			1	41	
Cylinder for hydraulic jack			1	42	
O-ring with back-up ring			1	43	
O-ring with back-up ring			1	44	
Piston for hydraulic jack			1	45	
Hydraulic jack as item 17, 27, 37, 37, 42, 43, 44, 45			1	46	
Hose as item 54, 56, 57 (3 pieces)			1	49	
Quick coupling with protecting cap			1	54	
Hose			1	56	
Disc			1	57	
Measuring device (not a part of Hydraulic tools complete, to be ordered separately)			2	533	

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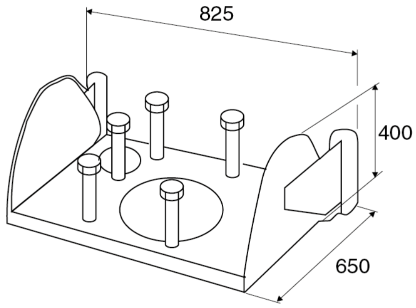
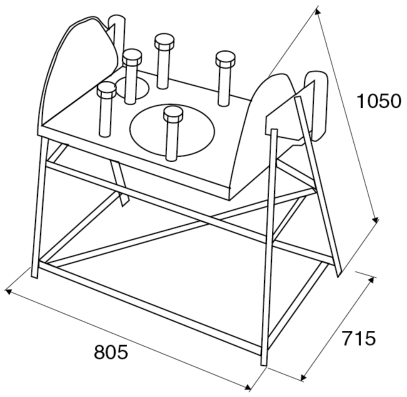
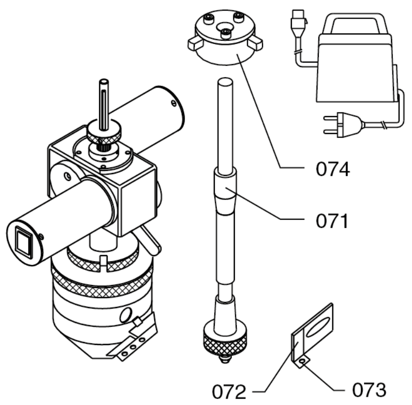
Additional tools

Cylinder head

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Grinding table for cylinder head with bracket for wall mounting, complete			1	025
Grinding table for cylinder head with frame for floor mounting, complete			1	030
Grinding machine for valve seat rings (H)	 Wooden box L x B x H = 450 x 380 x 190 mm		1	070
Mandrel			1	071
Cutting tool			1	072
Carbide cutting insert			1	073
Supporting spider			1	074

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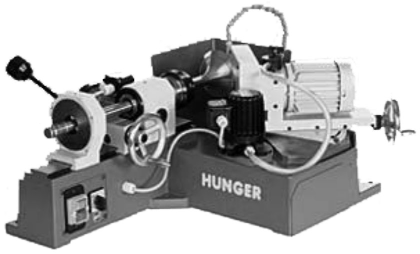
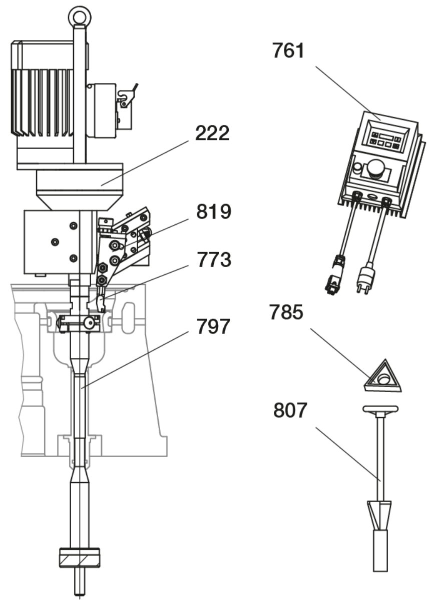
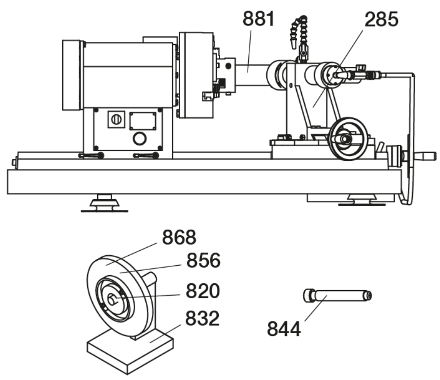
Name	Sketch	Supply per ship		Item no
		Working	Spare	
Grinding machine for valve spindle (H)			1	283
Grinding machine for valve seat rings (C) Frequence converter Tool holder Turning bit Pilot spindle incl. stabilizer Cleaning tool Tool holder bracket			1 1 1 1 1 1 1	222 761 773 785 797 807 819
Grinding machine for valve spindle, compl (C) Grinding wheel hub Balancing apparatus Grinding wheel dresser Grinding wheel, grain size 46 Grinding wheel, grain size 80 Stabilizer (valve stem ø10-18 mm)			1 1 1 1 1 1 1	285 820 832 844 856 868 881

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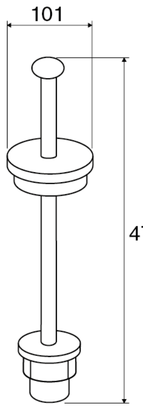
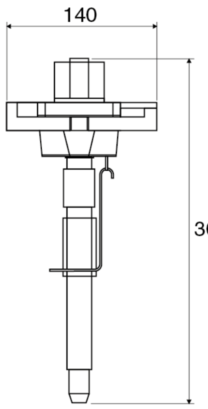
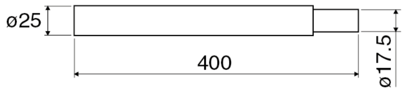
Name	Sketch	Supply per ship		Item no
		Working	Spare	
Mounting tool for valve seat ring, complete			1	045
Extractor for valve seat ring, complete			1	050
Mandrel for dismounting of valve guide			1	060
Reamer for valve guide			1	748

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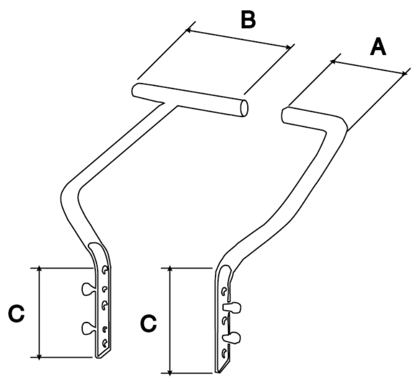
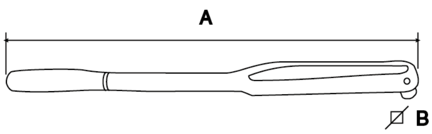
Piston, connecting rod and cylinder liner

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Pneumatic impact spanner			1	141
Micrometer screw for cylinder liner, measuring range 275-300 mm			1	160
Micrometer screw for connecting rod, measuring range 225-250 mm			1	161

Crankshaft and main bearings

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Lifting handle for main bearing cap			1	230
Torque spanner 3/4" (Vibration damper) 700-1500 Nm			1	245

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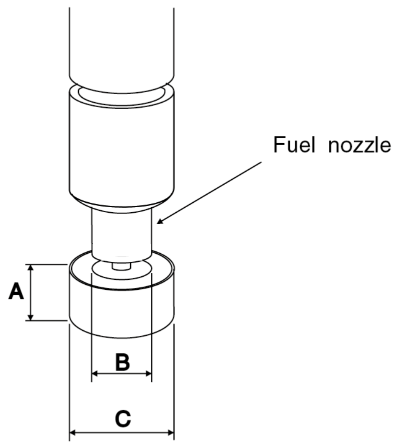
Turbocharger system

Name	Sketch	Supply per ship Working	Spare	Item no
Differential pressure tools, complete			1	915

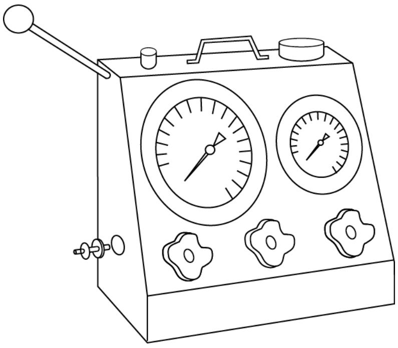
Compressed air system

Name	Sketch	Supply per ship Working	Spare	Item no
Set of tools, TDI air starter T50			1	928
Set of tools, TDI air starter T100			1	929

Fuel oil system

Name	Sketch	Working	Supply per ship Spare	Item no
Grinding tool for fuel injection valve			1	330

Hydraulic tools

Name	Sketch	Supply per ship		Item no
		Working	Spare	
Air driven high pressure pump for hydraulic tools			1	460
Remote controlled unit for hydraulic bolt tensioning			1	939

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Hand tools

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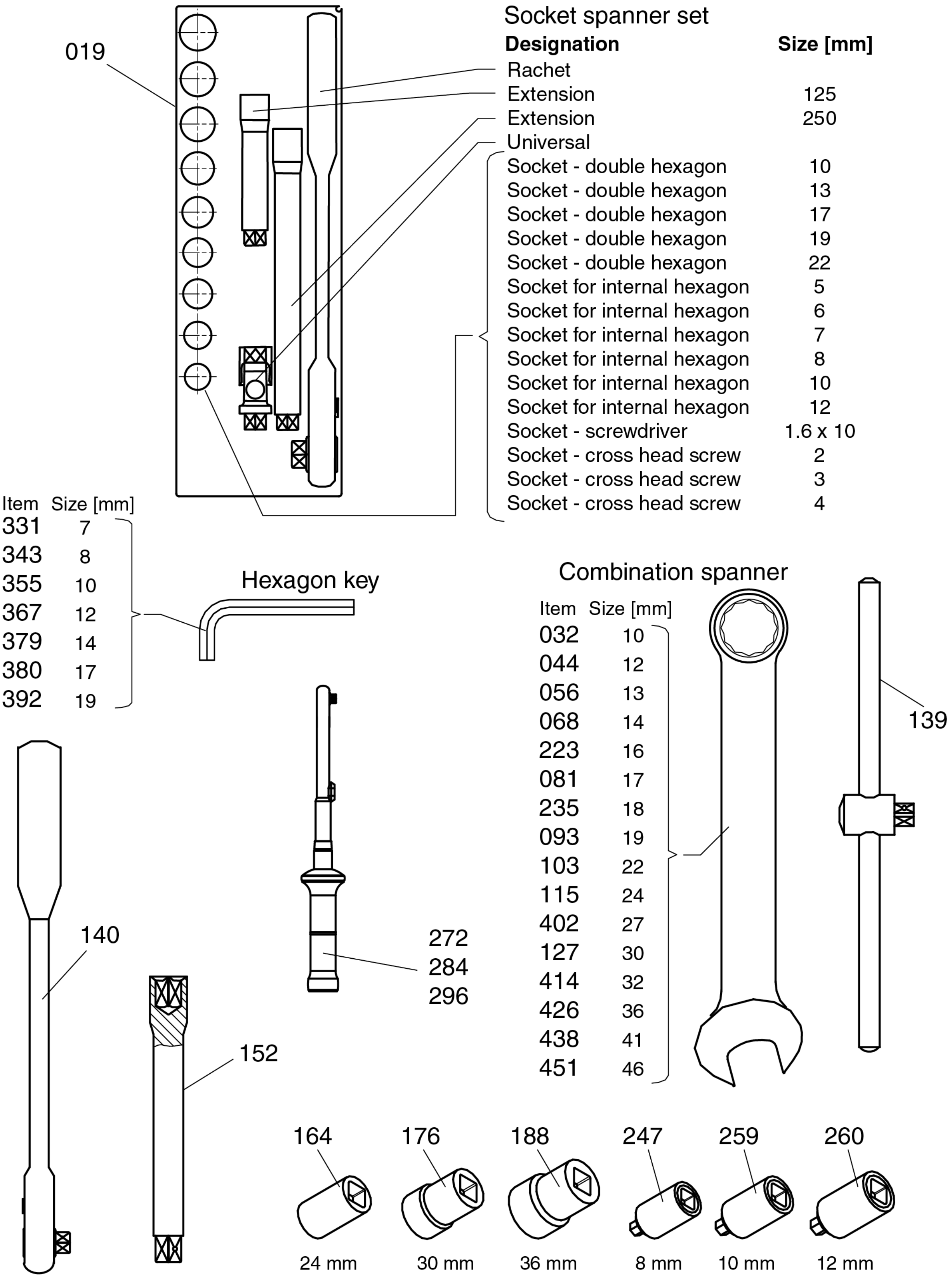
Hand tools

Plate



Socket spanner set

Designation	Size [mm]
Rachet	
Extension	125
Extension	250
Universal	
Socket - double hexagon	10
Socket - double hexagon	13
Socket - double hexagon	17
Socket - double hexagon	19
Socket - double hexagon	22
Socket for internal hexagon	5
Socket for internal hexagon	6
Socket for internal hexagon	7
Socket for internal hexagon	8
Socket for internal hexagon	10
Socket for internal hexagon	12
Socket - screwdriver	1.6 x 10
Socket - cross head screw	2
Socket - cross head screw	3
Socket - cross head screw	4

Hexagon key

Item	Size [mm]
331	7
343	8
355	10
367	12
379	14
380	17
392	19

Combination spanner

Item	Size [mm]
032	10
044	12
056	13
068	14
223	16
081	17
235	18
093	19
103	22
115	24
402	27
127	30
414	32
426	36
438	41
451	46

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Pos. No.	Qty	Item Designation
019	1/E	Set of tools
032	1/E	Combination spanner, 10 mm
044	1/E	Combination spanner, 12 mm
056	1/E	Combination spanner, 13 mm
068	1/E	Combination spanner, 14 mm
081	1/E	Combination spanner, 17 mm
093	1/E	Combination spanner, 19 mm
103	1/E	Combination spanner, 22 mm
115	1/E	Combination spanner, 24 mm
127	1/E	Combination spanner, 30 mm
139	1/E	Tee handle 1/2" square drive
140	1/E	Ratchet, 20 mm
152	1/E	Extension bar
164	1/E	Socket spanner, square drive, size 24
176	1/E	Socket spanner, square drive, size 30
188	1/E	Socket spanner, square drive, size 36
223	1/E	Combination spanner, 16 mm
235	1/E	Combination spanner, 18 mm
247	1/E	Bit, hexagon socket screw, square drive, size 8
259	1/E	Bit, hexagon socket screw, square drive, size 10
260	1/E	Bit, hexagon socket screw, square drive, size 12
272	1/E	Torque spanner, 20-120 nm - 1/2"
284	1/E	Torque spanner, 40-200 nm - 1/2"
296	1/E	Torque spanner, 60-320 nm - 1/2"
331	1/E	Hexagon key 7 mm
343	1/E	Hexagon key 8 mm
355	1/E	Hexagon key 10 mm
367	1/E	Hexagon key 12 mm
379	1/E	Hexagon key 14 mm
380	1/E	Hexagon key 17 mm
392	1/E	Hexagon key 19 mm
402	1/E	Combination spanner, 27 mm
414	1/E	Combination spanner, 32 mm
426	1/E	Combination spanner, 36 mm
438	1/E	Combination spanner, 41 mm
451	1/E	Combination spanner, 46 mm

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Information from the alternator supplier

Installation aspects

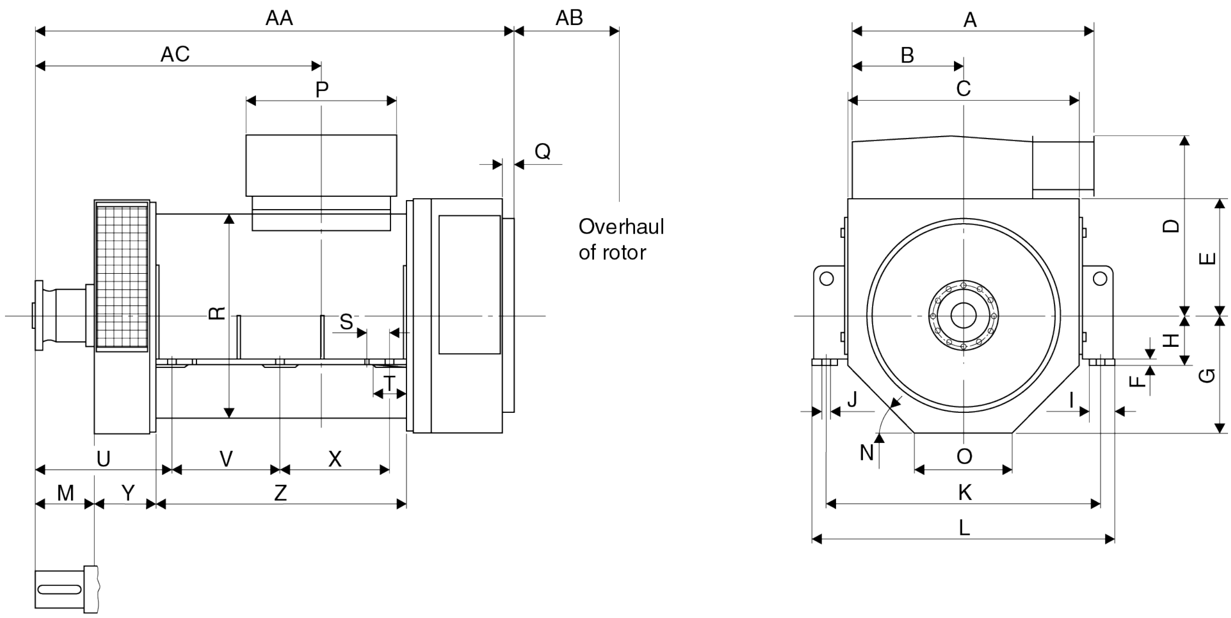

Figure 1: Outline drawing of alternator

Dimensions

Engine Type	H	I	øJ	K	L	M (min)
5-6L28/32H	295	160	39	1450	1600	280
7-8L28/32H	295	200	39	1600	1800	280
9L28/32H	295	200	39	1600	1800	280

For mounting of diesel engine and alternator on a common base frame, the alternator supplier should fullfill the dimensions given in fig. 1. Further, inspection shutters, components and other parts to be operated/maintained should not be placed below the level of the alternator feet on front edge of, and in the longitudinal direction of the alternator in the area covered by the base frame.

Regarding air cooled alternators, the ventilating outlet should be placed above the level of the alternator feet.

For water cooled alternators the flanges for cooling water should be placed on the left side of the alternator seen from the shaft end. The flanges should be with counter flanges.

Project Information

Drawings included in the alternator Project Information must have a max. size of A3.

3 sets of Project Information should be forwarded to MAN Energy Solutions, according to the delivery times stated in "Extent of Delivery".

Project Information should as a minimum contain the following documentation:

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1. General description of alternator.

2. "outline" drawing

Following information is required in order to be able to work out drawings for base frame and general arrangement of GenSet.

Side view and view of driving end with all main dimensions, i.e. length, width, height, foot position, foot width, shaft height, etc. as well as all the dimensions of the alternator's coupling flange, alt. groove shaft pin.

As minimum all the dimensions in fig. 1 should be stated.

Further the "outline" drawing is to include alternator type, total weight with placement of center of gravity in 2 directions (horizontal and vertical), direction of revolution, terminal box position, lifting eyes venthole position for air cooled alternators and min. overhaul space for rotor, cooler, filter, etc.

a. For water cooled alternators following information is required:

- position of connections
- dimension of connections
- dimensions of flange connections
- cooling water capacity
- cooling water temperature
- heat dissipation
- cooling water pressure loss across heat exchanger
- Amount of water in alt. cooling system

b. For alternators with extern lubricating of bearing(s) following information is required:

- position of connections
- dimensions of connections
- dimensions of flange connections
- required lub. oil flow
- required lub. oil pressure
- pressure regulator (if required/delivered)
- oil sight glas (if required/delivered)

c. For air cooled alternators following information is required:

- Max. permissible ambient inlet air temp.

3. Rotor shaft drawing

Following information is required in order to be able to work out torsional vibration calculations for the complete GenSet.

The rotor shaft drawing must show all the dimensions of the rotor shaft's lengths and diameters as well as information about rotor parts with regard to mass inertia moment - GD^2 or J (kgm^2) and weight (kg).

The following components, which are part of the complete rotor, must be mentioned:

- Shaft

- Pole wheel

- Exciter
- Ventilator

The shaft dimensions for alternator should be according to figure 2, 3 or 4.

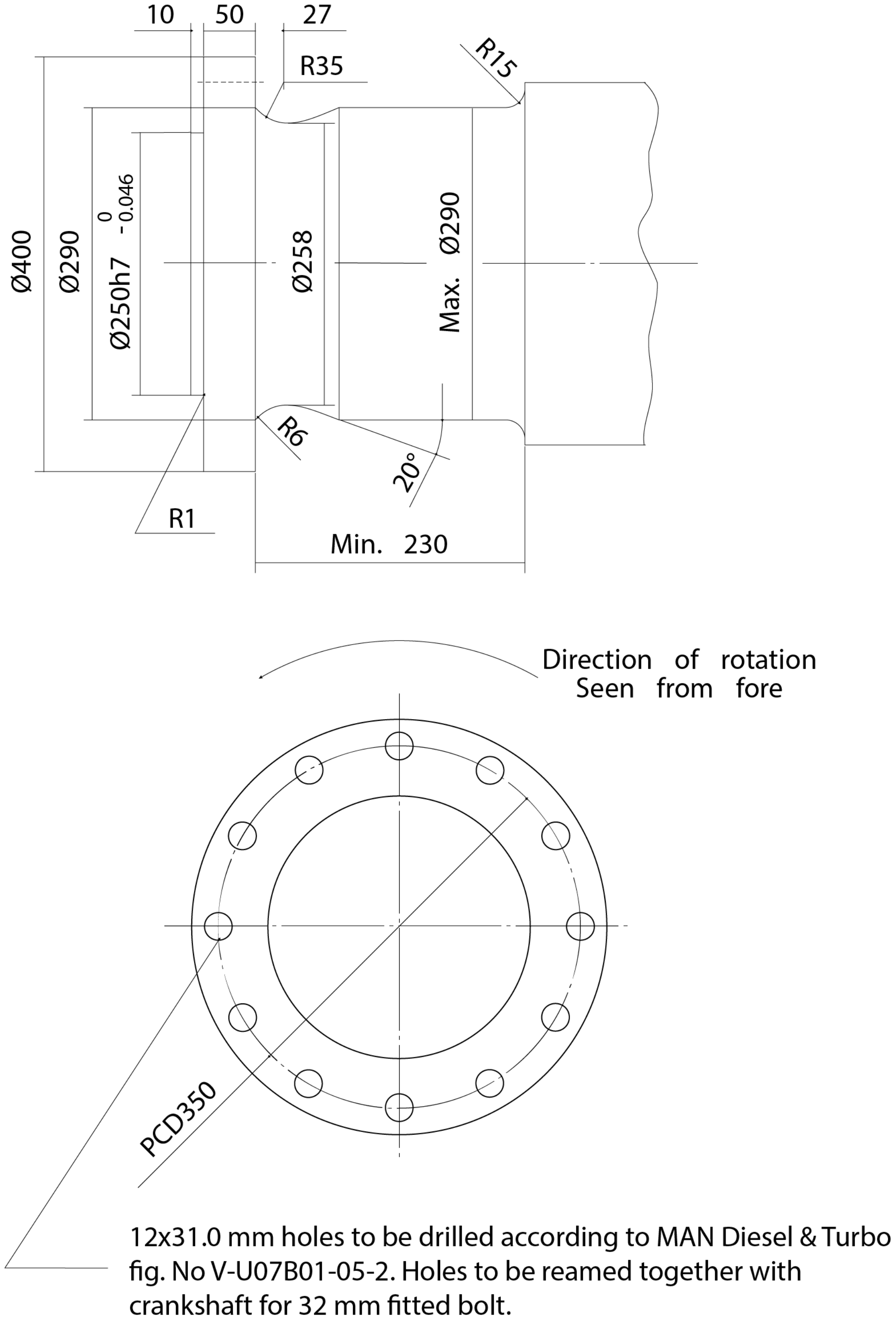

Figure 2: *Shaft dimension for alternator, type B 16, cyl. 5 - 6 - 9*

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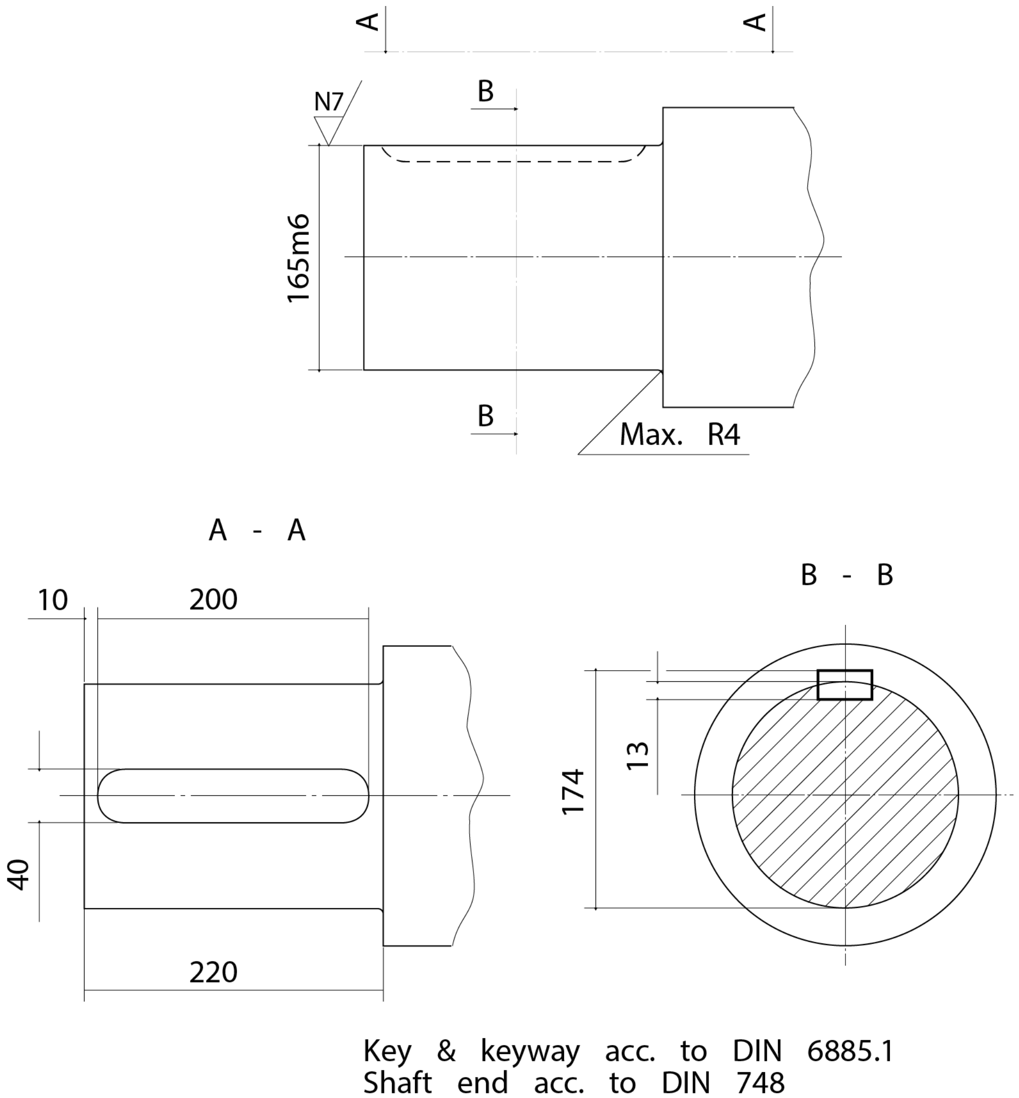

Figure 3: *Shaft dimension for alternator, type B 20, cyl. 7*

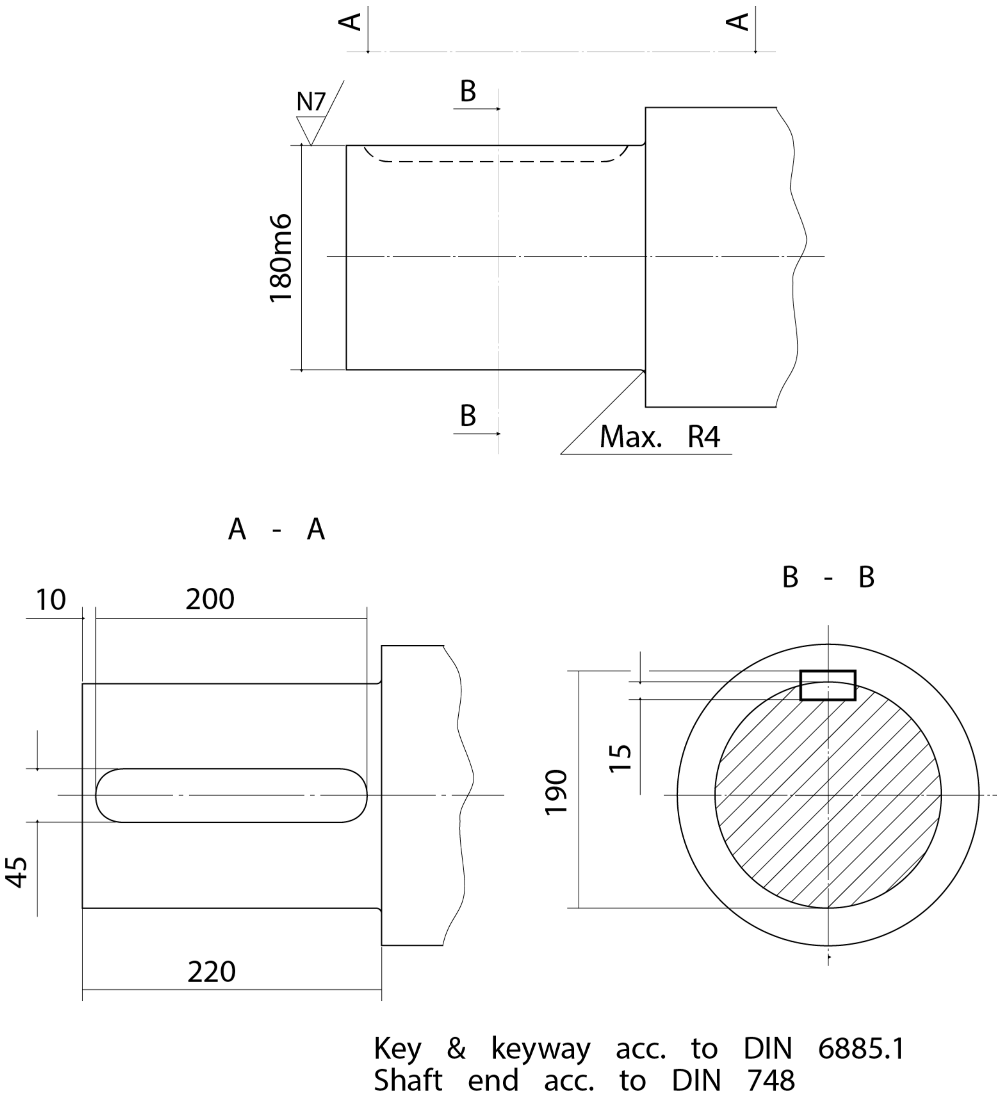

Figure 4: *Shaft dimension for alternator, type B 20, cyl. 8*

4. Other drawings necessary for installation.

5. Spare parts list.

6. List of loose supplied components.

7. Data:

- Construction form.
- Rated voltage.
- Rated power kVA.
- Rated current, amp.
- Rated power factor.
- Frequency, Hz.
- Insulation class.
- Load efficiency in % of nominal load at 1/4 - 1/2 - 3/4 - 1/1 load (with cos.phi. = 0.8 and 1.0).

- If the alternator bearings are lubricated by the engines' intermal lub. oil system:

- Max. lub. oil pressure.

- Lub. oil capacity (m^3/h).

- Heat radiation.

Besides the above-mentioned documentation, 3 sets of alternator test reports should be forwarded.

In connection with the delivery of alternator, documentation and spare parts, these should be specified with our order no. and the specific yard or project identification.

For further information, please contact MAN Energy Solutions.

Engine/Alternator Type

General

Engine speed 720/750 RPM				
Cyl. No	Standard		Alternative option	
	Alternator type	Requirements	Alternator type	Requirements
5 Cyl.	B 16	None	B 20	Elastic coupling*
6 Cyl.	B 16	None	B 20	Elastic coupling*
7 Cyl.	B 20	Elastic coupling*	-	-
8 Cyl.	B 20	Elastic coupling*	-	-
9 Cyl.	B 16	None	B 20	Elastic coupling*

Alternator type B 16

One bearing type, shaft end with flange.

Alternator type B 20

Two bearing types, shaft end with keyway.

One bearing shall be of the guide bearing type.

* Is required due to torsional vibration calculations.

Note for Re-engineering

In case of using an existing alternator, calculation for torsional vibrations has to be carried out before determination concerning intermediate bearing and elastic coupling can be established.

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Alternator cable installation

Description

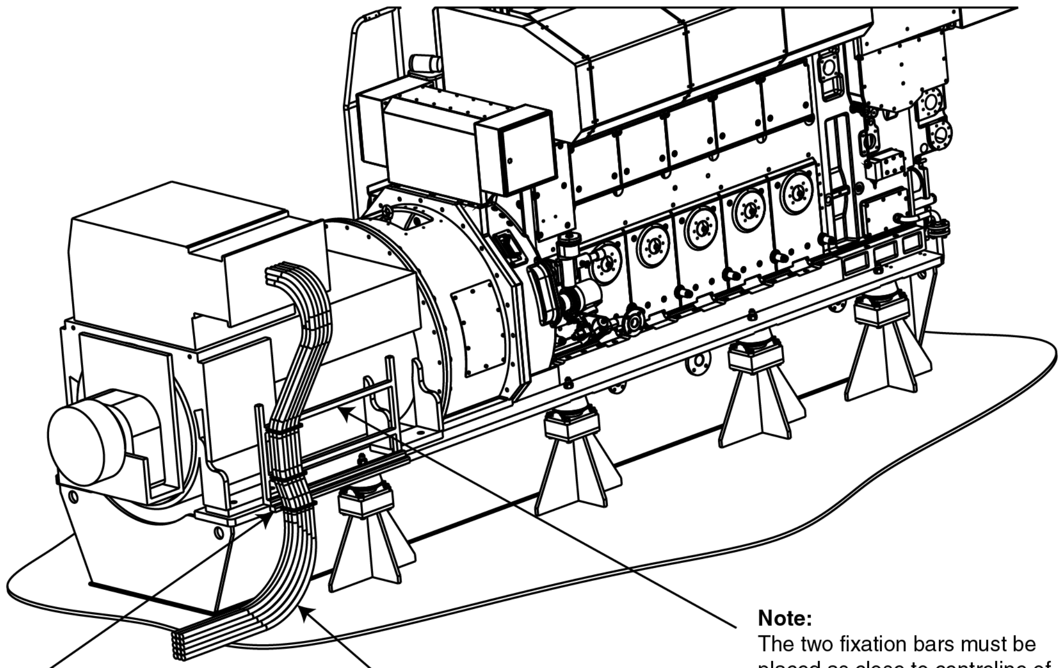

Figure 1: Connection of cables (example)

Main cables

The resilient installation of the GenSet must be considered when fixing the alternator cables.

The cables must be installed so that no forces have any effect on the terminal box of the alternator.

A support bracket can be welded on the engine base frame. If this solution is chosen, the flexibility in the cables must be between the cable tray and the support bracket.

The free cable length from the cable tray to the attachment on the alternator must be appropriate to compensate for the relative movements between the GenSet and the foundation.

The following can be used as a guideline:
The fix point of the alternator cables must be as close as possible to the centre line of the rotor.

Bending of the cables must follow the recommendations of the cable supplier regarding minimum bending radius for movable cables.

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.

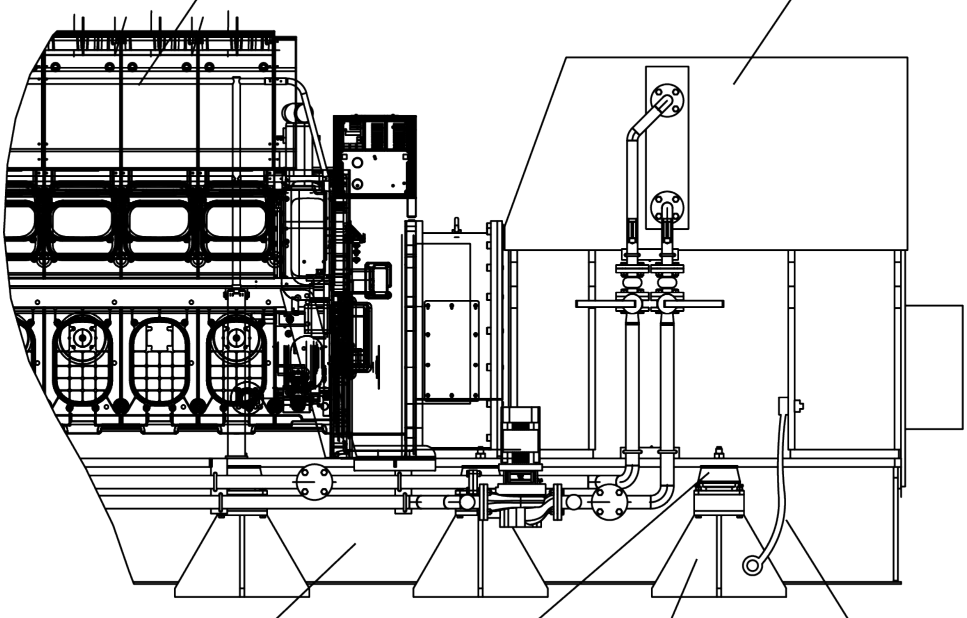

Figure 2: Marine operation (example)

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.

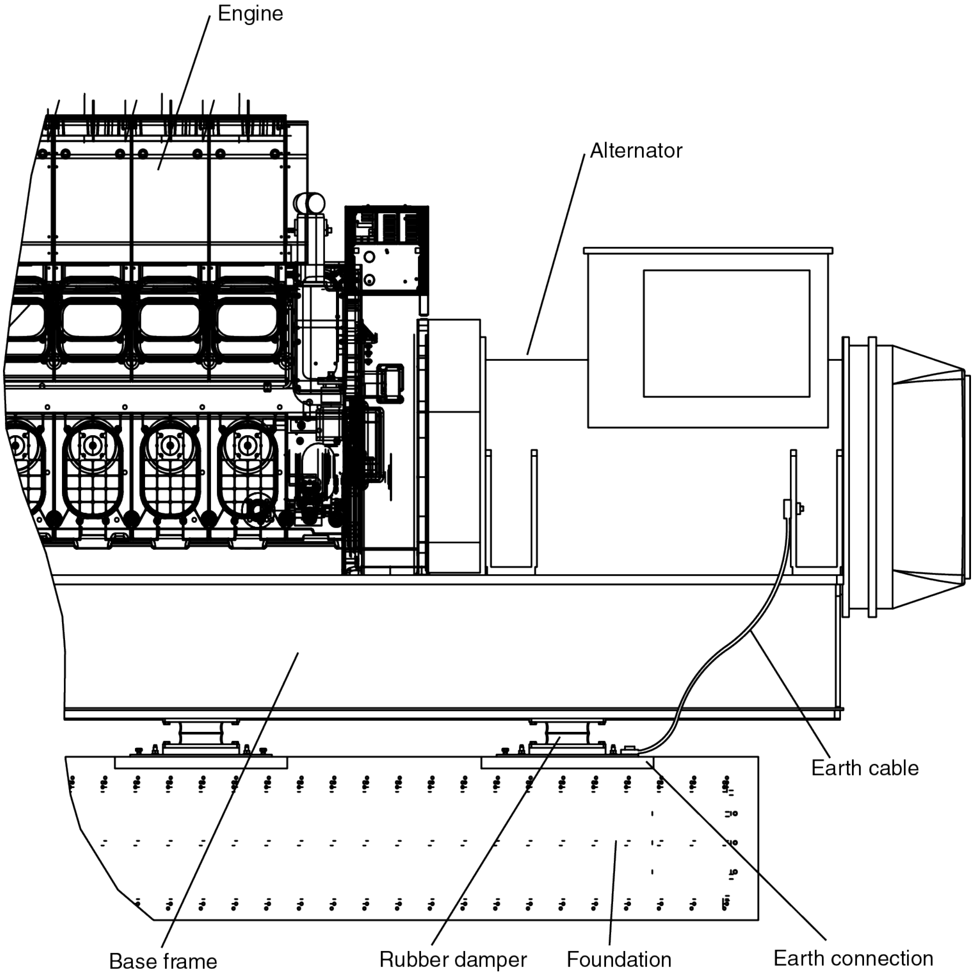

Figure 3: Stationary operation (example)

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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	•	#	#	#

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For a GenSet the engine and alternator are fixed on a common base frame, which is flexibly installed. This is to isolate the GenSet vibration-wise from the environment. As part of the GenSet design a full FEM calculation has been done and due to this and our experience some combinations of engine type and alternator type concerning one - or two bearings must be avoided. In the below list all combinations can be found.

Comments to possible combinations:

• : Standard
: Option
X : Not recommended

1) : Only in combination with "top bracing" between engine crankcase and alternator frame
2) : Need for 'topbracing' to be evaluated case by case

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.

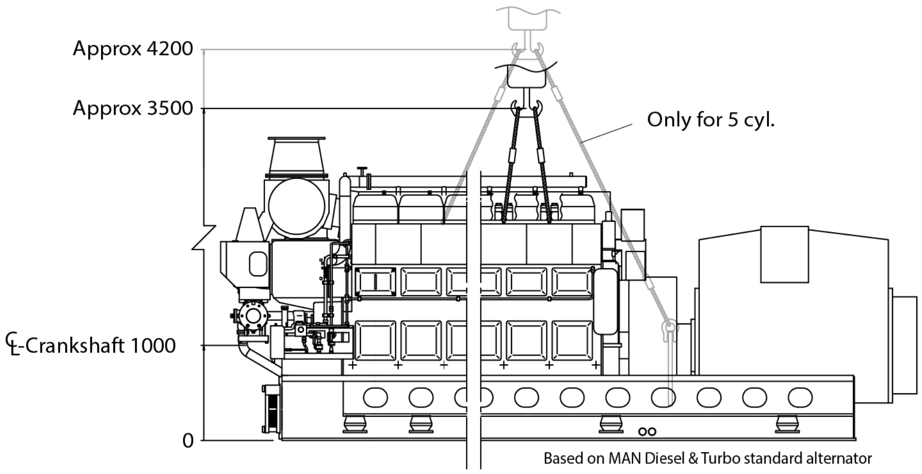

Figure 1: Crossbars' and wires placing on engine.

The generating sets should only be lifted in the two wire straps. Normally, the lifting crossbars and the wire straps are mounted by the factory. If not, it must be observed that the fixing points for the crossbars are placed differently depending on the number of cylinders.

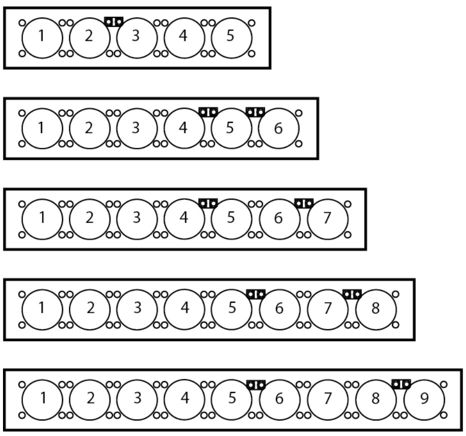
Figure 2: Crossbars' placing on engine.

The crossbars are to be removed after the installation, and the protective caps should be fitted.

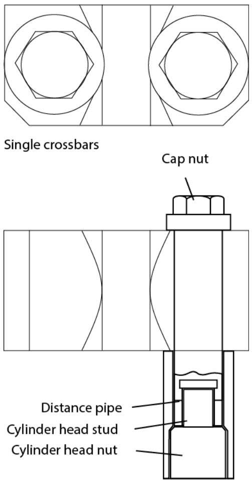

Figure 3: Crossbars.