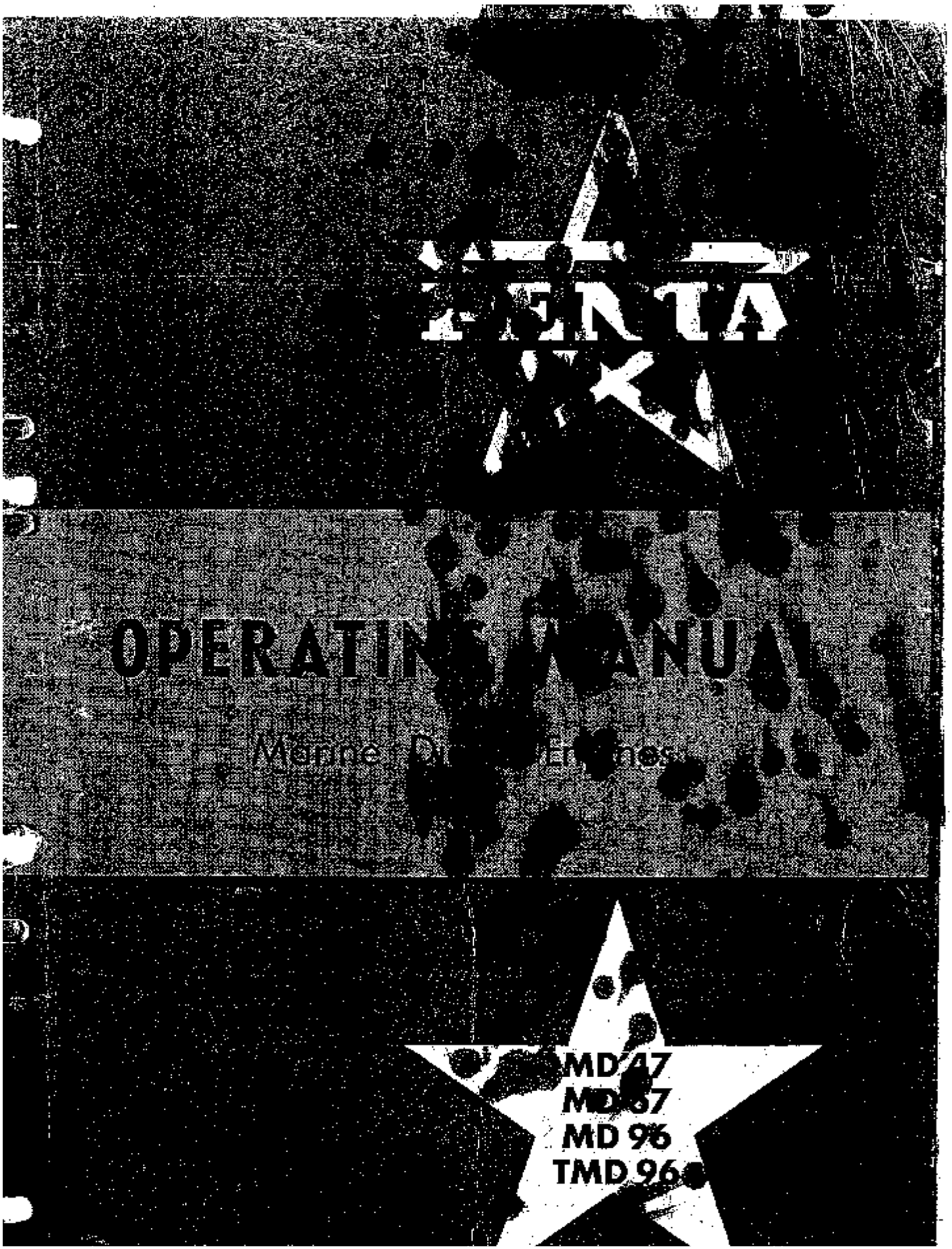
SEGA
OPERATING MANUAL
MD 47
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FOR

PENTA MARINE DIESEL ENGINES

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9423

> In all correspondence with Aktiebolaget Penta or your dealer concerning your engine and when ordering spare parts, always state the type designation and serial number of the engine.
> The engine type designation and serial numbers are stamped on a plate attached to one side of the engine.

Ex "YE 42" Oester Stichting H.V.E.

D67 C 233.39.555 No 726

C.A.V. Brandstofpomp

Twin Disc Keerkoppeling
M 601
Marine reverse gear

34

AKTIEBOLAGET PENTA
GÖTEBORG SWEDEN
Cables: PENTA

GENERAL DESCRIPTION

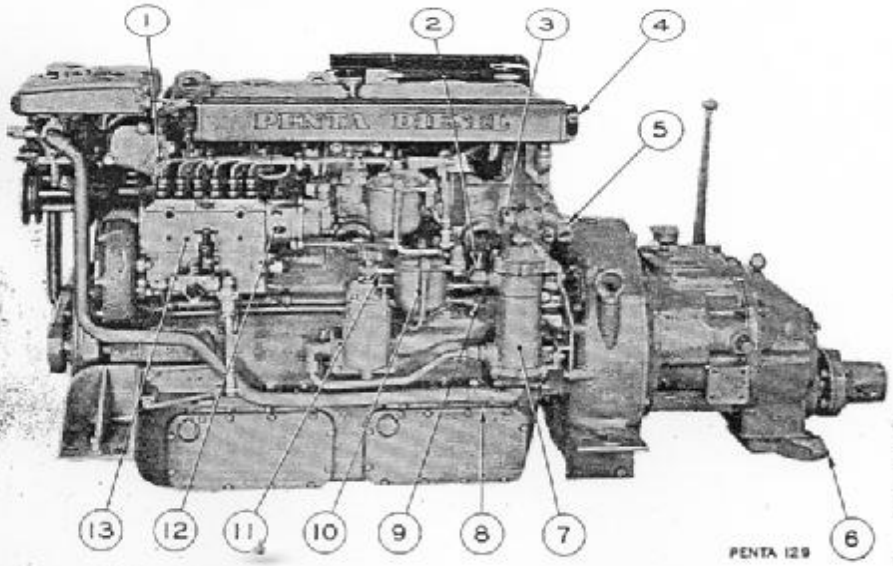
The marine Diesel engines are of the 6-cylinder, 4-stroke, direct-injection type with capacities of 4.7, 6.7 and 9.6 litres respectively.

All moving parts are carefully dimensioned and particularly carefully balanced. This, in combination with the design of the combustion chambers and special fuel injection equipment, ensures vibration-free and quiet operation.

The cylinder block is made of cast-iron and is cast in one unit. There are two cylinder heads containing the valve mechanism, each covering three cylinders. The cylinder liners are separate and replaceable. The same applies to the main bearings and big-end bearings.

The pistons are made of light-alloy and the upper compression ring on each piston is chromed to reduce wear. The auxiliary drive gears for the camshaft and fuel injection pump consist of silent-running bevel gears which are built into a casing.

The engines are water-cooled with pressure lubrication systems. An electric starter is standard equipment.



1. Connection for coolant thermo meter
2. Coolant drain point on cylinder block
3. Connection for sea-water outlet overboard
4. Exhaust pipe connection
5. Connection for sea-water to exhaust system
6. Connection for sea-water to reduction gear
7. Oil cooler
8. Sea-water drain point, pipe-line and oil cooler
9. Connection for oil pressure gauge
10. Fuel filter
11. Lubricating oil filter
12. Stop control and cold starting device
13. Fuel injection pump

Fig. 1. MD 47 engine with Snow Nabstedt reverse gear.

1. Oil filler cap for reverse gear
2. Air cleaner
3. Throttle control
4. Oil filler cap for engine
5. Plate showing valve clearances
6. Filler cap for coolant
7. Zinc electrode
8. Drain point for heat exchanger
9. Extra pulley
10. Dynamo
11. Sea-water pump
12. Lubricator for fresh-water pump
13. Oil scavenging pump
14. Oil dipstick for engine
15. Starter motor
16. Oil dipstick for reverse gear

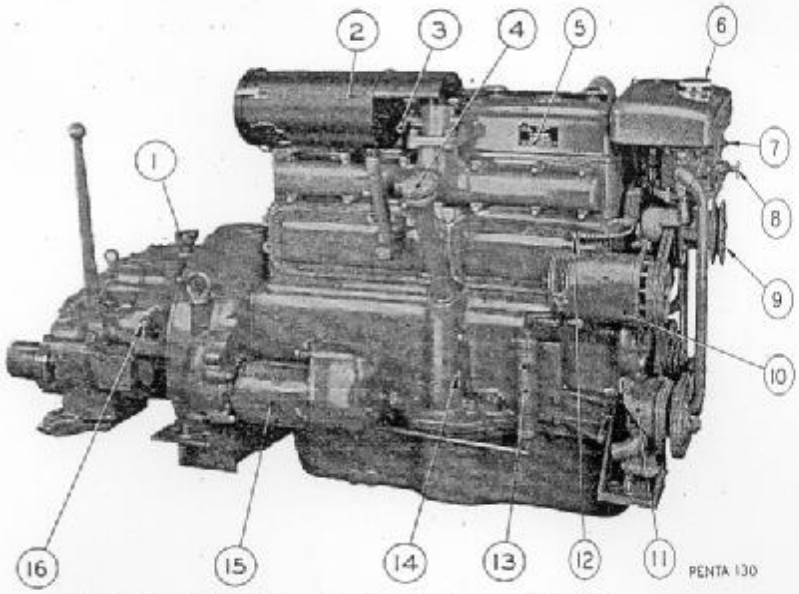
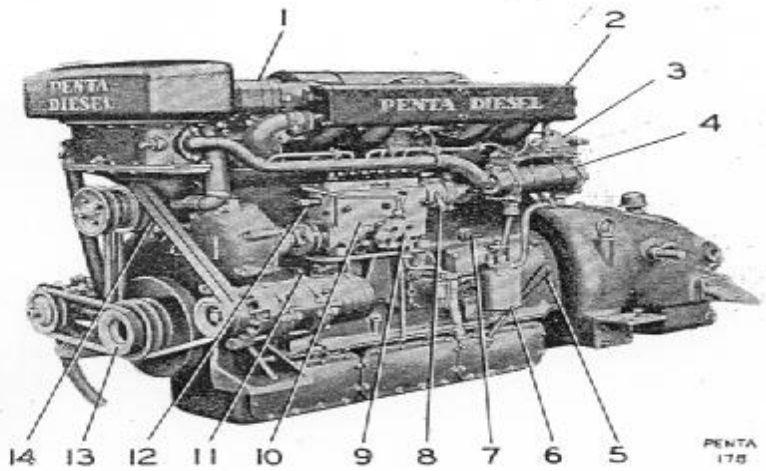


Fig. 2. MD 47 engine with Snow Nabstedt reverse gear.



1. Thermostat housing
2. Exhaust manifold
3. Fuel filter
4. Oil cooler
5. Oil dipstick for engine
6. Lubricating oil filter
7. Coolant drain point for engine
8. Stop control
9. Fuel feed pump
10. Fuel injection pump
11. Connection for oil pressure gauge
12. Cold starting control
13. Pulleys
14. Fresh-water pump

Fig. 3. MD 67 engine with Twin Disc reverse gear.

1. Throttle control
2. Air cleaner
3. Plate showing valve clearances
4. Oil filler cap for engine
5. Coolant filler cap
6. Zinc electrode
7. Drain point for heat exchanger
8. Extra pulley
9. Plate showing engine number
10. Dynamo
11. Sea-water pump
12. Oil scavenging pump (early production)
13. Crankcase ventilator
14. Starter motor
15. Oil dipstick for reverse gear
16. Oil filler cap for reverse gear

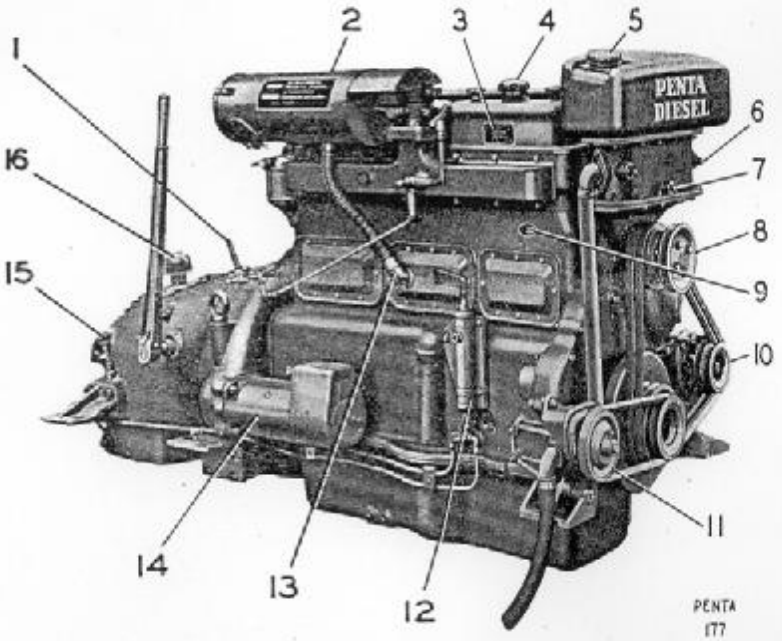


Fig. 4. MD 67 engine with Twin Disc reverse gear.

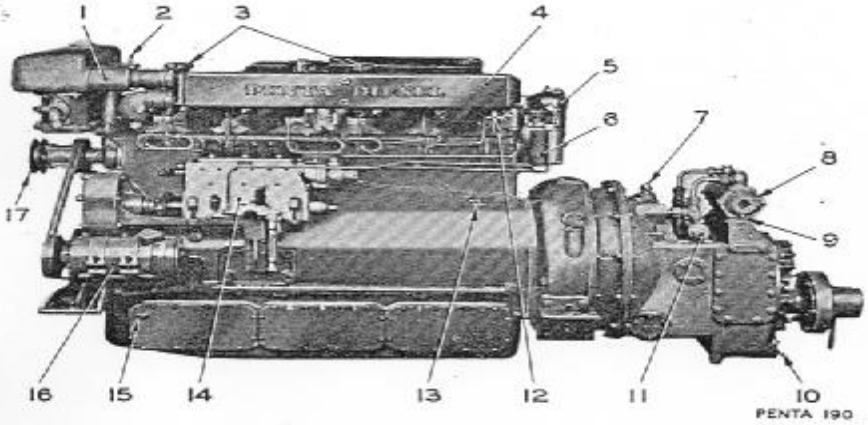


Fig. 5. MD 96 engine with Self Changing Gear reverse gear.

1. Thermostat housing
2. Air-venting cock for coolant channels
3. Oil filter and ventilation caps
4. Exhaust manifold
5. Upper fuel filter
6. Lower fuel filter
7. Oil filler cap for reverse gear
8. Sea-water connection; oil cooler reverse gear
9. Sea-water drain point; oil cooler
10. Suction filter, reverse gear
11. Main filter, reverse gear
12. Coolant drain point, exhaust manifold
13. Coolant drain point, cylinder jackets
14. Fuel injection pump
15. Oil relief valve, lubricating oil
16. Dynamo
17. Extra pulley

1. Sea-water, connection
2. Oil dipstick for reverse gear
3. Oil filler cap for reverse gear
4. Air cleaner
5. Charging control
6. Throttle control
7. Engine serial number plate
8. Oil filler cap for engine
9. Connection for coolant thermometer
10. Air-venting cock for coolant channels
11. Thermostat housing
12. Coolant filler cap
13. Coolant tank
14. Heat exchanger
15. Zinc electrode
16. Sea-water drain point, heat exchanger
17. Oil cooler
18. Sea-water drain point, oil cooler
19. "Conax" power take-off
20. Sea-water pump
21. Lubricating oil filter
22. Oil dipstick for engine
23. Three way cock for oil drain
24. Oil scavenging pump (later production)
25. Electrical starter motor

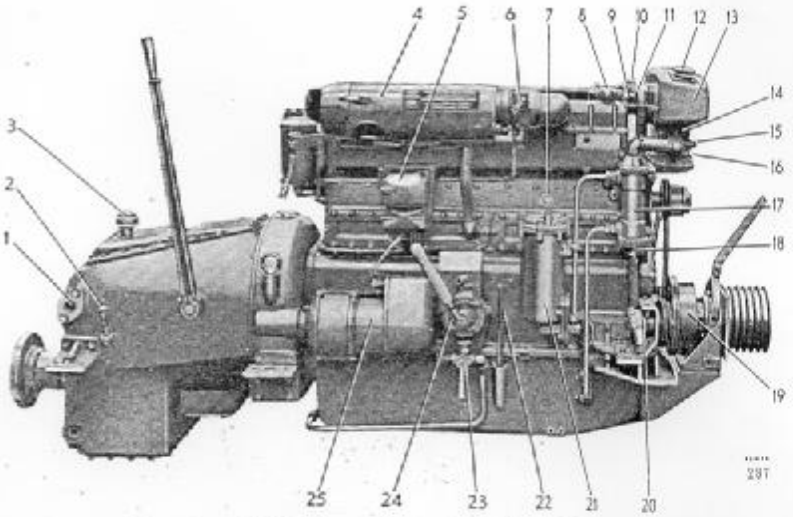
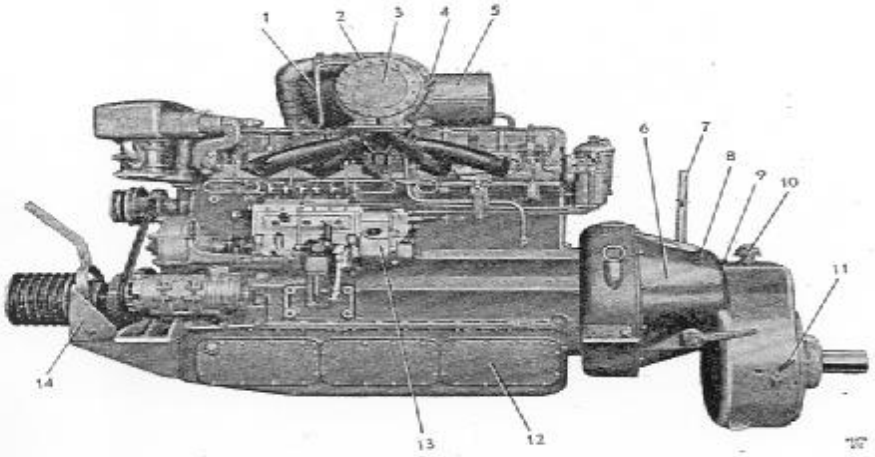


Fig. 6. MD 96 engine with Twin Disc reverse gear and Conax power take-off.



1. Coolant pipe for turbo-compressor
2. Turbo-compressor
3. Protector plate for use during transportation
4. Oil dipstick
5. Air cleaner
6. Clutch and reduction gear, Twin Disc
7. Operating lever
8. Lubricating nipple for clutch throw-out bearing
9. Lubricating nipple for flywheel pilot bearing
10. Oil filler cap and breather
11. Oil dipstick
12. Crankcase inspection cover
13. Centrifugal governor on fuel injection pump
14. Power take-off with Conax friction clutch

Fig. 7. TMD 96 engine with Twin Disc clutch and reduction gear as well as a power take-off with a Conax friction clutch.

1. Fuel filter
2. Air cleaner, oil-bath type
3. Crankcase ventilator
4. Oil filler cap
5. Connection for coolant thermometer
6. Air-venting screw for coolant channels
7. Coolant filler cap
8. Zinc electrodes
9. Oil cooler
10. Fresh-water pump
11. Belt tensioner
12. Sea-water pump
13. Engine bed
14. Lubricating oil filter
15. Oil dipstick
16. Oil scavenging pump (early production)
17. Drain cock, compressed-air starter motor
18. Compressed-air starter motor

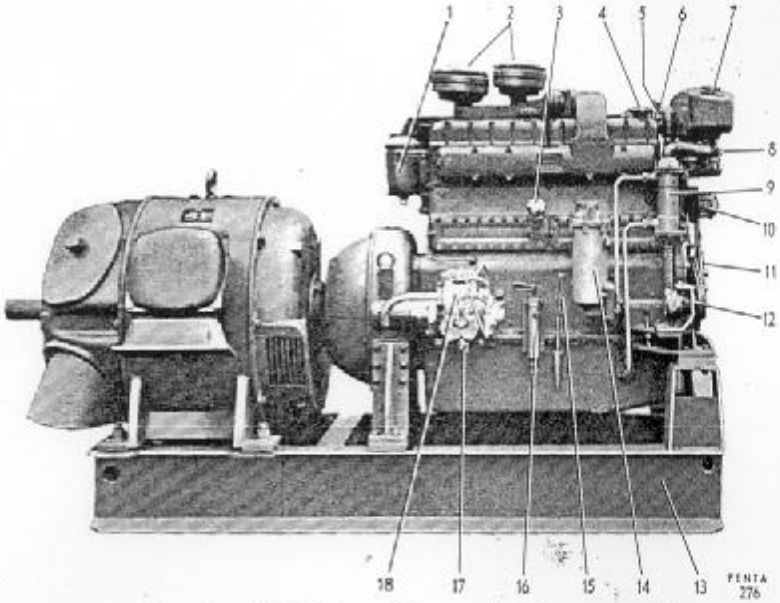


Fig. 8. MD 96 auxiliary unit with compressed-air starter motor.

SPECIFICATIONS

General

	MD 47	MD 67	MD 96	TMD 96
Type designations				
Max. output b.h.p/r.p.m.	91/2500	115/2400	152/2200	174/1800
Marine output b.h.p.	41—82	59/103	89—137	138—157
light-duty operation r.p.m.	1200—2500	1200—2400	1200—2200	1500—1800
Marine output b.h.p.	41—70	59—87	89—127	138—157
heavy-duty operation r.p.m.	1200—2000	1200—1800	1200—1800	1500—1800
Max. torque kgm (lb.ft.)/r.p.m.	28 (203)/1400	40 (289)/1200	59 (427)/1100	73 (528)/1400
Marine toque kgm (lb.ft.)/r.p.m.	25 (181)/1400	36 (260)/1200	53 (384)/1100	66 (476)/1400
Number of cylinders	6	6	6	6
Bore mm (in.)	95.25 (3.750)	104.77 (4.125)	120.65 (4.750)	120.65 (4.750)
Stroke mm (in.)	110 (4.331)	130 (5.118)	140 (5.512)	140 (5.512)
Total displacement lit. (cu.in.)	4.70 ((287)	6.73 (410)	9.60 (585)	9.60 (585)
Compression ratio	17:1	17:1	17:1	17:1
Compression pressure at 200 r.p.m. kg/cm² (p.s.i.)	27 (384)	28 (398)	27 (384)	27 (384)
Order of firing		1 — 5 — 3 — 6 — 2 — 4		
Maximum speed, unloaded engine r.p.m.	2700	2500	2000	1970
Idling speed r.p.m.	500—600	500—550	500—550	500—550
Direction of rotation, seen from front end of engine	Clockwise	Clockwise	Clockwise	Clockwise
Weight of engine, incl. reverse gear and 2:1 reduction gear, excl. oil, approx. kg (lb.)	750 (1650)	1000 (2200)	1200 (2650)	1250 (2760)
Max. inclination of engine when boat is under way	15°	12°	12°	12°

Engine unit

Replaceable cylinder liners, type	Dry	Wet	Wet	Wet
Cylinder liners and pistons are matched and sold in sets. On MD 47 engines, the liners and block are also classified into Class 3 and Class 4				
Pistons, material	Light-alloy	Light-alloy	Light-alloy	Light-alloy
Piston clearance, Specialloid.. mm (in.)	0.09-0.11 (0.0035-0.0043)	—	—	—
Mahle..... mm (in.)	—	0.11-0.13 (0.0043-0.0051)	0.17-0.19 (0.0067-0.0075)	0.17-0.19 (0.0067-0.0075)
Wellworthy mm (in.)	—	0.10-0.12 (0.0039-0.0047)	0.17-0.19 (0.0067-0.0075)	0.17-0.19 (0.0067-0.0075)
Piston rings:				
Upper ring chromed, number	1	1	1	1
Number of lower compression rings	2	2	2	2
Number of oil control rings	2	2	2	2
Piston ring gap measured at ring opening mm (in.)	0.25—0.50 (0.010—0.020)	0.35—0.65 (0.014—0.025)	0.35—0.60 (0.014—0.023)	0.35—0.60 (0.014—0.023)
Crankshaft, drop-forged, statiscally and dynamically balanced				
Replaceable lead-bronze, steel-backed bearing shells (main and big-end bearings)				
Number of main bearings	7	7	7	7
Effective main bearing surface area, total cm² (sq.in.)	172 (27)	215 (33)	297 (46)	297 (46)
Connecting rods, drop-forged and case-hardened, classified by weight, various classes denoted by letters. Only connecting rods with the same letter may be used together in the same engine.				
Camshaft, drop-forged and case-hardened with ground cams and bearing surfaces.				
Camshaft setting (cold engine): tappets on inlet valves at 10° after T.D.C. should have lifted mm (in.)	1.6±0.25 (0.063±0.010)	1.6±0.25 (0.063±0.010)	1.4±0.25 (0.055±0.010)	1.4±0.25 (0.055±0.010)

	MD 47	MD 67	MD 96	TMD 96
Overhead valves, nickel-steel inlet valves, chrome-nickel steel exhaust valves, with seats stellited and valve stems hard-chromed.				
Clearance, warm engine, inlet valves mm (in.)	0.40 (0.016)	0.40 (0.016)	Hydraulic tappets, no adjustment required	
" " " exhaust valves mm (in.)	0.45 (0.018)	0.45 (0.018)		
Valves may not be adjusted while the engine is running.				

Lubricating system (engine)

Oil sump, type		Cast, separate inspection covers		
Oil capacity, including oil filter, approx. litres (Imp. gallons)	10 (2¼)	20 (4½)	28 (6)	28 (6)
Oil pressure, warm engine kg/cm² (p.s.i.)	3—4 (42—56)	3—4 (42—56)	3—4 (42—56)	3—4 (42—56)
Lubricants (see chapter dealing with lubricating oils)				
Oil pump, type	Gear	Gear	Gear	Gear
Oil filter, type	Screen	Screen	Cloth	Cloth
Oil cooler, type	Tubular	Tubular	Tubular	Tubular

Fuel system

Fuel injection pump:				
Injection setting ° before T.D.C.	30	30	30	30
Setting mark on steel disc coupling	—	R	A	A
Max. injected charge:				
1000 r.p.m. (engine) mg/shot	33—34	48—49	71—72	—
1400 r.p.m. (engine) mg/shot	—	—	—	88—90
Test bench max. fuel setting for 200 strokes at 500 r.p.m. (pump) with test injector: BDN 12 SD 12 cc	8,6	12,0	17,7	22,2
SH 14 S 584 cc	8,4	11,3	16,6	20,9
Fuel feed pump, suction lift capacity (see chapter dealing with seed pumps on page 20)				
Fuel feed pressure kg/cm² (p.s.i.)	0.6-1.0 (8.5-14.2)	0.6-1.0 (8.5-14.2)	0.6-1.0 (8.5-14.2)	0.6-1.0 (8.5-14.2)
Twin fuel filters, type	583 0112 NO Replaceable elements Type F28			
Injector opening pressure kg/cm² (p.s.i.)	135±5 (1920±71)	135±5 (1920±71)	135±5 (1920±71)	135±5 (1920±71)

Cooling system

Fresh-water system:				
Pump, type	Centrifugal	Centrifugal	Centrifugal	Centrifugal
Thermostat starts to open at °C (°F)	74 (165)	72 (162)	72 (162)	72 (162)
Thermostat fully open at °C (°F)	88 (190)	85 (185)	85 (185)	85 (185)
Heat exchanger, type	Tubular cooler	Tubular cooler	Tubular cooler	Tubular cooler
Cooling system capacity, approx... litres (imp. gallons)	18 (4)	20 (4½)	27 (6)	27 (6)
Sea-water system:				
Pump, make	Jabsco	Jabsco	Jabsco	Jabsco

Electrical system

Voltage, standard volts	12	24	24	24
Specific gravity of electrolyte, fully charged battery	1.275—1.285	1.275—1.285	1.275—1.285	1.275—1.285
Specific gravity of electrolyte, when battery should be re-charged	1.230	1.230	1.230	1.230
Dynamo output, standard, max. watts	450	480	480	480
Dynamo output, standard, continuous ("lamp load") watts	300	380	380	380
Starter motor output b.h.p.	4	4	6	6

THE ENGINE UNIT

The general description and specifications on previous pages show the design of the engines.

Tightening torques

		MD 47	MD 67
Cylinder head	kgm (lb.ft.)	14—16 (100—116)	14—16 (100—116)
Main bearings	„ „	14—16 (100—116)	19,5—22 (140—160)
Big-end bearings	„ „	14—16 (100—116)	14—16 (100—116)
Flywheel	„ „	8.5—10 (60— 72)	8.5—10 (60— 72)
Fuel injection pump, delivery valve retainers, CAV	„ „	6.3 (45)	6.3 (45)
Fuel injection pump, delivery valve retainers, Bosch	„ „	4.5 (32)	4.5 (32)
Injectors, retaining bolts	„ „	2.3—3.0 (17—22)	2.3—3.0 (17—22)

		MD 96, TMD 96
Cylinder heads, 14 mm nuts	kgm (lb.ft.)	18—20 (130—145)
Cylinder heads, 12 mm nuts	„ „	12—14 (87—101)
Main bearings	„ „	19.5—22 (140—160)
Big-end bearings	„ „	19.5—22 (140—160)
Flywheel	„ „	14—16 (100—116)
Fuel injection pump, delivery valve retainers, Bosch	„ „	4.5 (32)
Injectors, retaining bolts	„ „	2.3—3.0 (17— 22)

Tightening the cylinder head nuts

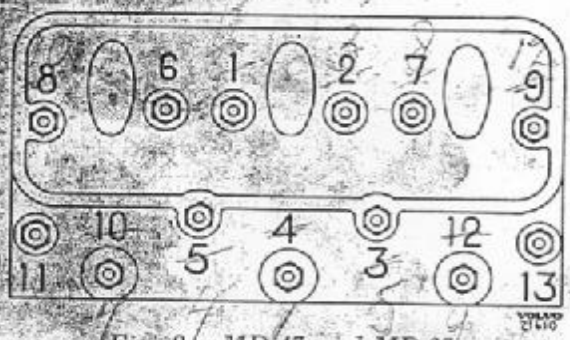


Fig. 9. MD 47 and MD 67.

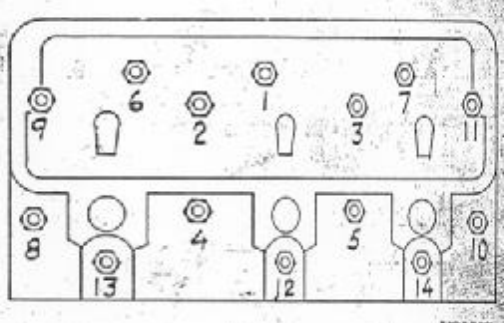


Fig. 10. MD 96 and TMD 96.

Due to the high compression and combustion pressures in Diesel engines, it is of the utmost importance that the cylinder head nuts are tightened evenly and sufficiently hard. Otherwise there is a risk of the cylinder head gaskets blowing out. The tightness of these nuts should therefore be checked at regular intervals, for example after every 1200 hours of operation.

When the engine is new or after cylinder head gaskets have been replaced, however, this check should be carried out after every 25 hours of operation.

Tightening should be carried out in the order shown in Figs. 9 and 10 and to the correct torque as shown in the tables above.

The engine should be run thoroughly warm before checking is carried out.

Some people argue that if the nuts are tightened harder to begin with, then subsequent tightening is not necessary. This is *incorrect*.

Subsequent tightening takes time but is absolutely necessary. Smear the cylinder head gaskets with grease or oil before fitting them. This prevents the gaskets from "shrinking".

NOTE. Each time the cylinder head nuts are tightened, this must be followed by adjustment of the valve clearances since otherwise these will be too small.

Turning the engine over by hand

Remove the inspection cover on the flywheel housing. Use a small crowbar or a large screwdriver as a lever with the flywheel housing as a fulcrum and exert pressure on the flywheel ring gear. Be careful not to damage the pointer for engine settings.

Adjusting valve clearance

If the cylinder heads have been removed from the engine, then the valve clearances must be checked. Rough adjustment should be carried out before the engine is started. Then the engine is started and run until it has warmed up to normal operating temperature after which it is stopped. *The valves must not be adjusted while the engine is running* otherwise the pistons and valves can come into contact with each other.

The valves are adjusted when the piston in the cylinder in question is in its T.D.C. position after the compression stroke.

Adjustment is carried out by loosening the locknut and turning the adjuster screw before tightening the locknut again.

Measurements are carried out by using a feeler gauge (0.40 mm = 0.016") for the inlet valves and (0.45 mm = 0.018") for the exhaust valves.

NOTE. These valve clearances apply to a warm engine.

We recommend that valve clearances are adjusted after every 1200 hours of operation or once a year.

In the same way it is absolutely essential that the valves are adjusted following every tightening of the cylinder head nuts.

The MD 96 and TMD 96 engines are fitted with hydraulic tappets so that no adjustment of valve clearance is necessary.

Wear tolerances

	MD 47	MD 67	MD 96 and TMD 96
Cylinders:			
Cylinder liners and pistons with piston rings should be replaced when liner wear reaches	0.25—0.30 mm (0.010"—0.012")	0.35—0.40 mm (0.014"—0.016")	0.40—0.45 mm (0.016"—0.018")
or ovality (out-of-roundness) reaches	0.08 mm (0.003")	0.08 mm (0.003")	0.08 mm (0.003")
Crankshaft:			
Permissible ovality (out-of-roundness) on main bearings and big-end bearings, max.	0.06 mm (0.0023")	0.075 mm (0.0030")	0.08 mm (0.0031")
Permissible taper on main bearing journals and crankpins	0.05 mm (0.0020")	0.05 mm (0.0020")	0.05 mm (0.0020")
Max. crankshaft end play	0.30 mm (0.0118")	0.30 mm (0.0118")	0.35 mm (0.0138")
Valves:			
Valve spindles, permissible wear	0.02 mm (0.0008")	0.02 mm (0.0008")	0.02 mm (0.0008")
Permissible clearance between valve spindles and valve guides:			
Inlet valves	0.15 mm (0.0059")	0.15 mm (0.0059")	0.15 mm (0.0059")
Exhaust valves	0.17 mm (0.0067")	0.17 mm (0.0067")	0.17 mm (0.0067")

	MD 47	MD 67	MD 96 and TMD 96
Valve disc seating face must be at least	1 mm (0.040″)	1 mm (0.040″)	1 mm (0.040″)
Permissible distance (A, Fig. 13) between valve disc and cylinder head surface when measured with a new valve may not exceed	2 mm (0.080″)	2 mm (0.080″)	2 mm (0.080″)

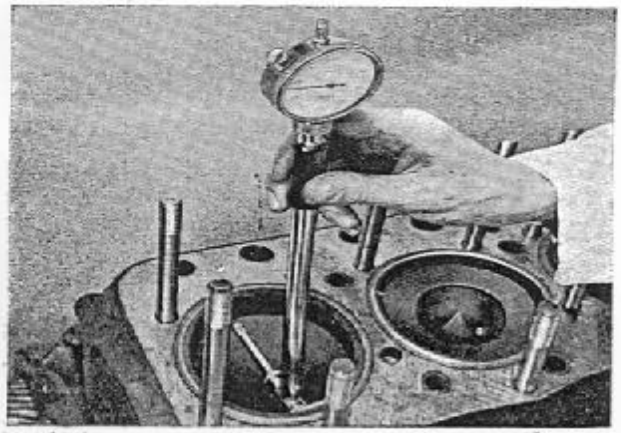


Fig. 11. *Measuring the cylinder bore. Zero the indicator on the upper edge of the liner.*

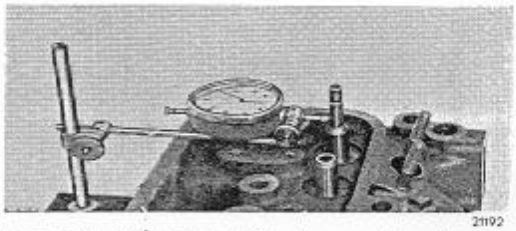


Fig. 12. *Checking the clearance the valve stem and valve guide.*

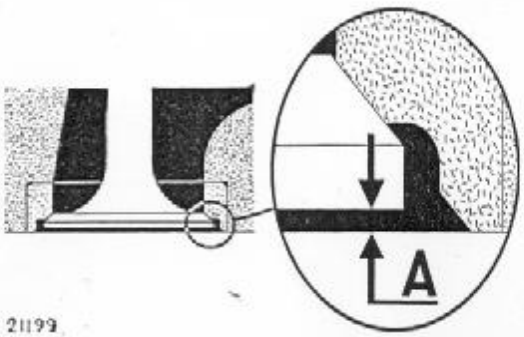


Fig. 13. *The depth of the valve below cylinder head level.*

Engine reconditioning

It is difficult to state a general time after which the engine should be reconditioned since conditions of operation and maintenance vary considerably. By watching the consumption of lubricating oil it is possible to judge approximately when the engine should be disassembled and wear checked. When an engine is new, the consumption of lubricating oil is low but this increases as the engine becomes more worn.

When the consumption of lubricating oil reaches 1/100th. of the consumption of fuel oil, this is a sign that the engine is due for reconditioning.

First check to make sure that oil leakage is not responsible for the increased oil consumption. If this is not the case then there is reason to suspect that the increased oil consumption is due to gummed piston rings or engine wear. The engine should be disassembled so that the components which are subject to wear can be measured.

See the compression test described below.

As a preventive procedure, we recommend that the engine is decarbonized and the valves ground after every 3600 hours of operation or every other year. At the same time it is convenient to check engine settings and the degree of wear.

Piston and cylinder liner replacement

Piston and cylinder liner replacement can be carried out without removing the engine from its bed on condition that the bed is designed so that the covers on the port side of the oil sump are accessible and that the beam of the boat allows this. All the oil should be pumped out from the sump before this is done. Remember

that if there is an oil relief valve fitted on the forward cover, this must first be removed before the cover is taken off otherwise the spring and the push rod can be damaged. Remove the upper part of the engine including the cylinder heads so that the pistons can be removed upwards. First remove the big-end bearing caps and then push the connecting rods and pistons upwards through the cylinder bores.

Assembly is carried out in the reverse order. Fit new gaskets.

Compression test

A good way to determine the condition of the engine is to measure the degree of leakage in the cylinders by carrying out a compression test.

This test is carried out by first running the engine warm and then removing the injectors and taking a compression test on all the cylinders in order.

While this is being done, *the stop button should be pulled out* and the engine should be turned over by using the starter motor with the throttle fully open. The battery must be in good condition so that it is capable of turning over the engine sufficiently fast (about 200 r.p.m.). Make sure that there is no leakage at the compression gauge connection.

The highest value obtained on the gauge should be noted. The use of a dial indicator gauge is recommended.

While the engine is being turned over by the starter motor, the compression pressure should be:

MD 67	28 kg/cm² (398 p.s.i.)
MD 47, MD 96, TMD 96	27 kg/cm² (384 p.s.i.)

A deviation of up to 10 % below these figures is permissible. The difference in pressure between the individual cylinders, however, should not exceed 1.75 kg/cm² (25 p.s.i.).

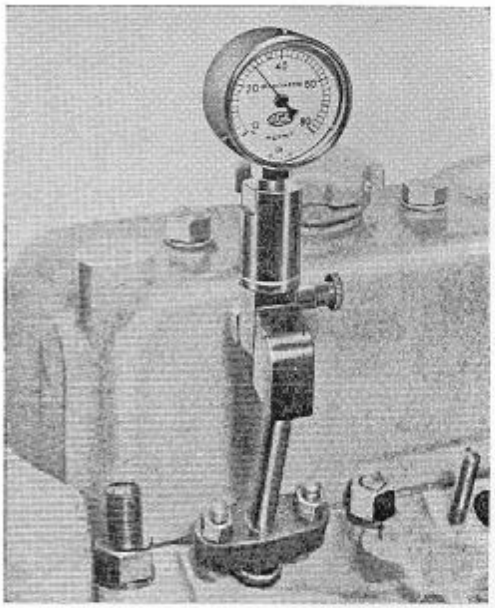
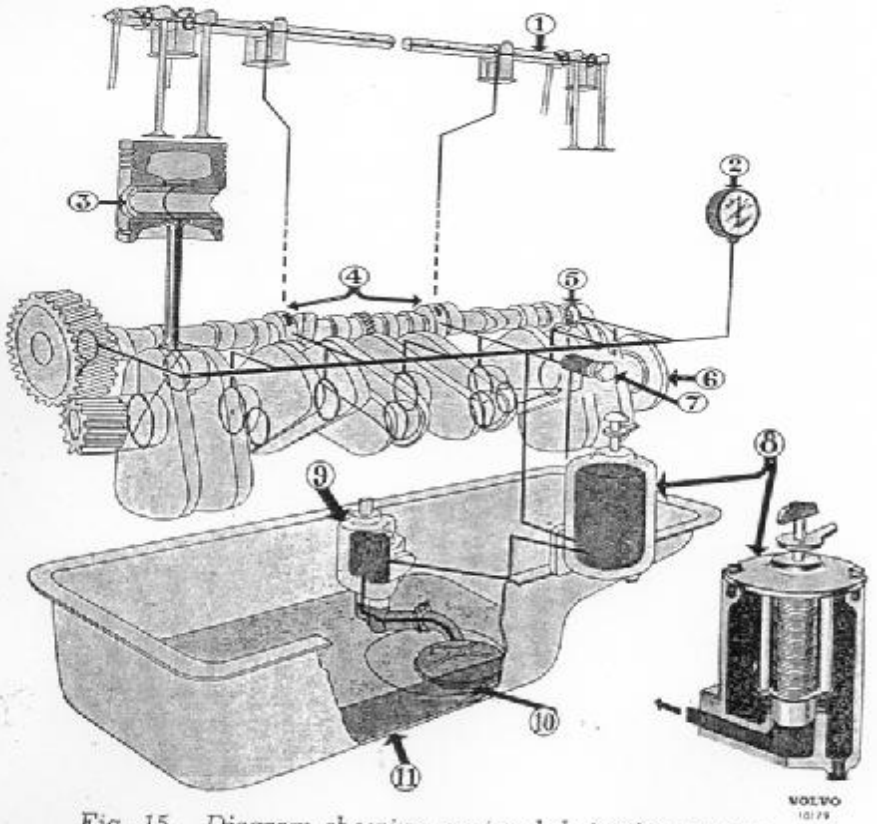


Fig. 14. Measuring the compression pressure.

THE ENGINE LUBRICATING SYSTEM

General description



1. Rocker arm shaft
2. Oil pressure gauge
3. Gudgeon pin
4. Intermittent pressure lubrication
5. Camshaft
6. Crankshaft
7. Oil relief valve
8. Lubricating oil filter
9. Oil pump
10. Oil strainer
11. Oil sump

Fig. 15. Diagram showing engine lubricating system.

The engines are lubricated by means of complete pressure lubricating systems. See Fig. 15. Oil under pressure is fed by the oil pump (9) which sucks up the oil through an oil strainer (10) in the oil sump (11). From the pump the oil is fed through drillings and channels to the various lubricating points before running back to the sump which is on the lower part of the crankcase. In order to limit the pressure in the system, there is an oil relief valve (7). The oil is cleaned the whole time when it passes through the oil filter (8) and is cooled in the oil cooler (not shown in diagram).

Lubricating oil

Use only special Diesel lubricating oil with the designations shown below that are recommended by the well-known oil companies. Never mix different makes and types of oil.

The type designations shown below are in accordance with the new API system which has been in effect since 1952.

Service DG To be used when the engine is subjected to even and average loading. The sulphur content of the fuel should not exceed 0.6 %.

Service DM To be used under favourable conditions of operation as above but when the sulphur content of the fuel exceeds approx. 0.6 %. or with high loading and unfavourable operating conditions when the sulphur content of the fuel does not exceed approx. 0.6 %.

Service DS To be used when the above-mentioned unfavourable operating conditions coincide with a fuel sulphur content exceeding approx. 0.6 %.

Oil of the following viscosity should be used:

Summer (temperatures exceeding +10° = +50° F) ..	SAE 30
Winter (temperatures between —10° C = +14° F and +10° C = +50° F)	SAE 20 or 20 W
Extremely low temperatures (below —10° C = +14° F)	SAE 10 W

Oil changes

Since the oil loses its lubricating properties due to oxidation, contamination, etc., it must be changed at certain intervals. Each time the oil is changed, the oil filter must be cleaned in accordance with the instructions on page 16.

Oil is removed from the crankcase by means of the pump on one side of the engine. The engine should be *warm* when this is carried out.

Change the engine oil after every 200 hours of operation.

Never use flushing oil. It is uncertain as to whether this oil can stand up to the high pressures prevailing in a Diesel engine.

The oil should be changed more often during the running-in period. See the instructions on page 59.

If the lubricating oil has been diluted with fuel due to injector failure, faulty piston rings or if it becomes thick very quickly for some reason, it must be changed immediately.

Diesel lubricating oils contain certain additives which maintain carbon particles etc. suspended in the oil and prevent the formation of carbon deposits in the engine. For this reason, the lubricating oil becomes black after a short time in use. This is a normal occurrance and should not be regarded as a reason for oil change.

Oil is added through the two filler holes on the top of the rocker arm covers. They are fitted with breathers. This does not apply to the MD 47 where there is an oil filler pipe on the starboard side of the engine.

Engine type:	*Oil capacity:*
MD 47	approx. 10 litres (2¼ Imp.gall.)
MD 67	approx. 20 litres (4½ „)
MD96, TMD96	approx. 28 litres (6 „)

Inspection

Check the oil level daily.

The oil level should never be permitted to sink below the lower mark on the dipstick.

Fig. 16. Oil dipstick.

While the engine is running, check now and then that the oil pressure gauge shows normal pressure, that is to say 3—4 kg/cm² (42—56 p.s.i.). If the pressure should suddenly go down (below 2 kg/cm² = 28 p.s.i.) and the pressure gauge needle should start swinging, this means that there is not sufficient oil in the engine and more should be added. Another reason for this pressure gauge reaction is that the filter is blocked. Clean the oil filter if necessary.

NOTE. *Always exercise great cleanliness when working on the lubricating system and its component parts. Any impurities can block the flow of oil or cause dirt to get into the bearings and ruin a job that was otherwise well done.*

Oil filler caps

2111 8

Fig. 17. Filler cap breather.

The oil filler caps are fitted with breathers containing air cleaners. At the same time as the engine oil is changed (after every 200 hours of operation) or more often when required, these air cleaners should be cleaned. The element is removed by removing the three screws retaining the cover and the lower section together and then separating the cover and lower section from each other with a screwdriver. Clean the filter elements in fuel oil and then oil them in.

Lubricating oil filter

Screen type

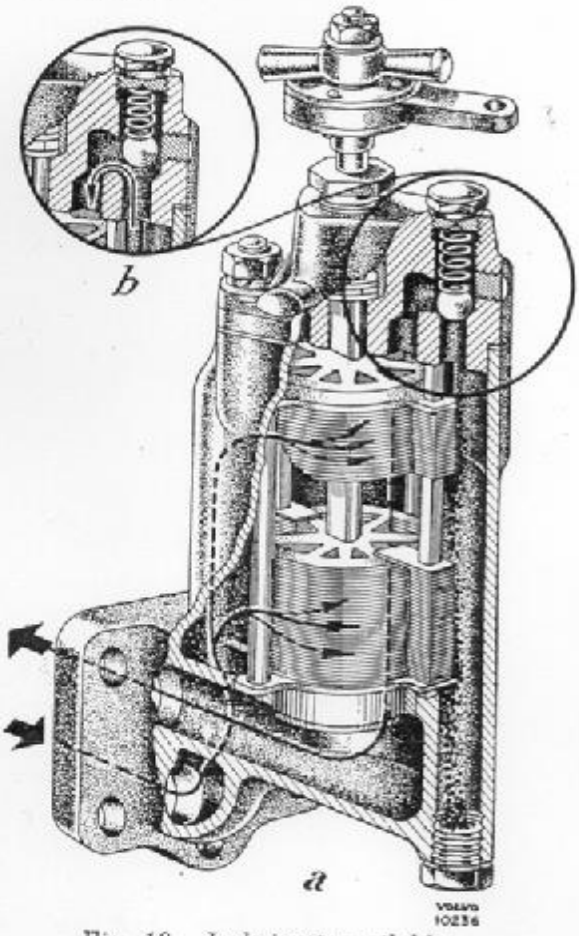


Fig. 18. Lubricating oil filter.

On MD 47 and MD 67 engines, the lubricating oil filter is of the self-cleaning type. It is fitted on the port side of the cylinder block and is connected directly with the lubricating oil channels. The in-coming oil passes through a screen filter which traps any impurities. There is a handle on top of the filter enabling the screen unit to be turned. This handle should be given a few turns after about every 5 hours of operation.

Quite a large amount of dirt and sludge collects in the lubricating oil filter gradually. This accumulation should be drained off through the drain hole in the bottom of the filter every time the engine oil is changed. After every 600 hours of operation or more often, the lubricating oil filter should be disassembled and thoroughly cleaned in petrol. The filter element should be blown dry with compressed air.

Cloth type

On MD 96 and TMD 96 engines, the lubricating oil filter consists of a cloth filter fitted on the starboard side of the engine.

Each time the engine oil is changed, the filter cloth should be cleaned with clean fuel oil or paraffin. If the cloth appears to be hard or worn, it should be replaced. Otherwise it should be changed after every 600 hours of operation or more often. Clean out the filter housing with clean rags. Do not use cotton waste.

Replacing the filter cloth

Fig. 19. Replacing the filter cloth.

1. Clean the lubricating oil filter thoroughly externally.
2. Drain off the oil by removing the bottom plug.
3. Loosen the cover nuts. Remove the cover and the filter element.
4. Clip the wire retaining the old filter cloth and remove it from the cloth holder. Clean the cloth holder.
5. Use clean hands to pull the new cloth over the cloth holder until about 10 mm (½") is outside the holder. Make a running loop in one end of the cord supplied with the cloth and tighten the cloth securely in the groove at the end of the cloth holder. Wind the cord twice in each groove (see Fig. 19) and knot it in the terminal groove (Fig. 20). Always use genuine Volvo filter cloths.
6. Fit the filter element. Use a new felt seal at the lower part of the filter if necessary. Fit a new gasket. Fit the cover and bottom plug.

Fig. 20. The filter cloth fitted.

Lubricating oil strainer

The oil strainer, which is attached to the oil pump, is accessible after the rear inspection cover on the oil sump has been removed.

In cases where the strainer is of the float type, the cotter pin on the pump cover suction channel is removed and the strainer can be pulled out.

Where the strainer is fixed, it consists of a strainer housing which is bolted into position on the pump cover and a strainer mesh which is maintained in the housing by means of a lock ring. To clean the mesh, the lock ring is removed whereby the mesh can be taken out.

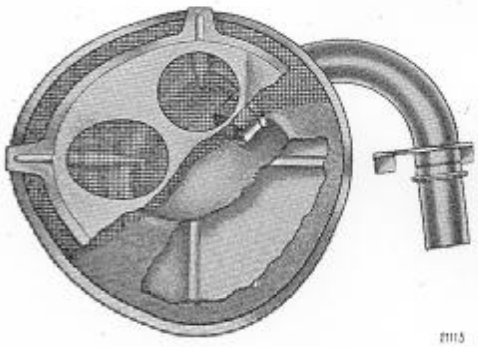


Fig. 21. Oil strainer, float type.

After every 1200 hours of operation or once a year, the oil strainer should be removed and cleaned if the inspection cover is not altogether inaccessible. If the inspection cover is not accessible, then the strainer can only be cleaned at the same time as the engine is given a major overhaul after about every 3600 hours of operation. It should be cleaned in petrol and blown dry with compressed air. Check after cleaning that the net is in good condition.

At the same time, the sump can be dried out with clean rags. Do not use cotton waste.

Always use a new gasket when fitting the cover. The same applies to the gasket between the cylinder block and the oil sump if this has been removed.

Oil cooler

Marine Diesel engines are filled with an oil cooler to chill the oil.

It is of the tubular type with sea water passing through the longitudinal tubes while the lubricating oil passes round the tubes. All the pressure oil passes through the oil cooler.

Cleaning the oil cooler

The oil cooler must be removed and cleaned when the engine is subjected to a major overhaul. It should be cleaned in petrol and blown dry with compressed air. The surfaces of the tubes which are in contact with water should be scraped clean.

Use new seal rings and gaskets when refitting.

If zinc electrodes are fitted, they should be removed for inspection once a month. If there are any deposits on the electrodes, a scraper or a steel brush should be carefully used to get rid of them. If an electrode has been corroded away to 50 % of its original size, it should be replaced with a new electrode.

THE FUEL SYSTEM

General Description

The fuel system consists of: the fuel tank, the fuel feed pump with pre-filter, the fuel filters with relief valve, the fuel injection pump and governor, the injectors and various pipe-lines.

Fuel is sucked by the feed pump from the fuel tank through the pre-filter and is then forced through the fuel filters to the fuel injection pump. The fuel injection pump then forces the fuel oil under high pressure to the injectors.

Excess fuel oil from the relief valve and leak-off fuel oil from the injectors runs back to the tank.

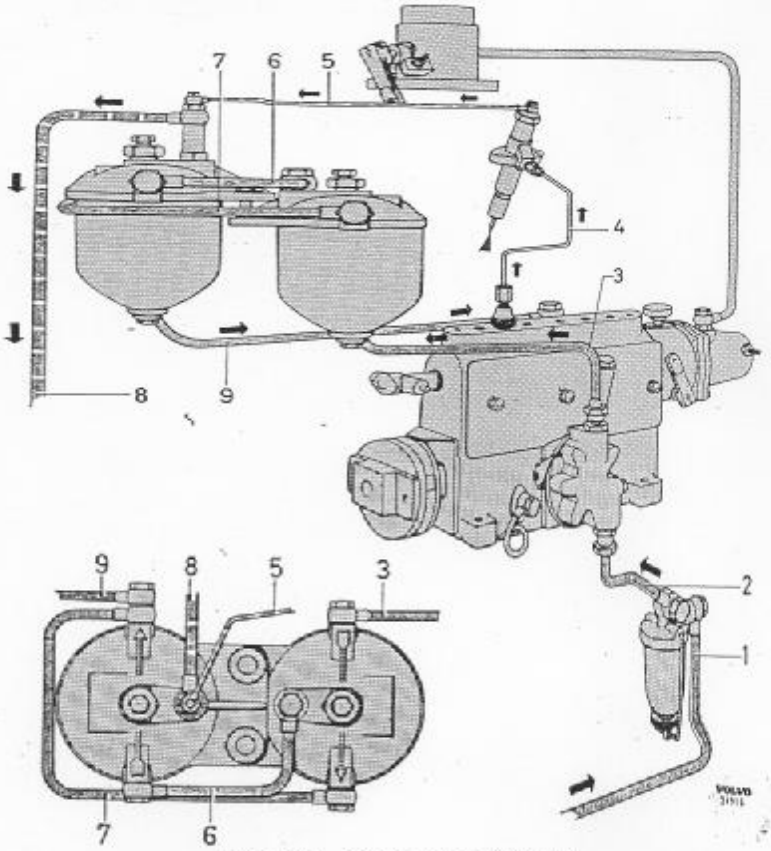


Fig. 22. Fuel system (C.A.V.)

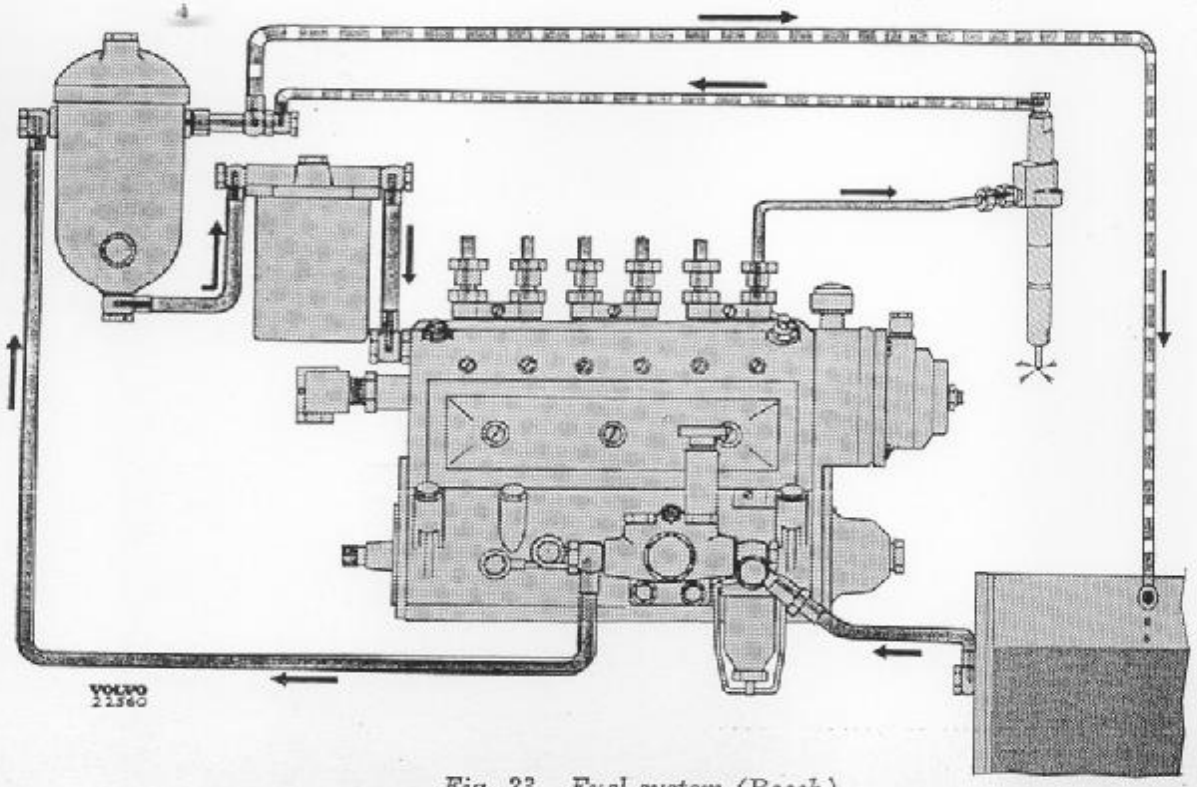


Fig. 23. Fuel system (Bosch).

Fuel

The fuel used in the engine should have the correct composition and should, above all, be free from impurities. Use only fuel oil of a well-known make.

Never use poor quality fuel oil since this can cause failure in the fuel injection pump and injectors.

The various makes of fuel oil that are available on the market contain a certain amount of impurities. If the fuel oil is stored in carelessly cleaned tanks and drums, the quantity of impurities will increase.

The engine is fitted with three built-in filters which are intended to serve as safety filters. Since the capacity of these filters is limited, however, the fuel oil must be free from impurities as much as possible before the tank is filled. It is absolutely essential for trouble-free operation to ensure that the fuel oil is absolutely free from impurities before it passes through the fine precision-made parts in the injection pump and injectors.

When tanking, always make sure that the vessels used are well cleaned. One way is to filter through an Ulax filter or a fine strainer (50 meshes per inch) with a cloth filter.

Always filter the fuel before filling the tank.

Before filling the fuel tank from storage tanks or drums, make sure that the fuel oil in these has stood still long enough for impurities to sink to the bottom. The storage tank or drum should be inclined 25 mm per metre (1 inch per yard) away from the drain cock in order to prevent impurities from collecting at the cock. If fuel oil is taken directly from a large storage tank without any smaller tank being used, there should be a sludge trap since the impurities will have a chance to settle in the large tank. The sludge trap should be drained now and then, preferably once a week.

Fuel feed pump

The function of the fuel feed pump is to suck the fuel oil from the fuel tank and pump it to the injection pump through the fuel filters. The capacity of the feed pump is calculated so that the amount of fuel oil supplied exceeds the requirements of the injection pump by a considerable margin. The excess fuel is taken through a relief valve and a return pipe to the fuel tank. This ensures a continuous air-venting of the fuel system.

The maximum pressure exerted by the feed pump is 1.5—2.5 kg/cm² (21—36 p.s.i.).

The normal feed pressure, however, is lower and should be 0.6—1.0 kg/cm² (8.5—14 p.s.i.), this pressure being obtained by the operation of the relief valve in the system.

The fuel feed pump is fitted directly onto the injection pump and is driven from the camshaft on the injection pump.

Plunger type feed pump

Hand priming is carried out by unscrewing the handle (1) from its lowest position and then pumping it up and down. Do not screw the handle back into position again too hard

Fuel recommendation

	Units	Specifications
Mechanical impurities		none
Water and sediment	% by vol.	max. 0.05
Combustion rating	cetane number	min. 45
Viscosity at +20° C	centistokes	min. 1.8
		max. 10
Pour point		at least 5° C below the lowest working temperature of the fuel
Distillation, 90 % distillation point	°C	max. 360
Carbon residue (Ramsbotten) on 10 % distillation residue	% by wt.	max. 0.2
Ash	% by wt.	max. 0.01
Sulphur	% by wt.	max. 1.0
Corrosion		neutral

after use since the tightening on the underside of the hand primer pump can thus be damaged.

Since the internal parts of the pump obtain sufficient lubrication through the circulation of the fuel oil, only a few drops of oil are required now and then on the hand primer pump plunger rod (2).

The maximum lift of the pump is about 1.4 metres.

1. Primer handle
2. Lock pin
3. Guide for plunger rod
4. Plunger rod
5. Housing for hand pump
6. Plunger for hand pump
7. Inlet valve
8. Valve spring
9. Screw connection
10. Pre-filter holder
11. Banjo plug
12. Filter cover
13. Filter element
14. Bail
15. Spring for filter element
16. Tension nut
17. Plug
18. Plunger spring
19. Plunger
20. Valve seat
21. Pump housing
22. Screw connection
23. Lifter shaft
24. Lifter roller
25. Lifter
26. Push rod

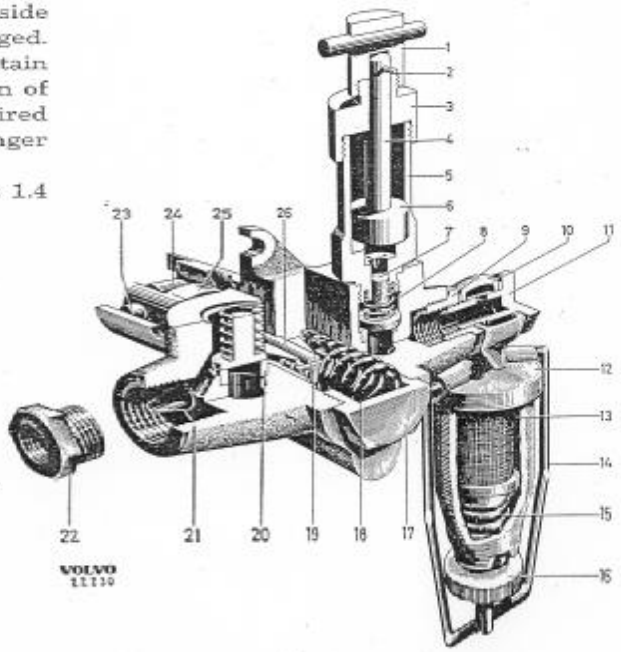


Fig. 24. Fuel feed pump, plunger type.

Plunger-diaphragm type feed pump

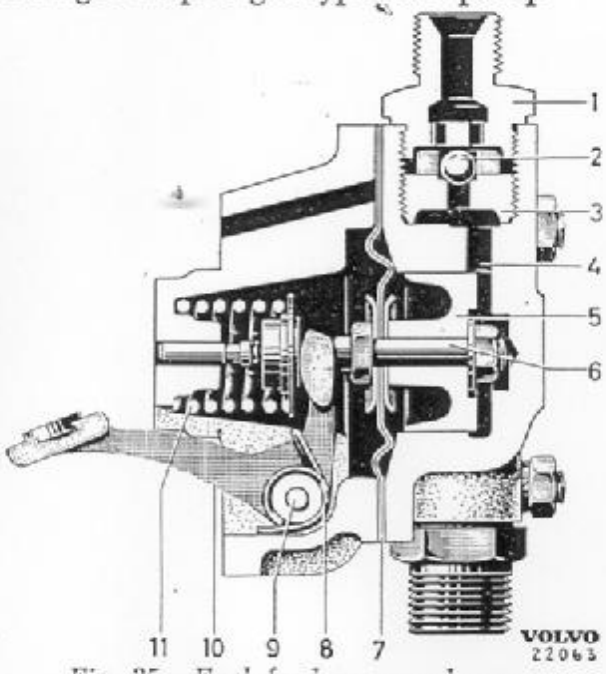


Fig. 25. Fuel feed pump, plunger-diaphragm type.

1. Valve housing
2. Valve ball
3. Valve seat
4. Pressure channel
5. Plunger
6. Pull rod
7. Diaphragm
8. Rocker arm springs
9. Rocker arm shaft
10. Rocker arm
11. Plunger spring

The hand primer is in the form of a lever and operates through a cam directly on the diaphragm thrust plate. If the handle operates very easily then it is probable that the injection pump cam is holding the diaphragm in its inner position. The hand primer will not then function. Use a lever or use the starter motor to turn the engine over to another position and then try the hand primer again.

The maximum lift of the pump is about 7 metres.

Fuel filter system

Pre-filter

This is fitted directly to the feed pump and its element consists of fine-mesh wire net. Under normal operating conditions, this filter should be cleaned after every 200 hours of operation. If the gasket on the bowl is hard or damaged, it should be replaced.

Fuel filters

The purity of the fuel when it enters the injection pump is completely dependent on the capa-

bility of the fuel filters to trap impurities. Since the purity of the fuel is a vital factor for the length of life of the pump elements and the injectors, the servicing of the fuel filters should be given very special attention.

C.A.V.

Engines fitted with C.A.V. Diesel equipment have two fuel filters connected in parallel (see fig. 22), each consisting of a metal container with a filter element made of specially-treated paper.

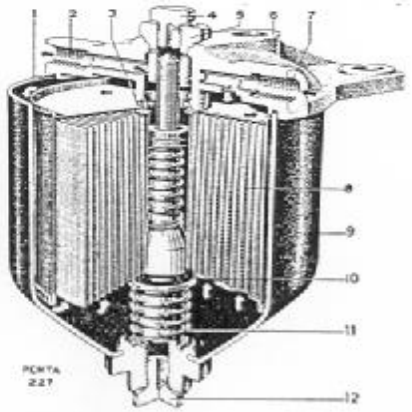


Fig. 26. Fuel filter, C.A.V.

1. Gasket
2. Oulet connection
3. O-ring
4. Air-venting screw
5. Nut
6. Filter cover
7. Inlet connection
8. Filter element
9. Filter housing
10. O-ring
11. Spring
12. Plug

Replacement of filter element

The time when filter element replacement is to be carried out is decided by the feed pressure. This should therefore be checked before replacement is carried out. When the feed pressure has gone down to 0.5 kg/cm² (7 p.s.i.), both filter elements should be replaced simultaneously. An operating time of 1200 hours between filter element replacement may be considered normal.

Fuel filters are replaced in the following way:

1. Clean the filters and pipeline thoroughly externally. Take care to remove all dirt from projecting edges. Blow clean with compressed air. Remove the drain plug and let the fuel oil run out.
2. Remove the nut above the cover and remove the filter containers with filter elements from both filters.
3. Remove the filter elements and remove the sludge trap plugs from the bottoms of the containers.
   Clean the containers thoroughly and blow them dry with compressed air.
4. Remove the gaskets from both covers, clean the covers internally and blow dry with compressed air.
5. Screw the plugs in the containers and insert the filter elements. Fit new cover gaskets, fit the containers and tighten the cover nuts.
6. Open the air-venting screws and operate the hand primer pump to feed fuel to the filters. Continue this until fuel free from air has passed out through the air-venting screws. Then close the air-venting screws.
7. Air-vent the fuel system in accordance with the instructions under the heading "Air-venting the fuel system".

BOSCH

Engines fitted with Bosch Diesel equipment have two fuel filters which are connected in series, i.e. the fuel passes first through one of the filters and then through the other. See fig. 23. Each filter consists of a filter housing with cover, filter element, connections, drain screw and air-venting valve.

The question of replacement affects the upper, large filter first. The reason for this is that the fuel oil passes first through the pre-filter and then through the large fuel filter. The smaller, lower filter is sealed and serves as a safety filter. It should not be opened before this proves to be absolutely necessary.

Replacement of filter element

The time when filter element replacement is to be carried out depends on the fuel feed pressure. This should therefore be checked before deciding on filter replacement. Then the fuel feed pressure has gone down to 0.3 kg/cm² (5 p.s.i.), the upper filter element should be replaced. An operating time of 1200 hours between filter element replacement may be considered normal.

Should the fuel feed pressure be found to be low even after replacement of the upper filter

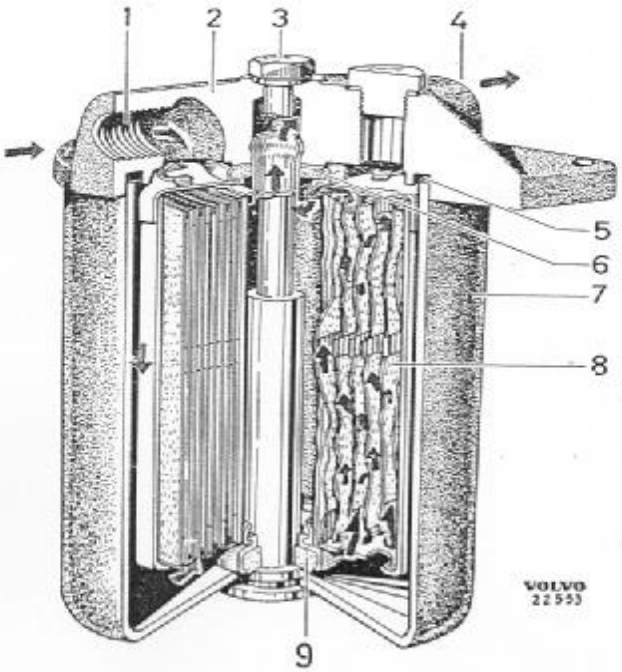


Fig. 27. Fuel filter, Bosch.

1. Inlet
2. Cover
3. Bolt
4. Outlet
5. Gasket
6. Felt packing
7. Housing
8. Filter element
9. Felt packing

element, the lower filter element must be replaced as well.

The filter elements are replaced in accordance with the instructions for C.A.V. where these apply. In cases where it is necessary to replace the element in the lower filter, this should be sealed again after replacement.

Checking the fuel feed pressure

If the engine output decreases or there is reason to believe that the fuel filter is blocked, the fuel feed pressure should be checked.

If the relief valve spring is weak or the valve is leaking, the engine output will be weak or it will be difficult to start.

Fuel feed pressure is checked by connecting a pressure gauge to the fuel injection pump air-venting screw as shown in Fig. 28. The engine

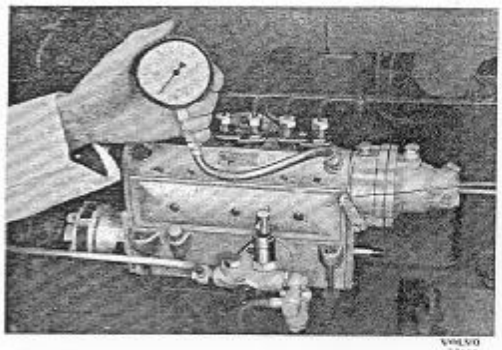


Fig. 28. Checking the fuel feed pressure.

is then run at idling speed and the pressure gauge reading is noted. Feed pressure should normally be 0.6—1.0 kg/cm² (8.5—14 p.s.i.). If the feed pressure is lower than 0.5 kg/cm² (7 p.s.i.) for C.A.V. and 0.3 kg/cm² (4 p.s.i.) for Bosch, make sure that there is sufficient fuel in the tank. Then check the pre-filter, fuel filters, relief valve and feed pump in that order.

Relief valve

The function of the relief valve is to limit the pressure in the fuel system and to make possible a continuous air-venting of the fuel system. The relief valve is fitted to the upper fuel filter.

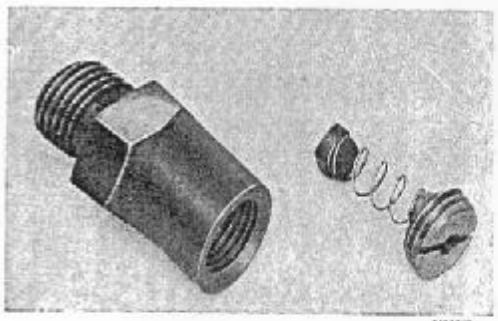


Fig. 29. Relief valve.

The relief valve consists of a sleeve in which a spring-loaded peg moves, the spring holding the peg on its seat. As soon as the pressure exceeds 0.6 kg/cm² (8.5 p.s.i.), the peg is forced back against the spring and fuel can flow out past the peg to the fuel tank. Any air bubbles there may be in the tank are also returned to the tank at the same time.

Testing

If there is reason to suppose that the relief valve is opening at excessively low pressures or functions in an unsatisfactory way then it should be examined. This is carried out in the following way:

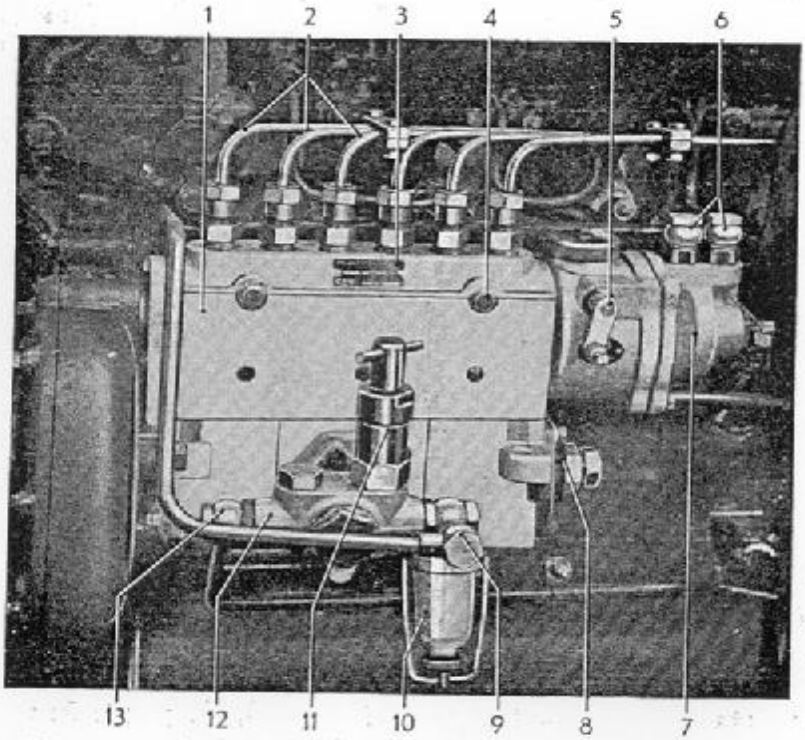
1. Give the hand primer pump a few strokes and open the air-venting screw on the fuel filter. There should be a fairly powerful surge of fuel out.
2. Operate the hand primer pump a few strokes, then wait ½—1 minute before opening the air-venting screw. If the surge of fuel passing out is weaker than before then this can depend on a leaking valve. The spring and peg should be replaced. If the seat is damaged, the complete valve should be replaced.

If test apparatus is available, then the relief valve should be removed and tested. The opening presure should be 0.6—1.0 kg/cm² (8.5—14 p.s.i.).

Fuel injection pump

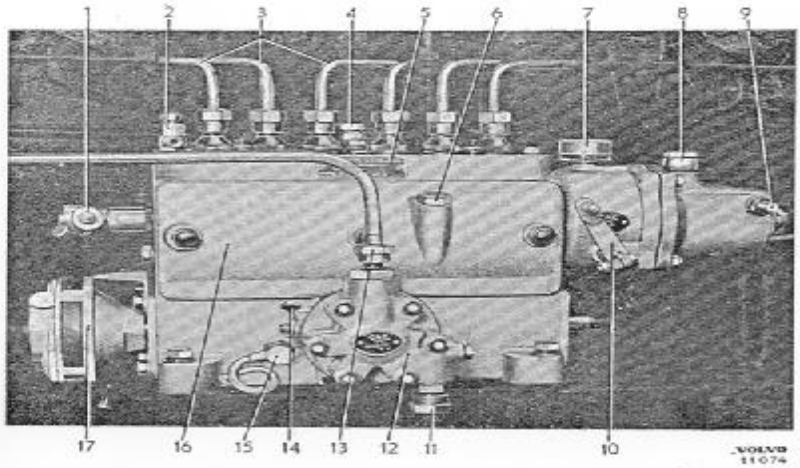
The engines are fitted with either C.A.V. or Bosch fuel injection pumps. Either of these types may be fitted on the same type of engine. The function and servicing of both types of pump are mainly similar. The following important rule always applies:

NOTE. *Adjustments and repair work on components in the Diesel system may only be carried out by experienced Diesel mechanies.*



1. Inspection cover
2. Delivery pipe
3. Plate showing type designation
4. Air-venting screw
5. Stop lever and cold starting device
6. Vacuum line from throttle housing
7. Vacuum governor
8. Disc with setting mark
9. Line from fuel tank
10. Pre-filter
11. Hand primer pump
12. Fuel feed pump
13. Fuel line to filter

Fig. 30. Fuel injection pump with vacuum governor, C.A.V. (on MD 47).



1. Cold starting device
2. Air-venting screw
3. Delivery pipe
4. Line from fuel filter
5. Plate showing type designation
6. Oil filler plug
7. Breather
8. Vacuum line
9. Shaft for idler lever
10. Stop lever
11. Pipe from pre-filter
12. Fuel feed pump
13. Pipe to fuel filter
14. Hand primer pump
15. Oil level pipe
16. Inspection cover
17. Coupling

Fig. 31. Fuel injection pump with vacuum governor, C.A.V. (on MD 67).

1. Cold starting device
2. Plate showing type designation
3. Delivery pipe
4. Air-venting screw
5. Air filter and lubrication
6. Stop lever
7. Idling setting
8. Connection for revolution counter
9. Fuel feed line
10. Hand primer pump
11. Fuel feed pump
12. Oil level pipe
13. Fuel dipstick
14. Steel disc coupling

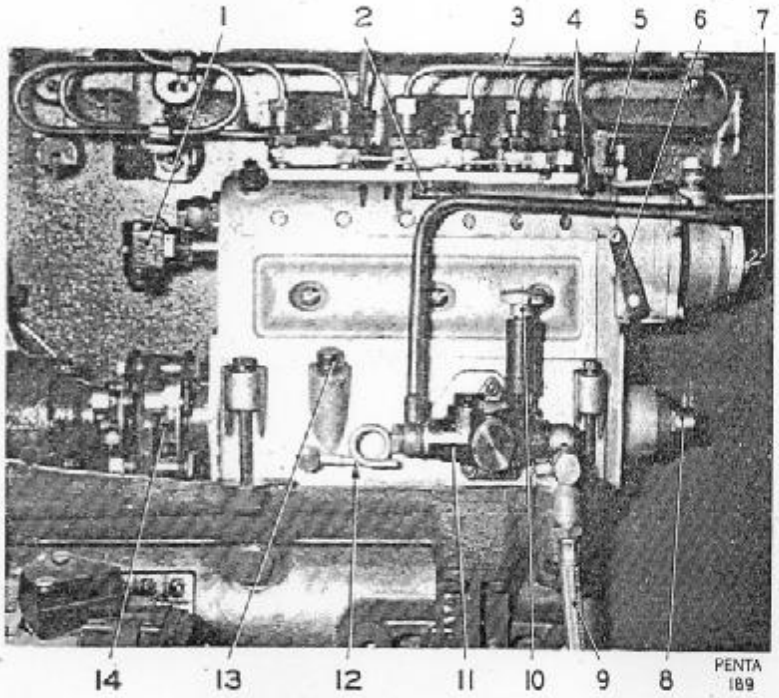
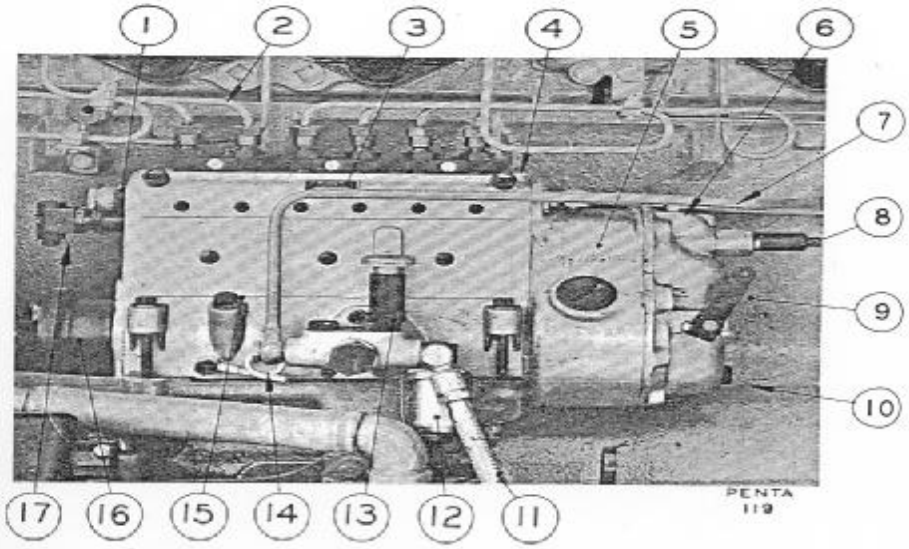


Fig. 32. Fuel injection pump with vacuum governor, Bosch (on MD 96).



1. Pipe from filter
2. Delivery pipe
3. Plate showing type designation
4. Air-venting valve
5. Centrifugal governor
6. Oil filler
7. Fuel pipe to filter
8. Stop control
9. Setting arm (speed control)
10. Oil level plug (oil dipstick on late production models)
11. Pipe connection from fuel tank
12. Pre-filter
13. Hand primer on feed pump
14. Oil level pipe
15. Oil dipstick
16. Coupling
17. Cold starting device

Fig. 33. Fuel injection pump with centrifugal governor, Bosch (on TMD 96).

1. Breather
2. Stop lever and cold starting device
3. Inspection plug
4. Idling damper
5. Control rod
6. Idling adjuster screw
7. Max. speed adjuster screw
8. Oil level plug
9. Cooling water temperature control
10. Automatic stop device

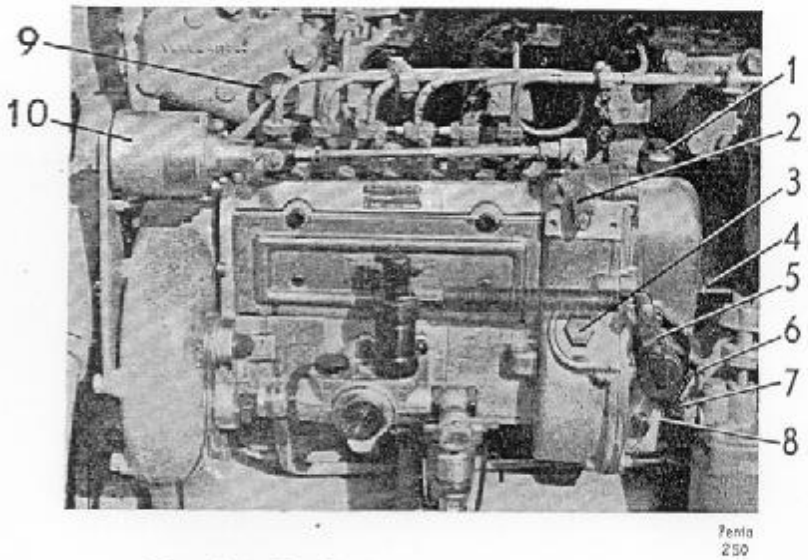


Fig. 34. Fuel injection pump with centrifugal governor C.A.V. (on MD 47).

Lubrication

The injection pump elements are normally lubricated by the fuel oil which seeps down into the crankcase to a small extent and dilutes the lubricating oil. Excess oil runs out through the level pipe.

The oil level should be checked at least once a week. In order to arrange a successive replacement of the lubricating oil in the camshaft housing, we recommend that even in cases where the injection pump is fitted with an oil dipstick, lubricating oil is added so generously that pure lubricating oil runs out through the level pipe.

Only lubricating oil should be added when fitting a new or reconditioned pump.

Use the same type of oil being used in the engine.

On the C.A.V. pump fitted to the MD 47 A engine, the inspection cover (1, Fig. 30) must be first removed before lubricating oil can be added through the connecting hole to the pump camshaft housing.

Inspection

After each 600 hours of operation, all breathers fitted on the injection pump and governor which are not sealed, should be removed and cleaned. Rinse them in petrol and oil them in before re-fitting.

The sealed breathers do not usually need to be cleaned except when the injection pump is tested. After cleaning, these breathers should be sealed again.

Always use a spanner on the hexagon when removing breathers otherwise they can be damaged.

The performance of the engine depends to a great extent on the fact that the injection pump settings are correct. Since conditions of operation vary considerably, it is difficult to state any particular intervals but, as a rule, a check of the pump coupling, injection setting, maximum and idling speeds, cold starting device, exhaust smoke etc., should be carried out after every 1200 hours of operation. The injectors should always be cleaned before this is done.

A thorough check of the injection pump in a test bench every other year or about every 3600 hours of operation is recommended to ensure that all the pump barrels are being equally loaded, that the pressure valves are in good order, etc. This is important for the length of life and reliability of operation of the engine. This check can suitably be carried out in conjunction with decarbonizing, valve-grinding, etc.

Governors

Fuel injection pumps are available fitted with either vacuum or variable centrifugal governors.

Marine Diesel engines used to drive propellers, are usually fitted with vacuum governors. An exception to this is TMD 96 which has a centrifugal governor.

Engines used to drive auxiliary equipment, on the other hand, are usually fitted with centrifugal governors.

Vacuum governor

Each position of the throttle flap in the throttle housing on the induction manifold corresponds to a certain speed. The governor tends to maintain engine speed as constant as possible.

The diaphragm in a vacuum governor, which is made of specially-treated hide, separates the governor into two sections, the governor housing and the diaphragm housing. Atmospheric pressure always prevails in the governor housing. Dependent on the degree of vacuum produced in the diaphragm housing by the throttle housing, the travel of the control rod varies and so the amount of fuel injected into the cylinders by the fuel injection pump is controlled by the position of the diaphragm.

When the engine is idling, comparatively great pressure variations in the throttle housing and in the governor occur so that the engine tends to run unevenly and the result is apparent in the form of "hunting" or "surging". In order to counteract this, the governor is fitted with a damping device.

There are two set-screws on the throttle housing (T and U) in order to carry out adjustments of the maximum and idling speeds of the engine. Adjustments are made at the factory before the engine is delivered and the set-screw for maximum engine speed (T) is sealed. This seal may only be broken by an experienced Diesel mechanic. After re-adjustment has been carried out, the set-screw should be sealed again.

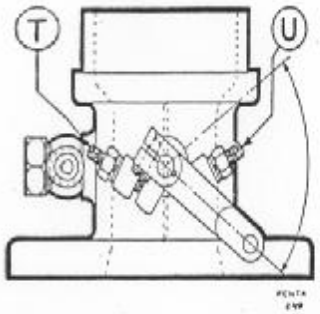


Fig. 35. Speed adjustment set-screws on throttle housing.

T. Set-screw for maximum engine speed (sealed).
U. Set-screw for idling speed.

Lubrication

If the vacuum governor is fitted with oil filler, a few drops of oil should be added each week. If a breather is fitted, on the other hand,

no lubrication is required since a mist of oil comes up through a channel from the pump housing and keeps the diaphragm sufficiently well lubricated.

Testing a vacuum governor

Leakage through a governor diaphragm that is not sealing properly can result in excessively high idling and maximum speeds. In order to find out if there is any leakage, the vacuum line(s) are disconnected from the top of the governor housing. All the connections should be carefully cleaned before this is done. Move the control rod and the diaphragm over to the stop position with the help of the injection pump stop arm. Block the hole(s) with your fingers and release the stop arm (Fig. 36). If the control rod remains in the stop position then the vacuum governor is not leaking. If, on the other hand, it returns to its original position, then the governor must be disassembled for replacement of the diaphragm or packing.

If there is no leakage in the diaphragm housing, then there is reason to believe that the vacuum pipe from the throttle housing to the governor is leaking. A check for leakage here is carried out in the same way but the screw unions at the throttle housing are loosened instead.

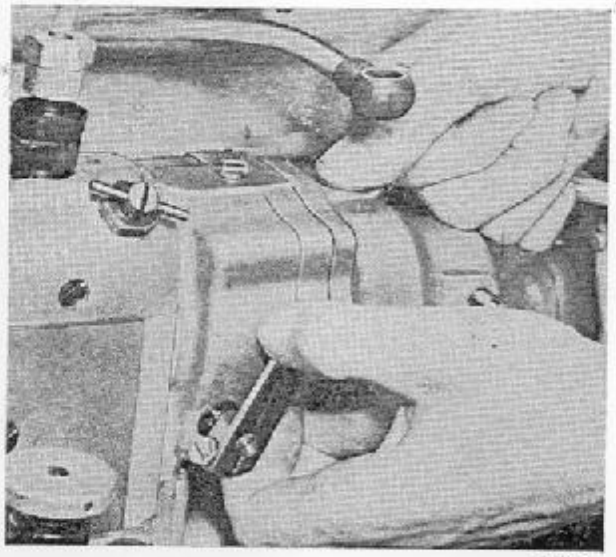


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Fig. 36. Testing the diaphragm for leakage.

Checking idling speed and maximum engine speed

A regular check should be carried out, preferably by an experienced Diesel mechanic, of the idling and maximum speeds. This can be done in conjunction with the pump inspection after every 1200 hours of operation. A check of the idling and maximum speeds should also be carried out if the pump has been removed for adjustment, if the seal on the throttle housing maximum speed set-screw has been broken as well as in other cases where it may be considered necessary.

Before checking and adjustment is carried out, the engine should be run warm and the air filter should be cleaned. Engine speed is checked either on the outer camshaft end on the injection pump or on the forward end of the crankshaft. This will also give a good check of the revolution counter on the instrument panel. Remember that the speed of rotation of the fuel injection pump is half that of the engine.

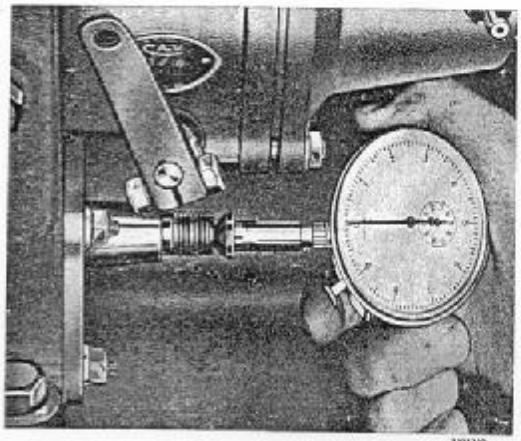

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Fig. 37. Checking engine speed.

Adjusting the idler damper device

Three different types of idling damper are used.

Model 1: Damping valve operated by the vacuum through an extra pipe from the throttle housing.

Model 2: An eccentric turned by a link system connected to the throttle control

Model 3: A damping spring in contact with the injection pump control rod.

Adjustment of the idler damper should be done at the same time as the idling and maximum speeds are checked. If the engine shows signs of "surging" or "hunting" while idling in spite of the fact that the engine has been run warm and the air filter has been cleaned, a minor adjustment can be carried out as follows while the engine is idling (500 r.p.m.).

For Model 1: Screw the damper valve on the rear edge of the governor housing, (see Fig. 30 and 39) out and in. Secure it immediately in the position giving the best idling. One quarter of a turn in each direction is usually sufficient. While carrying out adjustments, keep the lock nut as close to the housing as possible in order to avoid air leakage.

For Model 2: Loosen the clamp screw on the lever fitted to the port side of the control shaft. This control shaft is fitted on the after end of engine and the lever is connected through a link system to the idling shaft on the fuel injection pump (9, Fig. 31).

Seen from the port side, the lever is moved carefully so that the idling shaft is turned in a clockwise direction until good idling is obtained. Then lock the clamp screw.

For Model 3: Turn the screw on the after edge of the governor housing (7, Fig. 32). First loosen the nut then screw in the screw carefully and then outwards until the "hunting" or "surging" disappears. Then tighten the nut.

Never carry out excessive adjustments. The effect of this can be to alter the idling and maximum speeds. Should this happen, an experienced Diesel mechanic must be called in to carry out a complete checking and adjustment procedure.

If uneven idling should persist even though the adjustments mentioned above have been carried out, the reason can be:

Water in the fuel oil
Air in the fuel system
Blocked fuel filter
Uneven fuel feed
Faulty injector
Faulty governor
Faulty fuel injection pump.

Centrifugal governor

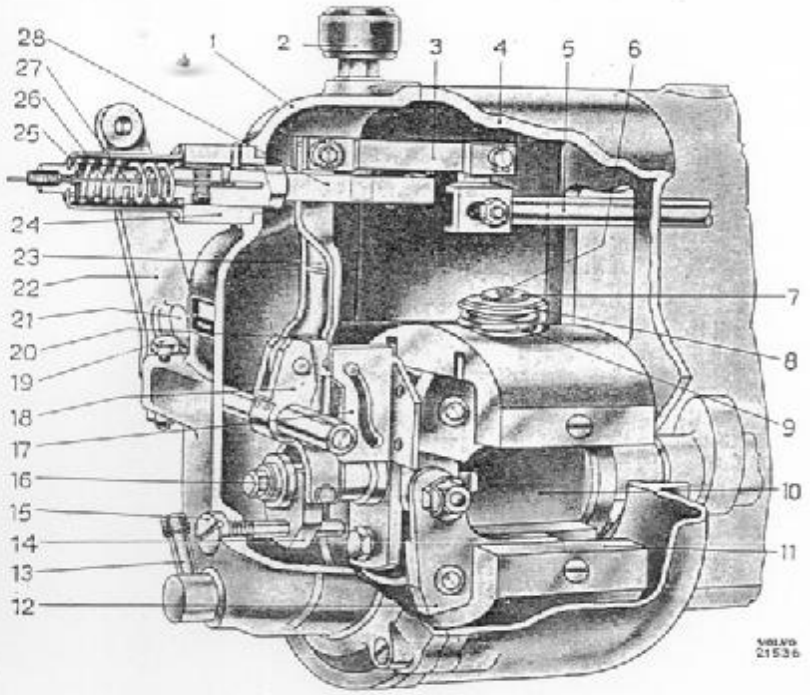


Fig. 38. Bosch centrifugal governor.

1. Cover
2. Evacuator and lubricator (for lubrication, the evacuator hexagon is loosened).
3. Yoke link
4. Housing
5. Control rod
6. Bolt
7. Adjuster nut
8. Outer washer
9. Springs
10. Hub
11. Governor weight
12. Bell crank
13. Plug (dipstick on late production)
14. Joint block
15. Guide pin
16. Joint coupling
17. Slotted plate
18. Link
19. Stop screw (idling adjustment)
20. Slide
21. Limiting stop
22. Adjuster arm
23. Connector arm
24. Sleeve for stop device
25. Spring casing
26. Spring
27. Cable
28. Catch unit

As opposed to vacuum governors, where the vacuum influences the control rod through a diaphragm, the control rods on centrifugal governors are influenced by weights acting under the effect of centrifugal force.

The centrifugal governor is of such a design that it controls the engine over its complete speed range. But in order to maintain the best degree of stability at any certain speed independent of the fact that the loading on the engine increases or decreases, a certain combination of springs should be used. (This occurs when the engine is being used to drive auxiliary equipment on board.) The correct spring combination is fitted and the maximum speed adjusted in accordance with the requirements of the customer at the factory before the engine is delivered. The set-screw is also sealed before the engine is delivered. If a higher engine speed is required than that for which the governor is set, the seal may not be broken before instructions in this respect have been ordered from Aktiebolaget Penta.

The idling speed may be adjusted (19, Fig. 38).

Lubrication

The centrifugal governor is splash-lubricated and the level of oil should therefore always be up to the level of the plug, (13, Fig. 38), in the end of the governor. Check the level of the oil both in the governor and the pump at least once a week. The plug should be removed and oil added through the lubricator on the top of the governor or, if there is no lubricator, through the large inspection plug hole until oil runs out through the plug hole. Use the same oil as you use in the engine. Regular oil changes are not necessary but the governor should be filled with completely new oil each time it is reconditioned.

In cases where the plug has been replaced by a dipstick, check that the oil is between the two marks on the dipstick. We also recommend that after about every 600 hours of operation, the dipstick retainer should be screwed out and the housing flushed out with a small quantity of oil. Then replace the dipstick retainer and fill with oil up to the right level.

Inspection

The function of the governor should be checked at the same time as injection pump inspection is carried out, or about every 1200 hours of operation.

Cold starting device

Starting in cold weather is facilitated if the fuel injection pump is equipped to supply the engine with extra fuel. Make a rule of always having the throttle "at the bottom" when starting the engine cold.

On C.A.V. fuel injection pumps, there are often cold starting devices connected to the stop control shaft. Such devices are operated by pulling out the shaft in the direction of the arrow in Fig. 39.

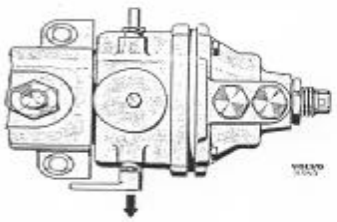


Fig. 39. Cutting-in the cold starting device, C.A.V. (on MD 47).

The most usual system on Bosch fuel injection pumps, and also on certain C.A.V. pumps, is to bring the cold starting device into effect by pressing the cold starting button, on the forward edge of the pump (1, Fig. 31 and 32).

On Bosch injection pumps with centrifugal governors as fitted to the MD 47, the cold starting device is automatically cut in when the throttle control is moved "to the bottom".

When the engine starts, the cold starting device is automatically disconnected in all cases.

NOTE. It is absolutely forbidden to block the cold starting device whereby it remains in operation all the time. The result will be that the engine receives too much fuel which can cause extensive damage without increasing output to any noticeable degree.

Stop control

The stop lever is fitted on the fuel injection pump. When this is moved to its outer position, the control rod moves the pump plungers to their zero feed position and the engine receives no fuel at all. Keep the stop control in its pulled-out position until the engine has stopped completely. Do not push the stop control in again until the engine is to be started again.

Injectors

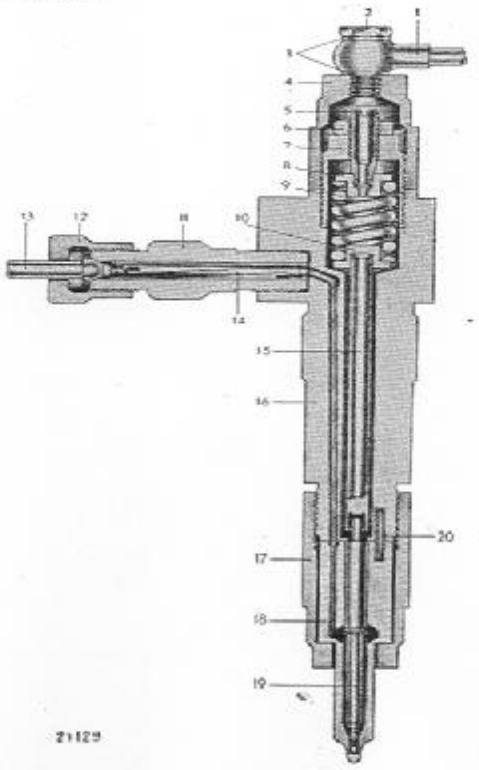


Fig. 40. Bosch injector.

1. Nipple for leak-off line
2. Nipple bolt
3. Metal washers
4. Cap nut
5. Set-screw
6. Lock nut
7. Spring retainer
8. Guide sleeve, upper
9. Spring
10. Guide sleeve, lower
11. Screw union
12. Cap nut
13. Delivery pipe
14. Filter (rod-type)
15. Push rod
16. Nozzle holder body
17. Nozzle nut
18. Nozzle
19. Nozzle needle
20. Guide pin

The injectors have the function of finely atomizing the fuel and injecting it into the cylinders. In order to ensure that the fuel oil is finely atomized, injection is carried out under extremely high pressure.

The movements of the nozzle needle are controlled by the pressure of the fuel oil and a spring. When the fuel pressure reached a certain value, the needle is lifted from its seat.

The injectors are fitted with four-hole tips. When the needle is lifted from its seat, four precision-calibrated holes are exposed. The opening pressure for the injectors should be 130—140 kg/cm² (1850—2000 p.s.i.), the value of each injector being as near that of the others as possible within these limits.

There is a leak-off line fitted to return to the fuel tank the small amounts of fuel oil that normally leaks past the nozzle needles in the injectors.

In order to ensure that the injectors are well cooled, they are fitted in special copper sleeves in the cylinder head. These copper sleeves are directly flushed by the cooling water.

Inspection

The extremely small holes in the tips of the injectors through which the fuel oil is injected into the combustion chambers can be blocked with carbon. It is therefore advisable to have spare injectors available at all times. If the engine runs unevenly and injector failure is suspected, it is easy to decide which of the injectors is at fault by loosening the nuts on the delivery pipes at the injector, one at a time. The injector in question will then be put out of action. If one of these nuts is loosened and there is no difference in the behaviour of the engine, then it is this injector that is faulty. This injector should be removed and one of the spares fitted. The faulty injector should be sent to a Diesel service station as soon as possible. Always exercise the greatest cleanliness when replacing an injector.

The injectors should be cleaned and adjusted at a Diesel service station at regular intervals. We recommend an operating time of 600 hours between reconditioning procedures but the most suitable time intervals depend on the fuel used and experience from the prevailing operating conditions. Faulty injectors mean incomplete combustion and subsequent damage to the engine. Make sure, therefore, that the intervals between injector reconditioning are not too long.

Removing

1. Clean and blow off all dirt from the injector and the delivery pipe as well as the adjacent parts of the cylinder block.
2. Disconnect the delivery pipe from the injector and fit a protector cap. Then disconnect the leak-off oil line.

3. Remove the nuts which retain the injector in the cylinder head. Lift up the injector.

   In order to avoid damage to the copper sleeve removing an injector, the injector should be twisted backwards when removing it. A special tool for the purpose can be used to advantage. In order to prevent water from seeping out when the sleeve is loosened, we recommend that part of the cooling water is drained off before an injector is removed.

Fitting

1. Rotate the engine a few times with the starter motor so that the copper sleeve (1, Fig. 41) is blown clean. Make sure that the stop control is pulled out. Check that the contact surface between the injector and the copper sleeve in the bottom is free from dirt and undamaged.

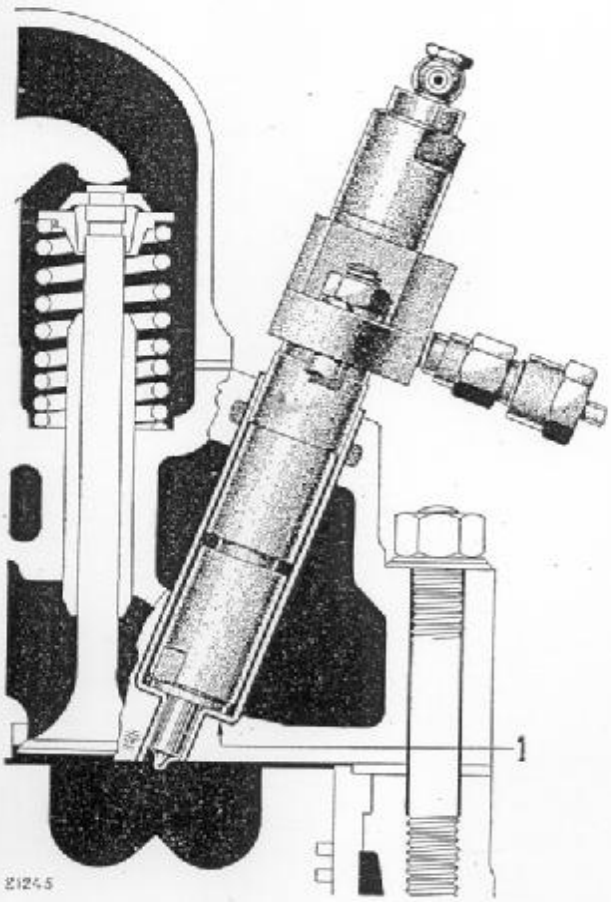
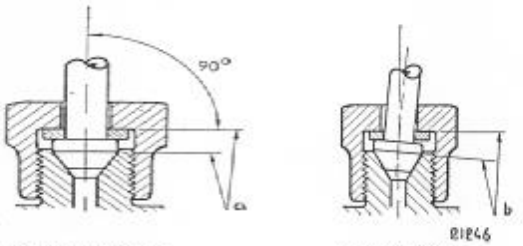


Fig. 41. An injector in position on the engine.

2. Insert the injector and tighten it. Tighten the nuts evenly and carefully. If the nuts are tightened unevenly, the nozzle needle can chafe in the nozzle. The tightening torque is 2.3—3.0 kgm (17—22 lb.ft.).
3. Connect the leak-off line. Replace damaged washers.
4. Connect the delivery pipe. Make sure that the cone is correctly located as shown in Fig. 42. If the cone is tightened when it is crooked, there is a risk of the delivery pipe fracturing after a time due to the stresses that develope.



Correct fitting
The planes (a) are parallel

Incorrect fitting
The planes (b) are not parallel

Fig. 42.

Delivery pipes

Replacing a delivery pipe

Fractured or leaking delivery pipes must be replaced. Repair by welding must not be carried out since the welding scale that results will gradually loosen and will be carried into the injector where it will cause severe damage.

A new delivery pipe should be flushed through with clean fuel oil before it is fitted.

The cones on the ends of the pipe should be carefully fitted in the screw unions on the fuel injection pump and the injetcor. It should be possible to tighten the nuts most of the way by hand. Final tightening should be carried out with an open-end spanner. If the pipe does not fit precisely, stresses can occur when the pipe is tightened causing fracture after a short time of use. See Fig. 42.

First tighten the screw union on the fuel injection pump and then the screw union on the injector. Do not forget to fit the clamps in position. If this is not done, the effective life-time of the delivery pipe will be considerably shortened.

Air-venting the fuel system

If the engine has not been used for some time or adjusting work has been carried out on the fuel system, careful air-venting must be carried out on the fuel system before the engine is started. The fuel filters are air-vented first and then the fuel injection pump.

1. Open the air-venting valves on the covers of both the fuel filters.
2. Feed up fuel oil by operating the hand primer pump until the fuel oil passing out is free from air bubbles. Then close air-venting valves.
3. Open the air-venting valve on the fuel injection pump and operate the hand primer pump until the fuel passing out is completely free from air bubbles. Then close the air-venting valve.
4. Continue to operate the hand primer pump to build up a good feed pressure.
5. If necessary, loosen the delivery pipes at the injectors and turn over the engine with the starter motor until the fuel running out is free from air bubbles. Then tighten the nuts.

COOLING SYSTEM

The engines are water-cooled. For protection against the corrosive effects of sea water, the cooling system is divided up into two separate parts — one for fresh water and the other for sea water.

Fresh water system

Water circulation is taken care of by means of a pump fitted to the front end of the engine. This pump sucks cooling water from the lower part of the heat exchanger and forces this water into the cylinder block. Inside the block it first cools the cylinder liners and then passes up to the cylinder heads and the exhaust manifold. The heated water is then taken through the thermostat(s) to the tank and the upper part of the heat exchanger. In the heat exchanger, the cooling water passes downwards through a system of tubes where it is cooled by sea water.

As long as the cooling water is cold, the thermostat(s) are closed and prevent flow to the heat exchanger. Instead, the water passes directly through a by-pass to the suction side of the pump. This means that the engine rapidly attains its operating temperature at the same time as the engine temperature is prevented from being too low when the weather is cold.

Coolant

The water used should be as clean as possible. The best type is rain water. Never add cold water to a hot engine since the sudden temperature change can cause cracks in the cylinder block or cylinder heads.

When water is being added, the air-venting screw on the thermostat housing should be open to get rid of any air in the cooling system.

On MD 47 engines, there is an air-venting pipe that terminates in the tank so that manual air-venting is not necessary.

In order to give the cooling water space to expand, the tank should not be filled to more than half; another check is to add water until it begins to run out through the air-venting screw on the thermostat housing.

Capacity of cooling system

MD 47	approx. 18 litres (4 Imp. gallons)
MD 67	approx. 20 litres (4.4 Imp. gallons)
MD 96	approx. 27 litres (6 Imp. gallons)
TMD 96 ..	approx. 27 litres (6 Imp. gallons)

To avoid having to drain off the fresh water in the event of frost, anti-freeze should be added to the cooling system. A good anti-freeze agent is a mixture of water and ethylene glycol (with added anti-rust agent). The amount of ethylene glycol should never exceed 60 % since a mixture of 60 % glycol and 40 % water gives the maximum depression of freezing point.

The table below shows the freezing points and specific gravities of various mixtures of water and ethylene glycol.

Freezing point	Spec. grav.	% by volume of glycol
— 4° C (+25° F)	1.012	10
— 9° C (+15° F)	1.027	20
—13° C (+ 9° F)	1.042	30
—22° C (— 8° F)	1.055	40
—38° C (—36° F)	1.068	50
—56° C (—69° F)	1.076	60

Before anti-freeze is added, the following procedure should be carefully carried out: (see also page 36).

1. Flush out the cooling system well with clean water.
2. Check that there are no leaks on the cooling system units, hoses, etc.
3. Tighten the cylinder head nuts. Check that the gaskets on the thermostat housing and cooling water pump seal effectively.
4. Check that the thermostat(s) function properly.

After the anti-freeze has been drained off after the winter, the cooling system should be thoroughly flushed out. Never use the same anti-freeze more than one season.

As far as drainage of the cooling system is concerned, see page 36.

Thermostat

In order to ensure that the engine reaches its normal operating temperature as soon as possible after it has been started, a thermostat is fitted. This has an important function since a suitable engine temperature and a shorter warmnig-up time reduces cylinder wear considerably.

If some fault should develope on the thermostat, it should not merely be removed but a new thermostat should be fitted in its place.

The thermostat is of the bellows type and is

balanced, that is to say it does not open under the effect of the pressure exerted by the cooling water pump. The thermostat is fitted in a special housing on the forward, upper part of the engine. On MD 96 and TMD 96 engines, two thermostats are fitted.

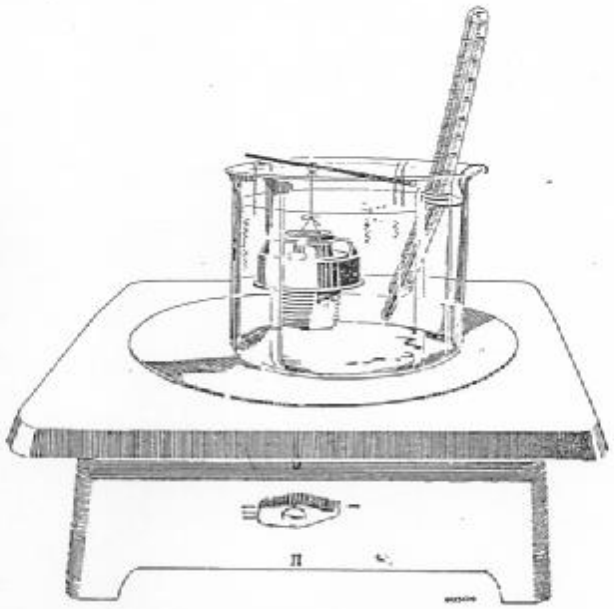


Fig. 43. Testing the thermostat.

The normal operating temperature of the cooling water is 70—85° C (158—185° F). If the engine temperature gauge shows large variations from this range, the thermostat(s) should be removed for testing. The thermostat should be heated up togother with a thermometer and the temperature at which it opens should be noted. The normal opening temperature is 74° C (165° F) for MD 47 engines and 72° C (162° F) for other engine types. If the thermostat does not open at the stipulated value, it should be replaced.

NOTE. The engine temperature gauge is by no means a precision thermometer so that any small variations indicated on this should not be taken as an indication that the thermostat should be replaced or the temperature gauge. The indicated temperature is, in point of fact, a check which shows that the thermostat is working and that the engine is not overheating.

Fresh water pump

The fresh water pump is of the centrifugal type and is driven from the crankshaft through the medium of a drive belt.

Lubrication

Use heat-resisting bearing grease. Lubricate with a grease gun after every 200 hours of operation but be careful not to pump in too much grease. 4—5 strokes with the grease gun is sufficient.

Sea water system

Usually, water is sucked in through the sea cock in the bottom of the boat through the reverse gear oil cooler to the sea water pump which then forces the water through the heat exchanger and the engine oil cooler. The water is then taken through a three-way cock either overboard or else to the exhaust pipe system depending on whether a dry or watercooled exhaust system is fitted.

Sea water pump

The sea water pump is made completely of bronze. The shaft is made of special metal and is carried in cased ball bearings. The impeller is made of neoprene rubber.

The function of the pump is shown in the illustrations below.

Check that the pump never runs dry. Friction can cause the impeller to loosen.

The pump is drained by removing the cover.

Fig. 44. Function of sea water pump.

Lubrication

The sea water pump requires no servicing from the point of view of lubrication. The ball bearings are completely enclosed and have sufficient grease to last the lifetime of the pump.

Replacement of impeller and seal

The impeller is replaced as follows: Loosen the screws in the pump cover and remove the cover. Insert two screwdrivers towards each other and force out the impeller, exerting pressure on the pump housing. Remove any bits of the impeller that may remain in the housing. Push the new impeller into position in the housing. Push the two rubber washers in the impeller to the end of the shaft. These washers are there to prevent sand and other solid particles from coming in and causing wear on the splines. Fit the cover. Make sure that there is always a spare impeller on board.

If the pump leaks on the opposite side to the cover, then the seal and the rubber O-ring should be replaced. They are accessible when the impeller has been removed. Use a hook or some similar tool to pull out the seal first and then the O-ring. The new components should be fitted in the reverse order to that used when removing.

Zinc electrodes

In order to provide as much protection as possible to metal parts in contact with sea water from corrosion by galvanic currents, there are zinc electrodes built into the heat exchanger and possibly in oil cooler. These electrodes should be removed and inspected once a month. Any deposits on them should be carefully removed by scraping or brushing with a steel wire brush. If an electrode has been corroded to 50 % of its original size, it should be replaced with a new electrode.

General

Draining off the cooling systems

After the engine has been run warm, the filler cap should be removed, the air-venting valve (if any) on the thermostat housing should be opened and the sea cock in the bottom of the boat should be closed. The following drain points on the fresh water and sea water cooling system are then opened:

1. Cock on port side of engine.
2. Cock on underside of exhaust manifold (if fitted).
3. Cock on forward edge of heat exchanger.
4. Cock on engine oil cooler.
5. Cover on sea water pump.
6. Plug or cock on reverse gear oil cooler.
7. All cocks that may be fitted on water pockets in the cooling water and exhaust pipe cooling systems.

When only the sea water cooling system is to be drained, se points 3—7.

Cleaning the cooling system

The cooling system only functions completely effectively when all the channels in the cylinder block, cylinder heads and the heat exchanger are free from deposits and impurities.

Water almost invariably contains certain salts which, due to the relatively high temperatures occurring in the fresh water cooling system, form deposits in the cooling channels and jackets. These deposits together with the rust that is always there as well as solid impurities which gradually block the channels, combine to make the cooling system so ineffective that the engine will boil as soon as it is loaded or the temperature of the sea water goes up.

This trouble can be avoided by:

(a) using clean water, preferably rain water with rust preventitive added. (Always make sure that the rust preventitive used has not a damaging effect on aluminium alloys. There are parts made of these alloys in the fresh-water system.)

(b) keeping the clean water in the engine for long periods. Change the water only twice a year when anti-freeze is added or drained off. Flush out the fresh-water system with water, steam at a pressure of 1 kg/cm² (14 p.s.i.) or suitable soda solution.

Flushing with soda solution should be carried out when there is reason to suspect that there are deposits in the fresh water system channels and jackets. Dissolve 1 kg. of ordinary soda in 20—25 litres of boiling water (2.2 lb. of soda in 4.4—5.5 gallons of boiling water). The cooling

system should be drained and the soda solution added. Then run the engine (preferably without thermostats) with the sea water pump drive belts removed so that the engine starts boiling. Maintain the soda solution at this temperature for about 20 minutes before draining and flushing out the system with clean water. While the engine is boiling, the filler cap should be removed.

During normal operation, if the engine temperature should go up and the engine should begin to boil, then there is reason to believe that the fresh water cooling system has become blocked as described above. But since the boilnig can depend on so many other factors, an examination should be carried out to determine the cause of the poor cooling. Make sure that the sea cock is not blocked first, then check that there is good flow through all the cooling water pipes in the sea water system. Make sure that the cocks and valves in the system are not blocked. Check that the sea water pump is working properly and that its drive belts are not slipping. Make sure that the thermostats are in good condition.

If it is found that the heat exchanger is blocked or has an excess of heat-insulating deposits on the sea water side, the following procedure is recommended:

1. Remove the heat exchanger from the engine.
2. Remove the zinc electrodes and drain cocks.
3. Prepare a bath consisting of 1 part of hydrochloric acid to 2 parts of water. Add 0.2 kg. (7.5 oz.) of oxalic acid to every 10 litres (2.2 Imp. gallons) of the above bath.
4. Immerse the heat exchanger in this bath and lift it out as soon as foaming and bubbling has ceased. This should take between 30 seconds and one minute.
5. Flush out thoroughly with hot water.
6. Fit the heat exchanger. Check the gaskets.

Leakage in the heat exchanger

Leakage can occur in the heat exchanger due to heat tensions and galvanic corrosion. Since the sea water is under higher pressure, it will be forced into the fresh water in the case of leakage and will dilute the fresh water. The amount of water in the fresh water cooling system will then increase so that the water tank is filled and water will run out through the filler cap air hole.

The engine suffers in no way by being run under such conditions but the heat exchanger should be repaired, naturally, as soon as possible.

Drive belts

Due to wear or due to the presence of oil grease, the drive belts can start slipping and cause the engine to boil.

The drive belts are tensioned by loosening bolts 1 and 2 and pulling the dynamo or tensioner outwards. See Fig. 45. When correctly tensioned, it should be possible to push in the belts about 5—10 mm (¼"—½") at a point midway between the pulleys, depending on the distance between them.

NOTE. Do not stretch the belts too much. The most common cause of belt breakage is excessive tensioning.

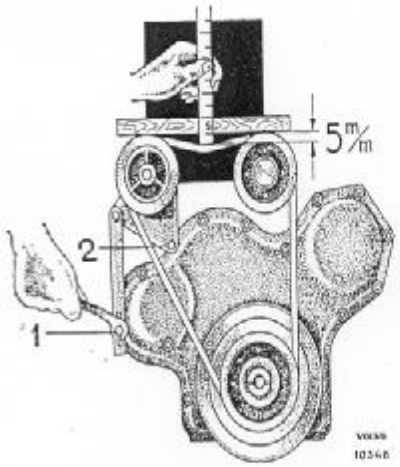


Fig. 45. Adjusting drive belt tension.

Belt tensioner

In cases where a belt tensioner is fitted, this should be lubricated with bearing grease after about every 50 hours of operation if there is a lubricating nipple. Otherwise, the tensioner should be removed and the cage on the enclosed ball bearing should be cleaned and packed with new bearing grease once a year or after every 1200 hours of operation.

AIR FILTER

All the air passing into the engine through the induction manifold must first go through a dry-type air filter which traps all particles of dust and other impurities. Since the air filter becomes gradually blocked by these impurities, it must be cleaned after a certain time. It is usually sufficient to clean the air filter at the same time as the engine oil is changed, that is to say after about every 200 hours of operation. When the engine is running under dusty conditions, the air filter must be cleaned more often.

Regular cleaning of the air filter is of particular importance in the servicing of a Diesel engine. If the air filter is blocked, the degree of vacuum prevailing in the induction manifold will increase and influence the vacuum governor on the fuel injection pump so that this comes into operation at a lower engine speed than it should. This does not apply, however, on engines fitted with centrifugal governors. In this case, the indication of a blocked air filter is usually thick heavy smoke.

Another reason why the air filter should be cleaned thoroughly is that on an engine with the crankcase breather hose attached to the air filter, the consumption of lubricating oil will increase. The reason for this is that the suction effect from the crankcase is increased and oil vapour is sucked over and is burned in the engine cylinders.

The air filter element(s) should be removed and rinsed thoroughly in fuel oil before being blown dry with compressed air.

THE ELECTRICAL SYSTEM

The electrical system consists of the battery, the dynamo, the charging regulator and the starter motor.

Standard MD 47 engines have a 12-volt system while the other types of engines have 24-volt systems. There are both single and double-pole systems. A special wiring diagram accompanies each engine when it is delivered.

Battery (lead accumulator)

The starter motor is the unit which exerts the greatest loading on the battery. For this reason, the starter button should not be depressed for more than 5—10 seconds at a time. If the engine does not start the first time, wait for a few seconds to allow the battery to recover. Heavy and continuous loading will shorten the life of the battery considerably.

Check every 14 days or more regularly that the level of the electrolyte is always about 5—10 mm (¼"—½") above the upper edges of the plates. Top-up with distilled water when necessary.

The state of charge of the battery can be determined by the use of a hydrometer which shows the specific gravity of the electrolyte. When a battery is fully charged, the specific gravity of the electrolyte is 1.275—1.285 at 20° C (68° F). When the specific gravity has gone down to 1.230, the battery should immediately be sent to a charging station.

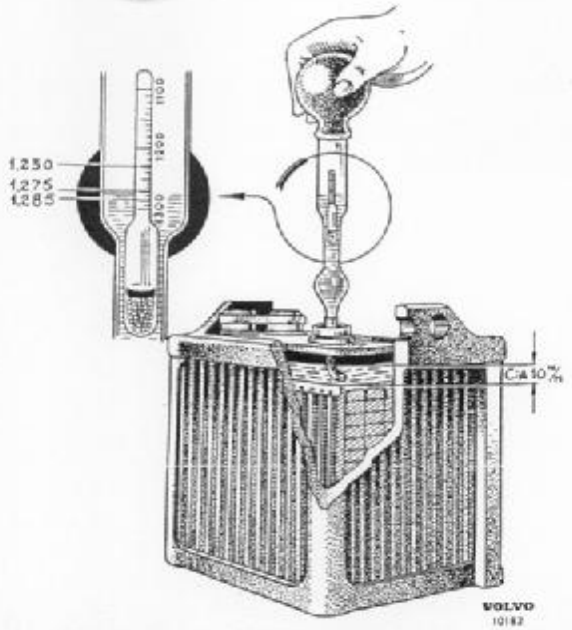


Fig. 46. Checking the specific gravity of the battery electrolyte and the electrolyte level.

During the winter, the loading on the battery is always greater than during warm weather due to more difficult starting and subsequent increased current consumption. Since the risk of damage by freezing increases as the state of charge of the battery decreases, then the state of charge of the battery should be checked more often during the winter.

Check that cable terminals are well tightened and smeared with vaseline free from acid.

New batteries are available in three states of charge: uncharged, dry-charged and finally charged. The directions supplied by the manufacturers should be followed in all cases.

If the battery is uncharged, it must be filled with electrolyte and then charged with a low current (60—70 %) compared with subsequent charging, for a comparatively long time, normally 50—60 hours.

A dry-charged battery is already charged but the electrolyte has been drained off and must thus be added again. The battery can then be used directly without any further charging being necessary.

A finally charged battery is filled with electrolyte and is therefore ready for use straight away.

We recommend that only authorised charging stations are used so as to avoid any mistakes that may affect the strength and condition of the battery. Charging time for subsequent charging varies depending on the strength of the charging current used and the condition of the battery. A normal time is 12—20 hours. The charging current depends, in its turn, on the capacity of the battery. A general rule is that the charging current should not exceed 1 amp. for every positive plate in a cell. If the battery has a total of 11 plates per cell then the charging current should not exceed 5 amps., for 13 plates 6 amps., 15 plates 7 amps., etc.

If the battery is to be stored for some considerable time than it should be kept in a fully charged condition. For this reason, it should be given a charge with a weak current once a month.

The size of the battery selected depends on the output required for different periods of time and the size of the dynamo. Standard recommendations are: a battery capacity of 190 amp. hours for the MD 47 engine and 152 amp. hours for other engines.

Starter motor and dynamo

The commutators and brushes should be checked after about every 1200 hours of operation. If the commutator surface is rough and uneven, it should be polished with fine sandpaper (no. 00). Never use emery cloth or a file. If the brushes are dirty, they should be removed and cleaned in petrol.

At the same time as the engine is decarbonized (after about every 3600 hours of operation) or every other year, the starter motor and the dynamo should be checked over in a specialized auto-electric workshop.

Lubrication should only be carried out in association with this check-over.

If electrical apparatus is connected to the system, it is important to ensure that the dynamo is not overloaded with resultant burning.

Normal dynamo output used as standard is:

Engine type	Max. output	Continuous output "lamp load"
MD 47	450 watts	300 watts
Others	480 watts	380 watts

carried out on it, apart from routine servicing, is to replace it with a reconditioned unit.

Since there is oil in a turbo-compressor, it should never be tilted. If it should be tilted, oil can run onto the turbine and compressor rotors. When the unit is run, this oil carbonises and forms carbon deposits which disturb the balance to such an extent that the turbo-compressor is ruined very quickly.

Oil should, therefore, be drained off before disassembly. When fitting a turbo-compressor on an engine, bolt in into position on the engine before adding oil.

At the same time as a turbo-compressor unit is replaced, the setting of the fuel injection pump relative to the engine, the condition of the pump coupling and the maximum injected quantity of fuel should be checked.

Removing

1. Drain the oil off from the bearing housing so that the housing is empty when the turbo-compressor is removed from the engine.
2. Remove the bolts retaining the exhaust pipe compensator to the condensation collector vessel.
3. Disconnect both the rubber hoses at the compressor.
4. Loosen the nuts on the foot-plate and lift up the turbo-compressor.
5. Remove the compensator.

If the turbo-compressor is a water-cooled model, water should be drained off from the engine until it is certain that there is no water left in the turbo-compressor. Then loosen the water pipe-connections.

Fitting

1. Clean the contact surface on the exhaust manifold and fit a new gasket. Replace any of the stud bolts that are damaged.
2. Make sure that the reconditioned turbo-compressor to be fitted is clean. Remove the protector cover over the exhaust opening. Insert one hand and make sure that the exhaust turbine rotor and the compressor rotor rotate easily. Fit the compensator.
3. Lift up the turbo-compressor into position and bolt the foot-plate to the exhaust manifold.
4. Fit a new gasket and bolt the compensator to the condensation collector. Connect the rubber hoses to the compressor.
5. Fill the bearing housing with oil. This should be done slowly to allow the air to pass out. See under the heading "Oil changes".

Place the old turbo-compressor in the packing case and bolt it firmly into position to avoid damage during transport.

Depending on the way in which the engine is to be used and the way in which it is installed, various types of power take-offs are available both on the rear end of the engine (flywheel end) and the forward end.

When the engine is used to drive a propeller, there is normally a reverse gear with a reduction gear or a friction clutch with a reduction gear fitted on the rear end. On auxiliary units, there is normally a friction clutch or a flexible coupling fitted on the rear end. Power take-offs at the forward end are available in both cases in the form of friction clutches or flexible couplings. The following concerns maintenance procedure for the most usual types.

Reverse gears

All types of reverse gears with the exception of the S.L.M. type are directly flanged onto the flywheel housing and the reduction gears are built into the same unit as the reverse gears. Reverse gears are available in two models: either mechanical or hydraulic operation.

When installation is carried out, care must be taken to ensure that it is possible to slide the reverse gear about 200 mm (8″) astern in order to remove the reverse gear from the engine. It must thus be ensured that the propeller shaft with its flanges and the propeller have sufficient clearance astern.

If a remote control system is used between the wheel-house or the control position and the operating shaft on the mechanically-operated reverse gear, this must be carefully fitted and must be robust since the stresses on it are considerable. Attaching points for any right-angle levers used in the remote control system should be well bolted to the hull. Control rods in the system can be made to advantage out of tubular steel to reduce weight. Note that the control system should be designed so that full engagement in each direction is obtained and that the system is completely unloaded when in the "Ahead", "Neutral" or "Astern" positions. *Any loading on the operating mechanism in these positions will lead to rapid wear on the throw-out bearing.*

The control should always be operated with a steady, determined movement to the desired position. Check that full engagement has been obtained and that the clutch discs are not slipping. *When the reverse gear is being operated, engine speed may only exceed 800 r.p.m. in cases of emergency.*

"Twin Disc"

Description and operation

The Twin Disc reverse gear is mechanically operated and has a clutch of the Duplex type, that is to say there are two discs, one for running "Ahead" and the other for running "Astern". This design permits running "Astern" for comparatively long periods of time and, since the gear ratios for "Ahead" and "Astern" are the same for 2:1 and 3:1 reduction gears, this gives improved manoeuvring properties. This system

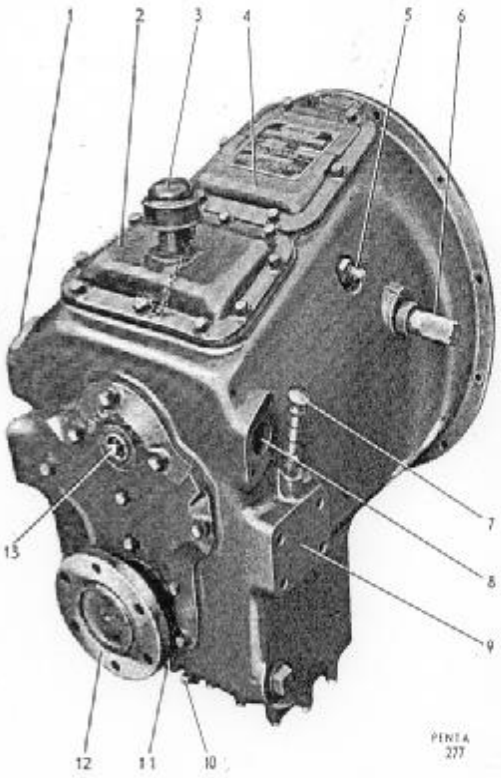


Fig. 50. Twin Disc reverse gear with reduction gear for MD 67 engine.

1. Sea-water connection
2. Inspection cover, reduction gear
3. Oil filler, breather
4. Inspection cover, reverse gear
5. Lubricating nipple for throw-out bearing
6. Operating shaft
7. Oil dipstick
8. Sea-water connection
9. Contact surface for support bracket
10. Oil drain point
11. Sea-water drain point
12. Propeller shaft flange
13. Lubricating nipple for flywheel pilot bearing

also provides the possibility for the installation of two contra-rotating propellers. The 4.38:1 reduction gear for "Ahead" operation, on the other hand, has a ratio of 3.80:1 in the "Astern" position so that contra-rotating propellers cannot be used in this case. The standard direction of rotation in the "Ahead" position is always opposed to the direction of rotation of the engine.

Adjustment

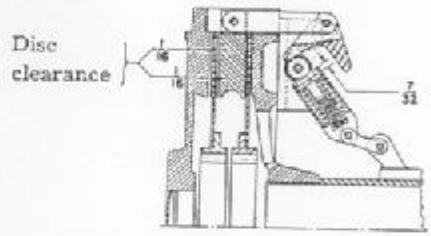
The spring-loaded levers (over-centre) are subjected to pressure from the springs in the thrust links. This spring-loaded mechanism is designed to compensate for wear on the discs so that no adjustment is necessary. With new discs, the clearance on each side is 1.5 mm (1/16") on one of the discs when the other is engaged. This clearance can reach a maximum value of 3 mm (⅛").

The easiest way to check for wear on the discs and determine the time for replacement is to check the position of the plunger i nthe thrust link. See fig. 51.

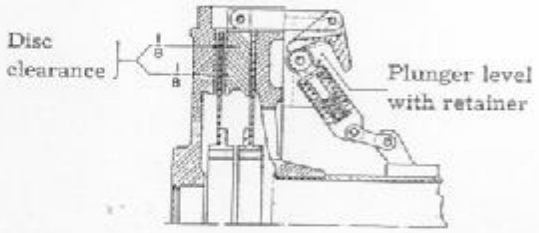
When the discs are new, the plunger in the thrust link is 5.5 mm (7/32") from the upper edge of the retainer when the reverse gear is engaged in the "Ahead" or "Astern" position. When the discs are so worn that they require replacement, the plunger is level with the upper edge of the spring retainer.

The normal operating torque for the MD 67 is approx. 13 kgm (94 lb.ft.).

The normal operating torque for the MD 96 is approx. 16 kgm (115 lb.ft.).



Engaged position with new discs



Engaged position with worn-out discs

Fig. 51. Clutch mechanism.

Lubrication

The reduction gear in the reverse gear unit should be lubricated with good quality SAE 40 engine lubricating oil (HD type) or SAE 80 gearbox (transmission) oil.

Check the oil level daily by means of the dipstick. The oil level should be between the two marks on the dipstick.

Change the lubricating oil and preferably flush out the gear housing after about every 600 hours of operation or at least once a year. The oil capacity is 3—3.5 litres (5¼—6¼ Imp. pints). During the running-in period, an extra oil change should be carried out at the same time as the corresponding oil change in the engine.

After about every 50 hours of operation, the flywheel pilot bearing (lubricating nipple 13, Fig. 50) and the throw-out bearing (lubricating nipple 5, Fig. 50) should be lubricated with high-class, heat-resistant grease with a melting point not below 150° C (300° F). Do not lubricate too much otherwise oil can come onto the dry disc clutch and cause slipping.

After about every 50 hours of operation, also the forward inspection cover should be removed and the moving parts of the clutch mechanism should be lubricated with a few drops of light oil.

"Snow Nabstedt"

Description and adjustment

The characteristic for this type of mechanically-operated reverse gear is that gear-changing is carried out through the medium of planetary gears.

For the MD 96:

"Ahead operation is obtained when the double cone clutch (4 H, Fig. 53) is pushed in. This is spring-loaded and designed so that no adjustment of the "Ahead" position is necessary between the normal inspections of the reverse gear which should be carried out at the same time as the engine is reconditioned.

If inspection shows that the cone clutch, though worn, is in good condition, it need not be replaced. Wear can then be compensated for by inserting a 1,5 mm (1/16") thick washer (18B) under each of the plungers on the engaging mechanism lever (13 x).

"Astern" operation is obtained when the band brake is applied so that it prevents the planetary

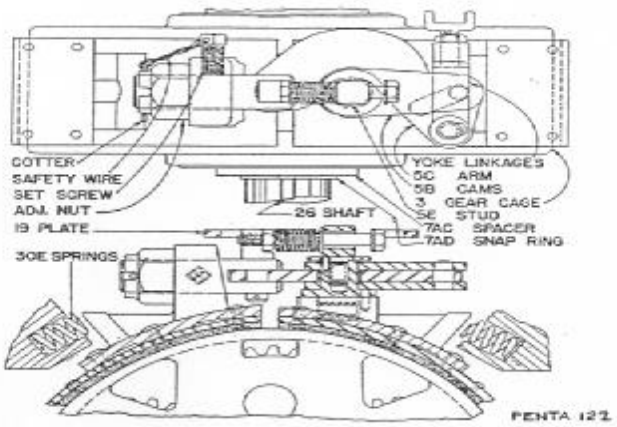


Fig. 52. "Astern" mechanism for MD 96 engine.

gear cage (3, Fig. 52) from rotating. The brake band becomes worn gradually and the reverse gear will slip in the "Astern" position. The brake band must then be adjusted as follow: Move the reverse gear lever to the neutral position, remove the cover on the upper part of the housing so that the mechanism is accessible. Then loosen the set screw (Fig. 52) and the cotter. Tighten the adjusting nut one sixth of a turn. Start the engine and engage "Astern". If the gear still slips, tighten the adjusting nut another sixth of a turn until the engine can be run full speed astern without the reverse gear slipping.

For the MD 47:

Adjustment in the "Ahead" position is carried out by loosening the stop-screw on the adjuster plate which is attached to the rear edge of the planetary gear housing. Turn the adjuster plate in a clockwise direction one notch at a time until the adjustment is correct.

Adjustment in the "Astern" position is carried out on the same principle as described above for the MD 96.

Never adjust the reverse gear while the engine is running. Before any adjustment is carried out, the remote control system (if any) must be disconnected. Use the reverse gear lever when carrying out adjustments.

When adjustments have been completed, fit the cotter and set screw and then attach the cover on the housing in position.

The normal operating torque for the MD 47 is approx. 15 kgm (155 lb.ft.).

The normal operating torque for the MD 96 is approx. 27 kgm (200 lb.ft.).

The reverse gear can be used separately or together with various reduction gears. In all cases, the speed is the same "Ahead" or "Astern". This type of reverse gear, however, does not permit running "Astern" for any long period of time.

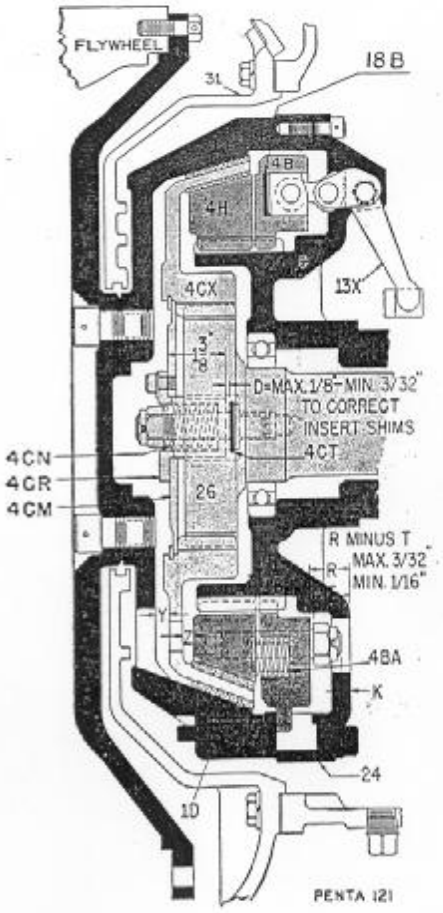


Fig. 53. "Ahead" mechanism for MD 96 engine.

Lubrication

The reverse gear and reduction gear are lubricated completely by means of splash lubrication. Use the same type of oil as used in the engine with a viscosity of SAE 30.

Check the oil level daily by means of the dipstick. The level should be up to the upper mark "H".

Change the lubricating oil and preferably flush out the reverse gear after about every 600 hours of operation or at least once a year. The oil capacity varies depending on the model of reduction gear used. For example: with a 2:1 reduction gear on the MD 47 approx. 4 litres (7 Imp. pints) and for the MD 96 approx. 6,5 litres (11¾ Imp. pints). During the running-in period, an extra oil change should be carried out at the same time as the corresponding oil change in the engine. All oil is added through the reverse gear. Never add oil to the reduction gear.

"Self-Changing Gears" (see Fig. 5) with "Standard" operating valve

Description and operation

This reverse gear is operated hydraulically through the medium of oil under pressure supplied by a pump which is built into the reverse gear. When the operating lever is turned to the "Ahead" or "Astern" positions, the oil passes through the operating valve to one or other of the clutches. Only slight pressure is needed to move the operating lever. Since the clutches are engaged and disengaged with the help of oil under pressure from the pump which is indirectly driven by the engine, then the engine must be running when the gear is operated. The oil pressure is nomally 5—7 kg/cm² (70—100 p.s.i.).

The planetary gears in the reverse gear do not permit "Astern" operation for any extended length of time. Since there is no reduction effect in the planetary gears, the speed of revolution is the same for "Ahead" and "Astern" operation. If different speeds of rotation are required for twin installations, reduction units with two or three gears are available. Reverse gears with or without reduction gears can be supplied. The normal reduction ratios are 2:1 and 3:1 (to be more precise: 2,03:1 and 2,95:1).

Adjustment and inspection

Engagement of the "Ahead", "Astern" and neutral positions is carried out hydraulically and no adjustment is necessary before the discs and the facings respectively are completely worn out. When this happens, the time taken for engagement will increase or, in extreme cases, the reverse gear unit will slip and the engine will show a tendency to race. Normally, the time taken for the gear to engage should not exceed 5 seconds after the operating lever has been moved from the neutral to the "Ahead" or "Astern" position. If the reverse gear slips, it should be disassembled and worn parts should be replaced. Another cause of gear slip is an excessively low oil pressure and this can depend on worn bushings or oil seals. At normal operating speed, the oil pressure should never be less than 3.5 kg/cm² (50 p.s.i.).

The reverse gear should be carefully inspected at the same time as the engine is checked over or after about every 3600 hours of operation.

Lubrication

The lubricating oil for the reverse gear is also used to move the gears between the "Ahead", "Astern" and neutral positions. Use the same type of oil as in the engine but with a viscosity of SAE 20 or 20 W. The oil capacity for the MD 67 and the MD 96 engines with reduction gears is about 14 litres (3 ⅛ Imp. gallons). Without the reduction gear, the oil capacity of the reverse gear is about 8 litres (1 ¾ Imp. gallons).

Check the oil level and the oil pressure daily. When the engine is switched off, the oil level should be as near the upper mark on the dipstick as possible.

Change the oil after every 1200 hours of operation or at least once a year. The oil is drained off by means of the plug on the rear edge of the reduction gear housing. At the same time, the suction filter (10, Fig. 5) should be cleaned. This is low down on the left side of the reduction gear housing and is attached by means of five stud bolts and nuts. There are puller holes in the filter housing flange to aid removal. The filter should be cleaned with fuel oil and brushed with a steel brush if necessary, Do not forget the gasket under the filter housing when re-fitting.

After every 200 hours (at the same time as the engine oil change), the main filter in the operating valve should be removed and cleaned in the same way as described above. Neither cotton waste nor rags should be used for cleaning purposes. When the filter in re-fitted, make sure that it comes correctly into position both on the guide in the bottom of the operating valve and on the guide in the hexagon. Run the engine and make sure that there is no leakage between the hexagon and the operating valve.

During the running-in period, an extra oil change should be carried out and the main filter should be cleaned at the same time as the corresponding oil change in the engine is carried out.

"Self-Changing Gears" with "Sequent" operating valve

The advantage with this operating valve is that both operation of the reverse gear and adjustment of engine speed can be carried out by means of the lever on the valve. The reverse gear is operated as described earlier while the engine speed is adjusted by means of a hydraulic control cylinder fitted on the engine and this influences the throttle controls through a series of links. Excess oil from the operating cylinder goes back to the reverse gear through another line. A further advantage of this valve is that all operation of the reverse gear is carried out while the engine is running at idling speed and this considerably reduces wear in the reverse gear.

When the lever is moved to the "Ahead" or "Astern" position, the reverse gear is first engaged while the engine, as already mentioned, is running the whole time at idling speed. When the respective gear has been engaged, further movement of the lever gradually increases the speed of the engine.

The instructions already given for the reverse gear with a standard operating valve apply also here but with the following exceptions: The oil pressure, which is controlled by a relief valve, should be 5.6 kg/cm² (80 p.s.i) at normal operating speed. At idling speed, this pressure can go down to 4.9 kg/cm² (69.5 p.s.i.). Abnormal variations in oil pressure can indicate that the relief valve is chafing. If the pressure is lower than 4.5 kg/cm² (64 p.s.i.) at normal running speed, check to ensure that the gear is not slipping or that gear engagement is not taking too long (5 seconds).

The main filter in this case consists of a large cloth filter which is fitted separately on the outside of the reverse gear. The filter has an element which can be removed for cleaning. The pleated cloth should be taken out of the perforated metal retainer and should be cleaned in fuel oil or paraffin before being allowed to dry. The element should be cleaned for the first time after 25 hours operation and thereafter at intervals of 200 hours. The filter cloth should be replaced after 1800 hours of operation. Check the gaskets on the ends of the metal retainer.

The intervals between inspections are twice as great as for reverse gear units with standard operating valves, that is to say about 7200 hours.

"Penta"

Description and operation

This reverse gear is of the Duplex type and is mechanically operated. The design consisting of two discs, one for operation "Ahead" and the other for operation "Astern", permits relatively long periods of operation "Astern". Continuous "Astern" operation, however, as in the case of twin installations, is permissible for a 2:1 reduction gear but not for a 3:1 gear. The standard direction of rotation in the "Ahead" position is opposed to that of the engine. Reduction gear ratios are normally 2:1 (to be more precise: "Ahead" 2.00:1 and "Astern" 1.97:1) or 3:1 (to be more precise: "Ahead" 2.88:1 and "Astern" 2.53:1).

Adjustment

The powerful Duplex clutch with rocker locking (over-centre) is subjected to the pressure of the springs in each of the spring sleeves on the clutch. This spring-loaded mechanism is so designed that it follows and compensates for wear on the discs so that no adjustment is necessary. The mechanism is designed in such a way that there is a clearance of 2.1—3.2 mm (0.083"—0.126") on each side of a disc when the other clutch is engaged. This clearance increases to a maximum of 6.5 mm (0.260") when replacement is necessary. A simple way to check wear on the discs and determine when they need replacing is to check the position of the pin on the engaging mechanism. With new discs, the distance between the shoulder on the pin and the upper part

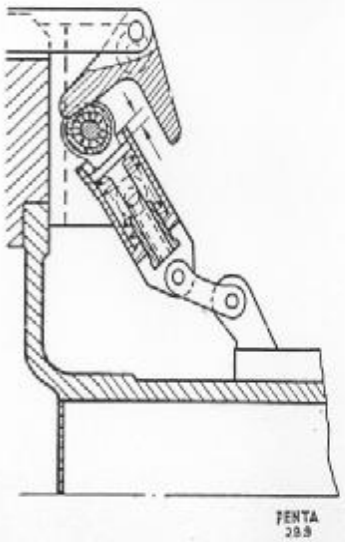


Fig. 54. New discs.

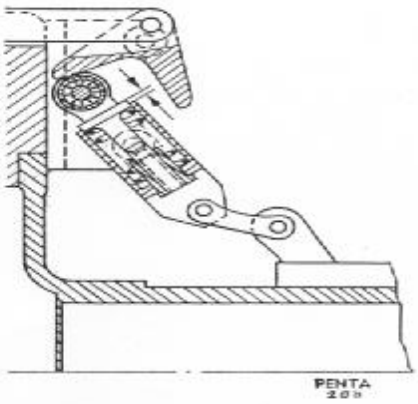


Fig. 55. Worn discs.

of the spring sleeve is about 4 mm (0.160") — see Fig. 54 — when either of the clutches is engaged. When the discs are so worn that they need replacing, the shoulder on the pin is about 1 mm (0.040") above the upper part of the spring sleeve, see Fig. 55. If the clutch has been disassembled for some reason or if worn discs have been replaced, make sure that the flanges on the toothed disc hub face one another. This is essential if the discs are to assume their correct position during operation.

Lubrication

The reverse gear reduction gear should be lubricated with good-quality engine lubricating oil (HD type) with a viscosity of SAE 40 or SAE 80 gearbox (transmission) oil. Check the oil level daily by means of the dipstick. It should be between the two marks on the dipstick.

Change the lubricating oil and preferably flush out the gear housing after about every 600 hours of operation or at least once a year. The oil capacity is 3—3.5 litres (5¼—6¼ Imp. pints). During the running-in period, an extra oil change should be carried out at the same time as the corresponding oil change in the engine.

Fig. 56. Oil dipstick.

After about every 50 hours of operation, the flywheel pilot bearing and the throw-out bearing should be lubricated with good-quality, heat-resistant grease.

The lubricating nipple for the flywheel pilot bearing is in the rear end of the reverse shaft. When the bearings are to be lubricated, the hexagonal plug in the end cover must first be removed.

Do not lubricate too much since excess grease can come onto the dry disc clutch and cause slipping.

After every 50 hours of operation, the forward, smaller inspection cover should be removed and the moving parts in the clutch mechanism should be lubricated with a few drops of light lubricating oil.

"Modern Wheel Drive" (S.L.M.)

When a twin engine installation is driving a common propeller shaft, this type of reverse gear is used. A model with only a friction clutch is available for use with variable pitch propeller equipment. In both cases, operation is hydraulic and the built-in reduction gear usually has a ratio of 4:1.

As far as servicing instructions for periodical inspection are concerned, see page 62 and the special instruction book.

Friction clutch with reduction gear

"Twin Disc" (see Fig. 7)

This is a single disc clutch of the over-centre type. The reduction gear is available with either internal or external gears, that is to say the direction of rotation can be either similar to or opposed to that of the engine. The ratio is usually 3:1 or 4:1.

Adjustment

If the clutch slips, runs warm or shows a tendency to disengage, adjustment should be carried out. Remove the cover over the casing. Move the lever to the neutral position. Rotate

OPERATING INSTRUCTIONS

Running in the engine

The running-in period is the most important time in the life of the engine. During this period, that is to say the first 100 hours of operation, the engine must be run with a certain amount of care. The reason for this is to ensure that the cylinder bores, the pistons and the bearing surfaces obtain the hard, glazed condition that ensure maximum engine life.

The engine should be run with reduced loading during the first 25 hours of operation. We recommend a loading of about 60 % which corresponds to 200—300 r.p.m. at maximum speed in a boat with a fixed pitch propeller.

The degree of loading can gradually be increased from 25 hours of operation to 100 hours of operation, due care being exercised. Check now and then while the engine is running that the water temperature and the oil pressure are normal.

The engine may not be subjected to long periods of heavy loading during the running-in time. On the other hand, the engine should not be run with too low loading either since this delays the necessary wearing-in, can cause gumming of the piston rings and consequent high oil consumption.

After 100 hours of operation, the actual running-in period is over but this does not mean that the engine can be run directly for long periods of time with heavy loading. We recommend that a certain amount of care be exercised until the engine has run for 200 hours.

The engine oil should be changed more often during the running-in period than is necessary at a later stage. Change the oil for the first time after about 25 hours of operation. Do not use flushing oil since it is not certain that this will be able to stand up to the high bearing pressures. The lubricating oil filter should also be carefully cleaned. The oil strainer should also be cleaned and the oil pump should be dried out if it is not too inaccessible due to the design of the boat. *Re-tighten the cylinder head nuts when the engine has been run warm.* This applies even if cylinder head gaskets have been fitted. Valve clearance must also be adjusted. It is also advisable to re-tighten the nuts on the fuel injection pump coupling.

The oil should be changed for the second time after a further 75 hours of operation. This time the lubricating filter should be replaced and the filter cloth replaced where this applies. The oil is then changed at the normal intervals of 200 hours of operation.

All engines are test-run in test-benches at the factory. We are thus ensured that all clearances in the engine are satisfactory and *we cannot accept any responsibility for any bearing or piston seizures caused by careless running in, etc.*

Summary for running-in period

Operating time hrs.	*Degree of loading %*	*Procedure*
0—25	60	
25		Change the oil, clean the oil filter and oil strainer, tighten the cylinder head nuts, adjust the valves, tighten the fuel injection pump coupling nuts.
25—50	70	
50—75	80	
75—100	90	
100		Change the oil, clean the oil filter and change the filter cloth if required.
100—200		Run with a certain amount of care.

Operation

Engine

Before starting

Check:

that there is sufficient oil in the engine, fuel injection pump and reverse gear.

that grease nipples (if any) have been lubricated.

that there is sufficient fuel in the tank.

that the fuel cocks are correctly opened.

that the fuel system has been air-vented.

that coolant has been added to the fresh water system.

that the sea cocks for the sea water system are open.

that the batteries are sufficiently charged.

that the engine is in neutral.

Starting, particularly in *cold weather* can be facilitated by:

using thinner lubricating oil, SAE 10 W.

using winter grade fuel oil (Retains fluid state at low temperatures).

adding warm coolant to the engine.

using fully-charged, preferably warm batteries.

using the cold starting device on the fuel injection pump.

Starting

Push in the stop control.

Turn the key switch, whereby the charging control lamp lights up.

Press the starter button and the engine will start.

If the engine does not fire the first time, wait for a little while so that both the engine and the starter motor have completely stopped and the battery has had time to recover before making another attempt.

Procedure after starting

When the engine has started allow it to warm up under light loading or at a rapid idling speed. Check that the charging control lamp is out, that coolant is circulating, that the sea water pump is feeding correctly and that the oil pressure gauge is showing pressure.

Never, under any conditions, race the engine or subject it to heavy loading immediately after starting.

Oil pressure, normal 3—4 kg/cm² (42—56 p.s.i.)
Oil pressure, minimum 2 kg/cm² (28 p.s.i.)
Coolant temperature 70—85° C (158—185° F)

Reverse gear operation may not be carried out at speeds exceeding 800 r.p.m.

Stopping

Unload the engine and allow it to run for a few minutes without loading. This is to prevent the cooling system from boiling after the engine has been stopped.

Pull out the stop control and the engine will stop.

Switch off the key switch, otherwise the battery will discharge.

Procedure after stopping

If there is a risk of frost damage, the sea water system should be drained. The fresh water system should also be drained unless it contains anti-freeze.

Examine and remedy any faults which may have been noticed or suspected during operation.

Carry out the periodic servicing which is necessary. Do not wait until it is time to start the engine again since there is then risk that essential servicing might not be carried out at all.

Periodic servicing

The following intervals are normal on condition that the recommended types of fuel oil and lubricating oil are used and that the engine is serviced in accordance with the instructions.

NOTE. This summary is by no means intended to replace the instruction book completely. The instruction book must be followed otherwise the guarantee becomes becomes null and void.

	Engine	See page
Every day	Check the oil level	15
	Check the coolant level	34
	Check the fuel level	20
	Give the screen-type lubricating oil filter a twist	16
After every 50 hrs. of operation	Check the battery	39
	Check the belt tension	37
	Check the oil level in the fuel injection pump and in the centrifugal governor	26, 30
	Lubricate the vacuum governor	27
	Grease the belt tensioner	37
	Drain the sludge trap in the fuel tank	72
After every 200 hrs. of operation	Change the engine oil	15
	Drain off screen-type lubricating oil filter	16
	Clean cloth type lubricating oil filter	16
	Clean the air filter	38
	Clean the oil filler cap	16
	Clean the pre-filter on the fuel feed pump	21
	Lubricate the fresh water pump	35
	Check the zinc electrodes	36, 18
After every 600 hrs. of operation	Check injectors	31
	Clean screen-type lubricating oil filter	16
	Replace cloth in cloth type lubricating oil filter	16
	Change the lubricating oil in the fuel injection pump and in the centrifugal governor	26, 30
	Clean breathers (if any) on the fuel injection pump and the governor	27
After every 1200 hrs. of operation	Change fuel filter elements	22
	Check the settings on the fuel injection pump and the governor	27, 28, 30
	Tighten the cylinder head nuts	10
	Check valve clearances	11
	Check the carbon brushes and the commutators in the starter motor and the dynamo	40
	Clean the lubricating oil strainer	17
	Lubricate the revolution counter drive cable	
After every 3600 hrs. of operation	Decarbonize the engine and grind the valves	12
	Have the starter motor and dynamo checked in a specialist electrical workshop	40
	Have the fuel injection pump and governor checked in a diesel test bench	27
	Check engine settings, engine wear, etc.	12

Turbo-Compressor

Every day

Check the lubricating oil level.

After every 50 hrs. of operation

Check that the rotating parts run easily. (Listen to the sound of the compressor after the engine has been stopped).

After every 200 hrs. of operation

Change the lubricating oil.

After every 600 hrs. of operation

Flush out and change oil.

After every 1800 hrs. of operation

Replace the turbo-compressor with a reconditioned unit. (Early production.)

After every 3600 hrs. of operation

Replace the turbo-compressor with a reconditioned unit. (Late production.)

Twin Disc, reverse gear

Every day

Check the lubricating oil level.

After every 50 hrs. of operation

Lubricate the inner ball bearing and throw-out bearing. Lubricate the clutch mechanism moving parts.

After every 600 hrs. of operation

Change the lubricating oil.

Snow Nabstedt, reverse gear

Every day

Check the lubricating oil level.

After every 600 hrs. of operation

Change the lubricating oil.

Self Changing Gear, reverse gear

Every day

Check the lubricating oil level.
Check the lubricating oil pressure.

After every 200 hrs. of operation

Clean the main filter.

After every 1200 hrs. of operation

Change the lubricating oil.
Clean the suction filter.

After every 1800 hrs. of operation

Replace cloth in cloth type main filter.

After every 3600 hrs. of operation

or when the oil pressure sinks below 3.5 kg/cm² (50 p.s.i.) at operating speed or the engaging time exceeds 5 seconds, the reverse gear fitted with the *standard* control valve should be inspected.

After every 7200 hrs. of operation

or when the oil pressure sinks below 4,5 kg/cm² (64 p.s.i.) at operating speed or the engaging time exceeds 5 seconds, the reverse gear with a *sequent* control valve should be inspected.

Penta, reverse gear

Every day

Check the lubricating oil level.

After every 50 hrs. of operation

Lubricate the inner ball bearing and throw-out bearing. Lubricate the clutch mechanism moving parts.

After every 600 hrs. of operation

Change the lubricating oil.

Modern Wheel Drive (SLM), reverse gear and clutch with reduction gear

Use as lubricant Caltex Regal Oil G; ESSO-MAR 85, GULF HARMONY 97, Mobil DTE Oil BB, Shell VITREA Oil 72 or corresponding grades. Diesel engine oils (HD-grade) may not be used.

Oil capacity approx. 60 litres (13 Imp. gallons).
Normal oil pressure approx. 5 kg/cm² (70 p.s.i.).

When running in after 25 hrs. of operation
Clean the lubricating oil filter.

When running in after 200 hrs. of operation
Change the lubricating oil. Flush the housing clean.

Every day
Check the lubricating oil level.
Check the lubricating oil pressure.

After every 200 hrs. of operation
Clean the lubricating oil filter.

After every 1200 hrs. of operation
(at least once a year).
Change the lubricating oil.

Twin Disc, clutch with reduction gear

Every day
Check the lubricating oil level.
Lubricate the throw-out bearing.

After every 100 hrs. of operation
Lubricate the inner ball bearing.
Lubricate the clutch mechanism moving parts.

After every 600 hrs. of operation
Change the lubricating oil.

Snow Nabstedt, clutch with reduction gear

Every day
Check the lubricating oil level.
Lubricate the throw-out bearing.

After every 100 hrs. of operation
Lubricate the clutch mechanism moving parts.

After every 600 hrs. of operation
Change the lubricating oil.

Twin Disc, friction clutch

Every day
Lubricate the throw-out bearing.

After every 100 hrs. of operation
Lubricate ball bearings.

Fault-tracing procedure

Engine

The following table shows the more usual reasons for running disturbances as well as how to remedy them.

Never trace a fault in a haphazard manner. Examine one thing at a time and determine the result of any action taken before starting on something else.

If something has gone wrong with any of the fuel injection components, call in an authorized Diesel mechanic.

A. The engine will not start

Fault and reason:	Remedy:	See page
1. Discharged battery.	1. Have the battery charged or replace it.	39
2. Master switch not switched on.	2. Switch it on.	76
3. The stop control is pulled out.	3. Push it in.	76
4. The engine is not receiving any fuel.	4. Open the fuel and return cocks.	72
a) Not enough fuel in the tank.	a) Fill the tank with fuel. Air vent the fuel system.	33
b) Air leakage on the fuel line.	b) Open the air-venting cock on the fuel filter and operate the hand primer pump. If air or fuel containing air bubbles is delivered the whole time then there is a leak on the fuel line between the fuel tank and the feed pump. Seal the leak (examine the washers) and air-vent the fuel system.	33
c) Blocked pre-filter.	c) If no fuel passes out through the air-venting plug on the fuel filter after the hand primer pump has been operated for some time then there is either a large air leak on the suction line or the pre-filter is completely blocked. Remove and clean the bowl. Fit a new gasket.	21
d) Air in the fuel system (the engine has stood idle for some time).	d) Air-vent the fuel system.	33

B. The engine starts but stops again

Fault and reason:	Remedy:	See page
1. Air pipe in fuel tank blocked.	1. Clean out the pipe.	72
2. Pre-filter blocked.	2. See A, 4c.	21
3. Fuel filter blocked.	3. Replace filter element.	22
4. Feed pump not functioning properly.	4. Clean valves (replace if necessary). Replace feed pump thrust spring.	20
5. Air in fuel injection pump.	5. See A, 3d.	33
6. Relief valve leaking.	6. Check relief valve.	23

C. Engine not delivering full output

Fault and reason:	Remedy:	
1. Engine runs evenly but output low.	1.	
a) Blocked air cleaner.	a) Clean out air cleaner.	38
b) Delivery pipe leaking.	b) Check delivery pipes. Tighten screw connections.	32
c) Faulty injector.	c) Check to locate faulty injector and replace it.	31
d) Faulty injection pump setting. Worn pump coupling.	d) Have pump setting checked. Call in a Diesel mechanic.	27
e) Low feed pressure due to blocked fuel filter, damaged feed pump or faulty relief valve.	e) Examine these components.	23
2. Poor compression.	2.	
a) Valves not sealing.	a) Grind valves. Examine valve springs.	12
b) Leakage through cylinder head gaskets.	b) Tighten cylinder head nuts. If this does not help, fit new gaskets.	10
c) Gummed-up piston rings. Excessively large piston clearance.	c) Remove and clean pistons. Replace piston and liner if necessary.	12

D. Engine knocks

Fault and reason:	Remedy:	
1. Combustion knock.	1.	
a) Faulty setting on fuel injection pump.	a) Have a Diesel mechanic check the pump settings.	27
b) Faulty injector.	b) Remove the injector and replace. Send in the faulty injector for cleaning and check of opening pressure.	31

Fault and reason:	Remedy:	See page
c) Poor compression causing delayed combustion.	c) See C, 2.	13
2. Mechanical knock.	2.	
a) Excessive clearance in crankpins, big-end bearings and main bearings.	a) Replace faulty parts.	12

E. Heavy exhaust smoke

Fault and reason:	Remedy:	
1. Air cleaner blocked.	1. Clean out air cleaner.	38
2. Injection pump adjusted for excessively late injection.	2. Have adjusted by Diesel mechanic.	27
3. Damaged nozzle in one of injectors (dripping).	3. Replace with spare nozzle, send in faulty nozzle for adjustment.	31
4. Vacuum governor diaphragm damaged causing air leakage and increased fuel injection.	4. Check vacuum governor and replace diaphragm if damaged. Examine line to throttle housing.	28
5. One of exhaust valves burned or chafing.	5. Replace faulty exhaust valve.	12
6. Injection pump maximum stroke excessively large.	6. Have the injection pump checked.	27
7. Poor compression caused by worn pistons, rings and cylinder liners.	7. Have the engine recontioned.	13
8. Turbo-compressor not functioning.	8. Check the turbo-compressor.	43

F. Engine runs unevenly

Fault and reason:	Remedy:	
1. Fuel filter blocked.	1. See B, 3.	22
2. Feed pump not working properly.	2. See B, 4.	20
3. Air in injection pump.	3. Air-vent injection pump.	33
4. Looseness in control system.	4. Check and alleviate any looseness.	—
5. Fuel injection pump not working properly.	5. Check governor damper. Have the injection pump checked by a Diesel mechanic.	28
6. Centrifugal governor chafing or loose.	6. Have it adjusted by a Diesel mechanic.	29

G. Engine will not run at maximum speed

Fault and reason:	Remedy:	See page
1. Throttle not opening fully.	1. Check that control system is not bent. Adjust links so that throttle opens fully.	27
2. Air cleaner blocked.	2. Clean air cleaner.	38
On engines with centrifugal governors:		
3. Amount of fuel delivered by injection pump faulty.	3. Have pump adjusted in Diesel workshop. The pump stroke may never be adjusted due to exhaust smoke.	27
4. The control system is not pushing the setting arm on the pump to the maximum position.	4. Adjust the control system.	—
5. The governor is limiting the engine speed too early.	5. Have it adjusted by a Diesel mechanic.	30
6. The limiting stop on the pump housing for the setting arm is faultily adjusted.	6. Have it adjusted by a Diesel mechanic.	30
7. The stop control "hangs on" and prevents the maximum pump stroke on the injection pump.	7. Remove the inspection cover on the fuel injection pump. Move the throttle control to the "full speed" position. NOTE. The engine must be switched off while this examination is being carried out. Watch the control rod through the inspection cover opening. Press in the the cold start device. The control rod should then move forward to the cold starting position. If it does not do this, then the stop control should be checked.	30

H. Engine maximum speed too high

Fault and reason:	Remedy:	
1. An air leak on the vacuum line or a fault on the governor.	1. Check the vacuum line. Adjust the governor.	28
On engines with centrifugal governors:		
2. The limiting stop on the pump housing for the setting arm is faultily adjusted.	2. See G, 6.	30
3. The governor is not limiting the engine speed correctly.	3. See G, 5.	30
4. Faulty pump setting.	4. See G, 3.	27

J. Engine overheats

Fault and reason:	Remedy:	See page
1. Not enough water in the cooling system.	1. Add more water.	34
2. Insufficient drive belt tension.	2. Tension belt correctly.	37
3. Sea cock blocked.	3. Examine and clean.	35
4. Sea water pump impeller damaged.	4. Examine and replace.	35
5. Faulty thermostats.	5. Check the thermostats.	34
6. Damaged water pump.	6. Examine.	34
7. Channels in cooling system blocked.	7. Clean channels.	36

K. High oil consumption

Fault and reason:	Remedy:	
1. Blocked air cleaner.	1. Clean out the air cleaner.	38
2. Oil leakage, for example on lower part of crankcase, crankshaft, rocker arm covers, inspection covers, etc.	2. Replace gaskets.	12
3. Worn piston rings.	3. Have the compression rings measured. Replace the rings if the values obtained are poor.	12

On the turbo-compressor bearing housing:

4. Leaking seal plug or filler plug.	4. Tighten plugs. Replace washers if necessary.	42
5. Dirt and blockage in ventilation channel in shaft.	5. Replace turbo-compressor.	43

L. Low oil pressure

Fault and reason:	Remedy:	
1. Oil level too low.	1. Top up with oil.	15
2. Faulty oil pressure gauge.	2. Fit check gauge and replace oil pressure gauge if it is faulty.	15
3. Oil relief valve worn.	3. Examine. Replace relief valve plunger.	14
4. Blocked lubricating oil strainer. Blocked lubricating oil filter.	4. Pump out lubricating oil. Clean oil strainer and oil filter.	16, 17
5. Worn parts such as oil pump, main bearings and big-end bearings.	5. Examine. Recondition pump, replace bearing shells.	12

Recommendations concerning laying up the engine during the winter

Even insignificant attack by rust on the precision-made parts in the engine can mean a serious deterioration in its general condition. In the same way, resin deposits precipitated from the fuel oil can cause interruptions in the fuel injection system.

If the engine is to lie idle for *a time not exceeding one month*, it should be started every other week and should be run warm for about one hour. The sea-water system should also be carefully drained and glycol anti-freeze containing anti-rust should be added to the fresh-water system. The concentration of glycol should correspond to the lowest temperatures that could possibly be encountered. Se page 34. The sea-water drive belt should also be removed since otherwise the pump will run dry. Check the cooling water temperature while the engine is running. If there is a dry, vertical exhaust system fitted, the plug in the condensation water collector vessel should be removed to allow condensation water to come out and prevent it running into the engine.

The lubricating oil should be changed before the engine is taken into service again. The cooling water should also be changed if the glycol has been used for a long time.

If, on the other hand, the engine is to lie idle *for more than one month* then preservative oil should be added as described below.

In both cases it is wise to utilize this "idle time" to carry out the periodical inspections and overhauls that must be done. See pages 61—63.

Laying up the engine:

1. Run the engine warm in the normal way.
2. Stop the engine and drain off the lubricating oil from the sump and the oil filter.
3. Fill up with preservative oil to the lower mark on the dipstick. Use ESSO RUST BAN 603 or corresponding types.
4. Add the same type of oil to the fuel injection pump and the centrifugal governor.
5. Drain off the fuel from the fuel filters by removing the drain plugs.
6. Loosen the fuel line banjo plugs at the fuel feed pump and the upper fuel filter and connect up two plastic hoses. The other ends of these hoses should be dippend into a tin of preservative oil, ESSO RUST BAN 392 or corresponding types.
7. Air-vent the fuel system and start the engine. Let it run at a rapid idling speed until 1—1½ litres (1,7—2,7 Imp. pints) of the preservative oil in the tin ahs been used up.
8. While the engine is running, remove the rocker arm covers and pour preservative oil, of the same type used in the sump, over the valve mechanism.
9. When the engine has been stopped, drain off the oil from the sump, oil filter, fuel injection pump and centrifugal governor. Then re-connect up the normal fuel lines and drain the fuel filters.
   FROM NOW ON, THE ENGINE MAY NOT BE TURNED OVER UNTIL IT IS TO BE TAKEN INTO USE AGAIN. ATTACH A LARGE LABEL TO THE ENGINE SHOWING THAT PRESERVATIVE OIL HAS BEEN ADDED AND THE DATE WHEN THIS WAS DONE.
10. If the engine is to be laid up for a long time — more than six months — or if the conditions under which the engine is to be stored are unfavourable, for example out-of-doors or in unheated premises with low air temperatures, then the best procedure is to loosen the injectors and spray ESSO RUST BAN 603 or corresponding types into the cylinders. This provides a more effective protection for the piston rings and the combustion chambers.

    NOTE. Care must always be taken not to inject too much preservative oil since this can cause a liquid "cushion" the next time the engine is started. We recommend the use of 25 cm^3 (1 fl.oz.) for each litre of the engine displacement. This means about 20 cm^3 (⅘ fl. oz.) in each cylinder on the MD 47, about 25 cm^3 (1 fl. oz.) in each cylinder on the MD 67 and about 40 cm^3 (1½ fl. oz.) in each cylinder on the MD 96 and TMD 96.

    Make a habit of *always* turning the engine over by hand before starting it again if the above procedure has been adopted.

11. Drain off the cooling water.
Alternative no. 1: Leave the drain cocks and the filler cap open.
Alternative no. 2: Fill up the whole cooling system with glycol anti-freeze containing anti-rust medium. Make sure that the glycol solution is sufficiently concentrated to be able to stand up to repeated freezing. Otherwise there is a risk of the upper fluid levels containing too much water which can freeze and exert a "bursting" effect.
ATTACH A LARGE "OIL AND WATER DRAINED OFF" LABEL TO THE ENGINE.

12. If there is a dry, vertical exhaust system fitted, the plug in the condensation water collector vessel should be removed to allow condensation water to come out and prevent it running into the engine.

13. All external, un-enamelled parts of the engine should be coated with preservative oil, ESSO RUST BAN 330 or corresponding types. The surfaces should be clean and dry before being covered with oil.

Before taking the engine into use again

No extensive work is necessary before the engine is to be started. The layers of preservative oil are dissolved by the lubricating oil and the fuel oil immediately.

Clean the engine externally with white spirit.

Add lubricating oil to the oil sump, fuel injection pump and centrifugal governor.

Fill the cooling system with coolant.

Air-vent the fuel system.

Turn over the engine a few revolutions, see point 10 above.

Start the engine and let it run warm at rapid idling speed before subjecting it to loading.

While the engine is running, check that everything functions as it should.

INSTALLATION

Installation of the engine should be carried out with as much care as possible. Our experience has shown that most of the faults which occur depend on bad or careless engine installation. If the engine is correctly installed to begin with, this will avoid the necessity for later modifications which cost more than if the engine had been correctly installed in the first place.

The engine bed

The engine bed should be as stable as possible and should be designed so that its attachments are extended over as wide an area of the hull as possible. Recesses should be made in the engine bed so that if a relief valve is fitted in the lubricating system (in the forward cover, port side), this is readily accessible. If the design of the boat allows the engine bed to be constructed as shown in Figs. 68 and 69, this should be done since it enables piston and cylinder liner replacement to be carried out without removing the engine from its bed. There are large openings on the lower part of the crankcase (port side). These openings are fitted with covers and enable the big-end bearing caps to be removed through the side of the engine. Since these bearing caps are diagonally divided, the pistons and connecting rods can be pushed up through the cylinder bores and removed after the cylinder head has been taken off.

The brackets for the power take-off units such as the reverse gear, clutches, couplings, etc., should be fitted and accurately aligned on the engine bed.

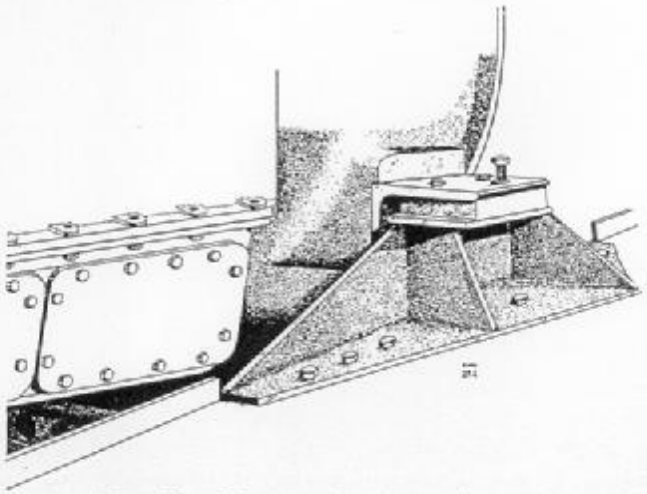


Fig. 68. Rear engine mountings.

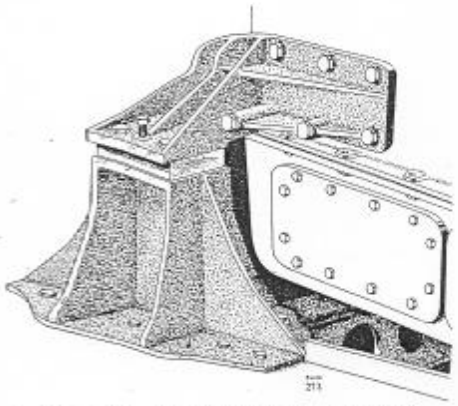


Fig. 69. Forward engine mountings.

Aligning the engine

Before the engine is bolted into position on the engine bed, a check should be carried out to ensure that there are no stresses between the mounting brackets and the engine bed. Ensure also that the crankshaft centre line coincides with the centre line of the propeller shaft. The brackets are fitted with adjuster bolts at four points to facilitate alignment. After alignment has been completed, these bolts should be screwed out so that the engine does not rest on these bolts but on spacers which should be inserted as required between the brackets and the engine bed.

After the boat has been launched, a further check should be carried out to ensure that there are no stresses between the propeller shaft and the engine due to alterations in the form of the hull. Repeat this check after 2—3 days and later at regular intervals. Alignment is carried out in the following way:

Disconnect the reverse gear flange from the propeller shaft flange and move the propeller shaft flange astern. Fit an indicator on the propeller shaft flange so that it registers on the guiding edge of the reverse gear flange. Rotate the propeller shaft flange one complete turn. The maximum reading on the indicator should not exceed 0.15 mm (0.006"). If the reading obtained is greater than this, the engine should be loosened from its bed and should be correctly aligned by means of the adjuster bolts. Before

bolting the flanges together again, make sure that they are parallel. Push the flanges together by hand. Rotate the propeller shaft one complete turn and check the clearance between the flanges. It should not be possible to insert an 0.10 mm. (0.04″) feeler gauge at any point between the flanges while they are being rotated. This alignment procedure should be carried out when the boat is floating freely with full tanks and all equipment on board. The hull of a boat is always flexible to some extent and has not the same form when on the slips as it has in the water.

Poor alignment between the engine and the propeller shaft is often the case of other faults such as vibrations and settling in the hull, rapid wear of the propeller shaft and stuffing box as well as serious damage to the reverse gear.

NOTE. *The angle of inclination of the engine when the boat is under way may not exceed: 15° for the MD 47 and 12° for other engines.*

Make sure that there is always sufficient clearance between the propeller and the rudder. This clearance should be at least 200 mm (8″) to enable the reverse gear to be removed (this does not apply, naturally, where there is a divided propeller shaft). There should be no bulkheads in the way to prevent the reverse gear from being moved 200 mm (8″) astern. There must also be sufficient clearance between the propeller and the stern bearing so that the propeller does not exert pressure on this bearing.

Fuel tank and fuel lines

One of the most important points concerning engine installation concerns the fuel tanks since weaknesses here concerning the material of which the tanks are made, the way in which they are connected, their state of cleanliness, etc., can affect the running of the engine.

The tank or tanks used can be of any form depending on the construction of the hull. They can be fitted where they are least in the way for other equipment. The amount of fuel required for the range of the boat can be distributed between several tanks so that the centre of gravity is low and they can be used for trimming purposes. This may serve to show how careful planning of fuel tank installation is well worth the trouble.

The tanks should be fitted low in the boat. It is a great advantage to arrange them so that they are on the same level and so that their top surfaces are level with the upper part of the engine. They can, however, be fitted either higher or lower. Due consideration must be paid to the maximum suction lift of the fuel feed pump. (See the information concerning the fuel feed pump on page 20, 21).

If the main tanks are fitted in the bottom of the boat at some distance from the fuel feed pump, then the fuel should be transferred by means of a hand pump or a motor pump to the tank from which the engine obtains its fuel directly.

Fuel tanks should be made of black sheet metal or Monel metal. Tanks of galvanised material or copper (see below) must not be used for Diesel fuel since they corrode rapidly causing blocked filters and other troubles.

The fuel tanks should be welded and fitted with splash plates to prevent excessive movement of the fuel oil in heavy seas. The splash plates also function as reinforcing plates. The tanks should be fitted with man-holes for cleaning purposes. The tank from which the engine receives the fuel directly should also be fitted with a sludge trap and a drain cock. These should be used regularly to drain off the sludge and water that sinks to the bottom of the tank.

After manufacture, the tanks should be cleaned extremely carefully. Welds should be brushed clean and all scale removed. Before being fitted in the boat, they should be rinsed out repeatedly with clean fuel oil and be painted externally to provide rust-proofing. No rust-proofing in the form of painting or galvanising may be carried out on the insides of the tanks.

The fuel filler pipe should be well dimensioned with a diameter of not less than 1 ½″. It should be so long that it terminates about 25 mm. (1″) from the bottom of the tank. This prevents air from being blown up together with the fuel when tanking is being carried out. The filler pipe should be taken up to a deck fitting by means of an oil-resistant rubber hose. If possible, the filler pipe should be arranged so that a measuring rod can be inserted through it.

An air vent pipe should be taken from the highest point in every tank to a point as high as possible in the boat. These pipes should have a diameter of not less than ½″ and the top end of each pipe should be curved in such a way as to prevent water from coming into it.

The tanks should be connected with each other by means of pipes both at the top and the bottom. These pipes must be fitted with shut-off cocks as shown in the installation drawing, Fig. 71. The lower connecting pipe on each tank should be well dimensioned with an internal diameter of not less than ¾" so that the tanks can be filled from both sides of the boat specially if they are fitted along the side of the hull.

The fuel lines should be fitted in accordance with the principles shown in the installation drawing, Fig. 71. The lower connecting pipe on the tank from which the engine receives fuel oil directly is connected by means of the pipe (7) to the fuel feed pump (20) via a fuel filter (12) fitted on the pipe. This fuel filter (12) serves as a trap for the coarsest impurities. It should have a large capacity and should be fitted with two filter containers and a three-way cock to enable cleaning to be carried out while the engine is running.

The fuel feed pump sucks the fuel oil through i filter fitted to the pump and then forces it through the twin fuel filters (10) to the fuel injection pump. The pipe (7) should be 8×10 mm ($^{5}/_{16}$"×$^{25}/_{64}$"). If the suction line is very long, a larger pipe is needed, 10×12 mm ($^{25}/_{64}$"×$^{15}/_{32}$") being suitable.

Leak-off fuel oil from the injectors, excess fuel oil from the fuel feed pump and any air that has been separated off in the filter pass through a relief valve on the upper of the twin fuel filters. A return pipe-line from this valve is connected to the upper connections on the fuel tanks (upper surface of tank supplying engine directly). This return line should consist of 8×10 mm ($^{5}/_{16}$"×$^{25}/_{64}$") piping.

While the engine is running both the feed and return cocks on the tank being used should be open. If the tanks are fitted on the same level, it is an advantage to use them together in which case all the feed and return cocks should be open. Note that the engine must not be run with the cocks closed since this can cause pressure in the fuel system which can result in damage.

As already mentioned, copper tanks are not suitable for use with Diesel fuel oil. But if such tanks are already fitted in the boat, for example when converting from petrol to Diesel operation, they can be used on condition that they are cleaned very carefully. In practically all petrol tanks there are deposits which are dissolved by the fuel oil and which can cause running interruptions. Very careful consideration should be given to the question as to whether it would not be better to fit new black sheet metal tanks in any case.

If the old tanks are to be used, they must be carefully cleaned no matter whether they have been used for petrol or fuel oil earlier. Manholes should be made in the tanks if they do not already exist. The tanks should be well blown through with steam before being rubbed out with clean rags. The tanks should then be rinsed out repeatedly (at least three or four times) with clean fuel oil.

If a tank is not fitted with a sludge trap, this should be done (see the installation drawing). If confined space does not permit this, the feed pipe to the engine should be fitted at least 100 mm (4") above the bottom of the tank. A cock to drain off water and sludge should be fitted at the lowest point on the tank.

Cooling water lines

The installation drawing, Fig. 71, shows how these should be fitted. A 25×28 mm (1"×1⅛") copper pipe should be taken from the sea cock to the reverse gear oil cooler and from this to the suction side of the sea-water pump. The sea-water pump then forces this water through the oil cooler and the heat exchanger. A threaded R 1" flange is fitted on the port side of the heat exchanger. From this flange a 25×28 mm (1"×1⅛") copper pipe goes to a three-way cock which is included in the tool kit. From this cock a further 25×28 mm (1"×1⅛") copper pipe goes to the outlet fitting in the hull through which the cooling water is taken overboard. The third connection on the three-way cock (marked E on the hexagon) is fitted with a reducing nipple for 13×16 mm ($^{33}/_{64}$"×$^{5}/_{8}$") copper pipe and this is connected to the water-cooled section of the exhaust system as shown in the illustration. This three-way cock can be used to determine the amount of water entering the exhaust system or it can be completely closed in order to get rid of the cooling water in the exhaust system by the ejector effect of the exhaust gases. This is particularly important in cases where the exhaust goes upwards from the engine.

Exhaust system

The installation drawing, Fig. 71, shows two alternative suggestions for the exhaust system. Alternative I shows the complete exhaust system water-jacketed. The jacketed part of the exhaust is made of copper while the unjacketed part nearest the hull consists of acid-resistant piping. The exhaust gases from a Diesel engine contain sulphur compounds which, when dissolved in water, have a corrosive action on copper. For this reason acid-resistant piping should be used in that part of the exhaust system where the exhaust gases and water come into contact with each other.

Alternative II shows the exhaust system made of specially-manufactured rubber hose. On the water-jacketed bend, which consists of copper piping, there is a short section of acid-resisting piping flanged. This forms the hose attachment and through it passes the water on its way from the water jacket into the exhaust pipe. To prevent the cooling water from being sucked back into the engine in the case of a backfire when the engine is stopped, the difference in level between the exhaust manifold and the inlet for cooling water into the exhaust pipe itself should not be less than 300 mm (12"). The other end of the exhaust rubber hose is attached by means of hose clamps to an acid-resistant pipe going out through the hull. In order to prevent water from coming into the exhaust pipe from the outside, the acid-resistant pipe should be bent into an S-curve as shown in the installation drawing. There should be a water drain cock at the lowest point.

NOTE. When a rubber exhaust hose is fitted, the exhaust system should never be run dry or should be done so very carefully since the hose will then be subjected to over-heating. Never run the engine for more than one minute when the cooling water has been shut off. When running dry, the engine may never be subjected to loading.

When installation is carried out and it is found that that the exhaust pipe slopes downwards towards the exhaust manifold or with such a slight slope away from it that there is risk of cooling water and condensation water getting into the engine, then a condensation water collector vessel must be fitted as shown in Fig. 70. Late production engines have a threaded hole on the exhaust manifold flange for the attachment of a condensation water collector. The collector vessel used should be drained at regular intervals.

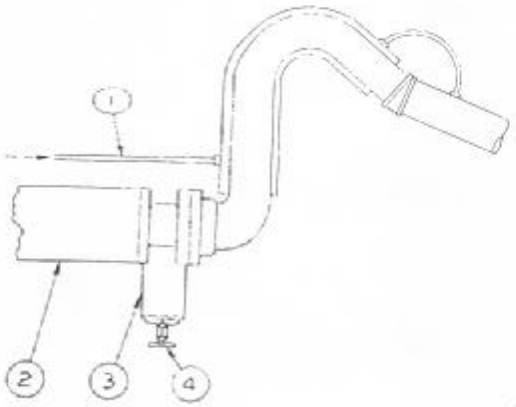


Fig. 70.

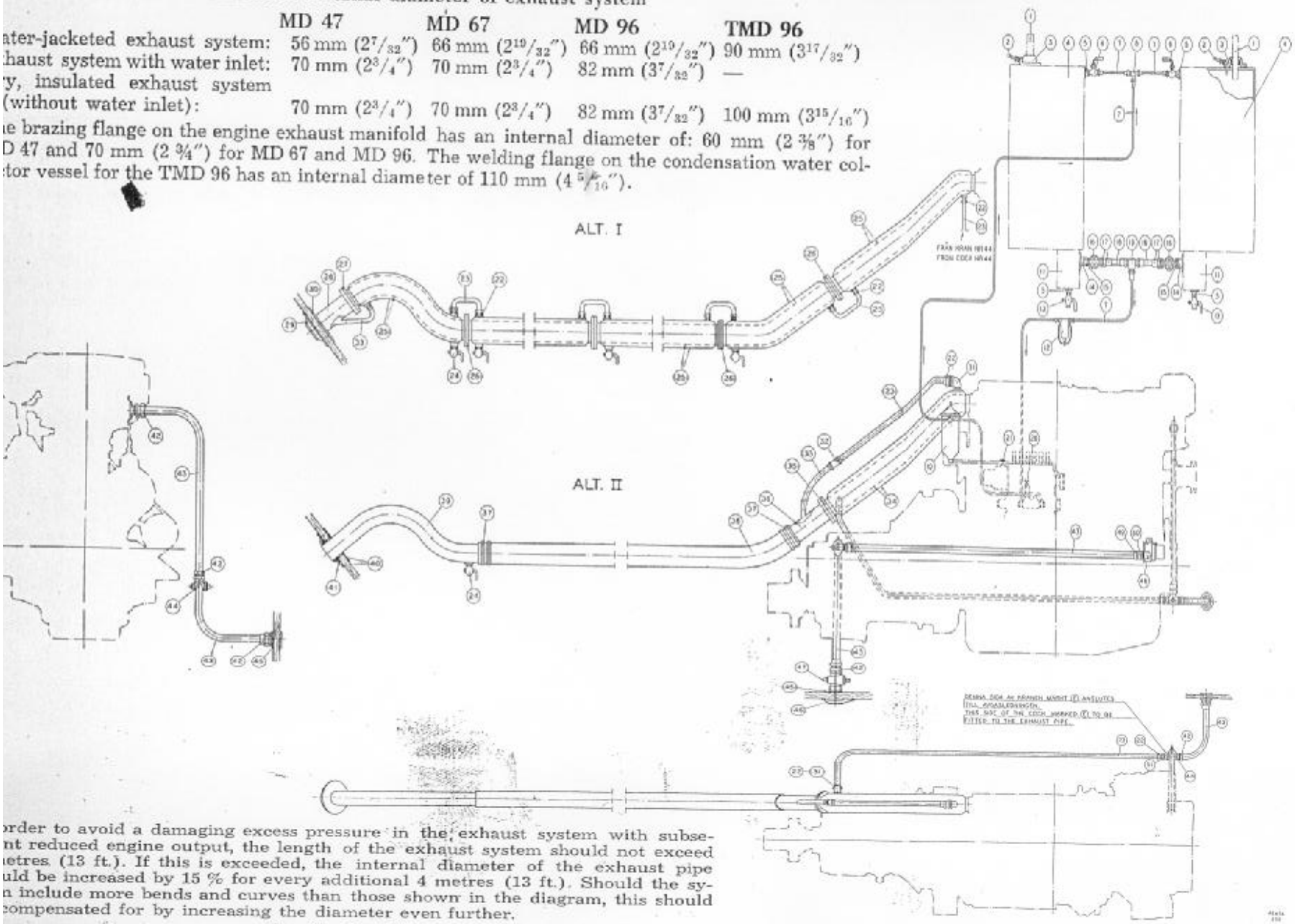
If the exhaust system is fitted without water cooling (dry exhaust system) and is insulated with asbestos instead, it can be made of iron or steel piping. We recommend, however, that acid-resisting piping should be used since this is cheaper in the long run. The exhaust pipe should always be attached to the exhaust manifold on the engine by means of a flexible connection to absorb the heat stresses in the exhaust system.

As far as the exhaust system on the TMD 96 engine is concerned, this is particularly sensitive for back pressure and other external stresses. We refer to the chapter dealing with the turbo-compressor on page 41.

Minimum internal diameter of exhaust system

	MD 47	MD 67	MD 96	TMD 96
ater-jacketed exhaust system:	56 mm ($2^{7}/_{32}$″)	66 mm ($2^{19}/_{32}$″)	66 mm ($2^{19}/_{32}$″)	90 mm ($3^{17}/_{32}$″)
haust system with water inlet:	70 mm ($2^{3}/_{4}$″)	70 mm ($2^{3}/_{4}$″)	82 mm ($3^{7}/_{32}$″)	—
y, insulated exhaust system (without water inlet):	70 mm ($2^{3}/_{4}$″)	70 mm ($2^{3}/_{4}$″)	82 mm ($3^{7}/_{32}$″)	100 mm ($3^{15}/_{16}$″)

ıe brazing flange on the engine exhaust manifold has an internal diameter of: 60 mm (2 3/8″) for D 47 and 70 mm (2 3/4″) for MD 67 and MD 96. The welding flange on the condensation water collector vessel for the TMD 96 has an internal diameter of 110 mm (4 5/16″).



order to avoid a damaging excess pressure in the exhaust system with subsent reduced engine output, the length of the exhaust system should not exceed ıetres (13 ft.). If this is exceeded, the internal diameter of the exhaust pipe uld be increased by 15 % for every additional 4 metres (13 ft.). Should the sy- n include more bends and curves than those shown in the diagram, this should compensated for by increasing the diameter even further.

Fig. 71. Installation suggestions in principle for water-jacketed and water inlet exhaust systems.

Bilge pump, type Jabsco

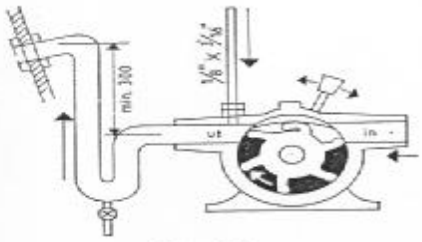


Fig. 72.

In cases where the engine is fitted with a bilge pump, there is a primer pipe-line (min. size 1/8" × 3/16") from the engine sea-water system to the pump in order to prevent it running dry. The outlet pipe from the pump should be arranged as shown in the sketch, Fig. 72, for the same reason.

Instrument panel

The instrument panel which is delivered with the engine should be fitted on the same panel as the various controls for the engine, electric lighting switches, etc., in the wheelhouse or at the control position. A separate wiring diagram is delivered with each engine and shows how the electrical installations should be carried out.

Master switch

The instrument panel includes a key-operated switch in the starter motor circuit and this prevents unauthorised presons from starting the engine. Since this type of protection is not completely satisfactory, however, a master switch should be connected into the circuit as shown in the wiring diagram. This switch should be contained in a locked compartment in the boat.

Throttle and manoeuvring controls

The control from the throttle on the engine are taken to a lever on the control panel. This is used to regulate the speed of the engine.

On engines fitted with a hydraulic reverse gear, a control should be taken from the reverse gear operating valve to the control position.

If the mechanical reverse gear is fitted with a remote control device operated from the control position, the linkage should be carefully installed and should be robust since it is subjected to powerful stresses. Attachments for any right-angle levers in the system should be well bolted to the hull. The control rods in the link system can be made to advantage of tubular steel in order to reduce weight. Notice that the control system should be arranged so that full engagement is obtained and that it is completely unloaded when "Ahead", "Astern" and neutral are engaged. Any residual pressure on the control system can mean that there will be rapid wear on the reverse gear.

Stop control

The "Stop" buttom on the instrument panel is connected to the fuel injection pump lever by means of a cable.

Revolution counter

The revolution counter on the instrument panel is connected to the revolution counter attachment on the engine by means of a flexible shaft.

The smallest radius of any bends in the revolution counter shaft must not be less than 300 mm. (12") and the length of the shaft should not exceed 3 metres (10 ft.). AB Penta give no guarantee for shafts exceeding 3 metres (10 ft.). If a longer shaft is required, we recommend the installation of an electric revolution counter.

Reverse gear oil pressure gauge (when a hydraulic reverse gear is fitted)

A line goes from a screw connection on the operating valve to a pressure gauge which is fitted at the control position.

Belt guard

When the engine is installed in the boat, a belt guard should be fitted to prevent anything from

being pulled into the drive belts. This belt guard can consist of a light angle-iron frame covered with wire netting and should be attached to the engine bed with wing nuts so that it easy to remove when the drive belts are to be replaced.

Power take-off

If a power take-off is to be used to drive pumps, winches, generators, etc., information and instructions must be ordered from AB Penta, Gothenburg.