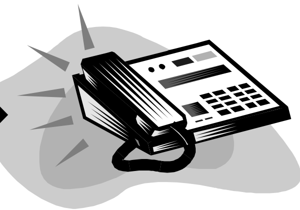
CONTACT WÄRTSILÄ

Any time...



Service Department

Wärtsilä Finland Oy, Service
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During office hours (7.30-16.30) call operator
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Wärtsilä Finland Oy, Service
P.O.Box 50, FIN-20810 Turku, Finland
During office hours (7.30-16.30) call operator
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Mobile Telephone Numbers

Nights and weekends please call mobile phone for service engineer or spare parts assistance.

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Service Telecopiers

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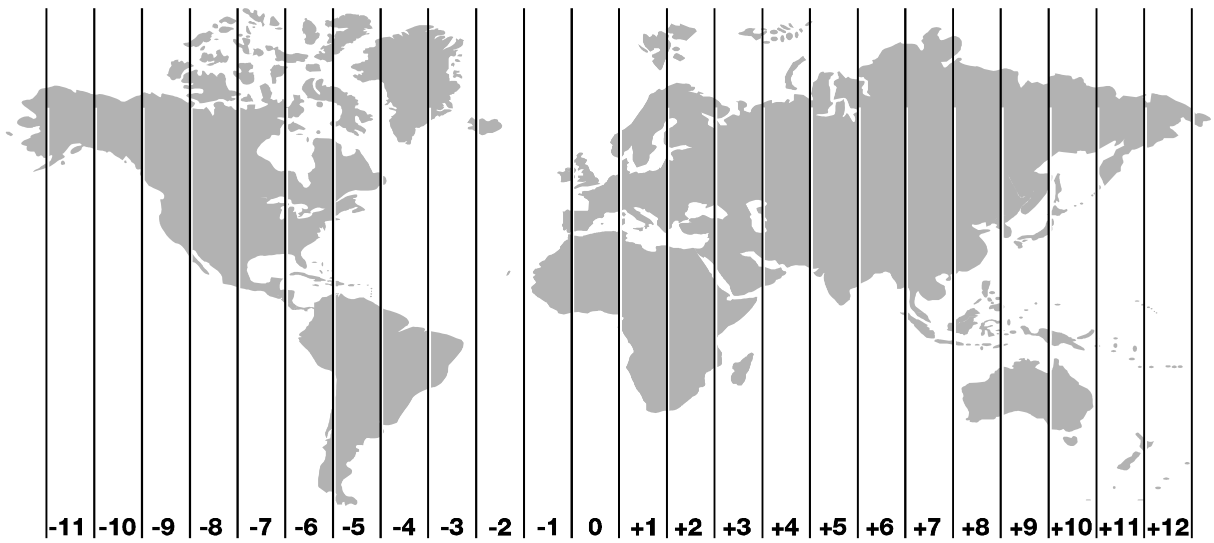
+358 10 709 2787	- South East & E Asia	**+358 10709 3455**	Field Service
+358 6 356 7336	- Finland	**+358 10709 3279**	Technical Service
+358 10 709 1847	Technical Service	**+358 10709 3595**	Training
+358 6 356 7376	Training	**+358 10709 3181**	Service Projects
+358 6 356 7339	Field Service		
+358 10 709 2777	Documentation and Software Systems	**+358 10709 3435**	Documentation and Software Systems
+358 6 356 7344	Logistics	**+358 10709 3435**	Logistics



WÄRTSILÄ

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Wärtsilä Engine (Shanghai) Co., Ltd - Workshop

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Fax Administration / Spare parts. . . 98-94 39 20
Fax Sales 98-94 40 16
Fax Service 98-94 60 44
Fax Workshop 98-94 52 53
24hrs phone 99-56 99 56
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Fax Service Sales 10-709 34 10
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Fax IT Services 10-709 27 40
Fax Logistics 10-709 73 46
Fax Logistics 10-709 73 44
Fax Operation Support 10-709 27 77
Fax Service Sales 10-709 13 80
Fax Service Sales 10-709 73 36
Fax Service Sales 10-709 73 39
Fax Service Sales 10-709 27 87
Fax Technical Service. 10-709 18 47
Fax Technical Service, Controls &
Measurements. 10-709 12 91
Fax Training 10-709 73 76
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Fax	44-230 10 89
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Fax	33-349 75 35

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Fax	824-443 556

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Direct phone Nro.2	22-757 53 71
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Fax Finance	22-757 51 78
Fax Operations & Maintenance	22-757 53 70
Fax Power Plants	22-757 51 77
Fax Service	22-757 51 76

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400 706 Navi Mumbai
Postal Address: Navi Mumbai

Direct phone	22-770 79 18
Direct phone Nro.2	22-770 79 19
Direct phone Nro.3	22-770 79 20
Direct phone Nro.4	22-770 79 21
Fax	22-770 81 66

Wärtsilä India Ltd.

Stores
GMT: +5:30
B1-E22 Mohan Cooperative Industrial Estate, Mathura Road
110 04 New Dehli
Postal Address: New Dehli

Direct phone	11-694 19 28
Direct phone Nro.2	11-694 04 00
Direct phone Nro.3	11-694 02 99
Fax Service	11-694 19 29

Wärtsilä India Ltd.

Sales & Service Office New Delhi
GMT: +5:30
24, Siri Fort Road
10 049 New Delhi
Postal Address: New Delhi

Direct phone	11-625 11 05
Direct phone Nro.2	11-625 11 06
Direct phone Nro.3	11-625 11 07
Direct phone Nro.4	11-625 11 08
Direct phone Sales & Service Office	11-625 07 23
Direct phone Sales & Service Office	11-625 02 25
Direct phone Sales & Service Office	11-625 02 26
Fax	11-625 11 09
Fax Nro.2	11-625 09 14
Fax Nro.3	11-625 25 04

Wärtsilä India Ltd.

Service Office Secunderabad
GMT: +5:30
Flat # 302, Oxford Plaza, S.D. Road
500 003, A.P Secunderabad
Postal Address: Secunderabad

Direct phone	40-771 53 83
Direct phone Nro.2	40-771 53 84
Direct phone Nro.3	40-771 53 85
Fax	40-771 53 77

INDONESIA +62

PT. Wärtsilä Indonesia

Service Office Bekasi
GMT: +7
Cikarang Industrial Estate, Jl. Jababeka XVI Kav. W-28
17530 Bekasi
Postal Address: Bekasi

Direct phone	21-893 76 54
Fax Management	21-893 76 60
Fax Service	21-893 76 61/893 76 55
24hrs phone	81-190 96 62

IRAN +98

Kalajoo Company

Representative
GMT: +3:30
Apt. # 302, Sayeh Bldg., 1409 Vali Asr. Ave.
19677 Tehran
Postal Address: P.O. Box 19945-583 Tehran

Direct phone	21-204 58 88
Direct phone Nro.2	21-204 35 28
Fax	21-204 45 32
24hrs phone	911-213 2083
e-mail	wartsilansd@neda.net

IRELAND +353

Wärtsilä Ireland Ltd.

Service Office Co. Donegal
GMT: GMT
St. Catherines Road, Killybegs
Co. Donegal
Postal Address: Co. Donegal

Direct phone	73-32 177
Fax	73-321 80
24hrs phone	87-250 27 29

Wärtsilä Ireland Ltd.

Service Office Dublin
GMT: GMT
Belgard Industrial Estate, Mayberry Road
24 Dublin
Postal Address: Dublin

Direct phone	1-459 56 68
Fax	1-459 56 72
24hrs phone	87-243 56 66

ITALY +39

Wärtsilä Italia S.p.A.

Service Office Augusta
GMT: +1
Contrada Costa Pisone - Meccano 1
96011 Augusta
Postal Address: Augusta

Direct phone	0931-512 380
Fax	0931-511 899

Wärtsilä Italia S.p.A.

Service Office Cagliari
GMT: +1
Molo Sant Agostino
09100 Cagliari
Postal Address: Cagliari

Direct phone	070-667 991
Fax	070-653 346

Wärtsilä Italia S.p.A.

Service Office Civitavecchia
GMT: +1
Molo Vespucci
00053 Civitavecchia
Postal Address: Civitavecchia

Direct phone	0766-324 54
Fax	0766-334 49

Wärtsilä Italia S.p.A.

Service Office Genova
GMT: +1
Via al Molo Giano
16128 Genova
Postal Address: Genova

Direct phone	010-599 58 91
Fax	010-247 23 41
24hrs phone F. Borsarelli	0335-679 07 83

Wärtsilä Navim Diesel S.r.l.

Head Office Genova
GMT: +1
Via Carrara 24/26
16147 Genova
Postal Address: Genova

Direct phone	010-373 07 79
Fax Accountancy	010-373 07 61
Fax Commissioning and Warranty	010-373 07 83
Fax Spare parts	010-373 09 92

Wärtsilä Navim Diesel S.r.l.

Workshop Genova
GMT: +1
Via dei Pescatori, Zona Porto Industriale del Levante
16129 Genova
Postal Address: Genova

Direct phone	010-247 09 32
Fax	010-247 09 38
24hrs phone Field service	335-716 76 78

Wärtsilä Italia S.p.A.

Service Office Golfo degli Aranci
GMT: +1
Via Angioy 8/A
07020 Golfo degli Aranci
Postal Address: Golfo degli Aranci

Direct phone	0789-615 075
Fax	0789-615 080

Wärtsilä Italia S.p.A.
Service Office La Spezia
GMT: +1
Via della Concia, 38
19100 La Spezia
Postal Address: La Spezia
Direct phone 0187-525 055
Fax 0187-523 346

Wärtsilä Italia S.p.A.
Service Office Livorno
GMT: +1
Via Negrelli, 16
57100 Livorno
Postal Address: Livorno
Direct phone 0586-887 200
Fax 0586-882 071

Wärtsilä Italia S.p.A.
Service Office Marghera Venezia
GMT: +1
Via Bottenigo 147 r.
30175 Marghera Venezia
Postal Address: Marghera Venezia
Direct phone 041-538 20 63
Fax 041-538 69 19

Wärtsilä Italia S.p.A.
Service Office Messina
GMT: +1
Via della Zagare, 8
98100 Messina
Postal Address: Messina
Direct phone 090-293 15 05
Fax 090-694 731

Wärtsilä Italia S.p.A.
Service Office Milano
GMT: +1
Via N. Sauro 5, Peschiera Borromeo
20068 Milano
Postal Address: Milano
Direct phone 02-553 90 61
Fax 02-553 90 638

Wärtsilä Italia S.p.A.
Service Office Napoli
GMT: +1
Calata Porta di Massa
80133 Napoli
Postal Address: Napoli
Direct phone 081-552 75 30
Direct phone Warehouse 081-552 73 90
Fax Service 081-552 76 80
Fax Warehouse 081-552 71 68
24hrs phone V. di Gennaro 0336-940 466

Wärtsilä Italia S.p.A.
Service Office Palermo
GMT: +1
Via C. Colombo, 16
90100 Palermo
Postal Address: Palermo
Direct phone 091-545 738
Fax 091-362 358

Wärtsilä Italia S.p.A.
c/o ARSENALE M.M.
GMT: +1
Via di Palma
74100 Taranto
Postal Address: Taranto
Direct phone 099-453 50 60
Fax 099-453 50 66

Wärtsilä Italia S.p.A.
Service Office Trieste
GMT: +1
Bagnoli della Rosandra, 334, San Dorligo della Valle
34018 Trieste
Postal Address: Trieste
Direct phone 040-319 50 00
Fax Service 040-319 56 47
24hrs phone 2-stroke engines, S. Urpis 0335-584 30 60
24hrs phone 4-stroke engines, R. Bertali 0335-641 25 17
24hrs phone I.A. M. Mazzone 0335-725 52 54
24hrs phone Spare Parts A. Fonda 0335 726 90 35
24hrs phone Technical Service, A. Guglia 0335-641 25 19

IVORY COAST +225

Wärtsilä NSD ACO.
Service Office Abidjan
GMT: -2
01 Abidjan
Postal Address: 01 B.P. 4432 01 Abidjan
Direct phone 21 35 03 51
Direct phone Nro.2. . . . . 21 35 18 76
Direct phone Nro.3. . . . . 21 24 31 59
e-mail . . . . .cwacom@comete.ci

JAPAN +81

Wärtsilä Diesel Japan Co Ltd.
Service Office Kobe
GMT: +9
Kobe Yusen Bldg., 1-1-1 Kaigan-dori, Chuo-Ku
650-0024 Kobe
Postal Address: Kobe
Direct phone Sulzer products 78-321 15 01
Direct phone Warehouse 78-392 86 70
Direct phone Wartsila products. . . . 78-392 53 33
Fax 78-392 86 88
24hrs phone . . . . 9-04.906 25 07 S. Kenich/ 9-02 116 02 34 T. Hitoshi

Wärtsilä Diesel Japan Co Ltd.
Branch Office Tokyo
GMT: +9
Binary Kita-Aoyama Bild., 8F, 3-6-19, Kita-Aoyama, Minato-ku
107-0061 Tokyo
Postal Address: Tokyo
Direct phone 3-3486 4531
Fax 3-3486 4153

Wärtsilä Diesel Japan Co Ltd.
Branch Office Yokohama
GMT: +9
COSMO Yokohama City Square RM 202, Aoki-cho 5-25, Kanagawa-ku
221 0057 Yokohama
Postal Address: Yokohama
Direct phone 45-461 57 10
Fax 45-461 57 07

KOREA +82

Wärtsilä Korea Ltd.
Service Office Pusan
GMT: +9
Pusan Marine Center Bldg., 10th Floor, 79-1, Chungang-Dong, 4 Ga
600 715 Pusan
Postal Address: Pusan
Direct phone 51-469 54 21
Fax 51-469 54 22
24hrs phone 17-546 02 02

Wärtsilä Korea Ltd.
Service Office Seoul
GMT: +9
Noksan Bldg. 6th Floor, 50-11, Yonggang-dong, Mapo-ku
121 070 Seoul
Postal Address: Seoul
Direct phone 2-32 72 80 32/5
Fax 2-32 72 80 36

MALAYSIA +65

Wärtsilä Singapore Pte Ltd
Representative
GMT: +8
Selangor
No. 1, Jalan SS3/51, Petaling Jaya,
47300 Darul Ehsan
Postal Address: Darul Ehsan
Direct phone 3-7877 24 87
Fax 3-7876 76 04
24hrs phone Mobile 12-210 03 09

MALTA +356

Malta Drydocks
Representative
GMT: +1
The Docks
CMR 01 Valetta
Postal Address: P.O. Box 581 Valetta
Direct phone 82 24 51
Direct phone Nro.2. . . . . 82 24 91
Fax 80 00 21
e-mail . . . . .info@maltadrydocks.com.mt
Telex . . . . .1810 drydks mw

MEXICO +52

Wärtsilä de Mexico S.A. de C.V.
GMT: -6
Guillermo Gonzalez Camarena # 1100, 5th Floor, Col. Centro Ciudad de Santa Fé, Delegacion Alvaro Obregón
01210 Mexico, D.F.
Postal Address: Mexico, D.F.
Direct phone 5-570 92 00
Fax 5-570 92 01
e-mail . . . . wdmex@mail.internet.com.mx

MOROCCO +212

HELVETEC SA
Representative
GMT: GMT
61, Avenue Hassan II
20000 Casablanca
Postal Address: Casablanca
Direct phone 2-2-29 78 34
Fax 2-2-26 93 49

Société Salva
Representative
GMT: GMT
93, Boulevard de la Résistance
21700 Casablanca
Postal Address: Casablanca
Direct phone 2-2-30 40 38
Direct phone Service . . . . .4-8-84 36 27 or 28
Fax 2-2-30 66 75
Fax Nro.2 . . . . 2-2-30 57 17
Fax Service 4-8-84 36 29
24hrs phone 6-1-52 49 81
Telex . . . . 27012 sosalva

NETHERLANDS +31

Wärtsilä Nederland B.V.
Service Office Delfzijl
GMT: +1
Damsterkade 6
9934 CT Delfzijl
Postal Address: Delfzijl
Direct phone 596-611 965
Fax 596-611 965

Wärtsilä Nederland B.V.
Service Office Den Helder
GMT: +1
Het Nieuwe Werk 102
1780 AK Den Helder
Postal Address: P.O. Box 116 Den Helder
Direct phone 223-635 988
Fax 223-633 890

Wärtsilä Nederland B.V.
Service Office Ijmuiden
GMT: +1
Trawlerkade 46
1976 CB Ijmuiden
Postal Address: Ijmuiden
Direct phone 255-511 678
Fax 255-536 724

NETHERLANDS +41

Wärtsilä Switzerland Ltd

Logistic Centre Ridderkerk

GMT: +1
Keurmeesterstraat 21
2984 BA Ridderkerk
Postal Address: Ridderkerk

Direct phone	180 41 30 97
Direct phone Logistics	180 44 66 80
Fax Logistics	180 41 22 13
Fax Quality Control	180 41 61 58
Mobile	651 80 26 67

NETHERLANDS +31

Wärtsilä Nederland B.V.

Service Office Benelux

GMT: +1
Havenstraat 18-24
3115 HD Schiedam
Postal Address: Schiedam

Direct phone	10-427 71 00
Fax	10-426 45 71
24hrs phone	10-427 71 00

Wärtsilä Nederland B.V.

Service Office Stellendam

GMT: +1
Deltahaven 7
3251 LC Stellendam
Postal Address: Stellendam

Direct phone	187-491 956
Fax	187-493 429

Wärtsilä Nederland B.V.

Service Office Urk

GMT: +1
Industrierondweg 6D
8321 EA Urk
Postal Address: Urk

Direct phone	527-682 053
Fax	527-685 902

Wärtsilä Nederland B.V.

Service Office Zwolle

GMT: +1
Hanzelaan 95
8000 GB Zwolle
Postal Address: P.O. Box 10608 Zwolle

Direct phone	38-425 32 53
Fax	38-425 35 38
Fax Contracting	38-425 38 13
Fax Logistics	38-425 32 90
Fax Parts global	38-425 33 97
Fax Project support	38-425 34 71
24hrs phone	38-425 32 53
Telex	42115 swdz nl

NEW ZEALAND +61

Wärtsilä Australia Pty Ltd.

New Zealand Service Office

GMT: +12
Port of Wellington Authority Complex, Shed 29, Hinemoa Street,
Port Wellington
Postal Address: P.O. Box 1375 Port Wellington

Direct phone	4-473 08 30
Fax	4-473 08 31

NORWAY +47

Wärtsilä Norway AS

Service Office Drobak

GMT: +1
Hestehagen 5, Holter Industriomrade
N-1440 Drobak
Postal Address: Drobak

Direct phone	64-93 76 50
Fax Sales	64-93 76 60
Fax Service	64-93 76 80
Fax Spare parts	64-93 76 70
24hrs phone	41 62 47 47

Wärtsilä Norway AS

Service Office Rubbestadneset

GMT: +1
N-5420 Rubbestadneset
Postal Address: Rubbestadneset

Direct phone	53-42 25 00
Fax Field Service/Spare Parts	53-42 25 06
Fax Service Logistics	53-42 25 08
Fax Ship Repair	53-42 25 09
24hrs phone Field service	94-56 75 90
24hrs phone Ship Repair	53-42 28 10
24hrs phone Spare parts	94-56 75 91

PAKISTAN +92

Wärtsilä Pakistan (Pvt.) Ltd.

Service (North)

GMT: +5
16 km Raiwind Road
Lahore
Postal Address: P.O. Box 10104 Lahore

Direct phone	42-541 88 46
Fax	42-541 98 33

Wärtsilä Pakistan (Pvt.) Ltd.

Service (South)

GMT: +5
2nd Floor, P.O.F. Liaison Offices, 252 Sarwar Shaheed Road
Saddar, Karachi
Postal Address: Saddar, Karachi

Direct phone	21-568 57 34, 568 87 50
Fax	21-568 27 97

PAPUA NEW GUINEA +61

Wärtsilä Australia Pty Ltd.

Papua New Guinea Service Workshop

GMT: +10
Lihir Island

Postal Address:

Direct phone	9865 638

PERU +51

Wärtsilä del Peru

Service Office Lima

GMT: -5
J. Arias Araguez #210 San Antonio, Miraflores
18 Lima
Postal Address: Lima

Direct phone	1-241 70 30
Fax	1-444 68 67
24hrs phone	1-996 86 97

PHILIPPINES +63

Wärtsilä Philippines Inc.

Service Office Laguna

GMT: +8
No. 6 Diode Street, Light Industry and Science Park, Bo. Diezmo, Cabuyao
Laguna
Postal Address: Laguna

Direct phone	49-543 03 82
Direct phone Nro.2.	2-843 73 01
Direct phone Nro.3.	2-664 62 14
Fax	49-543 03 81
Fax Nro.2	2-843 73 05
24hrs phone	912-304 48 26

POLAND +48

Wärtsilä Polska Sp. z o.o.

Service Office Gdansk

GMT: +1
ul. Grunwaldzka 139
PL-80-264 Gdansk
Postal Address: Gdansk

Direct phone	58-345 23 44
Fax	58-341 67 44

Wärtsilä Polska Sp. z o.o.

Service Office Warszawa

GMT: +1
Al. Wilanowska 372
PL-02-665 Warszawa
Postal Address: Warszawa

Direct phone	22-843 87 51
Fax	22-843 87 52
24hrs phone	602-471 951

PORTUGAL +351

Wärtsilä Portugal Lda.

Service Office Maia Codex

GMT: GMT
Zona Industrial da Maia I, Sector X, Lote 362, No. 43
4471 Maia Codex
Postal Address: P.O. Box 1415 Maia Codex

Direct phone Business controlling & finance	22-943 97 20
Direct phone Field service	22-943 97 26
Direct phone Spare parts	22-943 97 21
Direct phone Workshop	22-943 97 28
Fax	22-943 97 29
e-mail	wartsila.pt@mail.telepac.pt

PUERTO RICO +1

Wärtsilä Caribbean Inc.

Service Office Guaynabo

GMT: -4
Metro Office Park, 2 Calle 1, Suite 101
00968-1702 Guaynabo
Postal Address: Guaynabo

Direct phone	787-792 80 80
Fax	787-792 26 00
Fax Nro.2	787-792 26 60
24hrs phone	787-505 25 35

RUSSIA +7

Wärtsilä NSD Corporation, Russia

Service Office St. Petersburg

GMT: +3
Schwedsky per., 2
191186 St. Petersburg
Postal Address: St. Petersburg

Direct phone	812-118 63 31
Fax	812-118 63 30

Wärtsilä Vladivostok Ltd.

Service Office Vladivostok

GMT: +10
57 Krygina Str., 4th Floor
690090 Vladivostok
Postal Address: P.O. Box 90-265 Vladivostok

Direct phone	4232-510 710
Direct phone Nro.2.	4232-518 501
Fax	4232-510 711
24hrs phone	4232-488 744
e-mail	vdolgikh@fastmail.vladivostok.ru

SAUDI ARABIA +966

Wärtsilä Saudi Arabia Ltd.

Service Office Jeddah

GMT: +3
21451 Jeddah
Postal Address: P.O. Box 2132 Jeddah

Direct phone	2-637 64 70
Direct phone Nro.2.	2-637 68 84
Direct phone Nro.3.	2-636 09 17
Direct phone Nro.4.	2-638 06 98
Direct phone Nro.5.	2-637 01 23
Direct phone Nro.6.	2-637 22 11
Fax	2-637 64 82

SINGAPORE +65

Wärtsilä Singapore Pte Ltd

Service Office Singapore

GMT: +8
14 Benoi Crescent
SGP-629977 Singapore
Postal Address: Singapore

Direct phone	2659 122
Direct phone Nro.2.	2674 307
Direct phone Nro.3.	2674 308
Direct phone Nro.4.	2674 309
Fax	2650 910
Fax Marine	2640 802
Fax Power Plants	2643 186
Fax Service	2614 239
24hrs phone	9-8358 200

SOUTH AFRICA +27

Wärtsilä (South Africa) (Pty) Ltd.

Head Office Cape Town
GMT: +2
36 Neptune Street, Paarden Eiland 7405
Cape Town
Postal Address: P O Box 356, Paarden Eiland
7420 Cape Town
Direct phone 21-511 12 30
Fax 21-511 14 12
24hrs phone 83-658-6789
e-mail . . . . wartcape@iafrica.com

SPAIN +34

Wärtsilä Ibérica S.A.

Service Office Bermeo
GMT: +1
Polígono Industrial Landabaso s/n
48370 Bermeo
Postal Address: P.O. Box 137 Bermeo
Direct phone 94-617 01 00
Fax Field service 94-617 01 04
Fax Spare parts 94-617 01 14
24hrs phone 607-416 998

Wärtsilä Ibérica S.A.

Service Office Las Palmas de Gran Canaria
GMT: GMT
Misiones 8 (El Cebadal)
35008 Las Palmas de Gran Canaria
Postal Address: P.O. Box 2831 Las Palmas de
Gran Canaria
Direct phone 928-467 859
Fax 928-465 931
24hrs phone 607-416 998

SWEDEN +46

Wärtsilä Sweden AB

Marine Service Gothenburg
GMT: +1
Polstjärnegatan 10,
SE-402 77 Gothenburg
Postal Address: P.O. Box 8006 Gothenburg
Direct phone 31-656 100
Fax Marine 31-656 130
Fax Service Sales 31-656 107
24hrs phone 706 69 02 91

Wärtsilä Sweden AB

Service Trollhättan
GMT: +1
Åkerssjövägen
SE-461 29 Trollhättan
Postal Address: P.O. Box 920 Trollhättan
Direct phone 520-422 600
Fax Documentation 520-422 620
Fax Finance 520-422 781
Fax Service Sales 520-422 727
Fax Technical Service 520-422 777
Fax Training 520-422 721
24hrs phone Service 70-557 02 99
24hrs phone Spare parts. 70-536 47 25
ISDN 520-476 612

SWITZERLAND +41

Wärtsilä Switzerland Ltd

Service Winterthur
GMT: +1
Zürcherstrasse 12
CH-8401 Winterthur
Postal Address: P.O. Box 414 Winterthur
Direct phone 52-262 49 22
Direct phone Parts Sales After
Office Hours 52-262 80 10
Fax Service 52-262 07 09
Fax Spare parts . . . . 52-262 07 22 / 23
Fax Technical Service 52-262 07 31
Fax Training 52-262 07 31
24hrs phone Service 79-671 87 67

TAIWAN, R.O.C. +886

Wärtsilä Taiwan Ltd.

Service Office Kaohsiung
GMT: +8
Kaohsiung Service Station, 11F-1, 502 Chiu Ru 1st
Road
Kaohsiung
Postal Address: Kaohsiung
Direct phone 7-392 80 75
Fax 7-392 80 83
24hrs phone Marine. 932-209 041
24hrs phone Power Plants 932-029 849

Wärtsilä Taiwan Ltd.

Service Office Taipei 104
GMT: +8
3F/2, No. 111, Sung Chiang Road
Taipei 104
Postal Address: Taipei 104
Direct phone 2-2515 22 29
Fax 2-2517 19 16

THE UNITED KINGDOM +44

Wärtsilä UK Ltd.

Service Office Aberdeen
GMT: GMT
Scotland
Girdleness Trading Estate, Wellington Road
AB11 8DG Aberdeen
Postal Address: Aberdeen
Direct phone 1224-871 166
Fax 1224-871 188
24hrs phone Service 7775-807 108
24hrs phone Spare parts. 7775-807 109
ISDN 1224-87 15 22

Wärtsilä UK Ltd.

Service Office Brixham
GMT: GMT
South Devon
Units 30/31, Northfield Industrial Estate, Northfield
Lane South
TQ5 8UA Brixham
Postal Address: Brixham
Direct phone 1803-883 830
Fax 1803-882 685
24hrs phone Marine. 7775-807 112

Wärtsilä UK Ltd.

Service Office Glasgow
GMT: GMT
Scotland
Unit 3, Jubilee Court, Hillington Industrial Estate
G52 4NQ Glasgow
Postal Address: Glasgow
Direct phone 141-810 43 21
Fax 141-883 38 46
24hrs phone Service 7775-807 108
24hrs phone Spare parts. 7775-807 109
ISDN 141-88 39 375

Wärtsilä UK Ltd.

Service Office Sevenoaks
GMT: GMT
Kent
Tubs Hill House, London Road
TN13 1BL Sevenoaks
Postal Address: Sevenoaks
Direct phone 1732-744 400
Fax 1732-744 420
Fax Sulzer products. 1732-744 433
24hrs phone 7775-807 100
ISDN 1732-74 01 88

Wärtsilä UK Ltd.

Service Office Southampton
GMT: GMT
Hampshire
Units 3 & 5, Third Avenue, Millbrook Industrial
Estate
SO15 OLD Southampton
Postal Address: Southampton
Direct phone 2380-510 210
Fax 2380-510 310
Fax Spare parts 2380-787 650
24hrs phone Service 7775-807 100
24hrs phone Spare parts. 7775-807 119

TURKEY +90

Wärtsilä - Enpa Dis Ticaret A.S.

Service Office Besiktas/Istanbul
GMT: +2
Süleyman Seba Cad. No. 92 Besiktas Plaza A Blok
Zemin Kat
80690 Besiktas/Istanbul
Postal Address: Besiktas/Istanbul
Direct phone 212-327 15 30
Direct phone Nro.2. . . . . 212-258 55 16
Fax 212-327 15 35
Fax Nro.2 . . . . 212-258 99 98
24hrs phone 532-233 00 47

Wärtsilä - Enpa Dis Ticaret A.S.

Service Office Tuzla-Istanbul
GMT: +2
Aydintepe Mah. G.50 Sok. Tersaneler Mevkii Özek
Is Merkezi D Blok No. 5-6
81700 Tuzla-Istanbul
Postal Address: Tuzla-Istanbul
Direct phone 216-493 29 21
Fax 216-493 29 20

U.S.A +1

Wärtsilä North America, Inc.

Service Office Ft. Lauderdale/Hollywood
GMT: -5
Florida
2900 S.W. 42nd Street
33312 Ft. Lauderdale/Hollywood
Postal Address: Ft. Lauderdale/Hollywood
Direct phone 954-327 47 00
Fax Service 954-327 47 73
24hrs phone Customer Service . . . 954-931 83 30
24hrs phone Spare parts. 954-931 83 29
ISDN 954-327 03 93

Wärtsilä North America, Inc.

Service Office Harvey
GMT: -6
Louisiana
1313 MacArthur Blvd.
70058 Harvey
Postal Address: Harvey
Direct phone 504-341 72 01
Fax 504-341 04 26
24hrs phone Customer Service . . . 504-341 72 01

Wärtsilä North America, Inc.

Service Office Houston
Texas
Summit Tower 11 Greenway Plaza - Suite 2929
77046 Houston
Postal Address: Houston
Direct phone 713-840 0020
Fax 713-840 00 09

Wärtsilä North America, Inc.

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00. Contents, Instructions, Terminology

00.1 Contents of the Manual

This Manual contains data and instructions for operation and maintenance of the engine as well as instruction for handling, personal protection and first aid when fuel-, lubricating oils and cooling water additives are handled during normal operation and maintenance work.

Basic general knowledge has not been entered. Consequently, it is assumed that the engine operation and maintenance staff is well informed of the care of diesel engines.

Wärtsilä reserves for itself the right to minor alterations and improvements owing to engine development without being obliged to enter the corresponding changes in this Manual.

The diesel engines will be equipped as agreed upon in the sales documents. No claim can be made on the basis of this Manual as here are described also components not included in every delivery.

The system diagram plans (fuel, oil, cooling etc.) are just indicative and thus do not cover all installations. See installation specific system drawings for more details.

Exact engine build-up in all details is defined by the specification number on the name plate located on the engine. **In all correspondence or when ordering spare parts, be careful to state engine type, specification number and engine number.**

This Manual is supplemented by the Spare Parts Catalogue including sectional drawings or exterior views of all components (partial assemblies).

00.2 General rules

1 **Read the corresponding item carefully** in this Manual before any steps are taken.

2 **Keep an engine log book for every engine.**

3 **Observe the utmost cleanliness and order** at all maintenance work.

4 **Before dismantling,** check that all systems concerned are drained or the pressure released. After dismantling, immediately cover holes for lubricating oil, fuel oil and air with tape, plugs, clean cloth or the like.

5 **When replacing a worn-out or damaged part** provided with an identification mark stating cylinder or bearing number, mark the new part with the same number on the same spot. Every exchange should be entered in the engine log and the reason should be clearly stated.

6 **After reassembling,** check that all screws and nuts are tightened and locked, if necessary.

7 **Check that all shields and covers** are fully functional and in place.

Note! **Predictive maintenance is important when it comes to fire protection. Regular inspection of fuel oil lines, lubricating oil lines and connections must be done.**

00.3 Terminology

The most important terms used in this manual are defined as follows, see also Fig 00-1:

Operating side. The longitudinal side of the engine where the operating devices are located (start and stop, instrument panel, speed governor).

Rear side. The longitudinal side of the engine opposite the manoeuvering side.

Driving end. The end of the engine where the flywheel is located.

Free end. The end opposite the driving end.

Designation of cylinders. According to ISO 1204 and DIN 6265 the designation of cylinders begins at the driving end. In a V-engine the cylinders in the left bank, seen from the driving end, are termed A1, A2 etc. and in the right bank B1, B2 etc., see below:

Terminology

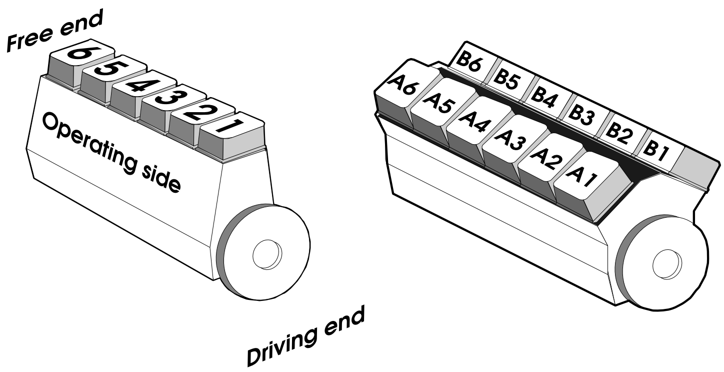


Fig 00-1 WV00519326

Designation of bearings.

- Main bearings. The shield bearing (nearest the flywheel) is No. 0, the first standard main bearing is No. 1, the second No. 2 etc.
- The thrust bearing rails are located at the shield bearing. The outer rails close to the flywheel are marked with 00 and the inner rails with 0.
- The camshaft bearings are designated as the main bearings, the thrust bearing bushes being designated 00 (outer) and 0.
- Camshaft gear bearings. The bearing bushes are designated 00 (outer) and 0.
- Upper and lower bearings shells. In bearings where both the shells are identical, the upper one is marked with “UP”.

Designation of bearings

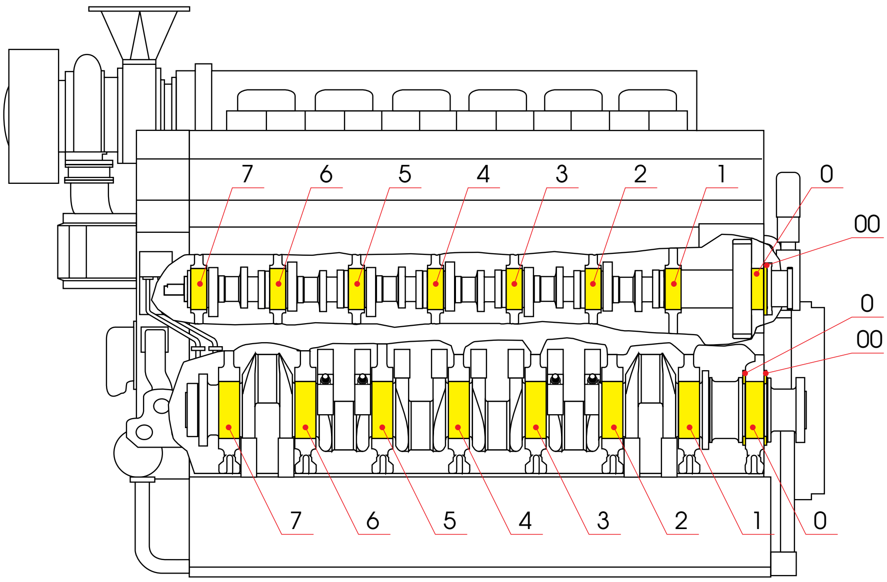


Fig 00-2 4000019601

Operating side and rear side. Details located at the operating side may be marked with “M” (Manoeuvering) and correspondingly “B” for the back of the engine (B-bank on a V-engine).

Clockwise rotating engine. When looking at the engine from the driving end the shaft rotates clockwise.

Counter-clockwise rotating engine. When looking at the engine from the driving end the shaft rotates counter-clockwise.

Bottom dead centre, abbreviated **BDC**, is the bottom turning point of the piston in the cylinder.

Top dead centre, abbreviated **TDC**, is the top turning point of the piston in the cylinder. TDC for every cylinder is marked on the graduation of the flywheel. During a complete working cycle, comprising in a four-stroke engine two crankshaft rotations, the piston reaches TDC twice:

a) For the first time when the exhaust stroke of the previous working cycle ends and the suction stroke of the following one begins. Exhaust valves as well as inlet valves are then somewhat open and scavenging takes place. If the crankshaft is turned to and fro near this TDC, both exhaust and inlet valves will move, a fact that indicates that the crankshaft is near the position which can be named **TDC at scavenging.**

b) The second time is after the compression stroke and before the working stroke. Slightly before this TDC the fuel injection takes place (on an engine in operation) and this TDC can therefore be defined **TDC at firing.** Characteristic is that all valves are closed and do not move if the crankshaft is turned. When watching the camshaft and the injection pump it is possible to note that the pump tappet roller is on the lifting side of the fuel cam.

Marking of the flywheel. The flywheel is divided in 360°, starting from **TDC at firing** for cylinder 1. TDC at firing for every cylinder is marked on the flywheel. There is a common marking for the cylinders in engines with even cylinder numbers, one cylinder is at TDC at firing and the other is at TDC at scavenging. There are separate scales for A- and B-bank in a V-engine. See also the firing order in chapter 01. Firing interval, in crank angles, can be determined by dividing 720° with the number of cylinder.

Example of reading the flywheel

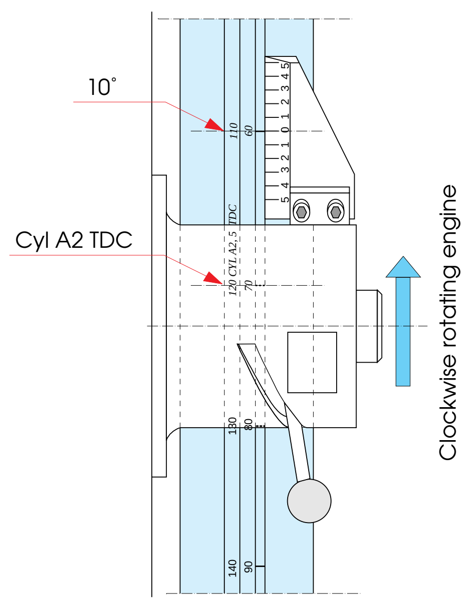


Fig 00-3 4000029706

Example: *On a 12V32 engine, the fuel timing is read to 10° for cylinder A2 when the flywheel is in the position shown in the above figure.*

00A. Risk Reduction

00A.1 General

Read the engine manual including this appendix before installing, operating or servicing the engine and/or related equipment.

Failure to follow the instructions can cause personal injury, loss of life and/or property damage.

Proper personal safety equipment, e.g. gloves, hard hat, safety glasses and ear protection must be used in all circumstances. Missing, imperfect or defective safety equipment might cause serious personal injury or loss of life.

This appendix contains listed general identified hazards, hazardous situations or events, which are to be noticed during normal operation and maintenance work.

Identified hazard,hazardous situation or event	Chapter of engine manual																
	3	4	8	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Dropping parts during maintenance work		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Turning device engaged during maintenance work [1)]	x	x		x	x	x	x	x		x							
Crankcase safety expl. valves will open if crank-case explosion	x			x													x
Noise level	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Running engine without covers	x	x		x	x	x	x	x		x					x	x	
In case of major failure, risk of ejected parts	x	x		x	x	x	x	x								x	
Contact with electricity during maintenance work if power not disconnected		x			x						x	x			x	x	x
Electrical hazard if grounding of electrical equip-ment is incorrect	x	x			x						x	x					
Ejection of components / high pressure gas due to high firing pressures	x	x				x	x	x		x					x		
Risk of ejected parts due to break down of turbo-charger	x								x								
Overspeed or explosion due to air-gas mixture in the charge air [2)]	x	x							x								
Ejection of fuel injector if not fastened and crank-shaft is turned		x				x				x							
Engine rotating due to engaged gear box or closed generator breaker during overhaul	x	x		x	x	x	x	x		x							
Fire or explosion due to leakage on fuel / gas line or lube oil system	x	x								x	x	x		x			
Inhalation of exhaust gases due to leakage [3)] Continues	x								x					x			

Identified hazard,hazardous situation or event	Chapter of engine manual																
	3	4	8	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Inhalation of exhaust gas dust		x	x	x	x	x			x					x			
Explosion or fire if flammable gas/vapour is leaking into the insulation box. 4)	x													x			
Touching of moving parts	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x
High pressure hoses, risk of oil spray.	x	x	x	x	x	x	x	x	x	x		x	x		x	x	

1) Warning light when turning device engaged.
2) Suction air to be taken from gas free space.
3) Require proper ventilation of engine room/plant.
4) Require proper ventilation and/or gas detector in the engine.

00A.1.1 General identified hazards, hazardous situations or events

00A.1.1.1 Hazards that may be due to moving parts

- Running engine without covers, coming in contact with moving parts,
- Touching pump parts during unintentional start of el. driven pump motor,
- Charger starts to rotate due to draft if not locked during maintenance,
- Somebody sticks his hand into the compressor housing when the silencer is removed and engine running,
- Unexpected movement of valve or fuel rack(s) due to broken wire or soft / hardware failure in the control system,
- Unexpected movement of components,
- Turning device engaged during maintenance work,
- Turning device not engaged e.g. Turning device removed for overhaul, during maintenance work could cause rotating crankshaft,
- Mechanical breakage (of e.g. speed sensor) due to erratic actuator assembly to engine or electrical connections.

00A.1.1.2 Hazards that may be due to incorrect operating conditions

- Overspeed or explosion due to air-gas mixture in the charge air,
- Overspeeding due to air-oil mist mixture in the charge air,
- Malfunction of crankcase ventilation,
- Oil mist detector will trip if water is present in lubricating oil,
- Crankcase explosion if oil mist is mixed with “fresh” air during inspection after an oil mist shut down,

- Crankcase safety explosion valves will open if there is a crankcase explosion.

00A.1.1.3 Hazards that may be due to different leakages, break-down or improper assembly of component

- Fuel or gas pipe will burst and spray fuel / gas,
- Leakage of:

— fuel in joints on low and/or high pressure side,
— lube oil,
— high pressure water on DWI engines,
— HT water,
— charge air,
— exhaust gas,
— pressurised air from air container, main manifold or pipes,
— high pressure gas and sealing oil on GD engines,

- Fire or explosion due to leakage on fuel line,
- Fire due to oil or fuel / gas leakage,
- Explosion or fire if flammable gas/vapour is leaking into the insulation box,
- Inhalation of exhaust gases or fuel gases due to leakage,
- Failure of pneumatic stop,
- Ejected components due to:

— breakdown of hydraulic tool,
— breakdown of hydraulic bolt,
— breakdown of turbocharger,
— high firing pressures,
— major failure,

- Ejection of:

— pressurised liquids and gases from the block and pipings,
— high pressure fluid due to breakdown of hydraulic tool,
— gas due to high firing pressures,
— pressurised gases from high pressure gas system,
— high pressure fluid due to breakdown of HP sealing oil pipe,
— high pressure air during maintenance of oil mist detector main air supply piping,
— cooling water or fuel/lube oil if sensor is loosened while the circuit is pressurised,
— springs during maintenance work,

- Oil spray if running without covers,
- Ejection of fuel injector if not fastened and

— turning device engaged and turned.
— engine turning due to closed generator breaker/coupling

00A.1.1.4 Hazards that may be due to electricity or incorrect connections of electricity

- Fire or sparks due to damage or short circuit in electrical equipment,
- Contact with electricity during maintenance work if power not disconnected,
- Electrical hazard if grounding of electrical equipment is incorrect,
- Electrical shock if electrical equipment has a lead isolation break or connector damage or is dismantled with power connected,
- Overheating of control system component due to erratic electrical connections,
- Incorrectly wired or disconnected emergency stop switch,
- Overload of control system components due to damaged control circuitry or incorrect voltage,
- Engine not controllable if failure in the shutdown circuitry,
- Unexpected start up or overrun,
- Crankcase explosion if:

— engine not safeguarded at high oil mist levels, due to energy supply failure,
— engine not (fully) safeguarded at high oil mist levels, due to failure in oil mist detector circuitry,
— engine not (fully) safeguarded at high oil mist levels, due to erratic electrical connector or leakage in pipe connection.

00A.1.1.5 Other hazards and hazardous situations where it's especially important to use personal safety equipment

- Slip, trip and fall,
- Water additives and treatment products (see appendix 02A, section 02A.4),
- Touching the insulation box, turbo-charger, pipes exhaust manifold or (other) unprotected parts without protection during engine operation,
- Dropping parts during maintenance work,
- Starting maintenance work too early i.e. causing risk when handling hot components,
- Neglecting use of cranes and/or lifting tools,
- Not using proper tools during e.g. maintenance work,
- Contact with fuel oil or oily parts during maintenance work (see appendix 02A),
- Noise level,
- Touching or removing Turbocharger insulation,
- Preloaded fixation springs during check / replacement of sensor.

00B. Welding Precautions

00B.1 Precautions General

Main principles:

- Prevent uncontrolled current loops
- Prevent radiation
- Prevent sparkles flying around
- If convenient, disconnect all global signals like power supply, data communication etc.

00B.1.1 Preventing uncontrolled current loops

Welding current path must always be checked, there should be a straight route from the welding point back to the return connection of the welding apparatus.
The biggest current is always going where it meets the lowest resistance, in certain cases the return current can therefore go via grounding wires and electronics in the control system.
To avoid this, the distance between the welding point and the return connection clamp of the welding apparatus should always be shortest possible and without electronic components in the returning loop path.
Attention must be paid to the connectivity of the return connection clamp, a bad contact might also cause sparkles and radiation.

00B.1.2 Preventing Radiation

The welding current and the arc is emitting a wide spectrum of electromagnetic radiation. This might cause damages on sensitive electronic equipment.
To avoid these damages all cabinets and terminal boxes must be kept closed during the welding. Sensitive equipment can also be protected by means of shielding with a conductive metal plate.
Also avoid having the cables of the welding apparatus going in parallel with wires and cables in the control system. The high welding current is easily inducting secondary currents in other conductive materials.

00B.1.3 Preventing damage due to sparkles

Sparkles are commonly flying around from the welding arc. Few materials withstand the heat from these sparkles. Therefore all cabinets and terminal boxes should be kept closed during the welding. Sensors, actuators, cables and other equipment out on the engine must be protected by means of proper protection.

Sparkles can also be a problem after they have cooled down, i.e. causing short circuits, sealing problems etc.

00B.2 Precaution checklists

00B.2.1 Checklists General

The checklists (preferable glued to a plastic plate) in this chapter should be put into the engines cabinet for respective system type. The checklist must be easily visible and accessible when opening the cabinet.

00B.2.2 Basic ECU (Despemes/Spemos) checklist

The following precautions must be paid attention to before welding in the vicinity of a basic ECU system:

- Close the cover of the cabinet
- Deactive the system by disconnecting all external connectors (X1...X4).
- If convenient, protect cables, sensors and other equipment from sparkles with a proper metal sheet.

00B.2.3 WECS 2000 checklist

The following precautions must be paid attention to before welding in the vicinity of a WECS 2000 control system:

- Close the covers of the cabinet and all the distributed units.
- Deactivate the system by disconnecting all external connectors (X1...X6).
- If convenient, protect cables, sensors and other equipment from sparkles with a proper metal sheet.

00B.2.4 WECS 3000 checklist

The following precautions must be paid attention to before welding in the vicinity of a WECS 3000 control system:

- Deactive the system by disconnecting all external connectors (X1...X5).
- Do not connect the welding apparatus return line to the aluminium profile containing CCU's, KDU's and ignition modules. The profile is used as a common ground for these modules.
- Open all terminal fuses (F1...F20) in the cabinet.
- Close the covers of the cabinet and all the distributed units.
- If convenient, protect cables, sensors and other equipment from sparkles with proper metal sheet.

00B.2.5 WECS 7000/8000 checklist

The following precautions must be paid attention to before welding in the vicinity of a WECS 7000 or 8000 control system:

- Deactive the system by disconnecting all external connectors (X1...X6).
- If the welding point is close to (approximately within a radius of 2 m) an electronic module (SSM-701, SSM-558, CCD/PDM, Cense etc.) disconnect all connectors of the unit
- Close the covers of the cabinet
- Disconnect the interconnections between the harnesses and the cabinet.
- If convenient, protect harnesses, cables, sensors and other equipment from sparkles with a proper metal sheet.

01. Main Data, Operating Data and General Design

01.1 Main data for Wärtsilä 32

Cylinder bore . . . . 320 mm
Stroke . . . . 400 mm
Piston displacement per cylinder . . . . 32.17 l

Firing order		
Engine type	Clockwise rotation	Counter-clockwise rotation
6L32	1-5-3-6-2-4	1-4-2-6-3-5
8L32	1-3-7-4-8-6-2-5	1-5-2-6-8-4-7-3
9L32	1-7-4-2-8-6-3-9-5	1-5-9-3-6-8-2-4-7
12V32	A1-B1-A5-B5-A3-B3-A6-B6-A2-B2-A4-B4	A1-B4-A4-B2-A2-B6-A6-B3-A3-B5-A5-B1
16V32	A1-B1-A3-B3-A7-B7-A4-B4-A8-B8-A6-B6-A2-B2-A5-B5	A1-B5-A5-B2-A2-B6-A6-B8-A8-B4-A4-B7-A7-B3-A3-B1
18V32	A1-B1-A7-B7-A4-B4-A2-B2-A8-B8-A6-B6-A3-B3-A9-B9-A5-B5	A1-B5-A5-B9-A9-B3-A3-B6-A6-B8-A8-B2-A2-B4-A4-B7-A7-B1

Normally the engine rotates clockwise.

Lubricating oil volume in the engine						
Engine type	6L32	8L32	9L32	12V32	16V32	18V32
App. oil volume in litres Wet sump	1630	2050	2270	3050	3860	4270
Oil volume between max. and min. marks appr. litres/mm	2.95	3.70	4.05	4.25	5.35	5.90

Lubricating oil volume in the turning device in litres	
LKV132	8.5 - 9.5

Lubricating oil volume in the speed governor in litres	
	1.9

App. cooling water volume in the engine in litres						
Engine only	410	510	560	740	840	890

01.2 Recommended operating data

Apply to normal operation at nominal speed. See also installation specific Modbus list.

	Normal values	Alarm (stop) limits
Load	100 %	0 - 100 %
Temperatures, (°C)		
Lube oil before engine	60-65	75 (80) (2)
Lube oil after engine	10 - 13 higher	
HT water after engine	91 - 96(1)	105 (110) (2)(3)
HT water before engine	5 - 8 lower	50
HT water rise over turbocharger (xx)	8 - 12	
LT water before charge air cooler	28 - 38	45
Charge air in air receiver	50 - 60	75
Exhaust gas after cylinder	See test records	500 (520) (2)
Exhaust gas before turbocharger		—
Preheating of HT water	50 (MDO) 70 (HFO)	45
Cylinder liner temp.	130 - 150	160 (180)(2)
Main bearing temp.	90 - 100	110 (120)(2)
Gauge pressures (bar)		
Lube oil before engine at a speed of 600 RPM (10.0 r/s)	4.5	3.0 (2.0)
720 RPM (12.0 r/s) - 750 RPM (12.5 r/s)	5.0 - 5.5	3.0 (2.0)
HT/LT water before HT/LT pump (=static)	0.7 - 1.5	
HT water before engine	2.5 + static press.(1)	1.5 + static press. (2) (2) (4)
LT water before charge air cooler	2.5 + static press. (1)	1.5 + static press.
Fuel before engine	4.5 - 6 (MDO) 6 - 8 (HFO)	4
Compressed air (start & control air)	max. 30	18
Charge air (CAC, outlet)	See test records	3
Other pressures (bar)		
CAC, pressure difference		75 mbar
Crankcase pressure		3 mbar
Firing pressure	See test records	
Opening pressure of safety valve on lube oil pump	6 - 8	
Lube oil filter pressure difference	0.8 - 1.8	0.8 (first) 1.8 (second alarm)

(1) Depending on speed and installation
(2) Load reduction, main engine
(3) Stop, auxiliary engine
(4) Stop, on GL installation, main engine
(xx) When water cooled turbocharger

01.3 Reference conditions

Reference conditions according to ISO 3046/I (1995):

Air pressure . . . . 100 kPa (1.0 bar)
Ambient temperature . . . . 298 K (25°C)
Relative air humidity . . . . 30 %
Cooling water temperature of charge air cooler . 298 K (25°C)

In case the engine power can be utilized under more difficult conditions than those mentioned above, it will be stated in the sales documents. Otherwise, the engine manufacturer can give advice about the correct output reduction. As a guideline additional reduction may be calculated as follows:

$$\text{Reduction factor} = (a + b + c)\ \%$$

a = 0.5 % for every °C the ambient temperature exceeds the stated value in the sales documents.
b = 1 % for every 100 m level difference above stated value in the sales documents.
c = 0.4 % for every °C the cooling water of the charge air cooler exceeds the stated value in the sales documents.

01.4 General engine design

The engine is a turbocharged after cooled 4-stroke diesel engine with direct fuel injection.
The engine block is cast in one piece. The crankshaft is mounted underslung the engine. The main bearing cap is supported by two hydraulically tensioned main bearing screws and two horizontal side screws.

The charge air receiver as well as the cooling water header are cast into the engine block. The crankcase covers, made of light metal, seal against the engine block by means of rubber sealing's.

The lubricating oil sump is welded.

The cylinder liners are cooled only in upper part. The cooling effect is optimized to give the correct temperature of the inner surface.

To eliminate the risk of bore polishing, the liner is provided with an anti polishing ring.

The main bearings are fully interchangeable trimetal or bimetal half shell bearings which can be removed by removing the main bearing cap.

The crankshaft is forged in one piece and is balanced by counterweights as required.

The connecting rods are of a three-piece design, so called “Marine type connecting rod”.

The connecting rod is forged and machined of alloyed steel. The lower end is splitted horizontally in three parts to allow removal of piston and connecting rod parts. All connecting rod bolts are hydraulically tightened to minimize the relative movements between mating surfaces.

The big end bearings are fully interchangeable trimetal or bimetal half shell bearings.

The pistons are fitted with a Wärtsilä patented skirt lubricating system. The top ring grooves are hardened. Cooling oil enters the cooling space through the connecting rod. The cooling spaces are designed to give an optimal shaker effect.

The piston ring set consists of two chrome-plated compression rings and one chrome-plated, spring-loaded oil scraper rings.

The cylinder head, made of nodular cast iron, is fixed by four hydraulically tensioned screws. The head is of the double deck design and cooling water is forced from the periphery towards the centre giving efficient cooling in important areas.

The inlet valves are stellited and the stems are chromium-plated. The valve seat rings are made of a special cast iron alloy and are changeable.

The exhaust valves, with Nimonic or stellite seats and chromium-plated stems, seal against the directly cooled valve seat rings.

The seat rings, made of a corrosion and pitting resistant material, are changeable.

The camshafts are made up from one-cylinder pieces with integrated cams.

The injection pumps have separated roller followers and can be changed by adjusting the base measure with the tappet screw.

The pumps and piping are located in a closed space which is heat insulated for heavy fuel running.

The turbocharger is normally located at the free end of the engine.

The charge air cooler is of a self-supported type.

The lubricating oil system includes a gear pump, automatic oil filter, centrifugal filter for cleaning the back-flush oil, cooler with thermostat valve and an electrically driven prelubricating pump.

The oil sump is dimensioned for the entire oil volume needed, and all cylinder numbers can be run in wet sump configuration. Dry sump running is also possible.

The starting system. The air supply to the cylinders is controlled by a starting air distributor run by the camshaft.

The instrumentation and automation is handled by the Wärtsilä Engine Control System - WECS 2000, or alternatively by the plant control system.

The cooling water system includes built-on cooling water pumps and thermostatic valves.

02A. Environmental Hazards

02A.1 General

Fuel oils, lubricating oils and cooling water additives are environmentally hazardous. Take great care when handling these products or systems containing these products. Detailed information and handling instructions can be found in the text below.

02A.2 Fuel oils

Prolonged or repetitive contact with the skin may cause irritation and increase the risk of skin cancer (polyaromatic hydrocarbons, etc.). Fumes, like hydrogen sulphide or light hydrocarbons, that are irritating for eyes and respiratory organs may be released during loading/bunkering. Fuel oils are mainly non-volatile burning fluids, but may also contain volatile fractions. Risk for fire and explosion. May cause long-term harm and damages in water environments. Risk of contamination of the soil and the ground water. Take every appropriate measure to prevent water and soil contamination.

02A.2.1 Handling

- Isolate from ignition sources, like sparks from static electricity for example.
- Avoid breathing evaporated fumes (may contain hydrogen sulphide, etc.) during pumping and opening of storage tanks for example. Use gas mask if necessary.
- The handling and storage temperatures must not exceed the flash point of the product. Should be stored in tanks or containers designed for flammable fluids.
- Must not be let into the sewage system, water systems or onto the ground.
- Methane may during long-term storage be formed in tanks, due to bacterial activities. Risk of explosions during unloading or storage tank opening for example.
- Cloths, paper or any other absorbent material used to soak up spills are fire hazards. Do not allow these to accumulate.
- Waste that contains the product is hazardous and has to be disposed of according to directives issued by the local or national environmental authorities. Collection, regeneration and burning should be handled by authorized disposal plants.

02A.2.2 Personal protection equipment

- **Respiratory organs protection:** Oil mist: Use respirator, combined particle and gas filter. Evaporated fumes (hydrogen sulphide, etc.): Use respirator, inorganic gas filter.
- **Hands protection:** Strong, heat and hydrocarbon resistant gloves (nitrile rubber for example).
- **Eye protection:** Wear goggles if splash risk exists.
- **Skin and body protection:** Wear facial screen and covering clothing as required. Use safety footwear when handling barrels. Wear protecting clothes if hot product is handled.

02A.2.3 First aid measures

- **Inhalation of fumes:** Move victim to fresh air, keep warm and lying still. Give oxygen or mouth to mouth resuscitation as needed. Seek medical advice after significant exposures. Inhalation of oil mist: Seek medical advice.
- **Skin contact:** Hot oil on the skin should be cooled immediately with plenty of cold water. Wash immediately with plenty of water and soap. Do not use solvents, the oil is spread and may be absorbed into the skin. Remove contaminated clothing. Seek medical advice if irritation develops.
- **Eye contact:** Rinse immediately with plenty of water, for at least 15 minutes and seek medical advice. If possible, keep rinsing until eye specialist has been reached.
- **Ingestion:** Rinse mouth with water. Do not induce vomiting, in order not to risk aspiration into respiratory organs. Seek medical advice.

Note! **Complete safety data sheets for the specific products used at your installation should be available from the fuel oil delivering company.**

02A.3 Natural gas

Natural gas is non-toxic and will not harm anyone breathing in the low concentrations near minor fuel leaks. Heavy concentrations, however, can cause drowsiness and eventual suffocation.

In a gas engine installation, gas may cause danger situations in some cases. The most serious situations are caused by gas leaks into the engine room, gas fires and gas explosions caused by unburned gas in the exhaust system.

If a gas explosion occurs, it is important to protect people, equipment and environment from damages. Damages are caused by shock wave and burning effect of the expanding and partly burning gases. Damages can be avoided by preventing pressure build up in equipment and guiding the released pressure to an open area.

Read the Gas Safety Manual that can be found at the end of chapter 03 for gas engine installations.

02A.4 Lubricating oils

Fresh lubricating oils normally present no particular toxic hazard, but all lubricants should always be handled with great care. Used lubricating oils may contain significant amounts of harmful metal and PAH (polyaromatic hydrocarbons) compounds. Avoid prolonged or repetitive contact with the skin. Prevent any risk of splashing and keep away from heat, ignition sources and oxidizing agents. Risk of long term contamination of the soil and the ground water. Take every appropriate measure to prevent water and soil contamination.

02A.4.1 Handling

- Ensure adequate ventilation if there is a risk of release of vapours, mists or aerosols. Do not breathe vapours, fumes or mist.
- Keep away from flammable materials and oxidants.
- Keep away from food and drinks. Do not eat, drink or smoke while handling.
- Use only containers, piping, etc. which are resistant to hydrocarbons. Open the containers in well ventilated surroundings.
- Immediately take off all contaminated clothing.
- Empty packaging may contain flammable or potentially explosive vapours.
- Cloths, paper or any other absorbent material used to recover spills are fire hazards. Do not allow these to accumulate. Keep waste products in closed containers.
- Waste that contains the product is hazardous and has to be disposed of according to directives issued by the local or national environmental authorities. Collection, regeneration and burning should be handled by authorized disposal plants.

02A.4.2 Personal protection equipment

- **Hand protection:** Impermeable and hydrocarbon resistant gloves (nitrile rubber for example).
- **Eye protection:** Wear goggles if splash risk exists.
- **Skin and body protection:** Wear facial screen and covering clothing as required. Use safety footwear when handling barrels. Wear protecting clothes if hot product is handled.

02A.4.3 First aid measures

- **Inhalation of fumes:** Move victim to fresh air, keep warm and lying still.
- **Skin contact:** Wash immediately with plenty of water and soap or cleaning agent. Do not use solvents (the oil is spread and may be absorbed into the skin). Remove contaminated clothing. Seek medical advice if irritation develops.
- **Eye contact:** Rinse immediately with plenty of water, continue for at least 15 minutes and seek medical advice.
- **Ingestion:** Do not induce vomiting, in order not to risk aspiration into respiratory organs. Seek medical advice immediately.
- **Aspiration of liquid product:** If aspiration into the lungs is suspected (during vomiting for example) seek medical advice immediately.

Note! **Complete safety data sheets for the specific products used at your installation should be available from the lubricating oil manufacturer or your local dealer.**

02A.5 Cooling water additives, nitrite based

The products are toxic if swallowed. Concentrated product may cause serious toxic symptoms, pain giddiness and headache. Significant intake results in greyish/blue discoloration of the skin and mucus membranes and a decreasing blood pressure. Skin and eye contact of the undiluted product can produce intense irritation. Diluted solutions may be moderately irritating.

02A.5.1 Handling

- Avoid contact with skin and eyes.
- Keep away from food and drinks. Do not eat, drink or smoke while handling.
- Keep in well ventilated place with access to safety shower and eye shower.

- Soak liquid spills in absorbent material and collect solids in a container. Wash floor with water as spillage may be slippery. Contact appropriate authorities in case of bigger spills.
- Bulk material can be land dumped at an appropriate site in accordance with local regulations.

02A.5.2 Personal protection equipment

- **Respiratory protection:** Not normally required. Avoid exposure to product mists.
- **Hands protection:** Rubber gloves should be worn (PVC or natural rubber for example).
- **Eye protection:** Eye goggles should be worn.
- **Skin and body protection:** Use protective clothing and take care to minimize splashing. Use safety footwear when handling barrels.

02A.5.3 First aid measures

- **Inhalation:** In the event of over exposure to spray mists move victim to fresh air, keep warm and lying still. If effects persists, seek medical advice.
- **Skin contact:** Wash immediately with plenty of water and soap. Remove contaminated clothing. If irritation persists, seek medical advice.
- **Eye contact:** Rinse immediately with plenty of clean water and seek medical advice. If possible, keep rinsing until eye specialist has been reached.
- **Ingestion:** Rinse mouth with water. Drink milk, fruit juice or water. Do not induce vomiting without medical advice. Immediately seek medical advice. Do not give anything to drink to an unconscious person.

Note! **Complete safety data sheets for the specific products used at your installation should be available from the cooling water additive manufacturer or local representative.**

02A.6 Fly ashes and exhaust gas dust contaminated components

When handling the fly ashes, exhaust gas dusts and when working inside the exhaust gas system or when handling any component contaminated with exhaust gas dust, at least the following minimum precautions and safety procedures must be applied:

Note! Inhaling, eye contacts, skin contacts and swallowing of fly ashes and dusts must be avoided.

Employees must be required to study the safety instructions before they start to overhaul the exhaust gas system or engine components that have been in contact with exhaust gases.

Note! Spreading and spillage of the fly ashes and dusts to the environment must be avoided.

When opening the manholes of the exhaust gas system and specially the SCR avoid spreading the dust in the surrounding area. During replacement of components in the exhaust gas system and during handling as well as during normal operation of the system, dust spreading must be avoided.

Appropriate flue gas dust spillage disposal instructions must be applied. The dusts collected from the exhaust gas system must be considered as hazardous waste and must be treated according to the local regulations and legislation.

02A.6.1 Personal protection equipment

- Respiratory organs protection: Toxi particles: Use P3 filter respirator or for work inside the SCR or other places in the exhaust gas system, where the dust concentration is high, a respiration mask with fresh filtered compressed air supply is recommended.
- Hands protection: Gloves.
- Eye protection: Wear goggles.
- Skin and body protection: Wear covering clothing.

Also when machining or cleaning engine components that have been in contact with exhaust gases, proper protection according to the above must be used.

Consideration must also be given to whether the ventilation is suitable for collecting dust from the machining and cleaning of the components.

02A.6.2 First aid measures

- Inhalation of ashes: Move victim to fresh air, keep warm and lying still. Give oxygen or mouth to mouth resuscitation as needed. Seek medical advice after significant exposures.
- Skin contact: Hot ash on the skin should be cooled immediately with plenty of cold water. Wash immediately with plenty of water and soap. Do not use solvents, the ash is spread and may be absorbed into the skin. Remove contaminated clothing. Seek medical advice if irritation develops.
- Eye contact: Rinse immediately with plenty of water, for at least 15 minutes and seek medical advice. If possible, keep rinsing until eye specialist has been reached.
- Ingestion: Rinse mouth with water. Do not induce vomiting, in order not to risk aspiration into respiratory organs. Seek medical advice.

02A.7 Lead in bearings

Lead has valuable lubricating properties and therefore it is incorporated into many bearing alloys.
The bearings in Wärtsilä engines consists of lead and are therefore a toxic hazardous waste. Lead containing parts that are not used anymore must be wasted according to local waste disposal plant instructions.

02A.8 Fluoride rubber products

02A.8.1 Handling instructions - normal sealing applications

In normal sealing applications the use of fluoride rubber products does not cause any health hazards. The handling of products, e.g. installation and service, can be made without any risk – provided that normal industrial hygiene is applied.

02A.8.2 Handling instructions in case of overheated seats and valve blow-by

When changing O-rings, for instance after a valve blow-by, operators handling the remains of burnt fluoride rubber must wear impenetrable acidproof gloves to protect the skin from the high corrosive remains. Appropriate glove materials are neoprene or PVC. All liquid state remains must be considered to be extremely corrosive.
Neutralisation of the remains can be done by using large amounts of calcium hydroxide solution (lime water). Used gloves must be disposed off.

02A.8.2.1 Use of fluoride rubber products at temperature above 275 °C (527 °F)

Fluoride rubber can be used in most applications (up to 275 °C) without any substantial degradation or health hazard. Use of or test of fluoride rubber at temperatures above 275 °C must be avoided. If the material, in spite of above recommendations, is exposed to higher temperatures, or in case of an accident, there is a risk that the temperature will rise out of control.

02A.8.3 Special conditions

02A.8.3.1 Grinding dust

Dust and particles which originates from grinding or abrasion (wear) of fluoride rubber can cause the formation of toxic degradation products when burned (incinerated). Smoking must therefore be prohibited in areas where there is fluoride rubber dust and particles present.

02A.8.3.2 Fire

In case of a fire, burning fluoride rubber can cause the formation of toxic and corrosive degradation products (e.g. hydrofluoric acid, carbonyl fluoride, carbon monoxide and carbon fluoride fragments of low molecular weight).
Burning (incineration) of fluoride rubber is allowed only when using approved incinerators equipped with gas emission reduction systems.

02A.8.3.3 Decontamination

Operators handling the remains of burnt fluoride rubber must wear impenetrable acid-proof gloves to protect the skin from the high corrosive remains of burnt fluoride rubber. Appropriate glove materials are neoprene or PVC. All liquid state remains must be considered to be extremely corrosive.

02A.8.4 Personal protection equipment

- Hand protection: impenetrable acidproof gloves (neoprene or PVC).
- Inhalation protection: breathing mask.

02A.8.5 First aid measures

- Inhaling: Move the patient from the danger zone. Make sure that he blows his nose. Consult medical personnel.
- Eye contact: Rinse immediately with water. Contact medical personnel.
- Skin contact: Rinse immediately with water, put a 2%-solution of calcium gluconate gel on the exposed skin. If calcium gluconate-gel is not available, continue to rinse with water. Contact medical personnel.

02. Fuel, Lubricating Oil, Cooling Water

For preventing and minimising the handling risks, read carefully chapter 02A., Environmental Hazards.

02.1 Fuel

02.1.1 General

The WÄRTSILÄ® medium-speed diesel engines are designed to operate on heavy fuel (residual fuel) with a maximum viscosity of 55 cSt at 100 °C (approx. 730 cSt at 50 °C, approx. 7200 Redwood No.1 seconds at 100 °F) and will operate satisfactorily on blended (intermediate) fuels of lower viscosity, as well as on distillate fuel. Avoid the use of fuels having a lower/higher viscosity than values found in the table below, as such fuels may cause fuel injection pump plunger or fuel nozzle needle seizure.

Fuel viscosity limits at engine inlet in running conditions (cSt)			
Fuel	WÄRTSILÄ®20	Vasa 32 & 32LN WÄRTSILÄ®32	WÄRTSILÄ®46
LFO, min.	1,8	2,0	2,8
HFO	16 - 24	16 - 24	16 - 24

The maximum limits of fuel characteristics for a certain engine are stated in the documentation delivered with the engine.

Blended fuels (residuals and distillate) with a viscosity between approx. 4 and 7 cSt at 100 °C (12 and 30 cSt at 50 °C, 75 and 200 Redwood No.1 seconds at 100 °F) containing between 30 and 60 % distillate should, however, be avoided due to the risk of precipitation of heavy components in the blend, with filter clogging and large amount of centrifuge sludge as a consequence.

When difficulties with filter clogging are experienced, fuel incompatibility can be tested by the ASTM D4740-93 or ISO 10307-1/93 (LFO) or ISO 10307-2/A/93 (HFO) test methods.

02.1.2 Fuel treatment

02.1.2.1 Purification

Heavy fuel (residuals, and mixtures of residuals and distillate) must be purified in an efficient centrifuge before entering the day tank. The fuel is to be heated before centrifuging.

Recommended temperatures, depending on the fuel viscosity, are stated in the diagram, chapter 02, Fig 02-1.

Be sure that the correct gravity disc is used. Never exceed the flow rates recommended for the centrifuge for the grade of fuel in use. The lower the flow rate the better the efficiency.

Recommended centrifuge flow rate						
	Fuel in use					
Max. viscosity (cSt/100°C)	10	15	25	35	45	55
Approx. viscosity (cSt/50°C)	50	90	205	350	530	730
Centrifuge flow rate (% of rated capacity)	60	40	30	25	20	15

Note! **Recommended centrifuge flow rates, see separator manufacturers instruction manual.**

In case pure distillate fuel is used, centrifuging is still recommended as fuel may be contaminated in the storage tanks.

Rated capacity of the centrifuge may be used provided the fuel viscosity is less than 12 cSt at centrifuging temperature.

Marine Gas Oil viscosity is normally less than 12 cSt at 15 °C.

02.1.2.2 Heating

See diagram, Fig 02-1. Keep the fuel temperature about 10 °C above the minimum storage temperature indicated in the diagram in order to minimize the risk of wax formation, and the temperature after the final heater 5 - 10 °C above the recommended temperature before injection pumps to compensate for heat losses between heater and engine.

Fuel oil viscosity-temperature diagram

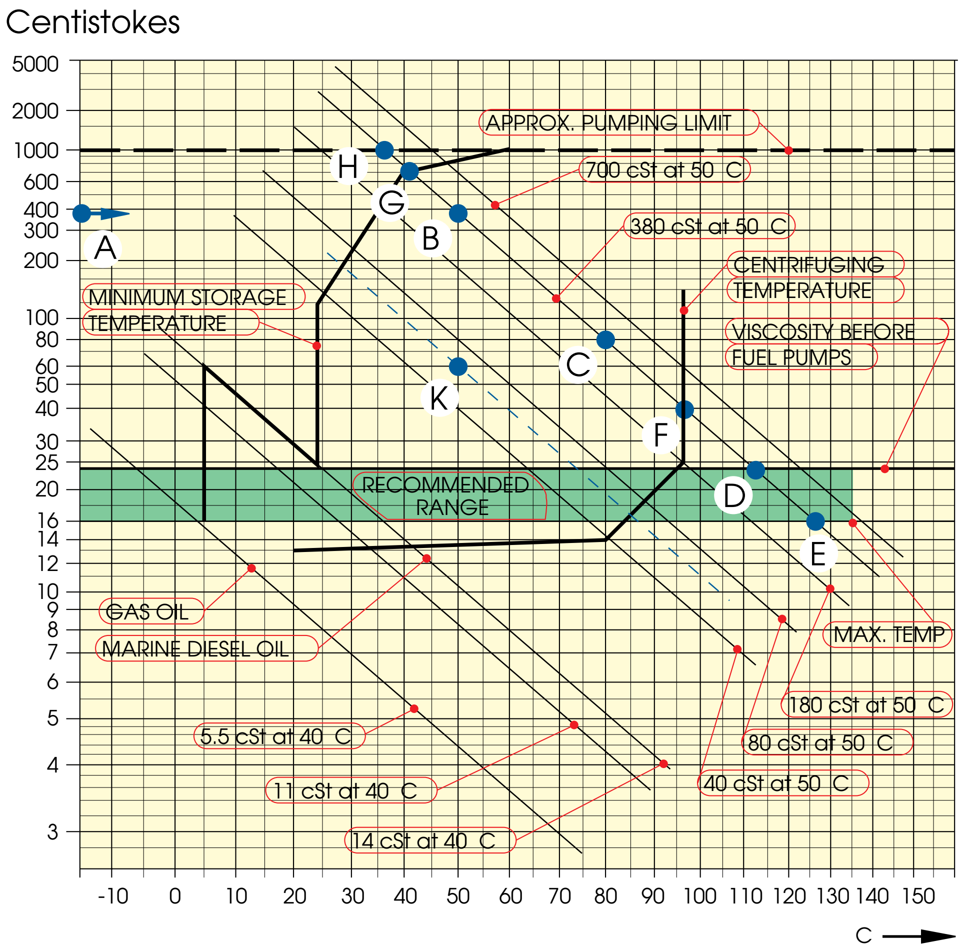


Fig 02-1 3202529238

Example: *A fuel oil with a viscosity of 380 cSt (A) at 50 °C (B) or 80 cSt at 80 °C (C) must be preheated to 112 - 126 °C (D-E) before the fuel injection pumps, to 97 °C (F) at the centrifuge and to minimum 40 °C (G) in storage tanks. The fuel oil may not be pumpable below 36 °C (H).*

To obtain temperatures for intermediate viscosities, draw a line from the known viscosity/temperature point in parallel to the nearest viscosity/temperature line in diagram.

Example: *Known viscosity 60 cSt at 50 °C (K). The following can be read along the dotted line: Viscosity at 80 °C = 20 cSt, temperature at fuel injection pumps 74 - 86°C, centrifuging temperature 86 °C, minimum storage tank temperature 28 °C.*

Conversion from various current and obsolete viscosity units to centistokes can be made in the diagram, Fig 02-2. The diagram should be used only for conversion of viscosities at the same temperature. The same temperatures should then be used when entering the viscosity/temperature point into the diagram, Fig 02-1.

Viscosity conversion diagram

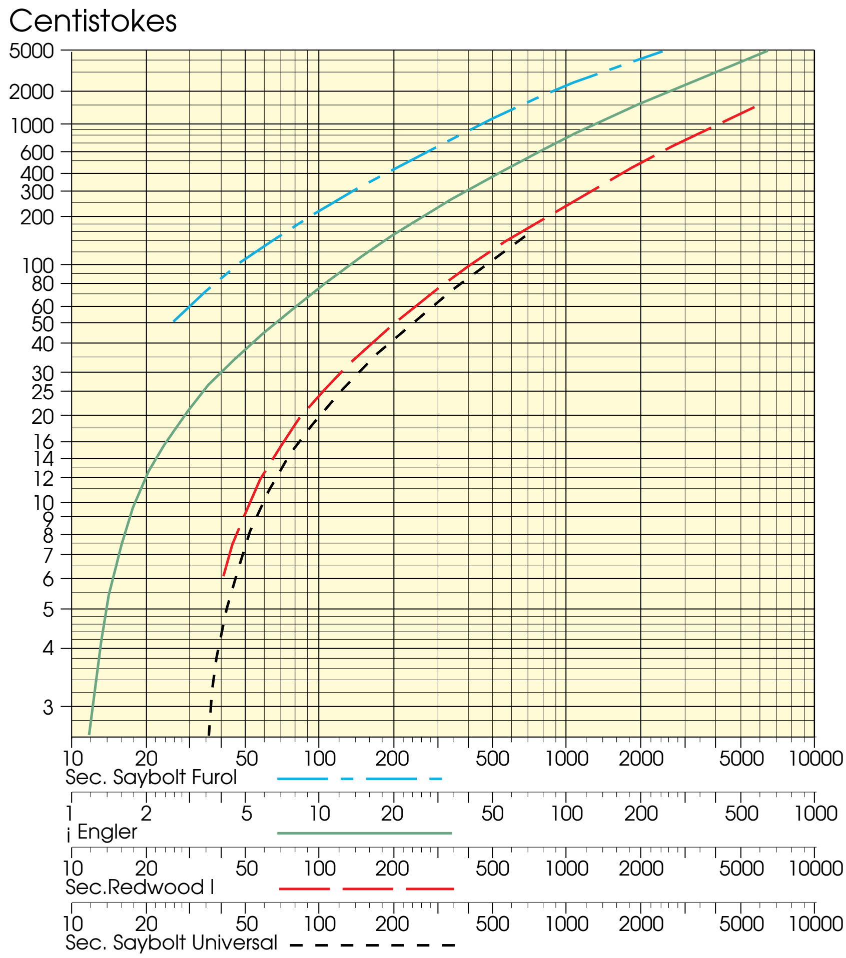


Fig 02-2 3202538935

When converting viscosities from one of the units on the abscissa to centistokes or vice-versa, keep in mind that the result obtained is valid only at one and the same temperature. When converting the viscosity in any unit at a given temperature to a viscosity at another temperature, a viscosity-temperature diagram or conversion rule must be used.

02.1.2.3 Viscosity control

An automatic viscosity controller, or a viscosimeter, at least, should be installed in order to keep the correct viscosity of the fuel before the fuel enters the engine fuel system.

02.1.3 Maximum limits of fuel characteristics

The diesel engines WÄRTSILÄ® Vasa 32 & 32LN, WÄRTSILÄ® 20, WÄRTSILÄ® 32 and WÄRTSILÄ® 46 are designed and developed for continuous operation, without reduction of the rated output, on fuels with the following properties:

Fuel characteristics, maximum limits		
Kinematic viscosity	cSt at 100 °C cSt at 50 °C Redwood No.1 sec. at 100 °F	55 730 7200
Kinematic viscosity	cSt at engine inlet	see 02.1.1
Density	kg/m^3 at 15 °C	991
Density [1)]	kg/m^3 at 15 °C	1010[1)]
Water	vol-%	1.0
Water, before engine	vol-%	0.3
Flash point, min. (PMCC)	°C	60
Pour point	°C	30
Total Sediment Potential	mass-%	0.10

The limits above also correspond to the demands:

- ISO 8217:1996(E), ISO-F-RMH 55 and RMK 55[1)]
- BS MA 100:1996, RMH 55 and RMK 55[1)]
- CIMAC 1990, class H 55 and K 55[1)]

1) Provided the fuel treatment system can remove water and solids.

Four types of fuels are defined for the WÄRTSILÄ® Vasa 32 & 32LN, WÄRTSILÄ® 20, WÄRTSILÄ® 32 and WÄRTSILÄ® 46 engines:

- HFO 1, heavy fuel oil of normal quality.
- HFO 2, heavy fuel oil below normal standard quality.
- DO, diesel oil or LFO, light fuel oil.
- CRO, Crude oil.

The maintenance intervals are decided by the characteristics of the used fuel, see Chapter 04 Maintenance Schedule.

The differences between HFO 1 and HFO 2 are seen below:

Fuel characteristics, maximum limits			
		HFO 1	**HFO 2**
Sulphur	mass-%	2.0	2.0 - 5.0
Ash	mass-%	0.05	0.05 - 0.20
Vanadium	mg/kg	100	100 - 600
Sodium	mg/kg	50	50 - 100
Sodium, bef. engine	mg/kg	30	30
Aluminium + Silicon	mg/kg	30	30 - 80
Aluminium + Silicon, bef. engine	mg/kg	15	15
Conradson Carbon Residue	mass-%	15	15 - 22
Asphaltenes	mass-%	8	8 - 14
CCAI		850	850 - 870

Foreign substances or chemical waste, hazardous to the safety of the installation or detrimental to the performance of engines, should not be contained in the fuel.

Note! **If any of specified fuel properties exceed HFO 1 maximum value the fuel should be classified as HFO 2.**

02.1.4 Comments on fuel characteristics

a) **The viscosity** is not a measure of the fuel quality, but determines the complexity of the fuel heating and handling system, as a heavy fuel oil has to be heated to reach a viscosity of 16 - 24 cSt at the point of injection. At low viscosities, the flow past the plunger in the injection pump increases. This leads to a decrease in the amount of injected fuel, which in bad cases might make it impossible to reach full engine output.

The standard engine fuel system is laid out for max. 55 cSt at 100 °C fuel (approx. 730 cSt at 50 °C, approx. 7200 Redwood No.1 seconds at 100 °F).

b) **The density** influences mainly on the fuel separation. Separators can remove water and to some extent solid particles from fuels having densities of up to 991 kg/m^3 at 15 °C. There are also separators on the market that can clean fuel with densities of up to 1010 kg/m^3 at 15 °C. The separator capability must be checked before purchasing a fuel with a very high density, as a bad separation will lead to abnormal wear due to unremoved particles and water. The separator disc must be chosen according to the fuel density.

Caution! **Fuels having a low viscosity in combination with a high density usually have bad ignition properties!**

c) **Ignition quality.** Heavy fuels may have very low ignition quality. This may cause trouble at start and low load operation, particularly if the engine is not sufficiently preheated. Low ignition quality may also result in a long ignition delay and can cause a fast pressure rise and very high maximum pressures. This increases the mechanical load and can even damage engine components such as e.g. piston rings and bearings severely. Deposits on the piston top, on the exhaust valves, in the exhaust system, and on the turbine nozzle ring and turbine blades can also be expected. The turbocharger fouling will lead to decreased turbocharger efficiency, and increased thermal load.

A symptom of low ignition quality is diesel knock, i.e. hard, high pitched combustion noise. The effects of diesel knocking are increased mechanical load on components surrounding the combustion space, increased thermal load, as well as increased lubricating oil consumption and contamination.

Caution! **Although low ignition quality produces long ignition delays, advancing the injection timing makes things only worse: The fuel will be injected at a lower compression temperature, and this will produce an even longer ignition delay!**

Ignition quality is not defined, nor limited, in marine residual fuel standards. The same applies to ISO-F-DMC marine distillate fuel.

The ignition quality of a distillate fuel can be determined according to several methods, i.e. Diesel Index, Cetane Index, and Cetane Number.

The ignition quality of a heavy fuel oil can be roughly determined by calculating the CCAI (= Calculated Carbon Aromaticity Index) from the viscosity and density of a fuel.

Determining of CCAI:

$$CCAI = \rho - 81 - 141 \log_{10}\log_{10} (\nu_K + 0.85)$$

where ρ = density (kg/m^3 at 15 °C)
ν_K = kinematic viscosity (cSt at 50 °C)

Note! **An increased CCAI value indicates decreased ignition quality!**

CCAI can also be determined (but with limited accuracy) by the nomogram, see Fig 02-3.

Straight run fuels show CCAI values in the 770 - 840 range, and are very good igniters. Cracked residues may run from 840 to over 900, while most bunkers remain in the 840 to 870 range at present.

The CCAI is not an exact tool for judging fuel ignition properties. Following rough guidelines can however be given:

- Engines running at constant speed and load over 50 % can without difficulty use fuels with CCAI-values of up to 870.
- Engines running at variable speed and load can without difficulty run on fuels with CCAI-values up to 860.

To avoid difficulties with poor ignition quality fuels the following should be noted:

- Sufficient preheating of the engine before start.
- Proper function of the inverse cooling system.
- Proper function of the injection system, especially the injection nozzle condition must be good.

Nomogram for deriving CCAI

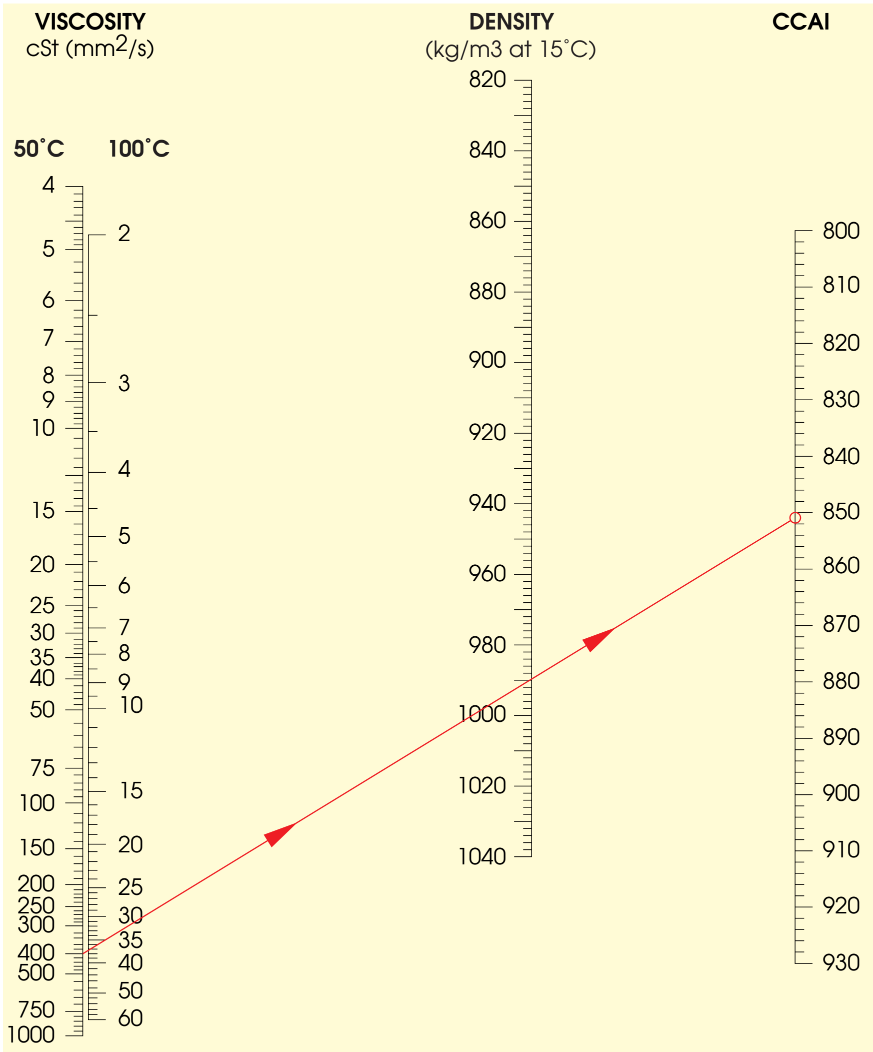


Fig 02-3 3202599716

d) The water content

of heavy fuel oils varies widely. Water may come from several different sources, it can either be fresh or salt. It can also originate from e.g. condensation in the installation's bunker tanks.

- If the water is sweet and very well emulsified in the fuel, the effective energy content of the fuel decreases with increasing water content, leading to an increase in fuel consumption.
- If the fuel is contaminated with sea water, the chlorine in the salt will cause corrosion of the fuel handling system, including the injection equipment. The effects of sodium, that also originates from salt, are described more in detail below.

To avoid difficulties in the engine fuel injection system the water content must be reduced to a max. of 0.3 % prior to the engine.

e) **The sulphur** in the fuel may cause cold corrosion and corrosive wear, especially at low loads. Sulphur also contributes to deposit formation in the exhaust system, normally together with vanadium and/or sodium in the form of sulphates. The deposits can also cause high temperature corrosion, as described below.

f) **A high ash content** may be detrimental in several ways. Different ash components can cause different problems:

- **Aluminium and silicon** oxides originate from the refining process, and can cause severe abrasive wear mainly of the injection pumps and nozzles, but also of cylinder liners and piston rings. An efficient fuel separation is a must for minimising wear.
- Oxides of **vanadium and sodium**, mainly sodium vanadyl vanadates, are formed during the combustion, and mix or react with oxides and vanadates of other ash components, e.g. nickel, calcium, silicon and sulphur. The sticking temperature of the mixture may be such, that a deposit is formed on a valve, in the exhaust gas system, or in the turbo-charger. This deposit is highly corrosive in the molten state, destroying the protective oxide layer on e.g. an exhaust valve, and leading to hot corrosion and a burned valve. Deposits and hot corrosion in the turbocharger, especially on the nozzle ring and turbine blades will cause a decreased turbocharger efficiency. The gas exchange will be disturbed, less air flows through the engine, and thus the thermal load on the engine increases. The deposit formation increases at increased temperatures and engine outputs.

To avoid the above mentioned problems when running on high ash fuels, it is important to:

- Have an efficient fuel separation.
- Clean the turbocharger regularly with water, see section 15.3.
- Have a strict quality control of the bunkered fuel, i.e. to see that the amounts of ash and dangerous ash constituents stay low.
- Maintain clean air filters and charge air coolers by regular cleaning based on pressure drop monitoring.

g) **High carbon residue content** may lead to deposit formation in the combustion chamber and in the exhaust system, especially at low loads.

- Deposit formation on injection nozzle tips will disturb the fuel atomisation and deform the fuel sprays, decreasing the combustion process efficiency, and even leading to locally increased thermal loads.
- Deposits in the piston ring grooves and on the rings will hinder the movement of the rings, causing a.o. increased blow-by of combustion gases down to the crank case, which in turn increases the fouling of the lubricating oil.
- Deposits in the exhaust gas system and in the turbocharger will disturb the gas exchange and increase the thermal load.

h) **High asphaltene content** may contribute to deposit formation in the combustion chamber and in the exhaust system, especially at low loads.

Asphaltenes are complex, highly aromatic compounds with a high molecular weight, that usually contain sulphur, nitrogen and oxygen, as well as metals like vanadium, nickel, and iron (see “Ash” above). A high asphaltene content indicates that a fuel may be difficult to ignite and that it burns slowly.

If the fuel is unstable, the asphaltenes may precipitate from the fuel and block filters and/or cause deposits in the fuel system, as well as excessive centrifuge sludge.

i) **A low flash point** (high vapour pressure) is often seen especially for crude oils.

The low flash point will not influence the combustion, but the fuel can be dangerous to handle and store. This is especially the case if the pour point is high, and the fuel has to be heated due to this. Special explosion proof equipment and separators can be used in extreme cases.

A high vapour pressure (low flash point) can also give cavitation and gas pockets in the fuel pipes. These can be avoided by using an elevated pressure in the fuel handling system.

It is to be noted that some insurance companies demand the use of fuels having a flash point higher than 60 °C.

j) **The pour point** tells below which temperature the fuel does not flow, and determines how easy it will be to handle the fuel. The whole fuel handling system, including tanks and pipes, must be heated to a temperature at least 10 - 15 °C above the pour point.

k) **Total sediment potential** tells something about the fuels stability. If the TSP is high, the danger of sediment and sludge formation in tanks and fuel handling systems increases, as well as the probability for filter clogging.

TSP can also be used as a check for the compatibility of two different fuels: The two fuels are mixed, and if the TSP for the mix remains low, the fuels are compatible.

02.1.5 Measures to avoid difficulties when running on heavy fuel

Poor fuel quality will influence on wear, engine part lifetime and maintenance intervals adversely.

In order to obtain maximum operating economy it is recommendable:

a) **to limit maximum continuous output** as much as operating conditions allow if fuel is known or suspected to have high vanadium content (above 200 ppm) and sodium content.

b) **to limit low load operation** as much as operating conditions allow if fuel is known or suspected to have high sulphur content (above 3 mass-%), carbon content (Conradson carbon above 12 mass-%) and/or asphaltene content (above 8 mass-%).

Operating below 20 % of rated output should be limited to max. 100 hours continuously, by loading the engine above 70 % of rated load for one hour before continuing the low load operation or shutting down the engine.

Idling (i.e. main engine declutched, generator set disconnected) should be limited as much as possible. Warming-up of the engine at no load for more than 3 - 5 minutes before loading, as well as idling for more than 3 minutes before stopping is unnecessary and should be avoided.

02.1.6 General advice

To avoid stability and incompatibility problems (precipitation of heavy components in the fuel), avoid, if possible, blending of fuels from different bunker stations, unless the fuels are known to be compatible.

If stability and compatibility problems occur, never add distillate fuel, as this will probably increase precipitation. A fuel additive with a highly powerful dispersing characteristics can be of help until a new fuel delivery takes place.

The characteristics of heavy fuels blended from residuals from modern refinery processes like catalytic cracking and visbreaking may approach at least some of the limits of fuel characteristics given in the chapter 02., sect. 02.1.3.

Compared with “traditional” heavy fuels blended from straight run residuals, the “modern” heavy fuels may have reduced ignition and combustion quality.

Fuels blended from catalytic cracking residuals may contain very abrasive catalytic fines (silicon and aluminium oxides) which, if allowed to enter the injection system, may wear down injection pumps and nozzles in a few hours.

Some of the difficulties that may occur when operating on heavy fuels blended from cracked residuals can be avoided by:

- Sufficient centrifuging capacity. The best and most disturbance-free results are obtained with the purifier and clarifier in series. Alternatively the main and stand-by separators may be run in parallel, but this makes heavier demands on correct gravity disc choice and constant flow and temperature control to achieve optimum results. Flow rate through the centrifuges should not exceed the maximum fuel consumption by more than 10 %.
- Sufficient heating capacity to keep centrifuging and injection temperatures at recommended levels. It is important that the

temperature fluctuations are as low as possible (± 2 °C before centrifuge) when centrifuging high viscosity fuels with densities approaching or exceeding 991 kg/m^3 at 15 °C.

- Sufficient preheating of the engine and the fuel systems before starting the engine.
- Keeping fuel injection equipment and the inverse cooling system in good condition.

See also section 02.2.7., Handling of oil samples.

02.2 Lubricating oil

02.2.1 System oil characteristics

Viscosity. Viscosity class SAE 40. In WÄRTSILÄ® Vasa 32 engine type also the use of SAE 30 class lubricating oil is allowed.
Viscosity Index (VI). Min.95.
Alkalinity (BN). The required lubricating oil alkalinity is tied to the fuel specified for the engine.

Fuel standards and lubricating oil requirements			
Category	Fuel standard		Lube oil BN
A	ASTM D 975-94 ISO 8217: 1996(E) BS MA 100:1996 CIMAC 1990	GRADE 1D, 2D DMX, DMA DMX, DMA DX, DA	10 - 30
B	ASTM D 975-94 ISO 8217: 1996(E) BS MA 100:1996 CIMAC 1990	GRADE 4D DMB DMB DB	15 - 30
C	ASTM D 396-94 ISO 8217: 1996(E) BS MA 100:1996 CIMAC 1990	GRADE No. 4-6 DMC, RMA10-RMK55 DMC, RMA10-RMK55 DC, A10-K55	30 - 55
D	CRUDE OIL (CRO)		30

It is recommended to use in the first place BN 50-55 lubricants when operating on heavy fuel. This recommendation is valid especially for engines having wet lubricating oil sump and using heavy fuel with sulphur contents above 2.0 % mass. BN 40 lubricants can be used when operating on heavy fuel as well if experience shows that the lubricating oil BN equilibrium remains at an acceptable level.
BN 30 lubricants are recommended to be used only in special cases, such as installations equipped with an SCR catalyst. Lower BN products eventually have a positive influence on cleanliness of the SCR catalyst. With BN 30 oils lubricating oil change intervals may be rather short, but lower total operating costs may be achieved because of better plant availability provided that the maintenance intervals of the SCR catalyst can be increased.

BN 30 oils are also a recommended alternative when operating on crude oil. Though crude oils many times have low sulphur content, they can contain other acid compounds and thus an adequate alkali reserve is important.

Additives. The oils should contain additives that give good oxidation stability, corrosion protection, load carrying capacity, neutralization of acid combustion and oxidation residues, and should prevent deposit formation on internal engine parts (piston cooling gallery, piston ring zone and bearing surfaces in particular).

Foaming characteristics. Fresh lubricating oil should meet the following limits for foaming tendency and stability (according to the ASTM D 892-92 test method):

- Sequence I: 100/0 ml
- Sequence II: 100/0 ml
- Sequence III: 100/0 ml

In this test a certain amount of air is blown through the lubricating oil sample. The first number in the results is the foam volume after a blowing period of 5 minutes and should be less than or equal to 100 ml. The second number is the foam volume after a settling period of 10 minutes and should always be 0 ml.

Sequences I and III are performed at a temperature of 24 °C and sequence II at a temperature of 93.5 °C.

02.2.2 Lubricating oil qualities

Lubricating oil is an integrated engine component and thus the quality of it is upmost important. All lubricating oils, which have been approved for use in WÄRTSILÄ® Vasa 32, WÄRTSILÄ® Vasa 32LN, WÄRTSILÄ® 20, WÄRTSILÄ® 32 and WÄRTSILÄ® 46 engine types, have gone through an approval test according to the engine manufacturer's procedure.

The use of approved lubricating oil qualities during the warranty period is mandatory and is also strongly recommended after the warranty period.

The list of approved lubricating oils can be found in the end of this chapter.

Note! **Never blend different oil brands unless approved by the oil supplier, and during the warranty period, by the engine manufacturer.**

Attention! **Before using a lubricating oil not listed in the table the engine manufacturer must be contacted. Lubricating oils that are not approved have to be tested according to the engine manufacturer's procedures.**

02.2.3 Maintenance and control of the lubricating oil

a) **Centrifuging of the system oil** is recommended in order to separate water and insolubles from the oil. Water must not be added when centrifuging ("washing"). The oil should be pre-heated to 80 - 95 °C. Many oil manufacturers recommend a separation temperature of 90 - 95 °C for an effective separation. Please check with the supplier of your lubricating oil what the optimal temperature is. Use the highest recommended temperature. For efficient centrifuging, use only about 20 % of the rated flow capacity of the separator. For optimum conditions the centrifuge should be capable of passing the entire oil quantity in circulation 4 - 5 times every 24 hour at 20 % of rated flow. Gravity disc should be chosen acc. to oil density at separation temperature. Follow the operation instructions given by the separator manufacturer for optimal performance of the separator.

Note! **The lubricating oil separation efficiency influences the condition of the lubricating oil and the change interval of the lubricating oil batch. Depending on type of application and from the different lubricating oil system arrangements point of view, the following separation routines are adviced:**
- Continous running of the separator(s) when the engine(s) is running, recommended in the first place.
- Periodical separation of auxiliary engine in stand-by or running mode in installation equipped with one or more separator(s), which treats lubricating oil of more than one engine.

Caution! **Defects on automatic, "self-cleaning" separators can quickly increase the water content of the oil under certain circumstances! (The water control valve fails.)**

b) **During the first year of operation** it is advisable to take samples of the lubricating oil at 500 operating hours intervals. The sample should be sent to the oil supplier for analysis. On the basis of the results it is possible to determine suitable intervals between oil changes. Frequent oil analysis at 500 - 1000 operating hours intervals is also recommended after the first year of operation to ensure safe engine operation.

See also section 02.2.7., Handling of oil samples.

When estimating the condition of the used oil, the following properties should be observed. Compare with guidance values (type analysis) for new oil of the brand used.

Viscosity. Should not decrease by more than 20 % and not rise by more than 25% above the guidance value at 100 °C.

Should not decrease by more than 25 % and not rise by more than 45% above the guidance value at 40 °C.

Flash point. Should not fall by more than 50 °C below the guidance value. Min. permissible flash point 190 °C (open cup) and 170 °C (closed cup) . At 150 °C risk of crankcase explosion.

Water content. Should not exceed 0.3 %. A value higher than 0.3% can not be accepted for longer periods, but measures must be taken; either centrifuging or oil change.

BN (Base Number).

- Fuel category A and B:
  The minimum allowable BN value of a used oil is 50 % of the nominal value of a new oil.
- Fuel categories C and D:
  The minimum allowable value of used oil is BN 20.

Insolubles. The quantity allowed depends on various factors. The oil supplier's recommendations should be followed. However, an n-Pentane insoluble value above 1.5 % calls for attention. A value higher than 2 % cannot be accepted for longer periods.

In general it can be said that the changes in the analyses give a better basis of estimation than the absolute values.

Fast and great changes may indicate abnormal operation of the engine or of a system.

c) **Compensate for oil consumption** by adding max. 10 % new oil at a time. Adding larger quantities can disturb the balance of the used oil causing, for example, precipitation of insolubles. Measure and record the quantity added.

Attention to the lubricating oil consumption may give valuable information about the engine condition.

A continuous increase may indicate that piston rings, pistons and cylinder liners are getting worn, and a sudden increase motivates pulling the pistons, if no other reason is found.

d) **Guidance values for oil change intervals** are to be found in chapter 04. Intervals between changes are influenced by system size (oil volume), operating conditions, fuel quality, centrifuging efficiency and total oil consumption. Efficient centrifuging and large systems (dry sump operation) generally allow for long intervals between changes. It is recommended to follow up that the BN value of the lubricating oil keeps within engine manufacturer's limits during the whole oil change interval.

When changing oil the following procedure is recommended:

1 **Empty oil system** while oil is still hot. Be sure that oil filters and coolers are also emptied.

2 **Clean oil spaces,** including filters and camshaft compartment. Insert new filter cartridges.

3 **Fill a small quantity of new oil** in the oil sump and circulate with the pre-lubricating pump. Drain!

4 **Fill required quantity of oil** in the system, see chapter 01, section 01.1.

Oil samples taken at regular intervals analyzed by the oil supplier, and the analysis results plotted as a function of operating hours is an efficient way of predicting oil change intervals.

Send or ask the oil supplier to send copies of oil analyses to the engine manufacturer who will then assist in the evaluation.

In order to minimise the risk of lubricating oil foaming, deposit formation, blocking of lubricating oil filters, damage of engine components, etc., the following procedure should be followed when lubricating oil brand is changed from one to another:

- If possible, change the lubricating oil brand in connection with an engine (piston) overhaul
- Drain old lubricating oil from the lubricating oil system
- Clean the lubricating oil system in case of an excessive amount of deposits on the surfaces of engine components, like crankcase, camshaft compartment, etc.
- Fill the lubricating oil system with fresh lubricating oil

If the procedure described above is not followed, responsibility of possible damage and malfunctions caused by lubricating oil change should always be agreed between the oil company and customer.

02.2.4 Lubricating oil for the governor

See the Instruction Book for the governor, attached. An oil of viscosity class SAE 30 or SAE 40 is suitable, and the same oil can be used as in the engine. Turbocharger oil can also be used in the governor. In low ambient conditions it may be necessary to use multigrade oil (e.g. SAE 5W-40) to get a good control during start-up. Oil change interval, see maintenance schedule chapter 04.

Condensed water, high temperature or leaking drive shaft seal may cause the oil to deteriorate, or internal surfaces of the governor to collect deposits. If the reason cannot be clarified and rectified, a shorter oil change interval or change of oil type should be considered.

The governor should be flushed with the oil in use or gasoil if heavy contamination of the oil is evident.

Examples of suitable lubricating oils for governor can be found from the end of this chapter, where the lists of approved lubricating oils for an engine and turbocharger are available.

- If the system is equipped with a start booster, then this should also be emptied when changing oil.
- In installations whereby the actuator is equipped with a filter, it has to be cleaned when changing oil.
- Depending on the governor type, oil should be separately emptied from the power cylinder. This is done by removing the plug in the bottom of the power cylinder.
- Some governors are equipped with a magnetic oil plug, this plug should be cleaned in connection with an oil change.

Caution! **If turbine oil is used in the governor, take care not to mix it with engine lubricating oil. Only a small quantity of engine lubricating oil into the turbine oil may cause heavy foaming.**

02.2.5 Lubricating oils for turbochargers

Please note that different types of turbochargers can be used for the engine. The lubricating system is different for the different turbocharger. One type of chargers has a common lubricating oil system with the engine, see chapter 15, while the other type of chargers has an internal lubricating system for the bearings, see chapter 15. See the Instruction Book for the turbocharger, attached.

Note! **In the ABB VTR..4 series turbochargers the use of synthetic low friction lubricating oils is strongly recommended by the engine and the turbocharger manufacturers!**

Oil change interval is1500 h service for special mineral oils and 2500 h service for synthetic lubricating oils.

Caution! **Take care that the turbine oil is not mixed with engine lubricating oil. Only a small quantity may cause heavy foaming.**

The list of approved lubricating oils for the ABB VTR..4 series turbochargers can be found in the end of this chapter. These lubricating oils are, regarding viscosity and quality, according to the recommendations.

02.2.6 Lubricating oils for engine turning device

It is recommended to use EP-gear oils, viscosity 400-500 cSt at 40 °C=ISO VG 460 as lubricating oils for the turning device.
The list of lubricating oils for the engine turning device approved by the turning device manufacturer can be found in the end of this chapter.

02.2.7 Handling of oil samples

When taking fuel oil or lubricating oil samples the importance of proper sampling can not be over-emphasised. The accuracy of the analysis results is significantly dependent on proper sampling and the results will only be as good as the quality of the sample.

Use clean sample containers holding approximately 1 litre. Clean sample containers and accessories (IATA carton boxes for transportation, ready made address labels, etc.) are available for example from Wärtsilä local network office. Rinse the sampling line properly before taking the actual sample. Preferably also rinse the sample bottles with the oil a couple of times before taking the sample, especially if "unknown" sample bottles need to be used. Close the bottles tightly using the screw caps provided. Seal all bottles and record all the separate seal numbers carefully. Put the bottles to be sent for analysing in “Ziploc” plastic bags to prevent any spillage. Gently squeeze the “Ziploc” bag to minimise any air content prior to sealing.

The background information for the fuel oil/lubricating sample is as important as the sample itself. Oil samples with no background information are of very limited value. The following data are essential to note when taking the sample:

- Installation name
- Engine type and number
- Engine operating hours
- Lubricating oil brand/fuel oil type
- Lubricating oil operating hours
- Where in the system the lubricating oil/fuel oil sample was taken
- Sampling date and seal number of the separate samples if seals are available
- Reason for taking and analysing the sample
- Contact information: Name (of the person who took the sample), telephone, fax, e-mail, etc.

Use for example the ready made "Oil Analyse Application" form, see Instruction Manual attachments .

Observe personal safety precautions when taking and handling fuel oil and lubricating oil samples. Avoid breathing oil fumes and mist, use respirator if necessary. Use strong, heat and hydrocarbon resistant gloves (nitrile rubber for example). Wear eye goggles if splash risk exists. Wear facial screen and protecting clothes if hot product is handled.

02.2.7.1 Lubricating oil sampling

Lubricating oil samples should be taken with the engine in operation immediately after the lubricating oil filter on the engine. Always take lubricating oil samples before adding fresh oil to the system.

02.2.7.2 Fuel oil sampling

Fuel oil samples can be drawn from different places in the fuel oil system. Fuel samples “as bunkered” or “before the engine” (after fuel oil separation and filtration) are perhaps the most common sample types. From the engines point of view the most important fuel oil sample is naturally the one which enters the engine, i.e. taken after fuel oil separation and filtration. But if for example fuel oil separator efficiency needs to be checked samples should be taken just before and after the separator. It is not advisable to take samples from tank bottom drain valves, since these will probably contain high levels of water and sediment and thus the samples will not be representative of the bulk phase.

02.2.8 Dispatch and transportation

Place the bottle with the “Ziploc” bag inside the IATA carton box and fold the box according to the assembly instructions given on the box. Enclose a copy of the "Bunker Receipt", if available, before closing the last flap on the IATA carton.

Check the DNVPS Air Courier Directory and use appropriate label for the IATA carton box to ensure that the sample is forwarded to the nearest DNVPS laboratory. Complete the courier dispatch instructions on the side of the IATA carton. Fill in the DNVPS universal account number (950 500 010) to prevent rejection from the courier company (DHL). Complete the Proforma Invoice Form and tape it to the outside of the IATA carton.

Call the air courier directly at the number as indicated in the Air Courier Directory and request urgent pick-up, if necessary. When the courier arrives you will need to complete an Airway Bill.

It is recommendable to handle the dispatching of the fuel oil and lubricating oil samples at site. The results will be achieved faster when the dispatching is handled at site and additionally it is illegal to carry fuel oil samples as personal luggage on normal aeroplanes.

Support with interpretation of the analysis results and advice on possible corrective actions is available from Wärtsilä, if needed.

02.3 Cooling water

02.3.1 General

In order to prevent corrosion, scale deposits or other deposits in closed circulating water systems, the water must be treated with additives.

Before treatment, the water must be limpid and meet the specification found in the end of this chapter. Further, the use of an approved cooling water additive or treatment system is mandatory.

Caution! **Distilled water without additives absorbs carbon dioxide from the air, which involves great risk of corrosion.**

Sea water will cause severe corrosion and deposit formation even if supplied to the system in small amounts.

Rain water has a high oxygen and carbon dioxide content; great risk of corrosion; unsuitable as cooling water.

If risk of freezing occurs, please contact the engine manufacturer for use of anti-freeze chemicals.

Fresh water generated by a reverse osmosis plant onboard often has a high chloride content (higher than the permitted 80 mg/l) causing corrosion.

Caution! **The use of glycol in the cooling water is not recommended, if it is not necessary. Since glycol alone does not protect the engine against corrosion, additionally an approved cooling water additive must always be used!!**

02.3.2 Additives

As additives, use products from well-known and reliable suppliers with vast distribution nets. Follow thoroughly the instructions of the supplier.

Attention! **The use of emulsion oils, phosphates and borates (sole) is not accepted.**

In an emergency, if compounded additives are not available, treat the cooling water with sodium nitrite ($NaNO_2$) in portions of 5 kg/m^3. To obtain a pH value of 9, add caustic soda (NaOH), if necessary.

Attention! **Sodium nitrite is toxic.**

Corrosion rate as a function of nitrite concentration

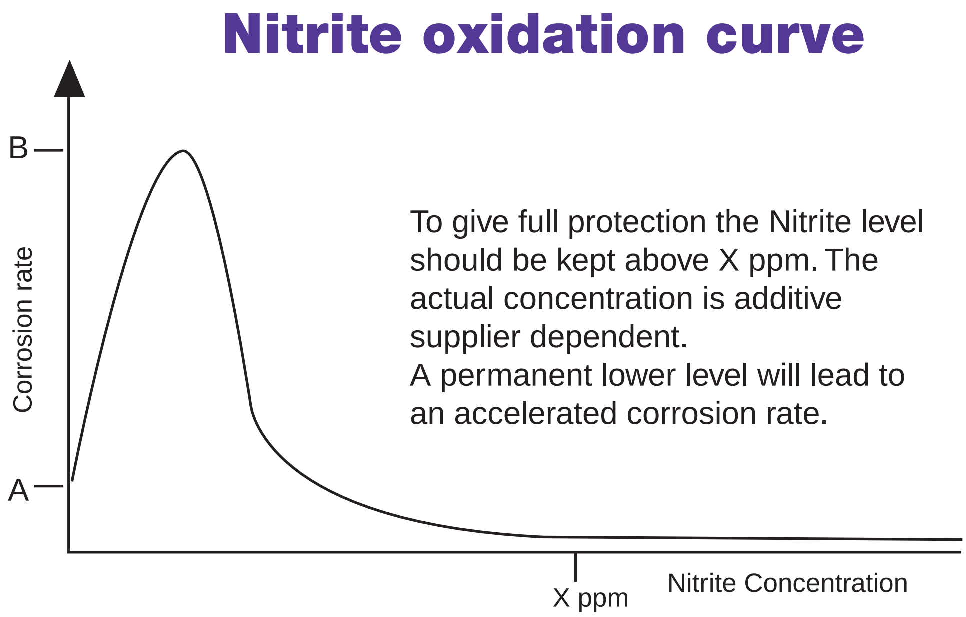


Fig 02-4 3202602002

Nitrite based cooling water additives are so called anodic inhibitors and require proper dosing and maintenance in order to serve as intended. The nitrite of the additive is as such a salt and it will increase the conductivity of the water. The conductivity is on the other hand one of the main parameters affecting the corrosion rate once a corrosion process gets started, the higher the conductivity the higher the corrosion rate.

If the conditions (nitrite level, chlorides, pH, etc.) in the systems are such that the nitrite based additive is no longer able to protect the entire surface of the system there may occur a rapid, local corrosion in the areas that are not protected. The corrosion rate at the attacked areas will even be much greater than it would be with no additive at all present in the system, see schematic graph of the corrosion rate as a function of the nitrite dosage in Fig 02-4. Observe that the position of the curve peak on the x-axis (= dangerous condition for corrosion) is not stable, but will shift depending on temperature, pH, chlorides & sulphates contents, etc. in the cooling water.

The table below shows shows examples of the most common cooling water additive types.

Summary of the most common cooling water additives		
Additive	**Advantages**	**Disadvantages**
Sodium nitrite	- good efficiency, if dosage is controlled carefully - small active quantities, 0.5 % by mass - cheap	- suitable as additive except in air cooled heat ex-changers with large soft solder surfaces - **toxic** - risk of spot corrosion when too low concentration
Nitrite + borate	- no increased risk of corrosion at over doses - innocuous for the skin	- tendency to attack zinc coverings and soft solde-rings - **toxic:** lethal dosage 3 - 4 g solid nitrite - risk of spot corrosion when too low concentration
Sodium silicate	- not toxic - harmless to handle	- not active when water velocity exceeds 2 m/s - commercial products very expensive - increased risk of corrosion when too low concen-tration; spot corrosion - limited suitability
Sodium molybdate	- not toxic - harmless to handle	- more expensive than toxic additives - increased risk of corrosion, if unsufficently dosed - can cause deposit formation (molybdates can collect to ferrous sulphates)
Organic and inorcanic synergistic based	- not toxic	- more expensive than sodium nitrite and molybdate based additives - big active quantitives by mass

02.3.3 Treatment

When changing the additive or when entering an additive into a system where untreated water has been used, the complete system must be cleaned (chemically) and rinsed before fresh treated water is poured into the system. If, against our recommendations, an emulsion oil has been used, the complete system must be absolutely cleaned of oil and greasy deposits.

Evaporated water should be compensated by untreated water; if treated water is used the content of additives may gradually become too high. To compensate for leakage or other losses, add treated water.

In connection with maintenance work calling for drainage of the water system, take care of and reuse the treated water.

The list of approved cooling water additives and treatment systems can be found in the end of this chapter.

Attention! **Ask the supplier of the treatment product for instructions about treatment procedure, dosage and concentration control.**

Most suppliers will provide a test kit for the concentration control. Additionally a frequent laboratory analysis of cooling water at 3 months interval is recommended to ensure safe engine operation.

02.4 Injection water (DWI-engines)

02.4.1 Water quality

Water used for Direct Water Injection (DWI) has to fulfill the following requirements:

Requirements for DWI-water		
pH	5-9	
Total Hardness	max. 10	°dH
Chlorides	max. 80	mg/l
Suspended Solids	max. 50	mg/l
Silicon	max. 50	mg/l
Temperature	max. 50	°C

Fresh water to be used, see also section 02.3.1.
The water must not be contaminated by oil, grease, surfactants or similar impurities. These kind of impurities may cause blocking of the filters or other malfunctions in the direct water injection system.

02.5 Water quality requirements for CASS-system

Water quality used for Combustion Air Saturation System (CASS) has to fulfill the following requirements:

Requirements for CASS-water		
Property	**Maximum value**	**Unit**
pH	6-8	
Hardness	0.4	°dH
Chlorides as Cl	5	mg/l
Suspended Solids	5	mg/l
Temperature before pump	60	°C

In order to achieve a safe operation of the CASS system and the engine, water produced with a fresh water generator / distiller has to be used. The water must not be contaminated by oil, grease, surfactants or similar impurities. These kind of impurities may cause blocking of the filters or other malfunctions in the CASS-system.

1.2.5 REQUIREMENTS AND OIL QUALITY

SYSTEM OIL REQUIREMENTS AND QUALITY FOR WÄRTSILÄ 32 ENGINES

Viscosity
Viscosity class SAE 40

Viscosity Index (VI)
Min. 95

Alkalinity (BN)
The required lubricating oil alkalinity is tied to the fuel specified for the engine, which is shown in the table below.

FUEL STANDARDS AND LUBRICATING OIL REQUIREMENTS			
Category	Fuel standard		Lube oil BN
A	ASTM D 975-94, BS MA 100: 1996 CIMAC 1990 ISO 8217: 1996(E)	GRADE 1D, 2D DMX, DMA DX, DA ISO-F-DMX, DMA	10 - 30
B	ASTM D 975-94, BS MA 100: 1996 CIMAC 1990 ISO 8217: 1996(E)	GRADE 4D DMB DB ISO-F-DMB	15 - 30
C	ASTM D 396-94, BS MA 100: 1996 CIMAC 1990, ISO 8217: 1996(E)	GRADE NO 4-6 DMC, RMA10-RMK55 DC, A10-K55 ISO-F-DMC, RMA10-RMK55	30 - 55
D	Crude oil (CRO)		30

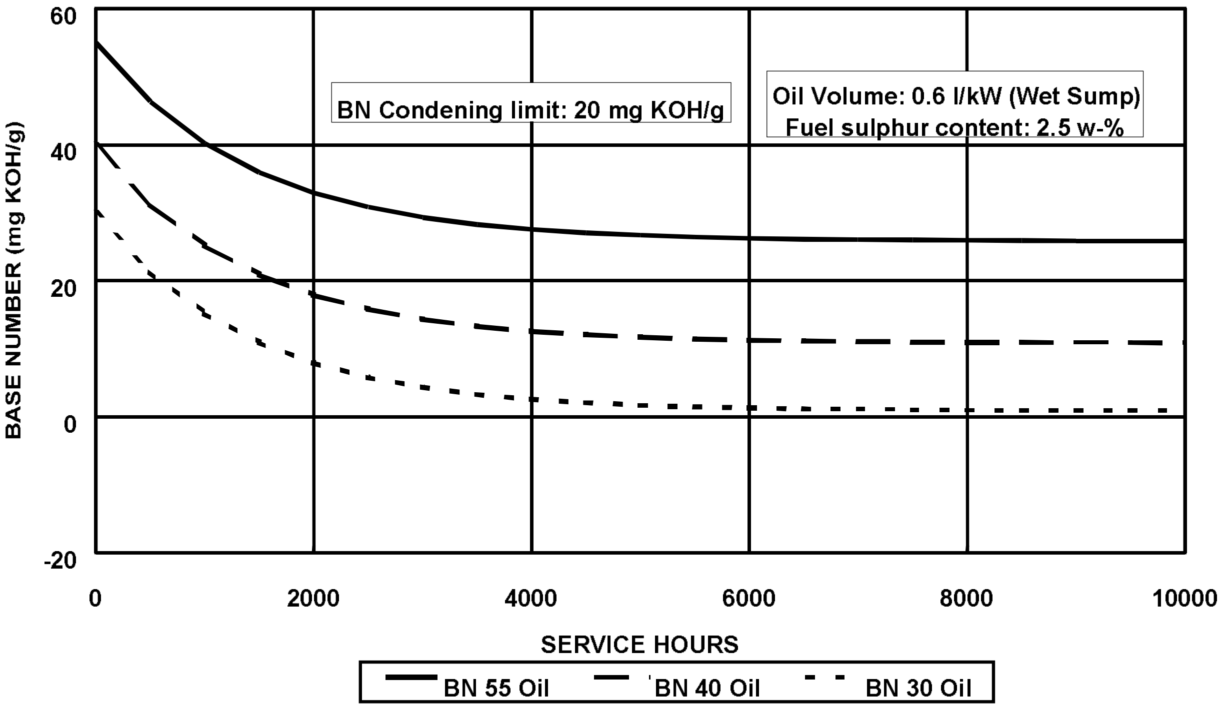
It is recommended to use in the first place BN 50-55 lubricants when operating on heavy fuel. This recommendation is valid especially for engines having wet lubricating oil sump and using heavy fuel with sulphur content above 2.0 % mass. BN 40 lubricants can be used when operating on heavy fuel as well if experience shows that the lubricating oil BN equilibrium remains at an acceptable level.

BN 30 lubricants are recommended to be used only in special cases, such as installations equipped with an SCR catalyst. Lower BN products eventually have a positive influence on cleanliness of the SCR catalyst. With BN 30 oils lubricating oil change intervals may be rather short, but lower total operating costs may be achieved because of better plant availability provided that the maintenance intervals of the SCR catalyst can be increased.

BN 30 oils are also a recommended alternative when operating on crude oil. Though crude oils many times have low sulphur content, they can contain other acid compounds and thus an adequate alkali reserve is important.

The intervals between lubricating oil changes may be extended by adding oil daily to keep the oil level constantly close to the maximum level.

An example of BN depletion curve with different BN lubricating oils is shown below.



Additives

The oils should contain additives that give good oxidation stability, corrosion protection, load carrying capacity, neutralisation of acid combustion and oxidation residues and should prevent deposit formation on internal engine parts (piston cooling gallery, piston ring zone and bearing surfaces in particular).

Foaming characteristics

Fresh lubricating oil should meet the following limits for foaming tendency and stability, according to the ASTM D 892-92 test method:

Sequence I:	100/0 ml
Sequence II:	100/0 ml
Sequence III:	100/0 ml

Base oils

Use of virgin base stocks only is allowed, i.e. recycled or re-refined base oils are not allowed.

CONDEMNING LIMITS FOR USED LUBRICATING OIL

When estimating the condition of used lubricating oil, the following properties along with the corresponding limit values must be noted. If the limits are exceeded, measures must be taken. Compare also with guidance values for fresh lubricating of the brand used.

Property	Unit	Limit	Test method
Viscosity	cSt at 40 °C	max. 25% decrease max. 45% increase	ASTM D 445
Viscosity	cSt at 100 °C	max. 20% decrease max. 25% increase	ASTM D 445
Water	vol-%	max. 0.30	ASTM D 95 or D 1744
Base Number	mg KOH/g	min. 20 in HFO operation, max. 50% depletion in LFO operation	ASTM D 2896
Insolubles	w-% in n-Pentane	max. 2.0	ASTM D 893b
Flash Point, PMCC Flash Point, COC	°C °C	min. 170 min. 190	ASTM D 93 ASTM D 92

CHANGE OF LUBRICATING OIL BRAND

In order to minimize the risk of lubricating oil foaming, deposit formation, blocking of lubricating oil filters, damage of engine components, etc., the following procedure should be followed when lubricating oil brand is changed from one to another:

- If possible, change the lubricating oil brand in connection with an engine (piston) overhaul
- Drain old lubricating oil from the lubricating oil system
- Clean the lubricating oil system in case of an excessive amount of deposits on the surfaces of engine components, like crankcase, camshaft compartment, etc.
- Fill the lubricating oil system with fresh lubricating oil

If the procedure described above is not followed, responsibility of possible damage and malfunctions caused by lubricating oil change should always be agreed between the oil company and customer.

APPROVED LUBRICATING OIL QUALITIES FOR WÄRTSILÄ 32 ENGINES

Should unapproved lubricating oils be used during the engine warranty period, and there exist no agreement with the engine manufacturer about testing, the engine guarantee does not hold.

GAS OIL AND MARINE DIESEL OIL OPERATION

If gas oil or marine diesel oil is used as fuel, lubricating oils with a BN of 10-25 are recommended to be used. Also BN 30 lubricating oils included in Table 3 can be used in gas oil and marine diesel oil fuelled engines.

Table 1.

Approved system oils - fuel categories A and B, recommended in the first place in gas oil or marine diesel oil installations:

SUPPLIER	BRAND NAME	VISCOSITY	BN	FUEL CATEG.
BP	Energol HPDX 40	SAE 40	12	A
	Energol IC-HFX 204	SAE 40	20	A,B
Castrol	MHP 154	SAE 40	15	A,B
	Seamax Extra 40	SAE 40	15	A,B
	TLX 204	SAE 40	20	A,B
ChevronTexaco (Caltex + FAMM)	Delo 1000 Marine 40	SAE 40	12	A
	Delo 2000 Marine 40	SAE 40	20	A,B
	Taro 20 DP 40	SAE 40	20	A,B
ExxonMobil	Mobilgard ADL 40	SAE 40	15	A,B
	Mobilgard 412	SAE 40	15	A,B
	Mobilgard 1 SHC	SAE 40	15	A,B
Petrobras	Marbrax CCD-410-AP	SAE 40	12	A
	Marbrax CCD-415	SAE 40	15	A,B
	Marbrax CCD-420	SAE 40	20	A,B
Shell	Gadinia Oil 40	SAE 40	12	A
	Sirius FB Oil 40	SAE 40	13	A
Statoil	MarWay SP40	SAE 40	12	A
TotalFinaElf / Lubmarine	Disola M 4015	SAE 40	14	A
	Aurelia 4020	SAE 40	20	A,B
	Caprano S 412	SAE 40	12	A
	Stellano S 420	SAE 40	20	A,B

HEAVY FUEL AND CRUDE OIL OPERATION

Today’s modern trunk piston diesel engines are stressing the lubricating oils heavily due to a.o. low specific lubricating oil consumption. Also ingress of residual fuel combustion products into the lubricating oil can cause deposit formation on the surface of certain engine components resulting in severe operating problems. Due to this many lubricating oil suppliers have developed new lubricating oil formulations with better fuel and lubricating oil compatibility. The lubricating oils mentioned in Table 2 are representing new detergent/ dispersant additive chemistries and have shown good performance in Wärtsilä engines.

Table 2.

Approved system oils - fuel category C, recommended in the first place when operating on heavy fuel in order to reach full service intervals, BN 50-55 lubricating oils preferred in the first place:

LUBRICATING OILS WITH IMPROVED DETERGENT/DISPERSANT ADDITIVE CHEMISTRY				
SUPPLIER	**BRAND NAME**	**VISCOSITY**	**BN**	**FUEL CATEG.**
BP	Energol IC-HFX 404	SAE 40	40	C
	Energol IC-HFX 504	SAE 40	50	C
Castrol	TLX 404	SAE 40	40	C
	TLX 504	SAE 40	50	C
	TLX 554	SAE 40	55	C
Cepsa	Troncoil 4040 PLUS	SAE 40	40	C
	Troncoil 4050 PLUS	SAE 40	50	C
	Ertoil Koral 4040 SHF	SAE 40	40	C
	Ertoil Koral 5040 SHF	SAE 40	50	C
ChevronTexaco (Caltex + FAMM)	Taro 40 XL 40	SAE 40	40	C
	Taro 50 XL 40	SAE 40	50	C
	Delo 3400 Marine 40	SAE 40	40	C
	Delo 3550 Marine 40	SAE 40	55	C
ExxonMobil	Exxmar 40 TP 40	SAE 40	40	C
	Exxmar 50 TP 40	SAE 40	50	C
	Mobilgard M 440	SAE 40	40	C
	Mobilgard M50	SAE 40	50	C
	Mobilgard 440	SAE 40	40	C
	Mobilgard 50 M	SAE 40	50	C
	Mobilgard SP 55	SAE 40	55	C
Pertamina	Martron 440	SAE 40	40	C
	Martron 450	SAE 40	50	C
Petrobras	Marbrax CCD-440	SAE 40	40	C
	Marbrax CCD-450	SAE 40	50	C
Petron	Petromar XC 4040	SAE 40	40	C
	Petromar XC 5540	SAE 40	55	C
Repsol YPF	Neptuno W NT 4000 SAE 40	SAE 40	40	C
	Neptuno W NT 5500 SAE 40	SAE 40	55	C
Shell	Argina X 40	SAE 40	40	C
	Argina XL 40	SAE 40	50	C
Statoil	MarWay 4040	SAE 40	40	C
	MarWay 5040	SAE 40	50	C
TotalFinaElf / Lubmarine	Aurelia XL 4055	SAE 40	55	C
	Aurelia XT 4040	SAE 40	40	C
	Aurelia XT 4055	SAE 40	55	C
	Stellano S 440	SAE 40	40	C
	Stellano S 450	SAE 40	50	C

Table 3.

Approved system oils - fuel categories A, B, C and D. Lubricating oils with BN 30 included in Table 3 are designed to be used when operating on crude oil and in special cases when operating on heavy fuel, e.g. in installations equipped with an SCR catalyst.

BN 30 LUBRICATING OILS WITH IMPROVED DETERGENT/DISPERSANT ADDITIVE CHEMISTRY				
SUPPLIER	**BRAND NAME**	**VISCOSITY**	**BN**	**FUEL CATEG.**
BP	Energol IC-HFX 304	SAE 40	30	A,B,C,D
Castrol	TLX 304	SAE 40	30	A,B,C,D
Cepsa	Troncoil 3040 PLUS	SAE 40	30	A,B,C,D
	Ertoil Koral 3040 SHF	SAE 40	30	A,B,C,D
ChevronTexaco (Caltex + FAMM)	Taro 30 DP 40	SAE 40	30	A,B,C,D
	Delo 3000 Marine 40	SAE 40	30	A,B,C,D
ExxonMobil	Exxmar 30 TP 40	SAE 40	30	A,B,C,D
	Mobilgard M 430	SAE 40	30	A,B,C,D
	Mobilgard 430	SAE 40	30	A,B,C,D
Pertamina	Martron 430	SAE 40	30	A,B,C,D
Petrobras	Marbrax CCD-430	SAE 40	30	A,B,C,D
Petron	Petromar XC 3040	SAE 40	30	A,B,C,D
Shell	Argina T 40	SAE 40	30	A,B,C,D
Statoil	MarWay 3040	SAE 40	30	A,B,C,D
TotalFinaElf / Lubmarine	Aurelia 4030	SAE 40	30	A,B,C,D
	Stellano S 430	SAE 40	30	A,B,C,D

Before using a lubricating oil not listed in Tables 1-3, the engine manufacturer must be contacted. Lubricating oils that are not approved have to be tested according to engine manufacturer's procedures.

APPROVED LUBRICATING OILS FOR ENGINE TURNING DEVICE

It is recommended to use EP-gear oils, viscosity 400-500 cSt at 40 °C = ISO VG 460 as lubricating oils for turning device.

LUBRICATING OILS FOR ENGINE TURNING DEVICE				
SUPPLIER	**BRAND NAME**	**VISCOSITY cSt at 40 °C**	**VISCOSITY cSt at 100 °C**	**VISCOSITY INDEX (VI)**
Agip	**Blasia**	**300**	**23.0**	**95**
BP	**Energol GR-XP 460**	**425**	**27.0**	**88**
Castrol	**Alpha SP 460**	**460**	**30.5**	**95**
ChevronTexaco (Caltex + FAMM)	**Meropa 460**	**460**	**31.6**	**100**
ExxonMobil	**Spartan EP 460** **Mobilgear 634**	**460** **437**	**30.8** **27.8**	**96** **96**
Shell	**Omala Oil 460**	**460**	**30.8**	**97**
TotalFinaElf / Lubmarine	**Epona Z 460**	**470**	**30.3**	**93**

LUBRICATING OILS FOR GOVERNOR / ACTUATOR

An oil of viscosity class SAE 30 or SAE 40 is suitable and usually the same oil can be used as in the engine. Turbocharger oil can also be used in the governor. In low ambient conditions it may be necessary to use a multigrade oil (e.g. SAE 5W-40) to get a good control during start-up. Oil change interval: 2000 service hours.

RAW WATER QUALITY, APPROVED COOLING WATER ADDITIVES AND TREATMENT SYSTEMS

FOR WÄRTSILÄ VASA 32, WÄRTSILÄ 20, WÄRTSILÄ 32, WÄRTSILÄ 46, WÄRTSILÄ 64, WÄRTSILÄ 32DF, WÄRTSILÄ 50DF AND WÄRTSILÄ 34SG ENGINE TYPES

RAW WATER QUALITY

Raw water quality to be used in the closed cooling water circuits of engines has to meet the following specification.

Property	Limit
pH	min. 6.5
Hardness	max. 10 °dH
Chlorides	max. 80 mg/l
Sulphates	max. 150 mg/l

APPROVED COOLING WATER ADDITIVES

Manufacturer	Additive name
S.A. Arteco N.V. Technologiepark-Zwijnaarde 2 B-9052 Ghent/Zwijnaarde, Belgium	Havoline XLi
GE Betz Europe Interleuvenlaan 25 B-3001 Heverlee, Belgium GE Betz 4636 Somerton Road Trevose PA 19053, United States	CorrShield NT 4293 CorrShield NT 4200
Drew Ameroid Marine Division Ashland Chemical Company One Drew Plaza Boonton, NJ 07005, USA	DEWT-NC powder Drewgard 4109 Liquidewt Maxigard Vecom CWT Diesel QC-2
Houseman Ltd The Priory, Burnham Slough SL1 7LS, UK	Cooltreat 651
Kuwait Petroleum (Danmark) AS Hummetoftveij 49 DK-2830 Virum, Denmark	Q8 Corrosion Inhibitor Long-Life

Manufacturer	Additive name
Maritech AB Box 143 S-29122 Kristianstad, Sweden	Marisol CW
Nalco Chemical Company One Nalco Centre Naperville, Illinois 60566-1024 USA	Nalco 39 (L) Nalcool 2000
Nalfleet Marine Chemicals PO Box 11 Winnington Avenue, Northwich Cheshire, CW8 4DX, UK	Nalcool 2000 Nalfleet EWT 9-108 Nalfleet CWT 9-131C
Rohm & Haas La Tour de Lyon 185, Rue de Bercy 75579 Paris, Cedex 12, France	RD11 RD11M RD25
RRS-Yhtiöt Pieksämäentie 398A 77570 Jäppilä, Finland	Korrostop KV
Tampereen Prosessi-Insinöörit Oy Keisarinviitta 22 33960 Pirkkala, Finland	Ruostop XM
Texaco Global Products, LLC 1111 Bagby Houston, TX 77002	Havoline XLi
TotalFinaElf Diamant B, 16, rue de la République 92922 Paris La Défense Cedex, France	WT Supra
Unitor ASA P.O. Box 300 Skøyen N-0212 Oslo, Norway	Dieselguard NB Rocor NB liquid Cooltreat AL
Vecom Holding BV PO Box 27 3140 AA Maassluis, The Netherlands	Vecom CWT Diesel QC-2

In order to prevent corrosion in the cooling water system, the instructions of right dosage and concentration of active corrosion inhibitors should always be followed. The information can be found in the table below.

Product designation	Dosage per 1 m³ of system capacity	Concentration of active corrosion inhibitor
Corrshield NT 4293 CorrShield NT 4200	10 litres	670 – 1000 ppm as NO_2
DEWT-NC powder Drewgard 4109 Liquidewt Maxigard	3 – 4.5 kg 16 – 30 litres 8 – 12 litres 16 – 30 litres	1500 – 2250 ppm as NO_2 640 – 1200 ppm as NO_2 470 – 700 ppm as NO_2 640 – 1200 ppm as NO_2
Cooltreat 651	5 litres	800 ppm as NO_2

Product designation	Dosage per 1 m³ of system capacity	Concentration of active corrosion inhibitor
Q8 Corrosion Inhibitor Long-Life	50 – 100 litres	1.6 - 3.2 w-% of active compounds measured with a supplier's refractometer
Maricol CW	8 – 16 litres	1000 – 2000 ppm as NO_2
Nalco 39 (L) Nalcool 2000 Nalfleet EWT 9 - 108 Nalfleet CWT 9 - 131C	16 - 36 litres 32 - 48 litres 2.2 - 3.4 litres 8 - 12 litres	550 - 1200 ppm as NO_2 1000 - 1500 ppm as NO_2 1000 - 1500 ppm as NO_2 1000 - 1500 ppm as NO_2
Korrostop KV	20 – 25 litres	120 - 150 ppm as Mo
RD11 (RD11M) RD25	5 kg 50 litres	1250 ppm as NO_2 710 ppm as Mo
Ruostop XM	20 litres	120 ppm as Mo
Havoline XLi	50 - 100 litres	1.6 - 3.2 w-% of active compounds measured with a supplier's refractometer
WT Supra	50 - 100 litres	1.6 - 3.2 w-% of active compounds measured with a supplier's refractometer
Dieselguard NB Rocor NB Liquid Cooltreat AL	2 - 4.8 kg 10 - 24 litres 50 – 100 litres	1500 ppm as NO_2 1500 ppm as NO_2 1.6 - 3.2 w-% of active compounds measured with a supplier's refractometer
Vecom CWT Diesel QC-2	6 - 10 litres	1500 - 2500 ppm as NO_2

Note 1: For some products the recommended minimum and maximum limits are listed in the table above. Since the amount of active corrosion inhibitors, especially nitrites, is decreasing during the service of engines, the engine manufacturer recommends to start the dosage from the upper level.

Note 2: The nitrite content of nitrite-based cooling water additives tends to decrease in use. The risk of local corrosion increases substantially when nitrite content goes below the recommended limit.

APPROVED COOLING WATER TREATMENT SYSTEMS

ELYSATOR

As an alternative to the approved cooling water additives, the Elysator cooling water treatment system can also be used. The Elysator protects the engine from corrosion without any chemicals. It provides a cathodic/anodic protection to engine's cooling water system by letting magnesium anodes corrode instead of the engine itself. Raw water quality specification is the same as in connection with cooling water additives. More information in document 4V92A1322.

The Elysator can be a sensible alternative in installations where the environmental factors are considered important.

The installation, operation and maintenance instructions of the manufacturer should always be followed. The contact information can be found in the table below.

Supplier	**Treatment system**
International Watertreatment Maritime AS N-3470 Slemmestad Norway	Elysator

03. Start, Stop and Operation

03.1 Turning of crankshaft

Turning is performed by means of an electrically driven turning device built on the engine.

03.1.1 Electrically driven turning device

The turning device consists of an electric motor which drives the turning gear through a gear drive and a worm gear. There is a control box available, including a cable, which allows the turning to be accomplished from any position near the engine. The turning speed of the flywheel is about 0.6 RPM.

The engaging and disengaging of the turning gear is made by the lever (1) with yellow ball knob. The turning gear is spring-loaded outwards in order to prevent it from meshing with the flywheel when out of operation.

The turning device is provided with a start blocking valve which prevents starting in case the turning gear is engaged. See chapter 21, section 21.1.

For careful adjustment of the crankshaft position there is a hand wheel (2) with which it is possible to perform manual turning.

Electrically driven turning device

1. Lever with yellow ball knob
2. Hand wheel
3. Vent hole
4. Drain hole
5. Filling hole
6. Gauge glass

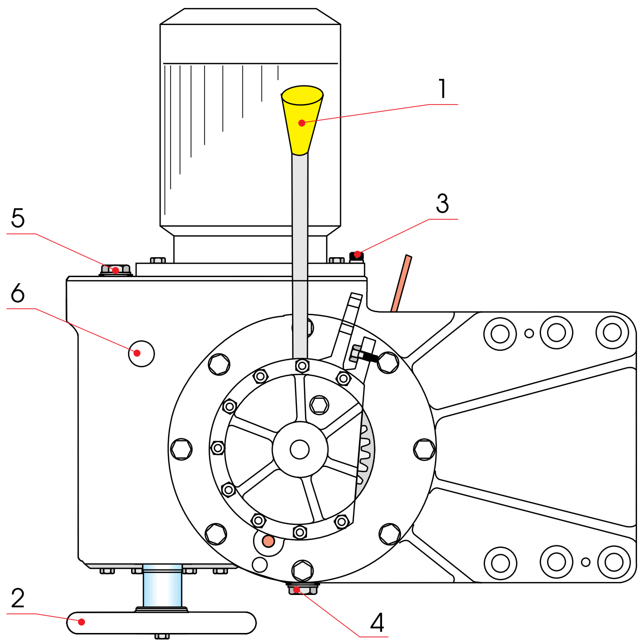


Fig 03-1 4003019601

03.2 Start

1. Remote start
2. Local start
3. Emergency start (solenoid valve)
4. Emergency start (starting valve)

Before starting the engine, check that:

- the lubricating oil level is correct
- the fuel system is in running order (correct preheating, correct pressure, sufficient precirculation to heat the fuel injection pumps)
- both cooling water system circuits, LT and HT water circuit, are in running order (correct pressures, circulating water preheated and pre-circulated sufficiently to heat the engine)
- the oil level in the governor is correct
- the starting air pressure exceeds 15 bar
- the starting air system is drained of condensate
- the drain pipe of the air cooler casing is open, no leakage
- stop lever is in work position
- prelubricating oil pump is running and pressure is over 0.3 bar
- turning device is disengaged
- indicator valves are closed
- that the automation system indicates ready for start.

All covers and protecting shields are to be mounted and closed before starting the engine. Covers should be removed or opened occasionally only for measurements and checks, and they must be immediately mounted again.

Note! **Never leave the engine running when covers are removed.**

03.2.1 Local start

1 **Start the prelubricating oil pump** to obtain a lubricating oil pressure, over 0.3 bar.

2 **Open the valve in the starting air supply system** and drain condensate via the blow-off valve. Close the blow-off valve when there is no more condensate.

3 **Turn the crankshaft either two revolutions** by using the turning device **or** run the engine on starting air for some revolutions by pressing the button on the solenoid valve and keeping the **stop lever in stop position** (red ball knob) and the indicator valves open. In doing so the risk of water locks is eliminated. After blowing, close the indicator valves.

4 **Disengage the turning gear** from the flywheel (yellow ball kob).

5 **Check start blocking on the LDU.** Remove blockings and return to the main page.

6 **Check that the automation system** indicates ready for start.

7 **Check that the stop lever is in work position.**

8 **Local/Remote switch in local position.**

9 **Push the start button.** If the engine does not start after starting sequence, the reason should be checked.

10 **Check that the automation system** indicates that the engine is running and that the running parameters are normal.

Note! **The starting air supply should be open when the engine is running, otherwise the pneumatic stop may not work.**

03.2.2 Remote and automatic start

See installation specific instructions.

03.2.3 Emergency start

Emergency situation engine can also be start manually by pushing the button on the starting solenoid or main starting valve.

03.3 Stop

03.3.1 Manual stop

1 **Idle the engine 1 min** before stopping.

2 **Stop the engine** by moving the stop lever into stop position or by pressing the stop button (LCP). The time of slowing down offers a good opportunity to detect possible disturbing sounds.

3 **Prelubricating oil pump** should be operated 10 min. after stop.

03.3.2 General

The engine can always be stopped manually (with the stop lever) independent of the remote control or automation system.

Caution! **When overhauling the engine, make absolutely sure that the automatic start and the priming pump are disconnected. Make also sure that the starting air shut-off valve located before main starting valve is closed and the starting air line drained. Otherwise it might cause engine damage and/or personal injury.**

Move the stop lever into STOP position.

If the engine is to be stopped for a lengthy time, close the indicator valves. It is also advisable to cover the exhaust pipe opening.

The lubricating oil system on a stopped engine should be filled with oil every second day by priming the engine. At the same time, turn the crankshaft into a new position. This reduces the risk of **corrosion** on journals and bearings when the engine is exposed to vibrations.

Blow the engine with open indicator valves and start the engine once a week to check that everything is in order.

03.4 Normal operation supervision

If an alarm limit is reached and an alarm is activated, the engine situation is already serious. All necessary countermeasures must be taken to remove this emergency condition and return to normal operating conditions. As the abnormal operating situation may cause damages to the engine, all efforts must be put into returning to the normal operating situation instead of just waiting for an automatic shut down of the engine.

03.4.1 Every second day or after every 50 running hours

1 **Read all temperatures and pressures** as well as the load of the engine. All temperatures are more or less dependent on the load, and the lubricating oil, cooling water pressures (built--on pumps) are dependent on the speed. Therefore, always compare the values read with those at corresponding load and speed in the Acceptance Test Records and curves. **Guidance values are stated in chapter 01.**

The charge air temperature should, in principle, be as low as possible, however, not so low that condensation occurs, see Fig 03-2.

2 **Check pressure drop** over the lubricating oil filter. Too large of a pressure drop indicates clogged candles, which results in reduced oil filtration when the by-pass valve is open. Reduced oil filtration results in increased wear. Change the candles.

3 **Check the oil level** in the oil sump/oil tank. Estimate the appearance and consistency of the oil. A simple control of the water content: A drop of oil on a hot surface (about 150°C), e.g. a hot-plate. If the drop keeps “quiet”, it does not contain water; if it “frizzles” it contains water. Compensate for oil consumption by adding max. 10 % fresh oil at a time.

4 **Check the ventilation** (de-aerating) of the engine cooling water system. Check that the leakage from the telltale hole of the HT-water- and the LT-water pump is normal (slight).

5 **Check the quantity of leak-fuel** from the draining pipes and from the telltale hole of the fuel feed pump.

6 **Check that the drain pipes** of the air coolers are open.

7 **Check that the telltale holes** of the oil coolers and the cooling water coolers are open.

8 **Clean the compressor side** of the turbocharger by injecting water. See the instruction manual of the turbocharger.

9 **Drain the fuel day tank** of water and sediments, if any, and drain the starting air receiver of water.

Condensation in charge air coolers

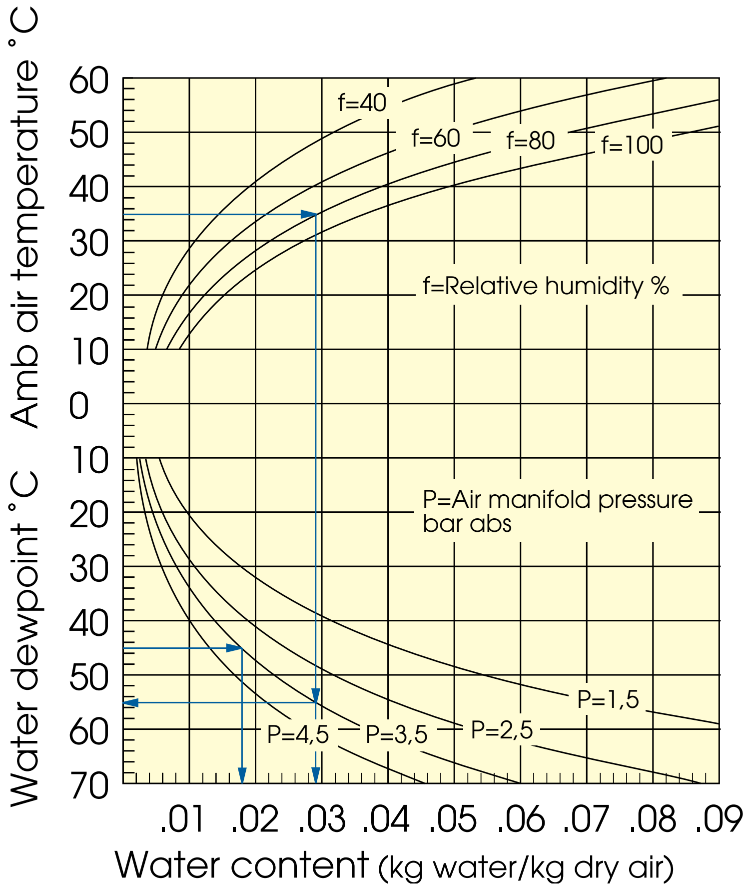


Fig 03-2 3203528930

Example: If the ambient air temperature is 35°C and the relative humidity is 80 % the water content in the air can be read from the diagram (0.029 kg water/kg dry air). If the air manifold pressure (receiver pressure) under these conditions is 2.5 bar, i.e. absolute air pressure in the air manifold is abt. 3.5 bar (ambient pressure + air manifold pressure), the dew point will be 55°C (from diag.). If the air temperature in the air manifold is only 45°C, the air can only contain 0.018 kg/kg (from diag.). The difference, 0.011 kg/kg (0.029-0.018) will appear as condensed water.

03.4.2 Other maintenance works

To avoid malfunction of the engine a regulary maintenance work must be done, see chapter 04.

03.4.3 In connection with maintenance work

1 **Record the following steps** and the running hours in the engine log:

- lubricating oil sampling (record also operating time of oil). Lubricating oil analyses without statement of operating time is of limited value ("go - no go" only)
- lubricating oil changes
- cleaning of centrifugal lubricating oil filter, see section 18.8
- cleaning or changing of lubricating oil automatic filter candles, see section 18.7
- change of parts in connection with maintenance according to chapter 04.

03.4.4 General

1 **There is no automatic supervision** or control arrangement that can replace an experienced engineer's observations. **LOOK at and LISTEN to the engine!**

2 **Strong gas blow-by past the pistons** is one of the most dangerous things that can occur in a diesel engine. If gas blow-by is suspected (e.g. because of a sudden increase of the lubricating oil consumption) check the crankcase pressure. If the pressure exceeds 30 mm H_2O, check the crankcase venting system, if in order, pull the pistons!

3 **Operation at loads below 20 %** of rated output should be limited to maximum 100 hours continuously when operating on heavy fuel by loading the engine above 70 % of the rated load for one hour before continuing the low load operation or stopping the engine.

Idling (i.e. main engine declutched, generator set disconnected) should be limited as much as possible. Warming-up of the engine for more than 3 - 5 minutes before loading, as well as idling more than 3 minutes before stopping is unnecessary and should be avoided.

03.5 Start after a prolonged stop (more than 8 h)

03.5.1 Manual start

1 **Check**

- the lubricating oil level
- the cooling water level in the expansion tank
- the water supply to heat exchangers
- the fuel oil level in the day tank (troublesome and time consuming job to vent the fuel system if the feed pump has sucked air!)
- the starting air pressure — min. 15 bar
- that the parts of the fuel control shaft system and the injection pump racks move freely. **Otherwise risk of overspeed.**

2 **Observe all points** in section 03.2.1. Point 3 grows **more important the longer the engine has been stopped.**

3 **After starting,** check that the starting air distributing pipe is not heated at any cylinder (leakage from the starting valve in the cylinder head).

03.6 Start after overhaul

1 **Check that the connection** between the speed governor and injection pumps are set correctly (especially the injection pump rack position) and does not jam, that all connections are properly locked and the injection pump racks move freely in the pumps.

2 **The speed governor control lever** being in max. position and the stop lever in work position and press the stop button in Local Control Panel (LCP). Check that all injection pump racks move to a value less than 2 mm.

3 **If the injection pumps,** the adjusting screws in the guide blocks, camshaft or its driving mechanism have been touched, check the injection timing.

4 **Check the cooling water system** for leakage, especially:

- the oil cooler
- the charge air cooler

5 **Check/adjust the valve clearances.** If the camshaft or its driving mechanism have been touched, check the valve timing of one cylinder, at least (on each cylinder bank in a V-engine). Guidance values, see chapter 06.

6 **Vent the fuel oil system** if it was opened.

7 **Start the priming pump.** Vent the lubricating oil filter. Check that lubricating oil appears from all bearings and lubricating nozzles, from the piston cooling oil outlet and from the valve mechanism. Check that there is no leakage from the pipe connections inside or outside the engine.

Note! **Observe that the crankshaft has to be turned in order to get oil through all connecting rods.**

8 **Rags or tools left in the crankcase,** untensioned or unlocked screws or nuts (those which are to be locked), worn-out self-locking nuts, **may cause** total breakdown.

Well cleaned oil spaces (oil sump and camshaft spaces) save the oil pump and oil filter.

9 **See the instructions** in section 03.2 and 03.5 when starting.

03.7 Operation supervision after overhaul

1 **At the first start,** listen carefully for possible jarring sounds. If anything is suspected, stop the engine immediately, otherwise stop the engine after 5 minutes idling at normal speed. Check at least the temperatures of the main and big end bearing and of all other bearings which have been opened. If everything is in order, restart.

2 **Check that there is no leakage** of gas, water, fuel or lubricating oil. Especially observe the fuel lines, injection pumps and injection valves. Watch the quantities emerging from the leak oil pipes!

3 **Check that the starting air distributing block is not heated** at any cylinder (leaky starting valve). May cause **explosion!**

4 **After overhauling,** the following instructions are especially important:

- Check pressures and temperatures
- Check the automatic alarm and stop devices
- Check the pressure drop over the lubricating oil automatic filter
- Check the oil level in the oil sump/oil tank. Estimate the condition of the oil
- Check the ventilation (de-aerating) of the engine cooling water system
- Check the quantity of leak fuel
- Check the telltale holes of the coolers

- Check the content of additives in the cooling water
- Check the cylinder pressures
- Listen for jarring sounds
- Check the crankcase pressure.

03.8 Running-in

The running-in of a new engine must be performed according to programme in Fig 03-3. It is also recommended that running-in procedure is performed after following maintenance jobs.

1 **After changing piston rings, pistons or cylinder liners, after honing of cylinder liners,** follow programme in Fig 03-3 as closely as possible. If the programme cannot be followed, **do not load the engine fully for at least 10 h.**

Avoid “running-in” at continuous and constant low load!

The important thing is to vary the load several times. The ring groove will have a different tilting angle at each load stage, and consequently the piston ring a different contact line to the cylinder liner.

The running-in may be performed either on distillate or heavy fuel, using the normal lubricating oil specified for the engine.

Running-in programme

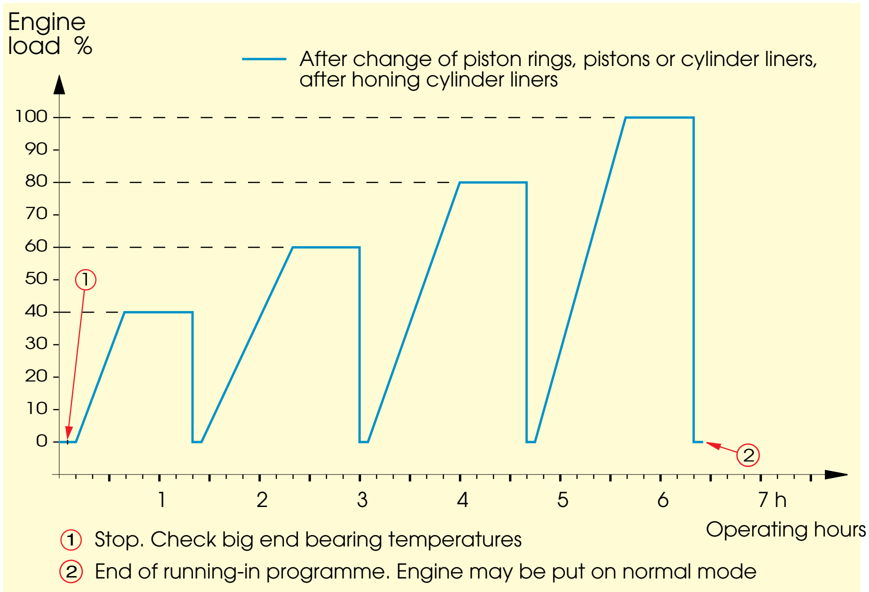


Fig 03-3 4003029701

03.9 Maintenance of turning device

The turning device needs no other maintenance than change of the gear box lubricating oil and regreasing of the drive shaft. Change the lubricating oil once during the first year of operation. After that, the oil should be changed according to chapter 04. Regrease the drive shaft according to chapter 04.

The list of lubricating oils for the engine turning device approved by the turning device manufacturer can be found in the end of chapter 02.

Check also that the vent hole (3), Fig 03-1 is open.

1 **Drain old oil,** preferably when warm, through the drain hole (4).

2 **Rinse the gear box** with clean, thinly fluid oil.

3 **Fill the gear box with oil** (according to the table in section 01.1) through the filling hole (5) until the oil level reaches the level gauge glass (6). Utmost cleanliness should be observed.

4 **Close the oil holes** and drive the turning device a few revolutions.

5 **Check the oil level** and fill, if necessary.

04. Maintenance Schedule

04.1 General

The maintenance necessary for the engine is mainly dependent on the operating conditions. The periods stated in this schedule are guidance values only, but must not be exceeded during the guarantee period. When using diesel oil or intermediate fuels of comparatively good quality as fuel oil it may be possible to lengthen the stated maintenance intervals considerably depending on the engine load. See also the instruction books of the turbocharger and the governor, separate instructions for additional equipment and chapter 03.

1 **Before any steps are taken,** carefully read the corresponding item in this Manual.

2 **Note the Risk Reduction** in chapter 00A.

3 **Note the Environmental Hazards** in chapter 02A.

4 **At all maintenance work,** observe the utmost cleanliness and order.

5 **Before dismantling,** check that all systems concerned are **drained or the pressure released**. After dismantling, immediately cover holes for lubricating oil, fuel oil and air with tape, plugs, clean cloth or the like.

6 **When exchanging a worn-out or damaged part** provided with an identification mark stating cylinder or bearing number, mark the new part with the same number on the same spot. Every exchange should be entered in the engine log and the reason should be clearly stated.

7 **Always renew all gaskets, sealing rings and O-rings** at maintenance work. **Note!** The O-rings in the cooling water system must not be lubricated with oil based lubricants, use soap or similar.

8 **After reassembling,** check that all screws and nuts are tightened and locked, if necessary.

Caution! **When overhauling the engine, make absolutely sure that the automatic start and the priming pump are disconnected. Make also sure that the starting air shut-off valve located before main starting valve is closed. Then drain the engine starting air system to avoid engine damage and/or personal injury.**

Caution! **When overhauling the engine, make absolutely sure that the generator breaker is secured/gear box is not engaged to avoid accidental turning of engine.**

Caution! **Accidental turning of engine may cause engine damage and/or personal injury.**

04.1.1 How to select application and fuel quality

There are two different types of applications defined:

- Average load is above 75 % of nominal engine output.
- Average load is below 75 % of nominal engine output.

Three types of fuel are defined:

- HFO 1 Heavy fuel oil of normal quality.
- HFO 2 Heavy fuel oil of below normal standard quality.
- DO Diesel oil or light fuel oil (LFO).

Fuel characteristics, maximum limits			
		HFO 1	**HFO 2**
Sulphur	mass-%	2.0	2.0 - 5.0
Ash	mass-%	0.05	0.05 - 0.20
Vanadium	mg/kg	100	100 - 600
Sodium	mg/kg	20	20 - 50
Al + Si	mg/kg	30	30 - 80
CCAI		850	850 - 870

Note! **If any of specified fuel properties exceed HFO 1 maximum value the fuel should be classified as HFO 2.**

04.2	Every second day, irrespective of the engine being in operation or not	
Automatic prelubrication	**Check operation**	03.2 18.9
Crankshaft	**Marine engine:** In a stopped engine, turn the crankshaft into a new position.	03.1

04.3	Once a week irrespective of the engine being in operation or not	
Start process	**Test start (if the engine on stand-by).**	03.2

04.4	Interval: 50 operating hours	
Air coolers	**Check draining of air coolers** Check that the draining pipe is open, check if any leakage.	15.5 03.4.1
Cooling water system	**Check water level in cooling system** Check the water level in the expansion tank(s) and/or the static pressure in the engine cooling circuits.	19.1.3
Connecting rod	**Check tightening of the connecting rod screws** Check the tightening of the connecting rod screws after the first 50 operating hours on a new engine and, after overhaul, those screws that have been opened. **Note!** Pump to stated pressure. Tighten if possible. **Do not loosen!**	11.3.5 07.3
Gauges and indicators	**Take readings** Read and record (using eg. form No. WV98V091) all temperatures and pressures, and at the same time the load of the engine.	03.4.1
Governor, actuator	**Check oil level in governor** Check oil level, and look for leaks	02.2.4 22.4.1
Injection and fuel system	**Check leak fuel quantity** Check the amount of leak fuel from the injection pumps and nozzles.	03.4.1 17.1
Injection pipes	**Check tightening of injection pipe connections** Check the tightening of injection pipe connections on a hot engine after the first 50 operating hours on a new engine and, after overhaul, those connections that have been opened.	16.3 07.1
Lubricating oil filter	**Check pressure drop** Clean or change filter candles if high pressure drop is indicated.	03.4.1 18.7
Lubricating oil sump	**Check oil level in sump** Check oil level by means of dip stick, compensate for consumption.	18.2 02.2
Main bearings	**Check tightening of main bearing screws** Check the tightening of main bearing screws after the first 50 operating hours on a new engine and, after overhaul, those screws that have been opened. **Note!** Pump to stated pressure. Tighten if possible. **Do not loosen!**	10.3.3 07.3
Multiduct	**Check tightening of the multiduct screws** Check the tightening of the multiduct screws after the first 50 operating hours on a new engine and, after overhaul, those screws that have been opened. The engine shoud be in normal operating temperature.	07.1
Running-in filter	**Remove the running-in filter** After the first 50 operating hours, remove the running-in filter and pump up the hydraulic jack. Continue	

Turbocharger	**Water cleaning of compressor** Clean the compressor by injecting water.	15.3.3
Valve mechanism	**Check valve clearances** Check the valve clearances after 50 hours' running in new and overhauled engines.	12.2.4 06.1

04.5	**Interval: 100 operating hours**	
Turbocharger	**Water cleaning of turbine** Clean the turbine by injecting water; more often if necessary.	15.3.2

04.6	**Interval: 500 operating hours**	
Centrifugal filter	**Clean centrifugal filter(s)** Clean more often if necessary. Remember to open the valve before the filter after cleaning.	18.8.2
Control mechanism	**Maintenance of control mechanism** Check for free movement, clean and lubricate.	22.2
Cooling water	**Check water quality** Check content of additives.	19.2 02.3
Cylinder pressure	**Check cylinder pressure** Record firing pressures of all cylinders.	12.4 03.4.3
Lubricating oil	**Take oil sample** In a new installation or after change to use of a new lubricating oil brand, take samples for analyzing.	02.2.3

04.7	**Interval: 1000 operating hours**	
Air filter (on-built)	**Clean turbocharger air filter** Remove the filter(s) and clean according to instructions of the manufacturer (more often, if necessary).	15.2
Automation	**Functional check of automation** Check function of the alarm and automatic stop devices.	23.2 01.2
Electrical fuel feed pump	**Regrease electrical fuel feed pump** Regrease the pump under running condition.	
Flexible coupling Geislinger (Oil filled)	**Oil change/check of the coupling** At first interval, change oil of the coupling. Following (1000h) intervals, check oil level. See manufacturers instructions.	
Fuel filter	**Replace fuel oil filter cartridges** Clean the wire gauze and filter housing. Replace the filter cartridges. (The cartridges are to be replaced when the pressure difference indicator shows too high pressure drop). See manufacturers instructions.	
Valves	**Check valve condition** Check that the inlet and exhaust valves move freely in their guides. This should preferably be done when the engine has been out of operation for a couple of hours. Check valve clearances. Check cylinder tightness (valves, piston rings) with a pneumatic test.	12.2.4 06.1 12.A

04.8	Interval: 2000 operating hours	
Air cooler(s)	**Check waterside of charge air cooler(s)** The first time check of the waterside, clean if necessary.	15.5
El.-pneu. overspeed trip device	**Check el.-pneumatic overspeed trip device** Check function and tripping speed.	22., 23 06.1
El.-pneu. overspeed trip device	**Check el.-pneumatic overspeed trip device** Check functional tripping speed, controlled by relay module.	22., 23 06.1
Governor	**Change oil in governor** Change lubricating oil.	02.2.4 22.4.1
Injection valves	**Inspect injection valves** Test the opening pressure. Dismantle and clean nozzles. Check the effective needle lift. Check the springs. Replace the O-rings. Check the nozzle condition in a test pump. Replace the nozzles if necessary.	16.4.4
Injection valves Direct Water Injection	**Inspect injection valves** Test the opening pressure. Dismantle and clean nozzles. Check the effective needle lift. Check the springs. Replace the O-rings. Check the nozzle condition in a test pump. Replace the nozzles if necessary.	16.7
Lubricating oil	**Change lubricating oil** Change oil in a new installation (wet sump installations). Take samples for analyzing. If the analyzing values are positive and if the oil supplier or engine manufacturer so recommend, the intervals between changes can be prolonged in steps of 500 operating hours. In dry sump installations the oil change intervals may be in the order of 8000 hours or more. Clean all oil spaces when changing lubricating oil.	18.2 02.2
Measuring instruments	**Check sensors** Check pressure and temperature sensors. Replace faulty ones.	
Turning device	**Regrease the drive shaft** Regrease the drive shaft when turning device is connected (engine stopped).	02.2.5 03.9

04.9	Interval: 4000 operating hours	
Air cooler(s)	**Check charge air cooler(s)** Check and clean the waterside if necessary. Look carefully for corrosion. Check for possible leakage. Replace parts if necessary. Check accurate pressure difference over the charge air cooler (air side) by using u-tube.	15.5
Automation	**Check connectors and cables** Check mounting and connections. Apply contact lubricant to contact surfaces. Check tightness of connections. Check condition of cables, wires and cable glands. Replace damaged connectors and cables.	23.8
Camshaft	**Inspect contact faces of camshaft** Check the contact faces of the cams and tappet rollers. Check that the rollers rotate. Rotate the engine with the turning gear.	14.1.3 03.1
Cooling water spaces	**Inspect HT-water spaces on engine with cooled turbocharger** Inspect turbocharger cooling water ducts for possible deposits. Clean if the deposits are 1mm or thicker. Remove air venting pipe and adapter plug on the multiduct, inspect the water side of one duct . If the deposits are thicker than 1 mm, clean all liners and engine block water space. Improve the cooling water treatment.	15.2 19.2 19.1.2 02.3 10.5
	Inspect HT-water spaces on engine with uncooled turbocharger Remove air venting pipe and adapter plug on the multiduct, inspect the water side of one duct . If the deposits are thicker than 1 mm, clean all liners and engine block water space. Improve the cooling water treatment.	15.2 19.2 19.1.2 02.3 10.5
Control mechanism	**Check control mechanism** Check for wear in all connecting links between the governor and all injection pumps.	22.2
Crankshaft	**Check crankshaft alignment** Check alignment, use form. Alignment check is performed on a warm engine.	11.2.2
Crankshaft	**Check thrust bearing clearance** Check axial clearance	11.2.3 06.2
Exhaust manifold	**Check for leaks** Check for leaks once a year. Replace parts if necessary.	20.
Flexible coupling Geislinger (Oil filled)	**Oil change of the coupling** Change oil of the coupling. See manufacturers instructions.	
Fuel system	**Check and adjust fuel system** Check the adjustment of fuel system. Check for possible leakage. Replace parts if necessary.	17.
Injection valves	**Inspect injection valves** Test the opening pressure. Dismantle and clean nozzles. Check the effective needle lift. Check the springs. Replace the O-rings. Check the nozzle condition in a test pump. **Recommendation:** Replace the nozzle by new ones.	16.4.4
Lubricating oil cooler	**Check lubricating oil cooler** Check that the lube oil temperature before the engine is within normal operating values (Section 01.1). Check for possible leakage. Continue	18.5

Starting fuel limiter	**Check starting fuel limiter** Check the function.	22., 23.
Turbocharger	**Inspect and clean** Clean the compressor and turbine mechanically if necessary.	15.2

04.10	**Interval: 8000 operating hours**	
Air cooler(s)	**Clean the charge air cooler(s)** Clean and pressure test. Look carefully for corrosion.	15.5
Lubricating oil automatic filter	**Replace lubricating oil filter candles** Drain the filter housing. Clean the wire gauze. Replace the filter candles.	18.7.2 18.2
Lubricating oil coolers	**Clean lubricating oil cooler** If the lube oil temperature before the engine is within normal operating values (Section 01.1), the interval can be prolonged. Unnecessary opening of the cooler should be avoided. Clean the lube oil cooler before the alarm limit is reached. Examine carefully for corrosion.	18.5 19.2
Throttle valve and actuator	**Check the function of air throttle valve and actuator**	
Wastegate	**Check the function of the wastegatevalve and actuator** Replace the positioner pilot valve.	

04.11	**Interval: 12000 operating hours**	
Fuel system (Only V-engines)	**Replace fuel feed pipes between A- and B-bank** The fuel pipes between A- and B-bank has to be replaced.	17.
Governor driving gear	**Inspect governor driving gear** Replace parts if necessary.	22.4.2 06.2
HT-water pump	**Inspect HT-water pump** Dismantle and check. Replace worn parts.	19.3.1 19.3.2
HT-water pump driving gear	**Inspect HT-water pump driving gear** Replace parts if necessary.	19.3.1 06.2
HT-water thermostatic valve	**Clean and inspect HT-water thermostatic valve** Clean and check the thermostatic element, valve cone-casing and O-rings.	19.4.3
LT-water pump	**Inspect LT-water pump** Dismantle and check. Replace worn parts.	19.3.1 19.3.2
LT-water pump driving gear	**Inspect LT-water pump driving gear** Replace parts if necessary.	19.3.1 06.2
LT-water thermostatic valve	**Clean and inspect LT-water thermostatic valve** Clean and check the thermostatic element, valve cone-casing and O-rings.	19.4.2
Lube oil pump	**Inspect the lube oil pump** Replace parts if necessary.	18.3.3
Lube oil pump driving gear	**Inspect lube oil pump driving gear** Replace parts if necessary.	18.3.3 06.2
Oil thermostatic valve	**Clean and inspect oil thermostatic valve** Clean and check the thermostatic element, valve cone-casing and O-rings. Continue	18.6

Prelubricating oil pump	**Inspect the prelubricating oil pump** Replace parts if necessary.	18.9.3
Turbocharger ABB TPL-chargers	**Inspect turbocharger bearings** Check and change if necessary. See manufacturers instructions.	15.2
Turbocharger Napier NA-chargers	**Inspect turbocharger bearings** Check and change if necessary. See manufacturers instructions.	15.2

Fuel	Overhaul interval	
	Average load > 75 %	Average load < 75 %
HFO 2	12 000	12 000
HFO 1	16 000	16 000
DO	20 000	20 000

04.12	Interval: see table above	
Camshaft	**Inspect camshaft bearings** Replace if necessary.	14.3.1 06.2
Camshaft driving gear	**Inspect intermediate gears** Replace parts if necessary.	13.1 06.2
Connecting rods	**Replace big end bearings** Replace big end bearings. Measure the big end bore, use form 3211V017.	11.3.4 06.2
Connecting rods	**Replace connecting rod screws** Replace connecting rod screws by new ones at **every second overhaul** when doing piston overhauls at 12 - 16 000 h intervals and at **every overhaul** when doing piston overhauls at longer intervals than 16 000 h.	11.3
Connecting rods	**Replace connecting rod shims** Replace connecting rod shims by new ones at **every second overhaul** when doing piston overhauls at 12 - 16 000 h intervals and at **every overhaul** when doing piston overhauls at longer intervals than 16 000 h.	11.3
Connecting rods	**Inspect the small end bearings** Inspect the small end bearings. Replace if necessary.	11.3.4 06.2
Crankshaft	**Inspect main bearings** One main bearing to be inspected, if in bad condition, change and check/change all main bearings.. Note the type of bearing in use and do the inspection accordingly.	10.3.2 06.2
Cylinder heads	**Overhaul of cylinder head** Dismantle and clean the underside, inlet and exhaust valves and ports. Inspect cooling spaces and clean, if necessary. Grind the valves . Inspect the valve rotators. Check rocker arms. Replace the O-rings in the valve guides. Replace the O-rings at bottom of cylinder head screws at every overhaul.	12.2.2 12.2 12.3
Cylinder liners	**Inspect the cylinder liners** Measure the bore using form No. 3210V018, replace liner if wear limits are exceeded. **Hone the liners.** Renew the anti-polishing ring. Continue	10.5.1 06.2

Engine fastening bolts	**Check tightening of engine fastening bolts** Replace if necessary	07.3
Hydraulic jack for main bearing caps	**Check function** Change O-rings in the hydraulic jack if they are leaking when lifting the main bearing cap.	10.3.1
Pistons	**Inspect the pistons** Composite pistons must be dismantled for inspection of mating surfaces between piston skirt and piston crown. Inspect and clean oil spaces.	11.3.4
Piston, piston rings	**Inspect pistons and piston rings** Pull, inspect and clean. Check the height of the ring grooves (the height clearance of the rings), use form No. 3211V022. Check the retainer rings of the gudgeon pins. Replace complete set of piston rings. Note the running-in programme.	11.3.4 11.3 06.2 03.8
Starting valves	**Check starting valves** Check starting valves in cylinder head. Replace parts if necessary.	21.4
Valve mechanism	**Check valve mechanism parts** Check valve mechanism parts. Replace parts if necessary.	14.1.3 06.2

04.13	**Interval: 12000 - 16000 operating hours**	
Injection pumps	**Overhaul of injection pumps** Clean and inspect injection pumps, replace worn parts. Replace the erosion plugs.	16.2.5

04.14	**Interval: 16000 operating hours**	
Exhaust manifold	**Check expansion bellows** Replace if necessary.	20.1.2
Flexible coupling (Oil filled)	**Check the flexible coupling** Dismantle and check flexible coupling according to manufacturers recommendations.	
Fuel feed pump	**General overhaul of fuel feed pump** Dismantle and check, replace worn parts. See manufacturers instructions.	
Governor drive	**Check governor drive bearing** Check governor driving shaft bearing clearance in situ.	22.4.2 06.2
Governor	**General overhaul of the governor** Can be sent to engine manufacturer for overhaul.	
Booster servomotor for governor	**General overhaul of the booster servomotor** Replace worn parts. See manufacturers instructions.	
Turning device	**Change oil in turning device** Regrease the drive shaft.	02.2.5 03.9
Vibration damper Viscous type	**Take oil sample from vibration damper** Take oil sample for analyzing.	11.2.1

04.15	Interval: 24000 operating hours	
Flexible coupling (Oil supply from engine)	**Check the flexible coupling** Dismantle and check flexible coupling according to manufacturers recommendations.	
Main starting valve	**General overhaul of main starting valve** Replace worn parts.	21.2
Starting air distributor	**General overhaul of starting air distributor** Replace worn parts.	21.3.2
Turbocharger ABB TPL-chargers	**Replace turbocharger bearings** See manufacturers instructions.	15.2
Vibration damper Geislinger	**Check vibration damper** Dismantle and check vibration damper, see manufacturers instructions.	11.2.1

04.16	Interval: 48000 operating hours	
Camshaft driving gear	**Replace intermediate gear bearings** Replace parts if necessary.	13.1 06.2
Crankshaft	**Inspect crankshaft** Inspect the crankshaft for wear.	06.2
Engine foundation Flexible mounted	**Check flexible elements of engine foundation** Replace if necessary.	
Flexible coupling	**Check the flexible coupling** Dismantle and check flexible coupling according to manufacturers instructions. Replace spring packs/inner star if necessary.	
Turbocharger	**Replace rotor** Lifetime dependent of operating conditions. See manufacturers instructions.	15.2

05.Maintenance Tools

05.1 General

Maintenance of the Wärtsilä engines requires some special tools developed in the course of engine design. Some of these tools are supplied with the engine, and others are available through our service stations or for direct purchase by the customer.

Tool requirements for a particular installation may vary greatly, depending on the use and service area. Standard tool sets are therefore selected to meet basic requirements.

This list presents a comprehensive selection of tools for the Wärtsilä W32 and W34SG engines.

The tool sets are grouped in order to facilitate selection for specific service operations.

05.1.1.How to use this list

1 **Read the corresponding item** in this Manual before any maintenance work is started.

2 **Check with the list** below that all the maintenance tools are available on the site.

3 **Check** that necessary spare parts and consumable parts are available.

05.1.2.Ordering of maintenance tools

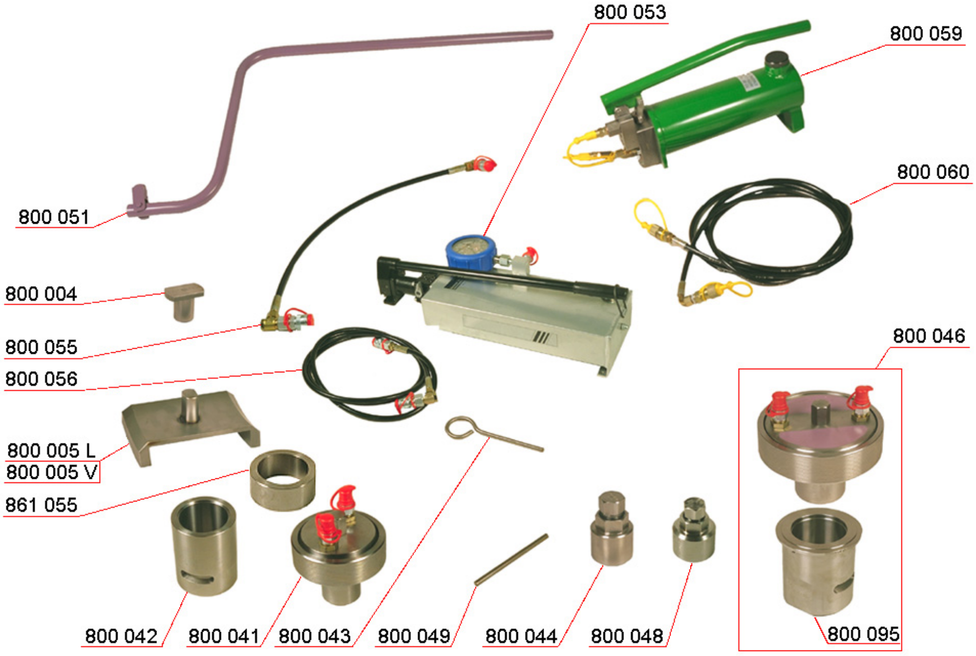
1 **Find the part(s)** that interests you in the following pages.

2 **Select the tools or parts required.** Note that all the tools are not part of the standard delivery. You can use the part number below the figure when ordering.

3 **Make a note of the specifications** and other information on your order.

4 **Send the order** to your local service station. When possible, state installation name and engine number(s) when ordering.

Note! **This chapter includes all available tools for the engines specified hereabove. See also specific installation's tool list. Some of the tools are applicable for certain cylinder numbers and with certain engine mounted equipment.**

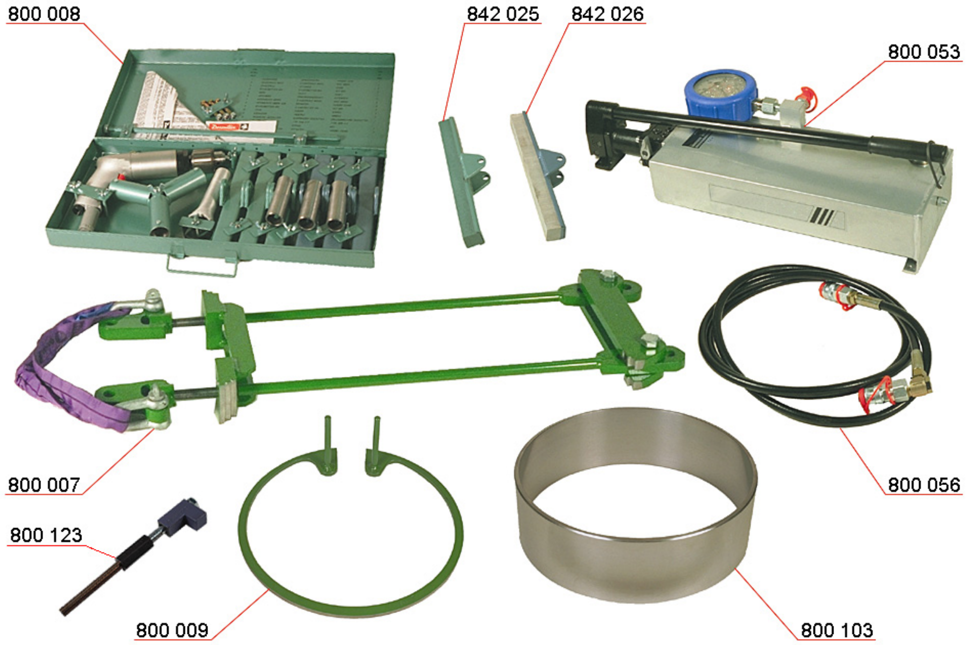


Main Bearing 100

Code	Description	Drawing No.
800004	Turning tool for main bearing shell	4V85B0024
800005	Turning tool for thrust bearing shell, L-engine	3V85B0026
800005	Turning tool for thrust bearing shell, V-engine	3V85B0031
800041	Hydraulic cylinder M42 **(1)**	3V86B0078
800042	Distance sleeve M42	3V86B0046
800043	Pin for tightening of nuts M42	4V86B0011
800044	Stud remover M42	3V80D0028
800046	Hydraulic tools M56 **(1)**, including 800095	3V86B0218
800048	Stud remover M56	3V84G0189
800049	Pin for tightening of nuts M56	4V86B0002
800051	Lifting tool for hydraulic cylinder M56, L-engine	3V86B0288
800051	Lifting tool for hydraulic cylinder M56, V-engine	3V86B0357
800053	High pressure pump (1000 bar) **(1)**	4V86A0033
800055	Flexible hose 800 mm **(1)**	
800056	Flexible hose 3000 mm **(1)**	
800059	Low pressure pump (150 bar)	1V86A0018
800060	Flexible hose 3000 mm **(1)**, low pres. pump	
800095	Distance sleeve M56	3V86B0217
861055	Distance sleeve, counterweight screws	4V86B0081

(1) Including quick couplings

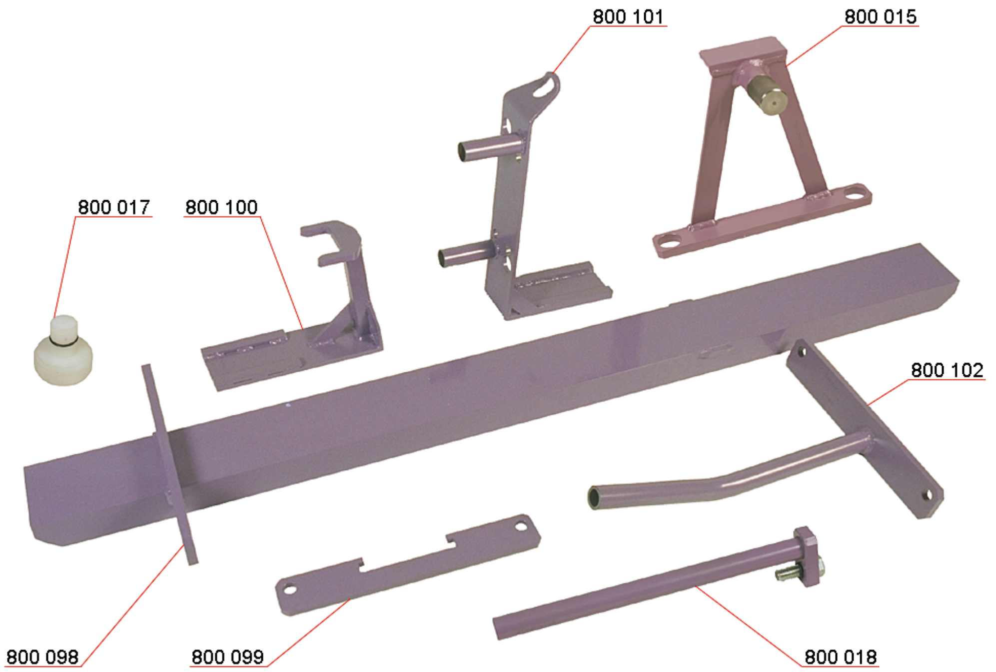
Cylinder Liner 100



Code	Description	Drawing No.
800007	Extracting & lifting tool	3V83G0078
800008	Honing equipment	2V84C0031
800009	Dismantling tool for antipolishing ring	2V83G0077
800053	High pressure pump (1000 bar) **(1)**	4V86A0033
800056	Flexible hose 3000 mm **(1)**	
800103	Assembly tool for piston	3V83F0135
842025	Honong stones 25x25x250, coarse, including holder	
842026	Honong stones 25x25x250, fine, including holder	
800123	Fastening tool for cylinder liner	2V10T2272

(1) Including quick couplings

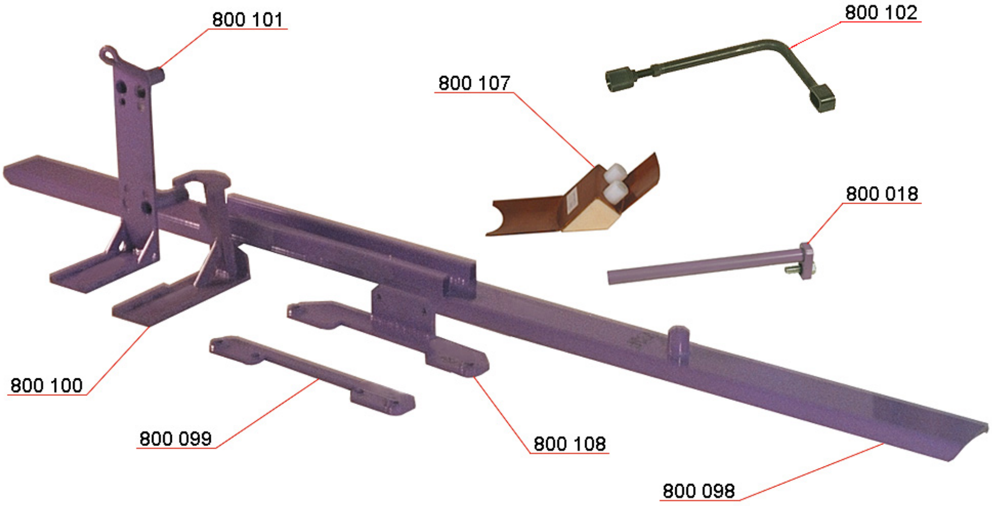
Connecting Rod, L-engine 110



Code	Description	Drawing No.
800015	Locking tool for connecting rod big end	2V83F0200
800017	Guiding plug	4V83F0157
800018	Limiter	3V83F0156
800098	Assembly rail **(1)**	2V83F0183
800099	Support **(1)**	3V83F0186
800100	Mounting sledge **(1)**	2V83F0191
800101	Mounting sledge **(1)**	2V83F0189
800102	Mounting support **(1)**	2V83F0196

(1) Belongs to complete tool set, code 800016.

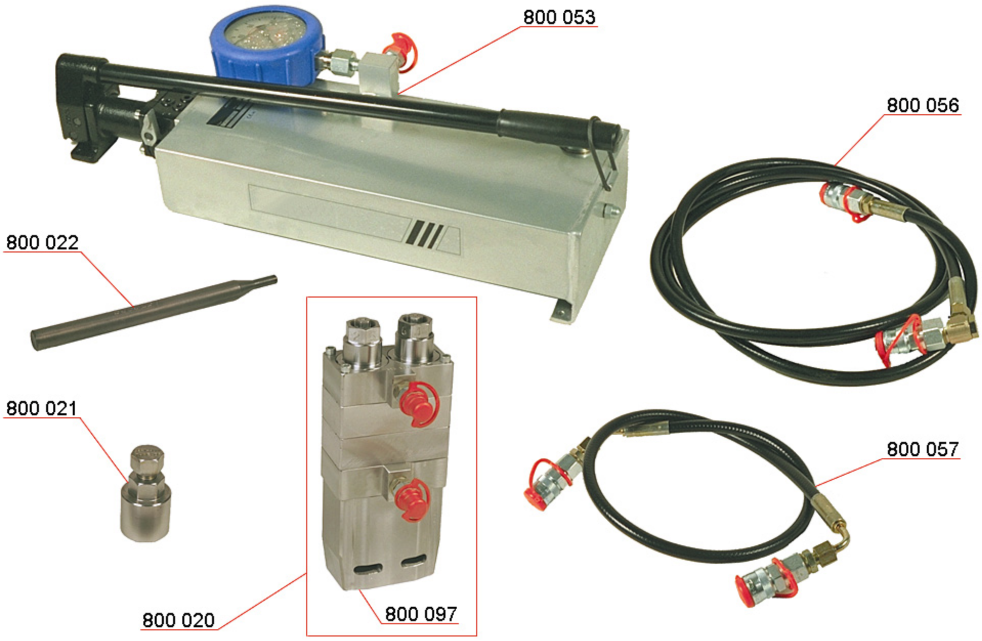
Connecting Rod, V-engine 110



Code	Description	Drawing No.
800018	Limiter	3V83F0156
800098	Assembly rail **(1)**	2V83F0238
800099	Support **(1)**	3V83F0240
800100	Mounting sledge **(1)**	2V83F0191
800101	Mounting sledge **(1)**	2V83F0189
800102	Support arm	3V83F0363
800107	Protecting sleeve for connecting rod	3V83F0249
800108	Support **(1)**	3V83F0241

(1) Belongs to complete tool set, code 800016.

Connecting Rod 110



Code	Description	Drawing No.
800020	Hydraulic tools M27x2 **(1)**, including 800097	2V86B0214
800021	Stud remover M27x2	4V80D0032
800022	Pin for tightening of nuts M27x2	4V86B0231
800053	High pressure pump (1000 bar) **(1)**	4V86A0033
800056	Flexible hose 3000 mm **(1)**	
800057	Flexible hose 1100 mm **(1)**	
800097	Distance sleeve M27x2	2V86B0208

(1) Including quick couplings

Piston 110

Code	Description	Drawing No.
800001	Piston ring pliers	4V84L0018
800002	Pliers for securing ring	4V84L0016
800012	Lifting tool **(1)**	3V83D0234
800012	Lifting tool **(2)**	2V11T1482
800013	Clamp tool for piston rings	1V84D0011
800105	Measurement tool for piston ring grooves	
800106	Spare tips for pliers 800002, straight	
800160	Hydraulic jack for lifting of piston **(2)**	2V11T1498

(1) Diesel engines

(2) SG engines

Cylinder Head 120

Code	Description	Drawing No.
800026	Lifting tool	2V83C0191
800027	Mounting & dismantling tool for valves	2V12T0110
800028	Turning tool for grinding of valves	3V84B0197
800047	Hydraulic tools M56 **(1)**, including 800096	2V86B0224
800050	Lifting tool for hydraulic cylinders	1V87B0054
800053	High pressure pump (1000 bar) **(1)**	4V86A0033
800055	Flexible hose 800 mm **(1)**	
800063	Hydraulic extractor **(1)**	3V83E0061
800096	Distance sleeve M56	3V86B0222
800130	Extractor for yoke pin	3V83H0485
800133	Extractor tool for cylinder head sleeve	3V83H0475
800142	Lifting tool **(2)**	2V83C0395
848115	Valve clearance gauge feeler for pcc valve (0,65)	4V84K0067

(1) Including quick couplings

(2) SG-engines

Cylinder Head 120

Code	Description	Drawing No.
800000	Pliers for securing ring	
800010	Stud remover 5-20	
800029	Removing tool for injection & starting valve	3V83H0202
800030	Valve clearence feeler gauge	3V84K0052
800031	T-wrench for indicator valve	4V80K0006
800049	Pin for tightening of nuts M56	4V86B0002
800056	Flexible hose 3000 mm **(1)**	
800094	Box wrench head 24 mm	4V92K0208
800126	Extraction mandrel for valve guide	3V83H0492
800146	Adapter M16	4V83H0520
820000	Torque wrench 20-100 Nm	4V92K0207
820006	Extension bar 12.5*250	
820011	Spark plug socket **(2)**	4V12T0273
846200	Adjusting tool for prechamber valve **(2)**	2V12T0965
847022	Pressure test device for prechamber **(2)**	2V12T0961

(1) Including quick couplings

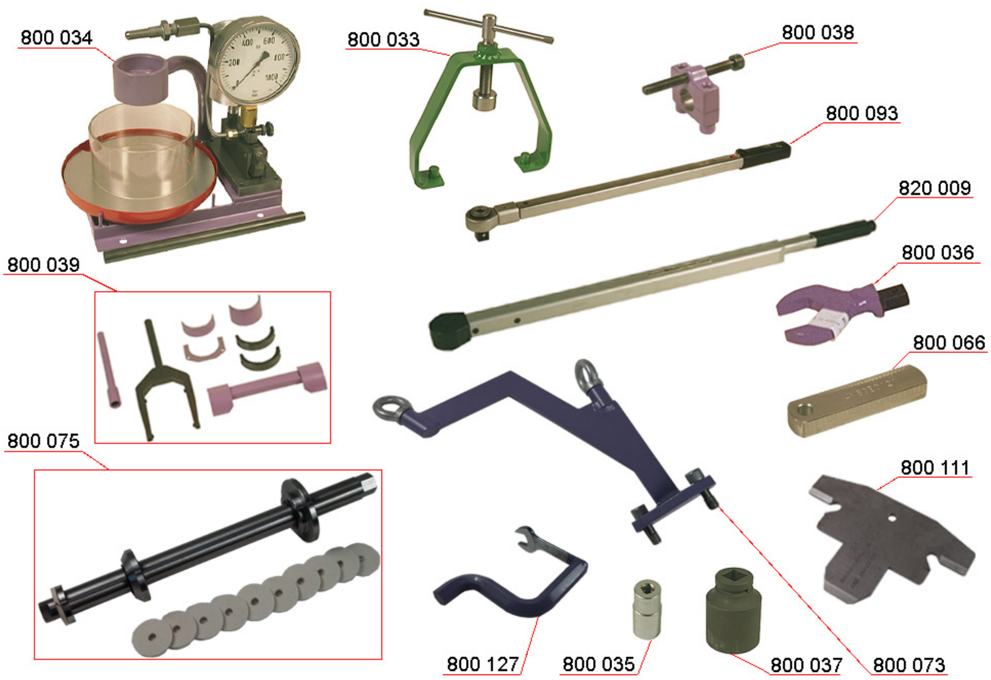
(2) SG-engines

Intermediate Gear and Camshaft Tools 130

Code	Description	Drawing No.
800024	Extractor plate	3V83H0201
800049	Pin for tightening of nuts	4V86B0002
800053	High pressure pump (1000 bar) **(1)**	4V86A0033
800056	Flexible hose 3000 mm **(1)**	
800062	Mounting & removing tool	3V83H0167
800063	Hydraulic extractor **(1)**	3V83E0061
800112	Hydraulic tools M80 for interm. gears **(1)**	3V86B0341
800113	Support for hydraulic tool	2V85G0015
800114	Mounting and removing tool for stud M80	3V80D0021
800125	Fastening arm	3V86B0351
800150	Mounting tool for camshaft piece	1V83G0166

(1) Including quick couplings

Injection Equipment 160

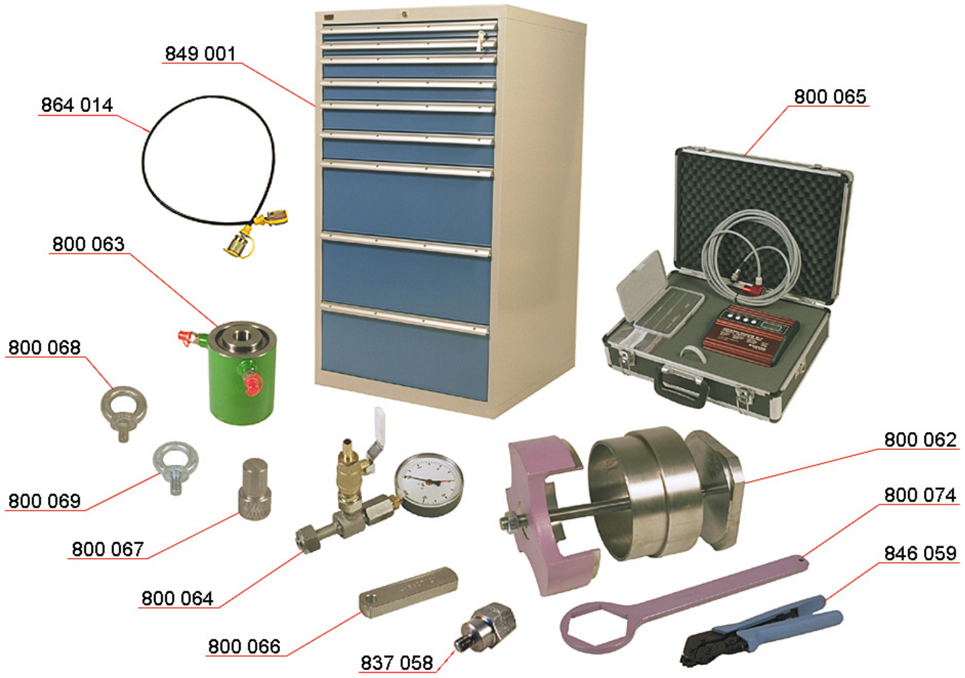


Code	Description	Drawing No.
800033	Dismantling tool for injection pump	3V84G0406
800034	Testing tool for injection valve	1V86E0115
800035	Socket wrench 36 mm	4V80H0025
800036	Flare nut wrench for tightening of injection pipes 41 mm	4V80G0053
800037	Socket wrench 55 mm for nozzle cap nut	4V80H0024
800038	Limiter for fuel rack movements	3V86D0005
800039	Moving tool for fuel pipe sleeves	3V80G0043
800066	Locking plate for injection pump tappet	4V83E0121
800073	Lifting tool for injection pump	2V16T0136
800075	Cleaning tool for seal surface for injection valve	2V84B0247
800093	Torque wrench 75-400 Nm	4V92K0207
800111	Measure gauge for injection pump tappet	3V84K0066
800127	Tool for connecting piece flange screws	3V86G0056
800140	Extractor tool for injection pump tappet	2V83G0152
820009	Torque wrench 150-800 Nm	4V92K0207
841016	Felt washer for cleaning tool 800075	4V84B0252
846195	Tool for injection pump sealing	3V16T0372

Turbocharger 372

Code	Description	Drawing No.
800070	Tools for turbocharger EGT 295i, 6L and 12V	
800070	Tools for turbocharger EGT 297, 6L and 12V	
800071	Tools for turbocharger EGT 355i, 8L, 9L, 16V and 18V	
800071	Tools for turbocharger EGT 357, 8L, 9L, 16V and 18V	
800078	Tools for turbocharger TPL 65, 6L and 12V	
800079	Tools for turbocharger TPL 65, 8L, 9L, 16V and 18V	
800079	Tools for turbocharger TPL 69, 8L, 9L, 16V and 18V	

Miscellaneous Tools 900



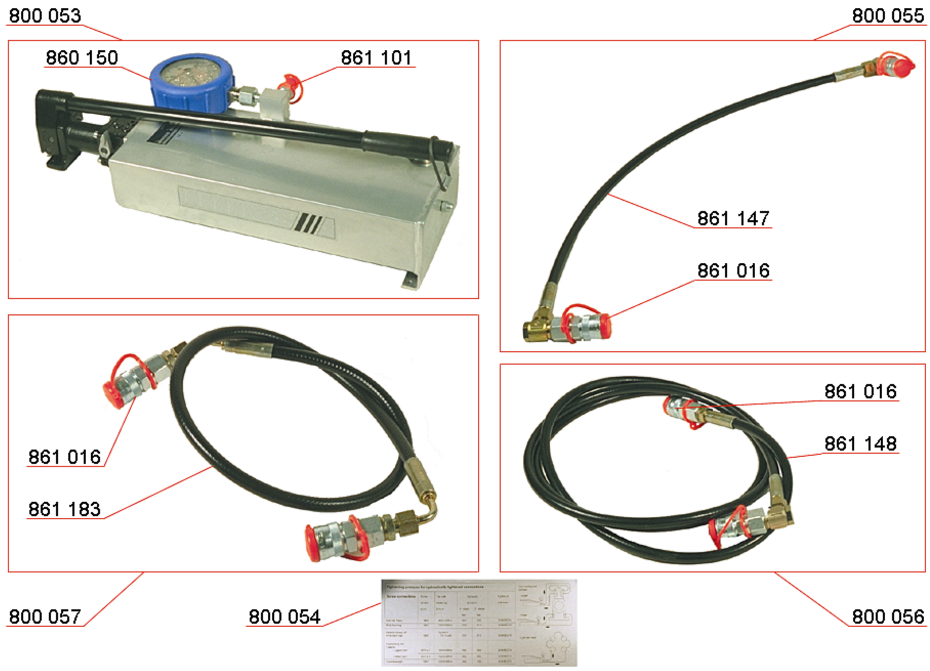
Code	Description	Drawing No.
800062	Mounting & removing tool for camshaft bearing bush	3V83H0167
800063	Hydraulic extractor **(1)**	3V83E0061
800064	Checking tool for cylinder/valves tightness	
800065	Deflection indicator	4V84K0058
800066	Locking plate for injection pump tappet	4V83E0121
800067	Securing pin for valve tappet	4V83E0124
800068	Lifting eye bolt M12	
800069	Lifting eye bolt M16	
800074	Wrench for centrifugal filter	4V80G0049
800122	Extractor plate for holder of thermostatic element	4V83H0490
800124	Mounting tool for connection piece **(2)**	1V84G0580
800132	Pneumatic test equipment for injection pump	1V16T0167
800151	Mounting tool for connection piece	2V84G0583
837058	Nut for extractor (water injection system)	4V83H0536
846059	AMP hand crimping tool	4V84G0475
846197	Mounting tool for pump cover, when TC in the free end	1V84G0613
849001	Tool locker	4V80L0003
864014	Air vent hose for water injection system	4V27L0041

(1) Including quick couplings
(2) Only for V32

Miscellaneous Tools 900

Code	Description	Drawing No.
800029	Removing tool for term. valve, see also section 120	3V83H0202
800127	Tool for connection piece flange screw	3V80G0056
800131	Extractor tool for thermostatic valve	2V83H0481
800141	Tool for cylinder liner temperature sensor	3V80G0059
800150	Mounting tool for camshaft piece	1V83G0166
806000	Hexagon bar kW27	4V80G0018
807053	Wrench for cylinder pressure sensor	3V80H0026
820000	Torque wrench 100-200 Nm	4V92K0207
832010	Lifting device for guide block	2V14T0372
837055	Extractor for water pump impeller	3V83H0491
846201	Tool for speed sensor adjustment	4V74T0015
846203	Bracket for PTO shaft	3V84G0612
846204	Bracket for PTO shaft	3V84G0611
846205	Guiding pin for PTO shaft	3V84G0610
846206	Guiding pin for damper	3V84G0607
848116	Woodward 723 handheld	4V50L3974
860170	Air operated hyraulic power pack	4V86B0107
862022	Fuel pump flushing device	2V84F0017

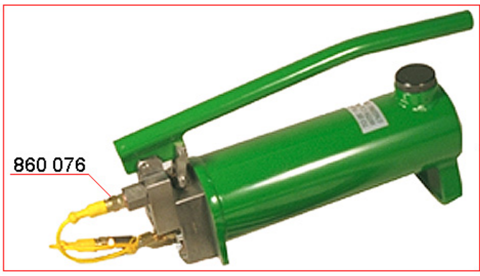
High Pressure pump 900

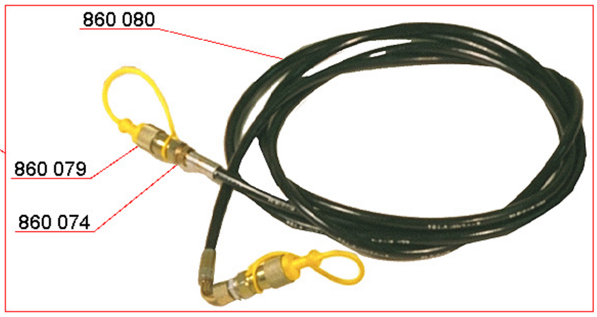


Code	Description	Drawing No.
800053	High pressure pump (1000 bar) **(1)**	4V86A0033
800054	Sign plate	3V52B0476
800055	Flexible hose 800 mm **(1)**	
800056	Flexible hose 3000 mm **(1)**	
800057	Flexible hose 1100 mm **(1)**	
860150	Manometer	4V51L0085
861016	Quick coupling, female	4V86A0035
861101	Quick coupling, male	4V86A0034
861147	Flexible hose 800 mm	
861148	Flexible hose 3000 mm	
861183	Flexible hose 1100 mm	

(1) Including quick couplings

Low Pressure Pump 900

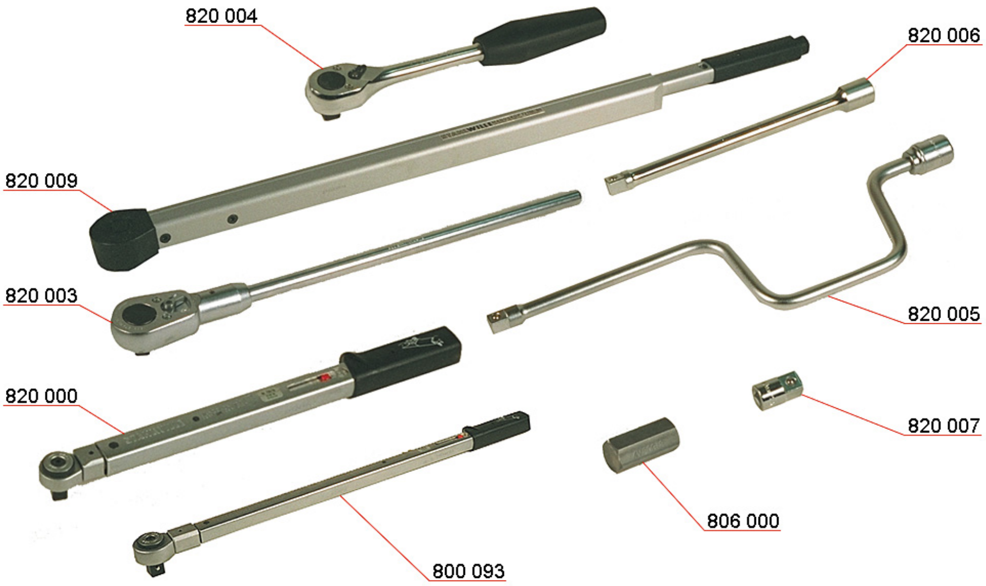




Code	Description	Drawing No.
800059	Low pressure pump (150 bar) **(1)**	1V86A0018
800060	Flexible hose 3000 mm **(1)**	
860074	Straight male stud	4V34L0135
860076	Quick coupling, male	4V86A0012
860079	Quick coupling, female	4V86A0012
860080	Flexible hose 3000 mm	4V86A0067

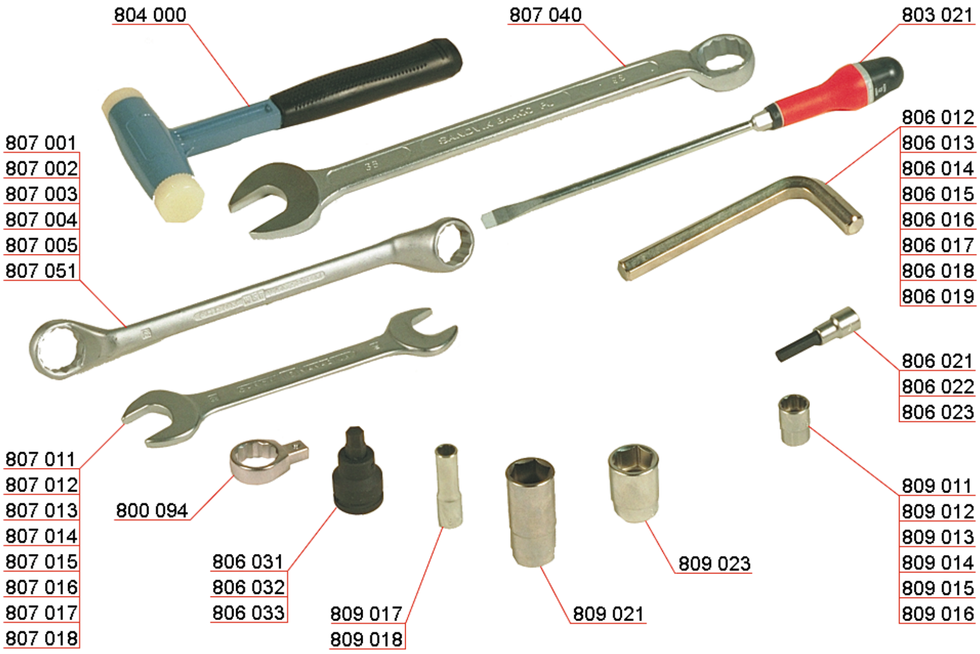
(1) Including quick couplings

Tightening Tools 900



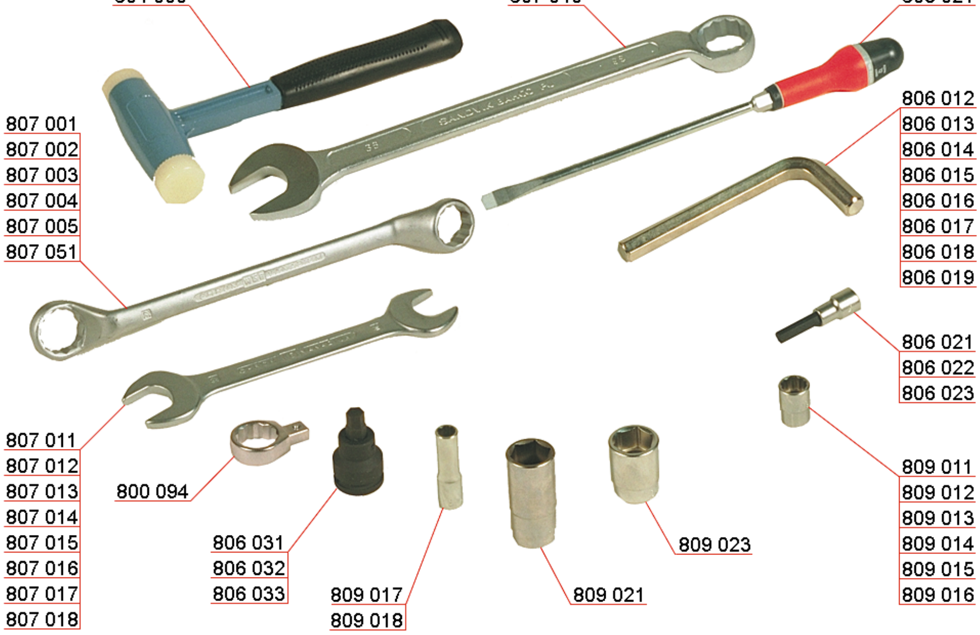
Code	Description	Drawing No.
800093	Torque wrench 75-400 Nm	4V92K0207
806000	Hexagon bar kW 27	4V80G0018
820000	Torque wrench 20-100 Nm	4V92K0207
820003	Ratchet handle 20x630 with 3/4" square drive	4V80K0014
820004	Ratchet handle 12.5x300 with 1/2" square drive	
820005	Speed brace B12.5x500	
820006	Extension bar B12.5x250 with 1/2" square drive	
820007	Adapter socket wrench A20x12.5, 3/4"x1/2"	
820009	Torque wrench 150-800 Nm	4V92K0207

Hand Tools 900



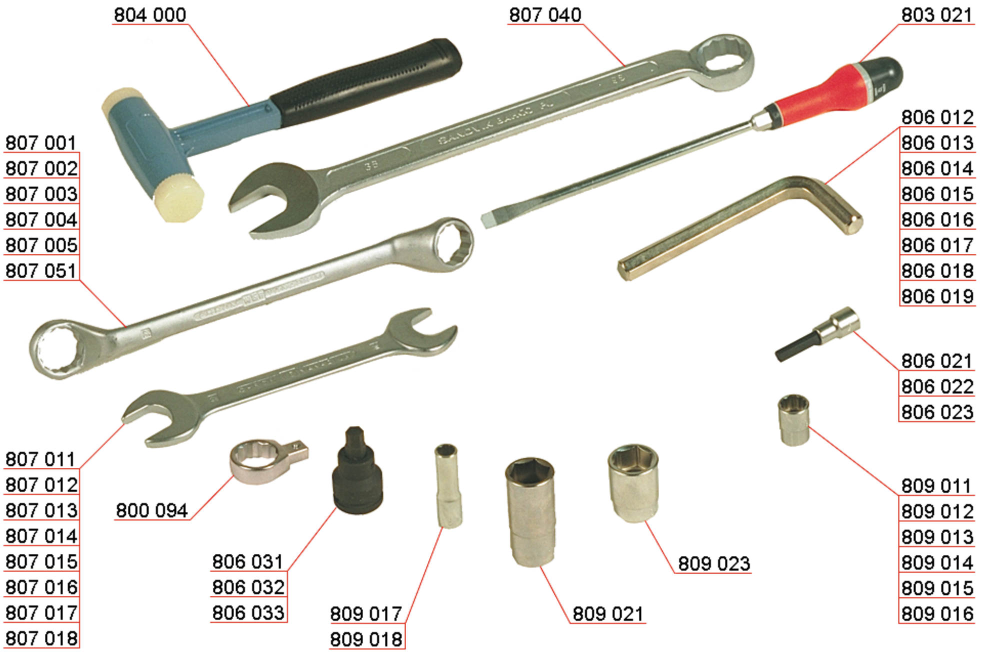
Code	Description	Drawing No.
800094	Box wrench head 24 mm	4V92K0208
803021	Screwdriver 2x12M	4V84L0019
804000	Non recoiling hammer D40	4V80L0005
806012	Key for hexagon socket screw 4	
806013	Key for hexagon socket screw 5	
806014	Key for hexagon socket screw 6	
806015	Key for hexagon socket screw 8	
806016	Key for hexagon socket screw 10	
806017	Key for hexagon socket screw 12	
806018	Key for hexagon socket screw 14	
806019	Key for hexagon socket screw 17	
806021	Bit, hexagon socket screw 6 with 1/2" square drive	4V80L0001
806022	Bit, hexagon socket screw 8 with 1/2" square drive	4V80L0001
806023	Bit, hexagon socket screw 10 with 1/2" square drive	4V80L0001
806031	Bit, hexagon socket screw 14 with 3/4" square drive	4V80L0001
806032	Bit, hexagon socket screw 17 with 3/4" square drive	4V80L0001
806033	Bit, hexagon socket screw 19 with 3/4" square drive	4V80L0001

Hand Tools 900



Code	Description	Drawing No.
807001	Box wrench 10-11	
807002	Box wrench 12-14	
807003	Box wrench 13-17	
807004	Box wrench 19-22	
807005	Box wrench 30-32	
807011	Engineers wrench 10-11	
807012	Engineers wrench 12-14	
807013	Engineers wrench 13-17	
807014	Engineers wrench 19-22	
807015	Engineers wrench 24-27	
807016	Engineers wrench 30-32	
807017	Engineers wrench 36-41	
807018	Engineers wrench 46-50	
807040	Combination wrench AL36	
807051	Box wrench 24-27	

Hand Tools 900



Code	Description	Drawing No.
809011	Socket wrench 10x12.5 with 1/2" square drive	
809012	Socket wrench 13x12.5 with 1/2" square drive	
809013	Socket wrench 17x12.5 with 1/2" square drive	
809014	Socket wrench 19x12.5 with 1/2" square drive	
809015	Socket wrench 24x12.5 with 1/2" square drive	
809016	Socket wrench 27x12.5 with 1/2" square drive	
809017	Long socket wrench 13x12.5L with 1/2" square drive	
809018	Long socket wrench 24x12.5L with 1/2" square drive	
809021	Long socket wrench 30x20L with 3/4" square drive	
809023	Socket wrench 30x20 with 3/4" square drive	

Measuring and testing equipment 900

Code	Description	Drawing No.
800105	Micrometer for piston ring grooves	
800121	Pressure calibrator -1 bar ... 25 bar, Keller	
800134	Frequency generator	4V50T0014
800135	Tools for timing check	2V86T0012
800136	Tools for meas. backlash of direct driven fuel feed pump	3V17T0007
800137	Tools for meas. backlash of direct driven water pumps	3V19T0053
800138	Tool for removing pins in AMP-connectors	
846059	AMP hand crimping tool	4V84G0475
848039	Micrometer (0...25 mm.)	
848040	Cylinder gauges	008610027
848041	Dial indicator	
848042	Bar micrometer	
848043	Endoscope	
848062	Measuring instrument for piston (Inc. dial gauge)	1V11T0020

Measuring and testing equipment 900

Code	Description	Drawing No.
800117	Cylinder pressure indicator, Kistler 2515A electronic model	
800118	Laser temp.meter Thermo-Hunter PT3LF	
800119	Multi loop calibrator Jofra MLC	
800120	Charger for Jofra MLC	
847010	Pressure sensor tester	3V84H0038
848030	Tachometer	
848031	Temperature transducer control equipment	
848033	Cylinder pressure indicator, electronic model	
848034	Voltmeter	
848035	Voltmeter, universial	
848036	Oscilloscope	

06. Adjustments, Clearances and Wear Limits

06.1 Adjustments

Valve timing

The valve timing is fixed and cannot be changed individually, cylinder by cylinder.

Valve timing

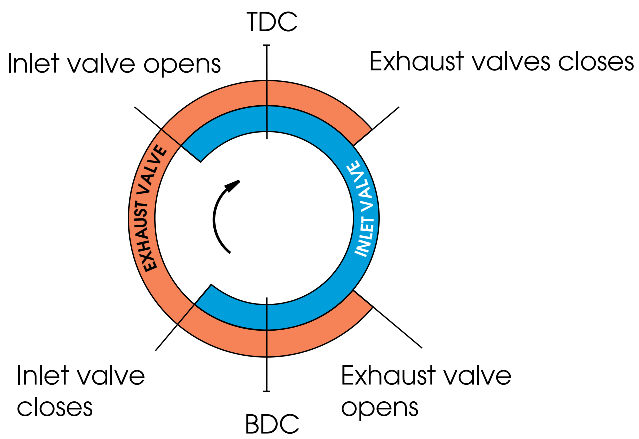


Fig 06-1 4006019601

Set values:

- Valve clearances: inlet valves 0.4 mm
  exhaust valves 0.8 mm
- Fuel delivery commencement: See test records
- Opening pressure of fuel injection valve: 600 bar (not Common Rail)

Electro-pneumatic tripping speed (Std engines):

Nominal speed	WECS or Plant automation	Relay-Module
720 RPM	820 ± 10 RPM	840 ± 10 RPM
750 RPM	860 ± 10 RPM	880 ± 10 RPM

Tripping speed (Common Rail engines):

Nominal speed	WECS 2000	WECS 7500
720 RPM	820 ± 10 RPM	850 ± 10 RPM
750 RPM	860 ± 10 RPM	885 ± 10 RPM

06.2 Clearances and wear limits (at 20°C)

	Part, measuring point	Normal clearance (mm)	Wear limit (mm)
10	Main bearing clearance (also flywheel bearing)	0.225-0.346	
	Journal, diameter		339.85
	Journal, out of circularity		0.05
	Journal, taper		0.025/100
	Main bearing shell thickness Trimetal shells Bimetal shells		Section 10.2.2 7.35 mm
	Assembled bearing bore		340.360
	Thrust bearing, axial clearance	0.30 -0.50	0.80
	Thrust washer thickness		14.60
	Camshaft bearing clearance	0.160-0.269	
	Assembled bearing bore (Vertical direction)		230.350
	Camshaft thrust bearing, axial clearance	0.250-0.700	1.0
	Cylinder liner, diameter		top: 320.80 bottom: 320.30
	Cylinder liner, out of cylindricity at TDC		0.25
11	Big end bearing clearance	0.210-0.307	
	Crank pin, out of circularity		0.05
	Crank pin, taper		0.035/100
	Big end bearing shell thickness Trimetal shells Bimetal shells		Section 11.3.4 7.37
	Big end bore ovality		324.90 0.10
	Assembled bearing bore (Rod assembled)		310.400
	Gudgeon pin bearing clearance	0.09-0.159	
	Assembled bearing bore		150.180
	Connecting rod axial clearance in piston	0.5 -1.0	
	Clearance gudgeon pin - piston	0.050-0.084	
	Bore diameter in piston		135.1
	Piston ring gap I (Clamped ø 320)	0.7 -1.1	
	Piston ring gap II (Clamped ø 320)	1.3 -1.6	
	Oil scraper ring gap (Clamped ø 320)	1.2 - 1.5	
	Piston ring height clearance: Compression ring I (C84) Compression ring II (C99) Oil scraper ring (C79)	 0.143-0.185 0.143-0.185 0.063-0.105	 0.50 0.50 0.35
	Piston ring groove height: Groove I Groove II Groove III		8.50 8.50 8.30
12	Valve guide diameter assembled		24.25
	Valve stem diameter		23.90
	Valve stem clearance	0.100-0.156	0.30

	Part, measuring point		Normal clearance (mm)	Wear limit (mm)
13	**Intermediate gear of camshaft drive** bearing clearance axial clearance		0.2-0.299 0.4-0.6	0.35 0.9
	Camshaft driving gear backlash:			
	Crankshaft gear wheel (6)/ large intermediate gear wheel (3)		0.42-0.82	
	Small intermediate gear wheel (5)/ camshaft gear wheel (1)		0.33-0.65	
14	Valve tappet, diameter clearance		0.072-0.161	
	Bush diameter, bore			40.09
	Bearing clearance bush-tappet pin before 08/1999 after 08/1999		0.034-0.066 0.059-0.091	
	Rocker arm bore			75.35
	Clearance rocker arm-shaft		0.01-0.075	
	Yoke bore diameter			30.1
	Yoke diameter clearance		0.065-0.103	
16	Nozzle needle lift (std engines) Nozzles stamped, before 04/99 Nozzles stamped, after 04/99		0.68- 0.72 0.83- 0.87	0.77 0.92
	Nozzle needle lift (DWI, diesel)		0.85- 0.90	0.95
	Nozzle needle lift (DWI, water)		0.70- 0.75	0.80
	Injection pump tappet Distance (X) between adjusting screw and the upper surface of the tappet housing, see Fig 16-1.		80 ±0.05	
	Prelift of the tappet		6	
16 CR	Nozzle needle lift (Common Rail engines)		0,85 ±0.02	0,95
	Prelift of the high pressure pump (Common Rail engines)		5,8	
17	Fuel feed pump backlash for driving gear	- L32	0.26-0.61	
	Base tangent length over three (3) teeth, spanned	- L32	62.027-61.939	
18	Lubricating oil pump bearing clearance	-L32 -V32	0.13 -0.17 0.19 -0.25	0.20 0.30
	Axial clearance		0.20 -0.40	
	Backlash for driving gear	-L 32 - V32	0.24 -0.62 0.27 -0.75	
	Base tangent length (driving gear) over four (4) teeth, spanned over seven (7) teeth, spanned	 - L32 - V32	86.312 -86.4 160.084-160.156	
	Prelubricating oil pump bearing clearance	-L32 -V32	0.01- 0.10 0.02- 0.17	
	Axial clerance	-L32 -V32	0.07- 0.15 0.10 -0.30	
	Backlash for pump gears	-L 32 - V32	0.10- 0.30 0.15 -0.40	
18A	Control oil pressure on Common Rail engines		200 ±2.5 bar	
	Backlash for control oil pump gear		0.35 -0.72	
19	Water pump backlash for driving gear	-L32 -V32	0.35 -0.72 0.30 -0.63	
	Base tangent length over three (3) teeth, spanned		61.939-62.027	

	Part, measuring point	Normal clearance (mm)	Wear limit (mm)
22	Bearing clearance for governor driving shaft	0.025-0.066	0.1
	Axial clearance	0.2 -0.5	
	Backlash for driving gear	0.10 -0.40	
	Control shaft bearing clearance	0.010-0.126	0.25

07. Tightening Torques and Use of Hydraulic Tools

07.1 Tightening torques for screws and nuts

Note! **See section 07.3 for hydraulically tightened connections!**

The position numbers in the tables below refer to the corresponding figures A to J, which are located in the engine according to Fig 07-1. Always tighten to stated torque shown in the tables. A loosen screw connection might cause serious damages/human injury.Threads and contact faces of nuts and screw heads should be oiled with lubricating oil unless otherwise stated. Note that locking fluids are used in certain cases.

Note! **Molycote or similar low friction lubricants must not be used for any screws or nuts. Great risk of over tensioning of screws.**

1 Nm = 0.102 kpm

Tightening torques

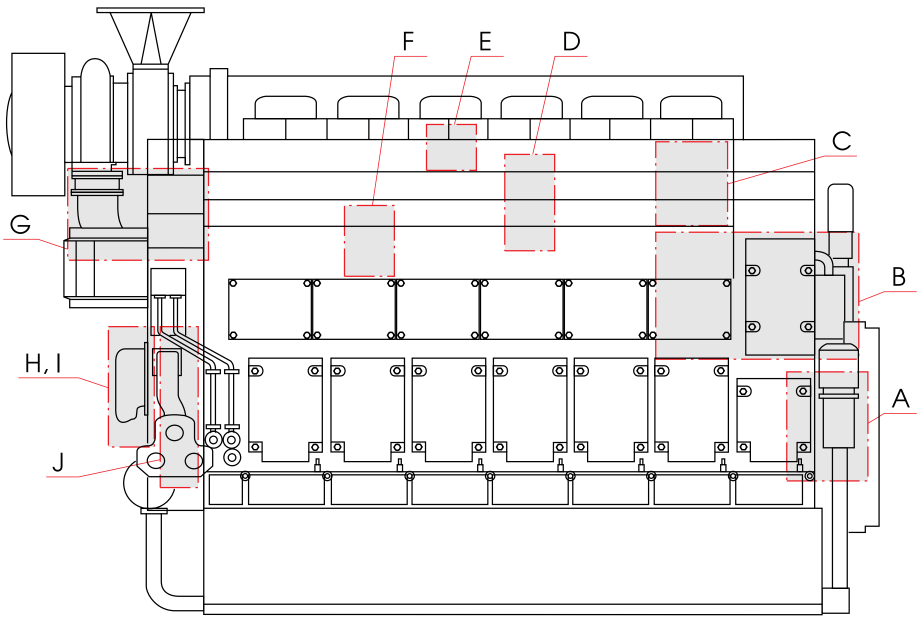


Fig 07-1 4007019601

A: Crankshaft and flywheel

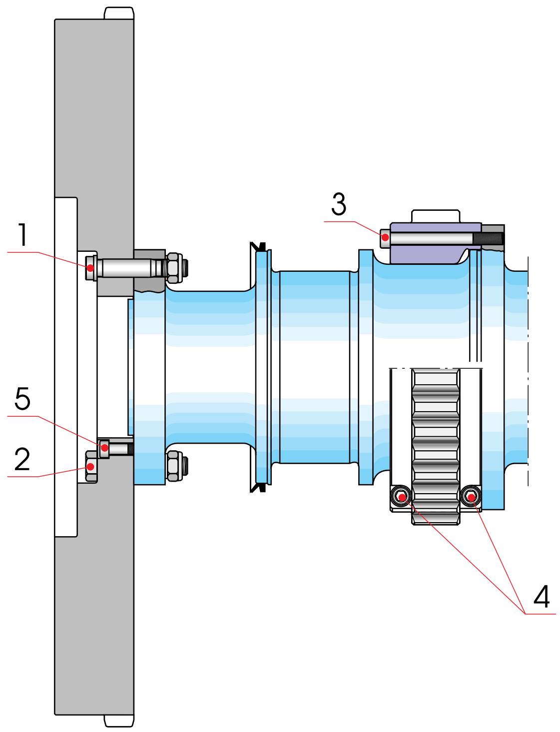
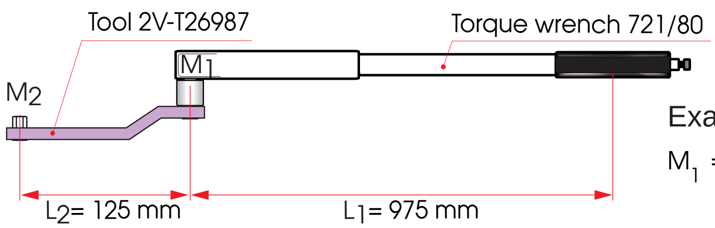


Fig 07-2

4007029601

Pos.	Screw connection	Torque (Nm)
1.	Flywheel bolts, fitted bolts, M30	600±30
2.	Flywheel elongation bolts, M30	1200±60
3.	Split gear on crankshaft, M20*190, 10.9 screws(M_2) Torque wrench setting (M_1) with tool combination, see Fig below. Lubricate threads with engine lubricating oil.	550±30 **488**
4.	Split gear on crankshaft, M20*120, 12.9 screws(M_2) Torque wrench setting (M_1) with tool combination, see Fig below. Lubricate threads with engine lubricating oil.	600±30 **532**
5.	Flywheel mounting bolts, M20	390±20

Note! **Torque wrench settings must be recalculated if an other tool combination than Fig below is used for the split gear wheel screws.**



Example:

$$M_1 = 550 * \frac{L_1}{L_1+125}$$

B: Intermediate gear and camshaft

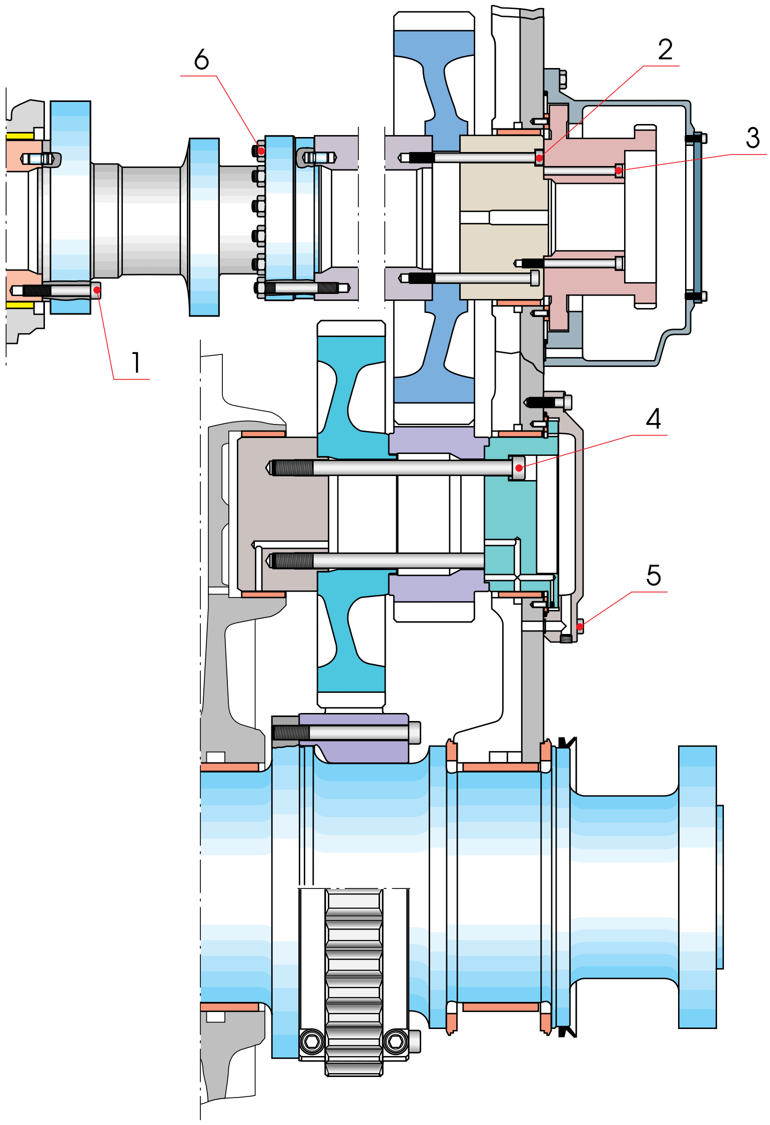


Fig 07-3

4007049601

Pos.	Screw connection	Torque (Nm)
1.	Camshaft flange connection screws	290±10
2.	Camshaft driving gear screws	290±10
3.	Governor gear wheel screws	117±10
4.	Intermediate gear wheel screws Hydraulically tensioned screw, see section 07.3	560±30
5.	Flange fastening screws	80±5
6.	Camshaft flange connection nuts	290±10

Note! **See section 13.2 for intermediate gears and camshaft drive.**

B: Governor drive

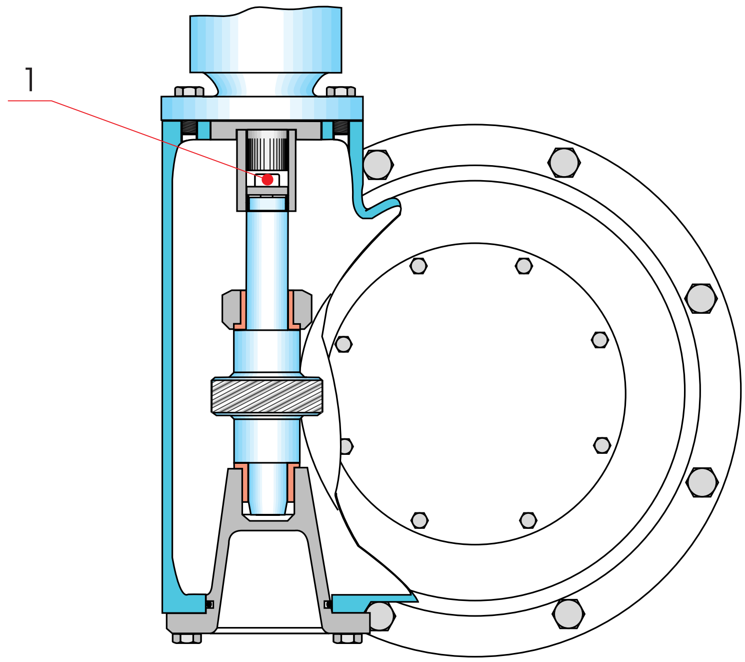


Fig 07-4

4007149913

Pos.	Screw connection	Torque (Nm)
1.	Governor drive shaft screw	80±5

C: Cylinder head

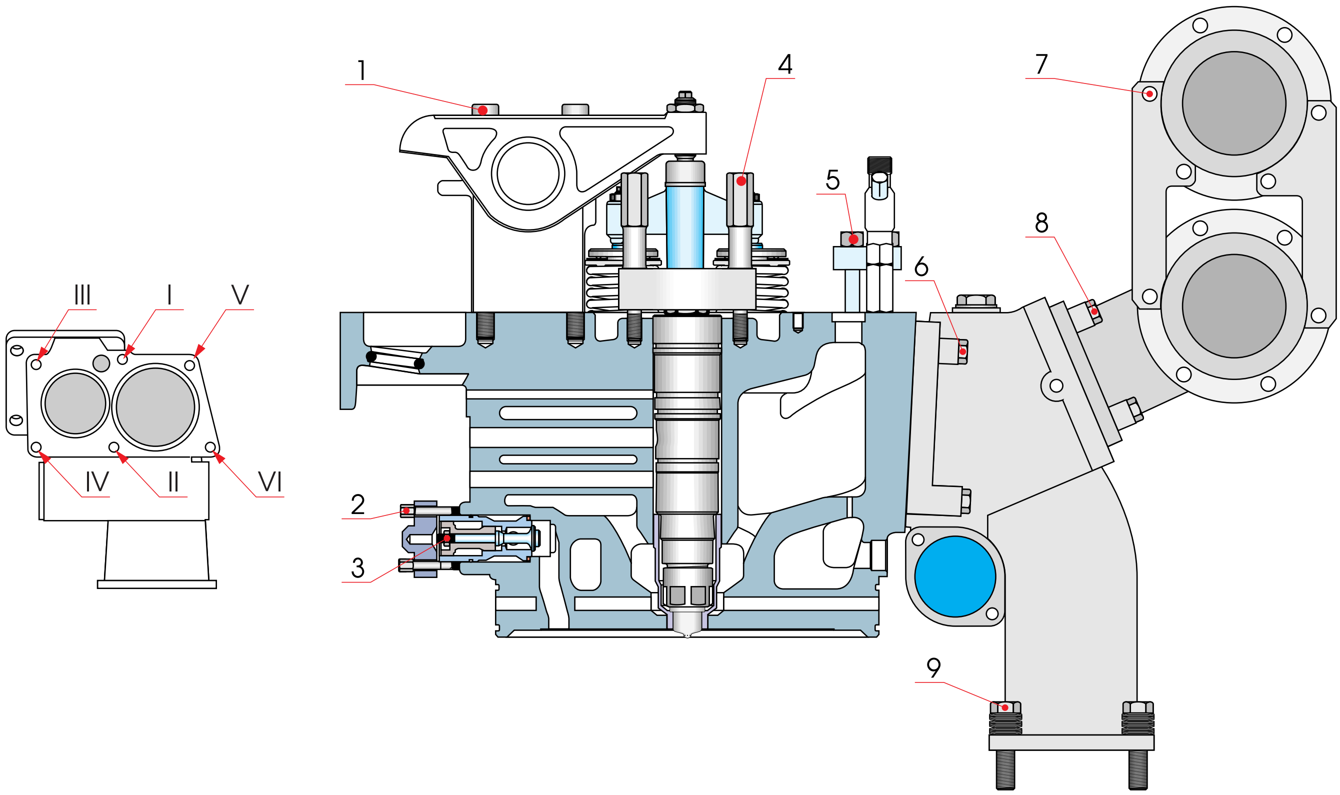


Fig 07-5

400705200001

Pos.	Screw connection	Torque (Nm)
1.	Rocker arm console, fastening screws	400±20
2.	Starting valve fastening screws	55±5
3.	Nut for starting valve spindle	35±5
4.	Nuts for injection valve	125±10
5.	Safety valve in cylinder head, fastening nuts	85±5
6.	Fastening screws, cylinder head/multiduct **Note!** Tightening order. **Recheck the screws.** **Apply Nova Lube or similar heat resistant grease on threads.**	195±10
7.	Fastening screws for flange connections	79±5
8.	Fastening screws, multiduct/exhaust manifold	195±10
9.	Fastening screws, multiduct/engine block	195±10

D: Injection pump

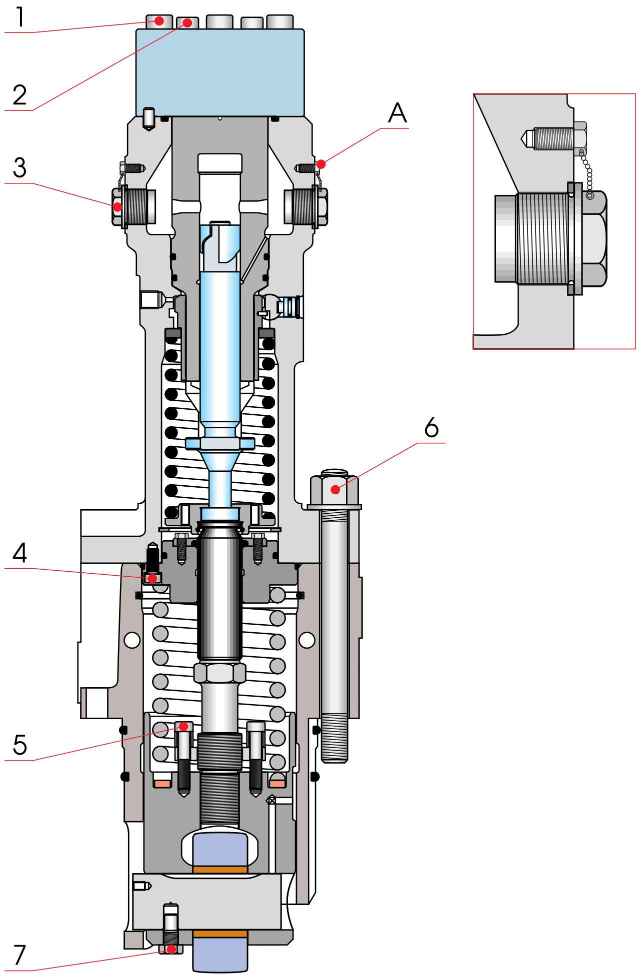


Fig 07-6

4007069601

Pos	Screw connection	Torque (Nm)	
		DELPHI	L'Orange
1.	Fastening screws for head piece, M16	105±10	160±10
2.	Fastening screws for head piece, M12		120±10
3.	Erosion plugs **Note!. The erosion plugs must be secured!** See section 16.2.5	215±10	200±10
4.	Flange fastening screws	19±3	30±5
5.	Locking screws for injection pump adjusting screw	50±5	50±5
6.	Fastening nuts for injection pump Lubricate threads and contact surfaces with engine oil.	400±20	400±20
7.	Locking screw for roller pin **Apply Loctite 2701 on threads**, see section 07.2.	80±5	80±5

D: Injection pump, Common Rail

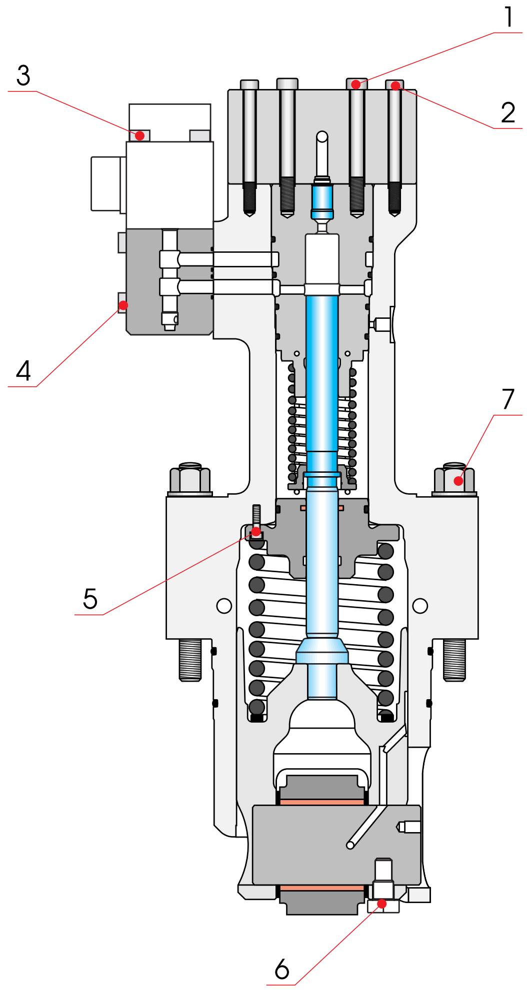


Fig 07-7

4007340240

Pos	Screw connection	Torque (Nm)
1.	Fastening screw for pump element M10.	80±8
2.	Fastening screw for head piece M8.	33±3
3.	Fastening screw for control valve coil.	11±1
4.	Fastening screws for control valve.	39±4
5.	Spring holder fastening screw.	9±1
6.	Locking screw for roller pin. **Apply Loctite 2701 on threads,** see section 07.2.	70±7
7.	Fastening nut for injection pump Lubricate threads and contact surfaces with engine oil	400±20

D: Valve tappet housing

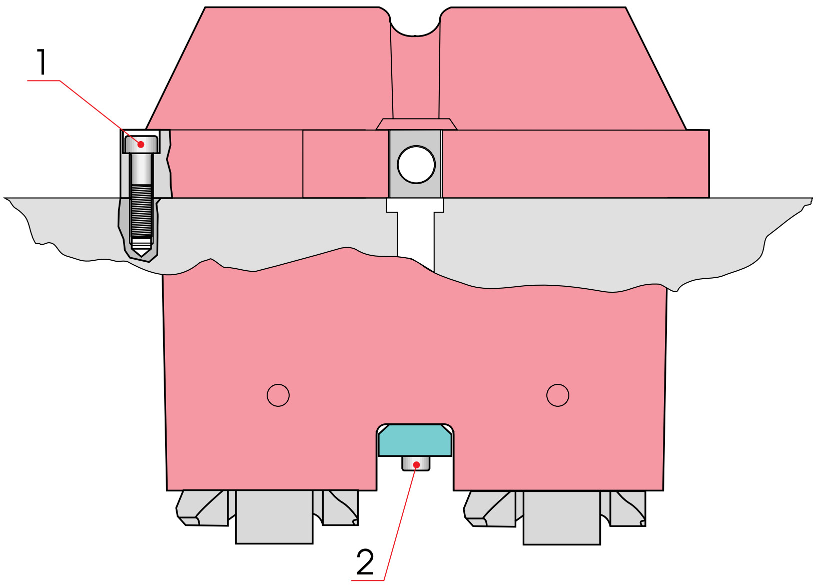


Fig 07-8

4007139837

Pos.	Screw connection	Torque (Nm)
1.	Valve tappet housing fastening screw	200±10
2.	Guide plate fastening screw **Apply Loctite 242 on threads**, see section 07.2.	23±5

E: Fuel injection valve

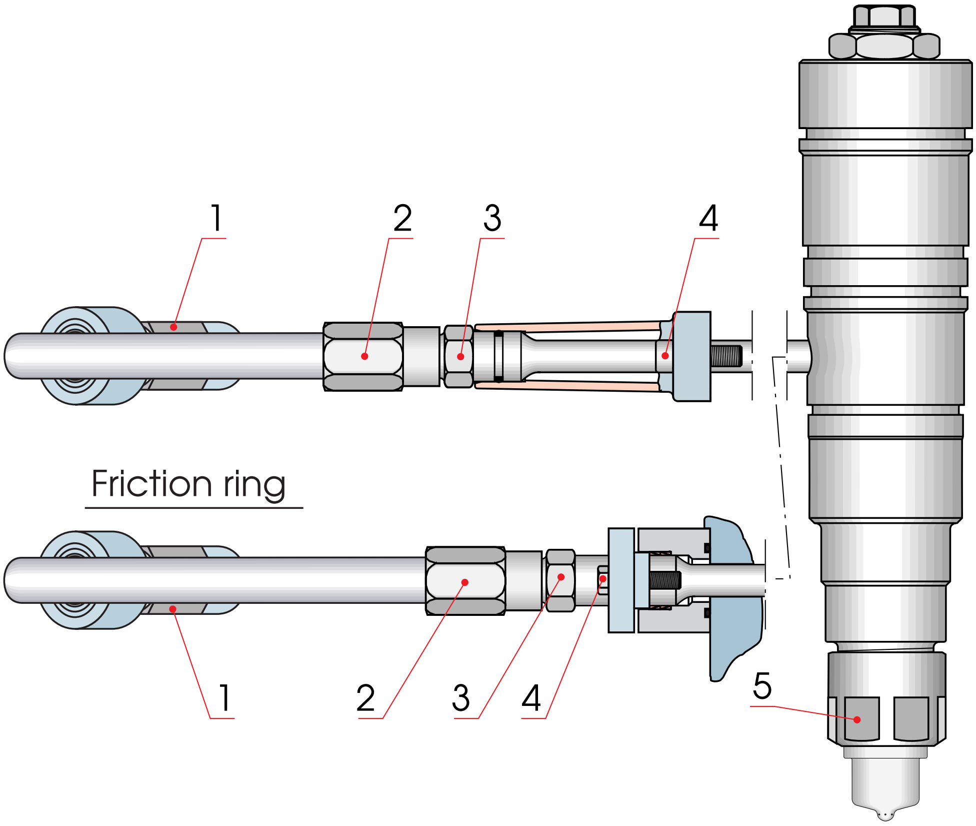


Fig 07-9

4007079601

Pos.	Screw connection	Torque (Nm)
1.	Injection pipe cap nut to injection pump	140±10
2.	Injection pipe cap nut to connection piece	90±10
3.	Connection piece to nozzle holder	160±10
4.	Screws for protecting sleeve	80±5
5.	Injection nozzle cap nut (L'Orange)	450±20
5.	Injection nozzle cap nut (Woodward)	678±40

Fuel injection pipe of Friction ring type		
Pos.	**Screw connection**	**Torque (Nm)**
1.	Injection pipe cap nut to injection pump	265±10
2.	Injection pipe cap nut to connection piece	180±10
3.	Connection piece to nozzle holder	160±10
4.	Screws for flange	80±5
5.	Injection nozzle cap nut (L'Orange)	450±20
5.	Injection nozzle cap nut (Woodward)	678±40

E: Fuel injection valve, DWI

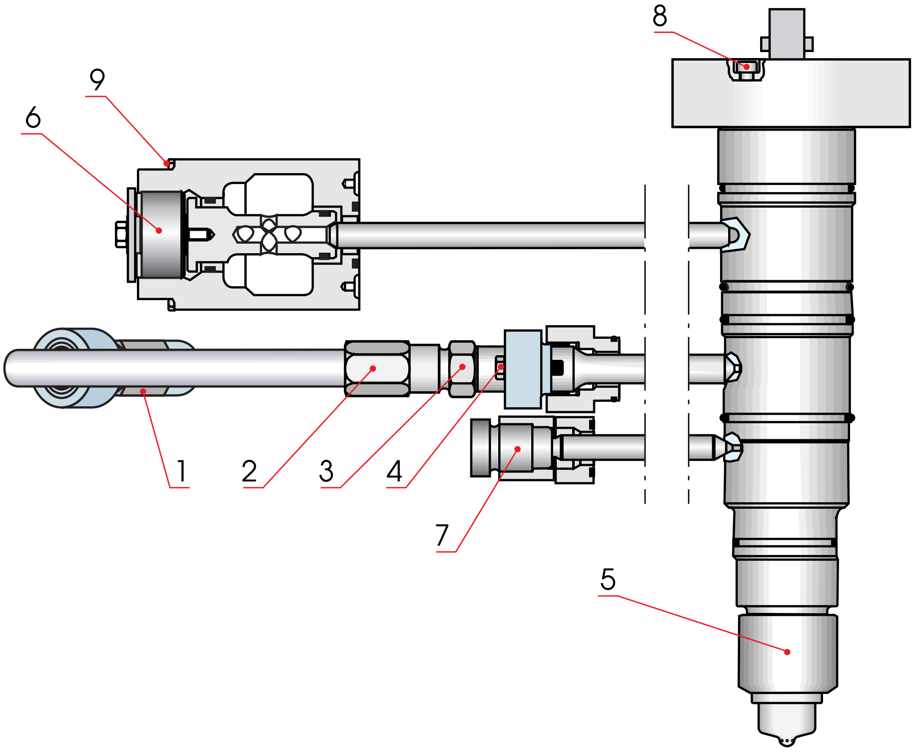


Fig 07-10

400729200143

Pos.	Screw connection	Torque (Nm)
1.	Injection pipe cap nut to injection pump	265±10
2.	Injection pipe cap nut to connection piece	180±10
3.	Connection piece to nozzle holder	70±5
4.	Screws for flange	80±5
5.	Injection nozzle cap nut	600±20
6.	Screw for high pressure water connection **Lubricate with Molykote G-Rapid Plus**	100±10
7.	Screw for leakage water connection **Lubricate with Molykote G-Rapid Plus**	35±5
8.	Screws for valve body	70±5
9.	Water accumulator fastening screws **Lubricate with Molykote G-Rapid Plus**	75±5

E: Fuel injection valve, Common Rail

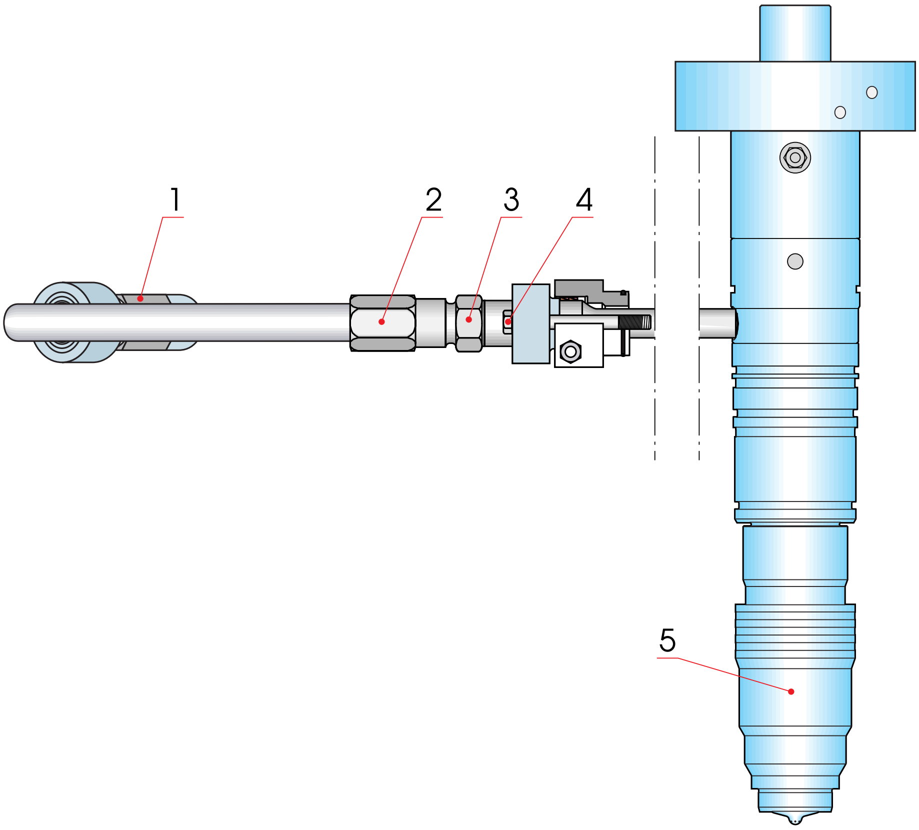


Fig 07-11

4007439601

Pos.	Screw connection	Torque (Nm)
1.	Injection pipe cap nut to injection pump	290±30
2.	Injection pipe cap nut to connection piece Apply engine oil on threads and seat cones.	210±20
3.	Connection piece to nozzle holder	160±10
4.	Screws for protecting sleeve	80±5
5.	Injection nozzle cap nut	600±20

E: Water injection flow fuse, DWI

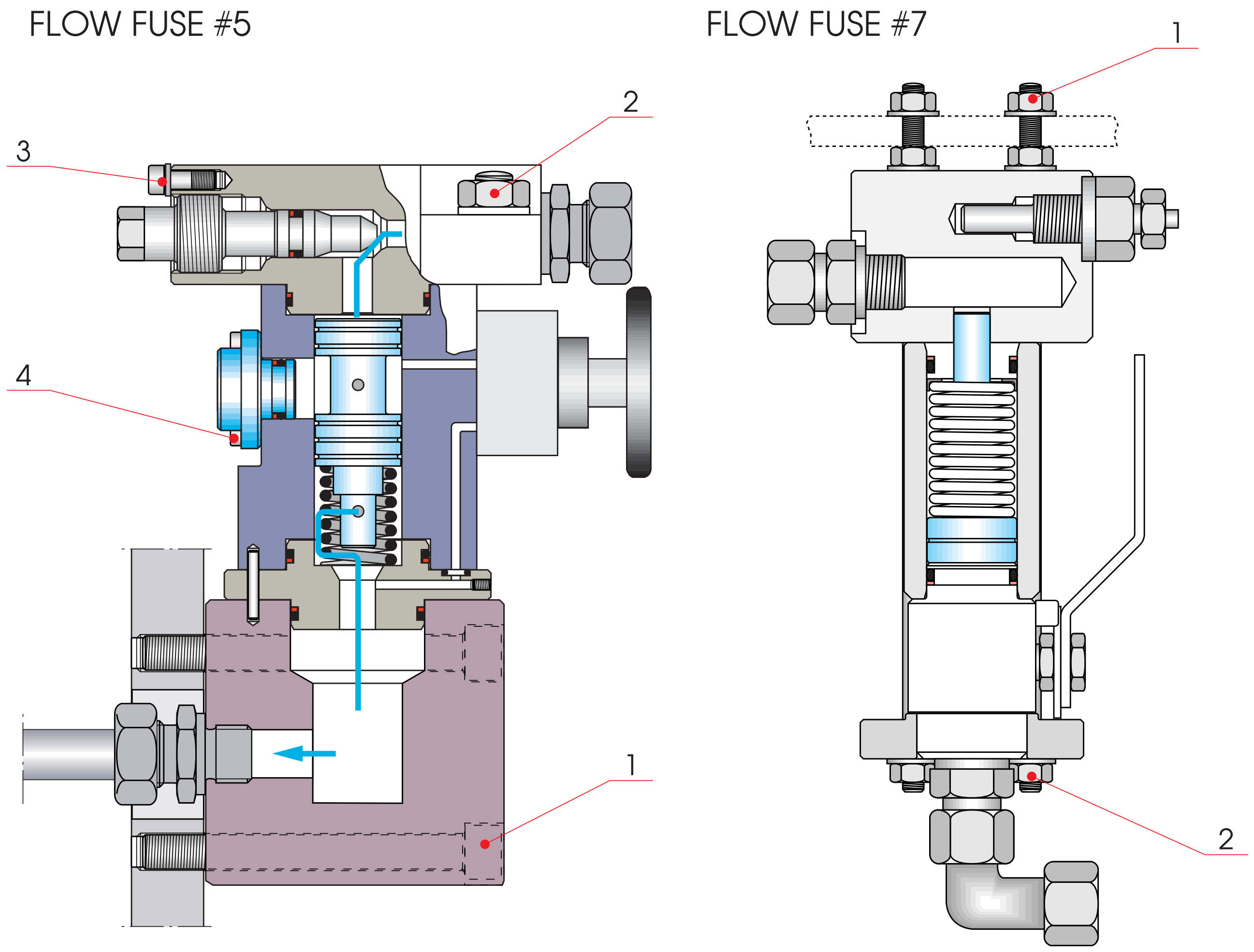


Fig 07-12

4007320243

Flow fuse #5		
Pos.	**Screw connection**	**Torque (Nm)**
1.	Fastening screw	79±5
2.	Fastening nut	80±5
3.	Limiter screw for shut off stem	5±1
4.	Fastening screw for plug	7±1

Flow fuse #7		
Pos.	**Screw connection**	**Torque (Nm)**
1.	Fastening nut	25±2
2.	Nut	34±2

E: Injection pump and accumulators, Common Rail

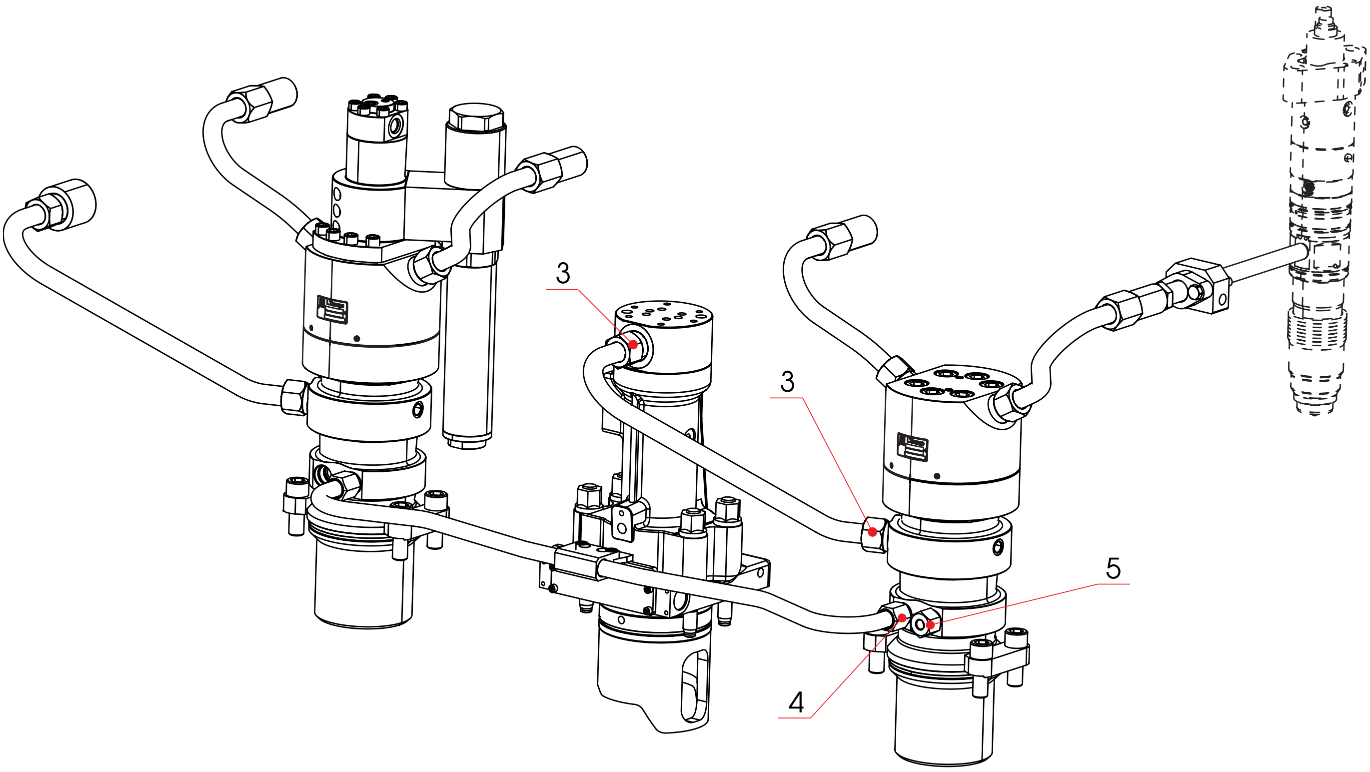


Fig 07-13

4007330240

High pressure pipes		
Pos.	**Connection**	**Torque (Nm)**
3.	Injection pipe cap nut to accumulator and pump Apply engine oil on threads and seat cones.	290±30
4.	Rail pipe cap nut to accumulator Apply engine oil on threads and seat cones.	140±15
5.	Plug Apply engine oil on threads	140±15

E: Accumulator, Common Rail

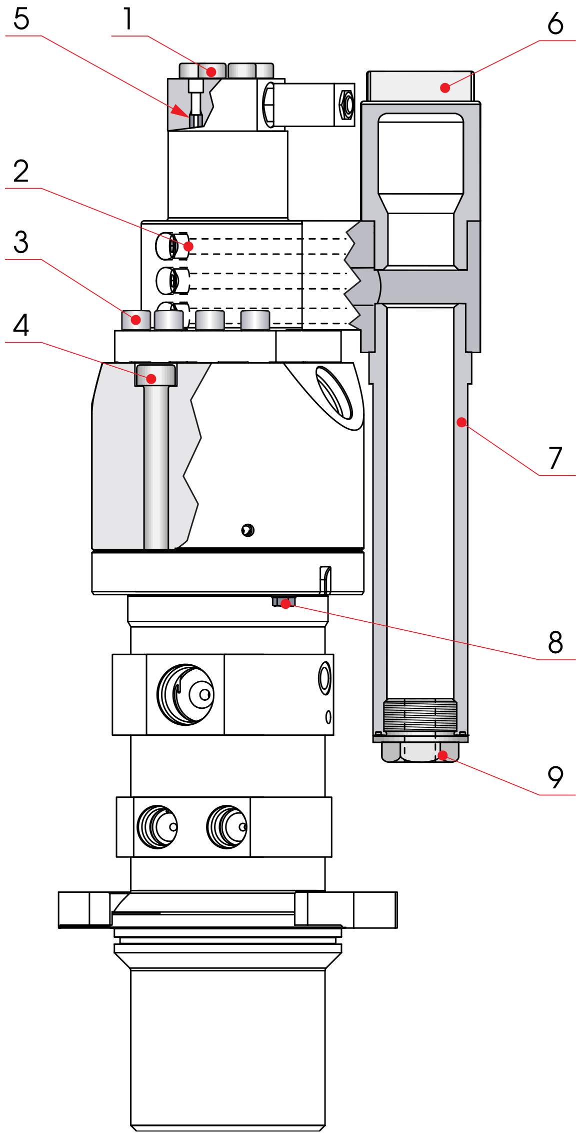


Fig 07-14

4007330240

Pos.	Connection	Torque (Nm)
1.	SSV-valve connection piece fastening screw **Apply Loctite 243 on threads**.	80±5
2.	Fastening screws for air bottle.	80±5
3.	Fastening screws for SSV-valve.	110±10
4.	Fastening screws for head piece.	520±20
5.	Reducing plug **Apply Loctite 542on threads**.	1±0,1
6.	Air bottle top piece.	350±20
7.	Air bottle.	350±20
8.	Fastening screws for leak detecting ring.	20±5
9.	Air bottle bottom plug.	270±10

F: Piston

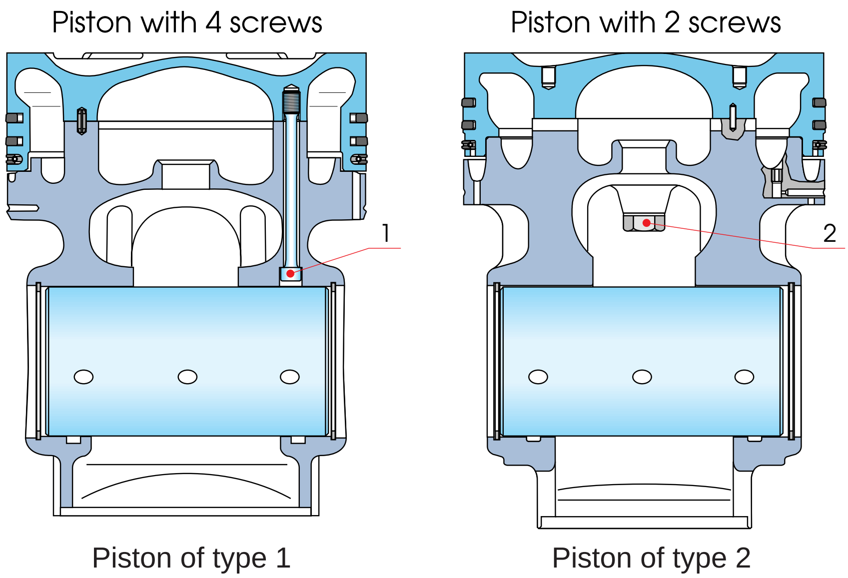


Fig 07-15

400708200142

Piston type 1		
Pos.	**Screw connection**	**Torque (Nm)**
1.	Piston crown connection screws. 1. Lubricate threads and contact surfaces with engine oil. 2. Tighten the screws crosswise. 3. Loosen the screws. 4. Pre-tighten the screws crosswise. 5. Tighten the screws crosswise further with an angle of 6. Test for the right tightness. Screw should not move when tightening by125 Nm torque. **Note!** When changing piston top renew the screws if overall lenght exceeds **169.5 mm**	155 Nm 40 Nm 80°±5°

Piston type 2		
Pos.	**Screw connection**	**Torque (Nm)**
2.	Piston crown connection screws. 1. Lubricate threads and contact surfaces with engine oil. 2. Tighten the screws. 3. Loosen the screws. 4. Tighten the screws. 5. Tighten the screws further with an angle of 7. Test for the right tightness. Screw should not move when tightening by 250 Nm torque. **Note!** When changing piston top renew the screws if overall lenght exceeds **131.4 mm**	250Nm 80 Nm $90°(^{+0°}/_{-10°})$

F: Piston

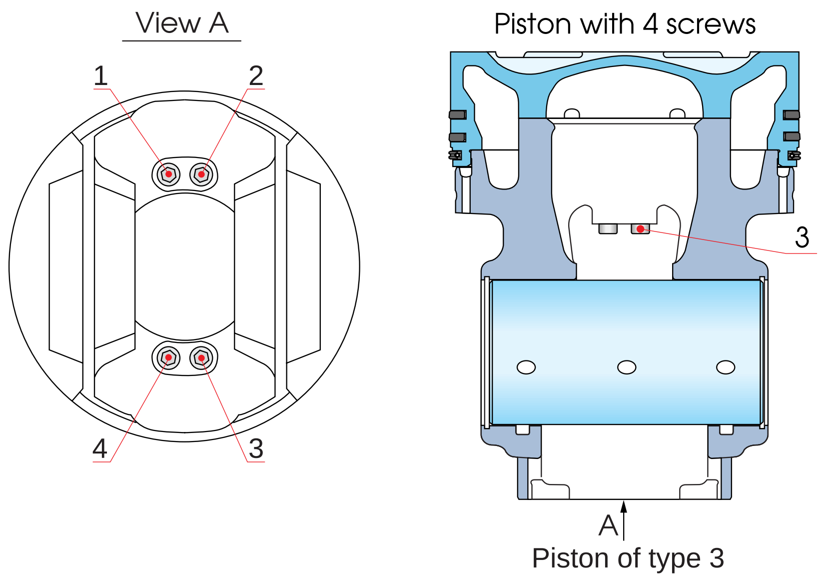


Fig 07-16

400730200142

Piston type 3		
Pos.	**Screw connection**	**Torque (Nm)**
3.	Piston crown connection screws. 1. Lubricate threads and contact surfaces with engine oil. 2. Tighten all screws. 3. Tighten all screws further with an angle of 4. Loosen screws 1 and 3. 5. Tighten screws 1 and 3. 6. Tighten screws 1 and 3 further with an angle of 7. Loosen screws 2 and 4. 8. Tighten screws 2 and 4. 9. Tighten screws 2 and 4 further with an angle of 10. Test for the right tightness. Screw should not move when tightening by **165** Nm torque. **Note!** When changing piston crown renew all screws	30±1 Nm 96° ($^{+5°}/_{-0°}$) 30±1 Nm 81° ($^{+5°}/_{-0°}$) 30±1 Nm 81° ($^{+5°}/_{-0°}$)

G: Turbocharger fastening screws

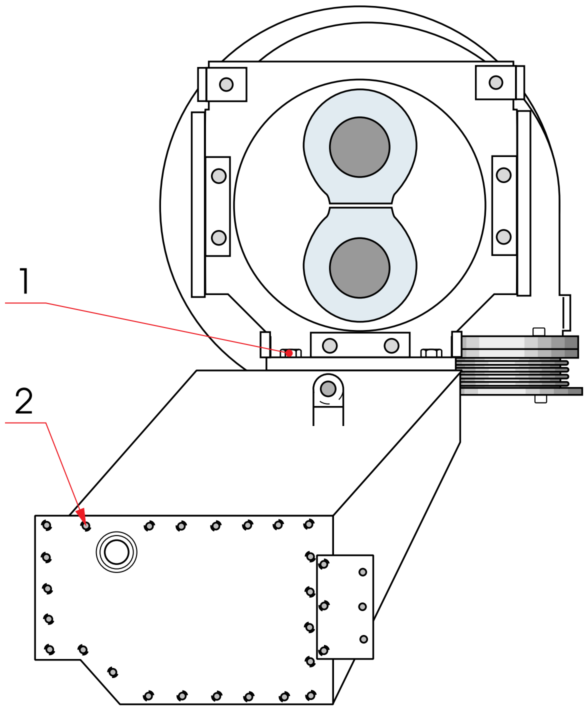


Fig 07-17 4007129601

Pos.	Screw connection	Torque (Nm)
1.	Turbocharger fastening screw — TPL61, TPL65, M20 — NA295, NA297, M20 — NA355, M24 — TPL69, M24 — NA357, M24	 560±20 560±30 650±30 920±40 920±40
2.	Fastening screws for turbo charger bracket — L32, M16 — V32, M24	 195±10 650±30

H, I: Engine driven pumps

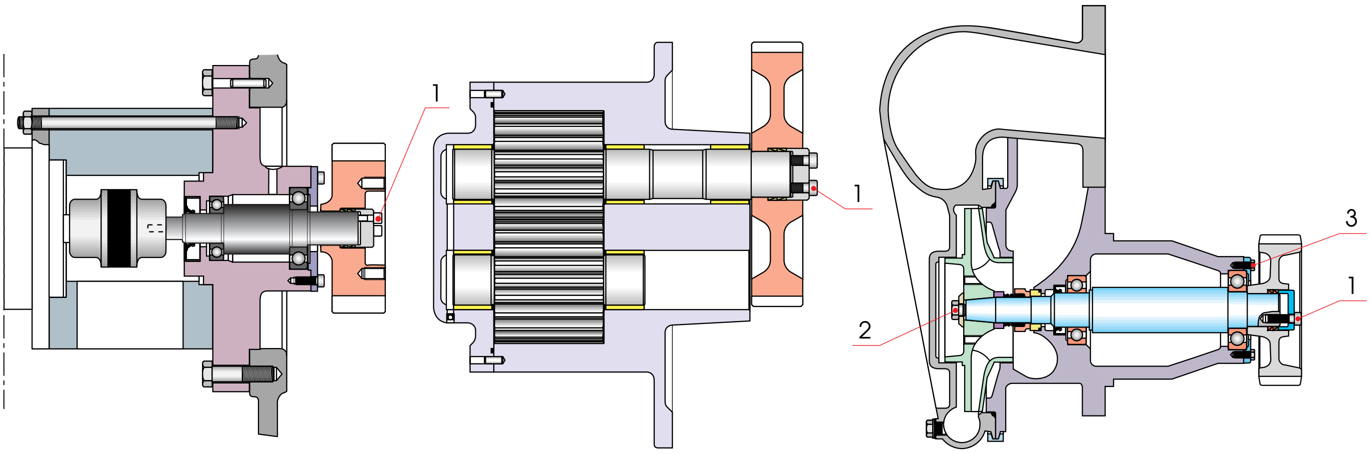


Fig 07-18

4007099601

Pos.	Screw connection	Torque (Nm)
1.	Driving gear of engine driven pumps: Tighten screws crosswise — Fuel feed pump (*) — Lubricating oil pump L32 (*) — Lubricating oil pump V32 (*) — Water pump L32 (*) — Water pump V32 (*) Tighten the screws crosswise (0 - 20 - 40 - 50 Nm) (*) The screws are threated with locking compound and can be used only once. Replace the screws with new, treated ones. Only Driloc 201 or Driloc 211 should be used.	 32±2 75±5 150±5 32±2 50±2
2.	Impeller screw for HT and LT water pump Pump type WD-90/ -91/ -120: Pump type WD-121: **Apply Loctite 2701 on threads**, see section 07.2.	 85±5 110±5
3.	Screws for bearing retainer **Apply Loctite 242 on threads**, see section 07.2.	10±3

Note! **To avoid damaging the threads (Pos. 2 and 3), heat up the screws before loosening.**

H, I Engine driven control oil pump, Common Rail

1. Screw

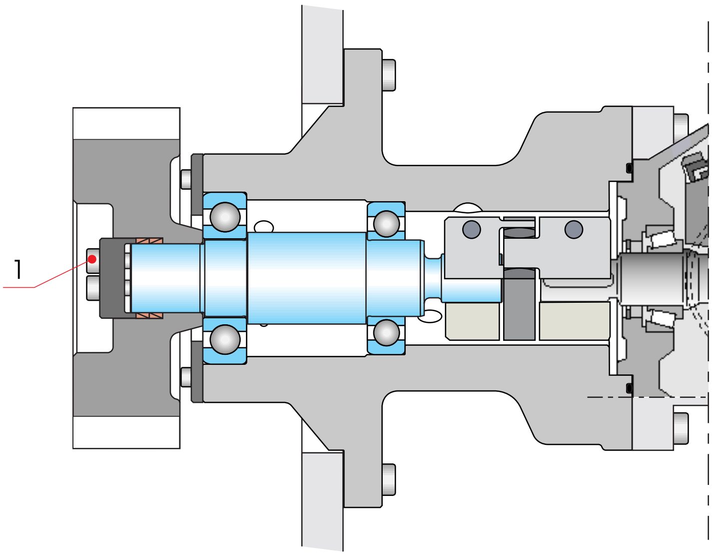


Fig 07-19

4007360243

Pos.	Screw connection	Torque (Nm)
1.	Fastening screws for driving gear Tighten the screws crosswise The screws are treated with locking compound and can be used only once. Replace the screws with new, treated ones. Only Driloc 201 or Driloc 211 should be used.	35±2

J: Free end of crankshaft

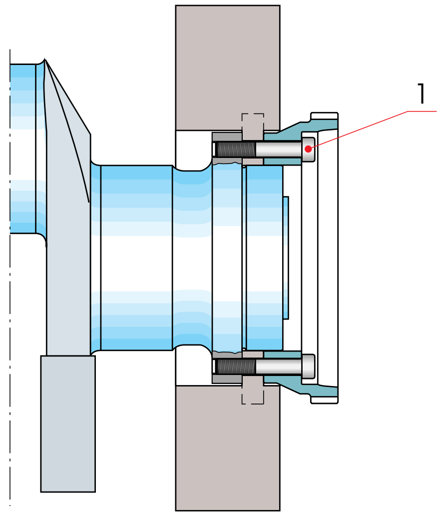


Fig 07-20 4007109601

Pos.	Screw connection	Torque (Nm)
1.	Screws of pump driving gear at free end of crankshaft. Lubricate threads with engine lubricating oil.	1800±25

We recommend the use of torque measuring tools also when tightening other screws and nuts. The following torques apply to screws of the strength class 8.8; when oiled with lubricating oil or treated with Loctite.

Screw dimension	Width across flats of hexagon screws (mm)	Key width of hexagon socket head screws (mm)	Torque	
			(Nm)	(kpm)
M8	13	6	23	2.3
M10	17	8	45	4.6
M12	19	10	80	8.1
M16	24	14	190	19.3
M20	30	17	370	37.5
M24	36	19	640	65.0

07.2 Use of locking fluid

When using locking fluid (Loctite), clean parts carefully in degreasing fluid and let then dry completely before applying locking fluid.

07.3 Hydraulically tightened connections

07.3.1 Tightening pressures

Hydraulically tightened connections

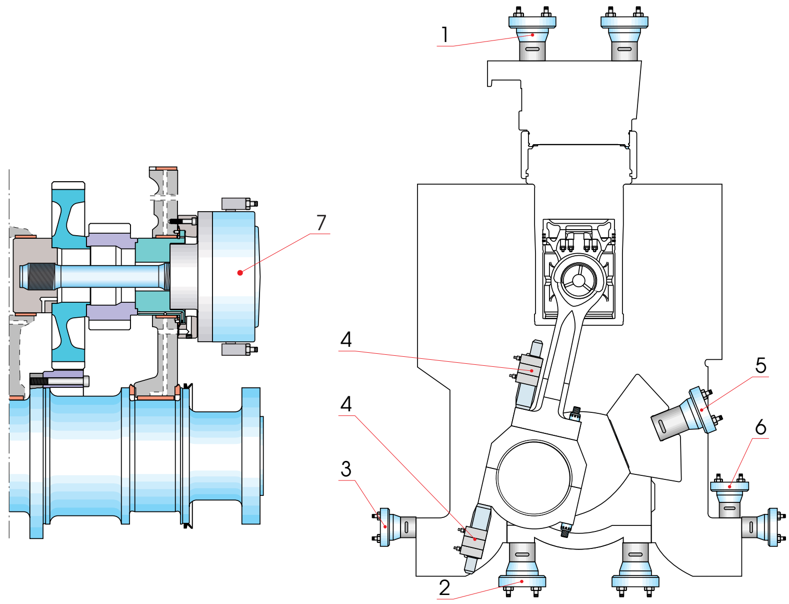


Fig 07-21 4007159901

Pos.	Screw connection	Max. hydraulic pressure (bar)		Hydraulic cylinder
		tightening	loosening	
1.	Cylinder head screws M56 in two steps: First step Second step	 520 520	 540	2V86B224
2.	Main bearing screws M56 in two steps: First step Second step	 250 615	 635	3V86B218
3.	Lateral screws of main bear. M42 in two steps: First step Second step	 250 615	 635	3V86B78
4.	Connecting rod screws : — Upper- and lower con. M27 in two steps First step Second step	 400 800	 820	2V86B478
5.	Counterweight screws M42 in two steps, V32 First step Second step L32 **(Screw stamped:940)** First step Second step L32 **(Screw stamped:1569)** First step Second step	 300 700 300 700 400 800	 720 720 820	3V86B78 3V86B78 3V86B78
6.	Engine fastening screws	x)		
7.	Intermediate gears M80 First step Second step	 760 760	 780	2V86B341

x) Pos. 6 see installation instructions.

The stud bolts are tightened to the casting at the following torques:

Screw dimension	Tightening torque (Nm)
M56 Cylinder head	400±20
M56 Main Bearing	300±10
All M27 studs on connecting rod	100±10
M42 and M48 x 3	200±10
M80 Intermediate gear	200±10

Exception! **Screws acc. to pos. 3 and 6.**
Pos. 3 see chapter 10, section 10.3.3.

Caution! **The screws will be overloaded if the maximum hydraulic pressure is exceeded.**
It is recommended to change the screws if maximum hydraulic pressure is exceeded for some reason.

It is recommended to replace the screws and nuts for the hydraulic tightening tool of the **alternative 1** design before reaching **250** loading cycles.
The screw and nuts of the **alternative 2** design must be replaced before reaching **750** loading cycles.
If the hydraulically tensioned nuts not easilly can be turned when the maximum hydraulic pressure is reached: check for corrosion in threads; check tool condition and manometer error.

Hydraulic tightening tool

1. Hydraulic tightening tool
2. Nut
3. Screw

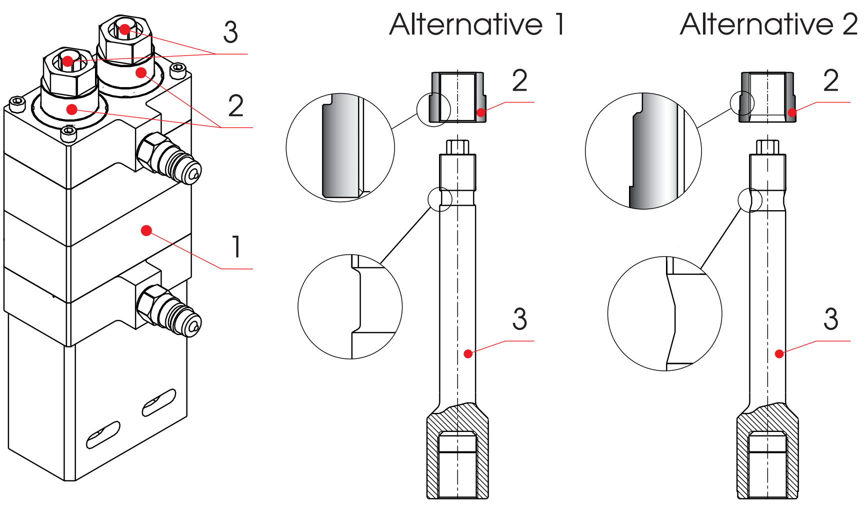


Fig 07-22

400731200227

07.3.2 Filling, venting and control of the high pressure hydraulic tool set

The hydraulic tool set consists of a high pressure hand pump with an integrated oil container, hoses fitted with quick-coupling's and non-return valves, cylinders and a pressure gauge mounted on the hand pump but not connected to the pressure side of the pump.

The components are coupled in series with the pressure gauge being the last component thus securing that every cylinder is fed with the correct pressure.

The non-return valves in the hoses are integrated with the quick-coupling's and are opened by the pins located in the centre of the male and female parts. If these pins get worn the coupling must be replaced because of the risk of blocking.

- In the high pressure hydraulic tool set it is recommended to use a special hydraulic oil or in any case an oil with a viscosity of about 12cSt at 20°C.
- During the filling of the container of the high pressure pump it is recommendable to couple the set according to scheme B, Fig 07-23. Before filling, open the release valve (2) and empty the cylinders (4) by pressing the piston and cylinder together. After that, drain the oil and re-fill through the filling plug (1).
- After filling, vent the system by pressing in, with a finger, the centre pin of the female part of the last quick-coupling, the coupling being disconnected from the pressure gauge. Keep on pumping until air free oil emerges from the coupling.
- Check the pressure gauge of the hydraulic tool set regularly. For this purpose a comparison pressure gauge is delivered. This pressure gauge can be connected to the plug hole (7), the outlet hose of the pump being connected direct to the pressure gauges.

07.3.2.1 Instructions for high pressure hydraulic tools

Caution! **Pay special attention to cleanliness and carefulness when using and maintaining the hydraulic high pressure tools.**

- When the hoses are pressurised, any maintenance, adjustments nor repairing are allowed, not even tightening of the connections.
- Before rising the pressure in the high pressure tool, all hydraulic parts (pump, pipes, hoses, regulating units) has to be vented.
- The weakest parts maximum allowed pressure must not be exceeded.
- Keep a logbook or similar of the hydraulic tools.

07.3.3 Dismantling hydraulically tightened screw connections

1 Attach distance sleeves and hydraulic cylinders according to Fig 07-23 A. Screw on cylinders by hand.

2 Connect the hoses to the pump and cylinders according to scheme Fig 07-23 B. Open the release valve (2) and screw cylinders in clockwise direction to expel possible oil.

3 Screw the cylinders in counter-clockwise direction about half a revolution (180°), otherwise the nut is locked by the cylinder and impossible to loosen.

4 Close the release valve and pump pressure to the stated value.

5 Screw the nut in counter-clockwise direction about half a revolution with the pin.

6 Open the release valve and remove the hydraulic tool set.

7 Screw off the nuts by hand.

Hydraulic cylinder

1. Filling plug
2. Release valve
3. Hose
4. Hydraulic cylinder
5. Hose
6. Pressure gauge
7. Plug hole

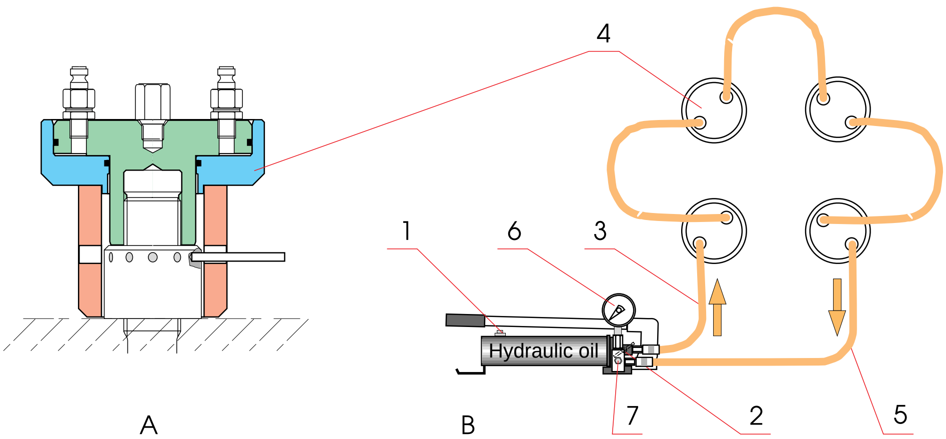


Fig 07-23 3207528935

07.3.4 Reassembling hydraulically tightened screw connections

Check that the threads and contact surfaces are clean and free from particles.

1 **Screw on nuts and attach distance sleeves.** Screw on cylinders by hand.

2 **Connect the hoses to the pump and cylinders.** Check that the release valve is open and screw the cylinders in clockwise direction to expel possible oil.

3 **Close the release valve and pump pressure** to the stated value.

4 **Screw the nuts** in a clockwise direction until in close contact with the face. Use the pin intended for this purpose and tighten the nut as much as possible without breaking the pin. Keep the pressure constant at the stated value.

5 **Open the release valve and remove the hydraulic tool set.**

To ensure that the nut will be properly tightened, the pressure can be raised in two steps. Pump the pressure according to section 07.3.1 and screw the nut in a clockwise direction until in close contact with the face. Increase the pressure further to the stated pressure, and screw the nut until in close contact with the face again. This time the nut should move just a limited angle but approximately the same angle for all nuts of the same kind.

Note! **Before the engine is started, ensure that all screw connections that have been opened are properly tightened and locked.**

07.4 Use of hydraulic extractor cylinder

For some power demanding operations a hydraulic extractor cylinder (800063) is used. In connection with this cylinder, the hydraulic high pressure hand pump is utilized, coupling scheme acc. to Fig 07-24.

Hydraulic extractor cylinder

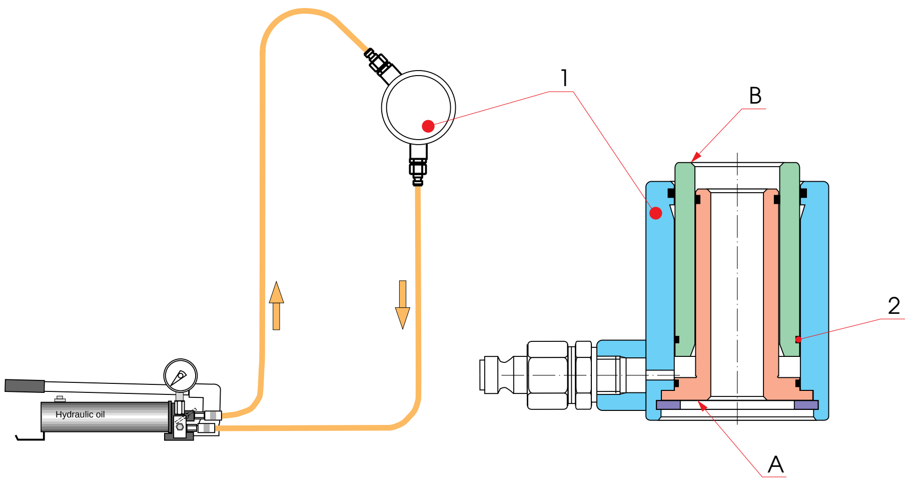


Fig 07-24 3207538935

According to the design of the cylinder, the outer cylinder (1) must not be loaded, but the force is created between the surfaces A and B.

The piston is prevented from running out of the cylinder by an expansion ring (2). The strength of this ring is limited, and it is recommended to be careful when operating at the end of the stroke.

The effective area of the piston is 32,2 cm^2 which gives the following relation between pressure and force (using tool 2V83E0186), see Fig 07-25, **(1)**

In the previous tool (marked with 3V83E0061) the effective area of the piston is 14,42 cm^2. The relation between pressure and force is shown in Fig 07-25, **(2)**.

Relation between pressure and force

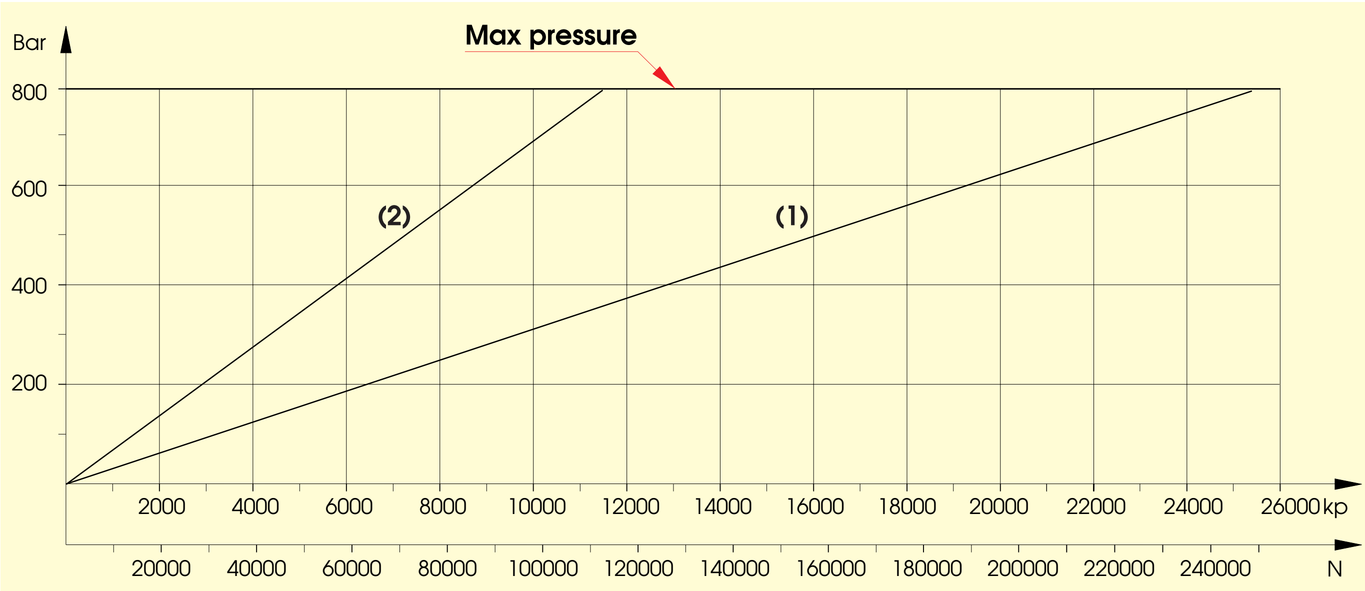


Fig 07-25 400727200142

07.5 Low pressure pump for lifting purposes in the crankcase

A special low pressure pump (150 bar) 800 059 is delivered for lifting tools used in the crankcase. Normal engine oil, which is used in the engine lubricating system (sump) must be used in this pump because the drain oil from the tools is led to the sump of the engine.

08. Operating Troubles, Emergency Operation

08.1 Trouble shooting

Preventive measures, see chapter 03. and 04. Some possible operating troubles require prompt action. Operators should acquire knowledge of this chapter for immediate action when needed.

	Trouble Possible reason	**See chapter, section**
1.	**Crankshaft does not rotate at starting attempt**	
a)	Turning device is connected. **NOTE!** Engine cannot be started when turning device is connected. However, before starting, always check that turning device is disconnected.	03.1.1, 21.1
b)	Starting air pressure too low, shut-off valve on starting air inlet pipe closed	21.1, 21.5
c)	Jamming of starting valve in cylinder head	21.4
d)	Jamming of starting air distributor piston	21.3
e)	Jamming of blocking valve on turning device.	21.1
f)	Starting air solenoid valve faulty	21.2
g)	Inlet or exhaust valve jamming when open. "Negative" valve clearance (strong blowing noise).	12.
h)	Starting automation on outside engine faulty	03.2, 23.
2.	**Crankshaft rotates but engine fails to fire**	
a)	Too low speed (1b),	
b)	Automatic shut-down device is not in start position	23.
c)	Load limit of control shaft or of governor is set at too low a value	Fig 22-1
d)	Starting fuel limiter wrongly adjusted	23.
e)	Some part of fuel control mechanism jamming and prevents fuel admission	22.
f)	Fuel and injection system not vented, pipe connections between injection pumps and valves not tightened	16.3, 17.
g)	Fuel filter outside the engine clogged	
h)	Three-way cock of fuel filter wrongly set, valve in fuel inlet pipe closed, fuel day tank empty, fuel feed pump not started or faulty	
i)	Stop lever in stop position	
j)	Very low air and engine temperatures (preheat circulating water!) in connection with fuel of low ignition quality	02.1
k)	Fuel insufficiently preheated or precirculated	02.1 Fig 02-1
l)	Too low compression pressure (1f)	
3.	**Engine fires irregularly, some cylinders do not fire at all**	
a)	See point 1f, 2f, g, h, k, l, 4d	
b)	Injection pump control rack wrongly adjusted	22.3
c)	Injection pump control sleeve does not mesh properly with rack (may cause overspeed if set in direction towards increased fuel quantity)	16.5
d)	Injection pump faulty (plunger or tappet sticking; delivery valve spring broken, delivery valve sticking, constant pressure relief valve leaking)	16.

e)	Injection valve faulty; nozzle holes clogged	16.
f)	Piston rings ruined; too low compression pressure	11.3.3
g)	8...18-cylinder engines. It may be troublesome to make these fire on all cylinders when idling, due to the small quantity of fuel required. **In normal operation this is acceptable.** In special cases, in engines which have to idle continuously for longer periods (several hours), for some reason, it is advisable to adjust the rack positions carefully (reduce rack position somewhat on those cylinders having the highest exhaust gas temperatures, increase somewhat on those cylinders not firing). This adjustment should be done in small steps and the difference between rack positions of various cylinders should not exceed 0.5 mm.	
4.	**Engine speed not stable**	
a)	Governor adjustment faulty (normally too low compensation)	22.
b)	See point 2f	
c)	Fuel feed pressure too low	01.2
d)	Water in preheated fuel (vapour lock in injection pumps)	
e)	Loading automation (e.g. controllable pitch propeller) outside engine faulty	23.
5.	**Knocks or detonations occur in engine (if reason cannot be found immediately, stop the engine!)**	
a)	Big end bearing clearance too large (loose screws!)	06.2 pos. 11, 07.3, 11.3.4
b)	Valve springs or injection pump tappet spring broken	12., 16.
c)	Inlet or exhaust valve jamming when open	
d)	Too large valve clearances	06.1, 12.2.4
e)	One or more cylinders badly overloaded (3b, c)	
f)	Injection pump or valve tappet guide block loose	16.3, 14.1.3.3, 07.1
g)	Initial phase of piston seizure	
h)	Insufficient preheating of engine in combination with fuel of low ignition quality	
i)	Fuel injection timing wrong. See point 9c.	
6.	**Dark exhaust gases**	
a)	Late injection (wrongly set camshaft drive)	06.1, 16.2.3, 13.2.2
b)	See points 3b, c, d, e	
c)	Insufficient charge air pressure: - air intake clogged - turbocharger compressor dirty - charge air cooler clogged on air side - turbocharger turbine badly fouled **Note!** Engines starting on heavy fuel may smoke if left idling.	Test Records 15.2 15.2, 04.4 04.5
7.	**Engine exhaust gases blue-whitish or gray-whitish**	
a)	Excessive lubricating oil consumption due to: gas blow-by past piston rings; worn or broken oil scraper rings or worn cylinder liners; sticking compression rings; compression rings turned upside-down; ring scuffing (burning marks on sliding surfaces)	03.4.5, 11.3.3
b)	Blue-whitish exhaust gases may occasionally occur when engine has been idling for a lengthy time or at low ambient temperature, or for a short time after starting	
c)	Gray-whitish exhaust gases due to water leakage from exhaust boiler, turbocharger/ water in fuel	
8.	**Exhaust gas temperature of all cylinders abnormally high**	
a)	Engine badly overloaded (check injection pump rack positions)	Test Records
b)	See point 6c	

c)	Charge air temperature too high - charge air cooler clogged on water side or dirty on air side - water temperature to air cooler too high, water quantity insufficient - engine room temperature abnormally high	Test Rec, 01.2 01.3 01.3
d)	Excessive deposits in cylinder head inlet or exhaust ports	
e)	Exhaust pipe pressure after turbine high	04.4, 04.5, 15.3
9.	**Exhaust gas temperature of one cylinder above normal**	Test Records
a)	Faulty exhaust gas temperature measurement	23., 03.4.1
b)	Exhaust valve - jamming when open - "negative" valve clearance - sealing surface blown by (burned)	
c)	Faulty injection valve - opening pressure much too low - sticking of nozzle needle when open - broken spring - nozzle cracked	 06.1 16.4.4
d)	Late injection	06.1, 16.2.3
e)	Fuel supply insufficient (filter clogged)	17.
f)	Injection pump faulty , fuel rack sticking in high	16.
g)	Screw in injection pump lifter loose, check hight of screw	16.2
10.	**Exhaust gas temperature of one cylinder below normal**	
a)	Faulty exhaust gas temperature sensor	23., 03.4.1
b)	See points 2f, h, 3b, c, d, e	
c)	Leaky injection pipe or pipe fittings	16.3
d)	When idling, see point 3g	03.4.1
11.	**Exhaust gas temperatures very unequal**	
a)	See points 9a, c, e	
b)	Too low fuel feed pressure; too small flow through injection pumps (see points 2h, i). May cause great load differences between cylinders although inje-ction pump rack positions are the same. **Dangerous!** Causes high thermal overload in individual cylinders.	01.2
c)	See points 1f, 6b	
d)	When idling, see point 3g	
e)	Exhaust pipe or turbine nozzle ring partly clogged	
f)	Apply to 8- and 16-cylinder engines. The difference in exhaust gas temperatures between two cylinders is normally higher.	
12.	**Lubricating oil pressure lacking or too low**	01.2
a)	Faulty pressure sensor	23
b)	Lubricating oil level in oil sump too low	01.1, 18.2
c)	Lubricating oil pressure control valve out of adjustment or jamming	18.4
d)	Leakage in lubricating oil suction pipe connections	18.1
e)	Lubricating oil badly diluted with diesel oil, viscosity of oil too low	02.2.1, 02.2.3
f)	Lubricating oil pipes inside engine loose or broken	18.
g)	Lubricating oil filter clogged	18.
13.	**Too high lubricating oil pressure**	
a)	See points 12a and c	
14.	**Too high lubricating oil temperature**	01.2
a)	Faulty thermometer	

b)	Insufficient cooling water flow through oil cooler (faulty pump, air in system, valve closed), too high raw water temperature	19.1.4 01.3
c)	Oil cooler clogged, deposits on tubes	18.5
d)	Faulty thermostat valve	18.6
15.	**Abnormally high cooling water outlet temperature,** difference between cooling water inlet and outlet temperatures too large	01.2
a)	One of temperature sensors faulty	
b)	Circulating water cooler clogged, deposits on tubes	
c)	Insufficient flow of cooling water through engine (circulating water pump faulty), air in system, valves closed	19.3 03.4.1
d)	Thermostat valve faulty	19.4
16.	**Water in lubricating oil**	02.2.3, 03.4.1
a)	Leaky oil cooler	18.5
b)	Faulty lubricating oil separator. See separator instruction book!	02.2.3
17.	**Water in charge air receiver** (escapes through drain pipe in air cooler housing)	15.5
a)	Leaky air coolers	
b)	Condensation (too low charge air cooling water temperature)	03.4.1, Fig 03-2
18.	**Engine looses speed at constant or increased load**	
a)	Engine overloaded, a further increase of fuel supply is prevented by the mechanical load limiter	22.1, Fig 22-1 pos. 11
b)	See points 2c, f, g, h, i	
c)	See points 4c, d, 5g	
19.	**Engine stops**	
a)	Shortage of fuel, see points 2h, i	
b)	Automatic stop device has tripped	23.2.3
c)	Faulty governor or governor drive	22.
d)	Faulty power supply to automation system	23.
20.	**Engine does not stop although stop lever is set in stop position or remote stop signal is given**	
a)	Injection pump control rack wrongly set (3b, c) Block fuel supply as near the engine as possible (e.g. by fuel filter three-way cock). Before restarting the engine, the fault must be located and corrected. **Great risk of overspeed.**	
b)	Faulty stop automation. Stop by means of stop lever	23.2.3
c)	The engine driven by generator or propeller or by another engine connected to same reduction gear	
21.	**Engine overspeeds and does not stop although overspeed trip device trips**	
a)	Injection pump control rack wrongly set (3b,c). **Load the engine, if possible.** Block fuel supply, e.g. by means of fuel filter three-way cock.	
b)	An overspeeding engine is hard to stop. Therefore, check regularly the adjustment of the control mechanism (the injection pump rack positions): 1) the stop lever being in stop position or the overspeed trip device being tripped and the speed governor at max. fuel admission 2) the stop lever and the overspeed trip being in work position and the speed governor in stop position. This control should be done always when the control mechanism or the injection pumps have been touched.	22.3

08.2 Emergency operation

08.2.1 Operation with defective air cooler(s)

If the water tubes of an air cooler are defective, the cooling water may enter the cylinders. If water or water mist flows out of the drain pipe at the bottom of the cooler housing, check whether it is raw water or condensate. If condensate, reduce cooling (see chapter 03, Fig 03-2). If raw water, stop the engine as soon as possible and fit a spare cooler.

If no spare cooler is available, the following can be done as an emergency solution:

a) **If there is not time enough to remove the defective cooler** and repair it, shut off water supply and return pipes.

b) **Operating with a partially plugged, shut-down or removed air cooler.** Engine output must be limited so that the normal full load exhaust temperatures are not exceeded. The turbocharger may surge before the admissible exhaust temperatures are reached. In such a case, engine load must be reduced further to avoid continuous surging.

08.2.2 Operation with defective turbocharger(s)

A defective turbocharger is to be treated in accordance with the service instructions given in the turbocharger instruction book (blocking of rotor, blanking of turbocharger etc.). See chapter 15, section 15.4.

08.2.3 Operation with defective cams

If the camshaft piece with damaged cams cannot be removed and replaced by a new one, the engine can be kept running by the following measures:

a) **Injection pump cams:**
Lock the injection pump tappet in upper position by a locking plate 800066 included in the tool set.

Attention! **Concerning torsional vibrations and other vibrations, see sec. 08.2.5.**

When operating with a shut-off injection pump over a long period, the valve push rods of the inlet and outlet valves are to be removed, and the indicator valve on the respective cylinder is to be opened once an hour to allow any accumulated oil to escape.

With one cylinder out of operation, reduce load to prevent exhaust temperature of the remaining cylinders from exceeding normal full load temperatures.

b) Valve cams

Stop fuel injection to the cylinder concerned, see chapter 16. Remove the valve push rods and hang up the tappet in upper position by locking pins 800067 included in the tool set. Mount the tubes covering the push rods.

Warning! **Note with locked tappet in upper position should the push rods be removed otherwise will the piston contact with the valves.**

Attention! **Concerning torsional vibrations and other vibrations, see sec. 08.2.5.**

With one cylinder out of operation, reduce load to prevent exhaust temperatures of the remaining cylinders from exceeding full load temperatures.

08.2.4 Operation with removed piston and connecting rod

If damage on piston, connecting rod or big end bearing cannot be repaired, the following can be done to allow emergency operation:

1. **Remove the piston and the connecting rod.**
2. **Cover lubricating oil bore in crank pin** with a suitable hose clip, and secure.
3. **Fit completely assembled cylinder head** but omit valve push rods.
4. **Prevent starting air entry to the cylinder head** by removing pilot air pipe.
5. **Hang up the injection pump tappet** and valve tappets as described in section 08.2.3.

Attention! **Concerning torsional vibrations and other vibrations, see sec. 08.2.5.**

With one cylinder out of operation, reduce load to prevent exhaust temperature of the remaining cylinders from exceeding normal full load temperatures.

If the turbocharger(s) surges, reduce load further to avoid continuous surging.

Operation with removed piston and connecting rod, from one or more cylinders, should be performed only in absolute emergency conditions when there are no other means of proceeding under own power.

08.2.5 Torsional vibrations and other vibrations

When running the engine with one cylinder, or more, out of operation, the balance of the engine is disturbed and severe, or even dangerous, vibrations may occur. The vibration conditions are, in practice, dependent on the type of the installation.

As a general advice, when there are cylinders out of order:

- Reduce load as much as possible.
- Keep the speed in a favourable range (completely depending on the type of installation).
- If one or several pistons are removed, lowest possible speed should be used.

09. Specific Installation Data

09.1 General

All test reports and certificates are collected in series 8 Quality records. The specific installation data can be found from binder 7A 02 01.

10. Engine Block with Bearings, Oil Sump and Cylinder Liner

10.1 Description

Data and dimensions

Material: Nodular cast iron

Weight (dry): 9100 kg (6L32)
12 000 kg (8L32)
13 600 kg (9L32)
12 000 kg (12V32)
16 000 kg (16V32)
18 000 kg (18V32)
20 000 kg (20V34SG)

The engine block is cast in one piece. The main water and lubricating oil distributing pipes and the charge air receiver are integrated in the engine block. The main bearing caps, which support the underslung crankshaft, are clamped by hydraulically tensioned screws, two from below and two horizontally. The bearing shells are axially guided by lugs to provide correct assembly.

A combined flywheel/thrust bearing is located at the driving end. The flywheel bearing shells are of the same type as the main bearings. The four thrust washers guide the crankshaft axially.

The camshaft bearing bushes are fitted in housings directly machined in the engine block.

The cylinder liners are made of special alloyed cast iron. To eliminate the risk of bore polishing, the liner is provided with an anti-polishing ring at the upper part.

The crankcase covers, as well as other covers, tighten against the engine block by rubber sealing's and four screws each. On one side of the engine the crankcase covers are equipped with safety valves which relieve the over pressure in case of a crankcase explosion. The crankcase is furthermore provided with a vent pipe. This pipe should be conducted away from the engine room.

10.2 Oil sump

Data and dimensions

Material: Steel plates

Weight: 930 kg (6L32)
1200 kg (8L32)
1400 kg (9L32)
1300kg (12V32)
1700 kg (16V32)
1900 kg (18V32)
2100 kg (20V34SG)

The light, welded oil sump is attached to the engine block and is sealed off by a rubber sealing. Suction pipes to the lube oil pump and if used, for the separator, as well as for the main lube oil distributing pipe for crankshaft bearings, are incorporated in the oil sump.

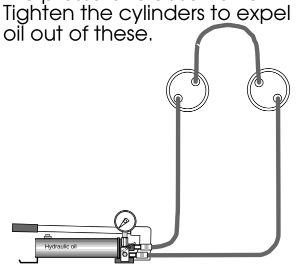
From the main distributing pipe the lube oil is led up to the main bearing through a hydraulic jack, by means of which the bearing cap can be lowered and lifted, e.g. when inspecting the bearings.

An oil dipstick is located in the engine block. The oil dipstick indicates the maximum and minimum limits between which the oil level may vary. Keep the oil level near the max. mark and never allow the level to go below the min. mark. The limits apply to the oil level in a running engine. One side of the dipstick is graduated in centimeter. This scale can be used when checking the lubricating oil consumption. **Note! In marine installations; Check the oil level only when the ship has a same trim.**

10.3 Main bearings

10.3.1 Dismantling of the main bearing

DISMANTLING
1. Mount the cylinders.
2. Connect the hoses and open the pressure release valve. Tighten the cylinders to expel oil out of these.



3. Turn the cylinders 180 counter-clockwise.
4. Close the valve and pump pressure according to stated value.
5. Open the nuts about half a turn.
6. Open the release valve and remove the tool.

1 Remove the crankcase covers on each side of the bearing, on both sides of the engine.

2 Remove the main bearing temperature sensor and the clamps for the cable.

3 Mount the distance sleeve 800042 and the hydraulic tool 800041 into position on the side screw (A), see Fig 10-1. One or two nuts can be loosened simultaneously.

4 Open the nuts of the side screws as described in adjacent figure.

5 Turn the crankshaft to the BDC at the cylinder concerned.

6 Mount the distance sleeve 800095 into position on the main bearing screw (B_1) and insert the pin 800049, see Fig 10-1.

7 Mount the hydraulic tool 800046 on the same main bearing screw, by using the tool 800051.

8 Apply the sleeve and hydraulic cylinder onto main bearing screw (B_2) by the same procedure.

9 Open the nuts of the main bearing screws as described in adjacent figure. Both nuts should be loosened at the same time.

10 Remove the hydraulic tools.

11 Remove the nuts of the main bearing screws.

12 Connect the hoses of the hydraulic pump 800059 and to the side marked DOWN on the hydraulic jack, see Fig 10-2. Connect the return hose to the side marked UP and an additional quick coupling male part to the free end of the return hose and place it in the crankcase.

13 Unscrew the side screws of the main bearing cap to be lowered. Use the stud tool 800044.

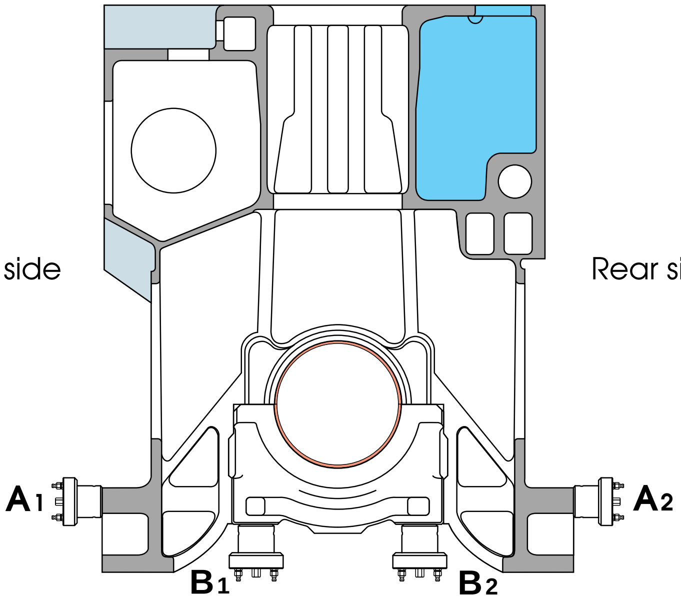
14 Lower the main bearing cap by pumping oil to the hydraulic jack with the hydraulic pump.

15 Remove the lower bearing shell.

16 Insert the turning tool 800004 into the main bearing journal radial oil hole.

17 Turn the crankshaft carefully until the bearing shell has turned 180° and can be removed. Remove the turning tool.

Use of hydraulic cylinders



Hydraulic cylinder combination			
Screw		A1 A2	B1 B2
Hydraulic tool		Main bearing and thrust bearing screws	Main bearing screws
Cylinder		800041 (3V86B78)	800046 (3V86B218)
Sleeve		800042 (3V86B46)	800095 (3V86B333)
Pin		800043 (4V86B11)	800049 (4V86B02)
Action/Screw		**Comments**	**Hydraulic pressure**
Loosening	A1 A2	One by one in order according to free choice. Two nuts per side can be loosened simultaneously	615...635 bar
	B1 B2	Always loosened simultaneously	615...635 bar
Tightening	B1 B2	Simultaneously hand tight with pin 4V86B02	
	A2	A2 bolt tensioned first with 100 bar hydraulic pressure and the nut turned with pin to contact	100 bar
	B1 B2	1. Tighten simultaneously with 250 bar hydraulic pressure 2. Release the pressure 3. Tighten simultaneously with 615 bar hydraulic pressure	250 bar 0 bar 615 bar
	A2	Tighten one or two nuts simultaneously on the same side, **first step with 250 bar** hydraulic pressure	250 bar
	A1	Tighten one or two nuts simultaneously on the same side, **first step with 250 bar** hydraulic pressure	250 bar
	A2	Tighten one or two nuts simultaneously on the same side, **second step with 615 bar** hydraulic pressure	615 bar
	A1	Tighten one or two nuts simultaneously on the same side, **second step with 615 bar** hydraulic pressure	615 bar

Fig 10-1 4010019601

18 Cover the main bearing journal oil holes with tape.
Note! At least every third main bearing must always remain mounted to support the crankshaft.

Hydraulic jack

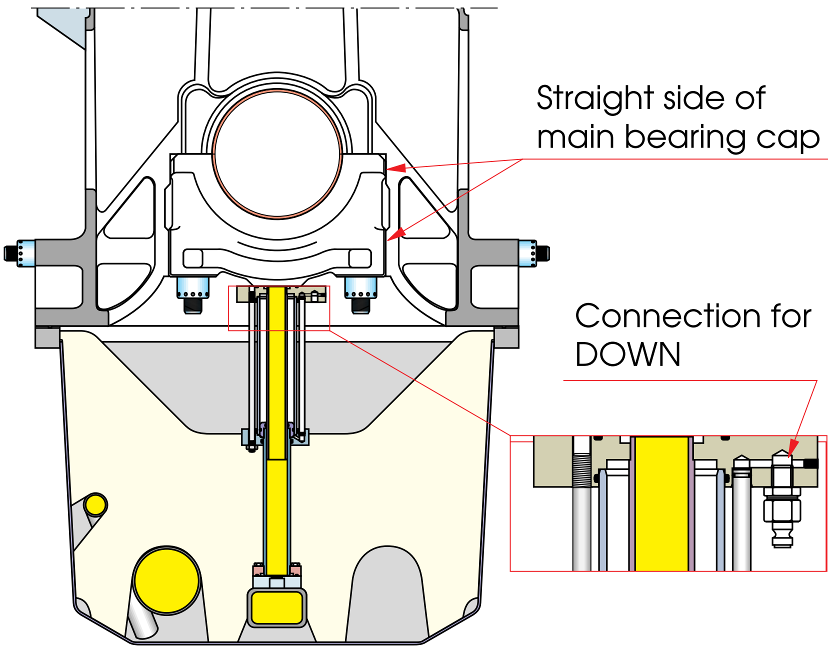


Fig 10-2 4010029601

10.3.2 Inspection of main bearings and journals

Clean the bearing shells and check for wear, scoring and other damages.

a) Trimetal bearings can be used until the overlay is partially worn off. When the under-laying nickel-barrier or the lining material is exposed in any area, the bearing must be replaced.

Never re-install a bearing with the nickel-barrier exposed in any part of the bearing shell.

b) Bi-metal bearings. Wear is settled by measuring the thickness of the lower bearing shells. For this purpose a ball anvil micrometer can be used. The wear limit in section 06.2 must be applied. If the thickness of lower bearing shells have not reached the wear limit and the difference in thickness of all lower bearing shells is max. 0.03 mm, the shells can be used again.

Mark the new bearings with the bearing numbers.

The main bearing journals should be inspected for surface finish. Damaged journals, i.e. rough surface, scratches, marks of shocks etc., should be polished. If, after a longer running period, considerably uneven wear appears, see section 06.2, the crankshaft may be reground and used together with thicker bearing shells, see Spare Parts Catalogue.

No scraping or other damage of bearing shells, caps and saddles is allowed. Burrs should be locally removed, only.

10.3.3 Assembly of main bearing

1 **Clean the main bearing shells,** the cap and the journal very carefully.

2 **Remove the protecting tape** from the journal oil holes and lubricate the journal with clean engine oil.

3 **Lubricate the bearing surface,** back side and end faces of the upper bearing shell with clean lubricating oil.

The bearing shell can be completely destroyed (deformed) during the assembly, if it is not lubricated carefully.

4 **Place the end of the bearing shell** in the slot between the journal and the bearing bore, with the lug guiding in the oil groove, and push it by hand as far as possible (recommended 2/3 of its length).

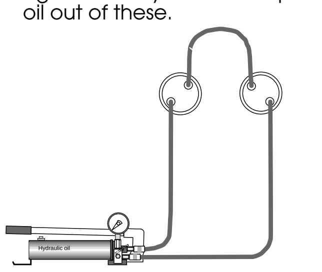
5 **Insert the turning tool** 800004 into the main bearing journal radial oil hole and turn the crankshaft carefully until the bearing shell has turned into position. Take care that the bearing shell lug slides into the oil groove without being damaged.

Caution! **A bearing shell forced into its place can be completely destroyed due to deformation.**

6 **Remove the turning tool.**

7 **Lubricate the bearing surface** of the lower bearing shell with clean lubricating oil and place it in the bearing cap.

REASSEMBLY
1. Mount the nuts, the distance sleeves and the cylinders.
2. Connect the hoses, open the pressure release valve. Tighten the cylinders to expel oil out of these.



3. Close the valve and pump pressure to stated value for step 1.
4. Turn the nuts until close contact is reached.
5. Release the pressure by opening the valve.
6. Close the valve and pump pressure to the full stated value.
7. Turn the nuts until close contact is reached.
8. Open the valve and remove the tool set.

8 **Remove the quick coupling from the return hose** and reverse the oil feed to the hydraulic jack. Mount the quick coupling male part to the free end of the hose and place it in the crankcase.

9 **Lift the main bearing cap** by pumping oil to the hydraulic jack with the hydraulic pump. Mount the main bearing nuts by hand. Remove the hoses from the hydraulic jack.

10 **Mount the side screws** into the main bearing cap. Lubricate those threads of the screw that enters the bearing cap. Note! Replace the O-rings on the side screws.

11 **Tighten the side screws** using the stud tool 800044. Mount the nuts by hand.

12 **Mount the distance sleeves 800042** and the hydraulic tool 800041 into position on the side screw (A_2) on the rear side on a in-line engine, and B-bank on a V-engine, i.e. the straight side of the bearing cap, see Fig 10-2. One or two nuts can be tightened simultaneously on the same side, see Fig 10-1.

13 **Rise the hydraulic pressure in the tool** to 100 bar and turn the nut to contact by the pin 800043.

14 **Mount the distance sleeve** 800095 into position on the main bearing screw (B_1) and insert the pin 800049, see Fig 10-1.

15 **Mount the hydraulic tool** 800046 on the same main bearing screw, by using the tool 800051.

16 **Apply the sleeve and hydraulic cylinder** onto main bearing screw (B_2) by the same procedure.

17 **Tighten the nuts of the main bearing screws** as described in adjacent figure. Both screws must be tightened at the same time and in two steps. Turn the nuts with the pin 800049.

Note! **The hydraulic pressure in the tool must keep stable when tightening the nuts.**

18 **Connect the hydraulic pump and hose** to the tool on the already pretightened side screw (A_2), see Fig 10-1.

19 **Rise the hydraulic pressure in the tool** to 250 bar and turn the nut to contact by the pin 800043.

20 **Mount the distance sleeve 800042** and the hydraulic tool 800041 into position on the opposite side screw (A_1).

21 **Rise the hydraulic pressure in the tool** to 250 bar and turn the nut (A_1) to contact.

22 **Tighten the side screw (A_2)** to full stated pressure.

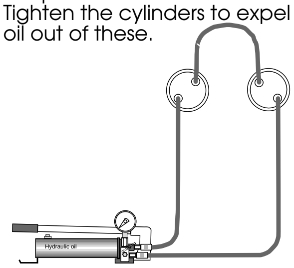
23 **Tighten the side screw (A_1)** to full stated pressure.

24 **Remove the tools,** mount the main bearing temperature sensor, the cable clamps and the crankcase covers.

10.4 Flywheel/thrust bearing

10.4.1 Dismantling of flywheel/thrust bearing

DISMANTLING
1. Mount the cylinders.
2. Connect the hoses and open the pressure release valve. Tighten the cylinders to expel oil out of these.



3. Turn the cylinders 180 counter-clockwise.
4. Close the valve and pump pressure according to stated value.
5. Open the nuts about half a turn.
6. Open the release valve and remove the tool.

1 **Remove the crankcase covers** next to the flywheel end, on both sides of the engine.

2 **Remove the main bearing** temperature sensor and the clamps for the cable.

3 **Mount the distance sleeve** 800042 and the hydraulic tool 800041 into position on the side screw (A), see Fig 10-1. One or two nuts can be loosened simultaneously.

4 **Open the nuts of the side screws** as described in adjacent figure.

5 **Mount the distance sleeve** 800095 into position on the main bearing screw (B_1) and insert the pin 800049, see Fig 10-1.

6 **Mount the hydraulic tool** 800046 on the same main bearing screw, by using the tool 800051.

7 **Apply the sleeve and hydraulic cylinder** onto main bearing screw (B_2) by the same procedure.

8 **Open the nuts of the main bearing screws** as described in adjacent figure. Both nuts should be loosened at the same time.

9 **Remove the hydraulic tools.**

10 **Remove the nuts of the flywheel/thrust bearing screws.**

11 **Connect the hoses to the hydraulic pump** 800059 and to the side marked DOWN on the hydraulic jack, see Fig 10-2. Connect the return hose to the side marked UP and an additional quick coupling male part to the free end of the return hose and place the end in the crankcase.

12 **Unscrew the side screws** of the flywheel/thrust bearing cap. Use the stud tool 800044.

13 **Lower the bearing cap** by pumping oil to the hydraulic jack with the hydraulic pump.

14 **Remove the lower bearing shell and the thrust washers.** To remove the thrust washer next to the driving end, an M6 screw can be fitted to each end of the washer, see Fig 10-3.

15 **Insert the turning tool** 800005 into the bearing journal radial oil hole.

16 **Turn the crankshaft carefully** until the bearing shell has turned 180° and can be removed. Remove the turning tool.

17 **Remove the thrust washers.**

18 **Cover the main bearing journal oil holes with tape.**

19 **Check the bearing** in the same way as the main bearings, section 10.3.2. The thrust washers on the same side have to be changed in pairs.

Thrust bearing

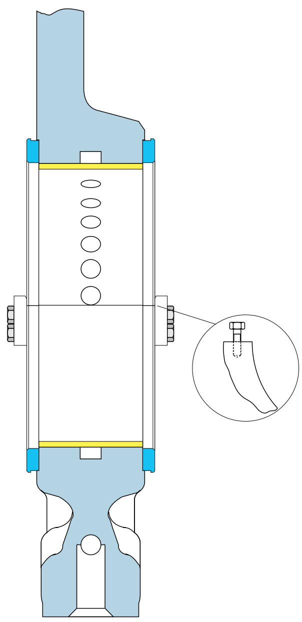


Fig 10-3 4010069901

10.4.2 Assembling of flywheel/thrust bearing

1 **Clean the bearing shells, washers, cap and journal** very carefully.

2 **Remove the protecting tape** from the main bearing journal oil holes and lubricate the journal with clean engine oil.

3 **Lubricate the bearing surface,** back side and end faces of the upper bearing shell with clean lubricating oil.

4 **Place the end of the bearing shell** in the slot between the journal and the bearing bore and push it by hand as far as possible (recommended 2/3 of its length).

5 **Insert the turning tool** 800005 into the bearing journal radial oil hole and turn the crankshaft carefully until the bearing shell has turned into position.

Caution! **A bearing shell forced into its place can be completely destroyed due to deformation.**

6 **Remove the turning tool.**

7 **Lubricate the bearing surfaces and back sides** of the upper thrust washers and push the washers into position by hand. To facilitate the mounting of the washer, the crankshaft can be axially displaced in each direction.

8 **Lubricate the bearing surfaces** of the lower thrust washers and push them into position on the guiding pins in the bearing cap. For mounting the thrust washer next to the driving end an M6 screw can be fitted to each end of the washer, see Fig 10-3.

9 **Lubricate the bearing surface** of the lower bearing shell with clean lubricating oil and place the shell in bearing cap.

10 **Remove the quick coupling from the return hose** and reverse the oil feed to the hydraulic jack. Mount the quick coupling male part to the free end of the hose and place it in the crankcase.

11 **Lift the main bearing cap** by pumping oil to the hydraulic jack with the hydraulic pump. Mount the main bearing nuts by hand. Remove the hoses from the hydraulic jack.

12 **Mount the side screws** into the main bearing cap. Lubricate those threads of the screw that enters the bearing cap. Note! Replace the O-rings on the side screws.

13 **Tighten the side screws** using the stud tool 800044. Mount the nuts by hand.

14 **Mount the distance sleeves 800042** and the hydraulic tool 800041 in position on the side screws (A_2) on the rear side on a in-line engine, or B-bank on a V-engine, i.e. the straight side of the bearing cap, see Fig 10-2. One or two side screws (A_2) can be tightened simultaneously on the same side,see Fig 10-1.

15 **Rise the pressure in the hydraulic tool** to 100 bar and turn the nut to contact by the pin 800043.

16 **Mount the distance sleeve** 800095 into position on the main bearing screw (B_1) and insert the pin 800049, see Fig 10-1.

17 **Mount the hydraulic tool** 800046 on the same main bearing screw, by using the tool 800051.

18 **Apply the sleeve and hydraulic cylinder** onto main bearing screw (B_2) by the same procedure.

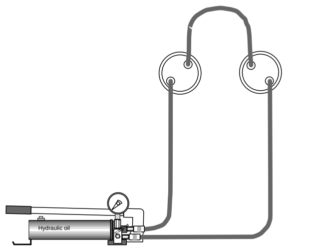
19 **Tighten the nuts of the main bearing screws** as described in adjacent figure. Both screws must be tightened at the same time and in two steps, see Fig 10-1. Turn the nuts using the pin 800049.

Note!

The hydraulic pressure in the tool must keep stable when tightening the nuts.

REASSEMBLY

1. Mount the nuts, the distance sleeves and the cylinders.
2. Connect the hoses, open the pressure release valve. Tighten the cylinders to expel oil out of these.



3. Close the valve and pump pressure to stated value for step 1.
4. Turn the nuts until close contact is reached.
5. Release the pressure by opening the valve.
6. Close the valve and pump pressure to the full stated value.
7. Turn the nuts until close contact is reached.
8. Open the valve and remove the tool set.

20 **Connect the hydraulic pump and hose** to the tool on the already pretightened side screw (A_2), see Fig 10-1.

21 **Rise the pressure in the hydraulic tool** to 250 bar and turn the nut to contact with the pin 800043.

22 **Mount the distance sleeve 800042** and the hydraulic tool 800041 in position on the opposite side screw (A_1), see Fig 10-1.

23 **Rise the pressure in the hydraulic tool** to 250 bar and turn the nut (A1) to contact.

24 **Tighten the side screw (A_2)** to full stated pressure.

25 **Tighten the side screw (A_1)** to full stated pressure.

26 **Remove the tools,** mount the main bearing temperature sensor, the cable clamps and the crankcase covers.

10.5 Cylinder liner

10.5.1 Maintenance of cylinder liner

Data and dimensions

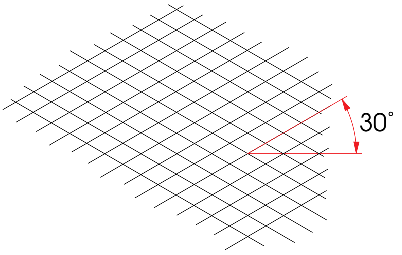
Material: Special grey cast

Weight: 238 kg

a) **Honing of cylinder liner bore**

Always hone the cylinder liner when new piston rings are mounted. Normally a light honing is sufficient. If the honing is done when the cylinder liner is on its place in the engine block, the crankshaft under the cylinder liner concerned must be covered by plastic film. Honing rests must be prevented from falling into the oil sump of the engine. For the honing process the following instructions are prescribed:

- The honing is to be carried out by means of Plateau honing.
- Only ceramic hones with a coarseness of 80 and 400 should be used. The hones with a coarseness of 80 should be used for about 20 strokes or until the polished areas in the cylinder liner are over scraping. The hones with a coarseness of 400 should be used for about 30 strokes to give the correct surface finish.



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- The pitch angle of the honing lines in the cross hatch pattern should be about 30°, which is achieved by combining for example 40 strokes/min with a rotational speed of 100 RPM.
- As coolant a honing oil is preferred, but a light fuel oil 2-15 cSt could also be used.
- After honing, the liner bore must be carefully cleaned by using a suitable brush, water (preferably hot) and soap or cleaning fluid, alternatively, light fuel oil. Then dry with a cloth and lubricate with engine oil for corrosion protection.

The honing equipment 800008 is delivered with the engine.

b) **Check the inner diameter** of the cylinder liner.

c) **Cleaning of the cylinder liner cooling bores**
The cooling bores in the collar can be cleaned by boring with a suitable drill (ø 9.5 - 10 mm).

10.5.2 Removing the cylinder liner

1 **Drain the engine cooling water** and remove the cylinder head and piston with connecting rod upper part. See sections 12.2.1. and 11.3.2.

2 **Remove the protecting cover** and assemble the lifting tool 800007 , see Fig 10-4.

3 **Unscrew the fixing screws** from the water jacket.

4 **Lift the cylinder liner** with water jacket 15-20 cm to enable removal of the sensors.

5 **Remove the temperature sensors**

6 **Lower the liner carefully back into the bore** of the engine block.

7 **Tighten the fixing screws** by hand.

8 **Loosen the fastening screw (5)** (only in alternative design).

9 **Lift out the cylinder liner.**

10 **Remove the water jacket (1),** see Fig 10-4.

10.5.3 Mounting of the cylinder liner

1 **Check that all guide and contact faces** of the engine block and cylinder liner are clean and intact, if needed use a fine grinding stone or emery cloth.

2 **Check that the O-ring groove** for the cooling water channel on the engine block is clean and insert new O-ring.

3 **Mount the water jacket (1)** and tighten the fixing screws by hand.

4 **Lubricate the guiding faces** with grease and assemble the lifting tool, see Fig 10-4.

5 **Check that the O-ring grooves** of the cylinder liner are clean and insert new O-rings. Lubricate the O-rings with soap or similar. **Note !** The O-rings in the cooling water spaces must not be lubricated with oil based lubricants.

6 **Lower the liner carefully into the bore** of the engine block. When the lower part of the liner touches the engine block, align the liner so that the distinct mark on the liner is directed towards the driving end of the engine, on the V-engine B-bank towards the free end of the engine, see Fig 10-4.
Note! Design with sensors slight upwards, do not lower it completely yet, to ease the mounting of the temperature sensors.

7 **Mount the screw (5)** and loosen the water jacket fixing screws (only in alternative design).

8 **Lift the cylinder liner** with water jacket 15-20 cm to enable assembling of the sensors (only in alternative design).

9 **Assemble the temperature sensors.**

10 **Lower the liner into the bore** and remove the lifting tool.

11 **Tighten the water jacket fixing screws** to the stated torque.

12 **Check the inner diameter of the cylinder liner,** especially at the level of the guiding surfaces.

13 **Mount the piston with the connecting rod upper part,** anti polishing ring and cylinder head, see sections 11.3.5 and 12.2.3. Refill the cooling water.

14 **Check the O-ring seals** from the water jacket while circulating cooling water. If there is an engine driven cooling water pump, apply 3 bar static pressure.

Removing and lifting of cylinder liner

800007 Lifting tool for cylinder liner

800123 Fastening tool for cylinder liner

1. Water jacket
2. O-ring
3. O-ring
4. O-ring
5. Screw*)

*) only in alternative design

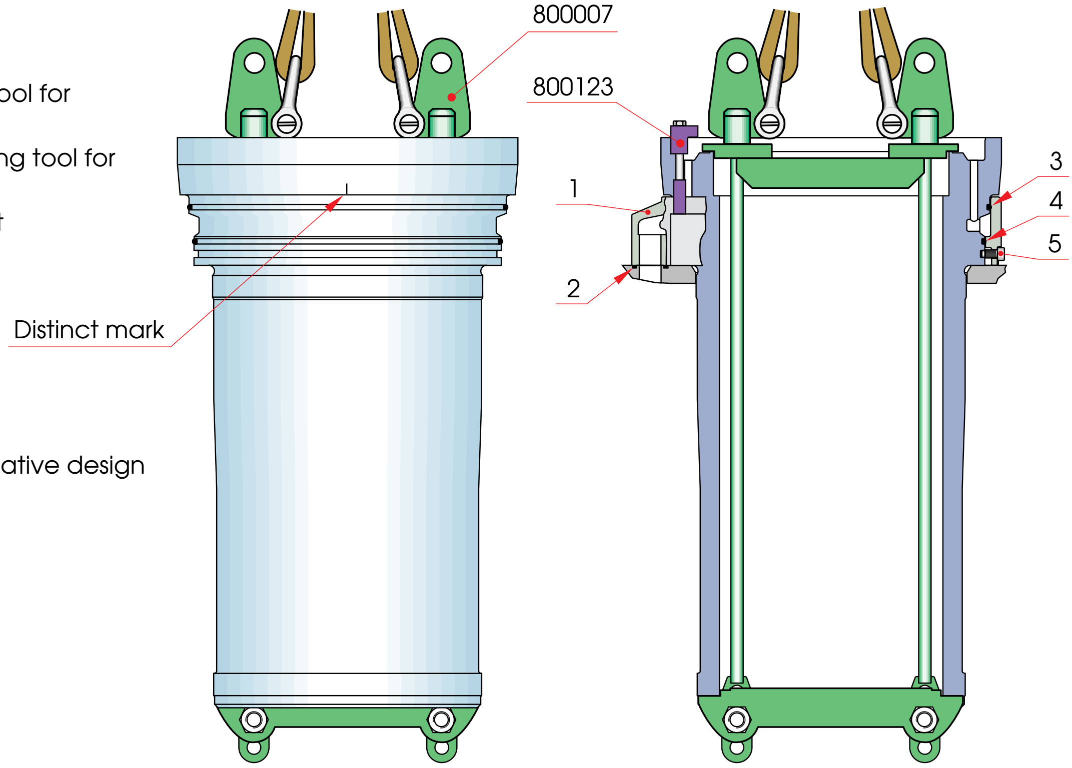


Fig 10-4 4010059601

11. Crank Mechanism: Crankshaft, Connecting Rod, Piston

11.1 Counterbalancing of crankshaft

11.1.1 General

The crankshaft is counterbalanced by means of weights on the crank webs. The Wärtsilä 32 engines have counterweights on all webs.

11.2 Crankshaft

11.2.1 Description of crankshaft

The crankshaft is forged in one piece and provided with counterweights fastened with hydraulically tensioned screws.

At the driving end of the engine, the crankshaft is equipped with a V-ring for sealing of the crankcase, a combined flywheel/thrust bearing and a split gear wheel for camshaft driving.

At the free end, there is a gear for driving of pumps and usually a vibration damper.

The crankshaft can be turned by a electrical turning device operating the flywheel. Separate instructions for the vibration damper are submitted, if the engine is equipped with such.

11.2.2 Crankshaft alignment

The crankshaft alignment is always done on a thoroughly warm engine, immediately after the engine is stopped. The crankshaft alignment should be carried out rapidly but carefully. Only the crankcase cover for the cylinder being measured should be opened and it should be closed immediately after measuring. It is recommended to switch off any forced ventilation close to the engine.

1 **Combine extensions with the transducer** to the required length.

2 **Connect cable** on the measuring unit.

3 **Turn on the measuring unit** by pressing Power-button. Push “Light” if needed.

4 **Reset the measuring unit** by pressing Reset-button.

5 **Turn crank of the first cylinder** near BDC (bottom dead centre) and fit the transducer to the centre marks (marked with yellow paint mark) between two crank webs. The distance between centre mark and contact surface of the counter weight and crank web is 145 mm, see Fig 11-1.

The distance between the transducer and the connecting rod should be as small as possible. Fix the cable on the crank web by using suitable bandage or magnetic holder (4), see Fig 11-1.

6 **Adjust the transducer** to a reading somewhere between +0.500 and -0.500 and push “Zero”.

Transducer position and crankshaft alignment

1. Measuring unit
2. Cable
3. Transducer
4. Cable holder

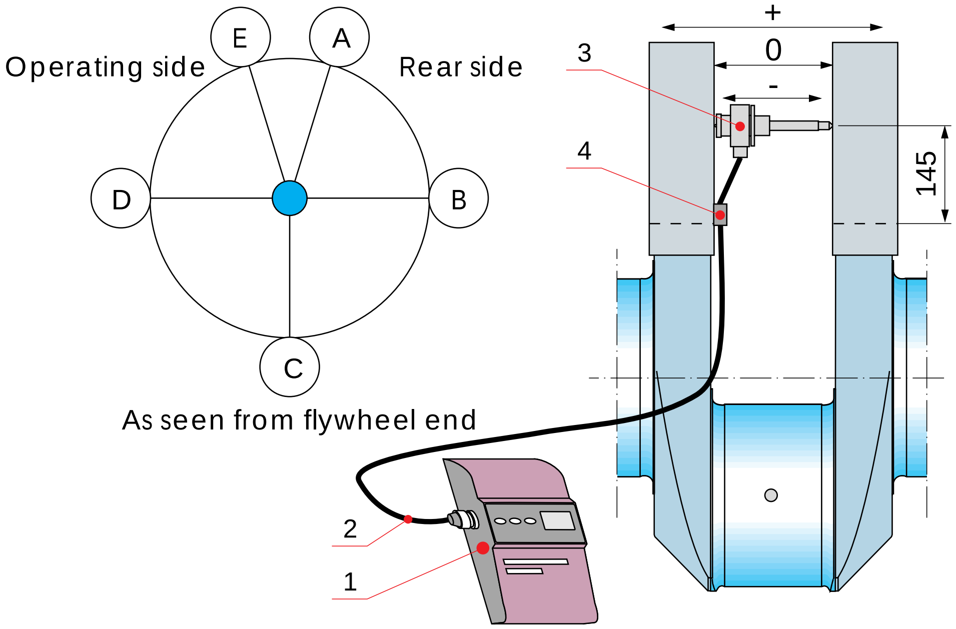


Fig 11-1 4011079706

7 **Turning the crank and read deflections** in the marked positions according to Fig 11-1. Starting point for clockwise rotating engine is measuring point “A” and counter-clockwise rotating engine measuring point “E”. B is rear side, C is TDC (top dead centre), D is operating side, A and E are BDC (bottom dead centre). Record readings in the Measuring Record: “Crankshaft alignment”.

Note! **During the alignment procedure the crankshaft should be turned in the direction of rotation, only.**

8 **Repeat this procedure with other cylinders.**

9 **Following limits of misalignment** are stated for an engine having normal running temperature (within 10 min after running at 60 % load, or higher, for 6 h, or more):
For evaluating the vertical alignment should the difference between C and it's opposite reading, i.e. the mean value E and A be used.

a) on the same crank, the difference between two diametrically opposed readings must not exceed 0.08 mm after installing or re-aligning. Re-alignment is necessary if this limit is exceeded by more than 0.04 mm. **Except the cranks in the both ends.**

b) on two adjacent cranks, the difference between two corresponding readings must not exceed 0.06 mm, for crank No.1 to No.2 0.08 mm if flex. coupling and 0.06 mm if fixed coupling. Re-alignment is necessary if these limits are exceeded by more than 0.02 mm.

c) when the crank pin for cyl.1 is at TDC, the reading should be negative, max. -0.12 mm (-0.13 mm if flex. coupling).

d) when the last crank pin in the free end is at TDC in case of PTO with support bearing, should the reading be positive max. 0.13 mm.

Before re-aligning the engine and the driven machinery, a control measurement of the main bearings should be made.

Note! **In an engine having a normal ambient temperature, the corresponding values must be based on experiences from the particular installation.**

11.2.3 Measurement of thrust bearing axial clearance

1 **Lubricate the bearings** by running the prelubricating pump for a few minutes.

2 **Apply a measure gauge,** for instance, against the plane end surface of the flywheel.

3 **Move the crankshaft** by a suitable lever in either direction until contact is established with the thrust bearing.

4 **Set the measure gauge at zero.**

5 **Move the crankshaft** in the opposite direction, and read the axial clearance from the measure gauge.

Note! **Repeat the movement of crankshaft to ensure that correct clearance is measured.**

11.3 Connecting rod and piston

11.3.1 Description of connecting rod and piston

The connecting rod is of a three-piece design, so called “Marine type connecting rod”. The combustion forces are distributed over a maximum bearing area. The relative movements between mating surfaces are minimized.

The connecting rod is forged and machined of alloyed steel and splitted horizontally in three parts to allow removal of piston and connecting rod parts. All connecting rod bolts are hydraulically tightened.

The piston is of the composite type with an nodular cast iron skirt and a forged steel crown screwed together. The space, formed between the crown and the skirt, is supplied with lubricating oil for cooling of the crown by means of the cocktail shaker effect. The lubricating oil is led from the main bearing, through the drilling’s in the crankshaft, to the big end bearing, and further through the drilling’s in the connecting rod, gudgeon pin and piston skirt, up to the cooling space, and from there back to the oil sump.

Note! **Always handle the pistons with care.**

The piston ring set consists of two chrome-plated compression rings and one spring-loaded oil scraper ring.

Connecting rod parts

1. Connecting rod, upper part
2. Shim
3. Big end, upper half
4. Big end, lower half
5. Big end

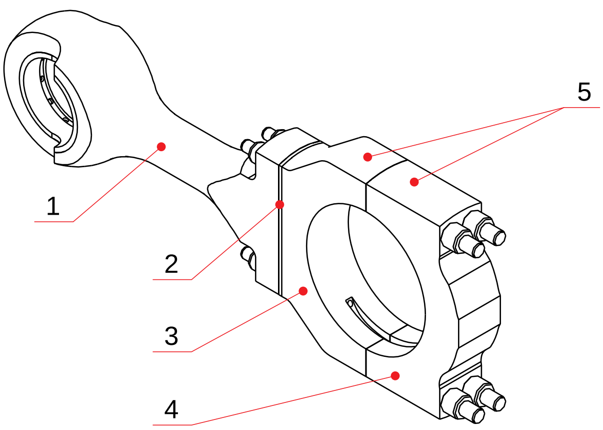
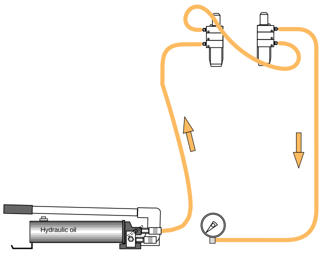


Fig 11-2 4011019601

11.3.2 Removing of piston and upper part of connecting rod for overhaul

1 **Remove both crankcase covers** adjacent to the connecting rod concerned on both side of engine.



DISMANTLING
1. Lift the distance sleeve.
2. Lift the hydraulic cylinder and screws in a one package in pos.
3. Connect hoses, open valve.
4. Tighten the tool assembly, until the piston and cylinder is on the same level, open the nuts by 180°.
5. Close the valve, pump to required pressure. Open the nuts about half a turn.
6. Open the valve slowly and remove the tool.

2 **Remove the cylinder head** according section 12.2.1.

3 **Mount the fastening tool** for cylinder liner 800123, see Fig 10-4.

4 **Remove the anti-polishing ring.** Insert the tool 800009 in the cylinder, by cranking the engine, the piston pushes the anti-polishing ring out, see Fig 11-3.

5 **Clean the threaded hole(s)** in the piston crown and fasten the lifting tool 800012 by using the hexagon screws M12×40 (6).

6 **Turn the crankshaft to the BDC** the cylinder concerned.

7 **Open the upper connection** by lifting the distance sleeves and the hydraulic tools in to position, see Fig 11-3.

8 **Connect the hoses** of the hydraulic pump 800053 and proceed to open the upper connection as described in adjacent figure.

9 **Strain the screws by raising the pressure** to the value stated in the section 07.3 and proceed with opening the nuts.

Piston and connecting rod assembly

6. Screw
7. Securing ring
800009 Dismounting tool for antipolishing ring
800010 Assembly tool for piston
800012 Lifting tool for piston
800013 Clamp device for piston rings
800020 Hydraulic tightening tool for connecting rod nuts

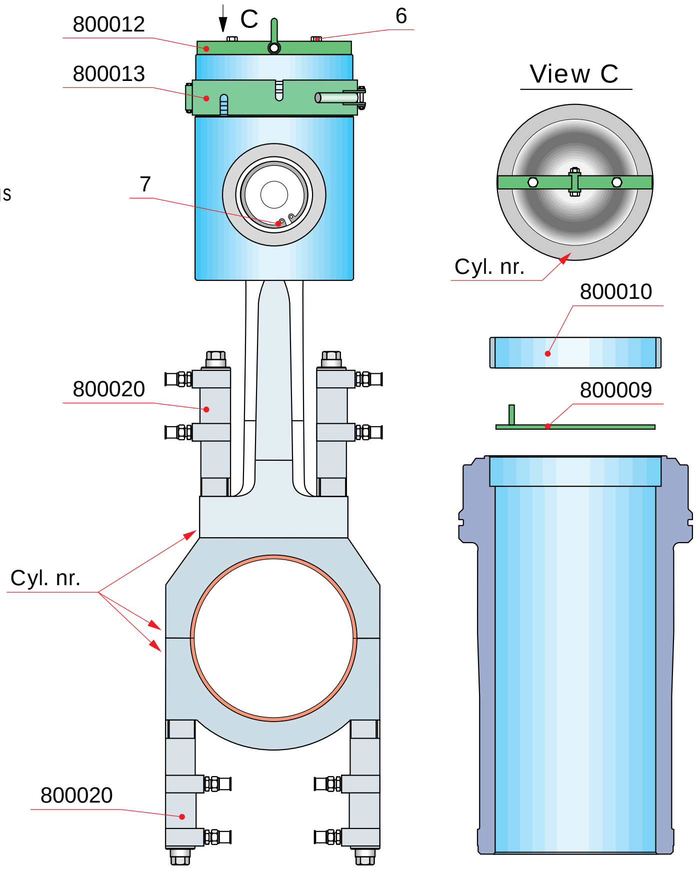


Fig 11-3 4011059601

Caution! **The screws will be overloaded if the maximum hydraulic pressure is exceeded.**
It is recommended to change the screws if maximum hydraulic pressure is exceeded for some reason.

10 **Release the pressure slowly** and disconnect the hoses, unscrew the tightening nuts and remove hydraulic tool as one package.

11 **Remove the nuts.**

12 **Rotate the crank pin** of the cylinder concerned in the TDC.

13 **Separate the upper part (1) from** the big end (5) by lifting the piston.

Support the upper part of the connecting rod to avoid damaging the cylinder liner.

Note! **To avoid damaging the guiding pins the separation of the upper part (1) and the big end (5) should be done aligned.**

14 **Remove the shim (2),** see Fig 11-2.

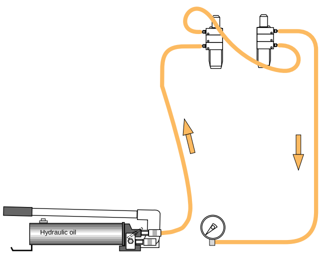
Note! **Do not mix the shims (2) with other connecting rod shims.**

15 **Mount the guiding plug** 800017 in the screw hole on the upper part of the connecting rod, see Fig 11-5.

16 **Lift out the piston and the upper part of connecting rod.**

17 **Repeat the steps above in the other** connecting rod on the same crank pin on an V-engine.

11.3.3 Changing of big end bearings



DISMANTLING
1. Lift the distance sleeve.
2. Lift the hydraulic cylinder and screws in a one package in pos.
3. Connect hoses, open valve.
4. Tighten the tool assembly, until the piston and cylinder is on the same level, open the nuts by 180°.
5. Close the valve, pump to required pressure. Open the nuts about half a turn.
6. Open the valve slowly and remove the tool.

1 **Remove both crankcase covers** adjacent to the connecting rod concerned on both side of engine.

2 **Turn the crankshaft to the BDC** the cylinder concerned.

3 **Open the upper connection** by lifting the distance sleeves and the hydraulic tools in to position, see Fig 11-3.

4 **Connect the hoses** of the hydraulic pump 800053 and proceed to open the upper connection as described in adjacent figure.

5 **Strain the screws by raising the pressure** to the value stated in the section 07.3 and proceed with opening the nuts.

Caution! **The screws will be overloaded if the maximum hydraulic pressure is exceeded.**
It is recommended to change the screws if maximum hydraulic pressure is exceeded for some reason.

6 **Release the pressure slowly** and disconnect the hoses, unscrew the tightening nuts and remove hydraulic tool as one package.

7 **Remove the nuts.**

8 **Rotate the crank pin** of the cylinder concerned in to TDC.

9 **Mount the limiter** 800018 in the lower part of cylinder liner and tighten the screw, see Fig 11-5.

10 **Separate upper part** and big end (5) by turning the crankshaft towards BDC.

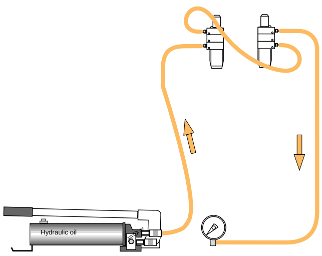
Support the upper part of the connecting rod to avoid damaging the cylinder liner.

Note! **To avoid damaging the guiding pins the separation of the upper part (1) and the big end (5) should be done aligned.**

11 **Remove the shim (2),** see Fig 11-2.

Note! **Do not mix the shims (2) with other connecting rod shims.**

Always when mounting flute or/and the limiter is/are mounted in the crankcase observe extremely cautiousness when using the turning device.



DISMANTLING
1. Lift the distance sleeve.
2. Lift the hydraulic cylinder and screws in a one package in pos.
3. Connect hoses, open valve.
4. Tighten the tool assembly, until the piston and cylinder is on the same level, open the nuts by 180°.
5. Close the valve, pump to required pressure. Open the nuts about half a turn.
6. Open the valve slowly and remove the tool.

12 **Rotate the crankshaft** towards the operating side to the position 55° from TDC by using the turning device.

13 **Mount the mounting support 800102** on the upper stud of the crank case cover, see Fig 11-5. Tighten the nut.

14 **Lift the hydraulic tools** 800020 in to the position.

15 **Connect the hoses** of the hydraulic pump 800053 and proceed to open the upper connection as described in adjacent figure.

16 **Strain the screws by raising the pressure** to the value stated in the section 07.3 and proceed with opening the nuts.

Caution! **The screws will be overloaded if the maximum hydraulic pressure is exceeded.**
It is recommended to change the screws if maximum hydraulic pressure is exceeded for some reason.

17 **Release the pressure slowly** and disconnect the hoses, unscrew the tightening nuts and remove hydraulic tool as one package.

18 **Mount the mounting flute** through the crank case openings on the lower crank case cover studs and tighten the nuts.

19 **Mount the supporting plate** 800099 on the rear side of the engine on the lower crank case cover studs and tighten the nuts, see Fig 11-5.

20 **Remove the nuts.**

21 **Mount the sledge** 800100 in the mounting flute 800098 according to Fig 11-4.

22 **Remove the mounting support** 800102.

23 **Mount the sledge 800101** on the studs and tighten the nuts, see Fig 11-4.

Removing and mounting of big end lower halves

800018 Limiter for piston
800101 Mounting sledge
800100 Mounting sledge

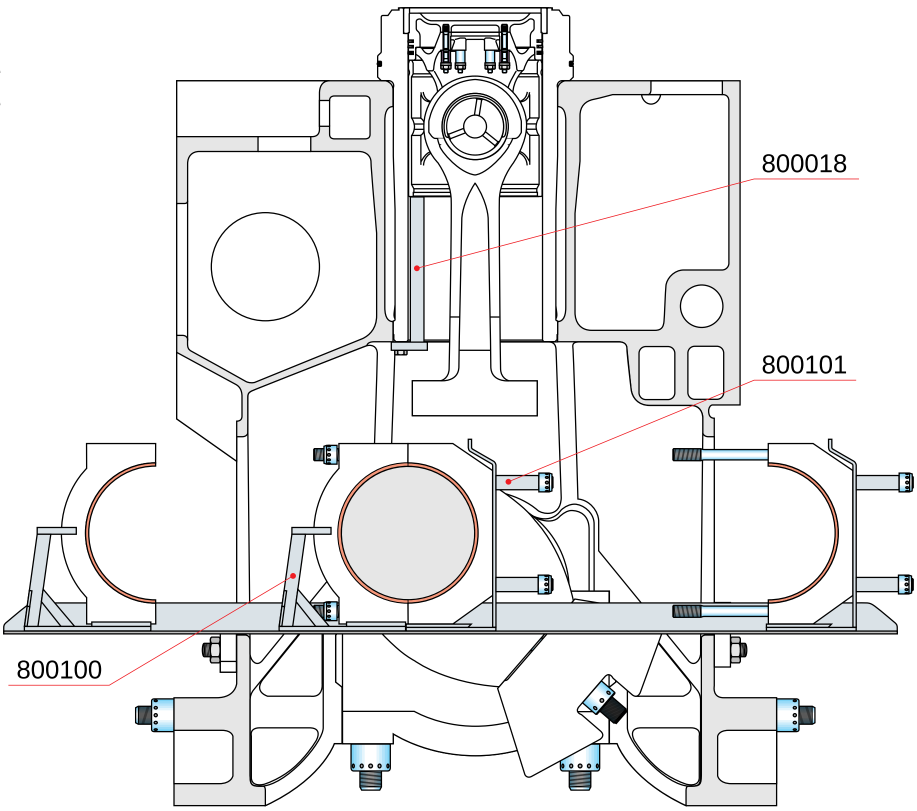


Fig 11-4 4011039601

24 **Pull lower part of the big end bearing cap out** of the crankcase, by using the sledge. Take care not to damage the crank pin. Support the lower half sideways and don't drop it.

25 **Pull the upper part of the big end bearing cap out** of the crankcase rear side of the engine, by using the sledge. Support the upper half sideways and don't drop it.

Note! **Take care not to damage the crank pin or the threads of the studs.**

26 **Remove the mounting flute.**

27 **Cover the crank pin and oil holes** with clean plastic and tape.

28 **For mounting, see section 11.3.5.**

11.3.4 Maintenance of piston, rings and connecting rod bearings

1 **Remove the securing ring (7)** from the gudgeon pin hole in the piston, on the side where the gudgeon pin drawing number is located, by using the pliers 800002.

Note! **Never compress the securing ring more than necessary to remove it from the groove.**

2 **Drive out the gudgeon pin** from the opposite side. In low temperatures the gudgeon pin may stick but will be easily removed after heating the piston to about 30°C.

3 **If the rings and grooves require cleaning, measuring etc.,** remove the piston rings by using the pliers 320D12/6-S7/8. Before removing, note the positions of the rings to ensure mounting in the same grooves. The design of the pliers prevents overstressing of the rings. Using other means may overstress the rings.

4 **Clean all the parts carefully.** Remove the piston rings, and remove burned carbon deposits from the piston and piston ring grooves e.g. by using an old piston ring. Special care should be taken not to damage the piston material. Never use emery cloth on the piston skirt.

The cleaning is facilitated if coked parts are soaked in kerosene or fuel oil. An efficient carbon solvent — e.g. ARDROX No. 668 or similar — should preferably be used to facilitate cleaning of the piston crown. When using chemical cleaning agents, take care not to clean piston skirt with such agents because the phosphate/graphite overlay may be damaged.

5 **Measure the height** of the piston ring grooves, e.g. with an inside micrometer.

6 **Inspect anti-polishing ring.** Turn ring upside down after first period. Change the ring every second period.

When mounting a new cylinder liner, or honing the old liner, all rings are to be replaced by new ones, acc. to chapter 04.

7 **Check the gudgeon pin and big end bearing clearances** by measuring the pin diameters and assembled bearing bores separately. When measuring the big end bearing bore all the connecting rod screws (upper and lower) must be tightened to the stated pressure.
a) Big end bearings of trimetal type can be used until the overlay is worn through. When the underlaying nickel barrier of the lining material is exposed the bearing must be replaced.
b) Wear of bimetal bearing shells can be settled by measuring thickness. For this purpose a ball anvil micrometer should be used.

For bimetal-type bearing, the wear limits given in chapter 06.2 must be applied.

When replacing a big end bearing both the upper and the lower bearing shell must be renewed.
Only bearings of same type to be used as a pair.

Mark new bearings with the bearing number.

Note! **It is very important that the bearing shells are mounted straight.**

11.3.5 Assembling and mounting of piston and connecting rod

1 **Lubricate the gudgeon pin,** and mount it from the same side from where it was removed, with the end marked with the drawing number in the same direction. The cylinder number is stamped on the piston crown and connecting rod, Fig 11-3. When changing the piston, mark the new piston with the same cylinder number in the same place as on the replaced one.

At low temperatures, the gudgeon pin may stick but will be easily fitted after heating the piston to about 30°C, e.g. in oil.

2 **Mount the securing ring (7).**

Note! **Never compress the securing ring more than necessary to fit into the groove. If the ring is loose in its groove after mounting, it must be replaced by a new one.**

3 **Take off the protecting tape** from the crank pin oil holes and lubricate the crank pin with clean engine oil.

Always when mounting flute or/and the limiter is/are mounted in the crankcase observe extremely cautiousness when using the turning device.

4 **Rotate the crankshaft** by using the turning device manually until the big end halves can be placed on the crank pin.

5 **Mount the mounting flute** through the crank case openings on the crankcase cover lower studs and tighten the nuts, see Fig 11-5.

Mounting tools for connecting rod

800017 Guiding plug
800018 Limiter for piston
800020 Hydraulic tool
800098 Mounting flute
800099 Supporting plate
800102 Mounting support

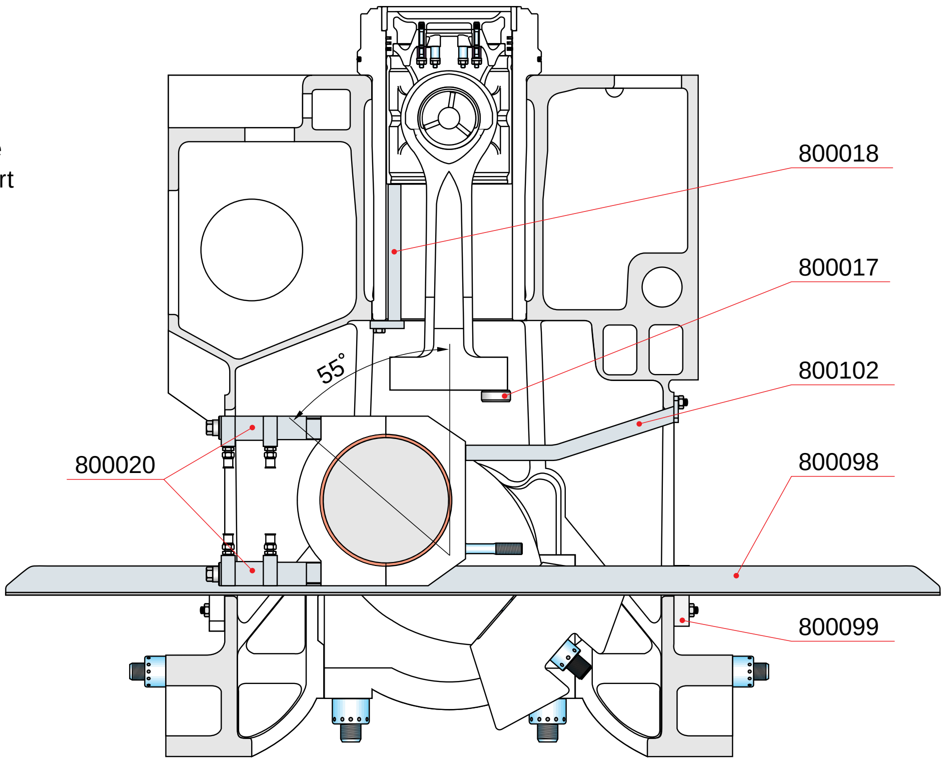


Fig 11-5 4011029601

Note! **The guiding pins between upper part of connecting rod and big end should be towards free end.**

6 **Clean the big end upper half carefully.** Lubricate the bearing surface and back side of the bearing shell with oil. Mount the shell, so that the lug guides in its groove.

Note! **It is very important that the bearing shells are mounted straight.**

7 **Lift the upper big end half** with the sledge in the mounting flute.

8 **Push the upper big end half** carefully against the crankshaft, take care not to damage the crank pin.

9 **Clean the big end lower half carefully.** Lubricate the bearing surface and back side of the bearing shell with oil. Mount the shell, so that the lug guides in its groove.

Note! **It is very important that the bearing shells are mounted straight.**

10 **Lift the big end lower half** on the sledge.

11 **Push the lower big end half carefully** against the crankshaft and check that guiding pins are in right position, take care not to damage the crank pin.

12 **Mount the nuts** and tighten by hands.

13 **Remove the sledge** from operating side of the engine.

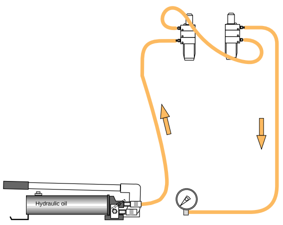
14 **Remove the sledge from** rear side of the engine by opening the nuts.

15 **Mount the mounting support 800102** on the upper crank case stud, see Fig 11-5. Tighten the nut.

16 **Remove the mounting flute** and supporting plate by opening nuts.

17 **Lift the hydraulic tools** 800020 in to the position.

18 **Connect the hoses** of the hydraulic pump 800053 and proceed with tightening of the nuts in **two steps** as described in adjacent figure. Tightening torques see section 07.3.



REASSEMBLING
1. Lift the distance sleeve.
2. Lift the hydraulic cylinder and screws in a one package in pos.
3. Connect hoses, open valve.
4. Tighten the tool assembly, until the piston and cylinder is on the same level.
5. Close the valve, pump to required pressure. Tighten the nuts. Release the pressure slowly.
6. Repeat steps 4, and 5.
7. Open the valve slowly and remove the tool.

Caution! **The screws will be overloaded if the maximum hydraulic pressure is exceeded.**
It is recommended to change the screws if maximum hydraulic pressure is exceeded for some reason.

19 **Fasten the lifting tool 800012 to the piston crown** by using hexagon socket head screws M12×40 (6), see Fig 11-3.

20 **Lift the piston and upper part of connecting rod.**

21 **Mount the piston rings** by using the pliers 800001. If rings are reused, take care not to turn them upside down. The rings should be placed with gaps located 120° in relation to each other. The marking “TOP” to be upwards.

Piston ring locations shown in the table below.

Groove #	Marking near the ring gap
I	“TOP GROOVE I”
II	“TOP C99 GROOVE II”
III	(oil scraper ring)

22 **Lubricate the piston** and place the clamp device for piston rings, 800013, around the piston, checking that the piston rings slide into their grooves.

23 **Mount the guiding plug** 800017 in the screw hole on the upper part of the connecting rod, see Fig 11-5.

24 **Mount the limiter** 800018 for piston inside the cylinder liner.

25 **Rotate the crank pin** of the cylinder concerned in the BDC by using turning device.

Note! **Observe extremely cautiousness always when upper part of the connecting rod and big end are dismantled, when cranking the engine.**

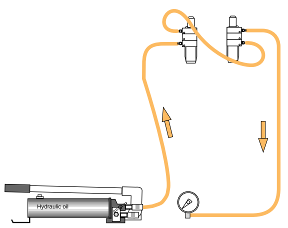
26 **Place the mounting tool 800103** into the cylinder liner.

27 **Lower the piston/connecting rod upper part** carefully into the cylinder liner.

28 **Turn the lower part (5)** of the connecting rod straight upwards. Mount the shim (2).

29 **Rotate the crank pin** of the cylinder concerned in the TDC.

Check that guiding pins are in right position.



REASSEMBLING
1. Lift the distance sleeve.
2. Lift the hydraulic cylinder and screws in a one package in pos.
3. Connect hoses, open valve.
4. Tighten the tool assembly, until the piston and cylinder is on the same level.
5. Close the valve, pump to required pressure. Tighten the nuts. Release the pressure slowly.
6. Repeat steps 4, and 5.
7. Open the valve slowly and remove the tool.

30 **Place the upper part of the connecting rod** and the big end, take care not to damage the studs and threads. Remove the limiter.

31 **Turn the crankshaft counter-clockwise** until the nuts can be mounted. Remove the mounting tools.

32 **Assemble the hydraulic tools,** hoses and proceed with tightening of the nuts in **two steps** as described in adjacent figure. Tightening torques see section 07.3.

33 **Mount the anti-polishing ring.**

Note! **Check that the connecting rod is movable axially after tightening.**

11B. Piston Overhaul

11B.1 General

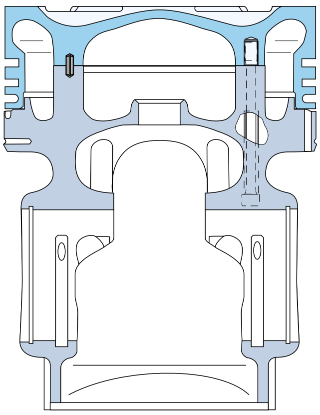
All the engines mentioned in the table below are fitted with composite type pistons.

Manufacturer/ type marked in Instruction Manual	Fastening screws for the crown	W32	32LN	W32DF	W34SG
KS / (type 1)	Four (4) M16 screws	X(1)	X		X
Mahle / (type 2)	Two (2) M22 screws	X	X	X	
Wecometal / (type 3)	Four (4) M14 screws	X	X		

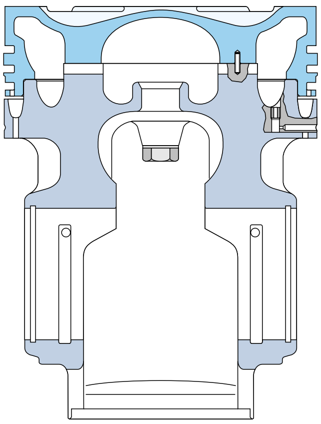
Note! **(1) On W32 KS-piston crown, there is only an inner support surface.**

For these pistons it is necessary to make more extensive inspections at every piston overhaul.

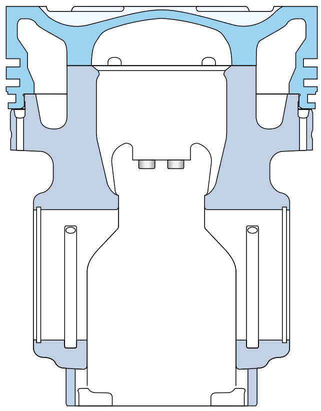
Pistons



Piston of type 1



Piston of type 2



Piston of type 3

Fig 11B-1 321180200112

11B.2 Pistons

The piston assembly must be dismantled for inspection of mating surfaces between piston skirt and piston crown and for inspection and cleaning of cooling oil spaces.

11B.3 Piston crown

11B.3.1 Visual inspection

The combustion space must be checked for corrosion and/or burning marks.

- If marks deeper than 2 mm are found the piston crown should be replaced.

Deposits in the cooling oil space thicker than 0.5 mm is an indication of contaminated lubricating oil. Such extensive deposit layers can cause overheating of the piston crown.

11B.3.2 Crack detection test

A crack detection test by use of liquid penetrant or, preferably, magnetic particle detection method should be performed, comprising all surfaces.

- No cracks are allowed.

11B.3.3 Measurements

Piston ring grooves to be measured regarding wear in accordance with normal practice.

Measurements of the distance between the inner and outer support surfaces must be made, see piston type specific instructions below. Please note that a special measuring tool has been designed for this measurement.

11B.3.4 Reconditioning

Please contact Wärtsilä for reconditioning of piston crowns.

No repair welding is allowed.

11B.4 Piston skirt

11B.4.1 Visual inspection

The running surface of the skirt is coated with a graphite-phosphate layer. Consequently cleaning with use of emery cloth or other abrasives is not allowed.

- Excessive wear marks and/or scoring/seizure marks on the running surface may require replacement of the skirt.

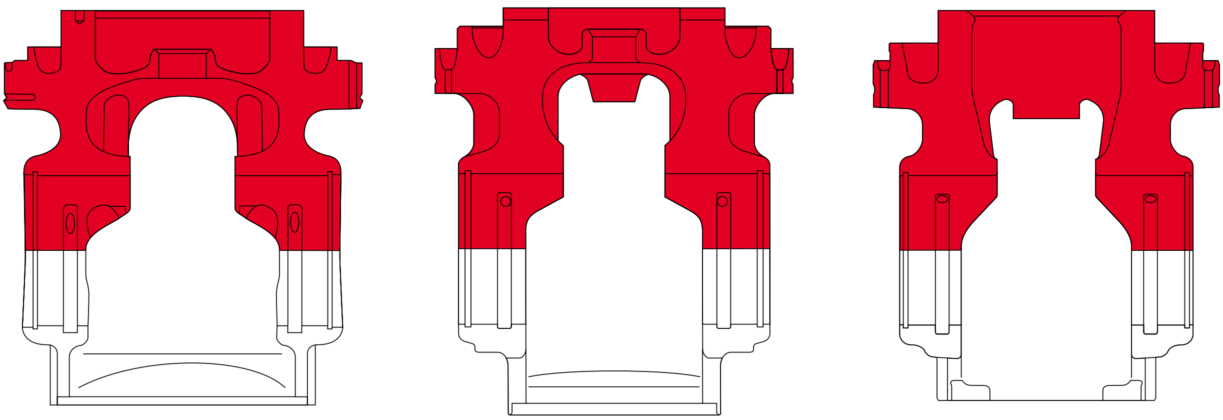
11B.4.2 Support surfaces

Assessment of wear of the support surfaces to be made by measurement of the distance between the inner and outer support surfaces, see measurement record 3211V025GB.

11B.4.3 Crack detection test

Crack detection test of the entire piston skirt with use of liquid penetrant must be made. Special attention must in this regard be given to the upper part of the piston skirt and to the gudgeon pin bore with its supports to the upper part and to the circumferential part of the skirt, see Fig 11B-2.

Piston skirt



Piston of type 1 Piston of type 2 Piston of type 3

Fig 11B-2 321180200112

- As piston skirts are cast pieces a crack detection test may also give indications for surface “defects” which are normal in castings. Indications exceeding 5 mm in length should be examined more in detail. If a crack is confirmed, the piston skirt must be replaced with a new or reconditioned one.

11B.4.4 Measuring of piston crown and piston skirt

Measurements of the distance between the inner and outer support surfaces must be measured according to the measurement record 3211V025GB.

11B.4.5 Assembling of pistons (All types)

If the inspections are resulting in a conclusion that a piston can be reused **the same pair of crown and skirt must be assembled together again**.

It is not allowed to mix partly worn but reusable crowns and skirts!

When assembling a piston crown to a piston skirt follow tightening procedure mentioned in chapter 07.

12. Cylinder Head with Valves

12.1 General description

Data and dimensions
Material: nodular cast iron
Weight: 430 kg
Water space
- test pressure: 10 bar
Starting air space
- test pressure: 60 bar

The cylinder heads are cast of nodular cast iron. Each head includes two inlet valves, two exhaust valves, a centrally located injection valve and an indicator valve. The cylinder heads are individually tightened to the cylinder liner with four studs and hydraulically tightened nuts. A metallic gasket is sealing between the cylinder liner and the cylinder head. The combustion air, exhaust gas and water channels are connected to a common multi-duct, which is connected to the cylinder head by six screws.

The four screw and box-cone design is a traditional and well proven design for cylinder heads. The design eases maintenance and allows the design of large channels for combustion air and exhaust gases. In a heavy fuel engine the correct material temperatures are a crucial factor to ensure long lifetime of the components being in contact with combustion gases. Efficient cooling and a rigid design is best achieved with the “double deck” design in which the flame plate is relatively thin and the mechanical load is transferred to the strong intermediate deck. The most sensitive areas of the cylinder head are cooled by drilled cooling channels optimized to distribute the water flow evenly around valves and the centrally located fuel injector.

The injection valve is described in chapter 16.

Cylinder head assembly

1. Bearing bracket
2. Rocker arm
3. Yoke for valves
4. Yoke for injection valve
5. Cylinder head
6. Rotocap
7. Screws for connection piece
8. Exhaust valve seat
9. Exhaust valve
10. Inlet valve
11. Inlet valve seat
12. Indicator valve
13. Temperature sensor

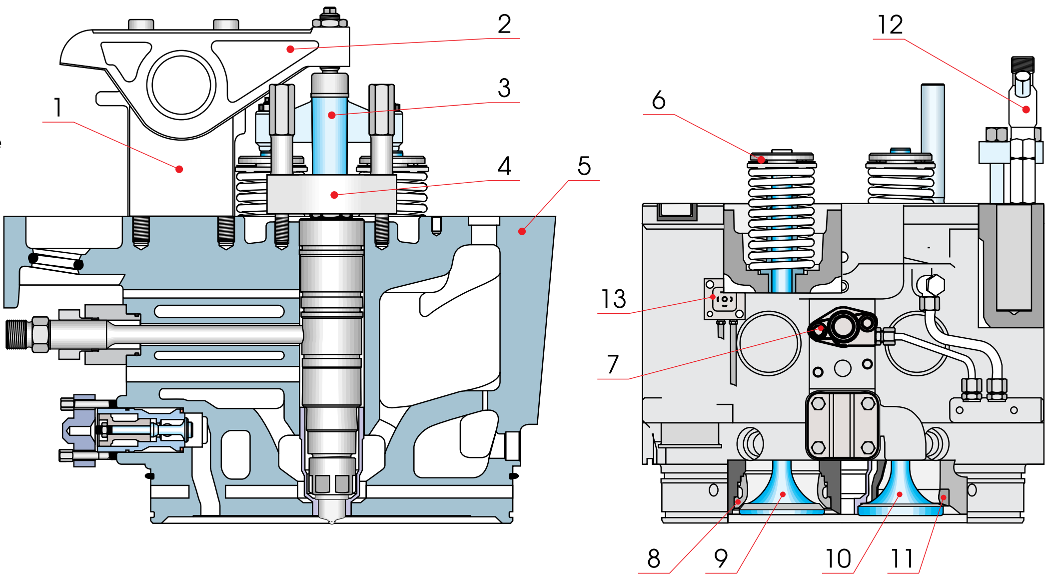


Fig 12-1 4012019701

12.1.1 Functions

The flame plate of the cylinder head is a part of the combustion chamber. During the combustion, the flame plate is exposed to high pressures and high temperatures. Combustion air is led from the air receiver through the multiduct and the cylinder head inlet channel into the cylinder. The air flow is governed by two inlet valves in the flame plate. In a similar way, the exhaust gas is led from the cylinder through the cylinder head exhaust channel and the multiduct to the exhaust manifold. The gas flow is governed by two exhaust valves.

The multi-orifice injection valve, as well as injection valve sleeve, is centrally mounted in the cylinder head. The injection valve sleeve holds the injection valve in position and separates the injection valve from the cooling water.

Each cylinder head is individually cooled by a water flow entering the cylinder head from the cylinder jacket through one single bore. There are drilled cooling passages to the exhaust valve seats. The cooling water is collected to a single flow after passing the flame plate and the seat rings. The cooling water flows out from the cylinder head direct to the multiduct. Any possible air or gas in the cooling water is vented from the top of the multiduct.

The valve mechanism is lubricated from the lube oil system. The oil is led through a pipe from the valve tappet guide in the multihousing to the rocker arm bracket. All other flows in the cylinder head are through drilling's.

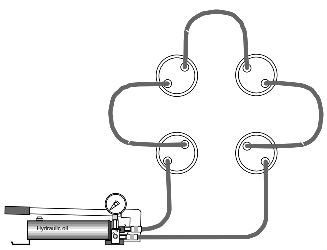
The controlled leaks of the injection valve is returned through the protection pipe.

The fuel pipe is also provided with protection against hazardous leaks from the high pressure connection stud.

12.2 Removing and mounting of the cylinder head

12.2.1 Removing of the cylinder head

DISMANTLING
1. Mount the cylinders by hand
2. Connect hoses, open valve.
   Tighten cylinders by hand.



3. Turn the cylinders 180°
   counter -clockwise.
4. Close valve, rise pressure.
5. Open the nut about half a turn.
6. Open release valve, remove tool.

1 **Drain the cooling water.**

2 **Open the indicator valves.**

3 **Remove the side covers.**

4 **Remove the cylinder head cover.**

5 **Turn the engine until both the inlet and exhaust valves are closed** and remove the valve rocker arm bracket and the push rods.

6 **Remove the fastening screws of the multiduct.**

7 **Remove the injection pipe** according to section 16.2. Protect all pipe connections.

8 **Remove the connector** of the temperature sensor.

9 **Put on the distance sleeves** and hydraulic cylinders 800047 and proceed with opening of cylinder head nuts.

10 **Remove the cylinder head nuts.**

11 **Apply the lifting tool** 800026 and lift off the cylinder head. **Note! There is a risk of the cylinder liner coming loose which, in such a case, must be checked.**

12 **Cover the cylinder opening** with a piece of plywood or something similar. Cover the air, fuel and oil connections with suitable plugs.

Lifting of cylinder head

800 026 Lifting tool for cylinder head

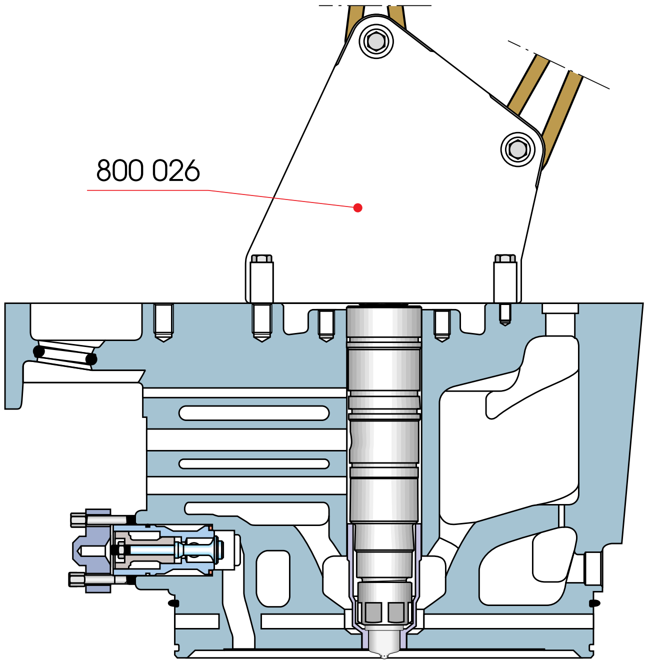


Fig 12-2 4012029601

12.2.2 General maintenance of the cylinder head

General maintenance of the cylinder head includes a thorough visual check, including water cooling spaces. Possible scale formation in cooling spaces can disturb the cooling effect and therefore it has to be cleaned, see chapter 02.

Combustion spaces must be inspected carefully for possible wear. Valve seats and the injection valve sleeve should be inspected for possible water leakage and replaced if necessary.

Valve guides should be checked and replaced if worn. O-rings must be replaced with new ones at every overhaul.

Sealing surfaces between the cylinder head and cylinder liner should be inspected and reconditioned if necessary.

12.2.3 Mounting of the cylinder head

1 **Clean the sealing surfaces** and put a new cylinder head gasket, new multiduct gasket and new O-rings for the cooling water jacket, push rod protecting pipes and sliding connections.

Note! **It is very important to clean the sealing surfaces of the multiduct carefully and renew the gasket, otherwise there is a great risk that cooling water will leak into the cylinder.**

2 **Lubricate the O-ring sealing surfaces with grease.**

3 **Fit the push rod protecting pipes** and the push rods.

4 **Apply the lifting tool** 800026 to the cylinder head.

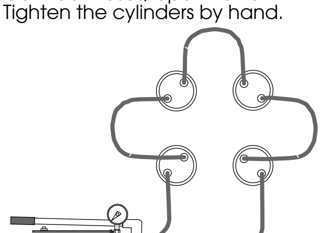
5 **Lift on the cylinder head.** Pay special attention to the multiduct gasket and sliding connections that they are intact and correctly mounted.

6 **Screw on the cylinder head nuts.**

7 **Connect the multiduct** and tighten the screws according to the torque in section 07.1. **Note! Tighten the screws in mentioned order.**

8 **Put on the distance sleeves,** mount the hydraulic cylinders 800047 and proceed with tightening of the cylinder head nuts. Tightening in two steps is recommended, see section 07.3.

REASSEMBLING
1. Mount the nuts, attach the distance sleeve.
   Mount the cylinders by hand.
2. Connect hoses, open valve.
3. Tighten the cylinders by hand.



4. Close the valve and pump pressure to the stated value.
5. Turn the nuts until close contact to face.
6. Open the valve
7. Repeat steps 4, 5 and 6
8. Remove the tool set.

9 **Mount the injection pipe** according to section 16.2.

10 **Connect the connector** of the temperature sensor and lock it with the screw.

11 **Fit the rocker arm bracket.** Tighten screws to the torque given in section 07.1.

12 **Adjust the valve clearance,** see section 12.2.4. See chapter 06. for clearances.

13 **Put on the cylinder head cover** and the side cover.

14 **Before starting, fill the engine cooling water system.** Turn the crankshaft two revolutions, with the indicator valves open.

12.2.4 Adjusting valve clearance and yoke

1 **Turn the crankshaft to TDC at ignition** for the cylinder concerned.

2 **Loosen the counter nuts** of the adjusting screws on the rocker arm (2) as well as on the yoke (4), and turn the adjusting screws in counter-clockwise direction to provide ample clearance.

3 **Press the fixed end of the yoke against the valve stem** by pressing down the adjustable end. Screw down the adjusting screw (3) until it touches the valve end and note the position of the spanner (pos. a). Now press down the fixed end. Keep on screwing down while the yoke tilts, until the guide clearance is on the other side and the fixed end of the yoke starts lifting from the valve stem. Note the position of the spanner (b).

4 **Turn the adjusting screw** counter-clockwise to the middle position between "a" and "b", i.e. "c", and lock the counter nut of the adjusting screw.

5 **Put a feeler gauge** corresponding to the valve clearance between the surface of the yoke and the shoe at the rocker arm. Tighten the adjusting screw (1) until the feeler gauge can be moved to and fro only with slight force. Hold the adjusting screw and tighten the counter nut. Check that the clearance has not changed while tightening.

Adjusting valve clearance

1. Adjusting screw for rocker arm
2. Counter nut
3. Adjusting screw for valve yoke
4. Counter nut

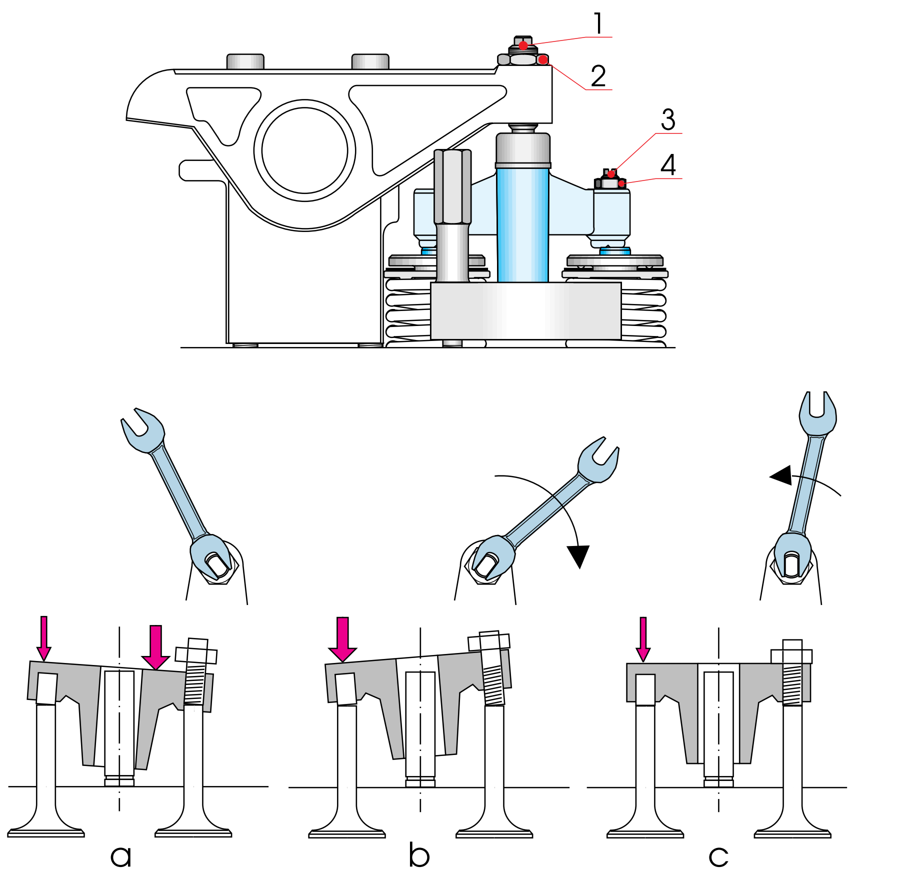


Fig 12-3 2012539314

12.3 Exhaust and inlet valves and seat rings

12.3.1 General description

Data and dimensions
Material: High quality steel
Diameter
-inlet valve: 112 mm
-exhaust valve: 107 mm

Valve seat ring
Material: High quality steel
Angle
- inlet seat: 20°
- exhaust seat 40°

The cylinder head has four valves fitted, two inlet valves and two exhaust valves. The inlet valves are bigger than the exhaust valves.

The valves move in cast iron guides, which are press fitted in the cylinder head and can be replaced. The valve guides have an O-ring (sealing against the valve stem), which is located at the top of the guide bore.

The valves are provided with one valve spring per valve and valve rotating devices or valve spring retainers.

Valve seat rings are fitted in the cylinder head for both inlet and exhaust valves. The exhaust valve seat rings are cooled and hence provided with two O-rings.

12.3.2 Dismantling valves

1 **Fit the tool** 800027 according to Fig 12-4.

2 **Compress the springs** about 15-20 mm by the screw.

3 **Knock at the centre of the valve discs** with a soft piece of wood, plastic hammer or similar, whereby the valve cotters come loose and can be removed.

4 **Unload the tool.**

5 **Spring retainers and springs can now be removed.**

Tool assembly for dismantling valves

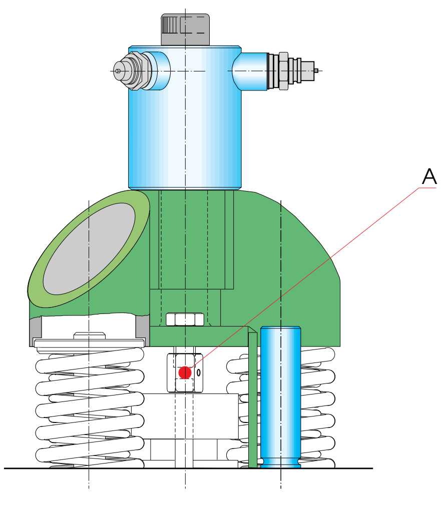


Fig 12-4 2012529312

6 **Note the marks of the valves** or mark them so they can be re-installed into the same guide if they are in good condition.

12.3.3 Checking and reconditioning of valves and seats

1 **Clean the valves,** seats, ducts and guides as well as the underside of the cylinder head.

2 **Control the burning-off on the exhaust valve disc** according to Fig 12-5. The measure "Y" should be more than 7.8 mm (nominal 8.8 mm) and measure "Z" should be less than 1 mm. If the measures exceed these limits the valve must be replaced.

Control of burning-off on valve

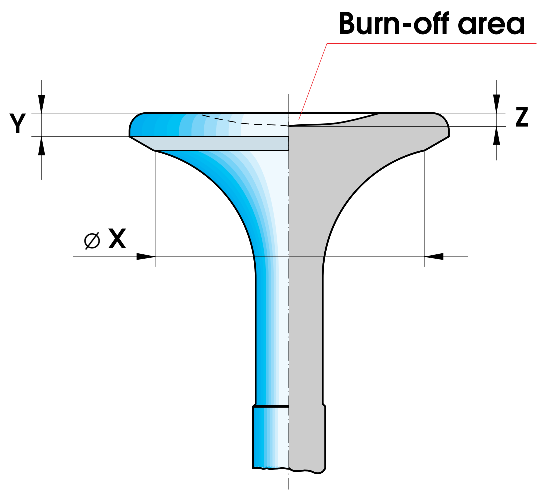


Fig 12-5 4012049706

3 **Reconditioning of inlet valve and valve seat ring** is recommended to be done by grinding or by machining. If there is only slight pitting, lapping is adequate. Valve and seat ring grinding, see section 12.3.5.

4 **Reconditioning of exhaust valve and valve seat ring** has to be done by grinding or by machining. If the sealing faces are bright or if there is a coherent sealing face, grinding is not necessary. Valve and seat ring grinding, see section 12.3.5.

Note! **If blow-by has occurred, the O-ring for the corresponding valve seat ring must be changed. Blow-by increases the temperature and the O-ring is "burned", which will result in water leakage into the cylinder.**

5 **Before grinding, check the valve stem clearance.** If the clearance is too large, measure the stem and guide, and change the worn part; the valve guide can be pressed out. Check the bore in the cylinder head. When refitting, cooling in with liquid nitrogen is recommended, but pressing in with oil lubrication can also be accepted. After fitting in, check the guide bore and calibrate, if necessary.

12.3.4 Lapping of inlet valves

If there are slight pits on the sealing faces they can be lapped by hand:

Note! **Lapping is not allowed for exhaust valves.**

1 **Fit the turning tool** to the valve.

2 **Apply a thin layer of lapping compound** to the sealing surface of the valve; No.1 for coarse lapping, No.3 for fine lapping.

3 **Rotate the valve to and fro** towards the seat with the turning tool 800028. Lift the valve from the seat at intervals while lapping.

4 **Remove the smallest possible amount of material** because the sealing faces have hardened during operation and are valuable. It is not necessary to grind off all pits.

5 **Clean the valve and seat** carefully after lapping.

12.3.5 Machine grinding of exhaust and inlet valves

Note! **The valve should be cooled by water during the grinding.**

1 **Seat face of the inlet valve:** The seat angle of the inlet valve is 20° with a tolerance of 0°- +0.10°. Minimum allowable inner diameter “X” of the seat face after grinding is 92 mm, see Fig 12-5; after that, the valve must be replaced by a new one.

2 **Seat face of the exhaust valve:** The seat angle of the exhaust valve is 40° with a tolerance of 0.10°- +0.20° to achieve contact to the seat ring at the periphery of the valve. Minimum allowable inner diameter “X” of the seat face after grinding is 82 mm, see Fig 12-5; after that, the valve must be replaced by a new one.

3 **Seat ring for the inlet valve:** The seat angle of the inlet valve seat ring is 20° with a tolerance of -0.30°- -0.10°. The seat can be ground until the outer seat diameter is 113 mm; after that, the ring must be replaced by a new one.

4 **Seat ring for the exhaust valve:** The seat angle of the exhaust valve seat ring is 40° with a tolerance of +0.20°-0°. The seat can be ground until the outer diameter is 110 mm; after that, the ring must be replaced by a new one.

Note! **After grinding a light lapping is recommended to provide contact between valve and seat with marking colour.**

12.3.6 Change of seat ring

12.3.6.1 Removal of the old ring

The exhaust seat ring can most conveniently be removed hydraulically by using tool 800110 which can be ordered from the engine manufacturer. In case the special tool is not available a scrapped valve can be used.

1 **Fit a scrapped valve to the seat** and weld it to the seat by means of electric beam welding. Preferably the valve disc should be machined to a diameter 95-100 mm to get a better welding.

2 **Press or knock out the ring** but be careful not to damage the valve guide.

12.3.6.2 Fitting a new inlet valve seat ring

1 **Check the bore diameter** in the cylinder head, see section 06.2.

2 **The ring can be assembled** by freezing in with liquid nitrogen of -190°C, the cylinder head temperature being min. 20°C, or by pressing in with a guided arbor.

3 **Check the eccentricity** of the sealing face in relation to the valve guide, and if it exceeds 0.1 mm, the seat surface must be ground in a seat grinding machine.

12.3.6.3 Fitting a new exhaust valve seat ring

1 **Clean the bore carefully** with a grit 400 or finer emery cloth.

2 **Check the bore diameter in the cylinder head,** see section 06.2 in this manual.

3 **Heat up the entire cylinder head** to 100°C by means of either steam heating, e.g. put the cylinder head into a closed box, or a gas burner.

4 **Cool the seat ring** to about -75°C prior to fitting.

Note! **It is important that the entire cylinder head is heated up, not only the seat bore.**

5 **Mount the O-rings** in the cylinder head bores.

6 **Mount the exhaust valve seat** by using one of following methods:

- Put the seat rings into a guiding bush and press in the seat with a guided arbor. A special tool 800148 is also available. This tool can be ordered from the engine manufacturer.
- Insert the seat ring by using an exhaust valve. Knock on the valve until the seat ring is correctly seated.

Note! **Mounting of a exhaust valve seat ring should be done carefully so that the seat ring is correctly seated.**

7 **Check the eccentricity of the sealing face** in relation to the valve guide, and if it exceeds 0.1 mm, the seat surface should be ground in a seat grinding machine.

8 **Pressure test the cylinder head water side before mounting** with a test pressure (800109) of 10 bar if possible.

12.3.7 Reassembling of the engine valves

1 **Check the valve springs** for cracks, corrosion or wear marks, and if any, replace the springs by new ones.

2 **Put new seal rings** in the valve guides.

3 **Lubricate the valve stems** with engine oil.

4 **Put in the valves** and check for free movement.

5 **Put on the springs** and rotators. Replace the valve rotators if they are worn or damaged.

6 **Compress the springs** with the tool set.

7 **Put in the valve cotters** and unload the springs.

8 **Check that the valve cotters fit properly.**

9 **Check function of the valve rotators** by putting a mark on the valve disc and a corresponding mark on the cylinder head. Hit gently on the valve stem by using a non-recoiling hammer to check the rotation.

12.4 Indicator valve

12.4.1 Operation and maintenance of the indicator valve

The inside construction of the indicator valve is such that the pressure in the cylinder tightens it. Consequently the force needed to close the valve is relatively low. The valve has a left-handed screw and is opened and closed respectively as follows, Fig 12-6. Use the T-handle wrench 800031 to open and close the indicator valve.

1 **When starting the engine** the indicator valves should be closed using only so weak a force that the sealing surfaces go together. The pressure of the cylinder will push them tightly together.

2 **When stopping the engine,** the indicator valves should be opened only half a turn. Then the tightening caused by a temperature decrease cannot have an effect.

3 **When opening the indicator valve** for measuring the cylinder pressure, tightening to open position by force must be avoided.

4 **When closing the indicator valve** after measuring the cylinder pressure, only a weak torque is needed. A so called “finger torque” is usually enough.

5 **Add a high temperature lubricant** (up to 1000°C) to the valve stem threads when you feel that it is not moving easily.

Use only the right T-handle wrench to open and close the indicator valve.

Open and close indicator valve

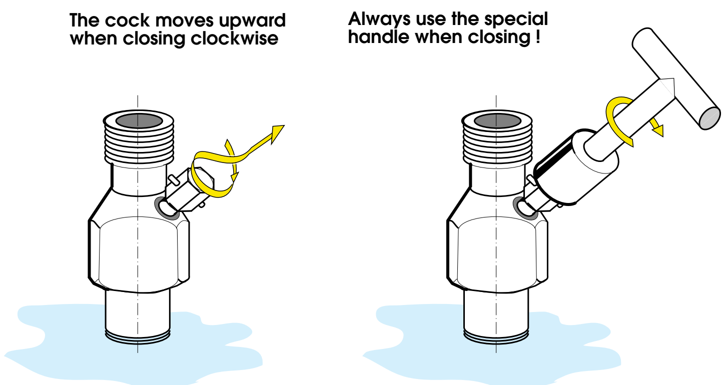


Fig 12-6 3212558935

12.4.2 Pf “Maximum firing pressure”, measured at the indicator valve

The Pf “Maximum firing pressure” has to be measured as a mean value of at least 32 cycles. It is recommended to measure the Pf by using Kistler Engine tester type 2507A or 2515A (848033) and sensor type 7613B or 7613C. Operation and adjustments of the amplifier, see the tester manual.

12.A. Testing of cylinder tightness

12.A.1 Testing

A tool can be used for control of cylinder and valve tightness.
Note! Should be done immediately after engine stop.

1 **Turn the piston to TDC** (all valves closed) for the cylinder concerned.

12.A.1.1 Connecting of the tool for Wärtsilä 20/32 and Vasa 32

1 **Connect the tool** (848020, Wärtsilä 20), (800064, Wärtsilä 32), (848020, Vasa 32) to the open indicator valve. Continue with section 12.A.1.4.

12.A.1.2 Connecting of the tool for Wärtsilä 34SG

1 **Remove the cover plate ,** ignition coil and the spark plug extension and other necessary components. See section 12.2.

2 **Remove the spark plug,** mount the distance sleeve 3V84H85 (848052) with seal ring and tighten to the stated torque.

3 **Connect the pressure gauge and valve assembly** to the distance sleeve.

4 **Install the tool** (848020) to the cylinder head. Continue with section 12.A.1.4.

12.A.1.3 Connecting of the tool for Wärtsilä 32DF

1 **Remove injection valve** with neccessary pipes. See section 12.2.

2 **Assembly the distance sleeves** 3V84H85 (848052) and 2V84H97 (848061) with necessary seals.

3 **Connect the pressure gauge and valve assembly** to the distance sleeves.

4 **Install the tool** (848020) to the cylinder head. Continue with section 12.A.1.4.

Testing tool of cylinder tightness

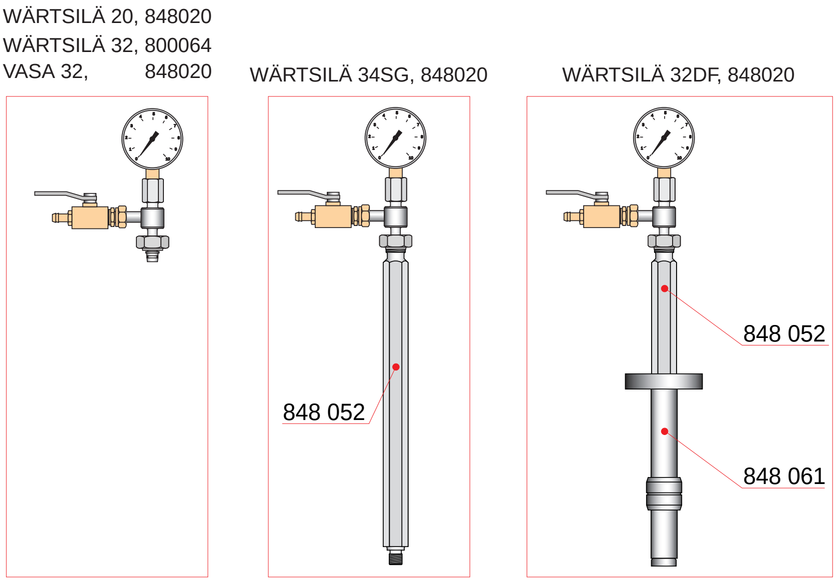


Fig A-1 321260200142

12.A.1.4 Measurement

1 **Connect air to the tool with a pressure of 6-7 bar** (= normal working air pressure). Open the valve on the tool and record the pressure.

2 **Close the valve.** Measure the time in seconds it takes for the pressure dropping to 0.5 bar.

- If the pressure from the beginning was 6 bar and it takes more than 10 sec. for the pressure to drop to 0.5 bar, the result is acceptable.
- If the pressure drops directly to 0 bar, it is possible that one or more valves are sticking or the valve(s) are burnt.
  A sticking valve can be found from the immobility of the valve when the engine is turned.
  A burnt valve can normally be seen from the exhaust temperature. If the valve clearance is zero that would also cause an direct pressure drop.
- Carbon particles trapped between the valve and the seat when the engine is stopped could also prevent the valve to close properly thus causing a direct pressure drop. If that is suspected, the engine should be run for a few minutes and after that a new check of the same cylinder.
- If a blow-by between the cylinder liner and piston is suspected e.g. from fast fouling of filters or high crankcase pressure, it is best to take readings of the complete engine and make a comparison.
  For example: From a six cyl. engine you get a serial: 12, 17, 15,

4, 19 and 18 seconds.
This shows that cyl.no.4 is the one to be suspected for a blow-by.
The test can be verified by listening for leaking sounds inside crankcase during testing.

- If the time is limited to overhaul only one piston, it is recommended to dismantle the worst measured blow-by piston for inspection. The result of inspection gives a hint of general engine condition.
- When re-testing the cylinder after an overhaul a rapid pressure drop can be observed. The reason for this is because the running in of piston rings is not yet performed.

Note! **Keep pre-lubricating pump running during test.**

Note! **The turning gear should be engaged during test.**

- In general, the location of leakage can be found by listening when the air valve is open.

Attention! **A general condition of engine is indicated with the test device, but more important is the operation data records.**
The overhauls must be made according to recommended overhaul intervals and not only when the pressure test shows a big blow-by.

13. Camshaft Driving Gear

13.1 General description

The camshaft is driven by the crankshaft through a gearing. The gearing consists of a gear wheel ring (6), which is splitted and fixed to a flange on the crankshaft by the axial screws (26) and two intermediate gears (3 and 5) and a camshaft driving gear (1), see Fig 13-1.

The bearing pieces of the intermediate wheels are journalled in the engine block. The camshaft driving wheel (1) is fixed between camshaft extension piece (2) and extension piece (8) by axial screws (11). For the speed governor drive a helical gear wheel (13) is located at the end of the camshaft. Lube oil nozzles provide for lubrication and cooling of the gearing.

The camshaft rotates with half of the engine speed in the same direction as the engine.

Camshaft driving gear

1. Drive gear for camshaft
3. Bigger intermediate gear wheel for camshaft drive
5. Smaller intermediate gear wheel for camshaft drive
6. Gear wheel for crankshaft

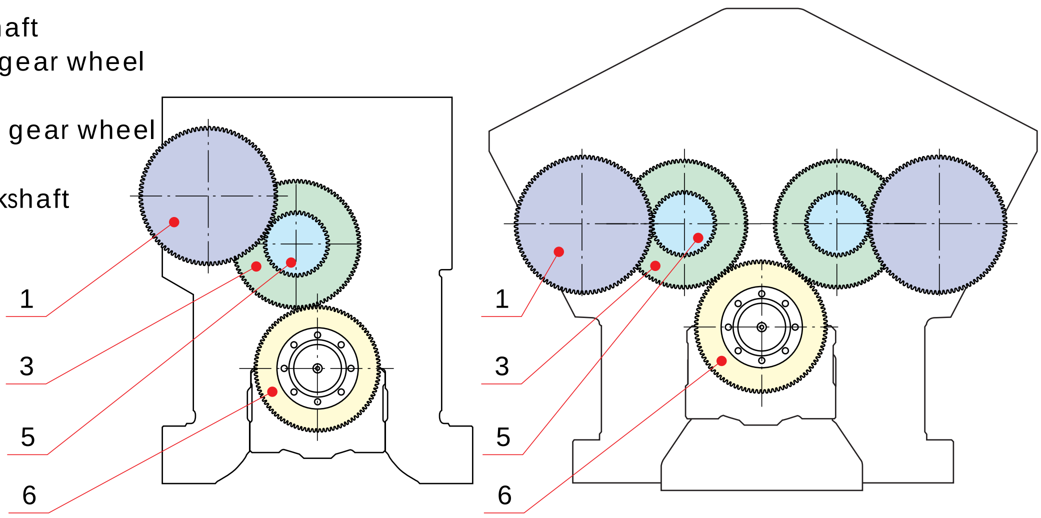


Fig 13-1 401304200047

13.2 Intermediate gears and camshaft gear

The intermediate gear wheels are case hardened. The wheels have a common shaft and are fixed to each other by a friction connection. The lubrication for the bearings is arranged through drilling's in the crankshaft, engine block and for the wheels from a distributing pipe through the nozzles.

The basic adjustment of valve timing and fuel injection is done with the intermediate gear wheel pair. The timing can be adjusted if the gear wheels are rotated in relation to each other.

Note! **The valves and the pistons will come in contact with each other if the valve timing is set wrong, which will cause serious damages to the engine.**

13.2.1 Maintenance of camshaft gearing

Whenever the opportunity occurs, check the condition of the gears. Measure tooth backlash and bearing clearances, see section 06.2. An early detection of any tooth damage can prevent serious damage.

13.2.2 Basic adjustment of valve timing

The basic adjustment of the valve and injection timing is done by changing the relative position between the intermediate wheels (3) and (5). If the position is changed, the position of the camshaft is changed in relation to the crankshaft.

Note! **The relative position between the two wheels is adjusted at the factory and should not be changed unless it is absolutely necessary.**

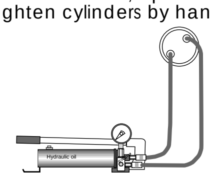
1 **Remove the injection pump** on cylinder No. 1., see section 16.2.1. Prelift can also be checked without removal of injection pump by using tool 800135. Tool can be ordered from the local service station.

2 **Turn cylinder concerned** to the position until pump tappet roller is on the base circle of the camshaft.

3 **Place a dial indicator** at the adjusting screw (24) for injection pump tappet and adjust the dial indicator to zero.

4 **Turn the engine and camshaft** by using turning device in the rotation direction until the dial indicator shows that the adjusting screw (24) is lifted 6 mm. **Note, it is recommended to do the final turning by using the hand wheel of the turning device.**

DISMANTLING
1. Screw on cylinders by hand
2. Connect hoses, open valve.
   Tighten cylinders by hand.



3. Screw cylinders 180° counter -clockwise.
4. Close valve, rise pressure.
5. Open the nut about half a turn.
6. Open release valve, remove tool.

5 **Read the timing** from the flywheel pointer as degrees before TDC (Top Dead Center). Compare your reading to the values given by the manufacturer.

6 **If the timing differs** from the stated value, proceed as follows.

7 **Unscrew the cover fastening screws (18).** Remove intermediate gear wheel cover (21) and outer O-ring (29), see Fig 13-2.

8 **Apply support tool 800113** to the engine block.

9 **Apply hydraulic tool 2V86B341 (800112)** to the fastening bolt (20).

10 **Connect the hoses** on the hydraulic pump 800053, see adjacent figure.

Camshaft driving gear

1. Gear wheel for camshaft
2. Extension piece
3. Bigger intermediate gear wheel
4. Bearing bush
5. Smaller intermediate gear wheel
6. Gear wheel for crankshaft
7.Crankshaft
8. Extension piece
9. Screw
10. Thrust bearing
11. Screw
12. Cover
13. Gear wheel for governor drive
14. Cover
15. Screw
16. Screw
17. Guiding pin
18. Screw
19. Bearing piece
20. Bolt
21. Cover
22. Nut
23. Guiding pin
24. Thrust bearing
25. Bearing bush
26. Screw
27. Screw
28. Bearing piece
29. O-ring
30. O-ring
31. Screw
32. Washer
33. Cover

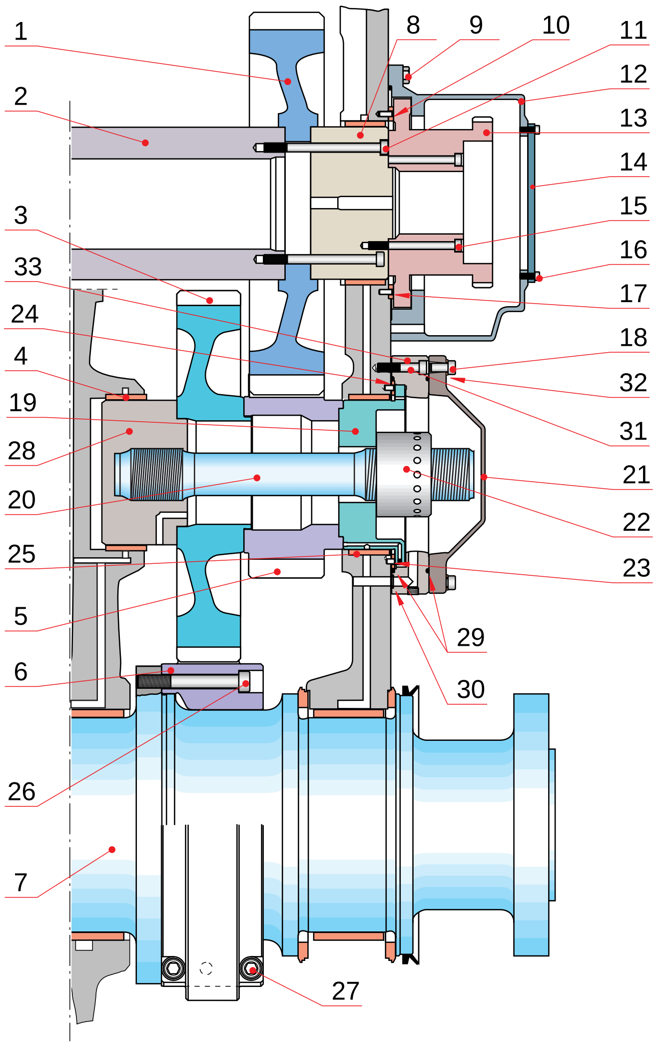


Fig 13-2

401305200047

11 **Strain the bolt by raising the pressure** to the value stated in the chapter 07.

12 **Loosen the hydraulically tightened nut (22)** and release the pressure from the hydraulic cylinder. Turn the crankshaft as much as necessary to obtain the stated value, see section 07.3. The bigger intermediate gear wheel should then rotate while the smaller intermediate gear wheel should stand still.

Warning! **Cranking of engine with the hydraulically tightened nut (22) loosened is allowed only for some degrees to adjust the timing. Otherwise great risk for contact between pistons and valves.**

13 **Tighten the nut (22) in two steps** for the intermediate gear wheels to stated pressure when the desired movement is reached, see section 07.3.

14 **Check the fuel injection timing** of one cylinder.

15 **Mount the cover (21)** and replace the outer O-ring (29) with new one. Tighten the screws (18) to stated torque.

16 **Mount the injection pump** to the engine. Tighten nuts to the stated torque.

17 **Mount necessary pipes,** injection pipe, fuel leak pipes and lube oil pipe. Connect the fuel rack.

13.2.3 Removing of camshaft gearing

1 **Remove the gearing covers** and all camshaft covers.

2 **Remove the governor unit** and the speed pick-ups and governor drive cover plate (14).

3 **Open the screws (9)** and remove the complete governor drive assembly.

4 **Open the screws (15)** and remove the helical gear wheel (13) for governor drive and the thrust bearing (10).

5 **Open the screws** and remove the sleeve and lubricating oil pipe from the engine block.

6 **Remove the rocker arm brackets** of all cylinders, see section 14.1.3.

7 **Crank the engine** and lock all valve- and injection pump tappets in upper position, see section 14.2.2.

Warning! **When the valve tappet(s) is/are locked in the upper position the rocker arm bracket(s)/ push rods must be removed, otherwise when cranking the engine the pistons will come in contact with the valves.**

8 **Remove the cover** at free end and the flange in the middle of starting air distributor (A-bank) and/or flange from B-bank.

9 **Open the nuts for camshaft extension piece (2)** on back side of camshaft.

10 **Turn the crankshaft** to TDC at firing for cylinder No. 1.

11 **Mount the lifting tool** for the camshaft gear wheel (1).

12 **Open the screws (11)** and remove the extension piece (8).

13 **Mount the hydraulic cylinder 800063** between engine block and camshaft cam. Place piece of wood or similar between cam and piston of the cylinder.

14 **Rise the pressure slowly** and move the camshaft sideways towards the free end until the gear wheel (1) can be removed. **Do not damage the camshaft piece or engine block.**

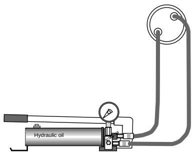
15 **Remove the camshaft gear wheel (1).**

16 **Remove the extension piece (2).**

17 **Unscrew the cover fastening screws (18).** Remove intermediate gear wheel cover (21), outer O-ring (29) and oil spray nozzles.

Note! **The intermediate wheels (3) and (5) should not be dismantled unless it is absolutely necessary. The relative position between the two wheels is adjusted at the factory and should not be changed, while it influence on the valve and fuel injection timing.**

DISMANTLING
1. Screw on cylinders by hand
2. Connect hoses, open valve.
   Tighten cylinders by hand.



3. Screw cylinders 180° counter-clockwise.
4. Close valve, rise pressure.
5. Open the nut about half a turn.
6. Open release valve, remove tool.

18 **Apply support tool 800113** and hydraulic tool 2V86B341 (800112) to the fastening bolt (20).

19 **Connect the hoses** on the hydraulic pump 800053, see adjacent figure.

20 **Strain the bolt by raising the pressure** to the value stated in the chapter 07., and proceed with opening the nut.

Caution! **The bolt will be overloaded if the maximum hydraulic pressure is exceeded.**
It is recommended to change the bolt if maximum hydraulic pressure is exceeded for some reason.

21 **Release the pressure slowly,** disconnect the hoses and remove hydraulic tool.

22 **Remove the nut (22)** and the bolt (20) by using the tool 800114. The locking screw of the tool has left-hand threads.

Note! **When using the stud remover 800114 only the inner hexagon 36 key grip should be used when the stud is removed or tightened to torque. The outer left hand hexagon 30 screw is only for locking the tool onto the stud and will break if used to loosen the bolt.**

23 **Unscrew the fastening screws (31)** and remove the cover (33). Remove also the O-rings (29) and (30).

Note! **Before removing the screws (31) and cover (33), ensure that the gear wheels (3) and (5) are supported with suitable method. Othewise great risk damaging the gear wheels or related components.**

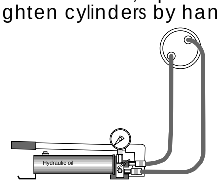
24 **Remove the bearing piece (19),** thrust bearing (24) and the small intermediate gear wheel (5).

25 **Remove the big intermediate gear wheel (3)** and bearing piece (28).

13.2.4 Mounting of the camshaft gearing

Note! **Make sure that the crankshaft is in TDC at ignition for cylinder No. 1 before proceeding with the job.**

REASSEMBLING
1. Screw on nuts, attach distance sleeve. Screw on cylinders by hand.
2. Connect hoses, open valve. Tighten cylinders by hand.



3. Close the valve and pump pressure to the stated value.
4. Screw the nuts until close contact to face.
5. Open the valve and remove tool set.

1 **Lubricate the bearing bushes (4) and (25).**

2 **Lift the bearing piece (28)** into position.

3 **Lift the big intermediate gear wheel (3)** onto the collar of the bearing piece.

4 **Insert the small intermediate gear wheel (5)** onto the collar of the big intermediate gear wheel.

5 **Insert the thrust bearing (24),** bearing piece (19).

6 **Mount the cover (33)** and replace the O-rings (29) and (30) with new ones. Tighten the screws (31) to stated torque.

7 **Screw in the bolt (20)** by using the tool 800114 and tighten to the torque stated in chapter 07.3. The locking screw of the tool has left-hand threads. Remove the tool.

Note! **When using the stud mounting tool 800114 only the inner hexagon 36 key grip should be used when the stud is removed or tightened to torque. The outer left hand hexagon 30 screw is only for locking the tool onto the stud and will break if used to loosen the bolt.**

8 **Tighten the nut (22) in two steps** by hydraulic tool 2V86B341 (800112) to stated pressure. Release the pressure and pump to stated pressure again. Tighten the nut finally and release the pressure.

9 **Insert the extension piece (2)** and tighten nuts.

10 **Lift the camshaft gear wheel (1)** into position.

11 **Insert the extension piece (8)** and tighten the fastening screws (11) **crosswise in two steps** to stated torque.
Check tightening of the screws (11) to stated torque.

12 **Check the injection timing** of one cylinder according to the section 13.2.2.

13 **Mount the oil pipe** and the sleeve inside the engine block. Replace the O-rings with a new ones and tighten the screws.

14 **Mount the thrust bearing (10)** and governor drive gear (13). Tighten the screws (15) to stated torque.

15 **Mount the housing (12) for the governor drive.** Replace the O-rings with a new ones. Tighten the screws (9) to stated torque.

16 **Check all axial bearing clearances** and the backlashes between the gear wheels.

17 **Mount the oil spray nozzles.**

18 **Mount the cover (21)** and replace the O-rings with new ones. Tighten the screws (18) to stated torque.

19 **Mount the governor unit** and the speed pick-ups, see section 22.4.

20 **Release the tappets** and mount the rocker arm brackets, see section 14.1.3.

21 **Mount all the covers** and the oil pipes.

Note! **Check the valve timing before the engine is started.**

13.3 Crankshaft gear wheel

If only the split gear wheel has to be changed, one half of the wheel can be removed/mounted at a time. Hereby the valve timing will be unchanged and it will not be necessary to adjust it. However the timing should be checked.

13.3.1 Removing of the split gear wheel

After the gearing is removed according to section 13.2.3, the split gear wheel (6) can be removed from the crankshaft.

1 **Lower the bearing cap** for main bearing No.1, see chapter 10., section 10.3.1.

2 **Loosen the fastening screws (27).**

3 **Unscrew the axial screws (26).**

4 **Unscrew the fastening screws (27)** and remove the gear wheel halves.

13.3.2 Mounting of the split gear wheel

1 **Clean the parting surfaces of the wheel halves** and the contact faces of the gear wheel and the crankshaft.

2 **Lower the bearing cap for main bearing No.1,** see chapter 10, section 10.3.1.

3 **Apply Loctite 262 on the threads of the screws (26) and (27).**

4 **Mount the gear wheel halves on the crankshaft** with the parting face at right angles with the crank of cylinder No. 1 and fasten the screws (26) and (27) by hand.

5 **Tighten the axial screws (26)** to a torque of 10 Nm and check that contact is established between the gear wheel and the crankshaft flange.

6 **Tighten the fastening screws (26)** to a torque of 40 Nm. The screws closer to the crankshaft flange are to be tightened at first.

7 **Tighten the fastening screws (27)** to stated torque. The tightening order is the same as in the previous point.

8 **Tighten the axial screws (26)** to the stated torque.

9 **Check the gear wheel roundness.** Place a cylindrical pin (ø16 mm) in the tooth gap as shown in Fig 13-3. Turn the engine and use a dial indicator to get an indication for the diameters. The maximum permissible difference between the measured values is 0.05 mm.

10 **Lift the bearing cap for main bearing No.1,** see chapter 10 section 10.3.1.

Measuring split gear wheel

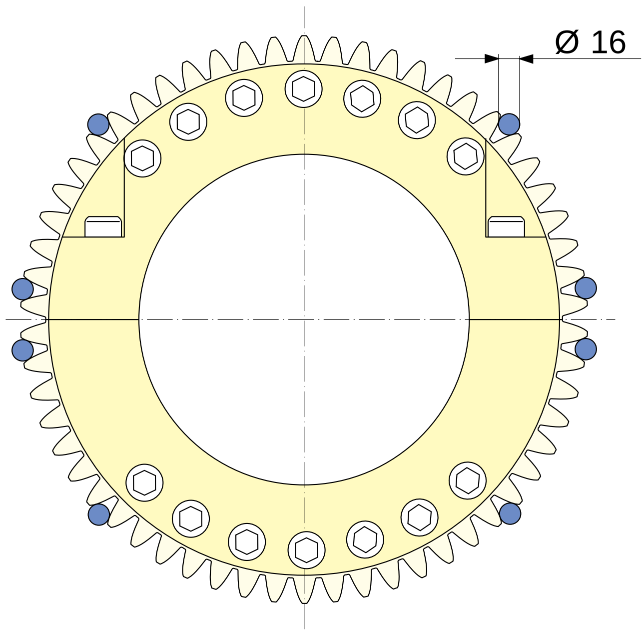


Fig 13-3 4013039601

14. Valve Mechanism and Camshaft

14.1 Valve mechanism

14.1.1 Description of valve mechanism

The valve mechanism operates the inlet and outlet valves at the required timing. The valve mechanism consists of piston type valve tappets (9) moving in a common guide block (8), tubular push rods (6) with ball joints, rocker arms (2) journalled on a rocker arm bearing bracket (5), yokes (4) guided by a yoke pin (15) at the cylinder head.

Valve mechanism

1. Screw
2. Rocker arm
3. Retainer ring
4. Valve yoke
5. Rocker arm bracket
6. Push rod
7. Protecting pipe
8. Guide block
9. Valve tappet
10. Roller pin
11. Screw
12. Guiding plate
13. Securing screw
14. Tappet spring
15. Yoke pin
16. Adjusting screw
17. Bearing bush
18. Tappet roller
19. Locking pin
20. Shaft

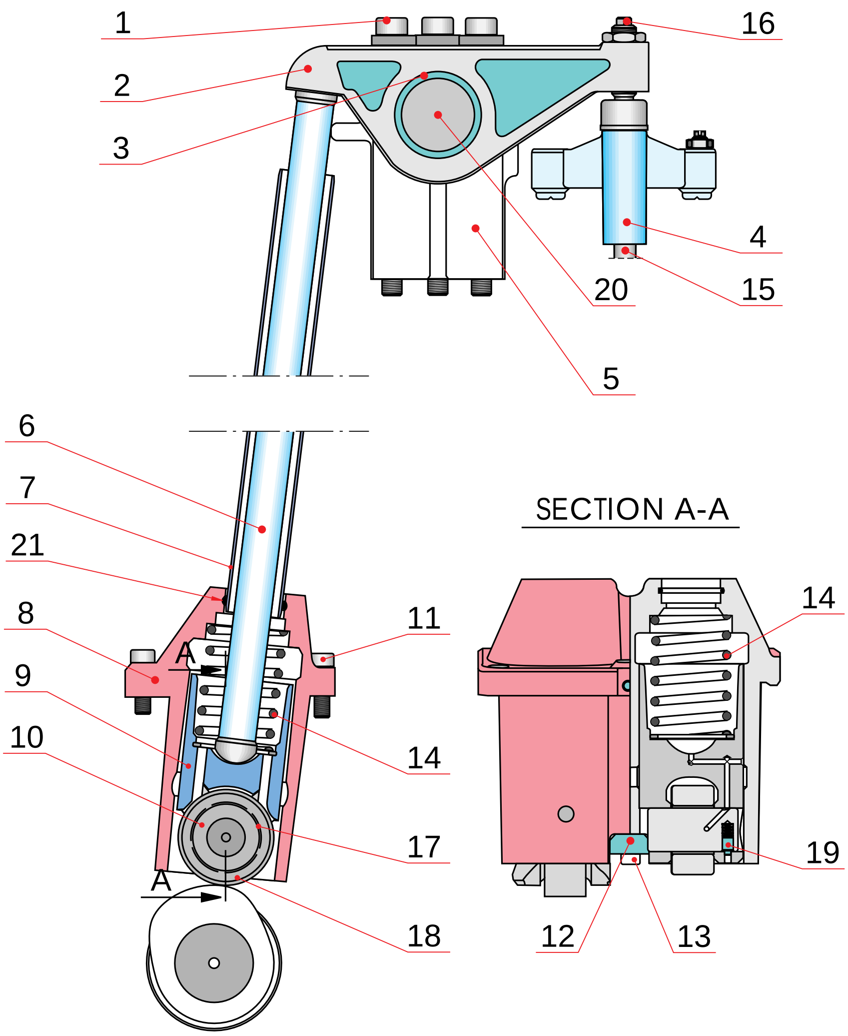


Fig 14-1 4014029601

14.1.2 Function

The movement of the valve tappets (9) is governed by the cam profile on the camshaft. The valve tappets transfer the movement through push rods (6) to the rocker arms (2). The rocker arms operate the inlet and exhaust valves through a yoke (4).

The bracket (5) for the rocker arms is fastened to the cylinder head by three long screws (1). The shaft is positioned by one fixing screw (1) in the bracket. The positioning of the shaft is essential for the oil supply.

The adjusting screws in the rocker arms act on the valve yokes, which are guided by an yoke pin. To compensate for heat expansion a clearance, valve clearance, must exist in the valve mechanism. All adjustments are made on a cold engine, and this adjusting procedure is explained in chapter 12. Each valve yoke operates two valves simultaneously, one for inlet and one for exhaust.

The valve mechanism is lubricated from the main flow through oil drilling's. Oil to the valve yokes (4) and to push rod upper bull joint passes through the rocker arm bracket (5) in an intermittent flow controlled by the drilling's in the rocker arm and shaft. The rocker arm is in position to supply oil only when it is in the "open valve" position. When the rocker arm is in "valve closed" position is the surface between rocker arm and shaft lubricated. Oil which is passed to the yoke is lubricating the yoke guidance and through the drilling's also lubricates the valve rotators. Oil is returned to the crankcase in a free flow through the protecting pipes (7) for the push rod.

Note! **The intermittent oil flow will cause an optimized oil flow to the valve mechanism. To completely check the oil flow to a cylinder head, the engine must be cranked during prelubrication.**

14.1.3 Maintenance of valve mechanism

Normally, the valve mechanism need no maintenance, but inspection of the components and check for wear should be made at intervals stated in chapter 04. See chapter 06. for adjustments and wear limits. If the valve mechanism is dismantled, the components should be marked and later assembled in the same position and cylinder as before to avoid unnecessary wear.

14.1.3.1 Dismantling of valve mechanism

1 **Open the upper cover for** the cylinder head and remove the camshaft cover from the cylinder concerned.

2 **Turn the crankshaft** to a position where the valve tappet rollers of the valves are on the base circle of the cam.

3 **Unscrew the screws (1)** and remove the rocker arm bearing bracket (5) with accessories from the cylinder head.

4 **Remove the retainer rings (3)** by using pliers 800002. Remove the positioning screw (1) and press out the shaft (20).

5 **Remove the push rods (6)** and the protecting pipes (7).

6 **Remove necessary pipes,** injection pipe, leak fuel pipes and lube oil pipe.

7 **Loosen the fastening screws (11)** and remove the guide block (8).

8 **Remove the screws (13) and guiding plate (12).** Notice! Tappets are spring loaded.

9 **The tappet roller and pin can now be separated** by depressing the locking pin (19) and pushing out the roller pin (10). The tappet should be covered, as the locking pin is under spring load.

14.1.3.2 Inspection of valve mechanism parts

1 **Clean the rocker arm bore** and the shaft (20) and measure for wear. When cleaning, pay special attention to the oil holes.

2 **Clean and inspect all parts of the valve tappet.** When cleaning, pay special attention to the oil holes.

3 **Measure the valve tappet boring** and the tappet (9) as well as the tappet roller (18) for wear.

4 **Change the O-rings (21) of the protecting pipes (7)** if they are damaged or hard.

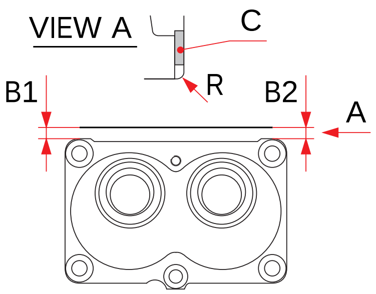
14.1.3.3 Assembling of valve mechanism

1 **Lubricate the parts of the valve tappet** with clean engine oil and assemble together. Observe the marks for correct positions.

2 **Insert the tappet spring (14) and the valve tappets (9)** into the guide block (8).

3 **Mount the guiding plate (12)** and tighten the screws (13) to the stated torque according to chapter 07.

4 **Mount the complete guide block** on the engine and measure the distance to the engine block on both sides of the guide block with a feeler gauge (C), i.e. measures B1=B2, see adjacent figure. Note the corner radius (R) on the engine block, i.e. do not push the feeler gauge too deep in the vertical direction. Tighten the screws to the stated torque according to chapter 07.



5 **Mount necessary pipes** and injection pipe. Tighten the injection pipe to the stated torque according to chapter 07.

6 **Grease the O-rings (21),** insert the protecting pipes (7) and push rods (6) into the guide block.

7 **Mount the yoke.** For adjusting the yokes, see section 12.2.4.

8 **Lubricate the rocker arm bore** with engine oil and mount the rocker arms (2) on the bracket (5).

9 **Apply the retainer rings (3)** by using pliers 800002 and check the axial clearance and free rotation of rocker arms.

10 **Mount the rocker arm bracket** on the cylinder head and tighten the screws (1) to the stated torque, see section 07.1.

Note! **The rocker arm bracket have to be centered.**

11 **Check the valve clearances,** see sections 06.1 and 12.2.4. Mount the covers.

14.2 Camshaft

14.2.1 Description of camshaft

Data and dimension
Weight of one camshaft piece: 92 kg

The camshaft is built up of one -cylinder camshaft pieces (5) and separate bearing journals (3). The camshaft pieces have integrated cams. The camshaft is driven by the crankshaft through a camshaft drive consisting of gear wheels at the driving end of the engine. At this end the camshaft is provided with a helical gear wheel (7) for driving the speed governor. At the free end, the camshaft has an extension piece (2) with a cam for operating the starting air distributor.

The camshaft has an axial bearing (8) in the driving end. The oil supply is arranged to the axial bearing from the driving end of the engine. The engine block has a drilling, through which oil is supplied to every camshaft bearing. The rotation speed of the camshaft is only half of the engine speed.

14.2.2 Removing of camshaft piece

1 **Remove the camshaft covers** and open cylinder head covers. Remove rocker arm brackets from all cylinder heads. Lift up tappets (injection pump and valve tappets) and secure tappets in the upper position by means of the locking device 800066.

Warning! **When the valve tappet(s) is/are locked in the upper position the rocker arm bracket(s)/ push rods must be removed, otherwise when cranking the engine the pistons will come in contact with the valves.**

2 **Unscrew the flange connection screws (4)** from both ends of the camshaft piece.

3 **Mount the support tool** on the block by the camshaft cover fixing screw.

4 **Remove the camshaft end cover (1)** from the starting air distributor. Move the part of the camshaft locating towards the free end of the engine as much as possible in direction of the free end by using suitable lever.

5 **Remove the governor and governor drive housing.** Push the other parts of the camshaft towards flywheel end as much as possible.

6 **Remove the camshaft piece** by means of the tool.

Camshaft

1. Cover
2. Extension piece for starting air distributor
3. Bearing journal
4. Screw
5. Camshaft piece
6. Extension
7. Gear wheel for governor drive
8. Axial bearing
9. Guiding pin

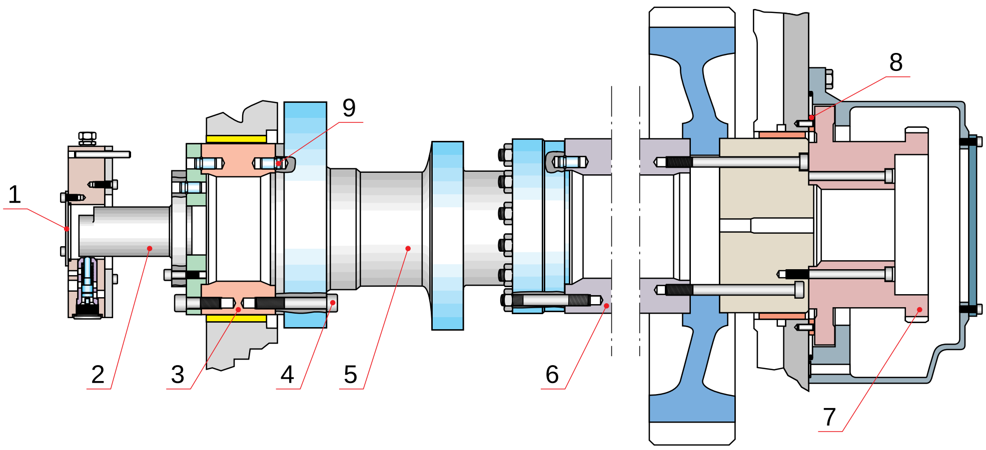


Fig 14-2 4014039601

14.2.3 Mounting of camshaft piece

1 **Check the valve tappets and rollers and bearing bushes** carefully. Even slightly damaged tappet rollers have to be changed.

2 **Clean and degrease the flange connection surfaces** and threaded holes.

3 **Mount the camshaft piece** (5) on the fixing pin and centering at either end, then pull the camshaft together. Use two or three screws.

4 **Insert the other connection screws** and tighten to the stated torque.

5 **Mount the cover (1)** of the starting air distributor, governor drive, etc.

6 **Release the tappets** and mount the rocker arm brackets.

7 **Check the valve clearances,** see section 12.2.4. Check delivery commencement of the injection pumps on all cylinders towards the free end, see chapter 01 “firing order” and section 13.2.2.

14.3 Camshaft bearing

14.3.1 Inspection of the camshaft bearing bush

When the camshaft bearing journal has been removed, the inner diameter of the bearing bush can be measured at site, by using a ball anvil micrometer screw. Measure three diameters in a position 120° from each other. The average diameter to be compared with wear limit. The wear limit is stated in chapter 06, section 06.2 If the wear limit for one camshaft bearing bush is reached, all camshaft bearing bushes should be replaced. For visual inspection of the camshaft bearing bush has the camshaft piece and bearing journal to be removed according to section 14.2.2.

14.3.2 Removing of camshaft bearing bush

1 **Remove the camshaft piece** adjacent to the bearing bush and bearing journal concerned according to section 14.2.2.

2 **Remove the camshaft bearing journal.**

3 **Assemble the removing device** 800062 according to Fig 14-3. Notice the difference in tool assembly for the bearing next to the driving end of the engine.

4 **Tighten the hydraulic tool** 3V83E61 by tensioning the pull screw 4V83G45.

5 **Connect the hoses of the hydraulic pump** 800053 to the hydraulic tool.

6 **Pump pressure to the hydraulic tool** to withdraw the bearing bush. The pressure must not exceed the value stated in chapter 07, Fig 07-14. If the bearing bush does not move when this pressure is achieved, a light knock on the end flange 3V83H166 can be of use.

7 **Open the pump valve for removing the pressure,** disconnect the hoses of the hydraulic tool and dismantle the removing device.

Removing of camshaft bearing bush

4V83G45 Screw
3V83H61 Hydraulic cylinder
3V83H164 Guide sleeve
3V83H165 Distance piece
3V83H166 Pressure plate

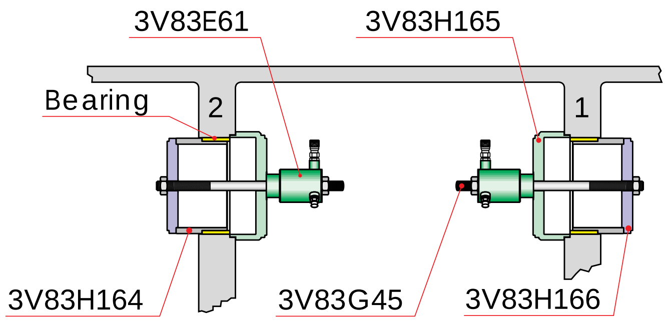


Fig 14-3 4014019601

14.3.3 Mounting of camshaft bearing bush

1 **Lightly lubricate the new bearing bush** with clean engine oil on the outer surface and put it on the guide sleeve 3V83H164. The notch on the bearing bush side should be positioned downwards, i.e. lubricating hole in the engine block and the oil hole in the bearing bush must be in the same position.

2 **Assemble the mounting device** according to Fig 14-4. Notice the difference in tool assembly for the bearing next to the flywheel end of the engine.

3 **Tighten the hydraulic tool** 3V83E61 by tensioning the pull screw 4V83G45 lightly.

4 **Connect the hoses of the hydraulic pump** 800053 to the hydraulic tool.

5 **Pump pressure to the hydraulic tool** to mount the bearing bush. The pressure must not exceed the value stated in chapter 07, Fig 07-14.

6 **Open the pump valve for removing the pressure,** disconnect the hoses of the hydraulic tool and dismantle the mounting device.

7 **Check that the oil hole in the bearing bush** is in the correct position.

8 **Lubricate the bearing surface of the bearing bush** and insert the camshaft bearing journal.

9 **Mount the camshaft pieces,** bearing journals, guide blocks, injection pumps and camshaft covers according to the section 14.2.3.

Mounting of camshaft bearing bush

4V83G45 Screw
3V83H61 Hydraulic cylinder
3V83H164 Guide sleeve
3V83H165 Distance piece
3V83H166 Pressure plate

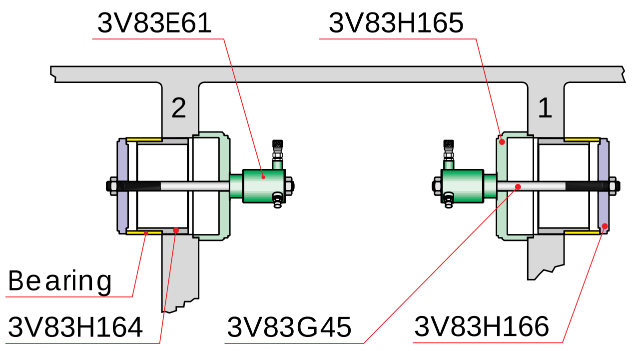


Fig 14-4 4014049601

15. Turbocharging and Air Cooling

15.1 Description

The turbochargers are of axial turbine type. The charge air coolers are of rigid frame -type and are on in-line engines fitted to the side of the engine block, while V-engines have the cooler fitted to the turbocharger bracket.

The turbocharger is equipped with plain bearings and is connected to the engine lubrication system.

The air outlet is connected to the air duct (2) with metal bellows (1). The exhaust pipes from the cylinders are also connected to the charger with metal bellows. The exhaust pipe after the turbocharger should be arranged according to the installation instructions with a fixed support immediately after the bellows.

The turbocharger is equipped with cleaning devices for cleaning both the compressor and the turbine by water injection.

Charge air system L-engine

1. Bellows
2. Air duct
3. Water box
4. Charge air cooler
5. Water box
6. Diffuser
7. Air box
8. Drain pipe

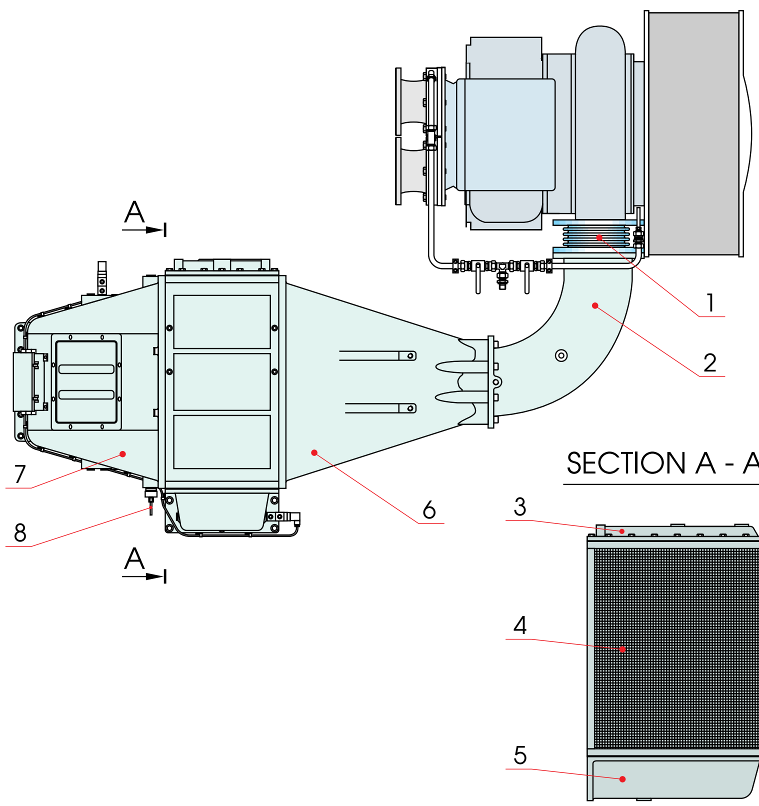


Fig 15-1

4015122001

Charge air system V-engine

1. Bellows
2. Air duct
4. Charge air cooler
7. Cover
8. Drain pipe
9. Cover
10. Cover
11. Screw
12. Plate
13. Screw
37. Cover
38. Cable

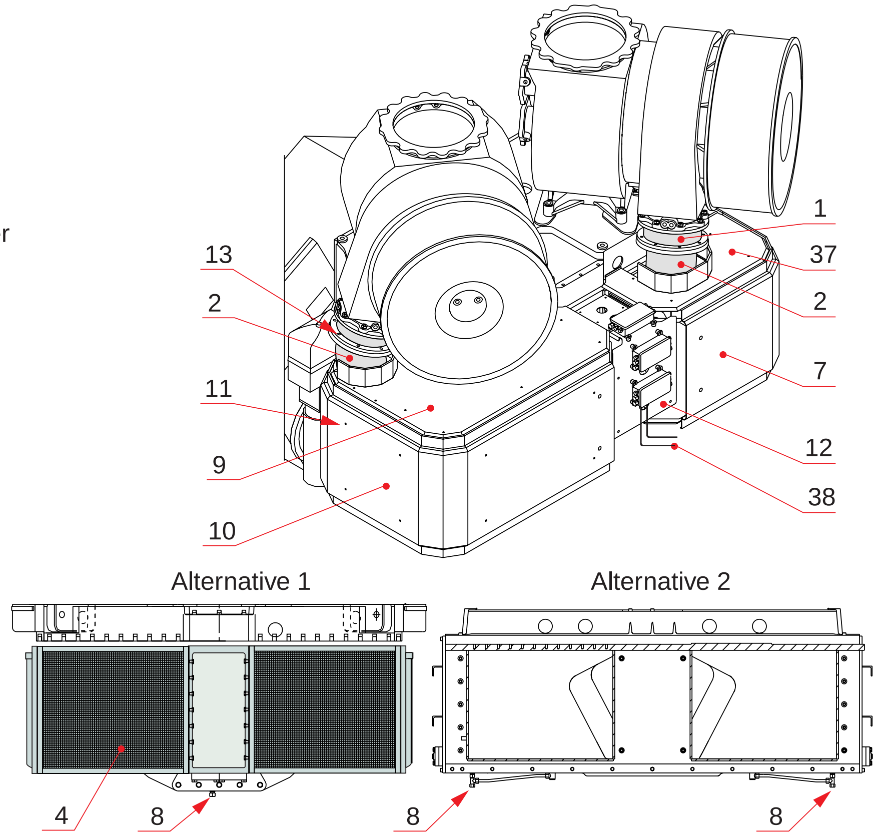


Fig 15-2 4015190406

15.2 Turbocharger maintenance

The plain bearings of the charger are lubricated by the engine lubricating oil system. The oil is fed through the turbocharger bracket and the pressure lowered with an orifice. The oil drain is connected to a channel in the turbocharger bracket from where the oil is lead to the crankcase.

The cartridge design of the turbocharger allows all normal service work to be done from the compressor side of the turbocharger without removing the whole unit from the engine.

When reassembling, use new seals.

Maintenance of the turbocharger is carried out according to section 15.3 and the instructions of the turbocharger manufacturer. It is recommended to use the service network of the engine manufacturer or the turbocharger manufacturer.

15.3 Water cleaning of turbocharger during operation

15.3.1 Water cleaning of turbine

The dirt deposits on the turbine side can be reduced by periodic cleaning (washing) during operation. The overhaul periods can thus be extended. Dirty turbines cause higher temperatures of the exhaust gas and higher stress to the bearings due to imbalance. Washing of the turbine side is necessary only when running on heavy fuel.

During long periods of operation, periodic water cleaning prevents the build-up of significant deposits on the turbine blades and nozzle blades. This cleaning method does not work on very dirty turbines which have not been washed regularly.

If the normal water cleaning of the turbine does not lower the exhaust gas temperature level, hard deposits have probably built up on the nozzle ring and the turbine blades in the turbocharger, and they have to be cleaned mechanically. For that purpose, the rotor cartridge and the nozzle ring have to be removed from the turbocharger.

When washing with water, the water must be injected into the exhaust system with the engine running at reduced output (see 15.3.2, step 2). The disadvantages of occasionally reducing the output is not significant compared to the advantages of cleaning. The necessary water flow is basically dependent upon the volume of gas and its temperature. Additives or solvents must not be used in the cleaning water. The use of salt water is prohibited.

Every gas inlet of the charger is equipped with a washing nozzle. The nozzles are all connected to a common water connection which has a valve and a quick-coupling. The water flow is controlled by flow meter (4) to a suitable value, see table below.

Water cleaning of turbine	
Turbocharger size	**Water flow (l/min)**
TPL 65	16 - 19
TPL 69	23 - 27

Cleaning should take place regularly according to maintenance schedule, see chapter 04. Depending on the results obtained, the washing interval may be increased or reduced.

Water cleaning of turbocharger

1. Valve for turbine cleaning
2. Valve for compressor cleaning
3. Quick-coupling
4. Flow meter
5. Valve

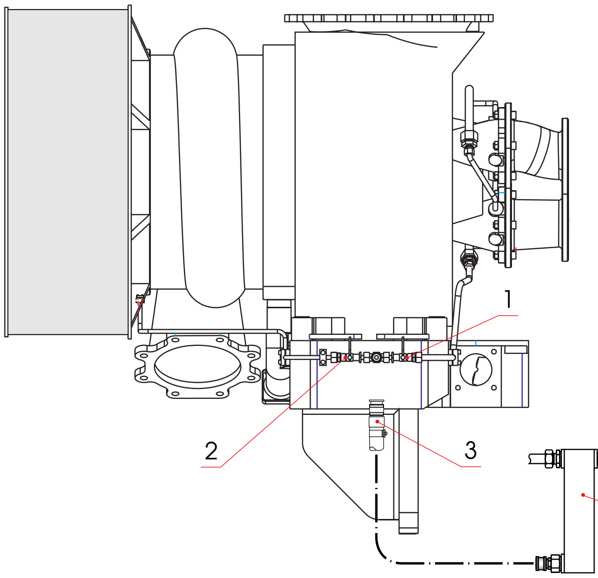


Fig 15-3 4015049708

15.3.2 Turbine cleaning procedure

The turbocharger can be designed without drain pipe (steps 1 - 7) or with drain pipe (steps 1 - 2 and 8 - 17).

1 **Record charge air pressure,** cylinder exhaust gas temperatures, charger speed at nominal load, for later use to evaluate efficiency of the cleaning.

2 **Reduce engine load** corresponding to a **maximum exhaust gas temperature at turbine inlet < 430°C** at nominal speed or in marine main engine installations, reduce the speed to between 400 and 600 RPM. Run the engine for ten minutes on this load before the washing is started.

Note! **Observe the above mentioned limits for engine speed or exhaust gas temperature.**

Note! **If the washing is started earlier than after ten minutes on stable load as above, this may have negative consequences for the turbocharger.**

Turbocharger without drain pipe.

3 **Open the valve (1)** and check that the nozzles are not clogged, see Fig 15-3.

4 **Connect the water hose.**

5 **Open the valve (5)** slowly and increase the water flow until the correct flow is reached according to the table shown in section 15.3.1. Lock the valve (5) with the counter nut.

6 **Close the valve (1) after 60 seconds.** Interval between injections is 90 sec.

Note! **It is not allowed to inject water for longer than 60 seconds at a time because the gas outlet casing does not have a drain.**

7 **Repeat the injection procedure five times** according the step 6. above and continue with step 13.

Turbocharger with drain pipe.

8 **Open the drain valve,** and check that the drain is not clogged.

9 **Open the valve (1)** and check that the nozzles are not clogged, see Fig 15-3.

10 **Connect the water hose.**

11 **Open the valve (5)** slowly and increase the water flow until the correct flow is reached according to the table shown above. Lock the valve (5) by using the counter nut.

12 **Close the valve (1) after 10 minutes.**

13 **After termination of water injection** the engine must run for at least five minutes before the load is increased.

14 **Close all valves** and disconnect the hose to ensure that no water can possibly enter exhaust pipes after washing.

15 **Open the valve (1)** and drain the water.

16 **Resume normal engine operation** at higher output and, as soon as possible, repeat the readings taken in step 1 above for evalutation.

17 **In case the engine shall be stopped after the cleaning,** run the engine for 10 to 20 minutes after the turbocharger has been cleaned. Doing so it is ensured that all the parts in the exhaust system are completely dry.

15.3.3 Water cleaning of compressor

The compressor can be cleaned by injecting water during operation. The method is efficient provided that contamination is not too far advanced. If the deposit is very heavy and hard, the compressor must be dismantled and cleaned mechanically.

The injected water does not act as a solvent, the cleaning effect is achieved by the physical impact of the drops on the deposit. It is therefore advisable to use clean water containing no additivities either in the form of solvents or softening agents, which could be precipitated in the compressor and form deposits.

Regular cleaning of the compressor prevents or delays the formation of deposit, but it does not eliminate the need of normal overhauls, for which the turbocharger has to be dismantled.

The water must be injected while the engine is running and at the highest possible load, i.e. at a high compressor speed.

Note! **Clean the compressor (air side) of the turbocharger at as high load as possible (at least 75% load).**

Cleaning should take place regularly according to maintenance schedule, see chapter 04. Depending on the results obtained, the interval between two washings may be increased or reduced.

15.3.4 Compressor cleaning procedure

1 **Record charge air pressure,** cylinder exhaust gas temperatures, charger speed. These for later use to evaluate the efficiency of the cleaning.

2 **Open the valve (2),** see Fig 15-3.

3 **Connect the water hose.**

4 **Use same adjustment as** for turbine side, i.e. wash the turbine side first and lock the valve (5) by using the counter nut, see Fig 15-3.

Water cleaning of compressor	
Turbocharger size	**Washing time (s)**
TPL 65	5 - 6
TPL 69	2 - 3

Note! **Do not exceed the maximum washing times, see table above.**

5 **Close the valve (2).**

6 **Disconnect the water hose.**

7 **Open the valve (2)** and drain out the water.

8 **Repeat the readings taken in step 1 above** for evaluation. The success of injection can be recognized by the change in charge air pressure and in the exhaust gas temperature.

9 **Run the engine for 5 minutes more** after the compressor has been cleaned with water. Doing so it is ensured that all the parts in the compressor side are completely dry.

Note! **If washing is not successful, it must not be repeated within ten minutes.**

15.4 Operation with damaged turbocharger

15.4.1 General

In case of a serious breakdown of the turbocharger, a blanking device can be fitted according to the instructions below, see also turbocharger manual, section 06. In an emergency situation like this, the engine can be temporarily operated at max.20 % output.

Thermal overload is a limiting factor on the diesel engine. Therefore, the exhaust gas temperatures must be carefully watched during operation with a blanked turbocharger.

Note! **The exhaust gas temperature after the cylinder head must not exceed 500°C.**

A marine engine can in emergency cases for a short period be operated with only the damaged turbocharger blanked, as requested by the classification societies.

In such case, the damaged turbocharger shall be blanked according to below mentioned instruction.

Wärtsilä strongly recommends both turbochargers on a V-engine should be blanked also at above mentioned emergency cases.

In case only the other turbocharger in a V-engine is blanked, both bellows (at air side) must be removed.

15.4.2 Mounting of blanking device

1 **Remove insulation dishes** from turbocharger(s).

2 **Remove the bellows (1)** between turbocharger(s) and air cooler housing, see Fig 15-1.

Note! **In a V-engine, if one of the turbochargers is to be blanked, both bellows (at air side) must be removed.**

3 **Mount the screen plate(s) (2)** on the flange connection of the air cooler housing, see Fig 15-4.

4 **Remove the silencer** or air suction branch.

5 **Disconnect the cable for speed sensor(s).**

6 **Remove the locking plate** for the lubricating oil connection pipes. Press the connection pipes downwards. On a V-engine, remove the lubricating oil connection piece.

7 **Mount the lifting equipment** and open the nuts (8). Remove the compressor casing.

8 **Mount the lifting equipment** and open the screws. Remove the cartridge assembly.

Blanking device

1. Blanking cover
2. Screen plate
3. Distance sleeve
4. Plug
5. Plug
6. Cover plate
7. Flange
8. Nut

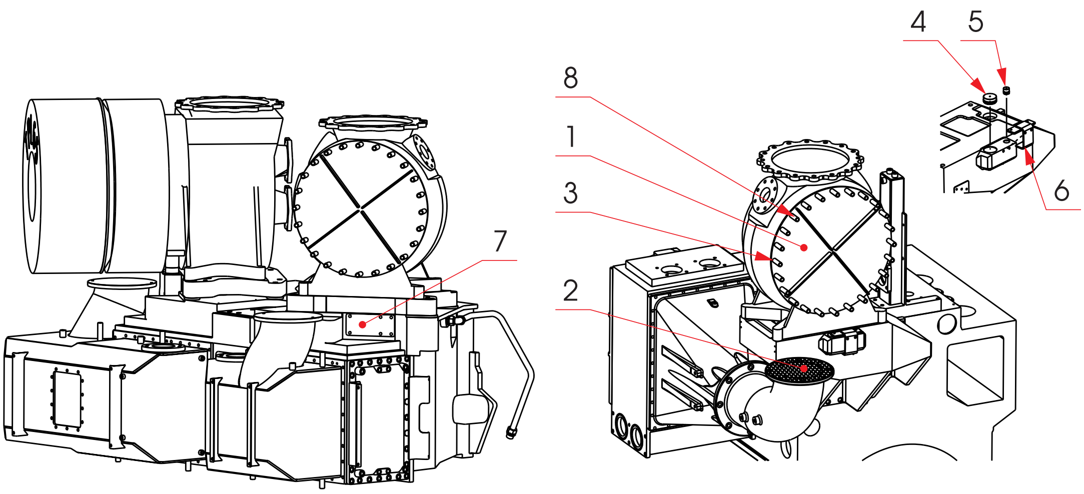


Fig 15-4 401507200102

9 **Mount the plugs (4) and (5) with O-rings** in the lubricating oil connection piece. Mount the cover plate (6) and tighten screws. On V-engine, mount the flange (7) with O-rings and tighten screws.

Note! **The oil flow to and from the damaged turbocharger must be blocked in the turbocharger bracket by using suitable plugs/flanges.**

10 **Mount the blanking cover(s) (1),** attach distance sleeves (3) and tighten nuts (8).

15.5 Charge air cooler

Data and dimension

Material

-Tubes:	copper alloy
-Water boxes:	cast iron.
Test pressure:	8 bar (water side)

The charge air cooler is of self-supported type. The housing is fitted to the engine block.

The air cooler is of tube type. The tubes are provided with thin fins to get a more efficient cooling of the air. The cooling water circulates in the tubes, while the charge air passes between the fins on the outside of the tubes.

15.5.1 General maintenance

1 **Condensate from the air is drained** through a small hole/pipe (8) at the bottom of the cooler housing after the cooler. Examine regularly that the drain pipe is open by checking the air flow when running.

If water keeps on dripping or flowing from the draining pipe for a longer period (unless running in conditions with very high humidity or with too low LT temperature due to a defective LT thermostatic valve) the cooler may be leaky and must be dismantled and pressure tested.

2 **At longer stops,** the cooler should be either completely filled or completely empty, as a half-filled cooler increases the risk of corrosion. If there is a risk of a lowwater level in the system when the engine is stopped, drain the cooler completely. Open the air vent screw at the top of the cooler to avoid vacuum when draining.

3 **Clean and pressure test the cooler** at intervals according to chapter 04. or if the receiver temperature cannot be held within stipulated values at full load.

4 **Always when cleaning,** check for corrosion

15.5.2 Dismantling (V-engines)

1 **Drain the cooler** trough the draining plugs (36), see Fig 15-8.

2 **Loosen the fixing screws** and remove the covers (7), (9), (10) and (37), see Fig 15-2.

3 **Disconnect the external connector X3** if WECS system is used.

4 **Carefully loosen and remove under the cooler 2 pcs of electrical cables (38),** see Fig 15-2, to enable dismantling of the air cooler. Loosen and remove the plate (12) holding the electrical boxes.

5 **Remove the additional supports** on both the banks.

Air cooler housing

13. Screw
14. Nut
15. Nut
16. Air box
17. Air box
19. Cover
20. Protecting plate

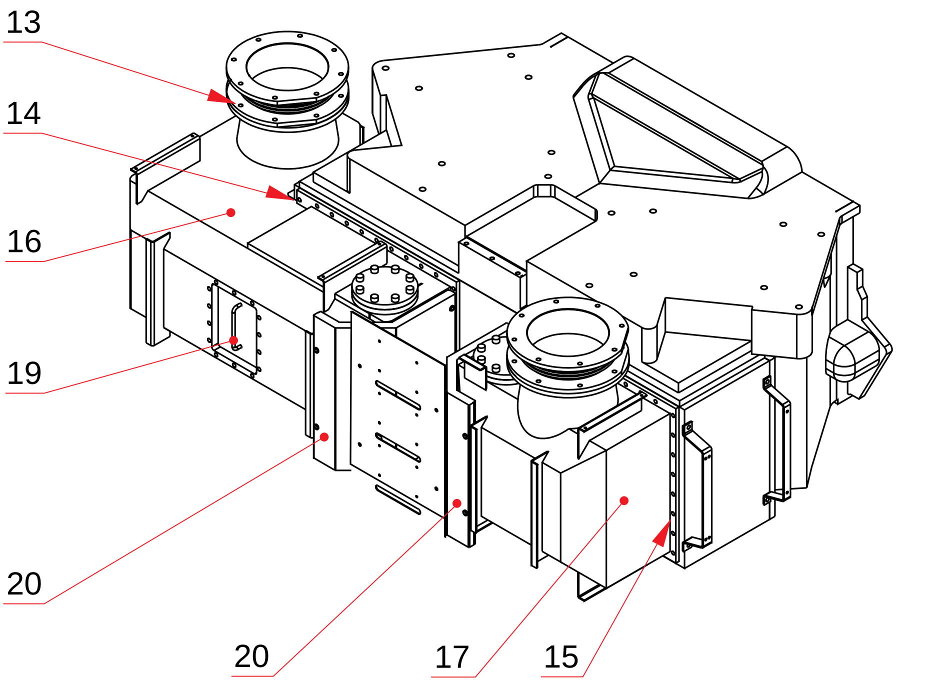


Fig 15-5 4015210306

6 **Unscrew and remove the screws (13),** see Fig 15-5. Ensure that there is a gap (approx. 2 - 5 mm) between the bellows and the tubocharger ducts.

7 **Open the inspection cover (19),** loosen and remove the nuts inside.

8 **Remove the nuts (14) and(15)** of the air inlet boxes (16) and (17), after making proper arrangement to support the boxes.

9 **Mount eye bolts with straps** on the top of the air inlet boxes (16) and (17). Prepare lifting of the box with a crane.

10 **Slowly pull the air inlet boxes out and remove them.**

Air cooler lifting tool

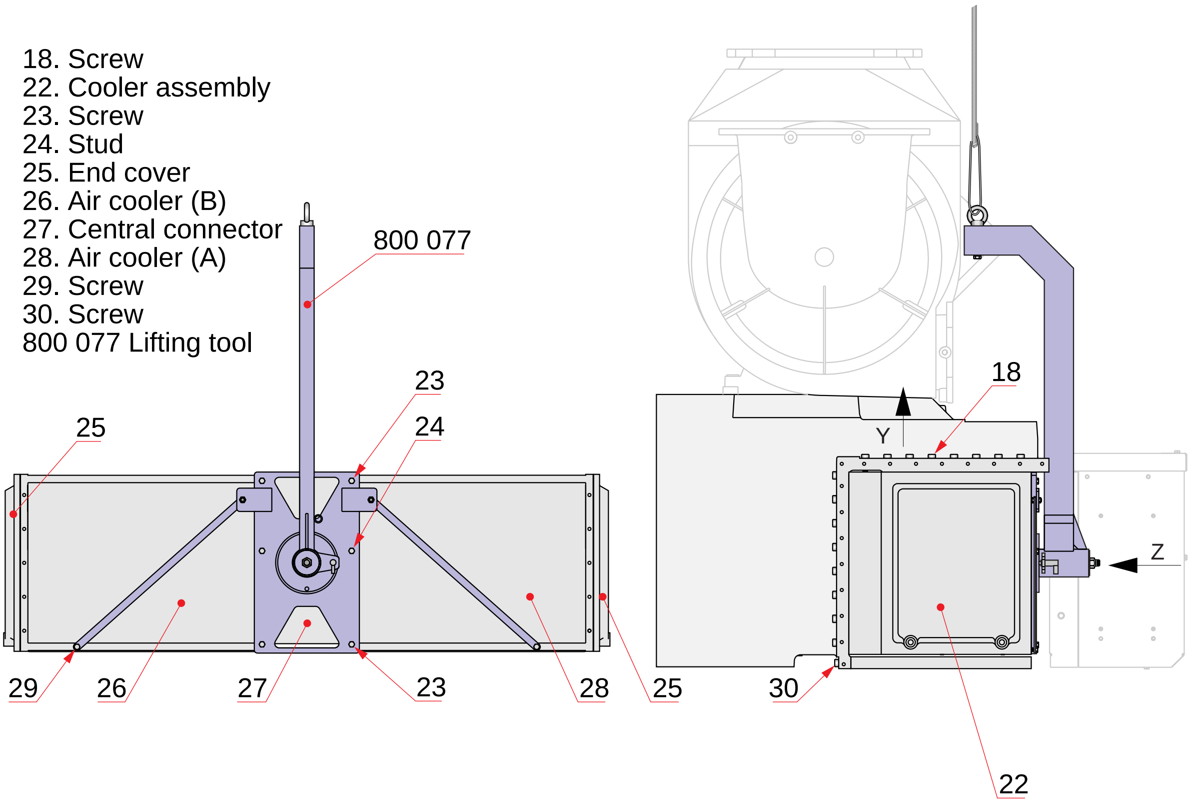


Fig 15-6 4015160351

11 **Remove the center studs (24)** with help of double nuts to enable fixing of the lifting tool 800 077.

12 **Mount the Lifting Tool 800 077** and tighten the screws (23) and (29).

13 **Remove the air cooler fastening screws (35),** see Fig 15-7.

14 **Remove the air cooler fastening screws (18 and 30),** (top screws (18) last), see Fig 15-6.

Note! **Take care that the load of the cooler is carried by the lifting tool.**

Air cooler top fastening screws

33. O-ring
34. Distance sleeve
35. Screw

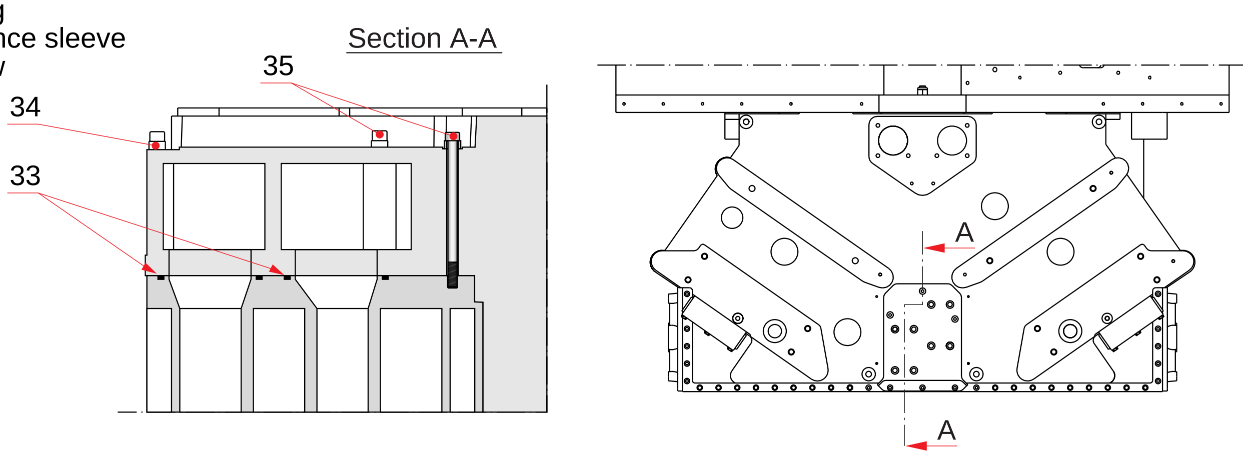


Fig 15-7 4015260408

15 **Remove the flanges (40),** see Fig 15-11.

16 **Slightly lower the air cooler.** Ensure that all screws are removed and that the cooler moves freely.

17 **Guide the air cooler to the floor.** Place e.g. 2 pieces of I-bars under the cooler.

Air cooler assembly

25. End cover
26. Air cooler (B)
27. Central connector
28. Air cooler (A)
31. Screw
33. O-ring
36. Drain

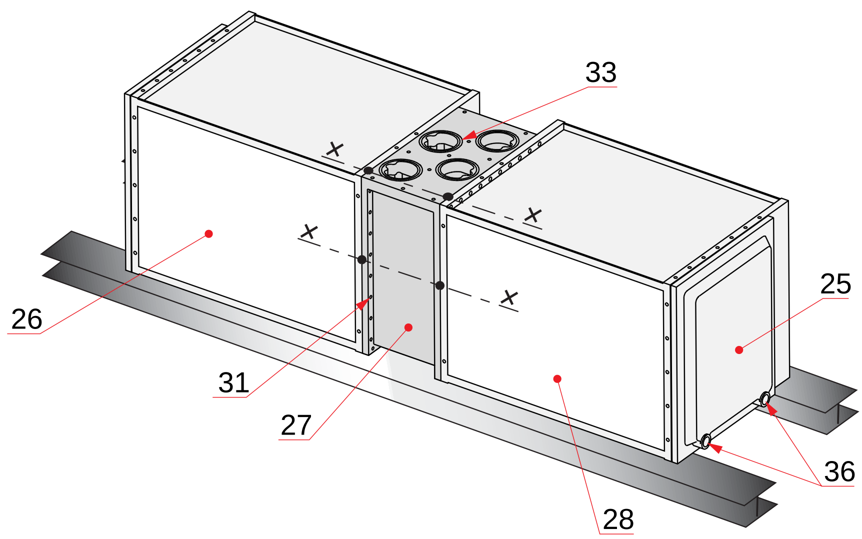


Fig 15-8 4015180351

18 **Split the cooler assembly into 3 parts** (A-bank, B-bank and central connector).

19 **Remove the end covers (25) of the air coolers,** see Fig 15-8.

15.5.3 Cleaning of air cooler

Clean air cooler heat exchange surfaces are essential for a long and trouble-free engine operation. The cleaning should be done in regular intervals following the pressure drop (Δp) over the charge air cooler.

1 **Remove the cooler** according to section 15.5.2.

2 **Clean the air side of the cooler** by immersing the air cooler in a chemical cleaning bath for at least 24 hours. See chapter 02 for approved cleaning detergents.
The best cleaning effect is achived if the cleaning tank is equipped with perforated pipes, see Fig 15-9. During cleaning, steam or pressurized air is fed through the pipes. When cleaning is completed, the cooler should be flushed thoroughly with water.

Note! **The use of a high pressure water jet for flushing, should be avoided because:**
- it will pack the dirt into the middle of the cooler
- the cooler fins will be damaged
This will cause lowered air cooling efficiency.

3 **Clean the water side** by immersing the tube bundle into a chemical cleaning bath for at least 24 hours. Follow the recommendations given for the air side.

4 **Mount the cooler on the engine** according to section 15.5.5

Air cooler cleaning tank

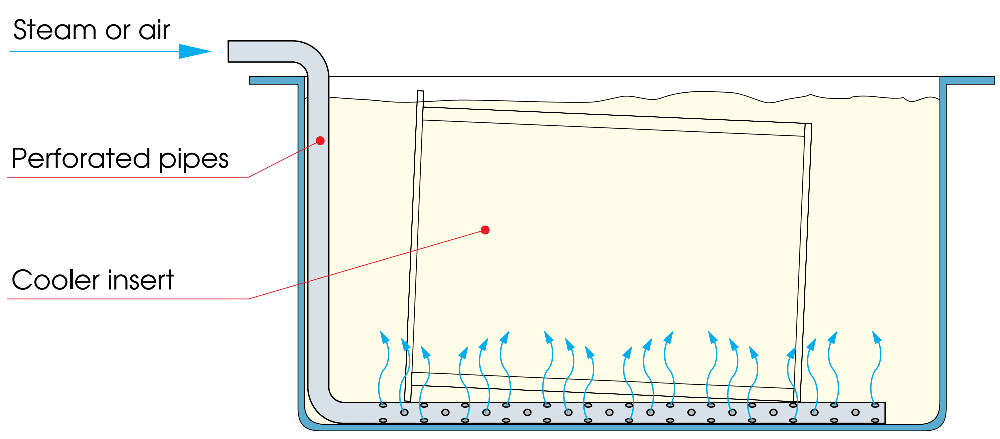


Fig 15-9 4015039701

15.5.4 Pressure testing of air cooler

1 **Mount the testing tool, see Fig 15-10** onto the cooler and fill it up with water by the hand pump.

2 **Pressure test the air cooler for 30 minutes.** See instructions for testing device, according to cooler type, in the table below.

3 **Drain the air cooler.**

4 **Remove the testing tool.**

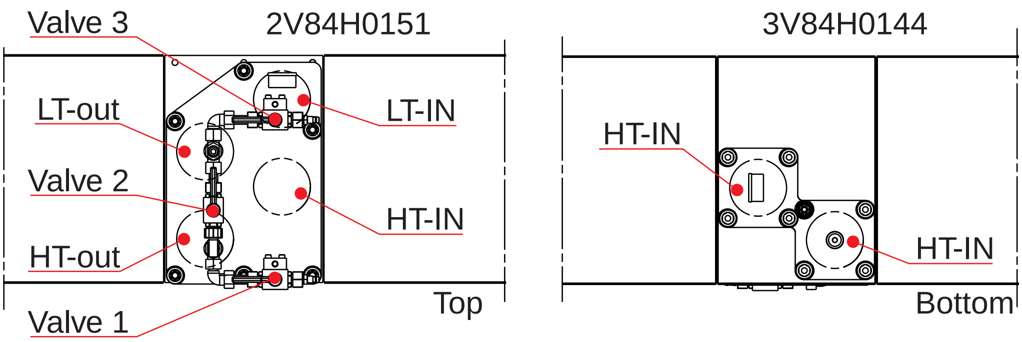
2-stages air cooler V-engine			
Circuit	Water hose connection	**Valves**	**Pressure**
HT	HT-circuit	Valve 1 open, valve 2 closed	1,5 bar
LT	LT-circuit	Valve 3 open, valve 2 closed	1,5 bar
LT and HT	HT-circuit	Valve 1 and 2 open, valve 3 closed	8,0 bar

2-stages air cooler L-engine			
Circuit	Water hose connection	**Valves**	**Pressure**
HT	HT-circuit	Valve 1 open, remove hose from LT-circuit	1,5 bar
LT	HT-circuit	Valve 1 closed, connect hose to LT-circuit	1,5 bar
LT and HT	HT-circuit	Valve 1 open, connect hose to LT-circuit	8,0 bar

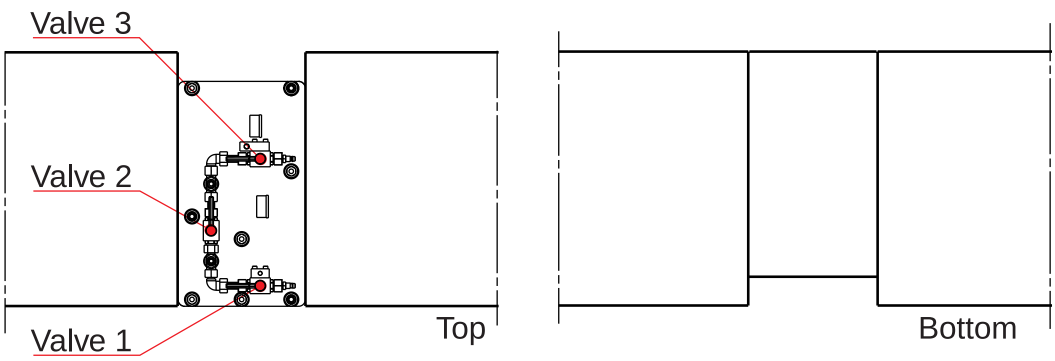
1-stages air cooler			
Circuit	Water hose connection	**Valves**	**Pressure**
LT	LT-circuit	-	8,0 bar

Test pressure tools

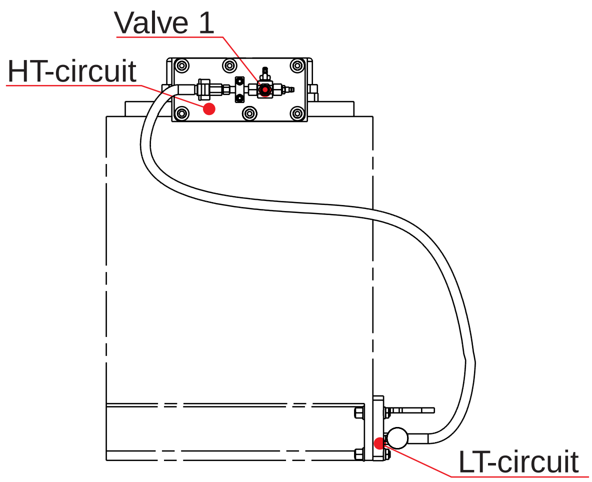
-2-stage cooler V-engines: 3V84H0157



-2-stage cooler V-engines: 3V84H0190



-2-stage cooler L-engines: 1V84H0180/1V84H0187



-1-stage cooler: 3V84H0159/3V84H0186

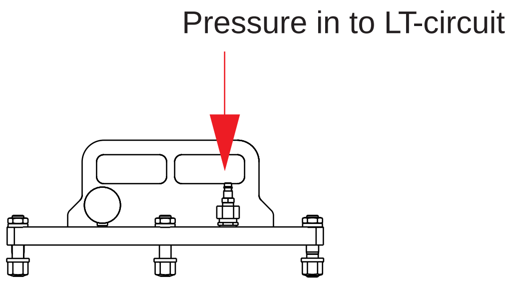


Fig 15-10 4015230406

15.5.5 Assembling (V-engines)

1 **Mount the coolers (26) and (28),** see Fig 15-8 and the central connector (27) with the screws (31). **Note! Renew all gaskets!** Take care that the coolers are well supported. The central connector has to be fitted with 2 pieces of O-rings on both sides. Align the cooler and central connector as in Fig 15-8 marked X - X.

2 **Mount the end covers (25).** Glue compound (e.g. Easy Work RTV 345) must to be applied on all gaskets.

3 **Mount the lifting tool (800 077) and lift the air cooler assembly** into position and ensure that there are no obstacles for the mounting before applying the glue compound.

4 **Lower the cooler assembly.**

5 **Apply glue compound** (e.g. Easy Work RTV 345) on all metallic surfaces/bellows surfaces.

6 **Apply approved sealant (39)** (e.g. Duramix 4031) according to Fig 15-11. **Note! The sealant sets within 10 - 15 minutes.**

Charge air cooler assembly

18a-d. Screw
39. Sealant
40. Flange

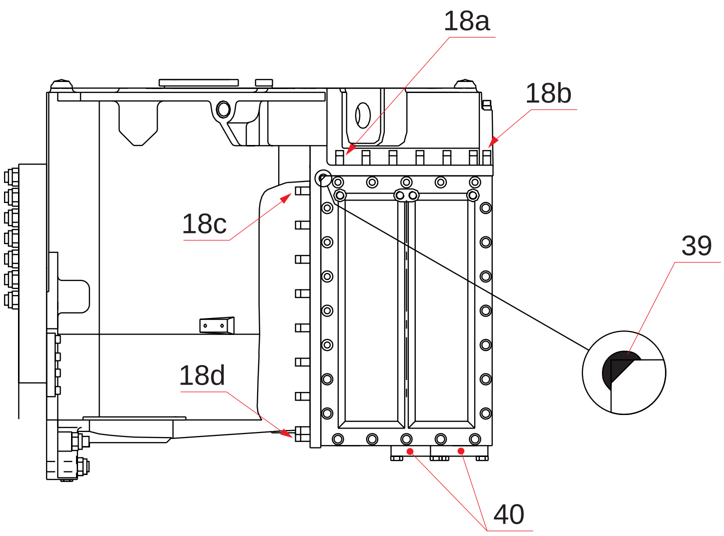


Fig 15-11 4015220406

7 **Lift the air cooler assembly** into correct position. Ensure that the O-rings (33) stays in place when lifting the cooler into position.

8 **Mount the screws (18a-18d)** on both sides, see Fig 15-11. **The charge air cooler has to be tightened in turn in directions Y and Z,** see Fig 15-6.

9 **Mount all screws (18), (30) and (35) of the air cooler,** see Fig 15-6 and Fig 15-7, and tighten these according to chapter 07. Remove the lifting tool.

10 **Mount the studs** and lift the air inlet box (16) into position, see Fig 15-5.

11 **Mount the air inlet box (17),** but do not tighten it before all the nuts (15) are hand tightened.

12 **Tighten the nuts (14) and (15) on the air inlet boxes** to torque according to chapter 07.

13 **Tighten the screws (13).**

14 **Mount the electrical equipment.**

15 **Fill the cooling system with water**

16 **Vent the air cooler** and check the tightness of the sealings at engine start-up.

15.5.6 Charge air pressure difference over air cooler

The charge air cooler maintains the thermal load of the diesel engine at a correct level. This is very important for keeping fuel consumption and operating costs down.

An increasing pressure drop (Δp) over the charge air cooler (on the “air side”) causes an increasing thermal load and increasing fuel oil consumption.

By constant measuring of the Δp over the charge air cooler, the condition of the charge air cooler can be evaluated, and the air cooler can be cleaned or changed to a spare air cooler at the right time.

Δp over clean charge air cooler (mmH_2O)/(mbar)			
Engine type	Single stage cooler	Two stage cooler	Alarm limit
6L and 12V	215/21	255/25	765/75
8, 9L, 16V and 18V	490/48	530/52	765/75

The pressure difference over the air cooler can be measured by using an u-tube manometer, see Fig 15-12.

1 **Disconnect pipes** from the pressure difference transducer (PDT 623).

2 **Connect the water filled u-tube** to the pipe unions.

3 **Measure the pressure difference** by using a measuring tape.

U-tube manometer

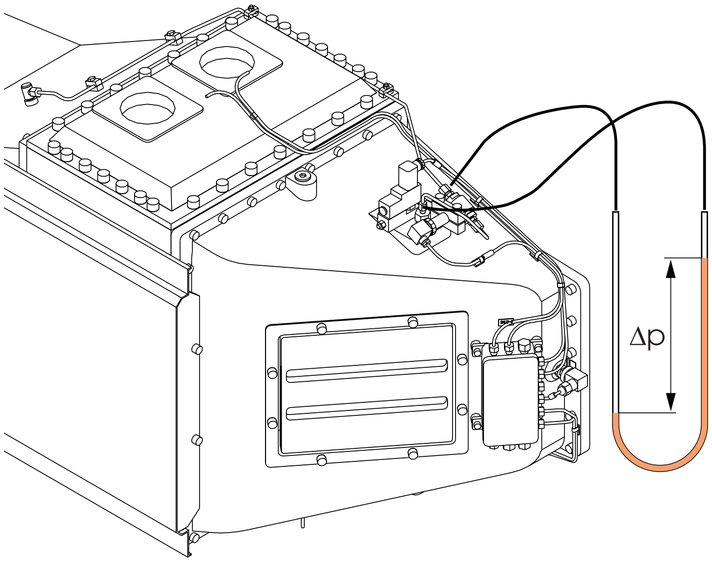


Fig 15-12 401508200050

16. Injection System

16.1 Injection pump

16.1.1 General description

Data and dimensions

Multihousing:
- material special cast iron
- weight: 37 kg

Injection pump element:
- weight: 6,5 kg

Injection press: 1800 bar

Plunger: coated

Constant pressure valve, opens when the pressure difference is: 130 bar

The engine is designed with one injection pump per cylinder. The injection pump is located in a “multihousing”. The functions of the multihousing are:

- Housing for the injection pump element,
- Fuel supply channel along the whole engine,
- Fuel return channel from each injection pump,
- Lubricating oil supply to the valve mechanism.

The arrangement with the multihousing represents the ultimate in safe fuel system. It also gives a compact design without fuel piping and with easy maintenance operations.

The injection pumps are one-cylinder pumps with separate roller tappets. The element, of mono element type, is fuel lubricated. The drain fuel is led in an integrated pipe system with atmospheric pressure back to the low pressure side of the injection pump.

Each injection pump is equipped with an emergency stop cylinder coupled to an electro-pneumatic overspeed protecting system.

16.1.2 Function

The injection pump pressurises fuel to the injection nozzle. It has a regulating mechanism for increasing or decreasing the fuel feed quantity according to the engine load and speed. The pumps are governed by the governor.

The plunger, pushed up by the camshaft via the roller tappet and pulled back by the spring acting on the plunger, reciprocate in the element on a predetermined stroke to feed fuel under pressure.

The plunger also controls the injected amount by adjusting the helix edge position relative to the discharge port. The plunger has an obliquely cut groove (lead) on its side. When the plunger is at the lowest position or bottom dead centre, fuel flows through the inlet port into the element bore. Rotation of the camshaft moves the plunger up. When the top edge of the plunger step is lined up with the ports, application of pressure to fuel begins. As the plunger moves up further, and the helix of the plunger meets with the ports, the high pressure fuel flows through the lead to the ports and the pressure feed of fuel is completed.

The plunger stroke during which the fuel is fed under pressure is called the effective stroke.

According to the engine load, the amount of fuel injected is increased or reduced by turning the plunger a certain angle to change the helix position where the ports are closed on the up stroke and hence increasing or reducing the effective stroke. The fuel rack is connected to the regulating mechanism of the governor. If the fuel rack is moved, the control sleeve in mesh with the rack is turned. Since the control sleeve acts on the plunger, the plunger turns with the control sleeve, thus the effective stroke changes and the injected fuel amount increases or decreases.

The fuel delivery valve and constant pressure valve are located in the head piece. The ports are of a special design to prevent cavitation.

The delivery valve, provided into the head piece, performs the function of discharging the pressurized fuel to the injection pipe. The fuel compressed to a high pressure by the plunger forces the delivery valve to pop up. Once the effective stroke of the plunger ends, the delivery valve is brought back to its original position by the spring and blocks the fuel path, thereby preventing counter flow of the fuel.

After the effective stroke, the fuel is drawn back through the constant pressure valve from the high pressure injection pipe to instantly lower the residual pressure between the delivery valve and the nozzle. This termination maintain consistent injection “shot to shot” by maintaining a constant pressure in the pipe line between injections.

The multihousing is provided with two erosion plugs, which can easily be replaced when necessary.

16.2 Maintenance of injection pump

Most maintenance operations can be done without removing the multihousing from the engine. It is recommendable that the engine will be run 5 minutes with light fuel before stopped for overhaul of injection pump. During maintenance utmost cleanliness must be observed.

16.2.1 Removal of injection pump and guide block

1 **Shut off fuel supply** to the engine and stop the prelubricating pump. Remove necessary covers.

2 **Drain out the fuel from** the multihousing fuel pipes by using a drain plug at the end part of the fuel pipes, see Fig 17-1.

3 **Turn the crankshaft** so that the injection pump tappet is in the bottom position, the roller resting on the base circle of the cam.

4 **Remove necessary pipes,** injection pipe, fuel leak pipes and lube oil pipe. Disconnect the fuel rack.

5 **Open the fuel pipe connections** between the injection pump concerned. Open hexagon socket screws and remove locking plates. Move the fuel line connecting sleeves clear of the adjacent fuel pipes by using the tool 800039.

6 **Open the injection pump fastening nuts (31).**

7 **Mount the lifting tool 800073** and lift off the pump.

8 **Open the fuel pipe connections** between the multi-housings concerned. Open hexagon socket screws and remove locking plates. Move the fuel line connecting sleeves clear of the adjacent fuel pipes by using the tool 800039.

9 **Open the guide block fastening screws** and lift off the guide block with the extractor tool 800140.

10 **Cover immediately all openings** with tape or plugs to prevent dirt from entering the system.

Injection pump

1. Screw
2. Screw
3. Head piece
4. Pin
5. Erosion plug
6. Control sleeve
7. Spring plate
8. Spring
9. Spring holder
10. Retainer ring
11. Screw
12. Cover
13. Screw
14. Flange
15. Push spindle
16. Spring
17. Spring disc
18. Spring
19. Screw/ Pin
20. Tappet
21. Locking plate
22. Sleeve
23. Screw
24. Adjusting screw
25. Element plunger
26. Element cylinder
27. Fuel rack
28. Delivery valve + spring
29. Pin
30. Pressure relief valve + spring
31. Nut

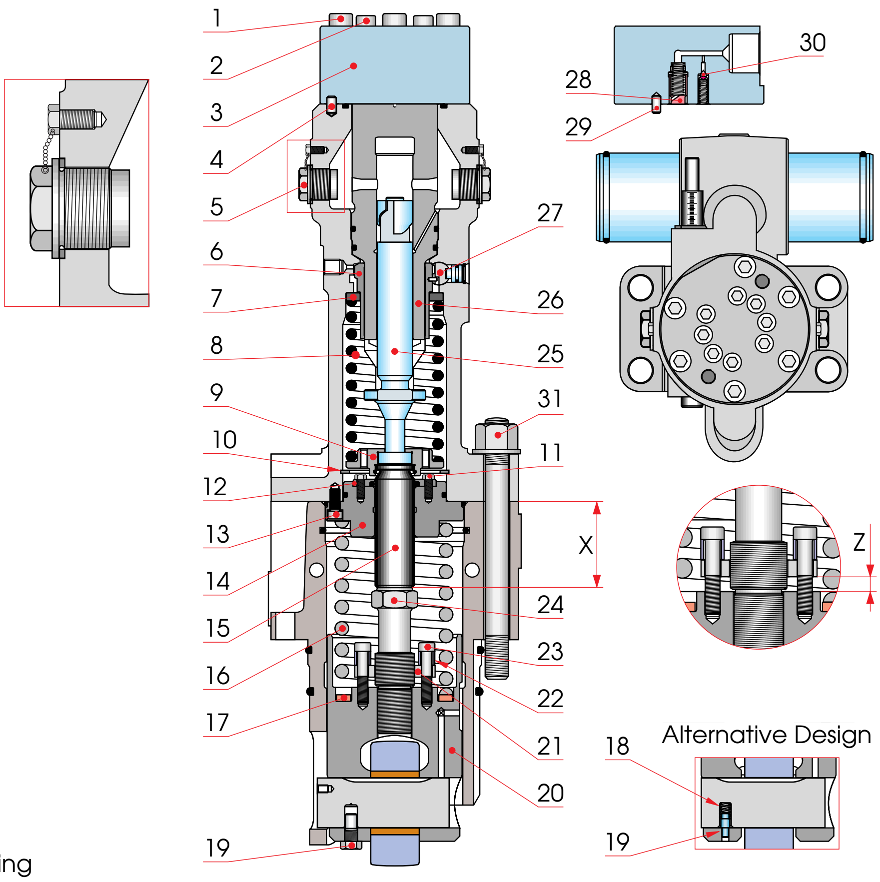
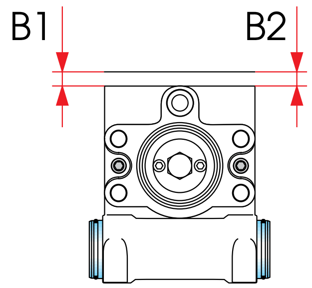


Fig 16-1 4016440315

16.2.2 Mounting of injection pump and guide block



1 **Clean the contact faces of the** guide block. Pay special attention to the O-ring sealing surfaces. Renew the O-rings and lubricate with grease or engine oil.

2 **Remove the protecting tapes or plugs.**

3 **Mount the complete housing** onto the engine.

4 **Check the parallelism of the roller axis** to the camshaft by measuring the distance to the engine block on both sides of the guide block with a feeler gauge, i.e. measures B1=B2, see adjacent figure. Tighten the screws to the stated torque according to chapter 07.

5 **Mount the lubricating oil pipes.**

6 **Connect the fuel pipes** between the multihousings concerned. Move the fuel line connecting sleeves on the adjacent fuel pipes by using the tool 800039.

7 **Check the adjustment of the injection pump** according to work steps 2 to 6 in section 16.2.3.

8 **Clean the contact faces of the** guide block and injection pump. Renew the O-rings and lubricate with grease or engine oil. Mount the spring (16) in the guide block.

9 **Mount the injection pump** and tighten the nuts (31) lightly.

10 **Connect the fuel pipes** between the injection pumps concerned. Move the fuel line connecting sleeves on the adjacent fuel pipes by using the tool 800039.

11 **Mount the locking plates** and tighten screws.

12 **Tighten the nuts (31) to the stated torque** according to chapter 07.

13 **Mount necessary pipes** and injection pipe. Tighten the injection pipe to the stated torque according to chapter 07. Connect the fuel rack. **Note! Check the injection pipe tightening torque after some running hours on a hot engine.**

14 **Rotate the control shaft** and check that all pumps follow the shaft movement. Check the fuel rack positions of all pumps, see chapter 22.

15 **Open fuel supply** to the engine and vent the fuel system according to the instructions in chapter 17.

16.2.3 Adjustment of injection pump

Pump timing can alter due to manufacturing tolerances in pumps, cams and gears or when doing some modifications to the engine. To get best possible operation to the engine it is important that fuel pump adjustments are done properly and are according to the setting table, see test records.

1 **Remove the injection pump** from the engine, see section 16.2.1.

2 **Turn cylinder concerned** to the position until pump tappet roller is on the base circle of the camshaft.

3 **Measure the distance "X",** between adjusting screw and the upper surface of the tappet housing, see Fig 16-1.

4 **Open the locking screws (23)** and adjust the distance "X" to the correct value, see section 06.2, by turning the screw (24).

5 **Tighten the screws (23)** to the torque given in chapter 07.

Note! **Distance "Z" between locking plate (21) and tappet (20) must be adjusted if locking screws (23) have been removed.**
- Hold the adjusting screw (24) and screw the locking plate (21) down until it is in contact with the tappet (20).
- Hold the adjusting screw and screw the locking plate upwards 5 to 5 1/2 turns (Z=10 - 11 mm).
- Mount the sleeves (22) and the screws (23).
- Proceed according to step 3 above.

6 **Check the distance "X"** and proceed from the workstep 9 in the section 16.2.2.

16.2.4 Injection pump overhaul

It is supposed that the multihousing is removed from the engine and it is properly cleaned.

Note! **The element cylinder, plunger and delivery valve assembly are matched and they must be kept together during the overhaul.**

1 **It is recommendable** to put the pump in a screw vice, in positions convenient for the different operations.

2 **Turn the pump up side down.**

3 **Open the screws (13)** and remove the flange (14).

4 **Secure the bush spindle assembly** by using the tool 800033 and remove the retainer ring (10) by using pliers.

Note! **The push spindle is spring loaded; Be careful when loosening the tool.**

5 **Release the spring tension** and remove the tool.

6 **The push spindle (15),** spring holder (9), spring (8) and the plunger (25) can now be removed.

7 **Remove the spring plate (7)** and control sleeve (6).

8 **Turn the pump** and open the screws (1) and (2) in crosswise steps of 30°.

9 **Remove the head piece (3)** and remove the fuel delivery valve (28) with spring and pressure relief valve (30) with spring.

10 **Remove the element cylinder (26)** by using a soft tool.

11 **Wash the parts** in absolutely clean diesel oil and lubricate these with engine oil. Pay special attention to the grooves and bores for leak fuel and lubricating oil. When handling small components of the injection equipment, keep hands absolutely clean and grease them with grease or oil. Keep the parts together, the plunger being inserted in the element.

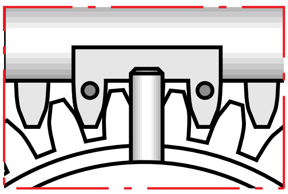
12 **Normally, further dismantling** is not necessary. It is recommendable to keep the components of different pumps apart from each other, or to mark them so they can be fitted into the same pump. The parts must be protected against rust, and the running surface of the element plunger especially should not be unnecessarily handled with bare fingers.

13 **Re-install the delivery valve with spring (28)** and pressure relief valve with spring (30) into the head piece (3).

14 **Screw the element cylinder** together with head piece using the screws (2). Check that the fixing pin (29) is fitted properly.

15 **Mount new O-rings/sealring(s)** and re-install the element cylinder with the head piece into the multi housing, tightening lightly the screws (2) crosswise.

16 **Tighten the screws (2)** crosswise in steps to the stated torque and then the screws (1) in the same way, see chapter 07.



17 **Turn the pump** and assemble the control sleeve (6) with the fixing pin aligned with the groove in the fuel rack, see adjacent figure.

18 **Re-install the spring plate (7)** and the spring (8).

19 **Re-install the element plunger (25)** assembly with the spring holder (9) and the push spindle (15) carefully into correct position.

Note! **The marker on one of plunger vanes. The marked plunger vane must slide into the fuel rack side of the control sleeve, i.e. correspond to the marks on the fuel rack and the chamfered tooth of control sleeve.**

20 **Press the push spindle** down carefully by using the tool 800033. To make the plunger vanes slide into the grooves on the control sleeve you can gently move the fuel rack.

21 **When plunger is deep enough** install the retainer ring (10) with pliers. Remove tool and check that fuel rack can be easily moved.

22 **Before mounting the flange (14),** check that sealing is intact. If necessary replace sealing by opening the screws (11) and removing the cover (12) and sealing.

23 **Mount the flange (14)** and tighten the screws (13) to the stated torque, see chapter 07.

24 **Check that fuel rack (27)** can be easily moved.

25 **Unless the pump is immediately mounted** on the engine, it must be well oiled and protected by a plastic cover or similar. The fuel ports and the injection line connection must always be protected by plugs or tape.

16.2.5 Changing of erosion plugs

1 **Remove the locking wire** between the locking screws and erosion plugs (5).

2 **Change erosion plugs** and tighten to correct torque, see chapter 07.1.

3 **Lock the erosion plugs** with a locking wire to the fastening screw, see Fig 16-1

Note! **To prevent a risk of a high pressure fuel leakage, the erosion plugs must be locked.**

16.3 Injection line

The injection line consists of two parts, the connection piece, which is screwed sideways into the nozzle holder, and the injection pipe.

The connection piece seals with plain metallic surfaces and these surfaces are to be checked before mounting. Always tighten the connection piece to correct torque before mounting the injection pipe; also in case only the injection pipe has been removed, because there is a risk of the connection piece coming loose when removing the pipe.

The injection pipe is covered by a shielding to protect the engine environment from fuel leakages. The injection pipes are delivered complete with connection nuts assembled. Always tighten the connections to correct torque.

When removed, the injection line details have to be protected against dirt and rust.

16.4 Injection valve

16.4.1 Description

Data and dimension
Orifices: 10 pcs
Orifice dia.: 0.54 mm
Angle: 155°
Opening press: See chapter 06.

The injection valve is centrally located in the cylinder head and includes the nozzle holder and the nozzle (15), see Fig 16-2. The fuel enters the nozzle holder sideways through a connection piece (2) mounted into the nozzle holder.

The nozzles receive high pressure fuel from the injection pipe and inject this fuel into the combustion chamber as a very fine spray. The pressure at which the nozzle operate can be corrected by turning the adjusting screw (7) in the injection valve.

Injection valve

1. Injection pipe
2. Connection piece
3. O-ring
4. Protecting sleeve
5. O-ring
6. Counter nut
7. Adjusting screw
8. Spring retainer
9. Guiding screw
10. Spring
11. Push rod
12. Injection valve housing
13. Fixing pin
14. Nozzle nut
15. Nozzle
16. Screw
17. Conical ring elements
18. Flange
19. Flange

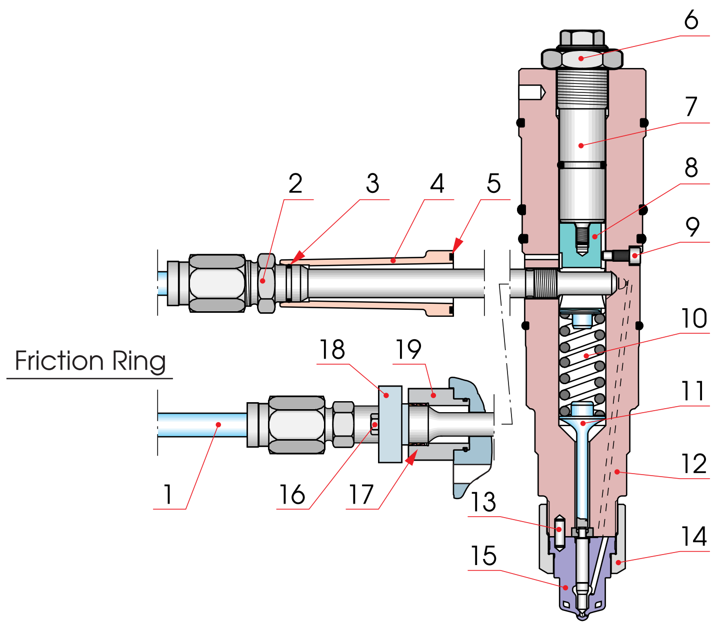


Fig 16-2 4016029601

16.4.2 Removing of injection valve

1. **Open the cylinder head-** and hot box covers.
2. **Remove the injection pipe (1),** see Fig 16-2.

3 **Unscrew the connection piece (2)** and loosen the protecting sleeve (4) if necessary. Friction ring design, see text below.

4 **Loosen the screw (16)** and unscrew the connection piece (2). The conical ring elements (17) come loose together with connection piece.

5 **Remove the fastening nuts** of the injection valve.

6 **Lift out the injection valve** with the tool 800029.

7 **Protect the fuel inlet hole** of the injection valve and the bore in the cylinder head.

16.4.3 Overhauling of injection valve

1 **Inspect the nozzle** immediately after removing the injection valve from the engine. Carbon deposits (trumpets) may indicate that the nozzle is in poor condition, or that the spring is broken. Clean outside of the nozzle with a brass wire brush. **Don't use steel wire brush**.

2 **Check the function and condition of the nozzle,** i.e. the opening pressure and spray uniformity.

3 **Release the nozzle spring tension** by opening the counter nut (6) and releasing the adjusting screw (7).

4 **Remove the nozzle from the holder** by turning the cap nut (14) using tool 800037 until it is loosened. Keep the nozzle together with the holder body, don't let it follow up with the nut. If there is coke between the nozzle and the nut, the dowel pins may break and damage the nozzle. To avoid this, knock on the nozzle, using a piece of pipe according to Fig 16-3, to keep it towards the holder. **Never knock directly on the nozzle tip**. Be careful not to drop the nozzle.

5 **Check the nozzle needle movement** which may vary as follows:

- needle completely free
- needle free to move within the normal lifting range
- needle is sticking

The needle must not be removed by force because this often results in complete jamming. Unless it can be easily removed, immerse the nozzle in lubricating oil and heat oil to 150 - 200°C. Normally, the needle can be removed from a hot nozzle.

Maximum lift of nozzle, removing of nozzle from holder

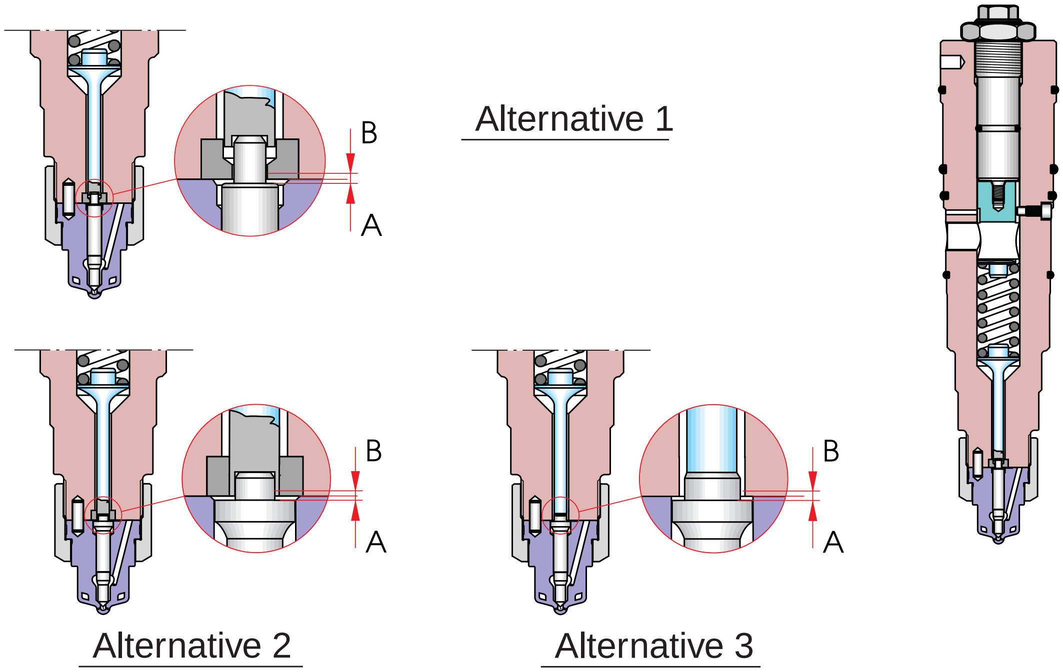


Fig 16-3 40162720026

6 **Clean the components.** If possible, use a chemical carbon dissolving solution. If there is no such available, immerse the details in clean fuel oil, white spirit or similar to soak carbon. Then clean the components carefully by tools included in the tool set. **Do not use steel wire brushes or hard tools**. Clean the nozzle orifices with needles provided for this purpose. After cleaning, rinse the details to remove carbon residues and dirt particles.

Before inserting the needle in the nozzle body, immerse the components in clean fuel oil or special oil for injection systems.

Seat surfaces, sliding surfaces (needle shaft) and sealing faces against the nozzle holder should be carefully checked.

7 **Clean the nozzle holder** and the cap nut carefully; if necessary, dismantle the nozzle holder to clean all details.

Check the nozzle spring.

8 **Check the high pressure sealing faces** of the nozzle holder, i.e. the contact face to nozzle and the bottom of the fuel inlet hole.

9 **Check maximum lift of nozzle,** i.e. sum of measures A and B in Fig 16-3. If the wear B exceeds 0.10 mm, the nozzle holder can be sent to the engine manufacturer for reconditioning. If the total lift is out of the value stated in chapter 06, section 06.2, the nozzle should be replaced by a new one.

10 **Reassemble the injection valve.** Tighten the cap nut to the torque given in section 07.1.

11 **Connect the injection valve** to the test pump. Pump to expel air. Shut the manometer valve and pump rapidly to blow dirt out of the nozzle orifices. Place a dry paper under the nozzle and give the pump a quick blow. Note fuel spray uniformity.

12 **Check the opening pressure:**

- open manometer valve,
- pump slowly and watch manometer to note the opening pressure.
  If the opening pressure is more than 20 bar below the stated value, with damped movement of the indicator, it indicates a broken spring or badly worn parts.

13 **The symmetry of the spray** can be evaluated when having the opening pressure adjusted first to 50 - 100 bar. Needle stroke using standard hand test pump is close to nominal with low opening pressure. Unequal distribution can mean blocked or worn spray holes.

14 **Check the needle seat tightness:**

- increase pressure to a value 20 bar below the stated opening pressure,
- keep pressure constant for 10 seconds and check that no fuel drops occur on the nozzle tip. A slight dampness may be acceptable.

15 **Check the needle guide tightness:**

- increase the pressure in test pump over 300 bar,
- stop pumping and measure the pressure drop time from 250 to 200 bar. In a new nozzle the time varies between 3 - 6 seconds but is much depending on the test equipment. To judge the wear correctly, you should note the pressure drop time in a new nozzle and compare the results to later testing results with same nozzle. If pressure drop time on a used nozzle dropped to 1/3 of the original, the guiding is worn too much and the nozzle has to be replaced.

16 **If the tests according to step 11...15** give satisfactory results the injection valve can be re-installed in the engine. Otherwise, replace the nozzle by a new one.

17 **If leakage occurs** on the high pressure sealing surfaces the damaged detail should be replaced by a new one or reconditioned.

18 **If nozzles or injection valves are to be stored** they should be treated with corrosion protecting oil.

16.4.4 Testing of nozzle function in general

- If abnormal running parameters are observed (abnormally high or low exh. gas temperatures, low firing pressure) one reason can be leaking or blocked fuel injector(s).
- The nozzle holes can be checked with the hand test pump by giving a quick and heavy blow and using a paper under the nozzle tip, **but keep your hands away**. All sprays should give an equal impression on paper; the number of impressions should correspond to the hole configuration (10 holes). An irregular form tells that the hole is partly blocked and should be cleaned.
- Testing of nozzle atomization with the hand test pump however is not completely reliable. When using hand test pump, the injected fuel amount is very small. Therefore, the needle stroke is very short and may give an impression of bad atomization.

A nozzle that gives bad atomization on the test pump can give good performance on an engine.
Fot tests of the nozzle function with fully amount of fuel injected, a special booster unit is developed and can be ordered as an optional tool.

16.4.5 Function of the booster unit

The aim with the booster unit after the hand test pump is to provide waving fuel pressure with a right quantity to the nozzle.

The booster unit is operating as follows:

1 **Fuel is supplied** from the hand test pump device through the port (1) to the chamber (2). see Fig 16-4.The first filling of the booster requires about 80 strokes.

2 **If the booster unit** has not been used, the trapped air is pumped out (requires 5-8 strokes) through the lower valve (3) to the leak channel. Close the valve (3) after venting the booster unit.

3 **The right pressure wave level** is reached by pumping prepressure to the high pressure line to fuel injector. This is done by opening the valve (4) and pumping with the test pump the pressure little over 200 bar. After this the valve (4) should be closed.

Booster unit

1. From hand pump
2. Chamber
3. Valve
4. Valve
5. Control valve

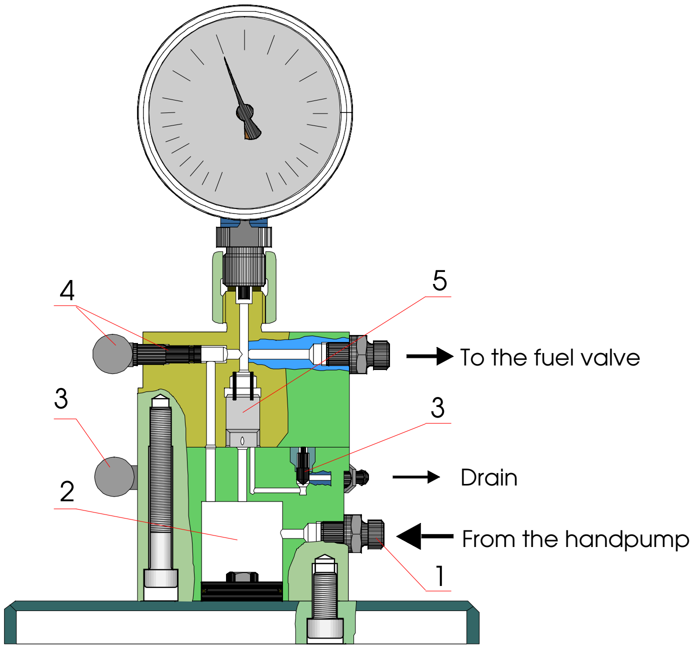


Fig 16-4 401620200209

Note! **The appearance in testing will be a big bang as well as fuel mist like in an actual engine.**
Therefore assure adequate ventilation of the space where testing is done and observe the normal safety regulations of fuel handling.
When adjusting the opening pressures of fuel valves with the booster unit connected, valve (3) is to be kept closed and valve (4) opened.
It is recommended to store the fuel valves with the adjusting screws loosened, i.e. to adjust the valves first just before putting them in the engine(s).

4 **When pumping** with the hand test pump device, the pressure increases inside the chamber (2). At the certain point the pressure/force against the control valve (5) is bigger than the force in opposite side (spring force + pressure). This will make the control valve (5) open. The function of the control valve is similar to the main delivery valve in the fuel injection pump head.

5 **The pressurized fuel having a step pressure wave** is entering to fuel injection valve. Now with a bigger volume than with the standard hand test device, the nozzle reaches full needle lift. After the test the pressure in high pressure line will be reduced by opening the draining valve (3).

16.4.6 Mounting of injection valve

1 **Check that the bottom surface** of the bore in the cylinder head is clean. If necessary, clean or lap the surface by the tool 800075. If lapping is necessary, the cylinder head must be lifted off. For lapping, a steel washer and fine lapping compound is used. **Note! The injection valve seals directly to the bottom of the cylinder head bore without seal ring.**

2 **Put new O-rings on the injection valve.** Lubricate the O-rings with lubricating oil or grease.

3 **Fit the injection valve** into the cylinder head bore and tighten the nuts by hand. **Note the guiding pin position.**

4 **Put new O-rings on the connection piece** and on the protecting sleeve if it has been removed.

5 **Mount the protecting sleeve on the connection piece** if it has been removed. Screw in the connection piece by hand. Tighten to correct torque. Tighten the protecting sleeve screws. Friction ring design, see step 6.

6 **Mount the connection piece** into the cylinder head. Screw in the connection piece by hand. Tighten to correct torque.(Friction ring design only, see Fig 16-2.)

7 **Tighten the fastening screws (16)** of the flange (18) to correct torque, see section 07.1. (Friction ring design only.)

8 **Tighten the fastening nuts** of the injection valve to correct torque, see section 07.1, in steps of 10 - 20 Nm.

9 **Mount the injection pipe** and tighten the cap nuts to torque.

10 **Close the covers.**

16.5 Pneumatic overspeed trip device

The pneumatic overspeed trip device is mounted on the multi-housing and acts directly on the fuel rack. If the overspeed trip device is activated, pressurized air acts on a piston in a cylinder attached to the multihousing. The piston forces the fuel rack to a “no fuel” position. The force of the overspeed trip device is stronger than the torsion spring in the regulating mechanism. For maintenance of pneumatic overspeed trip device see chapter 22.

Pneumatic overspeed trip device

1. Fuel rack
2. Piston
3. Cylinder
4. Slide ring

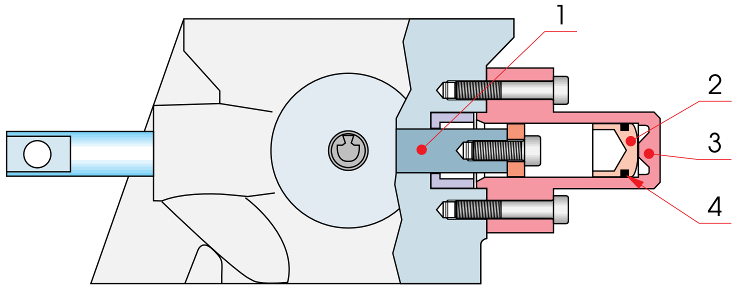


Fig 16-5 4016049601

17. Fuel System

17.1 General description

The engine is designed for continuous heavy fuel duty. The main engine as well as the auxiliary engine can be started and stopped on heavy fuel provided that the fuel is heated to operating temperature, fuel pumps running and the jacket water preheated to described temperature.

As the fuel treatment system before the engine can vary widely from one installation to another, this system is not described in detail in this manual. See separate instructions. Normally a fuel feed pump delivers the correct flow to the engine through a filter. The correct pressure in the engine system is maintained with an adjustable throttle valve or pressure regulating valve depending on the installation.

It is of great importance that the fuel treatment before the engine is done properly. The filtration of the fuel directly influences on the lifetime of the injection pumps and other components in the injection line and hence the performance of the engine. The fuel pressure and temperature can be seen on the LDU.

Fuel leaking from injection pumps and injection valves is collected in a separate enclosed system. Thus this fuel can be reused. A special module for automatic handling of this fuel back to the system can be delivered on request.

A separate pipe system leading from the top level of the engine block collects waste oil, fuel and water arising, for example, when overhauling cylinder heads.

The high pressure system, with injection pump and injection valve, is described in chapter 16.

Fuel system

1. Alarm for broken injection pipe
2. Leak fuel drain, clean fuel (Optional)
3. Adjustable orifice or pressure regulating valve
4. Pressure sensor
5. Temperature sensor
6. Plug
7. Fuel feed pump
8. Pressure regulating valve
9. Safety valve
10. Deaeration tank
11. Circulating pump
12. Safety valve
13. Pressure regulating valve
14. Valve
15. Valve
16. Valve

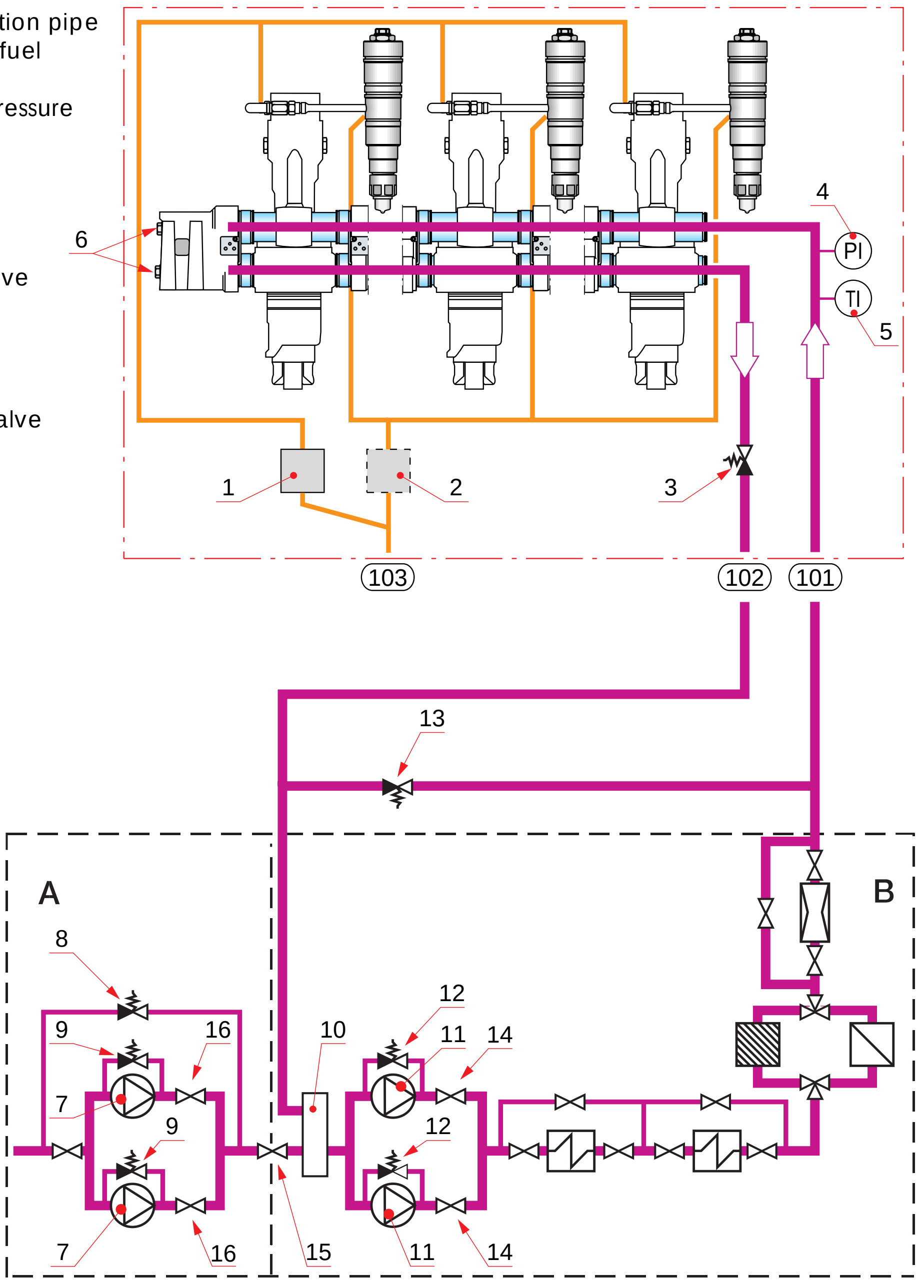


Fig 17-1 401701200001

17.2 Maintenance

When working with the fuel system, always observe utmost cleanliness. Pipes, tanks and the fuel treatment equipment, such as pumps, filters, heaters and viscosimeters, included in the engine delivery or not, should be carefully cleaned before taken into use.

The fuel should always be separated and it is recommendable to fit an automatic filter in the fuel treatment system.

Always when the system has been opened, it should be vented after reassembly, see section 17.3.

For maintenance of the fuel treatment equipment not mounted on the engine, see separate instructions.

17.3 Venting

Start the fuel feed pump if the static pressure from the day tank is not sufficient.

Always vent the filter after changing cartridges in the filter.

17.4 Adjustment of fuel system

Check the adjustment at intervals recommended in chapter 04. Adjust the valves at normal temperatures with an idling engine.

1 **Adjust the fuel system** before engine according to installation specific instructions or by following steps 2 to 5.

2 **The fuel feed pumps (7)** maintain a system pressure of 3 – 4 bar. The pressure is adjusted on the pressure regulating valve (8) when the valve (15) is closed.

3 **The safety valves (9)** on the fuel feed pumps should be adjusted to 12 bar and locked when the valves (16) are closed. The purpose of the safety valve is only to protect the pump.

These adjustments should be carried out rapidly as the pumps may run hot if the system is closed for a lengthy time.

4 **The fuel circulating pumps (11)** keep the fuel in constant circulation and maintain a system pressure between the circulating pumps and the pressure regulating valve (13). Adjust the opening pressure of the pressure regulating valve to 10 bar.

5 **The safety valves (12)** on the fuel circulating pumps should be adjusted to 12 bar and locked when the valves (14) are closed. The purpose of the safety valve is only to protect the pump.

These adjustments should be carried out rapidly as the pumps may run hot if the system is closed for a lengthy time.

6 **The engine mounted pressure regulating valve/adjustable orifice (3)** should be adjusted according as follows. Raise the pressure in the system slowly by closing the valve/ orifice (3), until the pressure meter in LDU is according to chapter 01., section 01.2.

7 **Adjust the other engines** according to workstep described above.

8 **Check that pressures** in all engines are according to chapter 01., section 01.2.

18. Lubricating Oil System

18.1 General design

Normally, a wet sump system is used, but also dry sump systems can be used.

The engine is provided with a lubricating oil pump (3) directly driven by the pump gear at the driving end of the crankshaft. It is possible to connect an electrically driven stand-by pump in parallel if needed. The pump sucks oil from the engine oil sump and forces it through the lubricating oil cooler (6) equipped with a thermostat valve (5) regulating the oil temperature, through the lubricating oil automatic filter (7) to the main distributing pipe in the oil sump, through the hydraulic jacks (in this respect acting ordinary pipes) to the main bearings and through bores in the connecting rods to the gudgeon pins (10), piston skirt lubricating and piston cooling spaces.

Lube oil system

1. Centrifugal filter
2. Prelubricating oil pump with pressure regulating valve
3. Lube oil pump
4. Pressure regulating valve
5. Thermostat valve
6. Lube oil cooler
7. Lube oil automatic filter
8. Oil dipstick
9. Camshaft bearings
10. Gudgeon pins
11. Rocker arm bearings
12. Lube oli to T/C
13. Lube oli from T/C
14. Lube oli sample valve

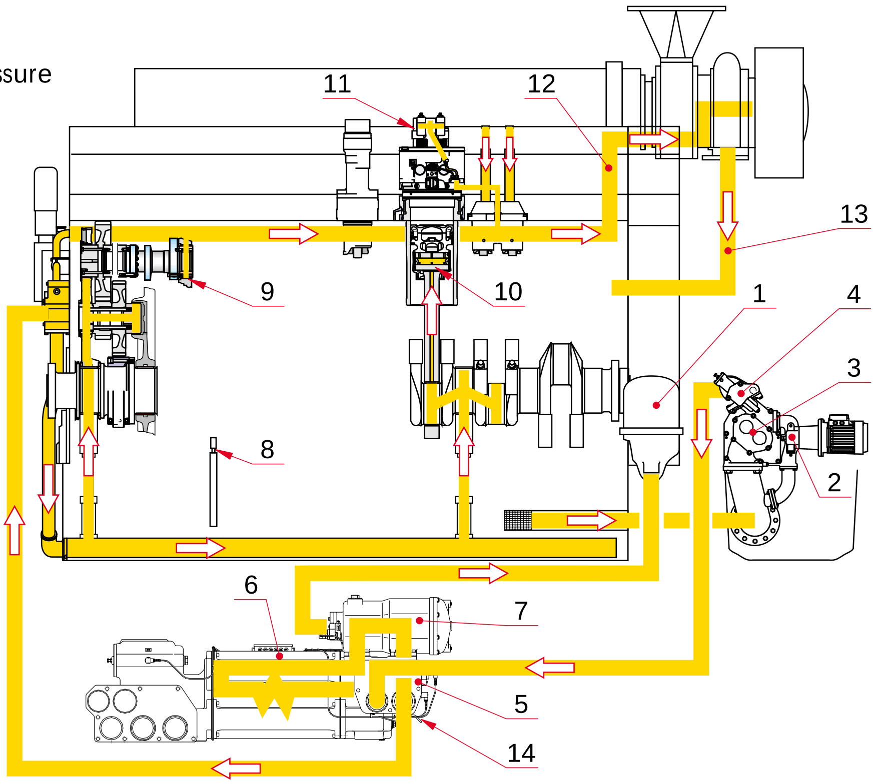


Fig 18-1 401801200051

Oil is led through bores to other lubricating points, like camshaft bearings (9), injection pump tappets and valves, rocker arm bearings (11) and valve mechanism gear wheel bearings, and to oil nozzles for lubricating and cooling. Turbocharger is also connected to the engine lubricating oil system.

Back-flushing oil from automatic filter flows through a pipes to the centrifugal filter (1) and back to the oil sump.

The electrically driven prelubricating pump is a gear type pump and is equipped with common overflow valve with lubricating oil pump. The pump is connected in parallel to the direct driven lubricating oil pump. The pump is used for:

- filling of the diesel engine lubricating oil system before starting, e.g. when the engine has been out of operation for a long time,
- continuous prelubrication of a stopped diesel engine through which heavy fuel is circulating,
- continuous prelubrication of stopped diesel engine(s) in a multi-engine installation always when one of the engines is running.

The pressure in the distributing pipe is regulated by a pressure control valve (4) on the pump. The pressure can be adjusted by means of a set screw (Fig 18-2, pos. 5) on the control valve. It is very important to keep the correct pressure in order to provide efficient lubrication of bearings and cooling of pistons. Normally, the pressure stays constant after having been adjusted to the correct value.

The pressure can rise above the nominal value when starting with cold oil but will return to the normal value when the oil is heated. A pressure gauge on the instrument panel indicates the lubricating oil pressure before the engine. The system includes three pressure switches for low lubricating oil pressure connected to the automatic alarm- and stop system (see chapter 23.).

The temperature can be checked from gauge on the instrument panel before and after the oil cooler (chapter 01., section 01.2). A temperature switch for high lubricating oil temperature is connected to the automatic alarm system (see chapter 23.).

The speed governor has own oil system, see separate instruction book.

The oil dipstick (8) is located at the middle of the engine.

Connections for a separator are provided on the oil sump at the free end of the engine.

For taking oil sample the valve (14) is available after oil filter.

18.2 General maintenance

Use only high quality oils approved by the engine manufacturer according to the list in the end of chapter 02.

Always keep a sufficient quantity of oil in the system. The oil dipstick indicates the maximum and minimum limits between which the oil level may vary. Keep the oil level near the max. mark and never allow the level to go below the min. mark. The limits apply to the oil level in a running engine. Add max. 10 % new oil at a time (see chapter 02., section 02.2). One side of the dipstick is graduated in centimeters. This scale can be used when checking the lubricating oil consumption.

Change oil regularly at intervals determined by experience from the installation concerned, see chapter 04. and 02., section 02.2.3.While the oil is still warm, drain the oil system, as well as the oil cooler and filter. Clean the crankcase and the oil sump with proper rags (not cotton waste). Clean the centrifugal filter.

Centrifuging of the oil is recommended, especially when using heavy fuels, see chapter 02., section 02.2.3.

Utmost cleanliness should be observed when treating the lubricating oil system. Dirt, metal particles and similar may cause serious bearing damage. When dismantling pipes or details from the system, cover all openings with blank gaskets, tape or clean rags. When storing and transporting oil, take care to prevent dirt and foreign matters from entering the oil. When refilling oil, use a screen.

18.3 Lubricating oil pump

18.3.1 Description

The pump is of the gear type. A combined pressure regulating/safety valve is mounted on the housing of the pump. Identical bronze bearings are used. No outside lubrication is required.

Lube oil pump

1. Drive gear
2. Frictional rings
3. Screw
4. Pressure plate
5. Adjusting screw
6. Sealing ring
7. Spring holder
8. Spring
9. Regulating piston
10. Ball for safety valve
11. Spring
12. Bearings lubrication grooves
13. Sleeve
14. Nut

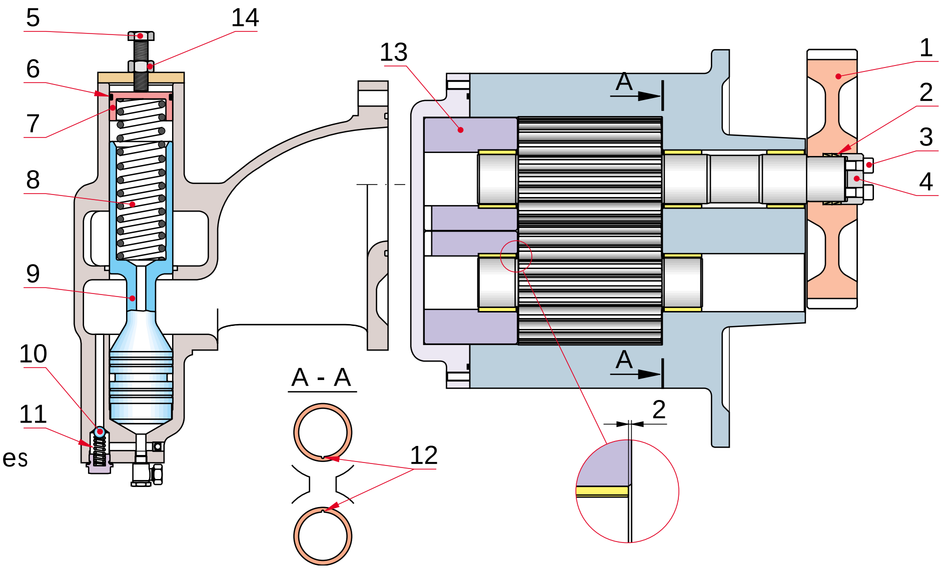


Fig 18-2 4018109701

18.3.2 Removing

1. **Drain the oil sump** if the installation is using wet oil sump.
2. **Loosen necessary pipe connections.**
3. **Remove the suction pipe** between oil sump and lubricating oil pump.
4. **Remove prelubricating oil pump unit.**
5. **Mount lifting eye bolts** to the lubricating oil pump unit.
6. **Remove lubricating oil pump unit.**

Note! **Before removing the unit, leave a couple of screws fastened until the unit is secured with lifting belts.**

7 **Protect the connections** with suitable plugs, clean plastic or similar.

18.3.3 Dismantling

1 **Remove and inspect the regulating valve** according to section 18.4.

2 **Remove the pressure plate (4)** by loosening the fastening screws (3).

3 **Pull off the gear wheel (1)** without using any tool. If the gear wheel does not come loose, a few strokes with a non-recoiling hammer will help. (The friction ring elements come loose together with the gear wheel.)

Using an extractor will only damage the shaft (axial scratches).

4 **Withdraw the pump cover** by using two of the fastening screws in the two threaded holes located in the cover.

18.3.4 Inspection

1 **Check all parts for wear** (chapter 06., section 06.2) and replace worn parts.

2 **Remove worn bearings** from the sleeves and the housing by driving them out with a suitable mandrel.

3 **Mount new bearings** (freezing is recommended) so that the bearings are two 2 mm below the sleeves and housing level, Fig 18-2. Be careful so that bearing lubrication grooves (12) slide into the right position according to section A-A in Fig 18-2.

4 **Mount the sleeves in the cover.** Notice position of the sleeves!

5 **Check the bearing diameter** after mounting. Check the gear wheel axial clearance (see chapter 06., section 06.2).

18.3.5 Assembling

1 **Clean all details carefully before assembling.** Check that the O-ring in the cover is intact and in position.

2 **Before installing the gear wheel,** all contact surfaces should be cleaned and oiled.

3 **Reinstall the friction ring elements (2).**

Reinstall the friction ring elements exactly as situated in Fig 18-3. The friction ring elements should fall easily in place and must not jam.

Mounting of gear wheel

1. Drive gear
2. Frictional rings
3. Screw
4. Pressure plate

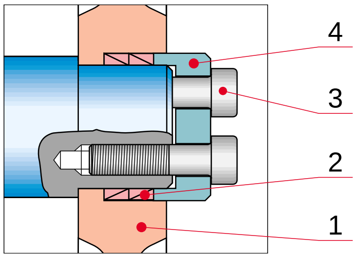


Fig 18-3 4018039601

4 **Reinstall the pressure plate.**

5 **Tighten the screws a little** and check that the gear wheel is in the right position.

6 **Tighten the screws to torque** according to chapter 07.

7 **If the gear wheel (1) has been changed,** check the backlash after mounting.

18.3.6 Mounting

1 **Clean all sealing surfaces carefully** and replace the O-rings with new ones.

2 **Mount the lubricating oil pump unit.**

3 **Mount the suction pipe** between oil sump and lubricating oil pump.

4 **Mount the prelubricating oil pump unit.**

5 **Tighten all fastening screws to stated torque,** see chapter 07.

6 **Connect all necessary pipe connections.**

18.4 Lubricating oil pressure regulating valve and safety valve

18.4.1 Description

The pressure regulating valve, see Fig 18-2, is integrated in the lubricating oil pump module and regulates the oil pressure before the engine by returning the surplus oil direct from the pressure side of the pump back to the sump.

This pressure actuates the regulating piston (9) and the spring (8) is tensioned to balance this force at the required pressure. Thus the pressure is kept constant in the distributing pipe, irrespective of the pressure in the pressure side of the pump and of the pressure drop in the system. By tensioning the spring a higher oil pressure is obtained.

In engines which are running at varying speeds, the valve is arranged to give a pressure depending on the speed, according to operating pressures recommended at various speeds (chapter 01.).

If, for some reason, the pressure should increase strongly in the pressure pipe, e.g. due to clogged system, the ball (10) will open and admit oil to pass to the regulating piston (9). This serves as a safety valve.

18.4.2 Maintenance

1 **Dismantle all moving parts.** Check them for wear and replace worn or damaged parts by new ones.

2 **Clean the valve carefully.**

3 **Check that no details are jamming** while reassembling.

18.4.3 Adjusting of the lubricating oil pressure

1 **Loosen the counter nut (14)** on the adjusting screw.

2 **Slowly turn the adjustment screw (5)** in clockwise direction until the pressure reaches the value mentioned in chapter 01, section 01.1., (can be seen from the engine's Local Display Unit (LDU)).

3 **Tighten the counter nut.**

4 **Check the pressure .**

18.5 Lubricating oil cooler

18.5.1 Description

A tube stack (3) is inserted in a jacket which belongs to lubricating oil module. The tube stack is fixed at one end while the other one is movable in a longitudinal direction to allow expansion. Both ends are provided with two O-rings (4).

The oil flows outside the tubes, while the cooling water flows inside the tubes through the cooler.

The tube stack is made of copper nickel and the water boxes of cast iron.

18.5.2 General maintenance

1 **Clean and test the cooler** by hydraulic pressure at intervals according to chapter 04. or if the lubricating oil temperature tends to rise abnormally.

2 **Water side can be cleaned** by removing the cooler module from the engine and then the lube oil cooler to clean more carefully.

3 **Always when cleaning, check for corrosion** and test by hydraulic pressure.

It is preferable to change the tube stack too early, rather than too late. Water leakage to lubricating oil has serious consequences

18.5.3 Disassembling and assembling of cooler

a) **Disassembling**

1 **Open the valve (2)** for the thermostatic valve and drain the housing. The rest of the lubricating oil in the cooler housing can be drained from the plug (7), see Fig 18-4.

Caution! **Be careful when opening the lube oil cooler! Despite the draining there will always be left a small amount of lube oil in the housing.**

2 **Drain the water side** as much as necessary.

3 **Loosen the housing fastening screws** and remove the complete LT thermostatic valve (6) and sealing (5).

4 **Remove the free O-rings (4).**

5 **Mark the position of the tube stack** relative to the jacket.

6 **Move the tube stack** towards LT control valve housing side until the second O-ring is accessible. Remove the O-ring.

7 **Remove the tube stack** from the lube oil thermostat housing side.

b) Assembling

1 **Check cleanliness and scratches** on all gasket surfaces. Recondition them and use new O-rings. Grease slightly with an appropriate O-ring lubricant.

2 **Move the tube stack into the jacket.** Check tube stack position using the marks mentioned above.

3 **Mount the O-rings** on the free tube sheet (LT-side).

Lube oil cooler

1. Lubricating oil thermostatic valve
2. Sample valve
3. Tube stack
4. O-ring
5. Sealing
6. LT-thermostatic valve
7. Plug

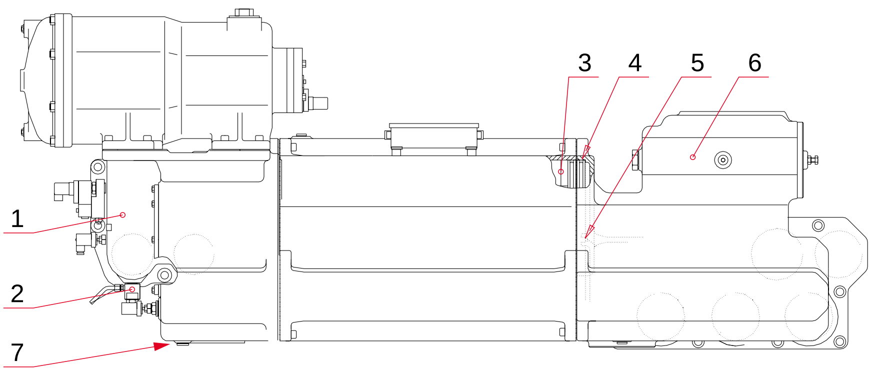


Fig 18-4 4018069601

4 **Move the tube stack** towards the lube oil thermostatic valve side as far as needed to expose the O-ring grooves.

5 **Mount the both O-rings.**

6 **Move the tube stack** towards LT-thermostatic valve until the groove for locking plates is in correct position.

7 **Mount the combined sealing/locking plates.**

8 **Mount the complete** LT-thermostatic valve.

9 **Mount the complete** lube oil thermostatic valve.

18.5.4 Cleaning of oil side

Fouling of the oil side is normally insignificant. On the other hand, possible fouling will influence the cooler efficiency very strongly.

Due to the design, the tube stack cannot be cleaned mechanically on the outside. Slight fouling can be removed by blowing steam through the tube stack.

If the amount of dirt is considerable, use chemical cleaning solutions available on the market:

Alkaline degreasing agents:

Suitable for normal degreasing, however, not effective for heavy greases, sludge and oil coke. Requires high temperature. Always pour degreasing agent slowly into hot water, never the contrary. Rinse carefully with water after treatment.

Hydrocarbon solvents:

Include the whole range from light petroleum solutions to chlorinated hydrocarbons, e.g. thrichlorethylene. These products should be handled with care as they are often extremely volatile, toxic and/or narcotic.

Solvent emulsions:

Heavy fouling, e.g. oil coke, can often be dissolved only by using these solutions. Several brands are available on the market.

Follow the manufacturer's instructions to achieve the best results.

18.5.5 Cleaning of water side

The cleaning should be carried out so that it does not damage the natural protective layer on the tubes. Use nylon brushes, metallic brushes can damage the natural protective layer.

Remove loose sludge and deposits with brush 4V84F06. Rinse with water.

If the deposit in the tubes is hard, e.g. calcium carbonate, it can be removed chemically by using commercial agents. After this treatment the tubes should be rinsed and, if necessary, treated with a solution neutralizing the residual washing agents. Otherwise, follow the manufacturer's instructions.

18.6 Thermostatic valve

18.6.1 Description

The Fig 18-5 shows the valve in a closed position (left). When the temperature exceeds the nominal value, the contents of the elements (1) expands and forces the valve unit (2) towards the end flange, thus passing part of the oil through the cooler. This movement continues until the right temperature of the mixed oil is obtained. As the cooler becomes dirtier, the temperature will rise a few degrees, which is quite normal, because the valve needs a certain temperature rise for a certain opening to increase the oil flow through the cooler.

Thermostatic valve for oil system

1. Thermostat elements
2. Valve unit
3. End flange

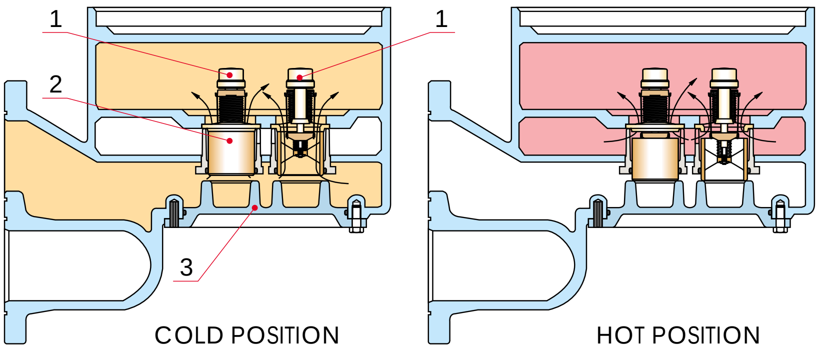


Fig 18-5 4018049601

18.6.2 Maintenance

Normally, no service is required. Too low an oil temperature depends on a defective thermostat, too high a temperature may depend on a defective thermostat, leaking O-rings, although, in most cases, it depends on a dirty cooler.

1 **Drain as much cooling water** as necessary to empty the valve.

2 **Remove the lube oil thermostat housing end flange (3).**

3 **Remove the thermostatic element holder** by opening the screws and withdraw the elements. Use extractor tools 800122 and 800029 for element holder if necessary.

4 **Check the element** by heating it slowly in water. Check at which temperatures the element starts opening and is fully open. The values can be found on the thermostatic element or in chapter 01.; the lower value for the lube oil temperature is the opening temperature, the higher for the fully open valve.

The set point marked on the element is the value when the element is half open.

5 **Change the defective element** and renew O-rings.

18.7 Lubricating oil automatic filter

18.7.1 Description

The filter is full flow filter, i.e. the whole oil flow passes through the filter.

The arrows in Fig 18-6 show the flow through the filter. At first, the oil flows through the inlet flange and turbine (9) to the right end of the filter candles (13); a partial stream of about 50 % is passed through the central connection tube (12) to the left end of the filter candles. This means that the oil flows through the filter candles at both ends from inside outwards and most of the dirt particles are retained in the inside of the candles. The oil filtered in this way now passes through the protective filter (2) to the filter outlet.

Lube oil automatic filter

1. Cover plate
2. Protective filter
3. Overflow valves
4. Flushing arm
5. Flange
6. Worm gear unit
7. Flushing bush
9. Turbine
10. Gear
11. Filter plate
12. Central connection tube
13. Filter candles
14. Plug
15. Flushing shaft
16. Plug
17. Cover
18. End plate

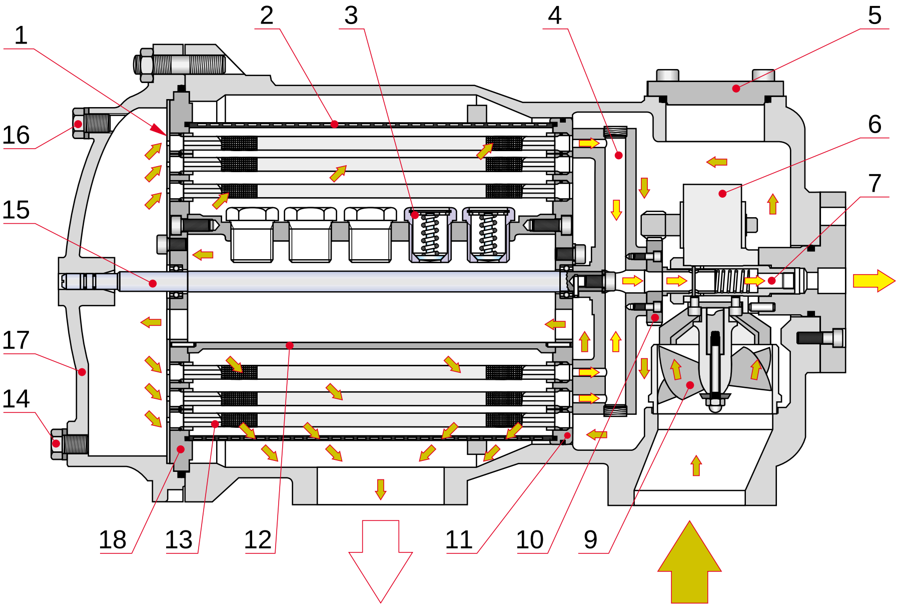


Fig 18-6 4018059601

The flow energy drives the turbine (9) installed in the inlet flange. The high speed of the turbine is reduced by the worm gear unit (6) and gear (10) to the lower speed required for turning the flushing arm (4).

The individual filter candles are now connected successively to the centrifugal filter by means of continuously rotating flushing arm (4) and the flushing bush (7).

The unfiltered oil passes through the optimally designed bores of the cover plate (1) into the individual filter candles from above. The resultant turbulent stream in the longitudial direction of the filter candles (cross-flow back flushing) and the counter flow back-flushing through the filter candles result in a particularly effective and lasting back-flushing action.

The lower pressure in the interior of the filter candles during the back-flushing operation (connected with the centrifugal filter) and the higher pressure (operating pressure) outside the filter candles produce a counter-flow though the mesh from the clean filter side through the dirty filter side to the centrifugal filter.

Should for any reason the filter candles (first filter stage) no longer be adequately cleaned, the overflow valves (3) are opened at a differential pressure of 2 bar upwards and the oil is only filtered through the protective filter (2) (second filter stage).

However, before this situation arises, the installed differential pressure indicator emits a differential pressure warning (first contact). The cause must now be localised and remedied.

If this warning is not heeded, an alarm is emitted by the second contact of the differential pressure indicator.

The filter may only be operated in this emergency condition for a short time (opened overflow valves and differential pressure warning). Prolonged operation in this mode can result in damage to downstream components.

The overflow valves are closed under normal operating conditions, even during start-up at lower fluid temperatures.

18.7.2 Maintenance

Even with automatic filters inspections and maintenance must be performed at regular intervals.

It is extremely important to remember that in spite of constant back-flushing the mesh may become clogged over the course of time, depending on the lube oil quality and separation.

In order to maintain trouble-free operation, the following aspects are to be observed during maintenance:

1. **Check filter and connections for leaks.**

2. **Conduct visual inspection** of all filter candles once a year.

Note! **Should a higher differential pressure occur beforehand, all the filter candles (13) and the protective filter (2) must be checked and, if necessary, cleaned or the candles are to be replaced by new ones.**

A highly contaminated protective filter is a sign of prolonged operation with defective or clogged filter candles and thus (from a differential pressure of 2 bar upwards) opened overflow valves. It is imperative to check these components.

3 **Check the ease of movement** of the worm gear unit (6), the turbine (9) including gear (10) with flushing arm (4) see Fig 18-6.
To this end the cover (5) or the screw plug must be removed. Now check the ease of movement with a suitable spanner (on the hexagon of the worm gear unit).

4 **It is recommended to replace** the filter candles after 2 years.

5 **Replace the O-rings.** It is advisable to replace all O-rings and seals during an overhaul and when opened.

18.7.2.1 Filter candle inspection and cleaning

1 **Drain the filter,** open the plug (16) then open the plug (14), thereafter discharge oil. **Do not refill the system with drained oil because it is very dirty.**

2 **Remove the cover (17)** by opening the nuts, see Fig 18-6.

3 **Pull the entire filter element** including flushing arm (4) and gear (10) out of the housing with a suitable tool.

Note! **Make sure that the exposed gear (10) is not damaged.**

4 **Remove the cover plate (1).**

5 **Remove the end plate (18)** by opening the screws.

6 **The filter candles (13)** and protective filter (2) can now be removed.

7 **Place the filter candles** and the protective filter in a suitable cleaner or diesel oil, max. soaking time 24 hours.

8 **After immersing** clean them from the outside inwards using high pressure.

It must be ensured that the filter candles are cleaned at a pressure of max. 60 bar and at a minimum distance of cleaning nozzle of 20 cm. Otherwise, damage to the mesh is possible.
To get a optimal cleaning effect it is recommended to use special

high-pressure cleaning unit (Part No. 471345) and cleaner (Part No. 471346).

9 **Clean the parts** and check the overflow valves. Replace worn parts if necessary.

10 **Mount the protective filter (2)** and end plate (18). Note the position of the guiding pin.

11 **Before the filter candles are installed,** they must be visually inspected and damaged candles replaced with new ones.

Note! **Defective filter candles must not be used again.**

12 **Mount the filter candles** in the position by chamfered end towards the flushing arm.
Before installation of the entire filter element, the ease of motion of the flushing facility must be checked.

The flushing arm (4) must not contact against the filter plate (11).

13 **Push the entire filter element** into the housing. By slightly turning the flushing shaft (15), the gear (10) is forced into the drive pinion of the gear unit (6).

Re-assemble the filter in the reverse sequence to that described above.

18.8 Centrifugal filter

18.8.1 Description

A by-pass filter of the centrifugal type is provided as a complement to the automatic filter.

The filter comprises a housing (1) containing a hardened steel spindle (5) on which a dynamically balanced rotor unit (3) is free to rotate. Oil flows through the housing, up the central spindle into the rotor.

Oil flows from the central tube (13) into the upper part of the rotor, where it is subject to a high centrifugal force, and the dirt is deposited on the walls of the rotor in the form of heavy sludge.

The oil then passes from the cleaning compartment into the stand-tube (4) and the lower part of the rotor, which carries two backflush nozzles (16). The passage of the clean oil through the nozzles and the oil returns through the filter housing to the engine oil sump.

The oil flow through the cut off shuttle (2) from the housing into the lower part of rotor and driving nozzles (15) which provides a driving torque to the rotor and the oil returns through the filter housing to the engine oil sump.

18.8.2 Cleaning

It is very important to clean the filter regularly (chapter 04.) as it collects considerable quantities of dirt.

If it is found that the filter has collected the maximum quantity of dirt (corresponds to a 18 mm thick layer) at the recommended cleaning intervals, it should be cleaned more frequently.

Clean the filter as follows, the engine being running, by closing the valve on the filter:

1 **Shut off the filter** by closing the valve (17), see Fig 18-7.

Centrifugal filter

1. Filter housing
2. Shuttle for cut off valve
3. Lower part of rotor
4. Stand tube
5. Spindle
6. Cover clamp ring
7. Rotor cap
8. Nut
9. Body cover
10. Cover nut
11. O-ring
12. O-ring
13. Central tube
14. O-ring
15. Nozzle for drive oil
16. Nozzle for backflush oil
17. Cut off valve

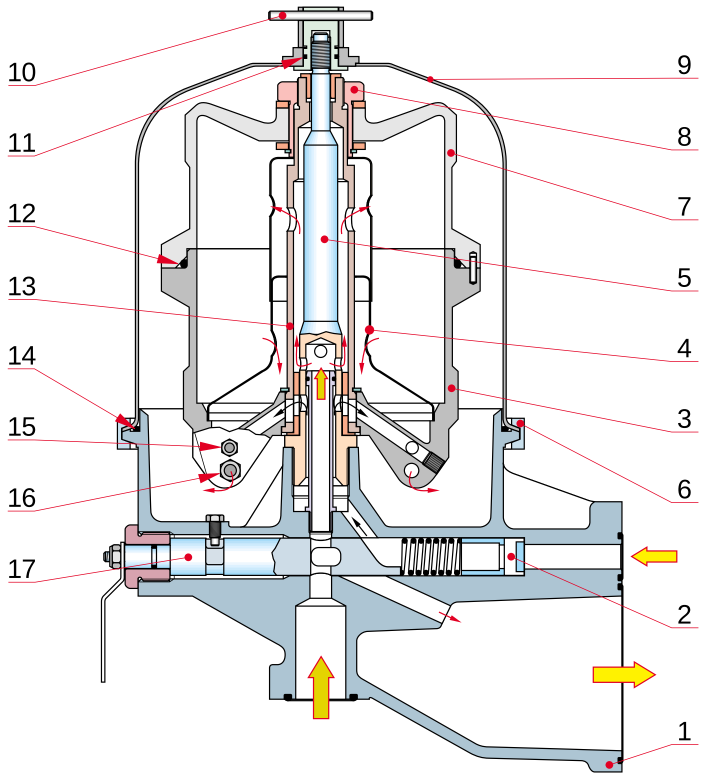


Fig 18-7 4018089601

2 **Slacken off filter cover clamp (6),** and remove.

3 **Unscrew the cover nut (10)** and lift off the filter body cover (9). Check top bearing and thrust pad for wear or damage. Examine O-ring (11) for damage. Renew if necessary.

4 **Lift out the rotor assembly** and allow oil to drain from nozzles before removing the rotor from the filter body. Hold the rotor body and unscrew the rotor cover nut (8). Separate rotor cover from the rotor body, and remove central stand tube (4).

5 **Measure the thickness of the sludge** for estimating the future cleaning intervals.

6 **Remove sludge from the inside of the rotor cover** and body by means of a wooden spatula or a suitably shaped piece of wood and wipe clean. If a paper insert has previously been fitted, remove this insert containing the sludge from the rotor and discard. Fit new paper insert.

7 **Clean out the nozzles** with brass wire to ensure free passage of oil. Ensure that bore of spindle is clear of sludge build-up. Examine spindle journals to ensure that they are free from damage or excessive wear. Examine the O-ring (12) for damage. Renew, if necessary.

8 **Clean and wash out the central stand tube** ensuring that the strainer holes are not blocked.

9 **Reassemble the rotor complete** and tighten the top nut (8), tightening torque = 60 Nm.

Over tightening of the rotor top nut can lead to rotor imbalance, which will effect filter performance.

10 **Examine the spindle journals** to ensure that they are free from damage or excessive wear. Examine the O-ring (11) for damage. Renew, if necessary.

11 **Reassemble the filter completely.** Check that the rotor assembly is free to rotate, then replace the filter body cover and secure the filter cover clamp.

12 **Check all connections and joints** for leakage with filter running.

The following steps from 13 to 15 are necessary only if some leak occurs from the cut off valve (17).

Note! **The engine must be stopped before the cut off valve is dismantled.**

13 **Unscrew the nut** and remove the handle for cut off valve. Unscrew the locating screw inside the filter housing.

14 **Remove locating nut** and remove valve body for cut off valve, spring and shuttle. Check that the spring and shuttle are undamaged and free to move. Examine O-ring for damage. Renew, if necessary.

15 **Reassemble the valve assembly.**

18.9 Prelubricating pump

18.9.1 Description

The pump is of the gear type, driven by an electric motor. The pump is provided with an adjustable pressure control valve (2), Fig 18-8. The pressure should be limited to the max. value, about 2 bar, by unscrewing the adjusting screw to the end position in order to prevent the electric motor from being overloaded when running with very cold oil.

Note! **Be careful when adjusting the pressure by unscrewing the adjusting screw oil may come out.**

Note! **Do not run the prelubricating oil pump when the engine is running, otherwise the shaft seal will be damaged due to over heating.**

Prelubricating pump with electric motor

1. Non-return valve
2. Pressure control valve
3. Screw
4. Bracket
5. Coupling

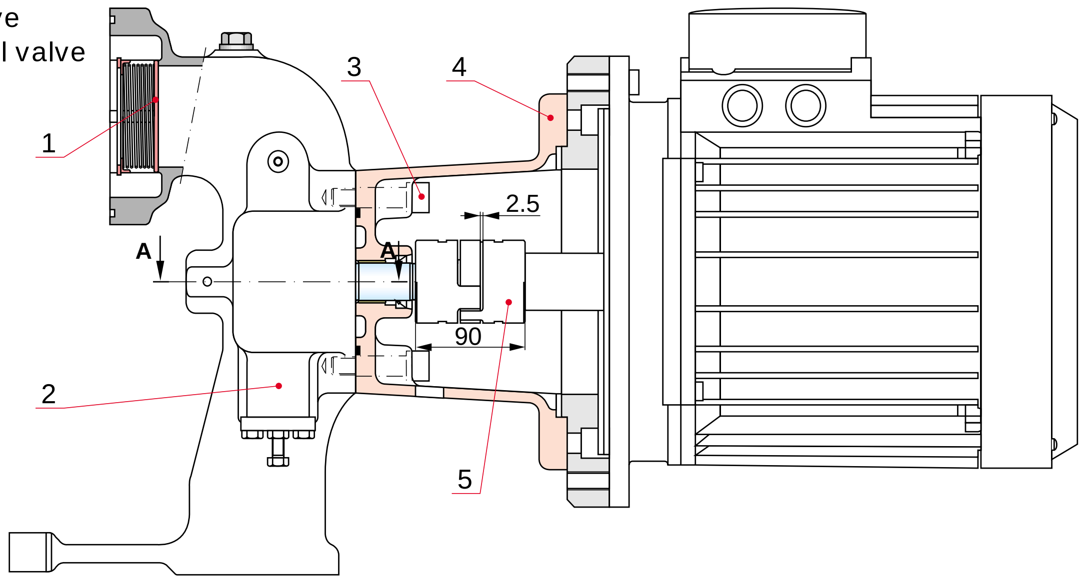


Fig 18-8 4018099601

18.9.2 Dismantling

1 **Dismantle and inspect the regulating valve** according to section 18.10.

2 **Remove the the coupling half** and the key by loosening the fastening screw.

3 **Remove the bracket (4) for** the electric motor by opening the screws (3).

4 **Withdraw the gear wheels** without using any tools.

Prelubricating pump

6. Bearing bush
7. Regulating piston
8. Spring
9. Spring holder
10. Adjusting screw
11. Axial seal

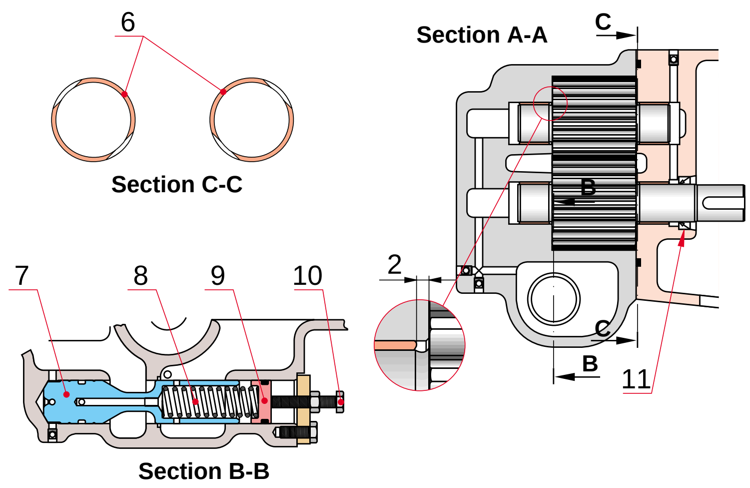


Fig 18-9 4018079601

18.9.3 Inspection

1 **Check all parts for wear** (chapter 06., section 06.2) and replace worn parts.

2 **Remove worn bearings** from the housing by machining and from the cover the bearing bush for the driving gear wheel with a suitable mandrel and the other by machining.

3 **Mount new bearings** (freezing is recommended) so that the bearings are two 2 mm below the cover and housing level, Fig 18-9. Be careful so that bearing lubrication grooves slide into the right position according to section C-C in Fig 18-9.

4 **Check the bearing diameter** after mounting. Check the gear wheel axial clearance (see chapter 06., section 06.2).

18.9.4 Assembling

1 **Before installing the gear wheels,** all contact surfaces should be cleaned and oiled.

2 **Mount the axial seal (11)** in the cover and lubricate with grease.

3 **Mount the bracket (4)** Check that the O-ring in the groove is intact and in position.

4 **Tighten the screws (3) to torque** according to chapter 07.

5 **Mount the key and the coupling half.** Check the coupling rubber and replace if necessary.

6 **Mount the electric motor** and tighten screws.

7 **Check the distance** between coupling halves and adjust if necessary, see Fig 18-8.

18.10 Pressure regulating valve for prelubricating oil pump

18.10.1 Description

The pressure regulating valve, see Fig 18-9, is integrated in the prelubricating oil pump housing and regulates the oil pressure before the engine by returning the surplus oil direct from the pressure side of the pump to the suction side.

This pressure actuates the regulating piston (7) and the spring (8) is tensioned to balance this force at the required pressure. By tensioning the spring by the screw (10) a higher oil pressure is obtained.

18.10.2 Maintenance

1 **Dismantle all moving parts.** Check them for wear and replace worn or damaged parts by new ones.

2 **Clean the valve carefully.**

3 **Check that no details are jamming** while reassembling.

19. Cooling Water System

19.1 Description

19.1.1 General

The engine is cooled by a closed circuit cooling water system, divided into a high temperature circuit (HT) and a low temperature circuit (LT). The cooling water is cooled in a separate central cooler.

The both circuits are provided with temperature control valves.

Cooling water system

1. Lube oil cooler
2. LT-thermostat valve
3. Central cooler
4. Water pump
5. Preheater
6. Preheting water pump
7. HT-water pump
8. LT-water pump
9. Charge air cooler
10. HT-thermostat valve
11. Expansion tank
12. Water box
13. Vent piping from multiduct

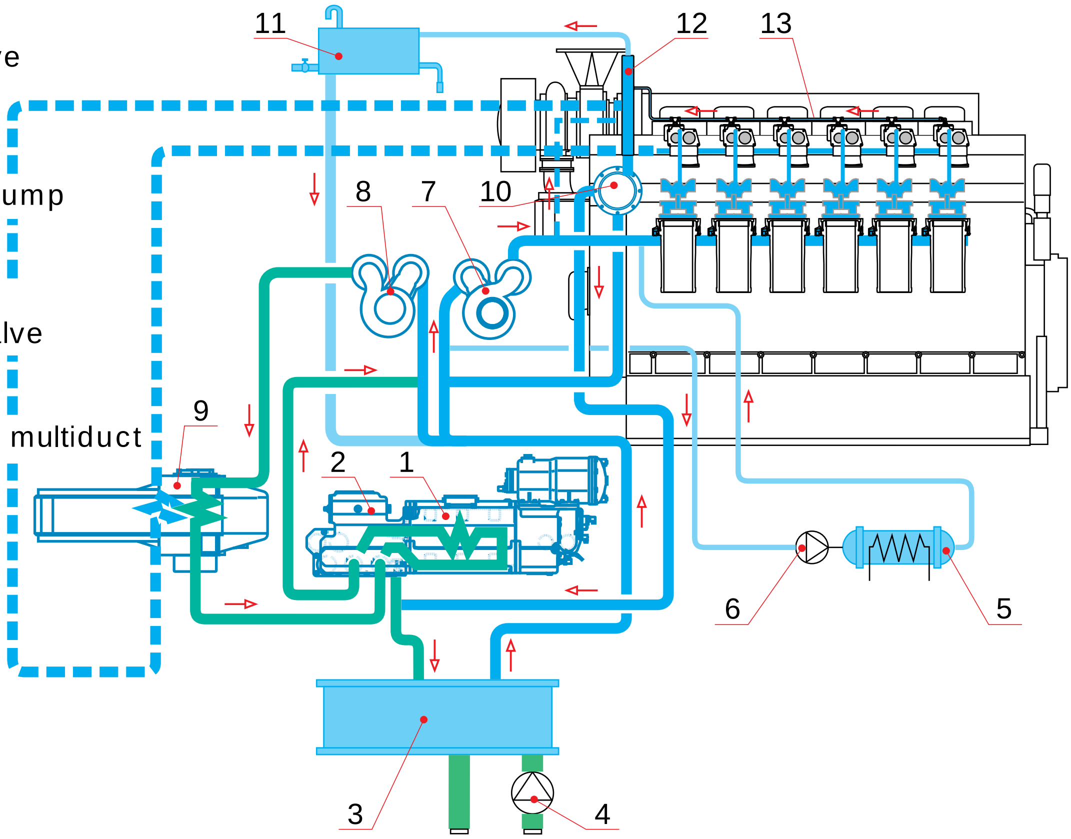


Fig 19-1 401906200020

19.1.2 HT circuit

The HT circuit cools the cylinders and cylinder heads.

A centrifugal pump (7) pumps the water through the HT circuit. From the pump the water flows to the distributing duct, cast in the engine block. From the distributing ducts the water flows to the cylinder water jackets, further through connection pieces to the cylinder heads where it is forced by the intermediate deck to flow along the flame plate, around the nozzle and the exhaust valve seats, efficiently cooling all these components. From the cylinder head the water flows through the multiduct to the collecting duct, if a two stage charge air cooler the water flows through the charge air cooler to the temperature control valve maintaining the temperature at the right level.

Depending on the type of turbocharger used, parallel to the flow to the cylinders, part of the water flows to the turbocharger.

19.1.3 Venting and pressure control of HT-circuit

For venting the system the turbocharger cooling water pipes and a venting pipe from the multiducts are connected to a box (12). From this box the vent pipe leads to the expansion tank (11) from which the expansion pipe is connected to the inlet pipe of the pumps (7 and 8). A static pressure of 0.7 - 1.5 bar is required before the pumps. If the expansion tank cannot be located high enough to provide this pressure, the system is to be pressurized.

19.1.4 LT circuit

The LT circuit consists of a charge air cooler (9) and a lube oil cooler (1) through which a pump (8) of similar design as the HT pump, pumps the water. The circuit temperature is controlled by a temperature control valve (2) maintaining the temperature at the right level. The necessary cooling is gained from the central cooler (3). The system outside the engine can vary from one installation to another.

19.1.5 Preheating

For preheating of the circuit, a heater circuit with the pump (6) and heater (5) are connected in the HT circuit before the engine. The non-return valves in the circuit force the water to flow in the right direction.

Before start, the HT circuit is heated up to 50 - 70°C by a separate heater. This is of utmost importance when starting and idling on heavy fuel.

19.1.6 Monitoring

The temperatures mentioned in chapter 01., section 01.2, should not be exceeded.

Pressure gauges on the instrument panel indicate HT and LT pressures after the pumps. The pressures depend on the speed and the installation. Guidance values, see chapter 01., section 01.2.

The HT water outlet after the engine is provided with an alarm switch and depending on installation with a stop switch. Main engines are provided with alarm switches for low HT and LT pressure.

For further information, see chapter 23.

19.2 Maintenance

19.2.1 General

The installation — including expansion, venting, preheating, pressurizing — should be carried out strictly according to the instructions of the engine manufacturer to obtain correct and trouble free service.

The cooling water should be treated according to the recommendations in chapter 02., section 02.3, to prevent corrosion and deposits.

If risk of frost occurs, drain all cooling water spaces. Avoid changing the cooling water. Save the discharged water and use it again.

Remember to close the drain and open the cooling water connections before the engine is started again.

19.2.2 Cleaning

In completely closed systems the fouling will be minimal if the cooling water is treated according to the instructions in chapter 02., section 02.3. Depending on the cooling water quality and the efficiency of the treatment, the cooling water spaces will foul more or less over the course of time. Deposits on cylinder liner water jackets, cylinder heads and cooler stacks should be removed as they may disturb the heat transfer to the cooling water and thus cause serious damage.

The need of cleaning should be examined, especially during the first year of operation. This may be done by overhauling a cylinder liner and checking for fouling and deposits on the water jacket and block.

The deposits can be of the most various structures and consistencies. In principle, they can be removed mechanically and/or chemically as described below. More detailed instructions for cleaning of coolers are stated in chapter 18., section 18.5.

a) Mechanical cleaning

A great deal of the deposits consists of loose sludge and solid particles which can be brushed and rinsed off with water.

On places where the accessibility is good, e.g. cylinder liners, mechanical cleaning of considerably harder deposits is efficient.

In some cases it is advisable to combine chemical cleaning with a subsequent mechanical cleaning as the deposits may have dissolved during the chemical treatment without having come loose.

b) Chemical cleaning

Narrow water spaces (e.g. cylinder heads, coolers) can be cleaned chemically. At times, degreasing of the water spaces may be necessary if the deposits seem to be greasy (see chapter 18., section 18.5).

Deposits consisting of primarily limestone can be easily removed when treated with an acid solution. On the contrary, deposits consisting of calcium sulphate and silicates may be hard to remove chemically. The treatment may, however, have a certain dissolving effect which enables the deposits to be brushed off if there is only access.

On the market there are a lot of suitable agents on acid base (supplied e.g. by the companies mentioned in the end of chapter 02. See the list of approved cooling water additives and treatment systems).

The cleaning agents should contain additives (inhibitors) to prevent corrosion of the metal surfaces. Always follow the manufacturer’s instructions to obtain the best result.

After treatment, rinse carefully to remove cleaning agent residuals. Brush surfaces, if possible. Rinse again with water and further with a sodium carbonate solution (washing soda) of 5 % to neutralize possible acid residuals.

19.3 Water pump

19.3.1 Description

The water pump is a centrifugal pump and is driven by the gear mechanism at the free end of the engine. The shaft is made of acid resistant steel, the impeller (6) of cast iron and the remaining details of cast iron.

The shaft is mounted in two ball bearings (8) and (10), which are lubricated by pressurized oil entering through the opening in the bearing housing. The shaft seal (16) prevents the oil from leaking out and, at the same time, dirt and leak water from entering.

The gear wheel (12) is fastened to the shaft by conical ring elements (13). When the screws (14) are tightened, the rings exert a pressure between the gear wheel and the shaft. Due to the friction, the power from the gear wheel is transmitted to the pump shaft.

The water side of the pump is provided with a mechanical shaft seal. The ring (4) rotates along with the shaft and seals against it with the O-ring. The spring presses the rotating ring against a fixed ring (3) which seals against the housing with the O-ring (7). Possible leak-off water from the sealing can flow out through an telltale hole in the bottom of the pump.

Cooling water pump

1. Cover clamp
2. O-ring
3. Fixed ring
4. Shaft sealing
5. Screw
6. Impeller
7. O-ring
8. Bearing
9. Shaft
10. Bearing
11. Bearing retainer
12. Drive gear
13. Friction rings
14. Screw
15. Pressure plate
16. Seal

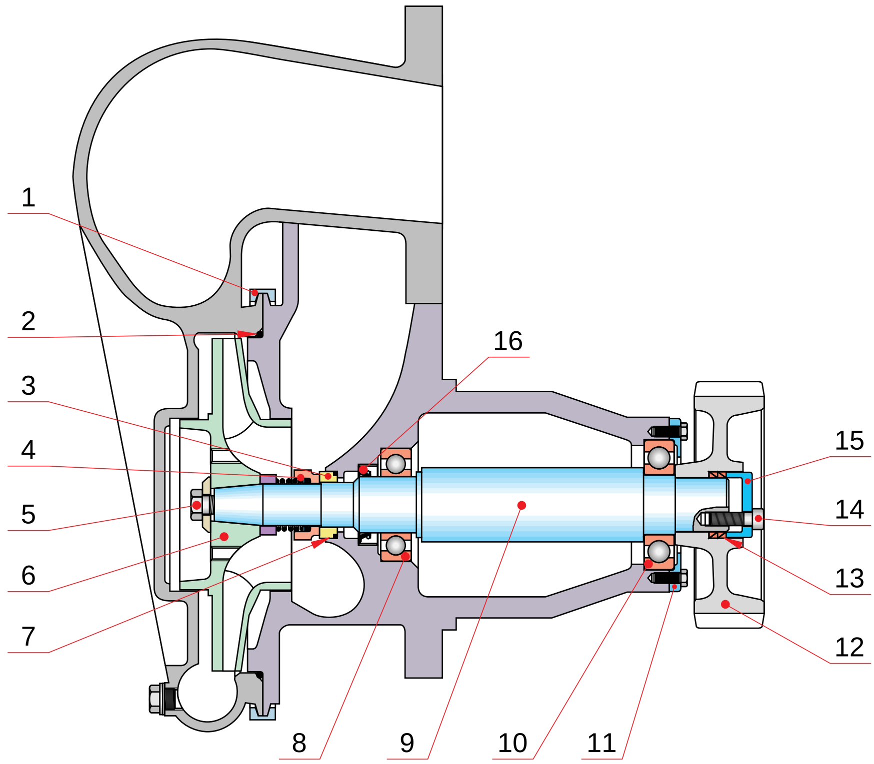


Fig 19-2 4019019601

19.3.2 Maintenance

Normal maintenance operations, like removal of impeller or replacing the mechanical seal, can be done without removing the complete pump from the engine.

Check the pump at intervals according to the recommendations in chapter 04. or, if water and oil leakage occurs, immediately.

Check that the telltale hole is open every now and then.

a) Disassembling and assembling of impeller

1 **Remove the volute casing** by loosening the clamp (1) and the fastening screws.

2 **Loosen the impeller fastening screw (5).**

3 **Pull off the impeller** by using an extractor 800076.

4 **When reassembling the impeller,** tighten the screw to torque, see chapter 07.

5 **Check that the O-ring (2)** and non-return valve O-rings between pump and engine pump cover are intact and in position when re-installing the volute casing. Check that the volute casing is in position.

6 **Mount the clamp and tighten the screws.**

b) Disassembling and assembling of mechanical shaft seal

1 **Remove the impeller** according to pos. a) above.

2 **Carefully dismantle all seal details.** Sealing rings are very fragile.

3 **Take particular care** not to damage sealing surfaces as a slight scratch may disturb the sealing function.

4 **Replace the complete seal** if it is leaky, or if sealing faces are corroded, uneven or worn. Avoid touching the sealing faces with fingers.

5 **Reassemble the details** in proper order and install the impeller according to pos. a) above. Do not forget the thin washer between the spring and the O-ring.

c) Replacing of bearings and shaft seal.

1 **Remove the pump** from the engine.

2 **Disassemble the impeller** and mechanical seal according to pos. a) and b) above.

3 **Loosen the screws (14)** and remove the pressure plate (15).

4 **Pull off the gear wheel** without using any tool. If the gear wheel does not come loose, a few strokes with a non-recoiling hammer will help. (The conical ring elements (13) come loose together with the gear wheel.)

Using an extractor will only damage the shaft (axial scratches).

5 **Loosen the bearing retainer (11)** by opening the screws and drive out the shaft and bearing.

6 **Check the seal (16)** and the bearings for wear and damage. If the seal is leaking, knock it out using a suitable brass piece.

7 **Remove the bearings.** Press the bearing by its inner ring with a suitable pipe.

8 **Inspect the shaft** for wear and damage.

9 **Oil the new seal** and insert it by pressing against the shoulder.

10 **Oil the collar** and press the bearing in by its inner ring with a suitable pipe. See Fig 19-3A.

11 **Turn the shaft** according to Fig 19-3B.

12 **Oil the collar** and press the bearing in by its inner ring with a suitable pipe. See Fig 19-3B.

13 **Turn the housing** according to Fig 19-3C and oil the outer surfaces of the bearings. Press the shaft into the housing by both the inner and outer ring of the bearing with a suitable pipe.

Mounting of bearings

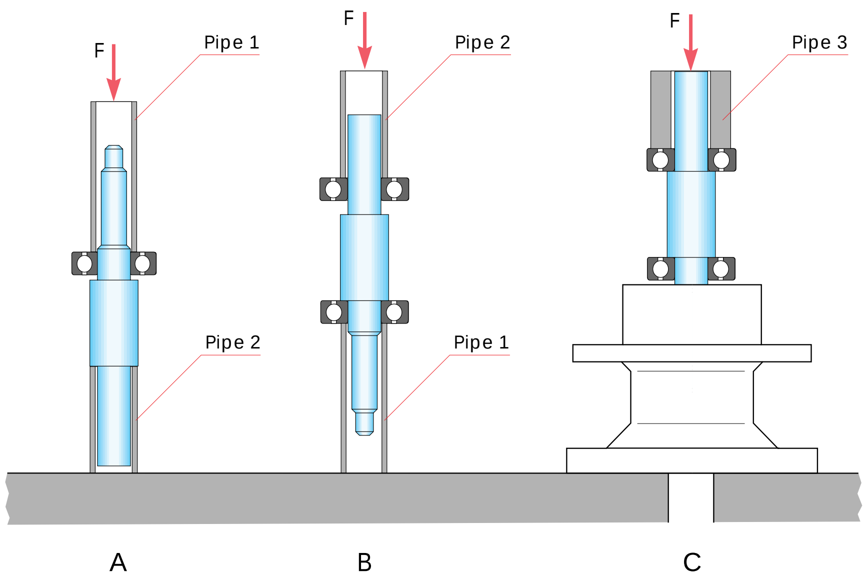


Fig 19-3 3219568935

14 **Fit the bearing retainer (11)** and tighten the screws.

15 **Before re-installing the gear wheel,** all contact surfaces should be cleaned and oiled.

16 **Re-install the gear wheel** and the conical ring elements (13).

Re-install the conical ring elements exactly as situated in Fig 19-4. The conical ring elements should fall easily in place and must not jam.

17 **Re-install the pressure plate (15).**

18 **Tighten the screws** a little and check that the gear wheel is in the right position.

19 **Tighten the screws** to torque according to chapter 07.

20 **Assemble the impeller and the mechanical seal** according to pos. a) and b) above.

21 **Mount the pump on the engine.**

Mounting of gear wheel to water pump

13. Friction rings
14. Screw
15. Pressure plate

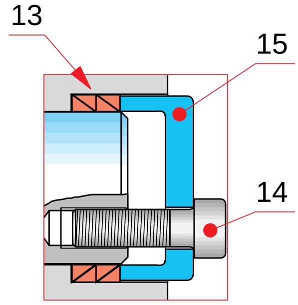


Fig 19-4 4019079601

19.4 Temperature control system

19.4.1 General description

The LT circuit is provided with a fixed thermostatic valve mounted on the lubricating oil module to maintain the LT outlet water temperature.

The HT circuit is provided also with a fixed thermostatic valve mounted inside the upper part of pump cover to maintain the HT outlet water temperature.

19.4.2 LT thermostatic valve

The LT thermostatic valve is integrated in the end of the lubricating oil cooler. The springs (4) keeps the control piston (6) to the correct (low temperature) position. When the temperature rises, the element (8) expands against the guiding pin (10) and moves the control piston (6) on the cooling position until steady state is reached.

LT thermostatic valve

1. Plug
2. Retainer ring
3. Washer
4. Springs
5. Control cylinder
6. Control piston
7. Element holder
8. Thermostat element
9. Retainer ring
10. Guiding pin
11. End flange
12. Screw
13. Adjusting screw

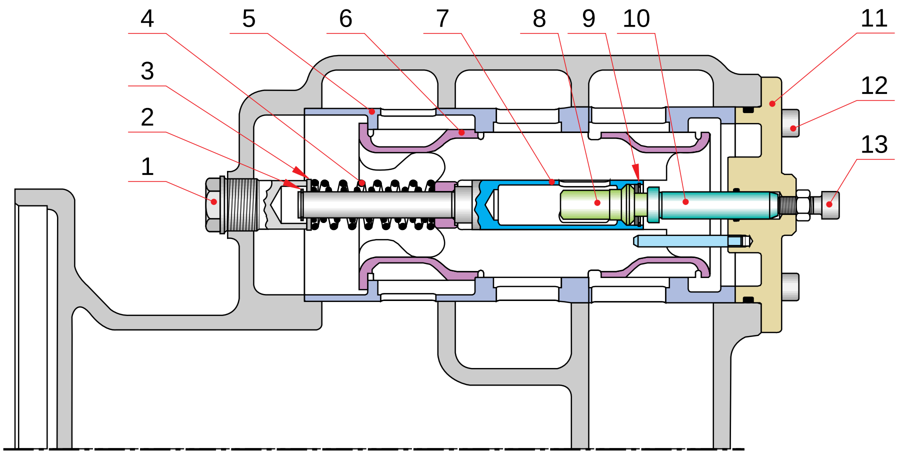


Fig 19-5 4019029601

19.4.2.1 Maintenance

Normally, no service is required. Too low water temperature depends on a defective thermostat, too high temperature may depend on a defective thermostat, leaking O-rings, although, in most cases, it depends on a dirty central cooler.

During normal overhaul, i.e. when changing the thermostat element, there is no need to remove the control- cylinder (5) or piston (6).

1 **Drain the cooling water circuit.**

2 **Release the spring force** by opening the adjusting screw (13), see Fig 19-5.

3 **Remove the cover (11)** by opening the screws (12).

4 **Remove the plug (1)** and push the control piston (6) against the spring force until the retainer ring (2) can be removed.

5 **Remove the element holder (7)** with element, springs (4) and washer (3).

6 **Remove the control piston (6)** with the control cylinder (5). Use extractor tools 800131 and 800063.

7 **Remove the retainer ring (9)** and the thermostat element (8).

8 **Check the element** by heating it slowly in water. Check at which temperatures the element starts opening and is fully open. The correct values can be found on the thermostatic element or in chapter 01.; the lower value for the water temperature is the opening temperature, the higher for the fully open valve.

The set point marked on the element is the value when the element is half open.

9 **Change the defective element** and renew O-rings.

10 **Re-assemble the valve** in reverse order.

19.4.2.2 Adjustment

1 **Turn the adjusting screw (13)** in clockwise direction until the guiding pin (10) and thermostat element (8) contact with each other.

2 **Turn the adjusting screw** in counter-clockwise direction half a turn.

3 **Hold the adjusting screw** and tighten the counter nut.

Note! **The adjustment procedure is to be done on a cold engine.**

Water flow in LT thermostat valve

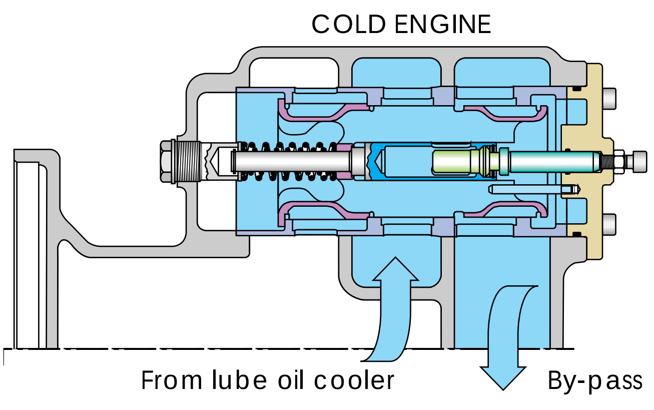


Fig 19-6 4019039601

19.4.3 HT thermostatic valve

The HT thermostatic valve is integrated in the pump cover at the free end of the engine. It is equipped with positive three-way valve action in which the water is positively made to flow in the direction required. When the engine is started up and is cold, the HT thermostatic valve causes all of the water to be positively by-passed back into the pump, thus providing the quickest warm-up period possible. After warm up, the correct amount of water is by-passed and automatically mixed with the cold water returning from the heat exchanger or other cooling device to produce the desired HT water outlet temperature. If ever required, the HT thermostatic valve will shut off positively on the by-pass line for maximum cooling. The three-way action of the valve allows a constant water flow through the pump and engine at all times with no pump restriction when the engine is cold.

No adjustments are ever required on the HT thermostatic valve. The temperature is permanently set at the factory. The temperature can be changed only by changing temperature element assemblies which is easily accomplished by unscrewing the cover. The HT valve is entirely self-contained, and there are no external bulbs or lines to become damaged or broken. There are no packing glands to tighten and no parts to oil.

The power creating medium utilizes the expansion of the element contents (2), Fig 19-7, which remains in a semi-solid form and is highly sensitive to temperature changes. Most of the expansion takes place during the melting period of approximately two minutes over a temperature change of approximately 8.5°C.

HT thermostatic valve

1. Screw
2. Screw
3. Cover
4. O-ring
5. Element holder
6. Thermostat element

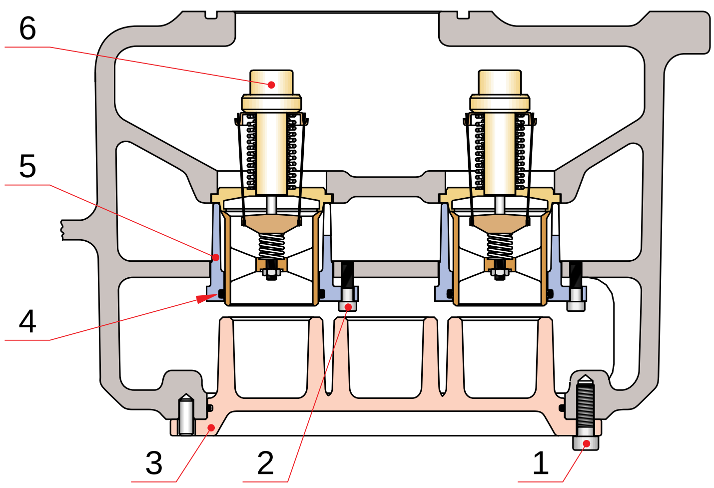


Fig 19-7 4019049601

The HT thermostatic valve is provided with four elements (in-line engine) and six elements (V-engine). Since flow is diverted either to by-pass or heat exchanger, failure of an element would cause no change in pressure drop.

The contents of the elements has an almost infinite force when heated and is positively sealed. When the elements are heated, this force is transmitted to the piston thus moving the sliding valve towards the seat (5) to the by-pass closed position. This force is opposed by a high spring force, which moves the sliding valve to the heat exchanger closed position when the elements are cooled. The high force available on heating is the basis of the fail safe feature in which failure of the element would cause the engine to run cold.

Water flow in HT thermostatic valve

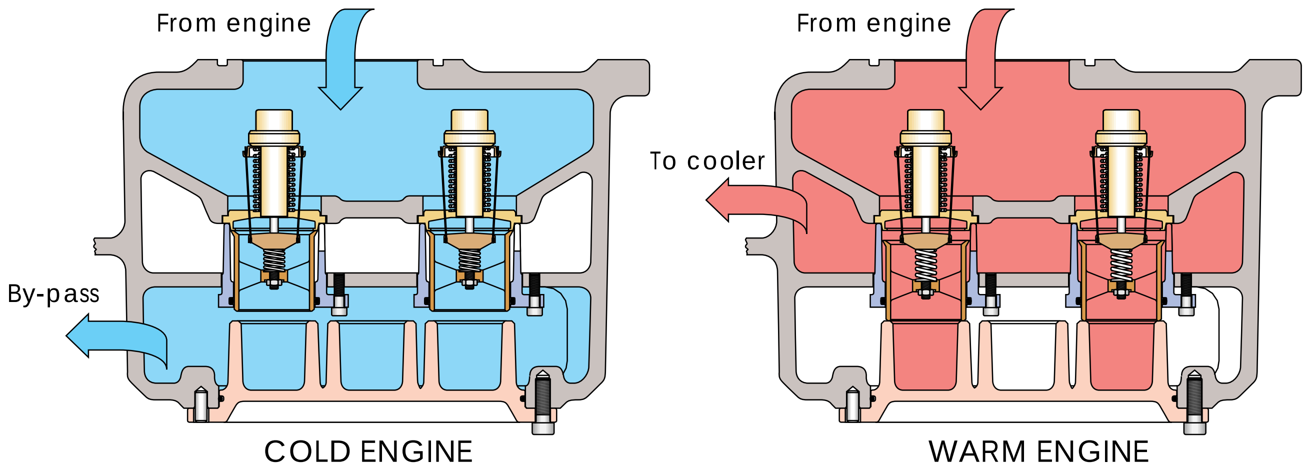


Fig 19-8 4019059601

19.4.4 Maintenance

Normally, no service is required. Too low water temperature depends on a defective thermostat, too high temperature may depend on a defective thermostat, leaking O-rings, although, in most cases, it depends on a dirty central cooler.

1 **Drain the cooling water circuit.**

2 **Remove the cover (3)** by opening the screws (1), see Fig 19-7.

3 **Open the screws (2)** and remove thermostat elements (6) with element holders (5). Use extractor tools 800122 and 800029 for element holder if necessary.

4 **Check the element** by heating it slowly in water. Check at which temperatures the element starts opening and is fully open. The correct values can be found on the thermostatic element or in chapter 01.; the lower value for the water temperature is the opening temperature, the higher for the fully open valve.

The set point marked on the element is the value when the element is half open.

5 **Change the defective element** and renew O-rings.

6 **Re-assemble the valve** in reverse order.

20. Exhaust System

20.1 Exhaust manifold

20.1.1 General description

Data and dimension
Multiduct
Material: Nodular cast iron
Weight: 60 kg
Test pressure: 10 bar
(water side)

Exhaust pipes
Material: Special, heat resistant alloy nodular cast iron

Bellows
Multiply design
Material: Heat resistant steel

The exhaust manifold is fitted between the cylinder head and the turbocharger. The manifold consists of the multiducts (3) and the exhaust pipes (2) with expansion bellows (1). The manifold is enclosed into an insulating box of sandwich design.

The turbocharging concept depends on the type of installation, alternatively a specific type of pulse charging or a constant pressure charging are used. The exhaust gases connected to one pipe are discharged from each cylinder during the period when the other cylinders connected to the same pipe have the exhaust valve closed. This gives an equal flow of gases to the turbocharger without any disturbing gas pulses to the other cylinders connected to the common pipe.

The multiduct, between the cylinder head and the exhaust pipes, acts as a bracket for the whole exhaust manifold, including the insulation box. The multiduct is cooled by the cooling water discharging from the cylinder head. The multiducts are vented through a venting pipe along the engine. The cooling water flows from the multiducts (3) through the water pipes (4) in the cooling water box. The multiduct also connects the air receiver in the engine block with the inlet air channel in the cylinder head. All the surfaces, engine block/multiduct, cylinder head/ multiduct and exhaust pipes/multiduct are sealed off.

Exhaust manifold

1. Bellows
2. Exhaust gas pipe
3. Multiduct
4. Water pipe

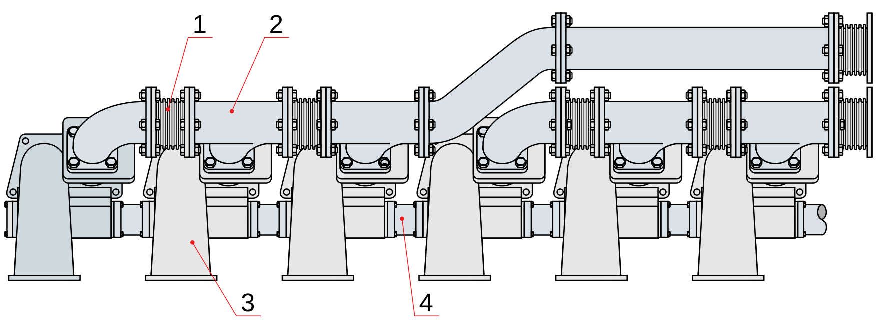


Fig 20-1 4020019601

The multiduct is rigidly mounted towards the cylinder head.

The exhaust pipes are cast of special alloy nodular cast iron, with separate sections for each cylinder. Metal bellows of multiply type absorb the heat expansion.

The complete exhaust system is enclosed by an insulation box built up of sandwich steel sheet.

Caution! **The surface of the insulation box is hot.**

The exhaust gas temperatures can be checked after each exhaust valve. Sensors for remote measuring of the temperatures after each exhaust valves as well as before and after the turbocharger are mounted.

Exhaust System

1. Lower insulation panel
2. Distance piece
3. Screw
4. Multiduct
5. Cover band
6. Upper insulation panel
7. Support

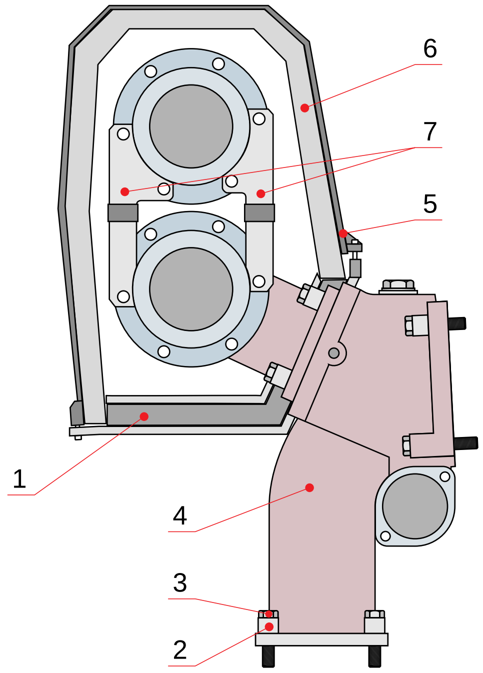


Fig 20-2 402002200020

20.1.2 Change of expansion bellows

1 **Remove necessary sheets** on the insulation box.

2 **Remove the screws** and remove the expansion bellows.

3 **Check that the exhaust pipe flanges are parallel** and positioned on the same centre line to avoid lateral forces on the bellows.

4 **Mount the new expansion bellows** and tighten the screws.

5 **Examine the supports (7)** for damage. Replace by new ones, if necessary.

6 **Mount necessary sheets and other parts.**

21. Starting Air System

21.1 Description

The engine is started with compressed air of max. 30 bar. Minimum pressure required is 15 bar. The pressure before the main starting valve (4) is indicated on the Local Display Unit (LDU) (1).

The inlet air pipe from the starting air receiver is provided with a non-return valve (2) and a drain valve (3) before the main starting valve (4). The main starting valve may be operated either by the push button (21) at manual starting, see Fig 21-2 or pneumatically by a solenoid valve, mounted under the LDU, at remote or automatic starting of the engine.

Starting air system

1. Local display unit
2. Non return valve
3. Drain valve
4. Main starting valve
5. Starting valve
6. Flame arrester
7. Connection piece
8. Air block
9. Blocking valve
11. End plate
13. Plate
14. Spring
15. Control piston
16. Liner
17. Plug
18. Connection piece
19. Safety valve

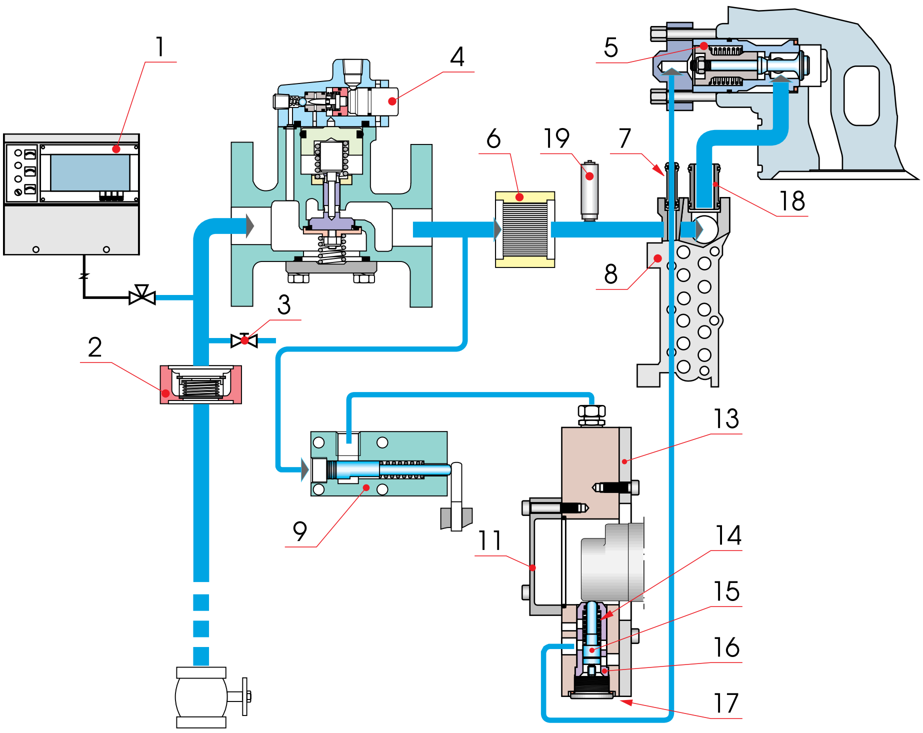


Fig 21-1 402102200020

When the main starting valve opens, the starting air passes partly through the flame arrester (6) and the air block to the starting valves in the cylinder heads. Partly it passes to the starting air distributor, which guides the control air to the starting valves, which open and admit starting air to flow to the various cylinders for suitable periods. V-engines have starting valves on the A-bank, only.

As a precaution the engine cannot be started when the turning gear is engaged. Starting air to the distributor is led through a blocking valve (9), mechanically blocked when the turning gear is engaged, thus preventing start.

The starting air system is equipped with the safety valve (19), which protect the system and the components in possible fault situations.

Note! **Before any maintenance steps are taken, make sure that the starting air shut-off valve located before the starting valve is closed and the engine starting air system is drained.**

21.2 Main starting valve

21.2.1 Description

Inlet pressure is led through drillings to a small pilot valve with a pilot piston (22). This valve can be manually operated by the push button (21) or pneumatically operated by a solenoid valve for remote or automatic start. When opening the valve, the air flows through drillings (23) to the power piston (24), which exerts its thrust through a valve stem (25) directly on to the main valve and opens this against the load provided by a return spring (26) and inlet pressure. The inlet pressure acts under the main valve and so helps to maintain a tight seal with the valve in closed position.

The standard valve is arranged to open when energized.

Main starting valve

21. Bush button
22. Pilot piston
23. Drilling
24. Power piston
25. Valve stem
26. Spring
27. Flange

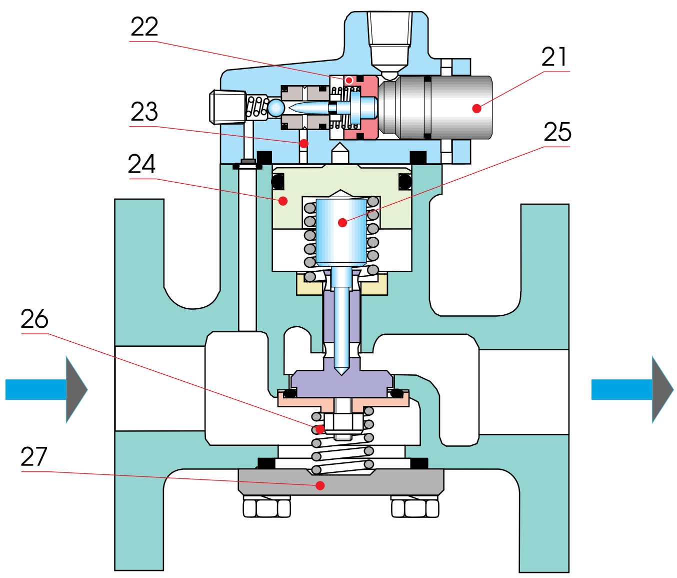


Fig 21-2 402101200020

21.2.2 Maintenance

1 **Remove the main starting valve** from the engine.

2 **Remove the hexagon socket head screws** and remove the pilot valve assembly.

3 **Remove the pilot valve piston (22).**

4 **Clean the pilot valve** of any dirt which may block the small air passages and holes.

5 **Check all O-rings** in the pilot valve and replace if they have developed flat, become hard and brittle or been damaged in any way. Lubricate the O-rings with oil.

6 **Remove the power piston (24)** and check the O-ring. Ensure that the small vent hole to atmosphere in the cylinder under the piston is clear.

7 **When reassembling the valve** ensure that the air passage hole in the upper body flange lines up with the hole in the lower body.

8 **Remove the flange (27),** spring (26) and main valve seat complete with the valve stem (25). Examine O-rings as in step 5 above.

21.3 Starting air distributor

21.3.1 Description (Fig 21-1)

The starting air distributor is of the piston type with precision machined interchangeable liners (16). The liners as well as the pistons are of corrosion resistant materials. The distributor pistons are controlled by a cam at the camshaft end. When the main starting valve opens, the control pistons (15) are pressed against the cam, whereby the control piston for that engine cylinder, which is in starting position, admits control air to the power piston (33) of the starting valve, see Fig 21-3. The starting valve opens and allows pressure air to pass into the engine cylinder.

The procedure will be repeated as long as the main starting valve is open or until the engine speed is so high that the engine fires.

After the main starting valve has closed, the pressure drops quickly and the springs (14) lift the pistons off the cam, which means that the pistons touch the cam only during the starting cycle, and thus the wear is insignificant.

21.3.2 Maintenance

Normally, the starting air distributor does not need maintenance. If it has to be opened for control and cleaning, remove the complete distributor from the engine. Certain pistons can be checked in situ.

1 **Remove the end plate (11).** Loosen all pipes from the distributor. Remove the fastening screws and lift the distributor off.

2 **Remove the plugs (17)** at which the pistons (15) will come out forced by the springs (14).

3 **Take care not to damage the sliding surfaces of pistons and liners.**

4 **In case of a stuck piston, use thread M8** at the end of the piston to get it out, if necessary.

5 **It is recommended not to change the place of the pistons,** although they are precision machined to be interchangeable. Utilize cylinder numbers stamped at the control air connections.

6 **Clean the parts and check for wear.**

7 **If a liner is worn, press it out.** It may be necessary to heat the distributor up to about 200°C as Loctite is used for fixation and sealing.

8 **Clean the bore** carefully so that the new liner can be inserted by hand. Otherwise there is a risk of deformation of the liner and sticking of the piston.

9 **Apply Loctite 242** on the outside surfaces when mounting the liner. Check that the openings in the liner correspond to those in the housing.

10 **Check that there is no Loctite** on the inside sliding surfaces.

11 **Renew the O-rings** inside the liners.

12 **Apply Molykote Paste G** to the piston sliding surfaces before reassembly. Wipe off surplus paste. Check that pistons do not stick.

13 **Apply silicon sealant** to both sides of the intermediate plate (13). Do not use too much as surplus sealant will be forced into the system when tightening the fastening screws.

14 **After mounting the distributor** to the engine but before connecting the control air pipes and end plate (11), check that all pistons work satisfactorily, e.g. by connecting compressed air (working air of 6 bar) to the distributor air inlet and by turning the crankshaft. It is then possible to see whether the pistons follow the cam profile.

Caution!

Do the testing with control air pipes and starting air pipe disconnected, otherwise the engine may start.

21.4 Starting valve

21.4.1 Description

The valve consists of a valve spindle (34) with a spring-loaded operating piston (33) mounted in a separate housing.

Starting valve

30. Nut
31. Cover
32. Nut
33. Piston
34. Spindle
35. O-ring
36. Sealing ring
37. Spring

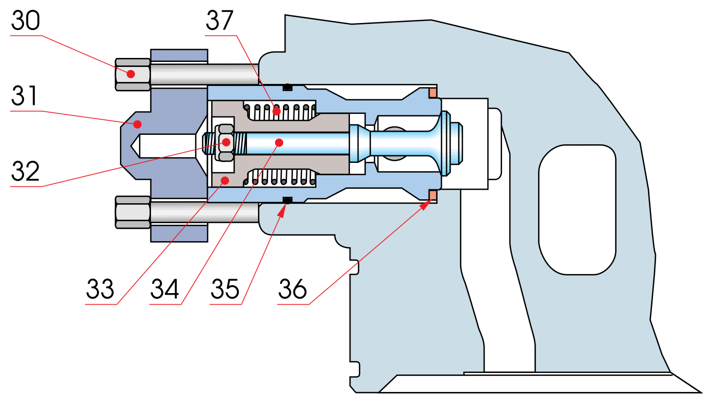


Fig 21-3 3221539045

21.4.2 Maintenance

Check and clean the valve in connection with overhauls of the cylinder head.

1 **Remove the fastening nuts (30)** and pull out the valve cover (31).

2 **Pull out the starting valve.**

3 **Open the self-locking nut (32)** and remove the spring (37) and the spindle (34).

4 **Clean all parts.**

5 **Check sealing faces** of the valve and valve seat. If necessary, lap the valve by hand. See instructions for the engine valves, chapter 12., section 12.3. Keep the piston on the valve spindle to get guiding.

6 **Replace the nut (32)** by a new one.

7 **After reassembling the valve,** check that the valve spindle with the piston moves easily and closes completely.

8 **Check that the O-ring (35)** of the valve housing are intact. Lubricate with oil.

9 **Check that the steel sealing (36) is intact** and in position, when mounting the valve into the cylinder head.

10 **Tighten the valve** to torque stated in chapter 07.

21.5 Starting air vessel and piping

The starting air system is designed to prevent explosions.

An oil and water separator as well as a non-return valve should be located in the feed pipe, between the compressor and the starting air vessel. At the lowest position of the piping there should be a drain valve. Immediately before the main starting valve on the engine, a non-return valve and a blow-off valve are mounted.

Drain the starting air vessel from condensate through the drain valve before starting.

The piping between the air vessels and the engines should be carefully cleaned when installing. Also later on they should be kept free from dirt, oil and condensate.

The starting air vessels should be inspected and cleaned regularly. If possible, they should then be coated with a suitable anti-corrosive agent. Let them dry long enough.

At the same time, inspect the valves of the starting air vessels. Too strong tightening may result in damages on the seats, which in turn cause leakage. Leaky and worn valves, including safety valves, should be reground. Test the safety valves under pressure.

21.6 Pneumatic system

21.6.1 General description

The engine is equipped with a pneumatic system for control of the following functions by means of two solenoid valves:

- start of the engine,
- stop of the engine,

The system includes a vessel (45) and a non-return valve (46) to ensure the pressure in the system in case of lacking feed pressure.

The main starting valve (4), which is described in detail in section 21.2, is actuated by the solenoid valve (43) at remote start. Fig 21-5 shows the solenoid valve. The valve is equipped with a push button and can be energized manually.

The pneumatic overspeed trip devices (42), described in detail in chapter 22., section 22.6, are controlled by the solenoid valve (44) which is actuated by the electric signal from the speed monitoring system, whereby the engine stops.

The push button of the solenoid valve can be used as a local mechanical stop.

Note! **When the engine is running, the air supply to the engine must always be open.**

Pneumatic system

2. Non return valve
3. Drain valve
4. Main starting valve
5. Starting valve
6. Flame arrester
9. Blocking valve
19. Safety valve
40. Starting air distributor
41. Starting booster
42. Pneumatic cylinder for overspeed trip device
43. Solenoid valve
44. Solenoid valve
45. Air container
46. Non return valve

301. Starting air inlet
311. Instrument air to Wastegate valve

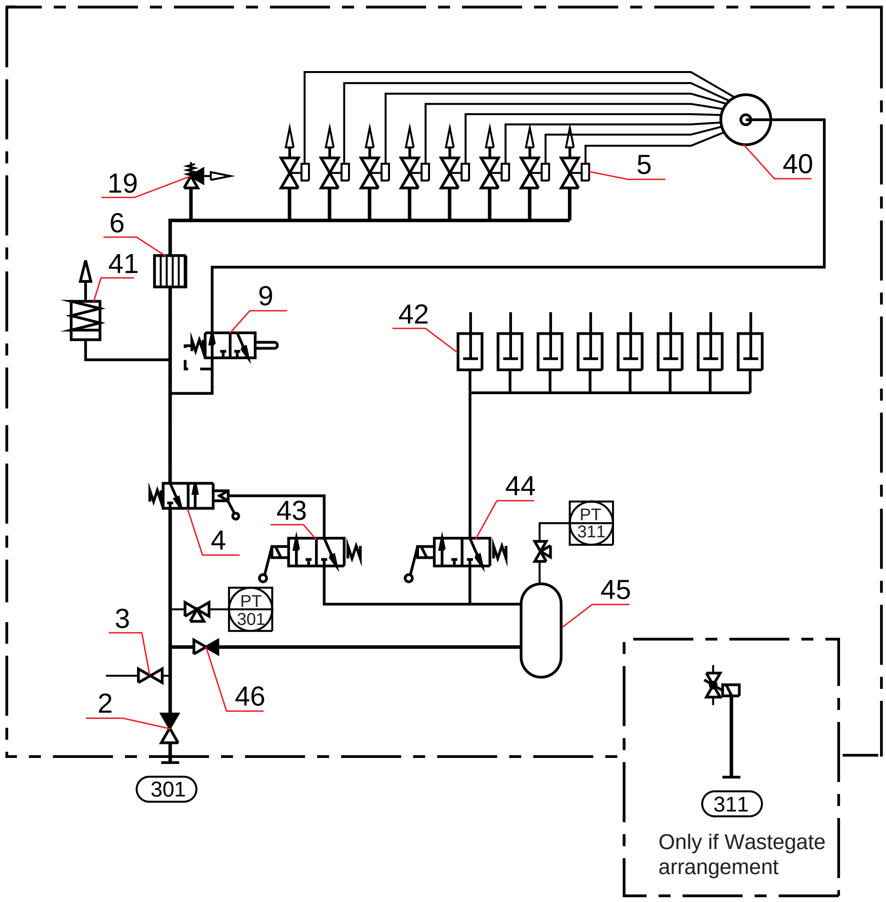


Fig 21-4 402111200151

21.6.2 Maintenance

The system is built up of high class components. Usually it requires no other maintenance than check of function and draining of condensated water from the vessel (45) using the draining plug.

21.6.3 Maintenance of pneumatic components

Solenoid valve (43 and 44, Fig 21-4). In case of disturbance in the electric function of the valve, test the valve by pushing the button (1), see Fig 21-5. Should there be a mechanical malfunction, open the valve using a special tool.

Check that the bores (2) and (3) in the seat are open and the gasket (4) is intact. Change the valve if it does not function after cleaning.

Solenoid valve

1. Button
2. Bore
3. Bore
4. Gasket

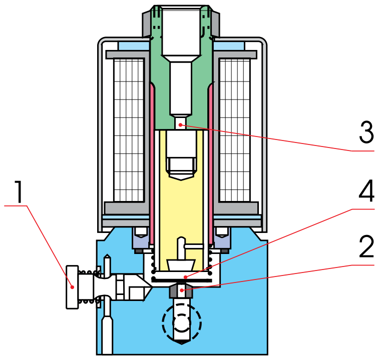


Fig 21-5 4021059601

21.7 Slow turning device

As additional equipment the engine can be provided with a system for slow rotation of the engine before starting, with intention to protect the engine if there is water, oil or fuel in a cylinder, at remote starting.

At manual starting the system can be activated separately or the engine can be rotated normally.

Pneumatic system for slow turning device

2. Non return valve
3. Drain valve
4. Main starting valve
5. Starting valve
6. Flame arrester
9. Blocking valve
19. Safety valve
21. Slow turning valve
22. Pressure regulator
40. Starting air distributor
41. Starting booster
42. Pneumatic cylinder for overspeed trip device
43. Solenoid valve
44. Solenoid valve
45. Air container
46. Non return valve
47. Solenoid valve
48. Non return valve
49. Throttle valve

301. Starting air inlet
311. Instrument air to Wastegate valve

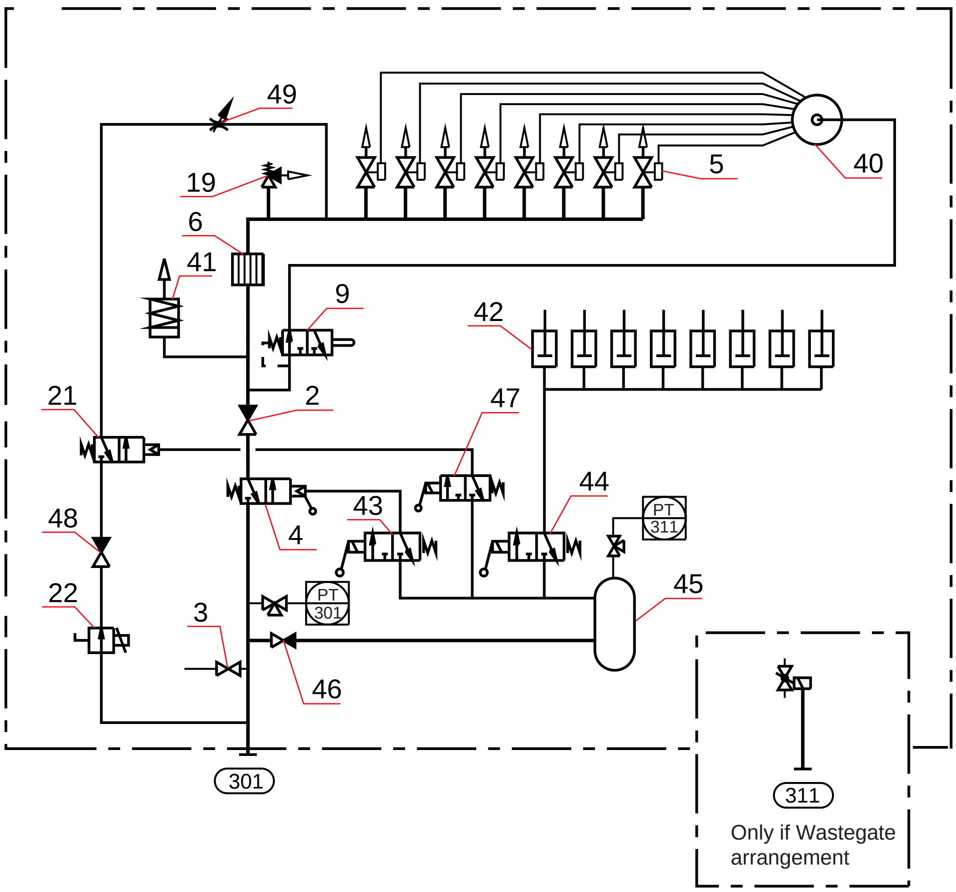


Fig 21-6 402112200151

21.7.1 Description

The slow turning device allows a reduced quantity of starting air to bypass the main starting valve. This amount of starting air rotates the engine with such a low speed that the engine will not be damaged even though there should be some kind of a fluid in a cylinder.

The system, (see Fig 21-6) is built on the engine and consists of a pressure regulator (22), non-return valve (48), slow turning valve (21) and a throttle valve (49).

At remote starting the slow turning valve (21), which is controlled by the solenoid valve (47), is activated for a time necessary to rotate the engine two revolutions. If there is some kind of fluid in a cylinder, the engine stops during these revolutions. Otherwise, both the slow turning valve (21) and the main starting valve (4) are automatically activated until the engine reaches a rotary speed of 300 RPM.

21.7.2 Settings

To attain an engine speed of 8 - 12 RPM, the pressure regulator (22) should be adjusted to about 14 bar and the throttle valve (49) opened 3-5 turns from closed position.

22. Control Mechanism

22.1 Description

During normal operation the engine speed is controlled by a governor (1) which regulates the injected fuel quantity to correspond with the load and engine speed.

The regulation movement is transferred to the control shaft (10) through a adjustable link rod (2).

The movement from the control shaft, to the injection pump fuel racks (15), is transferred through the regulating lever (6) and the spring (7). The torsion spring (5) enables the control shaft and, consequently, the other fuel racks to be moved to a stop position, even if one of the fuel racks has jammed. In the same way the torsion spring (7) enables the regulating shaft to be moved towards fuel-on position, even if an injection pump has jammed in a no-fuel position. This feature can be of importance in an emergency situation.

The engine can be stopped by means of the stop lever (16). When the stop lever is moved to stop position, the lever (17) actuates the lever (9) forcing the regulating shaft to stop position.

The engine is provided with an electro-pneumatic device with tripping speed about 15 % above the nominal speed. The electro-pneumatic device moves every fuel rack to a no-fuel position by means of a pneumatic cylinder on every injection pump. The cylinder actuates direct on the fuel rack. The electro-pneumatic device can also be tripped manually, see section 22.5.

When starting, the governor will automatically limit the movement of the regulating shaft to a suitable value.

The speed governor is provided with a stop solenoid which is connected to the engine automation system.

22.2 Maintenance

Special attention should be paid to the function of the system as a defect in the system may result in a disastrous overspeeding of the engine or in the engine not being able to take load.

a) **The system should work with minimal friction.** Regularly clean and lubricate racks, bearings (also self-lubricating bearings (8)) and ball joints with lubricating oil.

b) **The system should be as free from clearances** as possible. Check clearances of all connections. Total clearance may correspond to max. 0.5 mm of injection pump fuel rack positions.

c) **Check regularly** (see recommendations in chapter 04.) the adjustment of the system; stop position, overspeed trip devices and starting fuel limiter, see section 22.3.

d) **When reassembling the system,** check that all details are placed in the right position, that all nuts are properly tightened and to torque, if so prescribed, and that all locking elements like pins, retainer rings, locking plates are in their positions. Check according to pos. a) - c).

22.3 Check and adjustment

22.3.1 Stop lever stop position

a) **Check:**

- Set the terminal shaft lever (3) in the maximum fuel position and the stop lever (16) in the stop position.
- Check that the fuel rack position of all injection pumps is maximum 5 mm.

b) **Adjustment:**

- Set the stop lever in the stop position and check that the lever (9) contacts the dog (18) properly. A small torque can be set from the governor, but not a too large one, because this will twist the shaft unnecessarily, although little.
- Adjust the fuel rack position to 5 mm by adjusting the screws (14).

22.3.2 Governor stop position

a) **Check:**

- Move stop lever into work position.
- Set the governor terminal shaft lever in the stop position.
- Check that the fuel rack positions are 2 mm.

b) **Adjustment:**

- If the fuel rack positions are unequal, adjust first according to section 22.3.1b).
- Adjust the link rod so that the fuel rack position of 2 mm is obtained.
- If changing the governor, see section 22.4.

Control mechanism

1. Governor
2. Adjustable link rod
3. Lever for governor
4. Screw
5. Spring
6. Lever for injection pump
7. Spring
8. Bearing housing
9. Lever
10. Control shaft
11. Load limiter
12. Lever for control shaft
13. Adjustable link rod
14. Adjusting screw
15. Fuel rack
16. Stop lever
17. Lever for stop lever
18. Dog

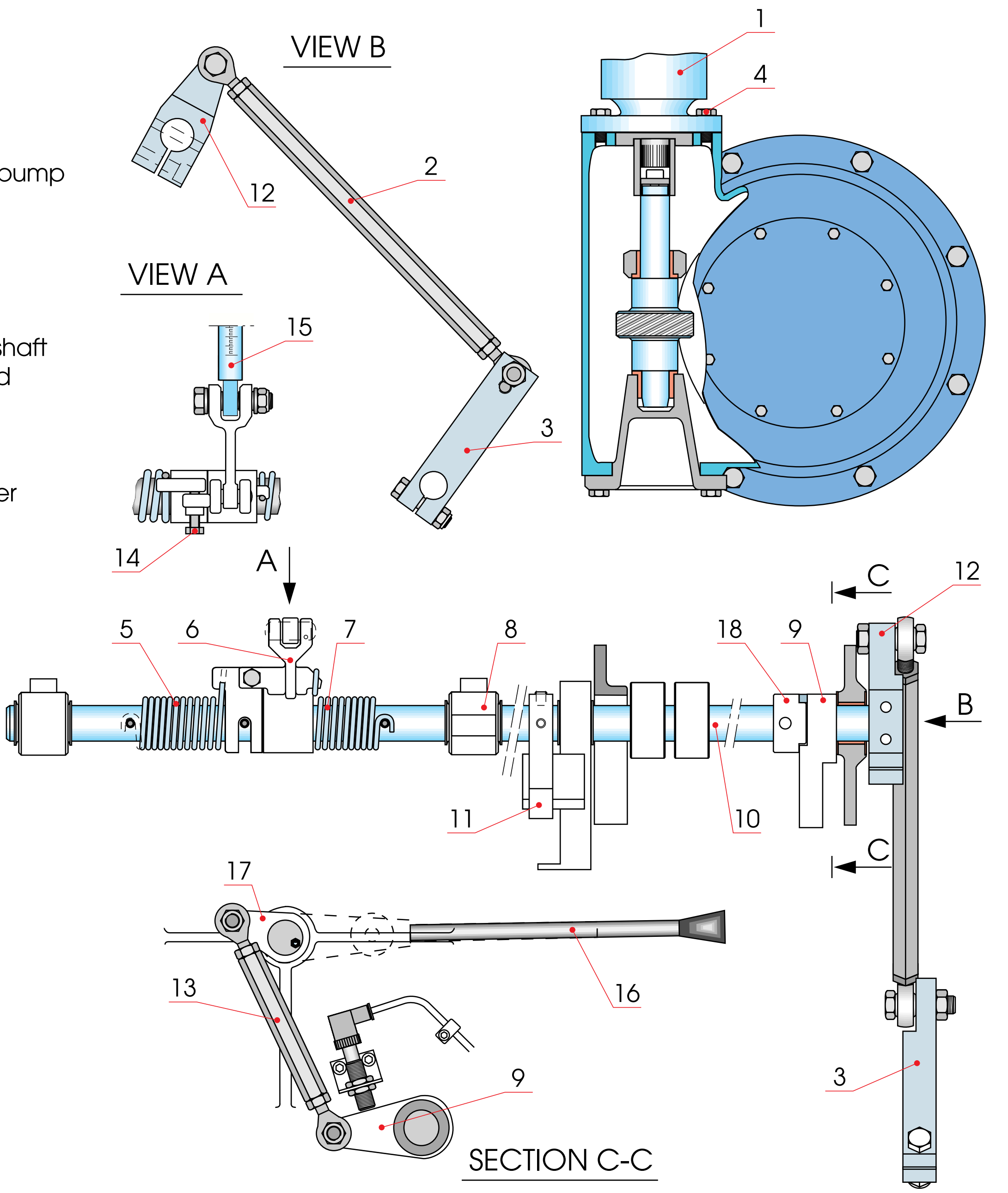


Fig 22-1

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22.3.3 Electro-pneumatic overspeed trip device

a) Check of stop position

- Set the stop lever in the work position and the terminal shaft lever in the max. fuel position.
- Press the STOP-button on the engine. (Stop sequence is activated approximately 1 min.) **Note! The starting air supply should be open.**
- Check that the fuel rack positions is less than 5 mm.

b) Adjustment of stop position

- The electro-pneumatic overspeed trip device requires no adjustment.
- If a fuel rack position of less than 5 mm cannot be obtained, check for wear.

c) Check of tripping speed

- See section 22.5.3.

Electro-pneumatic overspeed trip device

1. Fuel rack
2. Piston
3. Cylinder
4. Slide ring

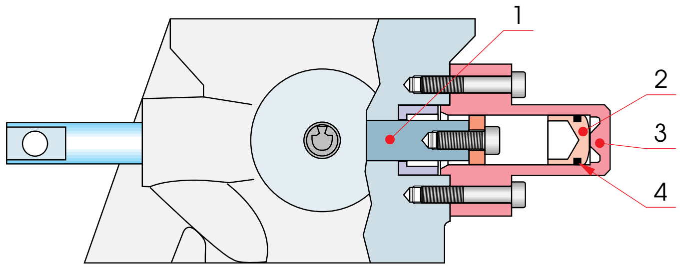


Fig 22-2

4016049601

22.4 Speed governor

22.4.1 General

Data and dimensions
Governor:
Mechanical-hydraulic type
Weight: ~ 65 kg

The engine can be equipped with various governor alternatives depending on the kind of application. Concerning the governor itself, see the attached governor instruction book.

22.4.2 Hydraulic governor drive

The governor is driven by a separate drive unit, which, in turn, is driven by the camshaft through helical gears. The governor is fastened to this drive unit and connected to the drive shaft through a serrated connection. The serrated coupling sleeve is secured with screw. The governor, with drive, can thus be removed and mounted as a unit or the governor can be changed without removing the drive unit.

Pressure oil is led, through drillings in the bracket, to the bearings and to a nozzle for lubricating the gears.

Check at recommended intervals:

- radial and axial clearances of bearings,
- gear clearance,
- oil drillings and nozzle to be open,
- serrated coupling sleeve to be firmly fastened to the shaft,
- serrations of coupling sleeve and governor drive shaft for wear.

Change worn parts.

22.4.3 Removal of governor

1 **Loosen the terminal shaft lever (3),** governor electrical connection and necessary pipe connections.

2 **Open the governor fastening screws (4)** and pull the governor vertically upwards. The governor must not fall or rest on its driving shaft.

22.4.4 Mounting of governor

When mounting the same governor, check that the mark on the lever (3) corresponds to that of the shaft. **Check the setting according to section 22.3.**

When mounting a new governor, proceed as follows:

1 **Mount the governor** into position on the governor drive.

2 **Turn the governor terminal shaft** to the stop position, see Fig 22-3 (in clockwise direction seen from the driving end).

3 **Mount the terminal shaft lever (3)** as follows, see Fig 22-3. Mount the governor electrical- and pipe connections.

4 **Lock the fastening screw** and mark the position of the terminal shaft lever with a mark on the shaft corresponding to that of the lever.

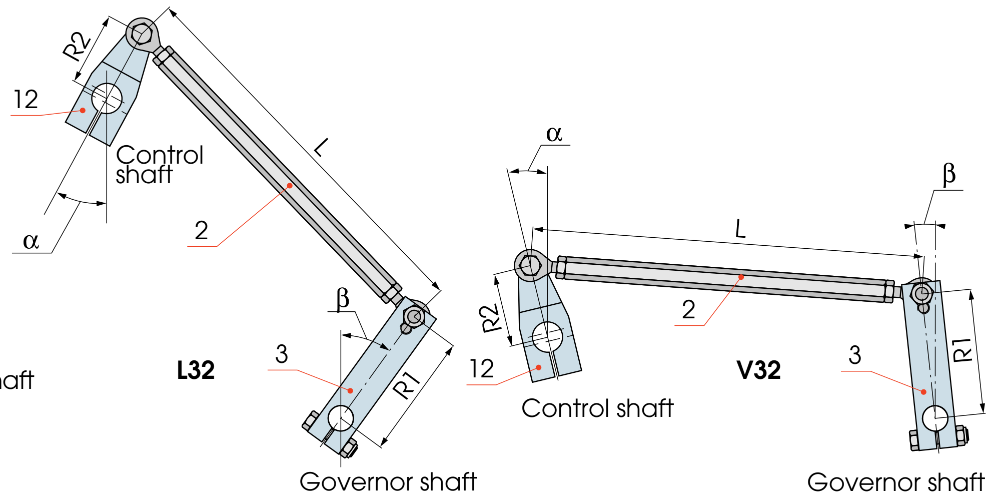
5 **Move the fuel racks** and governor shaft into the positions according to Fig 22-3.

6 **Adjust the adjustable link rod length** to fit between the levers (3) and (12), see Fig 22-3. Do not forget to secure the nuts.

7 **Check according to section 22.3**

Governor shaft settings

2. Adjustable link rod
3. Lever for governor
12. Lever for control shaft



Governor basic settings

Engine type	Governor type	L (mm)	R1 (mm)	R2 (mm)	α (˚)	β (˚)	Rack h (mm)	Governor indicator
L32	PGA	379±20	124	73	27	29±3.5	0* 5**	0* 1.5**
	PGG							
	PG-EG							
	EGB							
L32	Europa 2231	133	85	73	15	19	6*	2*
V32	PGA	486±20	124	73	14	3±4	0* 5**	0* 1.5**
	PG-EG							
	EGB							

*) When assembling levers.
**) When assembling adjustable link rod.

Fig 22-3 402203200201

22.5 Electro-pneumatic overspeed trip device

22.5.1 Description (Fig 22-2)

The overspeed trip device is electronically controlled. Air of max. 30 bar is used as operating medium. The tripping speed is 15 % above the nominal speed.

The three-way solenoid valve (44), Fig 21-4, gets the stop signal for overspeed from the engine automation system.

When the solenoid valve opens, air is fed to the three-way valve, which conveys pressure air to the cylinders (42, Fig 21-4), one for each injection pump. The piston of the air cylinder actuates on the fuel rack moving it to stop position.

The stop signal is energized long enough to stop the engine completely. When de-energized, the air is evacuated through the three-way valve.

The solenoid valve (44) can also be operated manually.

22.5.2 Check and adjustment of stop position

a) Check of stop position

- Set the stop lever in the work position and the terminal shaft lever in the max. fuel position.
- Press the STOP-button on the engine. (Stop sequence is activated approximately 1 min.) **Note! The starting air supply should be open.**
- Check that the fuel rack positions is less than 5 mm.

b) Adjustment of stop position

- The electro-pneumatic overspeed trip device requires no adjustment.
- If a fuel rack position of less than 5 mm cannot be obtained, check for wear.

22.5.3 Check of tripping speed

The tripping speed can be checked in two different methods, simulating the engine speed signal by using a signal generator or by running the engine and increasing the engine speed. The recommended method is to use a signal generator, see chapter 23., section 23.3.

Increasing engine speed

Check the tripping speed at idle by increasing the engine speed above the nominal speed by slowly bending the lever (12) with a suitable wrench in direction from the engine. When the nominal speed is reached and exceeded, the governor begins to decrease the fuel setting, i.e. the control shaft must be bended against the governor force.

Caution! **Do not increase the engine speed above the 920 RPM in any circumstances.**

The tripping speed should be 15 % above the nominal speed, see chapter 06., section 06.1.

Caution! **Special attention should be paid to the testing of tripping speed as an inadequate carefulness may result in a disastrous overspeeding of the engine.**

22.5.4 Maintenance

a) Three-way solenoid valve

- If the solenoid is out of order, replace it by a new one.
- If the valve does not move, clean all channels. Check the valve piston.
- If air is leaking to the cylinders, change the sealings.

b) Air cylinder, Fig 22-2

- Check for wear.
- Check the tightness of the piston. Replace sealings by new ones, if necessary. Take care not to deform the teflon ring outside the O-ring.
- Lubricate the sealings and piston with lubricating oil.
- Check that the piston does not stick.

23. Instrumentation and Monitoring

23.1 General

The Wärtsilä® 32 BEA (Basic Engine Automation) system is used for collecting and monitoring the measurement data from the engine. The system is developed for the harsh engine environment and it consists of relay cards, pressure transducers, temperature and speed sensors. The system is also designed to work in co-operation with the plant automation. See the operating and function instructions of the Wärtsilä Plant Control System witch are included in the installation specific instructions.

23.2 Monitoring equipment mounted on the engine

23.2.1 Instrumentation

The connecting box is flexible mounted on rubber elements at the free end of the engine and includes the following displays:

- Combined rpm-meter (1), a rpm-meter with an 80-leds display showing the engine speed and two 3-digit seven-segment displays showing the turbocharger speeds.

Local Display Unit

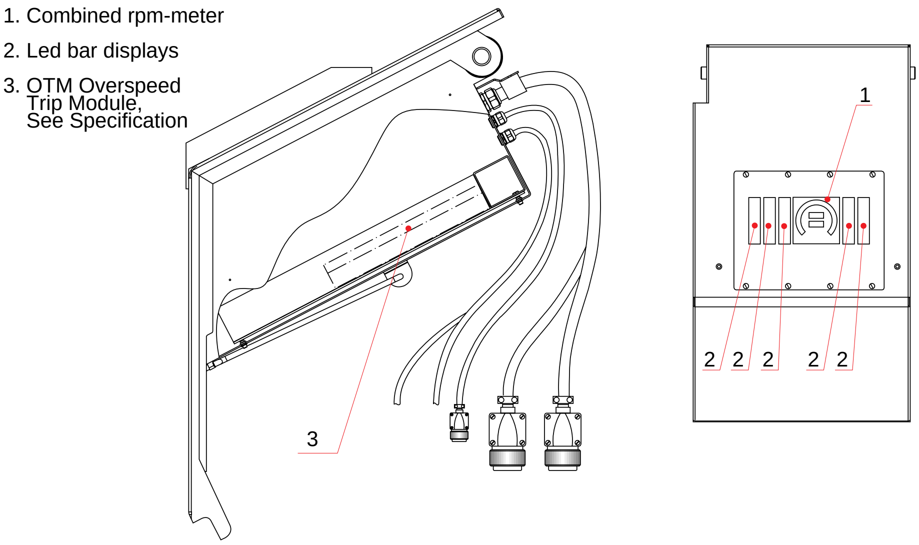


Fig 23-1

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- Led bar displays (2), the 30-leds bar displays are showing various measured information from the engine.

23.2.2 Manometers

The following manometers are used:

Manometer	Code
• Differential pressure over charge air cooler A-bank	PDI 623
• Differential pressure over charge air cooler B-bank	PDI 633

Normally the instruments need no service. All manometers can, however, be changed during operation. Fig 23-2. Faulty or damaged instruments should be repaired or replaced at the first opportunity.

The manometers at the charge air cooler

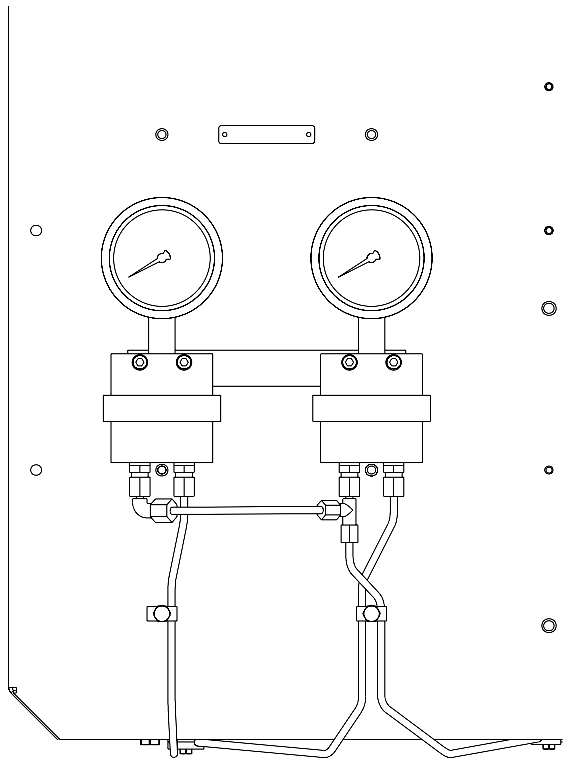

Fig 23-2 402344

23.2.3 Sensors for monitoring and alarm

The following set of sensors for monitoring, alarm and safety are mounted on the engine. Their locations are shown in Fig 23-3 .

Code	Name	Type
LS103A/B	Fuel oil leakage, injection pipe	B
LS108A/B	Fuel oil leakage, dirty fuel, flywheel end	B
PT101	Fuel oil pressure, inlet	A
TE101	Fuel oil temperature, inlet	A
SE167	Engine speed 1, if external governor	A
SE168	Engine speed 2, if external governor	A
LS204	Lube oil level	B
PT201	Lube oil pressure, inlet	A
PS201-1	Prelube pressure, inlet	A
PDT243	Lube oil filter pressure difference	A
TE201	Lube oil temperature, inlet	A
TE202	Lube oil temperature, outlet	A
PS210	Lube oil stand-by pump start	A
TE232	Lube oil temperature, LOC outlet	A
PT301	Start air pressure	A
PT311	Control air pressure	A
PT401	HT water pressure, inlet	A
PT471	LT water pressure, inlet	A
TE401	HT water temperature, inlet	A
TE402	HT water temperature, outlet	A
TEZ402	HT water temperature, jacket outlet	A
TE432	HT water temperature, CAC outlet	A
TE471	LT water temperature, CAC inlet	A
TE472	LT water temperature, CAC outlet	A
TE482	LT water temperature, LOC outlet	A
TE511	Exhaust gas temperature, Turbo inlet[2)]	A
TE521	Exhaust gas temperature, Turbo inlet[2)]	A
TE5##1A	Exh. gas temp., cylinder outlet[3)]	A
TE5##1B	Exh. gas temp., cylinder outlet[3)]	A
PT601	Charge air pressure, inlet	A
TE601	Charge air temperature, inlet	A
TE621	Charge air temperature, CAC inlet	A
TE631	Charge air temperature, CAC inlet	A

Code	Name	Type
TE7##	Main bearing temperature[4)]	A
PT700	Crankcase pressure	A
GS792	Turning gear engaged	A
GS171	Stop lever in stop position	B
ST173	Engine speed	A
ST174	Engine speed, backup system	A
SE518	Turbocharger speed	A
SE528	Turbocharger speed	A
PTZ201	Lube oil pressure, inlet	B

A = analogue sensors
B = binary (on/off) sensors
2) 1...4 pcs depending on exhaust gas system
3) 2 pcs/cylinder
4) (n +2) pcs, where n = numbers of cylinders

Even if the above mentioned sensors are considered as standard the amount and type of sensors can in some cases vary, depending on the needs for concerned installation. The actual set of sensors and other electrical equipment mounted on the engine, as well as alarm, load reduction and shutdown set points, can be found in the installation specific documentation.

23.2.4 Standard sensors

A standard set of sensors is always mounted on the engine according to the table below. The locations of the sensors are shown in Fig 23-3.

Standard sensors for:	Sensor code	Type
• Engine speed	ST173	A
• Turbocharger speed	SE518	A
• Fuel oil pressure low	PT101	A
• Fuel oil temperature before engine monitoring	TE101	A
• Fuel oil injection pipe leakage	LS103A	B
• Lube oil pressure low	PT201	A
• Lube oil filter pressure drop high	PDT243	B
• Lube oil temperature before engine high	TE201	A
• Lube oil level in wet oil sump low	LS204	B
• Starting air pressure low	PT301	A
• HT-water pressure low	PT401	A
• HT-water temperature after engine high	TE402	A
• LT-water pressure before CAC low	PT451	A
• Exhaust gas temperature after each cylinder high	TE5##1A/TE5##1B	A
• Charge air temperature after CAC high/low	TE601	A
• Charge air pressure after CAC	PT601	A
• Pneumatic overspeed trip device pressure low	PS311	B

A = analog sensor
B = binary (on/off) sensor

Monitoring equipment, Turbocharger on the free end

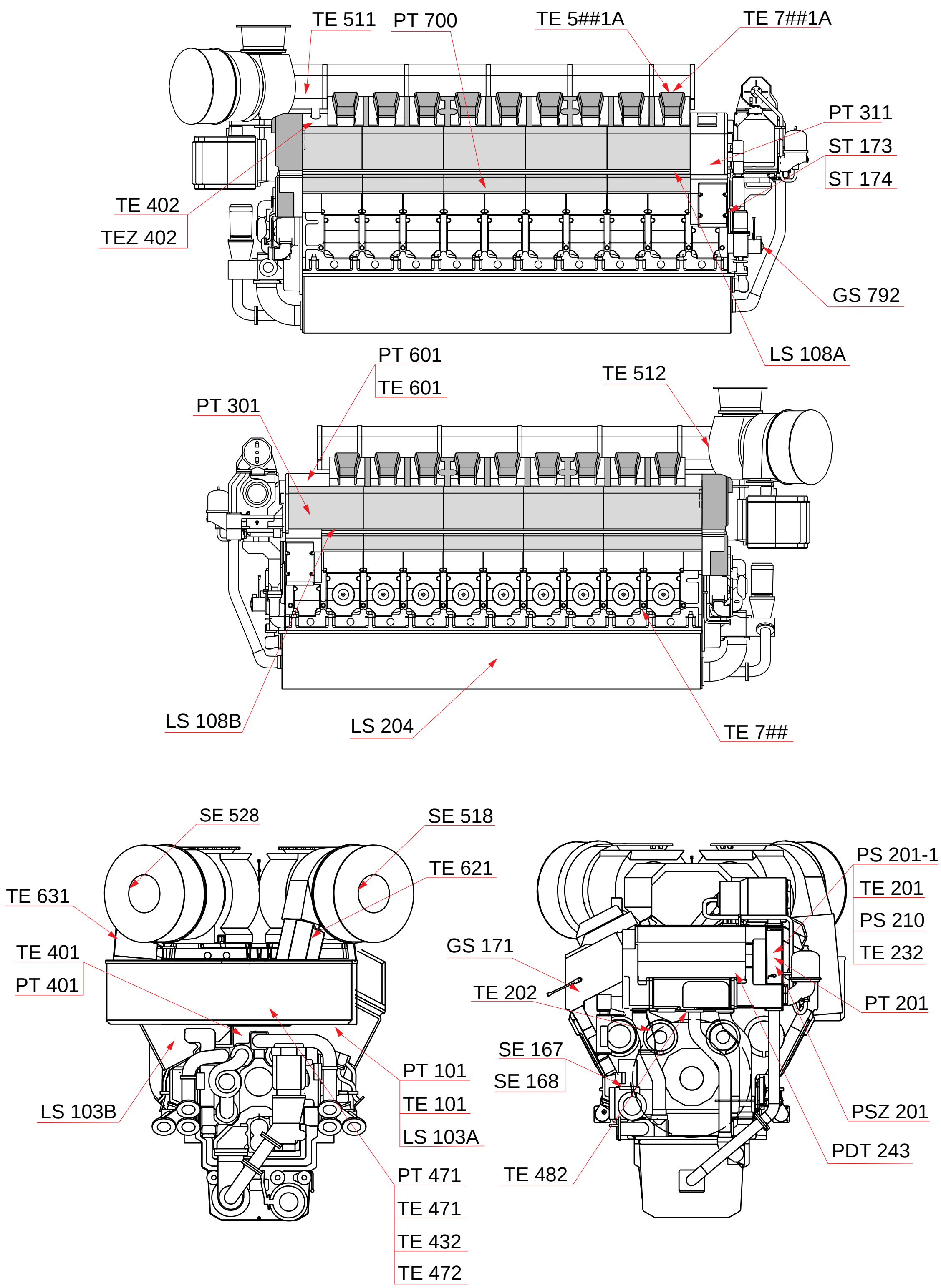

Fig 23-3

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23.2.5 Optional sensors

In addition to the standard set of sensors, any of the following optional sensors can be mounted on the engine according to the table below. The locations of the sensors are shown in Fig 23-3.

Optional sensors for:	Sensor code	Type
• Fuel rack position	GT165	A
• Fuel oil pressure low, start of stand-by pump	PS110	B
• Lube oil pressure low, start of stand-by pump	PS210	B
• Start of HT-water stand-by pump	PS410	B
• Start of LT-water stand-by pump	PS460	B
• Exhaust gas temperature before turbo-charger, A-bank	TE511	A
• Exhaust gas temperature before turbo-charger, B-bank	TE521	A
• Charge air pressure after CAC	PT601	A
• Cylinder liner temperature	TE7##A/B	A

23.2.6 Safety sensors

The safety sensors include the following sensors. All the safety sensors may not be included in the engine, depending on the engine specification.

Safety sensors for:	Sensor code	Type
• Lube oil pressure, engine inlet	PS201-1	B
• Lube oil pressure, engine inlet	PTZ201	B
• HT-water pressure, jacket inlet	PT401	B
• HT-water temperature, jacket outlet	TEZ402	B
• Stop lever in stop position	GS171	B
• Lube oil pressure, prelube, engine inlet	PS201-1	B
• Turning gear engaged	GS792	B

23.2.6.1 Checking the sensors

a) **Pressure sensors**

All sensors are adjusted and checked at the factory before delivery. For control of the sensor output signal a pressure calibrator is required. Testing of pressure sensor can be done without removing the sensor from the engine.

Testing of pressure transducers and switches

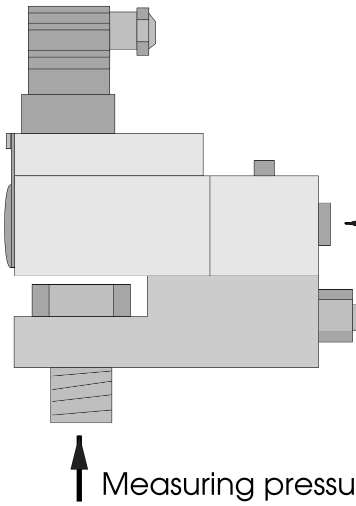

Fig23-4 0303A9648

Fig23-4 shows a pressure transducer with a shut-off valve and test pressure connection.

The pressure transducer is disconnected from the pressure measurement by the shut-off valve. The pressure calibration device is then connected to the plug for test pressure. The requested pressure is set with the help of the calibration device.

1 **Shut the valve below the transducer**

2 **Unscrew the plug just above the valve** and connect the pressure calibrator.

3 **Check for leakages** before pumping up the pressure.

4 **Adjust calibrator settings.**

5 **Read the sensor measuring values** at least at two points (e.g. the lowest and the highest points of the entire range) and check with the transducer specifications.

6 **Adjust or replace the transducer if necessary.**

7 **Open the valve when the transducer is checked.**

8 **If the transducer does not give any output check:**

- wiring and connections (with an ohm meter or multimeter)
- power supply (polarity printed on the sensor)
- transducer damages.

Note! **Open the shut-off valve after testing!**

b) Temperature sensors

All sensors are checked at the factory before delivery. For control of the sensor a temperature calibrator is required. All temperature sensors are fitted into shielded sensor pockets and can thus be lifted off for checking also during engine operation.

1 **Unscrew the sensor.**

2 **Insert the sensors into the calibrator.**

3 **Adjust the calibrator settings.**

4 **Read the measured value** at least at two points (lowest and highest points of the entire range) and check with the specifications.

5 **Replace the sensor if necessary.**

6 **If the sensor transmitter doesn't give any output check:**

- wiring and connections (with an ohm meter or multimeter),
- power supply (polarity printed on the transmitter),
- transmitter damages.

The example of sensors test points are shown in table below.

Temperature (°C)	PT 100 (Ω)	Termocouple type K (mV)
0	100,0	0
20	107,8	0,8
40	115,5	1,6
100	138,5	4,1
300	-	12,2

c) Pressure switches

All switches are preadjusted at the factory. Switches can be checked during operation.

1 **Shut the valve below the switch.**

2 **Unscrew the plug just above the valve** and connect a pressure calibrator.

3 **Check the switch** by observing at which pressure the micro switch breaks. Correct pressure is stated in the engine specifications and printed on the switch itself.

4 **Adjust or replace the switch if necessary.**

5 **In case of malfunction function** also check connection and wiring.

d) **Temperature switches**

Temperature switches are also fitted into sensor pockets and can be lifted off for checking during the engine operation. The check can be carried out with a temperature calibrator and by observing the temperature at which the microswitch breaks. The correct temperature is stated in the engine specifications and printed on the switch itself. If necessary the switch must be adjusted or replaced. Also check connection and wiring for damages.

e) **Load and other switches**

These switches are mechanical switches which can be checked while the engine is out of operation.

1 **Turn the control shaft** until the load indicating switch operates.

2 **Check which load this corresponds to.**

23.3 Speed Monitoring System (SPEMOS)

23.3.1 Introduction

SPEMOS — SPEed MOnitoring System — is an electronic speed measuring/monitoring system exclusively developed for use on Wärtsilä engines. It is used on both marine and stationary (power plant) applications.

The SPEMOS system provides the following functions of the diesel engine:

- measuring of engine speed,
- seven engine-speed operated relay functions, including overspeed trip of the engine,
- measuring of one or two turbocharger speeds,
- additional cards for special functions, if required.

23.3.2 Theory of operation

23.3.2.1 Power supply

The electronic cards of SPEMOS are all powered by an internal power supply card (C1). This card is a switching DC/DC converter with a stabilised 12 VDC output. This output is also galvanically isolated from the input voltage. The output of the card is short-circuit proof.

23.3.2.2 Engine speed measurment

The engine speed is detected by means of two touchfree, inductive proximity switches. These proximity switches are mounted on the engine body, and give an impulse for each cog passing their sensing head when the engine is running.

The frequency from these sensors, which is proportional to the engine speed, is compared and converted in the speed measuring card (C2) to a DC-voltage of 0 - 10 VDC. This voltage is buffered and fed out to be indicated on the local/remote engine speed instruments.

23.3.2.3 Engine speed operated relay functions

The analogue speed signal from the engine speed measuring card is internally connected in SPEMOS to the relay card (C3) and (C5). The cards have three individually adjustable relays each, and these relays can operate at any engine speed.

The relays have two change-over contacts each, and the breaking capacity of these contacts is 0.3 A at 110 VDC and 1.0 A at 24 VDC.

23.3.2.4 Turbocharger speed measurment

The turbocharger speed is detected by means of touchfree, inductive speed sensor, or by magnetic speed pick-up sensors.

The frequency from this sensors, which are proportional to the turbocharger speeds, are compared and converted in the speed measuring card (C4) to a DC-voltage of 0 - 10 VDC.

The output signal of this speed measuring card (C4) is buffered, and supplied to local/remote turbocharger speed instruments.

23.3.3 Functional circuit boards

23.3.3.1 Power supply card (C1)

Technical specification:

Dimensions: . . . . 80 x 100 mm
Supply voltage:. 18 - 40 VDC smoothed
. . . . alt. 40 - 160 VDC
Output voltage: . . . . 12 VDC stabilized
Output adjust range:. . . . . 1.5 VDC
Output ripple: . . . . 10 mV RMS
Output current: . . . . 500 mA max.
Amb. temperature: . . . . -25...+80°C
Short circuit proof:. . . . . Provided
Isolated voltage:. . . . . 2 kV, 50 Hz, 1 min.
. . . . 5 kV, 1.2/50 µs
Fuse: . . . . T 1.6 A, 5 x 20 mm

The power supply card is short-circuit proof and protected from overheating. A green LED indicates that voltage is provided on the output of the card.

The input supply voltage is galvanically insulated from the output voltage in this “switching” type DC/DC converter card.

Power supply card C1

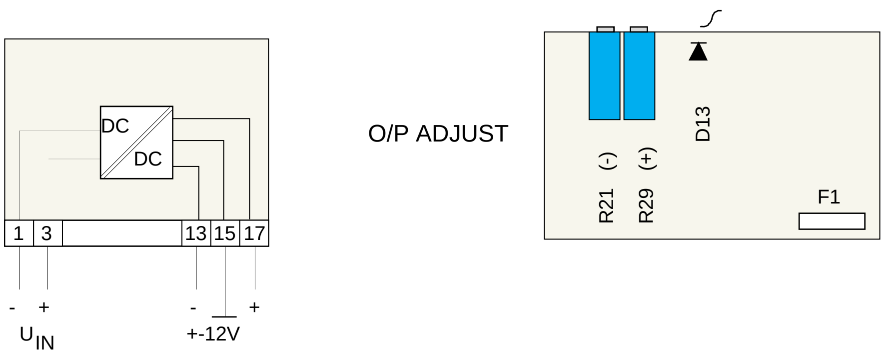

Fig 23-5

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23.3.3.2 Engine speed measuring card (C2)

a) **Theory of operation** The frequency from the proximity switch speed sensors, which is proportional to the engine speed, is compared in the C2-card. The higher frequency is always selected and converted in this card to a DC-voltage of 0 - 10 VDC. This voltage is buffered and supplied to the local and remote engine speed instruments.

For the Wärtsilä 32 engine the speed measuring range is 0 - 1000 RPM. 1000 RPM corresponds to frequency of 400 Hz from the speed sensor, and this frequency is converted into 10 VDC on the card.

The output voltage of the card is also controlling a speed operated relay internally on the card. The switchpoint of this relay is adjustable over the whole speed measuring range, and it also has an adjustable delay. This relay is controlling the start fuel limiter of the engine. An LED indicates that the relay is operated (= fuel lim. off).

A test oscillator is also provided on the card, which allows engine speed simulations.

b) **Adjustment procedure** The analogue output of the card is 0 - 10 V DC, which corresponds to 0 - 1000 RPM. The card is accurately precalibrated at the factory. However, if a recalibration is required, it can be performed according to following instructions:

1 **The output level.** For fine adjusting the output signal (0 - 10 V DC), an oscillator is required. Supply a frequency of 400 Hz to the frequency input of the card and adjust with P1 until 10.00 V DC is achieved on the voltage output.

2 **The fuel limiter function.** The switching level of the fuel limiter control is adjusted with potentiometer P2. The voltage on testpoint TP3 will indicate the switching speed level of this function. There is a relation of 1/168 between the actual switching level and the voltage on this testpoint, e.g. if setting the switching level to 260 RPM, adjust the voltage with P2 until 1.55 V is achieved on TP3.

Note! **The engine must not be running when performing this adjustment.**

3 **On- and off delay.** The on and off delay of the operation of this relay is adjusted with potentiometers P4 and P3 respectively. When checking the delay times, as well as simulating the engine speed, the testpoints TP1 and TP2 should be bridged. An LED will indicate the switching of the relay.

4 **The tacho/power failure function.** The setting of this function is fixed. If the frequency on one of the inputs is not present, or the frequency differs between the channels, a tachofailure alarm will be activated. In an alarm situation a relay makes a switchover and there will be an open circuit between board terminals 55 and 57. Also a power failure will cause the same operation.

5 **Test points.** **Testpoint TP1 & TP2:** Bridging the points using e.g. a small screwdriver, a built in test oscillator will start (the sensor must be unplugged when doing this). The test oscillator can be used whenever it is necessary to simulate the engine speed indication.
Testpoint TP3: Reference voltage test point for adjustment of switching level of fuel limit control relay.
Testpoint TP4: Internal ground (0 V DC).

Engine speed measuring card (C2)

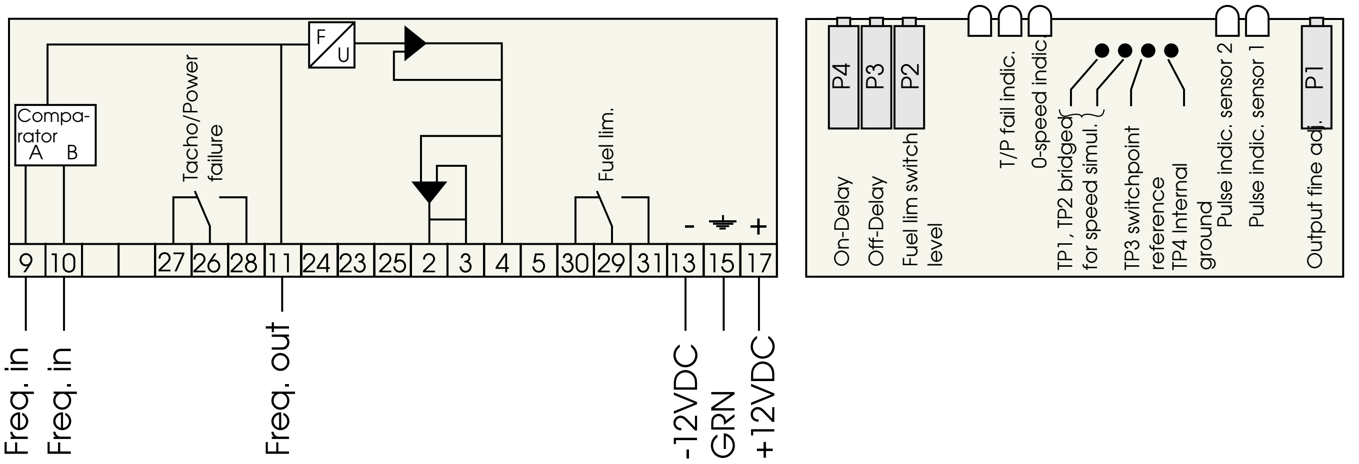

Fig 23-6 2023639335

c) Technical specification

Dimensions: . . . . 80 x 100 mm
Ambient temperature:. . . . . -25...+80C

Input:
Frequency range:. . . . . 0... 8000 Hz
Signal type: . . . . 12 V pk, square wave
Supply voltage:. . . . . 12 VDC
Current consumpt.: . . . . Max. 2x80 mA

Output:

Voltage: . . . . 0 - 10 VDC
. . . . Max. 15 mA, short circ. proof
Ripple: . . . . <20 mV at full scale
Frequency: . . . . 12 V pk at term. 13

Relay function:

Switchpoint:. . . . . 0 - 100 % of meas. range
Delay: . . . . 0.1 - 30 on/off delaysec.
Contact: . . . . One change-over contact
. . . . Max 220 V AC / 2 A / 110 VA

23.3.3.3 Relay card I (C3)

a) **Theory of operation, description of control functions.** The analogue speed signal from the engine speed measuring card (C2) is internally connected to the relay card. The card is equipped with three independent relays, each having two changeover contacts. The speed signal is supplied to three comparators on the card, which determine the speed operated switchpoint of each relay. The relays can thus be individually adjusted.

The relays are non-latching. Each relay has a LED, which indicates that the relay is operated.

The three relays of relay-card I provide the following functions of the diesel engine:

Relay n1 is set to 300 RPM. One of the two contacts of this relay controls directly the hour counter of the engine. When the relay operates, it connects on the 24 VDC (110 VDC) power supply to the hour counter. The other contact of this relay is connected to the diesel automation system. In the automation system this contact will indicate the condition “Engine Running”. In the automation system functions like priming pump control, alarm, interlock and startblocking will be operated according to the status of this relay.

Relay n2 is set to 540 RPM, and it is used for excitation on alternator.

Relay n3 is set to 15% above the nominal speed, see chapter 06., section 06.1. One contact of this relay operates the electropneumatic overspeed protection device of the engine. The other contact of this relay is connected to the alarm panel, for overspeed trip announcement.

b) Adjustment procedure. The switchpoint of the relays are adjustable with three trimpotentiometers; P601 - P603. The testpoints below will indicate the actual value of setting of the speed switches. The relation of all relays, trimpots and testpoints of the card is presented in the table below:

Relay	Sw.point	Testp.
n1	P601	TP1
n2	P602	TP2
n3	P603	TP3

All relays are accurately preadjusted at the factory. However, if a change of some reason is necessary, this is possible. The actual switchpoint of a relay (measured at this relays tespoint) is determined by the following correlation:

$$U_{TP4}\ (\text{V DC}) = \frac{\text{desired speed (rpm)} \times 10\ \text{V DC}}{1000\ \text{(rpm)}}$$

Relay card C3

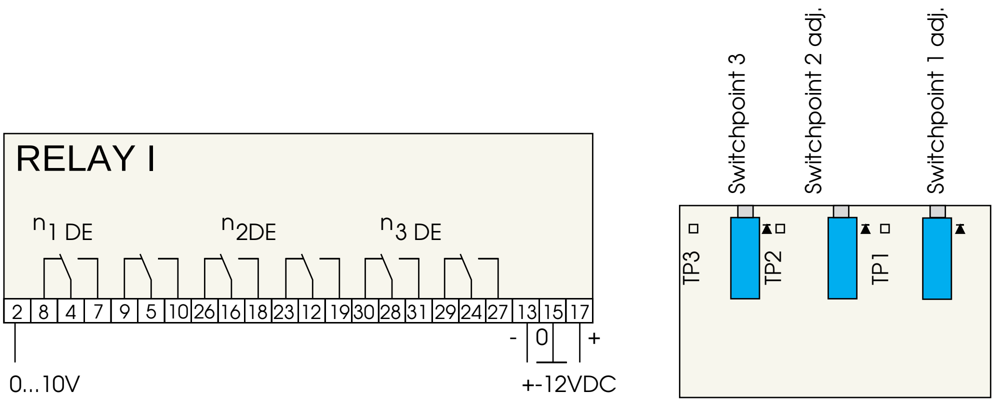

Fig 23-7 402347

c) Technical specification

Dimensions: . . . . 80 x 100 mm
Amb. temperature: . . . . -25...+80°C

Inputs:

Supply voltage:. . . . . 12 VDC
Current consumpt.: . . . . max. 60 mA
Control voltage: . . . . 0 - 10 VDC

Outputs:

Three relays, each having two change-over contacts:

Switchpoint:. 0 - 100 % of meas. range

Delay: . . . . 0 - 30 sec. (n1, n2 only)

Contacts: . . . . 0.3 A at 110 VDC

. . . . 1.0 A at 24 VDC

23.3.3.4 Turbocharger speed measuring card (C4)

a) **Theory of operation** The sinusoidal signal from the t.c speed sensor is in this card amplified and cut to a square wave signal before being converted into a speed proportional 0 - 10 VDC signal. The output of the card is buffered, and supplied to local and remote t.c. speed instruments. For the Wärtsilä 32 engine the speed measuring range of the turbocharger is 0 - 30000 RPM. 30000 RPM corresponds to a frequency of 1000 Hz on the speed sensor, and this frequency is converted into 10 VDC on the card. There is also a separate frequency output provided. The card is a single-channel card on in-line engines, and a two-cannel card on V-engines.

b) **Adjustment procedure** The card is accurately precalibrated. However if a re-calibration is necessary, this can be done by means of trimpotentiometers P701 (= nTC1), and P711 (= nTC2). When turning the trimpot. CW, the output will increase, and vice versa.

TC-card C4

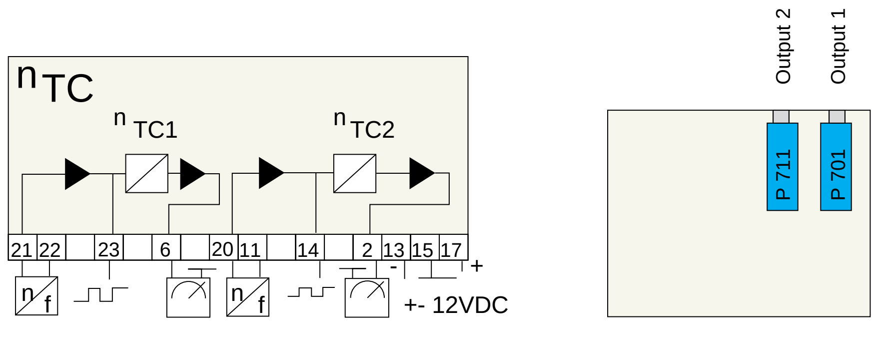

Fig 23-8 2023749335

c) **Technical specification**

Dimensions: . . . . 80 x 100 mm

Ambient temperature:. . . . . -25...+80°C

Input(s):

Freqvence range: . . . . 0 - 8000 Hz
Signal type: . . . . 100 mVpp sine
Supply voltage: . . . . 12 VDC
Current consumpt.: . . . . max. 35 mA

Output(s):

Voltage:. . . . . 0 - 10 VDC
. . . . Max. 15 mA, short circ. proof
Unlinearity: . . . . 0.1 %
Temperature coefficient: . . . . 0.03 %/K
Frequency: . . . . 12 Vpp
. . . . Max. 10 mA, short circ. proof

23.3.3.5 C5 Relay II (Used as a optional card)

a) **Theory of operation**

The card consists of 3 voltage-controlled relays, each having one change-over contact.Any external voltage between 0 and 10 V DC can be used as control. The switchpoints and delays are adjustable. LED indicates an activated relay.

b) **Adjustment procedures**

See adjustment instruction for C3 relay card.

c) **Technical specification:**

See Technical specification for C3 relay card.

Optional cards may be used if required, see installation specific data.

23.3.4 Engine speed sensor

a) **Theory of operation** The rotational speed of the engine is measured with a touch free inductive PNP-type proximity sensor. The sensor is supplied with a 12 VDC supply voltage from SPEMOS. The third pin of the sensor is the speed proportional pulse train output. The pulse output voltage level varies between two fixed levels; 0 VDC and 12 VDC.

The electronics of the sensor is resin-moulded into a tubular housing of nickel plated brass with external thread of M18 x 1.5 mm.

b) **Mounting the sensor** Turn the engine until the top of a cog is visual in the sensor mounting hole. Screw carefully the sensor completely in, by hand. Unscrew it approximately 1.5 revolutions for a sensing gap of 2.0 - 2.5 mm, and tighten the counternut well with a spanner.

Note! **The engine must not run while the sensor is adjusted.**

Engine speed sensor

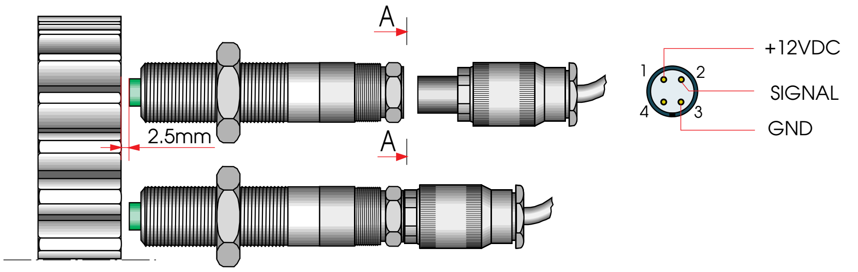

Fig 23-9 2023649335

23.3.5 Turbocharger speed sensor

23.3.5.1 ABB turbocharger speed sensor

The turbocharger speed sensor is a magnetic type and it does not require any supply voltage. The sensor is mounted eccentrically in the turbochargers bearing space cover. In a lubricating wheel on the shaft there are six embedded magnets, which are each generating a pulse in the sensor when passing the sensing head. The sinusoidal signal from the sensor is thus proportional to the rotation speed of the charger, and is connected to the turbocharger speed measuring card C4.

The metal housing of the sensor is M12 x 1.25 mm. The cable is connected by means of a four pole Euchner BS4 connector.

To install the sensor screw carefully the sensor completely in by hand. Unscrew it 2 revolutions for a sensing distance of 2.5 mm, and tighten the counter nut well with a spanner.

Note! **The engine must not run while the sensor is adjusted.**

ABB turbocharger speed sensor

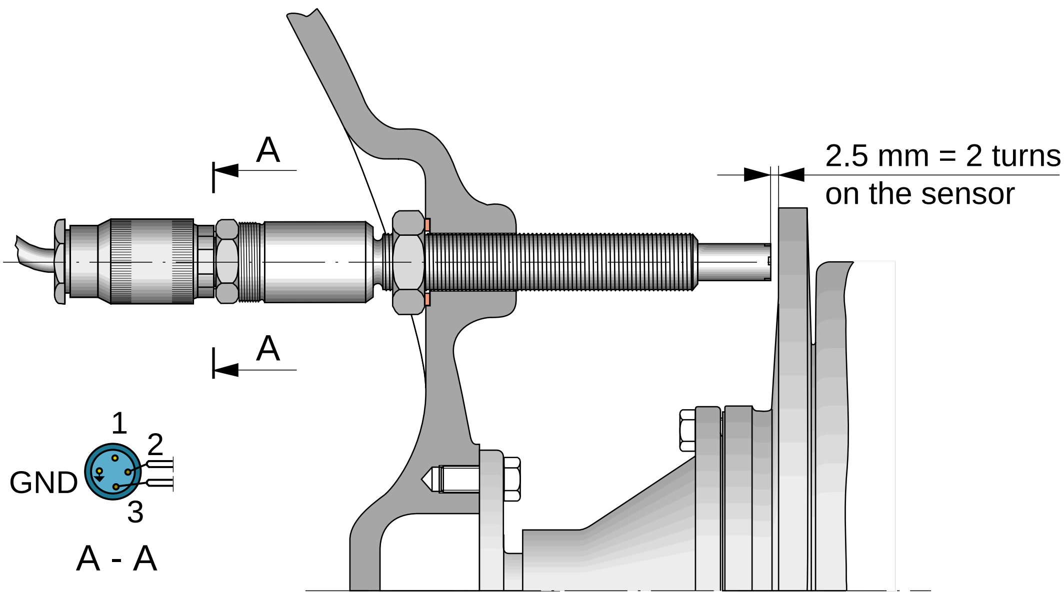

Fig23-10 322360a

23.3.5.2 Mounting of the NAPIER turbocharger speed sensor

See Fig 23-11. Screw carefully the sensor completely in by hand. Unscrew it 0.5 revolutions for a sensing distance of 0.7 mm, and tighten the locking plate securing screws.

Note! **The engine must not run while the sensor is adjusted.**

NAPIER turbocharger speed sensor

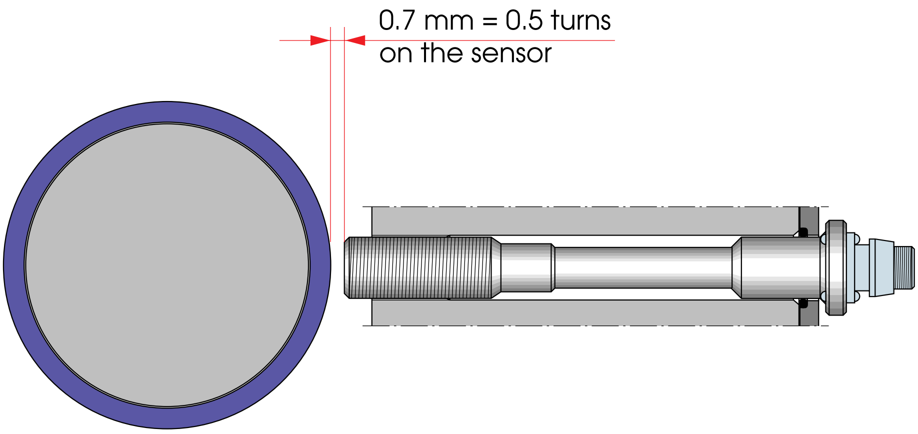

Fig 23-11 2023869911

23.3.6 Trouble shooting procedures

1. Power supply card

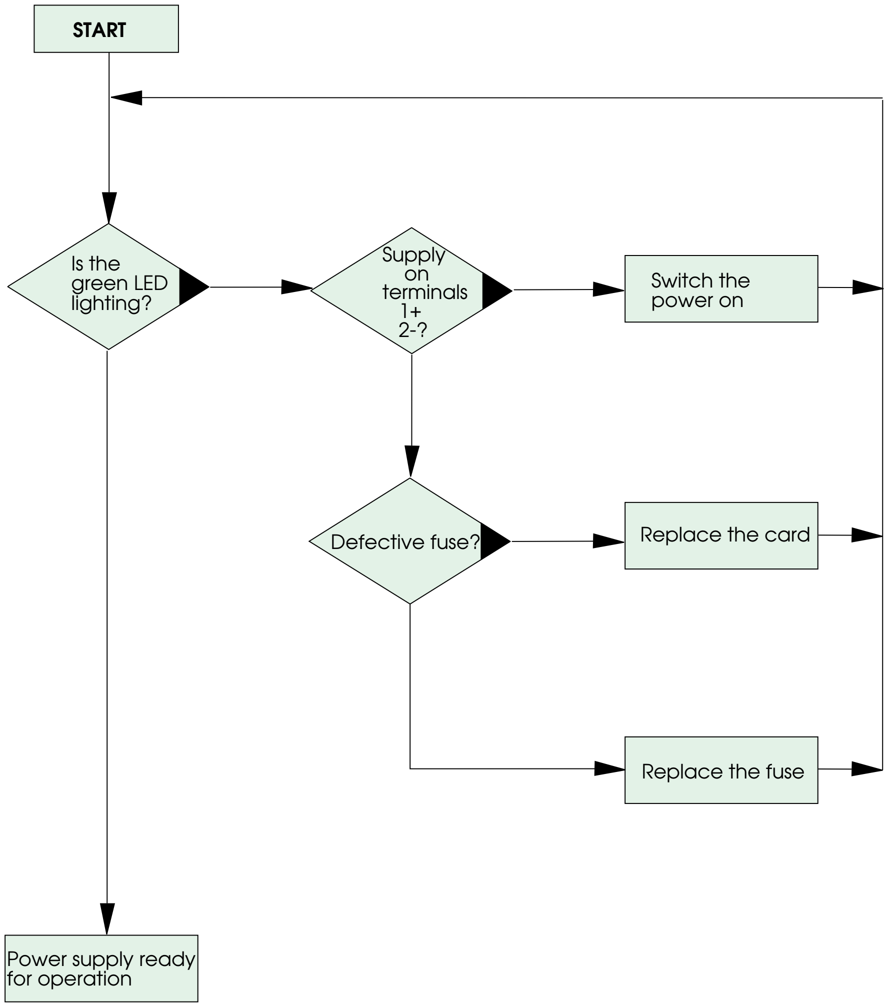

Fig 23-12

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2 Engine speed measuring card

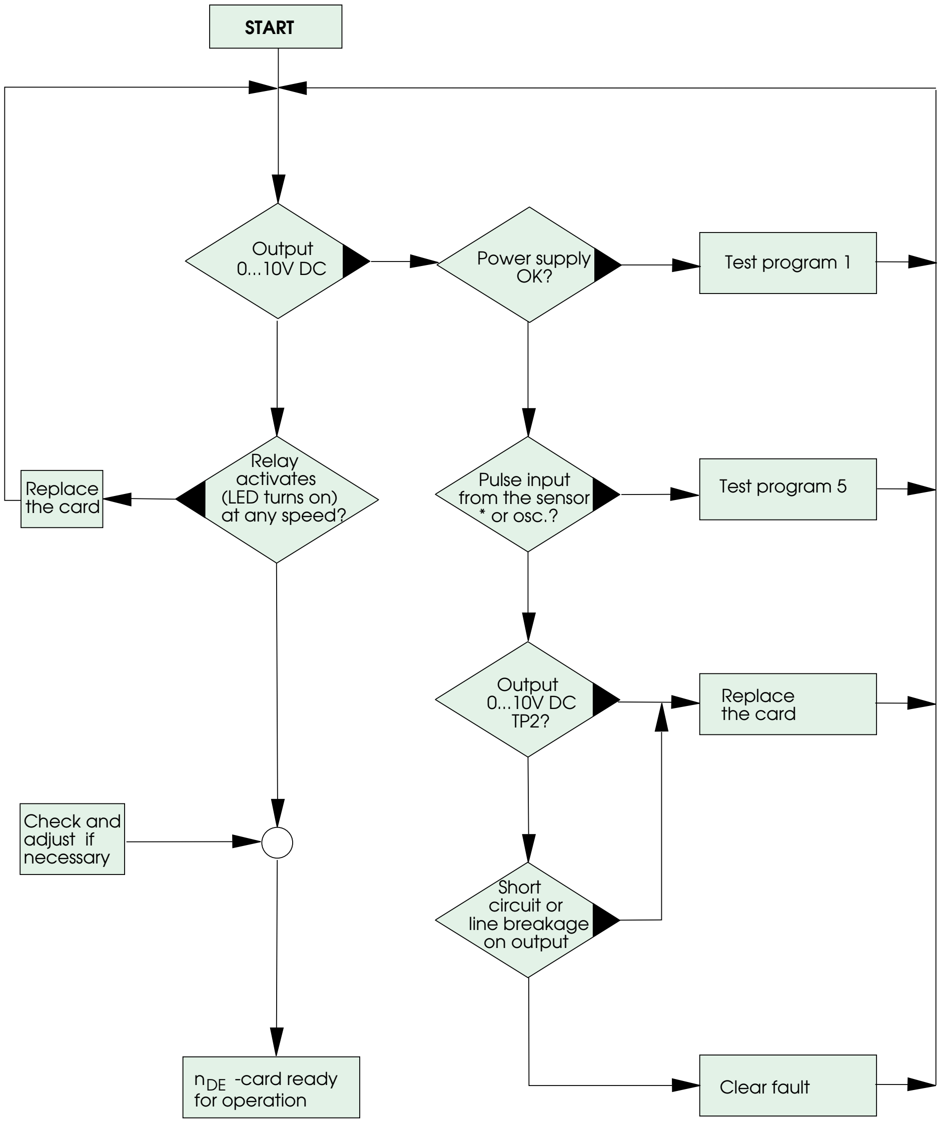

Fig 23-13

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3. Relay card

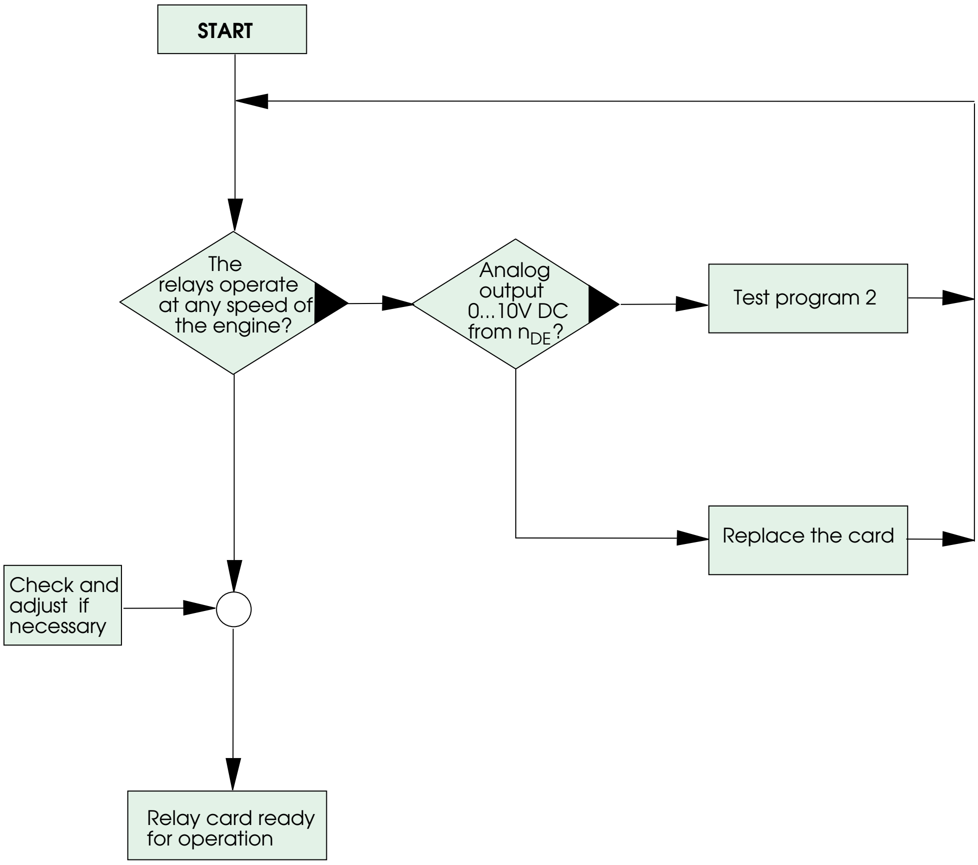

Fig 23-14

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4. Turbocharger speed measuring card

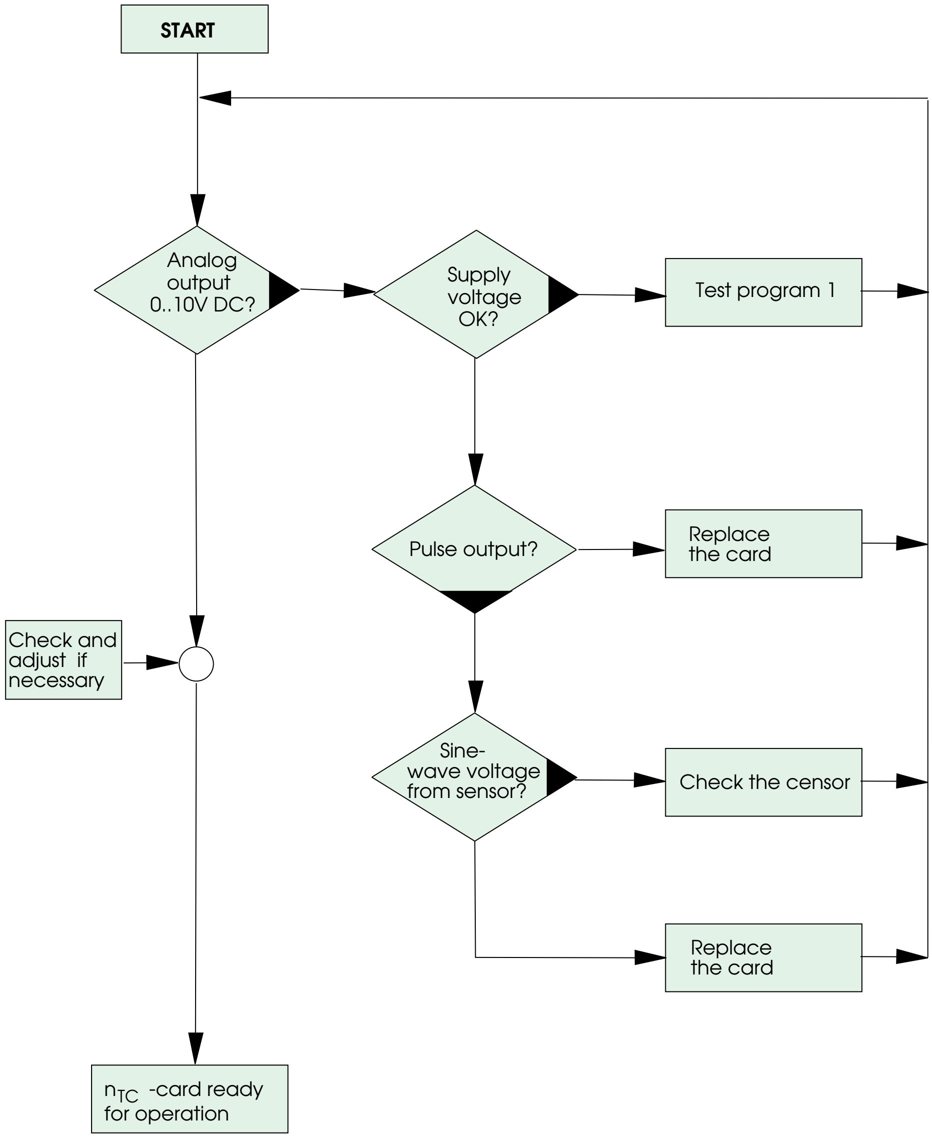

Fig 23-15

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5. Engine speed sensor

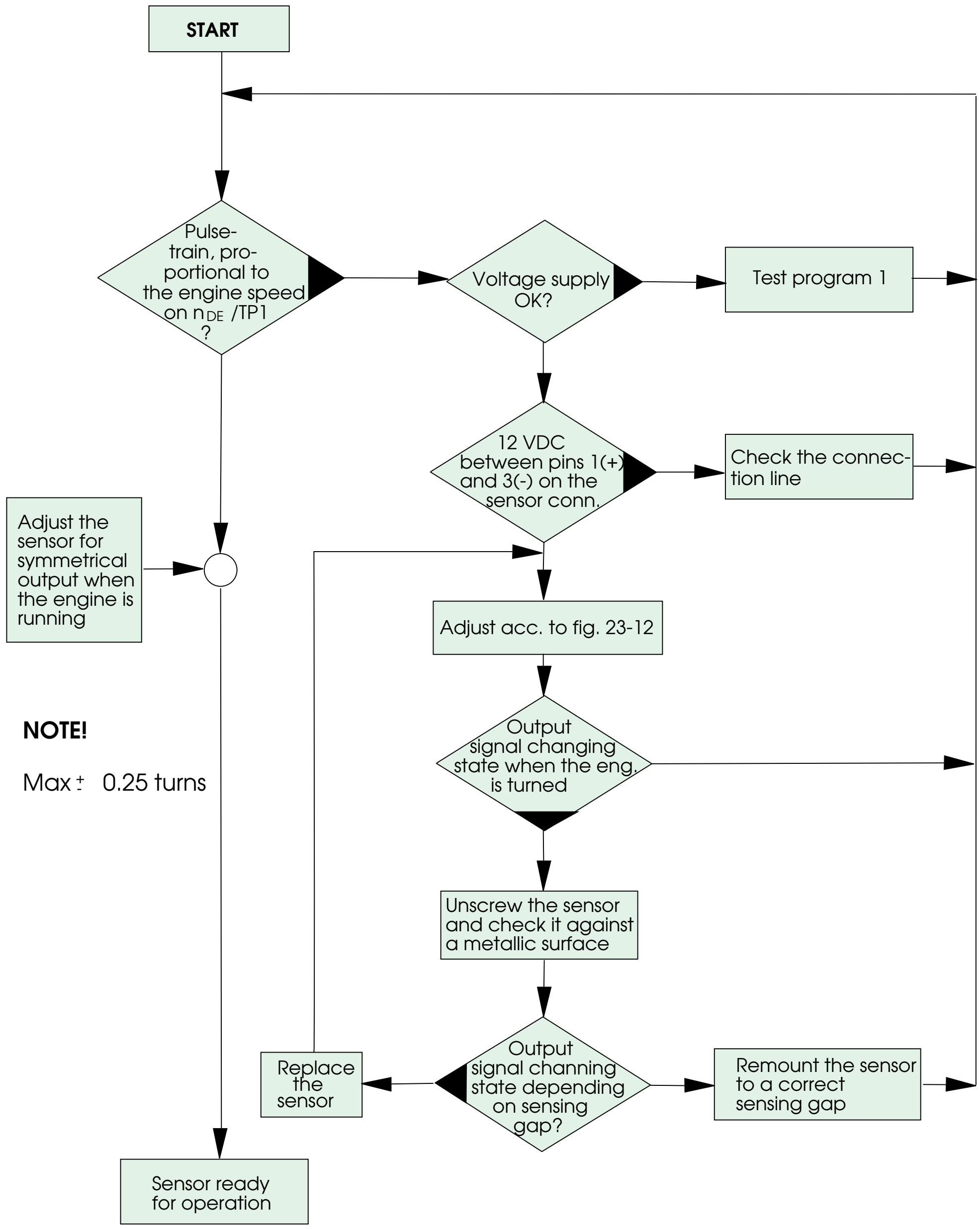

Fig 23-16

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